Case No. 84739

IN THE SUPREME COURT OF THE STATE OF NEVADA

ADAM SULLIVAN, P.E., NEVADA STATE ENGINEER, et al.

Appellants,

vs.

LINCOLN COUNTY WATER DISTRICT, et al.

JOINT APPENDIX

VOLUME 31 OF 49

SOUTHERN NEVADA WATER AUTHORITY

Muddy River Tributary Conservation Intentionally Created Surplus Certification Report

Calendar Year 2014

November 2015

Suggested citation: Southern Nevada Water Authority, 2015, Muddy River Tributary Conservation Intentionally Created Surplus Certification Report Calendar Year 2014: Southern Nevada Water Authority, Las Vegas, Nevada, Doc. No. WMP-ED-0006, 80 p.

United States Department of the Interior

BUREAU OF RECLAMATION
Lower Colorado Regional Office
P.O. Box 61470
Boulder City, NV 89006-1470

IN REPLY REFER TO:
LC-4220
WTR-4.03

FEB 10 2016

CERTIFIED – RETURN RECEIPT REQUESTED

Ms. Colby Pellegrino
Colorado River Programs Manager
Southern Nevada Water Authority
P.O. Box 99956
Las Vegas, NV 89193-9956

Subject: Verification of 2014 Tributary Conservation Intentionally Created Surplus (ICS) Created by the Southern Nevada Water Authority (SNWA)

Dear Ms. Pellegrino:

The 2007 Record of Decision for *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (2007 Interim Guidelines) establishes the requirements for the creation, delivery, and accounting for ICS. By letter dated January 11, 2016, SNWA submitted its Muddy River Tributary Conservation ICS and Virgin River Tributary Conservation ICS Certification Reports for Calendar Year (CY) 2014 (Certification Reports) in accordance with Section 3.D.1 of the 2007 Interim Guidelines. In accordance with Section 3.D.2 of the 2007 Interim Guidelines, this letter provides SNWA notice of my determination regarding the amount of ICS created by SNWA in CY 2014.

By letter dated September 21, 2013, the Bureau of Reclamation approved SNWA's 2014 Plans for the Creation of Tributary Conservation ICS and Imported ICS (ICS Plans), which described three separate projects from which SNWA intended to create ICS in CY 2014: (1) the Muddy River Tributary ICS project (up to 20,000 acre-feet (AF)); (2) the Virgin River Tributary ICS project (up to 17,000 AF); and (3) the Coyote Spring Valley Imported ICS project (up to 9,000 AF). SNWA's Certification Reports indicate that it created 15,098 AF of Muddy River Tributary Conservation ICS and 14,168 AF of Virgin River Tributary Conservation ICS in CY 2014, prior to the one-time deduction of 5 percent specified in Section 3.B.2 of the Interim Guidelines for the benefit of additional system storage in Lake Mead. SNWA did not create Imported ICS in CY 2014.

Reclamation has reviewed the information contained in SNWA's Certification Reports, and confirms that the information adequately demonstrates the amounts of ICS created and that the methods of creation were consistent with SNWA's approved ICS Plans, Exhibit A of the Lower Colorado River Basin ICS Forbearance Agreement, and the Delivery Agreement (Contract No. 07-XX-30-W0520) among the United States, SNWA, and the Colorado River Commission of Nevada. Therefore, I verify and make the final determination that SNWA created 15,098 AF of Muddy River Tributary Conservation ICS and 14,168 AF of Virgin River Tributary Conservation

ICS, for a total of 29,266 AF of Tributary Conservation ICS, in CY 2014 prior to accounting for the one-time deduction of 5 percent for the benefit of additional system storage.

If you have questions, please contact Mr. Paul J. Matuska, Water Accounting and Verification Group Manager, at 702-293-8164 or pmatuska@usbr.gov.

Sincerely,

Terrance J. Fulp, Ph.D.
Regional Director

cc: Ms. Tanya M. Trujillo
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BRIAN SANDOVAL
Governor

STATE OF NEVADA

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December 3, 2015

Colby Pellegrino
Manager, Colorado River Program
MS #520
Southern Nevada Water Authority
PO Box 99956
Las Vegas, NV 89193-9956

Subject: Muddy and Virgin Rivers Tributary Conservation Intentionally Created Surplus Certification Reports, Calendar Year 2014

Dear Ms. Pellegrino:

Our office has reviewed the Southern Nevada Water Authority's (Authority) Calendar Year 2014 Certification Reports for Tributary Conservation Intentionally Created Surplus (ICS) for the Muddy and Virgin Rivers, dated November, 2015. These Certification Reports demonstrate that the amount of Tributary Conservation ICS created by the Authority and conveyed to Lake Mead are consistent with Nevada Water Law and State Engineer's Orders 1193 and 1194.

The Nevada State Engineer's Office concurs that the Muddy and Virgin River water rights outlined in said reports are owned or controlled by the Authority, have a priority date prior to June 25, 1929 and were conveyed to the Colorado River mainstream (i.e., Lake Mead full pool elevation of 1,220 above mean sea level) as described and in the amounts indicated in the table below.

Calendar Year 2014	Volume, in acre-feet/year Cited in Certification Reports		
	Muddy River (Tributary Conservation)	Virgin River (Tributary Conservation)	Coyote Springs (Imported)
Created ICS	15,098	14,168	0

Should you have any questions, please contact Supervising Engineer, John Guillory, P.E. at (702) 486-2770.

Sincerely,

Jason King, P.E.
State Engineer

cc: Rick Felling, Deputy Administrator via email
John Guillory, SNBO via email
Jayne Harkins, Colorado River Commission of Nevada

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FIGURES

FIGURES (CONTINUED)

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ACRONYMS

AZMET	Arizona Meteorological Network
BCPA	Boulder Canyon Project Act
CEMP	Overton Nevada Community Environmental Monitoring Program
CY	Calendar Year
ET	Evapotranspiration
ICS	Intentionally Created Surplus
LCRAS	Lower Colorado River Accounting System
MET	Meteorological
MVIC	Muddy Valley Irrigation Company
NDWR	Nevada Division of Water Resources
OWMA	Overton Wildlife Management Area
MBPI	Moapa Band of Paiute Indians
MVWD	Moapa Valley Water District
NVE	NV Energy
PBU	Proof of Beneficial Use
POU	Place of Use
SNWA	Southern Nevada Water Authority
USGS	United States Geological Survey
WSNA	Warm Springs Natural Area

ABBREVIATIONS

af	acre-feet
afy	acre-feet per year
amsl	above mean sea level
cfs	cubic-feet per second
ft	foot
yr	year

ROUNDING DISCLAIMER

Due to rounding, numbers presented in tables throughout this document may not add up precisely to the totals provided.

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1.0 INTRODUCTION

The Secretary of Interior (Secretary) issued a Record of Decision for 'Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead' (Guidelines) on December 13, 2007, which established criteria for the development and delivery of Intentionally Created Surplus (ICS). One type of ICS is Tributary Conservation, which allows a Contractor, as defined in the Guidelines, to increase tributary flows into the mainstream of the Colorado River within its state for ICS credits. The conservation of tributary flows into the mainstream of the Colorado River is limited to water rights that have been used for a significant period of years and were perfected prior to June 25, 1929, the effective date of the Boulder Canyon Project Act (BCPA).

To generate ICS, the Guidelines require a Contract holder to enter into a Delivery Agreement with the United States of America and a Forbearance Agreement with Lower Basin Contract holders. On December 13, 2007, the Southern Nevada Water Authority (SNWA) and Colorado River Commission of Nevada entered into a Delivery Agreement with the United States of America and Forbearance Agreement with Lower Basin Contract holders. Exhibit A of the Forbearance Agreement describes the surface water rights on the Muddy and Virgin Rivers, pre-dating June 25, 1929, which SNWA plans to use to create Tributary Conservation ICS, and how the Muddy River flows reaching Lake Mead will be calculated (Appendix A).

The Guidelines, Forbearance Agreement, and Delivery Agreement require a plan for the creation of ICS (ICS Plan). An ICS Plan for Muddy River Tributary Conservation ICS was submitted to the Bureau of Reclamation (Reclamation) for Calendar Year (CY) 2014 on June 28, 2013. SNWA received a letter from Reclamation dated September 21, 2013 approving the ICS Plans for CY 2014 (Appendix B).

This report satisfies the requirements of Nevada State Engineer Order 1194 (Appendix C) and the Guidelines as follows:

- Under Nevada State Engineer Order 1194, an annual report will be submitted to the Nevada Division of Water Resources giving a "full accounting of adjudicated water rights on the Muddy River or its tributaries owned or controlled by the entity with an ICS Delivery Contract, which have been conveyed through the Muddy River system to the Colorado River mainstream for the creation of ICS." After review of the annual report, the Nevada State Engineer shall issue a letter verifying the quantity of water conveyed through the Muddy River system to the Colorado River mainstream for the purpose of creating ICS.

- Based on the Guidelines, an annual certification report will be submitted for the Secretary of Interior's review and verification to demonstrate the amount of Tributary Conservation ICS

created in the preceding year, and that the method of creation was consistent with SNWA's approved ICS Plan.

- Intentionally Created Surplus is declared a beneficial use under Nevada Revised Statutes 533.030.

2.0 PROJECT DESCRIPTION

Muddy River water rights that are being utilized to create Tributary Conservation ICS pursuant to the approved ICS Plan and Exhibit A of the Forbearance Agreement are decreed Nevada state water rights with an established history of use prior to 1929, but have experienced periods of non-use in the interim. Per Exhibit A of the Forbearance Agreement, SNWA is specifically allowed to utilize any and all pre-June 25, 1929, Muddy River water rights to create Tributary Conservation ICS regardless of the water rights history of use after 1928.

The Muddy River originates from regional springs in the Muddy River Springs Area in Nevada and flows into the Overton Arm of Lake Mead (Figure 2-1). Muddy River flows are relatively constant, because flows from the springs that form the river are consistent due to their regional source, the carbonate aquifer system of eastern Nevada. The average annual flow of the Muddy River at the United States Geological Survey (USGS) gaging station 09419000 *Muddy River near Glendale, Nevada* (Glendale gage) for Water Years 1950 through 2014 is 30,572 acre-feet per year (afy).

Muddy River water rights were judicially decreed in 1920, and the decree allocated the entire flow of the Muddy River (Appendix D). The Order of Determination, attached to the decree as Exhibit A, explicitly outlines the Place-of-Use (POU) for the water rights and established summer and winter diversion rates. For the most part, the summer season is May 1 to September 30 with a diversion rate of 1 cubic-foot per second (cfs) per 70 acres of land and the winter season is October 1 to April 30 with a diversion rate of 1 cfs per 100 acres of land. These diversion rates equate to an annual rate of 8.54 afy per acre (afy/acre).

Water rights on the upper reach of the Muddy River, from the Muddy River Springs to the Glendale gage, are owned and controlled by individual right holders. On the Lower Muddy River, downstream of the Glendale gage, water rights are held by the Muddy Valley Irrigation Company (MVIC) for use by its shareholders. In CY 2014, SNWA owned and leased individual water rights on the Upper Muddy River and owned and leased MVIC stock shares in MVIC on the Lower Muddy River.

The decreed Muddy River surface water rights owned and leased by SNWA are no longer being utilized for agriculture and are being conveyed to Lake Mead. The pre-June 25, 1929, water rights conveyed to Lake Mead represent the full right that is and has been historically used for agriculture or could have otherwise been diverted from the Muddy River and fully consumed by SNWA within Nevada.

Muddy River rights conveyed to Lake Mead passed through their historic points of diversion and either flowed through the irrigation company ditches and returned to the mainstream of the Muddy River further downstream or remained in the mainstream of the Muddy River. Muddy River water associated with rights owned and leased by SNWA and documented to flow to Lake Mead have been accounted for as Tributary Conservation ICS.

Figure 2-1
Map of the Upper and Lower Reaches of the Muddy River Divided by the Glendale Gage

2.1 Summary of Results for CY 2014

The total volume of Muddy River water for which SNWA created Tributary Conservation ICS in CY 2014 under the Guidelines was 15,098 af, prior to any overrun payback and one-time deduction of 5% for the benefit of additional system storage in Lake Mead, as outlined in the Guidelines (Table 2-1). This volume is within the 20,000 af outlined in the approved ICS Plan. Detailed data and calculations are described in subsequent sections of this report.

Table 2-1
Muddy River 2014 ICS

Water Right	Acre Feet Conserved in 2014
Muddy Valley Irrigation Company	8,627
LDS Church Rights Lease	2,001
NV Energy Lease	2,508
Hidden Valley Dairy	1,040
Knox and Holmes	811
SNWA Acquired Cox Right	85
SNWA Acquired Mitchell Right	26
SNWA Muddy River ICS Credit	**15,098**

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3.0 WATER CONSERVATION ASSOCIATED WITH SNWA MUDDY RIVER RIGHTS

On the Muddy River, there are two distinct reaches divided by the USGS gaging station *09419000 Muddy River Near Glendale, NV* (Glendale gage). By controlling water rights on the Muddy River within these two reaches, SNWA successfully conserved Muddy River water in CY 2014 that was conveyed to Lake Mead for Tributary Conservation ICS credits. The sections below describe the water rights and conservation measures.

3.1 Verification Process of Fallowed Land

Within the agricultural areas, fields were digitized using the 2006 National Agricultural Imagery Program data. Since 2008, SNWA funded aerial-photography flights specifically for the purpose of Tributary Conservation ICS verification. These flights have been strategically scheduled 3-times per year to assure they are capturing the agricultural activities during the summer and winter seasons over a calendar year. These flights are flown at a resolution of 6-inches per pixel. This high-quality photography allows for more accurate determinations of fallowed vs. active agricultural fields. An example of the high resolution aerial photography used to classify and delineate crop areas can be seen on Figure 3-1.

Aerial-photography flights were performed in December 2013, July 2014, and December of 2014 to effectively capture lands being flood irrigated or fallowed during the winter and summer irrigation seasons. The summer irrigation season spans May through September. The July photography documents areas that were actually being irrigated during the summer irrigation season, because by July most of the natural vegetation that was not receiving irrigation company water had died back.

Muddy River water rights have defined POU maps and many have subsequent Proof-of-Beneficial-Use (PBU) maps, showing the locations where the decreed and permitted water rights were beneficially used within the defined POU. These POU and PBU maps, when compared to recent aerial photography, serve as the baseline for proof of fallowed lands, documenting conservation of the water. In some instances, the recent digitized polygons of the current fields do not exactly match the fields on the POU or PBU maps from decades prior. This is due to improved mapping capabilities and changes in land/water right ownership resulting in divided/combined fields. However, since the water rights can be used anywhere within the defined POU, the breakdown of the fields is not as important as the total irrigated acreage within the POU.

Some of the fields on the aerial photography depict vegetation even though they are not being actively irrigated. This is due to the fact that many of the fallowed fields historically contained perennial alfalfa, which receive periodic water from winter rains that temporarily turn the fields

Figure 3-1
Example of Detailed 6-inch Aerial Photography on the Lower Muddy River

green. Many of the fields that appear to have some green in the aerial photography flown in the cooler months are brown in the July aerial photography.

3.2 Upper Muddy River Rights

The Upper Muddy River, for the purposes of this report, is defined as the reach from the Muddy River Springs Area to the Glendale gage. Within this reach, decreed water rights are individually owned with specific POUs describing the lands irrigated by the rights.

For each of the Upper Muddy River water rights controlled by SNWA, the following sections represent a series of figures that illustrates the original POU or PBU map associated with the water right and the aerial photography taken over the course of the calendar year. For reference, the quarter-quarter sections within the POU are outlined within an overlaying of the aerial photography.

The Upper Muddy River is a gaining stream from its headwaters to the Glendale Gage and natural vegetation in this area (eg. phreatophytes) is supplied by shallow groundwater and spring discharge. The river flows do not constitute a significant source of water supply for Evapotranspiration (ET) losses. Therefore no ET losses were deducted from the Muddy River water rights between the springs and Glendale Gage.

3.2.1 LDS Church Rights Lease / Cox and Mitchell Right Purchase

In 2006, SNWA in partnership with the Moapa Valley Water District (MVWD) agreed to lease 2,001 af of a total of 2,046 af of decreed Muddy River water rights held by the Corporation of the Presiding Bishop of the Church of Jesus Christ of Latter-day Saints (LDS Church). This water had been historically used to irrigate approximately 228 acres of agricultural lands in the Muddy River Springs Area, located in the headwaters of the Muddy River. The lease agreement allows MVWD to utilize up to 50% of the water leased based on coordination with SNWA. In CY 2014, MVWD did not exercise their 50% option on the LDS Church lease, and SNWA retained the entire 2,001 af.

In 2007, SNWA purchased the majority of land associated with the LDS Church water rights for the primary purpose of restoring habitat of the Moapa dace, an endangered fish species endemic to the warm waters of the Muddy River Springs. The management of this land, referred to as the Warm Springs Natural Area (WSNA), in combination with the U.S. Fish and Wildlife's management of the adjacent Moapa Wildlife Refuge, will protect the majority of the springs that make up the headwaters of the Muddy River. A key component of activities to preserve the Moapa dace's habitat is leaving the warm water that emanates from the regional springs, which was previously used for agricultural purposes, in the natural channels that meander through the WSNA and the Moapa Wildlife Refuge. This preservation activity is compatible with the creation of Tributary Conservation ICS on the Muddy River.

When SNWA purchased the WSNA in 2007, it also acquired two decreed water rights not related to the 2,001 afy LDS Church lease. These rights were originally decreed to Cox (V01619) and Mitchell (V01631) in 1920 for 85 afy and 26 afy, respectively.

It is important to note that although the land previously irrigated with the 2,001 afy of the LDS Church rights is now owned by SNWA, the LDS Church retained ownership of the water rights and is continuing to lease the rights to SNWA and MVWD.

Figure 3-2 presents the PBU map filed with the LDS Church water right certificates, with Figures 3-3 through Figure 3-5 comparing the PBU map for the LDS Church water rights with the aerial photography taken in December 2013, July 2014, and December of 2014, respectively. The POU boundary overlaid on the aerial image depicts land fallowing over the majority of the POU.

The fallowed lands are further emphasized on Figure 3-6, which compares the POU area as of July 2014 with an aerial photograph of the area from 1976. The 1976 map shows cultivated fields indicative of active agricultural irrigation, while the July 2014 photograph demonstrates irrigation has not occurred on much of the lands for several years, including CY 2014, and that some (non-irrigated) natural vegetation has replaced previously cultivated/irrigated fields. These naturally vegetated areas are located in the heart of the Muddy River Springs Area. This vegetation is being supported directly by groundwater seeps and the relatively shallow depths to groundwater. Since acquiring the WSNA property in September 2007, SNWA has ensured that none of the fields associated with either the LDS Church lease or the Cox and Mitchell rights were irrigated during CY 2014.

Figures 3-2 through Figure 3-5 demonstrate that lands associated with the 2,001 afy LDS Church lease as well as the 111 afy Cox and Mitchell rights remained fallowed during CY 2014. The 2,112 af of conserved water remained in the mainstream of the Muddy River and flowed downstream to the Glendale gage and then to Lake Mead. The conveyance of these rights from the Glendale gage to Lake Mead is accounted for in the calculations for the Lower Muddy River in subsequent sections of this report.

3.2.2 Moapa Band of Paiute Indians Lease

From CY 2009 through 2013, SNWA leased up to 3,700 af of pre-BCPA Muddy River consumptive use water rights controlled by the Moapa Band of Paiute Indians (MBPI). This lease expired at the end of CY 2013 and was not renewed for CY 2014. Therefore, no ICS was created from the Paiute water right for CY 2014.

3.2.3 Hidden Valley Purchase

In 2008, SNWA purchased 1,040 af of decreed Muddy River water rights along an upper reach of the Muddy River commonly referred to as Hidden Valley. The full volume of water available under the water-right certificate is 1,366 af; therefore, the land owner retained approximately 326 af. Figure 3-7 depicts a 1918 map showing the locations where the water right was originally put to beneficial use. The red outline on the map highlights the Public Land Survey System Quarter-Quarter sections that are included in the POU description in the Muddy River Decree. Figures 3-8 through Figure 3-10 compare the POU for the Hidden Valley lands with the aerial photography taken in December 2013, July 2014, and December of 2014, respectively.

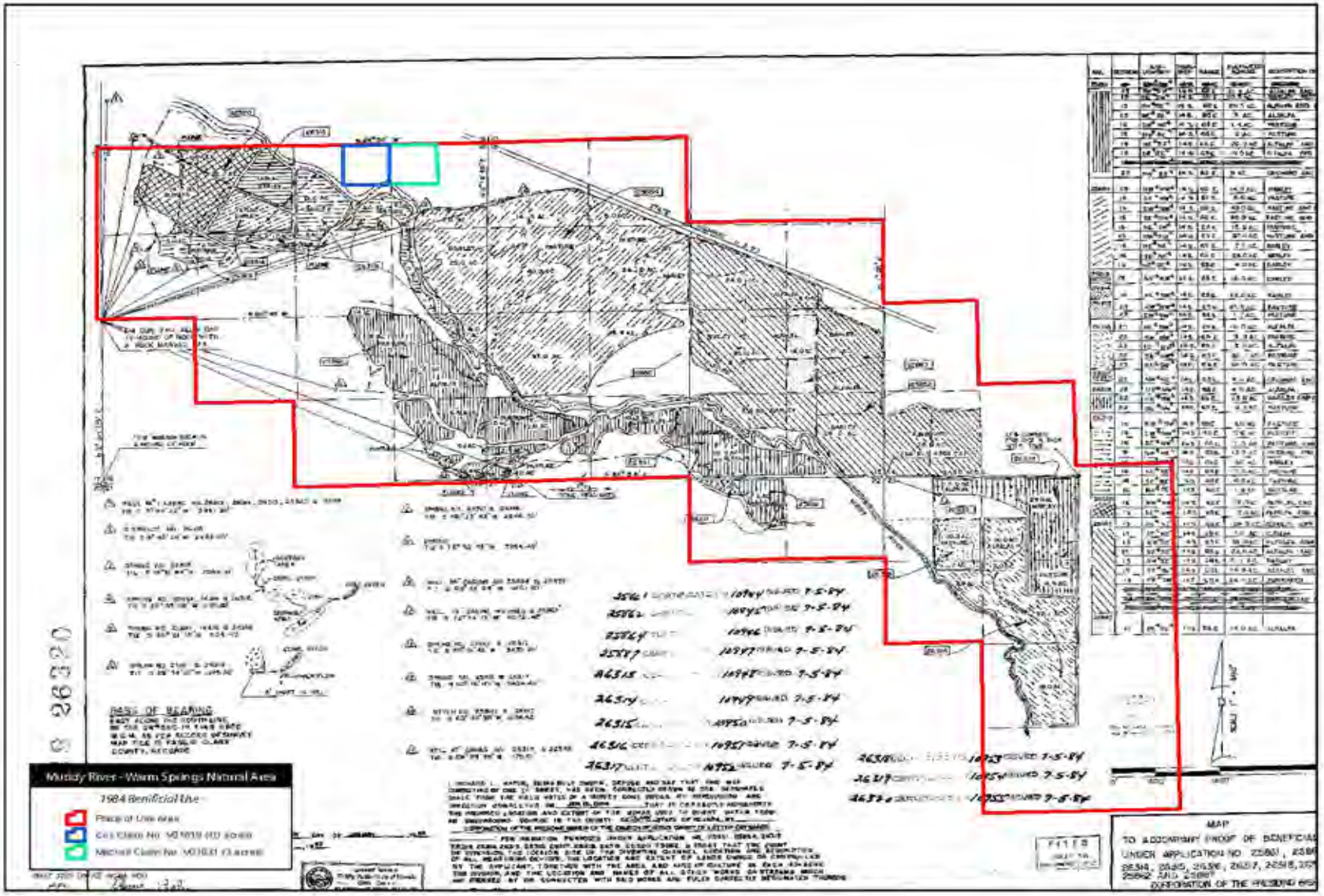


Figure 3-2
LDS Church Water Rights 1984 PBU Map; POU Quarter-Quarter Sections for LDS Church Rights Highlighted in Red; Cox and Mitchell Rights Highlighted in Blue and Green, Respectively

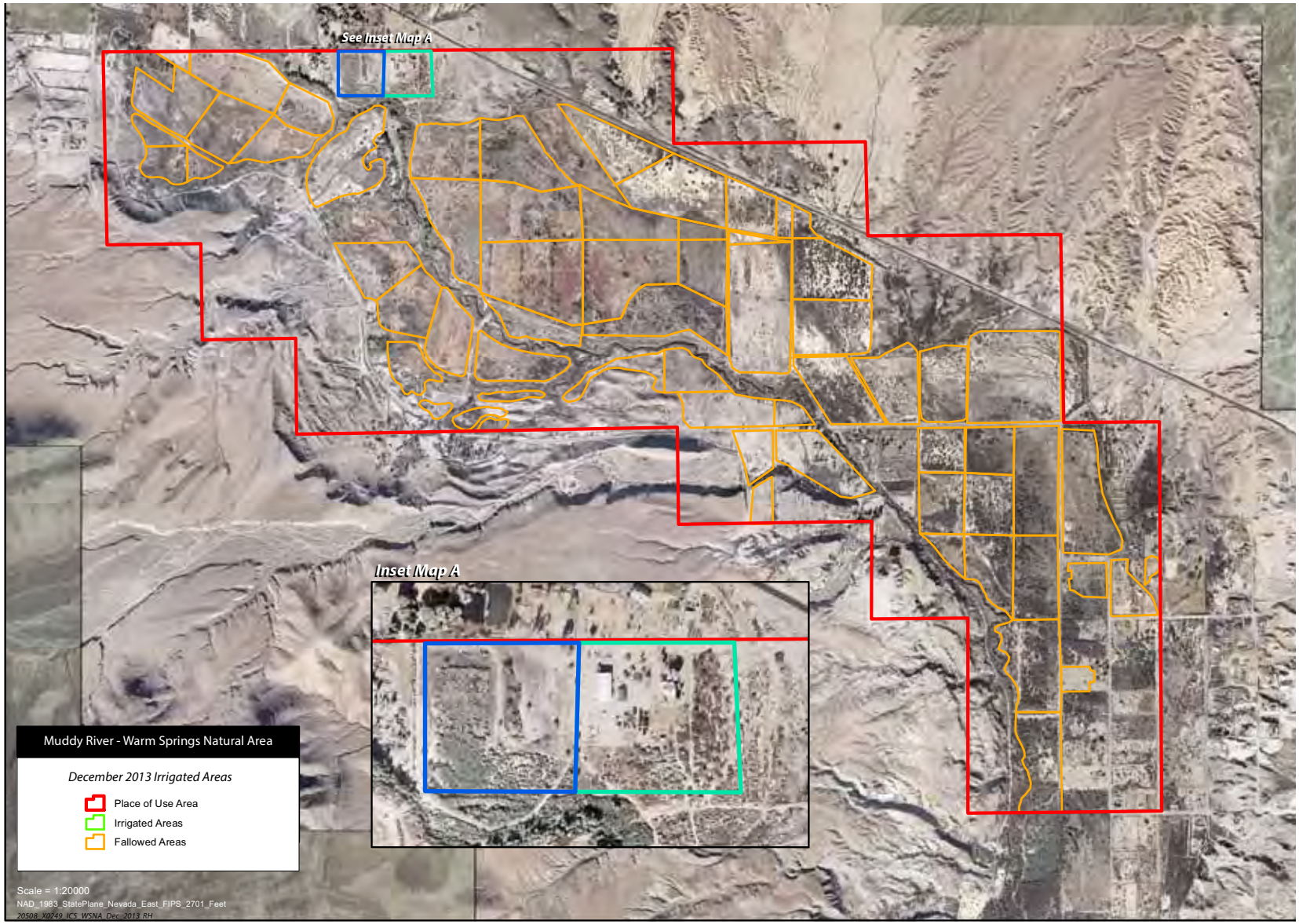


Figure 3-3
December 2013 Aerial Photography for LDS Church, Cox, and Mitchell Rights

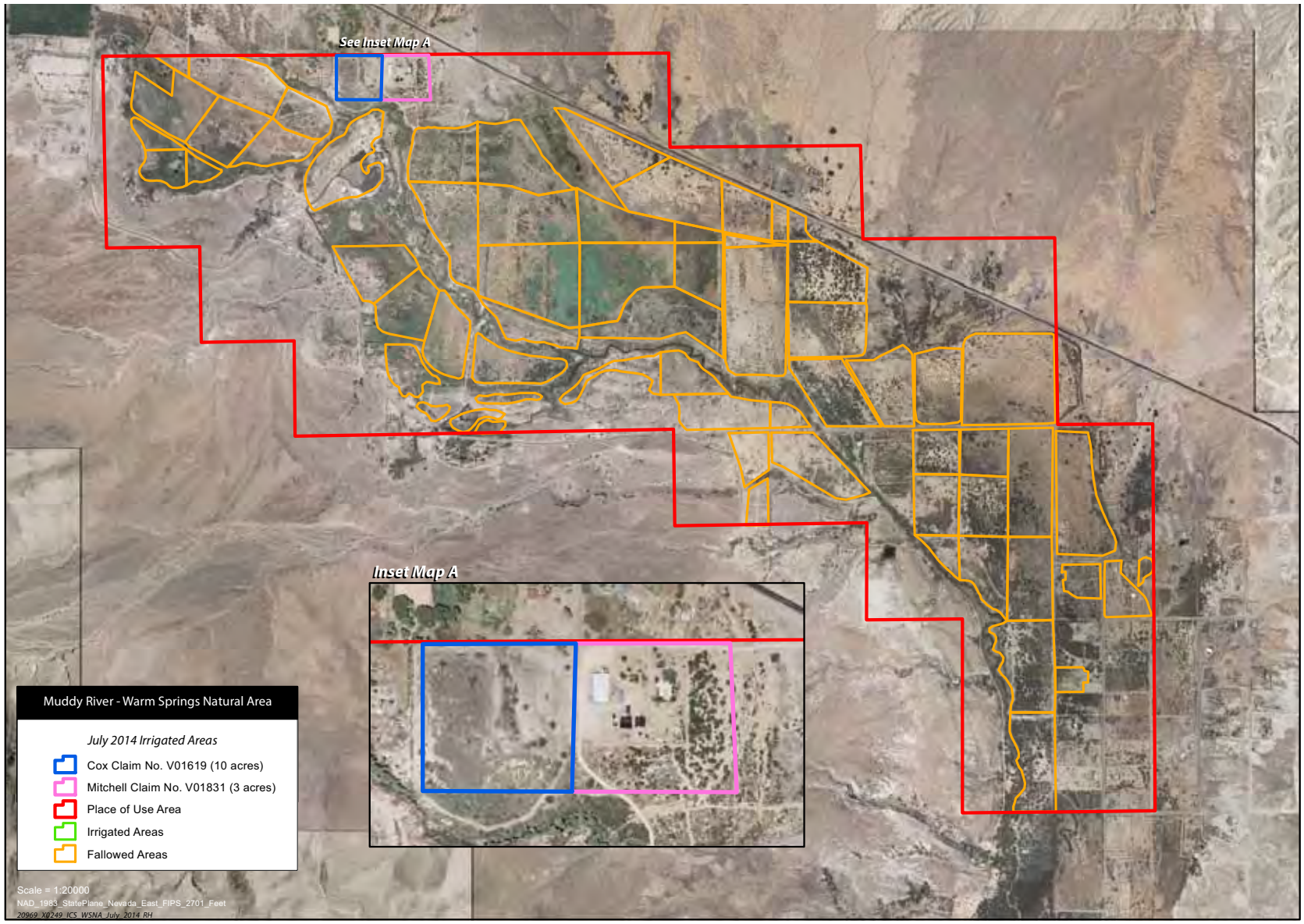


Figure 3-4
July 2014 Aerial Photography for LDS Church, Cox, and Mitchell Rights

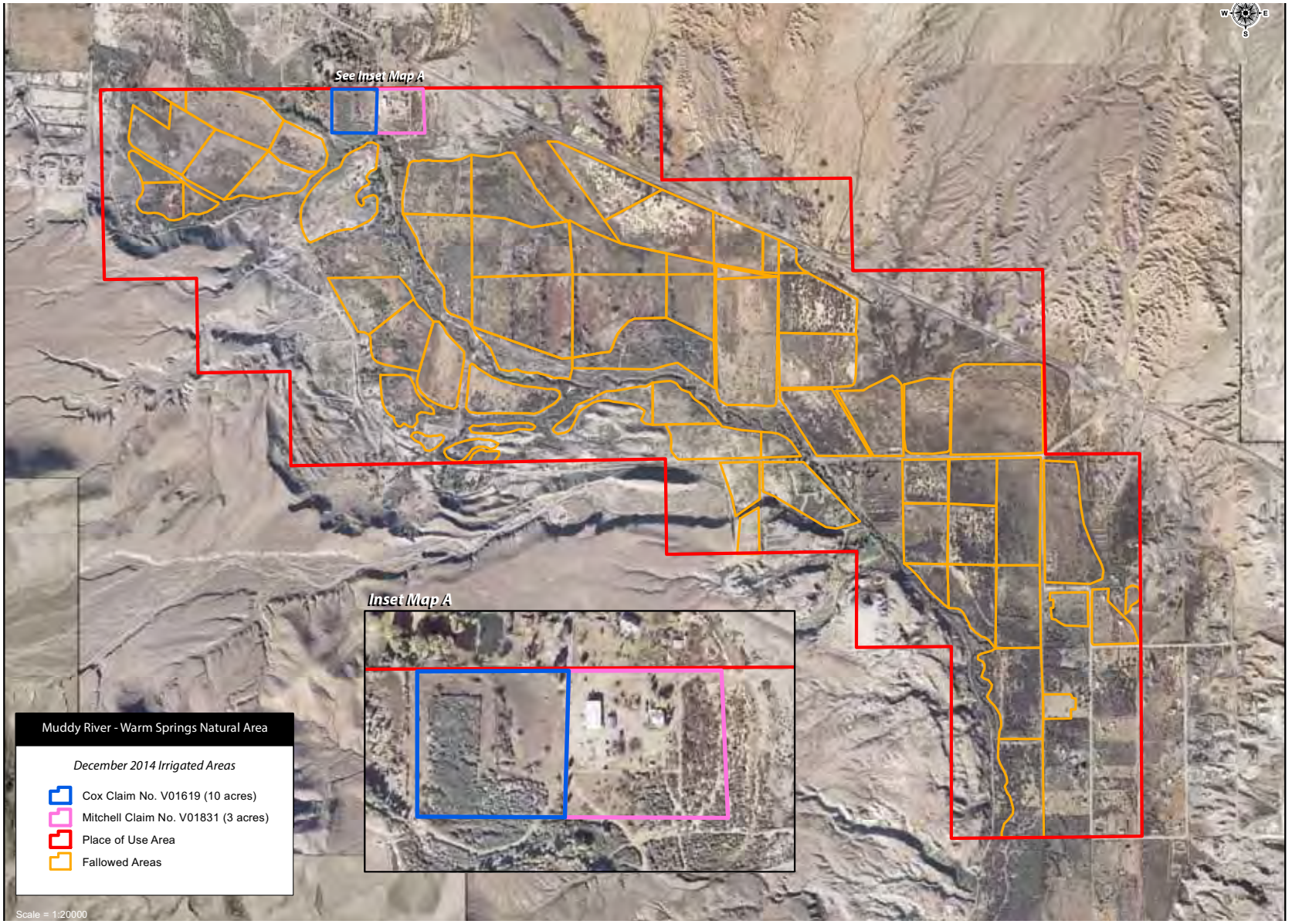


Figure 3-5
December 2014 Aerial Photography for LDS Church, Cox, and Mitchell Rights

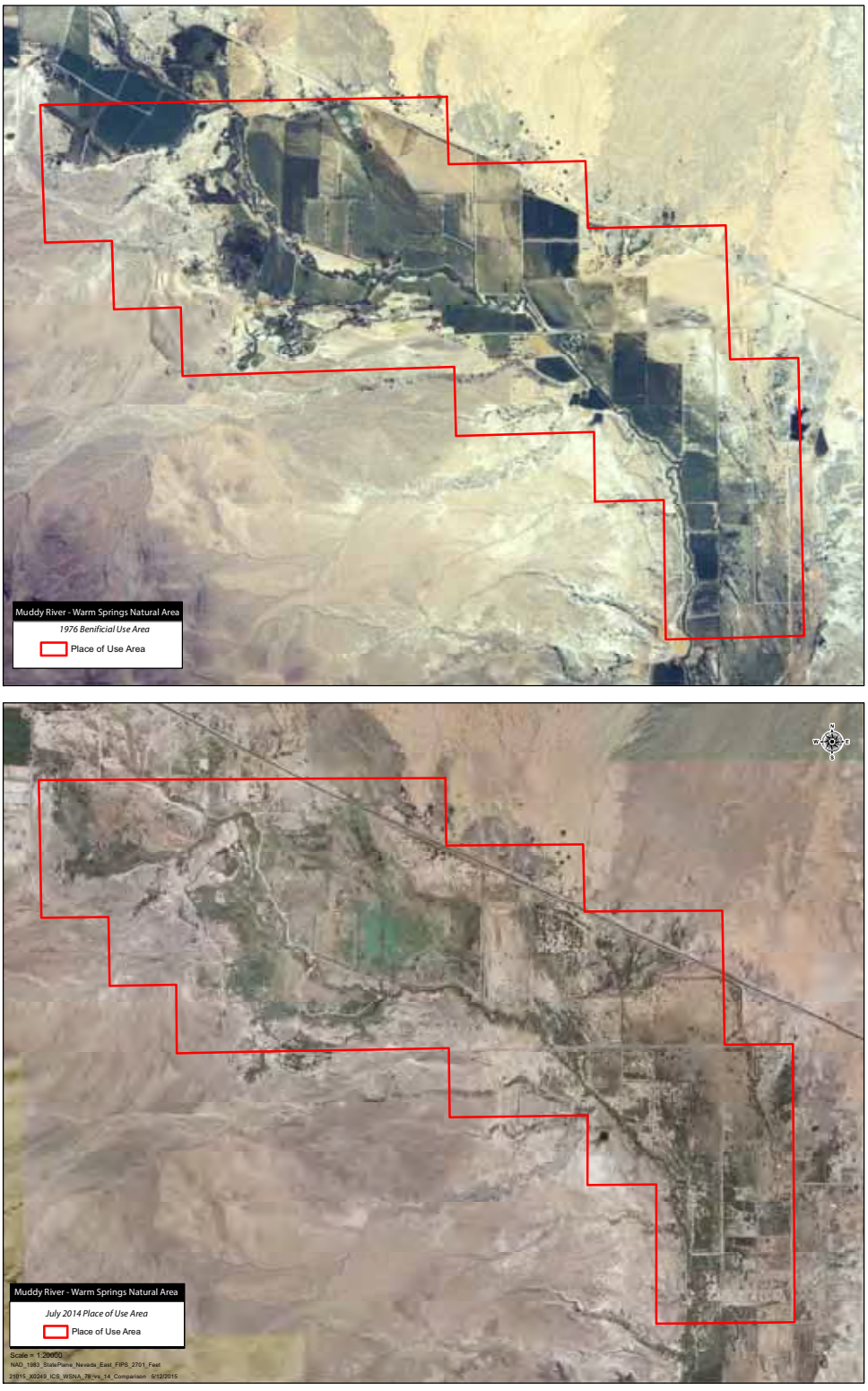


Figure 3-6
POU for the LDS Church Water Rights Overlaid on a 1976 Aerial Photograph (Top), and the July 2014 Aerial Photograph (Bottom)

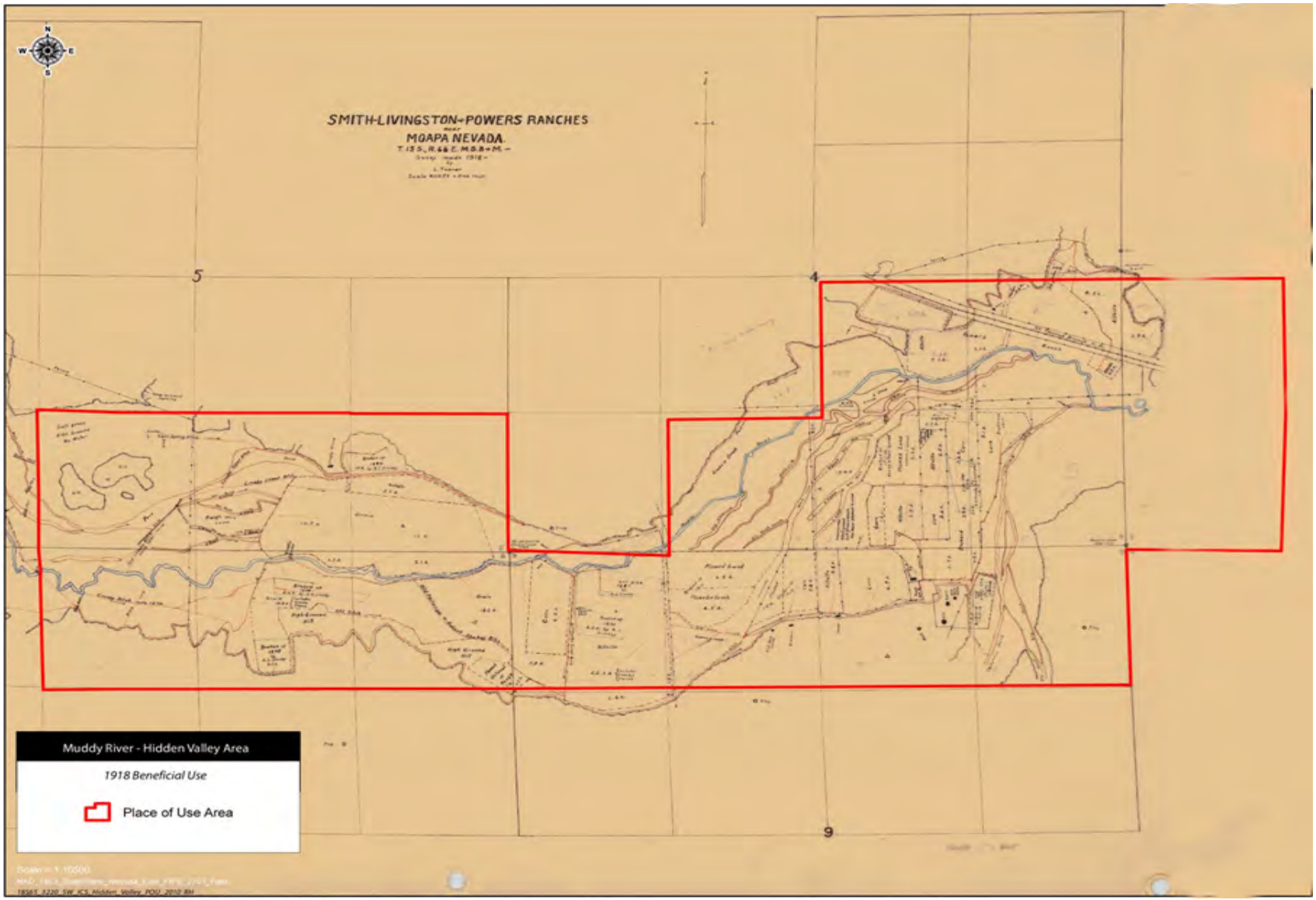


Figure 3-7
Hidden Valley PBU Map, POU Quarter-Quarter Sections Highlighted in Red

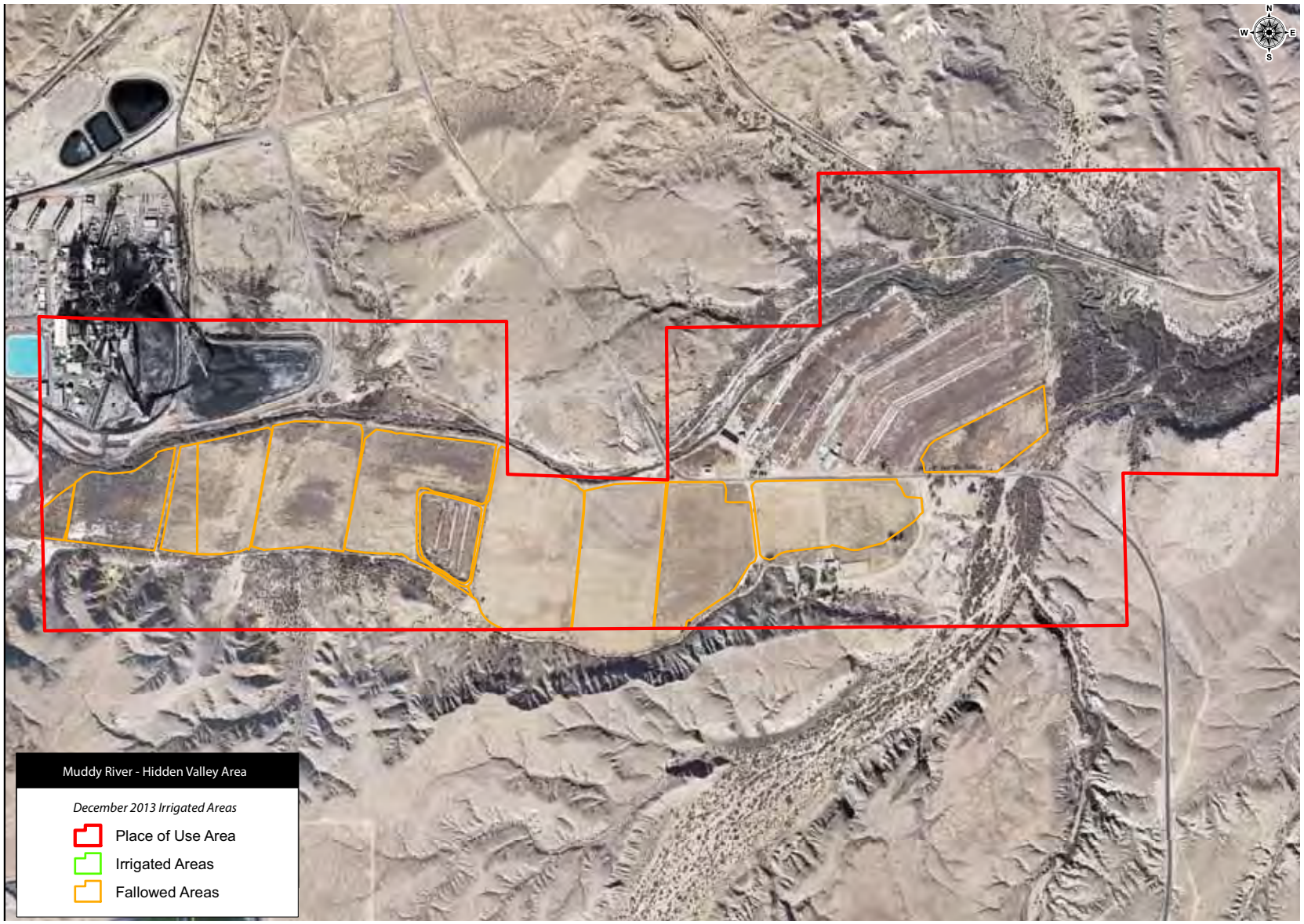


Figure 3-8
Hidden Valley December 2013 Aerial Photography

SE ROA 46137

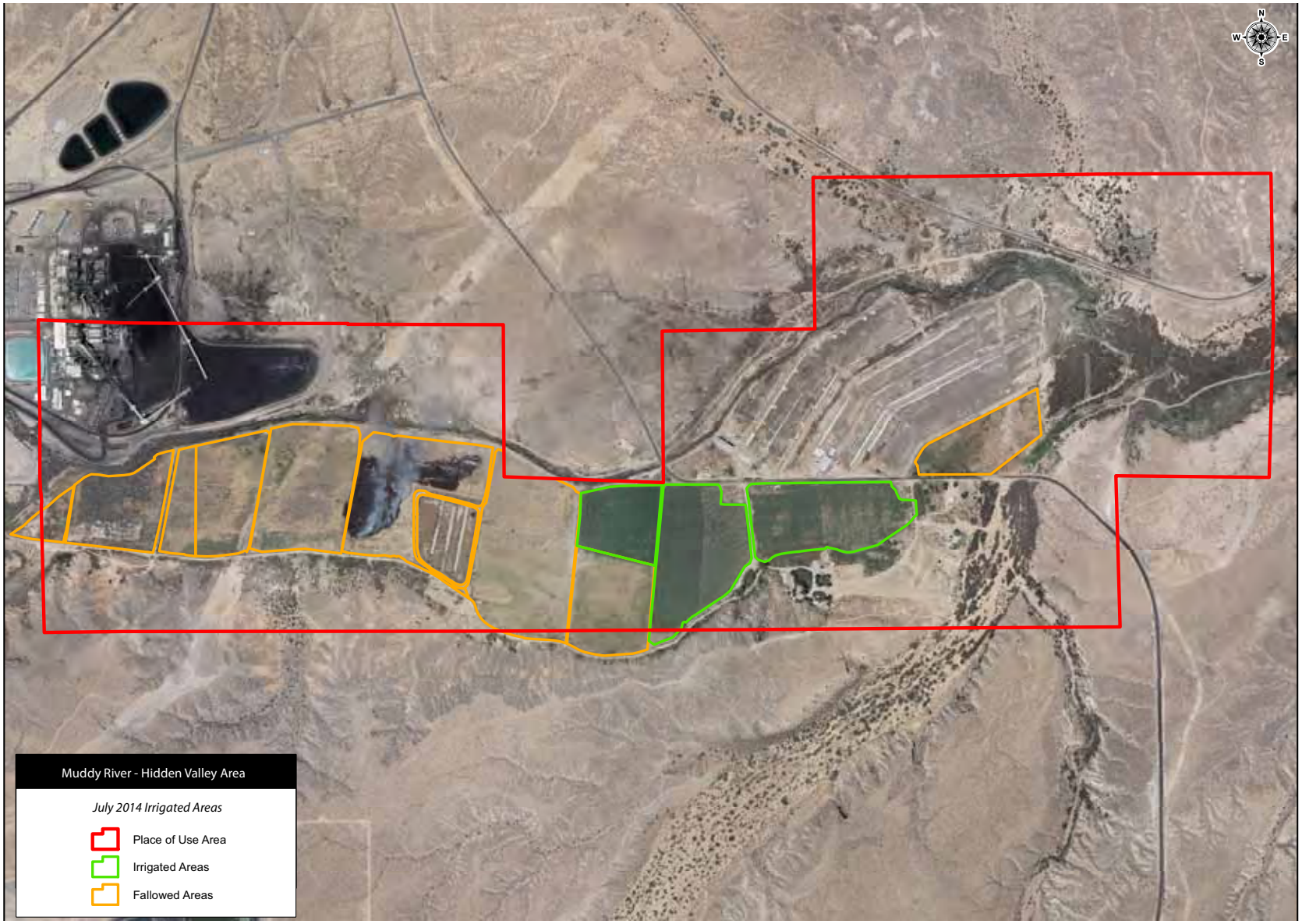


Figure 3-9
Hidden Valley July 2014 Aerial Photography

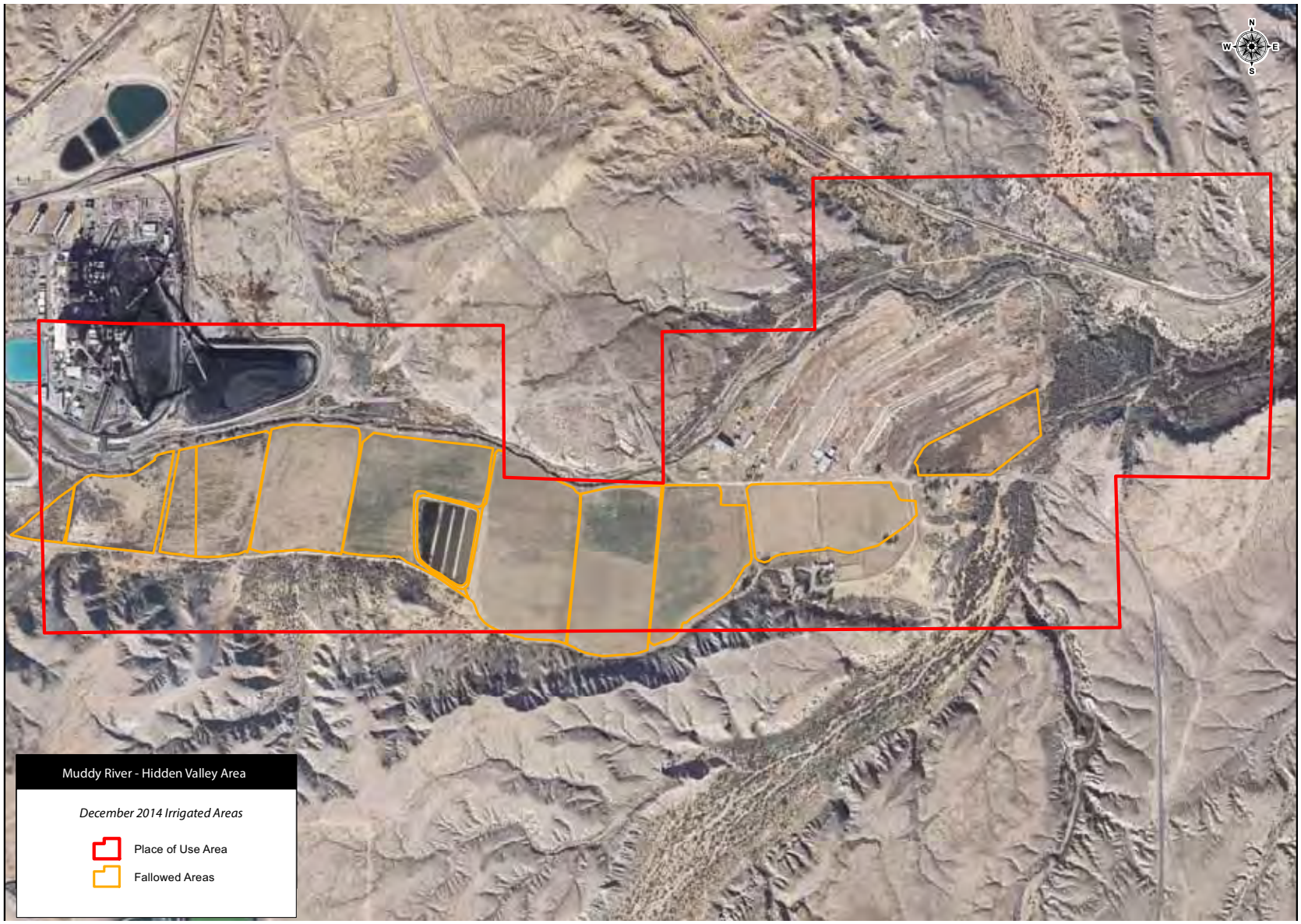


Figure 3-10
Hidden Valley December 2014 Aerial Photography

Table 3-1 details the calculations used to determine the monthly duty of water applied to irrigable lands in the Hidden Valley area along with the volume of Muddy River water conserved through non-use. As indicated in Table 3-1, 1,040 af of water was conserved in 2014.

3.2.4 MVIC Lease /NV Energy Sub-Lease

Since 2009, SNWA has leased 3,000 afy of winter (October-April) water rights from MVIC, and subleased a portion of the rights to NV Energy (NVE). The 3,000 afy had been previously leased from MVIC directly by NVE, from 1967 to 2009, for use at the NVE Reid Gardner Generating Station (Reid Gardner) located near Moapa, NV. Under agreements between SNWA, MVIC, and NVE, the 3,000 afy of MVIC water rights are assigned to SNWA, who then sub-leases the water to NVE. The lease agreements give NVE the ability to take only the amount of water they need and the remainder stays in the Muddy River as SNWA-controlled water rights which are eligible for ICS credits.

The change in the POU for the 3,000 afy from MVIC to Reid Gardner is documented under NDWR Certificates 7316 and 13851, and required the fallowing of agricultural land within MVIC equivalent to the 3,000 afy transfer. NVE's diversion of the subleased water rights is located at the Reid Gardner Muddy River diversion just upstream of the USGS gaging station *09416000 Muddy River near Moapa, NV.*

During the winter seasons, NVE submits monthly meter readings and lease payments to SNWA documenting the amount of water that NVE diverted from the river. Table 3-2 lists these diversion values. The diversion values are subtracted from the total potential amount of water that can be diverted for that month under the water right. The difference (Row E) of 2,508 af for CY 2014 is the amount of SNWA controlled water that remained in the Muddy River and is eligible for ICS credit. The water-right certificates associated with the meter data received from NVE can be found in Appendix E.

3.2.5 Knox and Holmes Water Right Purchase

In 2008, SNWA purchased 811.28 afy of Muddy River decreed water rights which are documented in the decree as Vested Proof No. 01620 under the names Knox and Holmes. Until 1975, these water rights were used for agricultural irrigation on the decreed POU as depicted in Figure 3-11.

In 1975, the decreed agricultural rights were leased by NVE for use at Reid Gardner and a change application was filed with the NDWR to change the POU of the Knox and Holmes right to Reid Gardner. Subsequently, the NDWR issued Permit No.29295 and corresponding Certificate No. 9609 based on the change application.

In 1985, the owners of the land previously irrigated with the Knox and Holmes Muddy River surface water rights applied for and were granted groundwater rights to irrigate the same land. In 2000, NDWR approved beneficial use of the groundwater rights based on pumping data and a field investigation by NDWR staff. Documents associated the permitted groundwater rights are in Appendix E.

Table 3-1
2014 Hidden Valley Water Rights

Notation	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2014 Total
	# Days	31	28	31	30	31	30	31	31	30	31	30	31	365
A	Total Permit 75247 POU (acres)	160	160	160	160	160	160	160	160	160	160.	160	160	
B	Duty of Hidden Valley Water Rights (af/acre)	0.6149	0.5554	0.6149	0.5951	0.8784	0.8501	0.8784	0.8784	0.8501	0.6149	0.5951	0.6149	8.54
C	Acres Being Irrigated in Permit 75247 POU	0.00	0.00	0.00	0.00	46.53	46.53	46.53	46.53	46.53	0.00	0.00	0.00	
D = A - C	Acres of Fallowed Land in Permit 75247 POU	160.00	160.00	160.00	160.00	113.47	113.47	113.47	113.47	113.47	160.00	160.00	160.00	
E = B * D	Water Conserved from Fallowed Acreage (af)	98.3816	88.8608	98.3816	95.208	99.6729	96.4576	99.6729	99.6729	96.4576	98.3816	95.208	98.3816	1,165.
F	Acre-Feet per Month of SNWA's Owned Right	88.3288	79.7808	88.3288	85.4795	88.3288	85.4795	88.3288	88.3288	85.4795	88.3288	85.4795	88.3288	1,040.
E > F	Is conservation ≥ than SNWA rights													Yes
	Total ICS Created (af)	**88.3288**	**79.7808**	**88.3288**	**85.4795**	**88.3288**	**85.4795**	**88.3288**	**88.3288**	**85.4795**	**88.3288**	**85.4795**	**88.3288**	**1,040**

Table 3-2
Nevada Energy Lease

Notation	Description	Jan	Feb	Mar	Apr	May - Sept	Oct	Nov	Dec	2014 Total
	# Days	31	28	31	30		31	30	31	212
A	Cert 7316 Volume (af)	292.4528	264.1509	292.4528	283.0189		292.4528	283.0189	292.4528	2,000
B	Cert 13851 Volume (af)	146.2264	132.0755	146.2264	141.5094	no diversions	146.2264	141.5094	146.2264	1,000
C = A + B	Total Volume (af)	438.6792	396.2264	438.6792	424.5283		438.6792	424.5283	438.6792	3,000
D	Water Use by NVE (af)	0.00	0.00	181.15	311.15		0.00	0.00	0.00	492
E = C - D	Water to Lake Mead for ICS (af)	438.6792	396.2264	257.5292	113.3783		438.6792	424.5283	438.6792	**2,508**

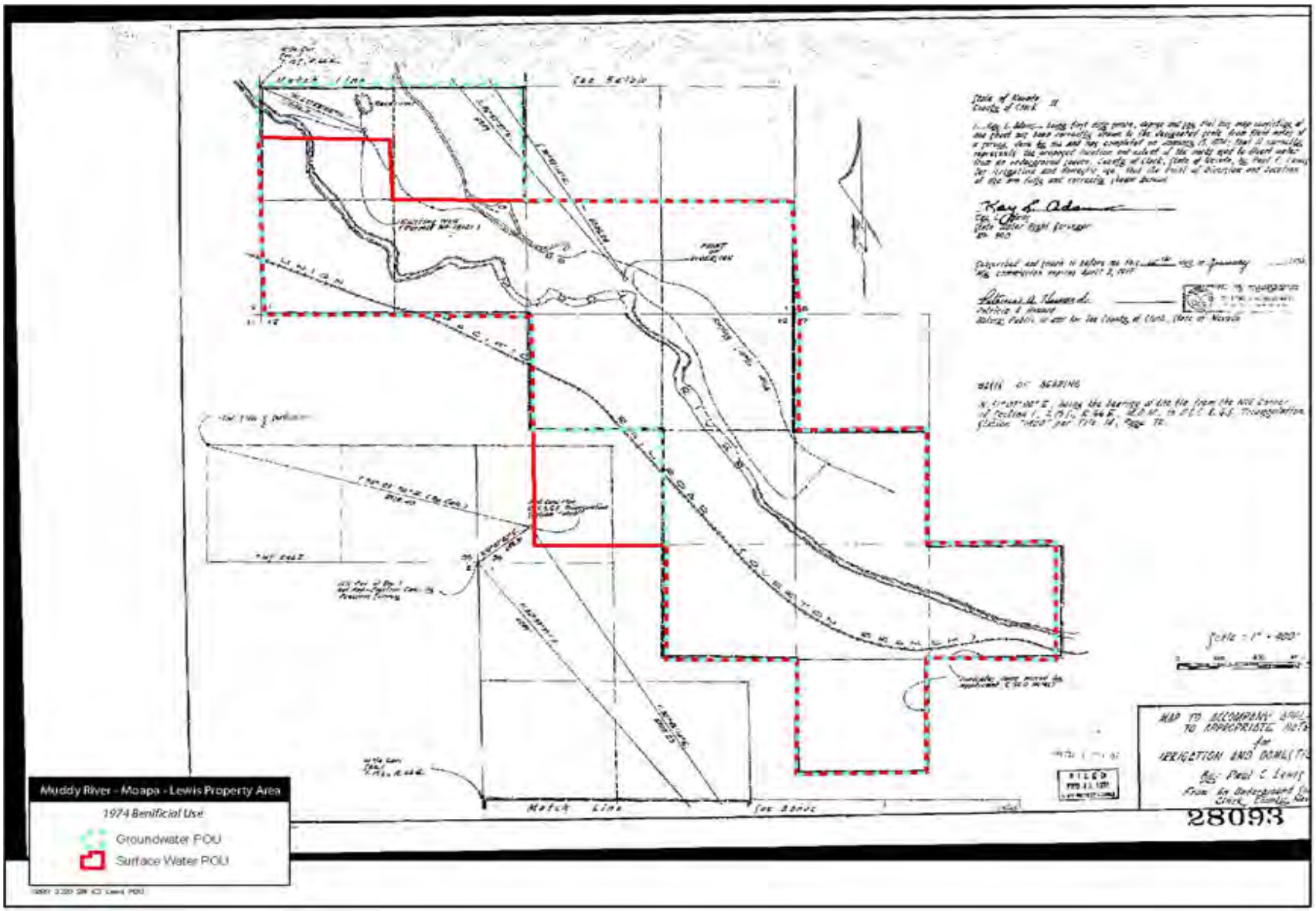


Figure 3-11
Former Surface Water POU for Permit 29295 and Current Groundwater POU for 48763

SE ROA 46143

The aerial images on Figures 3-12 through Figure 3-14 depict the fields and POU's fallowed as a result of the NVE lease and which are now irrigated with groundwater under groundwater Permit 48763. Under Nevada Revised Statutes the POU under Permit 48763 can only be irrigated with groundwater. Therefore, water represented by the Muddy River decreed Knox and Holmes surface water rights purchased by SNWA remain in the Muddy River and are eligible for ICS credits.

3.2.6 Upper Muddy River Water Rights Summary

Table 3-3 summarizes the 6,471 af of Upper Muddy River water rights controlled by SNWA in CY 2014 which were conveyed to Lake Mead for ICS credits. Included in the calculations for the LDS Church rights is the 45 afy that the LDS Church continues to hold, which was subtracted from the total LDS Church right to derive the SNWA controlled 2,001 afy. The current Certificates leased by SNWA are in Appendix E.

3.3 Lower Muddy River Rights Summary

The Lower Muddy River, for the purposes of this report, is defined as the reach from the Glendale gage to Lake Mead. Within this reach water rights are held by MVIC, which holds the largest quantity of decreed rights on the Muddy River. MVIC's service area begins downstream of the Glendale gage where MVIC diverts their decreed Muddy River water rights, and unused Upper Muddy River rights at their Wells Siding diversion structure (Wells Siding). MVIC delivers water to its shareholders through a network of concrete lined ditches and pipes.

MVIC decreed Muddy River water rights are owned by MVIC shareholders through ownership of shares of preferred and common MVIC stock. There are 2,432 preferred shares and 5,044 common shares in MVIC. Each share represents a pro-rata apportionment of the Muddy River decreed rights.

3.3.1 MVIC Water Rights Summary

This section summarizes the decreed Muddy River water rights owned by MVIC and the water represented by preferred and common shares.

In 1974, MVIC filed PBU maps for their decreed rights utilized along the Lower Muddy River. The certificates issued in 1974, based on the proofs can be found in Appendix F. Although these certificates were issued in 1974, they retain their original pre-1920 priority date. These PBU maps, when compared to recent aerial photography, serve as the baseline for proof of fallowed lands, demonstrating conservation of water supporting SNWA's accounting of Tributary Conservation ICS on the Lower Muddy River.

The irrigable lands along the Lower Muddy River under the 1974 PBU maps totaled 3,498.86 acres; however, the amount of land that can be irrigated under MVIC's water rights cannot exceed 2,784.75 acres with a decreed annual duty of 8.54 af/acre.

In addition to these decreed and certificated rights, the Muddy River decree states that the MVIC can divert any additional unused Muddy River flows that reach their diversion structure on the Muddy

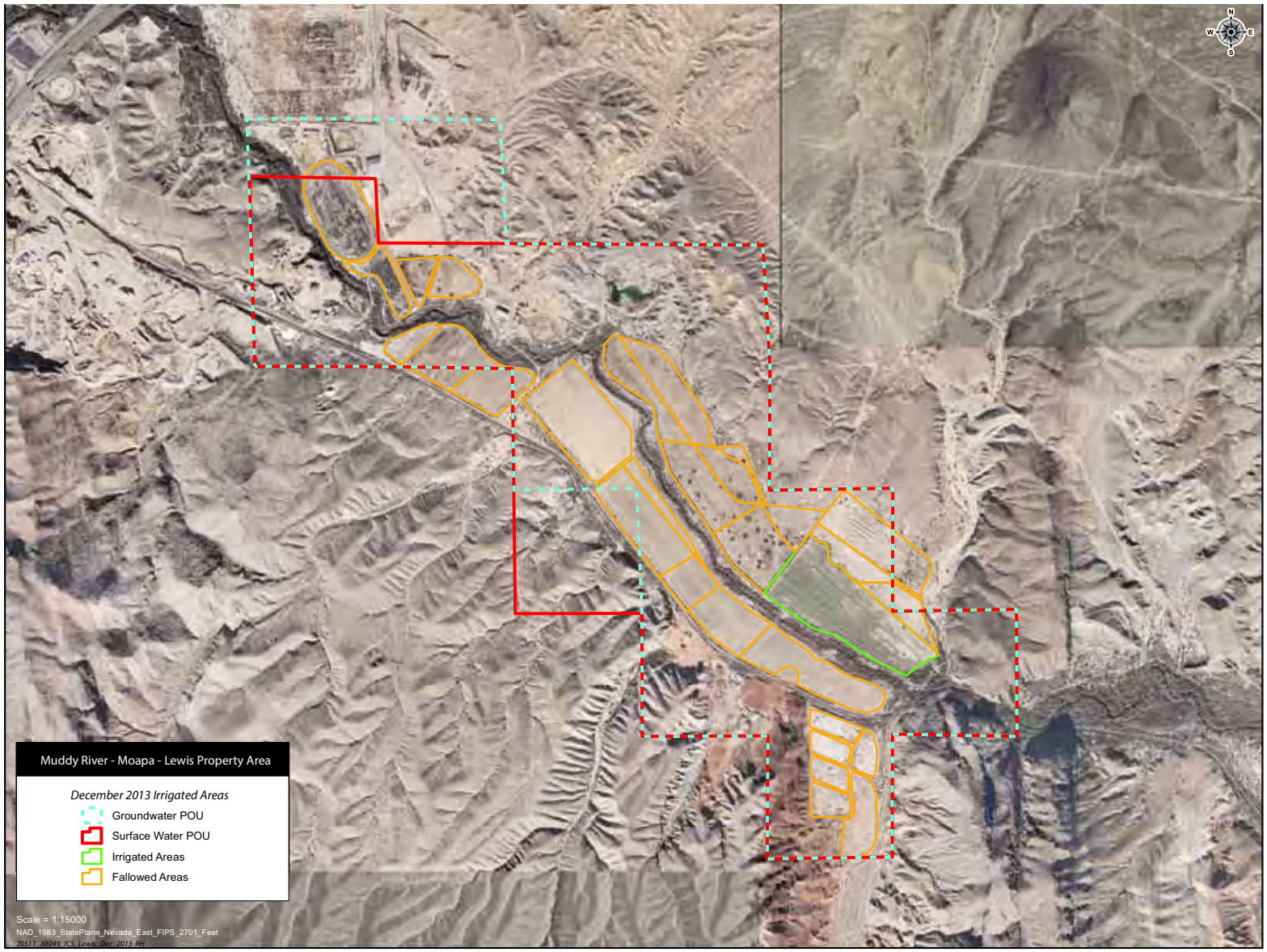


Figure 3-12
Knox and Holmes December 2013 Aerial Photography

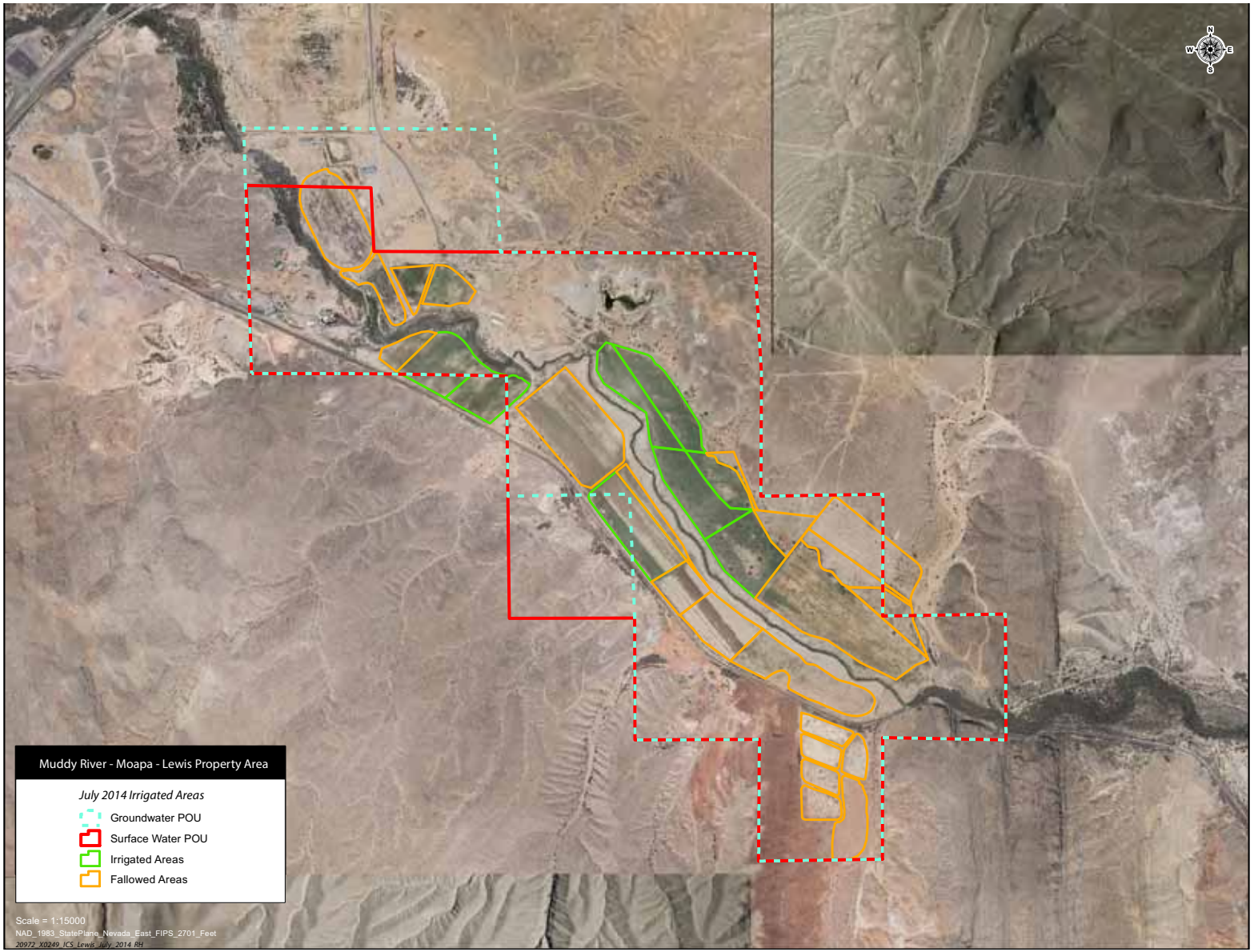


Figure 3-13
Knox and Holmes July 2014 Aerial Photography

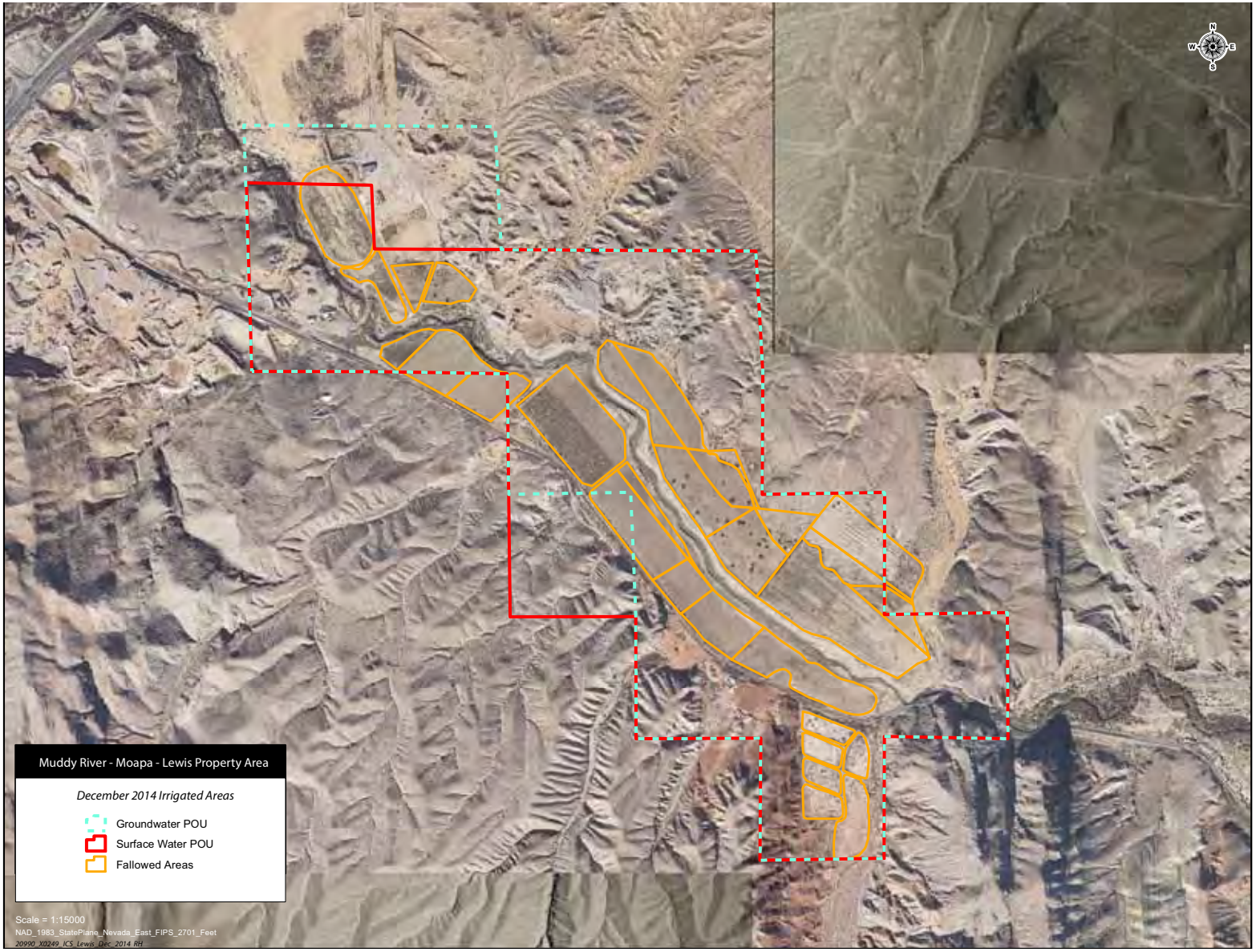


Figure 3-14
Knox and Holmes December 2014 Aerial Photography

Table 3-3
Upper Muddy River ICS Water Rights

Water Right	Data Source	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Total (afy)
	# Days	31	28	31	30	31	30	31	31	30	31	30	31	365
LDS Lease	Permit 6419	8.61	7.78	8.61	8.33	12.30	11.90	12.30	12.30	11.90	8.61	8.33	8.61	119.57
	Permit 25861	70.10	63.31	70.10	67.84	99.61	96.40	99.61	99.61	96.40	70.10	67.84	70.10	971.00
	Permit 26316	51.02	46.09	51.02	49.38	51.02	49.38	51.02	51.02	49.38	51.02	49.38	51.02	600.76
	Permit 26317	2.46	2.22	2.46	2.38	3.50	3.39	3.50	3.50	3.39	2.46	2.38	2.46	34.12
	Permit 26318	23.06	20.83	23.06	22.31	32.96	31.89	32.96	32.96	31.89	23.06	22.31	23.06	320.35
	Used by LDS	(3.24)	(2.93)	(3.24)	(3.14)	(4.63)	(4.48)	(4.63)	(4.63)	(4.48)	(3.24)	(3.14)	(3.24)	(45.00)
	LDS Lease Total	**152.01**	**137.30**	**152.01**	**147.10**	**194.77**	**188.48**	**194.77**	**194.77**	**188.48**	**152.01**	**147.10**	**152.01**	**2,001**
Cox	Decree	6.15	5.55	6.15	5.95	8.78	8.50	8.78	8.78	8.50	6.15	5.95	6.15	85
Mitchell	Decree	1.84	1.67	1.84	1.79	2.64	2.55	2.64	2.64	2.55	1.84	1.79	1.84	26
HV Dairy	Table 3-1	88.33	79.78	88.33	85.48	88.33	85.48	88.33	88.33	85.48	88.33	85.48	88.33	1,040
NVE Lease	Table 3-2	438.68	396.23	257.53	113.38	---	---	---	---	---	438.68	424.53	438.68	2,508
Knox and Holmes	Decree	58.41	52.76	58.41	56.53	83.45	80.76	83.45	83.45	80.76	58.41	56.53	58.41	811
Upper Total (af)		**745.42**	**673.28**	**564.27**	**410.23**	**377.96**	**365.77**	**377.96**	**377.96**	**365.77**	**745.42**	**721.38**	**745.42**	**6,471**

River. This makes the actual water that MVIC splits among its shareholders vary from year to year based on the actual divertible flows that reach Wells Siding.

MVIC's water rights are tied to their service area and not individually owned parcels. Therefore, the water rights associated with MVIC shares can be used anywhere within the MVIC service area, regardless of land ownership. So, the location of individual fields being irrigated is not as important as the total irrigated acreage within the MVIC POU.

Since the 1974 PBU maps were filed, land use along the Lower Muddy River has undergone a gradual transformation from predominately agricultural to a mix of residential and commercial property interspersed among the agriculture. This gradual urbanization can be seen on Figure 3-15, which compares aerial photography of the Lower Muddy River from October 1953 with aerial photography from July 2014.

The MVIC has and is leasing a portion of their decreed rights to users on the Upper Muddy River including water leased to the MVWD, which diverts the water from spring boxes in the Muddy River Springs Area for potable use. These leased rights are diverted and not returned to the Muddy River. Therefore, the flows measured at the Glendale gage account for these leased rights since the flows reaching the gage and Wells Siding have been depleted by these leases. In the same respect, unused water from MVIC's leases is measured by the Glendale gage and is available for diversion by MVIC.

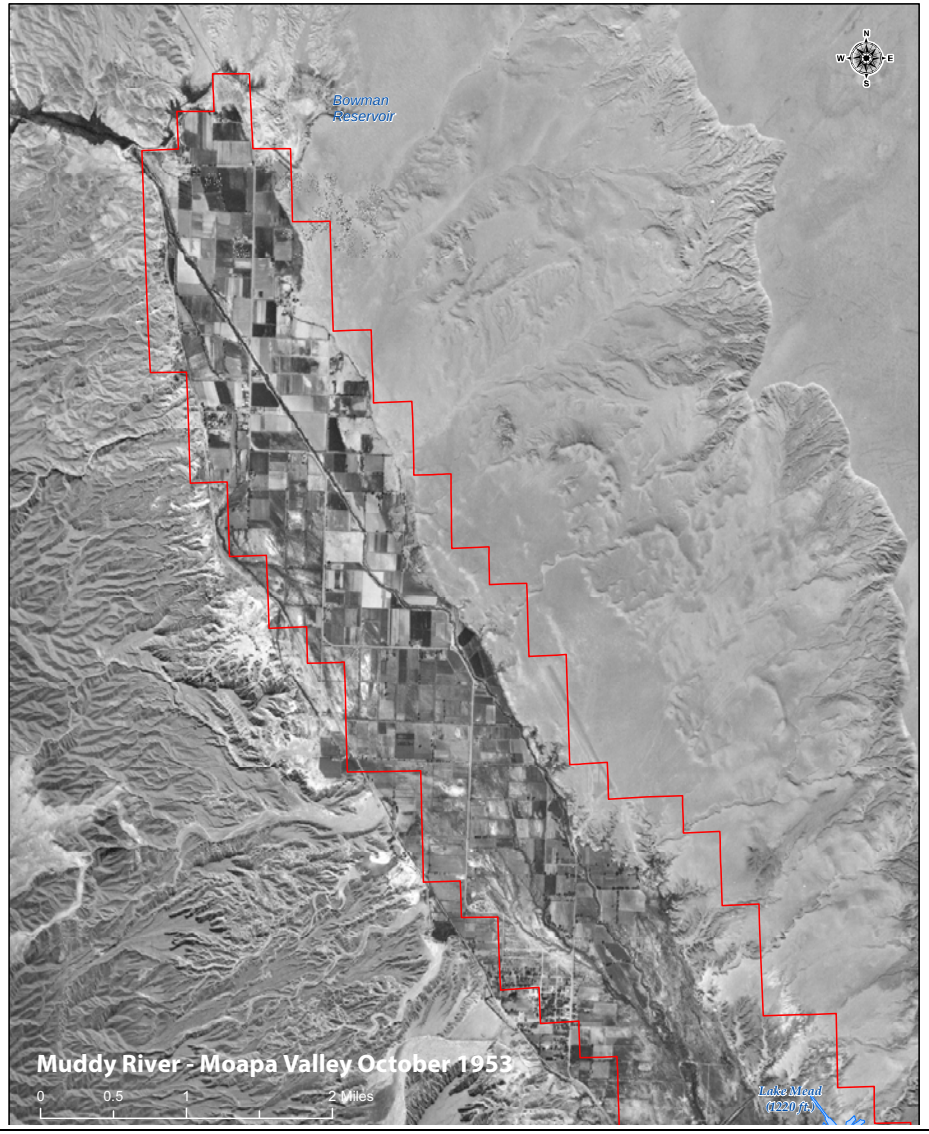
MVIC's operations and covenants define preferred shares as 100% of the Muddy River summer flow (May – September) plus 75% of the winter flow (October – April). Common shares represent the remaining 25% of the winter flow. The amount of water represented by preferred and common shares, therefore, varies slightly from year to year due to changes in unused Upper Muddy River rights and unused MVIC leases that reach Wells Siding. SNWA's Upper Muddy River rights may not be diverted by MVIC and are excluded from the af/shares calculations.

3.3.2 Quantification of SNWA MVIC Water Rights

By the end of CY 2014, SNWA controlled a total of 978.2010 preferred and 2,808.7100 common MVIC shares. Since the amount of water represented by a share can vary annually, the volume of water that SNWA holds in MVIC can vary as well. To calculate the amount of water represented by each share in MVIC during CY 2014, the volume of water rights available to MVIC (referred to as divertible flows) must be determined, and this volume then distributed to each preferred and common share. This section details these calculations.

3.3.3 Divertible flows by MVIC at Wells Siding

Records from the Glendale gage, which is located just upstream of Wells Siding, have been used to derive the amount of divertible flows that reach the diversion. The divertible flows at Wells Siding, equate to the flows at the Glendale gage (Table 3-4) less: (1) channel losses from ET between the Glendale gage and Wells Siding; (2) flood flows that exceed the Wells Siding capacity (approximately 70 cfs); and (3) SNWA Upper Muddy River rights being conveyed to Lake Mead for Tributary Conservation ICS credit (Table 3-3).



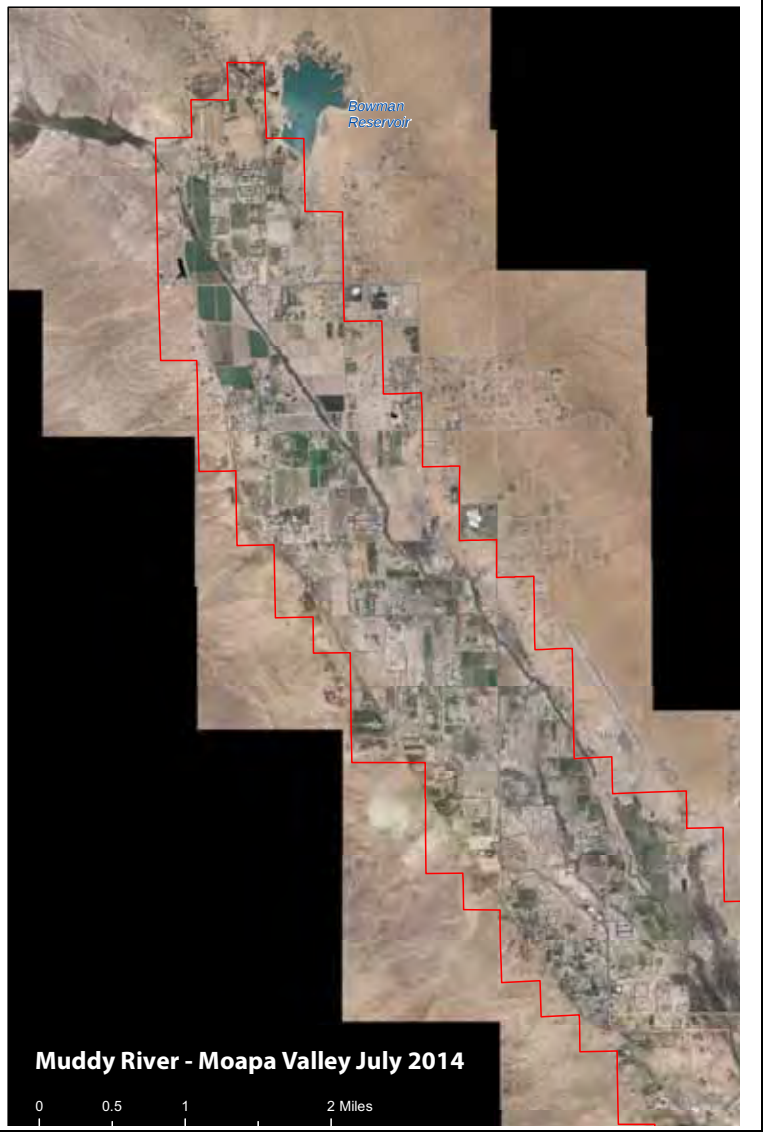


Figure 3-15
Lower Moapa Valley 1953 (left) and July 2014 (right)

Table 3-4
Mean Daily Flows for USGS Muddy River near Glendale Gage (09419000) (cfs)

Day	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Total
1	43	39	38	35	35	34	30	31	34	72	43	43	
2	43	39	38	35	35	34	30	31	33	55	43	43	
3	43	39	37	36	35	33	30	35	34	46	43	44	
4	43	39	36	36	37	32	30	241	33	43	43	44	
5	44	39	36	36	37	32	31	40	34	46	45	43	
6	43	39	36	38	36	31	31	39	34	46	44	43	
7	43	39	36	36	36	31	31	38	36	42	44	41	
8	43	39	35	36	35	32	31	38	836	39	43	42	
9	42	39	35	37	35	32	31	37	1,950	38	42	42	
10	42	39	35	36	36	31	31	38	95	38	43	43	
11	42	38	34	35	35	30	32	37	84	39	43	44	
12	42	38	35	35	35	30	31	36	51	39	43	44	
13	42	38	33	35	35	30	32	36	34	39	43	43	
14	42	38	33	35	35	30	32	35	41	40	43	42	
15	43	38	34	37	35	31	31	35	40	40	45	42	
16	42	38	34	38	35	31	31	35	41	41	44	42	
17	42	38	34	35	35	30	31	36	41	41	43	42	
18	42	38	34	36	35	30	31	36	42	42	43	44	
19	42	38	34	36	35	31	31	500	42	42	43	42	
20	41	38	34	35	35	31	32	95	42	43	43	42	
21	41	38	34	35	34	31	32	55	41	43	42	42	
22	41	37	35	35	34	31	32	46	42	43	42	42	
23	41	38	36	34	35	31	32	36	41	43	43	42	
24	41	37	35	34	35	30	32	35	40	43	43	42	
25	40	38	35	34	35	30	31	36	40	43	43	42	
26	40	37	34	34	35	30	32	35	104	43	43	41	
27	40	38	35	34	35	30	32	35	1,450	43	43	42	
28	39	38	34	35	34	30	33	34	703	43	43	43	
29	39	--	35	34	34	31	32	35	165	43	43	44	
30	39	--	35	34	34	31	31	34	97	43	43	44	
31	40	--	34	--	34	--	31	33	--	43	--	43	
Mean	42	38	35	35	35	31	31	60	210	43	43	43	
Median	42	38	35	35	35	31	31	36	41	43	43	42	
Count	31	28	31	30	31	30	31	31	30	31	30	31	
Minimum	39	37	33	34	34	30	30	31	33	38	42	41	
Maximum	44	39	38	38	37	34	33	500	1,950	72	45	44	
Total (af)	**2,560**	**2,120**	**2,150**	**2,100**	**2,150**	**1,850**	**1,920**	**3,700**	**12,500**	**2,670**	**2,570**	**2,620**	**38,910**

The ET losses between the Glendale gage and Wells Siding were determined to be 1,149 af, as discussed in subsequent sections. To subtract non-divertible flood flows, mean daily flows greater than 70 cfs were identified and replaced with 70 cfs, the maximum diversion rate at Wells Siding. Monthly and annual flow statistics were then recalculated with the non-divertible flood flows removed. In CY 2014, there were several monsoonal flooding events in August and September that resulted in flooding where flows were limited to 70 cfs for those dates (Table 3-5).

The flows for many of the upper rights were broken into monthly diversion volumes in Table 3-3. These monthly volumes were then subtracted from the Glendale gage flows on Table 3-4 prior to estimating the amount of water pro-rated to the MVIC shares.

The annual Glendale gage flows for CY 2014 were therefore reduced by 1,149 af for ET and 6,471 af for SNWA's Upper Muddy River rights to derive the volume of divertible flow.

3.3.4 MVIC Acre-Feet per Share Calculations

Table 3-6 summarizes the percent of divertible flows available to each MVIC share class. Using the divertible flows derived for CY 2014 listed in Table 3-5, the acre-foot per share value for preferred and common shares was calculated and is listed in Table 3-7.

3.3.5 MVIC Water Controlled by SNWA

The amount of MVIC water controlled by SNWA is calculated using the derived acre-foot per share values listed in Table 3-7. To account for month-to-month variability in SNWA controlled MVIC water rights due to purchases, leases, and leasebacks of purchased shares to original sellers, Table 3-8 lists SNWA's controlled water rights in af/month. A letter of concurrence signed by Scott Millington, MVIC General Manager (Appendix G) certifies that SNWA controlled the number of shares outlined in Table 3-8 during CY 2014. The preferred and common acre-foot per share values were divided by the number of months in which they can be used; 12-months for preferred shares and 7-months for common shares. The shares controlled by SNWA during each month (using only the number of shares controlled for the entire month) are multiplied by the acre-foot per share per month to obtain an acre-foot value of MVIC water controlled by SNWA per month for CY 2013.

The MVIC shares controlled by SNWA were either not diverted into the MVIC distribution system at Wells Siding, thus staying in the Muddy River, or allowed to be diverted into the MVIC system for the purpose of maintaining head on the ditches before being returned back to the mainstream of the Muddy River. Any water represented by SNWA controlled shares, which was diverted at Wells Siding, is included on MVIC's seasonal (winter and summer) water schedules (Appendix H). Based on these schedules, SNWA received a "turn" on the various ditches, and SNWA's shares were delivered to the Muddy River channel.

Table 3-5
Mean Daily Flows for USGS Muddy River near Glendale Gage (09419000) (70 cfs Limit)

Day	Jan-14	Feb-14	Mar-14	Apr-14	May-14	Jun-14	Jul-14	Aug-14	Sep-14	Oct-14	Nov-14	Dec-14	Total
1	43	39	38	35	35	34	30	31	34	**70**	43	43	
2	43	39	38	35	35	34	30	31	33	55	43	43	
3	43	39	37	36	35	33	30	35	34	46	43	44	
4	43	39	36	36	37	32	30	**70**	33	43	43	44	
5	44	39	36	36	37	32	31	40	34	46	45	43	
6	43	39	36	38	36	31	31	39	34	46	44	43	
7	43	39	36	36	36	31	31	38	36	42	44	41	
8	43	39	35	36	35	32	31	38	**70**	39	43	42	
9	42	39	35	37	35	32	31	37	**70**	38	42	42	
10	42	39	35	36	36	31	31	38	**70**	38	43	43	
11	42	38	34	35	35	30	32	37	**70**	39	43	44	
12	42	38	35	35	35	30	31	36	51	39	43	44	
13	42	38	33	35	35	30	32	36	34	39	43	43	
14	42	38	33	35	35	30	32	35	41	40	43	42	
15	43	38	34	37	35	31	31	35	40	40	45	42	
16	42	38	34	38	35	31	31	35	41	41	44	42	
17	42	38	34	35	35	30	31	36	41	41	43	42	
18	42	38	34	36	35	30	31	36	42	42	43	44	
19	42	38	34	36	35	31	31	**70**	42	42	43	42	
20	41	38	34	35	35	31	32	**70**	42	43	43	42	
21	41	38	34	35	34	31	32	55	41	43	42	42	
22	41	37	35	35	34	31	32	46	42	43	42	42	
23	41	38	36	34	35	31	32	36	41	43	43	42	
24	41	37	35	34	35	30	32	35	40	43	43	42	
25	40	38	35	34	35	30	31	36	40	43	43	42	
26	40	37	34	34	35	30	32	35	**70**	43	43	41	
27	40	38	35	34	35	30	32	35	**70**	43	43	42	
28	39	38	34	35	34	30	33	34	**70**	43	43	43	
29	39	--	35	34	34	31	32	35	**70**	43	43	44	
30	39	--	35	34	34	31	31	34	**70**	43	43	44	
31	40	--	34	--	34	--	31	33	--	43	--	43	
Mean	42	38	35	35	35	31	31	40	48	43	43	43	
Count	31	28	31	30	31	30	31	31	30	31	30	31	
Minimum	39	37	33	34	34	30	30	31	33	38	42	41	
Maximum	44	39	38	38	37	34	33	70	70	70	45	44	
Acre-Feet	2,560	2,120	2,150	2,100	2,150	1,850	1.920	2,450	2,870	2,660	2,570	2,620	28,020
Phreatophyte Consumptive Use Glendale to Wells Siding (af)	18	21	37	76	160	202	191	173	141	86	31	13	1,149
SNWA Upper Rights (af)	745	673	564	410	378	366	378	378	366	745	721	745	6,471
AF/Share Basis Volume (af)	**1,796**	**1,426**	**1,549**	**1,614**	**1,612**	**1,283**	**1,351**	**1,899**	**2,363**	**1,828**	**1,817**	**1,861**	**20,400**

Table 3-6
MVIC Share Classes and Divertible Flow Percentages

Share Type	Number of Shares	Percent of Summer Flow	Percent of Winter Flow
		(May - September)	(October - April)
Preferred	2,432	100%	75%
Common	5,044	0%	25%

Table 3-7
Acre-Foot per Share Calculation Results

Calendar Year	Jan - Apr and Oct - Dec Flows (af)	May - Sept Flows (af)	100% Summer and 75% Winter Flows (af)	25% Winter Flow (af)	Preferred-af Divided by 2,432 shares (af / share)	Common-af Divided by 5,044 shares (af / share)
2014	11,892	8,508	14,427	2,973	7.1657	0.5894

3.3.6 Land Fallowing within MVIC's POU

The December 2013, July 2014, and December 2014, 6-inch aerial photography has been used to determine the fallowed and irrigated acreage within MVIC's service area during the summer and winter seasons of CY 2014. For the January through April 2014 portion of the winter season, aerial photography from December 2013 was used to calculate the irrigated acreage within MVIC. The July 2014 imagery was used for the summer 2014 irrigation season (May 1 to September 30). For the winter irrigation season (October 1 to December 31), aerial photography from December 2014 was used to determine irrigated acreage.

Figure 3-16 illustrates MVIC's service area and depicts the extent of the 1974 PBU map which is composed of three individual maps. Figures 3-17 through Figure 3-19 depicts these PBU maps, Figures 3-20 through Figure 3-28 depict the December 2013, July 2014, and December 2014 aerial photography overlaid with the field-verified fallowed and irrigated acreage.

Table 3-9 details the irrigated and fallowed acreage by season (on a monthly basis) and crop type as measured and field-verified by SNWA. This acreage was verified by MVIC's General Manager during various meetings. Land determined not irrigable due to urbanization was derived by subtracting the measured irrigated and fallowed lands from the certificated maximum acreage within MVIC's POU of 2,784.75 acres.

Table 3-8
SNWA Controlled MVIC Shares in CY 2014

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Water Available to MVIC (AF From Table 4-2)	1,796	1,426	1,549	1,614	1,612	1,283	1,351	1,899	2,363	1,828	1,817	1,862	20,400
Acre-Feet Per Share Per Month													
Common (af/share)	0.0890	0.0707	0.0768	0.0800	0	0	0	0	0	0.0906	0.0901	0.0923	0.5894
Preferred (af/share)	0.5539	0.4397	0.4777	0.4977	0.6630	0.5274	0.5555	0.7809	0.9716	0.5638	0.5604	0.5741	7.1657
Owned by SNWA													
Common Shares	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	
Preferred Shares	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	
Leased Back to Seller													
Common Shares	441.7917	441.7917	441.7917	441.7917	441.7917	441.7917	441.7917	441.7917	441.7917	382.1667	382.1667	382.1667	
Preferred Shares	222.0417	222.0417	222.0417	222.0417	222.0417	222.0417	222.0417	222.0417	222.0417	198.1667	198.1667	198.1667	
Leased by SNWA													
Common Shares	384.2500	384.2500	384.2500	384.2500	384.2500	384.2500	384.2500	384.2500	384.2500	351.7500	351.7500	351.7500	
Preferred Shares	185.7830	185.7830	185.7830	185.7830	185.7830	185.7830	185.7830	185.7830	185.7830	167.2830	167.7830	167.7830	
Controlled = (Owned - Leased Back + Leased)													
Common Shares	2,781.5850	2,781.5850	2,781.5850	2,781.5850	2,781.5850	2,781.5850	2,781.5850	2,781.5850	2,781.5850	2.808.7100	2.808.7100	2.808.7100	
Preferred Shares	972.8260	972.8260	972.8260	972.8260	972.8260	972.8260	972.8260	972.8260	972.8260	978.2010	978.2010	978.2010	
Water Controlled (af) = (Shares Controlled x Acre Foot Per Share)													
Common (af)	247.6425	196.5658	213.5656	222.4966	0	0	0	0	0	254.5037	252.9749	259.1388	1,647
Preferred (af)	538.8907	427.7437	464.7366	484.1712	644.9601	513.0803	540.3924	759.7278	945.1747	551.5033	548.1903	561.5474	6,980
Total (af)	**786.5332**	**624.3095**	**678.3021**	**706.6678**	**644.9601**	**513.0803**	**540.3924**	**759.7278**	**945.1747**	**806.0070**	**801.1651**	**820.6863**	**8,627**

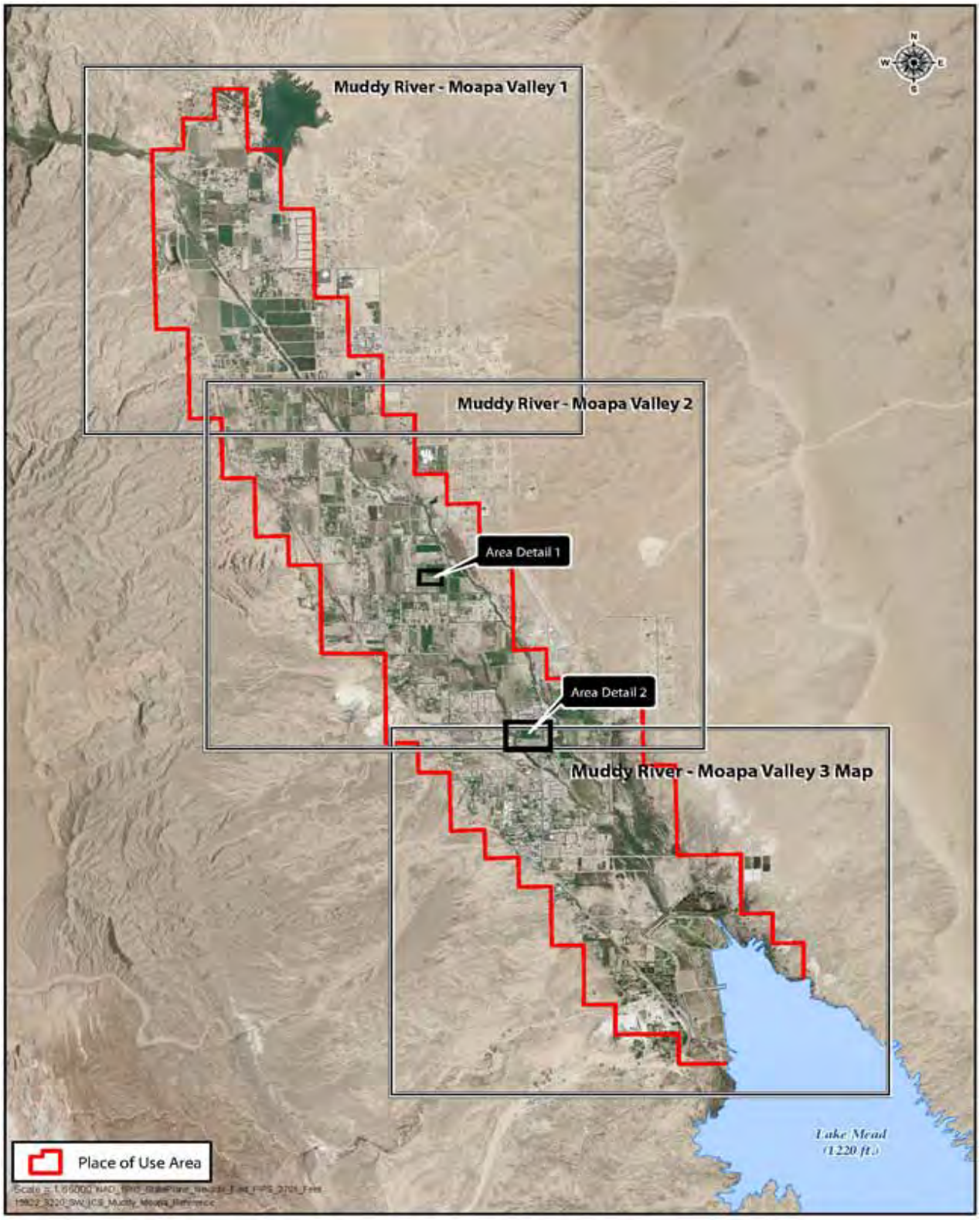


Figure 3-16
MVIC Service Area and Extent of PBU Maps and Location of the Detailed Photography on Figure 3-1

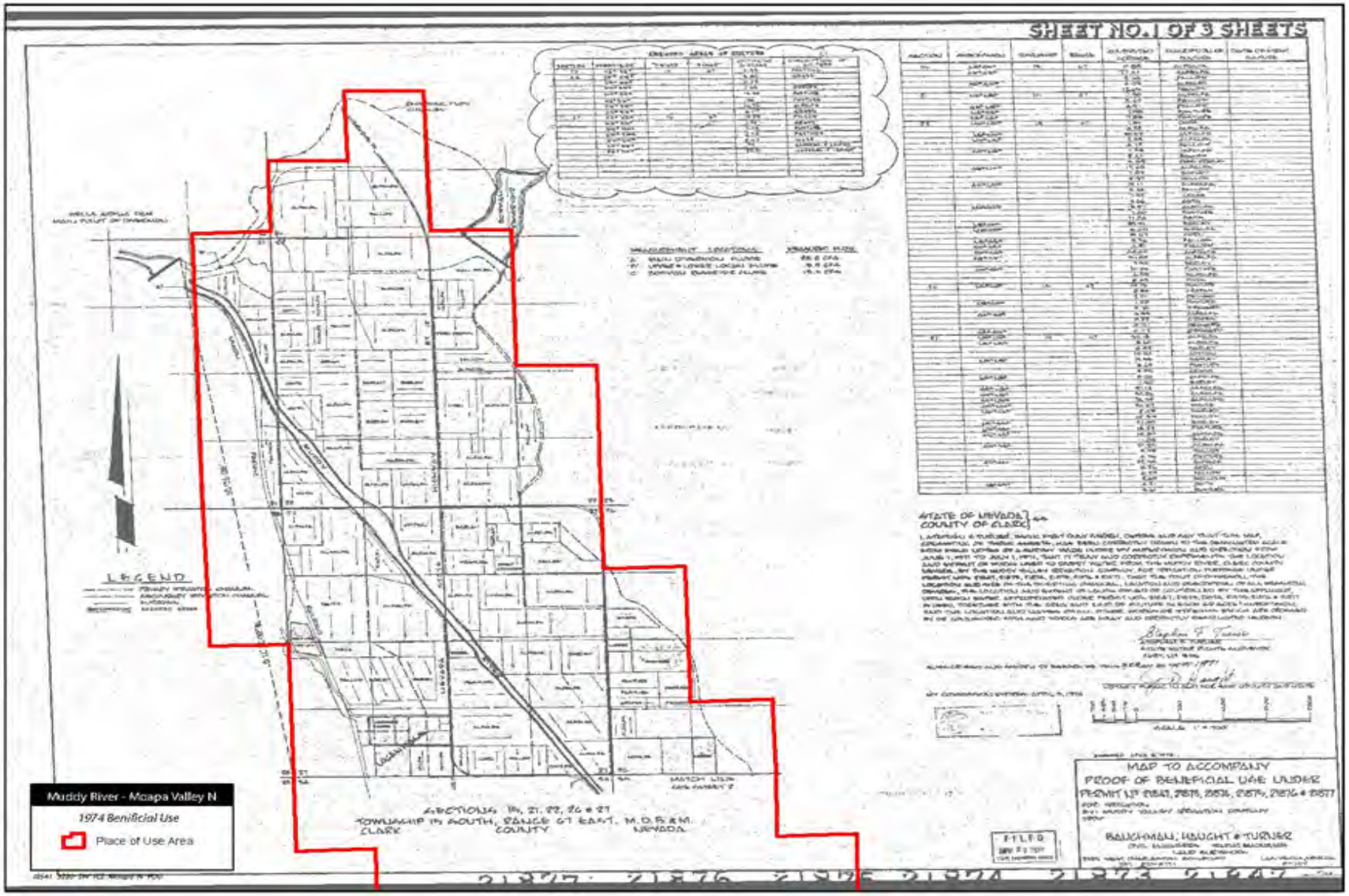


Figure 3-17
Upper Section of the MVIC Service Area Showing 1974 PBU.
POU Quarter-Quarter Sections Highlighted in Red

SE ROA 46157

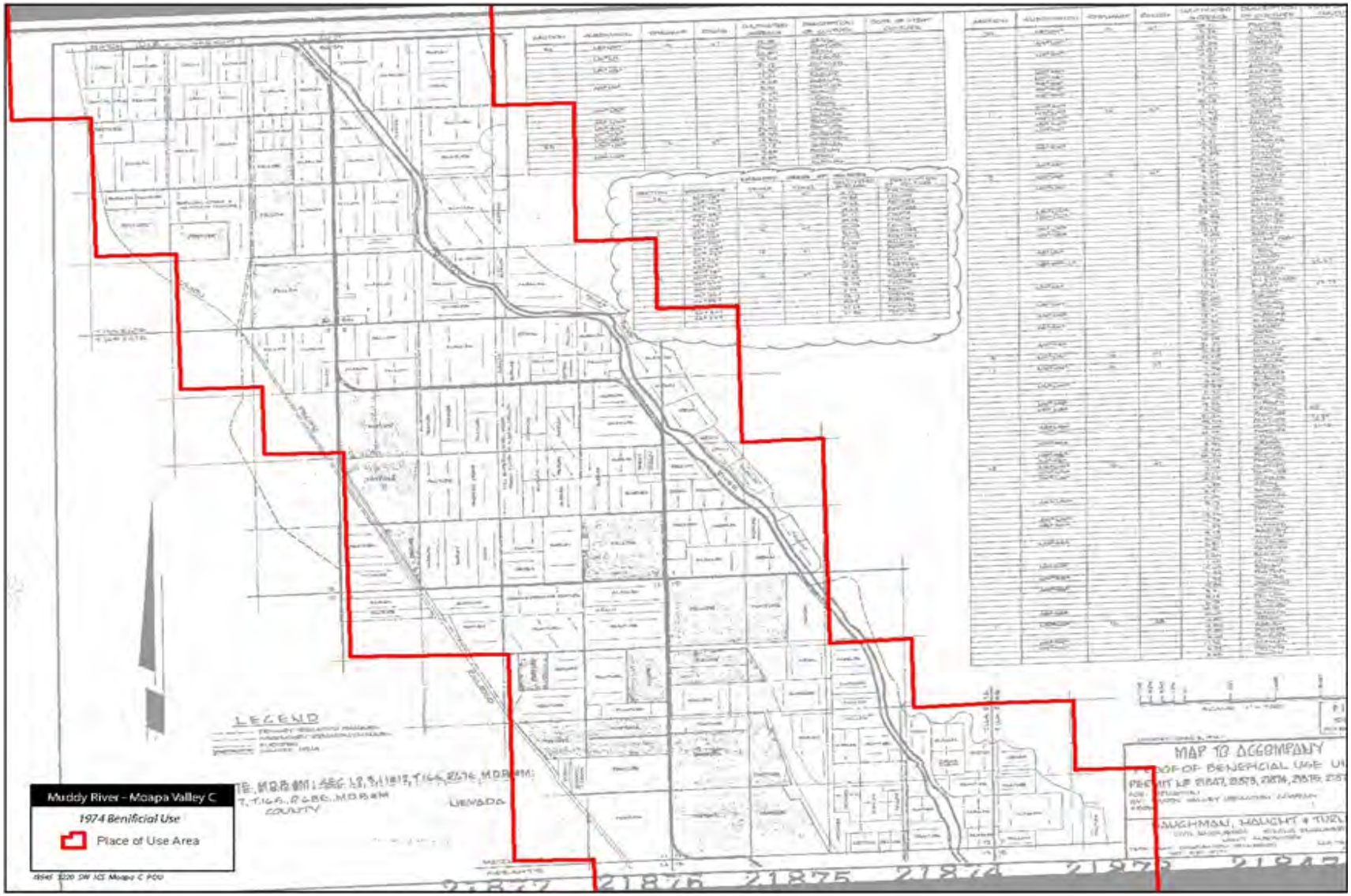


Figure 3-18
Middle Section of the MVIC Service Area Showing 1974 PBU.
POU Quarter-Quarter Sections Highlighted in Red

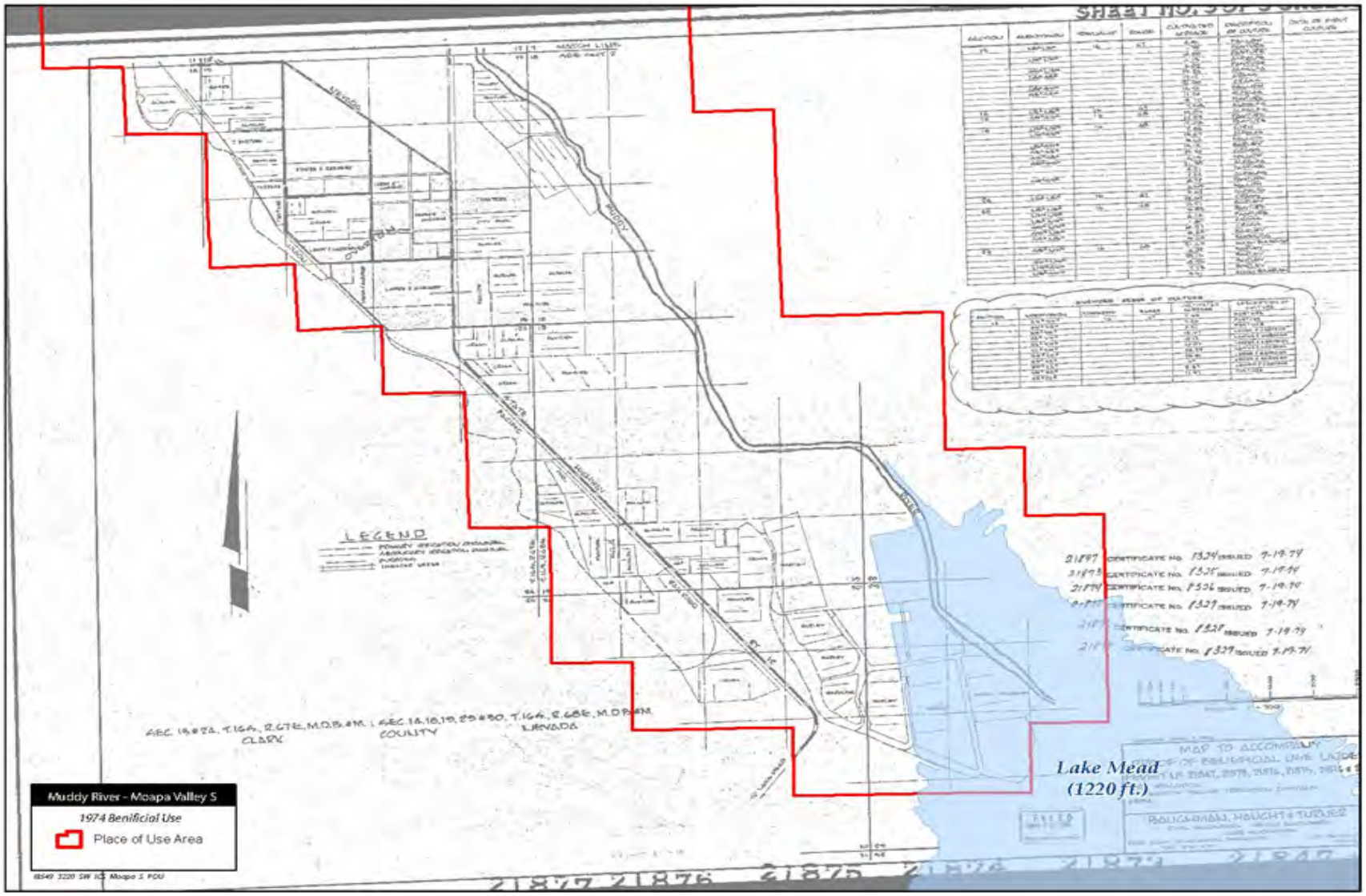


Figure 3-19
Lower Section of the MVIC Service Area Showing 1974 PBU.
POU Quarter-Quarter Sections Highlighted in Red

SE ROA 46159

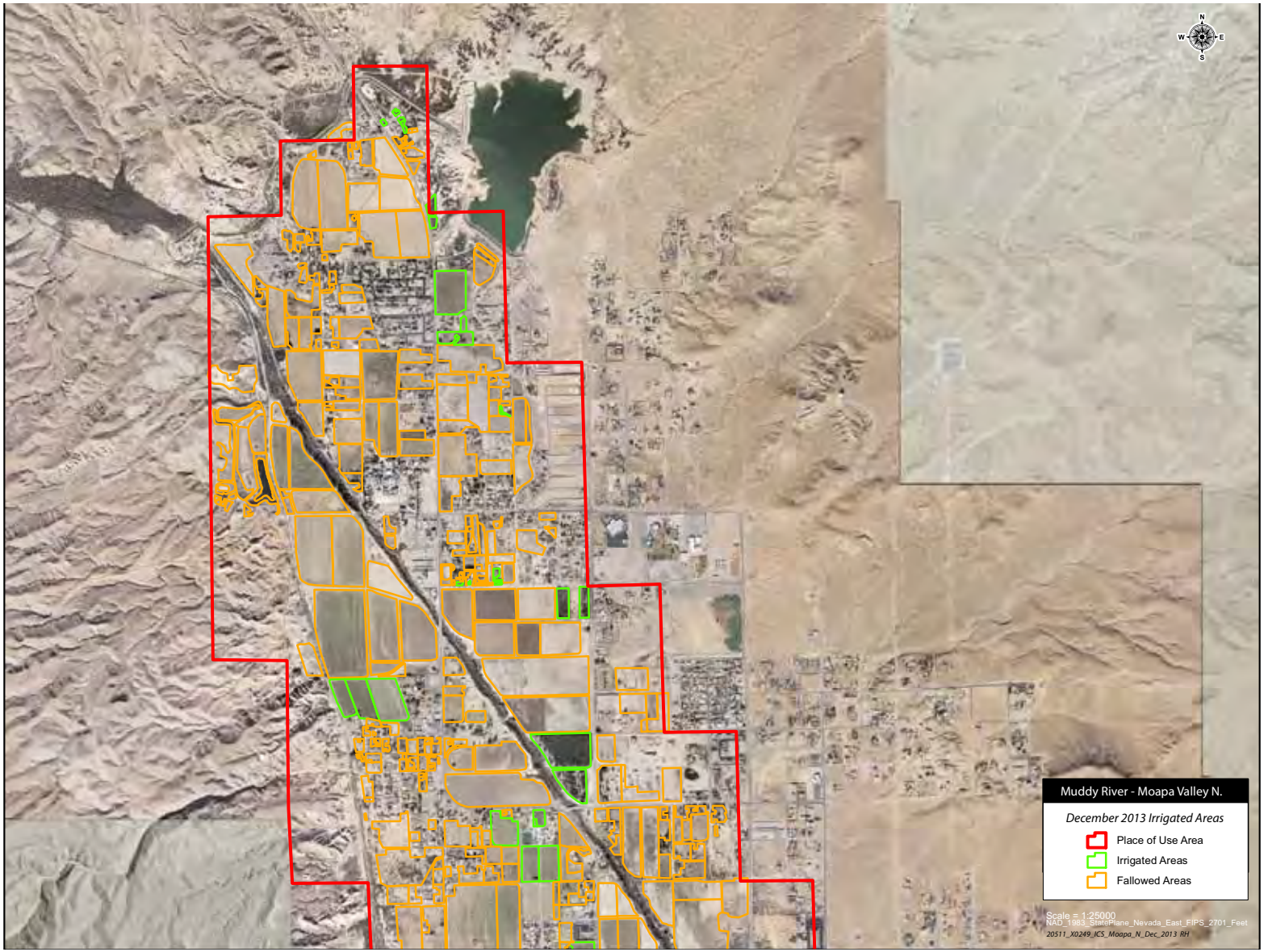


Figure 3-20
Upper Section of the MVIC Service Area December 2013 Aerial Photography

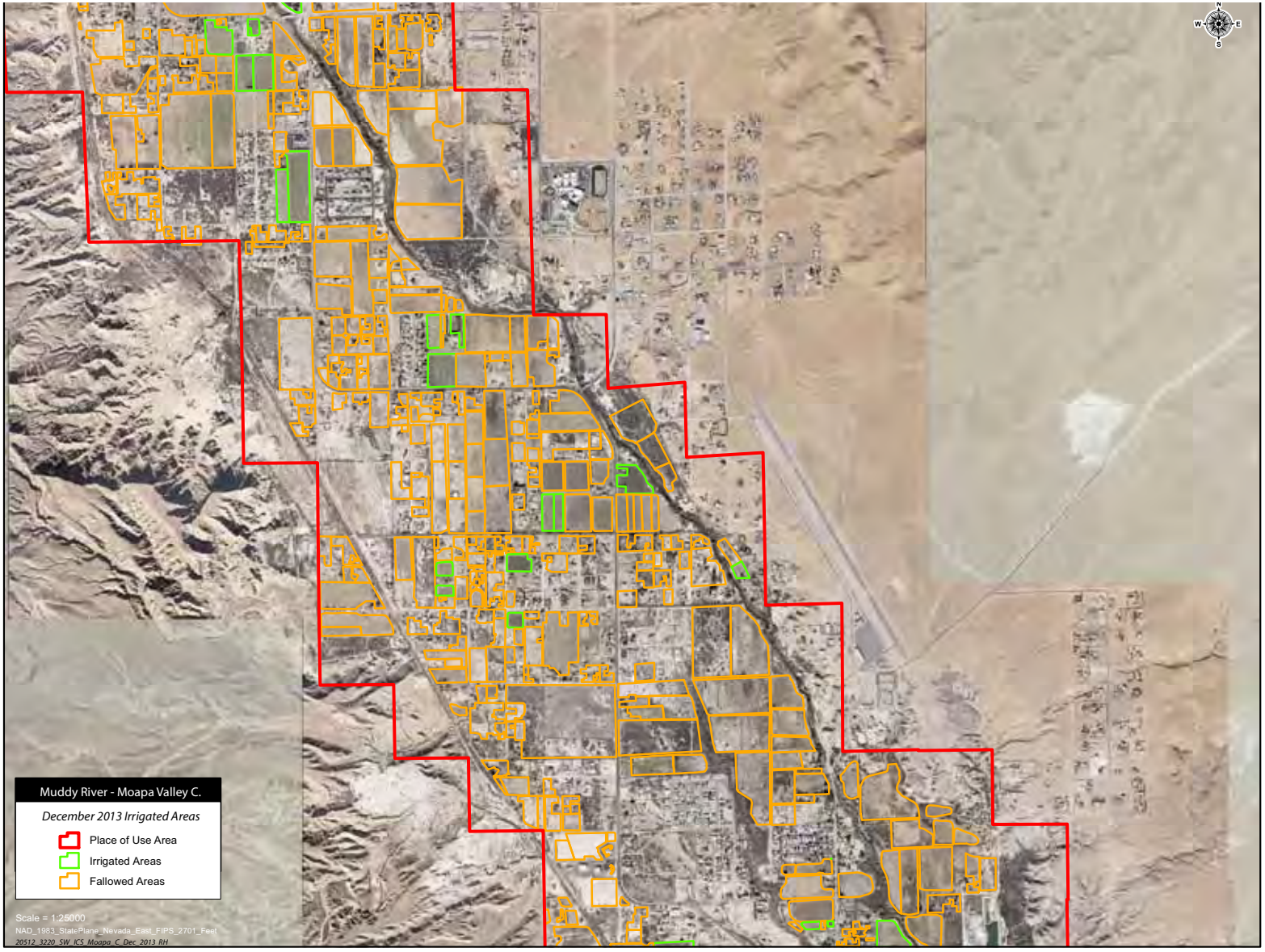


Figure 3-21
Middle Section of the MVIC Service Area December 2013 Aerial Photography

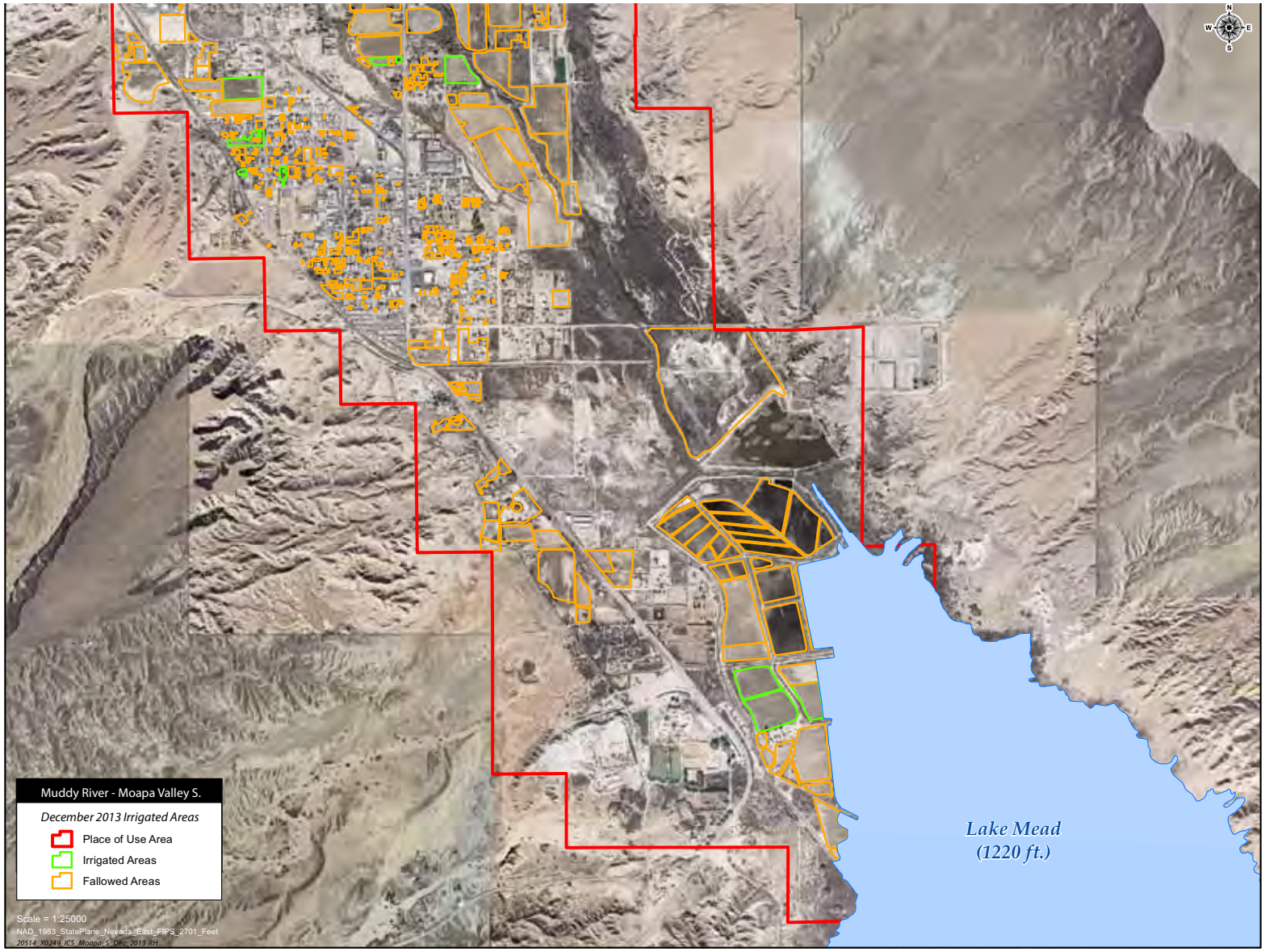


Figure 3-22
Lower Section of the MVIC Service Area December 2013 Aerial Photography

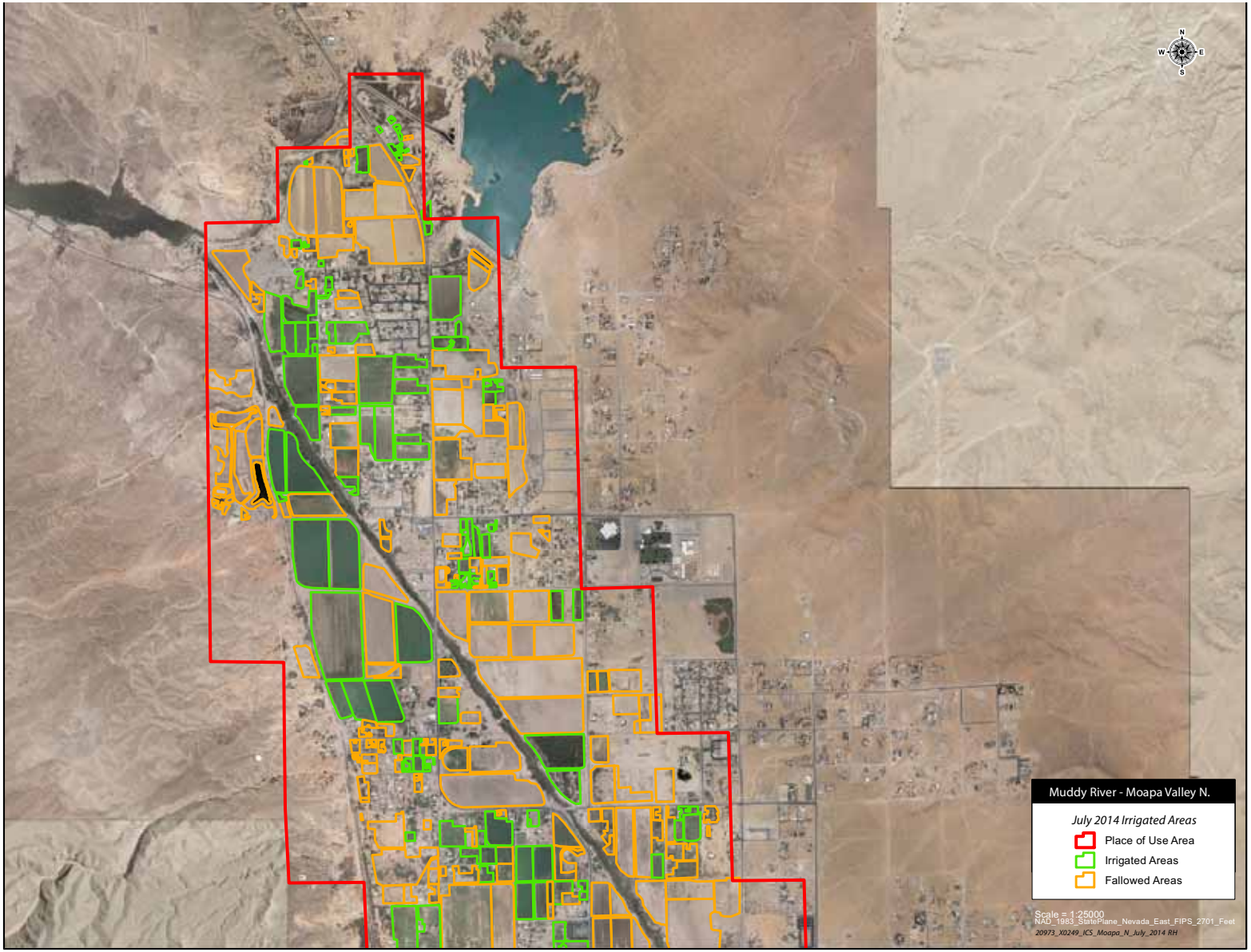


Figure 3-23
Upper Section of the MVIC Service Area July 2014 Aerial Photography

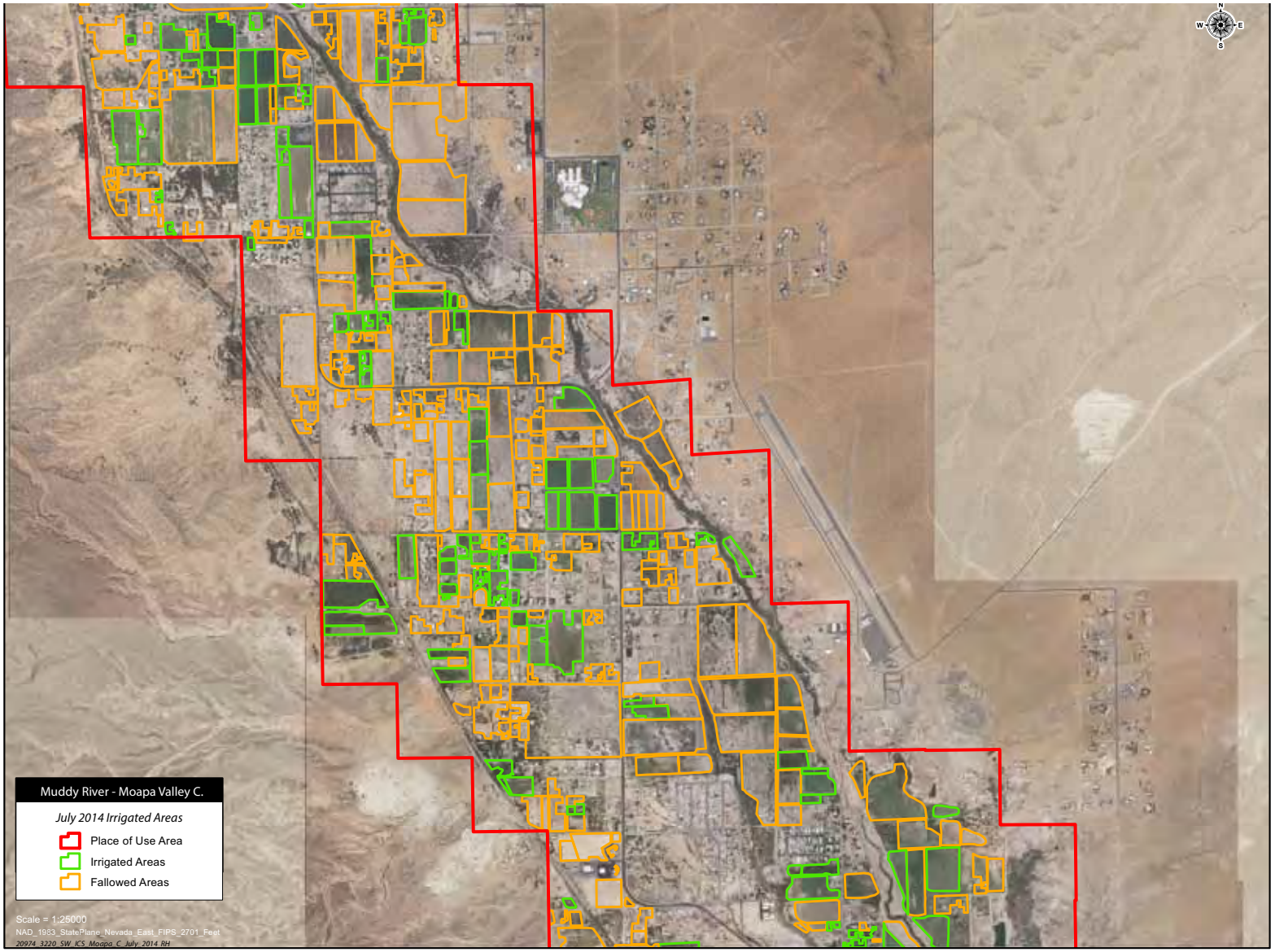


Figure 3-24
Middle Section of the MVIC Service Area July 2014 Aerial Photography

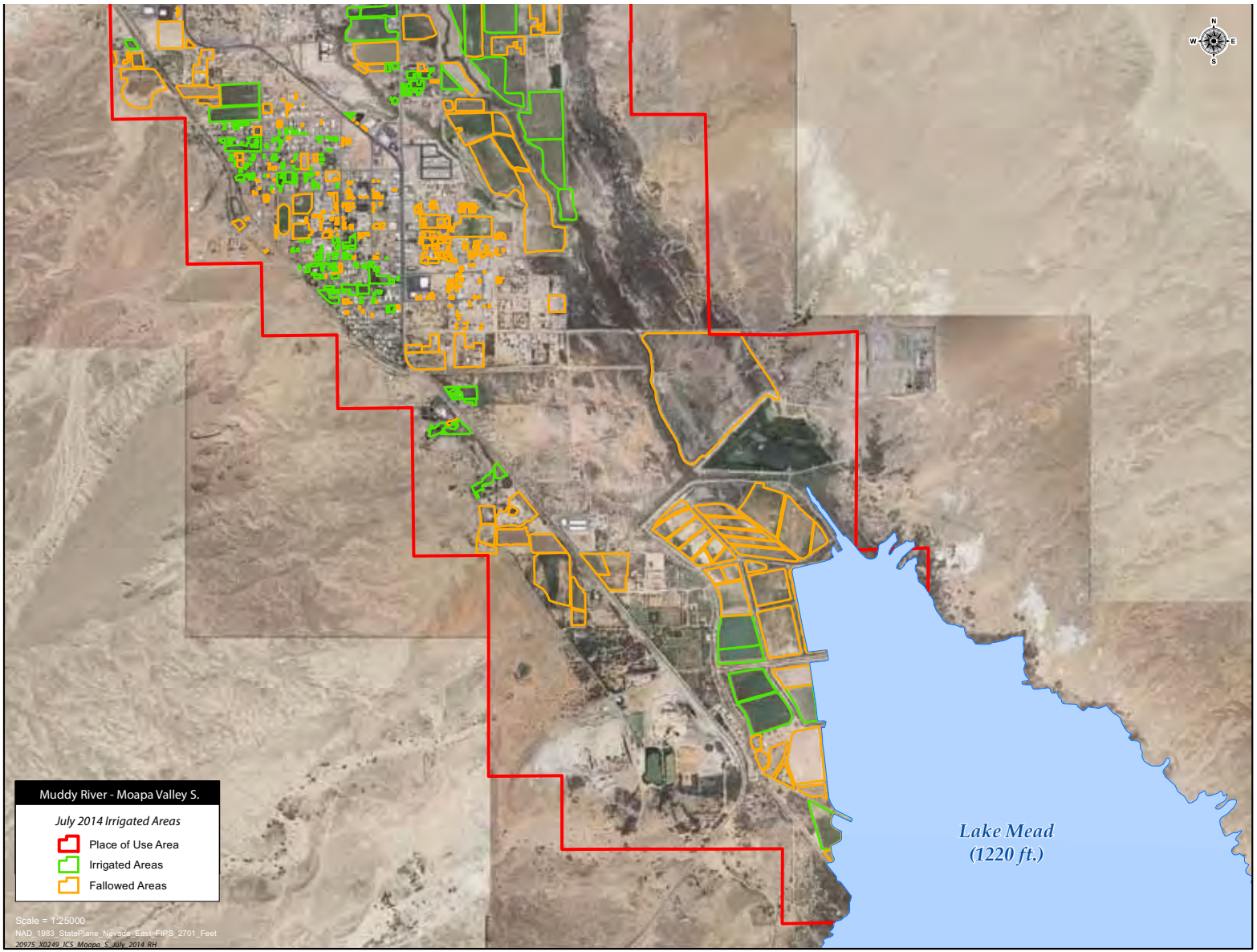


Figure 3-25
Lower Section of the MVIC Service Area July 2014 Aerial Photography

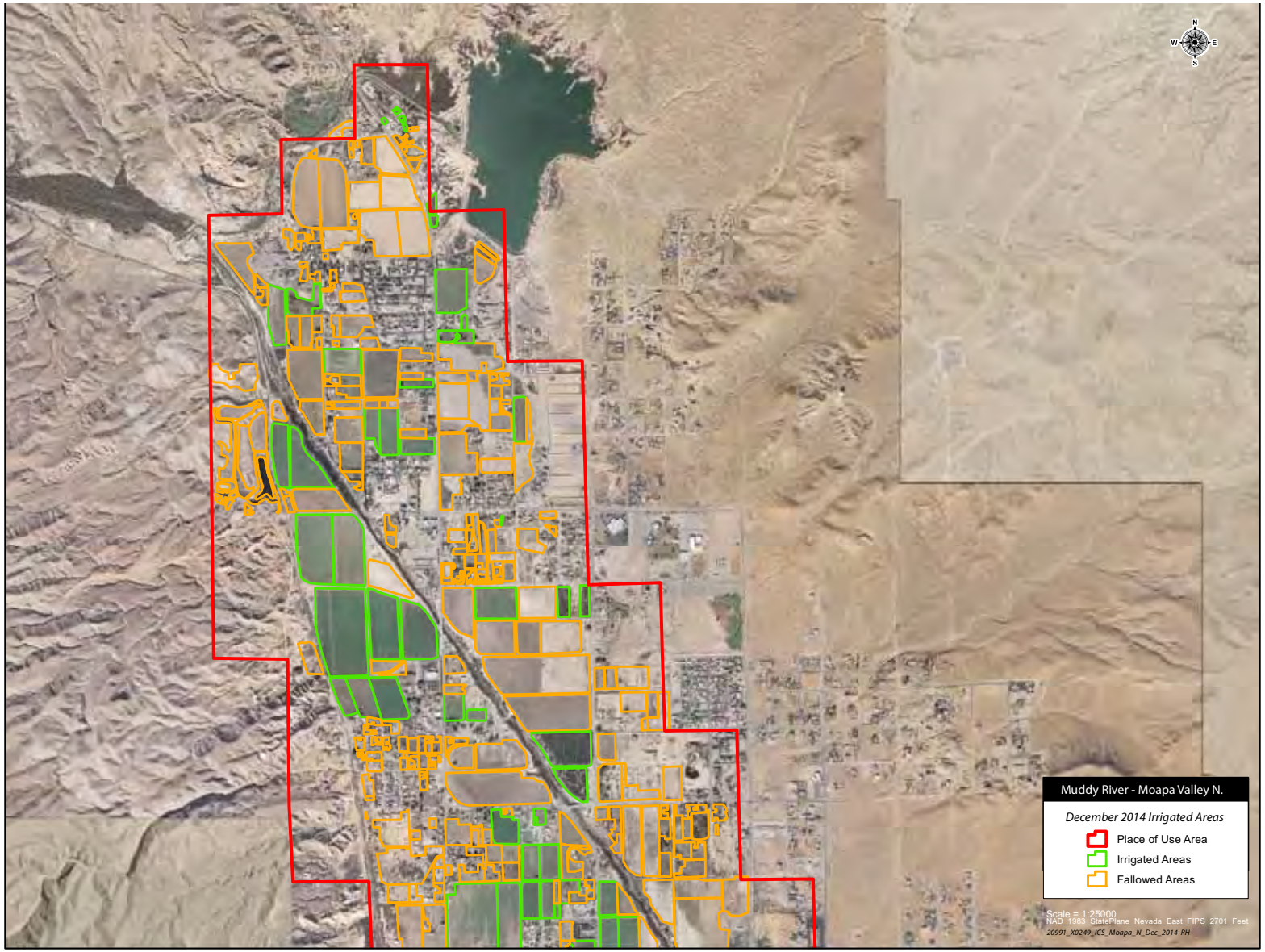


Figure 3-26
Upper Section of the MVIC Service Area December 2014 Aerial Photography

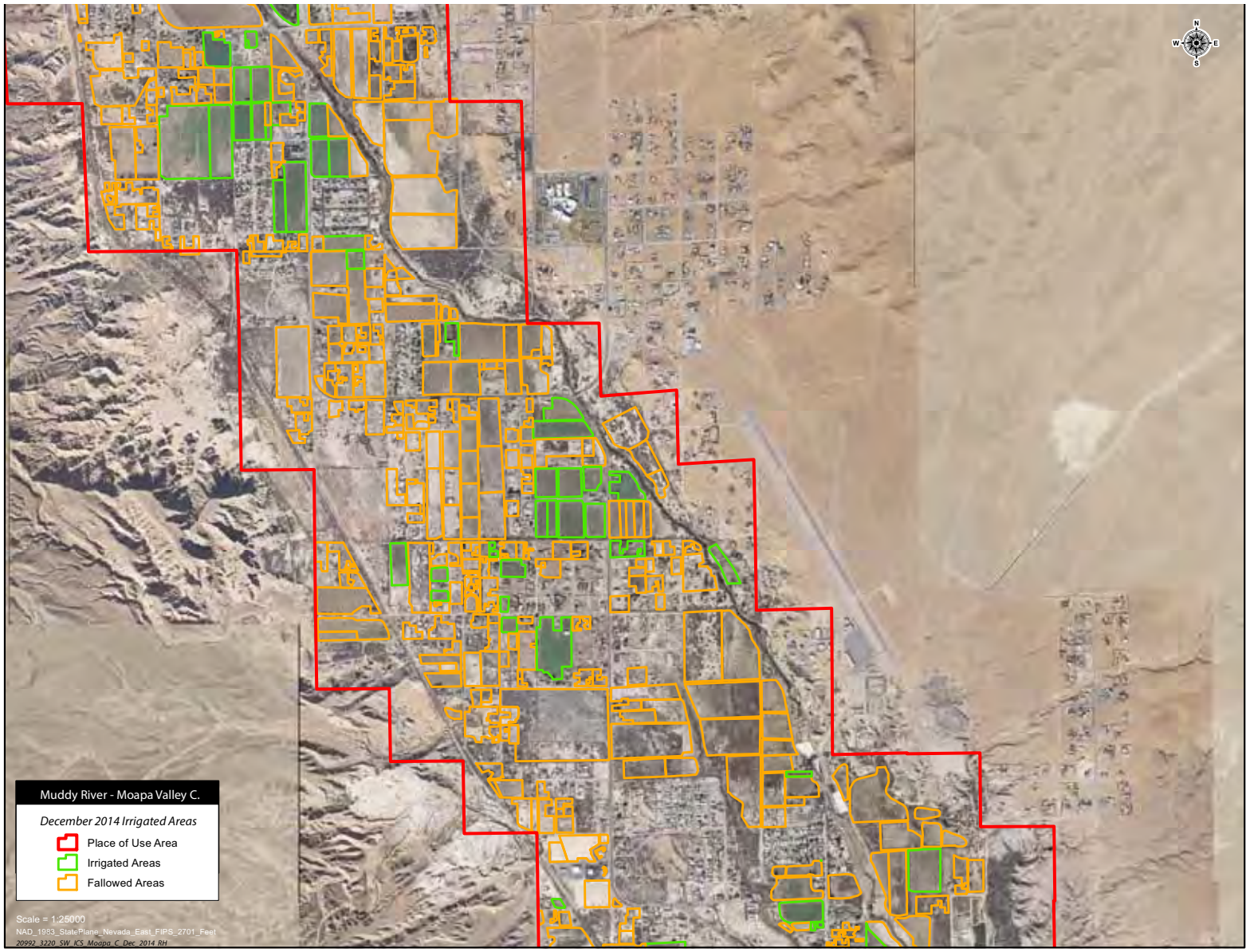


Figure 3-27
Middle Section of the MVIC Service Area December 2014 Aerial Photography

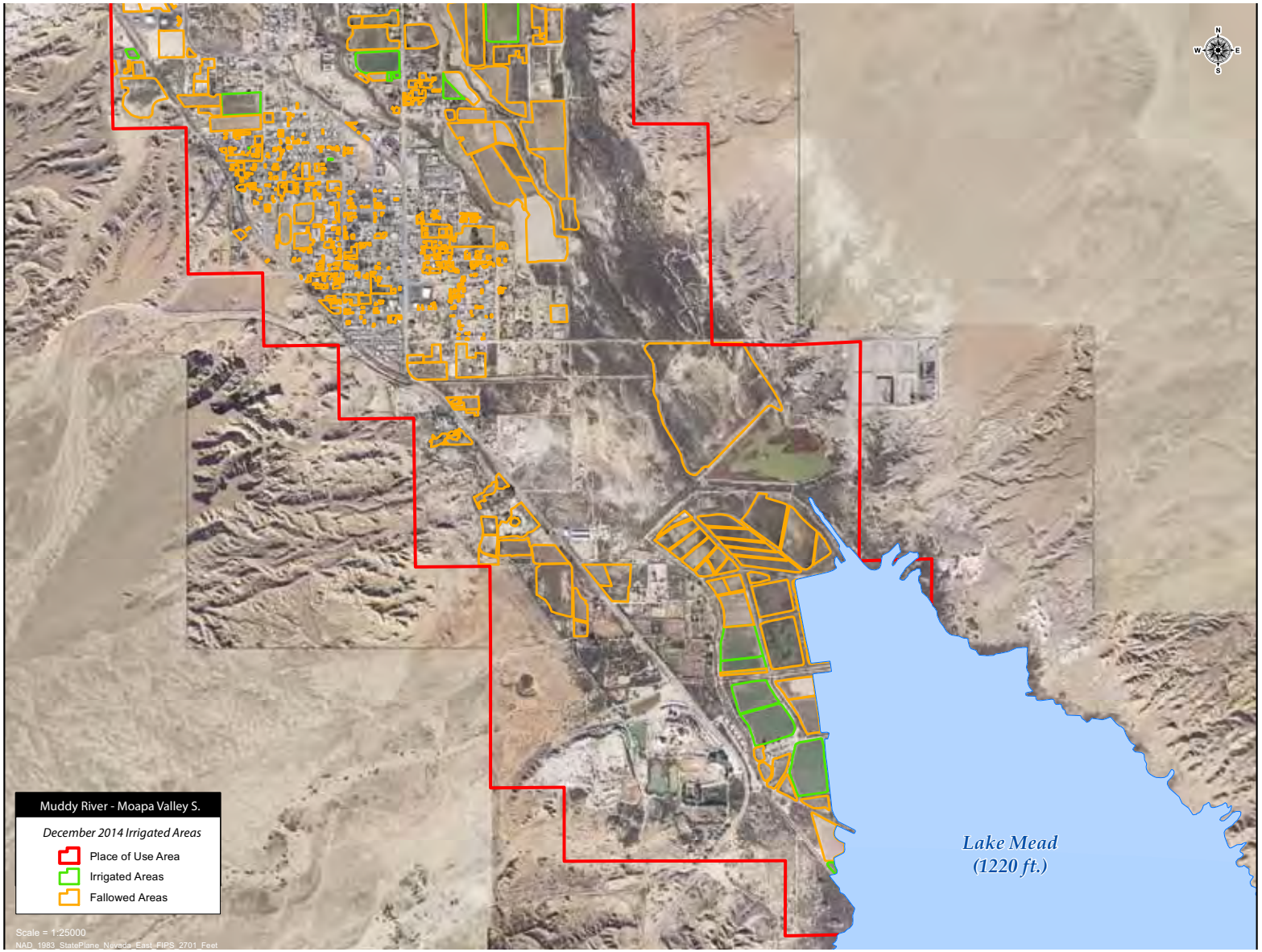


Figure 3-28
Lower Section of the MVIC Service Area December 2014 Aerial Photography

Table 3-9
Agricultural Land Status within MVIC's Place of Use

	January	February	March	April	May	June	July	August	September	October	November	December
MVIC Ag (acres)												
Alfalfa	73.65	73.65	73.65	73.65	262.28	262.28	262.28	262.28	262.28	263.96	263.96	263.96
Small Vegetables	1.34	1.34	1.34	1.34	9.85	9.85	9.85	9.85	9.85	3.70	3.70	3.70
Bermuda w/ Rye	27.26	27.26	27.26	27.26	313.69	313.69	313.69	313.69	313.69	317.35	317.35	317.35
Orchard	27.69	27.69	27.69	27.69	28.83	28.83	28.83	28.83	28.83	28.83	28.83	28.83
Sudan	-	-	-	-	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06
Total Ag	129.95	129.95	129.95	129.95	617.71	617.71	617.71	617.71	617.71	616.90	616.90	616.90
Not Irrigated	2,654.80	2,654.80	2,654.80	2,654.80	2,167.04	2,167.04	2,167.04	2,167.04	2,167.04	2,167.85	2,167.85	2,167.85
Total POU	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**

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4.0 VERIFICATION OF ICS WATER REACHING LAKE MEAD

Since the entire flow of the Muddy River is decreed, it is necessary to perform a water balance on the Lower Muddy River to verify that the water which SNWA is claiming as Tributary Conservation ICS credits is reaching Lake Mead (Figure 4-1). This water balance is outlined in Exhibit A of the Forbearance Agreement and approved 2014 ICS Plan as follows:

Flows measured by USGS at the Glendale gage
- (minus) consumptive uses by agriculture below the Glendale gage
- (minus) direct uses by industry below the Glendale gage
- (minus) channel evapotranspiration below Glendale gage to Lake Mead
- (minus) evapotranspiration from the managed acreage on the Overton Wildlife Management Area (OWMA)

= Total Flow to Lake Mead (Elevation 1,220 AMSL)

This comprehensive water balance uses the Glendale gage as the input, which was also used to calculate the af/share associated with MVIC shares. To account for consumptive uses in the riparian corridor and agricultural areas, detailed GIS coverages delineating the active fields and mapped riparian corridors, combined with Lower Colorado River Accounting System (LCRAS) data were used to derive consumptive uses by crops and plants supplied by the Muddy River. Other consumptive uses by industry and open water evaporation were also calculated. Uses of Muddy River water by the Nevada Division of Wildlife's Overton Wildlife Management Area (OWMA) are deducted from the total flows to Lake Mead. A final comparison is then made to ensure that the conserved Muddy River water reaching Lake Mead exceeds or is equal to SNWA's controlled Muddy River water rights.

The CY2014 water balance is presented in Table 4-1. A more detailed seasonal calculation of the water balance is presented in Table 4-2. The following sub-sections describe each component of the water balance. When data used in the water balance is described, a reference is given to the row in Table 4-2 where the data was applied.

$$Q_{LM} = Q_G - CU_{AG} - CU_{IND} - CU_{CHN} - CU_{OWM} \quad \text{(Eq. 4-1)}$$

Where:

Q_{LM} = Flow to Lake Mead (ac-ft)

Q_G = Flow measured at Glendale Gage (Less Flood Flows) (ac-ft)

CU_{AG} = Consumptive Use by Agriculture (ac-ft)

Figure 4-1
Map of Lower Muddy River Riparian Area, Open Water, and the OWMA

CU_{IND}= Consumptive Use by Industry (ac-ft)

CU_{CHN}= ET along the Muddy River channel from the Glendale Gage to Lake Mead (ac-ft)

CU_{OWM}= ET within the Overton Wildlife Management Area (ac-ft)

Table 4-1
CY 2014 Water Balance (AF)

Q_G	Flows measured by USGS at the Glendale gage (Less Flood Flows)	28,020
CU_{AG}	consumptive uses by agriculture below the Glendale gage	(3,949)
CU_{IND}	direct uses by industry below the Glendale gage	(1,557)
CU_{CHN}	channel evapotranspiration below Glendale gage to Lake Mead (including Bowman Res. Evap)	(2,839)
CU_{OWM}	evapotranspiration from the managed acreage on the Overton Wildlife Management Area (OWMA)	(926)
Q_{LM} =	Total Flow to Lake Mead (Elevation 1,220 AMSL)	18,749
	Total Muddy River Water Rights Controlled by SNWA	15,098
=	**Total Flows to Lake Mead are greater than SNWA Water Rights ----------->**	**YES**

4.1 Glendale Gage Flows

As previously discussed in Section 3.3.3, the water available for use by MVIC equals the Glendale gage flows minus: 1) flood flows; 2) consumptive uses by phreatophytes in the riparian corridor between the Glendale gage and Wells Siding; and 3) Upper Muddy River rights owned or leased by SNWA. This “divertible flow” is used as the inflow component of the water balance verification.

The Glendale gage, for the purposes of calculating Tributary Conservation ICS credits, is believed to capture all surface water flows entering the lower reach of the Muddy River. The gage is located in a narrow cut of carbonate rocks commonly referred to as “the narrows.” Downstream of the narrows, the river enters the lower reach of the Muddy River and the floodplain begins to widen, until reaching Wells Siding. The Muddy River, downstream of Wells Siding, is an incised narrow channel that has artificially been constrained to facilitate farming on the river’s historic floodplain, and act a flood channel.

4.2 Consumptive Use by Agriculture (CU_{AG}) and by Natural Vegetation ET (CU_{CHN})

4.2.1 Bureau of Reclamation Evapotranspiration Data

To calculate consumptive uses by agriculture (CU_{AG}) and phreatophytes (CU_{CHN}) on the Muddy River, a literature search for ET data with a long period-of-record and monthly time-step data was performed. The Bureau of Reclamation's Lower Colorado River Accounting System Evapotranspiration and Evaporation Calculations reports for calendar years 1995-2007, were evaluated and found to contain monthly data for a similar climate. Therefore, data from the LCRAS reports were selected for use in this analysis.

Table 4-2
2014 Muddy River Intentionally Created Surplus Water Balance Sheet
(all units in acre-feet)

		Winter (Jan - Apr)	Summer (May - Sep)	Winter (Oct - Dec)	Total	Row Reference
Total Inflows to Lower Muddy River	Muddy River at Glendale Gage (Q_G)	8,930.00	11,240.00	7,850.00	28,020	A
	Phreatophyte Consumptive Use to Wells Siding [b]	151.83	866.46	130.89	1,149	B
	Controlled Upper Muddy River Water Rights	2,393.20	1,865.43	2,212.22	6,471	C
	Acre-feet per Share Basis (Divertible Flows)	6,384.97	8,508.11	5,506.90	20,400	D=A-B-C
Consumptive Uses Above OWMA	Simplot (CU_{IND})	555.24	585.78	416.43	1,557.46	E
	MVIC Crop Use (CU_{AG})	175.00	1,939.58	488.51	2,603.09	F
	Bowman Reservoir Evaporation [b]	278.79	453.26	166.89	898.93	G
	Phreatophyte Consumptive Use [b]	123.76	581.26	86.23	791.24	H
	MVIC Consumptive Uses above Lewis Ave	1,132.79	3,559.88	1,158.06	5,851	I=E+F+G+H
Bowman Reservoir Operations	Coyote Springs Imported ICS	-	-	-	-	J
	Net Muddy River Water In or (Out) of Bowman	2,333.17	(2,411.23)	1,423.79	1,346	K
	Measured Change in Bowman Reservoir Storage	2,333.17	(2,411.23)	1,423.79	1,346	L=J+K
Flows Above OWMA	Total Calculated Flows above OWMA	5,312.22	9,224.89	5,137.27	19,674	M=A-B-I+J-L
Overton Wildlife Management Area Water Use	OWMA Consumptive Use (CU_{OWM})	399.61	261.91	264.09	926	P
	Total Flows to Lake Mead (Q_{LM})	4,912.61	8,962.98	4,873.19	18,749	Q=M-P
SNWA Water Rights	Controlled Upper Muddy River Water Rights	2,393.20	1,865.43	2,212.22	6,471	C
	MVIC Rights	2,795.81	3,403.34	2,427.86	8,627	S
	Muddy River Water Rights Controlled by SNWA	5,189.02	5,268.77	4,640.08	15,098	T=R+S
	Coyote Spring Imported ICS (Not conducted in 2014)	-	-	-	-	U
	Total Muddy River and Coyote Spring Water Rights Controlled by SNWA	5,189.02	5,268.77	4,640.08	15,098	V=T+U
Flow Check	Difference Between total Flows to Lake Mead and SNWA Water Rights	(276.41)	3,964.21	233.11	3,651	W=Q-V
	Is conservation > than SNWA rights	No	Yes	Yes	Yes	Q > V

[a] Value is zero due to Muddy River flooding where surface water flows exceeded calculated subsurface flows.
Due to rounding, numbers presented throughout this table may not add up precisely to the totals provided and may not precisely reflect the absolute figures.
[b] CU_{CHN} is the sum of Row References: B + G + H

The LCRAS Reports document estimates of ET and Evaporation annually for the purpose of determining consumptive water use along the Lower Colorado River. The values are determined by collecting data from meteorological towers, determining potential ET, and applying various crop coefficients to the ET values.

The portion of the LCRAS ET data chosen for use in this analysis utilize data collected from two Arizona Meteorological Network (AZMET) stations located in the Mohave Valley in Arizona, which are used to calculate local phreatophyte and crop ET (Figure 4-2). This is the most northern area currently calculated by Reclamation and most closely represents climatic conditions of the Lower Muddy River. The Mohave Valley is, however, at a lower elevation and experiences higher temperatures than the Lower Muddy River, resulting in higher ET values. This makes the Mohave Valley ET values conservative, overestimating the actual ET demand in the Lower Muddy River.

4.2.2 Application of LCRAS to the Lower Muddy River

Phreatophyte vegetation on the Lower Muddy River was mapped and classified using the Anderson-Ohmart classification system. LCRAS uses a classification system that slightly differs from the Anderson-Ohmart system. To apply ET rates from LCRAS to the Lower Muddy River, the two vegetation classification systems were correlated. Table 4-3 shows an SNWA derived correlation between the two classification systems.

The LCRAS "Sc-low" phreatophyte classification was used for all of the salt-cedar classifications in the Anderson-Omart classification and is supported by a USGS Scientific Investigations Report 2008-5116 titled *Quantifying Ground-Water and Surface-Water Discharge from Evapotranspiration Processes in 12 Hydrographic Areas of the Colorado Regional Ground-Water Flow System, Nevada, Utah, and Arizona*. The purpose of the report was to estimate ground and surface water discharge from 12 hydrographic basins via ET. For the study the USGS placed ET measurement sites in various locations in Utah, Arizona, and Nevada including the Upper Muddy and Lower Virgin Rivers. The Virgin River ET station was placed in a "dense woodland vegetation" area which was predominantly salt cedar. The Virgin River site measured an annual ET rate of 3.9 ft/yr without subtracting precipitation. This rate is less than the LCRAS Sc-low value of 4.39 ft/yr using LCRAS Mohave Valley data. The USGS's Muddy River ET site was located in a stand of mesquite trees, in the Upper Muddy River. The USGS value of 3.6 ft/yr (without subtracting precipitation) is more than 1 ft less than the LCRAS "Ms-high" value of 5.0 ft/yr.

The USGS study demonstrates that by correlating the LCRAS Sc-low and Ms-high classifications to salt cedar and mesquite on the Lower Muddy River, a conservative estimate of ET can be determined. These variations in ET rates demonstrate the challenges of trying to estimate ET over large areas, as ET can only be physically measured at a single point. Conditions such as soil type, depth to groundwater below land surface, and calculation method used can all affect ET rates greatly. Comparison of the LCRAS rates used by SNWA (Sc-low) in the water balance (in this analysis) to the measurements performed by the USGS show that using the LCRAS rates tends to slightly overestimate ET along the Lower Muddy River based these recent reports.

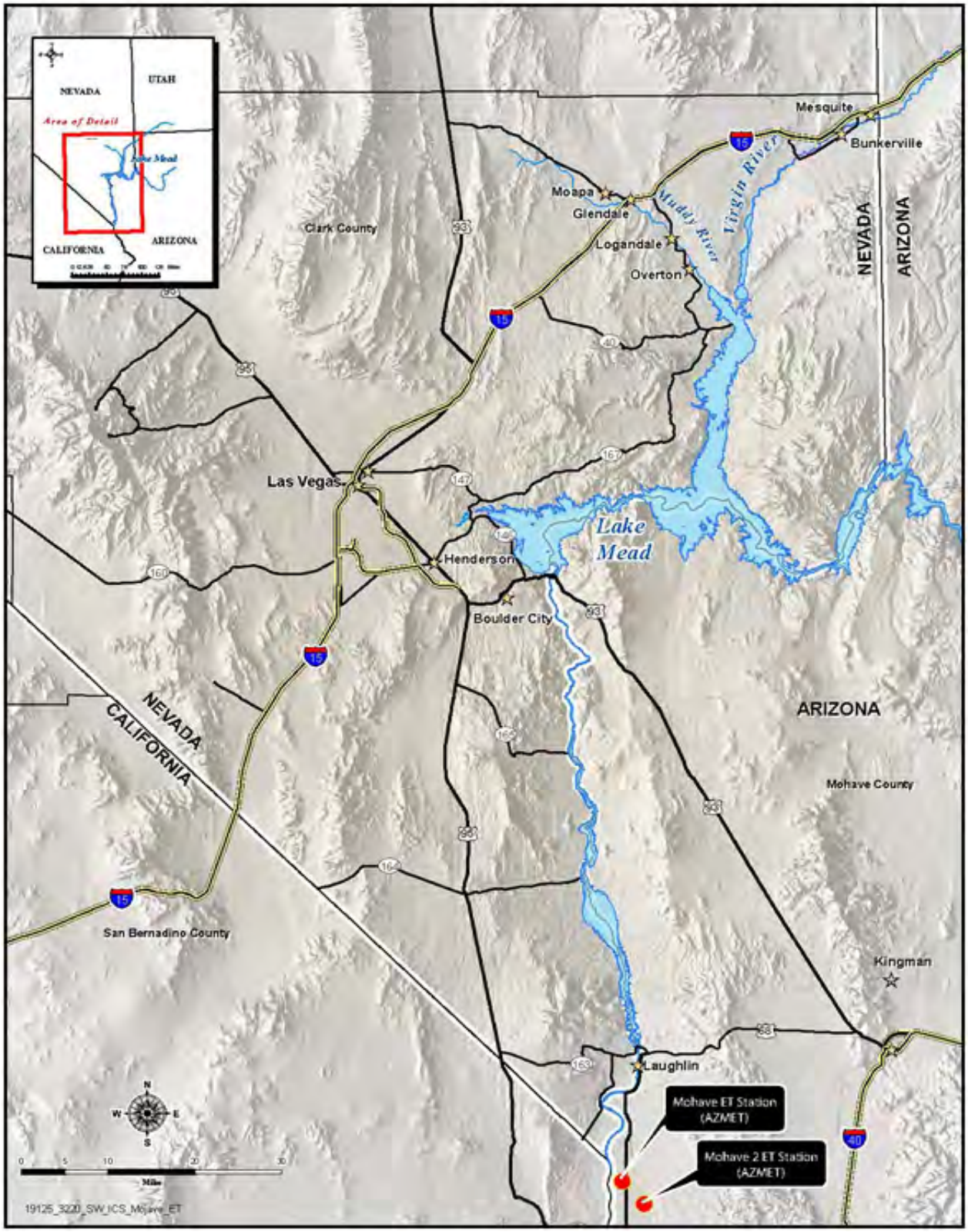

Figure 4-2
Mohave Valley AZMET ET Stations

Table 4-3
Anderson Ohmart Mapped Class

Anderson Ohmart Mapped Class	Correlating LCRAS Class	Acres
A	Low Veg	15.53
AW	AW	7.85
Acacia	Ms-high	0.00
Baccharis	Low Veg	1.37
C	CW	0.13
CW	CW	6.60
HM	Ms-high	4.26
I	Ms-high	2.03
L	Ms-high	0.83
MA	Marsh	20.00
RIV	Open Water	2.11
SC	Sc-low	97.73
SM	Sc/ms	8.94

The equation used in this analysis for calculating ET by phreatophytes is:

$$CU_{CHN} = A_R \times ET_{LCRAS} \quad \text{(Eq. 4-2)}$$

Where:

CU_{CHN} = Consumptive use along MR Channel from Glendale Gage to Lake Mead (ac-ft)

A_R= Area of Riparian Zone Specific to Each Vegetation Type (acres)

ET_{LCRAS}= Mohave Valley ET Rate Specific to Each Vegetation Type (ft)

The agricultural crop types in LCRAS were directly correlated with crop types on the Muddy River. Water use by crop type in LCRAS is adjusted for precipitation by using an effective precipitation coefficient. To more accurately represent conditions on the Lower Muddy River, provisional precipitation data recorded for CY 2014 by the Overton Nevada Community Environmental Monitoring Program (CEMP) Weather Station (http://www.cemp.dri.edu/) was used for calculating the effective precipitation used to derive crop consumptive uses. The equation for calculating Crop ET is listed below. The crop rates adjusted to Overton Nevada Precipitation are shown in Table 4-4.

$$CU_{AG} = A_C \times (ET_{LCRAS} - P_{EFF}) \quad \text{(Eq. 4-3)}$$

Where:

CU_{AG} = ET along MR Channel from Glendale Gage to Lake Mead

A_C= Area of Crops Specific to Each Vegetation Type (acres)

ET_{LCRAS}= Mohave Valley ET Rate Specific to Each Vegetation Type (feet)

P_{EFF}= Effective Precipitation (feet)

4.2.2.1 MVIC Crop Use

Tables 4-4 through Table 4-6 in this section detail the calculations performed to estimate the amount of consumptive uses by crops, phreatophytes, and open water. The Mohave Valley monthly ET rates for the crops and phreatophytes are adjusted to local precipitation collected at DRI's Overton Nevada Community Environmental Monitoring Program station.

The measured acreages of each vegetation type and open water are in Table 4-5. Vegetation mapping of the Muddy River riparian corridor was performed in 2006. In 2010, the survey data was updated to reflect removal of vegetation due to the construction of a bridge crossing the Muddy River. Given the incised nature of the channel, the total vegetated acreage along the riparian corridor has remained the same and is anticipated to remain the same into the future. The phreatophyte acreages were mapped in the field by biologists and verified using the high resolution 6-in aerial photography. The measured acreage values for the phreatophytes and crops are shown in Table 4-5. The final consumptive use calculations for the phreatophytes and crops are shown monthly in Table 4-6 and these results are then shown seasonally on Rows B, F, and H in Table 4-1.

Vegetation acreage mapped for OWMA is also shown in Table 4-5. OWMA is the downstream extent of MVIC's service area and is located immediately above the full pool elevation of Lake Mead. Water use by OWMA is described in the subsequent sections of this report.

4.2.2.2 Ongoing Evaluation of ET by Natural Vegetation

In the future to enhance the accuracy of ET consumptive use calculations along the Lower Muddy River, SNWA has installed a meteorological (MET) tower adjacent to an alfalfa field in the Lower Muddy River. With the cooperation of the Moapa Valley High School Future Farmers of America Farm, SNWA was able to place the MET tower in an area with the ideal fetch and agricultural conditions for measuring the meteorological parameters necessary to calculate reference ET using the ASCE Standardized Reference ET Equation –a similar method used by The Arizona Meteorological Network (AZMET) and California Irrigation Management Information System for the LCRAS program. The reference ET calculated from the MET tower could then be multiplied by the LCRAS crop coefficients to obtain a more accurate ET consumptive use estimate for the Lower Muddy River, once data from the site is reviewed.

Table 4-4
Mohave Valley ET Rates (ft)

	Average 1995 - 2007												
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Total**
Crops:													
Alfalfa Perennial	0.22	0.32	0.42	0.56	0.68	0.73	0.69	0.66	0.56	0.41	0.25	0.24	5.73
Alfalfa-Annual	0.16	0.27	0.34	0.39	0.65	0.50	0.57	0.29	0.23	0.26	0.13	0.18	3.96
Small Grain	0.26	0.37	0.58	0.68	0.27	0.00	0.00	0.00	0.00	0.00	0.02	0.08	2.25
Orchard	0.15	0.17	0.28	0.45	0.66	0.70	0.67	0.64	0.51	0.39	0.25	0.15	5.01
Melons (Fall)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.32	0.44	0.31	0.15	1.31
Small Vegetables	0.30	0.34	0.43	0.15	0.00	0.00	0.00	0.00	0.08	0.17	0.20	0.22	1.88
Bermuda Grass w/ Rye	0.27	0.30	0.37	0.28	0.64	0.69	0.66	0.62	0.48	0.23	0.26	0.21	5.00
Sudan	0.00	0.00	0.14	0.43	0.83	0.97	0.89	0.35	0.03	0.00	0.00	0.00	3.64
Moist Soil Unit	0.58	0.80	0.24	0.36	0.31	0.84	0.26	0.46	0.43	0.29	0.45	0.38	5.39
Phreatophytes:													
AW	0.08	0.10	0.20	0.41	0.69	0.80	0.76	0.68	0.51	0.31	0.12	0.07	4.73
CW	0.08	0.10	0.21	0.44	0.74	0.84	0.79	0.71	0.53	0.33	0.13	0.07	4.97
Low Veg	0.09	0.10	0.20	0.37	0.61	0.67	0.67	0.59	0.50	0.32	0.14	0.07	4.33
Marsh	0.07	0.08	0.37	0.74	0.92	0.96	0.91	0.82	0.67	0.27	0.07	0.06	5.94
Ms-High	0.08	0.10	0.21	0.43	0.71	0.82	0.77	0.70	0.57	0.38	0.16	0.07	5.00
Sc-ms	0.08	0.10	0.20	0.46	0.81	0.95	0.89	0.80	0.61	0.36	0.14	0.07	5.47
Sc-Low	0.07	0.08	0.14	0.29	0.61	0.77	0.73	0.66	0.54	0.33	0.12	0.05	4.39
Open Water Evaporation[a]	0.30	0.40	0.60	0.60	0.80	0.80	0.80	0.70	0.80	0.70	0.60	0.40	7.50
Precipitation[b]	0.00	0.04	0.01	0.00	0.00	0.00	0.01	0.10	0.09	0.00	0.00	0.05	0.30

[a]Westenberg et al. (2006)
[b]Overton Nevada Community Environmental Monitoring Program (CEMP) Weather Station (CY 2014) (http://www.cemp.dri.edu/)

Table 4-5
Acreages of Agriculture, Phreatophytes, and Open Water in the Lower Muddy River

	January	February	March	April	May	June	July	August	September	October	November	December
Bowman Reservoir	135.32	150.76	154.62	154.62	150.76	142.88	127.56	105.04	76.36	87.14	101.57	127.56
Riparian:												
Sc_Low above Wells Siding	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77
AW	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85
CW	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73
Ms-High	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11
Low Veg	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90
Marsh	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Sc-Low	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73
Sc/ms	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94
Open Water	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
Subtotal Below Wells Siding	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37
Total	429.14	429.14	429.14	429.14	429.14	429.14	429.14	429.14	429.14	429.14	429.14	429.14
MVIC Ag:												
Alfalfa	73.65	73.65	73.65	73.65	262.28	262.28	262.28	262.28	262.28	263.96	263.96	263.96
Small Vegetables	1.34	1.34	1.34	1.34	9.85	9.85	9.85	9.85	9.85	3.70	3.70	3.70
Bermuda w/ Rye	27.26	27.26	27.26	27.26	313.69	313.69	313.69	313.69	313.69	317.35	317.35	317.35
Orchard	27.69	27.69	27.69	27.69	28.83	28.83	28.83	28.83	28.83	28.83	28.83	28.83
Melons (Fall)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Small Grain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sudan	0.00	0.00	0.00	0.00	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06
Total	129.95	129.95	129.95	129.95	617.71	617.71	617.71	617.71	617.71	616.90	616.90	616.90
OWMA:												
Alfalfa	18.36	18.36	18.36	18.36	33.39	33.39	33.39	33.39	33.39	33.39	33.39	33.39
Bermuda w/Rye	5.59	5.59	5.59	5.59	10.67	10.67	10.67	10.67	10.67	10.67	10.67	10.67
Moist Soil Unit	155.16	155.16	155.16	155.16	0.00	0.00	0.00	0.00	0.00	155.16	155.16	155.16
Sudan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open Water	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88
Total	210.99	210.99	210.99	210.99	75.94	75.94	75.94	75.94	75.94	231.10	231.10	231.10

Table 4-6
Total ET in Acre Feet (2014)

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Bowman Reservoir	40.15	55.03	91.36	92.26	120.61	114.31	100.56	63.38	54.41	61.00	60.60	45.28	899
Riparian:													
Sc_Low above Wells Siding	18.32	20.94	36.65	75.91	159.68	201.56	191.09	172.77	141.36	86.38	31.41	13.09	1,149
AW	0.63	0.78	1.57	3.22	5.42	6.28	5.96	5.34	4.00	2.43	0.94	0.55	37
CW	0.54	0.67	1.41	2.96	4.98	5.65	5.32	4.78	3.57	2.22	0.87	0.47	33
Ms-High	0.57	0.71	1.49	3.06	5.05	5.83	5.48	4.98	4.05	2.70	1.14	0.50	36
Low Veg	1.52	1.69	3.38	6.25	10.31	11.33	11.33	9.97	8.45	5.41	2.37	1.18	73
Marsh	1.40	1.60	7.40	14.80	18.40	19.20	18.20	16.40	13.40	5.40	1.40	1.20	119
Sc-Low	6.84	7.82	13.68	28.34	59.62	75.25	71.34	64.5	52.77	32.25	11.73	4.89	429
Sc/ms	0.71	0.89	1.79	4.11	7.24	8.49	7.95	7.15	5.45	3.22	1.25	0.63	49
Open Water	0.63	0.77	1.24	1.26	1.69	1.69	1.66	1.27	1.5	1.47	1.26	0.75	15
Subtotal Below Wells Siding	13.00	15.00	32.00	64.00	113.00	134.00	127.00	114.00	93.00	55.00	21.00	10.00	791
Total	**31**	**36**	**69**	**140**	**272**	**335**	**318**	**287**	**235**	**141**	**52**	**23**	**1,940**
MVIC Ag:													
Alfalfa	16.11	23.27	30.8	41.25	178.35	191.47	180.98	173.11	146.88	108.22	65.64	63.88	1,220
Small Vegetables	0.40	0.45	0.58	0.20	-	-	-	-	0.79	0.63	0.73	0.82	5
Bermuda w/ Rye	7.33	8.07	10.04	7.63	200.76	216.44	207.03	194.49	150.57	72.99	82.09	67.28	1,225
Orchard	4.12	4.60	7.70	12.46	19.03	20.18	19.32	18.45	14.7	11.24	7.17	4.38	143
Melons (Fall)	-	-	-	-	-	-	-	-	-	-	-	-	
Sm Grain	-	-	-	-	-	-	-	-	-	-	-	-	
Moist Soil Unit	-	-	-	-	0.95	2.57	0.80	1.41	1.32	0.89	1.37	1.17	10
Total	**27.95**	**36**	**49**	**62**	**399**	**431**	**408**	**387**	**314**	**194**	**157**	**138**	**2,603**
OWMA:													
Alfalfa	4.01	5.80	7.68	10.28	22.70	24.37	23.04	22.04	18.70	13.69	8.30	8.08	169
Bermuda w/Rye	1.50	1.65	2.06	1.56	6.83	7.36	7.04	6.62	5.12	2.45	2.76	2.26	47
Moist Soil Unit	89.79	123.51	36.95	55.86	-	-	-	-	-	45.00	69.62	59.27	480
Sudan	-	-	-	-	-	-	-	-	-	-	-	-	
Open Water	9.46	11.64	18.84	19.02	25.50	25.50	25.13	19.23	22.71	22.32	19.02	11.32	230
Total	**105**	**143**	**66**	**87**	**55**	**57**	**55**	**48**	**47**	**83**	**100**	**81**	**926**

In addition to SNWA's data collection efforts, the NDWR recently published a report titled *Evapotranspiration and Net Irrigation Requirements for Nevada*. The report and ET database can be found on the NDWR website (http://water.nv.gov/mapping/et/et_general.cfm). Since there are not many MET stations collecting ET data under ideal conditions, data from National Weather Service Cooperative Observer Program weather stations was used to approximate reference ET. The NDWR report also modified standard crop curves to the climate and agricultural practices of Nevada. Using the NDWR database (http://water.nv.gov/mapping/et/et_general.cfm), the calculated alfalfa ET for the Lower Moapa Valley is 4.9 ft per year. This value is lower than the Mohave Valley value of 5.7 ft. These lower values are to be expected as the Muddy River is at a higher elevation and latitude than Mohave Valley, Arizona. SNWA will continue collecting MET data and may use the data collected from the Moapa Valley High School MET tower, possibly with the modified crop curves from the NDWR report in future ICS Certification Reports.

4.2.3 Open Water Evaporation

Open water bodies on the Lower Muddy River include Bowman Reservoir, the Muddy River channel, and a few small ponds on the OWMA. Bowman Reservoir is used by MVIC to augment irrigation flows during the summer irrigation season. The reservoir is also where SNWA's Coyote Spring Valley Imported ICS is delivered. Traditionally the 3,000 to 4,000 af capacity reservoir is filled in the winter months from the Muddy River via gravity flow and then a pump to reach higher storage volumes. The reservoir storage is then used to augment the summer irrigation season.

The open water evaporation rate used for Bowman Reservoir, the Muddy River channel, and the ponds on the OWMA was 7.50 ft/yr. This value is the open water evaporation rate determined and published by the USGS for Lake Mead. The monthly average evaporation data was published in the USGS SIR 2006-5252 titled *Evaporation from Lake Mead, Arizona, and Nevada, 1997-99*. The average monthly evaporation data from the report can be found in Table 4-4. The surface area of Bowman Reservoir and other open water on the Lower Muddy River can be found in Table 4-5, and the total evaporative loss can be found in Table 4-6 and in Row G of Table 4-2. Changes in storage in Bowman Reservoir along with inflows from SNWA's Imported ICS project are shown in Rows J and K of Table 4-2. Monthly water level elevations in Bowman Reservoir were manually recorded by MVIC personnel utilizing a surveyed stage measurement gage located on the side of the reservoir. A stage capacity curve was created by SNWA using high resolution LiDAR data collected when the reservoir was empty. The LiDAR data enables MVIC and SNWA to obtain a very accurate reservoir storage volume at any given reservoir elevation. Month-to-month Bowman Reservoir volumes were used to calculate changes in storage in the reservoir which translated to inflows and outflows of the reservoir.

4.3 Industrial Consumptive Use

A portion of MVIC's shares have been purchased and leased by Simplot, a sand and minerals operation in Overton, Nevada, which is using the water represented by shares they control for slurrying and washing sand for glass production. The water is 100% consumptively used, so the water represented by the shares controlled by Simplot is subtracted in its entirety from the water balance.

In 2014, Simplot controlled up to 196.196 preferred and 257.166 common shares (personal communication with Scott Millington, MVIC General Manager, May 2014). Using the acre-foot per share values of 7.1657 af/share preferred and 0.5894 af/share common, Simplot consumptively used 1,557 af of MVIC water in CY 2014. While the water delivered to Simplot is not directly measured, they are located at the end of the ditch and are subject to all users upstream obtaining their rights. Even SNWA's rights are taken on turn and returned to the natural channel above Simplot. Therefore, calculating their use at 100% of their controlled shares ensures a conservative estimate for their annual use. The monthly breakdown of Simplot's consumptive use is shown in Row E of the Water Budget (Table 4-2).

4.4 Overton Wildlife Management Area

The OWMA is located just above the Muddy River's confluence with Lake Mead, downstream of the Lewis Avenue gage. OWMA is managed for migrating birds, hunting, and most recently, a refugia for Razorback suckers in a small impoundment called Honey Bee Pond. The managed part of the facility, located above Lake Mead, is about 280 acres in size and consists of a series of seasonal wetlands that are flooded in the winter for migrating waterfowl, along with several fields of Alfalfa, Sudan grass, and Bermuda grass for bird habitat and minor farming, along with Honey Bee Pond and a couple other small impoundments.

The OWMA receives most of its water directly from the Muddy River and is permitted to do so under tail-water permits. In addition to the tail-water rights, OWMA owns shares in MVIC. In 2014, OWMA owned 415 afy of MVIC rights represented by 51.25 preferred and 80.50 common shares (personal communication with Scott Millington, MVIC General Manager, May 2014). MVIC water delivered to OWMA is diverted at Wells Siding and travels via ditch to OWMA, therefore bypassing the Lewis Avenue gage.

The managed area of OWMA above Lake Mead uses approximately 790 afy (Table 4-6), in addition to the 415 afy from MVIC shares, (Row P of Table 4-2) based on the type of vegetation/management practices for OWMA lands above Lake Mead. Aerial photography and discussions with OWMA management were used to determine the appropriate LCRAS Vegetation ET rates to apply to the managed areas.

4.5 Flows Entering Lake Mead

After the OWMA consumptive uses from the Muddy River are subtracted from the total flows measured at the Lewis Avenue gage, the total outflows to Lake Mead as both surface- and under-flows can be derived (Row Q of Table 4-2). As outlined in Table 4-2, 18,749 af of Muddy River water entered Lake Mead in CY 2014.

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5.0 SNWA TRIBUTARY CONSERVATION ICS

In CY 2014, SNWA controlled 15,098 af of Muddy River water rights. In 2014, SNWA did not deliver any Coyote Spring Valley Imported ICS (Imported) water to the Lower Muddy River for conveyance to Lake Mead.

The difference between the total outflows to Lake Mead and Tributary Conservation and Imported rights held by SNWA is 3,651 af. Since SNWA's are less than the total flow volume of water reaching Lake Mead, SNWA created Tributary Conservation ICS with the full volume of rights owned and controlled on the Muddy River – 15,098 af prior to overrun payback and the one-time deduction of 5% for the benefit of additional system storage in Lake Mead.

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6.0 REFERENCES

Anderson, B. and R. Ohmart. 1984. Lower Colorado River Riparian Methods of Quantifying Vegetation Communities to prepare Type Maps. Arizona State University, Tempe, Arizona.

Bureau of Reclamation, 2007, Lower Colorado River Accounting System evapotranspiration and evaporation calculations calendar year 2007: Boulder City, Nev., Bureau of Reclamation, Lower Colorado River Region.

DeMeo, G.A., Smith, J.L., Damar, N.A., and Darnell, Jon, 2008, Quantifying ground-water and surface-water discharge from evapotranspiration processes in 12 hydrographic areas of the Colorado Regional Ground-Water Flow System, Nevada, Utah, and Arizona: U.S. Geological Survey Scientific Investigations Report 2008-5116, 22 p.

Huntington, J.L., Allen, R.G., 2010, Evapotranspiration and Net Irrigation Water Requirements for Nevada, Nevada Division of Water Resources 96 p.

Westenburg, C.L., DeMeo G.A., and Tanko, D.J., 2006, Evaporation from Lake Mead, Arizona and Nevada, 1997–99: U.S. Geological Survey Scientific Investigations Report 2006-5252, 24 p.

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Appendices on CD

Appendix A	Muddy River Exhibit A Forbearance Agreement
Appendix B	Plan of Creation Submitted to the Bureau of Reclamation and Letter of Acceptance
Appendix C	Nevada State Engineer Order 1194
Appendix D	Copy of Muddy River Decree and Order of Determination
Appendix E	Certificates and Diversion Data for SNWA Controlled Upper Muddy River Water Rights
Appendix F	Water Right Certificates held by MVIC
Appendix G	MVIC Letter of Concurrence
Appendix H	Muddy Valley Irrigation Company Water Schedule

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SOUTHERN NEVADA
WATER AUTHORITY

Muddy River
Tributary Conservation
Intentionally Created Surplus
Certification Report

Calendar Year 2015

May 2016

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Suggested citation: Southern Nevada Water Authority, 2016, Muddy River Tributary Conservation Intentionally Created Surplus Certification Report Calendar Year 2015: Southern Nevada Water Authority, Las Vegas, Nevada, Doc. No. WMP-ED-0009, 82 p.

United States Department of the Interior

BUREAU OF RECLAMATION
Lower Colorado Regional Office
P.O. Box 61470
Boulder City, NV 89006-1470

IN REPLY REFER TO:
LC-4220
WTR-4.03

JUN 23 2016

CERTIFIED – RETURN RECEIPT REQUESTED

Ms. Colby Pellegrino
Colorado River Program Manager
Southern Nevada Water Authority
P.O. Box 99956
Las Vegas, NV 89193-9956

Subject: Verification of Tributary Conservation Intentionally Created Surplus (ICS) and System Conservation Water Created by the Southern Nevada Water Authority (SNWA) in Calendar Year (CY) 2015

Dear Ms. Pellegrino:

The 2007 Record of Decision for *Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead* (2007 Interim Guidelines) establishes the requirements for the creation, delivery, and accounting for ICS. By letter dated June 1, 2016, SNWA submitted to the Bureau of Reclamation its Muddy River Tributary Conservation ICS and Virgin River Tributary Conservation ICS Certification Reports for CY 2015 (Certification Reports) in accordance with Section 3.D.1 of the 2007 Interim Guidelines. SNWA did not create Imported ICS in CY 2015 and therefore did not submit a CY 2015 Imported ICS Certification Report.

In accordance with Section 4.5 of the System Conservation Implementation Agreement No. 15-XX-30-W0576 (SCIA) between Reclamation and SNWA dated June 4, 2015, SNWA's Certification Reports also serve to identify the volume of System Conservation Water created by SNWA in CY 2015 under the Pilot System Conservation Program. In accordance with Section 3.D.2 of the 2007 Interim Guidelines and Section 4.6 of the SCIA, this letter provides SNWA notice of my determination regarding the quantity of Tributary Conservation ICS and the quantity of System Conservation Water created by SNWA in CY 2015.

As documented in the Certification Reports, SNWA indicates that it created 18,472 acre-feet (AF) of Muddy River Tributary Conservation and 14,175 AF of Virgin River Tributary Conservation in CY 2015, for a total of 32,647 AF of Tributary Conservation. Of this total volume, SNWA indicates that 25,147 AF were conveyed to Lake Mead as Tributary Conservation ICS, prior to accounting for the one-time deduction of 5 percent for the benefit of additional system storage in Lake Mead, and 7,500 AF were conveyed to Lake Mead as System Conservation Water.

Reclamation has reviewed the information contained in SNWA's Certification Reports, and confirms that the information adequately demonstrates the amounts of ICS and System Conservation Water created and that the methods of creation were consistent with SNWA's approved ICS Plans, as amended, Exhibit A of the Lower Colorado River Basin ICS Forbearance Agreement, and the Delivery Agreement (Contract No. 07-XX-30-W0520) among the United States, SNWA, and the Colorado River Commission of Nevada. Therefore, I verify and make the final determination that SNWA created 18,472 AF of Muddy River Tributary Conservation and 14,175 AF of Virgin River Tributary Conservation, for a total of 32,647 AF of Tributary Conservation in CY 2015. Additionally, I verify that, of the total volume of Tributary Conservation created, 25,147 AF were conveyed to Lake Mead as Tributary Conservation ICS, prior to accounting for the one-time deduction of 5 percent for the benefit of additional system storage, and 7,500 AF were conveyed to Lake Mead as System Conservation Water in accordance with the SCIA.

Thank you for submitting SNWA's CY 2015 Certification Reports. If you have questions, please contact Mr. Paul J. Matuska, Water Accounting and Verification Group Manager, at 702-293-8164 or pmatuska@usbr.gov.

Sincerely,

Terrance J. Fulp, Ph.D.
Regional Director

cc: Ms. Tanya M. Trujillo
Executive Director
Colorado River Board of California
770 Fairmont Avenue, Suite 100
Glendale, CA 91203

Jayne Harkins, P.E.
Executive Director
Colorado River Commission of Nevada
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Mr. Thomas Buschatzke
Director
Arizona Department of Water Resources
3550 North Central Avenue
Phoenix, AZ 85012

Mr. John Entsminger
General Manager
Southern Nevada Water Authority, MS 480
1001 South Valley View Boulevard
Las Vegas, NV 89153

BRIAN SANDOVAL
Governor

STATE OF NEVADA

LEO DROZDOFF
Director

JASON KING, P.E.
State Engineer

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
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http://water.nv.gov

May 18, 2016

Colby Pellegrino
Manager, Colorado River Program
MS #520
Southern Nevada Water Authority
PO Box 99956
Las Vegas, NV 89193-9956

Subject: Muddy and Virgin Rivers Tributary Conservation Intentionally Created Surplus Certification Reports, Calendar Year 2015

Dear Ms. Pellegrino:

Our office has reviewed the Southern Nevada Water Authority's (Authority) Calendar Year 2015 Certification Reports for Tributary Conservation Intentionally Created Surplus (ICS) for the Muddy and Virgin Rivers, dated May and April, 2016 respectively. These Certification Reports demonstrate that the amount of Tributary Conservation ICS created by the Authority and conveyed to Lake Mead are consistent with Nevada Water Law and State Engineer's Orders 1193 and 1194.

The Nevada State Engineer's Office concurs that the Muddy and Virgin River water rights outlined in said reports are owned or controlled by the Authority, have a priority date prior to June 25, 1929 and were conveyed to the Colorado River mainstream (i.e., Lake Mead full pool elevation of 1,220 above mean sea level) as described and in the amounts indicated in the table below.

Calendar Year 2015	Volume, in acre-feet/year Cited in Certification Reports		
	Muddy River (Tributary Conservation)	Virgin River (Tributary Conservation)	Coyote Springs (Imported)
Created ICS	18,472	14,175	0

Should you have any questions, please contact Supervising Engineer, John Guillory, P.E. at (702) 486-2770.

Sincerely,

P.E.

Jason King, P.E.
State Engineer

cc: Rick Felling, Deputy Administrator via email
John Guillory, SNBO via email
Jayne Harkins, Colorado River Commission of Nevada

CONTENTS

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FIGURES (CONTINUED)

TABLES

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ACRONYMS

AZMET	Arizona Meteorological Network
BCPA	Boulder Canyon Project Act
CEMP	Overton Nevada Community Environmental Monitoring Program
CY	Calendar Year
ET	Evapotranspiration
ICS	Intentionally Created Surplus
LCRAS	Lower Colorado River Accounting System
MET	Meteorological
MVIC	Muddy Valley Irrigation Company
NDWR	Nevada Division of Water Resources
OWMA	Overton Wildlife Management Area
MBPI	Moapa Band of Paiute Indians
MVWD	Moapa Valley Water District
NIWR	Net Irrigation Water Requirement
NVE	NV Energy
PBU	Proof of Beneficial Use
POU	Place of Use
SCIA	System Conservation Implementation Agreement
SNWA	Southern Nevada Water Authority
USGS	United States Geological Survey
WSNA	Warm Springs Natural Area

ABBREVIATIONS

af	acre-feet
afy	acre-feet per year
amsl	above mean sea level
cfs	cubic-feet per second
ft	foot
yr	year

ROUNDING DISCLAIMER

Due to rounding, numbers presented in tables throughout this document may not add up precisely to the totals provided.

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1.0 INTRODUCTION

1.1 Intentionally Created Surplus (ICS)

The Secretary of Interior (Secretary) issued a Record of Decision for 'Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead' (Guidelines) on December 13, 2007, which established criteria for the development and delivery of Intentionally Created Surplus (ICS). One type of ICS is Tributary Conservation, which allows a Contractor, as defined in the Guidelines, to increase tributary flows into the mainstream of the Colorado River within its state for ICS credits. Conservation of tributary flows entering the mainstream of the Colorado River and available for ICS credit are limited to flows associated with water rights that have been used for a significant period of years and were perfected prior to June 25, 1929, the effective date of the Boulder Canyon Project Act (BCPA).

To generate ICS, the Guidelines require a Contract holder to enter into a Delivery Agreement with the United States of America and a Forbearance Agreement with Lower Basin Contract holders. On December 13, 2007, the Southern Nevada Water Authority (SNWA) and Colorado River Commission of Nevada entered into a Delivery Agreement with the United States of America and a Forbearance Agreement with Lower Basin Contract holders. Exhibit A of the Forbearance Agreement describes the surface-water rights on the Muddy and Virgin Rivers, pre-dating June 25, 1929, which SNWA plans to use to create Tributary Conservation ICS, and how the Muddy River flows reaching Lake Mead will be calculated (Appendix A).

1.2 Plan of Creation (ICS Plan)

The Guidelines, Forbearance Agreement, and Delivery Agreement require a plan for the creation of ICS (ICS Plan). An ICS Plan for Muddy River Tributary Conservation ICS was submitted to Reclamation for CY 2015 on June 30, 2014. SNWA received a letter from Reclamation dated September 25, 2014 approving the ICS Plans for CY 2015.

After the execution of the System Conservation Implementation Agreement (SCIA) on June 4th, 2015, an amended 2015 ICS Plan was submitted Reclamation on June 17, 2015 for the purpose of documenting the planned Pilot System Conservation Program (Pilot Program) water, as discussed in Section 1.3. The amended ICS Plan was approved by Reclamation in a letter dated September 10, 2015 (Appendix B).

This report satisfies the requirements the Guidelines and of Nevada State Engineer Order 1194 which is provided in Appendix C and summarized as follows:

- Under Nevada State Engineer Order 1194, an annual report will be submitted to the Nevada Division of Water Resources giving a "full accounting of adjudicated water rights on the Muddy River or its tributaries owned or controlled by the entity with an ICS Delivery Contract, which have been conveyed through the Muddy River system to the Colorado River mainstream for the creation of ICS." After review of the annual report, the Nevada State Engineer will issue a letter verifying the quantity of water conveyed through the Muddy River system to the Colorado River mainstream for the purpose of creating ICS.

- Based on the Guidelines, an annual certification report will be submitted for the Secretary of Interior's review and verification that documents the amount of Tributary Conservation ICS created in the preceding year, and demonstrates that the method of creation was consistent with SNWA's approved ICS Plan.

Intentionally Created Surplus is declared a beneficial use under Nevada Revised Statutes 533.030.

1.3 Pilot System Conservation Program (Pilot Program)

On July 30, 2014, the U.S. Bureau of Reclamation (Reclamation) and four municipal entities, the Central Arizona Water Conservation District, The Metropolitan Water District of Southern California, Denver Water, and SNWA entered into an agreement for a Pilot Program for funding the creation of Colorado River System water through voluntary water conservation and reductions in use.

The Pilot Program funds projects that keep water in Lakes Powell and Mead through temporary, voluntary, and compensated conservation mechanisms. SNWA submitted a Pilot Program proposal to dedicate to the Colorado River System a portion of Muddy and Virgin River water it owns or otherwise controls to the Colorado River System in Calendar years 2015 and 2016, in lieu of creating Tributary Conservation ICS Credits. The proposal was selected for funding and SNWA entered into a System Conservation Implementation Agreement (SCIA) with the Bureau of Reclamation on June 4, 2015, to conserve a total of 15,000 acre-feet of Colorado River water in calendar years 2015 and 2016. For each Calendar Year (CY) 2015 and 2016, SNWA will dedicate 7,500 af of its Muddy and Virgin River water to the Colorado River System, in lieu of creating Tributary Conservation ICS credits. The full duration of SNWA's Pilot Program is two calendar years, 2015 and 2016.

SNWA will use the approved methods consistent with the ICS program documented in Exhibit A of the Forbearance Agreement (Appendix A) and described in this document, to document the volume of conserved Muddy and Virgin River water to be dedicated as Pilot Program water that will remain in the Colorado River System.

2.0 PROJECT DESCRIPTION

Muddy River water rights that are being utilized to create Tributary Conservation ICS pursuant to the approved ICS Plan and Exhibit A of the Forbearance Agreement are decreed Nevada state water rights with an established history of use prior to 1929. Exhibit A of the Forbearance Agreement specifically allows SNWA to utilize any and all pre-June 25, 1929, Muddy River water rights to create Tributary Conservation ICS regardless of the water rights history of use after 1928.

The Muddy River originates from regional springs in the Muddy River Springs Area in Nevada and flows into the Overton Arm of Lake Mead (Figure 2-1). Muddy River flows are relatively constant, because flows from the springs that form the river are consistent due to their regional source, the carbonate aquifer system of eastern Nevada. The average annual flow of the Muddy River at the United States Geological Survey (USGS) gaging station 09419000 *Muddy River near Glendale, Nevada* (Glendale gage) for Water Years 1950 through 2014 is 30,572 acre-feet per year (afy).

Muddy River water rights were judicially decreed in 1920, and the decree allocated the entire flow of the Muddy River (Appendix D). The Order of Determination, attached to the decree as Exhibit A, explicitly outlines the Place-of-Use (POU) for the water rights and established summer and winter diversion rates. For the most of the decreed rights, the summer season is May 1 to September 30 with a diversion rate of 1 cubic-foot per second (cfs) per 70 acres of land and the winter season is October 1 to April 30 with a diversion rate of 1 cfs per 100 acres of land. These diversion rates equate to an annual rate of 8.54 afy per acre (afy/acre).

Surface water rights on the upper reach of the Muddy River, from the Muddy River Springs to the Glendale gage, are owned and controlled by individual right holders. On the Lower Muddy River, downstream of the Glendale gage, water rights are held by the Muddy Valley Irrigation Company (MVIC) for use by its shareholders.

Muddy River surface-water rights owned and controlled by SNWA are no longer utilized for agriculture and are therefore being conveyed to Lake Mead. The pre-June 25, 1929, water rights conveyed to Lake Mead represent the full right that is and has been historically used for agriculture or could have otherwise been diverted from the Muddy River and fully consumed by SNWA in Nevada.

Muddy River rights conveyed to Lake Mead passed through their historic points of diversion and either flowed through the irrigation company ditches and returned to the mainstream of the Muddy River further downstream or remained in the mainstream of the Muddy River. The full rights owned and leased by SNWA and documented to flow to Lake Mead have been accounted for as Tributary Conservation ICS or as Pilot Program water.

Figure 2-1
Map of the Upper and Lower Reaches of the Muddy River Divided by the Glendale Gage

2.1 Summary of Results for CY 2015

The total volume of Muddy River water for which SNWA created Tributary Conservation ICS and the Pilot Program was 18,472 af in CY 2015. This volume excludes any overrun payback and a one-time deduction of 5% for the benefit of additional system storage in Lake Mead, as outlined in the Guidelines (Table 2-1). This volume is less than the 20,000 af outlined in the approved, amended CY 2015 ICS Plan. Detailed data and calculations are described in subsequent sections of this report.

Table 2-1
Muddy River 2015 ICS and Pilot Program Water

Water Right	Acre Feet Conserved in 2015
Muddy Valley Irrigation Company	8,509
Moapa Paiute Lease	3,000
LDS Church Rights Lease	2,001
NV Energy Lease	3,000
Hidden Valley Dairy	1,040
Knox and Holmes	811
SNWA Acquired Cox Right	85
SNWA Acquired Mitchell Right	26
SNWA Muddy River ICS Credit and Pilot Program Water Credit	**18,472**

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3.0 WATER CONSERVATION ASSOCIATED WITH SNWA MUDDY RIVER RIGHTS

On the Muddy River, there are two distinct reaches above and below USGS gaging station *09419000 Muddy River Near Glendale, NV* (Glendale gage). By controlling water rights on the Muddy River within these two reaches, SNWA was able to successfully conserve Muddy River water in CY 2015 and convey it to Lake Mead for Tributary Conservation ICS credits or for the Pilot Program. The sections below describe the water rights and conservation measures.

3.1 Verification Process of Fallowed Land

Within the agricultural areas, irrigated areas were digitized using the 2006 National Agricultural Imagery Program data. Since 2008, SNWA has funded aerial-photography specifically for the purpose of Tributary Conservation ICS verification. This photography has been strategically scheduled 3-times per year to document agricultural activities during the summer and winter seasons of a given calendar year are documented. The high-resolution, aerial photography has a resolution of 6-inches per pixel and allows for more accurate determinations of fallowed versus active agricultural fields. An example of the high-resolution, aerial photography used to classify and delineate crop areas is presented in Figure 3-1.

The aerial photography combined with field reconnaissance and interviews with irrigation company managers ensured the highest degree of accuracy in determining the actual irrigated acreage along the Muddy River.

Aerial-photography flights were performed in December 2014, July 2015, and December of 2015 to identify lands being flood irrigated or fallowed during the winter and summer irrigation seasons. The summer irrigation season spans May through September. The July photography documents areas that were actually being irrigated during the summer irrigation season, because by July most of the natural vegetation that was not receiving irrigation water had died back.

Muddy River water rights have defined POU maps and many have subsequent Proof-of-Beneficial-Use (PBU) maps, showing the locations where the decreed and permitted water rights were beneficially used within the defined POU. These POU and PBU maps, when compared to recent aerial photography, serve as the baseline for proof of previously irrigated lands, documenting conservation of the water. In some instances, the recent digitized polygons of the current fields do not exactly match the fields on the POU or PBU maps from decades prior. This is due to improved mapping capabilities and changes in land/water right ownership resulting in divided/combined fields. However, since the water rights can be used anywhere within the defined POU, the breakdown of the fields is not as important as the total irrigated acreage within the POU.

Figure 3-1
Example of Detailed 6-inch Aerial Photography on the Lower Muddy River

Some of the fields on the aerial photography depict green vegetation even though they are not being irrigated. This is due to the fact that many of the fallowed fields historically contained perennial alfalfa, which receive periodic water from winter rains that temporarily turn the fields green. Many of the fields that appear to have some green in the photography of the cooler months are brown in the July photography. To ensure the fields were not irrigated, SNWA met with land owners or irrigation managers to review which fields were being irrigated. Additionally, written verification from the Muddy Valley Irrigation Company (MVIC) was obtained documenting that the shares controlled by SNWA were not being used for irrigation (Appendix G). The results of the interviews and documentation of conserved water on the Muddy River is presented in the following sections.

3.2 Upper Muddy River Rights

The Upper Muddy River, for the purposes of this report, is defined as the reach from the Muddy River Springs Area to the Glendale gage. Within this reach, decreed Muddy River water rights are individually owned with specific POUs describing the lands irrigated by the surface-water rights.

The Upper Muddy River is a gaining stream from its headwaters to the Glendale Gage and natural vegetation in this area (eg. phreatophytes) is supplied by shallow groundwater and spring discharge. The river flows do not constitute a significant source of water supply for Evapotranspiration (ET) losses. Therefore no ET losses were deducted from the Muddy River water rights between the headwater springs and the Glendale Gage.

3.2.1 LDS Church Rights Lease / Cox and Mitchell Right Purchase

In 2006, SNWA in partnership with the Moapa Valley Water District (MVWD) agreed to lease 2,001 afy of the 2,046 afy of decreed Muddy River water rights held by the Corporation of the Presiding Bishop of the Church of Jesus Christ of Latter-day Saints (LDS Church). This water had been historically used for agricultural irrigation on approximately 228 acres in the Muddy River Springs Area. The lease agreement allows MVWD and option to utilize up to 50% of the water leased based on coordination with SNWA. In CY 2015, MVWD did not exercise their 50% option on the LDS Church lease, and SNWA retained the entire 2,001 af.

In 2007, SNWA purchased the majority of land associated with the LDS Church water rights for the primary purpose of restoring habitat of the Moapa dace, an endangered fish species endemic to the warm waters of the Muddy River Springs Area. The management of this land, referred to as the Warm Springs Natural Area (WSNA), in combination with the U.S. Fish and Wildlife's management of the adjacent Moapa Wildlife Refuge, will protect the majority of the springs that make up the headwaters of the Muddy River. A key component of activities to preserve the Moapa dace's habitat is leaving the warm water that emanates from the Muddy River Springs Area, which was previously used for agricultural purposes, in the natural channels that meander through the WSNA and the Moapa Wildlife Refuge. This preservation activity is compatible with the creation of Tributary Conservation ICS on the Muddy River.

When SNWA purchased the WSNA in 2007, it also acquired two decreed water rights not related to the 2,001 afy LDS Church lease. These rights were originally decreed to Cox (V01619) and Mitchell (V01631) in 1920 for 85 afy and 26 afy, respectively.

Figure 3-2 presents the 1984 PBU map and POU for the decreed and certificated LDS Church, Cox, and Mitchell water rights. Figures 3-3 through Figure 3-5 present the aerial photography for these areas and vicinity during December 2014, July 2015, and December of 2015, respectively. The aerial photography illustrates land fallowing over the POU.

The fallowed lands are further emphasized on Figure 3-6, which presents a 1976 aerial photograph of the area along with the July 2015 photography. The 1976 photography depicts numerous agricultural fields indicative of active irrigation, while the July 2015 photography demonstrates irrigation has not occurred on much of the lands for several years, including CY 2015. There are some areas within the POU where natural vegetation that is not irrigated has replaced previously cultivated/irrigated fields. These naturally vegetated areas are located in the middle of the Muddy River Springs Area and are being supported by natural groundwater seeps and relatively shallow depths to groundwater. Since acquiring the WSNA property in September 2007, SNWA has ensured that none of the fields associated with either the LDS Church lease or the Cox and Mitchell rights were irrigated during CY 2015.

Figures 3-2 through Figure 3-5 demonstrate that lands associated with the 2,001 afy LDS Church lease as well as the 111 afy Cox and Mitchell rights remained fallowed during CY 2015. The 2,112 af of conserved water remained in the mainstream of the Muddy River and flowed downstream to the Glendale gage and then to Lake Mead. The conveyance of these rights from the Glendale gage to Lake Mead is accounted for in the calculations for the Lower Muddy River in subsequent sections of this report.

3.2.2 Moapa Band of Paiute Indians Lease

The Moapa Band of Paiute Indians (MBPI) controls 3,700 afy of Muddy River decreed water rights under Permits 73482, 73483, and 73695. These permits were previously controlled by the MVIC under Muddy River Decree Certificates 58A, 266, and 274. The MBPI Muddy River permits state they are in 'consumptive use' terms, defined in the permits as "*…intended to mean diversions less returns of Muddy River Water.*"

In April of 2015, SNWA entered into an agreement with the MBPI to lease up to 3,000 af of their pre-BCPA Muddy River consumptive use water rights during CY 2015 and CY 2016. In addition, the Hidden Valley Dairy leased 300 af from MBPI during CY 2015, leaving MBPI 400 af for irrigation on the MBPI reservation.

The MBPI utilizes a sprinkler irrigation system with a booster pump and flow meter. An additional meter had been installed at the bottom of the irrigation system where diverted water that remained in the distribution pipe and was not used would be metered back to the Muddy River.

For much of CY 2015 the meter at the bottom of the MBPI irrigation system was not functioning, and for a few months in the summer irrigation season the flow meter at the intake pump was also not

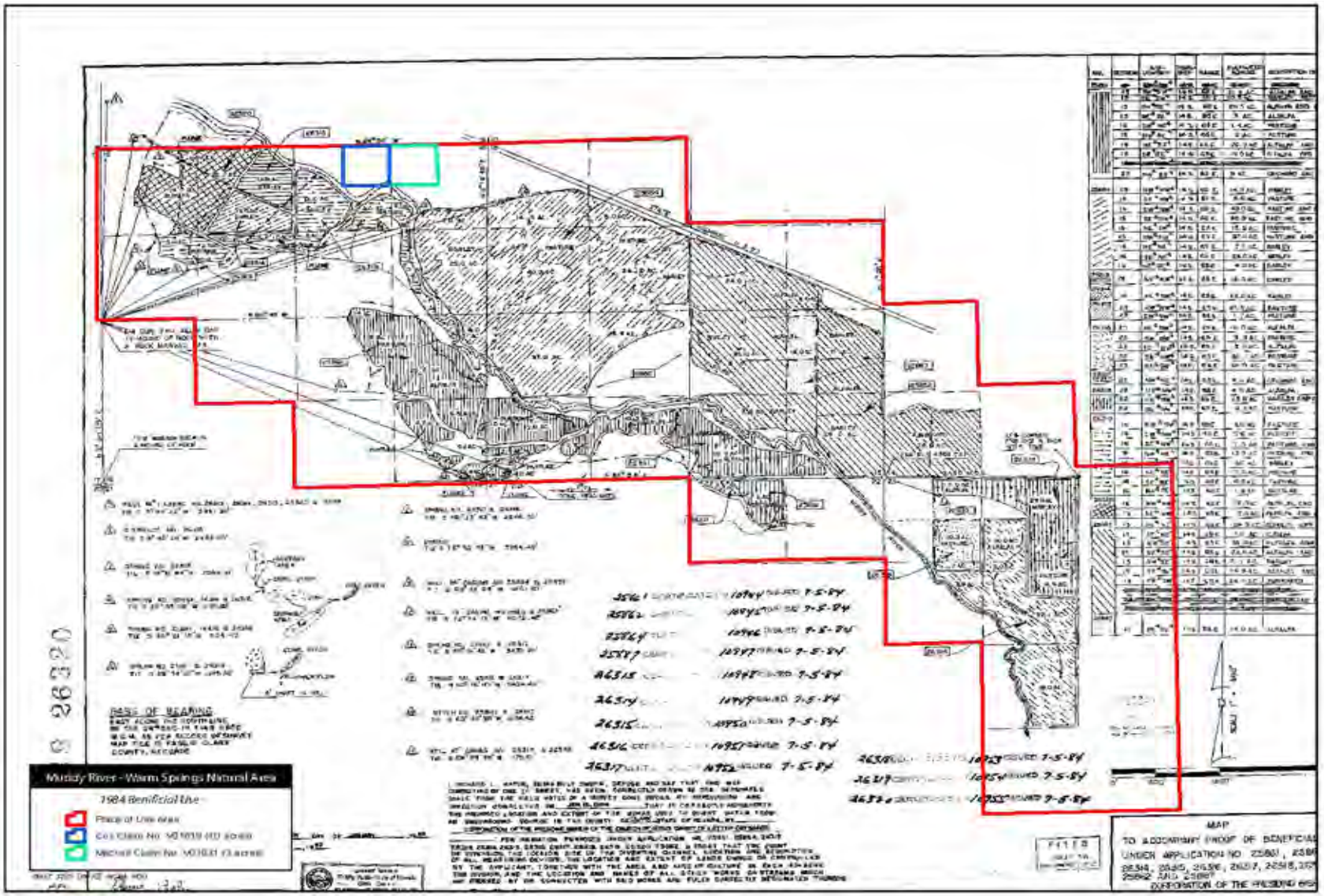

Figure 3-2
LDS Church Water Rights 1984 PBU Map; POU Quarter-Quarter Sections for LDS Church Rights Highlighted in Red; Cox and Mitchell Rights Highlighted in Blue and Green, Respectively

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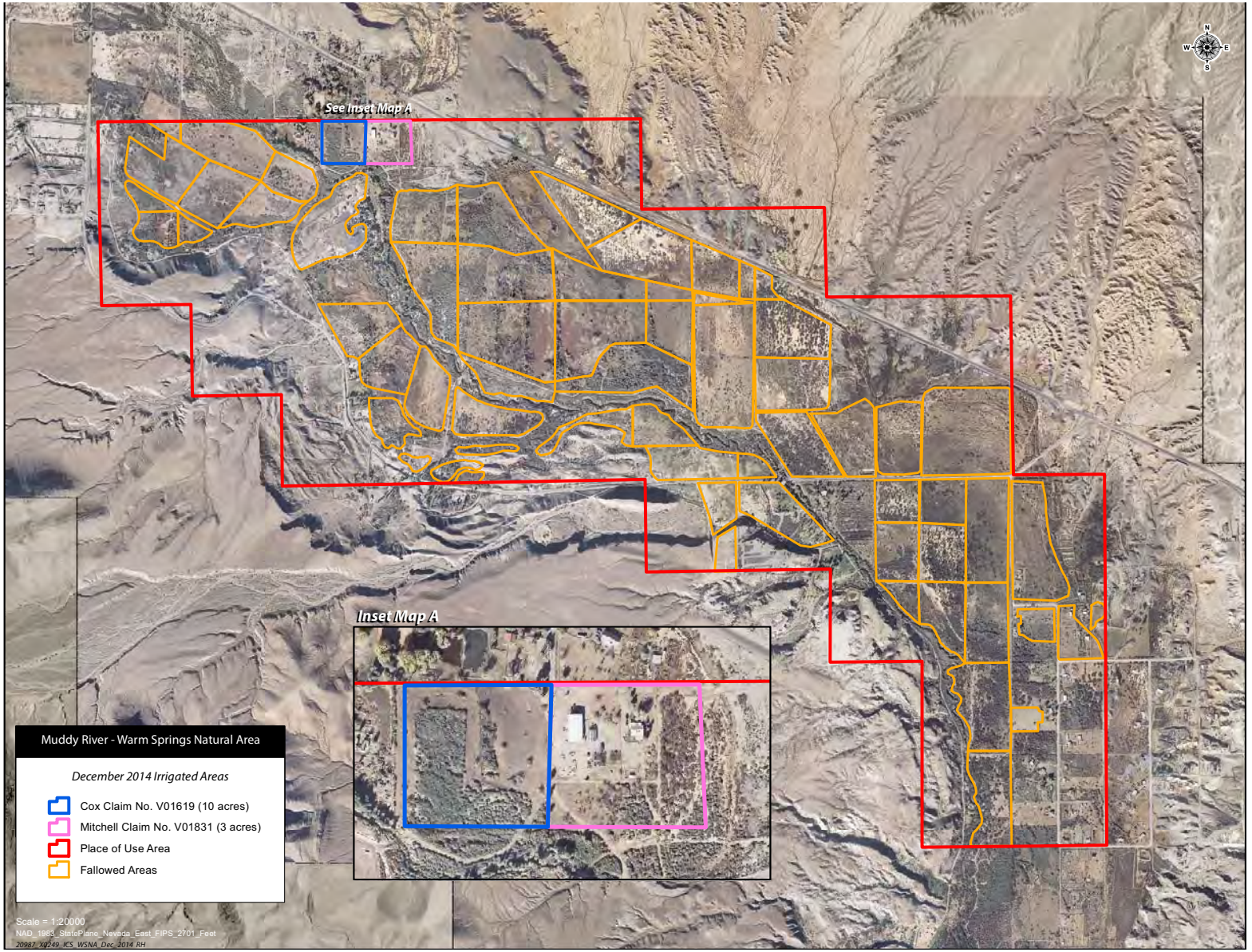

Figure 3-3
December 2014 Aerial Photography for LDS Church, Cox, and Mitchell Rights

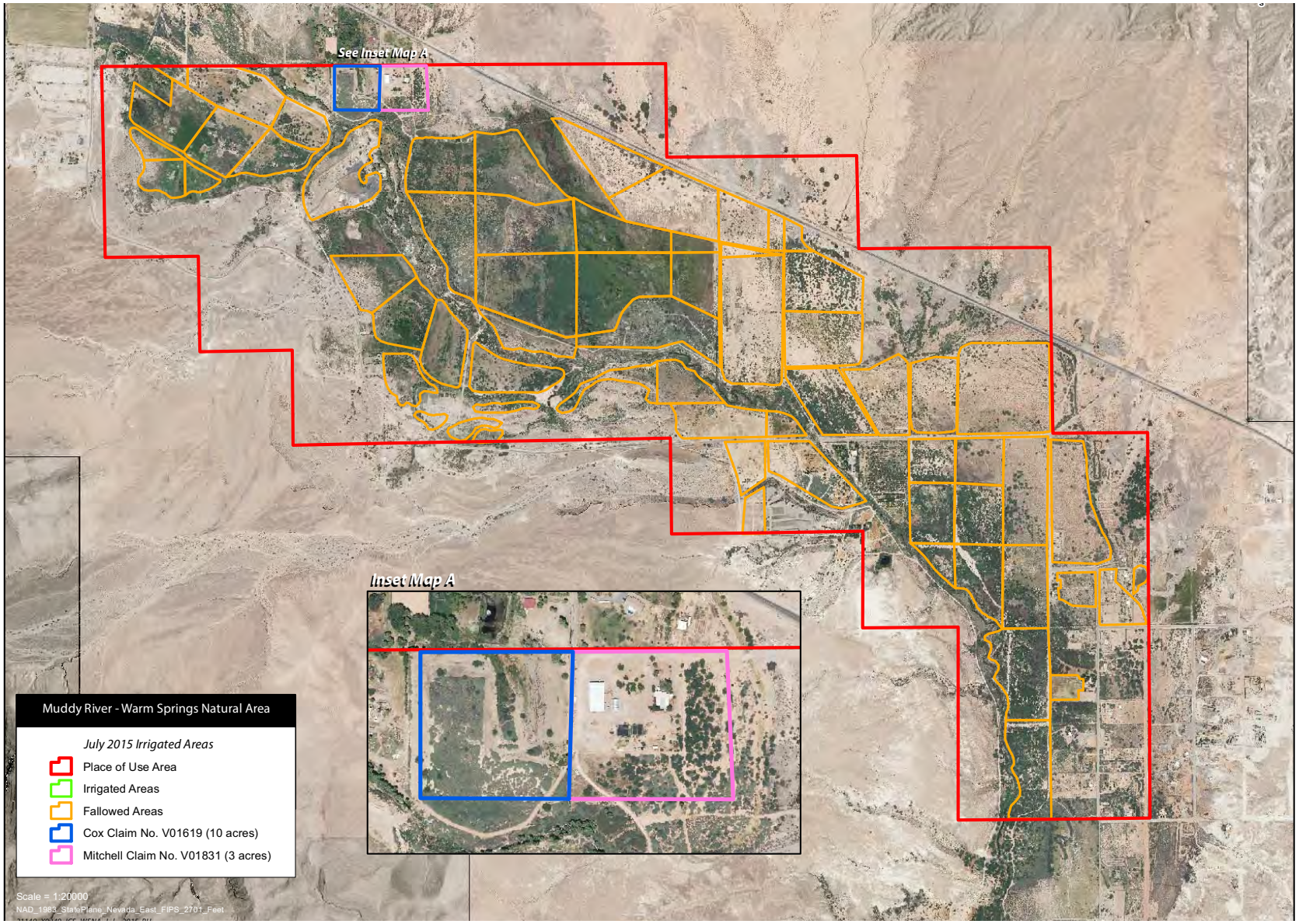

Figure 3-4
July 2015 Aerial Photography for LDS Church, Cox, and Mitchell Rights

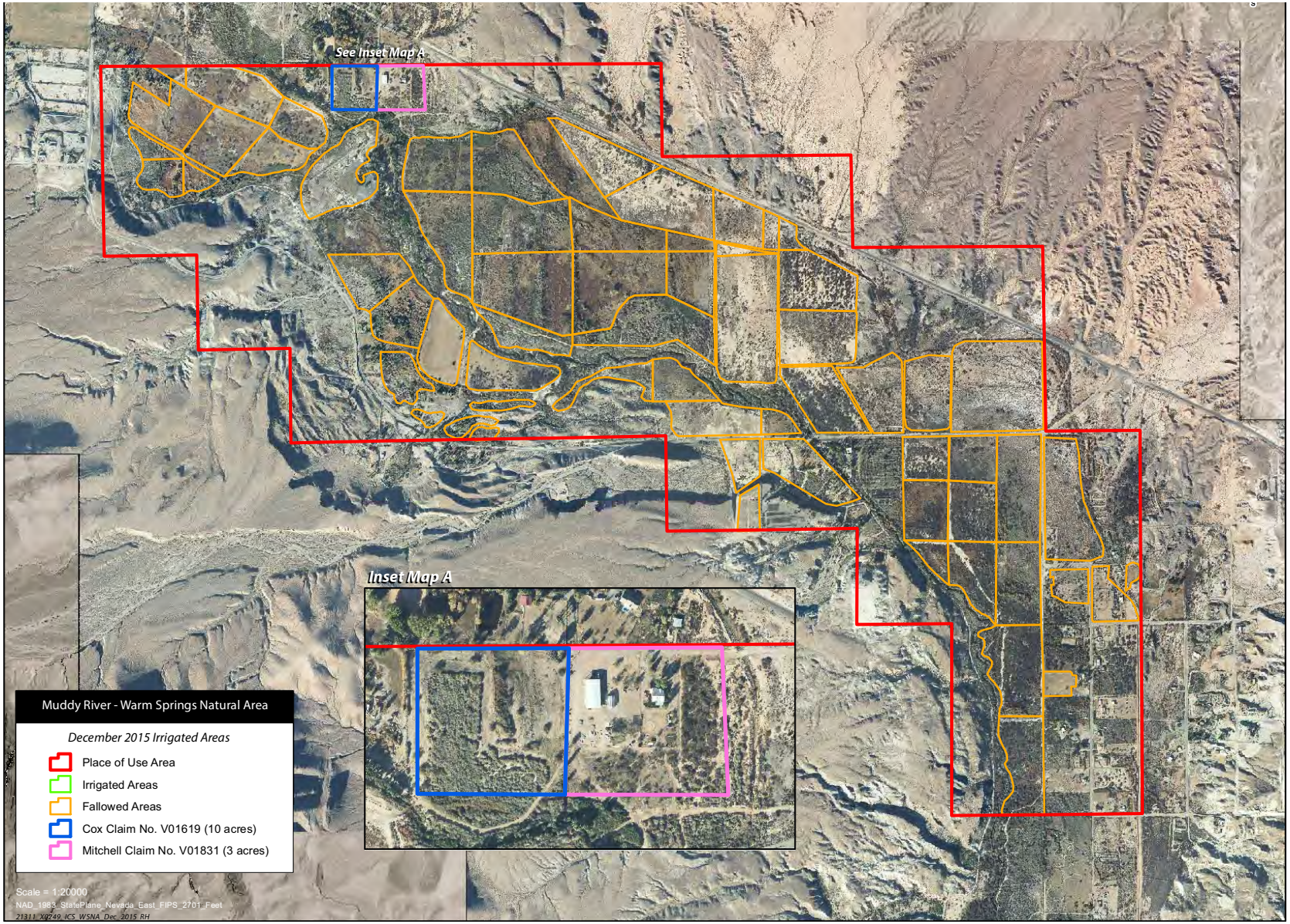

Figure 3-5
December 2015 Aerial Photography for LDS Church, Cox, and Mitchell Rights

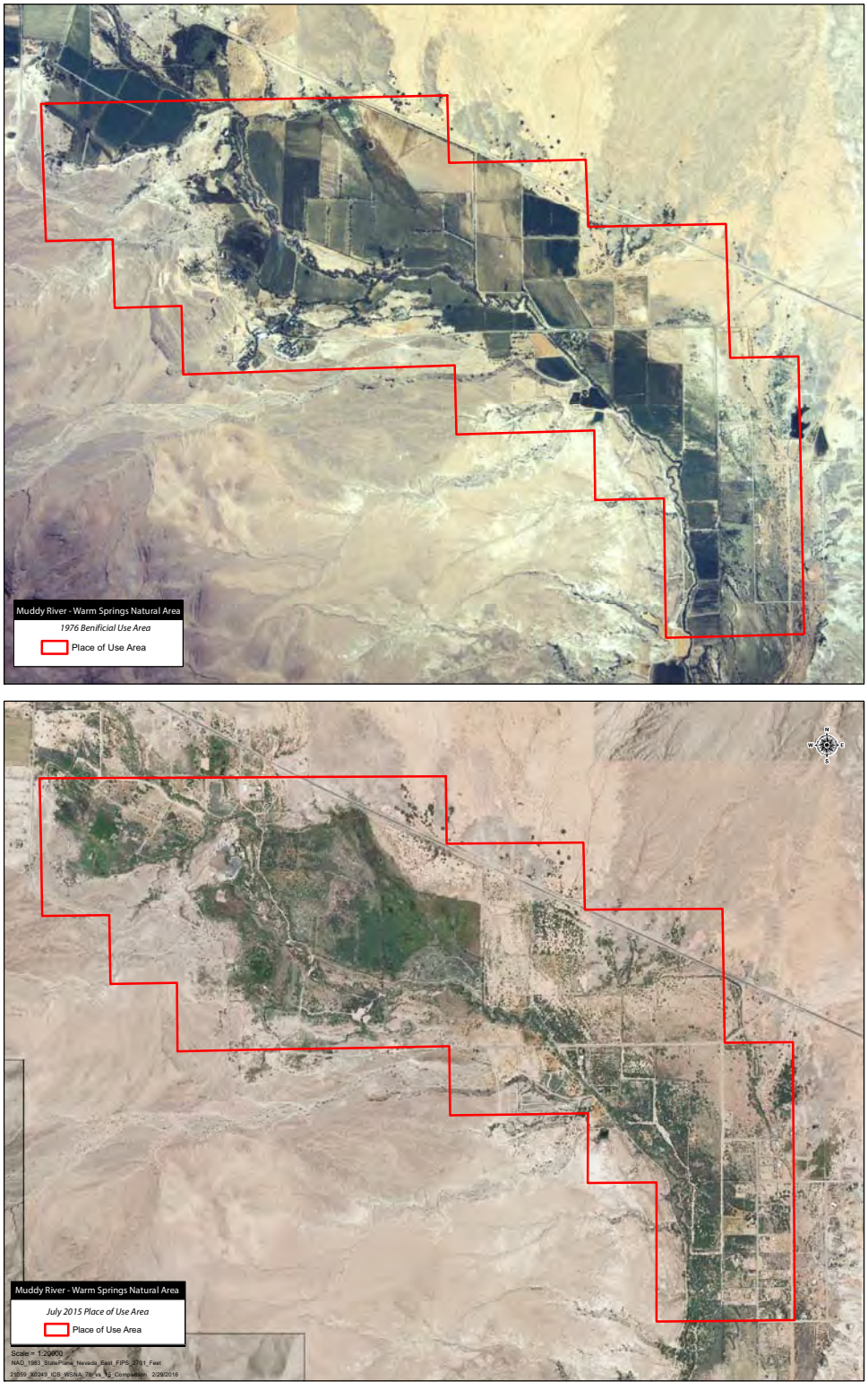

Figure 3-6
POU for the LDS Church Water Rights Overlaid on a 1976 Aerial Photograph (Top), and the July 2015 Aerial Photograph (Bottom)

functioning. Because of the missing periods of meter data, consumptive use of Muddy River by MPBI in CY 2015 was determined using the Net Irrigation Water Requirement (NIWR), which is the estimated amount of water a crop uses in a specific geographic location (Huntington, 2010). The monthly NIWR for lands irrigated by MPBI is based on data from an Overton, NV meteorological station, and was obtained from the Nevada Division of Water Resources (http://water.nv.gov/mapping/et/et_general.cfm).

Figure 3-7 through Figure 3-10 compare the POU for the MBPI lands with the aerial photography taken in December 2014, July 2015, and December of 2015, respectively. The aerial photography demonstrates MPBI irrigated three fields totaling 73.10 acres throughout CY 2015. Table 3-1 applies the NIWR to the irrigated acreage and illustrates MPBI used 334 af of water in CY 2015, conserving 3,366 af. This conserved water was sufficient to meet the SNWA lease of 3,000 af and the Hidden Valley Dairy lease of 300 af in CY 2015.

The 3,000 af of MPBI water leased by SNWA remained in the mainstream of the Muddy River and flowed downstream to the Glendale gage and then to Lake Mead. The conveyance of these rights from the Glendale gage to Lake Mead is accounted for in the calculations for the Lower Muddy River in subsequent sections of this report.

The 300 af of MPBI water leased by the Hidden Valley Dairy was transferred to their point of diversion and POU downstream under Permits 85529T and 85530T.

3.2.3 Hidden Valley Purchase

In 2008, SNWA purchased 1,040.91 af of decreed Muddy River water rights along an upper reach of the Muddy River commonly referred to as Hidden Valley. The full volume of water available under the water-right certificate is 1,340.91 af. The land owner, referred to as Hidden Valley Dairy, retained approximately 300 af. As discussed in the previous section, Hidden Valley Dairy leased an additional 300 af from MBPI.

Figure 3-11 depicts a 1918 PBU map of Hidden Valley. The red outline highlights the Public Land Survey System Quarter-Quarter sections that are included in the POU description in the Muddy River Decree. Figures 3-12 through Figure 3-14 present the aerial photography for this area taken in December 2014, July 2015, and December of 2015.

To enhance water accounting associated with Hidden Valley, a continuous flow measurement device was installed in 2014 on the Hidden Valley diversion from the Muddy River. In CY 2015 metered diversions were used to demonstrate that the Hidden Valley Dairy did not exceed their diversion right. The aerial photography provided additional verification that the metered diversions irrigated a reasonable number of acres. Table 3-2 presents the monthly metered diversions that total 455 af in CY 2015, which was less than the 600 af available to the Hidden Valley Dairy in CY 2015.

The 1,040.91 af owned by SNWA was conserved and remained in the mainstream of the Muddy River and flowed downstream to the Glendale gage and then to Lake Mead. The conveyance of these rights from the Glendale gage to Lake Mead is accounted for in the calculations for the Lower Muddy River in subsequent sections of this report.

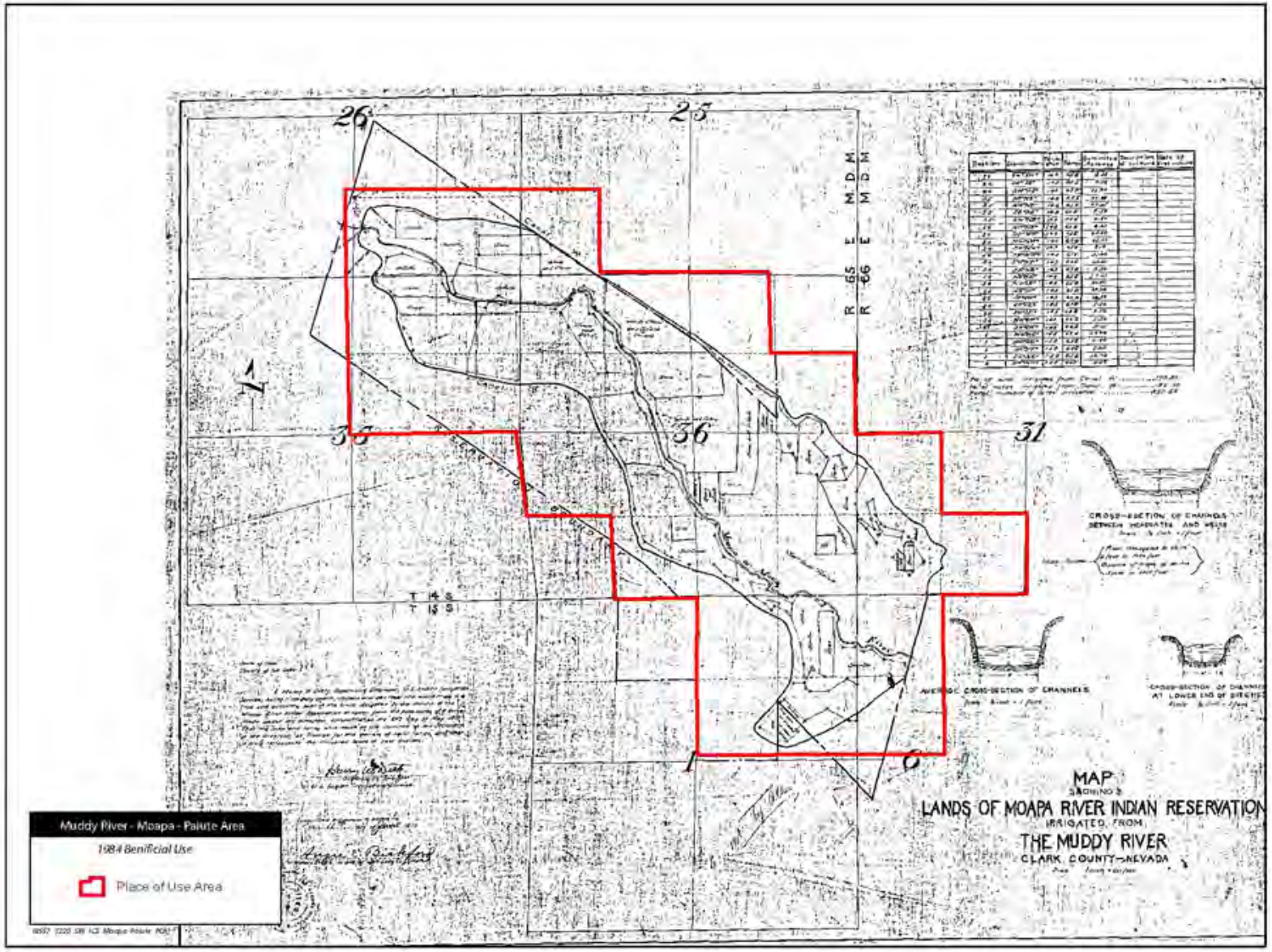

Figure 3-7
Moapa Band of Paiutes 1984 PBU Map; POU Quarter-Quarter Sections Highlighted in Red

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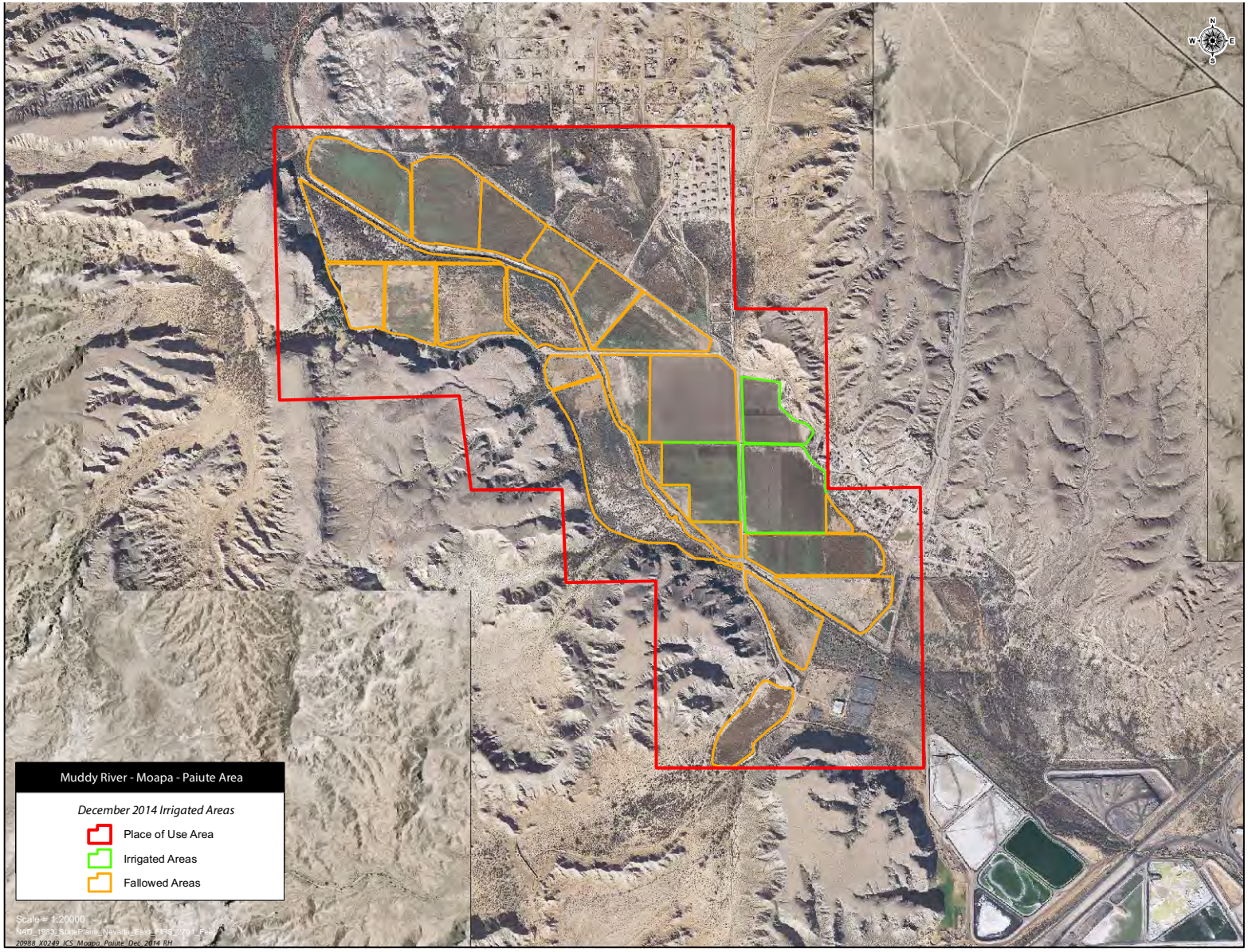

Figure 3-8
December 2014 Aerial Photography for Moapa Band of Paiutes

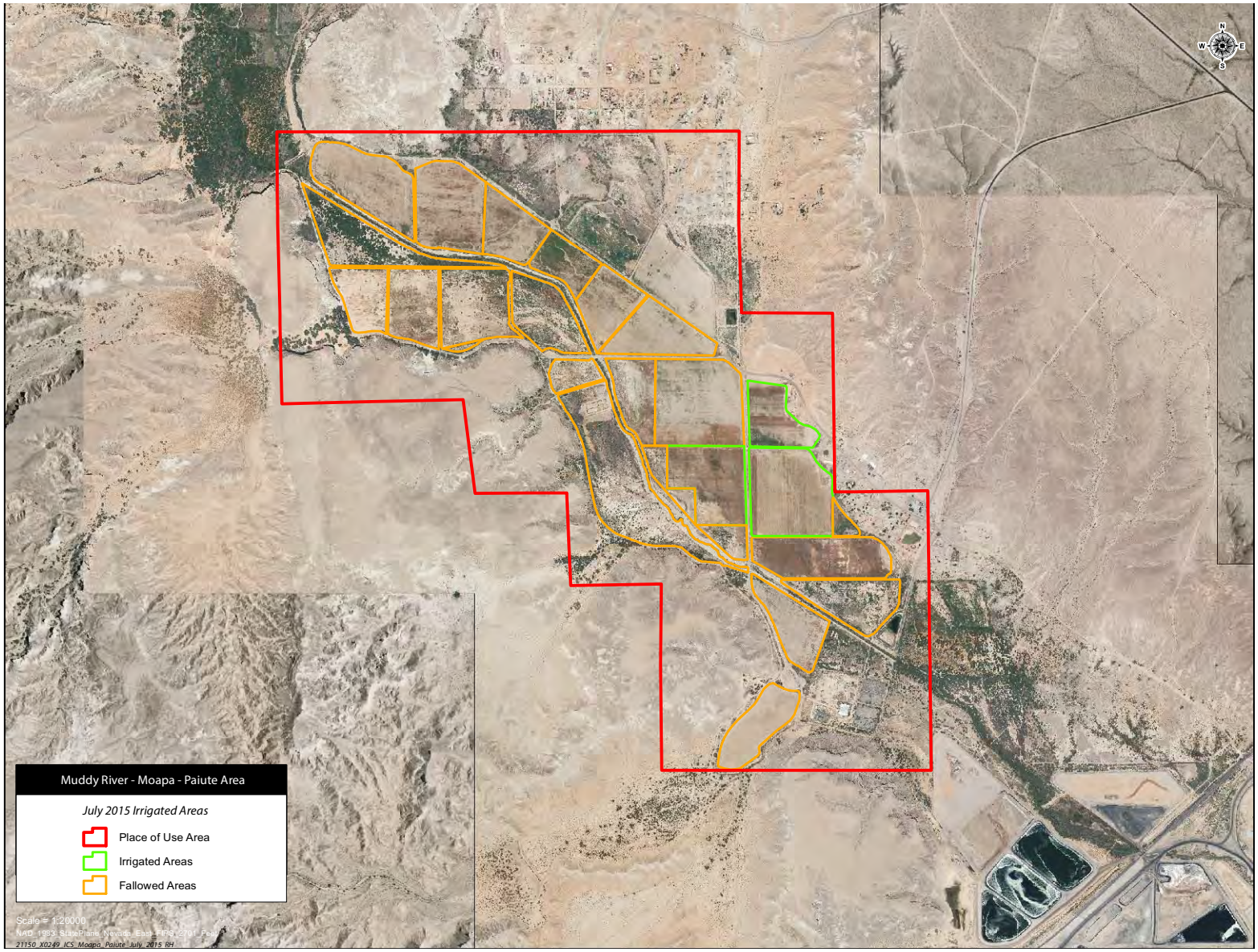

Figure 3-9
July 2015 Aerial Photography for Moapa Band of Paiutes

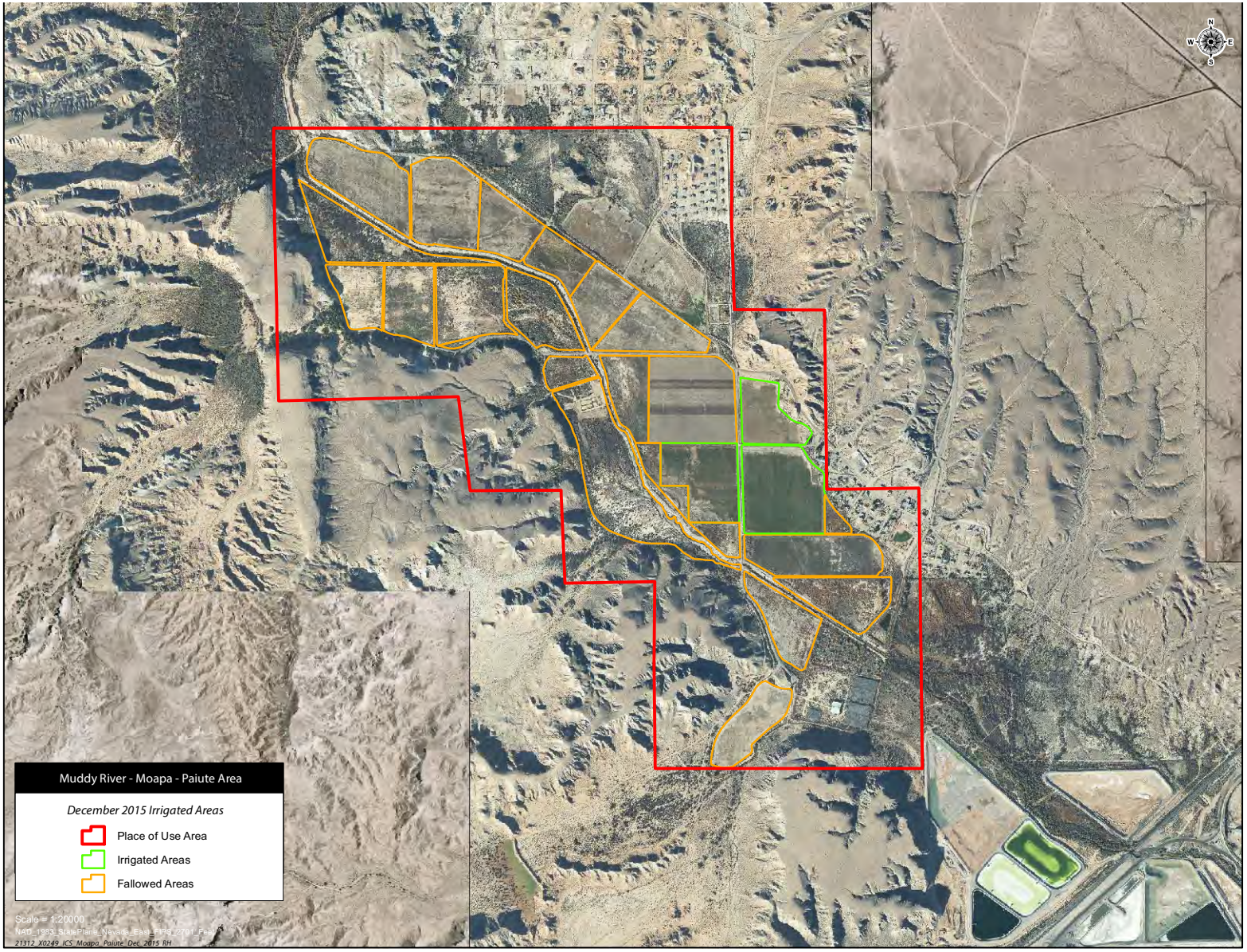

Figure 3-10
December 2015 Aerial Photography for Moapa Band of Paiutes

Table 3-1
Moapa Band of Paiutes Metered Usage

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2015 Total
A	Total MBPI Water Right (af)	258.67	233.63	258.67	357.60	369.52	357.60	369.52	369.52	357.60	258.67	250.32	258.67	3,700
B	Measured Irrigated Acres (acres)	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	73.10	
C	x NDWR Overton NIWR (ft)	0.01	0.10	0.40	0.44	0.64	0.72	0.69	0.61	0.47	0.31	0.13	0.06	
D = B x C	Agricultural Consumptive Use (af)	0.74	7.45	29.00	32.31	46.47	52.38	50.26	44.24	34.61	22.82	9.28	4.24	334
E = A - D	Total Water Conserved (af)	257.92	226.18	229.67	325.30	323.06	305.22	319.25	325.29	323.00	235.84	241.04	254.43	3,366
F	Leased to Hidden Valley Dairy													300
G = E - F	**Remaining Conserved Water**													**3,066**
H	**SNWA Leased Right (af)**													**3,000**
Is H < G														**YES**

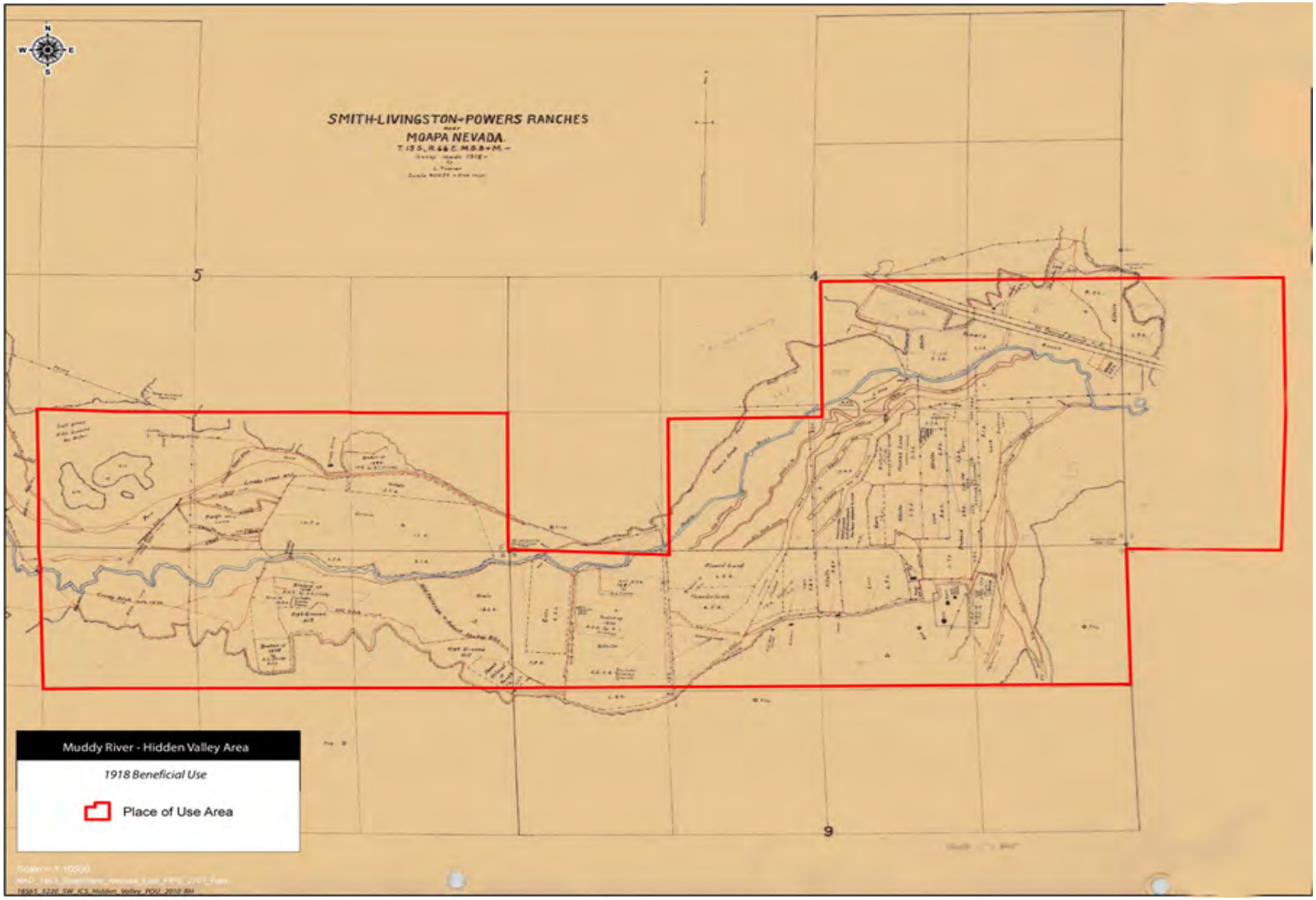

Figure 3-11
Hidden Valley PBU Map, POU Quarter-Quarter Sections Highlighted in Red

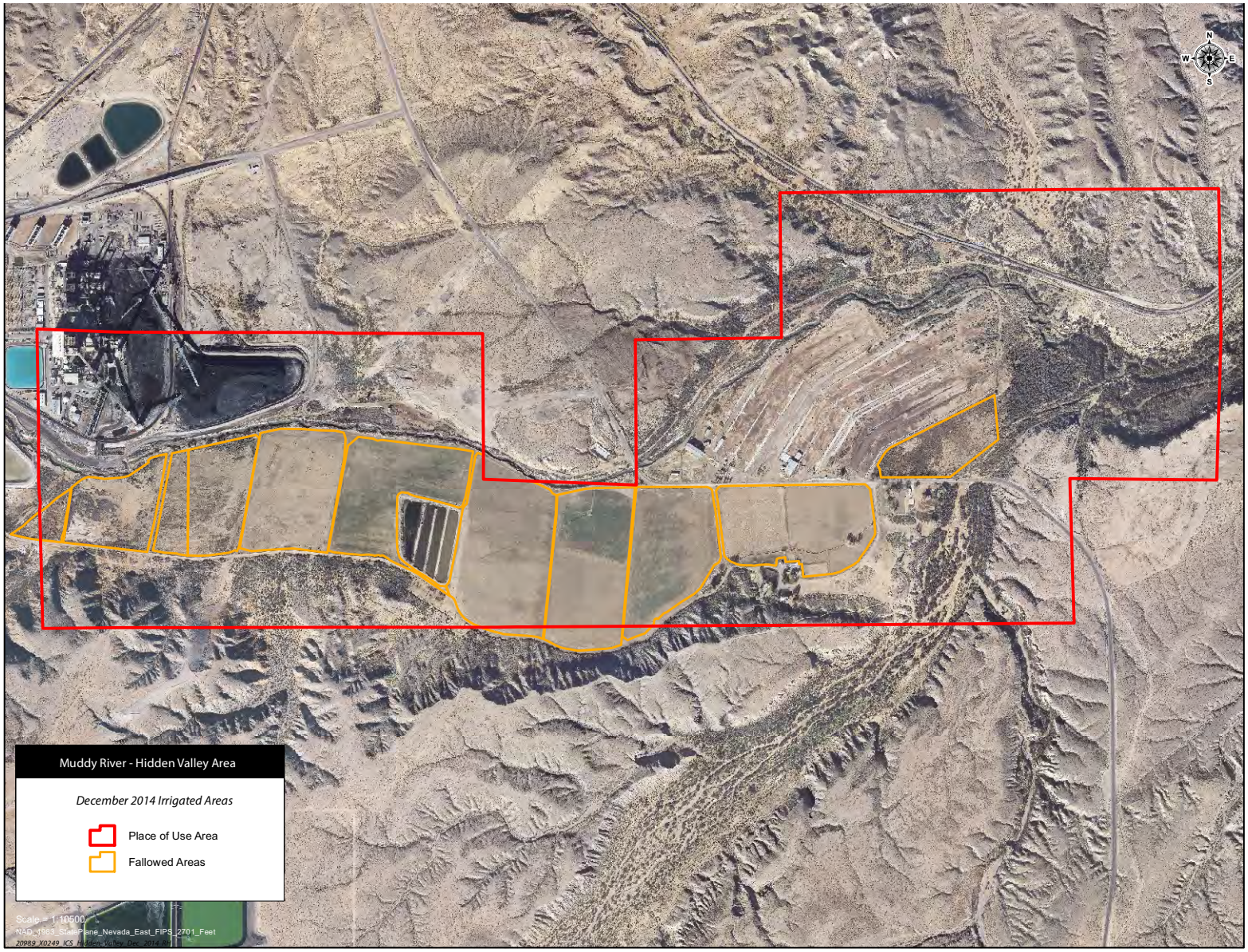

Figure 3-12
Hidden Valley December 2014 Aerial Photography

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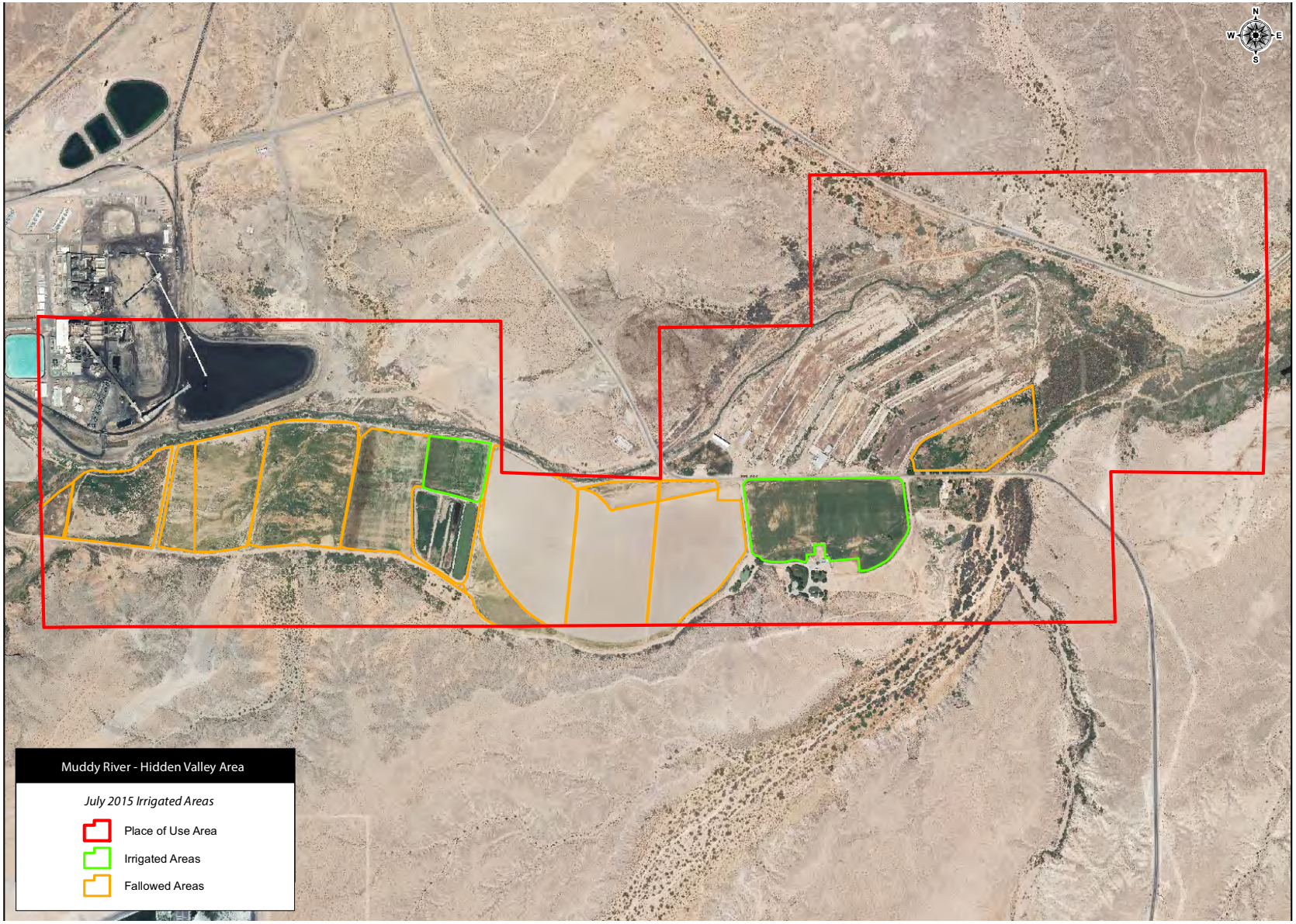

Figure 3-13
Hidden Valley July 2015 Aerial Photography

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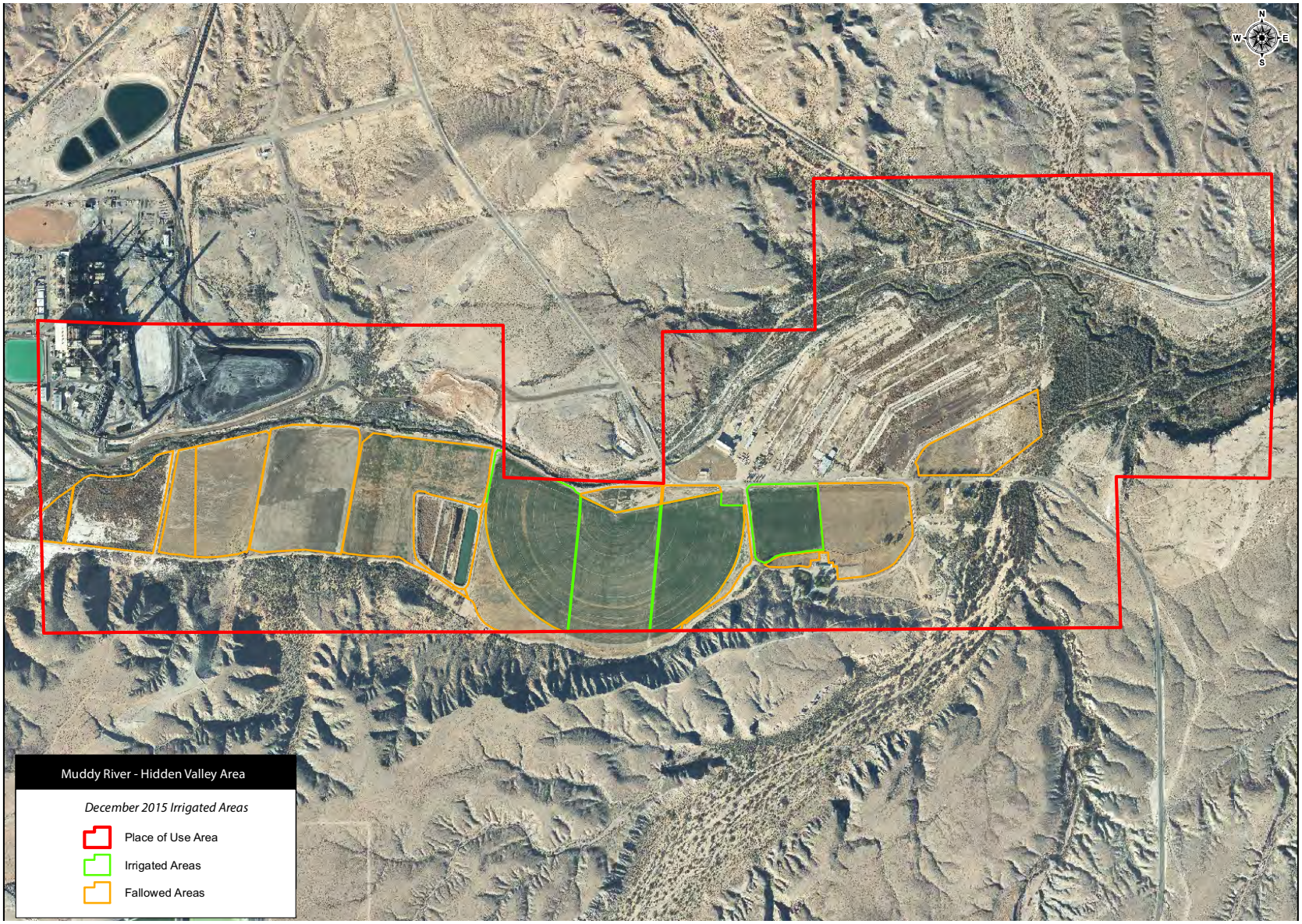

Figure 3-14
Hidden Valley December 2015 Aerial Photography

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Table 3-2
2015 Hidden Valley Water Rights

Notation	Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	2014 Total
A	Acre-Feet per Month of SNWA's Owned Right	74.88	67.63	74.88	72.47	106.97	103.52	106.97	106.97	103.52	74.88	72.47	74.88	1,040
B	Hidden Valley Retained Portion of Permit (af)													300
C	Leased from Paiutes (af)													300
D = B + C	Total Available to Hidden Valley (af)													600
E	Metered Hidden Valley Diversion (af)	27.09	22.22	25.21	46.24	58.26	65.85	63.73	66.86	42.59	34.16	0.00	3.07	455
F = D - E	Remaining Water Available to Hidden Valley (af)													145
Is F > 0?														Yes
	SNWA ICS Credit (af)													**1,040**

3.2.4 MVIC Lease /NV Energy Sub-Lease

Since 2009, SNWA has leased 3,000 afy of winter (October-April) water rights from MVIC, and subleased a portion of the rights to NV Energy (NVE). The 3,000 afy had previously been leased from MVIC directly by NVE, from 1967 to 2009, for use at the NVE Reid Gardner Generating Station (Reid Gardner) located near Moapa, NV. Under agreements between SNWA, MVIC, and NVE, the 3,000 afy of MVIC water rights are assigned to SNWA, who then sub-leases the water to NVE. The lease agreements give NVE the ability to take only the amount of water they need and the remainder stays in the Muddy River as SNWA-controlled water rights which are eligible for ICS credits.

The change in the POU for the 3,000 afy from MVIC to Reid Gardner is documented under NDWR Certificates 7316 and 13851 and required the fallowing of agricultural land within the MVIC POU equivalent to the 3,000 afy transfer. NVE's diversion of the subleased water rights is located at the Reid Gardner Muddy River diversion just upstream of USGS gaging station *09416000 Muddy River near Moapa, NV.*

During the winter seasons, NVE submits monthly meter readings and lease payments to SNWA documenting the amount of water that NVE diverted from the river. Table 3-3 lists these diversion values. For CY 2015, NVE did not divert any of the surface water rights. The water-right certificates associated with the meter data received from NVE are provided in Appendix E. The 3,000 af leased by SNWA was therefore conserved and remained in the mainstream of the Muddy River and flowed downstream to the Glendale gage and then to Lake Mead. The conveyance of these rights from the Glendale gage to Lake Mead is accounted for in the calculations for the Lower Muddy River in subsequent sections of this report.

3.2.5 Knox and Holmes Water Right Purchase

In 2008, SNWA purchased 811.28 afy of Muddy River decreed water rights which are documented in the decree as Vested Proof No. 01620 under the names Knox and Holmes. Until 1975, these water rights were used for agricultural irrigation on the decreed POU as depicted in Figure 3-15.

In 1975, the decreed agricultural rights were leased by NVE for use at Reid Gardner and a change application was filed with NDWR to change the POU of the Knox and Holmes right to Reid Gardner. Subsequently, NDWR issued Permit No. 29295 and corresponding Certificate No. 9609 based on the change application.

In 1985, the owners of the land previously irrigated with the Knox and Holmes Muddy River surface water rights applied for and were granted groundwater rights to irrigate the same land. In 2000, NDWR approved beneficial use of the groundwater rights based on pumping data and a field investigation by NDWR staff. Documents associated the permitted groundwater rights are in Appendix E.

Figures 3-16 through Figure 3-18 present the aerial photography and the POU fallowed as a result of the NVE lease that is now irrigated with groundwater under groundwater Permit 48763. Under Nevada Revised Statutes the POU under Permit 48763 can only be irrigated with groundwater. The 811.28 af owned by SNWA was therefore conserved and remained in the mainstream of the Muddy

Table 3-3
Nevada Energy Lease

Notation	Description	Jan	Feb	Mar	Apr	May - Sept	Oct	Nov	Dec	2015 Total
	# Days	31	28	31	30		31	30	31	212
A	Cert 7316 Volume (af)	292.4528	264.1509	292.4528	283.0189		292.4528	283.0189	292.4528	2,000
B	Cert 13851 Volume (af)	146.2264	132.0755	146.2264	141.5094	no diversions	146.2264	141.5094	146.2264	1,000
C = A + B	Total Volume (af)	438.6792	396.2264	438.6792	424.5283		438.6792	424.5283	438.6792	3,000
D	Water Use by NVE (af)	0.00	0.00	0.00	0.00		0.00	0.00	0.00	0
E = C - D	Water to Lake Mead for ICS (af)	438.6792	396.2264	438.6792	424.5283		438.6792	424.5283	438.6792	**3,000**

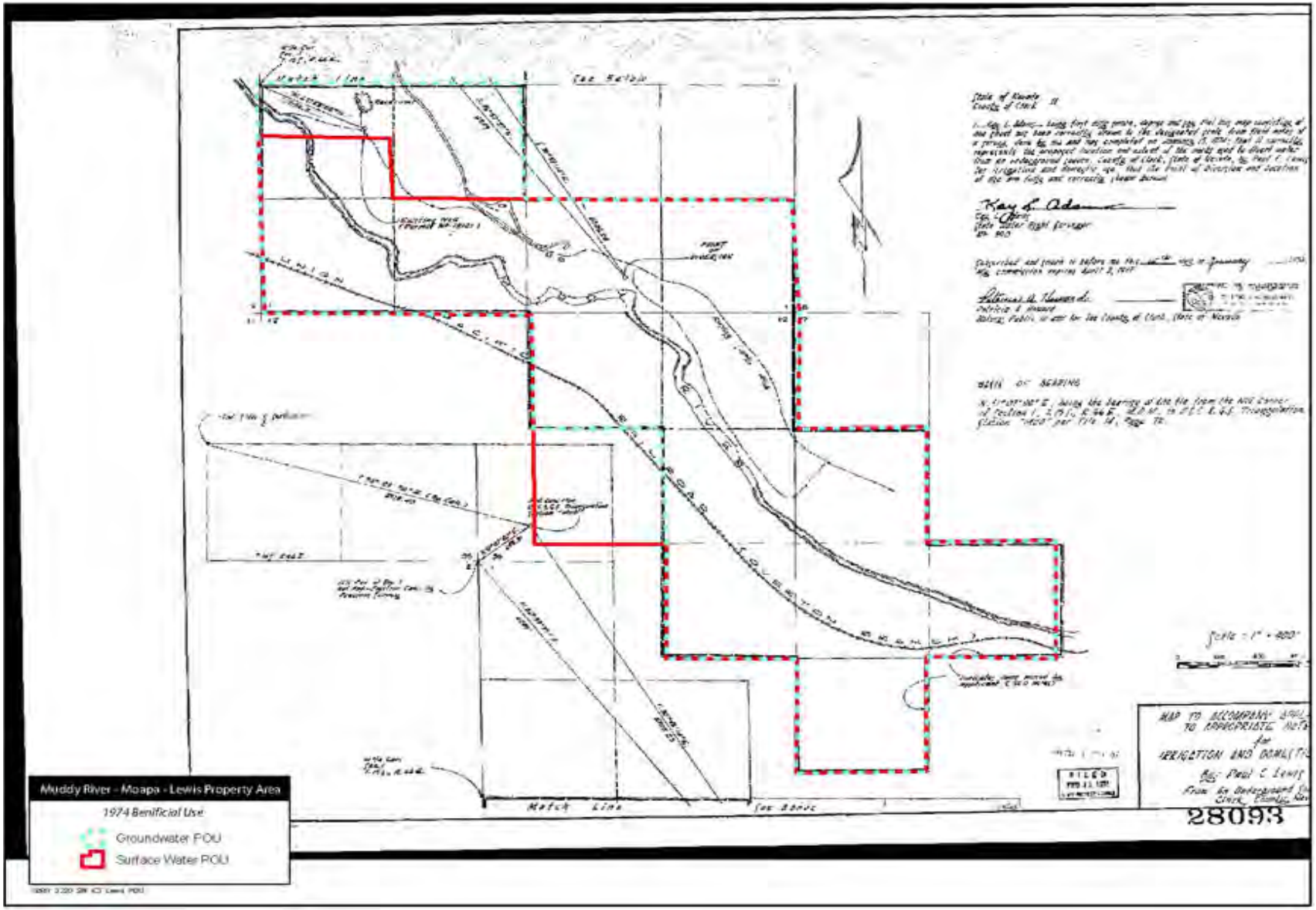


Figure 3-15
Former Surface Water POU for Permit 29295 and Current Groundwater POU for 48763

SE ROA 46387

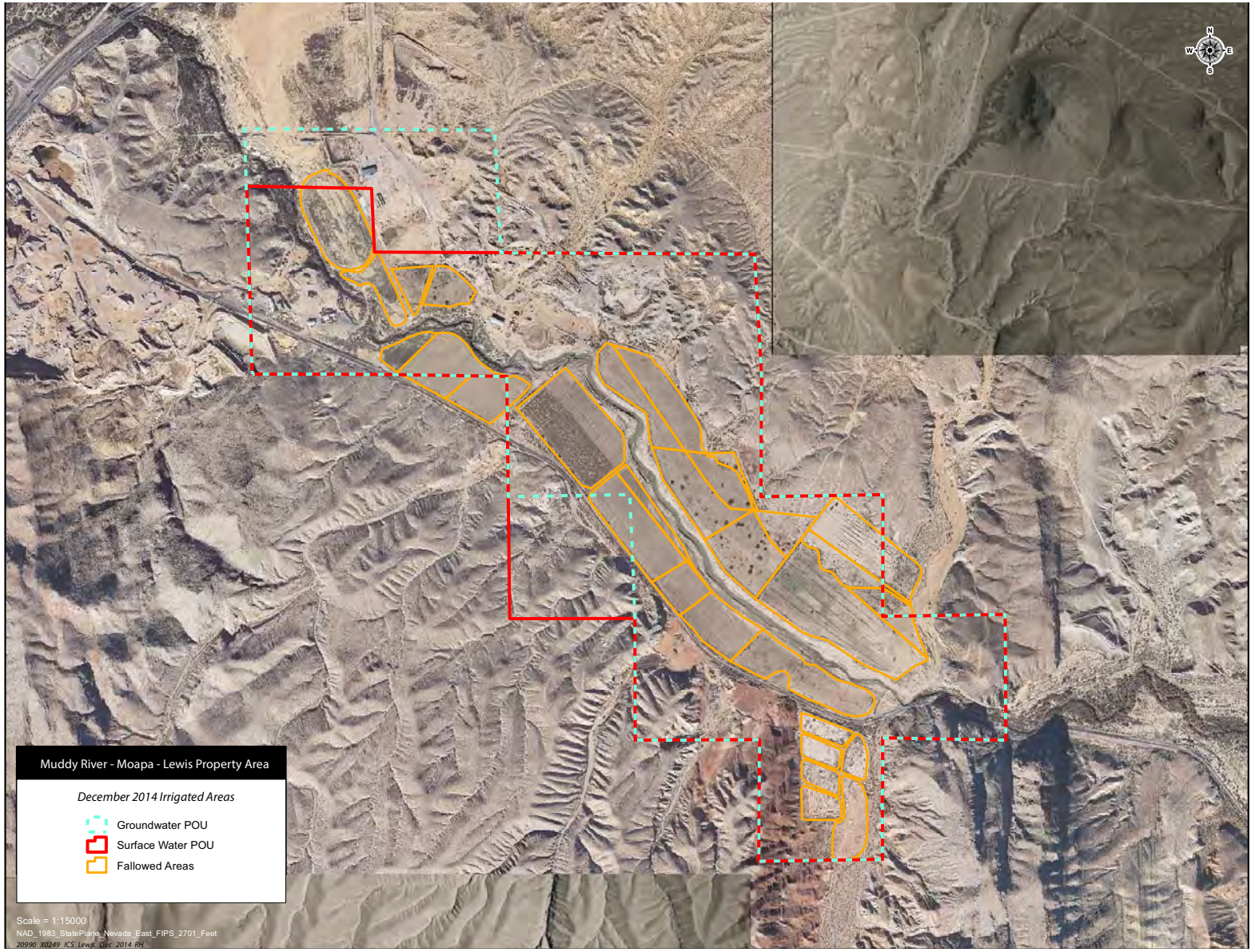


Figure 3-16
Knox and Holmes December 2014 Aerial Photography

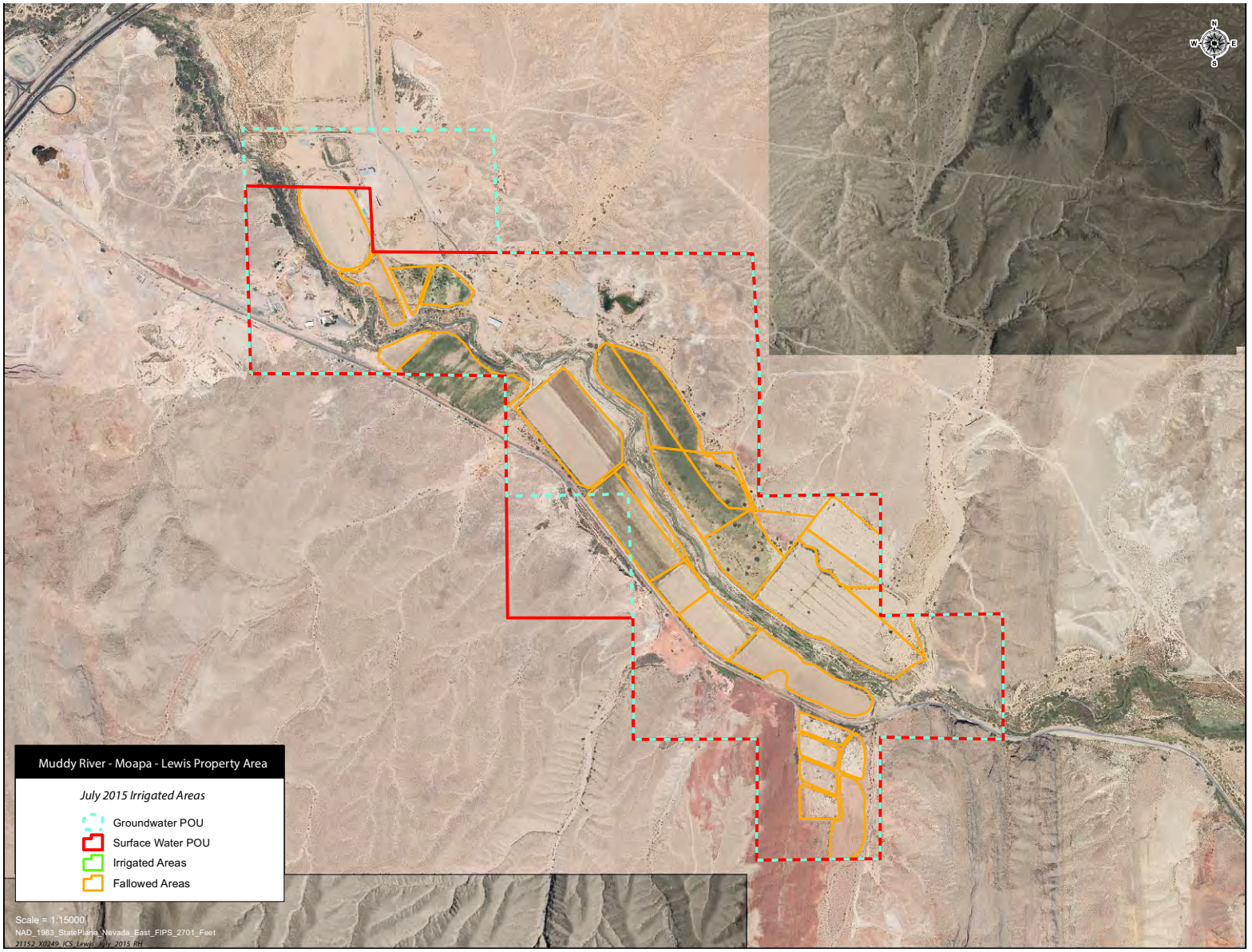


Figure 3-17
Knox and Holmes July 2015 Aerial Photography

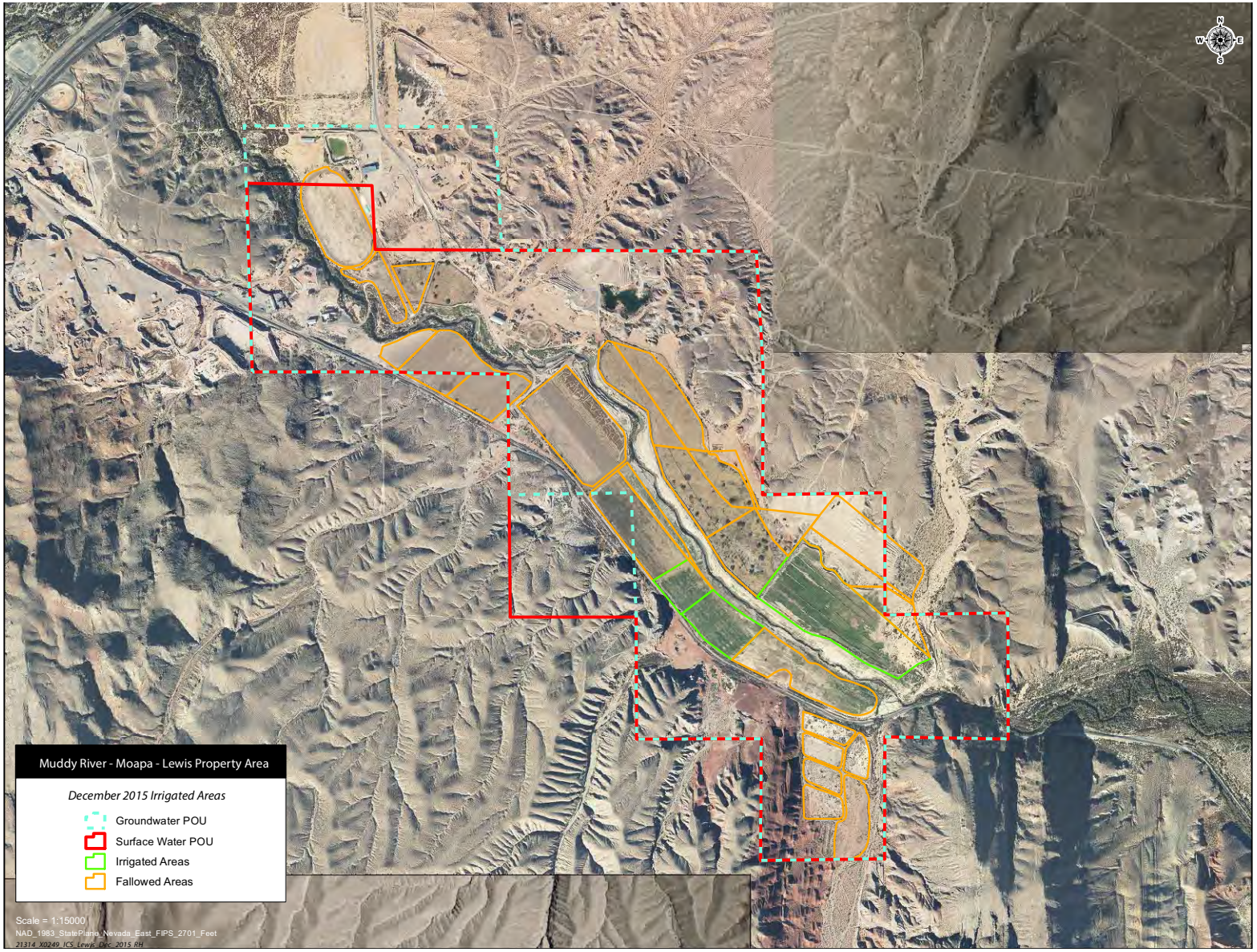


Figure 3-18
Knox and Holmes December 2015 Aerial Photography

River and flowed downstream to the Glendale gage and then to Lake Mead. The conveyance of these rights from the Glendale gage to Lake Mead is accounted for in the calculations for the Lower Muddy River in subsequent sections of this report.

3.2.6 Upper Muddy River Water Rights Summary

Table 3-4 summarizes the Upper Muddy River, water rights, owned and controlled by SNWA that were conserved and conveyed to Lake Mead. Included in the calculations for the LDS Church rights is the 45 afy that the LDS Church continues to hold, which was subtracted from the total LDS Church right to derive the SNWA controlled amount of 2,001 afy. The current Certificates leased by SNWA are provided in Appendix E. The total volume of Upper Muddy River water conserved by SNWA in CY 2015 is 9,963 af.

3.3 Lower Muddy River Rights Summary

The Lower Muddy River, for the purposes of this report, is defined as the reach from the Glendale gage to Lake Mead. Within this reach water rights are held by MVIC, which holds the largest quantity of decreed rights on the Muddy River. MVIC's service area begins downstream of the Glendale gage at the MVIC Wells Siding diversion structure (Wells Siding), where MVIC diverts their decreed Muddy River water rights and unused Upper Muddy River rights. MVIC delivers water to its shareholders through a network of concrete-lined ditches and pipes.

MVIC decreed Muddy River water rights are owned by MVIC shareholders through ownership of shares of preferred and common MVIC stock. There are 2,432 preferred shares and 5,044 common shares in MVIC. Each share represents a pro-rata apportionment of the Muddy River decreed rights.

3.3.1 MVIC Water Rights Summary

This section summarizes the decreed Muddy River water rights owned by MVIC and the water represented by preferred and common shares.

In 1974, MVIC filed PBU maps for their decreed rights used along the Lower Muddy River. The water-right certificates issued to MVIC in 1974 based on the proofs can be found in Appendix F. Although these certificates were issued in 1974, they retain their original pre-1920 priority date. These PBU maps, when compared to recent aerial photography, serve as the baseline for verifying fallowed land and demonstrating conservation of water to support SNWA's accounting of Tributary Conservation ICS on the Lower Muddy River.

The irrigable lands along the Lower Muddy River under the 1974 PBU maps total 3,498.86 acres. However, the amount of land that can be irrigated under MVIC's water rights cannot exceed 2,784.75 acres with a decreed annual duty of 8.54 af/acre.

In addition to these decreed and certificated rights, the Muddy River Decree states that MVIC can divert any additional unused Muddy River flows that reach their diversion structure on the Muddy

Table 3-4
Upper Muddy River ICS Water Rights

Water Right	Data Source	Jan	Feb	Mar	Apr	May	June	Jul	Aug	Sept	Oct	Nov	Dec	Total (afy)
	# Days	31	28	31	30	31	30	31	31	30	31	30	31	365
LDS Lease	Permit 6419	8.61	7.78	8.61	8.33	12.30	11.90	12.30	12.30	11.90	8.61	8.33	8.61	119.57
	Permit 25861	70.10	63.31	70.10	67.84	99.61	96.40	99.61	99.61	96.40	70.10	67.84	70.10	971.00
	Permit 26316	51.02	46.09	51.02	49.38	51.02	49.38	51.02	51.02	49.38	51.02	49.38	51.02	600.76
	Permit 26317	2.46	2.22	2.46	2.38	3.50	3.39	3.50	3.50	3.39	2.46	2.38	2.46	34.12
	Permit 26318	23.06	20.83	23.06	22.31	32.96	31.89	32.96	32.96	31.89	23.06	22.31	23.06	320.35
	Used by LDS	(3.24)	(2.93)	(3.24)	(3.14)	(4.63)	(4.48)	(4.63)	(4.63)	(4.48)	(3.24)	(3.14)	(3.24)	(45.00)
	LDS Lease Total	**152.01**	**137.30**	**152.01**	**147.10**	**194.77**	**188.48**	**194.77**	**194.77**	**188.48**	**152.01**	**147.10**	**152.01**	**2,001**
Cox	Decree	6.15	5.55	6.15	5.95	8.78	8.50	8.78	8.78	8.50	6.15	5.95	6.15	85
Mitchell	Decree	1.84	1.67	1.84	1.79	2.64	2.55	2.64	2.64	2.55	1.84	1.79	1.84	26
Paiute Lease	Table 3-1	209.73	189.43	209.73	289.95	299.61	289.95	299.61	299.61	299.95	209.73	202.96	209.73	3,000
HV Dairy	Table 3-2	74.88	67.63	74.88	72.47	106.97	103.52	106.97	106.97	103.52	74.88	72.47	74.88	1,040
NVE Lease	Table 3-3	438.68	396.23	438.68	424.53	---	---	---	---	---	438.68	424.53	438.68	3,000
Knox and Holmes	Decree	58.41	52.76	58.41	56.53	83.45	80.76	83.45	83.45	80.76	58.41	56.53	58.41	811
Upper Total (af)		**941.70**	**850.57**	**941.70**	**998.31**	**696.22**	**673.76**	**696.22**	**696.22**	**673.76**	**941.70**	**911.33**	**941.70**	**9,963**

River. This makes the actual water that MVIC splits among its shareholders vary from year to year based on the actual divertible flows that reach Wells Siding.

MVIC's water rights are tied to their service area and not individually-owned parcels. Therefore, the water rights associated with MVIC shares can be used anywhere within the MVIC service area, regardless of land ownership. Consequently, the location of individual fields being irrigated is not as important as the total irrigated acreage within the MVIC POU.

Since the 1974 PBU maps were filed, land use along the Lower Muddy River has undergone a gradual transformation from predominately agricultural to a mix of residential and commercial property interspersed among the agriculture. This gradual urbanization is illustrated by Figure 3-19, which compares aerial photography of the Lower Muddy River from October 1953 with aerial photography from July 2014.

The MVIC has and is leasing a portion of their decreed rights to users on the Upper Muddy River including water leased to the MVWD, which diverts the water from spring boxes in the Muddy River Springs Area for potable use. These leased rights are diverted and not returned to the Muddy River. Therefore, the flows measured at the Glendale gage account for these leased rights since the flows reaching the gage and Wells Siding have been depleted by these diversions. In the same respect, unused water from MVIC's leases is measured by the Glendale gage and is available for diversion by MVIC.

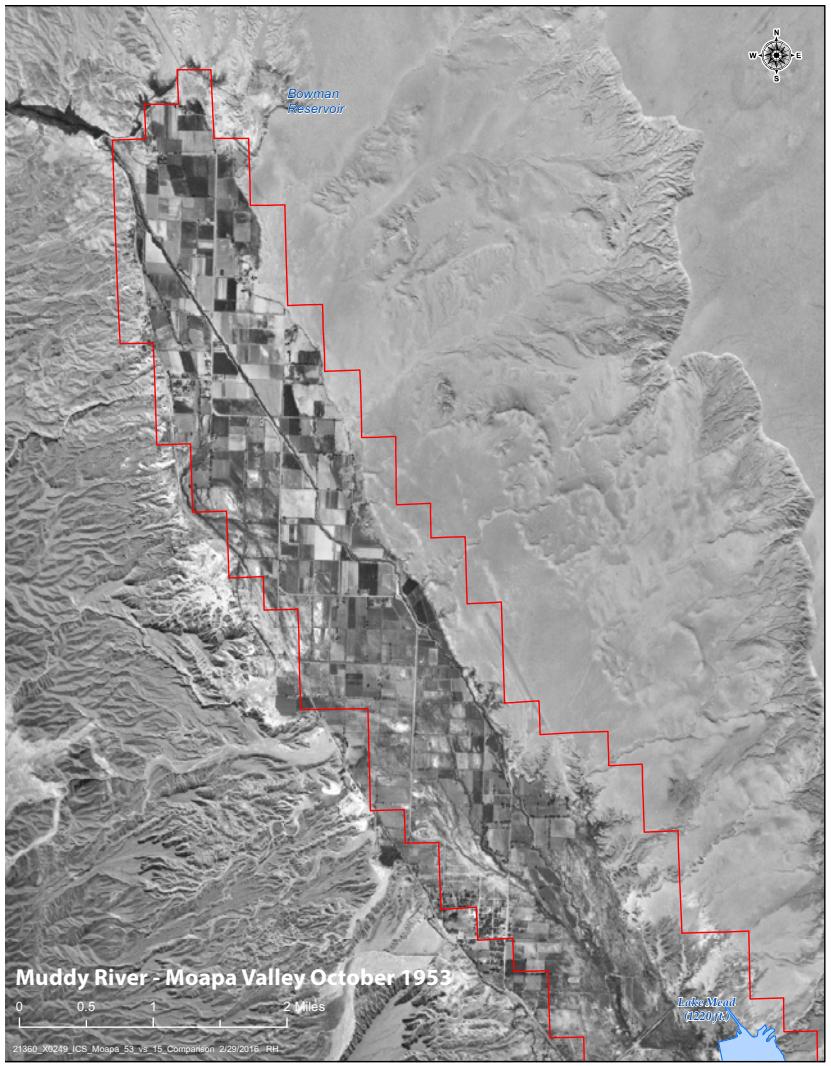
MVIC's operations and covenants define preferred shares as 100% of the Muddy River summer flow (May – September) plus 75% of the winter flow (October – April). Common shares represent the remaining 25% of the winter flow. The amount of water represented by preferred and common shares, therefore, varies slightly from year to year due to changes in unused Upper Muddy River rights and unused MVIC leases that reach Wells Siding. SNWA's Upper Muddy River rights may not be diverted by MVIC and are excluded from the af/shares calculations.

3.3.2 Quantification of SNWA MVIC Water Rights

By the end of CY 2015, SNWA controlled a total of 978.5760 preferred and 2,798.0850 common MVIC shares. Since the amount of water represented by a share can vary annually, the volume of water that SNWA holds in MVIC can vary as well. To calculate the amount of water represented by each share in MVIC during CY 2015, the volume of water rights available to MVIC (referred to as divertible flows) must be determined. This volume is then distributed to the preferred and common share. This section details these calculations.

3.3.3 Divertible flows by MVIC at Wells Siding

Records from the Glendale gage, which is located just upstream of Wells Siding, are used to derive the amount of divertible flows that reach the diversion. The divertible flows at Wells Siding, equate to the flows at the Glendale gage (Table 3-5) less: (1) channel losses from ET between the Glendale gage and Wells Siding; (2) flood flows that exceed the Wells Siding capacity (approximately 70 cfs);



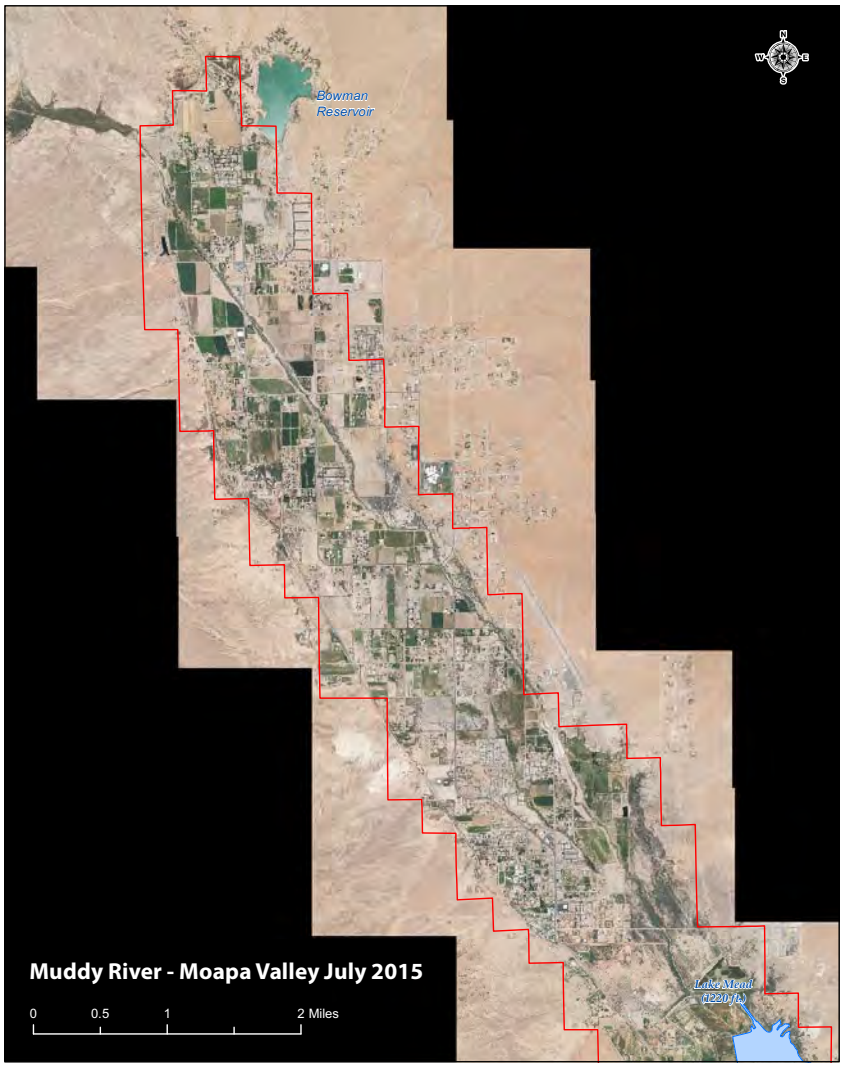


Figure 3-19
Lower Moapa Valley 1953 (left) and July 2015 (right)

Table 3-5
Mean Daily Flows for USGS Muddy River near Glendale Gage (09419000) (70 cfs Limit)

Day	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Total
1	44	45	47	43	39	45	41	36	35	39	46	45	
2	44	45	50	45	42	44	42	37	35	37	45	44	
3	45	45	48	44	43	45	40	37	35	37	45	44	
4	45	43	46	45	43	44	39	38	35	37	50	44	
5	46	42	46	45	41	43	39	36	35	**70**	50	44	
6	46	41	46	44	40	42	39	36	35	**70**	47	44	
7	47	40	47	44	40	42	39	37	36	50	46	43	
8	47	42	47	42	43	42	38	37	35	50	46	43	
9	46	40	47	42	43	43	42	38	36	48	46	43	
10	46	40	47	41	45	43	37	37	35	50	45	44	
11	46	40	47	42	44	43	37	35	35	52	46	45	
12	46	40	48	42	43	42	37	38	35	52	46	45	
13	44	40	48	41	42	44	37	38	35	52	45	44	
14	45	41	50	37	42	43	36	49	35	51	44	45	
15	44	42	50	38	42	44	35	48	37	50	44	43	
16	44	42	50	40	44	42	34	39	39	50	45	43	
17	44	42	50	38	44	42	35	39	37	50	44	43	
18	44	42	50	42	44	42	34	39	35	**70**	43	44	
19	44	43	50	42	56	42	47	39	35	**70**	43	44	
20	43	45	50	42	46	41	68	39	35	**70**	44	44	
21	42	45	50	39	45	40	59	39	35	**70**	44	44	
22	43	44	50	42	45	40	36	39	36	**70**	44	45	
23	43	49	50	38	45	39	35	39	36	51	43	45	
24	44	47	50	39	46	41	35	39	36	48	44	44	
25	44	47	50	42	47	40	35	39	37	45	44	45	
26	44	48	49	43	47	41	35	38	37	43	45	44	
27	47	47	48	43	45	42	35	38	37	44	45	45	
28	48	47	48	42	44	41	35	37	38	43	45	45	
29	48	--	48	40	45	40	36	37	38	45	45	45	
30	48	--	47	39	45	39	37	36	39	46	44	45	
31	48	--	44	--	46	--	38	36	--	46	--	45	
Mean	45	43	48	42	44	42	39	38	36	52	45	44	
Count	31	28	31	30	31	30	31	31	30	31	30	31	
Minimum	42	40	44	37	39	39	34	35	35	37	43	43	
Maximum	48	49	50	45	56	45	68	49	39	70	50	45	
Acre-Feet	2,770	2,410	2,970	2,470	2,710	2,500	2,400	2,350	2,140	3,190	2,680	2,720	31,310
Phreatophyte Consumptive Use Glendale to Wells Siding (af)	18	21	37	76	160	202	191	173	141	86	31	13	1,149
SNWA Upper Rights (af)	942	851	942	998	696	674	696	696	674	942	911	942	9,963
AF/Share Basis Volume (af)	**1,810**	**1,538**	**1,992**	**1,396**	**1,854**	**1,625**	**1,513**	**1,481**	**1,325**	**2,162**	**1,737**	**1,765**	**20,198**

and (3) SNWA Upper Muddy River rights being conveyed to Lake Mead for Tributary Conservation ICS credit (Table 3-4).

The ET losses between the Glendale gage and Wells Siding were determined to be 1,149 af, as discussed in subsequent sections. To subtract non-divertible flood flows, mean daily flows greater than 70 cfs were identified and replaced with 70 cfs, which is the maximum diversion rate at Wells Siding. Monthly and annual flow statistics were then recalculated without the non-divertible flood flows. In CY 2015, there were a few flood events in October 2015 that resulted in flows exceeding the 70 cfs maximum diversion, which were replaced with a daily flow value of 70 cfs. (Table 3-5).

Conserved Upper Muddy River flows for many of the SNWA water rights were distributed into monthly diversion volumes in Table 3-4. These monthly volumes were then subtracted from the Glendale gage flows on Table 3-5 prior to estimating the amount of water pro-rated to the MVIC shares.

The annual Glendale gage flows for CY 2015 were therefore reduced by 1,149 af for ET and 9,963 af for SNWA's Upper Muddy River rights to derive the volume of divertible flow available to MVIC.

3.3.4 MVIC Acre-Feet per Share Calculations

Table 3-6 summarizes the percent of divertible flows available to each MVIC share class. Using the divertible flows derived for CY 2015 listed in Table 3-5, the acre-foot per share values for preferred and common shares were calculated and listed in Table 3-7.

Table 3-6
MVIC Share Classes and Divertible Flow Percentages

Share Type	Number of Shares	Percent of Summer Flow	Percent of Winter Flow
		(May - September)	(October - April)
Preferred	2,432	100%	75%
Common	5,044	0%	25%

Table 3-7
Acre-Foot per Share Calculation Results

Calendar Year	Jan - Apr and Oct - Dec Flows (af)	May - Sept Flows (af)	100% Summer and 75% Winter Flows (af)	25% Winter Flow (af)	Preferred-af Divided by 2,432 shares (af / share)	Common-af Divided by 5,044 shares (af / share)
2015	12,400	7,797	17,098	3,100	7.0302	0.6146

3.3.5 MVIC Water Controlled by SNWA

The amount of MVIC water controlled by SNWA is calculated using the derived acre-foot per share values listed in Table 3-7. Table 3-8 lists SNWA's controlled water rights in af/month, accounting for month-to-month variability in SNWA controlled MVIC water rights due to purchases, leases, and leasebacks of purchased shares to original sellers. A letter of concurrence signed by Scott Millington, MVIC General Manager, certifies that SNWA controlled the number of shares outlined in Table 3-8 during CY 2015. The letter of concurrence is provided in Appendix G. The preferred and common acre-foot per share values were divided by the number of months in which they can be used: 12-months for preferred shares and 7-months for common shares. The shares controlled by SNWA during each month (using only the number of shares controlled for the entire month) are multiplied by the acre-foot per share per month to obtain an acre-foot value of MVIC water controlled by SNWA per month for CY 2015.

SNWA controlled MVIC shares were either not diverted into the MVIC distribution system at Wells Siding, thus staying in the mainstream of the Muddy River, or were diverted for the purpose of maintaining head on the ditches before being returned back to the mainstream of the Muddy River. Any water represented by SNWA controlled shares, which was diverted at Wells Siding, is included on MVIC's seasonal (winter and summer) water schedules (Appendix H). Based on these schedules, SNWA received a "turn" on the various ditches, and SNWA's shares were delivered to the mainstream Muddy River.

3.3.6 Land Fallowing within MVIC's POU

The December 2014, July 2015, and December 2015, 6-inch aerial photography has been used to determine the fallowed and irrigated acreage within MVIC's service area during the summer and winter seasons of CY 2015. For the January through April 2015 portion of the winter season, aerial photography from December 2014 was used to calculate the irrigated acreage within MVIC. The July 2015 imagery was used for the summer 2015 irrigation season (May 1 to September 30). For the winter irrigation season (October 1 to December 31), aerial photography from December 2015 was used to determine irrigated acreage.

Figure 3-20 illustrates MVIC's service area and depicts the extent of the 1974 PBU map which is composed of three individual maps. Figures 3-21 through Figure 3-23 depicts these PBU maps, Figures 3-24 through Figure 3-32 depict the December 2014, July 2015, and December 2015 aerial photography overlaid with the field-verified fallowed and irrigated acreage.

Table 3-9 details the irrigated and fallowed acreage by season (on a monthly basis) and crop type as measured and field-verified by SNWA. This acreage was verified by MVIC's General Manager during various meetings. Land determined not irrigable due to urbanization was derived by subtracting the measured irrigated and fallowed lands from the certificated maximum acreage within MVIC's POU of 2,784.75 acres.

Table 3-8
SNWA Controlled MVIC Shares in CY 2015

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Water Available to MVIC (AF From Table 3-5)	1,810	1,538	1,992	1,396	1,854	1,625	1,513	1,481	1,325	2,162	1,737	1,765	20,198
Acre-Feet Per Share Per Month													
Common (af/share)	0.0897	0.0763	0.0987	0.0692	0	0	0	0	0	0.1072	0.0861	0.0875	0.6146
Preferred (af/share)	0.5582	0.4745	0.6142	0.4304	0.7624	0.6680	0.6220	0.6090	0.5448	0.6667	0.5358	0.5444	7.0302
Owned by SNWA													
Common Shares	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	2,839.1267	
Preferred Shares	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	1,009.0847	
Leased Back to Seller													
Common Shares	458.9719	458.9719	458.9719	458.9719	458.9719	458.9719	458.9719	458.9719	458.9719	392.7917	392.7917	392.7917	
Preferred Shares	210.7917	210.7917	210.7917	210.7917	210.7917	210.7917	210.9717	210.7917	210.7917	197.7917	197.7917	197.7917	
Leased by SNWA													
Common Shares	351.7500	351.7500	351.7500	351.7500	351.7500	351.7500	351.7500	351.7500	351.7500	351.7500	351.7500	351.7500	
Preferred Shares	167.2830	167.2830	167.2830	167.2830	167.2830	167.2830	167.2830	167.2830	167.2830	167.2830	167.2830	167.2830	
Controlled = (Owned - Leased Back + Leased)													
Common Shares	2,731.9048	2,731.9048	2,731.9048	2,731.9048	2,731.9048	2,731.9048	2,731.9048	2,731.9048	2,731.9048	2,798.0850	2,798.0850	2,798.0850	
Preferred Shares	965.5760	965.5760	965.5760	965.5760	965.5760	965.5760	965.5760	965.5760	965.5760	978.5760	978.5760	978.5760	
Water Controlled (af) = (Shares Controlled x Acre Foot Per Share)													
Common (af)	245.0770	208.3169	269.6767	188.9933	0	0	0	0	0	299.8224	240.9302	244.8059	1,698
Preferred (af)	538.9597	458.1190	593.0578	415.6235	736.1327	645.0444	600.5819	588.0055	526.0177	652.4248	524.2731	532.7068	6,811
Total (af)	**784.0367**	**666.4359**	**862.7344**	**604.6188**	**736.1327**	**645.0444**	**600.5819**	**588.0055**	**526.0177**	**952.2472**	**765.2033**	**777.5127**	**8,509**

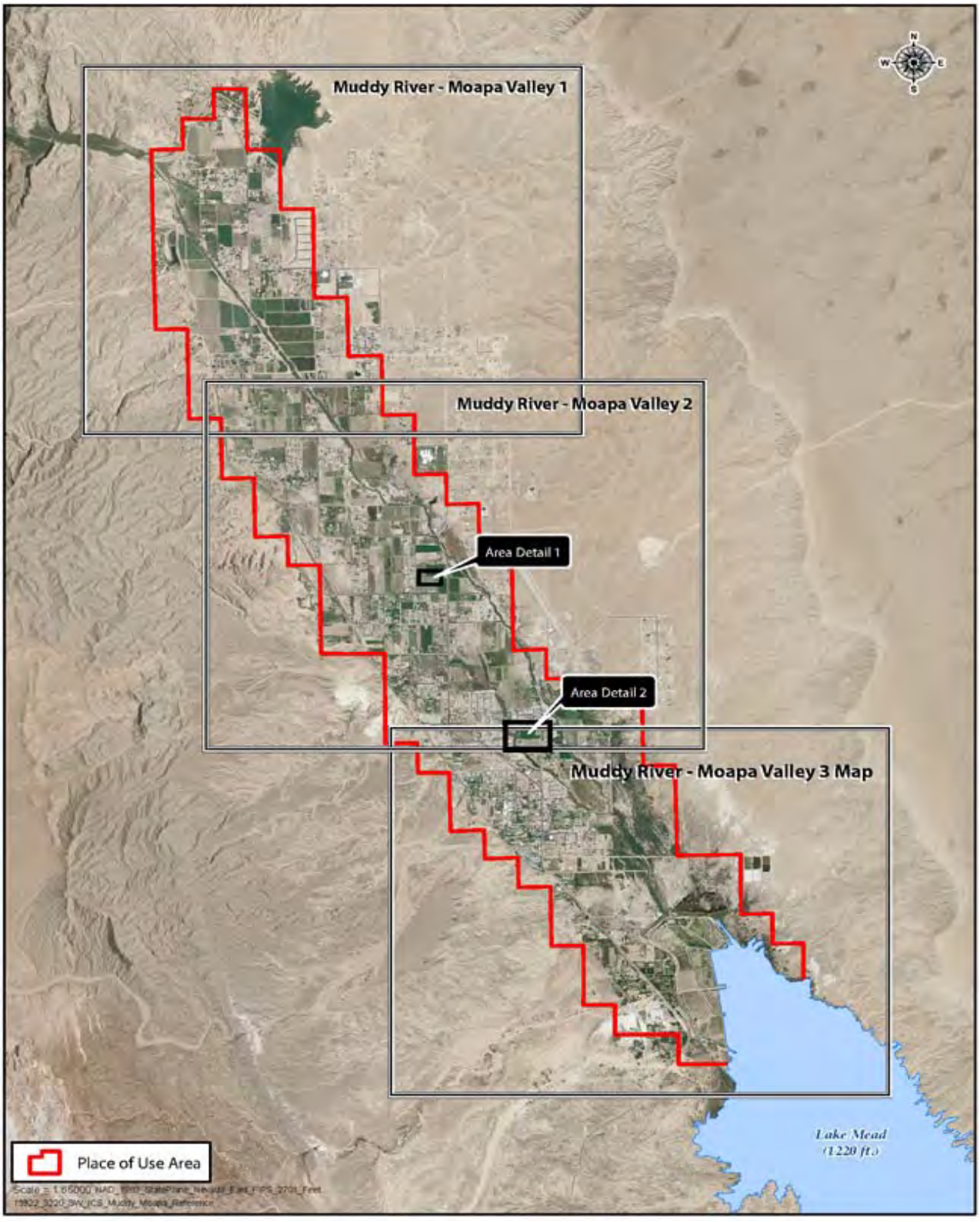


Figure 3-20
MVIC Service Area and Extent of PBU Maps and Location of the Detailed Photography on Figure 3-1

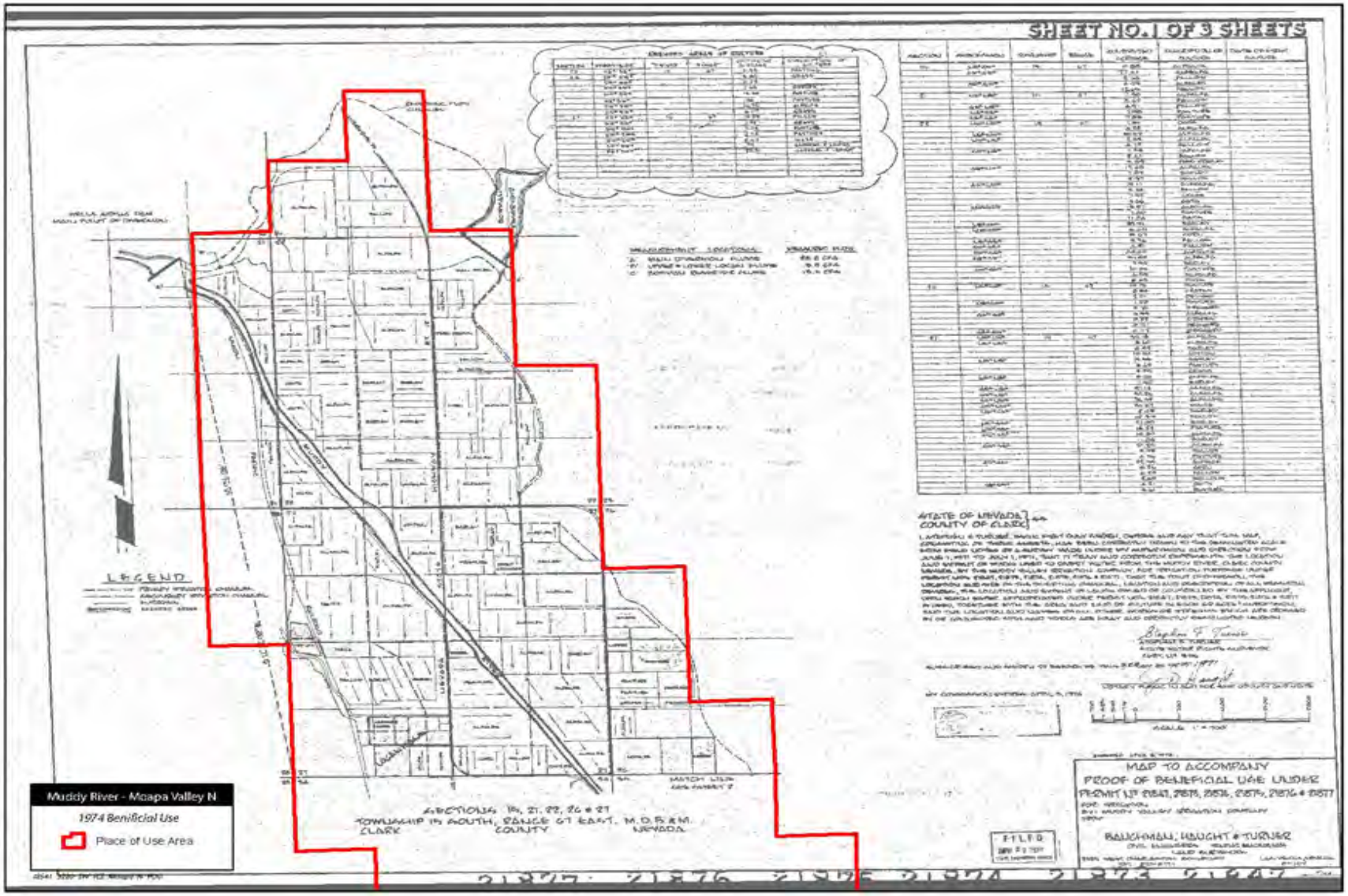


Figure 3-21
Upper Section of the MVIC Service Area Showing 1974 PBU.
POU Quarter-Quarter Sections Highlighted in Red

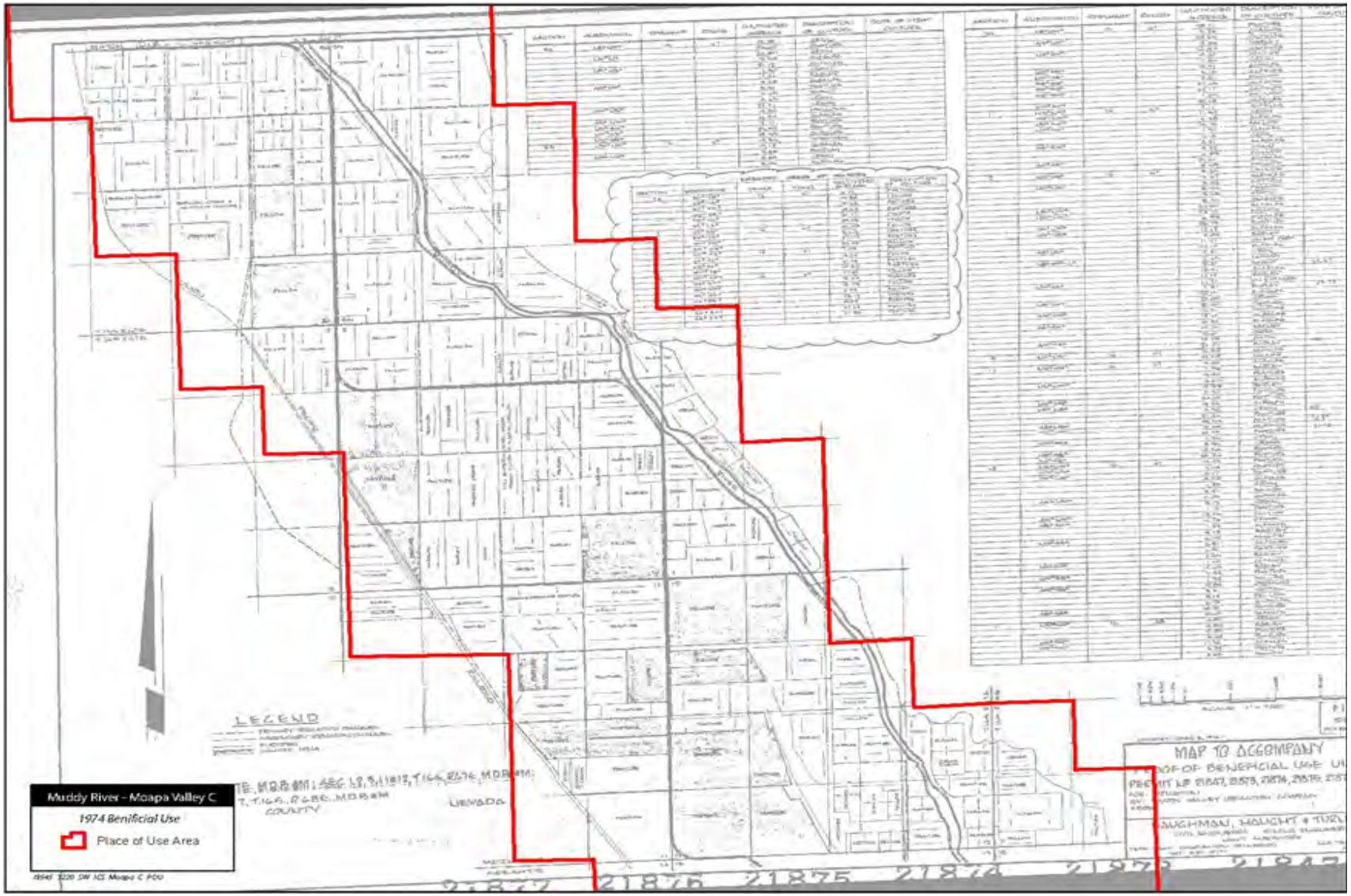


Figure 3-22
Middle Section of the MVIC Service Area Showing 1974 PBU.
POU Quarter-Quarter Sections Highlighted in Red

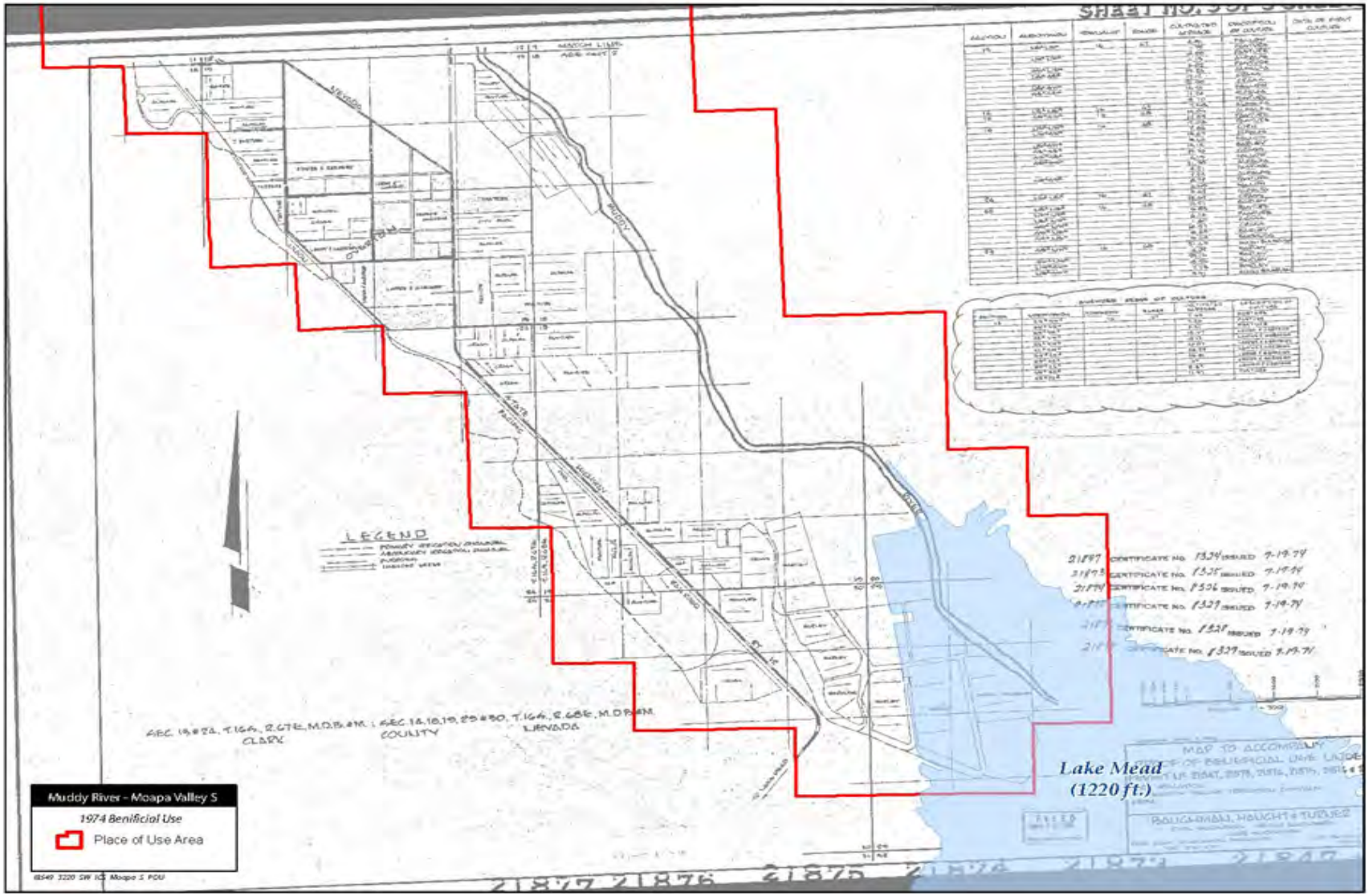


Figure 3-23
Lower Section of the MVIC Service Area Showing 1974 PBU.
POU Quarter-Quarter Sections Highlighted in Red

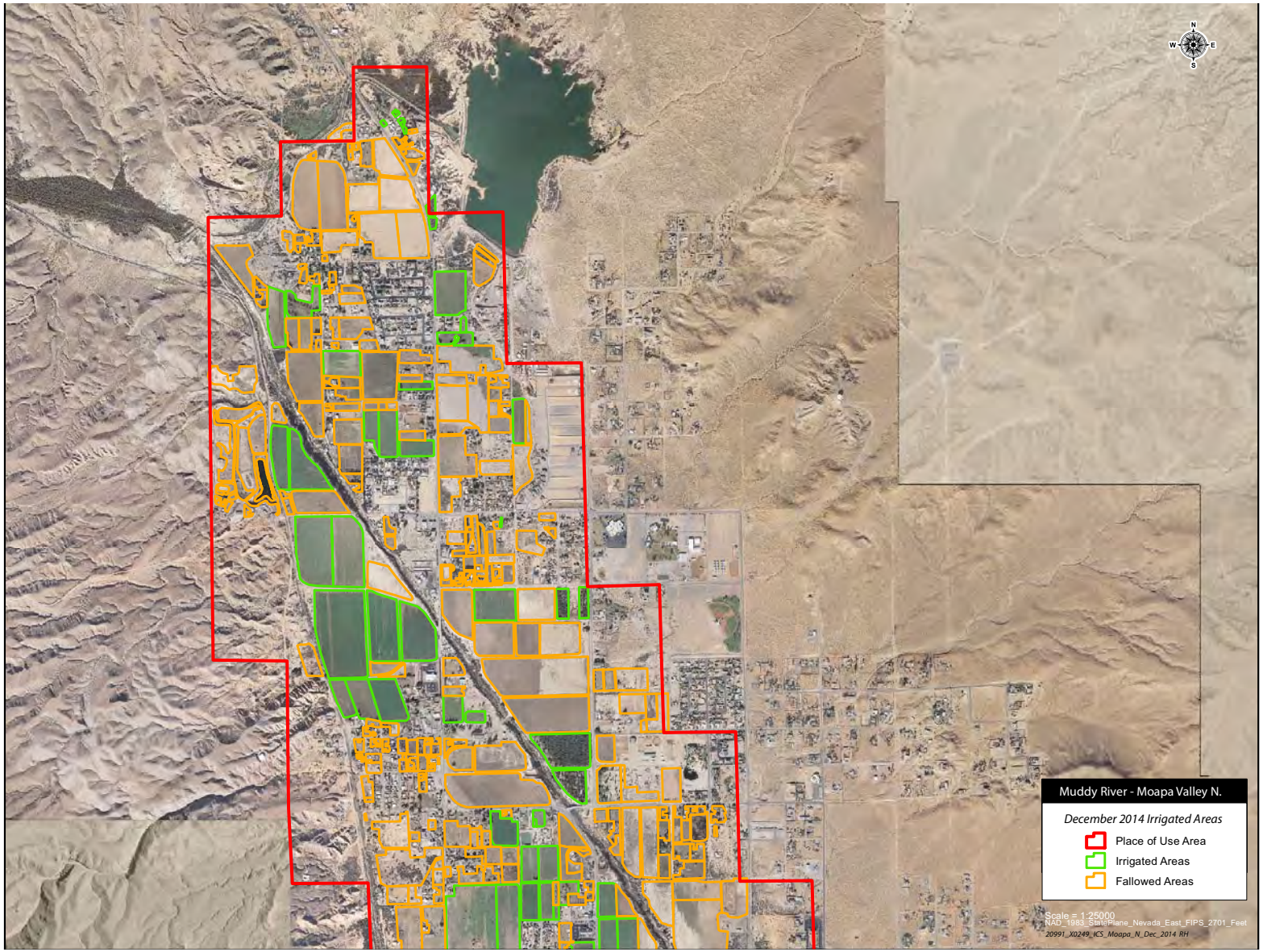


Figure 3-24
Upper Section of the MVIC Service Area December 2014 Aerial Photography

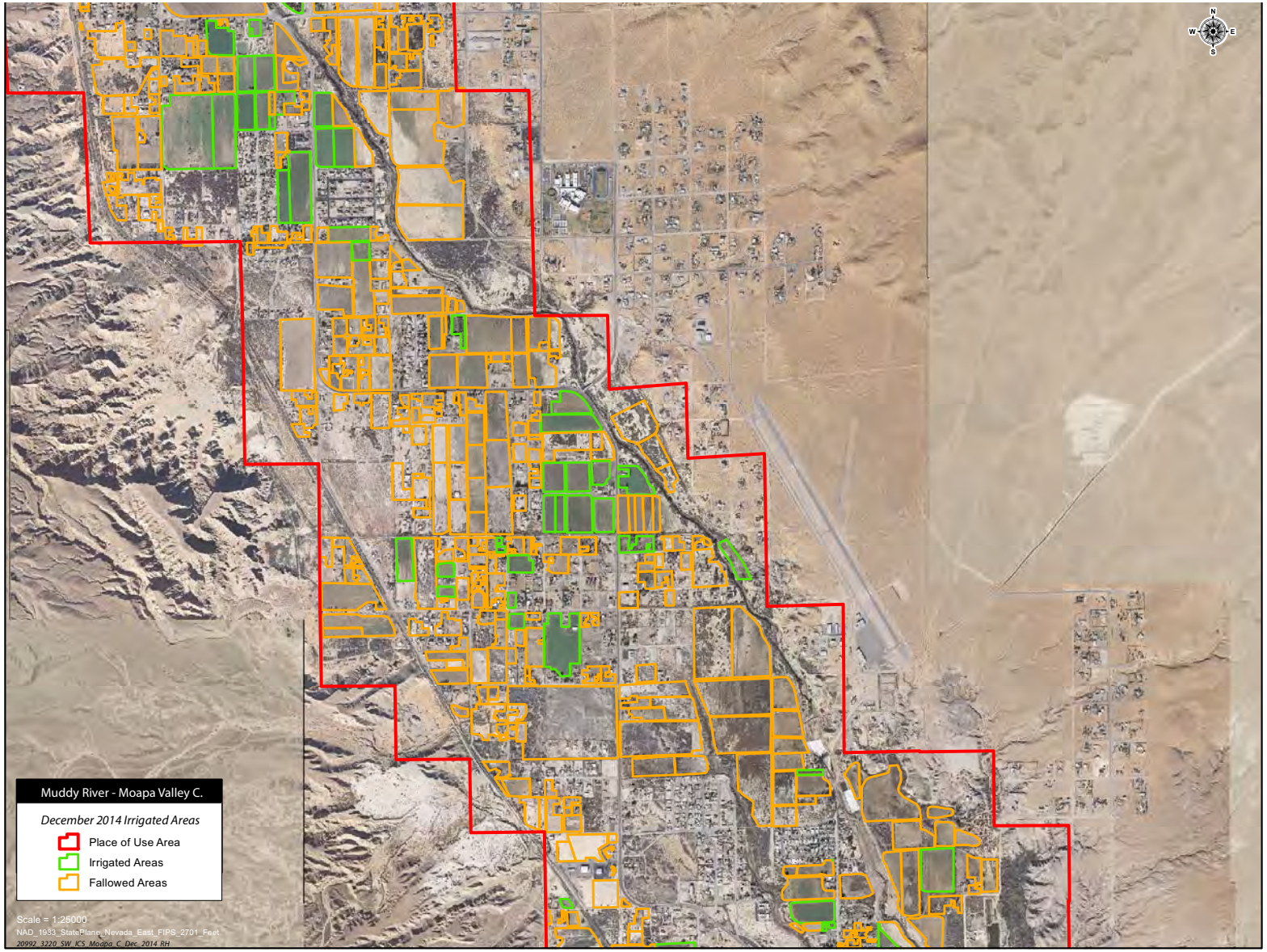


Figure 3-25
Middle Section of the MVIC Service Area December 2014 Aerial Photography

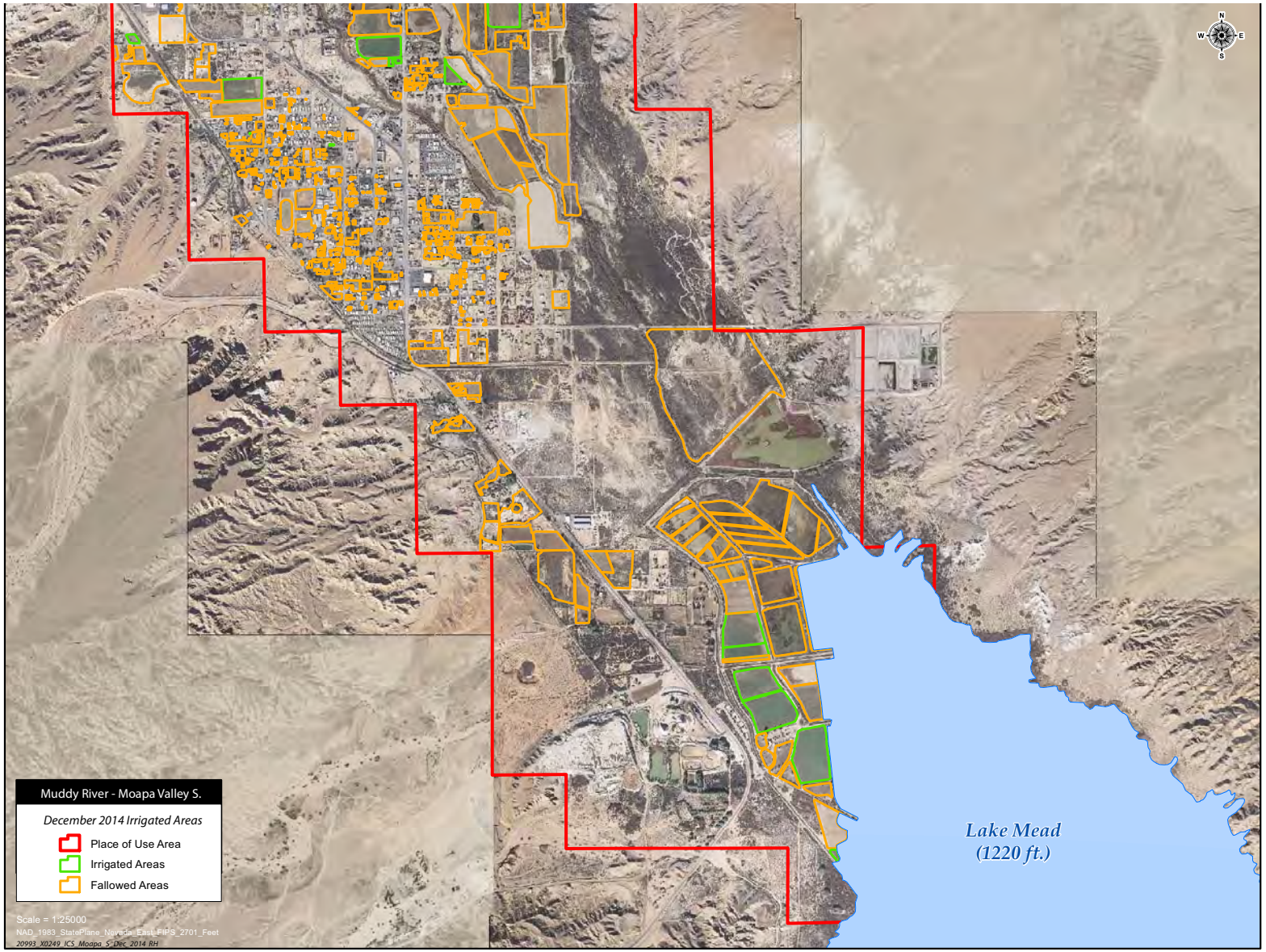


Figure 3-26
Lower Section of the MVIC Service Area December 2014 Aerial Photography

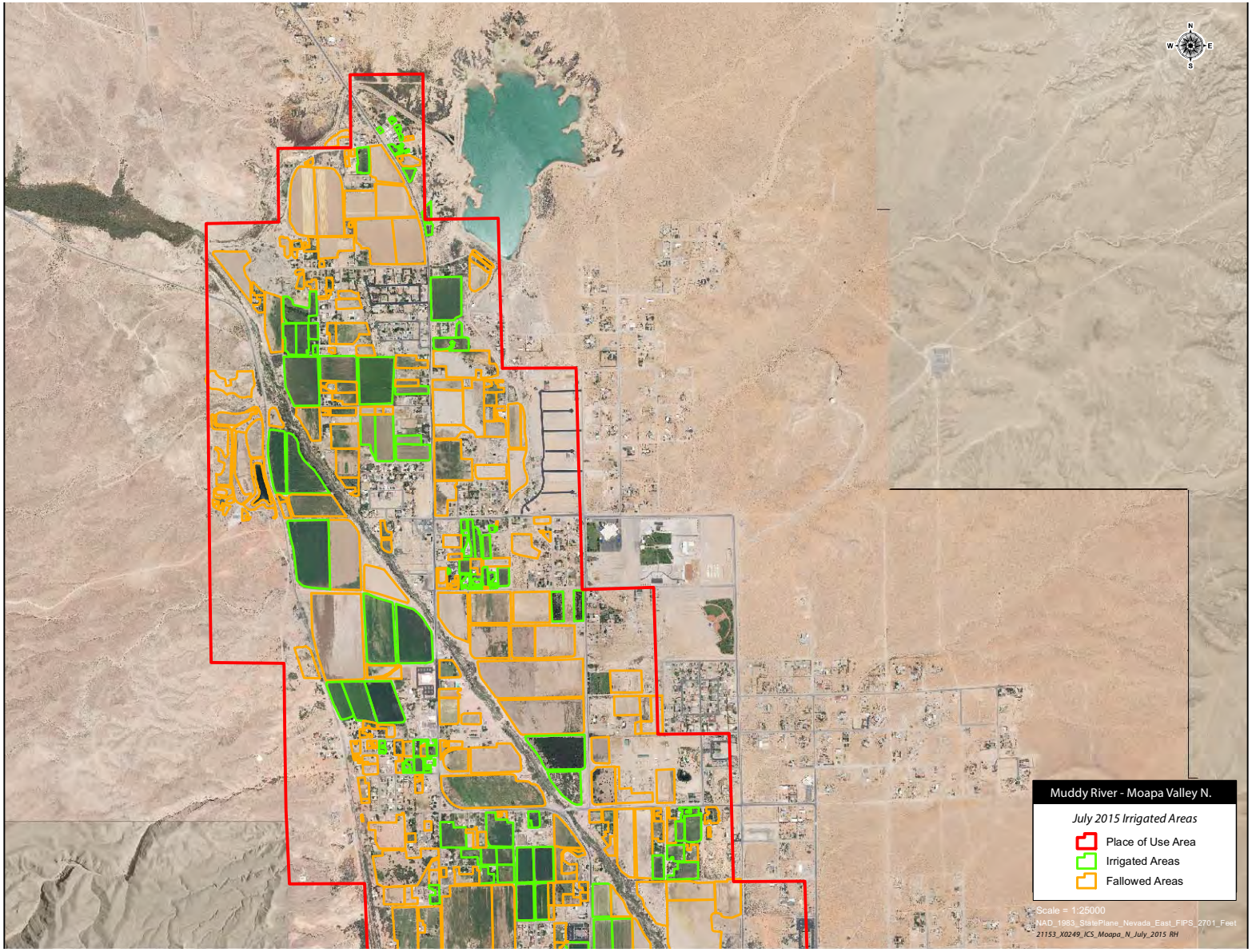


Figure 3-27
Upper Section of the MVIC Service Area July 2015 Aerial Photography

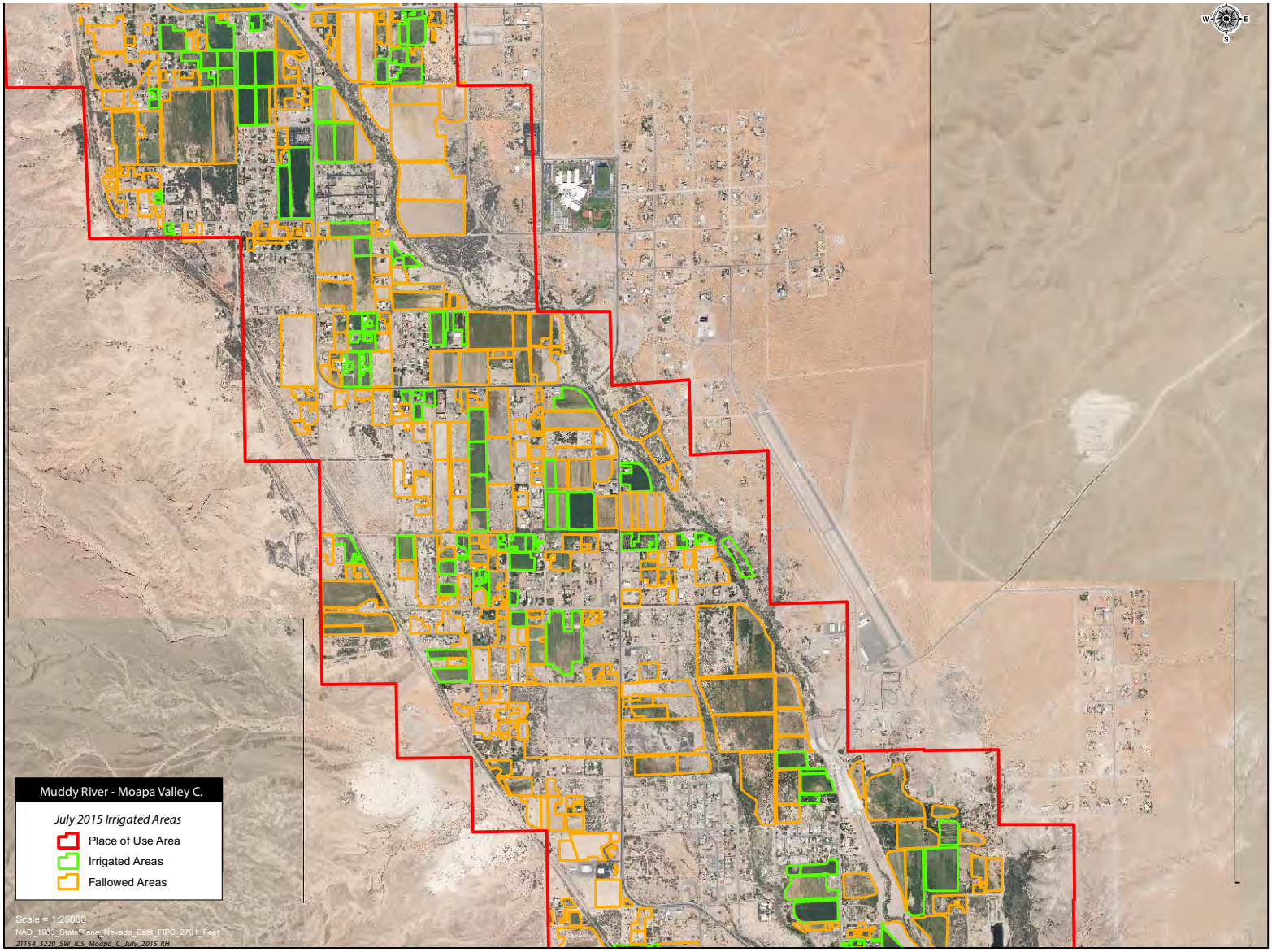


Figure 3-28
Middle Section of the MVIC Service Area July 2015 Aerial Photography

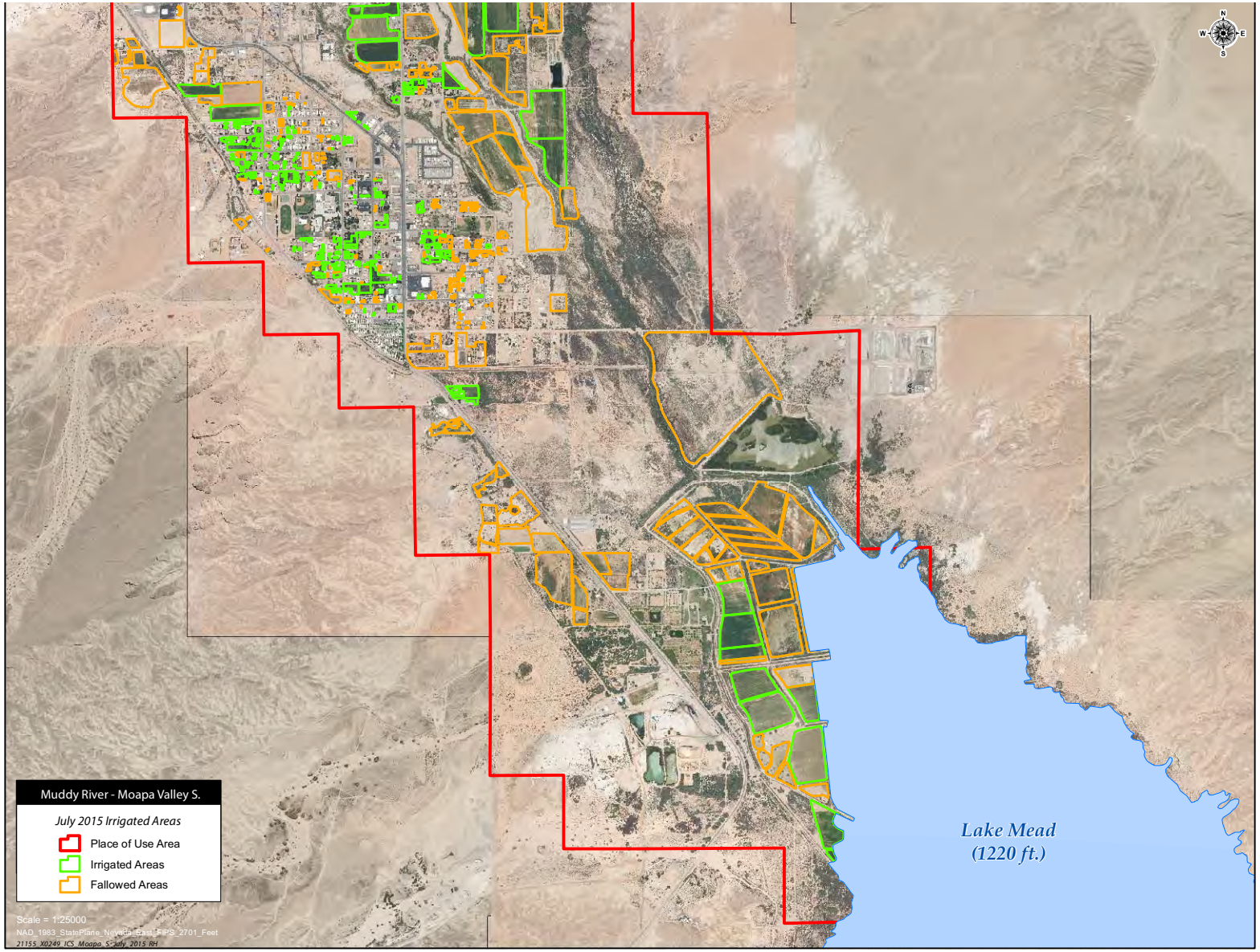


Figure 3-29
Lower Section of the MVIC Service Area July 2015 Aerial Photography

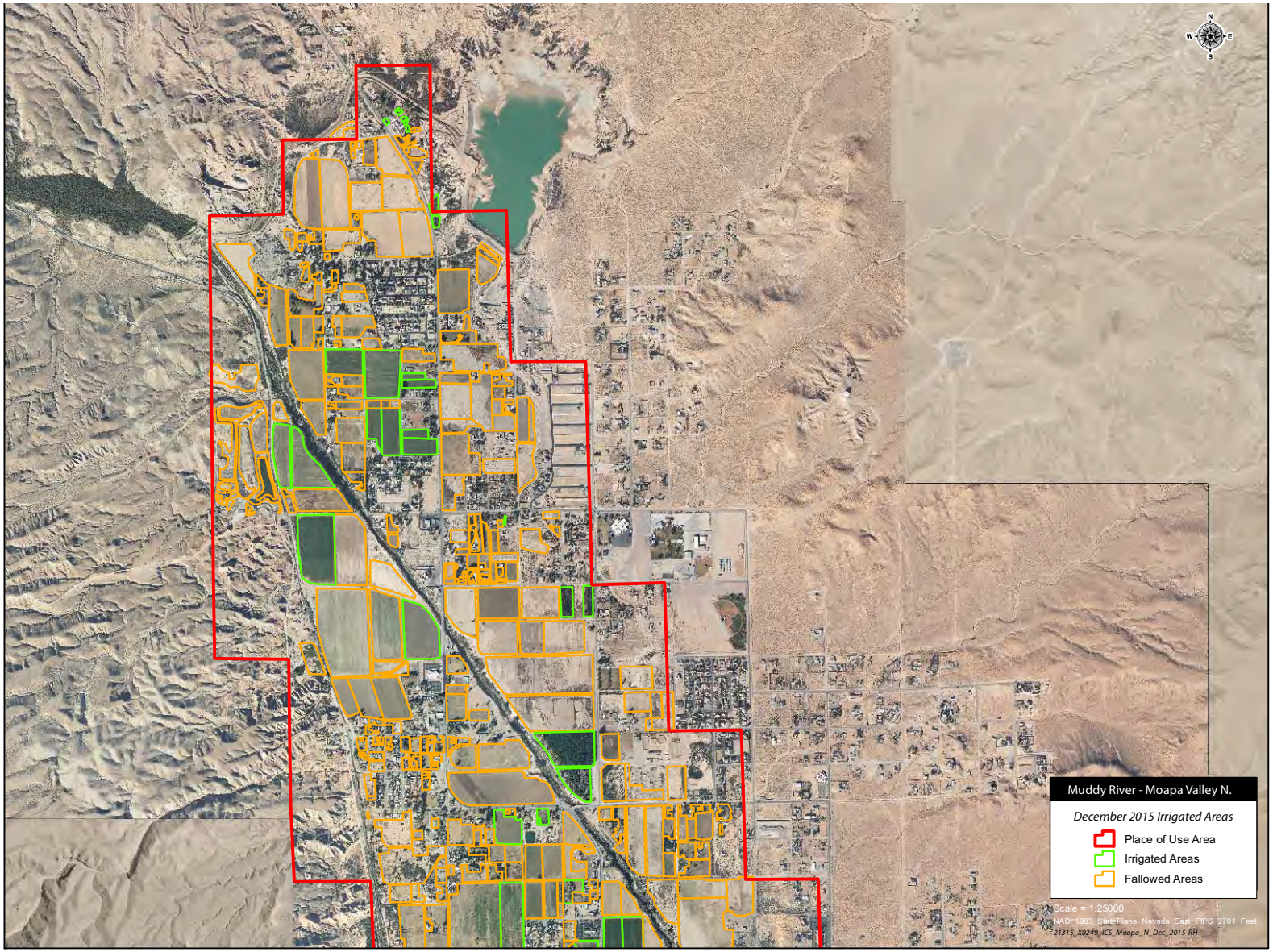


Figure 3-30
Upper Section of the MVIC Service Area December 2015 Aerial Photography

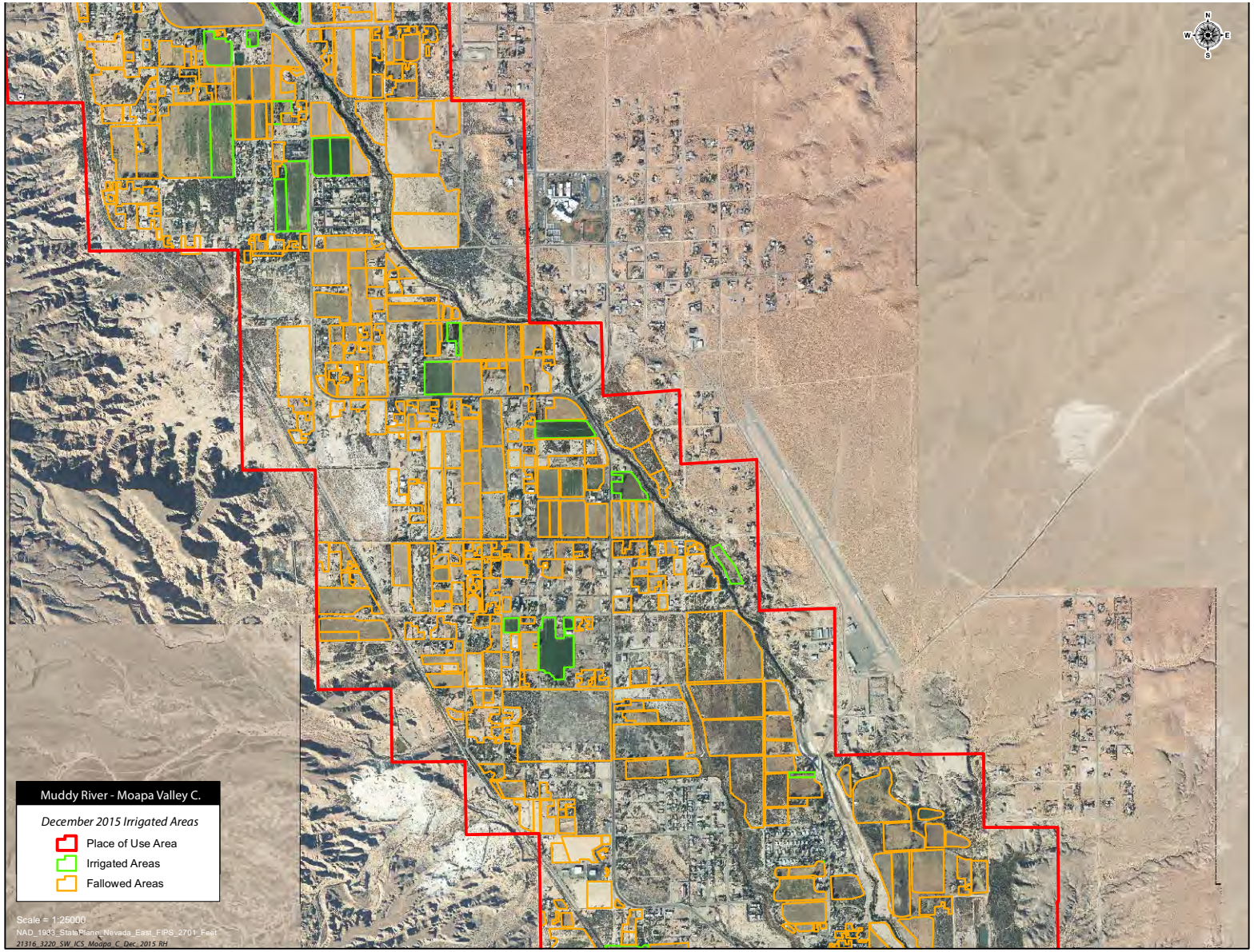


Figure 3-31
Middle Section of the MVIC Service Area December 2015 Aerial Photography

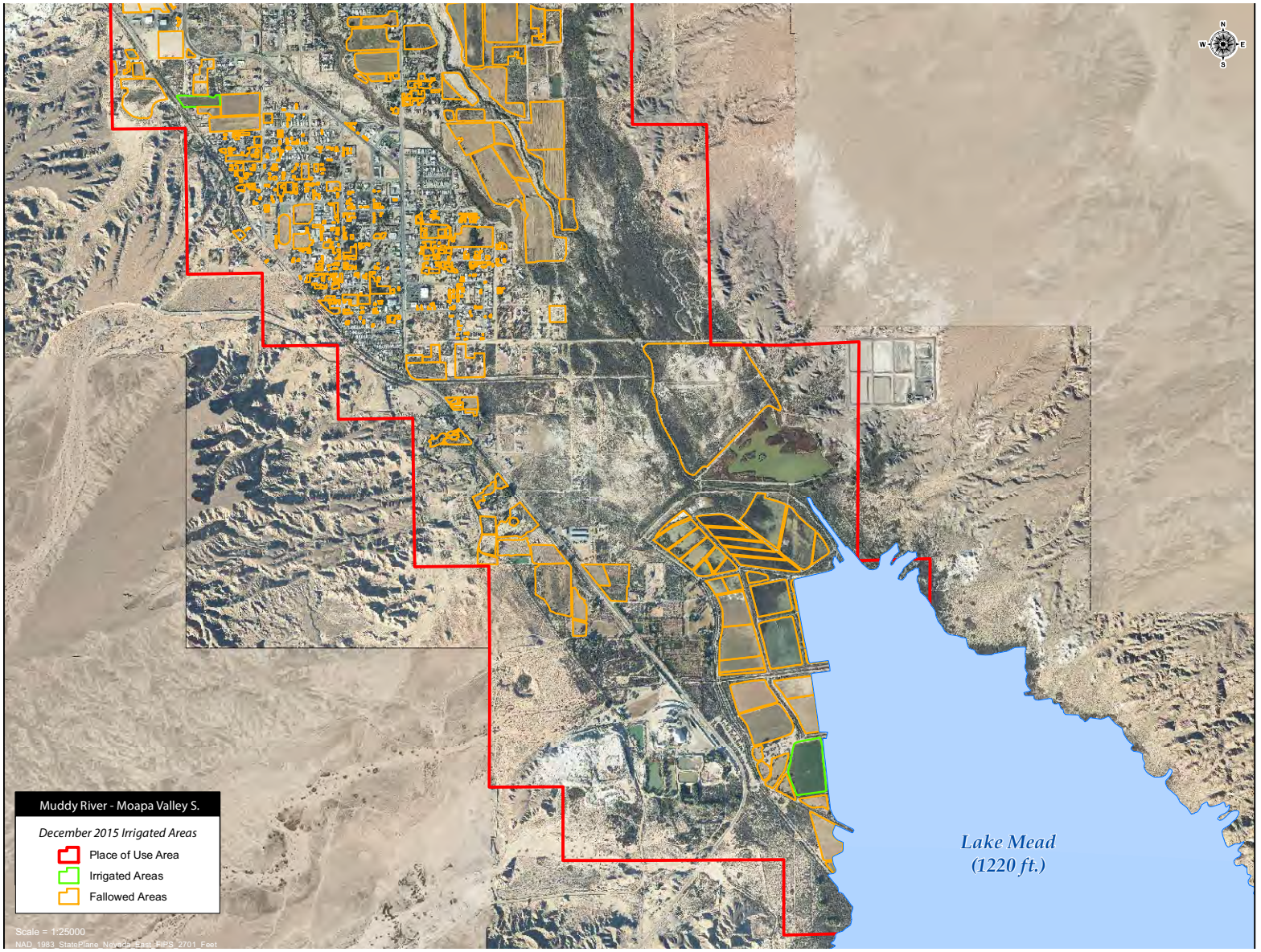


Figure 3-32
Lower Section of the MVIC Service Area December 2015 Aerial Photography

Table 3-9
Agricultural Land Status within MVIC's Place of Use.

	January	February	March	April	May	June	July	August	September	October	November	December
MVIC Ag (acres)												
Alfalfa	263.96	263.96	263.96	263.96	250.66	250.66	250.66	250.66	250.66	168.70	168.70	168.70
Small Vegetables	3.70	3.70	3.70	3.70	3.63	3.63	3.63	3.63	3.63	3.53	3.53	3.53
Bermuda w/ Rye	317.35	317.35	317.35	317.35	224.93	224.93	224.93	224.93	224.93	2.46	2.46	2.46
Orchard	28.83	28.83	28.83	28.83	28.59	28.59	28.59	28.59	28.59	28.62	28.62	28.62
Sudan	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	-	-	-
Total Ag	616.90	616.90	616.90	616.90	510.87	510.87	510.87	510.87	510.87	203.32	203.32	203.32
Not Irrigated (Total POU - Total Ag)	2,167.85	2,167.85	2,167.85	2,167.85	2,273.88	2,273.88	2,273.88	2,273.88	2,273.88	2,581.43	2,581.43	2,581.43
Total POU	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**	**2,784.75**

4.0 VERIFICATION OF ICS WATER REACHING LAKE MEAD

Since the entire flow of the Muddy River is decreed, it is necessary to perform a water balance on the Lower Muddy River to verify that the water which SNWA is claiming as Tributary Conservation ICS credits is reaching Lake Mead (Figure 4-1). This water balance is outlined in Exhibit A of the Forbearance Agreement and approved 2015 ICS Plan as follows:

Flows measured by USGS at the Glendale gage
- (minus) consumptive uses by agriculture below the Glendale gage
- (minus) direct uses by industry below the Glendale gage
- (minus) channel evapotranspiration below Glendale gage to Lake Mead
- (minus) evapotranspiration from the managed acreage on the Overton Wildlife Management Area (OWMA)

= Total Flow to Lake Mead (Elevation 1,220 above mean sea level)

This comprehensive water balance uses the Glendale gage as the input, which was also used to calculate the af/share associated with MVIC shares. To account for consumptive uses in the riparian corridor and agricultural areas, detailed GIS coverages delineating the active fields and mapped riparian corridors, combined with Lower Colorado River Accounting System (LCRAS) data were used to derive consumptive uses by crops and plants supplied by the Muddy River. Other consumptive uses by industry and open water evaporation were also calculated. Uses of Muddy River water by the Nevada Division of Wildlife's Overton Wildlife Management Area (OWMA) are deducted from the total flows to Lake Mead. A final comparison is then made to ensure that the conserved Muddy River water reaching Lake Mead exceeds or is equal to SNWA's controlled Muddy River water rights.

The CY2015 water balance is presented in Table 4-1. A more detailed seasonal calculation of the water balance is presented in Table 4-2. The following sub-sections describe each component of the water balance. Reference to these components are provided in the corresponding row in Table 4-2.

$$Q_{LM} = Q_G - CU_{AG} - CU_{IND} - CU_{CHN} - CU_{OWM} \quad \text{(Eq. 4-1)}$$

Where:

Q_{LM} = Flow to Lake Mead (ac-ft)

Q_G = Flow measured at Glendale Gage (Less Flood Flows) (ac-ft)

CU_{AG} = Consumptive Use by Agriculture (ac-ft)

Figure 4-1
Map of Lower Muddy River Riparian Area, Open Water, and the OWMA

CU_{IND}= Consumptive Use by Industry (ac-ft)

CU_{CHN}= ET along the Muddy River channel from the Glendale Gage to Lake Mead (ac-ft)

CU_{OWM}= ET within the Overton Wildlife Management Area (ac-ft)

Table 4-1
CY 2015 Water Balance (af)

Q_G	Flows measured by USGS at the Glendale gage (Less Flood Flows)	31,310
CU_{AG}	consumptive uses by agriculture below the Glendale gage	(1,185)
CU_{IND}	direct uses by industry below the Glendale gage	(1,695)
CU_{CHN}	channel evapotranspiration below Glendale gage to Lake Mead (including Bowman Res. Evap)	(2,718)
CU_{OWM}	evapotranspiration from the managed acreage on the Overton Wildlife Management Area (OWMA)	(854)
Q_{LM} =	Total Flow to Lake Mead (Elevation 1,220 AMSL)	24,858
	Total Muddy River Water Rights Controlled by SNWA	18,472
=	**Are Total Flows to Lake Mead greater than SNWA Water Rights ----------> YES**	

[a] CU_{AG} presented in this table differs from the CU_{AG} value in Table 4-2 due to changes in Bowman Reservoir storage being factored into the value in this table for the purposes of having the rows in this table conform to the Exhibit A of the Forbearance Agreement.

4.1 Glendale Gage Flows (Q_G)

As previously discussed in Section 3.3.3, the water available for use by MVIC equals the Glendale gage flows minus: 1) flood flows; 2) consumptive uses by phreatophytes in the riparian corridor between the Glendale gage and Wells Siding; and 3) Upper Muddy River rights owned or leased by SNWA. This “divertible flow” is used as the inflow component of the water balance verification.

The Glendale gage, for the purposes of calculating Tributary Conservation ICS credits, is believed to capture all surface water flows entering the lower reach of the Muddy River. The gage is located in a narrow cut of carbonate rocks commonly referred to as “the narrows.” Downstream of the narrows, the river enters the lower reach of the Muddy River and the floodplain begins to widen, until reaching Wells Siding. The Muddy River, downstream of Wells Siding, is an incised narrow channel that has artificially been constrained to facilitate farming on the river’s historic floodplain and act a flood channel.

4.2 Consumptive Use by Agriculture (CU_{AG}) and by Natural Vegetation ET (CU_{CHN})

4.2.1 Bureau of Reclamation Evapotranspiration Data

To calculate consumptive uses by agriculture (CU_{AG}) and phreatophytes (CU_{CHN}) on the Muddy River, a literature search for ET data with a long period-of-record and monthly time-step data was performed. The Bureau of Reclamation's Lower Colorado River Accounting System Evapotranspiration and Evaporation Calculations reports for calendar years 1995-2007 (Bureau of

Table 4-2
2015 Muddy River Intentionally Created Surplus Water Balance Sheet
(all units in acre-feet)

		Winter (Jan - Apr)	Summer (May - Sep)	Winter (Oct - Dec)	Total	Row Reference
Total Inflows to Lower Muddy River	Muddy River at Glendale Gage (Q_G)	10,620.00	12,100.00	8,590.00	31,310	A
	Phreatophyte Consumptive Use to Wells Siding [a]	151.83	866.46	130.89	1,149	B
	Controlled Upper Muddy River Water Rights	3,732.29	3,436.18	2,794.73	9,963	C
	Acre-feet per Share Basis (Divertible Flows)	6,735.89	7,797.36	5,664.38	20,198	D=A-B-C
Consumptive Uses Above OWMA	Simplot (CU_{IND})	607.01	632.48	455.26	1,694.74	E
	MVIC Crop Use (CU_{AG})	806.96	1,628.17	173.64	2,608.76	F
	Bowman Reservoir Evaporation [a]	264.70	391.99	121.32	778.01	G
	Phreatophyte Consumptive Use [a]	123.58	581.44	86.11	791.13	H
	MVIC Consumptive Uses above Lewis Ave	1,802.24	3,234.08	836.32	5,873	I=E+F+G+H
Bowman Reservoir Operations	Coyote Springs Imported ICS	0	0	0	0	J
	Net Muddy River Water In or (Out) of Bowman	262.73	(1,352.33)	(334.18)	(1,424)	K
	Measured Change in Bowman Reservoir Storage	262.73	(1,352.33)	(334.18)	(1,424)	L=J+K
Flows Above OWMA	Total Calculated Flows above OWMA	8,403.20	9,351.80	7,956.98	25,712	M=A-B-I+J-L
Overton Wildlife Management Area Water Use	OWMA Consumptive Use (CU_{OWM})	326.30	322.52	204.86	854	P
	Total Flows to Lake Mead (Q_{LM})	8,076.90	9,029.28	7,752.12	24,858	Q=M-P
SNWA Water Rights	Controlled Upper Muddy River Water Rights	3,732.29	3,436.18	2,794.73	9,963	C
	MVIC Rights	2,917.82	3,095.78	2,494.96	8,509	S
	Muddy River Water Rights Controlled by SNWA	6,650.11	6,531.96	5,289.69	18,472	T=R+S
	Coyote Spring Imported ICS (Not conducted in 2015)	0	0	0	0	U
	Total Muddy River and Coyote Spring Water Rights Controlled by SNWA	6,650.11	6,531.96	5,289.69	18,472	V=T+U
Flow Check	Difference Between total Flows to Lake Mead and SNWA Water Rights	1,426.79	2,497.32	2,462.42	6,387	W=Q-V
	Is conservation > than SNWA rights ?	Yes	Yes	Yes	Yes	Q > V

Due to rounding, numbers presented throughout this table may not add up precisely to the totals provided and may not precisely reflect the absolute figures.
[a] CU_{CHN} is the sum of Row References: B + G + H

Reclamation, 2007) were evaluated and found to contain monthly data for a similar climate. Therefore, data from the LCRAS reports were selected for use in this analysis.

The LCRAS Reports document estimates of ET and Evaporation annually for the purpose of determining consumptive water use along the Lower Colorado River. The values are determined by collecting data from meteorological towers, determining potential ET, and applying various crop coefficients to the ET values.

The portion of the LCRAS ET data chosen for use in this analysis utilize data collected from two Arizona Meteorological Network (AZMET) stations located in the Mohave Valley in Arizona, which are used to calculate local phreatophyte and crop ET (Figure 4-2). This is the most northern area currently used by Reclamation and most closely represents climatic conditions of the Lower Muddy River. The Mohave Valley is, however, at a lower elevation and experiences higher temperatures than the Lower Muddy River, resulting in higher ET values. This makes the Mohave Valley ET values conservative, overestimating the actual ET demand in the Lower Muddy River.

4.2.2 Application of LCRAS to the Lower Muddy River

Phreatophyte vegetation on the Lower Muddy River was mapped and classified using the Anderson-Ohmart classification system (Anderson, 1984). LCRAS uses a classification system that slightly differs from the Anderson-Ohmart system. To apply ET rates from LCRAS to the Lower Muddy River, the two vegetation classification systems were correlated. Table 4-3 lists the SNWA-derived correlation between the two classification systems.

The LCRAS "Sc-low" phreatophyte classification was used for all of the salt-cedar classifications in the Anderson-Omart classification and is supported by a USGS Scientific Investigations Report 2008-5116 titled *Quantifying Ground-Water and Surface-Water Discharge from Evapotranspiration Processes in 12 Hydrographic Areas of the Colorado Regional Ground-Water Flow System, Nevada, Utah, and Arizona (*Demeo, 2008). The purpose of the report was to estimate groundwater and surface-water ET from 12 hydrographic basins via ET. For the study the USGS placed ET measurement sites in various locations in Utah, Arizona, and Nevada including the Upper Muddy and Lower Virgin Rivers. The Virgin River ET station was placed in a "dense woodland vegetation" area which was predominantly salt cedar. The Virgin River site measured an annual ET rate of 3.9 ft/yr without subtracting precipitation. This rate is less than the LCRAS Sc-low value of 4.39 ft/yr using LCRAS Mohave Valley data. The USGS Muddy River ET site was located in a stand of mesquite trees, in the Upper Muddy River. The USGS value of 3.6 ft/yr (without subtracting precipitation) is more than 1 ft less than the LCRAS "Ms-high" value of 5.0 ft/yr.

The USGS study demonstrates that by correlating the LCRAS Sc-low and Ms-high classifications to salt cedar and mesquite on the Lower Muddy River, a conservative estimate of ET can be determined. These variations in ET rates demonstrate the challenges of trying to estimate ET over large areas, as ET can only be physically measured at a single point. Conditions such as soil type, depth to groundwater, and computational method used can all affect ET rates greatly. Comparison of the LCRAS rates used by SNWA (Sc-low) in the water balance (in this analysis) to the measurements performed by the USGS show that using the LCRAS rates tends to slightly overestimate ET along the Lower Muddy River based these recent reports.

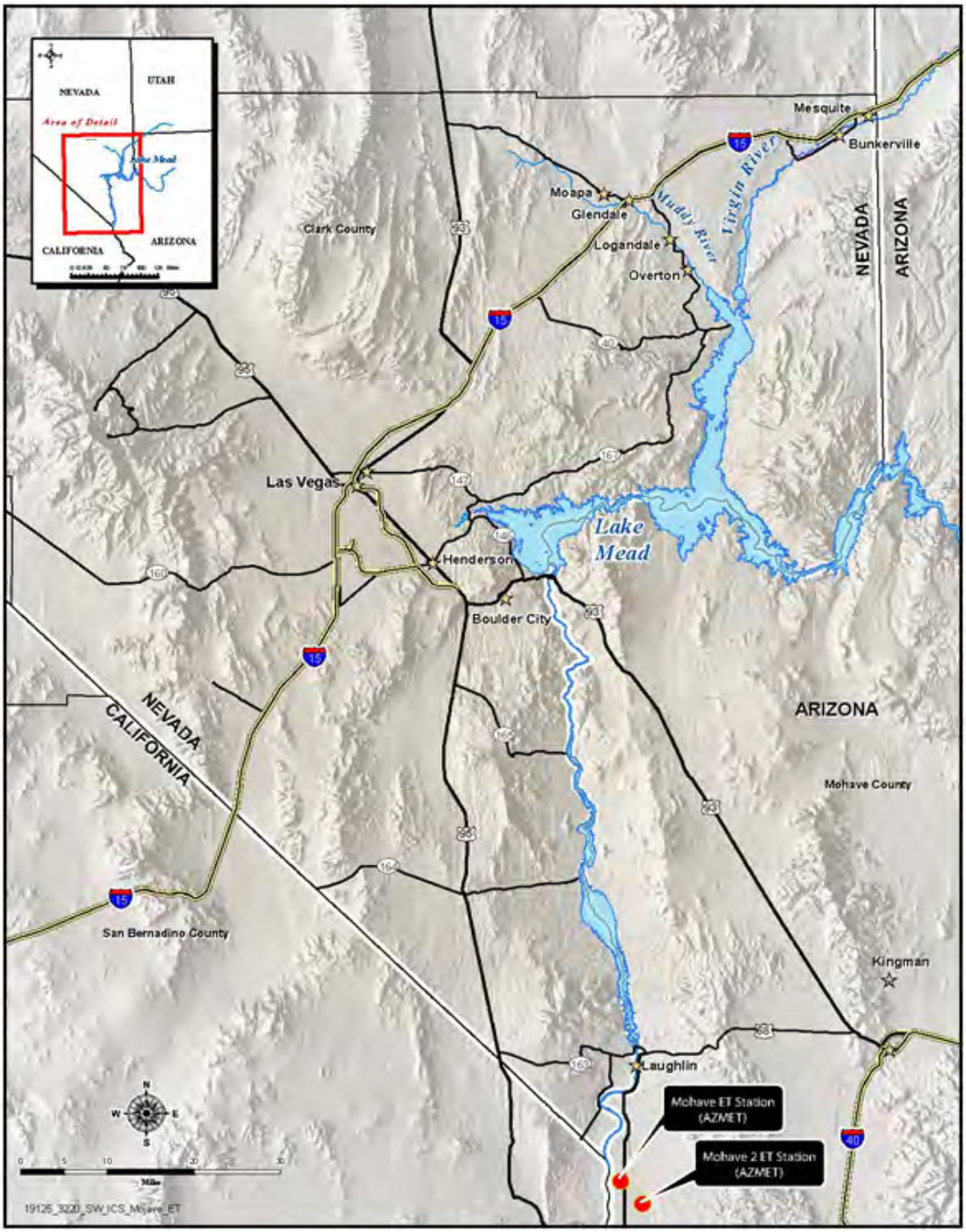


Figure 4-2
Mohave Valley AZMET ET Stations

Table 4-3
Anderson Ohmart Mapped Class

Anderson Ohmart Mapped Class	Correlating LCRAS Class	Acres
A	Low Veg	15.53
AW	AW	7.85
Acacia	Ms-high	0.00
Baccharis	Low Veg	1.37
C	CW	0.13
CW	CW	6.60
HM	Ms-high	4.26
I	Ms-high	2.03
L	Ms-high	0.83
MA	Marsh	20.00
RIV	Open Water	2.11
SC	Sc-low	97.73
SM	Sc/ms	8.94

The equation used in this analysis for calculating ET by phreatophytes is:

$$CU_{CHN} = A_R \times ET_{LCRAS} \quad \text{(Eq. 4-2)}$$

Where:

CU_{CHN} = Consumptive use along MR Channel from Glendale Gage to Lake Mead (ac-ft)

A_R= Area of Riparian Zone Specific to Each Vegetation Type (acres)

ET_{LCRAS}= Mohave Valley ET Rate Specific to Each Vegetation Type (ft)

The agricultural crop types in LCRAS were directly correlated with crop types on the Muddy River. Water use by crop type in LCRAS is adjusted for precipitation by using an effective precipitation coefficient. To more accurately represent conditions on the Lower Muddy River, provisional precipitation data recorded for CY 2015 by the Overton Nevada Community Environmental Monitoring Program (CEMP) Weather Station (http://www.cemp.dri.edu/) was used for calculating the effective precipitation used to derive crop consumptive uses. The equation for calculating Crop ET is listed below. The crop rates adjusted by the Overton Nevada CEMP precipitation data are listed in Table 4-4.

$$CU_{AG} = A_C \times (ET_{LCRAS} - P_{EFF}) \quad \text{(Eq. 4-3)}$$

Where:

CU_{AG} = MVIC Crop Use (af)

A_C= Area of Crops Specific to Each Vegetation Type (acres)

ET_{LCRAS}= Mohave Valley ET Rate Specific to Each Vegetation Type (feet)

P_{EFF}= Effective Precipitation (feet)

4.2.2.1 MVIC Crop Use

Tables 4-4 through Table 4-6 in this section detail the calculations performed to estimate the amount of consumptive uses by crops, phreatophytes, and open water. The Mohave Valley monthly ET rates for the crops and phreatophytes are adjusted to local precipitation measured at the Overton Nevada CEMP station.

The measured acreages of each vegetation type and open water are listed in Table 4-5. Vegetation mapping of the Muddy River riparian corridor was performed in 2006. In 2010, the survey data were updated to reflect removal of vegetation due to the construction of a bridge crossing the Muddy River. Given the incised nature of the channel, the total vegetated acreage along the riparian corridor has remained the same and is anticipated to remain the same into the future. The phreatophyte acreages were mapped in the field by biologists and verified using the high resolution 6-in aerial photography. The estimated acreage for the phreatophytes and crops are listed in Table 4-5. The final consumptive use calculations for the phreatophytes and crops are provided monthly in Table 4-6 and these results are then shown seasonally on Rows B, F, and H of Table 4-2.

Vegetation acreage mapped for OWMA is also listed in Table 4-5. OWMA is the downstream extent of MVIC's service area and is located immediately above the full-pool elevation of Lake Mead. Water use by OWMA is described in the subsequent sections of this report.

4.2.2.2 Ongoing Evaluation of ET by Natural Vegetation

To improve the accuracy of future ET consumptive use calculations along the Lower Muddy River, SNWA has installed a meteorological (MET) tower adjacent to an alfalfa field in the Lower Muddy River. With the cooperation of the Moapa Valley High School Future Farmers of America Farm, SNWA was able to place the MET tower in an area representing the ideal fetch and agricultural conditions for measuring the meteorological parameters necessary to calculate reference ET using the ASCE Standardized Reference ET Equation –a similar method used by The Arizona Meteorological Network (AZMET) and California Irrigation Management Information System for the LCRAS program.

Table 4-4
Mohave Valley ET Rates (ft)

	Average 1995 - 2007												
	January	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**	**Total**
Crops:													
Alfalfa Perennial	0.20	0.31	0.41	0.56	0.68	0.73	0.69	0.66	0.56	0.38	0.24	0.25	5.69
Alfalfa-Annual	0.14	0.26	0.33	0.39	0.65	0.50	0.57	0.29	0.23	0.23	0.12	0.19	3.92
Small Grain	0.24	0.36	0.57	0.68	0.27	0.00	0.00	0.00	0.00	0.00	0.01	0.09	2.24
Orchard	0.13	0.16	0.27	0.45	0.66	0.70	0.67	0.64	0.51	0.36	0.24	0.16	4.97
Melons (Fall)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.32	0.41	0.30	0.16	1.29
Small Vegetables	0.28	0.33	0.42	0.15	0.00	0.00	0.00	0.00	0.08	0.14	0.19	0.23	1.84
Bermuda Grass w/ Rye	0.25	0.29	0.36	0.28	0.64	0.69	0.66	0.62	0.48	0.20	0.25	0.22	4.96
Sudan	0.00	0.00	0.13	0.43	0.83	0.97	0.89	0.35	0.03	0.00	0.00	0.00	3.63
Moist Soil Unit	0.56	0.79	0.23	0.36	0.31	0.84	0.26	0.46	0.43	0.26	0.44	0.39	5.35
Phreatophytes:													
AW	0.08	0.10	0.20	0.41	0.69	0.80	0.76	0.68	0.51	0.31	0.12	0.07	4.73
CW	0.08	0.10	0.21	0.44	0.74	0.84	0.79	0.71	0.53	0.33	0.13	0.07	4.97
Low Veg	0.09	0.10	0.20	0.37	0.61	0.67	0.67	0.59	0.50	0.32	0.14	0.07	4.33
Marsh	0.07	0.08	0.37	0.74	0.92	0.96	0.91	0.82	0.67	0.27	0.07	0.06	5.94
Ms-High	0.08	0.10	0.21	0.43	0.71	0.82	0.77	0.70	0.57	0.38	0.16	0.07	5.00
Sc-ms	0.08	0.10	0.20	0.46	0.81	0.95	0.89	0.80	0.61	0.36	0.14	0.07	5.47
Sc-Low	0.07	0.08	0.14	0.29	0.61	0.77	0.73	0.66	0.54	0.33	0.12	0.05	4.39
Open Water Evaporation[a]	0.30	0.40	0.60	0.60	0.80	0.80	0.80	0.70	0.80	0.70	0.60	0.40	7.50
Precipitation[b]	0.04	0.05	0.03	0.02	0.00	0.00	0.01	0.09	0.01	0.08	0.01	0.01	0.35

[a]Westenberg et al. (2006)
[b]Overton Nevada Community Environmental Monitoring Program (CEMP) Weather Station (CY 2015) (http://www.cemp.dri.edu/)

Table 4-5
Acreages of Agriculture, Phreatophytes, and Open Water in the Lower Muddy River

	January	February	March	April	May	June	July	August	September	October	November	December
Bowman Reservoir	154.62	163.62	154.62	135.32	112.58	108.82	105.04	98.20	90.86	80.05	71.87	76.36
Riparian:												
Sc_Low above Wells Siding	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77	261.77
AW	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85	7.85
CW	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73	6.73
Ms-High	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11	7.11
Low Veg	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90	16.90
Marsh	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Sc-Low	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73	97.73
Sc/ms	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94	8.94
Open Water	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11	2.11
Subtotal Below Wells Siding	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37	167.37
Total	**429.14**	**429.14**	**429.14**	**429.14**	**429.14**	**429.14**	**429.14**	**429.14**	**429.14**	**429.14**	**429.14**	**429.14**
MVIC Ag:												
Alfalfa	263.96	263.96	263.96	263.96	250.66	250.66	250.66	250.66	250.66	168.70	168.70	168.70
Small Vegetables	3.70	3.70	3.70	3.70	3.63	3.63	3.63	3.63	3.63	3.53	3.53	3.53
Bermuda w/ Rye	317.35	317.35	317.35	317.35	224.93	224.93	224.93	224.93	224.93	2.46	2.46	2.46
Orchard	28.83	28.83	28.83	28.83	28.59	28.59	28.59	28.59	28.59	28.62	28.62	28.62
Melons (Fall)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Small Grain	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sudan	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	3.06	0	0	0
Total	**616.90**	**616.90**	**616.90**	**616.90**	**510.87**	**510.87**	**510.87**	**510.87**	**510.87**	**203.32**	**203.32**	**203.32**
OWMA:												
Alfalfa	33.39	33.39	33.39	33.39	31.41	31.41	31.41	31.41	31.41	0.00	0.00	0.00
Bermuda w/Rye	10.67	10.67	10.67	10.67	31.50	31.50	31.50	31.50	31.50	12.74	12.74	12.74
Moist Soil Unit	155.16	155.16	155.16	155.16	0.00	0.00	0.00	0.00	0.00	155.16	155.16	155.16
Sudan	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Open Water	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88	31.88
Total	**231.10**	**231.10**	**231.10**	**231.10**	**94.79**	**94.79**	**94.79**	**94.79**	**94.79**	**199.78**	**199.78**	**199.78**

Table 4-6
Total ET in Acre Feet (2015)

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Bowman Reservoir	39.82	58.08	87.75	79.05	89.69	87.06	83.34	59.90	72.00	49.63	42.16	29.53	778
Riparian:													
Sc_Low above Wells Siding	18.32	20.94	36.65	75.91	159.68	201.56	191.09	172.77	141.36	86.38	31.41	13.09	1,149
AW	0.63	0.78	1.57	3.22	5.42	6.28	5.96	5.34	4.00	2.43	0.94	0.55	37
CW	0.54	0.67	1.41	2.96	4.98	5.65	5.32	4.78	3.57	2.22	0.87	0.47	33
Ms-High	0.57	0.71	1.49	3.06	5.05	5.83	5.48	4.98	4.05	2.70	1.14	0.50	36
Low Veg	1.52	1.69	3.38	6.25	10.31	11.33	11.33	9.97	8.45	5.41	2.37	1.18	73
Marsh	1.40	1.60	7.40	14.80	18.40	19.20	18.20	16.40	13.40	5.40	1.40	1.20	119
Sc-Low	6.84	7.82	13.68	28.34	59.62	75.25	71.34	64.5	52.77	32.25	11.73	4.89	429
Sc/ms	0.71	0.89	1.79	4.11	7.24	8.49	7.95	7.15	5.45	3.22	1.25	0.63	49
Open Water	0.54	0.75	1.20	1.23	1.68	1.69	1.67	1.29	1.67	1.31	1.24	0.81	15
Subtotal Below Wells Siding	13.00	15.00	32.00	64.00	113.00	134.00	127.00	114.00	93.00	55.00	21.00	10.00	791
Total	**31**	**36**	**69**	**140**	**272**	**335**	**318**	**287**	**235**	**141**	**52**	**23**	**1,940**
MVIC Ag:													
Alfalfa	53.58	82.36	109.15	147.82	170.45	182.99	172.96	165.44	140.37	63.77	41.27	42.96	1,373
Small Vegetables	1.05	1.23	1.57	0.55	-	-	-	-	0.29	0.49	0.69	0.83	7
Bermuda w/ Rye	80.29	92.67	115.36	88.86	143.96	155.20	148.45	139.46	107.97	0.49	0.63	0.55	1,074
Orchard	3.83	4.67	7.88	12.97	18.87	20.01	19.15	18.29	14.58	10.25	7.00	4.71	142
Melons (Fall)	-	-	-	-	-	-	-	-	-	-	-	-	-
Sm Grain	-	-	-	-	-	-	-	-	-	-	-	-	-
Sudan	0.41	0.50	0.84	1.38	2.02	2.14	20.5	1.96	1.56	-	-	-	13
Total	**139.16**	**181**	**235**	**252**	**335**	**360**	**343**	**325**	**265**	**75**	**50**	**49**	**2,609**
OWMA:													
Alfalfa	6.78	10.42	13.81	18.70	21.36	22.93	21.67	20.73	17.59	-	-	-	154
Bermuda w/Rye	2.70	3.12	3.88	2.99	20.16	21.73	20.79	19.53	15.12	2.52	3.24	2.86	119
Moist Soil Unit	45.46	53.06	56.04	52.75	-	-	-	-	-	64.86	44.17	36.41	353
Sudan	-	-	-	-	-	-	-	-	-	-	-	-	-
Open Water	8.21	11.32	18.09	18.62	25.40	25.50	25.29	19.45	25.26	19.77	18.70	12.33	228
Total	**63**	**78**	**92**	**93**	**67**	**70**	**68**	**60**	**58**	**87**	**66**	**52**	**854**

In addition to SNWA's data collection efforts, in 2010 the NDWR published a report titled *Evapotranspiration and Net Irrigation Requirements for Nevada* (Huntington, 2010). The report and ET database can be found on the NDWR website (http://water.nv.gov/mapping/et/et_general.cfm). Since there are few MET stations collecting ET data under ideal conditions, data from National Weather Service Cooperative Observer Program weather stations were used to approximate reference ET. The NDWR report also modified standard crop curves to the climate and agricultural practices of Nevada. Using the NDWR database (http://water.nv.gov/mapping/et/et_general.cfm), the calculated alfalfa ET for the Lower Moapa Valley is 4.9 ft per year. This value is lower than the Mohave Valley value of 5.7 ft. These lower values are to be expected as the Muddy River is at a higher elevation and latitude than Mohave Valley, Arizona. SNWA will continue collecting MET data and may use the data collected from the Moapa Valley High School MET tower, possibly with the modified crop curves from the NDWR report in future ICS Certification Reports.

4.2.3 Open Water Evaporation (CU_{CHN})

Open water bodies on the Lower Muddy River include Bowman Reservoir, the Muddy River channel, and a few small ponds on the OWMA. Bowman Reservoir is used by MVIC to augment irrigation flows during the summer irrigation season. The reservoir is also where SNWA's Coyote Spring Valley Imported ICS is delivered. Traditionally the 3,000 to 4,000 af capacity reservoir is filled in the winter months from the Muddy River via gravity flow and then a pump to reach higher storage volumes. The reservoir storage is then used to augment the summer irrigation water supply for the summer season.

The open-water evaporation rate used for Bowman Reservoir, the Muddy River channel, and the ponds on the OWMA was 7.50 ft/yr. This value is the open-water evaporation rate determined and published by the USGS for Lake Mead. The monthly average evaporation data was published in the USGS SIR 2006-5252 titled *Evaporation from Lake Mead, Arizona, and Nevada, 1997-99* (Westenberg, 2006). The average monthly evaporation data from the report is listed in Table 4-4. The surface area of Bowman Reservoir and other open water on the Lower Muddy River is listed in Table 4-5, and the total evaporative loss is listed in Table 4-6 and in Row G of Table 4-2. Changes in storage in Bowman Reservoir along with inflows from SNWA's Imported ICS project are shown in Rows J and K of Table 4-2. Monthly water-level elevations in Bowman Reservoir were manually recorded by MVIC personnel utilizing a surveyed stage-measurement gage located on the side of the reservoir. A stage-capacity curve was created by SNWA using high-resolution LiDAR data collected when the reservoir was empty. The LiDAR data enables MVIC and SNWA to obtain a very accurate reservoir storage volume at any given reservoir elevation. Month-to-month Bowman Reservoir volumes were used to calculate changes in storage in the reservoir which translated to inflows and outflows of the reservoir.

4.3 Industrial Consumptive Use (CU_{IND})

A portion of MVIC's shares have been purchased and leased by Simplot, a sand and minerals operation in Overton, Nevada, which is using the water represented by shares they control for slurrying and washing sand for glass production. The water is 100% consumptively used, so the water represented by the shares controlled by Simplot is subtracted in its entirety from the water balance.

As of 2015, Simplot controlled up to 215.92 preferred and 287.67 common shares (personal communication with MVIC Staff, March 2016). Using the acre-foot per share values of 7.0302 af/share preferred and 0.5859 af/share common, Simplot consumptively used 1,695 af of MVIC water in CY 2015. While the water delivered to Simplot is not directly measured, they are located at the end of the ditch and are subject to all upstream users diverting their rights. Even SNWA's rights are taken on turn and returned to the natural channel above Simplot. Therefore, calculating their use at 100% of their controlled shares ensures a conservative estimate for their annual use. The monthly breakdown of Simplot's consumptive use is shown in Row E of the Water Budget (Table 4-2).

4.4 Overton Wildlife Management Area (CU_{OWM})

The OWMA is located just above the Muddy River's confluence with Lake Mead. OWMA is managed for migrating birds, hunting, and most recently, a refugia for Razorback suckers in a small impoundment called Honey Bee Pond. The managed part of the facility, located above Lake Mead, is about 280 acres in size and consists of Honey Bee Pond, a couple other small impoundments, and a series of seasonal wetlands that are flooded in the winter for migrating waterfowl, along with several fields of Alfalfa, Sudan grass, and Bermuda grass for bird habitat and minor farming.

The OWMA receives most of its water directly from the Muddy River and is permitted to do so under tail-water permits. In addition to the tail-water rights, OWMA owns shares in MVIC. As of CY 2014, OWMA owned 407 afy of MVIC rights represented by 51.25 preferred and 80.50 common shares (personal communication with MVIC Staff, March 2016). MVIC water delivered to OWMA is diverted at Wells Siding and travels via ditch to OWMA.

The managed area of OWMA above Lake Mead uses approximately 854 afy (Table 4-6), in addition to the 407 afy from MVIC shares, (Row P of Table 4-2) based on the type of vegetation/management practices for OWMA lands above Lake Mead. Aerial photography and interviews with OWMA management were used to determine the appropriate LCRAS Vegetation ET rates to apply to the managed areas.

4.5 Flows Entering Lake Mead (Q_{LM})

After the OWMA consumptive uses from the Muddy River are subtracted from the total flows calculated above the OWMA, the total surface-water to Lake Mead can be derived (Row Q of Table 4-2). As outlined in Table 4-2, 18,472 af of Muddy River water entered Lake Mead in CY 2015 to be used for the creation of Tributary Conservation ICS or be left in Lake Mead under the Pilot Program.

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5.0 SNWA TRIBUTARY CONSERVATION ICS AND PILOT PROGRAM WATER

The total volume of Muddy River water for which SNWA created Tributary Conservation ICS and Pilot Program Water was 18,472 af in CY 2015 using SNWA-owned and leased pre-BCPA Muddy River water rights. This total does not include any overrun payback or the one-time deduction of 5% for the benefit of additional system storage in Lake Mead. The method of creation was consistent with the approved, amended CY 2015 ICS Plan, Forbearance Agreement, and Guidelines.

The total volume of Virgin River water for which SNWA created Tributary Conservation ICS and Pilot Program Water was 14,175 af in CY 2015, as described in the CY 2015 Virgin River Tributary Conservation ICS Certification Report. The combined volume from the Muddy and Virgin rivers conveyed to Lake Mead as Tributary Conservation ICS and Pilot Program Water was 32,647 af. Of this total volume, 7,500 af was conveyed to Lake Mead as Pilot Program water and 25,147 af was conveyed to Lake Mead as Tributary Conservation ICS.

In CY 2015, SNWA did not deliver any Coyote Spring Valley Imported ICS to the Lower Muddy River for conveyance to Lake Mead.

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6.0 REFERENCES

Anderson, B. and R. Ohmart. 1984. Lower Colorado River Riparian Methods of Quantifying Vegetation Communities to prepare Type Maps. Arizona State University, Tempe, Arizona.

Bureau of Reclamation, 2007, Lower Colorado River Accounting System evapotranspiration and evaporation calculations calendar year 2007: Boulder City, Nev., Bureau of Reclamation, Lower Colorado River Region.

DeMeo, G.A., Smith, J.L., Damar, N.A., and Darnell, Jon, 2008, Quantifying ground-water and surface-water discharge from evapotranspiration processes in 12 hydrographic areas of the Colorado Regional Ground-Water Flow System, Nevada, Utah, and Arizona: U.S. Geological Survey Scientific Investigations Report 2008-5116, 22 p.

Huntington, J.L., Allen, R.G., 2010, Evapotranspiration and Net Irrigation Water Requirements for Nevada, Nevada Division of Water Resources 96 p.

Westenburg, C.L., DeMeo G.A., and Tanko, D.J., 2006, Evaporation from Lake Mead, Arizona and Nevada, 1997–99: U.S. Geological Survey Scientific Investigations Report 2006-5252, 24 p.

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Letter Report

Stable Isotope Evaluation of Water Budgets for the White River and Meadow Valley Wash Regional Groundwater Flow Systems in East-Central and Southeastern Nevada

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EXECUTIVE SUMMARY

- Stable isotope mass-balance models were developed to evaluate water budgets and interbasin flow for the White River and Meadow Valley Wash regional groundwater flow systems (WRFS and MVWFS, respectively). Water budgets for the regional flow systems are a compilation of recharge and predevelopment evapotranspiration (ET) estimates developed for each valley. Interbasin flow out of a valley is the amount of recharge to a valley plus any groundwater inflow to a valley that exceeds groundwater removed by ET. Three water budgets were evaluated using two different models. The three water budgets that were evaluated are the SNWA (2007), SNWA/BARCAS (SNWA, 2007; Welch and Bright, 2007), and Reconnaissance Report Series water budgets. Interbasin flow routing is based on geologic and hydrologic information (SNWA, 2007) for the SNWA (2007) and SNWA/BARCAS water budget evaluations and is from Eakin (1966) for the WRFS for the Reconnaissance Report Series water budget evaluations.
- Two isotope mass-balance models were used to evaluate the three water budgets. In the first model, groundwater ET is satisfied by a mixture of local recharge with interbasin flow entering a valley (if there is any interbasin flow entering the valley). In the second model, groundwater ET is initially satisfied by local recharge and if ET in a valley exceeds local recharge, the remainder of the ET is satisfied by interbasin flow. The isotopic mass-balance models use average deuterium and oxygen-18 values for recharge and discharge areas to evaluate how closely recharge and ET estimates in the WRFS and MVWFS match measured isotopic values for regional warm (>20 ^{o}C) spring discharge areas, small (< 50 afy) warm springs, and consolidated rock and alluvial wells with warm water.
- Both isotope mass-balance models using the SNWA (2007) water budget and interbasin flow routing have calculated deuterium and oxygen-18 values for all regional warm (>20 ^{o}C) spring areas that are excellent to acceptable matches with measured values, except for oxygen-18 for one model that was 0.01 permil outside the acceptable range. Furthermore, the mass-balance models have excellent to acceptable matches for calculated values as compared to measured values for all small warm springs and most wells with warm water. Thus, the SNWA (2007) water budget and interbasin flow routing for the WRFS and the MVWFS produce the best isotope mass-balance model results of the three water budgets evaluated and the model results show the water budget is reasonable for these flow systems. The mass-balance models using the SNWA/BARCAS water budget gave similar, but not quite as good, results as the SNWA water budget (two calculated deuterium values, not in the acceptable range for matching measured values of regional warm springs).
- Neither of the stable isotope mass-balance models using the Reconnaissance Report Series water budget for the WRFS and the MVWFS and Eakin (1966) interbasin flow routing for the WRFS produced realistic results. Thus, the Reconnaissance Report Series recharge and ET estimates are not in balance for the WRFS and MWVFS.
- Isotopic variability for six recharge area monitoring springs within the study area was relatively small with standard deviations of deuterium and oxygen-18 data ranging

from 0.7 to 1.6 permil and 0.06 to 0.33 permil, respectively. This range in standard deviation for these six sites is for samples taken quarterly throughout all four seasons with four of the six sites having more than three years of data. The isotopic composition of these springs varied little from season to season as spring flow varied a lot, ranging from about 100 to 2,500 gallons per minute during sample collection, and exceeding 5,000 gallons per minute at peak flow, at the largest discharging monitoring spring. This small amount of isotopic variability of recharge area springs is important for isotopic mass-balance models because this information indicates that the isotopic composition of recharge area groundwater varies little over time.

- Isotopic variability of 12 regional warm springs in the study area was relatively small with the standard deviation of deuterium and oxygen-18 data ranging from 0.5 to 1.9 permil for deuterium and 0.05 to 0.22 (except for one site with a standard deviation of 0.67) permil for oxygen-18. This range in values is for samples taken throughout all four seasons, with some regional warm spring data spanning almost 40 years and a significant number of springs having data that span 20 to 25 years. This lack of isotopic variability of regional warm springs is important for isotopic mass-balance models because this information indicates that the isotopic composition of regional groundwater varies little over time.
- Five recharge areas throughout the study area with 14, or more, springs showed that there was no relationship between stable isotope values and increasing altitude. This is important because the average isotopic composition of all sites in a recharge area could be used to assign average isotopic values to recharge areas, rather than having to use an altitude-precipitation weighting approach.
- Sensitivity analysis was performed on the SNWA (2007) water budget and flow routing mass-balance models by independently increasing or decreasing recharge and ET. The sensitivity analysis showed that when either recharge or ET were increased or decreased by 20 percent, most of the mass-balance model-calculated deuterium and oxygen-18 values were outside the range of acceptable matches for measured values of the Muddy River Springs discharge area. Thus, the SNWA (2007) water budget recharge and ET values balance such that a 20 percent change in either produces unacceptable isotopic mass-balance model results.

CONTENTS

APPENDICES:
1. Isotope mass-balance model summaries for the six mass-balance models.
2. Detailed isotope mass-balance models showing: (1) estimates of recharge amounts and their average deuterium and oxygen-18 values; (2) estimates of predevelopment ET amounts and their average deuterium and oxygen-18 values; and (3) all the sites that were used to calculate average deuterium and oxygen-18 values for recharge areas and regional warm spring areas.
3. Isotopic, field parameter, and water chemistry data for all sites used in this study

LIST OF FIGURES

The following plates are located in back of report:

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INTRODUCTION

A stable isotope mass-balance model was developed in 2001 to evaluate new groundwater recharge and discharge (predevelopment evapotranspiration [ET])estimates for the White River and Meadow Valley Wash regional groundwater flow systems that drain to the Colorado River (Thomas *et al*., 2001). This report is an update of the Thomas *et al*. (2001) study to evaluate water budgets and regional groundwater flow in eastern and southeastern Nevada. This study includes a significant amount of new data (about 450 new analyses) to help define the isotopic content of groundwater recharge areas both spatially and temporally, new recharge and discharge estimates (SNWA, 2007; Welch and Bright; 2007), and new geologic and hydrologic information (SNWA, 2007) that helps define interbasin groundwater flow routing. The 2001 study only presented one model for new recharge and discharge estimates. The 2001 model assumed that groundwater discharge in a valley was a mixture of local recharge and interbasin flow(s) entering a valley (if there was interbasin flow to the valley). This study presents two models. The first model is like the 2001 model, where ET is satisfied by a mixture of local recharge and interbasin flow. The second model assumes that ET is first satisfied by local recharge and if ET in a valley is greater than the local recharge, the remainder of the ET is satisfied by interbasin flow. This study also evaluated the reconnaissance report series recharge and ET estimates using the Eakin (1966) interbasin groundwater flow directions for the White River flow system (WRFS) for both models.

This study evaluates the same regional groundwater flow systems as the 2001 study, the WRFS and the Meadow Valley Wash flow system (MVWFS) that end at the Colorado River. In this study, the Lake Mead flow system of the 2001 study is included as part of the WRFS. The flow directions for the Lake Mead flow system, that is now part of the WRFS, are the same as for the 2001 study.

Stable isotopes of water, deuterium ($^{2}H/^{1}H$), and oxygen-18 ($^{18}O/^{16}O$) are ideal natural tracers to evaluate water budgets and interbasin flow. They are ideal natural tracers because they are part of the water molecule, rather than being dissolved in the water like most tracers, so they can be used to identify sources and flow paths of groundwater from recharge areas to discharge areas. Furthermore, deuterium and oxygen-18 concentrations are only affected by physical processes, such as evaporation, and are unchanged by chemical reactions. The ratio of the mass difference of ^{2}H as compared to ^{1}H (2/1) is significantly greater than that of ^{18}O to ^{16}O (18/16), so the fractionation of deuterium is greater than the fractionation of oxygen-18 during physical processes and water that has undergone any significant evaporation is easily identified. Isotopic fractionation is the change in concentration of deuterium and oxygen-18 that results from the mass differences during physical processes. This fractionation is known and can be easily calculated for physical processes.

Study Area Description

The area covered by this project is the White River and Meadow Valley Wash regional groundwater flow systems in east-central and southeastern Nevada (Figure 1). The WRFS extends from Long Valley in the north to Lake Mead in the south (Figure 2). A groundwater hydraulic gradient extends from Long Valley all the way to Lake Mead. In the

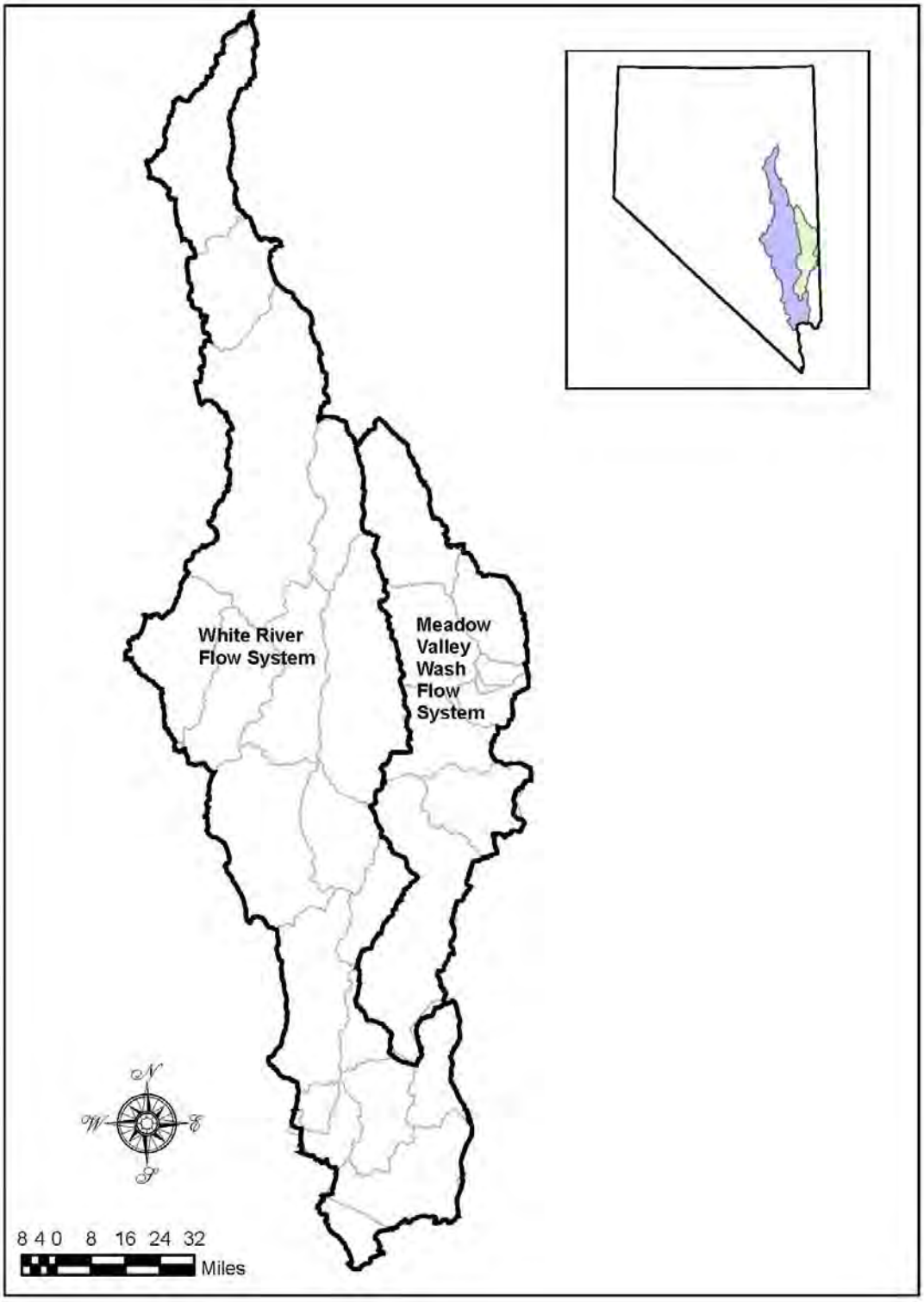

Figure 1. Study area location showing the White River and Meadow Valley Wash regional groundwater flow systems.

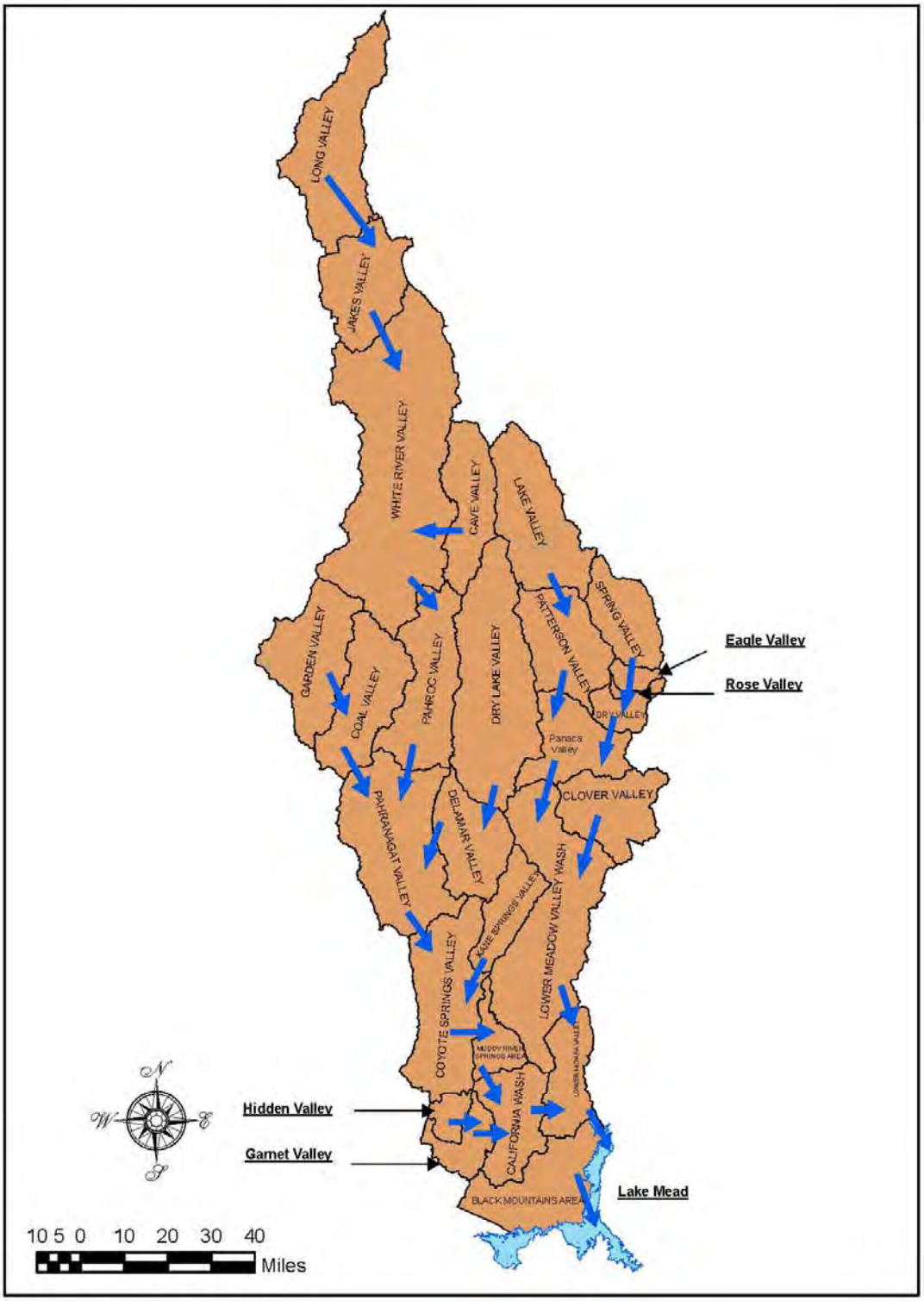

Figure 2. Groundwater flow directions as delineated by SNWA (2007) in the White River and Meadow Valley Wash regional groundwater flow systems.

Thomas *et al*. (2001) report, the Lake Mead part of the regional flow system was treated as a connected but separate flow system, but in this report, it is treated as part of the WRFS. The MVWFS extends from Lake Valley in the north and Spring Valley in the northeast (this Spring Valley is a small valley southeast of Lake Valley and not the large Spring Valley to the north of Lake Valley) to Lower Meadow Valley Wash. Groundwater in Lower Meadow Valley Wash flows to Upper Moapa Valley (Muddy River Springs area) and California Wash of the WRFS. Hydraulic gradients extend from Lake Valley and Spring Valley to Panaca Valley, from Panaca Valley to Lower Meadow Valley Wash, and from Lower Meadow Valley Wash to Upper and Lower Moapa valleys and California Wash (Thomas *et al*., 1986; LVVWD, 2001; SNWA, 2007).

Isotope Data

Most of the data used in the stable isotope mass-balance models were collected by Desert Research Institute (DRI) personnel and analyzed at the University of Nevada, Reno, Isotope Laboratory. Some additional samples were collected by SNWA personnel and these samples were also analyzed at the University of Nevada, Reno, Isotope Laboratory. Historical data used in this project were collected and analyzed by DRI at the DRI Isotope Laboratory in Las Vegas, Nevada, or the U.S. Geological Survey (USGS) at USGS isotope laboratories in Reston, Virginia, and Menlo Park, California.

Stable Isotope Mass-balance Models

The stable isotope mass-balance models developed for this study use the stable isotopes of water (deuterium and oxygen-18) to evaluate water budgets (groundwater recharge and discharge) and interbasin flow. As noted in the Introduction section, these stable isotopes are only subject to physical processes, they are not involved in chemical reactions. The main physical process that can change deuterium and oxygen-18 values in the study area is evaporation. Any groundwater that has undergone significant evaporation is not included in the isotope mass-balance models. A groundwater sample is assumed to have undergone significant evaporation if the deuterium value calculated from the oxygen-18 value of the sample is 10 permil (‰), or more, positive than the measured deuterium value. These samples are easily identified on deuterium versus oxygen-18 plots because they plot below (to the right of) the line “deuterium = 8 x oxygen-18.”

Groundwater budgets are evaluated by determining the average deuterium and oxygen-18 values of mountain block recharge areas in a valley. Valleys in east-central and southeastern Nevada generally have two main recharge areas, a mountain block on the east side and a mountain block on the west side of the valley. However, no matter if there are two, or more then two, recharge areas within a topographic basin (valley) they are treated separately and assigned their own average deuterium and oxygen-18 values. Deuterium and oxygen-18 values are assigned to recharge areas by taking the average stable isotope values of all the springs sampled in a recharge area. If a spring site contains more than one sample, then the average deuterium and oxygen-18 values for the site are used in determining the average stable isotope values of the recharge area.

These recharge area springs are used to represent the isotopic composition of groundwater recharge to a mountain block because they represent an integration of many recharge events and they often integrate recharge over large areas. These springs are great

integrators of recharge that is derived from precipitation in mountainous recharge areas because they: (1) average out the variability of individual precipitation events that become groundwater recharge; (2) account for the loss of most of the precipitation that does not become groundwater recharge (such as summer precipitation that seldom reaches the saturated zone and sublimation of the snow pack); (3) average out the seasonality of recharge (see Data Variability section for more details); and (4) represent a larger area than a single measurement point such as a precipitation station.

The stable isotopic composition of groundwater discharging from springs, or in wells on valley floors, can be used to validate the isotope mass-balance models and how well recharge and discharge estimates and volumes of interbasin flow represent water budgets of regional groundwater flow systems. In particular, the isotopic composition of large regional warm (>20°C, which represents an average flow depth of several thousand feet) springs can be used to evaluate water budgets and interbasin flows. These warm springs represent flow from an upgradient basin(s) that flows at depth into the valley containing the warm spring(s). Other data that offer evaluation points for water budgets and interbasin flow are wells completed in consolidated rock that contain warm (>20°C) water from regional groundwater flow. Additional information that can be used to evaluate water budgets in regional flow systems includes springs on valley floors along range front faults that are generally cool (<20°C). This information is used to evaluate mountain block recharge. If the average isotopic composition of springs in a mountainous recharge area represents the isotopic composition of recharge from that mountain block then springs along range-bounding faults should have similar isotopic compositions as the average recharge values determined from springs in the recharge area.

As presented in the Introduction, two isotope mass-balance models were used to evaluate water budgets and interbasin flow in the study area. The first model assumes that all groundwater discharge in a basin (ET; in valleys with spring discharge the spring discharge is included in the ET estimate, except for Upper Moapa Valley, where regional spring discharge leaves the valley as surface-water flow) is a complete mixture of local recharge to the valley and interbasin flow entering the valley. The second model assumes that all ET is first satisfied with local recharge and then any ET greater than local recharge is satisfied with interbasin flow. Finally, in both models, the isotopic composition of groundwater discharging from regional warm springs and wells completed in consolidated rock with warm groundwater is assumed to be interbasin flow into the valley. If a valley receives interbasin flow from more than one upgradient valley, then the calculated isotopic value of the warm spring or well water is the volume-weighted average of the interbasin flows.

DEUTERIUM AND OXYGEN-18 VARIABILITY

An important consideration in using deuterium and oxygen-18 to evaluate water budgets is their natural variability. This variability includes the spatial distribution of stable isotope values of springs in mountain block recharge areas, potential variability with altitude in recharge areas, and variability of recharge area spring isotopic values over time and with varying spring flows. Additionally, the isotopic variability of regional warm springs over time also needs to be considered. Ideally, isotopic variability will be small so that isotope mass-balance model solutions do not have a large uncertainty associated with them. Since the Thomas *et al*. (2001) study, about 450 samples have been collected and analyzed for stable

isotopes and major-ion chemistry to evaluate the isotopic variability of recharge area groundwaters and regional warm springs.

Recharge Area Isotopic Variability

A large amount of isotopic data has been collected in recharge areas during this study (Appendix 3). Three springs in major recharge areas of the WRFS and MVWFS (Monitoring Spring WR1 in the White Pine Range, Upper Terrace Spring WR2 in the Egan Range, and Patterson Pass Spring WR3 in the Schell Creek Range) have been continuously monitored for flow, water temperature, and electrical conductance and sampled quarterly for deuterium, oxygen-18, pH, and major-ion chemistry from October 2003 to the present. In addition, one recharge area spring (Headwaters Spring WR5 in the Wilson Creek Range) has been monitored and sampled from May 2004 to the present, one recharge area spring (Upper Riggs Spring WR4 in the Delamar Mountains) was monitored and sampled from April 2004 to February 2005 until the monitoring site was destroyed by a flood, and the Upper Riggs Spring monitoring site was moved to Grapevine Spring KSV-2 in the adjacent Meadow Valley Mountains, and this spring was monitored from April 2005 to May 2007. Numerous recharge area springs were also sampled for stable isotopes and major-ion chemistry to provide information for recharge areas that had little or no isotopic data in the Thomas *et al*. (2001) study and to provide more data for all mountainous recharge areas throughout the study area.

Continuous flow and quarterly deuterium data for recharge area monitoring springs are shown in Figures 3 through 6 (oxygen-18 is not shown on the plots because it is strongly correlated with deuterium and follows the same trend as deuterium). As is observed in all plots, the deuterium composition of the springs varies little with change in flow or season. For example, deuterium in Monitoring Spring WR1 in the White Pine Range only varies between -115.7 and -111.2‰ for a range in flow of about 100 to 2,500 gallons per minute and for the time period October 2003 to May 2007 (Figure 3 and Table 1). Oxygen-18 for these same samples varies between -15.69 and -15.32‰. During this period 14 samples were collected with an average deuterium value of -113.7‰ and a standard deviation of 1.3‰ and an average oxygen-18 value of -15.58‰ with a standard deviation of 0.11‰ (Table 1). A similar pattern is observed for the other five recharge area monitoring springs in the study area (Figures 4 through 6 and Table 1). Table 1 presents a summary of the data in Figures 3 through 6 and data for the shorter records at Upper Riggs Spring WR4 in the Delamar Range and Grapevine Spring (KSV-2) in the Meadow Valley Mountains, with minimum, maximum, median, mean, and standard deviation values for the isotopic data for all six recharge area monitoring sites. The greatest range in deuterium values for all six sites is 5.4‰ for the Headwaters Spring site in the Wilson Creek Range for 17 samples from May 2004 to May 2007, and the smallest range is 1.8‰ for 5 samples from January 2004 to February 2005 for the Upper Riggs site (Table 1). The standard deviation of the spring deuterium data is about 1‰, with the highest standard deviation being 1.6 for Headwaters Spring and the lowest being 0.7 for Upper Riggs Spring. Oxygen-18 follows a similar pattern, with the standard deviation ranging from 0.06 to 0.33‰ for the six recharge area monitoring sites (Table 1).

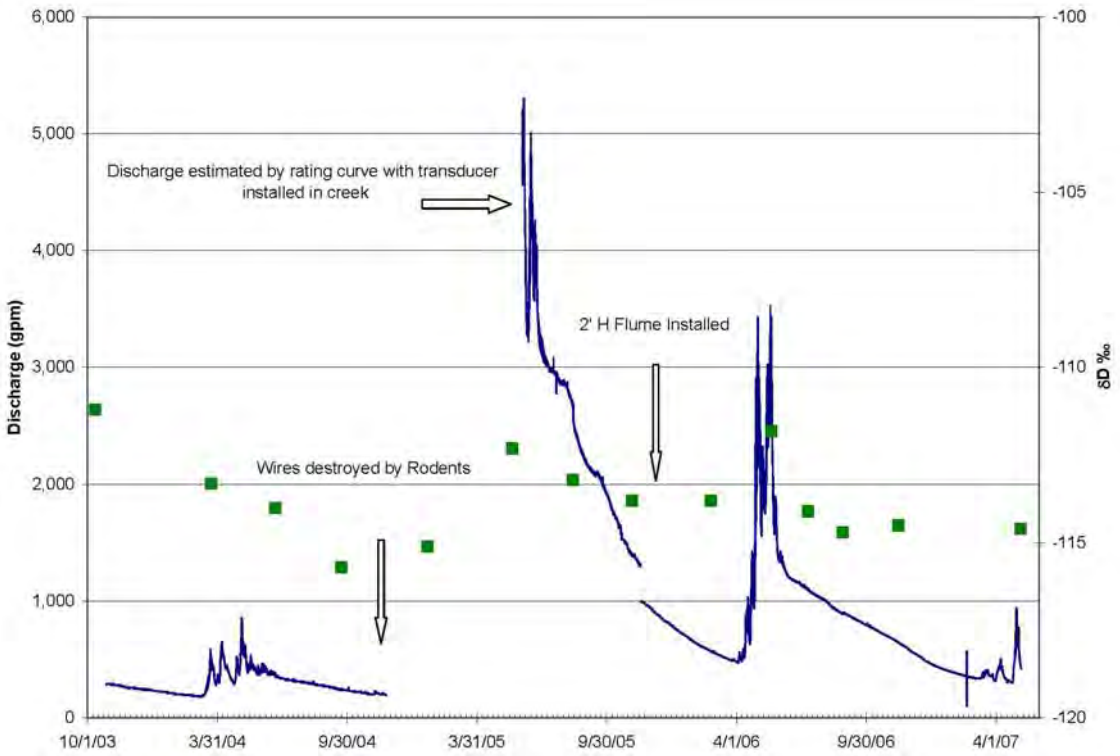

Figure 3. Deuterium and flow data for Monitoring Spring WR1 in the White Pine Range in northwestern White River Valley.

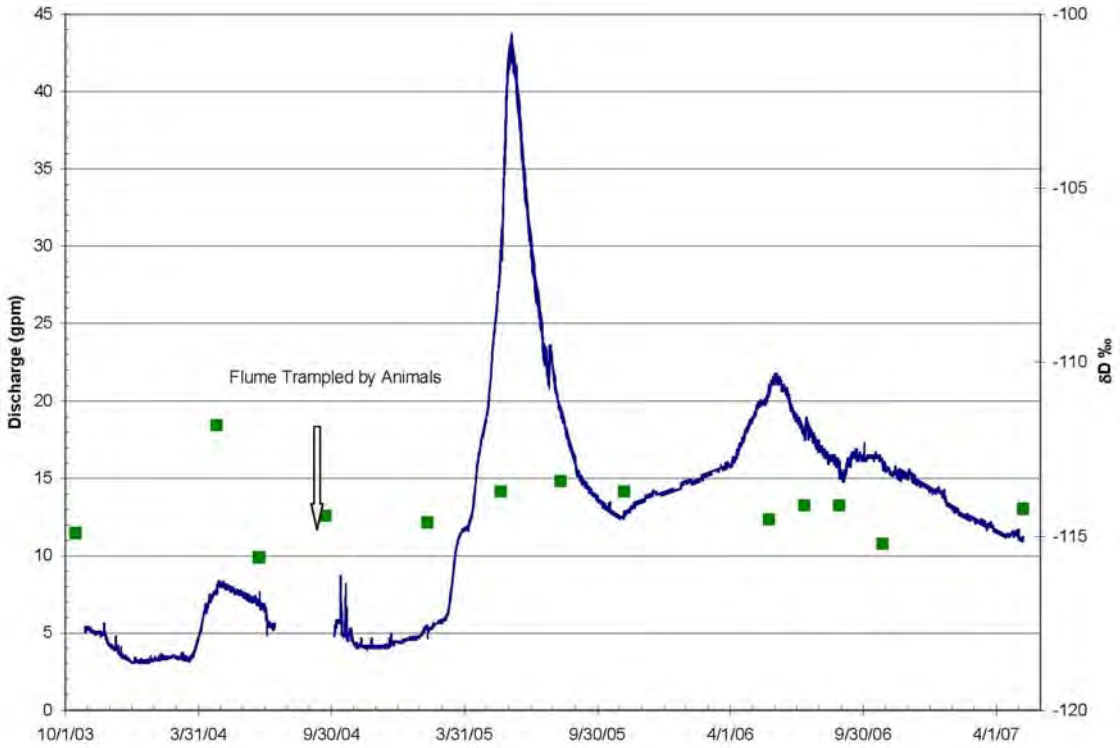

Figure 4. Deuterium and flow data for Upper Terrace Spring WR2 in the Egan Range in northeastern White River Valley.

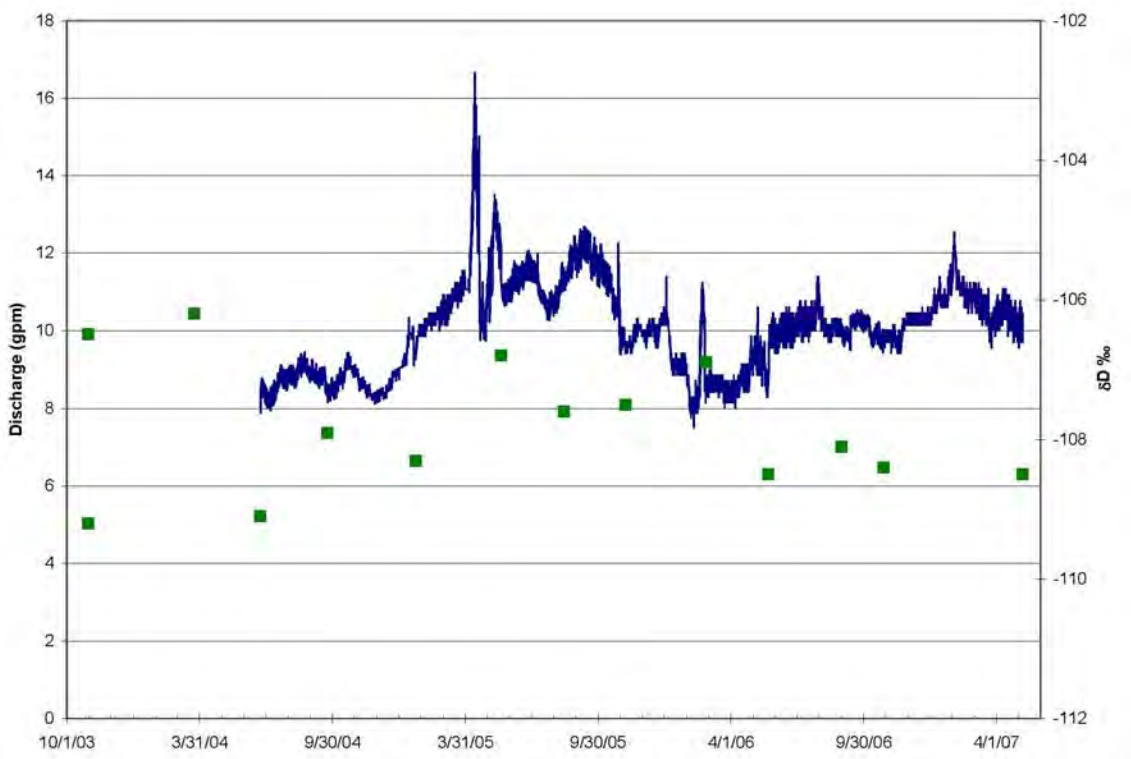

Figure 5. Deuterium and flow data for Patterson Pass Spring WR3 in the Schell Creek Range in western Lake Valley.

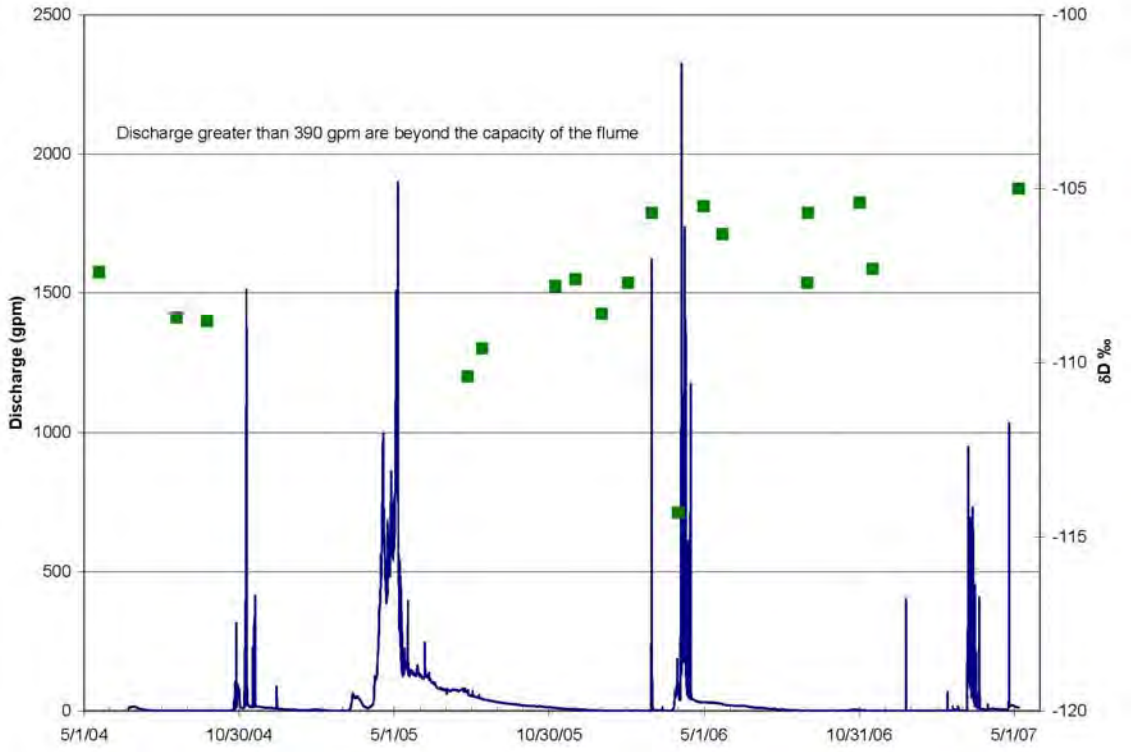

Figure 6 Deuterium and flow data for HeadwatersSpring WR5 in the Wilson Creek Range in southeastern Lake Valley.

Table 1. Variability of deuterium and oxygen-18 in recharge area springs.

Site Name		Number of Samples	Minimum	Maximum	Median	Mean	Standard Deviation
			White Pine Range				
Monitoring Spring WR1	δ^2H	14	-115.7	-111.2	-113.9	-113.7	1.3
Monitoring Spring WR1	$\delta^{18}O$	14	-15.69	-15.32	-15.62	-15.58	0.11
			Egan Range				
Upper Terrace Spring WR2	δ^2H	14	-115.6	-111.3	-114.2	-114.0	1.2
Upper Terrace Spring WR2	$\delta^{18}O$	14	-15.50	-15.24	-15.43	-15.42	0.06
			Schell Creek Range				
Patterson Pass Spring WR3	δ^2H	14	-109.2	-106.2	-108.0	-107.8	0.9
Patterson Pass Spring WR3	$\delta^{18}O$	14	-14.96	-14.71	-14.87	-14.85	0.07
			Wilson Creek Range				
Headwaters Spring WR5	δ^2H	17	-110.4	-105.0	-107.6	-107.4	1.6
Headwaters Spring WR5	$\delta^{18}O$	17	-15.01	-14.10	-14.59	-14.57	0.23
			Delamar Mountains				
Upper Riggs Spring WR4	δ^2H	5	-88.0	-86.2	-87.0	-87.1	0.6
Upper Riggs Spring WR4	$\delta^{18}O$	5	-12.46	-11.55	-11.90	-11.95	0.33
			Meadow Valley Mountains				
Grapevine Spring (KSV-2)	δ^2H	10	-88.6	-85.2	-87.5	-87.4	0.9
Grapevine Spring (KSV-2)	$\delta^{18}O$	10	-12.03	-11.60	-11.94	-11.92	0.12

The potential for variability of stable isotope values with altitude also needs to be considered, because if stable isotope values become more depleted (more negative) with altitude in the recharge areas, this would need to be accounted for in assigning average stable isotope values to recharge areas (an altitude-weighted approach would need to be taken instead of using an average value because the amount of precipitation and the percent of precipitation that becomes recharge increase with altitude). The relationship between deuterium and altitude was evaluated for five major recharge areas in the study area that contained 14, or more, springs. In the northern part of the study area, the White Pine Range and Central Egan Range deuterium data were plotted as a function of altitude (Figures 7 and 8). There is no apparent relationship of deuterium with altitude in these plots. In the central and southern part of the study area, White Rock Mountain, Delamar Mountain, and Fairview and Bristol ranges deuterium data were plotted as a function of altitude (Figures 9, 10, and 11). Again there is no relationship of deuterium with altitude, with the exception of the samples in the Delamar Range, where there is a small apparent relationship of heavier (less negative) deuterium values with lower altitude. The lack of a deuterium-with-altitude relationship, which does occur on the western side of the Sierra Nevada as storms track from the Pacific Ocean to the Sierra crest (Smith *et al*., 1979), is consistent with the results of Thomas *et al*. (1996) for the Spring Mountains in southern Nevada. Thomas *et al*. (1996; Figure 21) found no deuterium-altitude relationship for samples ranging in altitude from about 4,400 to 10,300 feet. The importance of a lack of deuterium-altitude relationship is that isotopic values in recharge areas do not have to be altitude weighted, and thus recharge volume weighted, to determine the average isotopic composition of recharge areas in the regional flow systems in east-central and southeastern Nevada.

Valley Cold Springs, Consolidated Rock Wells with Cold Water, and Local Recharge

White River Valley offers a relatively unique opportunity to evaluate the average isotopic composition of recharge area springs as being representative of mountain block recharge because of the presence of cold (<20 ^{o}C) valley springs along the range-bounding fault on the east side of the valley. In northern White River Valley, Lund Spring is located near the range-bounding fault on the east side of the valley. In addition to being cold, Lund Spring also has a variable flow rate, ranging from about 4,000 to 8,000 afy, even in the winter months (U.S. Geological Survey data). This large variability in flow is characteristic of locally recharged springs as compared to regional warm springs, which exhibit little variability in flow under natural conditions. The deuterium value of this spring is -113.0‰ and the oxygen-18 value is -15.40‰ (Appendix 3). These values are similar to the average deuterium and oxygen-18 values of -112.3 and -15.15‰, respectively, of northern Egan Range recharge, which is the local recharge source of this spring. In southern White River Valley, three springs—Emigrant, Butterfield, and Flag #3—are located near the range-bounding fault on the east side of the valley. Flag #3 Spring has a water temperature of 22.8 ^{o}C, but because of its location and similar isotopic and water chemistry content to that of Emigrant and Butterfield springs (Appendix 3), it is included as a cold range-bounding fault spring. These three springs have isotopic values that range from -107.8 to -105.0‰ for deuterium and -14.50 to -14.20‰ for oxygen-18 (Appendix 3). These values are similar to the average isotopic composition of recharge, - 106.9 and -14.15‰, to the southern Egan Range in southern White River Valley, which would be the local recharge source of these springs. The isotopic content of valley springs near the range-bounding fault on the east side of White River Valley that are supplied by local recharge to the valley shows that average spring isotopic values provide a good representation of mountain block recharge to a valley.

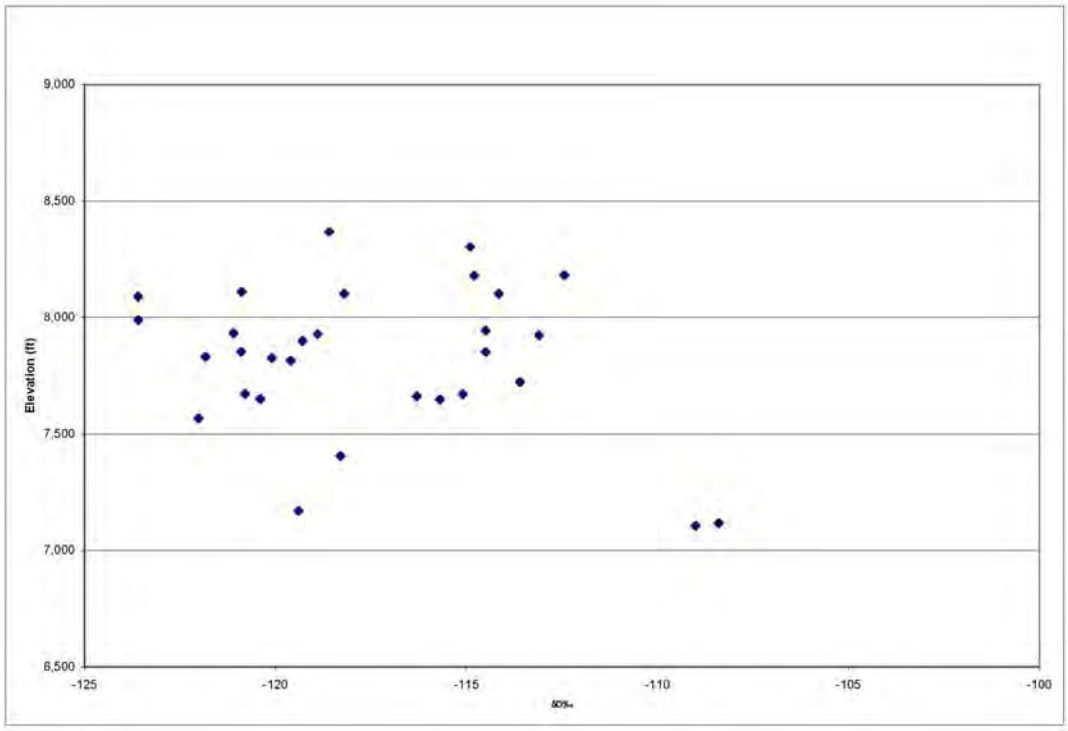

Figure 7. Deuterium as a function of altitude in the White Pine Range.

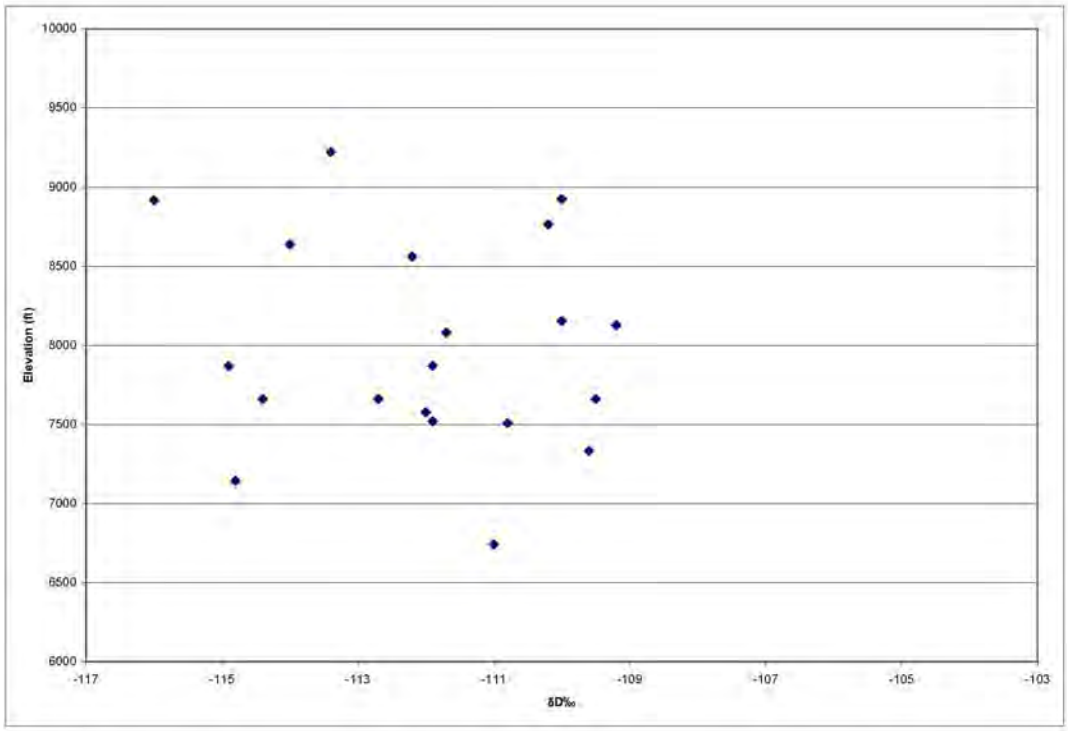

Figure 8. Deuterium as a function of altitude in the Central Egan Range.

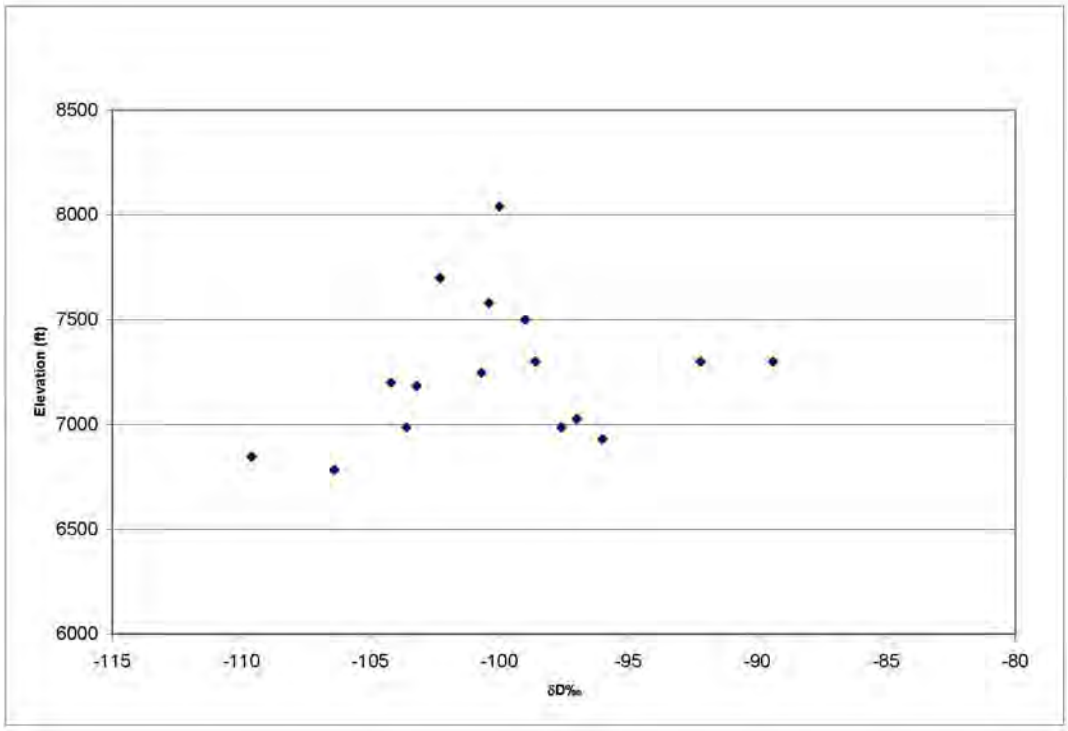

Figure 9. Deuterium as a function of altitude in the White Rock Mountains.

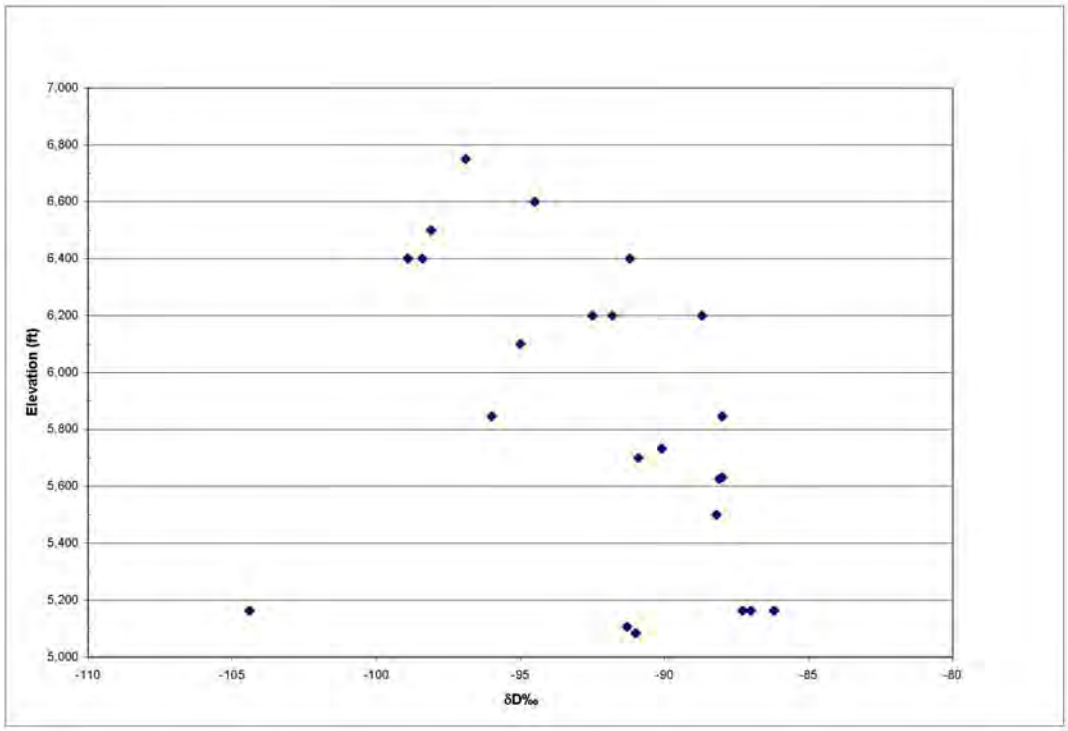

Figure 10. Deuterium as a function of altitude in the Delamar Mountains.

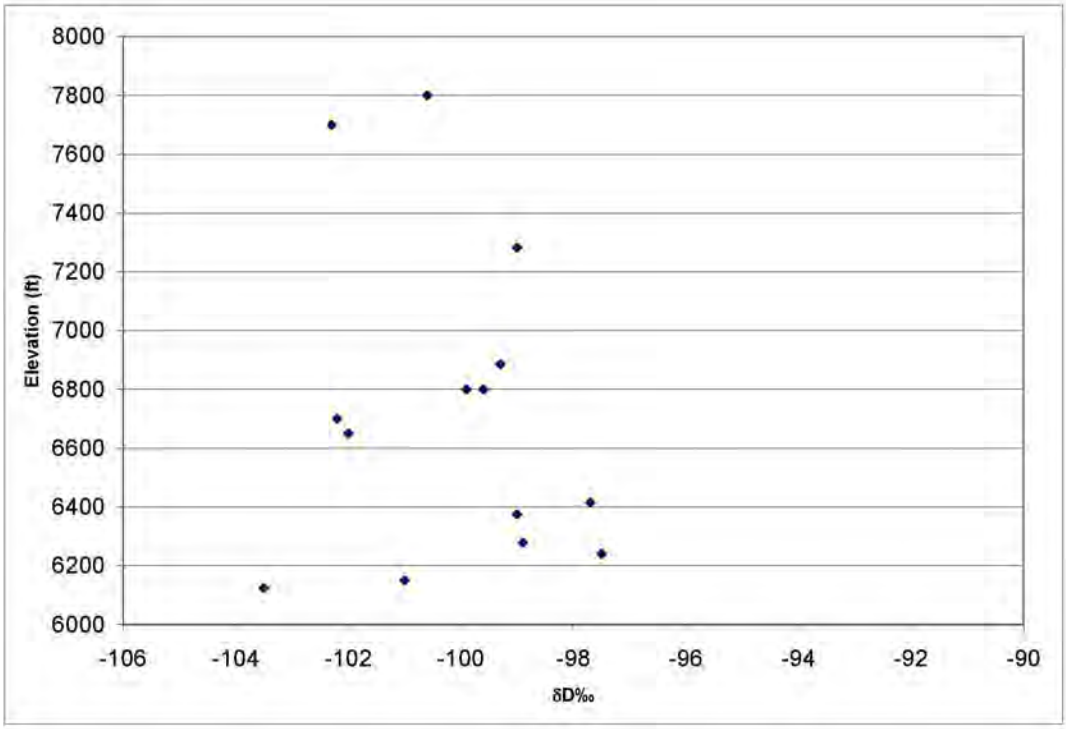

Figure 11. Deuterium as a function of altitude in the Highland and Fairview ranges.

In Cave Valley, east of White River Valley, two wells (180W501 and 180W902) completed in consolidated rock with cold temperatures (<20 ^{o}C) provide another relatively unique opportunity to evaluate average spring isotopic compositions as being representative of mountain block recharge. Cave Valley has no inflow, so the water in these wells should have an isotopic composition similar to recharge to the valley. The isotopic content of water in these two wells is -105.6 and -104.7‰ for deuterium and -14.12‰ for oxygen-18 for both wells. These values are similar to the isotopic content of water recharging Cave Valley, -106.5 and -14.28‰, so like the cool springs along the eastern range-bounding fault in White River Valley the groundwater in these wells has an isotopic composition very similar to local recharge to Cave Valley providing more evidence that springs in recharge areas can be used to represent recharge from mountainous areas.

Isotopic Variability of Regional Warm Springs

Regional warm springs in the WRFS and MVWFS are the integrators of interbasin groundwater flow in these systems and as such they provide the information needed to evaluate stable isotope mass-balance models of regional groundwater flow. Thus, it is important that isotopic variability of these springs is known and if this variability is large, then transient, rather than the current steady-state, isotope mass-balance models would be needed to evaluate water budgets and regional groundwater flow. To evaluate the isotopic variability of regional warm springs in the study area, new data were collected and combined with historical data to determine isotopic variability of the warm springs. Table 2 presents minimum, maximum, median, mean, and standard deviation values for deuterium and oxygen-18 for the warm springs in the study area. Data are presented for individual springs in

Table 2. Variability of deuterium and oxygen-18 in regional warm springs.

Site Name		Number of Samples	Minimum	Maximum	Median	Mean	Standard Deviation
			North White River Valley				
Preston Big Spring	δ^2H	11	-126.0	-120.0	-121.7	-122.0	1.6
Preston Big Spring	$\delta^{18}O$	11	-15.98	-15.60	-15.88	-15.88	0.10
North White River Valley	δ^2H	-124.0	-122.0	-123.5	-123.2	1.1	-124.0
North White River Valley	$\delta^{18}O$	3	-15.80	-15.80	-15.88	-15.93	0.16
			South White River Valley				
Hot Creek Springs	δ^2H	10	-120.5	-117.4	-119.0	-118.9	0.9
Hot Creek Springs	$\delta^{18}O$	10	-15.77	-15.50	-15.71	-15.69	0.08
South White River Valley	δ^2H	4	-120.0	-118.0	-119.0	-119.0	0.8
South White River Valley	$\delta^{18}O$	4	-15.80	-15.30	-15.70	-15.62	0.22
			Panaca Valley				
Caliente Hot Springs (Hotel)	δ^2H	8	-109.3	-106.4	-107.5	-107.9	1.1
Caliente Hot Springs (Hotel)	$\delta^{18}O$	8	-14.52	-14.29	-14.45	-14.44	0.07
Panaca Spring	δ^2H	13	-108.0	-105.8	-107.0	-106.9	0.6
Panaca Spring	$\delta^{18}O$	12	-14.25	-13.90	-14.17	-14.14	0.10
			Pahranagat Valley				
Crystal Springs	δ^2H	17	-110.1	-106.9	-109.0	-108.8	0.8
Crystal Springs	$\delta^{18}O$	14	-14.53	-14.30	-14.42	-14.41	0.07
Hiko Spring	δ^2H	7	-110.5	-105.0	-109.5	-108.7	1.9
Hiko Spring	$\delta^{18}O$	4	-15.30	-13.80	-14.23	-14.39	0.67
Ash Springs	δ^2H	6	-112.0	-107.0	-108.7	-109.1	1.8
Ash Springs	$\delta^{18}O$	3	-14.20	-14.03	-14.10	-14.11	0.09
Pahranagat Valley	δ^2H	4	-109.1	-107.2	-108.8	-108.5	0.9
Pahranagat Valley	$\delta^{18}O$	4	-14.41	-14.11	-14.29	-14.28	0.15

Table 2. Variability of deuterium and oxygen-18 in regional warm springs (continued).

Site Name		Number of Samples	Minimum	Maximum	Median	Mean	Standard Deviation
			Upper Moapa (Muddy) Valley				
Baldwin Spring	$\delta^{2}H$	9	-98.6	-96.3	-97.9	-97.6	0.8
Baldwin Spring	$\delta^{18}O$	9	-13.05	-12.91	-12.95	-12.97	0.05
Big Muddy Spring	$\delta^{2}H$	6	-99.0	-96.5	-98.0	-97.9	0.8
Big Muddy Spring	$\delta^{18}O$	5	-13.05	-12.75	-12.89	-12.89	0.11
Jones Spring Pumphouse	$\delta^{2}H$	6	-98.9	-97.3	-97.9	-97.9	0.5
Jones Spring Pumphouse	$\delta^{18}O$	6	-13.10	-12.99	-13.07	-13.05	0.05
Pederson's East	$\delta^{2}H$	9	-98.7	-97.0	-97.7	-97.8	0.6
Pederson's East	$\delta^{18}O$	9	-13.06	-12.89	-12.98	-12.98	0.06
Pederson's Warm Spring (M-13)	$\delta^{2}H$	15	-99.0	-96.5	-97.4	-97.5	0.6
Pederson's Warm Spring (M-13)	$\delta^{18}O$	13	-13.05	-12.75	-12.91	-12.93	0.09
Upper Moapa (Muddy) Valley	$\delta^{2}H$	9	-99.0	-96.5	-97.8	-97.7	0.7
Upper Moapa (Muddy) Valley	$\delta^{18}O$	8	-13.05	-12.45	-12.94	-12.87	0.19

a valley with three of more analyses and for the average of all warm springs in a valley. For example, in northern White River Valley, Preston Big Spring is a warm spring in the Preston warm spring area that has 11 samples. There are also two other warm springs in the area, Nicholas and Cold springs (actually a warm spring). Table 2 presents the values and standard deviation for Preston Big Spring data and also the values and standard deviation for the average values of the three springs in the area. Deuterium ranged from -126.0 to -120.0‰, with a mean value of -122.0‰ and a standard deviation of 1.6 for Preston Big Spring. For the three springs in the warm spring discharge area, the average deuterium values ranged from -124.0 to -122.0‰, with a standard deviation of 1.1. In general, the standard deviations for the individual spring deuterium data and the valley data for the average of the spring values are around 1‰ (Table 2). Oxygen-18 data follow a similar pattern, with standard deviations ranging from 0.05 to 0.22‰ (except for one site with a standard deviation of 0.67‰). This low variability of the stable isotopic data shows that the stable isotopic composition of regional warm springs provides good isotope mass-balance calibration points and a steady-state model is a valid approach.

Another indication of the stability and little variation in warm spring isotopic values is that some regional warm springs have samples covering a 20- to 40-year period with little change in isotopic composition. For example, isotopic data were first collected for Big Muddy Spring in Upper Moapa Valley in March 1970 and six samples from 1970 to 2004 have a range of only -99.0 to -96.5‰. Similarly, Hiko, Crystal, and Ash springs in Pahranagat Valley have isotopic data that were first collected in 1968. For all three springs during this time period of 1968 to 2006, deuterium only varied by 5.5‰. Preston Big Spring in northern White River Valley, Hot Creek Spring in southern White River Valley, and Panaca and Caliente hot springs in Panaca Valley all have samples that span a 22- to 26-year period with an average range in deuterium values of only 3.6‰ (Table 2).

An important question that needs to be answered if regional warm springs are going to be used to evaluate water budgets and interbasin flow is “are the regional warm springs discharging last glacial period water that was recharged during a cooler and wetter climate?” If they are, then regional warm spring discharge and groundwater ET throughout the WRFS and MWVFS would not be in balance with present-day recharge rates; present-day recharge rates would be less because some of the groundwater discharge would be from past wetter climates. Regional warm spring discharge is not glacial period water because: (1) regional warm spring discharge that greatly exceeds local recharge amounts in valleys in the southern part of the WRFS, the Muddy River and Pahranagat Valley warm spring areas, would even exceed local recharge during a much wetter climate because these spring flows are supported by interbasin flow; (2) additional evidence that regional warm springs are supported by interbasin flow is that they have isotopic values that are more negative than local recharge isotopic values because upgradient basins that supply interbasin flow are north of the regional spring discharge areas in both the WRFS and MVWFS, so this interbasin flow is isotopically more negative than local recharge; and (3) although regional warm springs have more negative isotopic values than local recharge, if these springs were discharging glacial period water these values would be even more negative even if they were only local recharge, but assuming that there would be interbasin flow during glacial periods as there is today, they would be even lighter. If regional spring discharge was from the last glacial period, then the isotopic composition of the springs would be at least 10 and 1.2‰ more negative for deuterium and oxygen-18, respectively, than present-day recharge (Winograd *et al*., 2006),

and could be as much as 16 and 2.0‰ more negative for deuterium and oxygen-18, respectively, than present-day recharge (Benson and Klieforth, 1989) because of cooler air temperatures. Thus, if any significant portion of local recharge or interbasin flow was recharged during the last glacial period, regional warm springs would be as much as 10 to 20‰ less negative in deuterium and 1.0 to 2.0 more negative in oxygen-18 than present-day spring discharge.

Additional information on the timing of recharge to the regional warm springs is provided by carbon-14 data for dissolved inorganic and dissolved organic carbon. Low carbon-14 (less than 10 percent modern carbon [pmc]) in some of these regional warm spring waters (Thomas *et al*., 1996) indicates that these waters could be as old as 20,000 years. However, regional warm springs in similar carbonate-rock aquifers that discharge in Ash Meadows and groundwater in nearby Devils Hole with only 2 to 3 pmc carbon-14 (with one spring having 11 pmc) are at most several thousand years old and could be less than 1,000 years old (Winograd *et al*., 1992, 2006; Thomas *et al*., 1996). To obtain realistic groundwater ages the dissolution of calcite and dolomite that comprise the carbonate-rock aquifer and adsorption and diffusion processes have to be accounted for in correcting the carbon-14 ages. The dissolution of calcite and dolomite add carbon-14 to the water with 0 pmc and adsorption and diffusion remove carbon-14 from the groundwater (Hershey and Howcroft, 1998; Hershey *et al*., 2003, 2007), so once these processes are accounted for the corrected groundwater ages of these low carbon-14 groundwaters are only a few thousand to less than a thousand years old. Dissolved organic carbon isotopic data also support regional warm springs in the WRFS being younger than the last glacial period (Thomas, 1996). Regional springs integrate flow all along the regional flow systems from many different recharge areas and basins, so the age of the water discharging from warm springs is an average age and a very small percent of the water could be Pleistocene-age water that is isotopically light. However, the isotopic, recharge, and discharge data do not support any significant amount of Pleistocene-age water being discharged at regional warm springs in these systems.

Summary of Isotopic Variability

The small range in isotopic values and standard deviations of the recharge area and regional warm spring monitoring stable isotope data shows that deuterium and oxygen-18 are good tracers of groundwater in the regional flow systems. Using the average isotopic composition of springs in recharge areas as representative of recharge from a mountain block recharge area is further supported by cold springs near the range-bounding fault in eastern White River Valley and two wells completed in consolidated rock in Cave Valley with cold water. If temporal variability of deuterium and oxygen-18 of recharge area monitoring springs and regional warm springs had been high, then the uncertainty associated with using them to evaluate water budgets in regional flow systems would have been high.

ISOTOPIC EVALUATION OF THE WHITE RIVER AND MEADOW VALLEY WASH REGIONAL GROUNDWATER FLOW SYSTEMS

The WRFS and MVWFS water budgets, including interbasin flows, were evaluated using stable isotope data for recharge area groundwaters and regional warm springs for two versions of the isotope mass-balance model. Additionally, wells completed in consolidated rock that are not in warm spring discharge areas and intercept groundwater flowing through

these regional flow systems were also used to evaluate water budgets and interbasin flow. Wells are point measurements in the flow system and provide good information on regional groundwater flow and water budgets but they are a secondary evaluation method as compared to regional warm springs, which integrate flow over large areas. For this report, two mass-balance models were developed to evaluate water budgets that handle ground discharge from these regional flow systems in two different ways (see Stable Isotope Mass-Balance Models section for a description of the two models). These two models were used to evaluate water budgets developed using: (1) SNWA recharge and discharge estimates (SNWA, 2007); (2) SNWA/BARCAS discharge estimates (SNWA, 2007; Welch and Bright, 2007; valleys with BARCAS study ET values were used in place of SNWA ET values in these valleys to determine recharge and discharge amounts for the different valleys); and (3) Water Resources Bulletin No. 8 (Maxey and Eakin, 1949), and the Reconnaissance Report series recharge and ET estimates (Maxey and Eakin, 1949; Eakin, 1962, 1963a, b, c, 1964, 1966, 1968; Rush, 1964; Rush and Eakin, 1963) and the Eakin (1966) interbasin groundwater flow directions for the WRFS. The evaluation of three water budgets using the two end-member models resulted in six isotope mass-balance models being developed for this study.

White River Regional Groundwater Flow System

The WRFS (Figure 1) was originally described by Eakin (1966), who postulated that some of the water discharging from the Muddy River Springs area in Upper Moapa Valley originated more than 200 miles north of the spring area and that this regional interbasin flow system included 13 valleys. Eakin reached these conclusions on the basis of "preliminary appraisals of the distribution and quantities of the estimated groundwater recharge and discharge within the region, the uniformity of discharge of the principal springs, the compatibility of the potential hydraulic gradient with regional groundwater movement, the relative hydrologic properties of the major rock groups in the region, and to a limited extent, the chemical character of water issuing from the principal springs." The main conclusions of his study were: (1) Paleozoic carbonate rocks form the regional aquifer, (2) recharge and discharge estimates balance within the flow system, and (3) the principal discharging springs have a uniform discharge rate, indicating a regional rather than local water source.

As noted in the Study Area Description section of this report, for this study the WRFS includes California Wash, Lower Moapa, Hidden, and Garnet valleys and the Black Mountains area in addition to the original 13 valleys described by Eakin (1966). These valleys are included because some groundwater in the WRFS continues flowing through these valleys on its way to Lake Mead on the Colorado River as indicated by hydraulic gradients (Thomas *et al*., 1986, 1996; LVVWD 2001, 2007). The lower part of the WRFS also receives groundwater inflow from the MVWFS. The MVWFS, to the east of the WRFS, has groundwater that flows into Upper Moapa and California Wash valleys. This MVWFS groundwater mixes with the WRFS groundwater and flows into Lower Moapa Valley from which groundwater discharges into Lake Mead. The MVWFS will be described in more detail later in this report.

White River Flow System Isotope Mass-Balance Models

Background

Kirk and Campana (1990) constructed a deuterium-calibrated mixing cell (water budget) model of the WRFS as delineated by Eakin (1966). Their mixing cell model was calibrated using average deuterium values for the model cells. The mixing cell model was a two-layer model with an upper layer representing basin-fill aquifers and a second layer representing the carbonate-rock aquifer. The cells were defined as the 13 individual topographic valleys within the WRFS, although not all valleys had a sufficient alluvial aquifer to warrant an upper layer cell in the model. The mixing model used the spring flow and ET estimates from Eakin (1966) and initially set recharge to Maxey-Eakin values but then let the model calculate new recharge values. The model-calculated recharge values were similar to initial Maxey-Eakin recharge estimates. Three different models were developed for the WRFS. The results of the Kirk and Campana (1990) study are: (1) recharge from the Sheep Range to Coyote Springs Valley is 5,000 to 6,000 acre feet per year (afy) as compared to the Maxey-Eakin estimate of 2,000 afy; (2) the Lower Meadow Valley Wash-Kane Springs Valley area contributes 5,500 to 9,000 afy to the Muddy River Springs discharge area, as compared to the Maxey-Eakin Kane Springs Valley recharge estimate of about 1,000 afy; and (3) 4,000 afy of groundwater is routed out of the WRFS in the Pahranagat Valley area to the west (similar to the 6,000 afy proposed by Winograd and Friedman [1972] and 7,000 afy proposed by Thomas *et al*. [1996]).

Thomas *et al*. (1996) used the average deuterium composition of water discharging from Big Muddy Spring in Upper Moapa Valley, the largest discharging spring in the Muddy River springs area, to calculate a deuterium mass-balance water budget for the lower part of the WRFS. This deuterium mass-balance water budget model simply used the estimated total spring discharge of the Muddy Springs area (after removing surface water flows due to storm events) and the average deuterium composition of the springs in the Muddy River Springs area. For a Muddy River Springs area discharge rate of 36,000 afy (Eakin and Moore, 1964), this calculation resulted in an input of 14,000 afy of recharge from the Sheep Range, 14,000 afy of inflow from Pahranagat Valley, and 8,000 afy of inflow from the Lower Meadow Valley Wash-Kane Springs Valley area.

Thomas *et al*. (2001) used new estimates of recharge and predevelopment ET derived by the Las Vegas Valley Water District (LVVWD, 2001) for the WRFS and MVWFS and deuterium and oxygen-18 values in recharge areas and for regional warm springs to develop a stable isotope mass-balance model. This effort was different from that of Kirk and Campana (1990) in that it assigned recharge and average isotopic values to individual recharge and discharge areas, rather than to a cell that represents an entire valley. The Kirk and Campana (1990) model also used spring flow and ET estimates from Eakin (1966) to represent ET for the model area. They initially set recharge to estimates from Maxey-Eakin (1949) but then let the model calculate new recharge values. The Thomas *et al*. (2001) study was different from the Thomas *et al*. (1996) study in that the 1996 study used the estimated spring discharge in the Muddy River Springs area to represent all groundwater discharge from the Muddy River Springs area. Then, Thomas *et al*. (1996) used this value in conjunction with the average deuterium composition of the Muddy River springs, the regional warm springs in Pahranagat Valley, and springs in recharge areas to develop a deuterium mass-balance model that only accounted for regional warm spring discharge.

Additionally, the Kirk and Campana study only modeled the WRFS and the Thomas *et al*. (1996) study only modeled the southern part of the WRFS from Pahranagat Valley to Upper Moapa Valley, whereas the Thomas *et al*. (2001) study included the MVWFS and the valleys between the Muddy River Springs area (Upper Moapa Valley) and Lake Mead on the Colorado River (the lowest point in the system).

The stable isotope mass-balance models developed for this study include the same area as the Thomas *et al*. (2001) study, but this study includes a significant amount of new data (about 450 new analyses) to help define the isotopic content of groundwater recharge areas both spatially and temporally, new recharge and discharge estimates (SNWA, 2007; Welch and Bright; 2007), and new interbasin flow directions and rates based on new geologic and hydrologic information (SNWA, 2007).

Model Development and Results

Stable isotopes of water were used to evaluate water budgets and interbasin flows for the WRFS by determining average deuterium and oxygen-18 values for all recharge and groundwater discharge (ET) areas in the study area and tracking the volumes of recharge added to and ET removed from the WRFS throughout the study area. For a water budget to be a reasonable estimate of recharge and predevelopment ET, calculated isotopic values for regional spring discharge areas have to be similar to measured values. Wells completed in consolidated rock with warm (>20 ^{o}C) water from the regional flow system that are not in warm spring discharge areas were also used to evaluate water budgets and interbasin flow by comparing measured isotopic values with calculated values.

To use a stable isotope mass-balance model for evaluating water budgets in regional flow systems, there needs to be an easily identifiable range in isotopic values throughout a flow system. A range in isotopic values is needed to identify inputs from different recharge areas and interbasin flow in a regional flow system. Fortunately, in the WRFS, deuterium and oxygen-18 vary greatly from the Lake Mead area in the south to Long Valley in the north (Figure 2). A plot of deuterium versus oxygn-18 (Figure 12) shows that isotopic compositions increase (become less negative) from north to south. This 50‰ increase in recharge area deuterium values, from -129.5‰ in Long Valley in the northern WRFS to -79‰ in the Black Mountain area in the southern WRFS and the 6.54‰ increase in recharge area oxygen-18 values, from -17.04‰ in Long Valley in the north to -10.50‰ in the Black Mountain area in the south (Figure 12 and Plate 2), makes deuterium and oxygen-18 excellent tracers for water budget evaluations in the WRFS. These differences in isotopic values from north to south in the WRFS are very significant because the analytical precision for deuterium is plus or minus 1.0‰ and for oxygen-18 is plus or minus 0.10‰ (analytical precision values represent one standard deviation; Simon Poulson, University of Nevada, Reno Isotope Laboratory, oral commun., 2007).

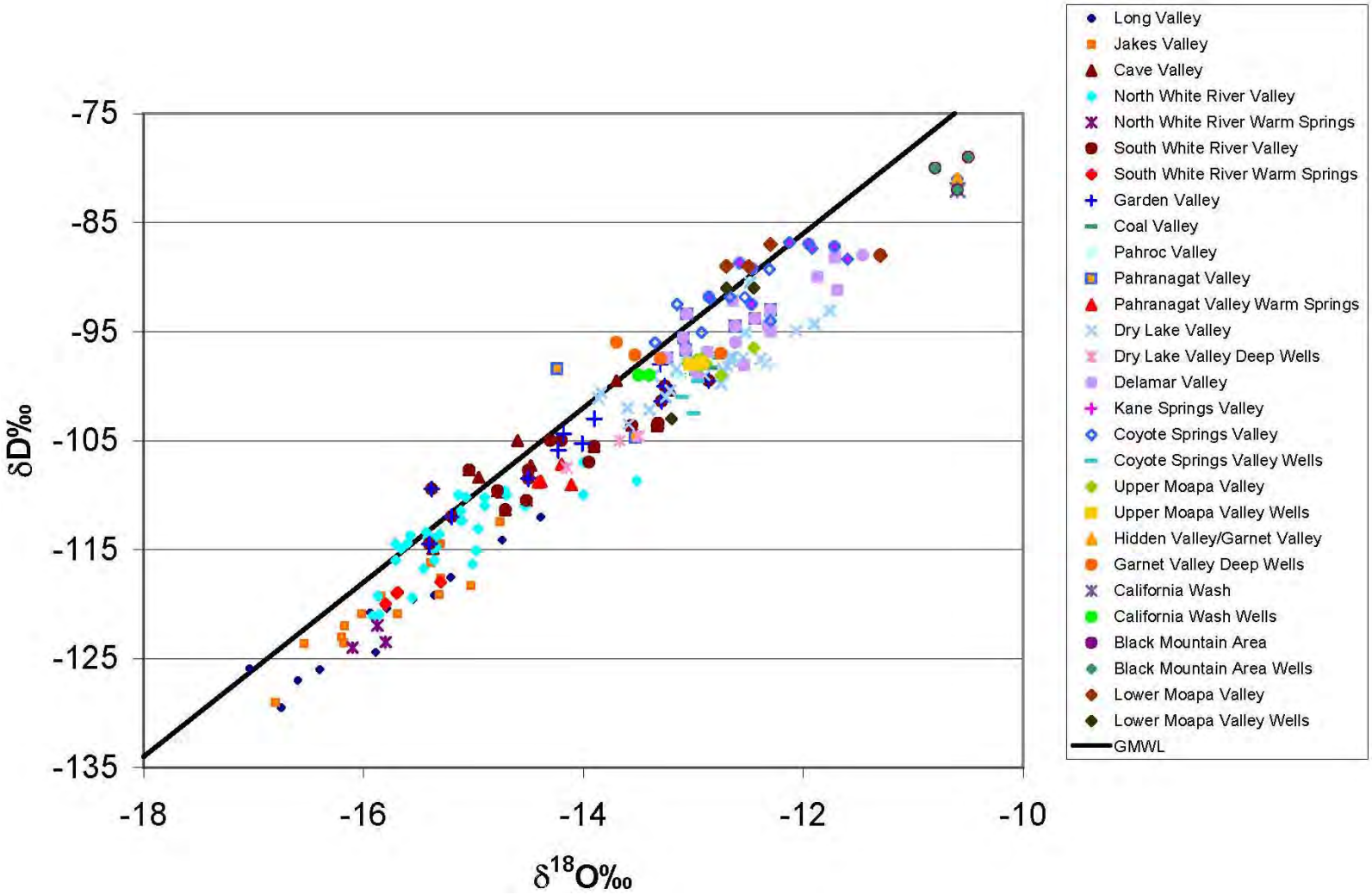

Figure 12. Plot of deuterium versus oxygen-18 for samples in the White River flow system. GMWL is the Global Meteoric Water Line from Craig (1961).

The water budgets evaluated in this report are based on estimates of recharge for the different mountainous recharge areas in a valley, predevelopment ET, and groundwater interbasin flow directions provided by SNWA (Figure 13), with the exception of the interbasin flow rates for the reconnaissance series reports, which are based on Eakin (1966) interbasin flow directions (Figure 14) and differences in reconnaissance report recharge and ET. As noted earlier in this report, three different sets of recharge and ET values (water budgets) were evaluated in this study: (1) new SNWA recharge and predevelopment ET rates (SNWA, 2007); (2) new SNWA recharge and ET rates combined with BARCAS study ET rates (BARCAS ET rates were used in place of new SNWA ET rates for those valleys in the WRFS with BARCAS ET estimates); and (3) reconnaissance report recharge and ET rates were used with Eakin (1966) groundwater interbasin flow routing. The ET values are for predevelopment conditions and do not include ET from fields irrigated by groundwater, but they do include spring discharge.

Interbasin groundwater flow results in the models when valley recharge plus groundwater inflow to a valley (when there is inflow) is greater than groundwater consumed by ET in the valley. This surplus groundwater is assumed to flow to the next downgradient valley(s). Interbasin groundwater flow is assigned deuterium and oxygen-18 values differently for the two models used in this study to evaluate water budgets. In one model, the isotopic composition of interbasin flow was calculated by using the volume-weighted isotopic compositions of recharge from different recharge areas within a valley and of groundwater inflow(s) to the valley from upgradient valleys. Thus, the isotopic value of groundwater outflow from valleys in this model is the volume weighted average of recharge to the valley plus any groundwater inflow from upgradient valleys. In the second mass-balance, the isotopic composition of groundwater outflow was calculated by assuming that all ET in a valley was first satisfied by local recharge and then if local recharge was not sufficient to meet ET demands, groundwater inflow from upgradient valleys was used to satisfy ET. Thus, the isotopic composition of groundwater outflow from a valley in this model is that of the groundwater inflow to a basin if ET exceeds local recharge, or is a volume weighted average of the amount of local recharge in excess of ET plus inflow(s) to the valley.

The isotope mass-balance models are used to evaluate WRFS water budgets by determining if estimated recharge and ET rates and interbasin flows within the WRFS are consistent with the deuterium and oxygen-18 data (Appendix 1). If mass-balance model-calculated deuterium and oxygen-18 values are similar to measured values for regional warm springs, then the proposed water budgets are reasonable. In contrast, if mass-balance model-calculated deuterium and oxygen-18 values are significantly different than measured values for regional warm springs, then the proposed water budgets are not reasonable, or interbasin flow routing may be incorrect. Wells completed in consolidated rock with warm water from the regional flow systems offer additional evaluation points in the system. Similar to the regional warm springs, the isotopic content of groundwater in a well needs to be similar to the calculated value for the proposed interbasin flows and water budgets to be reasonable. The isotopic mass-balance models are not used for determining how much recharge should be assigned to each recharge area or how much ET should be assigned to each valley; rather, the models evaluate whether the assigned recharge and ET values and interbasin flows are consistent with the stable isotope data of the WRFS. The isotopic mass-balance models are

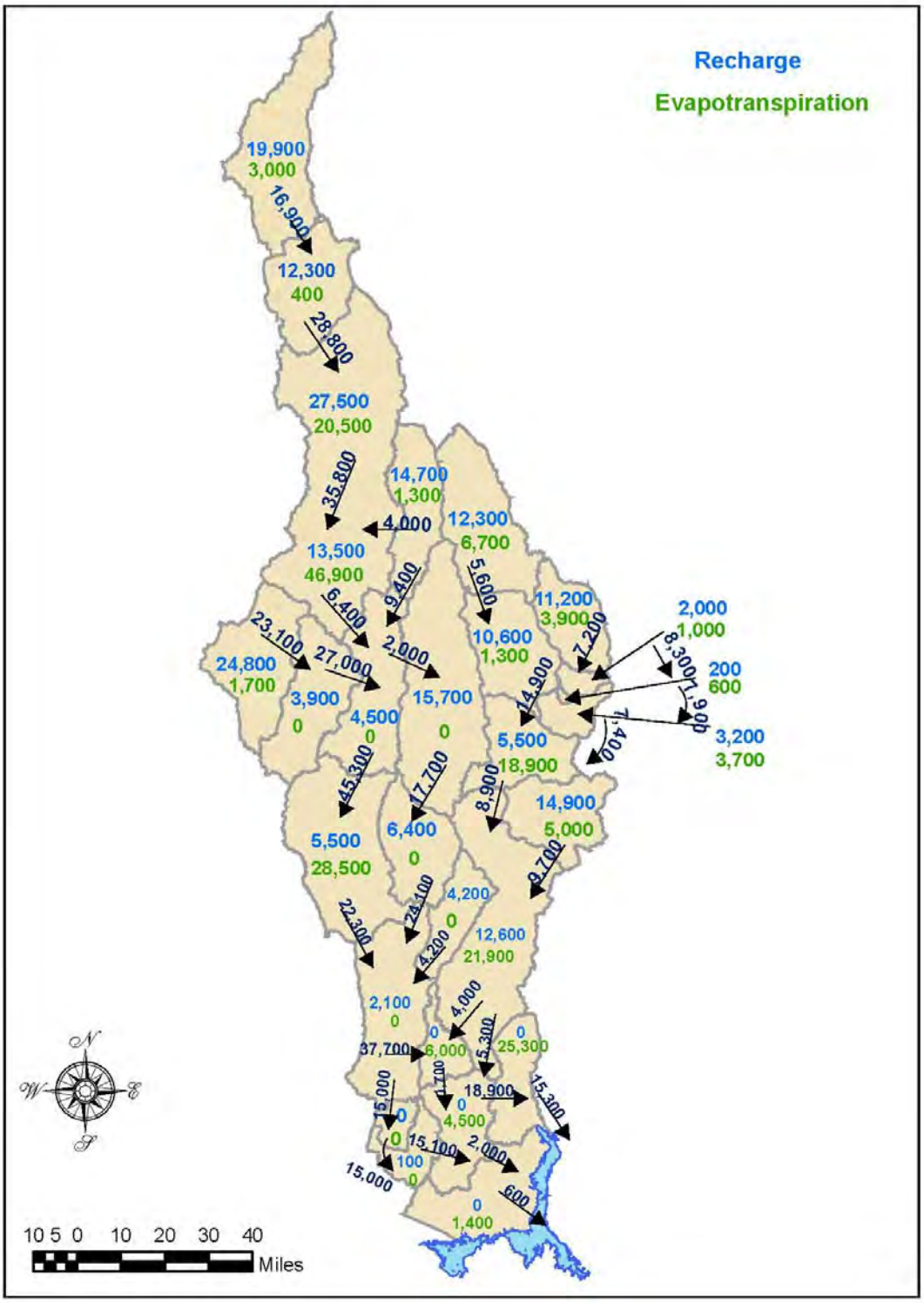

Figure 13. SNWA (2007) recharge values, predevelopment ET values, and interbasin flows. Interbasin flow directions and rates are shown as arrows with values. All values are in acre-feet per year.

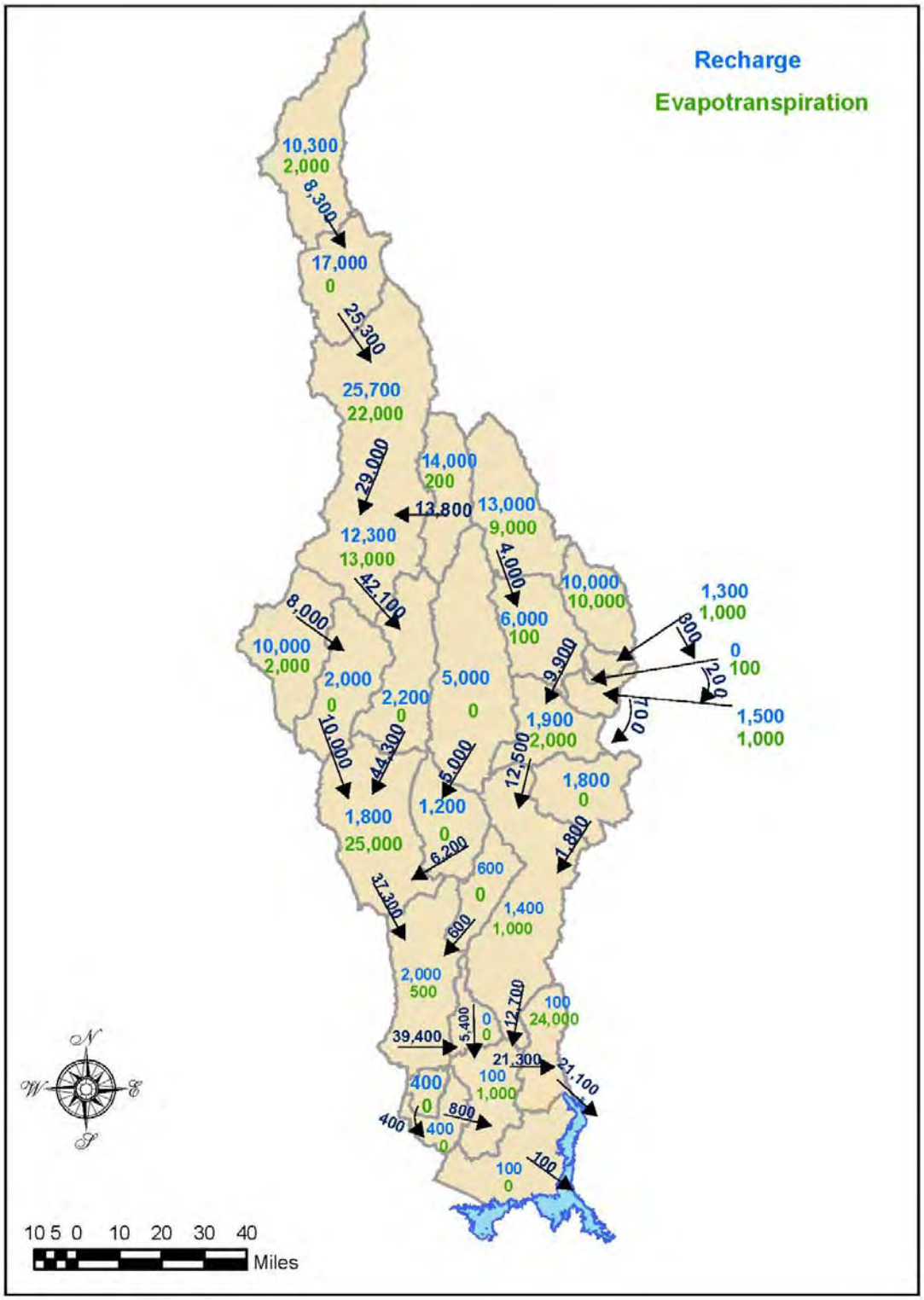

Figure 14. Reconnaissance Report Series recharge values, predevelopment ET values, and interbasin flows with Eakin (1966) interbasin flow routing for the White River Flow System. Interbasin flow directions and rates are shown as arrows with values. All values are in acre-feet per year.

nonunique; a reasonable result confirms the viability of a proposed water budget but it does not prove that the water budget is correct. An isotopic mass-balance model can be used to eliminate unrealistic water budget estimates, or interbasin flows, and to help identify areas where water budgets and/or interbasin flows need to be better understood.

Regional Warm Springs

A logical way to evaluate water budgets and interbasin flows for the WRFS with the isotope mass-balance model is to start at the upgradient part of the flow system in the north and move from north to south down the hydraulic gradient of the WRFS. In the WRFS, going from north to south there are four major regional warm spring areas that can be used to evaluate the isotopic mass-balance models; the Preston area in northern White River Valley; the Hot Creek area in southern White River Valley; the Alamo area in Pahranagat Valley; and the Muddy River Springs area in Upper Moapa Valley. Wells completed in consolidated rock that contain warm (>20 ^{o}C) water can also be used to evaluate water budgets and associated interbasin groundwater flow in the WRFS. Wells completed in consolidated rock with warm water in areas not in regional warm spring areas are present in Coal, Dry Lake, Delamar, Coyote Springs, Upper Moapa, Garnet, California Wash, and Lower Moapa valleys of the WRFS.

Using the approach of evaluating the isotopic mass-balance models following groundwater flow down the WRFS, the first regional warm spring discharge area where recharge and ET estimates and interbasin groundwater flow can be evaluated is in the Preston area in northern White River Valley. In the Preston area, three warm springs (Preston Big, Nicholson, and Preston Cold [Preston Cold is inappropriately named because it is 21.8 ^{o}C and it is in the regional warm spring province with Preston Big and Nicholson springs]) have significantly lighter (more negative) discharge-weighted average deuterium and oxygen-18 compositions of -122.6 and -15.92‰, respectively, than local recharge (Appendices 1 and 2; -112.3 and -15.15‰ for the northern Egan Range and -115.0 and -15.18‰ for the White Pine Range). The source of these warm springs is not local recharge from mountains surrounding northern White River Valley; rather, the source is interbasin flow from Jakes Valley. Jakes Valley groundwater flowing into northern White River Valley is recharge to Jakes Valley plus interbasin flow from Long Valley that is upgradient of Jakes Valley (Figure 13).

In the isotopic mass-balance models for the WRFS, the spring flow rates used to calculate flow-weighted deuterium and oxygen-18 values are for flows measured in the winter months (November to February) to avoid ET and groundwater pumping that might reduce spring flow. However, a comparison of average winter flow rates with the average yearly flow rates did not show a significant difference in spring flows for most regional warm springs (U.S. Geological Survey spring-flow data).

Six different models were developed to evaluate water budgets for the WRFS (Appendices 1 and 2). However, although results for all six isotope mass-balance models will be discussed, the interbasin flow volumes that are presented in detail in this report are for the SNWA 2007 water budget. An estimated 28,800 afy of groundwater flows into northern White River Valley from Jakes Valley. For both SNWA water budget models, the isotopic composition of this interbasin flow is -121.3 and -15.86‰ for deuterium and oxygen-18, respectively. The calculated values for both models are the same because of the very small amount of ET in Jakes Valley (400 afy) as compared to recharge (12,300 afy). This

calculated inflow deuterium value is within 1.3‰ of the flow weighted average of the regional warm springs in the Preston area (Table 3). The calculated oxygen-18 value is within 0.06‰ of the flow-weighted average of the regional springs in the Preston area. In comparison, the SNWA/BARCAS water-budget-calculated isotopic values are almost identical, within 1.2 and 0.06‰, for deuterium and oxygen-18, respectively (Table 3). These very similar values reflect that the ET differences between the SNWA and SNWA/BARCAS water budgets are small and also that there is little ET in Jakes Valley that would make the interbasin flow isotopic values different. The Reconnaissance Report Series water budg*et al*so produce similar results (2.3 and 0.20‰ for deuterium and oxygen-18, respectively), again because of little ET in Long and Jakes valleys (Table 3).

Given the analytical precision of 1.0‰ for deuterium, calculated deuterium values that are within 2.0‰ of measured values indicate an excellent fit, those within 3.0‰ represent a good fit, and those within 4.0‰ represent an acceptable fit. Any calculated deuterium values that are greater than 4.0‰ different than measured values indicate that the water budgets are not correct, and for warm spring areas above the Muddy River Springs area (the most downgradient warm springs area in the WRFS) they may also indicate incorrect flow routing (if calculated isotopic values are within the acceptable range at the Muddy Springs area, the overall water budget is acceptable). Given the analytical precision of 0.1‰ for oxgen-18, calculated oxygen-18 values that are within 0.20‰ of measured values indicate an excellent fit, those within 0.30‰ represent a good fit, and those within 0.40‰ represent an acceptable fit. Any calculated oxygen-18 values that are greater than 0.40‰ different than measured values indicate that the water budgets are not correct.

Isotope mass-balance model-calculated deuterium and oxygen-18 values for the SNWA and SNWA/BARCAS water budgets indicate that the recharge and ET estimates above the Preston warm springs area in northern White River Valley and interbasin flows result in an excellent match to measured values (Table 3). Calculated deuterium values for the Reconnaissance Report Series water budget result in a good fit and the oxygen-18 values result in an excellent fit to measured values. Thus, the isotope mass-balance models show that the SNWA and SNWA/BARCAS water-budget-calculated isotopic values closely match measured isotope values and the Reconnaissance Report Series water-budget-calculated isotopic values also match measured values, but not quite as well as the other two water budgets.

The next regional warm spring area downgradient of the Preston warm springs area in northern White River Valley in the WRFS is the Hot Creek warm springs area in southern White River Valley. For the isotope mass-balance models, Moorman Hot Spring, a relatively low flow (400 afy) regional warm spring located several miles north of the Hot Creek area, is included in the Hot Creek regional warm spring province because of its similar isotopic composition to Hot Creek and Moon River regional warm springs (Appendices 1 and 2). In the Hot Creek area, the discharge-weighted average deuterium and oxygen-18 compositions of the three warm springs are -119.2 and -15.71‰, respectively. The local recharge to Southern White River valley has average isotopic values of -109.6 and -14.15‰ for the southern Egan Range and -106.5 and -14.23‰ for the Grant Range. As with the northern White River Valley, the source of these warm springs is not local recharge from mountains surrounding southern White River Valley; rather, the source is interbasin flow.

Table 3. A comparison of the difference between measured and calculated deuterium and oxygen-18 values for regional warm (>20 °C) springs for the WRFS and MVWFS and small (<50 afy) warm springs in the MVWFS. Models 1 and 2 are for the SNWA water budget; models 3 and 4 are for the SNWA/BARCAS water budgets; models 5 and 6 are for Reconnaissance Report water budgets. Models 1, 3, and 5 are for ET that is a mixture of local recharge and interbasin flow and models 2, 4, and 6 are for ET that uses local recharge first to satisfy ET demands. Positive values show that calculate values are less negative than measured values and negative values show that calculated values are more negative than measured values.

Warm Spring Discharge Area	Model 1 δD (‰)	Model 1 $\delta^{18}O$ (‰)	Model 2 δD (‰)	Model 2 $\delta^{18}O$ (‰)	Model 3 δD (‰)	Model 3 $\delta^{18}O$ (‰)	Model 4 δD (‰)	Model 4 $\delta^{18}O$ (‰)	Model 5 δD (‰)	Model 5 $\delta^{18}O$ (‰)	Model 6 δD (‰)	Model 6 $\delta^{18}O$ (‰)
White River Flow System Regional Warm Springs												
Preston Spring Area Northern White River Valley	+13	+0.06	+1.3	+0.06	+1.2	+0.06	+1.2	+0.06	+2.3	+0.20	+2.3	+0.20
Hot Creek Spring Area Southern White River Valley	+1.7	+0.19	-0.6	-0.01	+1.6	+0.18	-2.2	-0.15	+2.2	+0.27	-0.3	+0.06
Alamo Spring Area Pahranagat Valley	+3.9	+0.22	+3.3	+0.16	+4.9	+0.34	+4.6	+0.31	-2.4	-0.51	-5.5	-0.83
Muddy Springs Area Upper Moapa Valley	-0.9	-0.35	-1.7	-0.41	-0.3	-0.26	-1.0	-0.31	-9.4	-1.39	-12.0	-1.66
Meadow Valley Wash Flow System Regional Warm Springs												
Panaca Spring Area Panaca Valley	+1.4	+0.06	+1.4	+0.06	+1.2	+0.02	+1.2	+0.02	+0.7	-0.10	+0.7	-0.10
Caliente Hot Springs Area Panaca Valley	+2.4	+0.36	+2.4	+0.36	+2.2	+0.32	+2.2	+0.32	+1.7	+0.20	+1.7	+0.20
Meadow Valley Wash Flow System Small Warm Springs												
Flatnose Spring Dry Valley	+1.8	+0.16	+1.7	+0.15	+1.8	+0.16	+1.7	+0.15	+2.1	+0.20	+2.1	+0.20
Bennett Spring Panaca Valley	+2.2	+0.31	+2.0	+0.27	+2.0	+0.27	+1.7	+0.23	+1.6	+0.19	+1.5	+1.8
Kershaw-Ryan Spring #1 Lower Meadow Valley Wash	-0.4	+0.29	-1.0	+0.21	-0.6	+0.27	-1.2	+0.19	-4.3	-0.17	-4.9	-0.25

Calculated deuterium and oxygen-18 values for the SNWA and SNWA/BARCAS water budgets indicate that the recharge and ET estimates above the Hot Creek warm springs area in southern White River Valley and interbasin flows result in an excellent match to measured values, except for one model (Table 3). The model using the SNWA/BARCAS water budget with local recharge meeting ET demands before any regional interbasin flow is used to meet ET needs has a calculated deuterium value that is only a good fit to the average measured value of the warm springs. Calculated deuterium and oxygen-18 values for the Reconnaissance Report Series water budget result in a good fit for the model that mixes local recharge and ET to meet ET demands and is an excellent fit for the model that uses local recharge to meet ET demands before any regional interbasin flow groundwater is used to meet ET needs. Thus, the isotope mass-balance models show that the SNWA water-budget-calculated isotopic values most closely match measured isotope values for both northern and southern White River Valley warm spring areas.

The next regional warm springs area downgradient from the Hot Creek area in southern White River Valley is the Alamo warm springs area in Pahranagat Valley. Three large (Hiko, Crystal, and Ash springs) and one smaller (Little Ash Spring) regional warm springs discharge in this area. The springs have a discharge-weighted isotopic composition of -108.9 and -14.26‰. The local recharge to Pahranagat Valley has average isotopic values of -94.9 and -12.83‰ for the south Pahroc Range and -98.4 and -14.24‰ for the Mount Irish/Pahranagat Range (Appendices 1 and 2). As with the other warm spring areas of the WRFS, the source of these warm springs is not local recharge from mountains surrounding Pahranagat Valley; rather, the source is interbasin flow and for this area that inflow is from Pahroc Valley.

Calculated deuterium values for the SNWA water budget indicate that the recharge and ET estimates above the Alamo warm springs area in Pahranagat Valley and interbasin flows result in an acceptable match to measured values (Table 3). The model-calculated oxygen-18 values are an excellent match for one model and a good match for the other model. SNWA/BARCAS water-budget-calculated deuterium values are not acceptable for either model, but calculated oxygen-18 values are in the acceptable range for both models. The calculated deuterium value for the Reconnaissance Report Series water budget model that mixes local recharge and ET to meet ET demands is a good match with the measured value, but the calculated oxygen-18 value for this model is outside the acceptable range when compared to the measured value. Calculated deuterium and oxygen-18 values for the Reconnaissance Report Series water budget for the model that uses local recharge to meet ET demands before any regional interbasin flow groundwater is used to meet ET demands are both outside the range of an acceptable match with measured values. Thus, the isotope mass-balance models show that the SNWA water budget is the only water budget that produces acceptable deuterium and oxygen-18 values for the Alamo warm springs area in Pahranagat Valley.

The Muddy River Springs area in Upper Moapa Valley is the most downgradient warm springs discharge area of the WRFS, so it is the most important site for isotope mass-balance water budget and interbasin flow evaluations, because these regional warm springs integrate all recharge, discharge, and interbasin flows in the WRFS above this discharge area. Additionally, because the Muddy River Springs area is downgradient of and

receives flow from the MVWFS, this warm spring discharge area also provides an evaluation point for the MVWFS, which will be discussed later in this report.

Coyote Springs Valley is the basin immediately upgradient of Upper Moapa Valley, from which the Muddy River Springs receive most of their flow (37,700 afy), with an additional 4,000 afy coming from Lower Meadow Valley Wash for the SNWA and SNWA/BARCAS water budgets and interbasin flow routing. Groundwater discharging from Muddy River Springs has flow-weighted average deuterium and oxygen-18 values of -97.8 and -12.90‰, respectively. The mass-balance model-calculated deuterium values for the SNWA and SNWA/BARCAS water budgets and interbasin flows are all excellent matches with the discharge-weighted average value (Table 3) and the oxygen-18 values are good to acceptable matches, except for model 2 which is 0.01‰ less than the acceptable range for oxygen-18 (Table 3). The mass-balance model-calculated deuterium and oxygen-18 values for the Reconnaissance Report Series water budget and interbasin flow were significantly less than the acceptable values for both models (Table 3). In summary, the SNWA and SNWA/BARCAS water budgets and interbasin flows produced isotope mass-balance model-calculated isotopic values that were acceptable for all four models, except for one oxygen-18 value that was 0.01‰ more negative than an acceptable match for the average measured value. The isotope mass-balance-calculated deuterium and oxygen-18 values for the Reconnaissance Report Series water budget were not even close to producing acceptable values.

In summary, the isotope mass-balance models that produced the most consistent and acceptable models for calculated deuterium and oxygen-18 values for all four of the hot spring areas in the WRFS used the SNWA (2007) water budget and interbasin flows. The isotope mass-balance models using the SNWA/BARCAS water budget and interbasin flows were also acceptable matches with measured values except for the Alamo hot springs area in Pahranagat Valley where the models did not produce calculated deuterium values that were acceptable matches with measured values. The isotope mass-balance models using the Reconnaissance Report Series water budget and Eakin (1966) interbasin flows only produced acceptable calculated isotopic values for the White River Valley hot spring areas, with the exception of one calculated deuterium value for the Alamo hot springs area in Pahranagat Valley. In conclusion, only the SNWA (2007) water budget and interbasin flows produced acceptable results for regional hot spring areas in the isotopic mass-balance model evaluations of the three different water budgets.

Consolidated Rock Wells with Warm Regional Groundwater

Wells completed in consolidated rock with warm regional groundwater that are not in regional warm spring discharge areas can be used to evaluate interbasin flow and water budgets. In the WRFS, starting with upgradient valleys in the north and moving downgradient to the south, the first consolidated rock wells encountered are south of White River Valley. As noted earlier in this report, warm water in wells completed in consolidated rock is assumed to represent interbasin flow from upgradient basins. The USGS-MX well (CV-DT-1) south of and downgradient from southern White River Valley is completed in the carbonate-rock aquifers and is located in northwest Coal Valley in a low-altitude pass between Coal and Garden valleys (Plate 1 and Appendix 3). The isotopic content of water in this well is -109.0 and -14.56‰ for deuterium and oxygen-18, respectively. The source of water for this well, in all six mass-balance models, is assumed to be interbasin flow from

Garden Valley. The model-calculated isotopic composition of Garden Valley inflow to Coal Valley is -104.7 and -14.08‰, except for the Reconnaissance Report Series water budget mass-balance models, which have calculated deuterium values of -104.2 and -104.5‰ and calculated oxygen-18 values of -14.00 and -14.06‰. The Reconnaissance Report Series water-budget-calculated isotopic values for Garden Valley interbasin flow to Coal valley are similar to the SNWA and SNWA/BARCAS water-budget-calculated values because this interbasin flow is only local recharge to Garden Valley, which has a similar isotopic composition in all six models. The mass-balance-calculated values for Garden Valley inflow to this well are significantly higher (more than 4 and 0.4‰ more positive in deuterium and oxygen-18, respectively) than the average measured values for water in the well (Table 4). This difference between calculated and measured values indicates that there is likely some interbasin flow from southern White River Valley to Coal Valley in the area of this well (Plates 1 and 2). Southern White River Valley groundwater outflow is isotopically lighter than Garden Valley recharge and the water in the Coal Valley well in all six isotope mass-balance models (appendix 2). Thus, mixing some outflow from southern White River Valley with some Garden Valley recharge could produce calculated isotopic values similar to measured values in this northern Coal Valley well. Having some interbasin flow from southern White River Valley to Coal Valley, instead of all interbasin flow going to Pahroc Valley, is possible given the geology along the boundary between southern White River Valley and Coal Valley (SNWA, 2007). Having some southern White River Valley groundwater flow into Coal Valley would have no effect on the water budget mass-balance calculations in the WRFS, because there is no groundwater ET in Coal Valley and all Coal Valley groundwater is assumed to flow into Pahroc Valley.

A second consolidated rock well with warm water (Fugro Dry Lake V Deep Well; Appendices 2 and 3) is located just south of White River and Cave valleys near the topographic divide between northern Dry Lake and northern Pahroc valleys (Plates 1 and 2). Water in this well has deuterium and oxygen-18 values of -107.5 and -14.16‰, respectively. Interbasin flow into northwestern Dry Lake Valley is most likely from southern Cave Valley because the geology and geologic structure along the southeastern part of Cave Valley and northwestern Dry Lake Valley are conducive to interbasin flow in this area (SNWA, 2007). In the mass-balance models, this interbasin flow is shown as entering northeastern Pahroc Valley, which it may do before flowing into northwestern Dry Lake Valley. Cave Valley outflow has a calculated isotopic content of -106.5 and -14.28‰ (1.0 and 0.12‰ different from measured values) for the mass-balance models using SNWA and SNWA/BARCAS water budgets, so the well water isotopic data support interbasin flow from Cave Valley as the source of this well water (Table 4). The Reconnaissance Report Series water budget was routed using Eakin's 1966 interbasin flow routing, so no interbasin flow to Dry Lake Valley is included in these mass-balance models. The calculated deuterium and oxygen-18 values of local recharge for these mass-balance models was -98.9 and -13.10‰ (8.6 and 1.06‰ different than measured values) for the Reconnaissance Report series water budget. Clearly, given the local recharge isotopic values, local recharge is not the source of the warm water in the well.

Table 4. A comparison of the difference between measured and calculated deuterium and oxygen-18 values for wells completed in consolidated rock that contain warm (>20 °C) water for the WRFS that are outside of regional warm spring areas. Models 1 and 2 are for the SNWA water budget; models 3 and 4 are for the SNWA/BARCAS water budget; models 5 and 6 are for the Reconnaissance Report Series water budget. Models 1, 3, and 5 are for ET that is a mixture of local recharge and interbasin flow and models 2, 4, and 6 are for ET that uses local recharge first to satisfy ET demands. Positive values show that calculate values are less negative than measured values and negative values show that calculated values are more negative than measured values.

Warm Spring Discharge Area or Well	Model 1 δD (‰)	Model 1 $\delta^{18}O$ (‰)	Model 2 δD (‰)	Model 2 $\delta^{18}O$ (‰)	Model 3 δD (‰)	Model 3 $\delta^{18}O$ (‰)	Model 4 δD (‰)	Model 4 $\delta^{18}O$ (‰)	Model 5 δD (‰)	Model 5 $\delta^{18}O$ (‰)	Model 6 δD (‰)	Model 6 $\delta^{18}O$ (‰)
USGS-MX CV well (CV-DT-1) Coal Valley	+4.3	+0.48	+4.3	+0.48	+4.3	+0.48	+4.3	+0.48	+4.8	+0.56	+4.5	+0.50
Fugro Dry Lake V Deep Well North Dry Lake Valley	+1.0	-0.12	+1.0	-0.12	+1.0	-0.12	+1.0	-0.12	+8.6	+1.06	+8.6	+1.06
Well 181M1 Dry Lake Valley	-1.5	-0.61	-1.5	-0.61	-1.5	-0.61	-1.5	-0.61	+6.1	+0.57	+6.1	+0.57
Well 181W909M Dry Lake Valley	-1.9	-0.78	-1.9	-0.78	-1.9	-0.78	-1.9	-0.78	+5.7	+0.40	+5.7	+0.40
Well 182W906M Delamar Valley	+1.4	+0.21	+1.4	+0.21	+1.3	+0.21	+1.3	+0.21	+1.4	+0.23	+1.4	+0.23
Well 209M-1 Pahranagat Valley	-0.3	-0.51	-0.9	-0.57	+0.7	-0.39	+0.4	-0.42	-6.6	-1.24	-9.7	-1.56
Average of 11 wells Coyote Springs Valley	+1.1	-0.24	+0.4	-0.17	+1.8	-0.14	+1.3	-0.17	-7.2	-1.26	-9.8	-1.52
Wells in Upper Moapa Valley	-0.8	-0.28	-1.6	-0.34	-0.2	-0.19	-0.9	-0.24	-9.3	-1.32	-11.9	-1.59
Wells in Garnet Valley	-2.4	0.00	-3.0	-0.03	-1.7	+0.10	-2.1	+0.08	+15.9	+2.72	+15.9	+2.72
Wells in California Wash V.	+1.2	+0.33	+0.1	+0.23	+1.7	+0.39	+0.7	+0.30	-4.8	-0.37	-7.1	-0.60

Dry Lake Valley also contains two wells in addition to the USGS MX well completed in consolidated rock that were recently drilled by SNWA. These two wells (181M1 and 181W909M; appendices 2 and 3 and Plates 1 and 2) are located in west- central and southeastern Dry Lake Valley. They were developed before sampling by removing a volume of water approximately equal to the volume used in drilling the wells. Thus, the isotopic data should be representative of the regional groundwater in the area of the wells, but the samples may contain some drilling fluid mixed with the regional groundwater. The samples from the two Dry Lake Valley wells have measured deuterium and oxygen-18 values of -105.0 and -104.6 and -13.67 and -13.50‰, respectively. The source of this water is Cave Valley, the same as for the northern Dry Lake Valley well. The mass-balance model-calculated deuterium values for these two wells for both the SNWA and SNWA/BARCAS water budgets are an excellent match to measured values. However, neither well has an acceptable mass-balance model-calculated oxygen-18 value for the SNWA or SNWA/BARCAS water budgets. The mass-balance model-calculated deuterium and oxygen-18 values for these two wells for the Reconnaissance Report Series water budget and Eakin (1966) interbasin flow routing exceed the acceptable range, except for oxygen-18 for well 181W909M, which is right at the limit of the acceptable range (Table 4). Thus, the isotope mass-balance models show that the SNWA and SNWA/BARCAS water budgets and interbasin flows produce an excellent match to measured deuterium values, but none of the mass-balance models produce an acceptable calculated oxygen-18 value. The more negative calculated oxygen-18 than measured values, indicates that some local recharge, which has more positive oxygen-18 values then Cave Valley interbasin flow, may be mixing with the interbasin flow from Cave Valley as it flows south to these two wells.

Downgradient from Pahroc Valley a consolidated rock well with warm water (well 209M-1) is located in northeastern Pahranagat Valley near the topographic divide between Pahranagat and Delamar valleys (Plates 1 and 2). This well water has deuterium and oxygen-18 values of -104.7 and -13.53‰, respectively. The location of the well indicates that the source of this groundwater is inflow from Pahroc Valley, which is immediately upgradient from Pahranagat Valley. For the SNWA water budget, mass-balance-calculated deuterium values for the two models are -105.0 and -105.6‰ and for oxygen-18 are -14.04 and -14.10‰ and for the SNWA/BARCAS water budget they are -104.0 and -104.3‰ and -13.92 and -13.95‰, respectively. For deuterium, all four of these model-calculated values are excellent matches with measured values, however, for oxygen-18 only one of the SNWA/BARCAS calculated values is an acceptable match and all the others are outside the acceptable range (Table 4). The location of the well in the South Pahroc Range recharge area and very near the topographic divide with Delamar Valley, along with the less negative oxygen-18 value than interbasin flow from Pahroc Valley, indicates that this well may be mixing some local recharge and/or inflow from Dry Lake Valley (with less negative oxygen-18 water) with regional groundwater flow in this area. All calculated isotopic values for the mass-balance model using the Reconnaissance Report Series water budget are significantly less than acceptable values as compared to the measured values (Table 4).

Wells completed in consolidated rock with warm water that are present in the WRFS before the next downgradient warm spring area in Upper Moapa Valley (Big Muddy Springs area) are in Delamar and Coyote Springs valleys. Delamar Valley contains Well 182W906M. Before sampling, this well was developed by removing a volume of water approximately equal to the volume used in drilling the well. Thus, the isotopic data for this well should be

representative of the regional groundwater in the area of the well, but the sample may contain some drilling fluid mixed with the regional groundwater. Water in this well should be regional groundwater inflow from upgradient Dry Lake Valley. Water from this well has a deuterium value of -100.3‰ and an oxygen-18 value of -13.33‰. All six mass-balance models produced calculated deuterium values that are excellent matches with the measured value and oxygen-18 values that are good matches with the measured value. Mass-balance model results show that SNWA, SNWA/BARCAS, and Reconnaissance Report Series water budgets and routing all indicate that water in this well is from interbasin flow from Dry Lake Valley (Table 4).

Downgradient of Pahranagat, Delamar, and Kane Springs valleys is Coyote Springs Valley. Numerous wells have recently been completed in the valley in consolidated rock, developed by aquifer testing, and sampled for chemical and isotopic analyses (Acheampong *et al*., 2007; and Stephen Acheampong, SNWA, written commun., 2007). The average isotopic content of water from 11 wells in Coyote Springs Valley with warm regional groundwater was used for evaluating water budgets and interbasin flow. Three of the 14 wells with isotopic data in the valley were not used in determining the average isotopic composition of interbasin flow because two of the wells are shallower than a nearby well and contain local recharge (wells CSVM-7 and VF-1) and one well is located on the Sheep Range alluvial fan (CSVM-5) and contains primarily recharge water from the Sheep Range. The average isotope values of the 11 well waters are -100.7‰ for deuterium and -13.11‰ for oxygen-18. The calculated deuterium and oxygen-18 values for interbasin flow into Coyote Springs Valley for the SNWA water budget and interbasin flows is -99.6 and -100.3‰ for deuterium and -13.35 and -13.38‰ for oxygen-18. The calculated deuterium values are excellent matches for the average measured value and one of the calculated oxygen-18 values is an excellent match and the other is a good match with the average measured value. For the SNWA/BARCAS water budget, mass-balance model-calculated deuterium and oxygen-18 values are excellent matches for the average measured values (Table 4). All calculated isotopic values for the mass-balance model using the Reconnaissance Report Series water budget are significantly less than acceptable values when compared to the measured values (Table 4).

Upper Moapa, Garnet, and California Wash valleys are all downgradient of Coyote Springs Valley and they contain wells completed in consolidated rock with warm water. The source of almost all of this groundwater is water in the carbonate-rock aquifers flowing out of the Coyote Springs Valley area. This interbasin flow has a deuterium composition of -99.9 to -99.3‰ and an oxygen-18 composition of -13.35 to -13.32‰ for the SNWA water budget. A comparison of the average isotopic values of these well waters with mass-balance-calculated values shows that deuterium values are good to excellent matches and oxygen-18 values range from excellent to acceptable matches with measured values (Table 4). The calculated isotope values for the SNWA/BARCAS water budget are all excellent to good matches with measured values, except for one oxygen-18 value, which was an acceptable match with measured values (Table 4). For Upper Moapa, Garnet, and California Wash valleys, all calculated isotopic values for the mass-balance model using the Reconnaissance Report Series water budget are significantly less than acceptable values when compared to the measured values, except for one acceptable oxygen-18 value for California Wash Valley (Table 4).

Lower Moapa Valley has two wells in the Weiser Wash area with isotopic data (EH-3, EH-7) that may be completed in consolidated rock. These wells have deuterium and oxygen-18 values of -91.0 (both wells) and -12.70 and -12.45‰, respectively. These wells do not reflect regional groundwater from the WRFS in this area (California Wash interbasin flow), rather they are most similar to the calculated isotope values of groundwater in Lower Meadow Valley Wash (-93.5 and -12.59‰; appendix 2). Thus, the source of these well waters, which are located north of California Wash and east of Lower Meadow Valley Wash (Plates 1 and 2), is interbasin flow from Lower Meadow Valley Wash near the area where interbasin flow enters California Wash.

The Black Mountains area basin contains several small springs that discharge both local recharge and regional groundwater (Pohlman *et al*., 1998). Three springs located in the southern part of the basin—Bitter, Cottonwood, and Sandstone springs—are cold (<20 ^{o}C) alluvial springs that discharge local recharge. There is no recharge to this area in the SNWA water budget, so either this small amount of discharge is overlooked as low-altitude recharge in the water budget or there is some low-altitude recharge from other nearby basins that discharge from these springs. In the Black Mountains area, there is a second group of springs in the eastern part of the basin. The two largest of these springs, Rogers and Blue Point springs, discharge directly out of carbonate rock and they are warm (>20 ^{o}C). Their deuterium and oxygen-18 compositions are -91.7 and -92.6‰ and -12.33 and -12.40‰, respectively. The proposed source of this water is inflow from California Wash. However, the calculated isotopic composition of inflow for the SNWA and SNWA/BARCAS water budgets ranges from -98.9 to -97.3‰ for deuterium and -13.22 to -13.06‰ for oxygen-18 (Appendix 2), which are outside the acceptable range for this to be the source of water for these springs. Possible sources of this water are: (1) interbasin flow directly from southern Lower Meadow Valley Wash to the springs (-96.3 to -93.5‰ for deuterium and -12.92 to -12.59‰ for oxygen-18 for SNWA and SNWA/BARCAS water budgets [Appendix 2]); or (2) regional flow from either California Wash or Lower Meadow Valley Wash that has mixed with local recharge, which is isotopically heavier (more positive) than the spring discharge in this area (Appendix 2).

In summary, the isotope mass-balance models produced similar and acceptable results for calculated deuterium and oxygen-18 values for wells completed in consolidated rock with warm water using the SNWA (2007) or the SNWA/BARCAS water budgets and interbasin flows. The isotope mass-balance models using the Reconnaissance Report Series water budget and Eakin (1966) interbasin flow routing only produced acceptable calculated isotopic values for wells in Dry Lake Valley, Well 182-906M in Delamar Valley, and wells in California Wash Valley.

White River Flow System Water Chemistry

An overview evaluation of water chemistry data for groundwater in the WRFS was performed by plotting water chemistry data on a trilinear diagram. Plotting water chemistry data for cold (<20^{o}C) and warm (>20^{o}C) springs discharging from and wells completed in the carbonate-rock aquifers of the WRFS on a trilinear diagram (Figure 15) shows that the water chemistry is generally similar from north to south down the flow system until Coyote Springs Valley. Groundwater flowing down the WRFS is generally a Ca-Mg-HCO_3-type water until the groundwater encounters evaporative salts, likely gypsum or anhydrite and halite, in the

southern part of the flow system. As groundwater flows through Coyote Springs Valley and into Upper Moapa Valley, evaporative salts are added to the water before it discharges in the Muddy River Springs area. This is observed on the trilinear plot as the concentrations of sodium (Na), sulfate (SO_4), and chloride (Cl) increase from the warm springs in Pahranagat Valley to the carbonate wells in Coyote Springs Valley to the warm springs and wells completed in the carbonate-rock aquifer in the Muddy River springs area.

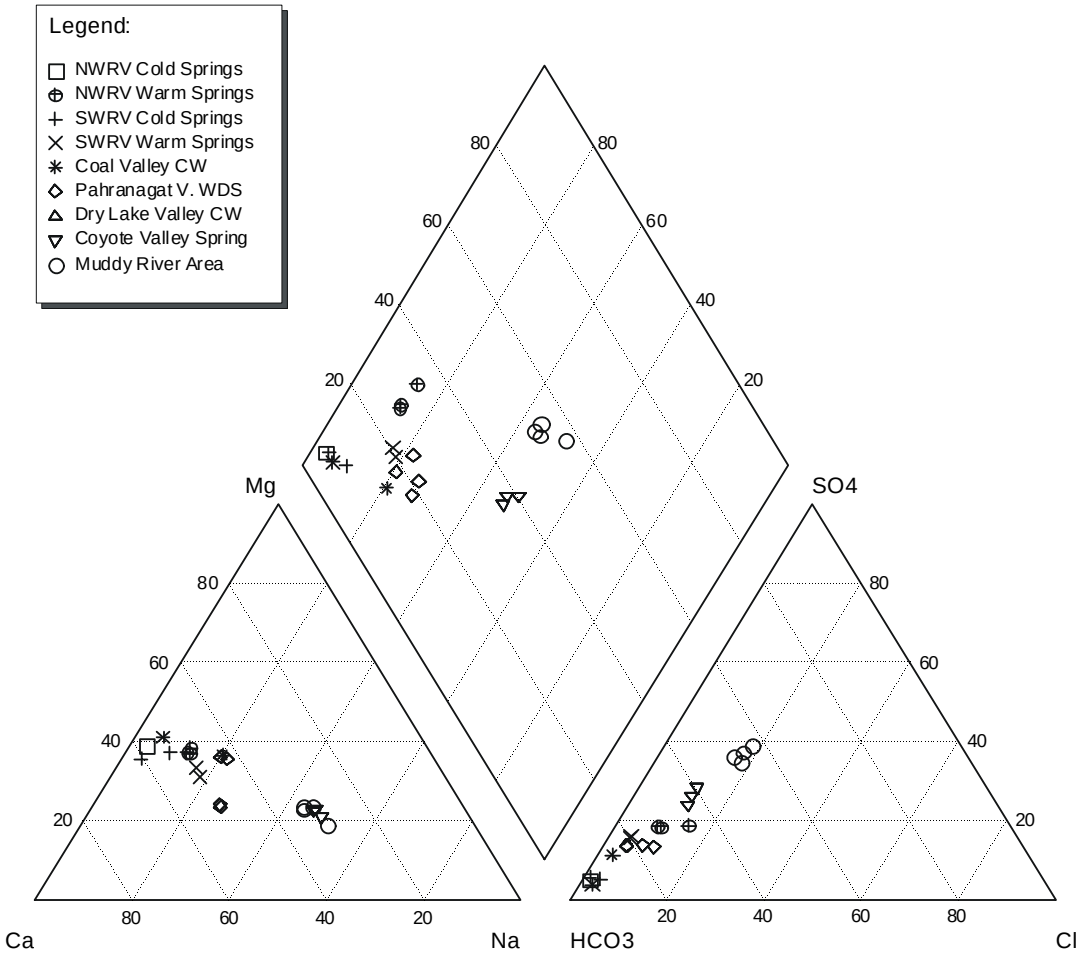

Figure 15. Trilinear plot of White River flow system water chemistry (from Thomas *et al*., 2001, Figure 6).

Meadow Valley Wash Regional Groundwater Flow System

Mifflin (1968) and Emme (1986) described regional groundwater flow in the MVWFS. The original flow delineations by Mifflin (1968) and Emme (1986) for parts of the MVWFS were further developed by the LVVWD (2001) and Thomas *et al*. (2001). Groundwater levels in the MVWFS show that groundwater recharged as far north as Lake Valley flows through Patterson Valley to Panaca Valley and as far to the northeast as Spring Valley (the Spring Valley southeast of Lake Valley and south of Spring Valley that has U.S. Highway 50 going through it and Snake Valley) flows through Eagle, Rose, and Dry valleys into Panaca Valley (Figures 2 and 14; Thomas *et al*., 2001). Panaca Valley groundwater flows into Meadow Valley Wash as does groundwater flowing out of Clover Valley. As

described for the White River regional flow system, groundwater in Meadow Valley Wash flows south into Upper Moapa and California Wash valleys.

In the MVWFS, regional warm springs that can be used to evaluate the isotope mass-balance models are present only in Panaca Valley. Panaca Warm Spring is a large spring discharging from the carbonate-rock aquifers in northern Panaca Valley and Caliente Hot Springs discharge from the carbonate rock aquifers in the southern part of Panaca Valley. The regional warm springs in the Muddy River springs area of the WRFS provide an additional evaluation point for calculated isotopic values for the MVWFS water budgets, because groundwater in the MVWFS flows into the WRFS in the area of the Muddy River Springs. In addition, there are small warm springs (flow < 50 afy) in the MVWFS that may represent interbasin flow or interbasin flow mixed with local recharge that can also be used to evaluate the mass-balance models. These smaller warm springs are Flat Nose Spring in Dry Valley, Bennett Spring in the west-central part of Panaca Valley, and Kershaw-Ryan Spring #1 in the northeastern part of Lower Meadow Valley Wash (Plates 1 and 2). Although the MVWFS does not contain consolidated rock wells with warm water that can be used to evaluate interbasin flow and water budgets for the MVWFS, as were present in the WRFS, the MVWFS does have alluvial wells with warm (>20 ^{o}C) water. These alluvial wells with warm water include Panaca Town, Lester Mathews, and North Lee wells in the Panaca Warm Spring area and the Railroad well (Farrier), EH-6 well, and EH-8 well in the southernmost part of Lower Meadow Valley Wash.

Meadow Valley Wash Flow System Isotope Mass-balance Models

The stable isotope mass-balance models developed for the MVWFS for this study include the same area as the Thomas *et al*. (2001) study. However, this study includes a significant amount of new data (about 450 new analyses) to help define the isotopic content of groundwater recharge areas both spatially and temporally and new recharge and groundwater ET estimates (SNWA, 2007; Welch and Bright; 2007).

Model Development and Results

Stable isotopes of water were used to evaluate water budgets and interbasin flows for the MVWFS by determining average deuterium and oxygen-18 values for all recharge and groundwater ET areas in the study area and tracking the volumes of recharge added to and ET removed from the MVWFS throughout the study area. For a water budget to be a reasonable estimate of recharge and ET, calculated isotopic values for regional spring discharge areas and small warm springs have to be similar to measured values. No wells completed in consolidated rock with warm (>20 ^{o}C) water from the regional flow system were identified in the MVWFS that could be used to help evaluate water budgets and interbasin flow, but some wells completed in alluvium contained warm water and they were used to help evaluate interbasin flows and water budget estimates.

To use a stable isotope mass-balance model for evaluating water budgets in regional flow systems, there needs to be an easily identifiable range in isotopic values throughout a flow system. A range in isotopic values is needed to identify inputs from different recharge areas and interbasin flow in a regional flow system. Fortunately, in the MVWFS deuterium and oxygen-18 vary greatly from Lower Meadow Valley Wash in the south to Lake Valley in the north. A plot of deuterium versus oxygen-18 (Figure 16) shows that isotopic values increase (become less negative) from north to south. This 25.5‰ increase in recharge area

deuterium values, from -112.0‰ in Lake Valley in the northern MVWFS to -86.5‰ in Lower Meadow Valley Wash in the southern MVWFS and the 3.64‰ increase in recharge area oxygen-18 values, from -15.10‰ in Lake Valley in the north to -11.46‰ in Lower Meadow Valley Wash in the south (Appendices 1 and 2 and plate 2), makes deuterium and oxygen-18 excellent tracers for water budget evaluations in the MVWFS.

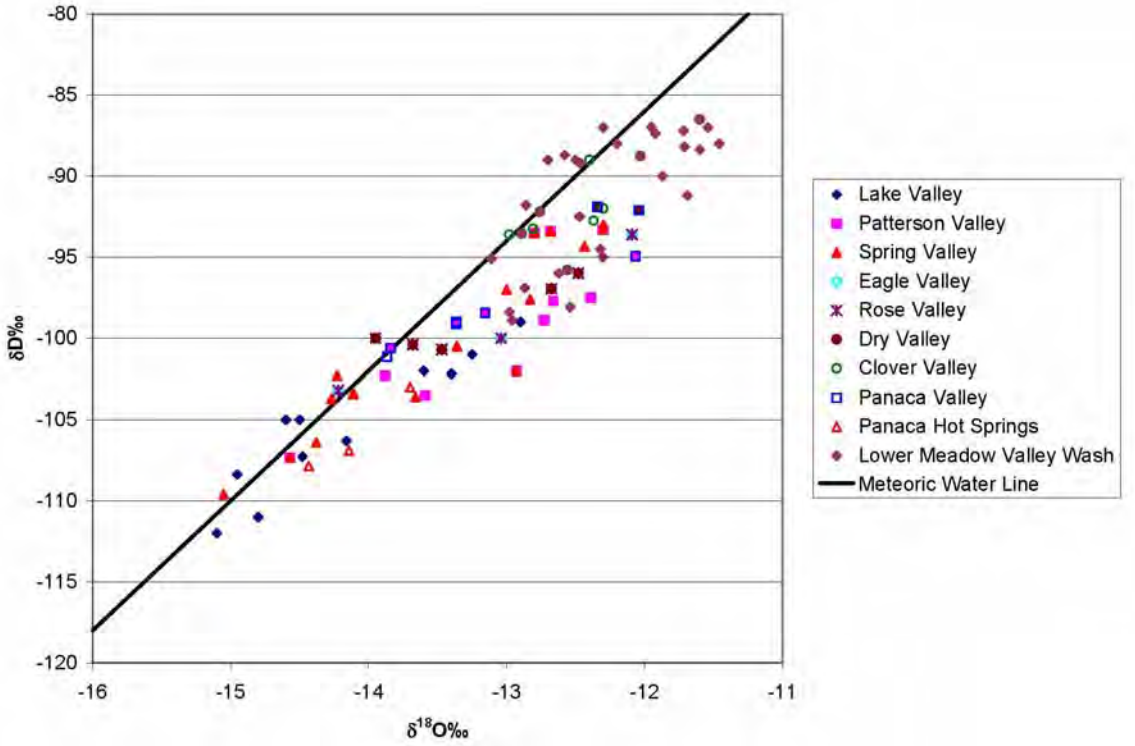

Figure 16. Plot of deuterium versus oxygen-18 for samples in the Meadow Valley Wash flow system. Meteoric Water Line from Craig (1961).

The water budgets evaluated in this report are based on estimates of recharge for the different mountainous recharge areas in a valley and predevelopment ET. Groundwater interbasin flow directions for the SNWA, SNWA/BARCAS, and Reconnaissance Report series water budgets are the same with groundwater flowing downgradient from northern valleys (Lake and Spring valleys) to Lower Meadow Valley Wash in the south and the amount of interbasin flow is recharge plus interbasin flow that is in excess of ET in a valley. As noted earlier in this report, three different water budgets were evaluated in this study: (1) new SNWA recharge and predevelopment ET rates (SNWA, 2007); (2) new SNWA recharge and ET rates combined with BARCAS study ET rates (SNWA, 2007; Welch and Bright, 2007; BARCAS ET rates were used in place of new SNWA recharge rates for Lake Valley in the MVWFS); and (3) Reconnaissance Report series recharge and ET rates. The ET values are for predevelopment conditions and do not include ET from fields irrigated by groundwater, but they do include spring discharge.

The isotope mass-balance models are used to evaluate MVWFS water budgets by determining if estimated recharge and ET rates and interbasin flows within the MVWFS are consistent with the deuterium and oxygen-18 data (Table 3 and Appendix 3). If mass-balance

model-calculated deuterium and oxygen-18 values are similar to measured values for regional warm springs, then the proposed water budgets are reasonable. In contrast, if mass-balance model-calculated deuterium and oxygen-18 values are significantly different than measured values for regional warm springs, then the proposed water budgets are not reasonable, or interbasin flow routing may be incorrect. In addition to regional warm springs, small warm springs and alluvial wells containing warm water are used as additional evaluation points in the MVWFS. Similar to the regional warm springs, the isotopic content of groundwater in small springs and warm water wells needs to be similar to the calculated value for the proposed interbasin flows and water budgets to be reasonable. The isotopic mass-balance models are not used for determining how much recharge should be assigned to each recharge area or how much ET should be assigned to each valley; rather, the models evaluate whether the assigned recharge and ET values and interbasin flows are consistent with the stable isotope data of the MVWFS. The isotopic mass-balance models are nonunique; a reasonable result confirms the viability of a proposed water budget but it does not prove that the water budget is correct. An isotopic mass-balance model can be used to eliminate unrealistic water budget estimates, or interbasin flows, and to help identify areas where water budgets and/or interbasin flows need to be better understood.

Regional Warm Springs

The same approach that was used for evaluating water budgets and interbasin flows for the WRFS with the isotope mass-balance model was used for the MVWFS. In the MVWFS, the only valley with large regional warm springs is Panaca Valley. Panaca warm spring in northern Panaca Valley has average measured deuterium and oxygen-18 values of -106.9 and -14.14‰, respectively, for 13 samples (Table 2). Interbasin flows from Patterson and Dry valleys into Panaca Valley are about 6 to 8‰ more positive for deuterium and 0.7 to 1.0‰ more positive for oxygen-18 than isotope mass-balance-calculated interbasin flows for the SNWA and SNWA/BARCAS water budgets. The only groundwater in carbonate-rock aquifers of the MWVFS with similar isotopic values to that of Panaca Spring is groundwater in Lake Valley. Panaca Spring discharges out the southern part of the highly faulted carbonate rocks of the Pioche Hills. Thus, the source of this carbonate aquifer water is likely interbasin flow from Lake Valley that flows under Patterson Valley alluvial and volcanic rock aquifers in carbonate-rock aquifers to Panaca Spring. Some of this flow passes through volcanic rock aquifers before discharging from carbonate-rock aquifers as indicated by the presence of elevated sodium and potassium concentrations as compared to other carbonate-rock aquifer groundwaters in the MVWFS (see Meadow Valley Wash Flow System Water Chemistry section in report). Isotope mass-balance model-calculated deuterium and oxygen-18 values for the SNWA, SNWA/BARCAS, and Reconnaissance Report series water budgets are an excellent match to measured values at Panaca Spring if the source of the spring is Lake Valley interbasin flow (Table 3). The lack of isotopic data for groundwater in Patterson Valley, only one site (Dodge Well) in the northern part of the valley with deuterium and oxygen-18 values -107.0 and -14.20‰, respectively, prohibits the determination of isotopic values for groundwater in the carbonate-rock aquifers in the valley. Although the cold (< 20 ^{o}C) water in this alluvial well has deuterium and oxygen-18 values that are very similar to Panaca Spring (Appendix 3), so this northern Patterson Valley groundwater may be representative of interbasin flow out of Lake Valley in the carbonate-rock aquifer. In summary, recharge to Lake Valley is the most likely source of water discharging from Panaca Spring.

The Caliente Hot Springs in southern Panaca Valley also have measured deuterium and oxygen-18 values similar to Lake Valley recharge (-107.9 and -14.44‰ for the average of 8 samples). Isotope mass-balance model-calculated deuterium values are a good match and calculated oxygen-18 values are an acceptable match for measured values for the SNWA and SNWA/BARCAS water budgets and interbasin flows (Table 3). Isotope mass-balance model-calculated deuterium and oxygen-18 values for the Reconnaissance Report series water budget and interbasin flows are an excellent match to measured values for the Caliente Hot Springs (Table 3). Thus, recharge to Lake Valley appears to be the source of water discharging from the Caliente Hot Springs.

The Muddy River springs area in Upper Moapa Valley receives interbasin flow from Lower Meadow Valley Wash at the terminus of the MVWFS, thus these regional warm springs also provide information that can be used to evaluate water budgets and interbasin flow for the MVWFS. As described above for the WRFS, the mass-balance model-calculated deuterium values for the SNWA and SNWA/BARCAS water budgets and interbasin flows are all excellent matches with the discharge-weighted average value (Table 3) and the oxygen-18 values are good to acceptable matches, except for model 2, which is 0.01‰ less than the acceptable range for oxygen-18 (Table 3). The mass-balance model-calculated deuterium and oxygen-18 values for the Reconnaissance Report series water budget and interbasin flow were significantly less than the acceptable values for both models (Table 3). In summary, the mass-balance-calculated isotopic values for springs in the Muddy River Springs area show that the SNWA and SNWA/BARCAS water budgets for the MVWFS is supported by the mass-balance models. However, interbasin flow to the Muddy River Springs area from the MVWFS is only about 10 percent of the interbasin flow to this area, so although isotope mass-balance models for the Muddy Springs area support the SNWA and SNWA/BARCAS MVWFS water budgets, a strong statement cannot be made about water budgets and interbasin flows of the MVWFS using mass-balance model results for the Muddy River Springs area data.

In summary, the isotope mass-balance models produced excellent matches for calculated deuterium and oxygen-18 values with measured values for Panaca Spring for all six water budgets. The isotope mass-balance models produced good matches for calculated deuterium values and acceptable values for calculated oxygen-18 values with measured values for Caliente Hot Spring for the SNWA and SNWA/BARCAS water budgets. The isotope mass-balance models produced excellent matches for calculated deuterium and good matches for calculated oxygen-18 values for Caliente Hot Spring for the Reconnaissance Report series water budget. Some interbasin flow moves from the MVWFS to the WRFS in the Muddy River Springs area, so this also provides information that can be used to evaluate water budgets for the MVWFS. The SNWA and SNWA/BARCAS water budgets produce excellent to acceptable matches for calculated and measured values for the Muddy River Springs and the Reconnaissance Report series water budget does not.

Small Warm Springs and Alluvial Wells with Warm Water

In addition to regional warm spring areas in the MVWFS, small warm springs and alluvial wells with warm water, which are likely fed by regional groundwater flow, are also present. These small warm springs and alluvial wells with warm water provide additional data that can be used to evaluate water budgets and interbasin flow. In the MVWFS, going from north to south down the hydraulic gradient the valleys with small warm springs and

alluvial wells with warm water are Dry, Panaca, and Lower Meadow Valley Wash valleys. Flat Nose Spring in Dry Valley has measured deuterium and oxygen-18 values of -101.0 and -13.40‰, respectively. The SNWA and SNWA/BARCAS water budget mass-balance models have calculated deuterium values of -99.3 and -99.2‰ and oxygen-18 values of -13.25 and -13.24‰, respectively, for interbasin flow into Dry Valley from Rose Valley. These calculated values are excellent matches with measured values for both deuterium and oxygen-18 (Table 3). The Reconnaissance Report Series water budget mass-balance models produced calculated deuterium and oxygen-18 values that were good matches with measured values for both deuterium and oxygen-18 (Table 3). Thus, the isotope mass-balance model-calculated deuterium and oxygen-18 values support the proposed water budgets and interbasin flows above Dry Valley in the MVWFS.

The next downgradient valley with a small warm spring is Panaca Valley. Bennett Spring is located in the west-central part of Panaca Valley. The measured isotopic content of this spring is -103.0 and -13.70‰, for deuterium and oxygen-18, respectively. The source of this spring water could be deep interbasin flow from Lake Valley, inflow from Patterson Valley, or a mixture of regional flow with local recharge. The mass-balance-calculated deuterium values are an excellent match with measured values for 3 of the 4 models and a good match for the other model and calculated oxygen-18 values are a good match with measured values for 3 of the 4 models and an acceptable match for the other model for Patterson Valley interbasin flow being the source of this spring for the SNWA and SNWA/BARCAS water budgets. If the source of Bennett Spring was interbasin flow from Lake Valley rather than Patterson Valley, the mass-balance calculated deuterium values are a good match with measured values for 4 models and calculated oxygen-18 values are an acceptable match with measured values for the SNWA water budget but they not an acceptable match for the SNWA/BARCAS water budget. The mass-balance models using the Reconnaissance Report series water budget produce similar results (Table 3). Thus, the most likely source of Bennett Spring is interbasin flow from Patterson Valley because all three water budgets produce excellent to good matches for calculated isotopic values with measured values, with the exception of one model-calculated oxgygen-18 value, which produced an acceptable match.

Three alluvial wells with warm water are located in the Panaca Warm Spring area—Panaca Town, Lester Mathews, and North Lee wells. The Panaca Town well water has similar deuterium and oxygen-18 values as Panaca Spring and thus likely has the same source water. The other two wells contain water with deuterium and oxygen-18 values that are more positive than Panaca Spring and more negative than local recharge, so the water in these wells is likely a mixture of regional groundwater in the Panaca Spring area with local recharge and/or inflow to the valley from Patterson and Dry valleys. This mixture is needed to produce calculated oxygen-18 values that are an acceptable, or better, match with measured values.

Downgradient of Panaca Valley is Meadow Valley Wash. Kershaw-Ryan Spring #1 is located in the northeastern part of Lower Meadow Valley Wash. The spring has measured deuterium and oxygen-18 values of -95.1 and -13.11‰, respectively. These values are more negative than recharge from the adjacent Clover Mountains (-90.4 and -12.25‰), so this small warm spring likely is interbasin flow rather than local recharge. Both Panaca and Clover valleys flow into northern Meadow Valley Wash. The inflow weighted-average

deuterium and oxygen-18 values for the SNWA and SNWA/BARCAS water budget models range from -100.1 to -95.5‰ and -13.36 to -12.82‰, respectively. All mass-balance model-calculated deuterium values for the SNWA and SNWA/BARCAS water budgets were excellent matches with measured values and were good matches for calculated oxygen-18 values with one calculated value being an excellent match to measured values (Table 3). The mass-balance model-calculated deuterium values for the Reconnaissance Report series water budget were outside of the acceptable level as compared to measured values, but the oxygen-18 values were an excellent and good match with measured values (Table 3). The isotope mass-balance models support the SNWA and SNWA/BARCAS water budgets and interbasin flow into northern Lower Meadow Valley Wash from Panaca and Clover valleys.

Alluvial wells with warm water in Lower Meadow Valley Wash are located in the southernmost part of the valley. These wells include the Railroad Well (Farrier), EH-6, and EH-8 in the Weiser Wash area (Plates 1 and 2 and appendix 3). These three wells have deuterium values ranging from -99.5 to -96.5‰ and oxygen-18 values ranging from -13.90 to -12.50‰. These wells appear to contain well-mixed carbonate aquifer water that is observed in the Muddy River Springs area in Upper Moapa Valley and at well CSV-2 in the northern part of Upper Moapa Valley about halfway between the Muddy River Springs area and the Railroad Well (Farrier). Regional groundwater in the Muddy River Springs area has deuterium values that range from -99.0 to -96.5‰ and oxygen-18 values that range from -13.05 to -12.45‰. The isotopic values of the alluvial wells with warm water fall within the range of Upper Moapa Valley regional groundwaters, except for two of the oxygen-18 values that are more negative than the Muddy River Springs area groundwater.

In summary, the isotope mass-balance models produced similar and excellent to good matches for model-calculated deuterium and oxygen-18 values for small flowing warm springs for the SNWA (2007) and SNWA/BARCAS water budgets and interbasin flows. The isotope mass-balance models using the Reconnaissance Report series water budget produced excellent to good matches for calculated isotopic values for two of the three springs and for oxygen-18 for the third spring, but the calculated deuterium values were outside the acceptable range for the third spring. Alluvial wells with warm water in the MVWFS were only in the Panaca Spring area and in the southernmost part of Lower Meadow Valley Wash. These well waters had isotopic values that were generally in the range of model-calculated isotopic values for those areas.

Meadow Valley Wash Flow System Water Chemistry

An overview evaluation of water chemistry data for groundwater in the MVWFS was performed by plotting water chemistry data on a trilinear diagram. In contrast to groundwater chemistry in the WRFS, groundwater in the MVWFS shows marked differences because of the movement of groundwater through volcanic rock and alluvial aquifers that contain volcanic rock (Figure 17). Groundwater in Lake Valley and the mountains along the western boundary of the MVWFS, which are predominately carbonate rock, is a Ca-Mg-HCO_3 water type, with the exception of one sample. Groundwater in the volcanic rocks of the MVWFS range from a Ca-Mg-HCO_3-type water to a more Na- and K-rich groundwater. Groundwater from alluvial wells has a chemical composition that overlaps that of the volcanic rock aquifer groundwaters, but most samples contain more sulfate and chloride than either the volcanic rock or carbonate-rock groundwaters. Panaca Spring contains a mixed water chemistry with

more Na and K and generally more SO_4 than the carbonate-aquifer groundwaters (Figure 17 and Appendix 3). The increase in Na and K in Panaca Spring, as compared to other carbonate-rock aquifer groundwater, indicates that these waters have flowed through volcanic rock or alluvial aquifers containing volcanic rock minerals and dissolved Na- and K-rich minerals.

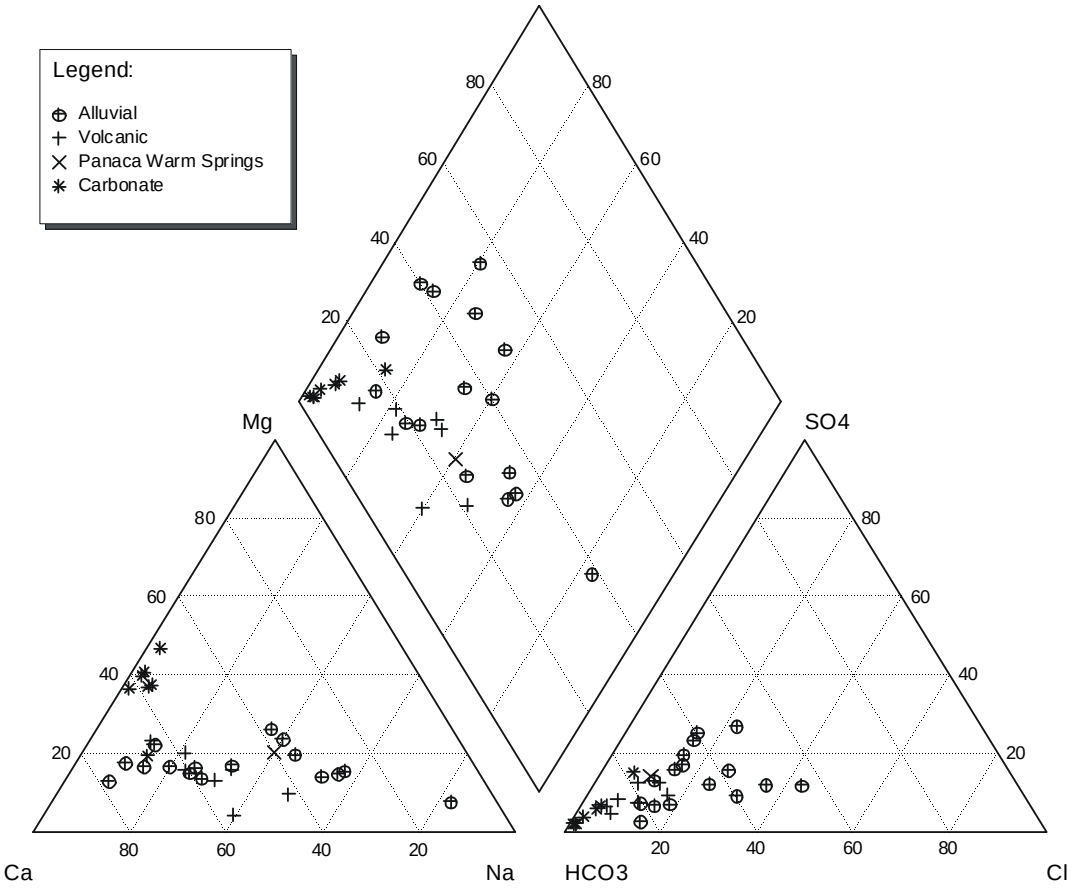

Figure 17. Trilinear plot of Meadow Valley Wash flow system water chemistry (from Thomas *et al*., 2001, Figure 8).

Isotopic Mass-balance Model Sensitivity

Sensitivity analysis of the isotope mass-balance models to changes in recharge and ET values was performed. The Muddy River Springs discharge area is the most downgradient regional warm spring area in the WRFS, so this spring area integrates all recharge and ET and interbasin flows above this spring discharge area. Additionally, there is some flow from the MVWFS that is also discharged in the Muddy River Springs area. Thus, Muddy River Springs is the best regional spring area in the study area to evaluate sensitivity of the isotope mass-balance models. Sensitivity analysis was performed for the two models that evaluated the SNWA (2007) water budget because: (1) this water budget had the best model results in terms of calculated isotopic values that most closely matched measured values throughout the study area, (2) the model results for the SNWA/BARCAS water budget were very similar to the SNWA water budget, so sensitivity analysis would produce

similar results for both water budgets, and (3) the Reconnaissance Report series water budget did not produce acceptable isotope mass-balance model results for the Muddy River Springs area.

The sensitivity analysis was performed in several steps. First, all recharge and ET values were increased and decreased by 20 percent because changing recharge and ET together by the same percent in the isotope mass-balance models should produce similar results as the original water budget. For increasing both recharge and ET by 20 percent, model 1 calculated deuterium increased by 0.1‰ and calculated oxygen-18 increased by 0.01‰, and for model 2 the calculated values increase by 0.0 and 0.01‰. For decreasing both recharge and ET by 20 percent, model 1 calculated deuterium decreased by 0.1‰ and calculated oxygen-18 decreased by 0.02‰, and for model 2 the calculated values decrease by 0.0 and 0.01‰. Thus, the concept of increasing or decreasing the current water budget recharge and ET estimates by the same amount will produce the very similar model results was proven to be valid. Next, only the recharge was increased by 10 percent while holding the ET the same. The calculated isotopic values increased by 1.4 and 1.7‰ and were 2.4 and 3.4‰ more positive than measured values for deuterium and increased by 0.18 and 0.21‰ and were 0.52 and 0.61‰ more positive than measured values for oxygen-18. This shows that calculated deuterium values changed from excellent matches to good and acceptable matches wtih measured values and calculated oxygen-18 values changed from acceptable to unacceptable matches with measured values by simply increasing recharge rates by 10 percent while maintaining the original ET rates. Decreasing ET by 10 percent while keeping recharge the same produced a similar range in calculated deuterium and oxygen-18 values as was observed for increasing recharge by 10 percent. Calculated deuterium and oxygen-18 values were 2.4 and 3.5‰ and 0.53 and 0.62‰ greater than measured values, respectively, and calculated values were a good to acceptable match for deuterium and an unacceptable match for oxygen-18 as compared with measured values in both models.

Next, recharge rates were increased and ET rates were decreased individually in the models by 20 percent. Increasing recharge by 20 percent while holding ET the same resulted in calculated isotopic values increasing by 2.4 and 2.9‰ to 3.4 and 4.6‰ more positive than measured values for deuterium and by 0.31 and 0.36‰ to 0.65 and 0.76‰ more positive than measured values for oxygen-18. A similar change in model-calculated deuterium and oxygen-18 values was observed for a 20-percent decrease in ET rates as for a 20-percent increase in recharge rates. Calculated deuterium values were 3.7 and 5.0‰ and calculated oxygen-18 values were 0.69 and 0.81‰ more positive than measured values. Thus, by either increasing recharge or decreasing ET by 20 percent the isotope mass-balance model-calculated values were unacceptable matches with measured values, except for calculated deuterium in model 1.

In summary, increasing or decreasing recharge and discharge rates of the SNWA (2007) water budget together will produce very similar model results to the original mass-balance model results. Increasing or decreasing recharge and discharge rates separately by 20 percent while keeping the other rate the same, produces model results that are generally unacceptable. Thus, an isotopic mass-balance model evaluation of the SNWA (2007) water budget shows that the recharge and ET rates and interbasin flows produce calculated deuterium and oxygen-18 values that match well with measured values, but increasing or decreasing the recharge or ET rates of the water budget by 20 percent results in

mostly unacceptable calculated deuterium and oxygen-18 values as compared to measured values for regional groundwater discharge at the Muddy River Springs area, the most downgradient regional spring area in the WRFS and MWVFS.

Comparison of this Study's Isotope Mass-balance Models with the 2001 and Other Studies

The new SNWA (2007) water budget and interbasin flows evaluated in this study, as compared to the Thomas *et al*. (2001) study, have overall decreased recharge and ET rates and some different interbasin flow routing. For the WRFS, the SNWA (2007) water budget had total recharge of 155,000 afy as compared to the LVVWD (2001) recharge of 210,000 afy, a 26-percent decrease in total recharge, and a total ET of 140,000 afy, as compared to the LVVWD (2001) ET of 178,000 afy, a 21-percent decrease. For the MVWFS, the SNWA (2007) water budget had total recharge of 73,000 afy as compared to the LVVWD (2001) recharge of 122,000 afy, a 40-percent decrease in total recharge, and a total ET of 63,000 afy, as compared to the LVVWD (2001) ET of 91,000 afy, a 31-percent decrease. Combining the WRFS and MVWFS recharge values for the entire study area shows a decrease from the LVVWD (2001) value of 332,000 afy to 228,000 afy for this study, a decrease of 31 percent. The ET rates for the WRFS and the MVWFS for the entire study area show a decrease from the LVVWD (2001) study of 269,000 to 203,000 afy for this study, an overall decrease in ET of 25 percent. The SNWA/BARCAS recharge and ET rates are very similar to the SNWA (2007) values, so a comparison of the LVVWD (2001) recharge and ET values with the SNWA/BARCAS values is not presented.

Differences in interbasin flows between the Thomas *et al*. (2001) and this study are based on new geologic and hydrologic information (SNWA, 2007). The differences in interbasin flow between this study (flow rates are for the SNWA [2007] water budget) and the Thomas *et al*. (2001) study are: (1) there is no interbasin flow from Long Valley to Newark Valley (Thomas *et al*. [2001] had 8,000 afy of water flowing from Long Valley to Newark Valley); (2) Cave Valley has interbasin flow going to both Southern White River Valley (4,000 afy) and northern Pahroc Valley (9,400 afy), whereas in the Thomas *et al*. (2001) study, all Cave Valley groundwater interbasin flow went to northern Pahroc Valley; (3) all Coal Valley interbasin flow goes into Pahroc Valley, whereas in the Thomas *et al*. (2001) study it all went to Pahranagat Valley; and (4) Lower Meadow Valley Wash interbasin flow goes to both Upper Moapa Valley (Muddy River Springs area; 4,000 afy) and California Wash (5,300 afy), whereas in Thomas *et al*. (2001) all Lower Meadow Valley Wash interbasin flow went to Lower Moapa Valley.

Reconnaissance Report series water budgets used by Eakin (1966) for the part of the WRFS that starts in Long Valley in the north and ends at Muddy River Springs in Upper Moapa Valley in the south did not produce mass-balance model-calculated deuterium and oxygen-18 values that were an acceptable match with measured values at Muddy River Springs. The Reconnaissance Report series recharge and ET values for the 13 valleys of the Eakin WRFS were 104,000 afy, as compared to the SNWA (2007) recharge and ET values of 155,000 and 144,000 afy (including Muddy River spring discharge), respectively. The interbasin flow routing of Eakin (1966) and this study is similar, with differences being in this study: (1) some minor interbasin flow (2,000 afy) from northern Pahroc Valley goes to Dry Lake Valley, (2) Coal Valley interbasin flow goes to Pahroc Valley rather than directly

to Pahranagat Valley, and (3) Delamar Valley interbasin flow enters northern Coyote Springs Valley rather than southern Pahranagat Valley.

The Kirk and Campana (1990) study included the same 13 valleys of the WRFS as the Eakin (1966) study and used Eakin's (1966) interbasin flow routing. They initially set recharge to Maxey-Eakin values but then let the model calculate new recharge values. The model-calculated recharge values were similar to initial Maxey-Eakin recharge estimates. The differences between the Kirk and Campana study and this study are the same as those for the Eakin (1966) study except for: (1) recharge from the Sheep Range to Coyote Springs Valley is 5,000 to 6,000 afy) as compared to the Maxey-Eakin estimate of 2,000 afy and 1,100 afy in this study; (2) the Lower Meadow Valley Wash-Kane Springs Valley area contributed 5,500 to 9,000 afy to the Muddy River Springs discharge area and this study has a total of 8,200 afy going to Muddy River Springs, as compared to the Maxey-Eakin Kane Springs Valley recharge estimate of about 1,000 afy; and (3) 4,000 afy of groundwater is routed out of the WRFS in the Pahranagat Valley area to the west and no interbasin flow leaves Pahranagat Valley to the west in this study or the Eakin (1966) study.

The Thomas *et al*. (1996) study was for the lower part of the WRFS from the Big Muddy Springs area in Upper Moapa Valley to the Alamo Springs area in Pahranagat Valley. The differences between this study and the Thomas *et al*. (1996) study arise primarily from the different approaches the studies used. This study applied average stable isotope values to recharge and discharge areas and used an isotope mass-balance model to evaluate these recharge and discharge estimates. Thomas *et al*. (1996) used average stable isotope values of regional springs and recharge areas and measured flows of regional springs as the total discharge from the lower WRFS. They calculated the amount of water needed from recharge areas and regional flows to obtained measured isotopic values at Muddy River Springs. The main differences between this study and the Thomas *et al*. (1996) study are: (1) the Thomas *et al*. (1996) study estimated that 14,000 afy of the spring discharge from the Muddy River springs area was recharge from the Sheep Range as compared to a Sheep Range recharge estimate of 1,100 afy used for this study, and (2) the Thomas *et al*. (1996) study had 6,000 afy of interbasin flow leaving Pahranagat Valley to the west, whereas this study has no flow leaving Pahranagat Valley to the west. A point of agreement between the two studies is the approximately 8,000 afy of inflow from the Lower Meadow Valley Wash-Kane Springs Valley area into the WRFS.

SUMMARY AND CONCLUSIONS

Isotope mass-balance models were used to evaluate three different water budgets for the regional White River and Meadow Valley Wash groundwater flow systems. The isotopic mass-balance models use average deuterium and oxygen-18 values for recharge and discharge areas to evaluate how closely calculated isotopic values match measured values for regional warm (>20 ^{o}C) spring discharge areas, small (<50 afy) warm springs, and consolidated rock and alluvial wells with warm water. The three water budgets that were evaluated include the SNWA (2007), SNWA/BARCAS (SNWA, 2007; Welch and Bright, 2007), and Reconnaissance Report series water budgets. Two different isotope mass-balance models were used to evaluate the water budgets. In the first model, groundwater ET is satisfied by a mixture of local recharge with interbasin flow entering a valley (if there is any interbasin flow entering the valley). In the second model, groundwater ET is initially

satisfied by local recharge and if ET in a valley exceeds local recharge the remainder of the ET is satisfied by interbasin flow.

Deuterium and oxygen-18 data for regional warm springs, small warm springs, groundwater from wells completed in consolidated rock with warm water, and alluvial wells containing warm water clearly show that there is interbasin groundwater flow in the WRFS and MVWFS. The isotopic data for groundwater at these sites shows that these groundwaters are not from local recharge, but rather they are primarily water that has flowed into a valley from an upgradient valley(s).

The isotopic mass-balance models show that the SNWA (2007) water budget and interbasin flows for the WRFS and the MVWFS produce excellent to acceptable matches of calculated deuterium and oxygen-18 values with measured values for regional warm spring areas, except for one calculated oxygen-18 value, which was only 0.01‰ outside the acceptable range. The models also produce excellent to acceptable matches for calculated values as compared to measured values for all small warm springs and most wells with warm water. An isotopic mass-balance model evaluation of the SNWA/BARCAS water budget and interbasin flows for the WRFS and the MVWFS gave similar but not quite as good results as the SNWA water budget. Two calculated deuterium values were not in the acceptable range for matching measured values of regional warm springs. Isotopic mass-balance model results using the Reconnaissance Report series recharge and ET estimates and Eakin (1966) interbasin flow routing were unacceptable for both the Alamo Warm Springs area in Pahranagat Valley and the Muddy River Springs area in Upper Moapa Valley, except for one of the calculated deuterium values for the Pahranagat Valley warm springs.

Isotopic variability for six recharge area monitoring springs within the study area was relatively small with standard deviations of deuterium and oxygen-18 data ranging from 0.7 to 1.6‰ and 0.06 to 0.33‰, respectively. This range in standard deviation for these six sites is for samples taken quarterly throughout all four seasons with four of the six sites having more than three years of data. The isotopic composition of these springs varied little from season to season as spring flow varied a lot, ranging from about 100 to 2,500 gallons per minute during sample collection, and exceeding 5,000 gallons per minute at peak flow, at the largest discharging monitoring spring. This lack of isotopic variability of recharge area springs is important for isotopic mass-balance models because the isotopic composition of recharge area groundwater varies little over time.

Isotopic variability of 12 regional warm springs in the study area was relatively small, with the standard deviation of deuterium and oxygen-18 data ranging from 0.5 to 1.9‰ for deuterium and 0.05 to 0.22‰ (except for one site with a standard deviation of 0.67‰) for oxygen-18. This range in values is for samples taken throughout all four seasons, with some regional warm spring data spanning almost 40 years and a significant number of springs having data that span 20 to 25 years. This lack of isotopic variability of regional warm springs is important for isotopic mass-balance models because this information indicates that the isotopic composition of regional groundwater varies little over time.

Sensitivity analysis was performed on the SNWA (2007) water budget and flow routing mass-balance models by independently increasing or decreasing recharge and ET. The sensitivity analysis showed that when either recharge or ET were increased or decreased by 20 percent most of the mass-balance model-calculated deuterium and oxygen-18 values

were outside the range of acceptable matches for measured values of the Muddy River Springs discharge area. Thus, the SNWA (2007) water budget recharge and ET values balance such that a 20-percent change in either produces unacceptable isotopic mass-balance model results.

Finally, the relationship of stable isotopes with altitude was evaluated for five major recharge areas in the study area with 14, or more, springs. These five recharge areas include the White Pine and Central Egan ranges in the northern part of the study area and the White Rock Mountains, Delamar Mountains, and Fairview and Bristol ranges in the central and southern part of the study area. There is no apparent relationship of deuterium with altitude in these five recharge areas, except for a slight trend of more negative values with increasing altitude in the Delamar Range. Because of the lack of a relationship of deuterium values with increasing altitude, all recharge area samples regardless of altitude can be used to determine the average isotopic composition of a mountain block recharge area. If a stable isotope-altitude relationship had been observed, then a model that weighted high recharge areas (higher altitude zones) would need to be developed to accurately assign isotopic values to mountain block recharge areas.

REFERENCES

Acheampong, S.Y., H.S. Eastman, and M.G. Cansdale, 2007. Chemical and radiochemical constituents of selected wells and springs in parts of Clark, Lincoln, and White Pine Counties, Nevada. Southern Nevada Water Authority, HAS-ID-0001, 36 p.

Benson, L.V. and H. Klieforth, 1989. Stable isotopes in precipitation and ground water in the Yucca Mountain region, southern Nevada—Paleoclimatic implications, *in* Peterson, D.H., *ed.*, Aspects of climate variability in the Pacific and the western Americas: Geophysical Monograph 55, p. 41-59.

Craig, H., 1961. Isotopic variations in meteoric waters. *Science*, 133: 1702-1703.

Eakin, T.E., 1962. Ground-water Appraisal of Cave Valley in Lincoln and White Pine Counties, Nevada. Ground-Water Resources Reconnaissance Series Report 13. State of Nevada Department of Conservation and Natural Resources.

Eakin, T.E., 1963a. Ground-water Appraisal of Dry Lake and Delamar Valleys, Lincoln County, Nevada. Ground-Water Resources Reconnaissance Series Report 16. State of Nevada Department of Conservation and Natural Resources.

Eakin, T.E., 1963b. Ground-water Appraisal of Garden and Coal Valleys, Lincoln and Nye Counties, Nevada. Ground-Water Resources Reconnaissance Series Report 18. State of Nevada Department of Conservation and Natural Resources.

Eakin, T.E., 1963c. Ground-water Appraisal of Pahranagat and Pahroc Valleys, Lincoln and Nye Counties, Nevada. Ground-Water Resources Reconnaissance Series Report 21. State of Nevada Department of Conservation and Natural Resources.

Eakin, T.E., 1964. Ground-water Appraisal of coyote Spring and kane Spring Valleys and Muddy River Springs Area, Lincoln and Clark Counties, Nevada. Ground-Water Resources Reconnaissance Series Report 25. State of Nevada Department of Conservation and Natural Resources.

Eakin, T.E., 1966. A regional interbasin ground-water system in the White River area, southeastern Nevada. *Water Resources Research*, 2: 251-271.

Eakin, T.E. and D.O. Moore, 1964. Uniformity of discharge of Muddy River Springs, southeastern Nevada, and relation to interbasin movement of ground water. U.S. Geological Survey Professional Paper 501-D: 171-176.

Emme, D.H., 1986. Delineation of subsurface flow in the upper Meadow Valley Wash Area, southeastern Nevada. University of Nevada-Reno, unpublished masters thesis: 90 p.

Hershey, R.L., and W.D. Howcroft, 1998. Laboratory experiments evaluating carbon-14 retardation in a carbonate aquifer. Geological Society of America, Abstracts with Programs, Vol. 30, No. 7, p. A-278.

Hershey, R.L., W. Howcroft, and P.W. Reimus, March 2003. Laboratory Experiments to Evaluate Diffusion of ^{14}C into Nevada Test Site Carbonate Aquifer Matrix. Desert Research Institute Publication No. 45180.

Hershey, R.L., D.L. Decker, S. Earman, J. Ryu, P. Reimus, and E.S. Garcia, Jr., 2007. Laboratory experiments of carbon-14 uptake on calcite and dolomite. The 233rd American Chemical Society National Meeting, March 25-29, 2007, Chicago, IL, Abstract # NUCL 135 (http://oasys2.confex.com/acs/233nm/techprogram/).

Kirk, S.T. and M.E. Campana, 1990. A deuterium-calibrated groundwater flow model of a regional carbonate-alluvial system. *Journal of Hydrology*, 119: 357-388.

Las Vegas Valley Water District (LVVWD), 2001. Water resources and ground-water modeling in the White River and Meadow Valley Flow Systems—White Pine, Lincoln, Nye, and Clark counties, Nevada, 285 p.

Maxey, G.B. and T.E. Eakin, 1949. Ground water in White River Valley, White Pine, Nye, and Lincoln Counties, Nevada. Nevada State Engineer Water Resources Bulletin 8: 59 p.

Mifflin, M.D., 1968. Delineation of ground-water flow systems in Nevada. Desert Research Institute, Technical Report Series H-W, Publication #4: 100 p.

Pohlmann, K.F., D.J. Campana, J.B. Chapman, and S. Earman, 1998. Investigation of the origin of springs in the Lake Mead National Recreation Area. Desert Research Institute Publication #41161: 92 p.

Rush, F.E., 1964. Ground-water appraisal of the Meadow Valley area, Lincoln and Clark Counties, Nevada. Nevada Department of Conservation and Natural Resources, Water Resources Reconnaissance Report 27: 43 p.

Rush, F.E. and T.E. Eakin, 1963. Ground-water appraisal of Lake Valley in Lincoln and White Pine Counties, Nevada. Nevada Department of Conservation and Natural Resources, Water Resources Reconnaissance Report 24: 29 p.

Smith, G.I., I. Friedman, H. Klieforth, and K. Hardcastle, 1979. Areal distribution of deuterium in eastern California precipitation, 1968-1969. *Applied Meteorology*, 18: 172-188.

Southern Nevada Water Authority (SNWA), 2007. Water-resources assessment and hydrogeologic report for Cave, Dry Lake, and Delamar Valleys. Southern Nevada Water Authority Report, Las Vegas, Nevada.

Thomas, J.M., J.L. Mason, and J.D. Crabtree, 1986. Ground-water levels in the Great Basin Region of Nevada, Utah, and adjacent states. U.S. Geological Survey Hydrologic Investigations Atlas HA-694-B: 2 plates.

Thomas, J.M., 1996. Geochemical and isotopic interpretation of groundwater flow, geochemical processes, and age dating of groundwater in the carbonate-rock aquifers of the southern Basin and Range: University of Nevada, Reno, Ph.D. dissertation, 135 p.

Thomas, J.M., A.H. Welch, and M.D. Dettinger, 1996. Geochemistry and isotope hydrology of representative aquifers in the Great Basin Region of Nevada, Utah, and adjacent states. U.S. Geological Survey Professional Paper 1409-C: 100 p.

Thomas, J.M., S.C. Calhoun, and W.B. Apambire, 2001. A deuterium mass-balance interpretation of groundwater sources and flows in southeastern Nevada. Desert Research Institute Publication #41169: 46 p.

Welch, A.H. and D.J. Bright, (in press). Water resources of the Basin and Range Carbonte-Rock Aquifer System (BARCAS), eastern Nevada and western Utah. U.S. Geological Survey Investigations Report.

Winograd, I.J. and I. Friedman, 1972. Deuterium as a tracer of regional ground-water flow, southern Great Basin, Nevada and California. *Bulletin of the Geological Society of America*, 83: 3691-3708.

Winograd, I.J., T.B. Coplen, J.M. Landwehr, A.C. Riggs, K.R. Ludwig, BJ. Szabo, P.T. Kolesar, and KM. Revesz, 1992. Continuous 500,000-year climate record from vein calcite in Devils Hole, Nevada. *Science,* 258: 255-260.

Winograd, I.J., J.M. Landwehr, T.B. Coplen, W.D. Sharp, A.C. Riggs, K.R. Ludwig and P.T. Kolesar, 2006. Devils Hole, Nevada, $\delta^{18}O$ record extended to the mid-Holocene. *Quaternary Research*, 66: 202-212.

APPENDIX 1. Isotope mass-balance model summaries for the six mass-balance models

		SNWA (2007 Water Budget)								
Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	Long Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	19,900				-122.4	-15.96			
ET	ET	3,000						-122.4	-15.96	
154	GW Outflow (Newark)	0						-122.4	-15.96	
174	GW Outflow (Jakes)	16,900						-122.4	-15.96	
174	Jakes Valley									
175	Inflow (Long)	16,900				-122.4	-15.96			
TR	Total Recharge	12,300				-119.9	-15.71			
ET	ET	400						-121.3	-15.86	
207N	GW Outflow (NWRV)	28,800						-121.3	-15.86	
180	Cave Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	14,700				-106.5	-14.28			
ET	ET	1,300						-106.5	-14.28	
Well	180W902		1	601	Deep Well	-104.7	-14.12	*-106.5*	*-14.28*	*Local recharge*
Well	180W501		1	600	Deep Well	-105.6	-14.12	*-106.5*	*-14.28*	*Local recharge*
208	GW Outflow (Pahroc)	9,400						-106.5	-14.28	
207S	GW Outflow (SWRV)	4,000						-106.5	-14.28	
207N	North White River Valley									
174	Inflow (Jakes)	28,800				-121.3	-15.86			
TR	Total Recharge	27,500				-113.4	-15.16			
Warm	Discharge Warm Sprs (Avg)	8,900	14			-122.6	-15.92	*-121.3*	*-15.86*	*Inter-basin flow from Jakes Valley*
ET	ET	20,500						-117.5	-15.52	
207S	GW Outflow (SWRV)	35,800						-117.5	-15.52	
207S	South White River Valley	WRV Tot Recharge 41,000								
207N	Inflow (N White River)	35,800				-117.5	-15.52			
180	Inflow (Cave)	4,000				-106.5	-14.28			
TR	Total Recharge	13,500				-106.7	-14.18			
Warm	Discharge Warm Sprs (Avg)	13,200	13			-119.2	-15.71	*-117.5*	*-15.52*	*Inter-basin flow from Northern White River Valley*
ET	ET	46,900						-113.9	-15.09	
208	GW Outflow (Pahroc)	6,400						-113.9	-15.09	
172	Garden Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	24,800				-104.7	-14.08			
ET	ET	1,700						-104.7	-14.08	
171	GW Outflow (Coal)	23,100						-104.7	-14.08	
171	Coal Valley									
172	Inflow (Garden)	23,100				-104.7	-14.08			

172	Inflow (SWRV)	0				-113.9	-15.09				
TR	Total Recharge	3,900				-98.4	-12.95				
Carb Well	USGS-MX C.V. Well (CV-DT-1)		2	176	Well	-109.0	-14.56	*-104.7*	*-14.08*	*Underflow from Garden Valley*	
ET	ET	0						-103.8	-13.91		
208	GW Outflow (Pahroc)	27,000						-103.8	-13.91		
208	Pahroc Valley										
207S	Inflow (S. White River)	6,400				-113.9	-15.09				
170	Inflow (Cave)	9,400				-106.5	-14.28				
171	Inflow (Coal)	27,000				-103.8	-13.91				
TR	Total Recharge	4,500				-96.4	-12.75				
ET	ET	0						-105.0	-14.04		
209	GW Outflow (Pahranagat)	45,300						-105.0	-14.04		
181	GW Outflow (Dry Lake)	2,000						-106.5	-14.28		
209	Pahranagat Valley										
208	Inflow (Pahroc)	45,300				-105.0	-14.04				
181	Inflow (Dry Lake)	0				-98.9	-13.12				
209	Inflow (Delamar)	0				-97.3	-12.92				
TR	Total Recharge	5,500				-97.6	-13.91				
Warm	Discharge Warm Springs (Avg)	25,400	31			-108.9	-14.26	*-105.0*	*-14.04*	*Inter-basin flow from Pahroc Valley*	
ET	ET	28,500						-104.2	-14.02		
Well	209M-1		1	608	Deep Well	-104.7	-13.53	*-105.0*	*-14.04*	*Inter-basin flow from Pahroc Valley*	
210	GW Outflow (Coyote Spr)	22,300						-104.2	-14.02		
181	Dry Lake Valley										
208	Inflow (Pahroc)	2,000				-106.5	-14.28				
TR	Total Recharge	15,700				-98.0	-12.97				
Carb Well	Fugro Dry Lake V Deep Well		2	179	Well	-107.5	-14.16	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*	
Carb Well	181M1		1	603	Deep Well	-105.0	-13.67	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*	
Carb Well	181W909M		1	604	Deep Well	-104.6	-13.50	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*	
ET	ET	0						-98.9	-13.12		
209	GW Outflow (Pahranagat)	0						-98.9	-13.12		
182	GW Outflow (Delamar)	17,700						-98.9	-13.12		
182	Delamar Valley										
181	Inflow (Dry Lake)	17,700				-98.9	-13.12				
TR	Total Recharge	6,400				-92.8	-12.39				
ET	ET	0						-97.3	-12.92		
Well	182W906M		1	607	Deep Well	-100.3	-13.33	*-98.9*	*-13.12*	*Inter-basin flow from Dry Lake Valley*	
209	GW Outflow (Pahranagat)	0						-97.3	-12.92		
210	GW Outflow (Coyote Spr)	24,100						-97.3	-12.92		
206	Kane Springs Valley										
0	Inflow (None)	0				0.0	0.00				
TR	Total Recharge	4,200				-88.9	-12.20				
ET	ET	0						-88.9	-12.20		
210	GW Outflow (Coyote Spr)	4,200						-88.9	-12.20		
210	Coyote Springs Valley										
209	Inflow (Pahranagat)	22,300				-104.2	-14.02				
182	Inflow (Delamar)	24,100				-97.3	-12.92				
206	Inflow (Kane Springs)	4,200				-88.9	-12.20				

TR	Total Recharge	2,100		-90.9	-12.53				
CARB	Carbonate Well (Avg)		6	-100.7	-13.11	*-99.6*	*-13.35*	*Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys*	
ET	ET	0				-99.3	-13.32		
219	GW Outflow (Muddy)	37,700				-99.3	-13.32		
217	GW Outflow (Hidden)	15,000				-99.3	-13.32		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
219	Upper Moapa (Muddy) Valley								
205	Inflow (LMVW)	4,000		-93.5	-12.59				
210	Inflow (Coyote)	37,700		-99.3	-13.32				
TR	Total Recharge	0		-87.4	-11.92				
Warm	Dicharge Warm Sprs (Avg)	8,300	49	-97.8	-12.90	*-98.7*	*-13.25*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*	
CARB	Deep Carbonate Well (Avg)		4	-97.9	-12.97	*-98.7*	*-13.25*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*	
ET	ET	6,000				-98.73	-13.25		
Gage	Moapa Gage	34,000							
218	SW Outflow (California)	34,000							
218	GW Outflow (California)	1,700				-98.7	-13.25		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
217	Hidden Valley								
210	Inflow (Coyote)	15,000		-99.3	-13.32				
TR	Total Recharge	0		-81.0	-10.60				
ET	ET	0				-99.3	-13.32		
216	GW Outflow (Garnet)	15,000				-99.3	-13.32		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
216	Garnet Valley								
217	Inflow (Hidden)	15,000		-99.3	-13.32				
TR	Total Recharge	100		-81.0	-10.60				
CARB	Wells (Avg)		6	-96.9	-13.32	*-99.3*	*-13.32*	*Inter-basin flow from Hidden Valley*	
ET	ET	0				-99.2	-13.30		
218	GW Outflow (California)	15,100				-99.2	-13.30		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
218	California Wash								
219	SW Inflow (Muddy)	34,000							
205	SW Inflow (LMVW)	0							
219	Inflow (Muddy)	1,700		-98.7	-13.25				
205	Inflow (Lower Meadow VW)	5,300		-93.5	-12.59				
216	Inflow (Garnet)	15,100		-99.2	-13.30				
TR	Total Recharge	0		0.0	0.00				
CARB	Carbonate Well (Avg)			-99.0	-13.45	*-97.8*	*-13.12*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*	
ET	ET	4,500				-97.8	-13.12		
220	GW Outflow (Lower Moapa)	18,900				-97.8	-13.12		
215	GW Outflow (Black Mtn Area)	2,000				-97.8	-13.12		
220	SW Outflow (Lower Moapa)	30,700							
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
215	Black Mountains Area								
218	Inflow (California Wash)	2,000		-97.8	-13.12				
TR	Total Recharge	0		0.0	0.00				
CARB	Carbonate Spr (Avg)	1,663	13	-91.3	-12.01	*-97.8*	*-13.12*	*Weighted Average of Inflow from Califronia Wash*	
ET	ET	1,400				-97.8	-13.12		
999	GW Outflow (Colorado River)	600				-97.8	-13.12		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
220	Lower Moapa Valley								
218	GW Inflow (California Wash)	18,900		-97.8	-13.12				
218	SW Inflow (California Wash)	30,700							

TR	Total Recharge	0		-88.3	-12.50			
CARB	Carbonate Well (Avg)		2	-91.0	-12.58	*-93.5*	*-12.59*	*Inter-basin flow from Lower Meadow Valley Wash*
ET	ET	25,300				-97.8	-13.12	
999	GW Outflow (Colorado River)	15,300				-97.8	-13.12	
999	SW Outflow (Colorado River)	9,000						
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Colorado R	Lake Mead (Colorado River)							
210	GW Inflow (Black Mountains Area)	600		-97.8	-13.12			
205	GW Inflow (Lower Moapa)	15,300		-97.8	-13.12			
999	Groundwater Total	15,900				-97.8	-13.12	
205	SW Inflow (Lower Moapa)	9,000						
999	Surface water Total	9,000						
999	Inflow Total	24,900						
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
183	Lake Valley							
0	Inflow (None)	0		0.0	0.00			
TR	Total Recharge	12,300		-105.5	-14.08			
ET	ET	6,700				-105.5	-14.08	
202	GW Outflow (Patterson)	5,600				-105.5	-14.08	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
202	Patterson Valley							
183	Inflow (Lake)	5,600		-105.5	-14.08			
TR	Total Recharge	10,600		-98.3	-13.03			
ET	ET	1,300				-100.8	-13.39	
203	GW Outflow (Panaca)	14,900				-100.8	-13.39	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
201	Spring Valley							
0	Inflow (None)	0		0.0	0.00			
TR	Total Recharge	11,200		-99.4	-13.28			
ET	ET	3,900				-99.4	-13.28	
200	GW Outflow (Eagle)	7,300				-99.4	-13.28	
200	SW Outflow (Eagle)	0				-97.5	-13.00	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
200	Eagle Valley							
201	Inflow (Spring)	7,300		-99.4	-13.28			
201	SW Inflow (Spring)	0		-97.5	-13.00			
TR	Total Recharge	2,000		-98.7	-13.15			
ET	ET	1,000				-99.3	-13.25	
199	GW Outflow (Rose)	8,300				-99.3	-13.25	
198	SW Outflow (Rose)	0				-99.3	-13.25	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
199	Rose Valley							
200	Inflow (Eagle)	8,300		-99.3	-13.25			
200	SW Inflow (Eagle)	0		-99.3	-13.25			
TR	Total Recharge	200		-98.4	-13.08			
ET	ET	600				-99.2	-13.24	
198	GW Outflow (Dry)	7,900				-99.2	-13.24	
198	SW Outflow (Dry)	0				-99.3	-13.25	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX

198	**Dry Valley**									
199	**Inflow (Rose)**	**7,900**				**-99.2**	**-13.24**			
199	**SW Inflow (Rose)**	**0**				**-99.3**	**-13.25**			
TR	**Total Recharge**	**3,200**				**-96.9**	**-12.96**			
ET	**ET**	**3,700**						**-98.6**	**-13.16**	
203	**GW Outflow (Panaca)**	**7,400**						**-98.6**	**-13.16**	
203	**SW Outflow (Panaca)**	**0**						**-99.2**	**-13.24**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
204	**Clover Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
TR	**Total Recharge**	**14,900**				**-92.1**	**-12.46**			
ET	**ET**	**5,200**						**-92.1**	**-12.46**	
205	**GW Outflow (LMVW)**	**9,700**						**-92.1**	**-12.46**	
205	**SW Outflow (LMVW)**	**0**						**-92.1**	**-12.46**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
203	**Panaca Valley**									
202	**Inflow (Patterson)**	**14,900**				**-100.8**	**-13.39**			
198	**Inflow (Dry)**	**7,400**				**-98.6**	**-13.16**			
198	**SW Inflow (Dry)**	**0**				**-99.2**	**-13.24**			
TR	**Total Recharge**	**5,500**				**-95.8**	**-12.78**			
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	***-100.8***	***-13.39***	***Inter-basin flow from Patterson Valley***
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	***-105.5***	***-14.08***	***Inter-basin flow from Lake Valley***
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	***-105.5***	***-14.08***	***Inter-basin flow from Lake Valley***
ET	**ET**	**18,900**						**-99.2**	**-13.21**	
205	**GW Outflow (LMVW)**	**8,900**						**-99.2**	**-13.21**	
205	**SW Outflow (LMVW)**	**0**						**-97.0**	**-13.10**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
205	**Lower Meadow Valley Wash**									
203	**Inflow (Panaca)**	**8,900**				**-99.2**	**-13.21**			
204	**Inflow (Clover)**	**9,700**				**-92.1**	**-12.46**			
203	**SW Inflow (Panaca)**	**0**				**-97.0**	**-13.10**			
204	**SW Inflow (Clover)**	**0**				**-92.1**	**-12.46**			
TR	**Total Recharge**	**12,600**				**-90.4**	**-12.24**			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	***-95.5***	***-12.82***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	**ET**	**21,900**						**-93.5**	**-12.59**	
206	**GW Outflow (Upper Moapa)**	**4,000**						**-93.5**	**-12.59**	
218	**GW Outflow (California Wash)**	**5,300**						**-93.5**	**-12.59**	
218	**GW Outflow (Lower Moapa)**	**0**						**-93.5**	**-12.59**	
218	**SW Outflow (California Wash)**	**0**						**-93.5**	**-12.59**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX

		SNWA (2007 Water Budget)								
Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	Long Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	19,900				-122.4	-15.96			
ET	ET	3,000						-122.4	-15.96	
154	GW Outflow (Newark)	0						-122.4	-15.96	
174	GW Outflow (Jakes)	16,900						-122.4	-15.96	
174	Jakes Valley									
175	Inflow (Long)	16,900				-122.4	-15.96			
TR	Total Recharge	12,300				-119.9	-15.71			
ET	ET	400						-119.9	-15.71	
207N	GW Outflow (NWRV)	28,800						-121.3	-15.86	
180	Cave Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	14,700				-106.5	-14.28			
ET	ET	1,300						-106.5	-14.28	
Well	180W902		1	601	Deep Well	-104.7	-14.12	*-106.5*	*-14.28*	*Local recharge*
Well	180W501		1	600	Deep Well	-105.6	-14.12	*-106.5*	*-14.28*	*Local recharge*
208	GW Outflow (Pahroc)	9,400						-106.5	-14.28	
207S	GW Outflow (SWRV)	4,000						-106.5	-14.28	
207N	North White River Valley									
174	Inflow (Jakes)	28,800				-121.3	-15.86			
TR	Total Recharge	27,500				-113.4	-15.16			
Warm	Discharge Warm Sprs (Avg)	8,900	14			-122.6	-15.92	*-121.3*	*-15.86*	*Inter-basin flow from Jakes Valley*
ET	ET	20,500						-113.4	-15.16	
207S	GW Outflow (SWRV)	35,800						-119.8	-15.7	
207S	South White River Valley	WRV Tot Recharge 41,000								
207N	Inflow (N White River)	35,800				-119.8	-15.72			
180	Inflow (Cave)	4,000				-106.5	-14.28			
TR	Total Recharge	13,500				-106.7	-14.18			
Warm	Discharge Warm Sprs (Avg)	13,200	13			-119.2	-15.71	*-119.8*	*-15.72*	*Inter-basin flow from Northern White River Valley*
ET	ET	46,900						-115.1	-15.18	
208	GW Outflow (Pahroc)	6,400						-118.5	-15.58	
172	Garden Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	24,800				-104.7	-14.08			
ET	ET	1,700						-104.7	-14.08	
171	GW Outflow (Coal)	23,100						-104.7	-14.08	
171	Coal Valley									
172	Inflow (Garden)	23,100				-104.7	-14.08			

172	Inflow (SWRV)	0				-118.5	-15.58				
TR	Total Recharge	3,900				-98.4	-12.95				
Carb Well	USGS-MX C.V. Well (CV-DT-1)		2	176	Well	-109.0	-14.56	*-104.7*	*-14.08*	*Underflow from Garden Valley*	
ET	ET	0						-98.4	-12.95		
208	GW Outflow (Pahroc)	27,000						-103.8	-13.91		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
208	Pahroc Valley										
207S	Inflow (S. White River)	6,400				-118.5	-15.58				
170	Inflow (Cave)	9,400				-106.5	-14.28				
171	Inflow (Coal)	27,000				-103.8	-13.91				
TR	Total Recharge	4,500				-96.4	-12.75				
ET	ET	0						-96.4	-12.75		
209	GW Outflow (Pahranagat)	45,300						-105.6	-14.10		
181	GW Outflow (Dry Lake)	2,000						-106.5	-14.28		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
209	Pahranagat Valley										
208	Inflow (Pahroc)	45,300				-105.6	-14.10				
181	Inflow (Dry Lake)	0				-98.9	-13.12				
209	Inflow (Delamar)	0				-97.3	-12.92				
TR	Total Recharge	5,500				-97.6	-13.91				
Warm	Discharge Warm Springs (Avg)	25,400	31			-108.9	-14.26	*-105.6*	*-14.10*	*Inter-basin flow from Pahroc Valley*	
ET	ET	28,500						-104.1	-14.07		
Well	209M-1		1	608	Deep Well	-104.7	-13.53	*-105.6*	*-14.10*	*Inter-basin flow from Pahroc Valley*	
210	GW Outflow (Coyote Spr)	22,300						-105.6	-14.10		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
181	Dry Lake Valley										
208	Inflow (Pahroc)	2,000				-106.5	-14.28				
TR	Total Recharge	15,700				-98.0	-12.97				
Carb Well	Fugro Dry Lake V Deep Well		2	179	Well	-107.5	-14.16	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*	
Carb Well	181M1		1	603	Deep Well	-105.0	-13.67	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*	
Carb Well	181W909M		1	604	Deep Well	-104.6	-13.50	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*	
ET	ET	0						-98.0	-12.97		
209	GW Outflow (Pahranagat)	0						-98.9	-13.12		
182	GW Outflow (Delamar)	17,700						-98.9	-13.12		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
182	Delamar Valley										
181	Inflow (Dry Lake)	17,700				-98.9	-13.12				
TR	Total Recharge	6,400				-92.8	-12.39				
ET	ET	0						-92.8	-12.39		
Well	182W906M		1	607	Deep Well	-100.3	-13.33	*-98.9*	*-13.12*	*Inter-basin flow from Dry Lake Valley*	
209	GW Outflow (Pahranagat)	0						-97.3	-12.92		
210	GW Outflow (Coyote Spr)	24,100						-97.3	-12.92		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
206	Kane Springs Valley										
0	Inflow (None)	0				0.0	0.00				
TR	Total Recharge	4,200				-88.9	-12.20				
ET	ET	0						-88.9	-12.20		
210	GW Outflow (Coyote Spr)	4,200						-88.9	-12.20		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
210	Coyote Springs Valley										
209	Inflow (Pahranagat)	22,300				-105.6	-14.10				
182	Inflow (Delamar)	24,100				-97.3	-12.92				
206	Inflow (Kane Springs)	4,200				-88.9	-12.20				

TR	Total Recharge	2,100		-90.9	-12.53				
CARB	Carbonate Well (Avg)		6	-100.7	-13.11	*-100.3*	*-13.38*	*Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys*	
ET	ET	0				-90.9	-12.53		
219	GW Outflow (Muddy)	37,700				-99.9	-13.35		
217	GW Outflow (Hidden)	15,000				-99.9	-13.35		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
219	Upper Moapa (Muddy) Valley								
205	Inflow (LMVW)	4,000		-96.1	-12.90				
210	Inflow (Coyote)	37,700		-99.9	-13.35				
TR	Total Recharge	0		-87.4	-11.92				
Warm	Dicharge Warm Sprs (Avg)	8,300	49	-97.8	-12.90	*-99.5*	*-13.31*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*	
CARB	Deep Carbonate Well (Avg)	Input into M	4	-97.9	-12.97	*-99.5*	*-13.31*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*	
ET	ET	6,000				-99.5	-13.31		
Gage	Moapa Gage	34,000							
218	SW Outflow (California)	34,000							
218	GW Outflow (California)	1,700				-99.5	-13.31		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
217	Hidden Valley								
210	Inflow (Coyote)	15,000		-99.9	-13.35				
TR	Total Recharge	0		-81.0	-10.60				
ET	ET	0				-81.0	-10.60		
216	GW Outflow (Garnet)	15,000				-99.9	-13.35		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
216	Garnet Valley								
217	Inflow (Hidden)	15,000		-99.9	-13.35				
TR	Total Recharge	100		-81.0	-10.60				
CARB	Wells (Avg)		6	-96.9	-13.32	*-99.9*	*-13.35*	*Inter-basin flow from Hidden Valley*	
ET	ET	0				-81.0	-10.60		
218	GW Outflow (California)	15,100				-99.8	-13.33		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
218	California Wash								
219	SW Inflow (Muddy)	34,000							
205	SW Inflow (LMVW)	0							
219	Inflow (Muddy)	1,700		-99.5	-13.31				
205	Inflow (Lower Meadow VW)	5,300		-96.1	-12.90				
216	Inflow (Garnet)	15,100		-99.8	-13.33				
TR	Total Recharge	0		-82.0	-10.6				
CARB	Carbonate Well (Avg)			-99.0	-13.45	*-98.9*	*-13.22*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*	
ET	ET	4,500				-82.0	-10.60		
220	GW Outflow (Lower Moapa)	18,900				-98.9	-13.22		
215	GW Outflow (Black Mtn Area)	2,000				-98.9	-13.22		
220	SW Outflow (Lower Moapa)	30,700							
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
215	Black Mountains Area								
218	Inflow (California Wash)	2,000		-98.9	-13.22				
TR	Total Recharge	0		-81.3	-10.75				
CARB	Carbonate Spr (Avg)	1,700	13	-91.3	-12.01	*-98.9*	*-13.22*	*Weighted Average of Inflow from Califronia Wash*	
ET	ET	1,400				-81.3	-10.75		
999	GW Outflow (Colorado River)	600				-98.9	-13.22		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
220	Lower Moapa Valley								
218	GW Inflow (California Wash)	18,900		-98.9	-13.22				
218	SW Inflow (California Wash)	30,700							

TR	Total Recharge	0		-88.3	-12.50			
CARB	Carbonate Well (Avg)		2	-91.0	-12.58	*-96.1*	*-12.90*	*Inter-basin flow from Lower Meadow Valley Wash*
ET	ET	25,300				-88.3	-12.50	
999	GW Outflow (Colorado River)	15,300				-98.9	-13.22	
999	SW Outflow (Colorado River)	9,000						
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Colorado R	Lake Mead (Colorado River)							
210	GW Inflow (Black Mountains Area)	600		-98.9	-13.22			
205	GW Inflow (Lower Moapa)	15,300		-98.9	-13.22			
999	Groundwater Total	15,900				-98.9	-13.22	
205	SW Inflow (Lower Moapa)	9,000						
999	Surfacewater Total	9,000						
999	Inflow Total	24,900						
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
183	Lake Valley							
0	Inflow (None)	0		0.0	0.00			
TR	Total Recharge	12,300		-105.5	-14.08			
ET	ET	6,700				-105.5	-14.08	
202	GW Outflow (Patterson)	5,600				-105.5	-14.08	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
202	Patterson Valley							
183	Inflow (Lake)	5,600		-105.5	-14.08			
TR	Total Recharge	10,600		-98.3	-13.03			
ET	ET	1,300				-98.3	-13.03	
203	GW Outflow (Panaca)	14,900				-101.0	-13.43	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
201	Spring Valley							
0	Inflow (None)	0		0.0	0.00			
TR	Total Recharge	11,200		-99.4	-13.28			
ET	ET	3,900				-99.4	-13.28	
200	GW Outflow (Eagle)	7,300				-99.4	-13.28	
200	SW Outflow (Eagle)	0				-97.5	-13.00	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
200	Eagle Valley							
201	Inflow (Spring)	7,300		-99.4	-13.28			
201	SW Inflow (Spring)	0		-97.5	-13.00			
TR	Total Recharge	2,000		-98.7	-13.15			
ET	ET	1,000				-98.7	-13.15	
199	GW Outflow (Rose)	8,300				-99.3	-13.26	
198	SW Outflow (Rose)	0				-98.7	-13.00	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
199	Rose Valley							
200	Inflow (Eagle)	8,300		-99.3	-13.26			
200	SW Inflow (Eagle)	0		-98.7	-13.00			
TR	Total Recharge	200		-98.4	-13.08			
ET	ET	600				-98.4	-13.08	
198	GW Outflow (Dry)	7,900				-99.3	-13.25	
198	SW Outflow (Dry)	0				-98.4	-13.08	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX

198	**Dry Valley**									
199	**Inflow (Rose)**	**7,900**				**-99.3**	**-13.25**			
199	**SW Inflow (Rose)**	**0**				**-98.4**	**-13.08**			
TR	**Total Recharge**	**3,200**				**-96.9**	**-12.96**			
ET	**ET**	**3,700**						**-97.2**	**-13.00**	
203	**GW Outflow (Panaca)**	**7,400**						**-99.3**	**-13.25**	
203	**SW Outflow (Panaca)**	**0**						**-97.2**	**-13.00**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
204	**Clover Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
TR	**Total Recharge**	**14,900**				**-92.1**	**-12.46**			
ET	**ET**	**5,200**						**-92.1**	**-12.46**	
205	**GW Outflow (LMVW)**	**9,700**						**-92.1**	**-12.46**	
205	**SW Outflow (LMVW)**	**0**						**-92.1**	**-12.46**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
203	**Panaca Valley**									
202	**Inflow (Patterson)**	**14,900**				**-101.0**	**-13.43**			
198	**Inflow (Dry)**	**7,400**				**-99.3**	**-13.25**			
198	**SW Inflow (Dry)**	**0**				**-97.2**	**-13.00**			
TR	**Total Recharge**	**5,500**				**-95.8**	**-12.78**			
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	***-101.0***	***-13.43***	***Inter-basin flow from Patterson Valley***
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	***-105.5***	***-14.08***	***Inter-basin flow from Lake Valley***
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	***-105.5***	***-14.08***	***Inter-basin flow from Lake Valley***
ET	**ET**	**18,900**						**-99.1**	**-13.20**	
205	**GW Outflow (LMVW)**	**8,900**						**-100.4**	**-13.37**	
205	**SW Outflow (LMVW)**	**0**						**-99.1**	**-13.20**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
205	**Lower Meadow Valley Wash**									
203	**Inflow (Panaca)**	**8,900**				**-100.4**	**-13.37**			
204	**Inflow (Clover)**	**9,700**				**-92.1**	**-12.46**			
203	**SW Inflow (Panaca)**	**0**				**-99.1**	**-13.20**			
204	**SW Inflow (Clover)**	**0**				**-92.1**	**-12.46**			
TR	**Total Recharge**	**12,600**				**-90.6**	**-12.25**			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	***-96.1***	***-12.90***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	**ET**	**21,900**						**-92.9**	**-12.53**	
206	**GW Outflow (Upper Moapa)**	**4,000**						**-96.1**	**-12.90**	
218	**GW Outflow (California Wash)**	**5,300**						**-96.1**	**-12.90**	
218	**SW Outflow (California Wash)**	**0**						**-90.6**	**-12.25**	
XXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXXX

SNWA/BARCASS (SNWA, 2007; Welch and Bright, 2007)

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	**Long Valley**									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	21,000				-122.4	-15.96			
ET	ET	1,200						-122.4	-15.96	
154	GW Outflow (Newark)	0						-122.4	-15.96	
174	GW Outflow (Jakes)	19,800						-122.4	-15.96	
174	**Jakes Valley**									
175	Inflow (Long)	19,800				-122.4	-15.96			
TR	Total Recharge	13,000				-119.9	-15.71			
ET	ET	900						-121.4	-15.86	
207N	GW Outflow (NWRV)	31,900						-121.4	-15.86	
180	**Cave Valley**									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	15,400				-106.5	-14.28			
ET	ET	1,600						-106.5	-14.28	
Well	180W902		1	601	Deep Well	-104.7	-14.12			
Well	180W501		1	600	Deep Well	-105.6	-14.12			
208	GW Outflow (Pahroc)	9,800						-106.5	-14.28	
207S	GW Outflow (SWRV)	4,000						-106.5	-14.28	
207N	**North White River Valley**									
174	Inflow (Jakes)	31,900				-121.4	-15.86			
TR	Total Recharge	28,600				-113.5	-15.16			
Warm	Discharge Warm Sprs (Avg)	8,900	14			-122.6	-15.92	*-121.4*	*-15.86*	*Inter-basin flow from Jakes Valley*
ET	ET	29,500						-117.6	-15.53	
207S	GW Outflow (SWRV)	31,000						-117.6	-15.53	
207S	**South White River Valley**	WRV Tot Recharge 42,900								
207N	Inflow (N White River)	31,000				-117.6	-15.53			
180	Inflow (Cave)	4,000				-106.5	-14.28			
TR	Total Recharge	14,300				-106.7	-14.18			
Warm	Discharge Warm Sprs (Avg)	13,200	13			-119.2	-15.71	*-117.6*	*-15.53*	*Inter-basin flow from Northern White River Valley*
ET	ET	47,200						-113.6	-15.04	
208	GW Outflow (Pahroc)	2,100						-113.6	-15.04	
172	**Garden Valley**									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	25,700				-104.7	-14.08			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
ET	ET	1,700						-104.7	-14.08	
171	GW Outflow (Coal)	24,000						-104.7	-14.08	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
171	Coal Valley									
172	Inflow (Garden)	24,000				-104.7	-14.08			
172	Inflow (SWRV)	0				-113.6	-15.04			
TR	Total Recharge	4,200				-98.4	-12.95			
ET	ET	0						-103.7	-13.91	
Carb Well	USGS-MX C.V. Well (CV-DT-1)		2	176	Well	-109.0	-14.56	*-104.7*	*-14.08*	*Underflow from Garden Valley*
208	GW Outflow (Pahroc)	28,200						-103.7	-13.91	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
208	Pahroc Valley									
207S	Inflow (S. White River)	2,100				-113.6	-15.04			
180	Inflow (Cave)	9,800				-106.5	-14.28			
171	Inflow (Coal)	28,200				-103.7	-13.91			
TR	Total Recharge	4,900				-96.4	-12.75			
ET	ET	0						-104.0	-13.92	
209	GW Outflow (Pahranagat)	43,000						-104.0	-13.92	
181	GW Outflow (Dry Lake)	2,000						-106.5	-14.28	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
209	Pahranagat Valley									
208	Inflow (Pahroc)	43,000				-104.0	-13.92			
181	Inflow (Dry Lake)	0				-99.0	-13.12			
209	Inflow (Delamar)	0				-97.3	-12.93			
TR	Total Recharge	5,900				-97.0	-13.67			
Warm	Discharge Warm Springs (Avg)	25,400	31			-108.9	-14.26	*-104.0*	*-13.92*	*Inter-basin flow from Pahroc Valley*
ET	ET	28,500						-103.2	-13.89	
Well	209M-1		1	608	Deep Well	-104.7	-13.53	*-104.0*	*-13.92*	*Inter-basin flow from Pahroc Valley*
210	GW Outflow (Coyote Spr)	20,400						-103.2	-13.89	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
181	Dry Lake Valley									
180	Inflow (Pahroc)	2,000				-106.5	-14.28			
TR	Total Recharge	16,700				-98.1	-12.98			
ET	ET	0						-99.0	-13.12	
Carb Well	Fugro Dry Lake V Deep Well		2	179	Well	-107.5	-14.16	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*
Carb Well	181M1		1	603	Deep Well	-105.0	-13.67	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*
Carb Well	181W909M		1	604	Deep Well	-104.6	-13.50	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*
209	GW Outflow (Pahranagat)	0						-99.0	-13.12	
182	GW Outflow (Delamar)	18,700						-99.0	-13.12	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
182	Delamar Valley									
181	Inflow (Dry Lake)	18,700				-99.0	-13.12			
TR	Total Recharge	6,800				-92.8	-12.39			
ET	ET	0						-97.3	-12.93	
Well	182W906M		1	607	Deep Well	-100.3	-13.33	*-99.0*	*-13.12*	*Inter-basin flow from Dry Lake Valley*
209	GW Outflow (Pahranagat)	0						-97.3	-12.93	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
210	GW Outflow (Coyote Spr)	25,500						-97.3	-12.93	
206	Kane Springs Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	4,500				-88.9	-12.20			
ET	ET	0						-88.9	-12.20	
210	GW Outflow (Coyote Spr)	4,500						-88.9	-12.20	
210	Coyote Springs Valley									
209	Inflow (Pahranagat)	20,400				-103.2	-13.89			
182	Inflow (Delamar)	25,500				-97.3	-12.93			
206	Inflow (Kane Springs)	4,500				-88.9	-12.20			
TR	Total Recharge	2,300				-90.8	-12.53			
CARB	Carbonate Well (Avg)		14			-100.7	-13.11	*-98.9*	*-13.25*	*Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys*
ET	ET	0						-98.6	-13.22	
219	GW Outflow (Muddy)	37,700						-98.6	-13.22	
217	GW Outflow (Hidden)	15,000						-98.6	-13.22	
219	Upper Moapa (Muddy) Valley									
205	Inflow (LMVW)	4,000				-93.6	-12.60			
210	Inflow (Coyote)	37,700				-98.6	-13.22			
TR	Total Recharge	0				-87.4	-11.92			
Warm	Dicharge Warm Sprs (Avg)	8,300	49			-97.8	-12.90	*-98.1*	*-13.16*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
CARB	Deep Carbonate Well (Avg)		4			-97.9	-12.97	*-98.1*	*-13.16*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
ET	ET	6,000						-98.1	-13.16	
Gage	Moapa Gage	34,000								
218	SW Outflow (California)	34,000								
218	GW Outflow (California)	1,700						-98.1	-13.16	
217	Hidden Valley									
210	Inflow (Coyote)	15,000				-98.6	-13.22			
TR	Total Recharge	0				-81.0	-10.60			
ET	ET	0						-98.6	-13.22	
216	GW Outflow (Garnet)	15,000						-98.6	-13.22	
216	Garnet Valley									
217	Inflow (Hidden)	15,000				-98.6	-13.22			
TR	Total Recharge	100				-81.0	-10.60			
CARB	Wells (Avg)		6			-96.9	-13.32	*-98.6*	*-13.22*	*Inter-basin flow from Hidden Valley*
ET	ET	0						-98.5	-13.20	
218	GW Outflow (California)	15,100						-98.5	-13.20	
218	California Wash									

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
219	SW Inflow (Muddy)	34,000								
205	SW Inflow (LMVW)	0								
219	Inflow (Muddy)	1,700				-98.1	-13.16			
205	Inflow (Lower Meadow VW)	5,200				-93.6	-12.60			
216	Inflow (Garnet)	15,100				-98.5	-13.20			
TR	Total Recharge	0				0.0	0.00			
ET	ET	4,500						-97.3	-13.06	
CARB	Carbonate Well (Avg)					-99.0	-13.45	*-97.3*	*-13.06*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*
220	GW Outflow (Lower Moapa)	18,800						-97.3	-13.06	
215	GW Outflow (Black Mtn Area)	2,000						-97.3	-13.06	
220	SW Outflow (Lower Moapa)	30,700								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
215	Black Mountains Area									
218	Inflow (California Wash)	2,000				-97.3	-13.06			
TR	Total Recharge	0				0.0	0.00			
ET	ET	1,400						-97.3	-13.06	
CARB	Carbonate Spr (Avg)	1,700	13			-91.3	-12.01	*-97.3*	*-13.06*	*Weighted Average of Inflow from Califronia Wash*
999	GW Outflow (Colorado River)	600						-97.3	-13.06	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
220	Lower Moapa Valley									
218	GW Inflow (California Wash)	18,800				-97.3	-13.06			
218	SW Inflow (California Wash)	30,700								
TR	Total Recharge	0				-88.3	-12.50			
ET	ET	25,300						-97.3	-13.06	
CARB	Carbonate Well (Avg)		2			-91.0	-12.58	*-93.6*	*-12.60*	*Inter-basin flow from Lower Meadow Valley Wash*
999	GW Outflow (Colorado River)	17,200						-97.3	-13.06	
999	SW Outflow (Colorado River)	7,000								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Colorado R	Lake Mead (Colorado River)									
210	GW Inflow (Black Mountains Area)	600				-97.3	-13.06			
205	GW Inflow (Lower Moapa)	17,200				-97.3	-13.06			
999	Groundwater Total	17,800						-97.3	-13.06	
205	SW Inflow (Lower Moapa)	7,000								
999	Surface water Total	7,000								
999	Inflow Total	24,800								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
183	Lake Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	12,200				-105.7	-14.12			
ET	ET	6,100						-105.7	-14.12	
202	GW Outflow (Patterson)	6,100						-105.7	-14.12	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
202	Patterson Valley									
183	Inflow (Lake)	6,100				-105.7	-14.12			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
TR	Total Recharge	10,500				-98.3	-13.03			
ET	ET	1,300						-101.0	-13.43	
203	GW Outflow (Panaca)	15,300						-101.0	-13.43	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
201	Spring Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	11,100				-99.4	-13.28			
ET	ET	3,900						-99.4	-13.28	
200	GW Outflow (Eagle)	7,200						-99.4	-13.28	
200	SW Outflow (Eagle)	0						-97.5	-13.00	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
200	Eagle Valley									
201	Inflow (Spring)	7,200				-99.4	-13.28			
201	SW Inflow (Spring)	0				-97.5	-13.00			
TR	Total Recharge	2,000				-98.7	-13.15			
ET	ET	1,000						-99.3	-13.25	
199	GW Outflow (Rose)	8,200						-99.3	-13.25	
198	SW Outflow (Rose)	0						-99.3	-13.25	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
199	Rose Valley									
200	Inflow (Eagle)	8,200				-99.3	-13.25			
200	SW Inflow (Eagle)	0				-99.3	-13.25			
TR	Total Recharge	200				-98.4	-13.08			
ET	ET	600						-99.2	-13.24	
198	GW Outflow (Dry)	7,800						-99.2	-13.24	
198	SW Outflow (Dry)	0						-99.3	-13.25	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
198	Dry Valley									
199	Inflow (Rose)	7,800				-99.2	-13.24			
199	SW Inflow (Rose)	0				-99.3	-13.25			
TR	Total Recharge	3,200				-96.9	-12.96			
ET	ET	3,700						-98.5	-13.16	
203	GW Outflow (Panaca)	7,300						-98.5	-13.16	
203	SW Outflow (Panaca)	0						-99.2	-13.24	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
204	Clover Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	14,700				-92.1	-12.46			
ET	ET	5,200						-92.1	-12.46	
205	GW Outflow (LMVW)	9,500						-92.1	-12.46	
205	SW Outflow (LMVW)	0						-92.1	-12.46	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
203	Panaca Valley									

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
202	Inflow (Patterson)	15,300				-101.0	-13.43			
198	Inflow (Dry)	7,300				-98.5	-13.16			
198	SW Inflow (Dry)	0				-99.2	-13.24			
TR	Total Recharge	5,500				-95.8	-12.78			
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	*-101.0*	*-13.43*	*Inter-basin flow from Patterson Valley*
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	*-105.7*	*-14.12*	*Inter-basin flow from Lake Valley*
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	*-105.7*	*-14.12*	*Inter-basin flow from Lake Valley*
ET	ET	18,900						-99.3	-13.24	
205	GW Outflow (LMVW)	9,200						-99.3	-13.24	
205	SW Outflow (LMVW)	0						-97.0	-13.10	
205	Lower Meadow Valley Wash									
203	Inflow (Panaca)	9,200				-99.3	-13.24			
204	Inflow (Clover)	9,500				-92.1	-12.46			
203	SW Inflow (Panaca)	0				-97.0	-13.10			
204	SW Inflow (Clover)	0				-92.1	-12.46			
TR	Total Recharge	12,400				-90.4	-12.24			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	*-95.7*	*-12.84*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	ET	21,900						-93.6	-12.60	
206	GW Outflow (Upper Moapa)	4,000						-93.6	-12.60	
218	GW Outflow (California Wash)	5,200						-93.6	-12.60	
218	GW Outflow (Lower Moapa)	0						-93.6	-12.60	
218	SW Outflow (California Wash)	0						-93.6	-12.60	

SNWA/BARCASS (SNWA, 2007; Welch and Bright, 2007)											
Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
175	Long Valley										
0	Inflow (None)	0				0.0	0.00				
TR	Total Recharge	21,000				-122.4	-15.96				
ET	ET	1,200						-122.4	-15.96		
154	GW Outflow (Newark)	0						-122.4	-15.96		
174	GW Outflow (Jakes)	19,800						-122.4	-15.96		
174	Jakes Valley										
175	Inflow (Long)	19,800				-122.4	-15.96				
TR	Total Recharge	13,000				-119.9	-15.71				
ET	ET	900						-119.9	-15.71		
207N	GW Outflow (NWRV)	31,900						-121.4	-15.86		
180	Cave Valley										
0	Inflow (None)	0				0.0	0.00				
TR	Total Recharge	15,400				-106.5	-14.28				
ET	ET	1,600						-106.5	-14.28		
Well	180W902		1	601	Deep Well	-104.7	-14.12				
Well	180W501		1	600	Deep Well	-105.6	-14.12				
208	GW Outflow (Pahroc)	9,800						-106.5	-14.28		
207S	GW Outflow (SWRV)	4,000						-106.5	-14.28		
207N	North White River Valley										
174	Inflow (Jakes)	31,900				-121.4	-15.86				
TR	Total Recharge	28,600				-113.5	-15.16				
Warm	Discharge Warm Sprs (Avg)	8,900	14			-122.6	-15.92	*-121.4*	*-15.86*	*Inter-basin flow from Jakes Valley*	
ET	ET	29,500						-113.7	-15.19		
207S	GW Outflow (SWRV)	31,000						-121.4	-15.86		
207S	South White River Valley	WRV Tot Recharge 42,900									
207N	Inflow (N White River)	31,000				-121.4	-15.86				
180	Inflow (Cave)	4,000				-106.5	-14.28				
TR	Total Recharge	14,300				-106.7	-14.18				
Warm	Discharge Warm Sprs (Avg)	13,200	13			-119.2	-15.71	*-121.4*	*-15.86*	*Inter-basin flow from Northern White River Valley*	
ET	ET	47,200						-115.8	-15.23		
208	GW Outflow (Pahroc)	2,100						-119.7	-15.68		
172	Garden Valley										
0	Inflow (None)	0				0.0	0.00				
TR	Total Recharge	25,700				-104.7	-14.08				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
ET	ET	1,700						-104.7	-14.08	
171	GW Outflow (Coal)	24,000						-104.7	-14.08	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
171	Coal Valley									
172	Inflow (Garden)	24,000				-104.7	-14.08			
172	Inflow (SWRV)	0				-119.7	-15.68			
TR	Total Recharge	4,200				-98.4	-12.95			
Carb Well	USGS-MX C.V. Well (CV-DT-1)		2	176	Well	-109.0	-14.56	*-104.7*	*-14.08*	*Underflow from Garden Valley*
ET	ET	0						-98.4	-12.95	
208	GW Outflow (Pahroc)	28,200						-103.7	-13.91	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
208	Pahroc Valley									
180	Inflow (Cave)	9,800				-106.5	-14.28			
207S	Inflow (S. White River)	2,100				-119.7	-15.68			
171	Inflow (Coal)	28,200				-103.7	-13.91			
TR	Total Recharge	4,900				-96.4	-12.75			
ET	ET	0						-96.4	-12.75	
181	GW Outflow (Dry Lake)	2,000						-106.5	-14.28	
209	GW Outflow (Pahranagat)	43,000						-104.3	-13.95	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
209	Pahranagat Valley									
208	Inflow (Pahroc)	43,000				-104.3	-13.95			
181	Inflow (Dry Lake)	0				-99.0	-13.12			
209	Inflow (Delamar)	0				-97.3	-12.93			
TR	Total Recharge	5,900				-97.0	-13.67			
Warm	Discharge Warm Springs (Avg)	25,400	31			-108.9	-14.26	*-104.3*	*-13.95*	*Inter-basin flow from Pahroc Valley*
ET	ET	28,500						-102.8	-13.89	
Well	209M-1		1	608	Deep Well	-104.7	-13.53	*-104.3*	*-13.95*	*Inter-basin flow from Pahroc Valley*
210	GW Outflow (Coyote Spr)	20,400						-104.3	-13.95	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
181	Dry Lake Valley									
208	Inflow (Pahroc)	2,000				-106.5	-14.28			
TR	Total Recharge	16,700				-98.1	-12.98			
Carb Well	Fugro Dry Lake V Deep Well		2	179	Well	-107.5	-14.16	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*
Carb Well	181M1		1	603	Deep Well	-105.0	-13.67	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*
Carb Well	181W909M		1	604	Deep Well	-104.6	-13.50	*-106.5*	*-14.28*	*Inter-basin flow from Cave Valley*
ET	ET	0						-98.1	-12.98	
209	GW Outflow (Pahranagat)	0						-99.0	-13.12	
182	GW Outflow (Delamar)	18,700						-99.0	-13.12	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
182	Delamar Valley									
181	Inflow (Dry Lake)	18,700				-99.0	-13.12			
TR	Total Recharge	6,800				-92.8	-12.39			
ET	ET	0						-92.8	-12.39	
Well	182W906M		1	607	Deep Well	-100.3	-13.33	*-99.0*	*-13.12*	*Inter-basin flow from Dry Lake Valley*
209	GW Outflow (Pahranagat)	0						-97.3	-12.93	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
210	GW Outflow (Coyote Spr)	25,500						-97.3	-12.93	
206	Kane Springs Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	4,500				-88.9	-12.20			
ET	ET	0						-88.9	-12.20	
210	GW Outflow (Coyote Spr)	4,500						-88.9	-12.20	
210	Coyote Springs Valley									
209	Inflow (Pahranagat)	20,400				-104.3	-13.95			
182	Inflow (Delamar)	25,500				-97.3	-12.93			
206	Inflow (Kane Springs)	4,500				-88.9	-12.20			
TR	Total Recharge	2,300				-90.8	-12.53			
ET	ET	0						-90.8	-12.53	
CARB	Carbonate Well (Avg)		6			-100.7	-13.11	*-99.4*	*-13.28*	*Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys*
219	GW Outflow (Muddy)	37,700						-99.0	-13.24	
217	GW Outflow (Hidden)	15,000						-99.0	-13.24	
219	Upper Moapa (Muddy) Valley									
205	Inflow (LMVW)	4,000				-96.3	-12.92			
210	Inflow (Coyote)	37,700				-99.0	-13.24			
TR	Total Recharge	0				-87.4	-11.92			
Warm	Dicharge Warm Sprs (Avg)	8,300	49			-97.8	-12.90	*-98.8*	*-13.21*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
CARB	Deep Carbonate Well (Avg)	Input into M	4			-97.9	-12.97	*-98.8*	*-13.21*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
ET	ET	6,000						-98.8	-13.21	
Gage	Moapa Gage	34,000								
218	SW Outflow (California)	34,000								
218	GW Outflow (California)	1,700						-98.8	-13.21	
217	Hidden Valley									
210	Inflow (Coyote)	15,000				-99.0	-13.24			
TR	Total Recharge	0				-81.0	-10.60			
ET	ET	0						-81.0	-10.60	
216	GW Outflow (Garnet)	15,000						-99.0	-13.24	
216	Garnet Valley									
217	Inflow (Hidden)	15,000				-99.0	-13.24			
TR	Total Recharge	100				-81.0	-10.60			
CARB	Wells (Avg)		6			-96.9	-13.32	*-99.0*	*-13.24*	*Inter-basin flow from Hidden Valley*
ET	ET	0						-81.0	-10.60	
218	GW Outflow (California)	15,100						-98.9	-13.23	
218	California Wash									

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
219	SW Inflow (Muddy)	34,000								
205	SW Inflow (LMVW)	0								
219	Inflow (Muddy)	1,700				-98.8	-13.21			
205	Inflow (Lower Meadow VW)	5,200				-96.3	-12.92			
216	Inflow (Garnet)	15,100				-98.9	-13.23			
TR	Total Recharge	0				-82.0	-10.6			
ET	ET	4,500						-82.0	-10.60	
CARB	Carbonate Well (Avg)					-99.0	-13.45	*-98.3*	*-13.15*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*
220	GW Outflow (Lower Moapa)	18,800						-98.3	-13.15	
215	GW Outflow (Black Mtn Area)	2,000						-98.3	-13.15	
220	SW Outflow (Lower Moapa)	30,700								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
215	Black Mountains Area									
218	Inflow (California Wash)	2,000				-98.3	-13.15			
TR	Total Recharge	0				-81.3	-10.75			
ET	ET	1,400						-81.3	-10.75	
CARB	Carbonate Spr (Avg)	1,700	13			-91.3	-12.01	*-98.3*	*-13.15*	*Weighted Average of Inflow from Califronia Wash*
999	GW Outflow (Colorado River)	600						-98.3	-13.15	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
220	Lower Moapa Valley									
218	GW Inflow (California Wash)	18,800				-98.3	-13.15			
218	SW Inflow (California Wash)	30,700								
TR	Total Recharge	0				-88.3	-12.50			
CARB	Carbonate Well (Avg)		2			-91.0	-12.58	*-96.3*	*-12.92*	*Inter-basin flow from Lower Meadow Valley Wash*
ET	ET	25,300						-88.3	-12.50	
999	GW Outflow (Colorado River)	17,200						-98.3	-13.15	
999	SW Outflow (Colorado River)	7,000								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Colorado R	Lake Mead (Colorado River)									
210	GW Inflow (Black Mountains Area)	600				-98.3	-13.15			
205	GW Inflow (Lower Moapa)	17,200				-98.3	-13.15			
999	Groundwater Total	17,800						-98.3	-13.15	
205	SW Inflow (Lower Moapa)	7,000								
999	Surfacewater Total	7,000								
999	Inflow Total	24,800								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
183	Lake Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	12,200				-105.7	-14.12			
ET	ET	6,100						-105.7	-14.12	
202	GW Outflow (Patterson)	6,100						-105.7	-14.12	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
202	Patterson Valley									
183	Inflow (Lake)	6,100				-105.7	-14.12			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
TR	Total Recharge	10,500				-98.3	-13.03			
ET	ET	1,300						-98.3	-13.03	
203	GW Outflow (Panaca)	15,300						-101.3	-13.47	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
201	Spring Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	11,100				-99.4	-13.28			
ET	ET	3,900						-99.4	-13.28	
200	GW Outflow (Eagle)	7,200						-99.4	-13.28	
200	SW Outflow (Eagle)	0						-97.5	-13.00	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
200	Eagle Valley									
201	Inflow (Spring)	7,200				-99.4	-13.28			
201	SW Inflow (Spring)	0				-97.5	-13.00			
TR	Total Recharge	2,000				-98.7	-13.15			
ET	ET	1,000						-98.7	-13.15	
199	GW Outflow (Rose)	8,200						-99.3	-13.26	
198	SW Outflow (Rose)	0						-98.7	-13.00	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
199	Rose Valley									
200	Inflow (Eagle)	8,200				-99.3	-13.26			
200	SW Inflow (Eagle)	0				-98.7	-13.00			
TR	Total Recharge	200				-98.4	-13.08			
ET	ET	600						-98.4	-13.08	
198	GW Outflow (Dry)	7,800						-99.3	-13.25	
198	SW Outflow (Dry)	0						-98.4	-13.08	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
198	Dry Valley									
199	Inflow (Rose)	7,800				-99.3	-13.25			
199	SW Inflow (Rose)	0				-98.4	-13.08			
TR	Total Recharge	3,200				-96.9	-12.96			
ET	ET	3,700						-97.2	-13.00	
203	GW Outflow (Panaca)	7,300						-99.3	-13.25	
203	SW Outflow (Panaca)	0						-97.2	-13.00	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
204	Clover Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	14,700				-92.1	-12.46			
ET	ET	5,200						-92.1	-12.46	
205	GW Outflow (LMVW)	9,500						-92.1	-12.46	
205	SW Outflow (LMVW)	0						-92.1	-12.46	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
203	Panaca Valley									
202	Inflow (Patterson)	15,300				-101.3	-13.47			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
198	Inflow (Dry)	7,300				-99.3	-13.25			
198	SW Inflow (Dry)	0				-97.2	-13.00			
TR	Total Recharge	5,500				-95.8	-12.78			
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	*-101.3*	*-13.47*	*Inter-basin flow from Patterson Valley*
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	*-105.7*	*-14.12*	*Inter-basin flow from Lake Valley*
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	*-105.7*	*-14.12*	*Inter-basin flow from Lake Valley*
ET	ET	18,900						-99.2	-13.22	
205	GW Outflow (LMVW)	9,200						-100.6	-13.40	
205	SW Outflow (LMVW)	0						-99.2	-13.22	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
205	Lower Meadow Valley Wash									
203	Inflow (Panaca)	9,200				-100.6	-13.40			
204	Inflow (Clover)	9,500				-92.1	-12.46			
203	SW Inflow (Panaca)	0				-99.2	-13.22			
204	SW Inflow (Clover)	0				-92.1	-12.46			
TR	Total Recharge	12,400				-90.4	-12.24			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	*-96.3*	*-12.92*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	ET	21,900						-93.0	-12.54	
206	GW Outflow (Upper Moapa)	4,000						-96.3	-12.92	
218	GW Outflow (California Wash)	5,200						-96.3	-12.92	
218	SW Outflow (California Wash)	0						-90.4	-12.24	
XXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXXX

Reconnaissance Series Water Budget

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	Long Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	10,300				-121.7	-15.85			
ET	ET	2,000						-121.7	-15.85	
174	GW Outflow (Jakes)	8,300						-121.7	-15.85	
174	Jakes Valley									
175	Inflow (Long)	8,300				-121.7	-15.85			
TR	Total Recharge	17,000				-119.7	-15.66			
ET	ET	0						-120.3	-15.72	
207N	GW Outflow (NWRV)	25,300						-120.3	-15.72	
180	Cave Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	14,000				-106.6	-14.28			
ET	ET	200						-106.6	-14.28	
Well	180W902		1	601	Deep Well	-104.7	-14.12			
Well	180W501		1	600	Deep Well	-105.6	-14.12			
181	GW Outflow (Dry Lake)	0						-106.6	-14.28	
207S	GW Outflow (SWRV)	13,800						-106.6	-14.28	
207N	North White River Valley									
174	Inflow (Jakes)	25,300				-120.3	-15.72			
TR	Total Recharge	25,700				-113.7	-15.16			
Warm	Discharge Warm Sprs (Avg)	8,900	14			-122.6	-15.92	*-120.3*	*-15.72*	*Inter-basin flow from Jakes Valley*
ET	ET	22,000						-117.0	-15.44	
207S	GW Outflow (SWRV)	29,000						-117.0	-15.44	
207S	South White River Valley	WRV Tot Recharge 38,000								
207N	Inflow (N White River)	29,000				-117.0	-15.44			
180	Inflow (Cave)	13,800				-106.6	-14.28			
TR	Total Recharge	12,300				-106.7	-14.18			
Warm	Discharge Warm Sprs (Avg)	13,200	13			-119.2	-15.71	*-117.0*	*-15.44*	*Inter-basin flow from Northern White River Valley*
ET	ET	13,000						-112.1	-14.87	
208	GW Outflow (Pahroc)	42,100						-112.1	-14.87	
208	GW Outflow (Garden Valley)	0						-112.1	-14.87	
172	Garden Valley									
172	Inflow (None)	0				-112.1	-14.87			
TR	Total Recharge	10,000				-104.2	-14.00			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
ET	ET	2,000						-104.2	-14.00	
171	GW Outflow (Coal)	8,000						-104.2	-14.00	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
171	Coal Valley									
172	Inflow (Garden)	8,000				-104.2	-14.00			
172	Inflow (SWRV)	0				-112.1	-14.87			
TR	Total Recharge	2,000				-98.7	-13.05			
Carb Well	USGS-MX C.V. Well (CV-DT-1)		2	176	Well	-109.0	-14.56	*-104.2*	*-14.0*	*Underflow from Garden Valley*
ET	ET	0						-103.1	-13.81	
208	GW Outflow (Pahranagat)	10,000						-103.1	-13.81	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
208	Pahroc Valley									
207S	Inflow (S. White River)	42,100				-112.1	-14.87			
171	Inflow (Coal)	0				0.0	0.00			
TR	Total Recharge	2,200				-96.8	-12.80			
ET	ET	0						-111.3	-14.77	
209	GW Outflow (Pahranagat)	44,300						-111.3	-14.77	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
209	Pahranagat Valley									
208	Inflow (Pahroc)	44,300				-111.3	-14.77			
171	Inflow (Coal)	10,000				-103.1	-13.81			
209	Inflow (Delamar)	6,200				-97.7	-12.96			
TR	Total Recharge	1,800				-97.4	-13.83			
Warm	Discharge Warm Springs (Avg)	25,400	31			-108.9	-14.26	*-111.3*	*-14.77*	*Inter-basin flow from Pahroc Valley*
ET	ET	25,000						-108.3	-14.41	
Warm	209M-1		1	608	Deep Well	-104.7	-13.53	*-111.3*	*-14.77*	*Inter-basin flow from Pahroc Valley*
210	GW Outflow (Coyote Spr)	37,300						-108.3	-14.41	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
181	Dry Lake Valley									
180	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	5,000				-98.9	-13.10			
Carb Well	Fugro Dry Lake V Deep Well		2	179	Well	-107.5	-14.16	*-98.9*	*-13.10*	*Local Recharge*
Carb Well	181M1		1	603	Deep Well	-105.0	-13.67	*-98.9*	*-13.10*	*Local Recharge*
Carb Well	181W909M		1	604	Deep Well	-104.6	-13.50	*-98.9*	*-13.10*	*Local Recharge*
ET	ET	0						-98.9	-13.10	
209	GW Outflow (Pahranagat)	0						-98.9	-13.10	
182	GW Outflow (Delamar)	5,000						-98.9	-13.10	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
182	Delamar Valley									
181	Inflow (Dry Lake)	5,000				-98.9	-13.10			
TR	Total Recharge	1,200				-92.7	-12.38			
ET	ET	0						-97.7	-12.96	
Well	182W906M		1	607	Deep Well	-100.3	-13.33	*-98.9*	*-13.10*	*Inter-basin flow from Dry Lake Valley*
209	GW Outflow (Pahranagat)	6,200						-97.7	-12.96	
210	GW Outflow (Coyote Spr)	0						-97.7	-12.96	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
206	Kane Springs Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	600				-89.0	-12.22			
ET	ET	0						-89.0	-12.22	
210	GW Outflow (Coyote Spr)	600						-89.0	-12.22	
210	Coyote Springs Valley									
209	Inflow (Pahranagat)	37,300				-108.3	-14.41			
182	Inflow (Delamar)	0				0.0	0.00			
206	Inflow (Kane Springs)	600				-89.0	-12.22			
TR	Total Recharge	2,000				-92.6	-12.81			
ET	ET	500						-107.2	-14.29	
219	GW Outflow (Muddy)	39,400						-107.2	-14.29	
217	GW Outflow (Hidden)	0						0.0	0.00	
216	GW Outflow (Garnet)	0						0.0	0.00	
219	Upper Moapa (Muddy) Valley									
205	Inflow (LMVW)	0				0.0	0.00			
210	Inflow (Coyote)	39,400				-107.2	-14.29			
TR	Total Recharge	0				-87.3	-11.86			
Warm	Dicharge Warm Sprs (Avg)	8,300	49			-97.8	-12.90	*-107.2*	*-14.29*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
CARB	Deep Carbonate Well (Avg)	Input into M	4			-97.9	-12.97	*-107.2*	*-14.29*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
ET	ET	0						-107.2	-14.29	
Gage	Moapa Gage	34,000								
218	SW Outflow (California)	34,000						-107.2	-14.29	
218	GW Outflow (California)	5,400						-107.2	-14.29	
217	Hidden Valley									
210	Inflow (Coyote)	0				0.0	0.00			
TR	Total Recharge	400				-81.0	-10.60			
ET	ET	0						-81.0	-10.60	
216	GW Outflow (Garnet)	400						-81.0	-10.60	
216	Garnet Valley									
217	Inflow (Hidden)	400				-81.0	-10.60			
TR	Total Recharge	400				-81.0	-10.60			
CARB	Wells (Avg)		6			-96.9	-13.32	*-81.0*	*-10.60*	*Inter-basin flow from Hidden Valley*
ET	ET	0						-81.0	-10.60	
218	GW Outflow (California)	800						-81.0	-10.60	
218	California Wash									
219	Inflow (LMVW)	12,700				-98.7	-13.20			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
219	Inflow (Muddy)	5,400				-107.2	-14.29			
216	Inflow (Garnet)	800				-81.0	-10.60			
218	SW Inflow (Muddy)	34,000								
TR	Total Recharge	100				-82.0	-10.60			
CARB	Carbonate Well (Avg)					-99.0	-13.45	*-103.8*	*-13.82*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*
ET	ET	1,000						-100.3	-13.38	
220	GW Outflow (Lower Moapa)	21,300						-100.3	-13.38	
215	GW Outflow (Black Mtn Area)	0						-100.3	-13.38	
220	SW Outflow (Lower Moapa)	30,700								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
215	Black Mountains Area									
218	Inflow (California Wash)	0				-100.3	-13.38			
TR	Total Recharge	100				-85.0	-10.95			
CARB	Carbonate Spr (Avg)	1,700	13			-91.3	-12.01	*-85.0*	*-10.95*	*Weighted Average of Inflow from Califronia Wash plus recharge from Muddy Mountains*
ET	ET	0						-85.0	-10.95	
999	GW Outflow (Colorado River)	100						-85.0	-10.95	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
220	Lower Moapa Valley									
219	Inflow (Muddy)	21,300				-107.2	-14.29			
218	SW Inflow (Muddy)	30,700								
TR	Total Recharge	100				-88.3	-12.50			
CARB	Carbonate Well (Avg)		2			-91.0	-12.58	*-107.2*	*-14.29*	*Inter-basin flow from Lower Meadow Valley Wash*
ET	ET	24,000						-107.1	-14.29	
999	GW Outflow (Colorado River)	21,100						-107.1	-14.29	
999	SW Outflow (Colorado River)	7,000								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Colorado R	Lake Mead (Colorado River)									
210	GW Inflow (Black Mountains Area)	0				0.0	0.00			
205	GW Inflow (Lower Moapa)	21,100				-107.1	-14.29			
999	Groundwater Total	21,100						-107.1	-14.29	
205	SW Inflow (Lower Moapa)	7,000								
999	Surfacewater Total	7,000								
999	Inflow Total	28,100								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
183	Lake Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	13,000				-106.2	-14.24			
ET	ET	9,000						-106.2	-14.24	
202	GW Outflow (Patterson)	4,000						-106.2	-14.24	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
202	Patterson Valley									
183	Inflow (Lake)	4,000				-106.2	-14.24			
TR	Total Recharge	6,000				-98.2	-13.03			
ET	ET	100						-101.4	-13.51	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
203	GW Outflow (Panaca)	9,900						-101.4	-13.51	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
201	Spring Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	10,000				-99.4	-13.26			
ET	ET	10,000						-99.4	-13.26	
200	GW Outflow (Eagle)	0						-99.4	-13.26	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
200	Eagle Valley									
201	Inflow (Spring)	0				-99.4	-13.26			
TR	Total Recharge	1,300				-98.9	-13.20			
ET	ET	1,000						-98.9	-13.20	
199	GW Outflow (Rose)	300						-98.9	-13.20	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
199	Rose Valley									
200	Inflow (Eagle)	300				-98.9	-13.20			
TR	Total Recharge	0				-98.6	-13.14			
ET	ET	100						-98.9	-13.20	
198	GW Outflow (Dry)	200						-98.9	-13.20	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
198	Dry Valley									
199	Inflow (Rose)	200				-98.9	-13.20			
TR	Total Recharge	1,500				-96.9	-12.99			
ET	ET	1,000						-97.1	-13.02	
203	GW Outflow (Panaca)	700						-97.1	-13.02	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
204	Clover Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	1,800				-92.1	-12.47			
ET	ET	0						-92.1	-12.47	
205	GW Outflow (LMVW)	1,800						-92.1	-12.47	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
203	Panaca Valley									
202	Inflow (Patterson)	9,900				-101.4	-13.51			
198	Inflow (Dry)	700				-97.1	-13.02			
TR	Total Recharge	1,900				-96.8	-12.95			
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	*-101.4*	*-13.51*	*Inter-basin flow from Patterson Valley*
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	*-106.2*	*-14.24*	*Inter-basin flow from Lake Valley*
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	*-106.2*	*-14.24*	*Inter-basin flow from Lake Valley*
ET	ET	2,000						-100.5	-13.40	
205	GW Outflow (LMVW)	12,500						-100.5	-13.40	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
205	**Lower Meadow Valley Wash**									
203	**Inflow (Panaca)**	**12,500**				**-100.5**	**-13.40**			
204	**Inflow (Clover)**	**1,800**				**-92.1**	**-12.47**			
TR	**Total Recharge**	**1,400**				**-91.1**	**-12.29**			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	***-99.4***	***-13.28***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	**ET**	**1,000**						**-98.7**	**-13.20**	
206	**GW Outflow (Upper Moapa)**	**0**						**-98.7**	**-13.20**	
218	**GW Outflow (California Wash)**	**12,700**						**-98.7**	**-13.20**	

Reconnaissance Series Water Budget

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	**Long Valley**									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	10,300				-121.7	-15.85			
ET	ET	2,000						-121.7	-15.85	
174	GW Outflow (Jakes)	8,300						-121.7	-15.85	
174	**Jakes Valley**									
175	Inflow (Long)	8,300				-121.7	-15.85			
TR	Total Recharge	17,000				-119.7	-15.66			
ET	ET	0						-119.7	-15.66	
207N	GW Outflow (NWRV)	25,300						-120.3	-15.72	
180	**Cave Valley**									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	14,000				-106.6	-14.28			
ET	ET	200						-106.6	-14.28	
Well	180W902		1	601	Deep Well	-104.7	-14.12			
Well	180W501		1	600	Deep Well	-105.6	-14.12			
181	GW Outflow (Dry Lake)	0						-106.6	-14.28	
207S	GW Outflow (SWRV)	13,800						-106.6	-14.28	
207N	**North White River Valley**									
174	Inflow (Jakes)	25,300				-120.3	-15.72			
TR	Total Recharge	25,700	2			-113.7	-15.16			
Warm	Discharge Warm Sprs (Avg)	8,900	14			-122.6	-15.92	*-120.3*	*-15.72*	*Inter-basin flow from Jakes Valley*
ET	ET	22,000						-113.7	-15.16	
207S	GW Outflow (SWRV)	29,000						-119.5	-15.65	
207S	**South White River Valley**	WRV Tot Recharge 38,000								
207N	Inflow (N White River)	29,000				-119.5	-15.65			
180	Inflow (Cave)	13,800				-106.6	-14.28			
TR	Total Recharge	12,300				-106.7	-14.18			
Warm	Discharge Warm Sprs (Avg)	13,200				-119.2	-15.71	*-119.5*	*-15.65*	*Inter-basin flow from Northern White River Valley*
ET	ET	13,000						-107.2	-14.24	
208	GW Outflow (Pahroc)	42,100						-115.3	-15.21	
208	GW Outflow (Garden Valley)	0						-115.3	-15.21	
172	**Garden Valley**									
172	Inflow (None)	0				-115.3	-15.21			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
TR	Total Recharge	10,000				-104.5	-14.06			
ET	ET	2,000						-104.5	-14.06	
171	GW Outflow (Coal)	8,000						-104.5	-14.06	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
171	Coal Valley									
172	Inflow (Garden)	8,000				-104.5	-14.06			
172	Inflow (SWRV)	0				-115.3	-15.21			
TR	Total Recharge	2,000				-98.7	-13.05			
Carb Well	USGS-MX C.V. Well (CV-DT-1)		2	176	Well	-109.0	-14.56	*-104.5*	*-14.06*	*Underflow from Garden Valley*
ET	ET	0						-98.7	-13.05	
208	GW Outflow (Pahranagat)	10,000						-103.4	-13.85	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
208	Pahroc Valley									
207S	Inflow (S. White River)	42,100				-115.3	-15.21			
TR	Total Recharge	2,200	2			-96.8	-12.80			
ET	ET	0						-96.8	-12.80	
209	GW Outflow (Pahranagat)	44,300						-114.4	-15.09	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
209	Pahranagat Valley									
208	Inflow (Pahroc)	44,300				-114.4	-15.09			
171	Inflow (Coal)	10,000				-103.4	-13.85			
209	Inflow (Delamar)	6,200				-97.7	-12.96			
TR	Total Recharge	1,800				-97.4	-13.83			
Warm	Discharge Warm Springs (Avg)	25,400	31			-108.9	-14.26	*-114.4*	*-15.09*	*Inter-basin flow from Pahroc Valley*
ET	ET	25,000						-109.9	-14.61	
Well	209M-1		1	608	Deep Well	-104.7	-13.53	*-114.4*	*-15.09*	*Inter-basin flow from Pahroc Valley*
210	GW Outflow (Coyote Spr)	37,300						-110.9	-14.67	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
181	Dry Lake Valley									
180	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	5,000				-98.9	-13.10			
Carb Well	Fugro Dry Lake V Deep Well		2	179	Well	-107.5	-14.16	*-98.9*	*-13.10*	*Local Recharge*
Carb Well	181M1		1	603	Deep Well	-105.0	-13.67	*-98.9*	*-13.10*	*Local Recharge*
Carb Well	181W909M		1	604	Deep Well	-104.6	-13.50	*-98.9*	*-13.10*	*Local Recharge*
ET	ET	0						-98.9	-13.10	
209	GW Outflow (Pahranagat)	0						-98.9	-13.10	
182	GW Outflow (Delamar)	5,000						-98.9	-13.10	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
182	Delamar Valley									
181	Inflow (Dry Lake)	5,000				-98.9	-13.10			
TR	Total Recharge	1,200				-92.7	-12.38			
ET	ET	0						-92.7	-12.38	
Well	182W906M		1	607	Deep Well	-100.3	-13.33	*-98.9*	*-13.10*	*Inter-basin flow from Dry Lake Valley*
209	GW Outflow (Pahranagat)	6,200						-97.7	-12.96	
210	GW Outflow (Coyote Spr)	0						-97.7	-12.96	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
206	Kane Springs Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	600				-89.0	-12.22			
ET	ET	0						-89.0	-12.22	
210	GW Outflow (Coyote Spr)	600						-89.0	-12.22	
210	Coyote Springs Valley									
209	Inflow (Pahranagat)	37,300				-110.9	-14.67			
182	Inflow (Delamar)	0				0.0	0.00			
206	Inflow (Kane Springs)	600				-89.0	-12.22			
TR	Total Recharge	2,000				-92.6	-12.81			
ET	ET	500						-92.6	-12.81	
219	GW Outflow (Muddy)	39,400						-109.8	-14.56	
217	GW Outflow (Hidden)	0						-109.8	-14.56	
216	GW Outflow (Garnet)	0						-109.8	-14.56	
219	Upper Moapa (Muddy) Valley									
205	Inflow (LMVW)	0				0.0	0.00			
210	Inflow (Coyote)	39,400				-109.8	-14.56			
TR	Total Recharge	0				-87.3	-11.86			
Warm	Dicharge Warm Sprs (Avg)	8,300	49			-97.8	-12.90	*-109.8*	*-14.56*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
CARB	Deep Carbonate Well (Avg)	Input into M	4			-97.9	-12.97	*-109.8*	*-14.56*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
ET	ET	0						-87.3	-11.86	
Gage	Moapa Gage	34,000								
218	SW Outflow (California)	34,000						-109.8	-14.56	
218	GW Outflow (California)	5,400						-109.8	-14.56	
217	Hidden Valley									
210	Inflow (Coyote)	0				-109.8	-14.56			
TR	Total Recharge	400				-81.0	-10.60			
ET	ET	0						-81.0	-10.60	
216	GW Outflow (Garnet)	400						-81.0	-10.60	
216	Garnet Valley									
217	Inflow (Hidden)	400				-81.0	-10.60			
TR	Total Recharge	400				-81.0	-10.60			
CARB	Wells (Avg)		6			-96.9	-13.32	*-81.0*	*-10.60*	*Inter-basin flow from Hidden Valley*
ET	ET	0						-81.0	-10.60	
218	GW Outflow (California)	800						-81.0	-10.60	
218	California Wash									
219	Inflow (LMVW)	12,700				-99.8	-13.33			
219	Inflow (Muddy)	5,400				-109.8	-14.56			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
216	Inflow (Garnet)	800				-81.0	-10.60			
218	SW Inflow (Muddy)	34,000								
TR	Total Recharge	100				-82.0	-10.60			
CARB	Carbonate Well (Avg)					-99.0	-13.45	*-106.1*	*-14.05*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*
ET	ET	1,000						-99.9	-13.3	
220	GW Outflow (Lower Moapa)	21,300						-101.9	-13.57	
215	GW Outflow (Black Mtn Area)	0						-101.9	-13.57	
220	SW Outflow (Lower Moapa)	30,700								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
215	Black Mountains Area									
218	Inflow (California Wash)	0				-101.9	-13.57			
TR	Total Recharge	100				-85.0	-10.95			
CARB	Carbonate Spr (Avg)	1,700	13			-91.3	-12.01	*-85.0*	*-10.95*	*Weighted Average of Inflow from Califronia Wash plus recharge from Muddy Mountains*
ET	ET	0						-85.0	-10.95	
999	GW Outflow (Colorado River)	100						-85.0	-10.95	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
220	Lower Moapa Valley									
219	Inflow (Muddy)	21,300				-101.9	-13.57			
218	SW Inflow (California Wash)	30,700								
TR	Total Recharge	100				-88.3	-12.50			
CARB	Carbonate Well (Avg)		2			-91.0	-12.58	*-101.9*	*-13.57*	*Inter-basin flow from Lower Meadow Valley Wash*
ET	ET	24,000						-101.8	-13.56	
999	GW Outflow (Colorado River)	19,100						-101.9	-13.57	
999	SW Outflow (Colorado River)	9,000								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
Colorado R	Lake Mead (Colorado River)									
210	GW Inflow (Black Mountains Area)	100				-85.0	-10.95			
205	GW Inflow (Lower Moapa)	19,100				-101.9	-13.57			
999	Groundwater Total	19,200						-101.8	-13.55	
205	SW Inflow (Lower Moapa)	9,000								
999	Surfacewater Total	9,000								
999	Inflow Total	28,200								
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
183	Lake Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	13,000				-106.2	-14.24			
ET	ET	9,000						-106.2	-14.24	
202	GW Outflow (Patterson)	4,000						-106.2	-14.24	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
202	Patterson Valley									
183	Inflow (Lake)	4,000				-106.2	-14.24			
TR	Total Recharge	6,000				-98.2	-13.03			
ET	ET	100						-98.2	-13.03	
203	GW Outflow (Panaca)	9,900						-101.5	-13.52	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
201	Spring Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	10,000				-99.4	-13.26			
ET	ET	10,000						-99.4	-13.26	
200	GW Outflow (Eagle)	0						-99.4	-13.26	
200	Eagle Valley									
201	Inflow (Spring)	0				-99.4	-13.26			
TR	Total Recharge	1,300				-98.9	-13.20			
ET	ET	1,000						-98.9	-13.20	
199	GW Outflow (Rose)	300						-98.9	-13.20	
199	Rose Valley									
200	Inflow (Eagle)	300				-98.9	-13.20			
TR	Total Recharge	0				-98.6	-13.14			
ET	ET	100						-98.6	-13.14	
198	GW Outflow (Dry)	200						-98.9	-13.20	
198	Dry Valley									
199	Inflow (Rose)	200				-98.9	-13.20			
TR	Total Recharge	1,500				-96.9	-12.99			
ET	ET	1,000						-96.9	-12.99	
203	GW Outflow (Panaca)	700						-97.4	-13.05	
204	Clover Valley									
0	Inflow (None)	0				0.0	0.00			
TR	Total Recharge	1,800				-92.1	-12.47			
ET	ET	0						-92.1	-12.47	
205	GW Outflow (LMVW)	1,800						-92.1	-12.47	
203	Panaca Valley									
202	Inflow (Patterson)	9,900				-101.5	-13.52			
198	Inflow (Dry)	700				-97.4	-13.05			
TR	Total Recharge	1,900				-96.8	-12.95			
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	*-101.5*	*-13.52*	*Inter-basin flow from Patterson Valley*
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	*-106.2*	*-14.24*	*Inter-basin flow from Lake Valley*
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	*-106.2*	*-14.24*	*Inter-basin flow from Lake Valley*
ET	ET	2,000						-97.1	-12.98	
205	GW Outflow (LMVW)	12,500						-101.2	-13.49	
205	Lower Meadow Valley Wash									

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
203	**Inflow (Panaca)**	**12,500**				**-101.2**	**-13.49**			
204	**Inflow (Clover)**	**1,800**				**-92.1**	**-12.47**			
TR	**Total Recharge**	**1,400**				**-91.1**	**-12.29**			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	***-100.0***	***-13.36***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	**ET**	**1,000**						**-91.1**	**-12.29**	
206	**GW Outflow (Upper Moapa)**	**0**						**-99.8**	**-13.33**	
218	**GW Outflow (California Wash)**	**12,700**						**-99.8**	**-13.33**	

APPENDIX 2. Detailed isotope mass-balance models showing: (1) estimates of recharge amounts and their average deuterium and oxygen-18 values; (2) estimates of pre-development ET amounts and their average deuterium and oxygen-18 values; and (3) all the sites that were used to calculate average deuterium and oxygen-18 values for recharge areas and regional warm spring areas.

		SNWA (2007 Water Budget)								
Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	**Long Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
175 SE	Butte Mtn. (S)	2,507				-119.6	-15.53			35
175 SW	Alligator Rdg.	3,496				-122.4	-15.96			36
175 NW	Maverick Springs	10,881				-123.9	-16.23			37
175 NE	Butte Mtn. (N)	3,044				-119.2	-15.36			164
TR	**Total Recharge**	**19,900**				**-122.4**	**-15.96**			
SE	Butte Spring		1	327	Spring	-120.4	-15.79			
SE	Cabin Spring		1	328	Spring	-124.4	-15.89			
SE	Robbers Roost #2 Spring (Butte)		1	340	Spring	-112.0	-14.39			
SE	Deer Spring (Butte)		1	332	Spring	-114.1	-14.74			
SE	Summit Spring		1	348	Spring	-120.8	-15.94			
SE	Thirty Mile Spring		1	242	Spring	-126.0	-16.40			
NW	Mud Spring (Buck Mts)		1	339	Spring	-117.6	-15.21			
NW	Ram. Res. Wtr Supply Well		1	244	Well	-129.5	-16.75			
NW	Unnamed Near Little Willow Spring		1	351	Spring	-125.9	-17.04			
NW	Well at Alligator Ridge		1	243	Well	-127.0	-16.60			
NW	Woodchuck Spring		1	356	Spring	-119.6	-15.55			
NE	White Rock Spring (Butte)		1	355	Spring	-119.2	-15.36			
ET	**ET**	**3,000**						**-122.4**	**-15.96**	
154	**GW Outflow (Newark)**	**0**						**-122.4**	**-15.96**	
174	**GW Outflow (Jakes)**	**16,900**						**-122.4**	**-15.96**	
174	**Jakes Valley**									
175	**Inflow (Long)**	**16,900**				**-122.4**	**-15.96**			
174 E	Egan Range	2,722				-118.4	-15.31			33
174 W	North White Pine	9,567				-120.3	-15.83			34
TR	**Total Recharge**	**12,300**				**-119.9**	**-15.71**			
W	Tunnel Spring		1	366	Spring	-118.3	-15.02			
W	Aspen Springs North		1	349	Spring	-119.3	-15.84			
W	Aspen Springs South		1	324	Spring	-120.9	-16.02			
W	Chicken Spring		1	330	Spring	-122.0	-16.17			
W	Circle Wash Spring		1	331	Spring	-114.5	-15.30			
W	Sage Hen Spring		1	342	Spring	-112.4	-14.76			
W	Sand Spring		1	239	Spring	-123.0	-16.20			
W	Shellback Spring		1	344	Spring	-123.6	-16.54			
W	Unnamed Hayden Canyon Spring		1	350	Spring	-120.9	-15.69			
W	Unnamed Shellback Ridge Spring		1	352	Spring	-123.6	-16.18			
W	Wild Horse Spring (White Pine)		1	240	Spring	-129.0	-16.80			
W	Unnamed Stone Cabin Spring		2	354	Spring	-116.2	-15.39			
W/E	Indian Spring (Butte)		1	334	Spring	-119.1	-15.31			
W/E	Sammy Spring		1	343	Spring	-117.6	-15.30			
W	Upper Illipah Crk		2	238	Surface	-123.5	-16.10	Surface Water not included in recharge average		
ET	**ET**	**400**						**-121.3**	**-15.86**	
207N	**GW Outflow (NWRV)**	**28,800**						**-121.3**	**-15.86**	
180	**Cave Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
180 E	S. Schell Cr. Rng	7,132				-105.0	-14.28			43,44
180 W	S. Egan Rng	7,527				-107.8	-14.28			45,46
TR	**Total Recharge**	**14,700**				**-106.5**	**-14.28**			
E	North Creek Spring		1	214	Spring	-105.0	-14.60			
E	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95			
E	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48			
E	Sheep Spring (Schell Ck)		1	212	Spring	-99.5	-13.70			
E	Robbers Roost Spring (Schell Ck)		1	389	Spring	-109.7	-14.75			
E	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21			

W	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
W	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
W	Granite Spring		1	440	Spring	-103.4	-13.32				
W	Haggerty Spring		1	387	Spring	-109.6	-14.78				
W	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
W	Silver Spring		2	385	Spring	-111.4	-14.71				
W	Shingle Spring		2	203	Spring	-103.7	-13.33				
W	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
W	Trough Spring		1	413	Spring	-103.6	-13.56				
ET	**ET**	**1,300**						**-106.5**	**-14.28**		
Well	**180W902**		**1**	**601**	**Deep Well**	**-104.7**	**-14.12**	***-106.5***	***-14.28***	***Local recharge***	
Well	**180W501**		**1**	**600**	**Deep Well**	**-105.6**	**-14.12**	***-106.5***	***-14.28***	***Local recharge***	
208	**GW Outflow (Pahroc)**	**9,400**						**-106.5**	**-14.28**		
207S	**GW Outflow (SWRV)**	**4,000**						**-106.5**	**-14.28**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
207N	**North White River Valley**										
174	**Inflow (Jakes)**	**28,800**				**-121.3**	**-15.86**				
207 NE	Egan Rng North	16,085				-112.3	-15.15			38	
207 NW	White Pine Rng.	11,430				-115.0	-15.18			39, 40	
TR	**Total Recharge**	**27,500**				**-113.4**	**-15.16**				
NE	on Creek Spring (Unnamed Spring in Gubler Canyon)		1	235	Spring	-111.0	-14.90				
NE	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
NE	Lone Pine Spring		3	223	Spring	-110.2	-14.90				
NE	High Springs		1	433	Spring	-113.4	-15.43				
NE	Lion Spring (Egan Range)		1	430	Spring	-114.8	-15.34				
NE	Mud Spring		1	446	Spring	-111.0	-14.53				
NE	Pine Springs (Egan Range)		1	434	Spring	-116.0	-15.71				
NE	Unnamed Spring #1(Egan)		1	435	Spring	-112.2	-15.14				
NE	Unnamed Spring #2 (Egan Range)		1	436	Spring	-110.0	-15.14				
NE	Unnamed Spring #3 (Egan Range)		1	437	Spring	-110.2	-15.07				
NE	Unnamed Spring #4 (Egan Range)		1	438	Spring	-114.0	-15.37				
NE	Unnamed Spring #5 (Egan Range)		1	445	Spring	-109.6	-14.72				
NE	North Spring		2	237	Spring	-112.4	-15.11				
NE	Second Sawmill Spring		1	222	Spring	-110.0	-14.70				
NE	South Spring (Egan)		2	236	Spring	-111.5	-15.12				
NE	Upper Terrace Spring WR2		14	270	Spring	-114.0	-15.42				
NE	Water Canyon Spring		1	358	Spring	-114.4	-15.60				
NE	Lund Spring		1	221	Spring	-113.0	-15.40	Local Valley spring not included in recharge calculation			
NE	Water Canyon		2	233	Surface	-116.0	-15.25	Surface Water not included in recharge average			
NW	Big Tom Plain Spring		1	326	Spring	-121.1	-15.92				
NW	Deer Spring (White Pine)		2	322	Spring	-119.3	-15.87				
NW	Unnamed Spring #1 (White Pine)		1	359	Spring	-114.8	-15.36				
NW	Unnamed Spring #2 (White Pine)		1	360	Spring	-114.9	-15.66				
NW	Unnamed Spring #3 (White Pine)		1	361	Spring	-113.1	-14.96				
NW	Unnamed Spring #4 (White Pine)		1	362	Spring	-116.3	-15.01				
NW	Unnamed Spring #5 (White Pine)		3	363	Spring	-116.0	-15.36				
NW	Unnamed Spring #6 (White Pine)		1	364	Spring	-115.1	-14.98				
NW	Halfway Spring (RS)		2	429	Spring	-108.7	-13.52				
NW	Easter Spring		1	365	Spring	-119.4	-15.56				
NW	Little Tom Plain Spring		2	337	Spring	-121.0	-15.86				
NW	Monitoring Spring WR1		14	320	Spring	-113.7	-15.58				
NW	Saddle Spring (White Pine)		3	357	Spring	-116.8	-15.45				
NW	Secret Spring		1	220	Spring	-110.0	-14.00				
NW	Unnamed Spring below Currant Mtn		1	226	Spring	-107.0	-14.00				
NW	Stove Spring		1	347	Spring	-114.5	-15.71				
NW	ied Spring in dry creek bed (White Pine Range)		1	321	Spring	-113.6	-15.31				
NW	Snowmelt Below Duckwater Peak	5,700	1	224	Surface	-105.0	-14.10	Surface Water not included in recharge average			
NW	Little Currant Creek		1	217	Surface	-113.0	-15.00	Surface Water not included in recharge average			
Warm	Cold Spring, Preston	1,000	2	230	Spring	-123.5	-15.80				
Warm	Nicholas Spring	2,000	1	227	Spring	-124.0	-16.10				
Warm	Preston Big Spring	5,900	11	231	Spring	-122.0	-15.88				
Warm	**Discharge Warm Sprs (Avg)**	**8,900**	**14**			**-122.6**	**-15.92**	***-121.3***	***-15.86***	***Inter-basin flow from Jakes Valley***	
ET	**ET**	**20,500**						**-117.5**	**-15.52**		
207S	**GW Outflow (SWRV)**	**35,800**						**-117.5**	**-15.52**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
207S	**South White River Valley**	WRV Tot Recharge									

		41,000									
207N	Inflow (N White River)	35,800				-117.5	-15.52				
180	Inflow (Cave)	4,000				-106.5	-14.28				
207 SE	Egan Rng South	7,423				-106.9	-14.15			41	
207 SW	Grant Rng	6,117				-106.5	-14.23			42	
TR	Total Recharge	13,500				-106.7	-14.18				
E	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
E	Granite Spring		1	440	Spring	-103.4	-13.32				
E	Haggerty Spring		1	387	Spring	-109.6	-14.78				
E	Silver Spring		2	385	Spring	-111.4	-14.71				
E	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
E	Shingle Spring		2	203	Spring	-103.7	-13.33				
E	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
E	Trough Spring		1	413	Spring	-103.6	-13.56				
E	Butterfield Spring	4,000	1	202	Spring	-105.0	-14.20	Local Valley spring not included in recharge calculation			
E	Emigrant Spring	1,900	2	207	Spring	-107.8	-14.50	Local Valley spring not included in recharge calculation			
E	Flag Spring #3		1	201	Spring	-105.0	-14.30	Local Valley spring not included in recharge calculation			
SW	Albert Spring		1	204	Spring	-107.0	-13.95				
SW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
SW	Brady Spring		2	282	Spring	-109.5	-15.38				
SW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
SW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
SW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
SW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
SW	Murphy Spring		1	373	Spring	-114.5	-15.40				
SW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
Warm	Hot Creek Campground Well	0	1	198	Well	-118.0	-15.30				
Warm	Hot Creek Springs	10,000	10	197	Spring	-118.9	-15.69				
Warm	Moon River Spring	2,800	1	192	Spring	-120.0	-15.80				
Warm	Moorman Spring	400	1	205	Spring	-119.0	-15.70				
Warm	Discharge Warm Sprs (Avg)	13,200	13			-119.2	-15.71	*-117.5*	*-15.52*	*Inter-basin flow from Northern White River Valley*	
ET	ET	46,900						-113.9	-15.09		
208	GW Outflow (Pahroc)	6,400						-113.9	-15.09		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
172	Garden Valley										
0	Inflow (None)	0				0.0	0.00				
SW	Quinn Canyon Range	15,120				-104.6	-14.08			171	
172 NW	Grant Range	7,757				-106.5	-14.27			170	
172 NE	Golden Gate Rng	980				-98.0	-13.30			55	
172 SE	Worthington Mountains	962				-98.0	-13.30			56	
TR	Total Recharge	24,800				-104.7	-14.08				
SW	Unnamed Spring #7 (Quinn)		1	367	Spring	-105.9	-14.23				
SW	Unnamed Spring #8 (Quinn)		1	368	Spring	-104.4	-14.18				
SW	Adaven Spring		2	177	Spring	-105.3	-14.01				
SW	Lower Little Cherry Cr Spring		1	182	Spring	-103.0	-13.90				
SW	Carpenter Spring		1	171	Spring	-95.0	-11.85	Evaporated so not used in recharge calculation			
NW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
NW	Brady Spring		2	282	Spring	-109.5	-15.38				
NW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
NW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
NW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
NW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
NW	Murphy Spring		1	373	Spring	-114.5	-15.40				
NW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
SE	The Seeps (Spring)		1	136	Spring	-98.0	-13.30				
ET	ET	1,700						-104.7	-14.08		
171	GW Outflow (Coal)	23,100						-104.7	-14.08		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
171	Coal Valley										
172	Inflow (Garden)	23,100				-104.7	-14.08				
172	Inflow (SWRV)	0				-113.9	-15.09				
171 E	Seaman Rng	1,182				-99.0	-13.13			75	
171 W	Golden Gate Rng	2,675				-98.2	-12.87			76	
TR	Total Recharge	3,900				-98.4	-12.95				
W	Cold Spring		1	288	Spring	-98.9	-12.98				

W	Henry Spring		1	287	Spring	-97.4	-12.77			
W	Little Cut Spring		2	286	Spring	-98.3	-12.85			
E	Seaman Spring		1	306	Spring	-99.0	-13.13			
Carb Well	**USGS-MX C.V. Well (CV-DT-1)**		**2**	**176**	**Well**	**-109.0**	**-14.56**	***-104.7***	***-14.08***	***Underflow from Garden Valley***
ET	**ET**	**0**						**-103.8**	**-13.91**	
208	**GW Outflow (Pahroc)**	**27,000**						**-103.8**	**-13.91**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
208	**Pahroc Valley**									
207S	**Inflow (S. White River)**	**6,400**				**-113.9**	**-15.09**			
170	**Inflow (Cave)**	**9,400**				**-106.5**	**-14.28**			
171	**Inflow (Coal)**	**27,000**				**-103.8**	**-13.91**			
208 E	N. Pahroc Rng.	2,390				-94.2	-12.42			73
208 W	Seaman Rng.	2,117				-99.0	-13.13			74
TR	**Total Recharge**	**4,500**				**-96.4**	**-12.75**			
E	Black Rock Spring		2	158	Spring	-93.8	-12.31			
E	Coyote Spring		2	169	Spring	-95.1	-12.53			
E	Hamilton Spring		1	298	Spring	-93.1	-11.76			
E	Little Boulder Spring		1	301	Spring	-97.2	-13.06			
E	Mustang Spring		2	135	Spring	-90.5	-12.49			
E	Pahroc Spring		3	131	Spring	-92.2	-12.65			
E	Rattlesnake Spring		1	302	Spring	-97.3	-12.65			
E	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90			
W	Seaman Spring		1	306	Spring	-99.0	-13.13			
Evaporated	White Rock Spring (Seaman Range)		1	154	Spring	-90.0	-12.10	Evaporated not used in recharge calculation		
ET	**ET**	**0**						**-105.0**	**-14.04**	
209	**GW Outflow (Pahranagat)**	**45,300**						**-105.0**	**-14.04**	
181	**GW Outflow (Dry Lake)**	**2,000**						**-106.5**	**-14.28**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
209	**Pahranagat Valley**									
208	**Inflow (Pahroc)**	**45,300**				**-105.0**	**-14.04**			
181	**Inflow (Dry Lake)**	**0**				**-98.9**	**-13.12**			
209	**Inflow (Delamar)**	**0**				**-97.3**	**-12.92**			
209 E	S. Pahroc Rng.	1,283				-94.9	-12.83			77, 78
209 W	Mt. Irish/Pahranagat Rng.	4,223				-98.4	-14.24			79, 80 (172, 173)
TR	**Total Recharge**	**5,500**				**-97.6**	**-13.91**			
E	Eightmile Spring		2	295	Spring	-95.6	-13.09			
E	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30			
E	Sixmile Spring		1	112	Spring	-93.4	-13.06			
E	Twin Spring		1	294	Spring	-97.4	-13.24			
E	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07			
E	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62			
E	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44			
S	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30	Local Valley spring not included in recharge calculation		
W	Reed Spring		1	289	Spring	-98.4	-14.24			
Warm	Ash Springs	12400	6	110	Spring	-109.1	-14.11			
Warm	Little Ash Spring (Ash Spring)	500	1	111	Spring	-107.2	-14.20			
Warm	Crystal Springs	8,200	17	116	Spring	-108.8	-14.41			
Warm	Hiko Spring	4,300	7	122	Spring	-108.7	-14.39			
Warm	**Discharge Warm Springs (Avg)**	**25,400**	**31**			**-108.9**	**-14.26**	***-105.0***	***-14.04***	***Inter-basin flow from Pahroc Valley***
ET	**ET**	**28,500**						**-104.2**	**-14.02**	
Well	**209M-1**		**1**	**608**	**Deep Well**	**-104.7**	**-13.53**	***-105.0***	***-14.04***	***Inter-basin flow from Pahroc Valley***
210	**GW Outflow (Coyote Spr)**	**22,300**						**-104.2**	**-14.02**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
181	**Dry Lake Valley**									
208	**Inflow (Pahroc)**	**2,000**				**-106.5**	**-14.28**			
181 NW	S. Schell Ck Range	852				-100.4	-13.21			59
181 SW	N. Pahroc Rng.	2,289				-94.2	-12.42			57
181 NE	Fairview Rng.	3,490				-99.5	-12.89			58
181 E	Bristol/Highland Rng.	7,465				-98.9	-13.28			61
181 SE	Chief Rng.	1,571				-94.6	-12.36			62
TR	**Total Recharge**	**15,700**				**-98.0**	**-12.97**			
E	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07			

E	Highland Spring		3	163	Spring	-99.1	-13.36				
E	Lime Spring		2	160	Spring	-98.5	-13.16				
E	Pine Spring		2	157	Spring	-99.0	-13.37				
E	Connor Spring		1	283	Spring	-100.6	-13.84				
E	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
SE	Red Rock Spring		1	256	Spring	-95.0	-12.30				
SE	Abandoned Spring		1	266	Spring	-94.5	-12.32				
SE	Buckboard Spring		1	264	Spring	-88.2	-11.71				
SE	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
SE	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
SE	Oak Spring		1	269	Spring	-90.0	-11.87				
SE	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
SE	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
SE	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
NE	Bailey Spring (Fairview)		2	277	Spring	-98.2	-12.69				
NE	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
NE	Littlefield Spring		1	275	Spring	-98.5	-12.73				
NE	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
NE	Meloy Spring		1	276	Spring	-99.8	-12.75				
NE	Scotty Spring		1	272	Spring	-98.9	-12.73				
NE	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
NE	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
NE	Fence Spring		1	278	Spring	-97.4	-12.55				
NE	Fox Cabin		1	273	Spring	-103.5	-13.59				
NE	Lower Fairview		1	281	Spring	-97.5	-12.39				
NE	Robison Spring		1	279	Spring	-97.9	-12.34				
NE	Upper Fairview		1	280	Spring	-97.7	-12.66				
SW	Black Rock Spring		2	158	Spring	-93.8	-12.31				
SW	Coyote Spring		2	169	Spring	-95.1	-12.53				
SW	Hamilton Spring		1	298	Spring	-93.1	-11.76				
SW	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
SW	Mustang Spring		2	135	Spring	-90.5	-12.49				
SW	Pahroc Spring		3	131	Spring	-92.2	-12.65				
SW	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
SW	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
NW	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
Evporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
Evaporated	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
Carb Well	**Fugro Dry Lake V Deep Well**		**2**	**179**	**Well**	**-107.5**	**-14.16**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
Carb Well	**181M1**		**1**	**603**	**Deep Well**	**-105.0**	**-13.67**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
Carb Well	**181W909M**		**1**	**604**	**Deep Well**	**-104.6**	**-13.50**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
ET	**ET**	**0**						**-98.9**	**-13.12**		
209	**GW Outflow (Pahranagat)**	**0**						**-98.9**	**-13.12**		
182	**GW Outflow (Delamar)**	**17,700**						**-98.9**	**-13.12**		

XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX

182	**Delamar Valley**										
181	**Inflow (Dry Lake)**	**17,700**				**-98.9**	**-13.12**				
182 E	Delamar Mtns.	5,415				-92.5	-12.32				81
182 W	S. Pahroc Rng.	986				-94.6	-12.81				82
TR	**Total Recharge**	**6,400**				**-92.8**	**-12.39**				
E	Abandoned Spring		1	266	Spring	-94.5	-12.32				
E	Red Rock Spring		1	256	Spring	-95.0	-12.30				
E	Oak Spring		1	269	Spring	-90.0	-11.87				
E	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
E	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
E	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
E	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
E	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
E	Bishop Spring		3	107	Spring	-87.2	-11.72				
E	Buckboard Spring		1	264	Spring	-88.2	-11.71				
E	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
E	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
E	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
E	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
E	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
E	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
E	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
W	Pahroc Spring		3	131	Spring	-92.2	-12.65				

W	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
W	Sixmile Spring		1	112	Spring	-93.4	-13.06				
W	Eightmile Spring		2	295	Spring	-95.6	-13.09				
W	Twin Spring		1	294	Spring	-97.4	-13.24				
W	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
W	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
W	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
ET	**ET**	**0**						**-97.3**	**-12.92**		
Well	**182W906M**		**1**	**607**	**Deep Well**	**-100.3**	**-13.33**	***-98.9***	***-13.12***	***Inter-basin flow from Dry Lake Valley***	
209	**GW Outflow (Pahranagat)**	**0**						**-97.3**	**-12.92**		
210	**GW Outflow (Coyote Spr)**	**24,100**						**-97.3**	**-12.92**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
206	**Kane Springs Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
206 W	Delamar Mtns.	3,910				-89.0	-12.22			90	
206 E	Meadow Valley Mtns.	279				-87.4	-11.92			91	
TR	**Total Recharge**	**4,200**				**-88.9**	**-12.20**				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
W	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
W	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
W	Bishop Spring		3	107	Spring	-87.2	-11.72				
W	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
W	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
W	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
W	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
W	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
ET	**ET**	**0**						**-88.9**	**-12.20**		
210	**GW Outflow (Coyote Spr)**	**4,200**						**-88.9**	**-12.20**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
210	**Coyote Springs Valley**										
209	**Inflow (Pahranagat)**	**22,300**				**-104.2**	**-14.02**				
182	**Inflow (Delamar)**	**24,100**				**-97.3**	**-12.92**				
206	**Inflow (Kane Springs)**	**4,200**				**-88.9**	**-12.20**				
210 NE	S. Delamar Mtns.	977				-89.0	-12.22			83	
210 E	S. Meadow Valley Mtns.	14				-87.4	-11.9			84	
210 NW	S. of Maynard Lake	0				-94.0	-12.30			87	
210 SE	Arrow Canyon Rng.	14				-81.0	-10.60			88	
210 W	Sheep Range	1,124				-92.7	-12.83			89	
TR	**Total Recharge**	**2,100**				**-90.9**	**-12.53**				
W	Cow Camp Spring		4	47	Spring	-91.9	-12.53				
W	Lamb Spring		1	86	Spring	-92.5	-13.15				
W	Mormon Well Spring		3	53	Spring	-91.8	-12.67				
W	Rye Patch Spring		1	341	Spring	-89.3	-12.31				
W	Sawmill Spring (Sheep)		1	58	Spring	-92.0	-12.85				
W	Sheep Spring (Sheep Range)		1	83	Spring	-96.0	-13.35				
W	Wiregrass Spring (Sheep)		13	49	Spring	-95.1	-12.93				
W	White Rock Spring (Sheep)		2	64	Spring	-85.5	-10.17	Evaporated not used in recharge calculation			
NW	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30				
SE	Wamp Spring		1	52	Spring	-81.0	-10.60				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
NE	Bishop Spring		3	107	Spring	-87.2	-11.72				
NE	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NE	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
NE	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NE	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NE	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NE	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
NE	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
Carb Well	CSVM-2		1	612	Well	-97.7	-13.14				
Carb Well	CSVM-3		1	613	Well	-98.0	-13.10				
Carb Well	CSVM-4		1	614	Well	-102.5	-13.41				
Carb Well	CSVM-6		1	616	Well	-100.7	-12.97				
Carb Well	CSI-1		1	609	Well	-102.6	-13.08				
Carb Well	CSI-2		1	610	Well	-100.2	-12.90				

Carb Well	CSI-3		1	611	Well	-99.6	-13.03			
Carb Well	USGS CSV-1		1	71	Well	-103.0	-13.55			
Carb Well	CE-VF-2 Well		2	81	Well	-101.0	-13.10			
Carb Well	Fugro CV Deep Well CE-DT-5		3	77	Well	-99.6	-12.96			
Carb Well	CE-DT-4		1	78	Well	-102.5	-13.00			
CARB	**Carbonate Well (Avg)**		**6**			**-100.7**	**-13.11**	***-99.6***	***-13.35***	***Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys***
ET	**ET**	**0**						**-99.3**	**-13.32**	
219	**GW Outflow (Muddy)**	**37,700**						**-99.3**	**-13.32**	
217	**GW Outflow (Hidden)**	**15,000**						**-99.3**	**-13.32**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
219	**Upper Moapa (Muddy) Valley**									
205	**Inflow (LMVW)**	**4,000**				**-93.5**	**-12.59**			
210	**Inflow (Coyote)**	**37,700**				**-99.3**	**-13.32**			
219 S	E. Arrow Canyon?	2				-87.4	-11.92			85
219 N	Wildcat Wash	36				-87.4	-11.92			86
TR	**Total Recharge**	**0**				**-87.4**	**-11.92**			
N/S	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92			
Warm	APCAR	0	1	292	Spring	-98.2	-12.94			
Warm	Baldwin Spring	2226	9	291	Spring	-97.6	-12.97			
Warm	Big Muddy Spring	5500	6	69	Spring	-97.9	-12.89			
Warm	Iverson's Spring	0	1	65	Spring	-97.0	--			
Warm	Jones Spring Pumphouse	0	6	292	Spring	-97.9	-13.05			
Warm	M-8 Spring (Unnamed Spring)	0	1	68	Spring	-99.0	-12.75			
Warm	M-9 Spring (Unnamed Spring)	200	1	70	Spring	-96.5	-12.45			
Warm	Pederson's East	0	9	290	Spring	-97.8	-12.98			
Warm	Pederson's Warm Spring (M-13)	400	15	67	Spring	-97.5	-12.93			
Warm	**Dicharge Warm Sprs (Avg)**	**8,300**	**49**			**-97.8**	**-12.90**	***-98.7***	***-13.25***	***Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys***
Carb Well	CE-DT-6 Well		2	72	Well	-98.0	-13.03			
Carb Well	CSV-2 Well		2	76	Well	-97.9	-12.92			
CARB	**Deep Carbonate Well (Avg)**		**4**			**-97.9**	**-12.97**	***-98.7***	***-13.25***	***Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys***
ET	**ET**	**6,000**						**-98.73**	**-13.25**	
Gage	Moapa Gage	34,000								
218	**SW Outflow (California)**	**34,000**								
218	**GW Outflow (California)**	**1,700**						**-98.7**	**-13.25**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
217	**Hidden Valley**									
210	**Inflow (Coyote)**	**15,000**				**-99.3**	**-13.32**			
217 E	E. Hidden	0				-81.0	-10.60			99
217 W	W. Hidden	42				-81.0	-10.60			100
TR	**Total Recharge**	**0**				**-81.0**	**-10.60**			
W	Wamp Spring		1	52	Spring	-81.0	-10.60			
ET	**ET**	**0**						**-99.3**	**-13.32**	
216	**GW Outflow (Garnet)**	**15,000**						**-99.3**	**-13.32**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
216	**Garnet Valley**									
217	**Inflow (Hidden)**	**15,000**				**-99.3**	**-13.32**			
216 E	Apex	0				-81.0	-10.60			104
216 W	Las Vegas Range	96				-81.0	-10.60			105
TR	**Total Recharge**	**100**				**-81.0**	**-10.60**			
W	Wamp Spring		1	52	Spring	-81.0	-10.60			
	Dry Lake Valley Well		1	34	Well	-97.5	-13.30			
Carb Well	GP Apex Well		3	17	Well	-97.2	-13.53			
Carb Well	Unnamed Well (Near Dry Lake Range)		1	24	Well	-96.0	-13.70			
Carb Well	US Lime Well (Genstar)		1	27	Well	-97.0	-12.75			
CARB	**Wells (Avg)**		**6**			**-96.9**	**-13.32**	***-99.3***	***-13.32***	***Inter-basin flow from Hidden Valley***
ET	**ET**	**0**						**-99.2**	**-13.30**	
218	**GW Outflow (California)**	**15,100**						**-99.2**	**-13.30**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
218	**California Wash**									

219	SW Inflow (Muddy)	34,000									
205	SW Inflow (LMVW)	0									
219	Inflow (Muddy)	1,700				-98.7	-13.25				
205	Inflow (Lower Meadow VW)	5,300				-93.5	-12.59				
216	Inflow (Garnet)	15,100				-99.2	-13.30				
218 E	Moapa Paiutes	0				-82.0	-10.60			110	
218 W	Muddy Mtns.	0				-82.0	-10.60			111	
TR	Total Recharge	0				0.0	0.00				
W	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Carb Well	Calpine Test Well 1a		1	43	Well	-99.0	-13.50				
Carb Well	Moapa Well		1	41	Well	-99.0	-13.40				
CARB	Carbonate Well (Avg)					-99.0	-13.45	-97.8	-13.12	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*	
ET	ET	4,500						-97.8	-13.12		
220	GW Outflow (Lower Moapa)	18,900						-97.8	-13.12		
215	GW Outflow (Black Mtn Area)	2,000						-97.8	-13.12		
220	SW Outflow (Lower Moapa)	30,700									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
215	Black Mountains Area										
218	Inflow (California Wash)	2,000				-97.8	-13.12				
215 NE	Muddy Mtns.	0				-85.0	-10.95			113	
215 SE	Black Mtns.	0				-79.5	-10.65			114	
215 W	Gypsum Wash	0				-79.5	-10.65			112, 166	
TR	Total Recharge	0				0.0	0.00				
SE	Cottonwood Spring (Black Mtns.)	0	1	8	Spring	-80.0	-10.80				
SE	Sandstone Spring	0	1	10	Spring	-79.0	-10.50				
NE	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
NE	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Alluvial Sprii	Bitter Spring	5	1	14	Spring	-77.0	-9.90				
Carb Spr	Blue Point Spring	440	5	26	Spring	-92.6	-12.40				
Carb Spr	Corral Spring (Unnamed Spring)	0	1	19	Spring	-91.5	-12.10				
Carb Spr	Rogers Spring	1,200	3	21	Spring	-91.7	-12.33				
Carb Spr	Scirpus Spring (No spring on Map)	0	1	20	Spring	-90.0	-12.00				
Carb Spr	VF Spring 1	0	1	28	Spring	-88.0	-11.20				
Carb Spr	VF Spring 2	6	1	29	Spring	-92.0	-11.80				
Carb Spr	VF Spring 3	17	1	30	Spring	-93.0	-12.20				
CARB	Carbonate Spr (Avg)	1,663	13			-91.3	-12.01	-97.8	-13.12	*Weighted Average of Inflow from Califronia Wash*	
ET	ET	1,400						-97.8	-13.12		
999	GW Outflow (Colorado River)	600						-97.8	-13.12		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
220	Lower Moapa Valley										
218	GW Inflow (California Wash)	18,900				-97.8	-13.12				
218	SW Inflow (California Wash)	30,700									
220 S	Valley of Fire	0				-88.0	-11.30			101	
220 N	S. Mormon Mtns.	33				-88.3	-12.50			102	
TR	Total Recharge	0				-88.3	-12.50				
N	Davies Spring		1	90	Spring	-89.0	-12.50				
N	Hackberry Spring		1	84	Spring	-87.0	-12.30				
N	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				
S	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
Carb Well	EH-7		1	56	Well	-91.0	-12.45				
Carb Well	EH-3 Weiser Wash		1	61	Well	-91.0	-12.70				
CARB	Carbonate Well (Avg)		2			-91.0	-12.58	-93.5	-12.59	*Inter-basin flow from Lower Meadow Valley Wash*	
ET	ET	25,300						-97.8	-13.12		
999	GW Outflow (Colorado River)	15,300						-97.8	-13.12		
999	SW Outflow (Colorado River)	9,000									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
Colorado R	Lake Mead (Colorado River)										
210	GW Inflow (Black Mountains Area)	600				-97.8	-13.12				
205	GW Inflow (Lower Moapa)	15,300				-97.8	-13.12				
999	Groundwater Total	15,900						-97.8	-13.12		
205	SW Inflow (Lower Moapa)	9,000									

999	Surface water Total	9,000									
999	Inflow Total	24,900									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX		
183	Lake Valley										
0	Inflow (None)	0				0.0	0.00				
183 NE	Fortification Rng	1,517				-106.3	-14.16			49	
183 NW	Cen. Schell Cr. Rng	4,239				-108.1	-14.74			51	
183 SE	Wilson Cr. Rng. @ Atlanta	4,816				-104.7	-13.75			50	
183 SW	Fairview Rng.	1,737				-101.1	-13.29			60	
TR	Total Recharge	12,300				-105.5	-14.08				
NE	Indian Springs		1	375	Spring	-106.3	-14.16				
NW	Big Spring North	700	1	211	Spring	-112.0	-15.10				
NW	Big Spring South	1,600	1	210	Spring	-111.0	-14.80				
NW	Geyser Spring	340	1	213	Spring	-105.0	-14.50				
NW	North Creek Spring	1,200	1	214	Spring	-105.0	-14.60				
NW	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
NW	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
SE	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
SE	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
SE	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
SW	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
SW	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
SW	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
SW	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
ET	ET	6,700						-105.5	-14.08		
202	GW Outflow (Patterson)	5,600						-105.5	-14.08		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX		
202	Patterson Valley										
183	Inflow (Lake)	5,600				-105.5	-14.08				
202 E	Wilson Cr. Rng. @ Mt. Wilson	6,542				-97.7	-12.99			47	
202 W	Bristol Rng.	4,039				-99.2	-13.10			48	
TR	Total Recharge	10,600				-98.3	-13.03				
E	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
E	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
E	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
E	Parsnip Spring		1	180	Spring	-93.5	-12.80				
E	Horsethief Spring		2	314	Spring	-97.0	-12.68				
E	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		1	156	Spring	-102.3	-13.88				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Fox Cabin		1	273	Spring	-103.5	-13.59				
W	Scotty Spring		1	272	Spring	-98.9	-12.73				
W	Upper Fairview		1	280	Spring	-97.7	-12.66				
W	Lower Fairview		1	281	Spring	-97.5	-12.39				
W	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
W	McDermitt Spring		1	323	Spring	-94.3	-11.21	Evaporated so not used in recharge calculation			
ET	ET	1,300						-100.8	-13.39		
203	GW Outflow (Panaca)	14,900						-100.8	-13.39		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX		
201	Spring Valley										
0	Inflow (None)	0				0.0	0.00				
201 E	White Rock Mtns.	5,975				-100.9	-13.52			52	
201 W	Wilson Cr. Rng. @ Parsnip Pk.	5,223				-97.7	-12.99			53	
TR	Total Recharge	11,200				-99.4	-13.28				
E	Barrel Spring		1	317	Spring	-100.5	-13.36				
E	anyon Spring (Unnamed Spring in Burnt Canyon)		1	187	Spring	-93.0	-12.30				

E	Lion Spring		1	318	Spring	-103.4	-14.11				
E	South Monument Spring		1	319	Spring	-102.3	-14.23				
E	Ripgut Sp #40		1	411	Spring	-106.4	-14.38				
E	Unnamed Spring #1(White Rock Mts)		1	415	Spring	-109.6	-15.05				
E	Unnamed Spring #2 (White RockMts)		1	417	Spring	-97.0	-13.00				
E	Upper Burnt Canyon Spring		1	416	Spring	-97.6	-12.83				
E	Upper Burnt Canyon Spring #2		1	416	Spring	-103.6	-13.66				
E	Jnnamed Spring nr Redd's Cabin Summit		2	173	Spring	-94.4	-12.44				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
E	Unnamed Spring in Miller Canyon		1	313	Spring	-103.7	-14.27				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
W	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
W	Parsnip Spring		1	180	Spring	-93.5	-12.80				
W	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
Surface	Camp Creek		1	184	Surface	-102.0	-14.00	Surface Water not included in recharge average			
Surface	MVW above Eagle Canyon		1	168	Surface	-93.0	-12.00	Surface Water not included in recharge average			
ET	**ET**	**3,900**						**-99.4**	**-13.28**		
200	**GW Outflow (Eagle)**	**7,300**						**-99.4**	**-13.28**		
200	**SW Outflow (Eagle)**	**0**						**-97.5**	**-13.00**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
200	**Eagle Valley**										
201	**Inflow (Spring)**	**7,300**				**-99.4**	**-13.28**				
201	**SW Inflow (Spring)**	**0**				**-97.5**	**-13.00**				
200 E	E. Eagle (Ursine) Valley	1,578				-99.1	-13.28				63
200 W	W. Eagle (Ursine) Valley	417				-97.0	-12.68				64
TR	**Total Recharge**	**2,000**				**-98.7**	**-13.15**				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**1,000**						**-99.3**	**-13.25**		
199	**GW Outflow (Rose)**	**8,300**						**-99.3**	**-13.25**		
198	**SW Outflow (Rose)**	**0**						**-99.3**	**-13.25**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
199	**Rose Valley**										
200	**Inflow (Eagle)**	**8,300**				**-99.3**	**-13.25**				
200	**SW Inflow (Eagle)**	**0**				**-99.3**	**-13.25**				
199 E	E. Rose Valley	165				-99.1	-13.28				65
199 W	W. Rose Valley	79				-97.0	-12.68				66
TR	**Total Recharge**	**200**				**-98.4**	**-13.08**				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**600**						**-99.2**	**-13.24**		
198	**GW Outflow (Dry)**	**7,900**						**-99.2**	**-13.24**		
198	**SW Outflow (Dry)**	**0**						**-99.3**	**-13.25**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
198	**Dry Valley**										
199	**Inflow (Rose)**	**7,900**				**-99.2**	**-13.24**				

199	SW Inflow (Rose)	0				-99.3	-13.25				
198 E	E. Dry Valley	2,895				-96.9	-12.99			67	
198 W	W. Dry Valley	324				-97.0	-12.68			68	
TR	Total Recharge	3,200				-96.9	-12.96				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
Warm Sprin	Flatnose Spring (Unnamed Spring)		1	153	Spring	-101.0	-13.40	-99.2	-13.24		***Inter-basin flow from Dry Valley***
Spring	Delmues Spring (Unnamed Spring)		1	149	Spring	-104.0	-13.40				Local Valley spring not included in recharge calculation
ET	ET	3,700						-98.6	-13.16		
203	GW Outflow (Panaca)	7,400						-98.6	-13.16		
203	SW Outflow (Panaca)	0						-99.2	-13.24		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
204	Clover Valley										
0	Inflow (None)	0				0.0	0.00				
204 N	South of Beaver Dam	8,332				-92.2	-12.42			71	
204 S	North of Jack's Mtn	6,529				-92.0	-12.52			72	
TR	Total Recharge	14,900				-92.1	-12.46				
N	Acoma Well		1	118	Well	-95.0	-12.60				
N	Cave Spring (Clover)		2	247	Spring	-92.8	-12.37				
N	Clover Creek Valley Well 246		1	120	Well	-89.0	-12.40				
N	Ramone Mathews Well		1	115	Well	-92.0	-12.30				
S	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
S	East Settling Spring		1	248	Spring	-92.2	-12.76				
S	Ella Spring		1	251	Spring	-95.8	-12.56				
S	Little Springs (Clover Mts)		2	254	Spring	-93.3	-12.81				
S	Quaking Aspen Spring		1	255	Spring	-93.6	-12.98				
S	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
S	Unnamed Spring		1	113	Spring	-86.5	-11.60				
Alluvial Well	Clover Creek Valley Well 232		1	114	Well	-84.0	-11.70				
ET	ET	5,200						-92.1	-12.46		
205	GW Outflow (LMVW)	9,700						-92.1	-12.46		
205	SW Outflow (LMVW)	0						-92.1	-12.46		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
203	Panaca Valley										
202	Inflow (Patterson)	14,900				-100.8	-13.39				
198	Inflow (Dry)	7,400				-98.6	-13.16				
198	SW Inflow (Dry)	0				-99.2	-13.24				
203 E	Condor Canyon	2,509				-92.0	-12.19			69	
203 W	Cathedral Gorge	3,020				-98.9	-13.28			70	
TR	Total Recharge	5,500				-95.8	-12.78				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	***-100.8***	***-13.39***		***Inter-basin flow from Patterson Valley***
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	***-105.5***	***-14.08***		***Inter-basin flow from Lake Valley***
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	***-105.5***	***-14.08***		***Inter-basin flow from Lake Valley***
Surface	Meadow Valley Wash, Cal.		1	130	Surface	-97.0	-13.10				
Warm	Lester Mathews Well		1	142	Well	-103.0	-13.30				
Warm	Panaca Town Well		1	143	Well	-106.0	-14.00				
Warm	North Lee Well		1	147	Well	-101.0	-13.30				
ET	ET	18,900						-99.2	-13.21		
205	GW Outflow (LMVW)	8,900						-99.2	-13.21		
205	SW Outflow (LMVW)	0						-97.0	-13.10		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	

205	**Lower Meadow Valley Wash**										
203	**Inflow (Panaca)**	**8,900**				**-99.2**	**-13.21**				
204	**Inflow (Clover)**	**9,700**				**-92.1**	**-12.46**				
203	**SW Inflow (Panaca)**	**0**				**-97.0**	**-13.10**				
204	**SW Inflow (Clover)**	**0**				**-92.1**	**-12.46**				
205 NW	Delamar Mtns.	3,114				-92.2	-12.28			92	
205 NE	Clover Mountains	7,378				-90.4	-12.25			93	
205 SW	Meadow Valley Mtns.	1,160				-87.4	-11.92			94	
205 SE	Mormon Mtns.	906				-88.3	-12.50			95	
TR	**Total Recharge**	**12,600**				**-90.4**	**-12.24**				
NE	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
NE	East Settling Spring		1	248	Spring	-92.2	-12.76				
NE	Ella Spring		1	251	Spring	-95.8	-12.56				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NE	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11				
NE	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
NE	Unnamed Spring		1	113	Spring	-86.5	-11.60				
NE	Unnamed Spring (Clover)		1	249	Spring	-88.0	-12.20				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NW	Abandoned Spring		1	266	Spring	-94.5	-12.32				
NW	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
NW	Buckboard Spring		1	264	Spring	-88.2	-11.71				
NW	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
NW	Bishop Spring		3	107	Spring	-87.2	-11.72				
NW	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NW	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
NW	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
NW	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NW	Oak Spring		1	269	Spring	-90.0	-11.87				
NW	Red Rock Spring		1	256	Spring	-95.0	-12.30				
NW	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
NW	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NW	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NW	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
NW	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
NW	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
NW	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
NW	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
SW	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
SE	Davies Spring		1	90	Spring	-89.0	-12.50				
SE	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				
SE	Hackberry Spring		1	84	Spring	-87.0	-12.30				
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	***-95.5***	***-12.82***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***	
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90				
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70				
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50				
ET	**ET**	**21,900**						**-93.5**	**-12.59**		
206	**GW Outflow (Upper Moapa)**	**4,000**						**-93.5**	**-12.59**		
218	**GW Outflow (California Wash)**	**5,300**						**-93.5**	**-12.59**		
218	**GW Outflow (Lower Moapa)**	**0**						**-93.5**	**-12.59**		
218	**SW Outflow (California Wash)**	**0**						**-93.5**	**-12.59**		

		SNWA (2007 Water Budget)								
Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	**Long Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
175 SE	Butte Mtn. (S)	2,507				-119.6	-15.53			35
175 SW	Alligator Rdg.	3,496				-122.4	-15.96			36
175 NW	Maverick Springs	10,881				-123.9	-16.23			37
175 NE	Butte Mtn. (N)	3,044				-119.2	-15.36			164
TR	**Total Recharge**	**19,900**				**-122.4**	**-15.96**			
SE	Butte Spring		1	327	Spring	-120.4	-15.79			
SE	Cabin Spring		1	328	Spring	-124.4	-15.89			
SE	Robbers Roost #2 Spring (Butte)		1	340	Spring	-112.0	-14.39			
SE	Deer Spring (Butte)		1	332	Spring	-114.1	-14.74			
SE	Summit Spring		1	348	Spring	-120.8	-15.94			
SE	Thirty Mile Spring		1	242	Spring	-126.0	-16.40			
NW	Mud Spring (Buck Mts)		1	339	Spring	-117.6	-15.21			
NW	Ram. Res. Wtr Supply Well		1	244	Well	-129.5	-16.75			
NW	Unnamed Near Little Willow Spring		1	351	Spring	-125.9	-17.04			
NW	Well at Alligator Ridge		1	243	Well	-127.0	-16.60			
NW	Woodchuck Spring		1	356	Spring	-119.6	-15.55			
NE	White Rock Spring (Butte)		1	355	Spring	-119.2	-15.36			
ET	**ET**	**3,000**						**-122.4**	**-15.96**	
154	**GW Outflow (Newark)**	**0**						**-122.4**	**-15.96**	
174	**GW Outflow (Jakes)**	**16,900**						**-122.4**	**-15.96**	
174	**Jakes Valley**									
175	**Inflow (Long)**	**16,900**				**-122.4**	**-15.96**			
174 E	Egan Range	2,722				-118.4	-15.31			33
174 W	North White Pine	9,567				-120.3	-15.83			34
TR	**Total Recharge**	**12,300**				**-119.9**	**-15.71**			
NW	Tunnel Spring		1	366	Spring	-118.3	-15.02			
W	Aspen Springs North		1	349	Spring	-119.3	-15.84			
W	Aspen Springs South		1	324	Spring	-120.9	-16.02			
W	Chicken Spring		1	330	Spring	-122.0	-16.17			
W	Circle Wash Spring		1	331	Spring	-114.5	-15.30			
W	Sage Hen Spring		1	342	Spring	-112.4	-14.76			
W	Sand Spring		1	239	Spring	-123.0	-16.20			
W	Shellback Spring		1	344	Spring	-123.6	-16.54			
W	Unnamed Hayden Canyon Spring		1	350	Spring	-120.9	-15.69			
W	Unnamed Shellback Ridge Spring		1	352	Spring	-123.6	-16.18			
W	Wild Horse Spring (White Pine)		1	240	Spring	-129.0	-16.80			
W	Unnamed Stone Cabin Spring		2	354	Spring	-116.2	-15.39			
W/E	Indian Spring (Butte)		1	334	Spring	-119.1	-15.31			
W/E	Sammy Spring		1	343	Spring	-117.6	-15.30			
W	Upper Illipah Crk		2	238	Surface	-123.5	-16.10	Surface Water not included in recharge average		
ET	**ET**	**400**						**-119.9**	**-15.71**	
207N	**GW Outflow (NWRV)**	**28,800**						**-121.3**	**-15.86**	
180	**Cave Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
180 E	S. Schell Cr. Rng	7,132				-105.0	-14.28			43,44
180 W	S. Egan Rng	7,527				-107.8	-14.28			45,46
TR	**Total Recharge**	**14,700**				**-106.5**	**-14.28**			
E	North Creek Spring		1	214	Spring	-105.0	-14.60			
E	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95			
E	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48			
E	Sheep Spring (Schell Ck)		1	212	Spring	-99.5	-13.70			
E	Robbers Roost Spring (Schell Ck)		1	389	Spring	-109.7	-14.75			
E	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21			

W	Big Spring (Egan)		4	206	Spring	-105.5	-13.90			
W	Chimney Rock Spring		2	219	Spring	-110.5	-14.52			
W	Granite Spring		1	440	Spring	-103.4	-13.32			
W	Haggerty Spring		1	387	Spring	-109.6	-14.78			
W	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37			
W	Silver Spring		2	385	Spring	-111.4	-14.71			
W	Shingle Spring		2	203	Spring	-103.7	-13.33			
W	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04			
W	Trough Spring		1	413	Spring	-103.6	-13.56			
ET	**ET**	**1,300**						**-106.5**	**-14.28**	
Well	**180W902**		**1**	**601**	**Deep Well**	**-104.7**	**-14.12**	***-106.5***	***-14.28***	***Local recharge***
Well	**180W501**		**1**	**600**	**Deep Well**	**-105.6**	**-14.12**	***-106.5***	***-14.28***	***Local recharge***
208	**GW Outflow (Pahroc)**	**9,400**						**-106.5**	**-14.28**	
207S	**GW Outflow (SWRV)**	**4,000**						**-106.5**	**-14.28**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
207N	**North White River Valley**									
174	**Inflow (Jakes)**	**28,800**				**-121.3**	**-15.86**			
207 NE	Egan Rng North	16,085				-112.3	-15.15			38
207 NW	White Pine Rng.	11,430				-115.0	-15.18			39, 40
TR	**Total Recharge**	**27,500**				**-113.4**	**-15.16**			
NE	on Creek Spring (Unnamed Spring in Gubler Canyon)		1	235	Spring	-111.0	-14.90			
NE	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37			
NE	Lone Pine Spring		3	223	Spring	-110.2	-14.90			
NE	High Springs		1	433	Spring	-113.4	-15.43			
NE	Lion Spring (Egan Range)		1	430	Spring	-114.8	-15.34			
NE	Mud Spring		1	446	Spring	-111.0	-14.53			
NE	Pine Springs (Egan Range)		1	434	Spring	-116.0	-15.71			
NE	Unnamed Spring #1(Egan)		1	435	Spring	-112.2	-15.14			
NE	Unnamed Spring #2 (Egan Range)		1	436	Spring	-110.0	-15.14			
NE	Unnamed Spring #3 (Egan Range)		1	437	Spring	-110.2	-15.07			
NE	Unnamed Spring #4 (Egan Range)		1	438	Spring	-114.0	-15.37			
NE	Unnamed Spring #5 (Egan Range)		1	445	Spring	-109.6	-14.72			
NE	North Spring		2	237	Spring	-112.4	-15.11			
NE	Second Sawmill Spring		1	222	Spring	-110.0	-14.70			
NE	South Spring (Egan)		2	236	Spring	-111.5	-15.12			
NE	Upper Terrace Spring WR2		14	270	Spring	-114.0	-15.42			
NE	Water Canyon Spring		1	358	Spring	-114.4	-15.60			
NE	Lund Spring		1	221	Spring	-113.0	-15.40	Local Valley spring not included in recharge calculation		
NE	Water Canyon		2	233	Surface	-116.0	-15.25	Surface Water not included in recharge average		
NW	Big Tom Plain Spring		1	326	Spring	-121.1	-15.92			
NW	Deer Spring (White Pine)		2	322	Spring	-119.3	-15.87			
NW	Unnamed Spring #1 (White Pine)		1	359	Spring	-114.8	-15.36			
NW	Unnamed Spring #2 (White Pine)		1	360	Spring	-114.9	-15.66			
NW	Unnamed Spring #3 (White Pine)		1	361	Spring	-113.1	-14.96			
NW	Unnamed Spring #4 (White Pine)		1	362	Spring	-116.3	-15.01			
NW	Unnamed Spring #5 (White Pine)		3	363	Spring	-116.0	-15.36			
NW	Unnamed Spring #6 (White Pine)		1	364	Spring	-115.1	-14.98			
NW	Halfway Spring (RS)		2	429	Spring	-108.7	-13.52			
NW	Easter Spring		1	365	Spring	-119.4	-15.56			
NW	Little Tom Plain Spring		2	337	Spring	-121.0	-15.86			
NW	Monitoring Spring WR1		14	320	Spring	-113.7	-15.58			
NW	Saddle Spring (White Pine)		3	357	Spring	-116.8	-15.45			
NW	Secret Spring		1	220	Spring	-110.0	-14.00			
NW	Unnamed Spring below Currant Mtn		1	226	Spring	-107.0	-14.00			
NW	Stove Spring		1	347	Spring	-114.5	-15.71			
NW	ied Spring in dry creek bed (White Pine Range)		1	321	Spring	-113.6	-15.31			
NW	Snowmelt Below Duckwater Peak	5,700	1	224	Surface	-105.0	-14.10	Surface Water not included in recharge average		
NW	Little Currant Creek		1	217	Surface	-113.0	-15.00	Surface Water not included in recharge average		
Warm	Cold Spring, Preston	1,000	2	230	Spring	-123.5	-15.80			
Warm	Nicholas Spring	2,000	1	227	Spring	-124.0	-16.10			
Warm	Preston Big Spring	5,900	11	231	Spring	-122.0	-15.88			
Warm	**Discharge Warm Sprs (Avg)**	**8,900**	**14**			**-122.6**	**-15.92**	***-121.3***	***-15.86***	***Inter-basin flow from Jakes Valley***
ET	**ET**	**20,500**						**-113.4**	**-15.16**	
207S	**GW Outflow (SWRV)**	**35,800**						**-119.8**	**-15.7**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
207S	**South White River Valley**	WRV Tot Recharge								

		41,000									
207N	Inflow (N White River)	35,800				-119.8	-15.72				
180	Inflow (Cave)	4,000				-106.5	-14.28				
207 SE	Egan Rng South	7,423				-106.9	-14.15			41	
207 SW	Grant Rng	6,117				-106.5	-14.23			42	
TR	Total Recharge	13,500				-106.7	-14.18				
E	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
E	Granite Spring		1	440	Spring	-103.4	-13.32				
E	Haggerty Spring		1	387	Spring	-109.6	-14.78				
E	Silver Spring		2	385	Spring	-111.4	-14.71				
E	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
E	Shingle Spring		2	203	Spring	-103.7	-13.33				
E	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
E	Trough Spring		1	413	Spring	-103.6	-13.56				
E	Butterfield Spring	4,000	1	202	Spring	-105.0	-14.20	local Valley spring not included in recharge calculation			
E	Emigrant Spring	1,900	2	207	Spring	-107.8	-14.50	local Valley spring not included in recharge calculation			
E	Flag Spring #3		1	201	Spring	-105.0	-14.30	local Valley spring not included in recharge calculation			
SW	Albert Spring		1	204	Spring	-107.0	-13.95				
SW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
SW	Brady Spring		2	282	Spring	-109.5	-15.38				
SW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
SW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
SW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
SW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
SW	Murphy Spring		1	373	Spring	-114.5	-15.40				
SW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
Warm	Hot Creek Campground Well	0	1	198	Well	-118.0	-15.30				
Warm	Hot Creek Springs	10,000	10	197	Spring	-118.9	-15.69				
Warm	Moon River Spring	2,800	1	192	Spring	-120.0	-15.80				
Warm	Moorman Spring	400	1	205	Spring	-119.0	-15.70				
Warm	Discharge Warm Sprs (Avg)	13,200	13			-119.2	-15.71	*-119.8*	*-15.72*	*Inter-basin flow from Northern White River Valley*	
ET	ET	46,900						-115.1	-15.18		
208	GW Outflow (Pahroc)	6,400						-118.5	-15.58		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
172	Garden Valley										
0	Inflow (None)	0				0.0	0.00				
172 SW	Quinn Canyon Range	15,120				-104.6	-14.08			171	
172 NW	Grant Range	7,757				-106.5	-14.27			170	
172 NE	Golden Gate Rng	980				-98.0	-13.30			55	
172 SE	Worthington Mountains	962				-98.0	-13.30			56	
TR	Total Recharge	24,800				-104.7	-14.08				
SW	Unnamed Spring #7 (Quinn)		1	367	Spring	-105.9	-14.23				
SW	Unnamed Spring #8 (Quinn)		1	368	Spring	-104.4	-14.18				
SW	Adaven Spring		2	177	Spring	-105.3	-14.01				
SW	Lower Little Cherry Cr Spring		1	182	Spring	-103.0	-13.90				
SW	Carpenter Spring		1	171	Spring	-95.0	-11.85	Evaporated so not used in recharge calculation			
NW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
NW	Brady Spring		2	282	Spring	-109.5	-15.38				
NW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
NW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
NW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
NW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
NW	Murphy Spring		1	373	Spring	-114.5	-15.40				
NW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
SE	The Seeps (Spring)		1	136	Spring	-98.0	-13.30				
ET	ET	1,700						-104.7	-14.08		
171	GW Outflow (Coal)	23,100						-104.7	-14.08		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
171	Coal Valley										
172	Inflow (Garden)	23,100				-104.7	-14.08				
172	Inflow (SWRV)	0				-118.5	-15.58				
171 E	Seaman Rng	1,182				-99.0	-13.13			75	
171 W	Golden Gate Rng	2,675				-98.2	-12.87			76	
TR	Total Recharge	3,900				-98.4	-12.95				
W	Cold Spring		1	288	Spring	-98.9	-12.98				

W	Henry Spring		1	287	Spring	-97.4	-12.77			
W	Little Cut Spring		2	286	Spring	-98.3	-12.85			
E	Seaman Spring		1	306	Spring	-99.0	-13.13			
Carb Well	**USGS-MX C.V. Well (CV-DT-1)**		**2**	**176**	**Well**	**-109.0**	**-14.56**	***-104.7***	***-14.08***	***Underflow from Garden Valley***
ET	**ET**	**0**						**-98.4**	**-12.95**	
208	**GW Outflow (Pahroc)**	**27,000**						**-103.8**	**-13.91**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
208	**Pahroc Valley**									
207S	**Inflow (S. White River)**	**6,400**				**-118.5**	**-15.58**			
170	**Inflow (Cave)**	**9,400**				**-106.5**	**-14.28**			
171	**Inflow (Coal)**	**27,000**				**-103.8**	**-13.91**			
208 E	N. Pahroc Rng.	2,390				-94.2	-12.42			73
208 W	Seaman Rng.	2,117				-99.0	-13.13			74
TR	**Total Recharge**	**4,500**				**-96.4**	**-12.75**			
E	Black Rock Spring		2	158	Spring	-93.8	-12.31			
E	Coyote Spring		2	169	Spring	-95.1	-12.53			
E	Hamilton Spring		1	298	Spring	-93.1	-11.76			
E	Little Boulder Spring		1	301	Spring	-97.2	-13.06			
E	Mustang Spring		2	135	Spring	-90.5	-12.49			
E	Pahroc Spring		3	131	Spring	-92.2	-12.65			
E	Rattlesnake Spring		1	302	Spring	-97.3	-12.65			
E	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90			
W	Seaman Spring		1	306	Spring	-99.0	-13.13			
Evaporated	White Rock Spring (Seaman Range)		1	154	Spring	-90.0	-12.10	Evaporated not used in recharge calculation		
ET	**ET**	**0**						**-96.4**	**-12.75**	
209	**GW Outflow (Pahranagat)**	**45,300**						**-105.6**	**-14.10**	
181	**GW Outflow (Dry Lake)**	**2,000**						**-106.5**	**-14.28**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
209	**Pahranagat Valley**									
208	**Inflow (Pahroc)**	**45,300**				**-105.6**	**-14.10**			
181	**Inflow (Dry Lake)**	**0**				**-98.9**	**-13.12**			
209	**Inflow (Delamar)**	**0**				**-97.3**	**-12.92**			
209 E	S. Pahroc Rng.	1,283				-94.9	-12.83			77, 78
209 W	Mt. Irish/Pahranagat Rng.	4,223				-98.4	-14.24			79, 80 (172, 173)
TR	**Total Recharge**	**5,500**				**-97.6**	**-13.91**			
E	Eightmile Spring		2	295	Spring	-95.6	-13.09			
E	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30			
E	Sixmile Spring		1	112	Spring	-93.4	-13.06			
E	Twin Spring		1	294	Spring	-97.4	-13.24			
E	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07			
E	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62			
E	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44			
S	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30	Local Valley spring not included in recharge calculation		
W	Reed Spring		1	289	Spring	-98.4	-14.24			
Warm	Ash Springs	12400	6	110	Spring	-109.1	-14.11			
Warm	Little Ash Spring (Ash Spring)	500	1	111	Spring	-107.2	-14.20			
Warm	Crystal Springs	8,200	17	116	Spring	-108.8	-14.41			
Warm	Hiko Spring	4,300	7	122	Spring	-108.7	-14.39			
Warm	**Discharge Warm Springs (Avg)**	**25,400**	**31**			**-108.9**	**-14.26**	***-105.6***	***-14.10***	***Inter-basin flow from Pahroc Valley***
ET	**ET**	**28,500**						**-104.1**	**-14.07**	
Well	**209M-1**		**1**	**608**	**Deep Well**	**-104.7**	**-13.53**	***-105.6***	***-14.10***	***Inter-basin flow from Pahroc Valley***
210	**GW Outflow (Coyote Spr)**	**22,300**						**-105.6**	**-14.10**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
181	**Dry Lake Valley**									
208	**Inflow (Pahroc)**	**2,000**				**-106.5**	**-14.28**			
181 NW	S. Schell Ck Range	852				-100.4	-13.21			59
181 SW	N. Pahroc Rng.	2,289				-94.2	-12.42			57
181 NE	Fairview Rng.	3,490				-99.5	-12.89			58
181 E	Bristol/Highland Rng.	7,465				-98.9	-13.28			61
181 SE	Chief Rng.	1,571				-94.6	-12.36			62
TR	**Total Recharge**	**15,700**				**-98.0**	**-12.97**			
E	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07			

E	Highland Spring		3	163	Spring	-99.1	-13.36				
E	Lime Spring		2	160	Spring	-98.5	-13.16				
E	Pine Spring		2	157	Spring	-99.0	-13.37				
E	Connor Spring		1	283	Spring	-100.6	-13.84				
E	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
SE	Red Rock Spring		1	256	Spring	-95.0	-12.30				
SE	Abandoned Spring		1	266	Spring	-94.5	-12.32				
SE	Buckboard Spring		1	264	Spring	-88.2	-11.71				
SE	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
SE	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
SE	Oak Spring		1	269	Spring	-90.0	-11.87				
SE	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
SE	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
SE	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
NE	Bailey Spring (Fairview)		2	277	Spring	-98.2	-12.69				
NE	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
NE	Littlefield Spring		1	275	Spring	-98.5	-12.73				
NE	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
NE	Meloy Spring		1	276	Spring	-99.8	-12.75				
NE	Scotty Spring		1	272	Spring	-98.9	-12.73				
NE	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
NE	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
NE	Fence Spring		1	278	Spring	-97.4	-12.55				
NE	Fox Cabin		1	273	Spring	-103.5	-13.59				
NE	Lower Fairview		1	281	Spring	-97.5	-12.39				
NE	Robison Spring		1	279	Spring	-97.9	-12.34				
NE	Upper Fairview		1	280	Spring	-97.7	-12.66				
SW	Black Rock Spring		2	158	Spring	-93.8	-12.31				
SW	Coyote Spring		2	169	Spring	-95.1	-12.53				
SW	Hamilton Spring		1	298	Spring	-93.1	-11.76				
SW	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
SW	Mustang Spring		2	135	Spring	-90.5	-12.49				
SW	Pahroc Spring		3	131	Spring	-92.2	-12.65				
SW	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
SW	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
NW	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
Evaporated	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
Carb Well	**Fugro Dry Lake V Deep Well**		**2**	**179**	**Well**	**-107.5**	**-14.16**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
Carb Well	**181M1**		**1**	**603**	**Deep Well**	**-105.0**	**-13.67**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
Carb Well	**181W909M**		**1**	**604**	**Deep Well**	**-104.6**	**-13.50**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
ET	**ET**	**0**						**-98.0**	**-12.97**		
209	**GW Outflow (Pahranagat)**	**0**						**-98.9**	**-13.12**		
182	**GW Outflow (Delamar)**	**17,700**						**-98.9**	**-13.12**		

XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
182	**Delamar Valley**										
181	**Inflow (Dry Lake)**	**17,700**				**-98.9**	**-13.12**				
182 E	Delamar Mtns.	5,415				-92.5	-12.32				81
182 W	S. Pahroc Rng.	986				-94.6	-12.81				82
TR	**Total Recharge**	**6,400**				**-92.8**	**-12.39**				
E	Abandoned Spring		1	266	Spring	-94.5	-12.32				
E	Red Rock Spring		1	256	Spring	-95.0	-12.30				
E	Oak Spring		1	269	Spring	-90.0	-11.87				
E	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
E	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
E	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
E	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
E	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
E	Bishop Spring		3	107	Spring	-87.2	-11.72				
E	Buckboard Spring		1	264	Spring	-88.2	-11.71				
E	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
E	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
E	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
E	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
E	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
E	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
E	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
W	Pahroc Spring		3	131	Spring	-92.2	-12.65				

W	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
W	Eightmile Spring		2	295	Spring	-95.6	-13.09				
W	Sixmile Spring		1	112	Spring	-93.4	-13.06				
W	Twin Spring		1	294	Spring	-97.4	-13.24				
W	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
W	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
W	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
ET	**ET**	**0**						**-92.8**	**-12.39**		
Well	**182W906M**		**1**	**607**	**Deep Well**	**-100.3**	**-13.33**	***-98.9***	***-13.12***	***Inter-basin flow from Dry Lake Valley***	
209	**GW Outflow (Pahranagat)**	**0**						**-97.3**	**-12.92**		
210	**GW Outflow (Coyote Spr)**	**24,100**						**-97.3**	**-12.92**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
206	**Kane Springs Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
206 W	Delamar Mtns.	3,910				-89.0	-12.22			90	
206 E	Meadow Valley Mtns.	279				-87.4	-11.92			91	
TR	**Total Recharge**	**4,200**				**-88.9**	**-12.20**				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
W	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
W	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
W	Bishop Spring		3	107	Spring	-87.2	-11.72				
W	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
W	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
W	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
W	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
W	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
ET	**ET**	**0**						**-88.9**	**-12.20**		
210	**GW Outflow (Coyote Spr)**	**4,200**						**-88.9**	**-12.20**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
210	**Coyote Springs Valley**										
209	**Inflow (Pahranagat)**	**22,300**				**-105.6**	**-14.10**				
182	**Inflow (Delamar)**	**24,100**				**-97.3**	**-12.92**				
206	**Inflow (Kane Springs)**	**4,200**				**-88.9**	**-12.20**				
210 NE	S. Delamar Mtns.	977				-89.0	-12.22			83	
210 E	S. Meadow Valley Mtns.	14				-87.4	-11.92			84	
210 NW	S. of Maynard Lake	0				-94.0	-12.30			87	
210 SE	Arrow Canyon Rng.	14				-81.0	-10.60			88	
210 W	Sheep Range	1,124				-92.7	-12.83			89	
TR	**Total Recharge**	**2,100**				**-90.9**	**-12.53**				
W	Cow Camp Spring		4	47	Spring	-91.9	-12.53				
W	Lamb Spring		1	86	Spring	-92.5	-13.15				
W	Mormon Well Spring		3	53	Spring	-91.8	-12.67				
W	Rye Patch Spring		1	341	Spring	-89.3	-12.31				
W	Sawmill Spring (Sheep)		1	58	Spring	-92.0	-12.85				
W	Sheep Spring (Sheep Range)		1	83	Spring	-96.0	-13.35				
W	Wiregrass Spring (Sheep)		13	49	Spring	-95.1	-12.93				
W	White Rock Spring (Sheep)		2	64	Spring	-85.5	-10.17	Evaporated not used in recharge calculation			
NW	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30				
SE	Wamp Spring		1	52	Spring	-81.0	-10.60				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
NE	Bishop Spring		3	107	Spring	-87.2	-11.72				
NE	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NE	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
NE	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NE	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NE	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NE	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
NE	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
Carb Well	CSVM-2		1	612	Well	-97.7	-13.14				
Carb Well	CSVM-3		1	613	Well	-98.0	-13.10				
Carb Well	CSVM-4		1	614	Well	-102.5	-13.41				
Carb Well	CSVM-6		1	616	Well	-100.7	-12.97				
Carb Well	CSI-1		1	609	Well	-102.6	-13.08				
Carb Well	CSI-2		1	610	Well	-100.2	-12.90				

Carb Well	CSI-3		1	611	Well	-99.6	-13.03			
Carb Well	USGS CSV-1		1	71	Well	-103.0	-13.55			
Carb Well	CE-VF-2 Well		2	81	Well	-101.0	-13.10			
Carb Well	Fugro CV Deep Well CE-DT-5		3	77	Well	-99.6	-12.96			
Carb Well	CE-DT-4		1	78	Well	-102.5	-13.00			
CARB	**Carbonate Well (Avg)**		**6**			**-100.7**	**-13.11**	***-100.3***	***-13.38***	***Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys***
ET	**ET**	**0**						**-90.9**	**-12.53**	
219	**GW Outflow (Muddy)**	**37,700**						**-99.9**	**-13.35**	
217	**GW Outflow (Hidden)**	**15,000**						**-99.9**	**-13.35**	

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219 **Upper Moapa (Muddy) Valley**

205	**Inflow (LMVW)**	**4,000**				**-96.1**	**-12.90**			
210	**Inflow (Coyote)**	**37,700**				**-99.9**	**-13.35**			
219 S	E. Arrow Canyon?	2				-87.4	-11.92			85
219 N	Wildcat Wash	36				-87.4	-11.92			86
TR	**Total Recharge**	**0**				**-87.4**	**-11.92**			
N/S	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92			
Warm	APCAR	0	1	292	Spring	-98.2	-12.94			
Warm	Baldwin Spring	2226	9	291	Spring	-97.6	-12.97			
Warm	Big Muddy Spring	5500	6	69	Spring	-97.9	-12.89			
Warm	Iverson's Spring	0	1	65	Spring	-97.0	--			
Warm	Jones Spring Pumphouse	0	6	292	Spring	-97.9	-13.05			
Warm	M-8 Spring (Unnamed Spring)	0	1	68	Spring	-99.0	-12.75			
Warm	M-9 Spring (Unnamed Spring)	200	1	70	Spring	-96.5	-12.45			
Warm	Pederson's East	0	9	290	Spring	-97.8	-12.98			
Warm	Pederson's Warm Spring (M-13)	400	15	67	Spring	-97.5	-12.93			
Warm	**Dicharge Warm Sprs (Avg)**	**8,300**	**49**			**-97.8**	**-12.90**	***-99.5***	***-13.31***	***Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys***
Carb Well	CE-DT-6 Well		2	72	Well	-98.0	-13.03			
Carb Well	CSV-2 Well		2	76	Well	-97.9	-12.92			
CARB	**Deep Carbonate Well (Avg)**	**Input into M**	**4**			**-97.9**	**-12.97**	***-99.5***	***-13.31***	***Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys***
ET	**ET**	**6,000**						**-99.5**	**-13.31**	
Gage	Moapa Gage	34,000								
218	**SW Outflow (California)**	**34,000**								
218	**GW Outflow (California)**	**1,700**						**-99.5**	**-13.31**	

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217 **Hidden Valley**

210	**Inflow (Coyote)**	**15,000**				**-99.9**	**-13.35**			
217 E	E. Hidden	0				-81.0	-10.60			99
217 W	W. Hidden	42				-81.0	-10.60			100
TR	**Total Recharge**	**0**				**-81.0**	**-10.60**			
W	Wamp Spring		1	52	Spring	-81.0	-10.60			
ET	**ET**	**0**						**-81.0**	**-10.60**	
216	**GW Outflow (Garnet)**	**15,000**						**-99.9**	**-13.35**	

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216 **Garnet Valley**

217	**Inflow (Hidden)**	**15,000**				**-99.9**	**-13.35**			
216 E	Apex	0				-81.0	-10.60			104
216 W	Las Vegas Range	96				-81.0	-10.60			105
TR	**Total Recharge**	**100**				**-81.0**	**-10.60**			
W	Wamp Spring		1	52	Spring	-81.0	-10.60			
	Dry Lake Valley Well		1	34	Well	-97.5	-13.30			
Carb Well	GP Apex Well		3	17	Well	-97.2	-13.53			
Carb Well	Unnamed Well (Near Dry Lake Range)		1	24	Well	-96.0	-13.70			
Carb Well	US Lime Well (Genstar)		1	27	Well	-97.0	-12.75			
CARB	**Wells (Avg)**		**6**			**-96.9**	**-13.32**	***-99.9***	***-13.35***	***Inter-basin flow from Hidden Valley***
ET	**ET**	**0**						**-81.0**	**-10.60**	
218	**GW Outflow (California)**	**15,100**						**-99.8**	**-13.33**	

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218 **California Wash**

219	SW Inflow (Muddy)	34,000									
205	SW Inflow (LMVW)	0									
219	Inflow (Muddy)	1,700				-99.5	-13.31				
205	Inflow (Lower Meadow VW)	5,300				-96.1	-12.90				
216	Inflow (Garnet)	15,100				-99.8	-13.33				
218 E	Moapa Paiutes	0				-82.0	-10.60			110	
218 W	Muddy Mtns.	0				-82.0	-10.60			111	
TR	Total Recharge	0				-82.0	-10.6				
W	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Carb Well	Calpine Test Well 1a		1	43	Well	-99.0	-13.50				
Carb Well	Moapa Well		1	41	Well	-99.0	-13.40				
CARB	Carbonate Well (Avg)					-99.0	-13.45	-98.9	-13.22		Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys
ET	ET	4,500						-82.0	-10.60		
220	GW Outflow (Lower Moapa)	18,900						-98.9	-13.22		
215	GW Outflow (Black Mtn Area)	2,000						-98.9	-13.22		
220	SW Outflow (Lower Moapa)	30,700									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
215	Black Mountains Area										
218	Inflow (California Wash)	2,000				-98.9	-13.22				
215 NE	Muddy Mtns.	0				-85.0	-10.95			113	
215 SE	Black Mtns.	0				-79.5	-10.65			114	
215 W	Gypsum Wash	0				-79.5	-10.65			112, 166	
TR	Total Recharge	0				-81.3	-10.75				
SE	Cottonwood Spring (Black Mtns.)	0	1	8	Spring	-80.0	-10.80				
SE	Sandstone Spring	0	1	10	Spring	-79.0	-10.50				
NE	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
NE	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Alluvial Sprii	Bitter Spring	5	1	14	Spring	-77.0	-9.90				
Carb Spr	Blue Point Spring	440	5	26	Spring	-92.6	-12.40				
Carb Spr	Corral Spring (Unnamed Spring)	0	1	19	Spring	-91.5	-12.10				
Carb Spr	Rogers Spring	1,200	3	21	Spring	-91.7	-12.33				
Carb Spr	Scirpus Spring (No spring on Map)	0	1	20	Spring	-90.0	-12.00				
Carb Spr	VF Spring 1	0	1	28	Spring	-88.0	-11.20				
Carb Spr	VF Spring 2	6	1	29	Spring	-92.0	-11.80				
Carb Spr	VF Spring 3	17	1	30	Spring	-93.0	-12.20				
CARB	Carbonate Spr (Avg)	1,700	13			-91.3	-12.01	-98.9	-13.22		Weighted Average of Inflow from Califronia Wash
ET	ET	1,400						-81.3	-10.75		
999	GW Outflow (Colorado River)	600						-98.9	-13.22		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
220	Lower Moapa Valley										
218	GW Inflow (California Wash)	18,900				-98.9	-13.22				
218	SW Inflow (California Wash)	30,700									
220 S	Valley of Fire	0				-88.0	-11.30			101	
220 N	S. Mormon Mtns.	37				-88.3	-12.50			102	
TR	Total Recharge	0				-88.3	-12.50				
N	Davies Spring		1	90	Spring	-89.0	-12.50				
N	Hackberry Spring		1	84	Spring	-87.0	-12.30				
N	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				
S	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
Carb Well	EH-7		1	56	Well	-91.0	-12.45				
Carb Well	EH-3 Weiser Wash		1	61	Well	-91.0	-12.70				
CARB	Carbonate Well (Avg)		2			-91.0	-12.58	-96.1	-12.90		Inter-basin flow from Lower Meadow Valley Wash
ET	ET	25,300						-88.3	-12.50		
999	GW Outflow (Colorado River)	15,300						-98.9	-13.22		
999	SW Outflow (Colorado River)	9,000									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
Colorado R	Lake Mead (Colorado River)										
210	GW Inflow (Black Mountains Area)	600				-98.9	-13.22				
205	GW Inflow (Lower Moapa)	15,300				-98.9	-13.22				
999	Groundwater Total	15,900						-98.9	-13.22		
205	SW Inflow (Lower Moapa)	9,000									

999	Surfacewater Total	9,000									
999	Inflow Total	24,900									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX		
183	Lake Valley										
0	Inflow (None)	0				0.0	0.00				
183 NE	Fortification Rng	1,517				-106.3	-14.16			49	
183 NW	Cen. Schell Cr. Rng	4,239				-108.1	-14.74			51	
183 SE	Wilson Cr. Rng. @ Atlanta	4,816				-104.7	-13.75			50	
183 SW	Fairview Rng.	1,737				-101.1	-13.29			60	
TR	Total Recharge	12,300				-105.5	-14.08				
NE	Indian Springs		1	375	Spring	-106.3	-14.16				
NW	Big Spring North	700	1	211	Spring	-112.0	-15.10				
NW	Big Spring South	1,600	1	210	Spring	-111.0	-14.80				
NW	Geyser Spring	340	1	213	Spring	-105.0	-14.50				
NW	North Creek Spring	1,200	1	214	Spring	-105.0	-14.60				
NW	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
NW	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
SE	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
SE	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
SE	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
SW	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
SW	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
SW	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
SW	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
ET	ET	6,700						-105.5	-14.08		
202	GW Outflow (Patterson)	5,600						-105.5	-14.08		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX		
202	Patterson Valley										
183	Inflow (Lake)	5,600				-105.5	-14.08				
202 E	Wilson Cr. Rng. @ Mt. Wilson	6,542				-97.7	-12.99			47	
202 W	Bristol Rng.	4,039				-99.2	-13.10			48	
TR	Total Recharge	10,600				-98.3	-13.03				
E	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
E	Blue Rock Spring		1	98	Spring	-93.4	-12.68				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
E	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
E	Parsnip Spring		1	180	Spring	-93.5	-12.80				
E	Horsethief Spring		2	314	Spring	-97.0	-12.68				
E	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		1	156	Spring	-102.3	-13.88				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Fox Cabin		1	273	Spring	-103.5	-13.59				
W	Scotty Spring		1	272	Spring	-98.9	-12.73				
W	Upper Fairview		1	280	Spring	-97.7	-12.66				
W	Lower Fairview		1	281	Spring	-97.5	-12.39				
W	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
W	McDermitt Spring		1	323	Spring	-94.3	-11.21	Evaporated so not used in recharge calculation			
ET	ET	1,300						-98.3	-13.03		
203	GW Outflow (Panaca)	14,900						-101.0	-13.43		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX		
201	Spring Valley										
0	Inflow (None)	0				0.0	0.00				
201 E	White Rock Mtns.	5,975				-100.9	-13.52			52	
201 W	Wilson Cr. Rng. @ Parsnip Pk.	5,223				-97.7	-12.99			53	
TR	Total Recharge	11,200				-99.4	-13.28				
E	Barrel Spring		1	317	Spring	-100.5	-13.36				
E	anyon Spring (Unnamed Spring in Burnt Canyon)		1	187	Spring	-93.0	-12.30				

E	Lion Spring		1	318	Spring	-103.4	-14.11				
E	South Monument Spring		1	319	Spring	-102.3	-14.23				
E	Ripgut Sp #40		1	411	Spring	-106.4	-14.38				
E	Unnamed Spring #1(White Rock Mts)		1	415	Spring	-109.6	-15.05				
E	Unnamed Spring #2 (White RockMts)		1	417	Spring	-97.0	-13.00				
E	Upper Burnt Canyon Spring		1	416	Spring	-97.6	-12.83				
E	Upper Burnt Canyon Spring #2		1	416	Spring	-103.6	-13.66				
E	Jnnamed Spring nr Redd's Cabin Summit		2	173	Spring	-94.4	-12.44				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
E	Unnamed Spring in Miller Canyon		1	313	Spring	-103.7	-14.27				
E	Headwaters Spring WR5		1	309	Spring	-107.3	-14.57				
W	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
W	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
W	Parsnip Spring		1	180	Spring	-93.5	-12.80				
W	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
Surface	Camp Creek		1	184	Surface	-102.0	-14.00	Surface Water not included in recharge average			
Surface	MVW above Eagle Canyon		1	168	Surface	-93.0	-12.00	Surface Water not included in recharge average			
ET	**ET**	**3,900**						**-99.4**	**-13.28**		
200	**GW Outflow (Eagle)**	**7,300**						**-99.4**	**-13.28**		
200	**SW Outflow (Eagle)**	**0**						**-97.5**	**-13.00**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
200	**Eagle Valley**										
201	**Inflow (Spring)**	**7,300**				**-99.4**	**-13.28**				
201	**SW Inflow (Spring)**	**0**				**-97.5**	**-13.00**				
200 E	E. Eagle (Ursine) Valley	1,578				-99.1	-13.28				63
200 W	W. Eagle (Ursine) Valley	417				-97.0	-12.68				64
TR	**Total Recharge**	**2,000**				**-98.7**	**-13.15**				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**1,000**						**-98.7**	**-13.15**		
199	**GW Outflow (Rose)**	**8,300**						**-99.3**	**-13.26**		
198	**SW Outflow (Rose)**	**0**						**-98.7**	**-13.00**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
199	**Rose Valley**										
200	**Inflow (Eagle)**	**8,300**				**-99.3**	**-13.26**				
200	**SW Inflow (Eagle)**	**0**				**-98.7**	**-13.00**				
199 E	E. Rose Valley	165				-99.1	-13.28				65
199 W	W. Rose Valley	79				-97.0	-12.68				66
TR	**Total Recharge**	**200**				**-98.4**	**-13.08**				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**600**						**-98.4**	**-13.08**		
198	**GW Outflow (Dry)**	**7,900**						**-99.3**	**-13.25**		
198	**SW Outflow (Dry)**	**0**						**-98.4**	**-13.08**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
198	**Dry Valley**										
199	**Inflow (Rose)**	**7,900**				**-99.3**	**-13.25**				

199	SW Inflow (Rose)	0				-98.4	-13.08				
198 E	E. Dry Valley	2,895				-96.9	-12.99			67	
198 W	W. Dry Valley	324				-97.0	-12.68			68	
TR	Total Recharge	3,200				-96.9	-12.96				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
Warm Sprin	Flatnose Spring (Unnamed Spring)		1	153	Spring	-101.0	-13.40	-99.3	-13.25		***Inter-basin flow from Dry Valley***
Spring	Delmues Spring (Unnamed Spring)		1	149	Spring	-104.0	-13.40				Local Valley spring not included in recharge calculation
ET	ET	3,700						-97.2	-13.00		
203	GW Outflow (Panaca)	7,400						-99.3	-13.25		
203	SW Outflow (Panaca)	0						-97.2	-13.00		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
204	Clover Valley										
0	Inflow (None)	0				0.0	0.00				
204 N	South of Beaver Dam	8,332				-92.2	-12.42			71	
204 S	North of Jack's Mtn	6,529				-92.0	-12.52			72	
TR	Total Recharge	14,900				-92.1	-12.46				
N	Acoma Well		1	118	Well	-95.0	-12.60				
N	Cave Spring (Clover)		2	247	Spring	-92.8	-12.37				
N	Clover Creek Valley Well 246		1	120	Well	-89.0	-12.40				
N	Ramone Mathews Well		1	115	Well	-92.0	-12.30				
S	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
S	East Settling Spring		1	248	Spring	-92.2	-12.76				
S	Ella Spring		1	251	Spring	-95.8	-12.56				
S	Little Springs (Clover Mts)		2	254	Spring	-93.3	-12.81				
S	Quaking Aspen Spring		1	255	Spring	-93.6	-12.98				
S	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
S	Unnamed Spring		1	113	Spring	-86.5	-11.60				
Alluvial Well	Clover Creek Valley Well 232		1	114	Well	-84.0	-11.70				
ET	ET	5,200						-92.1	-12.46		
205	GW Outflow (LMVW)	9,700						-92.1	-12.46		
205	SW Outflow (LMVW)	0						-92.1	-12.46		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
203	Panaca Valley										
202	Inflow (Patterson)	14,900				-101.0	-13.43				
198	Inflow (Dry)	7,400				-99.3	-13.25				
198	SW Inflow (Dry)	0				-97.2	-13.00				
203 E	Condor Canyon	2,509				-92.0	-12.19			69	
203 W	Cathedral Gorge	3,020				-98.9	-13.28			70	
TR	Total Recharge	5,500				-95.8	-12.78				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	***-101.0***	***-13.43***		***Inter-basin flow from Patterson Valley***
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	***-105.5***	***-14.08***		***Inter-basin flow from Lake Valley***
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	***-105.5***	***-14.08***		***Inter-basin flow from Lake Valley***
Surface	Meadow Valley Wash, Cal.		1	130	Surface	-97.0	-13.10				
Warm	Lester Mathews Well		1	142	Well	-103.0	-13.30				
Warm	Panaca Town Well		1	143	Well	-106.0	-14.00				
Warm	North Lee Well		1	147	Well	-101.0	-13.30				
ET	ET	18,900						-99.1	-13.20		
205	GW Outflow (LMVW)	8,900						-100.4	-13.37		
205	SW Outflow (LMVW)	0						-99.1	-13.20		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXXXXXXXXXXXXXXXX		XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	

205	**Lower Meadow Valley Wash**										
203	**Inflow (Panaca)**	**8,900**				**-100.4**	**-13.37**				
204	**Inflow (Clover)**	**9,700**				**-92.1**	**-12.46**				
203	**SW Inflow (Panaca)**	**0**				**-99.1**	**-13.20**				
204	**SW Inflow (Clover)**	**0**				**-92.1**	**-12.46**				
205 NW	Delamar Mtns.	3,114				-92.2	-12.28				92
205 NE	Clover Mountains	7,378				-90.4	-12.25				93
205 SW	Meadow Valley Mtns.	1,160				-87.4	-11.92				94
205 SE	Mormon Mtns.	906				-90.0	-12.65				95
TR	**Total Recharge**	**12,600**				**-90.6**	**-12.25**				
NE	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
NE	East Settling Spring		1	248	Spring	-92.2	-12.76				
NE	Ella Spring		1	251	Spring	-95.8	-12.56				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NE	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11				
NE	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
NE	Unnamed Spring		1	113	Spring	-86.5	-11.60				
NE	Unnamed Spring (Clover)		1	249	Spring	-88.0	-12.20				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NW	Abandoned Spring		1	266	Spring	-94.5	-12.32				
NW	Grassy Spring		3	117	Spring	-88.7	-11.08			Evaporated so not used in recharge calculation	
NW	Buckboard Spring		1	264	Spring	-88.2	-11.71				
NW	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
NW	Bishop Spring		3	107	Spring	-87.2	-11.72				
NW	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NW	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
NW	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
NW	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NW	Oak Spring		1	269	Spring	-90.0	-11.87				
NW	Red Rock Spring		1	256	Spring	-95.0	-12.30				
NW	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
NW	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NW	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NW	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
NW	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
NW	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
NW	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
NW	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
SW	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
SE	Davies Spring		1	90	Spring	-89.0	-12.50				
SE	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				
SE	Hackberry Spring		1	84	Spring	-87.0	-12.30				
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	***-96.1***	***-12.90***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***	
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90				
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70				
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50				
ET	**ET**	**21,900**						**-92.9**	**-12.53**		
206	**GW Outflow (Upper Moapa)**	**4,000**						**-96.1**	**-12.90**		
218	**GW Outflow (California Wash)**	**5,300**						**-96.1**	**-12.90**		
218	**SW Outflow (California Wash)**	**0**						**-90.6**	**-12.25**		

XXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXX XXXXXXXX XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX

		SNWA/BARCASS (SNWA, 2007; Welch and Bright, 2007)								
Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	**Long Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
175 SE	Butte Mtn. (S)	2,676				-119.6	-15.53			35
175 SW	Alligator Rdg.	3,667				-122.4	-15.96			36
175 NW	Maverick Springs	11,446				-123.9	-16.23			37
175 NE	Butte Mtn. (N)	3,228				-119.2	-15.36			164
TR	**Total Recharge**	**21,000**				**-122.4**	**-15.96**			
SE	Butte Spring		1	327	Spring	-120.4	-15.79			
SE	Cabin Spring		1	328	Spring	-124.4	-15.89			
SE	Robbers Roost #2 Spring (Butte)		1	340	Spring	-112.0	-14.39			
SE	Deer Spring (Butte)		1	332	Spring	-114.1	-14.74			
SE	Summit Spring		1	348	Spring	-120.8	-15.94			
SE	Thirty Mile Spring		1	242	Spring	-126.0	-16.40			
NW	Mud Spring (Buck Mts)		1	339	Spring	-117.6	-15.21			
NW	Ram. Res. Wtr Supply Well		1	244	Well	-129.5	-16.75			
NW	Unnamed Near Little Willow Spring		1	351	Spring	-125.9	-17.04			
NW	Well at Alligator Ridge		1	243	Well	-127.0	-16.60			
NW	Woodchuck Spring		1	356	Spring	-119.6	-15.55			
NE	White Rock Spring (Butte)		1	355	Spring	-119.2	-15.36			
ET	**ET**	**1,200**						**-122.4**	**-15.96**	
154	**GW Outflow (Newark)**	**0**						**-122.4**	**-15.96**	
174	**GW Outflow (Jakes)**	**19,800**						**-122.4**	**-15.96**	
174	**Jakes Valley**									
175	**Inflow (Long)**	**19,800**				**-122.4**	**-15.96**			
174 E	Egan Range	2,909				-118.4	-15.31			33
174 W	North White Pine	10,076				-120.3	-15.83			34
TR	**Total Recharge**	**13,000**				**-119.9**	**-15.71**			
W	Tunnel Spring		1	366	Spring	-118.3	-15.02			
W	Aspen Springs North		1	349	Spring	-119.3	-15.84			
W	Aspen Springs South		1	324	Spring	-120.9	-16.02			
W	Chicken Spring		1	330	Spring	-122.0	-16.17			
W	Circle Wash Spring		1	331	Spring	-114.5	-15.30			
W	Sage Hen Spring		1	342	Spring	-112.4	-14.76			
W	Sand Spring		1	239	Spring	-123.0	-16.20			
W	Shellback Spring		1	344	Spring	-123.6	-16.54			
W	Unnamed Hayden Canyon Spring		1	350	Spring	-120.9	-15.69			
W	Unnamed Shellback Ridge Spring		1	352	Spring	-123.6	-16.18			
W	Wild Horse Spring (White Pine)		1	240	Spring	-129.0	-16.80			
W	Unnamed Stone Cabin Spring		2	354	Spring	-116.2	-15.39			
W/E	Indian Spring (Butte)		1	334	Spring	-119.1	-15.31			
W/E	Sammy Spring		1	343	Spring	-117.6	-15.30			
W	Upper Illipah Crk		2	238	Surface	-123.5	-16.10	Surface Water not included in recharge average		
ET	**ET**	**900**						**-121.4**	**-15.86**	
207N	**GW Outflow (NWRV)**	**31,900**						**-121.4**	**-15.86**	
180	**Cave Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
180 E	S. Schell Cr. Rng	7,438				-105.0	-14.28			43,44

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
180 W	S. Egan Rng	7,944				-107.8	-14.28			45,46	
TR	**Total Recharge**	**15,400**				**-106.5**	**-14.28**				
E	North Creek Spring		1	214	Spring	-105.0	-14.60				
E	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
E	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
E	Sheep Spring (Schell Ck)		1	212	Spring	-99.5	-13.70				
E	Robbers Roost Spring (Schell Ck)		1	389	Spring	-109.7	-14.75				
E	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
W	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
W	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
W	Granite Spring		1	440	Spring	-103.4	-13.32				
W	Haggerty Spring		1	387	Spring	-109.6	-14.78				
W	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
W	Silver Spring		2	385	Spring	-111.4	-14.71				
W	Shingle Spring		2	203	Spring	-103.7	-13.33				
W	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
W	Trough Spring		1	413	Spring	-103.6	-13.56				
ET	**ET**	**1,600**						**-106.5**	**-14.28**		
Well	**180W902**		**1**	**601**	**Deep Well**	**-104.7**	**-14.12**				
Well	**180W501**		**1**	**600**	**Deep Well**	**-105.6**	**-14.12**				
208	**GW Outflow (Pahroc)**	**9,800**						**-106.5**	**-14.28**		
207S	**GW Outflow (SWRV)**	**4,000**						**-106.5**	**-14.28**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
207N	**North White River Valley**										
174	**Inflow (Jakes)**	**31,900**				**-121.4**	**-15.86**				
207 NE	Egan Rng North	16,554				-112.3	-15.15			38	
207 NW	White Pine Rng.	12,030				-115.0	-15.18			39, 40	
TR	**Total Recharge**	**28,600**				**-113.5**	**-15.16**				
NE	on Creek Spring (Unnamed Spring in Gubler Canyon)		1	235	Spring	-111.0	-14.90				
NE	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
NE	Lone Pine Spring		3	223	Spring	-110.2	-14.90				
NE	High Springs		1	433	Spring	-113.4	-15.43				
NE	Lion Spring (Egan Range)		1	430	Spring	-114.8	-15.34				
NE	Mud Spring		1	446	Spring	-111.0	-14.53				
NE	Pine Springs (Egan Range)		1	434	Spring	-116.0	-15.71				
NE	Unnamed Spring #1(Egan)		1	435	Spring	-112.2	-15.14				
NE	Unnamed Spring #2 (Egan Range)		1	436	Spring	-110.0	-15.14				
NE	Unnamed Spring #3 (Egan Range)		1	437	Spring	-110.2	-15.07				
NE	Unnamed Spring #4 (Egan Range)		1	438	Spring	-114.0	-15.37				
NE	Unnamed Spring #5 (Egan Range)		1	445	Spring	-109.6	-14.72				
NE	North Spring		2	237	Spring	-112.4	-15.11				
NE	Second Sawmill Spring		1	222	Spring	-110.0	-14.70				
NE	South Spring (Egan)		2	236	Spring	-111.5	-15.12				
NE	Upper Terrace Spring WR2		14	270	Spring	-114.0	-15.42				
NE	Water Canyon Spring		1	358	Spring	-114.4	-15.60				
NE	Lund Spring		1	221	Spring	-113.0	-15.40	Local Valley spring not included in recharge calculation			
NE	Water Canyon		2	233	Surface	-116.0	-15.25	Surface Water not included in recharge average			
NW	Big Tom Plain Spring		1	326	Spring	-121.1	-15.92				
NW	Deer Spring (White Pine)		2	322	Spring	-119.3	-15.87				
NW	Unnamed Spring #1 (White Pine)		1	359	Spring	-114.8	-15.36				
NW	Unnamed Spring #2 (White Pine)		1	360	Spring	-114.9	-15.66				
NW	Unnamed Spring #3 (White Pine)		1	361	Spring	-113.1	-14.96				
NW	Unnamed Spring #4 (White Pine)		1	362	Spring	-116.3	-15.01				
NW	Unnamed Spring #5 (White Pine)		3	363	Spring	-116.0	-15.36				
NW	Unnamed Spring #6 (White Pine)		1	364	Spring	-115.1	-14.98				
NW	Halfway Spring (RS)		2	429	Spring	-108.7	-13.52				
NW	Easter Spring		1	365	Spring	-119.4	-15.56				
NW	Little Tom Plain Spring		2	337	Spring	-121.0	-15.86				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NW	Monitoring Spring WR1		14	320	Spring	-113.7	-15.58				
NW	Saddle Spring (White Pine)		3	357	Spring	-116.8	-15.45				
NW	Secret Spring		1	220	Spring	-110.0	-14.00				
NW	Unnamed Spring below Currant Mtn		1	226	Spring	-107.0	-14.00				
NW	Stove Spring		1	347	Spring	-114.5	-15.71				
NW	ıed Spring in dry creek bed (White Pine Range)		1	321	Spring	-113.6	-15.31				
NW	Snowmelt Below Duckwater Peak	5,700	1	224	Surface	-105.0	-14.10	Surface Water not included in recharge average			
NW	Little Currant Creek		1	217	Surface	-113.0	-15.00	Surface Water not included in recharge average			
Warm	Cold Spring, Preston	1,000	2	230	Spring	-123.5	-15.80				
Warm	Nicholas Spring	2,000	1	227	Spring	-124.0	-16.10				
Warm	Preston Big Spring	5,900	11	231	Spring	-122.0	-15.88				
Warm	**Discharge Warm Sprs (Avg)**	**8,900**	**14**			**-122.6**	**-15.92**	***-121.4***	***-15.86***	***Inter-basin flow from Jakes Valley***	
ET	**ET**	**29,500**						**-117.6**	**-15.53**		
207S	**GW Outflow (SWRV)**	**31,000**						**-117.6**	**-15.53**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
207S	**South White River Valley**	WRV Tot Recharge									
		42,900									
207N	**Inflow (N White River)**	**31,000**				**-117.6**	**-15.53**				
180	**Inflow (Cave)**	**4,000**				**-106.5**	**-14.28**				
207 SE	Egan Rng South	7,844				-106.9	-14.15			41	
207 SW	Grant Rng	6,467				-106.5	-14.23			42	
TR	**Total Recharge**	**14,300**				**-106.7**	**-14.18**				
E	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
E	Granite Spring		1	440	Spring	-103.4	-13.32				
E	Haggerty Spring		1	387	Spring	-109.6	-14.78				
E	Silver Spring		2	385	Spring	-111.4	-14.71				
E	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
E	Shingle Spring		2	203	Spring	-103.7	-13.33				
E	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
E	Trough Spring		1	413	Spring	-103.6	-13.56				
E	Butterfield Spring	4,000	1	202	Spring	-105.0	-14.20	Local Valley spring not included in recharge calculation			
E	Emigrant Spring	1,900	2	207	Spring	-107.8	-14.50	Local Valley spring not included in recharge calculation			
E	Flag Spring #3		1	201	Spring	-105.0	-14.30	Local Valley spring not included in recharge calculation			
SW	Albert Spring		1	204	Spring	-107.0	-13.95				
SW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
SW	Brady Spring		2	282	Spring	-109.5	-15.38				
SW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
SW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
SW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
SW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
SW	Murphy Spring		1	373	Spring	-114.5	-15.40				
SW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
Warm	Hot Creek Campground Well	0	1	198	Well	-118.0	-15.30				
Warm	Hot Creek Springs	10,000	10	197	Spring	-118.9	-15.69				
Warm	Moon River Spring	2,800	1	192	Spring	-120.0	-15.80				
Warm	Moorman Spring	400	1	205	Spring	-119.0	-15.70				
Warm	**Discharge Warm Sprs (Avg)**	**13,200**	**13**			**-119.2**	**-15.71**	***-117.6***	***-15.53***	***Inter-basin flow from Northern White River Valley***	
ET	**ET**	**47,200**						**-113.6**	**-15.04**		
208	**GW Outflow (Pahroc)**	**2,100**						**-113.6**	**-15.04**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXXX
172	**Garden Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
SW	Quinn Canyon Range	15,621				-104.6	-14.08			171	
172 NW	Grant Range	7,993				-106.5	-14.27			170	
172 NE	Golden Gate Rng	1,063				-98.0	-13.30			55	
172 SE	Worthington Mountains	1,030				-98.0	-13.30			56	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
TR	**Total Recharge**	**25,700**				**-104.7**	**-14.08**				
SW	Unnamed Spring #7 (Quinn)		1	367	Spring	-105.9	-14.23				
SW	Unnamed Spring #8 (Quinn)		1	368	Spring	-104.4	-14.18				
SW	Adaven Spring		2	177	Spring	-105.3	-14.01				
SW	Lower Little Cherry Cr Spring		1	182	Spring	-103.0	-13.90				
SW	Carpenter Spring		1	171	Spring	-95.0	-11.85	Evaporated so not used in recharge calculation			
NW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
NW	Brady Spring		2	282	Spring	-109.5	-15.38				
NW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
NW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
NW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
NW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
NW	Murphy Spring		1	373	Spring	-114.5	-15.40				
NW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
SE	The Seeps (Spring)		1	136	Spring	-98.0	-13.30				
ET	**ET**	**1,700**						**-104.7**	**-14.08**		
171	**GW Outflow (Coal)**	**24,000**						**-104.7**	**-14.08**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
171	**Coal Valley**										
172	**Inflow (Garden)**	**24,000**				**-104.7**	**-14.08**				
172	**Inflow (SWRV)**	**0**				**-113.6**	**-15.04**				
171 E	Seaman Rng	1,282				-99.0	-13.13			75	
171 W	Golden Gate Rng	2,882				-98.2	-12.87			76	
TR	**Total Recharge**	**4,200**				**-98.4**	**-12.95**				
W	Cold Spring		1	288	Spring	-98.9	-12.98				
W	Henry Spring		1	287	Spring	-97.4	-12.77				
W	Little Cut Spring		2	286	Spring	-98.3	-12.85				
E	Seaman Spring		1	306	Spring	-99.0	-13.13				
ET	**ET**	**0**						**-103.7**	**-13.91**		
Carb Well	**USGS-MX C.V. Well (CV-DT-1)**		**2**	**176**	**Well**	**-109.0**	**-14.56**	***-104.7***	***-14.08***	***Underflow from Garden Valley***	
208	**GW Outflow (Pahroc)**	**28,200**						**-103.7**	**-13.91**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
208	**Pahroc Valley**										
207S	**Inflow (S. White River)**	**2,100**				**-113.6**	**-15.04**				
180	**Inflow (Cave)**	**9,800**				**-106.5**	**-14.28**				
171	**Inflow (Coal)**	**28,200**				**-103.7**	**-13.91**				
208 E	N. Pahroc Rng.	2,596				-94.2	-12.42			73	
208 W	Seaman Rng.	2,286				-99.0	-13.13			74	
TR	**Total Recharge**	**4,900**				**-96.4**	**-12.75**				
E	Black Rock Spring		2	158	Spring	-93.8	-12.31				
E	Coyote Spring		2	169	Spring	-95.1	-12.53				
E	Hamilton Spring		1	298	Spring	-93.1	-11.76				
E	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
E	Mustang Spring		2	135	Spring	-90.5	-12.49				
E	Pahroc Spring		3	131	Spring	-92.2	-12.65				
E	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
E	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
W	Seaman Spring		1	306	Spring	-99.0	-13.13				
Evaporated	White Rock Spring (Seaman Range)		1	154	Spring	-90.0	-12.10	Evaporated not used in recharge calculation			
ET	**ET**	**0**						**-104.0**	**-13.92**		
209	**GW Outflow (Pahranagat)**	**43,000**						**-104.0**	**-13.92**		
181	**GW Outflow (Dry Lake)**	**2,000**						**-106.5**	**-14.28**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
209	**Pahranagat Valley**										
208	**Inflow (Pahroc)**	**43,000**				**-104.0**	**-13.92**				
181	**Inflow (Dry Lake)**	**0**				**-99.0**	**-13.12**				
209	**Inflow (Delamar)**	**0**				**-97.3**	**-12.93**				
209 E	S. Pahroc Rng.	2,377				-94.9	-12.83			77, 78	
209 W	Mt. Irish/Pahranagat Rng.	3,545				-98.4	-14.24			79, 80 (172, 173)	
TR	**Total Recharge**	**5,900**				**-97.0**	**-13.67**				
E	Eightmile Spring		2	295	Spring	-95.6	-13.09				
E	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
E	Sixmile Spring		1	112	Spring	-93.4	-13.06				
E	Twin Spring		1	294	Spring	-97.4	-13.24				
E	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
E	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
E	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
S	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30	Local Valley spring not included in recharge calculation			
W	Reed Spring		1	289	Spring	-98.4	-14.24				
Warm	Ash Springs	12400	6	110	Spring	-109.1	-14.11				
Warm	Little Ash Spring (Ash Spring)	500	1	111	Spring	-107.2	-14.20				
Warm	Crystal Springs	8,200	17	116	Spring	-108.8	-14.41				
Warm	Hiko Spring	4,300	7	122	Spring	-108.7	-14.39				
Warm	**Discharge Warm Springs (Avg)**	**25,400**	**31**			**-108.9**	**-14.26**	***-104.0***	***-13.92***	***Inter-basin flow from Pahroc Valley***	
ET	**ET**	**28,500**						**-103.2**	**-13.89**		
Well	**209M-1**		**1**	**608**	**Deep Well**	**-104.7**	**-13.53**	***-104.0***	***-13.92***	***Inter-basin flow from Pahroc Valley***	
210	**GW Outflow (Coyote Spr)**	**20,400**						**-103.2**	**-13.89**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
181	**Dry Lake Valley**										
180	**Inflow (Pahroc)**	**2,000**				**-106.5**	**-14.28**				
181 NW	S. Schell Ck Range	1,307				-100.4	-13.21			59	
181 SW	N. Pahroc Rng.	2,081				-94.2	-12.42			57	
181 NE	Fairview Rng.	3,709				-99.5	-12.89			58	
181 E	Bristol/Highland Rng.	7,895				-98.9	-13.28			61	
181 SE	Chief Rng.	1,696				-94.6	-12.36			62	
TR	**Total Recharge**	**16,700**				**-98.1**	**-12.98**				
E	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
E	Highland Spring		3	163	Spring	-99.1	-13.36				
E	Lime Spring		2	160	Spring	-98.5	-13.16				
E	Pine Spring		2	157	Spring	-99.0	-13.37				
E	Connor Spring		1	283	Spring	-100.6	-13.84				
E	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
SE	Red Rock Spring		1	256	Spring	-95.0	-12.30				
SE	Abandoned Spring		1	266	Spring	-94.5	-12.32				
SE	Buckboard Spring		1	264	Spring	-88.2	-11.71				
SE	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
SE	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
SE	Oak Spring		1	269	Spring	-90.0	-11.87				
SE	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
SE	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
SE	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
NE	Bailey Spring (Fairview)		2	277	Spring	-98.2	-12.69				
NE	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
NE	Littlefield Spring		1	275	Spring	-98.5	-12.73				
NE	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
NE	Meloy Spring		1	276	Spring	-99.8	-12.75				
NE	Scotty Spring		1	272	Spring	-98.9	-12.73				
NE	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
NE	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
NE	Fence Spring		1	278	Spring	-97.4	-12.55				

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Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NE	Fox Cabin		1	273	Spring	-103.5	-13.59				
NE	Lower Fairview		1	281	Spring	-97.5	-12.39				
NE	Robison Spring		1	279	Spring	-97.9	-12.34				
NE	Upper Fairview		1	280	Spring	-97.7	-12.66				
SW	Black Rock Spring		2	158	Spring	-93.8	-12.31				
SW	Coyote Spring		2	169	Spring	-95.1	-12.53				
SW	Hamilton Spring		1	298	Spring	-93.1	-11.76				
SW	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
SW	Mustang Spring		2	135	Spring	-90.5	-12.49				
SW	Pahroc Spring		3	131	Spring	-92.2	-12.65				
SW	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
SW	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
NW	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
Evporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
Evaporated	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
ET	**ET**	**0**						**-99.0**	**-13.12**		
Carb Well	**Fugro Dry Lake V Deep Well**		**2**	**179**	**Well**	**-107.5**	**-14.16**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
Carb Well	**181M1**		**1**	**603**	**Deep Well**	**-105.0**	**-13.67**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
Carb Well	**181W909M**		**1**	**604**	**Deep Well**	**-104.6**	**-13.50**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
209	**GW Outflow (Pahranagat)**	**0**						**-99.0**	**-13.12**		
182	**GW Outflow (Delamar)**	**18,700**						**-99.0**	**-13.12**		
xxxxxxxx	xxxxxxxxxxxxxxxxxxxxxxxx	xxxxxxxx	xxxxxxx	xxxxx	xxxxxxxxx	xxxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	
182	**Delamar Valley**										
181	**Inflow (Dry Lake)**	**18,700**				**-99.0**	**-13.12**				
182 E	Delamar Mtns.	5,755				-92.5	-12.32			81	
182 W	S. Pahroc Rng.	1,073				-94.6	-12.81			82	
TR	**Total Recharge**	**6,800**				**-92.8**	**-12.39**				
E	Abandoned Spring		1	266	Spring	-94.5	-12.32				
E	Red Rock Spring		1	256	Spring	-95.0	-12.30				
E	Oak Spring		1	269	Spring	-90.0	-11.87				
E	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
E	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
E	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
E	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
E	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
E	Bishop Spring		3	107	Spring	-87.2	-11.72				
E	Buckboard Spring		1	264	Spring	-88.2	-11.71				
E	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
E	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
E	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
E	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
E	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
E	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
E	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
W	Pahroc Spring		3	131	Spring	-92.2	-12.65				
W	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
W	Sixmile Spring		1	112	Spring	-93.4	-13.06				
W	Eightmile Spring		2	295	Spring	-95.6	-13.09				
W	Twin Spring		1	294	Spring	-97.4	-13.24				
W	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
W	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
W	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
ET	**ET**	**0**						**-97.3**	**-12.93**		
Well	**182W906M**		**1**	**607**	**Deep Well**	**-100.3**	**-13.33**	***-99.0***	***-13.12***	***Inter-basin flow from Dry Lake Valley***	
209	**GW Outflow (Pahranagat)**	**0**						**-97.3**	**-12.93**		
210	**GW Outflow (Coyote Spr)**	**25,500**						**-97.3**	**-12.93**		

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
206	**Kane Springs Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
206 W	Delamar Mtns.	4,149				-89.0	-12.22			90	
206 E	Meadow Valley Mtns.	305				-87.4	-11.92			91	
TR	**Total Recharge**	**4,500**				**-88.9**	**-12.20**				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
W	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
W	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
W	Bishop Spring		3	107	Spring	-87.2	-11.72				
W	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
W	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
W	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
W	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
W	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
ET	**ET**	**0**						**-88.9**	**-12.20**		
210	**GW Outflow (Coyote Spr)**	**4,500**						**-88.9**	**-12.20**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
210	**Coyote Springs Valley**										
209	**Inflow (Pahranagat)**	**20,400**				**-103.2**	**-13.89**				
182	**Inflow (Delamar)**	**25,500**				**-97.3**	**-12.93**				
206	**Inflow (Kane Springs)**	**4,500**				**-88.9**	**-12.20**				
210 NE	S. Delamar Mtns.	1,059				-89.0	-12.22			83	
210 E	S. Meadow Valley Mtns.	16				-87.4	-11.9			84	
210 NW	S. of Maynard Lake	0				-94.0	-12.30			87	
210 SE	Arrow Canyon Rng.	15				-81.0	-10.60			88	
210 W	Sheep Range	1,202				-92.7	-12.83			89	
TR	**Total Recharge**	**2,300**				**-90.8**	**-12.53**				
W	Cow Camp Spring		4	47	Spring	-91.9	-12.53				
W	Lamb Spring		1	86	Spring	-92.5	-13.15				
W	Mormon Well Spring		3	53	Spring	-91.8	-12.67				
W	Rye Patch Spring		1	341	Spring	-89.3	-12.31				
W	Sawmill Spring (Sheep)		1	58	Spring	-92.0	-12.85				
W	Sheep Spring (Sheep Range)		1	83	Spring	-96.0	-13.35				
W	Wiregrass Spring (Sheep)		13	49	Spring	-95.1	-12.93				
W	White Rock Spring (Sheep)		2	64	Spring	-85.5	-10.17	Evaporated not used in recharge calculation			
NW	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30				
SE	Wamp Spring		1	52	Spring	-81.0	-10.60				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
NE	Bishop Spring		3	107	Spring	-87.2	-11.72				
NE	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NE	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
NE	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NE	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NE	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NE	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
NE	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
Carb Well	CSVM-2		1	612	Well	-97.7	-13.14				
Carb Well	CSVM-3		1	613	Well	-98.0	-13.10				
Carb Well	CSVM-4		1	614	Well	-102.5	-13.41				
Carb Well	CSVM-6		1	616	Well	-100.7	-12.97				
Carb Well	CSI-1		1	609	Well	-102.6	-13.08				
Carb Well	CSI-2		1	610	Well	-100.2	-12.90				
Carb Well	CSI-3		1	611	Well	-99.6	-13.03				
Carb Well	USGS CSV-1		1	71	Well	-103.0	-13.55				
Carb Well	CE-VF-2 Well		2	81	Well	-101.0	-13.10				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
Carb Well	Fugro CV Deep Well CE-DT-5		3	77	Well	-99.6	-12.96				
Carb Well	CE-DT-4		1	78	Well	-102.5	-13.00				
CARB	**Carbonate Well (Avg)**		**14**			**-100.7**	**-13.11**	***-98.9***	***-13.25***		***Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys***
ET	**ET**	**0**						**-98.6**	**-13.22**		
219	**GW Outflow (Muddy)**	**37,700**						**-98.6**	**-13.22**		
217	**GW Outflow (Hidden)**	**15,000**						**-98.6**	**-13.22**		
219	**Upper Moapa (Muddy) Valley**										
205	**Inflow (LMVW)**	**4,000**				**-93.6**	**-12.60**				
210	**Inflow (Coyote)**	**37,700**				**-98.6**	**-13.22**				
219 S	E. Arrow Canyon?	3				-87.4	-11.92			85	
219 N	Wildcat Wash	40				-87.4	-11.92			86	
TR	**Total Recharge**	**0**				**-87.4**	**-11.92**				
N/S	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
Warm	APCAR	0	1	292	Spring	-98.2	-12.94				
Warm	Baldwin Spring	2226	9	291	Spring	-97.6	-12.97				
Warm	Big Muddy Spring	5500	6	69	Spring	-97.9	-12.89				
Warm	Iverson's Spring	0	1	65	Spring	-97.0	--				
Warm	Jones Spring Pumphouse	0	6	292	Spring	-97.9	-13.05				
Warm	M-8 Spring (Unnamed Spring)	0	1	68	Spring	-99.0	-12.75				
Warm	M-9 Spring (Unnamed Spring)	200	1	70	Spring	-96.5	-12.45				
Warm	Pederson's East	0	9	290	Spring	-97.8	-12.98				
Warm	Pederson's Warm Spring (M-13)	400	15	67	Spring	-97.5	-12.93				
Warm	**Dicharge Warm Sprs (Avg)**	**8,300**	**49**			**-97.8**	**-12.90**	***-98.1***	***-13.16***		***Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys***
Carb Well	CE-DT-6 Well		2	72	Well	-98.0	-13.03				
Carb Well	CSV-2 Well		2	76	Well	-97.9	-12.92				
CARB	**Deep Carbonate Well (Avg)**		**4**			**-97.9**	**-12.97**	***-98.1***	***-13.16***		***Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys***
ET	**ET**	**6,000**						**-98.1**	**-13.16**		
Gage	**Moapa Gage**	**34,000**									
218	**SW Outflow (California)**	**34,000**									
218	**GW Outflow (California)**	**1,700**						**-98.1**	**-13.16**		
217	**Hidden Valley**										
210	**Inflow (Coyote)**	**15,000**				**-98.6**	**-13.22**				
217 E	E. Hidden	0				-81.0	-10.60			99	
217 W	W. Hidden	47				-81.0	-10.60			100	
TR	**Total Recharge**	**0**				**-81.0**	**-10.60**				
W	Wamp Spring		1	52	Spring	-81.0	-10.60				
ET	**ET**	**0**						**-98.6**	**-13.22**		
216	**GW Outflow (Garnet)**	**15,000**						**-98.6**	**-13.22**		
216	**Garnet Valley**										
217	**Inflow (Hidden)**	**15,000**				**-98.6**	**-13.22**				
216 E	Apex	0				-81.0	-10.60			104	
216 W	Las Vegas Range	106				-81.0	-10.60			105	
TR	**Total Recharge**	**100**				**-81.0**	**-10.60**				
W	Wamp Spring		1	52	Spring	-81.0	-10.60				
	Dry Lake Valley Well		1	34	Well	-97.5	-13.30				
Carb Well	GP Apex Well		3	17	Well	-97.2	-13.53				
Carb Well	Unnamed Well (Near Dry Lake Range)		1	24	Well	-96.0	-13.70				
Carb Well	US Lime Well (Genstar)		1	27	Well	-97.0	-12.75				
CARB	**Wells (Avg)**		**6**			**-96.9**	**-13.32**	***-98.6***	***-13.22***		***Inter-basin flow from Hidden Valley***

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Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
ET	ET	0						-98.5	-13.20		
218	GW Outflow (California)	15,100						-98.5	-13.20		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
218	California Wash										
219	SW Inflow (Muddy)	34,000									
205	SW Inflow (LMVW)	0									
219	Inflow (Muddy)	1,700				-98.1	-13.16				
205	Inflow (Lower Meadow VW)	5,200				-93.6	-12.60				
216	Inflow (Garnet)	15,100				-98.5	-13.20				
218 E	Moapa Paiutes	0				-82.0	-10.60			110	
218 W	Muddy Mtns.	0				-82.0	-10.60			111	
TR	Total Recharge	0				0.0	0.00				
W	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Carb Well	Calpine Test Well 1a		1	43	Well	-99.0	-13.50				
Carb Well	Moapa Well		1	41	Well	-99.0	-13.40				
ET	ET	4,500						-97.3	-13.06		
CARB	Carbonate Well (Avg)					-99.0	-13.45	*-97.3*	*-13.06*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*	
220	GW Outflow (Lower Moapa)	18,800						-97.3	-13.06		
215	GW Outflow (Black Mtn Area)	2,000						-97.3	-13.06		
220	SW Outflow (Lower Moapa)	30,700									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
215	Black Mountains Area										
218	Inflow (California Wash)	2,000				-97.3	-13.06				
215 NE	Muddy Mtns.	0				-85.0	-10.95			113	
215 SE	Black Mtns.	0				-79.5	-10.65			114	
215 W	Gypsum Wash	0				-79.5	-10.65			112, 166	
TR	Total Recharge	0				0.0	0.00				
SE	Cottonwood Spring (Black Mtns.)	0	1	8	Spring	-80.0	-10.80				
SE	Sandstone Spring	0	1	10	Spring	-79.0	-10.50				
NE	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
NE	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Alluvial Spri	Bitter Spring	5	1	14	Spring	-77.0	-9.90				
Carb Spr	Blue Point Spring	440	5	26	Spring	-92.6	-12.40				
Carb Spr	Corral Spring (Unnamed Spring)	0	1	19	Spring	-91.5	-12.10				
Carb Spr	Rogers Spring	1,200	3	21	Spring	-91.7	-12.33				
Carb Spr	Scirpus Spring (No spring on Map)	0	1	20	Spring	-90.0	-12.00				
Carb Spr	VF Spring 1	0	1	28	Spring	-88.0	-11.20				
Carb Spr	VF Spring 2	6	1	29	Spring	-92.0	-11.80				
Carb Spr	VF Spring 3	17	1	30	Spring	-93.0	-12.20				
ET	ET	1,400						-97.3	-13.06		
CARB	Carbonate Spr (Avg)	1,700	13			-91.3	-12.01	*-97.3*	*-13.06*	*Weighted Average of Inflow from Califronia Wash*	
999	GW Outflow (Colorado River)	600						-97.3	-13.06		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
220	Lower Moapa Valley										
218	GW Inflow (California Wash)	18,800				-97.3	-13.06				
218	SW Inflow (California Wash)	30,700									
220 S	Valley of Fire	0				-88.0	-11.30			101	
220 N	S. Mormon Mtns.	37				-88.3	-12.50			102	
TR	Total Recharge	0				-88.3	-12.50				
N	Davies Spring		1	90	Spring	-89.0	-12.50				
N	Hackberry Spring		1	84	Spring	-87.0	-12.30				
N	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
S	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
Carb Well	EH-7		1	56	Well	-91.0	-12.45				
Carb Well	EH-3 Weiser Wash		1	61	Well	-91.0	-12.70				
ET	**ET**	**25,300**						**-97.3**	**-13.06**		
CARB	**Carbonate Well (Avg)**		2			-91.0	-12.58	***-93.6***	***-12.60***	***Inter-basin flow from Lower Meadow Valley Wash***	
999	**GW Outflow (Colorado River)**	**17,200**						**-97.3**	**-13.06**		
999	**SW Outflow (Colorado River)**	**7,000**									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
Colorado R	**Lake Mead (Colorado River)**										
210	**GW Inflow (Black Mountains Area)**	**600**				**-97.3**	**-13.06**				
205	**GW Inflow (Lower Moapa)**	**17,200**				**-97.3**	**-13.06**				
999	**Groundwater Total**	**17,800**						**-97.3**	**-13.06**		
205	**SW Inflow (Lower Moapa)**	**7,000**									
999	**Surface water Total**	**7,000**									
999	**Inflow Total**	**24,800**									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
183	**Lake Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
183 NE	Fortification Rng	1,499				-106.3	-14.16			49	
183 NW	Cen. Schell Cr. Rng	4,759				-108.1	-14.74			51	
183 SE	Wilson Cr. Rng. @ Atlanta	4,188				-104.7	-13.75			50	
183 SW	Fairview Rng.	1,716				-101.1	-13.29			60	
TR	**Total Recharge**	**12,200**				**-105.7**	**-14.12**				
NE	Indian Springs		1	375	Spring	-106.3	-14.16				
NW	Big Spring North	700	1	211	Spring	-112.0	-15.10				
NW	Big Spring South	1,600	1	210	Spring	-111.0	-14.80				
NW	Geyser Spring	340	1	213	Spring	-105.0	-14.50				
NW	North Creek Spring	1,200	1	214	Spring	-105.0	-14.60				
NW	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
NW	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
SE	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
SE	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
SE	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
SW	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
SW	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
SW	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
SW	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
ET	**ET**	**6,100**						**-105.7**	**-14.12**		
202	**GW Outflow (Patterson)**	**6,100**						**-105.7**	**-14.12**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
202	**Patterson Valley**										
183	**Inflow (Lake)**	**6,100**				**-105.7**	**-14.12**				
202 E	Wilson Cr. Rng. @ Mt. Wilson	6,464				-97.7	-12.99			47	
202 W	Bristol Rng.	3,991				-99.2	-13.10			48	
TR	**Total Recharge**	**10,500**				**-98.3**	**-13.03**				
E	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
E	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
E	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
E	Parsnip Spring		1	180	Spring	-93.5	-12.80				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
E	Horsethief Spring		2	314	Spring	-97.0	-12.68				
E	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		1	156	Spring	-102.3	-13.88				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Fox Cabin		1	273	Spring	-103.5	-13.59				
W	Scotty Spring		1	272	Spring	-98.9	-12.73				
W	Upper Fairview		1	280	Spring	-97.7	-12.66				
W	Lower Fairview		1	281	Spring	-97.5	-12.39				
W	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
W	McDermitt Spring		1	323	Spring	-94.3	-11.21	Evaporated so not used in recharge calculation			
ET	**ET**	**1,300**						**-101.0**	**-13.43**		
203	**GW Outflow (Panaca)**	**15,300**						**-101.0**	**-13.43**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
201	**Spring Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
201 E	White Rock Mtns.	5,904				-100.9	-13.52			52	
201 W	Wilson Cr. Rng. @ Parsnip Pk.	5,161				-97.7	-12.99			53	
TR	**Total Recharge**	**11,100**				**-99.4**	**-13.28**				
E	Barrel Spring		1	317	Spring	-100.5	-13.36				
E	anyon Spring (Unnamed Spring in Burnt Canyon)		1	187	Spring	-93.0	-12.30				
E	Lion Spring		1	318	Spring	-103.4	-14.11				
E	South Monument Spring		1	319	Spring	-102.3	-14.23				
E	Ripgut Sp #40		1	411	Spring	-106.4	-14.38				
E	Unnamed Spring #1(White Rock Mts)		1	415	Spring	-109.6	-15.05				
E	Unnamed Spring #2 (White RockMts)		1	417	Spring	-97.0	-13.00				
E	Upper Burnt Canyon Spring		1	416	Spring	-97.6	-12.83				
E	Upper Burnt Canyon Spring #2		1	416	Spring	-103.6	-13.66				
E	Jnnamed Spring nr Redd's Cabin Summit		2	173	Spring	-94.4	-12.44				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
E	Unnamed Spring in Miller Canyon		1	313	Spring	-103.7	-14.27				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
W	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
W	Parsnip Spring		1	180	Spring	-93.5	-12.80				
W	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
Surface	Camp Creek		1	184	Surface	-102.0	-14.00	Surface Water not included in recharge average			
Surface	MVW above Eagle Canyon		1	168	Surface	-93.0	-12.00	Surface Water not included in recharge average			
ET	**ET**	**3,900**						**-99.4**	**-13.28**		
200	**GW Outflow (Eagle)**	**7,200**						**-99.4**	**-13.28**		
200	**SW Outflow (Eagle)**	**0**						**-97.5**	**-13.00**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
200	**Eagle Valley**										
201	**Inflow (Spring)**	**7,200**				**-99.4**	**-13.28**				
201	**SW Inflow (Spring)**	**0**				**-97.5**	**-13.00**				
200 E	E. Eagle (Ursine) Valley	1,560				-99.1	-13.28			63	
200 W	W. Eagle (Ursine) Valley	412				-97.0	-12.68			64	
TR	**Total Recharge**	**2,000**				**-98.7**	**-13.15**				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
E	Butcher Spring		1	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**1,000**						**-99.3**	**-13.25**		
199	**GW Outflow (Rose)**	**8,200**						**-99.3**	**-13.25**		
198	**SW Outflow (Rose)**	**0**						**-99.3**	**-13.25**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
199	**Rose Valley**										
200	**Inflow (Eagle)**	**8,200**				**-99.3**	**-13.25**				
200	**SW Inflow (Eagle)**	**0**				**-99.3**	**-13.25**				
199 E	E. Rose Valley	163				-99.1	-13.28			65	
199 W	W. Rose Valley	78				-97.0	-12.68			66	
TR	**Total Recharge**	**200**				**-98.4**	**-13.08**				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**600**						**-99.2**	**-13.24**		
198	**GW Outflow (Dry)**	**7,800**						**-99.2**	**-13.24**		
198	**SW Outflow (Dry)**	**0**						**-99.3**	**-13.25**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
198	**Dry Valley**										
199	**Inflow (Rose)**	**7,800**				**-99.2**	**-13.24**				
199	**SW Inflow (Rose)**	**0**				**-99.3**	**-13.25**				
198 E	E. Dry Valley	2,860				-96.9	-12.99			67	
198 W	W. Dry Valley	321				-97.0	-12.68			68	
TR	**Total Recharge**	**3,200**				**-96.9**	**-12.96**				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
Warm Sprin	Flatnose Spring (Unnamed Spring)		1	153	Spring	-101.0	-13.40	-99.2	-13.24	***Inter-basin flow from Dry Valley***	
Spring	Delmues Spring (Unnamed Spring)		1	149	Spring	-104.0	-13.40			Local Valley spring not included in recharge calculation	
ET	**ET**	**3,700**						**-98.5**	**-13.16**		
203	**GW Outflow (Panaca)**	**7,300**						**-98.5**	**-13.16**		
203	**SW Outflow (Panaca)**	**0**						**-99.2**	**-13.24**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
204	**Clover Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
204 N	South of Beaver Dam	8,232				-92.2	-12.42			71	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
204 S	North of Jack's Mtn	6,451				-92.0	-12.52			72	
TR	**Total Recharge**	**14,700**				**-92.1**	**-12.46**				
N	Acoma Well		1	118	Well	-95.0	-12.60				
N	Cave Spring (Clover)		2	247	Spring	-92.8	-12.37				
N	Clover Creek Valley Well 246		1	120	Well	-89.0	-12.40				
N	Ramone Mathews Well		1	115	Well	-92.0	-12.30				
S	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
S	East Settling Spring		1	248	Spring	-92.2	-12.76				
S	Ella Spring		1	251	Spring	-95.8	-12.56				
S	Little Springs (Clover Mts)		2	254	Spring	-93.3	-12.81				
S	Quaking Aspen Spring		1	255	Spring	-93.6	-12.98				
S	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
S	Unnamed Spring		1	113	Spring	-86.5	-11.60				
Alluvial Well	Clover Creek Valley Well 232		1	114	Well	-84.0	-11.70				
ET	**ET**	**5,200**						**-92.1**	**-12.46**		
205	**GW Outflow (LMVW)**	**9,500**						**-92.1**	**-12.46**		
205	**SW Outflow (LMVW)**	**0**						**-92.1**	**-12.46**		
203	**Panaca Valley**										
202	**Inflow (Patterson)**	**15,300**				**-101.0**	**-13.43**				
198	**Inflow (Dry)**	**7,300**				**-98.5**	**-13.16**				
198	**SW Inflow (Dry)**	**0**				**-99.2**	**-13.24**				
203 E	Condor Canyon	2,479				-92.0	-12.19			69	
203 W	Cathedral Gorge	2,984				-98.9	-13.28			70	
TR	**Total Recharge**	**5,500**				**-95.8**	**-12.78**				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	***-101.0***	***-13.43***	***Inter-basin flow from Patterson Valley***	
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	***-105.7***	***-14.12***	***Inter-basin flow from Lake Valley***	
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	***-105.7***	***-14.12***	***Inter-basin flow from Lake Valley***	
Surface	Meadow Valley Wash, Cal.		1	130	Surface	-97.0	-13.10				
Warm	Lester Mathews Well		1	142	Well	-103.0	-13.30				
Warm	Panaca Town Well		1	143	Well	-106.0	-14.00				
Warm	North Lee Well		1	147	Well	-101.0	-13.30				
ET	**ET**	**18,900**						**-99.3**	**-13.24**		
205	**GW Outflow (LMVW)**	**9,200**						**-99.3**	**-13.24**		
205	**SW Outflow (LMVW)**	**0**						**-97.0**	**-13.10**		
205	**Lower Meadow Valley Wash**										
203	**Inflow (Panaca)**	**9,200**				**-99.3**	**-13.24**				
204	**Inflow (Clover)**	**9,500**				**-92.1**	**-12.46**				
203	**SW Inflow (Panaca)**	**0**				**-97.0**	**-13.10**				
204	**SW Inflow (Clover)**	**0**				**-92.1**	**-12.46**				
205 NW	Delamar Mtns.	3,077				-92.23	-12.28			92	
205 NE	Clover Mountains	7,290				-90.4	-12.25			93	
205 SW	Meadow Valley Mtns.	1,146				-87.4	-11.92			94	
205 SE	Mormon Mtns.	895				-88.3	-12.50			95	
TR	**Total Recharge**	**12,400**				**-90.4**	**-12.24**				
NE	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
NE	East Settling Spring		1	248	Spring	-92.2	-12.76			
NE	Ella Spring		1	251	Spring	-95.8	-12.56			
NE	Garden Spring		1	246	Spring	-87.0	-11.54			
NE	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11			
NE	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03			
NE	Unnamed Spring		1	113	Spring	-86.5	-11.60			
NE	Unnamed Spring (Clover)		1	249	Spring	-88.0	-12.20			
NE	Garden Spring		1	246	Spring	-87.0	-11.54			
NW	Abandoned Spring		1	266	Spring	-94.5	-12.32			
NW	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation		
NW	Buckboard Spring		1	264	Spring	-88.2	-11.71			
NW	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87			
NW	Bishop Spring		3	107	Spring	-87.2	-11.72			
NW	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47			
NW	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98			
NW	Lower Indian Spring		1	267	Spring	-96.0	-12.62			
NW	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47			
NW	Oak Spring		1	269	Spring	-90.0	-11.87			
NW	Red Rock Spring		1	256	Spring	-95.0	-12.30			
NW	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60			
NW	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58			
NW	Sawmill Spring West		1	258	Spring	-91.8	-12.86			
NW	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54			
NW	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96			
NW	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69			
NW	Upper Indian Spring		1	268	Spring	-88.0	-11.46			
NW	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95			
SW	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92			
SE	Davies Spring		1	90	Spring	-89.0	-12.50			
SE	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70			
SE	Hackberry Spring		1	84	Spring	-87.0	-12.30			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	***-95.7***	***-12.84***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	**ET**	**21,900**						**-93.6**	**-12.60**	
206	**GW Outflow (Upper Moapa)**	**4,000**						**-93.6**	**-12.60**	
218	**GW Outflow (California Wash)**	**5,200**						**-93.6**	**-12.60**	
218	**GW Outflow (Lower Moapa)**	**0**						**-93.6**	**-12.60**	
218	**SW Outflow (California Wash)**	**0**						**-93.6**	**-12.60**	

SNWA/BARCASS (SNWA, 2007; Welch and Bright, 2007)											
Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
175	**Long Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
175 SE	Butte Mtn. (S)	2,673				-119.6	-15.53			35	
175 SW	Alligator Rdg.	3,664				-122.4	-15.96			36	
175 NW	Maverick Springs	11,435				-123.9	-16.23			37	
175 NE	Butte Mtn. (N)	3,224				-119.2	-15.36			164	
TR	**Total Recharge**	**21,000**				**-122.4**	**-15.96**				
SE	Butte Spring		1	327	Spring	-120.4	-15.79				
SE	Cabin Spring		1	328	Spring	-124.4	-15.89				
SE	Robbers Roost #2 Spring (Butte)		1	340	Spring	-112.0	-14.39				
SE	Deer Spring (Butte)		1	332	Spring	-114.1	-14.74				
SE	Summit Spring		1	348	Spring	-120.8	-15.94				
SE	Thirty Mile Spring		1	242	Spring	-126.0	-16.40				
NW	Mud Spring (Buck Mts)		1	339	Spring	-117.6	-15.21				
NW	Ram. Res. Wtr Supply Well		1	244	Well	-129.5	-16.75				
NW	Unnamed Near Little Willow Spring		1	351	Spring	-125.9	-17.04				
NW	Well at Alligator Ridge		1	243	Well	-127.0	-16.60				
NW	Woodchuck Spring		1	356	Spring	-119.6	-15.55				
NE	White Rock Spring (Butte)		1	355	Spring	-119.2	-15.36				
ET	**ET**	**1,200**						**-122.4**	**-15.96**		
154	**GW Outflow (Newark)**	**0**						**-122.4**	**-15.96**		
174	**GW Outflow (Jakes)**	**19,800**						**-122.4**	**-15.96**		
174	**Jakes Valley**										
175	**Inflow (Long)**	**19,800**				**-122.4**	**-15.96**				
174 E	Egan Range	2,909				-118.4	-15.31			33	
174 W	North White Pine	10,076				-120.3	-15.83			34	
TR	**Total Recharge**	**13,000**				**-119.9**	**-15.71**				
NW	Tunnel Spring		1	366	Spring	-118.3	-15.02				
W	Aspen Springs North		1	349	Spring	-119.3	-15.84				
W	Aspen Springs South		1	324	Spring	-120.9	-16.02				
W	Chicken Spring		1	330	Spring	-122.0	-16.17				
W	Circle Wash Spring		1	331	Spring	-114.5	-15.30				
W	Sage Hen Spring		1	342	Spring	-112.4	-14.76				
W	Sand Spring		1	239	Spring	-123.0	-16.20				
W	Shellback Spring		1	344	Spring	-123.6	-16.54				
W	Unnamed Hayden Canyon Spring		1	350	Spring	-120.9	-15.69				
W	Unnamed Shellback Ridge Spring		1	352	Spring	-123.6	-16.18				
W	Wild Horse Spring (White Pine)		1	240	Spring	-129.0	-16.80				
W	Unnamed Stone Cabin Spring		2	354	Spring	-116.2	-15.39				
W/E	Indian Spring (Butte)		1	334	Spring	-119.1	-15.31				
W/E	Sammy Spring		1	343	Spring	-117.6	-15.30				
W	Upper Illipah Crk		2	238	Surface	-123.5	-16.10	Surface Water not included in recharge average			
ET	**ET**	**900**						**-119.9**	**-15.71**		
207N	**GW Outflow (NWRV)**	**31,900**						**-121.4**	**-15.86**		
180	**Cave Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
180 E	S. Schell Cr. Rng	7,438				-105.0	-14.28			43,44	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
180 W	S. Egan Rng	7,944				-107.8	-14.28			45,46	
TR	**Total Recharge**	**15,400**				**-106.5**	**-14.28**				
E	North Creek Spring		1	214	Spring	-105.0	-14.60				
E	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
E	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
E	Sheep Spring (Schell Ck)		1	212	Spring	-99.5	-13.70				
E	Robbers Roost Spring (Schell Ck)		1	389	Spring	-109.7	-14.75				
E	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
W	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
W	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
W	Granite Spring		1	440	Spring	-103.4	-13.32				
W	Haggerty Spring		1	387	Spring	-109.6	-14.78				
W	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
W	Silver Spring		2	385	Spring	-111.4	-14.71				
W	Shingle Spring		2	203	Spring	-103.7	-13.33				
W	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
W	Trough Spring		1	413	Spring	-103.6	-13.56				
ET	**ET**	**1,600**						**-106.5**	**-14.28**		
Well	**180W902**		**1**	**601**	**Deep Well**	**-104.7**	**-14.12**				
Well	**180W501**		**1**	**600**	**Deep Well**	**-105.6**	**-14.12**				
208	**GW Outflow (Pahroc)**	**9,800**						**-106.5**	**-14.28**		
207S	**GW Outflow (SWRV)**	**4,000**						**-106.5**	**-14.28**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
207N	**North White River Valley**										
174	**Inflow (Jakes)**	**31,900**				**-121.4**	**-15.86**				
207 NE	Egan Rng North	16,554				-112.3	-15.15			38	
207 NW	White Pine Rng.	12,030				-115.0	-15.18			39, 40	
TR	**Total Recharge**	**28,600**				**-113.5**	**-15.16**				
NE	on Creek Spring (Unnamed Spring in Gubler Canyon)		1	235	Spring	-111.0	-14.90				
NE	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
NE	Lone Pine Spring		3	223	Spring	-110.2	-14.90				
NE	High Springs		1	433	Spring	-113.4	-15.43				
NE	Lion Spring (Egan Range)		1	430	Spring	-114.8	-15.34				
NE	Mud Spring		1	446	Spring	-111.0	-14.53				
NE	Pine Springs (Egan Range)		1	434	Spring	-116.0	-15.71				
NE	Unnamed Spring #1(Egan)		1	435	Spring	-112.2	-15.14				
NE	Unnamed Spring #2 (Egan Range)		1	436	Spring	-110.0	-15.14				
NE	Unnamed Spring #3 (Egan Range)		1	437	Spring	-110.2	-15.07				
NE	Unnamed Spring #4 (Egan Range)		1	438	Spring	-114.0	-15.37				
NE	Unnamed Spring #5 (Egan Range)		1	445	Spring	-109.6	-14.72				
NE	North Spring		2	237	Spring	-112.4	-15.11				
NE	Second Sawmill Spring		1	222	Spring	-110.0	-14.70				
NE	South Spring (Egan)		2	236	Spring	-111.5	-15.12				
NE	Upper Terrace Spring WR2		14	270	Spring	-114.0	-15.42				
NE	Water Canyon Spring		1	358	Spring	-114.4	-15.60				
NE	Lund Spring		1	221	Spring	-113.0	-15.40	Local Valley spring not included in recharge calculation			
NE	Water Canyon		2	233	Surface	-116.0	-15.25	Surface Water not included in recharge average			
NW	Big Tom Plain Spring		1	326	Spring	-121.1	-15.92				
NW	Deer Spring (White Pine)		2	322	Spring	-119.3	-15.87				
NW	Unnamed Spring #1 (White Pine)		1	359	Spring	-114.8	-15.36				
NW	Unnamed Spring #2 (White Pine)		1	360	Spring	-114.9	-15.66				
NW	Unnamed Spring #3 (White Pine)		1	361	Spring	-113.1	-14.96				
NW	Unnamed Spring #4 (White Pine)		1	362	Spring	-116.3	-15.01				
NW	Unnamed Spring #5 (White Pine)		3	363	Spring	-116.0	-15.36				
NW	Unnamed Spring #6 (White Pine)		1	364	Spring	-115.1	-14.98				
NW	Halfway Spring (RS)		2	429	Spring	-108.7	-13.52				
NW	Easter Spring		1	365	Spring	-119.4	-15.56				
NW	Little Tom Plain Spring		2	337	Spring	-121.0	-15.86				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NW	Monitoring Spring WR1		14	320	Spring	-113.7	-15.58				
NW	Saddle Spring (White Pine)		3	357	Spring	-116.8	-15.45				
NW	Secret Spring		1	220	Spring	-110.0	-14.00				
NW	Unnamed Spring below Currant Mtn		1	226	Spring	-107.0	-14.00				
NW	Stove Spring		1	347	Spring	-114.5	-15.71				
NW	ıed Spring in dry creek bed (White Pine Range)		1	321	Spring	-113.6	-15.31				
NW	Snowmelt Below Duckwater Peak	5,700	1	224	Surface	-105.0	-14.10	Surface Water not included in recharge average			
NW	Little Currant Creek		1	217	Surface	-113.0	-15.00	Surface Water not included in recharge average			
Warm	Cold Spring, Preston	1,000	2	230	Spring	-123.5	-15.80				
Warm	Nicholas Spring	2,000	1	227	Spring	-124.0	-16.10				
Warm	Preston Big Spring	5,900	11	231	Spring	-122.0	-15.88				
Warm	**Discharge Warm Sprs (Avg)**	**8,900**	**14**			**-122.6**	**-15.92**	***-121.4***	***-15.86***	***Inter-basin flow from Jakes Valley***	
ET	**ET**	**29,500**						**-113.7**	**-15.19**		
207S	**GW Outflow (SWRV)**	**31,000**						**-121.4**	**-15.86**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
207S	**South White River Valley**	WRV Tot Recharge									
		42,900									
207N	**Inflow (N White River)**	**31,000**				**-121.4**	**-15.86**				
180	**Inflow (Cave)**	**4,000**				**-106.5**	**-14.28**				
207 SE	Egan Rng South	7,844				-106.9	-14.15			41	
207 SW	Grant Rng	6,467				-106.5	-14.23			42	
TR	**Total Recharge**	**14,300**				**-106.7**	**-14.18**				
E	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
E	Granite Spring		1	440	Spring	-103.4	-13.32				
E	Haggerty Spring		1	387	Spring	-109.6	-14.78				
E	Silver Spring		2	385	Spring	-111.4	-14.71				
E	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
E	Shingle Spring		2	203	Spring	-103.7	-13.33				
E	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
E	Trough Spring		1	413	Spring	-103.6	-13.56				
E	Butterfield Spring	4,000	1	202	Spring	-105.0	-14.20	local Valley spring not included in recharge calculation			
E	Emigrant Spring	1,900	2	207	Spring	-107.8	-14.50	local Valley spring not included in recharge calculation			
E	Flag Spring #3		1	201	Spring	-105.0	-14.30	local Valley spring not included in recharge calculation			
SW	Albert Spring		1	204	Spring	-107.0	-13.95				
SW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
SW	Brady Spring		2	282	Spring	-109.5	-15.38				
SW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
SW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
SW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
SW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
SW	Murphy Spring		1	373	Spring	-114.5	-15.40				
SW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
Warm	Hot Creek Campground Well	0	1	198	Well	-118.0	-15.30				
Warm	Hot Creek Springs	10,000	10	197	Spring	-118.9	-15.69				
Warm	Moon River Spring	2,800	1	192	Spring	-120.0	-15.80				
Warm	Moorman Spring	400	1	205	Spring	-119.0	-15.70				
Warm	**Discharge Warm Sprs (Avg)**	**13,200**	**13**			**-119.2**	**-15.71**	***-121.4***	***-15.86***	***Inter-basin flow from Northern White River Valley***	
ET	**ET**	**47,200**						**-115.8**	**-15.23**		
208	**GW Outflow (Pahroc)**	**2,100**						**-119.7**	**-15.68**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXXX
172	**Garden Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
172 SW	Quinn Canyon Range	15,621				-104.6	-14.08			171	
172 NW	Grant Range	7,993				-106.5	-14.27			170	
172 NE	Golden Gate Rng	1,063				-98.0	-13.30			55	
172 SE	Worthington Mountains	1,030				-98.0	-13.30			56	

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Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
TR	**Total Recharge**	**25,700**				**-104.7**	**-14.08**			
SW	Unnamed Spring #7 (Quinn)		1	367	Spring	-105.9	-14.23			
SW	Unnamed Spring #8 (Quinn)		1	368	Spring	-104.4	-14.18			
SW	Adaven Spring		2	177	Spring	-105.3	-14.01			
SW	Lower Little Cherry Cr Spring		1	182	Spring	-103.0	-13.90			
SW	Carpenter Spring		1	171	Spring	-95.0	-11.85	Evaporated so not used in recharge calculation		
NW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20			
NW	Brady Spring		2	282	Spring	-109.5	-15.38			
NW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50			
NW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86			
NW	Teaspoon Spring		1	371	Spring	-100.0	-13.26			
NW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29			
NW	Murphy Spring		1	373	Spring	-114.5	-15.40			
NW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation		
SE	The Seeps (Spring)		1	136	Spring	-98.0	-13.30			
ET	**ET**	**1,700**						**-104.7**	**-14.08**	
171	**GW Outflow (Coal)**	**24,000**						**-104.7**	**-14.08**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
171	**Coal Valley**									
172	**Inflow (Garden)**	**24,000**				**-104.7**	**-14.08**			
172	**Inflow (SWRV)**	**0**				**-119.7**	**-15.68**			
171 E	Seaman Rng	1,282				-99.0	-13.13			75
171 W	Golden Gate Rng	2,882				-98.2	-12.87			76
TR	**Total Recharge**	**4,200**				**-98.4**	**-12.95**			
W	Cold Spring		1	288	Spring	-98.9	-12.98			
W	Henry Spring		1	287	Spring	-97.4	-12.77			
W	Little Cut Spring		2	286	Spring	-98.3	-12.85			
E	Seaman Spring		1	306	Spring	-99.0	-13.13			
Carb Well	**USGS-MX C.V. Well (CV-DT-1)**		**2**	**176**	**Well**	**-109.0**	**-14.56**	***-104.7***	***-14.08***	***Underflow from Garden Valley***
ET	**ET**	**0**						**-98.4**	**-12.95**	
208	**GW Outflow (Pahroc)**	**28,200**						**-103.7**	**-13.91**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
208	**Pahroc Valley**									
180	**Inflow (Cave)**	**9,800**				**-106.5**	**-14.28**			
207S	**Inflow (S. White River)**	**2,100**				**-119.7**	**-15.68**			
171	**Inflow (Coal)**	**28,200**				**-103.7**	**-13.91**			
208 E	N. Pahroc Rng.	2,596				-94.2	-12.42			73
208 W	Seaman Rng.	2,286				-99.0	-13.13			74
TR	**Total Recharge**	**4,900**				**-96.4**	**-12.75**			
E	Black Rock Spring		2	158	Spring	-93.8	-12.31			
E	Coyote Spring		2	169	Spring	-95.1	-12.53			
E	Hamilton Spring		1	298	Spring	-93.1	-11.76			
E	Little Boulder Spring		1	301	Spring	-97.2	-13.06			
E	Mustang Spring		2	135	Spring	-90.5	-12.49			
E	Pahroc Spring		3	131	Spring	-92.2	-12.65			
E	Rattlesnake Spring		1	302	Spring	-97.3	-12.65			
E	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90			
W	Seaman Spring		1	306	Spring	-99.0	-13.13			
Evaporated	White Rock Spring (Seaman Range)		1	154	Spring	-90.0	-12.10	Evaporated not used in recharge calculation		
ET	**ET**	**0**						**-96.4**	**-12.75**	
181	**GW Outflow (Dry Lake)**	**2,000**						**-106.5**	**-14.28**	
209	**GW Outflow (Pahranagat)**	**43,000**						**-104.3**	**-13.95**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
209	**Pahranagat Valley**										
208	**Inflow (Pahroc)**	**43,000**				**-104.3**	**-13.95**				
181	**Inflow (Dry Lake)**	**0**				**-99.0**	**-13.12**				
209	**Inflow (Delamar)**	**0**				**-97.3**	**-12.93**				
209 E	S. Pahroc Rng.	2,377				-94.9	-12.83			77, 78	
209 W	Mt. Irish/Pahranagat Rng.	3,545				-98.4	-14.24			79, 80 (172, 173)	
TR	**Total Recharge**	**5,900**				**-97.0**	**-13.67**				
E	Eightmile Spring		2	295	Spring	-95.6	-13.09				
E	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
E	Sixmile Spring		1	112	Spring	-93.4	-13.06				
E	Twin Spring		1	294	Spring	-97.4	-13.24				
E	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
E	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
E	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
S	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30	Local Valley spring not included in recharge calculation			
W	Reed Spring		1	289	Spring	-98.4	-14.24				
Warm	Ash Springs	12400	6	110	Spring	-109.1	-14.11				
Warm	Little Ash Spring (Ash Spring)	500	1	111	Spring	-107.2	-14.20				
Warm	Crystal Springs	8,200	17	116	Spring	-108.8	-14.41				
Warm	Hiko Spring	4,300	7	122	Spring	-108.7	-14.39				
Warm	**Discharge Warm Springs (Avg)**	**25,400**	**31**			**-108.9**	**-14.26**	***-104.3***	***-13.95***	***Inter-basin flow from Pahroc Valley***	
ET	**ET**	**28,500**						**-102.8**	**-13.89**		
Well	**209M-1**		**1**	**608**	**Deep Well**	**-104.7**	**-13.53**	***-104.3***	***-13.95***	***Inter-basin flow from Pahroc Valley***	
210	**GW Outflow (Coyote Spr)**	**20,400**						**-104.3**	**-13.95**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
181	**Dry Lake Valley**										
208	**Inflow (Pahroc)**	**2,000**				**-106.5**	**-14.28**				
181 NW	S. Schell Ck Range	1,307				-100.4	-13.21			59	
181 SW	N. Pahroc Rng.	2,081				-94.2	-12.42			57	
181 NE	Fairview Rng.	3,709				-99.5	-12.89			58	
181 E	Bristol/Highland Rng.	7,895				-98.9	-13.28			61	
181 SE	Chief Rng.	1,696				-94.6	-12.36			62	
TR	**Total Recharge**	**16,700**				**-98.1**	**-12.98**				
E	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
E	Highland Spring		3	163	Spring	-99.1	-13.36				
E	Lime Spring		2	160	Spring	-98.5	-13.16				
E	Pine Spring		2	157	Spring	-99.0	-13.37				
E	Connor Spring		1	283	Spring	-100.6	-13.84				
E	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
SE	Red Rock Spring		1	256	Spring	-95.0	-12.30				
SE	Abandoned Spring		1	266	Spring	-94.5	-12.32				
SE	Buckboard Spring		1	264	Spring	-88.2	-11.71				
SE	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
SE	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
SE	Oak Spring		1	269	Spring	-90.0	-11.87				
SE	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
SE	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
SE	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
NE	Bailey Spring (Fairview)		2	277	Spring	-98.2	-12.69				
NE	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
NE	Littlefield Spring		1	275	Spring	-98.5	-12.73				
NE	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
NE	Meloy Spring		1	276	Spring	-99.8	-12.75				
NE	Scotty Spring		1	272	Spring	-98.9	-12.73				
NE	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
NE	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
NE	Fence Spring		1	278	Spring	-97.4	-12.55				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NE	Fox Cabin		1	273	Spring	-103.5	-13.59				
NE	Lower Fairview		1	281	Spring	-97.5	-12.39				
NE	Robison Spring		1	279	Spring	-97.9	-12.34				
NE	Upper Fairview		1	280	Spring	-97.7	-12.66				
SW	Black Rock Spring		2	158	Spring	-93.8	-12.31				
SW	Coyote Spring		2	169	Spring	-95.1	-12.53				
SW	Hamilton Spring		1	298	Spring	-93.1	-11.76				
SW	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
SW	Mustang Spring		2	135	Spring	-90.5	-12.49				
SW	Pahroc Spring		3	131	Spring	-92.2	-12.65				
SW	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
SW	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
NW	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
Evaporated	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
Carb Well	**Fugro Dry Lake V Deep Well**		**2**	**179**	**Well**	**-107.5**	**-14.16**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
Carb Well	**181M1**		**1**	**603**	**Deep Well**	**-105.0**	**-13.67**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
Carb Well	**181W909M**		**1**	**604**	**Deep Well**	**-104.6**	**-13.50**	***-106.5***	***-14.28***	***Inter-basin flow from Cave Valley***	
ET	**ET**	**0**						**-98.1**	**-12.98**		
209	**GW Outflow (Pahranagat)**	**0**						**-99.0**	**-13.12**		
182	**GW Outflow (Delamar)**	**18,700**						**-99.0**	**-13.12**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
182	**Delamar Valley**										
181	**Inflow (Dry Lake)**	**18,700**				**-99.0**	**-13.12**				
182 E	Delamar Mtns.	5,755				-92.5	-12.32			81	
182 W	S. Pahroc Rng.	1,073				-94.6	-12.81			82	
TR	**Total Recharge**	**6,800**				**-92.8**	**-12.39**				
E	Abandoned Spring		1	266	Spring	-94.5	-12.32				
E	Red Rock Spring		1	256	Spring	-95.0	-12.30				
E	Oak Spring		1	269	Spring	-90.0	-11.87				
E	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
E	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
E	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
E	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
E	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
E	Bishop Spring		3	107	Spring	-87.2	-11.72				
E	Buckboard Spring		1	264	Spring	-88.2	-11.71				
E	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
E	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
E	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
E	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
E	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
E	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
E	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
W	Pahroc Spring		3	131	Spring	-92.2	-12.65				
W	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
W	Eightmile Spring		2	295	Spring	-95.6	-13.09				
W	Sixmile Spring		1	112	Spring	-93.4	-13.06				
W	Twin Spring		1	294	Spring	-97.4	-13.24				
W	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
W	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
W	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
ET	**ET**	**0**						**-92.8**	**-12.39**		
Well	**182W906M**		**1**	**607**	**Deep Well**	**-100.3**	**-13.33**	***-99.0***	***-13.12***	***Inter-basin flow from Dry Lake Valley***	
209	**GW Outflow (Pahranagat)**	**0**						**-97.3**	**-12.93**		
210	**GW Outflow (Coyote Spr)**	**25,500**						**-97.3**	**-12.93**		

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
206	**Kane Springs Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
206 W	Delamar Mtns.	4,149				-89.0	-12.22			90	
206 E	Meadow Valley Mtns.	305				-87.4	-11.92			91	
TR	**Total Recharge**	**4,500**				**-88.9**	**-12.20**				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
W	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
W	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
W	Bishop Spring		3	107	Spring	-87.2	-11.72				
W	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
W	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
W	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
W	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
W	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
ET	**ET**	**0**						**-88.9**	**-12.20**		
210	**GW Outflow (Coyote Spr)**	**4,500**						**-88.9**	**-12.20**		
210	**Coyote Springs Valley**										
209	**Inflow (Pahranagat)**	**20,400**				**-104.3**	**-13.95**				
182	**Inflow (Delamar)**	**25,500**				**-97.3**	**-12.93**				
206	**Inflow (Kane Springs)**	**4,500**				**-88.9**	**-12.20**				
210 NE	S. Delamar Mtns.	1,059				-89.0	-12.22			83	
210 E	S. Meadow Valley Mtns.	16				-87.4	-11.92			84	
210 NW	S. of Maynard Lake	0				-94.0	-12.30			87	
210 SE	Arrow Canyon Rng.	15				-81.0	-10.60			88	
210 W	Sheep Range	1,202				-92.7	-12.83			89	
TR	**Total Recharge**	**2,300**				**-90.8**	**-12.53**				
W	Cow Camp Spring		4	47	Spring	-91.9	-12.53				
W	Lamb Spring		1	86	Spring	-92.5	-13.15				
W	Mormon Well Spring		3	53	Spring	-91.8	-12.67				
W	Rye Patch Spring		1	341	Spring	-89.3	-12.31				
W	Sawmill Spring (Sheep)		1	58	Spring	-92.0	-12.85				
W	Sheep Spring (Sheep Range)		1	83	Spring	-96.0	-13.35				
W	Wiregrass Spring (Sheep)		13	49	Spring	-95.1	-12.93				
W	White Rock Spring (Sheep)		2	64	Spring	-85.5	-10.17	Evaporated not used in recharge calculation			
NW	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30				
SE	Wamp Spring		1	52	Spring	-81.0	-10.60				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
NE	Bishop Spring		3	107	Spring	-87.2	-11.72				
NE	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NE	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
NE	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NE	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NE	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NE	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
NE	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
Carb Well	CSVM-2		1	612	Well	-97.7	-13.14				
Carb Well	CSVM-3		1	613	Well	-98.0	-13.10				
Carb Well	CSVM-4		1	614	Well	-102.5	-13.41				
Carb Well	CSVM-6		1	616	Well	-100.7	-12.97				
Carb Well	CSI-1		1	609	Well	-102.6	-13.08				
Carb Well	CSI-2		1	610	Well	-100.2	-12.90				
Carb Well	CSI-3		1	611	Well	-99.6	-13.03				
Carb Well	USGS CSV-1		1	71	Well	-103.0	-13.55				
Carb Well	CE-VF-2 Well		2	81	Well	-101.0	-13.10				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
Carb Well	Fugro CV Deep Well CE-DT-5		3	77	Well	-99.6	-12.96				
Carb Well	CE-DT-4		1	78	Well	-102.5	-13.00				
ET	**ET**	**0**						**-90.8**	**-12.53**		
CARB	**Carbonate Well (Avg)**		**6**			**-100.7**	**-13.11**	***-99.4***	***-13.28***	***Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys***	
219	**GW Outflow (Muddy)**	**37,700**						**-99.0**	**-13.24**		
217	**GW Outflow (Hidden)**	**15,000**						**-99.0**	**-13.24**		
219	**Upper Moapa (Muddy) Valley**										
205	**Inflow (LMVW)**	**4,000**				**-96.3**	**-12.92**				
210	**Inflow (Coyote)**	**37,700**				**-99.0**	**-13.24**				
219 S	E. Arrow Canyon?	3				-87.4	-11.92			85	
219 N	Wildcat Wash	40				-87.4	-11.92			86	
TR	**Total Recharge**	**0**				**-87.4**	**-11.92**				
N/S	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
Warm	APCAR	0	1	292	Spring	-98.2	-12.94				
Warm	Baldwin Spring	2226	9	291	Spring	-97.6	-12.97				
Warm	Big Muddy Spring	5500	6	69	Spring	-97.9	-12.89				
Warm	Iverson's Spring	0	1	65	Spring	-97.0	--				
Warm	Jones Spring Pumphouse	0	6	292	Spring	-97.9	-13.05				
Warm	M-8 Spring (Unnamed Spring)	0	1	68	Spring	-99.0	-12.75				
Warm	M-9 Spring (Unnamed Spring)	200	1	70	Spring	-96.5	-12.45				
Warm	Pederson's East	0	9	290	Spring	-97.8	-12.98				
Warm	Pederson's Warm Spring (M-13)	400	15	67	Spring	-97.5	-12.93				
Warm	**Dicharge Warm Sprs (Avg)**	**8,300**	**49**			**-97.8**	**-12.90**	***-98.8***	***-13.21***	***Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys***	
Carb Well	CE-DT-6 Well		2	72	Well	-98.0	-13.03				
Carb Well	CSV-2 Well		2	76	Well	-97.9	-12.92				
CARB	**Deep Carbonate Well (Avg)**	**Input into M**	**4**			**-97.9**	**-12.97**	***-98.8***	***-13.21***	***Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys***	
ET	**ET**	**6,000**						**-98.8**	**-13.21**		
Gage	Moapa Gage	34,000									
218	**SW Outflow (California)**	**34,000**									
218	**GW Outflow (California)**	**1,700**						**-98.8**	**-13.21**		
217	**Hidden Valley**										
210	**Inflow (Coyote)**	**15,000**				**-99.0**	**-13.24**				
217 E	E. Hidden	0				-81.0	-10.60			99	
217 W	W. Hidden	47				-81.0	-10.60			100	
TR	**Total Recharge**	**0**				**-81.0**	**-10.60**				
W	Wamp Spring		1	52	Spring	-81.0	-10.60				
ET	**ET**	**0**						**-81.0**	**-10.60**		
216	**GW Outflow (Garnet)**	**15,000**						**-99.0**	**-13.24**		
216	**Garnet Valley**										
217	**Inflow (Hidden)**	**15,000**				**-99.0**	**-13.24**				
216 E	Apex	0				-81.0	-10.60			104	
216 W	Las Vegas Range	106				-81.0	-10.60			105	
TR	**Total Recharge**	**100**				**-81.0**	**-10.60**				
W	Wamp Spring		1	52	Spring	-81.0	-10.60				
	Dry Lake Valley Well		1	34	Well	-97.5	-13.30				
Carb Well	GP Apex Well		3	17	Well	-97.2	-13.53				
Carb Well	Unnamed Well (Near Dry Lake Range)		1	24	Well	-96.0	-13.70				
Carb Well	US Lime Well (Genstar)		1	27	Well	-97.0	-12.75				
CARB	**Wells (Avg)**		**6**			**-96.9**	**-13.32**	***-99.0***	***-13.24***	***Inter-basin flow from Hidden Valley***	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
ET	**ET**	**0**						**-81.0**	**-10.60**		
218	**GW Outflow (California)**	**15,100**						**-98.9**	**-13.23**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
218	**California Wash**										
219	**SW Inflow (Muddy)**	**34,000**									
205	**SW Inflow (LMVW)**	**0**									
219	**Inflow (Muddy)**	**1,700**				**-98.8**	**-13.21**				
205	**Inflow (Lower Meadow VW)**	**5,200**				**-96.3**	**-12.92**				
216	**Inflow (Garnet)**	**15,100**				**-98.9**	**-13.23**				
218 E	Moapa Paiutes	0				-82.0	-10.60			110	
218 W	Muddy Mtns.	0				-82.0	-10.60			111	
TR	**Total Recharge**	**0**				**-82.0**	**-10.6**				
W	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Carb Well	Calpine Test Well 1a		1	43	Well	-99.0	-13.50				
Carb Well	Moapa Well		1	41	Well	-99.0	-13.40				
ET	**ET**	**4,500**						**-82.0**	**-10.60**		
CARB	**Carbonate Well (Avg)**					**-99.0**	**-13.45**	***-98.3***	***-13.15***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***	
220	**GW Outflow (Lower Moapa)**	**18,800**						**-98.3**	**-13.15**		
215	**GW Outflow (Black Mtn Area)**	**2,000**						**-98.3**	**-13.15**		
220	**SW Outflow (Lower Moapa)**	**30,700**									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
215	**Black Mountains Area**										
218	**Inflow (California Wash)**	**2,000**				**-98.3**	**-13.15**				
215 NE	Muddy Mtns.	0				-85.0	-10.95			113	
215 SE	Black Mtns.	0				-79.5	-10.65			114	
215 W	Gypsum Wash	0				-79.5	-10.65			112, 166	
TR	**Total Recharge**	**0**				**-81.3**	**-10.75**				
SE	Cottonwood Spring (Black Mtns.)	0	1	8	Spring	-80.0	-10.80				
SE	Sandstone Spring	0	1	10	Spring	-79.0	-10.50				
NE	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
NE	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Alluvial Spri	Bitter Spring	5	1	14	Spring	-77.0	-9.90				
Carb Spr	Blue Point Spring	440	5	26	Spring	-92.6	-12.40				
Carb Spr	Corral Spring (Unnamed Spring)	0	1	19	Spring	-91.5	-12.10				
Carb Spr	Rogers Spring	1,200	3	21	Spring	-91.7	-12.33				
Carb Spr	Scirpus Spring (No spring on Map)	0	1	20	Spring	-90.0	-12.00				
Carb Spr	VF Spring 1	0	1	28	Spring	-88.0	-11.20				
Carb Spr	VF Spring 2	6	1	29	Spring	-92.0	-11.80				
Carb Spr	VF Spring 3	17	1	30	Spring	-93.0	-12.20				
ET	**ET**	**1,400**						**-81.3**	**-10.75**		
CARB	**Carbonate Spr (Avg)**	1,700	13			**-91.3**	**-12.01**	***-98.3***	***-13.15***	***Weighted Average of Inflow from Califronia Wash***	
999	**GW Outflow (Colorado River)**	**600**						**-98.3**	**-13.15**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
220	**Lower Moapa Valley**										
218	**GW Inflow (California Wash)**	**18,800**				**-98.3**	**-13.15**				
218	**SW Inflow (California Wash)**	**30,700**									
220 S	Valley of Fire	0				-88.0	-11.30			101	
220 N	S. Mormon Mtns.	37				-88.3	-12.50			102	
TR	**Total Recharge**	**0**				**-88.3**	**-12.50**				
N	Davies Spring		1	90	Spring	-89.0	-12.50				
N	Hackberry Spring		1	84	Spring	-87.0	-12.30				
N	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
S	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
Carb Well	EH-7		1	56	Well	-91.0	-12.45				
Carb Well	EH-3 Weiser Wash		1	61	Well	-91.0	-12.70				
CARB	**Carbonate Well (Avg)**		**2**			**-91.0**	**-12.58**	***-96.3***	***-12.92***		***Inter-basin flow from Lower Meadow Valley Wash***
ET	**ET**	**25,300**						**-88.3**	**-12.50**		
999	**GW Outflow (Colorado River)**	**17,200**						**-98.3**	**-13.15**		
999	**SW Outflow (Colorado River)**	**7,000**									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
Colorado R	**Lake Mead (Colorado River)**										
210	**GW Inflow (Black Mountains Area)**	**600**				**-98.3**	**-13.15**				
205	**GW Inflow (Lower Moapa)**	**17,200**				**-98.3**	**-13.15**				
999	**Groundwater Total**	**17,800**						**-98.3**	**-13.15**		
205	**SW Inflow (Lower Moapa)**	**7,000**									
999	**Surfacewater Total**	**7,000**									
999	**Inflow Total**	**24,800**									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
183	**Lake Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
183 NE	Fortification Rng	1,499				-106.3	-14.16			49	
183 NW	Cen. Schell Cr. Rng	4,759				-108.1	-14.74			51	
183 SE	Wilson Cr. Rng. @ Atlanta	4,188				-104.7	-13.75			50	
183 SW	Fairview Rng.	1,716				-101.1	-13.29			60	
TR	**Total Recharge**	**12,200**				**-105.7**	**-14.12**				
NE	Indian Springs		1	375	Spring	-106.3	-14.16				
NW	Big Spring North	700	1	211	Spring	-112.0	-15.10				
NW	Big Spring South	1,600	1	210	Spring	-111.0	-14.80				
NW	Geyser Spring	340	1	213	Spring	-105.0	-14.50				
NW	North Creek Spring	1,200	1	214	Spring	-105.0	-14.60				
NW	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
NW	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
SE	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
SE	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
SE	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
SW	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
SW	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
SW	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
SW	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
ET	**ET**	**6,100**						**-105.7**	**-14.12**		
202	**GW Outflow (Patterson)**	**6,100**						**-105.7**	**-14.12**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
202	**Patterson Valley**										
183	**Inflow (Lake)**	**6,100**				**-105.7**	**-14.12**				
202 E	Wilson Cr. Rng. @ Mt. Wilson	6,464				-97.7	-12.99			47	
202 W	Bristol Rng.	3,991				-99.2	-13.10			48	
TR	**Total Recharge**	**10,500**				**-98.3**	**-13.03**				
E	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
E	Blue Rock Spring		1	98	Spring	-93.4	-12.68				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
E	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
E	Parsnip Spring		1	180	Spring	-93.5	-12.80				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
E	Horsethief Spring		2	314	Spring	-97.0	-12.68				
E	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		1	156	Spring	-102.3	-13.88				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Fox Cabin		1	273	Spring	-103.5	-13.59				
W	Scotty Spring		1	272	Spring	-98.9	-12.73				
W	Upper Fairview		1	280	Spring	-97.7	-12.66				
W	Lower Fairview		1	281	Spring	-97.5	-12.39				
W	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
W	McDermitt Spring		1	323	Spring	-94.3	-11.21	Evaporated so not used in recharge calculation			
ET	**ET**	**1,300**						**-98.3**	**-13.03**		
203	**GW Outflow (Panaca)**	**15,300**						**-101.3**	**-13.47**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
201	**Spring Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
201 W	Wilson Cr. Rng. @ Parsnip Pk.	5,161				-97.7	-12.99			53	
201 E	White Rock Mtns.	5,904				-100.9	-13.52			52	
TR	**Total Recharge**	**11,100**				**-99.4**	**-13.28**				
E	Barrel Spring		1	317	Spring	-100.5	-13.36				
E	anyon Spring (Unnamed Spring in Burnt Canyon)		1	187	Spring	-93.0	-12.30				
E	Lion Spring		1	318	Spring	-103.4	-14.11				
E	South Monument Spring		1	319	Spring	-102.3	-14.23				
E	Ripgut Sp #40		1	411	Spring	-106.4	-14.38				
E	Unnamed Spring #1(White Rock Mts)		1	415	Spring	-109.6	-15.05				
E	Unnamed Spring #2 (White RockMts)		1	417	Spring	-97.0	-13.00				
E	Upper Burnt Canyon Spring		1	416	Spring	-97.6	-12.83				
E	Upper Burnt Canyon Spring #2		1	416	Spring	-103.6	-13.66				
E	Jnnamed Spring nr Redd's Cabin Summit		2	173	Spring	-94.4	-12.44				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
E	Unnamed Spring in Miller Canyon		1	313	Spring	-103.7	-14.27				
E	Headwaters Spring WR5		1	309	Spring	-107.3	-14.57				
W	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
W	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
W	Parsnip Spring		1	180	Spring	-93.5	-12.80				
W	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
Surface	Camp Creek		1	184	Surface	-102.0	-14.00	Surface Water not included in recharge average			
Surface	MVW above Eagle Canyon		1	168	Surface	-93.0	-12.00	Surface Water not included in recharge average			
ET	**ET**	**3,900**						**-99.4**	**-13.28**		
200	**GW Outflow (Eagle)**	**7,200**						**-99.4**	**-13.28**		
200	**SW Outflow (Eagle)**	**0**						**-97.5**	**-13.00**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
200	**Eagle Valley**										
201	**Inflow (Spring)**	**7,200**				**-99.4**	**-13.28**				
201	**SW Inflow (Spring)**	**0**				**-97.5**	**-13.00**				
200 E	E. Eagle (Ursine) Valley	1,560				-99.1	-13.28			63	
200 W	W. Eagle (Ursine) Valley	412				-97.0	-12.68			64	
TR	**Total Recharge**	**2,000**				**-98.7**	**-13.15**				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**1,000**						**-98.7**	**-13.15**		
199	**GW Outflow (Rose)**	**8,200**						**-99.3**	**-13.26**		
198	**SW Outflow (Rose)**	**0**						**-98.7**	**-13.00**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
199	**Rose Valley**										
200	**Inflow (Eagle)**	**8,200**				**-99.3**	**-13.26**				
200	**SW Inflow (Eagle)**	**0**				**-98.7**	**-13.00**				
199 E	E. Rose Valley	163				-99.1	-13.28			65	
199 W	W. Rose Valley	78				-97.0	-12.68			66	
TR	**Total Recharge**	**200**				**-98.4**	**-13.08**				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**600**						**-98.4**	**-13.08**		
198	**GW Outflow (Dry)**	**7,800**						**-99.3**	**-13.25**		
198	**SW Outflow (Dry)**	**0**						**-98.4**	**-13.08**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
198	**Dry Valley**										
199	**Inflow (Rose)**	**7,800**				**-99.3**	**-13.25**				
199	**SW Inflow (Rose)**	**0**				**-98.4**	**-13.08**				
198 E	E. Dry Valley	2,860				-96.9	-12.99			67	
198 W	W. Dry Valley	321				-97.0	-12.68			68	
TR	**Total Recharge**	**3,200**				**-96.9**	**-12.96**				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
Warm Sprin	Flatnose Spring (Unnamed Spring)		1	153	Spring	-101.0	-13.40	-99.3	-13.25	***Inter-basin flow from Dry Valley***	
Spring	Delmues Spring (Unnamed Spring)		1	149	Spring	-104.0	-13.40			Local Valley spring not included in recharge calculation	
ET	**ET**	**3,700**						**-97.2**	**-13.00**		
203	**GW Outflow (Panaca)**	**7,300**						**-99.3**	**-13.25**		
203	**SW Outflow (Panaca)**	**0**						**-97.2**	**-13.00**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
204	**Clover Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
204 N	South of Beaver Dam	8,232				-92.2	-12.42			71	
204 S	North of Jack's Mtn	6,451				-92.0	-12.52			72	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
TR	**Total Recharge**	**14,700**				**-92.1**	**-12.46**				
N	Acoma Well		1	118	Well	-95.0	-12.60				
N	Cave Spring (Clover)		2	247	Spring	-92.8	-12.37				
N	Clover Creek Valley Well 246		1	120	Well	-89.0	-12.40				
N	Ramone Mathews Well		1	115	Well	-92.0	-12.30				
S	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
S	East Settling Spring		1	248	Spring	-92.2	-12.76				
S	Ella Spring		1	251	Spring	-95.8	-12.56				
S	Little Springs (Clover Mts)		2	254	Spring	-93.3	-12.81				
S	Quaking Aspen Spring		1	255	Spring	-93.6	-12.98				
S	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
S	Unnamed Spring		1	113	Spring	-86.5	-11.60				
Alluvial Well	Clover Creek Valley Well 232		1	114	Well	-84.0	-11.70				
ET	**ET**	**5,200**						**-92.1**	**-12.46**		
205	**GW Outflow (LMVW)**	**9,500**						**-92.1**	**-12.46**		
205	**SW Outflow (LMVW)**	**0**						**-92.1**	**-12.46**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
203	**Panaca Valley**										
202	**Inflow (Patterson)**	**15,300**				**-101.3**	**-13.47**				
198	**Inflow (Dry)**	**7,300**				**-99.3**	**-13.25**				
198	**SW Inflow (Dry)**	**0**				**-97.2**	**-13.00**				
203 E	Condor Canyon	2,479				-92.0	-12.19			69	
203 W	Cathedral Gorge	2,984				-98.9	-13.28			70	
TR	**Total Recharge**	**5,500**				**-95.8**	**-12.78**				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	***-101.3***	***-13.47***	***Inter-basin flow from Patterson Valley***	
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	***-105.7***	***-14.12***	***Inter-basin flow from Lake Valley***	
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	***-105.7***	***-14.12***	***Inter-basin flow from Lake Valley***	
Surface	Meadow Valley Wash, Cal.		1	130	Surface	-97.0	-13.10				
Warm	Lester Mathews Well		1	142	Well	-103.0	-13.30				
Warm	Panaca Town Well		1	143	Well	-106.0	-14.00				
Warm	North Lee Well		1	147	Well	-101.0	-13.30				
ET	**ET**	**18,900**						**-99.2**	**-13.22**		
205	**GW Outflow (LMVW)**	**9,200**						**-100.6**	**-13.40**		
205	**SW Outflow (LMVW)**	**0**						**-99.2**	**-13.22**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
205	**Lower Meadow Valley Wash**										
203	**Inflow (Panaca)**	**9,200**				**-100.6**	**-13.40**				
204	**Inflow (Clover)**	**9,500**				**-92.1**	**-12.46**				
203	**SW Inflow (Panaca)**	**0**				**-99.2**	**-13.22**				
204	**SW Inflow (Clover)**	**0**				**-92.1**	**-12.46**				
205 NW	Delamar Mtns.	3,077				-92.2	-12.28			92	
205 NE	Clover Mountains	7,290				-90.4	-12.25			93	
205 SW	Meadow Valley Mtns.	1,146				-87.4	-11.92			94	
205 SE	Mormon Mtns.	895				-88.3	-12.50			95	
TR	**Total Recharge**	**12,400**				**-90.4**	**-12.24**				
NE	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
NE	East Settling Spring		1	248	Spring	-92.2	-12.76				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NE	Ella Spring		1	251	Spring	-95.8	-12.56				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NE	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11				
NE	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
NE	Unnamed Spring		1	113	Spring	-86.5	-11.60				
NE	Unnamed Spring (Clover)		1	249	Spring	-88.0	-12.20				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NW	Abandoned Spring		1	266	Spring	-94.5	-12.32				
NW	Grassy Spring		3	117	Spring	-88.7	-11.08				Evaporated so not used in recharge calculation
NW	Buckboard Spring		1	264	Spring	-88.2	-11.71				
NW	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
NW	Bishop Spring		3	107	Spring	-87.2	-11.72				
NW	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NW	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
NW	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
NW	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NW	Oak Spring		1	269	Spring	-90.0	-11.87				
NW	Red Rock Spring		1	256	Spring	-95.0	-12.30				
NW	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
NW	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NW	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NW	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
NW	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
NW	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
NW	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
NW	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
SW	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
SE	Davies Spring		1	90	Spring	-89.0	-12.50				
SE	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				
SE	Hackberry Spring		1	84	Spring	-87.0	-12.30				
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	*-96.3*	*-12.92*		***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90				
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70				
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50				
ET	**ET**	**21,900**						**-93.0**	**-12.54**		
206	**GW Outflow (Upper Moapa)**	**4,000**						**-96.3**	**-12.92**		
218	**GW Outflow (California Wash)**	**5,200**						**-96.3**	**-12.92**		
218	**SW Outflow (California Wash)**	**0**						**-90.4**	**-12.24**		
XXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	XXXXXXX	

Reconnaissance Series Water Budget

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	**Long Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
175 SE	Butte Mtn. (S)	2,379				-119.6	-15.53			35
175 SW	Alligator Rdg.	2,501				-121.7	-15.85			36
175 NW	Maverick Springs	3,911				-123.9	-16.23			37
175 NE	Butte Mtn. (N)	1,509				-119.2	-15.36			164
TR	**Total Recharge**	**10,300**				**-121.7**	**-15.85**			
SE	Butte Spring		1	327	Spring	-120.4	-15.79			
SE	Cabin Spring		1	328	Spring	-124.4	-15.89			
SE	Robbers Roost #2 Spring (Butte)		1	340	Spring	-112.0	-14.39			
SE	Deer Spring (Butte)		1	332	Spring	-114.1	-14.74			
SE	Summit Spring		1	348	Spring	-120.8	-15.94			
SE	Thirty Mile Spring		1	242	Spring	-126.0	-16.40			
NW	Mud Spring (Buck Mts)		1	339	Spring	-117.6	-15.21			
NW	Ram. Res. Wtr Supply Well		1	244	Well	-129.5	-16.75			
NW	Unnamed Near Little Willow Spring		1	351	Spring	-125.9	-17.04			
NW	Well at Alligator Ridge		1	243	Well	-127.0	-16.60			
NW	Woodchuck Spring		1	356	Spring	-119.6	-15.55			
NE	White Rock Spring (Butte)		1	355	Spring	-119.2	-15.36			
ET	**ET**	**2,000**						**-121.7**	**-15.85**	
174	**GW Outflow (Jakes)**	**8,300**						**-121.7**	**-15.85**	
174	**Jakes Valley**									
175	**Inflow (Long)**	**8,300**				**-121.7**	**-15.85**			
174 E	Egan Range	5,404				-118.4	-15.31			33
174 W	North White Pine	11,596				-120.3	-15.83			34
TR	**Total Recharge**	**17,000**				**-119.7**	**-15.66**			
W	Tunnel Spring		1	366	Spring	-118.3	-15.02			
W	Aspen Springs North		1	349	Spring	-119.3	-15.84			
W	Aspen Springs South		1	324	Spring	-120.9	-16.02			
W	Chicken Spring		1	330	Spring	-122.0	-16.17			
W	Circle Wash Spring		1	331	Spring	-114.5	-15.30			
W	Sage Hen Spring		1	342	Spring	-112.4	-14.76			
W	Sand Spring		1	239	Spring	-123.0	-16.20			
W	Shellback Spring		1	344	Spring	-123.6	-16.54			
W	Unnamed Hayden Canyon Spring		1	350	Spring	-120.9	-15.69			
W	Unnamed Shellback Ridge Spring		1	352	Spring	-123.6	-16.18			
W	Wild Horse Spring (White Pine)		1	240	Spring	-129.0	-16.80			
W	Unnamed Stone Cabin Spring		2	354	Spring	-116.2	-15.39			
W/E	Indian Spring (Butte)		1	334	Spring	-119.1	-15.31			
W/E	Sammy Spring		1	343	Spring	-117.6	-15.30			
W	Upper Illipah Crk		2	238	Surface	-123.5	-16.10	Not used in W average		
ET	**ET**	**0**						**-120.3**	**-15.72**	
207N	**GW Outflow (NWRV)**	**25,300**						**-120.3**	**-15.72**	
180	**Cave Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
180 E	S. Schell Cr. Rng	6,220				-105.0	-14.28			43,44
180 W	S. Egan Rng	7,780				-107.8	-14.28			45,46

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
TR	**Total Recharge**	**14,000**				**-106.6**	**-14.28**				
E	North Creek Spring		1	214	Spring	-105.0	-14.60				
E	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
E	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
E	Sheep Spring (Schell Ck)		1	212	Spring	-99.5	-13.70				
E	Robbers Roost Spring (Schell Ck)		1	389	Spring	-109.7	-14.75				
E	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
W	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
W	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
W	Haggerty Spring		1	387	Spring	-109.6	-14.78				
W	Granite Spring		1	440	Spring	-103.4	-13.32				
W	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
W	Silver Spring		2	385	Spring	-111.4	-14.71				
W	Shingle Spring		2	203	Spring	-103.7	-13.33				
W	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
W	Trough Spring		1	413	Spring	-103.6	-13.56				
ET	**ET**	**200**						**-106.6**	**-14.28**		
Well	**180W902**		**1**	**601**	**Deep Well**	**-104.7**	**-14.12**				
Well	**180W501**		**1**	**600**	**Deep Well**	**-105.6**	**-14.12**				
181	GW Outflow (Dry Lake)	0						-106.6	-14.28		
207S	**GW Outflow (SWRV)**	**13,800**						**-106.6**	**-14.28**		
xxxxxxxx	xxxxxxxxxxxxxxxxxxxxxxxx	xxxxxxxx	xxxxxxx	xxxxx	xxxxxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	
207N	**North White River Valley**										
174	**Inflow (Jakes)**	**25,300**				**-120.3**	**-15.72**				
207 NE	Egan Rng North	13,009				-112.4	-15.14			38	
207 NW	White Pine Rng.	12,727				-115.0	-15.18			39, 40	
TR	**Total Recharge**	**25,700**				**-113.7**	**-15.16**				
NE	on Creek Spring (Unnamed Spring in Gubler Canyon)		1	235	Spring	-111.0	-14.90				
NE	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
NE	Lone Pine Spring		3	223	Spring	-110.2	-14.90				
NE	North Spring		1	237	Spring	-113.0	-15.00				
NE	High Springs		1	433	Spring	-113.4	-15.43				
NE	Lion Spring (Egan Range)		1	430	Spring	-114.8	-15.34				
NE	Mud Spring		1	446	Spring	-111.0	-14.53				
NE	Pine Springs (Egan Range)		1	434	Spring	-116.0	-15.71				
NE	Unnamed Spring #1(Egan)		1	435	Spring	-112.2	-15.14				
NE	Unnamed Spring #2 (Egan Range)		1	436	Spring	-110.0	-15.14				
NE	Unnamed Spring #3 (Egan Range)		1	437	Spring	-110.2	-15.07				
NE	Unnamed Spring #4 (Egan Range)		1	438	Spring	-114.0	-15.37				
NE	Unnamed Spring #5 (Egan Range)		1	445	Spring	-109.6	-14.72				
NE	Second Sawmill Spring		1	222	Spring	-110.0	-14.70				
NE	South Spring (Egan)		2	236	Spring	-111.5	-15.12				
NE	Upper Terrace Spring WR2		14	270	Spring	-114.0	-15.42				
NE	Water Canyon Spring		1	358	Spring	-114.4	-15.60				
NE	Lund Spring		1	221	Spring	-113.0	-15.40	Local Valley spring not included in recharge calculation			
NE	Water Canyon		2	233	Surface	-116.0	-15.25	Surface Water not included in recharge average			
NW	Big Tom Plain Spring		1	326	Spring	-121.1	-15.92				
NW	Deer Spring (White Pine)		2	322	Spring	-119.3	-15.87				
NW	Unnamed Spring #1 (White Pine)		1	359	Spring	-114.8	-15.36				
NW	Unnamed Spring #2 (White Pine)		1	360	Spring	-114.9	-15.66				
NW	Unnamed Spring #3 (White Pine)		1	361	Spring	-113.1	-14.96				
NW	Unnamed Spring #4 (White Pine)		1	362	Spring	-116.3	-15.01				
NW	Unnamed Spring #5 (White Pine)		3	363	Spring	-116.0	-15.36				
NW	Unnamed Spring #6 (White Pine)		1	364	Spring	-115.1	-14.98				
NW	Easter Spring		1	365	Spring	-119.4	-15.56				
NW	Halfway Spring (RS)		2	429	Spring	-108.7	-13.52				
NW	Little Tom Plain Spring		2	337	Spring	-121.0	-15.86				
NW	Monitoring Spring WR1		14	320	Spring	-113.7	-15.58				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NW	Saddle Spring (White Pine)		3	357	Spring	-116.8	-15.45				
NW	Secret Spring		1	220	Spring	-110.0	-14.00				
NW	Unnamed Spring below Currant Mtn		1	226	Spring	-107.0	-14.00				
NW	Stove Spring		1	347	Spring	-114.5	-15.71				
NW	ıed Spring in dry creek bed (White Pine Range)		1	321	Spring	-113.6	-15.31				
NW	Snowmelt Below Duckwater Peak	5,700	1	224	Surface	-105.0	-14.10	Surface Water not included in recharge average			
NW	Little Currant Creek		1	217	Surface	-113.0	-15.00	Surface Water not included in recharge average			
Warm	Cold Spring, Preston	1,000	2	230	Spring	-123.5	-15.80				
Warm	Nicholas Spring	2,000	1	227	Spring	-124.0	-16.10				
Warm	Preston Big Spring	5,900	11	231	Spring	-122.0	-15.88				
Warm	**Discharge Warm Sprs (Avg)**	**8,900**	**14**			**-122.6**	**-15.92**	***-120.3***	***-15.72***	***Inter-basin flow from Jakes Valley***	
ET	**ET**	**22,000**						**-117.0**	**-15.44**		
207S	**GW Outflow (SWRV)**	**29,000**						**-117.0**	**-15.44**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
207S	**South White River Valley**	WRV Tot Recharge									
		38,000									
207N	**Inflow (N White River)**	**29,000**				**-117.0**	**-15.44**				
180	**Inflow (Cave)**	**13,800**				**-106.6**	**-14.28**				
207 SE	Egan Rng South	6,529				-106.9	-14.15			41	
207 SW	Grant Rng	5,735				-106.5	-14.23			42	
TR	**Total Recharge**	**12,300**				**-106.7**	**-14.18**				
E	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
E	Haggerty Spring		1	387	Spring	-109.6	-14.78				
E	Granite Spring		1	440	Spring	-103.4	-13.32				
E	Silver Spring		2	385	Spring	-111.4	-14.71				
E	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
E	Shingle Spring		2	203	Spring	-103.7	-13.33				
E	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
E	Trough Spring		1	413	Spring	-103.6	-13.56				
E	Butterfield Spring	4,000	1	202	Spring	-105.0	-14.20	local Valley spring not included in recharge calculation			
E	Emigrant Spring	1,900	2	207	Spring	-107.8	-14.50	local Valley spring not included in recharge calculation			
E	Flag Spring #3		1	201	Spring	-105.0	-14.30	local Valley spring not included in recharge calculation			
SW	Albert Spring		1	204	Spring	-107.0	-13.95				
SW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
SW	Brady Spring		2	282	Spring	-109.5	-15.38				
SW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
SW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
SW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
SW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
SW	Murphy Spring		1	373	Spring	-114.5	-15.40				
SW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
Warm	Hot Creek Campground Well	0	1	198	Well	-118.0	-15.30				
Warm	Hot Creek Springs	10,000	10	197	Spring	-118.9	-15.69				
Warm	Moon River Spring	2,800	1	192	Spring	-120.0	-15.80				
Warm	Moorman Spring	400	1	205	Spring	-119.0	-15.70				
Warm	**Discharge Warm Sprs (Avg)**	**13,200**	**13**			**-119.2**	**-15.71**	***-117.0***	***-15.44***	***Inter-basin flow from Northern White River Valley***	
ET	**ET**	**13,000**						**-112.1**	**-14.87**		
208	**GW Outflow (Pahroc)**	**42,100**						**-112.1**	**-14.87**		
208	GW Outflow (Garden Valley)	0						-112.1	-14.87		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
172	**Garden Valley**										
172	**Inflow (None)**	**0**				**-112.1**	**-14.87**				
172 SW	Quinn Canyon Range	5,348				-104.6	-14.08			171	
172 NW	Grant Range	3,502				-105.6	-14.12			170	
172 NE	Golden Gate Rng	428				-98.0	-13.30			55	
172 SE	Worthington Mountains	723				-98.0	-13.30			56	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
TR	**Total Recharge**	**10,000**				**-104.2**	**-14.00**				
SW	Unnamed Spring #7 (Quinn)		1	367	Spring	-105.9	-14.23				
SW	Unnamed Spring #8 (Quinn)		1	368	Spring	-104.4	-14.18				
SW	Adaven Spring		2	177	Spring	-105.3	-14.01				
SW	Lower Little Cherry Cr Spring		1	182	Spring	-103.0	-13.90				
SW	Carpenter Spring		1	171	Spring	-95.0	-11.85	Evaporated so not used in recharge calculation			
NW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
NW	Brady Spring		2	282	Spring	-109.5	-15.38				
NW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
NW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
NW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
NW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
NW	Murphy Spring		1	373	Spring	-114.5	-15.40				
NW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
SE	The Seeps (Spring)		1	136	Spring	-98.0	-13.30				
ET	**ET**	**2,000**						**-104.2**	**-14.00**		
171	**GW Outflow (Coal)**	**8,000**						**-104.2**	**-14.00**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
171	**Coal Valley**										
172	**Inflow (Garden)**	**8,000**				**-104.2**	**-14.00**				
172	**Inflow (SWRV)**	**0**				**-112.1**	**-14.87**				
171 E	Seaman Rng	631				-98.2	-12.87			75	
171 W	Golden Gate Rng	1,369				-99.0	-13.13			76	
TR	**Total Recharge**	**2,000**				**-98.7**	**-13.05**				
W	Cold Spring		1	288	Spring	-98.9	-12.98				
W	Henry Spring		1	287	Spring	-97.4	-12.77				
W	Little Cut Spring		2	286	Spring	-98.3	-12.85				
E	Seaman Spring		1	306	Spring	-99.0	-13.13				
Carb Well	**USGS-MX C.V. Well (CV-DT-1)**		**2**	**176**	**Well**	**-109.0**	**-14.56**	***-104.2***	***-14.0***	***Underflow from Garden Valley***	
ET	**ET**	**0**						**-103.1**	**-13.81**		
208	**GW Outflow (Pahranagat)**	**10,000**						**-103.1**	**-13.81**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
208	**Pahroc Valley**										
207S	**Inflow (S. White River)**	**42,100**				**-112.1**	**-14.87**				
171	Inflow (Coal)	0				0.0	0.00				
208 E	N. Pahroc Rng.	1,019				-94.2	-12.42			73	
208 W	Seaman Rng.	1,181				-99.0	-13.13			74	
TR	**Total Recharge**	**2,200**				**-96.8**	**-12.80**				
E	Black Rock Spring		2	158	Spring	-93.8	-12.31				
E	Coyote Spring		2	169	Spring	-95.1	-12.53				
E	Hamilton Spring		1	298	Spring	-93.1	-11.76				
E	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
E	Mustang Spring		2	135	Spring	-90.5	-12.49				
E	Pahroc Spring		3	131	Spring	-92.2	-12.65				
E	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
E	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
W	Seaman Spring		1	306	Spring	-99.0	-13.13				
Evaporated	White Rock Spring (Seaman Range)		1	154	Spring	-90.0	-12.10	Evaporated not used in recharge calculation			
ET	**ET**	**0**						**-111.3**	**-14.77**		
209	**GW Outflow (Pahranagat)**	**44,300**						**-111.3**	**-14.77**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
209	**Pahranagat Valley**										

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
208	**Inflow (Pahroc)**	**44,300**				**-111.3**	**-14.77**			
171	**Inflow (Coal)**	**10,000**				**-103.1**	**-13.81**			
209	**Inflow (Delamar)**	**6,200**				**-97.7**	**-12.96**			
209 E	S. Pahroc Rng.	528				-94.9	-12.83			77, 78
209 W	Mt. Irish/Pahranagat Rng.	1,272				-98.4	-14.24			79, 80 (172, 173)
TR	**Total Recharge**	**1,800**				**-97.4**	**-13.83**			
E	Eightmile Spring		2	295	Spring	-95.6	-13.09			
E	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30			
E	Sixmile Spring		1	112	Spring	-93.4	-13.06			
E	Twin Spring		1	294	Spring	-97.4	-13.24			
E	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07			
E	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62			
E	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44			
S	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30	Local Valley spring not included in recharge calculation		
W	Reed Spring		1	289	Spring	-98.4	-14.24			
Warm	Ash Springs	12400	6	110	Spring	-109.1	-14.11			
Warm	Little Ash Spring (Ash Spring)	500	1	111	Spring	-107.2	-14.20			
Warm	Crystal Springs	8,200	17	116	Spring	-108.8	-14.41			
Warm	Hiko Spring	4,300	7	122	Spring	-108.7	-14.39			
Warm	**Discharge Warm Springs (Avg)**	**25,400**	**31**			**-108.9**	**-14.26**	***-111.3***	***-14.77***	***Inter-basin flow from Pahroc Valley***
ET	**ET**	**25,000**						**-108.3**	**-14.41**	
Warm	**209M-1**		**1**	**608**	**Deep Well**	**-104.7**	**-13.53**	***-111.3***	***-14.77***	***Inter-basin flow from Pahroc Valley***
210	**GW Outflow (Coyote Spr)**	**37,300**						**-108.3**	**-14.41**	
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX
181	**Dry Lake Valley**									
180	**Inflow (None)**	**0**				**0.0**	**0.00**			
181 NW	S. Schell Ck Range	854				-100.4	-13.21			59
181 SW	N. Pahroc Rng.	124				-94.2	-12.42			57
181 NE	Fairview Rng.	1,180				-99.5	-12.89			58
181 E	Bristol/Highland Rng.	2,567				-98.9	-13.28			61
181 SE	Burnt Springs Rng.	274				-94.6	-12.36			62
TR	**Total Recharge**	**5,000**				**-98.9**	**-13.10**			
E	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07			
E	Highland Spring		3	163	Spring	-99.1	-13.36			
E	Lime Spring		2	160	Spring	-98.5	-13.16			
E	Pine Spring		2	157	Spring	-99.0	-13.37			
E	Connor Spring		1	283	Spring	-100.6	-13.84			
E	Upper Conner Spring		2	156	Spring	-101.2	-13.87			
SE	Red Rock Spring		1	256	Spring	-95.0	-12.30			
SE	Abandoned Spring		1	266	Spring	-94.5	-12.32			
SE	Buckboard Spring		1	264	Spring	-88.2	-11.71			
SE	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87			
SE	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98			
SE	Oak Spring		1	269	Spring	-90.0	-11.87			
SE	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54			
SE	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96			
SE	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69			
NE	Bailey Spring (Fairview)		2	277	Spring	-98.2	-12.69			
NE	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40			
NE	Littlefield Spring		1	275	Spring	-98.5	-12.73			
NE	Lower Pony Spring		2	190	Spring	-101.0	-13.25			
NE	Meloy Spring		1	276	Spring	-99.8	-12.75			
NE	Scotty Spring		1	272	Spring	-98.9	-12.73			
NE	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60			
NE	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90			
NE	Fence Spring		1	278	Spring	-97.4	-12.55			
NE	Fox Cabin		1	273	Spring	-103.5	-13.59			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NE	Lower Fairview		1	281	Spring	-97.5	-12.39				
NE	Robison Spring		1	279	Spring	-97.9	-12.34				
NE	Upper Fairview		1	280	Spring	-97.7	-12.66				
SW	Black Rock Spring		2	158	Spring	-93.8	-12.31				
SW	Coyote Spring		2	169	Spring	-95.1	-12.53				
SW	Hamilton Spring		1	298	Spring	-93.1	-11.76				
SW	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
SW	Mustang Spring		2	135	Spring	-90.5	-12.49				
SW	Pahroc Spring		3	131	Spring	-92.2	-12.65				
SW	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
SW	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
NW	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
Evaporated	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
Carb Well	**Fugro Dry Lake V Deep Well**		**2**	**179**	**Well**	**-107.5**	**-14.16**	***-98.9***	***-13.10***	***Local Recharge***	
Carb Well	**181M1**		**1**	**603**	**Deep Well**	**-105.0**	**-13.67**	***-98.9***	***-13.10***	***Local Recharge***	
Carb Well	**181W909M**		**1**	**604**	**Deep Well**	**-104.6**	**-13.50**	***-98.9***	***-13.10***	***Local Recharge***	
ET	**ET**	**0**						**-98.9**	**-13.10**		
209	**GW Outflow (Pahranagat)**	**0**						**-98.9**	**-13.10**		
182	**GW Outflow (Delamar)**	**5,000**						**-98.9**	**-13.10**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
182	**Delamar Valley**										
181	**Inflow (Dry Lake)**	**5,000**				**-98.9**	**-13.10**				
182 E	Delamar Mtns.	1,037				-92.5	-12.32			81	
182 W	S. Pahroc Rng.	163				-94.6	-12.81			82	
TR	**Total Recharge**	**1,200**				**-92.7**	**-12.38**				
E	Abandoned Spring		1	266	Spring	-94.5	-12.32				
E	Red Rock Spring		1	256	Spring	-95.0	-12.30				
E	Oak Spring		1	269	Spring	-90.0	-11.87				
E	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
E	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
E	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
E	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
E	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
E	Bishop Spring		3	107	Spring	-87.2	-11.72				
E	Buckboard Spring		1	264	Spring	-88.2	-11.71				
E	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
E	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
E	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
E	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
E	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
E	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
E	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
W	Pahroc Spring		3	131	Spring	-92.2	-12.65				
W	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
W	Sixmile Spring		1	112	Spring	-93.4	-13.06				
W	Eightmile Spring		2	295	Spring	-95.6	-13.09				
W	Twin Spring		1	294	Spring	-97.4	-13.24				
W	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
W	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
W	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
ET	**ET**	**0**						**-97.7**	**-12.96**		
Well	**182W906M**		**1**	**607**	**Deep Well**	**-100.3**	**-13.33**	***-98.9***	***-13.10***	***Inter-basin flow from Dry Lake Valley***	
209	**GW Outflow (Pahranagat)**	**6,200**						**-97.7**	**-12.96**		
210	GW Outflow (Coyote Spr)	0						-97.7	-12.96		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
206	**Kane Springs Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
206 W	Delamar Mtns.	563				-89.0	-12.22			90	
206 E	Meadow Valley Mtns.	0				-87.4	-11.92			91	
TR	**Total Recharge**	**600**				**-89.0**	**-12.22**				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
W	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
W	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
W	Bishop Spring		3	107	Spring	-87.2	-11.72				
W	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
W	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
W	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
W	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
W	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
ET	**ET**	**0**						**-89.0**	**-12.22**		
210	**GW Outflow (Coyote Spr)**	**600**						**-89.0**	**-12.22**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
210	**Coyote Springs Valley**										
209	**Inflow (Pahranagat)**	**37,300**				**-108.3**	**-14.41**				
182	Inflow (Delamar)	0				0.0	0.00				
206	**Inflow (Kane Springs)**	**600**				**-89.0**	**-12.22**				
210 NE	S. Delamar Mtns.	27				-89.0	-12.22			83	
210 E	S. Meadow Valley Mtns.	0				-87.4	-11.92			84	
210 NW	S. of Maynard Lake	0				-94.0	-12.30			87	
210 SE	Arrow Canyon Rng.	4				-81.0	-10.60			88	
210 W	Sheep Range	2,007				-92.7	-12.83			89	
TR	**Total Recharge**	**2,000**				**-92.6**	**-12.81**				
W	Cow Camp Spring		4	47	Spring	-91.9	-12.53				
W	Lamb Spring		1	86	Spring	-92.5	-13.15				
W	Mormon Well Spring		3	53	Spring	-91.8	-12.67				
W	Rye Patch Spring		1	341	Spring	-89.3	-12.31				
W	Sawmill Spring (Sheep)		1	58	Spring	-92.0	-12.85				
W	Sheep Spring (Sheep Range)		1	83	Spring	-96.0	-13.35				
W	Wiregrass Spring (Sheep)		13	49	Spring	-95.1	-12.93				
W	White Rock Spring (Sheep)		2	64	Spring	-85.5	-10.17	Evaporated not used in recharge calculation			
NW	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30				
SE	Wamp Spring		1	52	Spring	-81.0	-10.60				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
NE	Bishop Spring		3	107	Spring	-87.2	-11.72				
NE	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NE	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
NE	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NE	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NE	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NE	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
NE	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
Carb Well	CSVM-2		1	612	Well	-97.7	-13.14				
Carb Well	CSVM-3		1	613	Well	-98.0	-13.10				
Carb Well	CSVM-4		1	614	Well	-102.5	-13.41				
Carb Well	CSVM-6		1	616	Well	-100.7	-12.97				
Carb Well	CSI-1		1	609	Well	-102.6	-13.08				
Carb Well	CSI-2		1	610	Well	-100.2	-12.90				
Carb Well	CSI-3		1	611	Well	-99.6	-13.03				
Carb Well	USGS CSV-1		1	71	Well	-103.0	-13.55				
Carb Well	CE-VF-2 Well		2	81	Well	-101.0	-13.10				
Carb Well	Fugro CV Deep Well CE-DT-5		3	77	Well	-99.6	-12.96				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
Carb Well	CE-DT-4		1	78	Well	-102.5	-13.00				
ET	ET	500						-107.2	-14.29		
CARB	Carbonate Well (Avg)		6			-100.7	-13.11	*-107.9*	*-14.37*		*Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys*
219	GW Outflow (Muddy)	39,400						-107.2	-14.29		
217	GW Outflow (Hidden)	0						0.0	0.00		
216	GW Outflow (Garnet)	0						0.0	0.00		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
219	Upper Moapa (Muddy) Valley										
205	Inflow (LMVW)	0				0.0	0.00				
210	Inflow (Coyote)	39,400				-107.2	-14.29				
219 S	E. Arrow Canyon?	0				-87.3	-11.86	Grapevine Sp.		85	
219 N	Wildcat Wash	0				-87.3	-11.86	Grapevine Sp.		86	
TR	Total Recharge	0				-87.3	-11.86				
Warm	APCAR	0	1	292	Spring	-98.2	-12.94				
Warm	Baldwin Spring	2226	9	291	Spring	-97.6	-12.97				
Warm	Big Muddy Spring	5500	6	69	Spring	-97.9	-12.89				
Warm	Iverson's Spring	0	1	65	Spring	-97.0	--				
Warm	Jones Spring Pumphouse	0	6	292	Spring	-97.9	-13.05				
Warm	M-8 Spring (Unnamed Spring)	0	1	68	Spring	-99.0	-12.75				
Warm	M-9 Spring (Unnamed Spring)	200	1	70	Spring	-96.5	-12.45				
Warm	Pederson's East	0	9	290	Spring	-97.8	-12.98				
Warm	Pederson's Warm Spring (M-13)	400	15	67	Spring	-97.5	-12.93				
Warm	Dicharge Warm Sprs (Avg)	8,300	49			-97.8	-12.90	*-107.2*	*-14.29*		*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
Carb Well	CE-DT-6 Well		2	72	Well	-98.0	-13.03				
Carb Well	CSV-2 Well		2	76	Well	-97.9	-12.92				
CARB	Deep Carbonate Well (Avg)	Input into M	4			-97.9	-12.97	*-107.2*	*-14.29*		*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*
ET	ET	0						-107.2	-14.29		
Gage	Moapa Gage	34,000									
218	SW Outflow (California)	34,000						-107.2	-14.29		
218	GW Outflow (California)	5,400						-107.2	-14.29		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
217	Hidden Valley										
210	Inflow (Coyote)	0				0.0	0.00				
217 E	E. Hidden	0				-81.0	-10.60			99	
217 W	W. Hidden	400				-81.0	-10.60			100	
TR	Total Recharge	400				-81.0	-10.60				
W	Wamp Spring		1	52	Spring	-81.0	-10.60				
ET	ET	0						-81.0	-10.60		
216	GW Outflow (Garnet)	400						-81.0	-10.60		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
216	Garnet Valley										
217	Inflow (Hidden)	400				-81.0	-10.60				
216 E	Apex	10				-81.0	-10.60			104	
216 W	Las Vegas Range	390				-81.0	-10.60			105	
TR	Total Recharge	400				-81.0	-10.60				
W	Wamp Spring		1	52	Spring	-81.0	-10.60				
	Dry Lake Valley Well		1	34	Well	-97.5	-13.30				
Carb Well	GP Apex Well		3	17	Well	-97.2	-13.53				
Carb Well	Unnamed Well (Near Dry Lake Range)		1	24	Well	-96.0	-13.70				
Carb Well	US Lime Well (Genstar)		1	27	Well	-97.0	-12.75				
CARB	Wells (Avg)		6			-96.9	-13.32	*-81.0*	*-10.60*		*Inter-basin flow from Hidden Valley*
ET	ET	0						-81.0	-10.60		

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
218	**GW Outflow (California)**	**800**						**-81.0**	**-10.60**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXXX	XXXXXXX	XXXXXX	XXXXXX	XXXXXX	
218	**California Wash**										
219	**Inflow (LMVW)**	**12,700**				**-98.7**	**-13.20**				
219	**Inflow (Muddy)**	**5,400**				**-107.2**	**-14.29**				
216	**Inflow (Garnet)**	**800**				**-81.0**	**-10.60**				
218	**SW Inflow (Muddy)**	**34,000**									
218 E	Moapa Paiutes	45				-82.0	-10.60			110	
218 W	Muddy Mtns.	55				-82.0	-10.60			111	
TR	**Total Recharge**	**100**				**-82.0**	**-10.60**				
W	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Carb Well	Calpine Test Well 1a		1	43	Well	-99.0	-13.50				
Carb Well	Moapa Well		1	41	Well	-99.0	-13.40				
CARB	**Carbonate Well (Avg)**					**-99.0**	**-13.45**	***-103.8***	***-13.82***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***	
ET	**ET**	**1,000**						**-100.3**	**-13.38**		
220	**GW Outflow (Lower Moapa)**	**21,300**						**-100.3**	**-13.38**		
215	**GW Outflow (Black Mtn Area)**	**0**						**-100.3**	**-13.38**		
220	**SW Outflow (Lower Moapa)**	**30,700**									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXXX	XXXXXXX	XXXXXX	XXXXXX	XXXXXX	
215	**Black Mountains Area**										
218	**Inflow (California Wash)**	**0**				**-100.3**	**-13.38**				
215 NE	Muddy Mtns.	100				-85.0	-10.95			113	
215 SE	Black Mtns.	0				-79.5	-10.65			114	
215 W	Gypsum Wash	0				-79.5	-10.65			112, 166	
TR	**Total Recharge**	**100**				**-85.0**	**-10.95**				
SE	Cottonwood Spring (Black Mtns.)	0	1	8	Spring	-80.0	-10.80				
SE	Sandstone Spring	0	1	10	Spring	-79.0	-10.50				
NE	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
NE	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Alluvial Spri	Bitter Spring	5	1	14	Spring	-77.0	-9.90				
Carb Spr	Blue Point Spring	440	5	26	Spring	-92.6	-12.40				
Carb Spr	Corral Spring (Unnamed Spring)	0	1	19	Spring	-91.5	-12.10				
Carb Spr	Rogers Spring	1,200	3	21	Spring	-91.7	-12.33				
Carb Spr	Scirpus Spring (No spring on Map)	0	1	20	Spring	-90.0	-12.00				
Carb Spr	VF Spring 1	0	1	28	Spring	-88.0	-11.20				
Carb Spr	VF Spring 2	6	1	29	Spring	-92.0	-11.80				
Carb Spr	VF Spring 3	17	1	30	Spring	-93.0	-12.20				
CARB	**Carbonate Spr (Avg)**	1,700	13			**-91.3**	**-12.01**	***-85.0***	***-10.95***	***Weighted Average of Inflow from Califronia Wash plus recharge from Muddy Mountains***	
ET	**ET**	**0**						**-85.0**	**-10.95**		
999	**GW Outflow (Colorado River)**	**100**						**-85.0**	**-10.95**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXXX	XXXXXXX	XXXXXXX	XXXXXX	XXXXXX	XXXXXX	
220	**Lower Moapa Valley**										
219	**Inflow (Muddy)**	**21,300**				**-107.2**	**-14.29**				
218	**SW Inflow (Muddy)**	**30,700**									
220 S	Valley of Fire	0				-88.0	-11.30			101	
220 N	S. Mormon Mtns.	100				-88.3	-12.50			102	
TR	**Total Recharge**	**100**				**-88.3**	**-12.50**				
N	Davies Spring		1	90	Spring	-89.0	-12.50				
N	Hackberry Spring		1	84	Spring	-87.0	-12.30				
N	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				
S	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
Carb Well	EH-7		1	56	Well	-91.0	-12.45				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
Carb Well	EH-3 Weiser Wash		1	61	Well	-91.0	-12.70				
CARB	Carbonate Well (Avg)		2			-91.0	-12.58	-107.2	-14.29	Inter-basin flow from Lower Meadow Valley Wash	
ET	ET	24,000						-107.1	-14.29		
999	GW Outflow (Colorado River)	21,100						-107.1	-14.29		
999	SW Outflow (Colorado River)	7,000									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
Colorado R	Lake Mead (Colorado River)										
210	GW Inflow (Black Mountains Area)	0				0.0	0.00				
205	GW Inflow (Lower Moapa)	21,100				-107.1	-14.29				
999	Groundwater Total	21,100						-107.1	-14.29		
205	SW Inflow (Lower Moapa)	7,000									
999	Surfacewater Total	7,000									
999	Inflow Total	28,100									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
183	Lake Valley										
0	Inflow (None)	0				0.0	0.00				
183 NE	Fortification Rng	1,426				-106.3	-14.16			49	
183 NW	Cen. Schell Cr. Rng	6,436				-108.1	-14.74			51	
183 SE	Wilson Cr. Rng. @ Atlanta	3,974				-104.7	-13.75			50	
183 SW	Fairview Rng.	1,165				-101.1	-13.29			60	
TR	Total Recharge	13,000				-106.2	-14.24				
NE	Indian Springs		1	375	Spring	-106.3	-14.16				
NW	Big Spring North	700	1	211	Spring	-112.0	-15.10				
NW	Big Spring South	1,600	1	210	Spring	-111.0	-14.80				
NW	Geyser Spring	340	1	213	Spring	-105.0	-14.50				
NW	North Creek Spring	1,200	1	214	Spring	-105.0	-14.60				
NW	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
NW	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
SE	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
SE	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
SE	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
SW	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
SW	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
SW	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
SW	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
ET	ET	9,000						-106.2	-14.24		
202	GW Outflow (Patterson)	4,000						-106.2	-14.24		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
202	Patterson Valley										
183	Inflow (Lake)	4,000				-106.2	-14.24				
202 E	Wilson Cr. Rng. @ Mt. Wilson	4,059				-97.7	-12.99			47	
202 W	Bristol Rng.	1,941				-99.2	-13.10			48	
TR	Total Recharge	6,000				-98.2	-13.03				
E	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
E	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
E	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
E	Parsnip Spring		1	180	Spring	-93.5	-12.80				
E	Horsethief Spring		2	314	Spring	-97.0	-12.68				
E	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		1	156	Spring	-102.3	-13.88				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Fox Cabin		1	273	Spring	-103.5	-13.59				
W	Scotty Spring		1	272	Spring	-98.9	-12.73				
W	Upper Fairview		1	280	Spring	-97.7	-12.66				
W	Lower Fairview		1	281	Spring	-97.5	-12.39				
W	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
W	McDermitt Spring		1	323	Spring	-94.3	-11.21	Evaporated so not used in recharge calculation			
ET	**ET**	**100**						**-101.4**	**-13.51**		
203	**GW Outflow (Panaca)**	**9,900**						**-101.4**	**-13.51**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
201	**Spring Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
201 E	White Rock Mtns.	5,128				-100.9	-13.52			52	
201 W	Wilson Cr. Rng. @ Parsnip Pk.	4,872				-97.7	-12.99			53	
TR	**Total Recharge**	**10,000**				**-99.4**	**-13.26**				
E	Barrel Spring		1	317	Spring	-100.5	-13.36				
E	anyon Spring (Unnamed Spring in Burnt Canyon)		1	187	Spring	-93.0	-12.30				
E	Lion Spring		1	318	Spring	-103.4	-14.11				
E	South Monument Spring		1	319	Spring	-102.3	-14.23				
E	Jnnamed Spring nr Redd's Cabin Summit		2	173	Spring	-94.4	-12.44				
E	Ripgut Sp #40		1	411	Spring	-106.4	-14.38				
E	Unnamed Spring #1(White Rock Mts)		1	415	Spring	-109.6	-15.05				
E	Unnamed Spring #2 (White RockMts)		1	417	Spring	-97.0	-13.00				
E	Upper Burnt Canyon Spring		1	416	Spring	-97.6	-12.83				
E	Upper Burnt Canyon Spring #2		1	416	Spring	-103.6	-13.66				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
E	Unnamed Spring in Miller Canyon		1	313	Spring	-103.7	-14.27				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
W	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
W	Parsnip Spring		1	180	Spring	-93.5	-12.80				
W	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
Surface	Camp Creek		1	184	Surface	-102.0	-14.00	Surface Water not included in recharge average			
Surface	MVW above Eagle Canyon		1	168	Surface	-93.0	-12.00	Surface Water not included in recharge average			
ET	**ET**	**10,000**						**-99.4**	**-13.26**		
200	**GW Outflow (Eagle)**	**0**						**-99.4**	**-13.26**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
200	**Eagle Valley**										
201	**Inflow (Spring)**	**0**				**-99.4**	**-13.26**				
200 E	E. Eagle (Ursine) Valley	1,186				-99.1	-13.28			63	
200 W	W. Eagle (Ursine) Valley	160				-97.0	-12.68			64	
TR	**Total Recharge**	**1,300**				**-98.9**	**-13.20**				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**1,000**						**-98.9**	**-13.20**		
199	**GW Outflow (Rose)**	**300**						**-98.9**	**-13.20**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
199	**Rose Valley**										
200	**Inflow (Eagle)**	**300**				**-98.9**	**-13.20**				
199 E	E. Rose Valley	24				-99.1	-13.28			65	
199 W	W. Rose Valley	7				-97.0	-12.68			66	
TR	**Total Recharge**	**0**				**-98.6**	**-13.14**				
E	Butcher Spring		0	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		0	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		0	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		0	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**100**						**-98.9**	**-13.20**		
198	**GW Outflow (Dry)**	**200**						**-98.9**	**-13.20**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
198	**Dry Valley**										
199	**Inflow (Rose)**	**200**				**-98.9**	**-13.20**				
198 E	E. Dry Valley	1,478				-96.9	-12.99			67	
198 W	W. Dry Valley	0				-97.0	-12.68			68	
TR	**Total Recharge**	**1,500**				**-96.9**	**-12.99**				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		0	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		0	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		0	420	Spring	-100.4	-13.68				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
Warm Sprin	Flatnose Spring (Unnamed Spring)		1	153	Spring	-101.0	-13.40	-98.9	-13.20	***Inter-basin flow from Dry Valley***	
Spring	Delmues Spring (Unnamed Spring)		1	149	Spring	-104.0	-13.40			Local Valley spring not included in recharge calculation	
ET	**ET**	**1,000**						**-97.1**	**-13.02**		
203	**GW Outflow (Panaca)**	**700**						**-97.1**	**-13.02**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
204	**Clover Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
204 N	South of Beaver Dam	868				-92.2	-12.42			71	
204 S	North of Jack's Mtn	927				-92.0	-12.52			72	
TR	**Total Recharge**	**1,800**				**-92.1**	**-12.47**				
N	Acoma Well		1	118	Well	-95.0	-12.60				
N	Cave Spring (Clover)		2	247	Spring	-92.8	-12.37				
N	Clover Creek Valley Well 246		1	120	Well	-89.0	-12.40				
N	Ramone Mathews Well		1	115	Well	-92.0	-12.30				
S	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
S	East Settling Spring		1	248	Spring	-92.2	-12.76				
S	Ella Spring		1	251	Spring	-95.8	-12.56				
S	Little Springs (Clover Mts)		2	254	Spring	-93.3	-12.81				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
S	Quaking Aspen Spring		1	255	Spring	-93.6	-12.98				
S	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
S	Unnamed Spring		1	113	Spring	-86.5	-11.60				
Alluvial Well	Clover Creek Valley Well 232		1	114	Well	-84.0	-11.70				
ET	**ET**	**0**						**-92.1**	**-12.47**		
205	**GW Outflow (LMVW)**	**1,800**						**-92.1**	**-12.47**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
203	**Panaca Valley**										
202	**Inflow (Patterson)**	**9,900**				**-101.4**	**-13.51**				
198	**Inflow (Dry)**	**700**				**-97.1**	**-13.02**				
203 E	Condor Canyon	564				-92.0	-12.19			69	
203 W	Cathedral Gorge	1,337				-98.9	-13.28			70	
TR	**Total Recharge**	**1,900**				**-96.8**	**-12.95**				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	***-101.4***	***-13.51***	***Inter-basin flow from Patterson Valley***	
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	***-106.2***	***-14.24***	***Inter-basin flow from Lake Valley***	
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	***-106.2***	***-14.24***	***Inter-basin flow from Lake Valley***	
Surface	Meadow Valley Wash, Cal.		1	130	Surface	-97.0	-13.10				
Warm	Lester Mathews Well		1	142	Well	-103.0	-13.30				
Warm	Panaca Town Well		1	143	Well	-106.0	-14.00				
Warm	North Lee Well		1	147	Well	-101.0	-13.30				
ET	**ET**	**2,000**						**-100.5**	**-13.40**		
205	**GW Outflow (LMVW)**	**12,500**						**-100.5**	**-13.40**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
205	**Lower Meadow Valley Wash**										
203	**Inflow (Panaca)**	**12,500**				**-100.5**	**-13.40**				
204	**Inflow (Clover)**	**1,800**				**-92.1**	**-12.47**				
205 NW	Delamar Mtns.	713				-92.2	-12.28			92	
205 NE	Clover Mountains	589				-90.4	-12.25			93	
205 SW	Meadow Valley Mtns.	0				-87.4	-11.92			94	
205 SE	Mormon Mtns.	146				-88.3	-12.50			95	
TR	**Total Recharge**	**1,400**				**-91.1**	**-12.29**				
NE	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
NE	East Settling Spring		1	248	Spring	-92.2	-12.76				
NE	Ella Spring		1	251	Spring	-95.8	-12.56				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NE	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11				
NE	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
NE	Unnamed Spring		1	113	Spring	-86.5	-11.60				
NE	Unnamed Spring (Clover)		1	249	Spring	-88.0	-12.20				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NW	Abandoned Spring		1	266	Spring	-94.5	-12.32				
NW	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
NW	Buckboard Spring		1	264	Spring	-88.2	-11.71				
NW	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
NW	Bishop Spring		3	107	Spring	-87.2	-11.72				
NW	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NW	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
NW	Lower Indian Spring		1	267	Spring	-96.0	-12.62			
NW	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47			
NW	Oak Spring		1	269	Spring	-90.0	-11.87			
NW	Red Rock Spring		1	256	Spring	-95.0	-12.30			
NW	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60			
NW	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58			
NW	Sawmill Spring West		1	258	Spring	-91.8	-12.86			
NW	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54			
NW	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96			
NW	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69			
NW	Upper Indian Spring		1	268	Spring	-88.0	-11.46			
NW	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95			
SW	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92			
SE	Davies Spring		1	90	Spring	-89.0	-12.50			
SE	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70			
SE	Hackberry Spring		1	84	Spring	-87.0	-12.30			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	***-99.4***	***-13.28***	***Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys***
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	**ET**	**1,000**						**-98.7**	**-13.20**	
206	**GW Outflow (Upper Moapa)**	**0**						**-98.7**	**-13.20**	
218	**GW Outflow (California Wash)**	**12,700**						**-98.7**	**-13.20**	

Reconnaissance Series Water Budget

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
175	**Long Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
175 SE	Butte Mtn. (S)	2,379				-119.6	-15.53			35
175 SW	Alligator Rdg.	2,501				-121.7	-15.85			36
175 NW	Maverick Springs	3,911				-123.9	-16.23			37
175 NE	Butte Mtn. (N)	1,509				-119.2	-15.36			164
TR	**Total Recharge**	**10,300**				**-121.7**	**-15.85**			
SE	Butte Spring		1	327	Spring	-120.4	-15.79			
SE	Cabin Spring		1	328	Spring	-124.4	-15.89			
SE	Robbers Roost #2 Spring (Butte)		1	340	Spring	-112.0	-14.39			
SE	Deer Spring (Butte)		1	332	Spring	-114.1	-14.74			
SE	Summit Spring		1	348	Spring	-120.8	-15.94			
SE	Thirty Mile Spring		1	242	Spring	-126.0	-16.40			
NW	Mud Spring (Buck Mts)		1	339	Spring	-117.6	-15.21			
NW	Ram. Res. Wtr Supply Well		1	244	Well	-129.5	-16.75			
NW	Unnamed Near Little Willow Spring		1	351	Spring	-125.9	-17.04			
NW	Well at Alligator Ridge		1	243	Well	-127.0	-16.60			
NW	Woodchuck Spring		1	356	Spring	-119.6	-15.55			
NE	White Rock Spring (Butte)		1	355	Spring	-119.2	-15.36			
ET	**ET**	**2,000**						**-121.7**	**-15.85**	
174	**GW Outflow (Jakes)**	**8,300**						**-121.7**	**-15.85**	
174	**Jakes Valley**									
175	**Inflow (Long)**	**8,300**				**-121.7**	**-15.85**			
174 E	Egan Range	5,404				-118.4	-15.31			33
174 W	North White Pine	11,596				-120.3	-15.83			34
TR	**Total Recharge**	**17,000**				**-119.7**	**-15.66**			
W	Tunnel Spring		1	366	Spring	-118.3	-15.02			
W	Aspen Springs North		1	349	Spring	-119.3	-15.84			
W	Aspen Springs South		1	324	Spring	-120.9	-16.02			
W	Chicken Spring		1	330	Spring	-122.0	-16.17			
W	Circle Wash Spring		1	331	Spring	-114.5	-15.30			
W	Sage Hen Spring		1	342	Spring	-112.4	-14.76			
W	Sand Spring		1	239	Spring	-123.0	-16.20			
W	Shellback Spring		1	344	Spring	-123.6	-16.54			
W	Unnamed Hayden Canyon Spring		1	350	Spring	-120.9	-15.69			
W	Unnamed Shellback Ridge Spring		1	352	Spring	-123.6	-16.18			
W	Wild Horse Spring (White Pine)		1	240	Spring	-129.0	-16.80			
W	Unnamed Stone Cabin Spring		2	354	Spring	-116.2	-15.39			
W/E	Indian Spring (Butte)		1	334	Spring	-119.1	-15.31			
W/E	Sammy Spring		1	343	Spring	-117.6	-15.30			
W	Upper Illipah Crk		2	238	Surface	-123.5	-16.10	Not used in W average		
ET	**ET**	**0**						**-119.7**	**-15.66**	
207N	**GW Outflow (NWRV)**	**25,300**						**-120.3**	**-15.72**	
180	**Cave Valley**									
0	**Inflow (None)**	**0**				**0.0**	**0.00**			
180 E	S. Schell Cr. Rng	6,220				-105.0	-14.28			43,44
180 W	S. Egan Rng	7,780				-107.8	-14.28			45,46

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
TR	**Total Recharge**	**14,000**				**-106.6**	**-14.28**				
E	North Creek Spring		1	214	Spring	-105.0	-14.60				
E	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
E	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
E	Sheep Spring (Schell Ck)		1	212	Spring	-99.5	-13.70				
E	Robbers Roost Spring (Schell Ck)		1	389	Spring	-109.7	-14.75				
E	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
W	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
W	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
W	Haggerty Spring		1	387	Spring	-109.6	-14.78				
W	Granite Spring		1	440	Spring	-103.4	-13.32				
W	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
W	Silver Spring		2	385	Spring	-111.4	-14.71				
W	Shingle Spring		2	203	Spring	-103.7	-13.33				
W	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
W	Trough Spring		1	413	Spring	-103.6	-13.56				
ET	**ET**	**200**						**-106.6**	**-14.28**		
Well	**180W902**		**1**	**601**	**Deep Well**	**-104.7**	**-14.12**				
Well	**180W501**		**1**	**600**	**Deep Well**	**-105.6**	**-14.12**				
181	GW Outflow (Dry Lake)	0						**-106.6**	**-14.28**		
207S	**GW Outflow (SWRV)**	**13,800**						**-106.6**	**-14.28**		
xxxxxxxx	xxxxxxxxxxxxxxxxxxxxxxxxx	xxxxxxxx	xxxxxxx	xxxxxx	xxxxxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	xxxxxx	
207N	**North White River Valley**										
174	**Inflow (Jakes)**	**25,300**				**-120.3**	**-15.72**				
207 NE	Egan Rng North	13,009				-112.4	-15.14			38	
207 NW	White Pine Rng.	12,727				-115.0	-15.18			39, 40	
TR	**Total Recharge**	**25,700**	**2**			**-113.7**	**-15.16**				
NE	on Creek Spring (Unnamed Spring in Gubler Canyon)		1	235	Spring	-111.0	-14.90				
NE	Hole in the Bank Spring		1	386	Spring	-114.9	-15.37				
NE	Lone Pine Spring		3	223	Spring	-110.2	-14.90				
NE	North Spring		1	237	Spring	-113.0	-15.00				
NE	High Springs		1	433	Spring	-113.4	-15.43				
NE	Lion Spring (Egan Range)		1	430	Spring	-114.8	-15.34				
NE	Mud Spring		1	446	Spring	-111.0	-14.53				
NE	Pine Springs (Egan Range)		1	434	Spring	-116.0	-15.71				
NE	Unnamed Spring #1(Egan)		1	435	Spring	-112.2	-15.14				
NE	Unnamed Spring #2 (Egan Range)		1	436	Spring	-110.0	-15.14				
NE	Unnamed Spring #3 (Egan Range)		1	437	Spring	-110.2	-15.07				
NE	Unnamed Spring #4 (Egan Range)		1	438	Spring	-114.0	-15.37				
NE	Unnamed Spring #5 (Egan Range)		1	445	Spring	-109.6	-14.72				
NE	Second Sawmill Spring		1	222	Spring	-110.0	-14.70				
NE	South Spring (Egan)		2	236	Spring	-111.5	-15.12				
NE	Upper Terrace Spring WR2		14	270	Spring	-114.0	-15.42				
NE	Water Canyon Spring		1	358	Spring	-114.4	-15.60				
NE	Lund Spring		1	221	Spring	-113.0	-15.40	Local Valley spring not included in recharge calculation			
NE	Water Canyon		2	233	Surface	-116.0	-15.25	Surface Water not included in recharge average			
NW	Big Tom Plain Spring		1	326	Spring	-121.1	-15.92				
NW	Deer Spring (White Pine)		2	322	Spring	-119.3	-15.87				
NW	Unnamed Spring #1 (White Pine)		1	359	Spring	-114.8	-15.36				
NW	Unnamed Spring #2 (White Pine)		1	360	Spring	-114.9	-15.66				
NW	Unnamed Spring #3 (White Pine)		1	361	Spring	-113.1	-14.96				
NW	Unnamed Spring #4 (White Pine)		1	362	Spring	-116.3	-15.01				
NW	Unnamed Spring #5 (White Pine)		3	363	Spring	-116.0	-15.36				
NW	Unnamed Spring #6 (White Pine)		1	364	Spring	-115.1	-14.98				
NW	Easter Spring		1	365	Spring	-119.4	-15.56				
NW	Halfway Spring (RS)		2	429	Spring	-108.7	-13.52				
NW	Little Tom Plain Spring		2	337	Spring	-121.0	-15.86				
NW	Monitoring Spring WR1		14	320	Spring	-113.7	-15.58				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NW	Saddle Spring (White Pine)		3	357	Spring	-116.8	-15.45				
NW	Secret Spring		1	220	Spring	-110.0	-14.00				
NW	Unnamed Spring below Currant Mtn		1	226	Spring	-107.0	-14.00				
NW	Stove Spring		1	347	Spring	-114.5	-15.71				
NW	ıed Spring in dry creek bed (White Pine Range)		1	321	Spring	-113.6	-15.31				
NW	Snowmelt Below Duckwater Peak	5,700	1	224	Surface	-105.0	-14.10	Surface Water not included in recharge average			
NW	Little Currant Creek		1	217	Surface	-113.0	-15.00	Surface Water not included in recharge average			
Warm	Cold Spring, Preston	1,000	2	230	Spring	-123.5	-15.80				
Warm	Nicholas Spring	2,000	1	227	Spring	-124.0	-16.10				
Warm	Preston Big Spring	5,900	11	231	Spring	-122.0	-15.88				
Warm	**Discharge Warm Sprs (Avg)**	**8,900**	**14**			**-122.6**	**-15.92**	***-120.3***	***-15.72***	***Inter-basin flow from Jakes Valley***	
ET	**ET**	**22,000**						**-113.7**	**-15.16**		
207S	**GW Outflow (SWRV)**	**29,000**						**-119.5**	**-15.65**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
207S	**South White River Valley**	WRV Tot Recharge									
		38,000									
207N	**Inflow (N White River)**	**29,000**				**-119.5**	**-15.65**				
180	**Inflow (Cave)**	**13,800**				**-106.6**	**-14.28**				
207 SE	Egan Rng South	6,529				-106.9	-14.15			41	
207 SW	Grant Rng	5,735				-106.5	-14.23			42	
TR	**Total Recharge**	**12,300**				**-106.7**	**-14.18**				
E	Chimney Rock Spring		2	219	Spring	-110.5	-14.52				
E	Granite Spring		1	440	Spring	-103.4	-13.32				
E	Haggerty Spring		1	387	Spring	-109.6	-14.78				
E	Silver Spring		2	385	Spring	-111.4	-14.71				
E	Big Spring (Egan)		4	206	Spring	-105.5	-13.90				
E	Shingle Spring		2	203	Spring	-103.7	-13.33				
E	Perry Sp Barcass 37		1	408	Spring	-107.7	-15.04				
E	Trough Spring		1	413	Spring	-103.6	-13.56				
E	Butterfield Spring	4,000	1	202	Spring	-105.0	-14.20	local Valley spring not included in recharge calculation			
E	Emigrant Spring	1,900	2	207	Spring	-107.8	-14.50	local Valley spring not included in recharge calculation			
E	Flag Spring #3		1	201	Spring	-105.0	-14.30	local Valley spring not included in recharge calculation			
SW	Albert Spring		1	204	Spring	-107.0	-13.95				
SW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
SW	Brady Spring		2	282	Spring	-109.5	-15.38				
SW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
SW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
SW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
SW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
SW	Murphy Spring		1	373	Spring	-114.5	-15.40				
SW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
Warm	Hot Creek Campground Well	0	1	198	Well	-118.0	-15.30				
Warm	Hot Creek Springs	10,000	10	197	Spring	-118.9	-15.69				
Warm	Moon River Spring	2,800	1	192	Spring	-120.0	-15.80				
Warm	Moorman Spring	400	1	205	Spring	-119.0	-15.70				
Warm	**Discharge Warm Sprs (Avg)**	**13,200**				**-119.2**	**-15.71**	***-119.5***	***-15.65***	***Inter-basin flow from Northern White River Valley***	
ET	**ET**	**13,000**						**-107.2**	**-14.24**		
208	**GW Outflow (Pahroc)**	**42,100**						**-115.3**	**-15.21**		
208	GW Outflow (Garden Valley)	0						-115.3	-15.21		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXXX	
172	**Garden Valley**										
172	**Inflow (None)**	**0**				**-115.3**	**-15.21**				
172 SW	Quinn Canyon Range	5,348				-104.6	-14.08			170,171	
172 NW	Grant Range	3,502				-106.5	-14.27			170,171	
172 NE	Golden Gate Rng	428				-98.0	-13.30			55	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
172 SE	Worthington Mountains	723				-98.0	-13.30			56	
TR	**Total Recharge**	**10,000**				**-104.5**	**-14.06**				
SW	Unnamed Spring #7 (Quinn)		1	367	Spring	-105.9	-14.23				
SW	Unnamed Spring #8 (Quinn)		1	368	Spring	-104.4	-14.18				
SW	Adaven Spring		2	177	Spring	-105.3	-14.01				
SW	Lower Little Cherry Cr Spring		1	182	Spring	-103.0	-13.90				
SW	Carpenter Spring		1	171	Spring	-95.0	-11.85	Evaporated so not used in recharge calculation			
NW	Big Spring (Grant)		1	194	Spring	-112.0	-15.20				
NW	Brady Spring		2	282	Spring	-109.5	-15.38				
NW	Forest Home Spring (Unnamed Spring)		1	195	Spring	-108.5	-14.50				
NW	Horse Spring (Grant)		1	370	Spring	-99.5	-12.86				
NW	Teaspoon Spring		1	371	Spring	-100.0	-13.26				
NW	Wiregrass Spring (Grant)		1	372	Spring	-101.4	-13.29				
NW	Murphy Spring		1	373	Spring	-114.5	-15.40				
NW	Little Spring (Grant Range)		1	369	Spring	-99.4	-12.48	Evaporated so not used in recharge calculation			
SE	The Seeps (Spring)		1	136	Spring	-98.0	-13.30				
ET	**ET**	**2,000**						**-104.5**	**-14.06**		
171	**GW Outflow (Coal)**	**8,000**						**-104.5**	**-14.06**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
171	**Coal Valley**										
172	**Inflow (Garden)**	**8,000**				**-104.5**	**-14.06**				
172	**Inflow (SWRV)**	**0**				**-115.3**	**-15.21**				
171 E	Seaman Rng	631				-98.2	-12.87			75	
171 W	Golden Gate Rng	1,369				-99.0	-13.13			76	
TR	**Total Recharge**	**2,000**				**-98.7**	**-13.05**				
W	Cold Spring		1	288	Spring	-98.9	-12.98				
W	Henry Spring		1	287	Spring	-97.4	-12.77				
W	Little Cut Spring		2	286	Spring	-98.3	-12.85				
E	Seaman Spring		1	306	Spring	-99.0	-13.13				
Carb Well	**USGS-MX C.V. Well (CV-DT-1)**		**2**	**176**	**Well**	**-109.0**	**-14.56**	***-104.5***	***-14.06***	***Underflow from Garden Valley***	
ET	**ET**	**0**						**-98.7**	**-13.05**		
208	**GW Outflow (Pahranagat)**	**10,000**						**-103.4**	**-13.85**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
208	**Pahroc Valley**										
207S	**Inflow (S. White River)**	**42,100**				**-115.3**	**-15.21**				
171	Inflow (Coal)	0				0.0	0.00				
208 E	N. Pahroc Rng.	1,019				-94.2	-12.42			73	
208 W	Seaman Rng.	1,181				-99.0	-13.13			74	
TR	**Total Recharge**	**2,200**	**2**			**-96.8**	**-12.80**				
E	Black Rock Spring		2	158	Spring	-93.8	-12.31				
E	Coyote Spring		2	169	Spring	-95.1	-12.53				
E	Hamilton Spring		1	298	Spring	-93.1	-11.76				
E	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
E	Mustang Spring		2	135	Spring	-90.5	-12.49				
E	Pahroc Spring		3	131	Spring	-92.2	-12.65				
E	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
E	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
W	Seaman Spring		1	306	Spring	-99.0	-13.13				
Evaporated	White Rock Spring (Seaman Range)		1	154	Spring	-90.0	-12.10	Evaporated not used in recharge calculation			
ET	**ET**	**0**						**-96.8**	**-12.80**		
209	**GW Outflow (Pahranagat)**	**44,300**						**-114.4**	**-15.09**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
209	**Pahranagat Valley**										

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
208	**Inflow (Pahroc)**	**44,300**				**-114.4**	**-15.09**				
171	**Inflow (Coal)**	**10,000**				**-103.4**	**-13.85**				
209	**Inflow (Delamar)**	**6,200**				**-97.7**	**-12.96**				
209 E	S. Pahroc Rng.	528				-94.9	-12.83			77, 78	
209 W	Mt. Irish/Pahranagat Rng.	1,272				-98.4	-14.24			79, 80 (172, 173)	
TR	**Total Recharge**	**1,800**				**-97.4**	**-13.83**				
E	Eightmile Spring		2	295	Spring	-95.6	-13.09				
E	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
E	Sixmile Spring		1	112	Spring	-93.4	-13.06				
E	Twin Spring		1	294	Spring	-97.4	-13.24				
E	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
E	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
E	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
S	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30	Local Valley spring not included in recharge calculation			
W	Reed Spring		1	289	Spring	-98.4	-14.24				
Warm	Ash Springs	12400	6	110	Spring	-109.1	-14.11				
Warm	Little Ash Spring (Ash Spring)	500	1	111	Spring	-107.2	-14.20				
Warm	Crystal Springs	8,200	17	116	Spring	-108.8	-14.41				
Warm	Hiko Spring	4,300	7	122	Spring	-108.7	-14.39				
Warm	**Discharge Warm Springs (Avg)**	**25,400**	**31**			**-108.9**	**-14.26**	***-114.4***	***-15.09***	***Inter-basin flow from Pahroc Valley***	
ET	**ET**	**25,000**						**-109.9**	**-14.61**		
Well	**209M-1**		**1**	**608**	**Deep Well**	**-104.7**	**-13.53**	***-114.4***	***-15.09***	***Inter-basin flow from Pahroc Valley***	
210	**GW Outflow (Coyote Spr)**	**37,300**						**-110.9**	**-14.67**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
181	**Dry Lake Valley**										
180	**Inflow (None)**	**0**				**0.0**	**0.00**				
181 NW	S. Schell Ck Range	854				-100.4	-13.21			59	
181 SW	N. Pahroc Rng.	124				-94.2	-12.42			57	
181 NE	Fairview Rng.	1,180				-99.5	-12.89			58	
181 E	Bristol/Highland Rng.	2,567				-98.9	-13.28			61	
181 SE	Burnt Springs Rng.	274				-94.6	-12.36			62	
TR	**Total Recharge**	**5,000**				**-98.9**	**-13.10**				
E	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
E	Highland Spring		3	163	Spring	-99.1	-13.36				
E	Lime Spring		2	160	Spring	-98.5	-13.16				
E	Pine Spring		2	157	Spring	-99.0	-13.37				
E	Connor Spring		1	283	Spring	-100.6	-13.84				
E	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
SE	Red Rock Spring		1	256	Spring	-95.0	-12.30				
SE	Abandoned Spring		1	266	Spring	-94.5	-12.32				
SE	Buckboard Spring		1	264	Spring	-88.2	-11.71				
SE	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
SE	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
SE	Oak Spring		1	269	Spring	-90.0	-11.87				
SE	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
SE	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
SE	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
NE	Bailey Spring (Fairview)		2	277	Spring	-98.2	-12.69				
NE	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
NE	Littlefield Spring		1	275	Spring	-98.5	-12.73				
NE	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
NE	Meloy Spring		1	276	Spring	-99.8	-12.75				
NE	Scotty Spring		1	272	Spring	-98.9	-12.73				
NE	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
NE	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
NE	Fence Spring		1	278	Spring	-97.4	-12.55				
NE	Fox Cabin		1	273	Spring	-103.5	-13.59				

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Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
NE	Lower Fairview		1	281	Spring	-97.5	-12.39				
NE	Robison Spring		1	279	Spring	-97.9	-12.34				
NE	Upper Fairview		1	280	Spring	-97.7	-12.66				
SW	Black Rock Spring		2	158	Spring	-93.8	-12.31				
SW	Coyote Spring		2	169	Spring	-95.1	-12.53				
SW	Hamilton Spring		1	298	Spring	-93.1	-11.76				
SW	Little Boulder Spring		1	301	Spring	-97.2	-13.06				
SW	Mustang Spring		2	135	Spring	-90.5	-12.49				
SW	Pahroc Spring		3	131	Spring	-92.2	-12.65				
SW	Rattlesnake Spring		1	302	Spring	-97.3	-12.65				
SW	Unnamed Spring--nr Blackrock		1	299	Spring	-94.3	-11.90				
NW	Sidehill Spring	1,600	2	200	Spring	-100.4	-13.21				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
Evaporated	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
Carb Well	**Fugro Dry Lake V Deep Well**		**2**	**179**	**Well**	**-107.5**	**-14.16**	***-98.9***	***-13.10***	***Local Recharge***	
Carb Well	**181M1**		**1**	**603**	**Deep Well**	**-105.0**	**-13.67**	***-98.9***	***-13.10***	***Local Recharge***	
Carb Well	**181W909M**		**1**	**604**	**Deep Well**	**-104.6**	**-13.50**	***-98.9***	***-13.10***	***Local Recharge***	
ET	**ET**	**0**						**-98.9**	**-13.10**		
209	**GW Outflow (Pahranagat)**	**0**						**-98.9**	**-13.10**		
182	**GW Outflow (Delamar)**	**5,000**						**-98.9**	**-13.10**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
182	**Delamar Valley**										
181	**Inflow (Dry Lake)**	**5,000**				**-98.9**	**-13.10**				
182 E	Delamar Mtns.	1,037				-92.5	-12.32				81
182 W	S. Pahroc Rng.	163				-94.6	-12.81				82
TR	**Total Recharge**	**1,200**				**-92.7**	**-12.38**				
E	Abandoned Spring		1	266	Spring	-94.5	-12.32				
E	Red Rock Spring		1	256	Spring	-95.0	-12.30				
E	Oak Spring		1	269	Spring	-90.0	-11.87				
E	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96				
E	Upper Indian Spring		1	268	Spring	-88.0	-11.46				
E	Lower Indian Spring		1	267	Spring	-96.0	-12.62				
E	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
E	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
E	Bishop Spring		3	107	Spring	-87.2	-11.72				
E	Buckboard Spring		1	264	Spring	-88.2	-11.71				
E	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
E	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98				
E	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
E	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
E	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
E	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54				
E	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69				
W	Pahroc Spring		3	131	Spring	-92.2	-12.65				
W	Gulch Spring(Unnamed Spring in Hells Acres Gulch)		1	109	Spring	-93.0	-12.30				
W	Sixmile Spring		1	112	Spring	-93.4	-13.06				
W	Eightmile Spring		2	295	Spring	-95.6	-13.09				
W	Twin Spring		1	294	Spring	-97.4	-13.24				
W	ıamed Spring in Road(South Pahroc Range)		1	303	Spring	-96.7	-13.07				
W	Unnamed Spring nr Six Mile seep		1	296	Spring	-94.5	-12.62				
W	Water Tank 0.4mi West of Sixmile		1	297	Spring	-93.8	-12.44				
Evaporated	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
ET	**ET**	**0**						**-92.7**	**-12.38**		
Well	**182W906M**		**1**	**607**	**Deep Well**	**-100.3**	**-13.33**	***-98.9***	***-13.10***	***Inter-basin flow from Dry Lake Valley***	
209	**GW Outflow (Pahranagat)**	**6,200**						**-97.7**	**-12.96**		
210	GW Outflow (Coyote Spr)	0						-97.7	-12.96		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
206	**Kane Springs Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
206 W	Delamar Mtns.	563				-89.0	-12.22			90	
206 E	Meadow Valley Mtns.	0				-87.4	-11.92			91	
TR	**Total Recharge**	**600**				**-89.0**	**-12.22**				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
W	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
W	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
W	Bishop Spring		3	107	Spring	-87.2	-11.72				
W	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
W	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
W	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
W	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
W	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
ET	**ET**	**0**						**-89.0**	**-12.22**		
210	**GW Outflow (Coyote Spr)**	**600**						**-89.0**	**-12.22**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
210	**Coyote Springs Valley**										
209	**Inflow (Pahranagat)**	**37,300**				**-110.9**	**-14.67**				
182	**Inflow (Delamar)**	**0**				**0.0**	**0.00**				
206	**Inflow (Kane Springs)**	**600**				**-89.0**	**-12.22**				
210 NE	S. Delamar Mtns.	27				-89.0	-12.22			83	
210 E	S. Meadow Valley Mtns.	0				-87.4	-11.92			84	
210 NW	S. of Maynard Lake	0				-94.0	-12.30			87	
210 SE	Arrow Canyon Rng.	4				-81.0	-10.60			88	
210 W	Sheep Range	2,007				-92.7	-12.83			89	
TR	**Total Recharge**	**2,000**				**-92.6**	**-12.81**				
W	Cow Camp Spring		4	47	Spring	-91.9	-12.53				
W	Lamb Spring		1	86	Spring	-92.5	-13.15				
W	Mormon Well Spring		3	53	Spring	-91.8	-12.67				
W	Rye Patch Spring		1	341	Spring	-89.3	-12.31				
W	Sawmill Spring (Sheep)		1	58	Spring	-92.0	-12.85				
W	Sheep Spring (Sheep Range)		1	83	Spring	-96.0	-13.35				
W	Wiregrass Spring (Sheep)		13	49	Spring	-95.1	-12.93				
W	White Rock Spring (Sheep)		2	64	Spring	-85.5	-10.17	Evaporated not used in recharge calculation			
NW	Maynard Lake Spring (Unnamed Spring)		1	94	Spring	-94.0	-12.30				
SE	Wamp Spring		1	52	Spring	-81.0	-10.60				
E	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92				
NE	Bishop Spring		3	107	Spring	-87.2	-11.72				
NE	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47				
NE	Kane Springs (KSV-3)		3	97	Spring	-86.8	-12.13				
NE	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47				
NE	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58				
NE	Sawmill Spring West		1	258	Spring	-91.8	-12.86				
NE	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95				
NE	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60				
Carb Well	CSVM-2		1	612	Well	-97.7	-13.14				
Carb Well	CSVM-3		1	613	Well	-98.0	-13.10				
Carb Well	CSVM-4		1	614	Well	-102.5	-13.41				
Carb Well	CSVM-6		1	616	Well	-100.7	-12.97				
Carb Well	CSI-1		1	609	Well	-102.6	-13.08				
Carb Well	CSI-2		1	610	Well	-100.2	-12.90				
Carb Well	CSI-3		1	611	Well	-99.6	-13.03				
Carb Well	USGS CSV-1		1	71	Well	-103.0	-13.55				
Carb Well	CE-VF-2 Well		2	81	Well	-101.0	-13.10				
Carb Well	Fugro CV Deep Well CE-DT-5		3	77	Well	-99.6	-12.96				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
Carb Well	CE-DT-4		1	78	Well	-102.5	-13.00				
CARB	Carbonate Well (Avg)		6			-100.7	-13.11	-110.5	-14.63	Flow weighted average of inter-basin flow from Pahranagat, Kane Springs, and Delamar Valleys	
ET	ET	500						-92.6	-12.81		
219	GW Outflow (Muddy)	39,400						-109.8	-14.56		
217	GW Outflow (Hidden)	0						-109.8	-14.56		
216	GW Outflow (Garnet)	0						-109.8	-14.56		
219	Upper Moapa (Muddy) Valley										
205	Inflow (LMVW)	0				0.0	0.00				
210	Inflow (Coyote)	39,400				-109.8	-14.56				
219 S	E. Arrow Canyon?	0				-87.3	-11.86	Grapevine Sp.		85	
219 N	Wildcat Wash	0				-87.3	-11.86	Grapevine Sp.		86	
TR	Total Recharge	0				-87.3	-11.86				
Warm	APCAR	0	1	292	Spring	-98.2	-12.94				
Warm	Baldwin Spring	2226	9	291	Spring	-97.6	-12.97				
Warm	Big Muddy Spring	5500	6	69	Spring	-97.9	-12.89				
Warm	Iverson's Spring	0	1	65	Spring	-97.0	--				
Warm	Jones Spring Pumphouse	0	6	292	Spring	-97.9	-13.05				
Warm	M-8 Spring (Unnamed Spring)	0	1	68	Spring	-99.0	-12.75				
Warm	M-9 Spring (Unnamed Spring)	200	1	70	Spring	-96.5	-12.45				
Warm	Pederson's East	0	9	290	Spring	-97.8	-12.98				
Warm	Pederson's Warm Spring (M-13)	400	15	67	Spring	-97.5	-12.93				
Warm	Dicharge Warm Sprs (Avg)	8,300	49			-97.8	-12.90	*-109.8*	*-14.56*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*	
Carb Well	CE-DT-6 Well		2	72	Well	-98.0	-13.03				
Carb Well	CSV-2 Well		2	76	Well	-97.9	-12.92				
CARB	Deep Carbonate Well (Avg)	Input into M	4			-97.9	-12.97	*-109.8*	*-14.56*	*Flow weighted average of inter-basin flow from Coyote and Lower Meadow Valley Wash Valleys*	
ET	ET	0						-87.3	-11.86		
Gage	Moapa Gage	34,000									
218	SW Outflow (California)	34,000						-109.8	-14.56		
218	GW Outflow (California)	5,400						-109.8	-14.56		
217	Hidden Valley										
210	Inflow (Coyote)	0				-109.8	-14.56				
217 E	E. Hidden	0				-81.0	-10.60			99	
217 W	W. Hidden	400				-81.0	-10.60			100	
TR	Total Recharge	400				-81.0	-10.60				
W	Wamp Spring		1	52	Spring	-81.0	-10.60				
ET	ET	0						-81.0	-10.60		
216	GW Outflow (Garnet)	400						-81.0	-10.60		
216	Garnet Valley										
217	Inflow (Hidden)	400				-81.0	-10.60				
216 E	Apex	10				-81.0	-10.60			104	
216 W	Las Vegas Range	390				-81.0	-10.60			105	
TR	Total Recharge	400				-81.0	-10.60				
W	Wamp Spring		1	52	Spring	-81.0	-10.60				
	Dry Lake Valley Well		1	34	Well	-97.5	-13.30				
Carb Well	GP Apex Well		3	17	Well	-97.2	-13.53				
Carb Well	Unnamed Well (Near Dry Lake Range)		1	24	Well	-96.0	-13.70				
Carb Well	US Lime Well (Genstar)		1	27	Well	-97.0	-12.75				
CARB	Wells (Avg)		6			-96.9	-13.32	*-81.0*	*-10.60*	*Inter-basin flow from Hidden Valley*	
ET	ET	0						-81.0	-10.60		

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
218	GW Outflow (California)	800						-81.0	-10.60		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXX	XXXXXXX	XXXXXXX	XXXXXX	XXXXXX	XXXXXX	
218	California Wash										
219	Inflow (LMVW)	12,700				-99.8	-13.33				
219	Inflow (Muddy)	5,400				-109.8	-14.56				
216	Inflow (Garnet)	800				-81.0	-10.60				
218	SW Inflow (Muddy)	34,000									
218 E	Moapa Paiutes	45				-82.0	-10.60			110	
218 W	Muddy Mtns.	55				-82.0	-10.60			111	
TR	Total Recharge	100				-82.0	-10.60				
W	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Carb Well	Calpine Test Well 1a		1	43	Well	-99.0	-13.50				
Carb Well	Moapa Well		1	41	Well	-99.0	-13.40				
CARB	Carbonate Well (Avg)					-99.0	-13.45	-106.1	-14.05	Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys	
ET	ET	1,000						-99.9	-13.3		
220	GW Outflow (Lower Moapa)	21,300						-101.9	-13.57		
215	GW Outflow (Black Mtn Area)	0						-101.9	-13.57		
220	SW Outflow (Lower Moapa)	30,700									
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXX	XXXXXXX	XXXXXXX	XXXXXX	XXXXXX	XXXXXX	
215	Black Mountains Area										
218	Inflow (California Wash)	0				-101.9	-13.57				
215 NE	Muddy Mtns.	100				-85.0	-10.95			113	
215 SE	Black Mtns.	0				-79.5	-10.65			114	
215 W	Gypsum Wash	0				-79.5	-10.65			112, 166	
TR	Total Recharge	100				-85.0	-10.95				
SE	Cottonwood Spring (Black Mtns.)	0	1	8	Spring	-80.0	-10.80				
SE	Sandstone Spring	0	1	10	Spring	-79.0	-10.50				
NE	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
NE	Valley of Fire Well		1	31	Well	-82.0	-10.60				
Alluvial Spri	Bitter Spring	5	1	14	Spring	-77.0	-9.90				
Carb Spr	Blue Point Spring	440	5	26	Spring	-92.6	-12.40				
Carb Spr	Corral Spring (Unnamed Spring)	0	1	19	Spring	-91.5	-12.10				
Carb Spr	Rogers Spring	1,200	3	21	Spring	-91.7	-12.33				
Carb Spr	Scirpus Spring (No spring on Map)	0	1	20	Spring	-90.0	-12.00				
Carb Spr	VF Spring 1	0	1	28	Spring	-88.0	-11.20				
Carb Spr	VF Spring 2	6	1	29	Spring	-92.0	-11.80				
Carb Spr	VF Spring 3	17	1	30	Spring	-93.0	-12.20				
CARB	Carbonate Spr (Avg)	1,700	13			-91.3	-12.01	-85.0	-10.95	Weighted Average of Inflow from Califronia Wash plus recharge from Muddy Mountains	
ET	ET	0						-85.0	-10.95		
999	GW Outflow (Colorado River)	100						-85.0	-10.95		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXX	XXXXXXXXX	XXXXXXX	XXXXXXX	XXXXXX	XXXXXX	XXXXXX	
220	Lower Moapa Valley										
219	Inflow (Muddy)	21,300				-101.9	-13.57				
218	SW Inflow (California Wash)	30,700									
220 S	Valley of Fire	0				-88.0	-11.30			101	
220 N	S. Mormon Mtns.	100				-88.3	-12.50			102	
TR	Total Recharge	100				-88.3	-12.50				
N	Davies Spring		1	90	Spring	-89.0	-12.50				
N	Hackberry Spring		1	84	Spring	-87.0	-12.30				
N	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70				
S	Unnamed, Kaolin Wash		1	35	Spring	-88.0	-11.30				
Carb Well	EH-7		1	56	Well	-91.0	-12.45				
Carb Well	EH-3 Weiser Wash		1	61	Well	-91.0	-12.70				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
CARB	Carbonate Well (Avg)		2			-91.0	-12.58	*-101.9*	*-13.57*	*Inter-basin flow from Lower Meadow Valley Wash*	
ET	ET	24,000						-101.8	-13.56		
999	GW Outflow (Colorado River)	19,100						-101.9	-13.57		
999	SW Outflow (Colorado River)	9,000									
Colorado R	Lake Mead (Colorado River)										
210	GW Inflow (Black Mountains Area)	100				-85.0	-10.95				
205	GW Inflow (Lower Moapa)	19,100				-101.9	-13.57				
999	Groundwater Total	19,200						-101.8	-13.55		
205	SW Inflow (Lower Moapa)	9,000									
999	Surfacewater Total	9,000									
999	Inflow Total	28,200									
183	Lake Valley										
0	Inflow (None)	0				0.0	0.00				
183 NE	Fortification Rng	1,426				-106.3	-14.16			49	
183 NW	Cen. Schell Cr. Rng	6,436				-108.1	-14.74			51	
183 SE	Wilson Cr. Rng. @ Atlanta	3,974				-104.7	-13.75			50	
183 SW	Fairview Rng.	1,165				-101.1	-13.29			60	
TR	Total Recharge	13,000				-106.2	-14.24				
NE	Indian Springs		1	375	Spring	-106.3	-14.16				
NW	Big Spring North	700	1	211	Spring	-112.0	-15.10				
NW	Big Spring South	1,600	1	210	Spring	-111.0	-14.80				
NW	Geyser Spring	340	1	213	Spring	-105.0	-14.50				
NW	North Creek Spring	1,200	1	214	Spring	-105.0	-14.60				
NW	Patterson Pass Spring WR3		15	305	Spring	-108.4	-14.95				
NW	Unnamed Spring in Schell Creek Range		4	304	Spring	-107.3	-14.48				
SE	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
SE	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
SE	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
SW	Cottonwood Spring (Fairview)		1	274	Spring	-102.2	-13.40				
SW	Lower Pony Spring		2	190	Spring	-101.0	-13.25				
SW	Indian Spring near Steward Ranch		1	188	Spring	-102.0	-13.60				
SW	Unnamed Spring near Pony Spring		1	191	Spring	-99.0	-12.90				
ET	ET	9,000						-106.2	-14.24		
202	GW Outflow (Patterson)	4,000						-106.2	-14.24		
202	Patterson Valley										
183	Inflow (Lake)	4,000				-106.2	-14.24				
202 E	Wilson Cr. Rng. @ Mt. Wilson	4,059				-97.7	-12.99			47	
202 W	Bristol Rng.	1,941				-99.2	-13.10			48	
TR	Total Recharge	6,000				-98.2	-13.03				
E	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
E	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
E	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
E	Parsnip Spring		1	180	Spring	-93.5	-12.80				
E	Horsethief Spring		2	314	Spring	-97.0	-12.68				
E	Wilson Creek		1	189	Surface	-97.5	-13.20	Surface Water not included in recharge average			
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		1	156	Spring	-102.3	-13.88				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Fox Cabin		1	273	Spring	-103.5	-13.59				
W	Scotty Spring		1	272	Spring	-98.9	-12.73				
W	Upper Fairview		1	280	Spring	-97.7	-12.66				
W	Lower Fairview		1	281	Spring	-97.5	-12.39				
W	Wildhorse Spring (Fairview)		1	183	Spring	-92.5	-11.70	Evaporated so not used in recharge calculation			
W	McDermitt Spring		1	323	Spring	-94.3	-11.21	Evaporated so not used in recharge calculation			
ET	**ET**	**100**						**-98.2**	**-13.03**		
203	**GW Outflow (Panaca)**	**9,900**						**-101.5**	**-13.52**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
201	**Spring Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
201 E	White Rock Mtns.	5,128				-100.9	-13.52			52	
201 W	Wilson Cr. Rng. @ Parsnip Pk.	4,872				-97.7	-12.99			53	
TR	**Total Recharge**	**10,000**				**-99.4**	**-13.26**				
E	Barrel Spring		1	317	Spring	-100.5	-13.36				
E	anyon Spring (Unnamed Spring in Burnt Canyon)		1	187	Spring	-93.0	-12.30				
E	Lion Spring		1	318	Spring	-103.4	-14.11				
E	South Monument Spring		1	319	Spring	-102.3	-14.23				
E	Jnnamed Spring nr Redd's Cabin Summit		2	173	Spring	-94.4	-12.44				
E	Ripgut Sp #40		1	411	Spring	-106.4	-14.38				
E	Unnamed Spring #1(White Rock Mts)		1	415	Spring	-109.6	-15.05				
E	Unnamed Spring #2 (White RockMts)		1	417	Spring	-97.0	-13.00				
E	Upper Burnt Canyon Spring		1	416	Spring	-97.6	-12.83				
E	Upper Burnt Canyon Spring #2		1	416	Spring	-103.6	-13.66				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
E	Unnamed Spring in Miller Canyon		1	313	Spring	-103.7	-14.27				
E	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Blue Rock Spring		1	311	Spring	-93.4	-12.68				
W	Headwaters Spring WR5		17	309	Spring	-107.3	-14.57				
W	Bailey Spring (Wilson Ck)		1	310	Spring	-102.0	-12.93				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
W	Parsnip Spring		1	180	Spring	-93.5	-12.80				
W	Upper Tower Spring		1	312	Spring	-93.3	-12.30				
Surface	Camp Creek		1	184	Surface	-102.0	-14.00	Surface Water not included in recharge average			
Surface	MVW above Eagle Canyon		1	168	Surface	-93.0	-12.00	Surface Water not included in recharge average			
ET	**ET**	**10,000**						**-99.4**	**-13.26**		
200	**GW Outflow (Eagle)**	**0**						**-99.4**	**-13.26**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
200	**Eagle Valley**										
201	**Inflow (Spring)**	**0**				**-99.4**	**-13.26**				
200 E	E. Eagle (Ursine) Valley	1,186				-99.1	-13.28			63	
200 W	W. Eagle (Ursine) Valley	160				-97.0	-12.68			64	
TR	**Total Recharge**	**1,300**				**-98.9**	**-13.20**				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
E	Butcher Spring		1	424	Spring	-103.2	-14.22				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		1	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		1	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		1	420	Spring	-100.4	-13.68				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**1,000**						**-98.9**	**-13.20**		
199	**GW Outflow (Rose)**	**300**						**-98.9**	**-13.20**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
199	**Rose Valley**										
200	**Inflow (Eagle)**	**300**				**-98.9**	**-13.20**				
199 E	E. Rose Valley	24				-99.1	-13.28			65	
199 W	W. Rose Valley	7				-97.0	-12.68			66	
TR	**Total Recharge**	**0**				**-98.6**	**-13.14**				
E	Butcher Spring		0	424	Spring	-103.2	-14.22				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		0	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		0	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		0	420	Spring	-100.4	-13.68				
E	Tobe Spring		1	315	Spring	-100.0	-13.04				
E	Tobe Spring 2		1	316	Spring	-93.6	-12.09				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
ET	**ET**	**100**						**-98.6**	**-13.14**		
198	**GW Outflow (Dry)**	**200**						**-98.9**	**-13.20**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
198	**Dry Valley**										
199	**Inflow (Rose)**	**200**				**-98.9**	**-13.20**				
198 E	E. Dry Valley	1,478				-96.9	-12.99			67	
198 W	W. Dry Valley	0				-97.0	-12.68			68	
TR	**Total Recharge**	**1,500**				**-96.9**	**-12.99**				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
E	Newels Spring		1	423	Spring	-96.0	-12.48				
E	Ox Valley Spring		0	422	Spring	-100.0	-13.95				
E	Unnamed Spring #2 (Mahogany Mts)		0	421	Spring	-100.7	-13.47				
E	Water Canyon Spring (Mahogany)		0	420	Spring	-100.4	-13.68				
W	Horsethief Spring		2	314	Spring	-97.0	-12.68				
Warm Sprin	Flatnose Spring (Unnamed Spring)		1	153	Spring	-101.0	-13.40	-98.9	-13.20	***Inter-basin flow from Dry Valley***	
Spring	Delmues Spring (Unnamed Spring)		1	149	Spring	-104.0	-13.40			Local Valley spring not included in recharge calculation	
ET	**ET**	**1,000**						**-96.9**	**-12.99**		
203	**GW Outflow (Panaca)**	**700**						**-97.4**	**-13.05**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
204	**Clover Valley**										
0	**Inflow (None)**	**0**				**0.0**	**0.00**				
204 N	South of Beaver Dam	868				-92.2	-12.42			71	
204 S	North of Jack's Mtn	927				-92.0	-12.52			72	
TR	**Total Recharge**	**1,800**				**-92.1**	**-12.47**				
N	Acoma Well		1	118	Well	-95.0	-12.60				
N	Cave Spring (Clover)		2	247	Spring	-92.8	-12.37				
N	Clover Creek Valley Well 246		1	120	Well	-89.0	-12.40				
N	Ramone Mathews Well		1	115	Well	-92.0	-12.30				
S	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
S	East Settling Spring		1	248	Spring	-92.2	-12.76				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC	
S	Ella Spring		1	251	Spring	-95.8	-12.56				
S	Little Springs (Clover Mts)		2	254	Spring	-93.3	-12.81				
S	Quaking Aspen Spring		1	255	Spring	-93.6	-12.98				
S	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
S	Unnamed Spring		1	113	Spring	-86.5	-11.60				
Alluvial Well	Clover Creek Valley Well 232		1	114	Well	-84.0	-11.70				
ET	**ET**	**0**						**-92.1**	**-12.47**		
205	**GW Outflow (LMVW)**	**1,800**						**-92.1**	**-12.47**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
203	**Panaca Valley**										
202	**Inflow (Patterson)**	**9,900**				**-101.5**	**-13.52**				
198	**Inflow (Dry)**	**700**				**-97.4**	**-13.05**				
203 E	Condor Canyon	564				-92.0	-12.19			69	
203 W	Cathedral Gorge	1,337				-98.9	-13.28			70	
TR	**Total Recharge**	**1,900**				**-96.8**	**-12.95**				
W	Connor Spring		1	283	Spring	-100.6	-13.84				
W	Deadman Spring (Highland)		2	162	Spring	-95.0	-12.07				
W	Highland Spring		3	163	Spring	-99.1	-13.36				
W	Lime Spring		2	160	Spring	-98.5	-13.16				
W	Pine Spring		2	157	Spring	-99.0	-13.37				
W	Upper Conner Spring		2	156	Spring	-101.2	-13.87				
E	Kiln Spring		1	418	Spring	-91.9	-12.34				
E	Summit Spring (Mahogany Mts.)		1	419	Spring	-92.1	-12.04				
Warm	Bennett Spring	20	1	141	Spring	-103.0	-13.70	***-101.5***	***-13.52***	***Inter-basin flow from Patterson Valley***	
Warm	Caliente Hot Springs (Hotel)	0	8	129	Spring	-107.9	-14.44	***-106.2***	***-14.24***	***Inter-basin flow from Lake Valley***	
Warm	Panaca Spring	7700	13	144	Spring	-106.9	-14.14	***-106.2***	***-14.24***	***Inter-basin flow from Lake Valley***	
Surface	Meadow Valley Wash, Cal.		1	130	Surface	-97.0	-13.10				
Warm	Lester Mathews Well		1	142	Well	-103.0	-13.30				
Warm	Panaca Town Well		1	143	Well	-106.0	-14.00				
Warm	North Lee Well		1	147	Well	-101.0	-13.30				
ET	**ET**	**2,000**						**-97.1**	**-12.98**		
205	**GW Outflow (LMVW)**	**12,500**						**-101.2**	**-13.49**		
XXXXXXXX	XXXXXXXXXXXXXXXXXXXXXXXX	XXXXXXXX	XXXXXXX	XXXXXX	XXXXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	XXXXXX	
205	**Lower Meadow Valley Wash**										
203	**Inflow (Panaca)**	**12,500**				**-101.2**	**-13.49**				
204	**Inflow (Clover)**	**1,800**				**-92.1**	**-12.47**				
205 NW	Delamar Mtns.	713				-92.2	-12.28			92	
205 NE	Clover Mountains	589				-90.4	-12.25			93	
205 SW	Meadow Valley Mtns.	0				-87.4	-11.92			94	
205 SE	Mormon Mtns.	146				-88.3	-12.50			95	
TR	**Total Recharge**	**1,400**				**-91.1**	**-12.29**				
NE	Big Spring (Clover)		2	253	Spring	-93.6	-12.89				
NE	East Settling Spring		1	248	Spring	-92.2	-12.76				
NE	Ella Spring		1	251	Spring	-95.8	-12.56				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NE	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11				
NE	Sheep Spring (Clover)		2	108	Spring	-88.8	-12.03				
NE	Unnamed Spring		1	113	Spring	-86.5	-11.60				
NE	Unnamed Spring (Clover)		1	249	Spring	-88.0	-12.20				
NE	Garden Spring		1	246	Spring	-87.0	-11.54				
NW	Abandoned Spring		1	266	Spring	-94.5	-12.32				
NW	Grassy Spring		3	117	Spring	-88.7	-11.08	Evaporated so not used in recharge calculation			
NW	Buckboard Spring		1	264	Spring	-88.2	-11.71				
NW	Cottonwood Spring (Delamar)		1	265	Spring	-96.9	-12.87				
NW	Bishop Spring		3	107	Spring	-87.2	-11.72				

Region	Name	Volume Arce-ft/yr	# of Samples	Site#	Site Type	Obs. δD	Obs. δ18O	Calc. δD	Calc. δ18O	IC
NW	Boulder Spring (KSV-4)		4	98	Spring	-89.2	-12.47			
NW	Lower Chokecherry Spring		1	261	Spring	-98.4	-12.98			
NW	Lower Indian Spring		1	267	Spring	-96.0	-12.62			
NW	Narrow Canyon Spring		1	257	Spring	-92.5	-12.47			
NW	Oak Spring		1	269	Spring	-90.0	-11.87			
NW	Red Rock Spring		1	256	Spring	-95.0	-12.30			
NW	Willow Spring (KSV-1)		4	92	Spring	-88.4	-11.60			
NW	Sawmill Spring (Delamar Range)		1	259	Spring	-88.7	-12.58			
NW	Sawmill Spring West		1	258	Spring	-91.8	-12.86			
NW	Unnamed Chokecherry Spring		1	263	Spring	-98.1	-12.54			
NW	Upper Chokecherry Spring		1	262	Spring	-98.9	-12.96			
NW	Willow Spring 2 (So.of Oak Sps.summit)		1	260	Spring	-91.2	-11.69			
NW	Upper Indian Spring		1	268	Spring	-88.0	-11.46			
NW	Upper Riggs Spring WR4		5	105	Spring	-87.1	-11.95			
SW	Grapevine Spring (KSV-2)		10	93	Spring	-87.4	-11.92			
SE	Davies Spring		1	90	Spring	-89.0	-12.50			
SE	Horse Spring (Morman)		1	85	Spring	-89.0	-12.70			
SE	Hackberry Spring		1	84	Spring	-87.0	-12.30			
Warm	Kershaw-Ryan Spring #1		1	250	Spring	-95.1	-13.11	*-100.0*	*-13.36*	*Weighted Average of Infterbasin flow from Garnet and Upper Moapa Valleys*
Warm	EH-6 Weiser Wash		1	59	Well	-99.5	-13.90			
Warm	EH-8 Weiser Wash		1	57	Well	-96.5	-13.70			
Alluvial Well	Railroad Well (Farrier, NV)		1	80	Well	-97.5	-12.50			
ET	**ET**	**1,000**						**-91.1**	**-12.29**	
206	**GW Outflow (Upper Moapa)**	**0**						**-99.8**	**-13.33**	
218	**GW Outflow (California Wash)**	**12,700**						**-99.8**	**-13.33**	

APPENDIX 3. Isotopic, field parameter, and water chemistry data for all sites used in this study

Name	Y	X	Water Temp ©	DO (mg/L)	pH	dO18	dD	Ca	Mg	Na	K	Cl	HCO3	SO4	SiO2	F	Sample#	Total	REF_ID	SiteType	Site#	Date
Abandoned Spring	37.49914	-114.72889	10.2	7.7	7.8	-12.32	-94.5	81.0	20.0	50.0	2.3	35.2	357.0	41.8	27.8	--	59699	1		Spring	266	03/26/04
Abandoned Spring	**37.49914**	**-114.72889**	**10.2**	**7.7**	**7.8**	**-12.32**	**-94.5**	**81.0**	**20.0**	**50.0**	**2.3**	**35.2**	**357.0**	**41.8**	**27.8**	**--**	**59699**	**1**		**Spring**	**266**	**03/26/04**
Acoma Well	37.54861	-114.17306	17.0		7.7	-12.60	-95.0	38.0	5.3	21.0	7.0	17.0	149.0	10.0	54.0	0.3	244	1	GS91	Well	118	06/03/85
Acoma Well	**37.54861**	**-114.17306**	**17.0**		**7.7**	**-12.60**	**-95.0**	**38.0**	**5.3**	**21.0**	**7.0**	**17.0**	**149.0**	**10.0**	**54.0**	**0.3**	**244**	**1**	**GS91**	**Well**	**118**	**06/03/85**
Adaven Spring	38.13861	-115.60139	12.5	6.9	7.5	-13.95	-103.0	63.0	25.0	14.0	2.2	4.8	324.0	18.0	28.0	0.2	341	1	GS131	Spring	177	07/31/85
Adaven Spring	38.13861	-115.60139	9.9		7.1	-14.07	-107.6						358.0				340	1	IT115	Spring	177	02/03/97
Adaven Spring	**38.13861**	**-115.60139**	**11.2**	**6.9**	**7.3**	**-14.01**	**-105.3**	**63.0**	**25.0**	**14.0**	**2.2**	**4.8**	**341.0**	**18.0**	**28.0**	**0.2**		**2**		**Spring**	**177**	
Alamo City Well #7	37.36222	-115.16833	18.5		7.6	-13.46	-101.1	61.4	56.0	96.3	13.7	54.6	454.0	188.0	59.1	1.3	205	1	IT116	Well	104	08/08/95
Alamo City Well #7	**37.36222**	**-115.16833**	**18.5**		**7.6**	**-13.46**	**-101.1**	**61.4**	**56.0**	**96.3**	**13.7**	**54.6**	**454.0**	**188.0**	**59.1**	**1.3**	**205**	**1**	**IT116**	**Well**	**104**	**08/08/95**
Albert Spring	38.56833	-115.36167	14.5			-13.95	-107.0										403	1	GS182	Spring	204	07/24/85
Albert Spring	**38.56833**	**-115.36167**	**14.5**			**-13.95**	**-107.0**										**403**	**1**	**GS182**	**Spring**	**204**	**07/24/85**
APCAR	36.71099	-114.71682	--	--	--	-12.94	-98.2	62.9	27.2	95.0	11.2	62.1	257.0	176.0	31.6	--	61616	1		Spring	292	10/19/04
APCAR	**36.71099**	**-114.71682**	**--**	**--**	**--**	**-12.94**	**-98.2**	**62.9**	**27.2**	**95.0**	**11.2**	**62.1**	**257.0**	**176.0**	**31.6**	**--**	**61616**	**1**		**Spring**	**292**	**10/19/04**
Arrow Canyon	36.734208	-114.74778				-12.91	-99.4										SNWA			Well	619	2/1/2006
Arrow Canyon	**36.734208**	**-114.74778**				**-12.91**	**-99.4**										**SNWA**			**Well**	**619**	**2/1/2006**
Ash Springs	37.46361	-115.19250					-107.0										222		IT27	Spring	110	08/01/68
Ash Springs	37.46361	-115.19250					-109.0										223		IT28	Spring	110	01/01/69
Ash Springs	37.46361	-115.19250					-112.0										224		IT29	Spring	110	03/01/70
Ash Springs	37.46361	-115.19250	36.0	2.3	7.0	-14.10	-108.0	43.0	14.0	27.0	7.4	8.5		34.0	30.0	0.8	225		GS81	Spring	110	07/20/81
Ash Springs	37.463564	-115.19252				-14.03	-110.0										SNWA			Spring		5/24/2004
Ash Springs	37.46361	-115.19250	34.0	1.6	7.4	-14.20	-108.4	46.4	16.8	28.4	7.3	8.6	248.0	32.8	32.7	--	61099	1		Spring	110	07/30/04
Ash Springs	**37.46361**	**-115.19250**	**35.0**	**1.9**	**7.2**	**-14.11**	**-109.1**	**44.7**	**15.4**	**27.7**	**7.3**	**8.6**	**248.0**	**33.4**	**31.4**	**0.8**				**Spring**	**110**	
Aspen Springs South	39.21629	-115.39800	6.9	9.4	7.0	-16.02	-120.9									--	62721	1	DRI-WP-16	Spring	324	06/07/05
Aspen Springs South	**39.21629**	**-115.39800**	**6.9**	**9.4**	**7.0**	**-16.02**	**-120.9**									**--**	**62721**	**1**	**DRI-WP-16**	**Spring**	**324**	**06/07/05**
Aspen Springs North	39.22100	-115.39905	6.9	7.7	6.5	-15.84	-119.3									--	62716	1	DRI-WP-11	Spring	349	06/07/05
Aspen Springs North	**39.22100**	**-115.39905**	**6.9**	**7.7**	**6.5**	**-15.84**	**-119.3**									**--**	**62716**	**1**	**DRI-WP-11**	**Spring**	**349**	**06/07/05**
Bailey Spring (Fairview)	38.17593	-114.72829	18.9	7.0	7.8	-12.68	-98.5	86.4	21.4	29.8	2.1	48.3	331.0	26.6	32.4	--	60849	1		Spring	277	06/29/04
Bailey Spring (Fairview)	38.17593	-114.72829	10.7	6.0	7.0	-12.70	-97.9	96.2	25.8	42.4	1.7	70.3	327.0	49.7	33.1	--	62407	1	DRI-FR-5	Spring	277	05/01/05
Bailey Spring (Fairview)	**38.17593**	**-114.72829**	**14.8**	**6.5**	**7.4**	**-12.69**	**-98.2**	**91.3**	**23.6**	**36.1**	**1.9**	**59.3**	**329.0**	**38.2**	**32.8**	**#DIV/0!**				**Spring**	**277**	
Bailey Spring (Wilson Ck)	38.35295	-114.36718	17.9	6.4	7.8	-12.93	-102.0	45.0	9.4	18.5	2.1	40.6	135.0	16.1	36.7	--	60310	2		Spring	310	05/18/04
Bailey Spring (Wilson Ck)	**38.35295**	**-114.36718**	**17.9**	**6.4**	**7.8**	**-12.93**	**-102.0**	**45.0**	**9.4**	**18.5**	**2.1**	**40.6**	**135.0**	**16.1**	**36.7**	**--**	**60310**	**2**		**Spring**	**310**	**05/18/04**
Baldwin Spring	36.72035	-114.72415	31.9	2.6	7.3	-12.95	-96.3	63.8	28.1	96.3	11.6	63.8	260.0	180.0	32.0	--	58496		DRI-MV-3	Spring	291	01/12/04
Baldwin Spring	36.72035	-114.72415	32.0	3.0	7.5	-12.93	-96.8	63.7	27.6	94.7	11.1	64.1	263.0	180.0	29.2	--	60309		DRI-MV-3	Spring	291	05/18/04
Baldwin Spring	36.72035	-114.72415				-12.96	-98.6	62.8	27.4	95.0	11.2	61.4	258.0	174.0	32.1	--	61620		DRI-MV-3	Spring	291	10/19/04
Baldwin Spring	36.72035	-114.72415	31.8	2.7	7.3	-12.94	-98.1	63.1	27.4	95.7	11.2	61.7	252.0	178.0	29.6	--	62034	1	DRI-MV-3	Spring	291	02/10/05
Baldwin Spring	36.72035	-114.72415	32.0	2.8	6.8	-12.94	-97.2									--	62035		DRI-MV-3	Spring	291	06/08/05
Baldwin Spring	36.720350	-114.724150	31.8	2.64	7.32	-13.05	-98.0	63.5	27.2	96.8	10.9	61.1	253	176	29.6	2.21	64174		DRI-MV-3	Spring	291	02/16/06
Baldwin Spring	36.720350	-114.724150	30.2	5.26	7.35	-13.03	-98.2	71.1	22.1	93.4	11.2	63.4	254	180	30.4	2.18	64903		DRI-MV-3	Spring	291	06/21/06
Baldwin Spring	36.720350	-114.724150	32.30	4.75	7.29	-13.03	-97.1	64.5	28.0	83.9	9.35	61.7	259	178	29.1	2.18	65284		DRI-MV-3	Spring	291	08/23/06
Baldwin Spring	36.720350	-114.724150	31.7	4.33	7.33	-12.91	-97.9	61.8	27.4	93.5	11.2	60.0	251	175	29.5	2.21	65662		DRI-MV-3	Spring	291	10/30/06
Baldwin Spring	**36.72035**	**-114.72415**	**31.7**	**3.5**	**7.3**	**-12.97**	**-97.6**	**64.3**	**26.9**	**93.7**	**11.0**	**62.2**	**256.3**	**177.6**	**30.2**	**2.2**			DRI-MV-3	**Spring**	**291**	
Barrel Spring	38.13105	-114.05505	9.8	6.2	7.7	-13.36	-100.5	55.7	6.1	16.5	0.5	18.8	193.0	10.7	22.9	--	60316	1		Spring	317	05/21/04
Barrel Spring	**38.13105**	**-114.05505**	**9.8**	**6.2**	**7.7**	**-13.36**	**-100.5**	**55.7**	**6.1**	**16.5**	**0.5**	**18.8**	**193.0**	**10.7**	**22.9**	**--**	**60316**	**1**		**Spring**	**317**	**05/21/04**
Bennett Spring	37.78417	-114.52806	24.0		7.5	-13.70	-103.0	56.0	26.0	6.5	1.5	7.9	318.0	6.9	14.0	<.1	288		GS103	Spring	141	04/10/85
Bennett Spring	**37.78417**	**-114.52806**	**24.0**		**7.5**	**-13.70**	**-103.0**	**56.0**	**26.0**	**6.5**	**1.5**	**7.9**	**318.0**	**6.9**	**14.0**	**<.1**	**288**		**GS103**	**Spring**	**141**	**04/10/85**
Big Muddy Spring	36.72196	-114.71682					-98.0										121.2			Spring	69	3/00/70
Big Muddy Spring	36.72196	-114.71682	32.5	3.0	7.2	-12.90	-96.5	66.0	26.0	96.0	10.0	61.0		190.0	29.0	2.1	122		GS42	Spring	69	07/22/81
Big Muddy Spring	36.72196	-114.71682				-12.75	-98.0										125		jim	Spring	69	10/30/85
Big Muddy Spring	36.72196	-114.71682				-13.05	-99.0										124		GS44	Spring	69	01/07/88
Big Muddy Spring	36.72196	-114.71682	31.0	--	--	-12.84	-98.4	64.4	27.6	99.9	10.9	64.2	270.0	198.0	29.9	--	60308			Spring	69	05/18/04
Big Muddy Spring	36.72196	-114.71682				-12.89	-97.6	63.4	27.0	99.1	10.9	64.5	255.0	178.0	32.6	--	61615	2		Spring	69	10/19/04
Big Muddy Spring	**36.72196**	**-114.71682**	**31.8**	**3.0**	**7.2**	**-12.89**	**-97.9**	**64.6**	**26.9**	**98.3**	**10.6**	**63.2**	**262.5**	**188.7**	**30.5**	**2.1**				**Spring**	**69**	
Big Spring (Clover)	37.52781	-114.35258	17.2	7.4	7.3	-12.89	-94.2	27.3	4.3	9.5	2.6	7.3	111.0	3.9	48.2	--	61094	1		Spring	253	07/31/04
Big Spring (Clover)	37.52781	-114.35258	17.0	7.1	7.4	-12.89	-92.9	30.2	4.5	11.1	2.6	9.0	114.0	4.8	45.8	--	62401		DRI-CR-6	Spring	253	04/30/05
Big Spring (Clover)	**37.52781**	**-114.35258**	**17.1**	**7.2**	**7.4**	**-12.89**	**-93.6**	**28.8**	**4.4**	**10.3**	**2.6**	**8.2**	**112.5**	**4.4**	**47.0**	**#DIV/0!**				**Spring**	**253**	
Big Spring (Egan)	38.59947	-114.91624	14.0	5.4	6.8	-13.85	-106.0	34.0	5.8	13.0		4.2	156.0	7.2	50.0	0.1	408		GS187	Spring	206	08/03/85
Big Spring (Egan)	38.59947	-114.91624	13.0	5.8	6.5	-13.92	-104.2	--	--	--	--	--	--	--	--	--	--	1		Spring	206	10/14/03
Big Spring (Egan)	38.59947	-114.91624	12.9	5.24	6.1	-13.98	-106.1	34.7	5.78	12.4	2.36	3.8	152	7.1	51.7		62980		ER-4	Spring	206	07/31/05
Big Spring (Egan)	38.59947	-114.91624	12.8	5.35	6.76	-13.86	-105.8	34.1	5.83	12.6	2.38	3.9	146	7.0	52.1	0.11	65050		ER-24	Spring	441	07/13/06
Big Spring (Egan)	**38.59947**	**-114.91624**	**13.2**	**5.5**	**6.5**	**-13.90**	**-105.5**	**34.3**	**5.8**	**12.7**	**2.4**	**4.0**	**151.3**	**7.1**	**51.3**	**0.1**				**Spring**	**206**	
Big Spring (Grant)	38.37056	-115.48111	12.5		8.1	-15.20	-112.0	78.0	7.0	4.9		2.1	268.0	13.0	9.5	<.1	366		GS151	Spring	194	07/24/85
Big Spring (Grant)	**38.37056**	**-115.48111**	**12.5**		**8.1**	**-15.20**	**-112.0**	**78.0**	**7.0**	**4.9**		**2.1**	**268.0**	**13.0**	**9.5**	**<.1**	**366**		**GS151**	**Spring**	**194**	**07/24/85**
Big Spring Snake Valley	38.698920	-114.132230	17.2	5.3	7.5	-15.14	-112.2	47.8	20.3	5.5	1.5	5.1	228.0	8.5	12.6	--	61964	1		Spring	325	01/22/05
Big Spring Snake Valley	38.698920	-114.132230				-15.22	-112.2	48.3	19.5	5.3	1.5	5.5	8.5	234.0	12.7	0.05	63226	1	SU-2	Spring	325	08/13/05
Big Spring Snake Valley	38.698920	-114.132230	17.2	4.88	7.5	-15.10	-110.3	42.9	20.2	5.34	1.51	5.8	229	8.5	12.7	0.13	63569	1		Spring		8-Nov-05
Big Spring Snake Valley	38.698920	-114.132230	16.8	5.16	7.61	-15.17	-111.6	47.5	19.6	5.32	1.50	5.5	229	8.6	12.5	0.13	64238	1	SU-2	Spring	325	02/25/06

Big Spring Snake Valley	38.698920	-114.132230	17.2	5.27	7.43	-15.10	-112.6	49.0	20.3	6.18	2.61	7.3	232	9.3	12.8	0.13	64741	1	SU-2	Spring	325	05/21/06
Big Spring Snake Valley	38.698920	-114.132230	17.30	5.44	7.49	-15.15	-111.8	47.7	20.4	5.2	1.42	5.33	232	8.84	12.7	0.12	65291	1	SU-2	Spring	325	08/24/06
Big Spring Snake Valley	38.698920	-114.132230	17.0	4.83	7.44	-15.20	-111.1	49.7	20.3	5.93	1.45	6.1	232	8.5	12.9	0.13	65659	1	SU-2	Spring	325	10/29/06
Big Spring Snake Valley	38.698920	-114.132230	**17.1**	**5.1**	**7.5**	**-15.15**	**-111.7**	**47.6**	**20.1**	**5.5**	**1.6**	**5.8**	**198.6**	**40.9**	**12.7**	**0.1**		**7**		**Spring**	**325**	
Big Spring North	38.65611	-114.63306	20.5		7.6	-15.10	-112.0	49.0	19.0	5.3	2.1	6.0	240.0	12.0	21.0	0.2	416		GS193	Spring	211	04/04/85
Big Spring North	**38.65611**	**-114.63306**	**20.5**		**7.6**	**-15.10**	**-112.0**	**49.0**	**19.0**	**5.3**	**2.1**	**6.0**	**240.0**	**12.0**	**21.0**	**0.2**	**416**		**GS193**	**Spring**	**211**	**04/04/85**
Big Spring South	38.65417	-114.63306	18.5		7.5	-14.80	-111.0	45.0	18.0	5.4	1.9	5.6	200.0	12.0	18.0	0.2	415		GS192	Spring	210	04/04/85
Big Spring South	**38.65417**	**-114.63306**	**18.5**		**7.5**	**-14.80**	**-111.0**	**45.0**	**18.0**	**5.4**	**1.9**	**5.6**	**200.0**	**12.0**	**18.0**	**0.2**	**415**		**GS192**	**Spring**	**210**	**04/04/85**
Bishop Spring	37.41854	-114.64169				-11.70	-85.5										208		GS80	Spring	107	02/02/84
Bishop Spring	37.41854	-114.64169	17.5	6.3	7.0	-11.67	-88.0	68.0	24.1	17.1	0.9	13.4	332.0	14.5	54.8	--	58493	1		Spring	107	01/14/04
Bishop Spring	37.41854	-114.64169	18.4	4.6	6.9	-11.78	-88.1									--	62618		DRI-DR-6	Spring	107	05/20/05
Bishop Spring	**37.41854**	**-114.64169**	**18.0**	**5.4**	**7.0**	**-11.72**	**-87.2**	**68.0**	**24.1**	**17.1**	**0.9**	**13.4**	**332.0**	**14.5**	**54.8**	**#DIV/0!**				**Spring**	**107**	
Bitter Spring	36.28500	-114.51417	17.2	4.8	7.6	-9.90	-77.0										22		PL15	Spring	14	02/06/96
Bitter Spring	**36.28500**	**-114.51417**	**17.2**	**4.8**	**7.6**	**-9.90**	**-77.0**										**22**		**PL15**	**Spring**	**14**	**02/06/96**
Black Rock Spring	37.91204	-114.91906				-12.25	-94.0										313		GS117	Spring	158	03/22/88
Black Rock Spring	37.91204	-114.91906	12.1	8.3	7.6	-12.36	-93.6	36.7	8.0	16.1	4.6	13.9	146.0	15.9	63.6	--	59687	1		Spring	158	03/23/04
Black Rock Spring	37.91204	-114.91906	**12.1**	**8.3**	**7.6**	**-12.31**	**-93.8**	**36.7**	**8.0**	**16.1**	**4.6**	**13.9**	**146.0**	**15.9**	**63.6**	**#DIV/0!**				**Spring**	**158**	
Blue Point Spring	36.39000	-114.43306				-12.40	-93.0										49		PL8	Spring	26	06/24/85
Blue Point Spring	36.39000	-114.43306				-12.35	-92.5										47.5		USGS	Spring	26	07/01/85
Blue Point Spring	36.39000	-114.43306	30.0		7.8	-12.50	-93.5	470.0	160.0	330.0	23.0	400.0	160.0	1900.0	16.0	1.5	48		GS15	Spring	26	07/01/85
Blue Point Spring	36.39000	-114.43306	29.6	2.7	7.1	-12.30	-91.0										47		PL8	Spring	26	02/08/96
Blue Point Springs	36.39000	-114.43306				-12.47	-93.0										USGS			spring		6/5/2003
Blue Point Spring	36.39000	-114.43306	**29.8**	**2.7**	**7.4**	**-12.40**	**-92.6**	**470.0**	**160.0**	**330.0**	**23.0**	**400.0**	**160.0**	**1900.0**	**16.0**	**1.5**				**Spring**	**26**	
Blue Rock Spring	38.15344	-114.35401	--	--	--	-12.68	-93.4	--	--	--	--	--	--	--	--	--	--	1		Spring	311	04/28/04
Blue Rock Spring	38.15344	**-114.35401**	**--**	**--**	**--**	**-12.68**	**-93.4**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**311**	**04/28/04**
Boulder Spring (KSV-4)	37.31436	-114.67261				-12.00	-87.5										196		Kirk1027	Spring	98	--
Boulder Spring (KSV-4)	37.31436	-114.67261	16.8		7.9	-12.60	-87.0	21.0	4.9	12.0	2.3	7.8	100.0	6.0	41.0	1.7	198		GS74	Spring	98	02/02/84
Boulder Spring (KSV-4)	37.31436	-114.67261	5.0	8.8	7.4	-12.60	-91.0	19.4	4.5	11.4	0.3	6.6	88.9	5.7	42.8	--	58491	1		Spring	98	01/13/04
Boulder Spring (KSV-4)	37.31436	-114.67261	13.6	7.7	7.6	-12.66	-91.3	21.2	3.8	55.2	4.1	25.0	138.0	34.8	65.3	--	62394		DRI-DR-3	Spring	98	04/27/05
Boulder Spring (KSV-4)	37.31436	-114.67261	**11.8**	**8.3**	**7.6**	**-12.47**	**-89.2**	**20.5**	**4.4**	**26.2**	**2.2**	**13.1**	**109.0**	**15.5**	**49.7**	**1.7**				**Spring**	**98**	
Big Tom Plain Spring	39.08701	-115.37737	7.4	6.1	6.7	-15.92	-121.1									--	62713		DRI-WP-8	Spring	326	06/06/05
Big Tom Plain Spring	**39.08701**	**-115.37737**	**7.4**	**6.1**	**6.7**	**-15.92**	**-121.1**									**--**	**62713**		**DRI-WP-8**	**Spring**	**326**	**06/06/05**
Bradshaw Well	37.34917	-114.54389	14.8		7.3	-11.40	-88.5	85.0	28.0	120.0	11.0	52.0	550.0	76.0	63.0	2.3	202		GS76	Well	102	02/01/84
Bradshaw Well	**37.34917**	**-114.54389**	**14.8**		**7.3**	**-11.40**	**-88.5**	**85.0**	**28.0**	**120.0**	**11.0**	**52.0**	**550.0**	**76.0**	**63.0**	**2.3**	**202**		**GS76**	**Well**	**102**	**02/01/84**
Brady Spring	38.32746	-115.47509	10.3	--	--	-15.38	-108.5	82.8	8.5	2.9	1.0	0.8	292.0	2.9	13.8	--	57754	1		Spring	282	10/28/03
Brady Spring (duplicate sample)	38.32746	-115.47509	--	--	--	-15.38	-110.4	--	--	--	--	--	--	--	--	--	57754	1		Spring	282	10/28/03
Brady Spring	38.32746	-115.47509	**10.3**	**#DIV/0!**	**#DIV/0!**	**-15.38**	**-109.5**	**82.8**	**8.5**	**2.9**	**1.0**	**0.8**	**292.0**	**2.9**	**13.8**	**#DIV/0!**		**2**		**Spring**	**282**	
Buckboard Spring	37.58886	-114.63111	14.7	7.1	7.7	-11.71	-88.2	45.1	8.3	17.3	2.1	13.9	182.0	10.6	45.5	--	59697	1		Spring	264	03/26/04
Buckboard Spring	**37.58886**	**-114.63111**	**14.7**	**7.1**	**7.7**	**-11.71**	**-88.2**	**45.1**	**8.3**	**17.3**	**2.1**	**13.9**	**182.0**	**10.6**	**45.5**	**--**	**59697**	**1**		**Spring**	**264**	**03/26/04**
Burnt Canyon Spring (Unnamed Spring in Burnt Canyon)	38.28944	-114.20889	11.0		7.6	-12.30	-93.0	35.0	7.7	8.1	0.5	5.2	140.0	8.2	38.0	0.1	356		GS140	Spring	187	06/05/85
Burnt Canyon Spring (Unnamed Spring in Burnt Canyon)	**38.28944**	**-114.20889**	**11.0**		**7.6**	**-12.30**	**-93.0**	**35.0**	**7.7**	**8.1**	**0.5**	**5.2**	**140.0**	**8.2**	**38.0**	**0.1**	**356**		**GS140**	**Spring**	**187**	**06/05/85**
Butcher Spring	38.030347	-114.015314	10.1	7.62	7.1	-14.22	-103.2	25.5	5.44	10.8	1.01	18.1	78.3	10.9	26.9	0.20	64910		MG-7	Spring	424	06/23/06
Butcher Spring	**38.030347**	**-114.015314**	**10.1**	**7.62**	**7.1**	**-14.22**	**-103.2**	**25.5**	**5.44**	**10.8**	**1.01**	**18.1**	**78.3**	**10.9**	**26.9**	**0.20**	**64910**	**1**	**MG-7**	**Spring**	**424**	**06/23/06**
Butte Spring	39.75816	-115.24246	13.7	7.4	6.9	-15.79	-120.4									--	62619		DRI-BT-1	Spring	327	05/24/05
Butte Spring	**39.75816**	**-115.24246**	**13.7**	**7.4**	**6.9**	**-15.79**	**-120.4**									**--**	**62619**		**DRI-BT-1**	**Spring**	**327**	**05/24/05**
Butterfield Spring	38.43972	-115.01083	16.5	6.1	7.3	-14.20	-105.0	47.0	22.0	6.0	2.5	4.7	260.0	8.0	23.0	0.1	384		GS163	Spring	202	07/19/81
Butterfield Spring	**38.43972**	**-115.01083**	**16.5**	**6.1**	**7.3**	**-14.20**	**-105.0**	**47.0**	**22.0**	**6.0**	**2.5**	**4.7**	**260.0**	**8.0**	**23.0**	**0.1**	**384**		**GS163**	**Spring**	**202**	**07/19/81**
Caliente City Well	37.61583	-114.51333	14.3			-12.40	-89.0										263		GS95	Well	124	01/31/84
Caliente City Well	**37.61583**	**-114.51333**	**14.3**			**-12.40**	**-89.0**										**263**		**GS95**	**Well**	**124**	**01/31/84**
Cabin Spring	39.75790	-115.27245	11.0	8.7	7.0	-15.89	-124.4									--	62708		DRI-BT-7	Spring	328	06/05/05
Cabin Spring	**39.75790**	**-115.27245**	**11.0**	**8.7**	**7.0**	**-15.89**	**-124.4**									**--**	**62708**		**DRI-BT-7**	**Spring**	**328**	**06/05/05**
Cain Springs	39.542581	-114.225882	14.9	4.5	6.92	-10.85	-98.4	191	53.6	117	0.85	352	322	162	34.7	0.34	63282			Spring	400	26-Aug-05
Cain Springs	**39.542581**	**-114.225882**	**14.9**	**4.5**	**6.92**	**-10.85**	**-98.4**	**191**	**53.6**	**117**	**0.85**	**352**	**322**	**162**	**34.7**	**0.34**	**63282**			**Spring**	**400**	**26-Aug-05**
Caliente Hot Springs (Hotel)	37.62111	-114.51042	45.0		7.8	-14.50	-109.0	37.0	7.3	49.0	19.0	13.0	222.0	34.0	130.0	1.4	270		GS99	Spring	129	04/10/85
Caliente Hot Springs (Hotel)	37.62111	-114.51042	40.7	4.4	8.2	-14.52	-106.4	35.0	7.3	50.1	18.7	14.5	213.0	37.2	128.0	--	61621			Spring	129	10/20/04
Caliente Hot Springs (Hotel)	37.62111	-114.51042	40.4	4.1	8.1	-14.29	-109.3	35.6	7.2	51.8	19.0	14.5	208.0	44.8	119.0	--	61970	2		Spring	129	01/24/05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	41.0	4.0	7.5	-14.43	-107.0									--	62620		DRI-MW-2	Spring	129	05/19/05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	40.1	2.8	7.6	-14.47	-109.0										63230		DRI-MW-2	Spring	129	08/16/05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	41.5	3.12	7.71	-14.47	-107.2	35.0	7.36	51.2	18.8	13.7	214	39.1	122	1.47	63572			Spring	129	9-Nov-05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	39.7	4.5	7.91	-14.42	-107.7	38.4	7.61	52.2	18.9	17.3	215	43.6	119	1.44	64170		MW-2	Spring	129	02/17/06
Caliente Hot Springs (Hotel)	37.62111	-114.51042	39.9	3.3	7.98	-14.38	-107.3	39.0	7.93	53.6	21.1	18.5	224	46.5	118	1.43	64744		MW-2	Spring	129	05/22/06
Caliente Hot Springs (Hotel)	**37.62111**	**-114.51042**	**41.0**	**3.7**	**7.8**	**-14.44**	**-107.9**	**36.7**	**7.5**	**51.3**	**19.3**	**15.3**	**216.0**	**40.9**	**122.7**	**1.4**		**8.0**		**Spring**	**129**	
Calpine Test Well 1a	36.54611	-114.80194	30.5			-13.50	-99.0										999		ECP-1a	Well	43	04/07/00
Calpine Test Well 1a	**36.54611**	**-114.80194**	**30.5**			**-13.50**	**-99.0**										**999**		**ECP-1a**	**Well**	**43**	**04/07/00**

Camp Creek	38.24361	-114.25222	9.0		7.9	-14.00	-102.0									349		E3	Surface	184	04/09/85
Camp Creek	**38.24361**	**-114.25222**	**9.0**		**7.9**	**-14.00**	**-102.0**									**349**		**E3**	**Surface**	**184**	**04/09/85**
Carpenter Spring	38.05000	-115.61167	16.0			-11.85	-95.0									332		GS126	Spring	171	07/31/85
Carpenter Spring	**38.05000**	**-115.61167**	**16.0**			**-11.85**	**-95.0**									**332**		**GS126**	**Spring**	**171**	**07/31/85**
Cave Spring	38.64111	-114.79583	12.0	8.4	7.4	-13.85	-100.0	16.0	2.2	3.1		1.0	62.0	4.5	14.0	<.1	414		GS191	Spring	209	08/02/85
Cave Spring	38.64111	-114.79583	11.7	7.55	7.2	-14.20	-102.2	15.4	2.04	2.57	0.68	1.0	55.4	2.6	16.0	0.05	65057		SC-8	Spring	448	07/14/06
Cave Spring	**38.64111**	**-114.79583**	**11.9**	**8.0**	**7.3**	**-14.03**	**-101.1**	**15.7**	**2.1**	**2.8**	**0.7**	**1.0**	**58.7**	**3.6**	**15.0**	**0.1**	**414**		**GS191**	**Spring**	**209**	**08/02/85**
Cave Spring (Clover)	37.52979	-114.24092	18.7	4.7	7.0	-12.21	-90.8	47.8	9.1	26.4	8.4	20.0	219.0	10.8	57.4	--	61101			Spring	247	07/31/04
Cave Spring (Clover)	37.52979	-114.24092	18.7	4.7	7.0	-12.53	-94.7	--	--	--	--	--	--	--	--	--	61101B	2		Spring	247	07/31/04
Cave Spring (Clover)	37.52979	-114.24092	**18.7**	**4.7**	**7.0**	**-12.37**	**-92.8**	**47.8**	**9.1**	**26.4**	**8.4**	**20.0**	**219.0**	**10.8**	**57.4**	**#DIV/0!**				**Spring**	**247**	
Cave Valley MX	38.468592	-114.869444				-13.94	-105.0										USGS		602	Deep Well	620	7/10/2003
Cave Valley MX	**38.468592**	**-114.869444**				**-13.94**	**-105.0**										**USGS**		**602**	**Deep Well**	**620**	**7/10/2003**
Cedar Spring	39.77309	-114.211402	14.4	2.83	7.2	-15.52	-121.5	104	50.6	16.5	1.60	42.9	208	262	14.6	0.49	63275	1		Spring	393	23-Aug-05
Cedar Spring	**39.77309**	**-114.211402**	**14.4**	**2.83**	**7.2**	**-15.52**	**-121.5**	**104**	**50.6**	**16.5**	**1.60**	**42.9**	**208**	**262**	**14.6**	**0.49**	**63275**	**1**		**Spring**	**393**	**23-Aug-05**
Cedar Cabin Spring	38.79689	-114.22339	9.6	9.0	7.6	-14.10	-106.0	62.3	20.2	5.5	1.0	5.0	5.7	272.0	12.0	<.04	62913		SN-4	Spring	380	07/13/05
Cedar Cabin Spring	**38.79689**	**-114.22339**	**9.6**	**9.0**	**7.6**	**-14.10**	**-106.0**	**62.3**	**20.2**	**5.5**	**1.0**	**5.0**	**5.7**	**272.0**	**12.0**	**<.04**	**62913**		**SN-4**	**Spring**	**380**	
The Cedars	38.93537	-114.41800	18.7	8.0	8.0	-15.02	-110.3	20.0	1.7	5.9	0.9	2.0	74.9	3.2	20.7	--	61965	1		Spring	329	01/22/05
The Cedars	38.93537	-114.41800	18.9	8.4	8.0	-15.03	-108.1									--	62621		DRI-SV-1	Spring	329	05/20/05
The Cedars	38.93537	-114.41800				-15.00	-108.6	19.8	1.7	5.9	0.9	2.0	3.3	74.2	20.6	0.34	63225		SV-1	Spring	329	08/12/05
The Cedars	38.93537	-114.41800	18.3	7.3	7.95	-15.00	-108.2	20.1	1.69	5.71	0.82	2.0	73.1	3.3	20.7	0.19	63570			Spring	329	8-Nov-05
The Cedars	38.93537	-114.41800	18.2	7.72	8.1	-15.02	-108.4	20.1	1.59	5.60	0.84	2.1	74.8	3.4	20.5	0.19	64240		SV-1	Spring	329	02/26/06
The Cedars	38.93537	-114.41800	18.8	8.45	7.9	-15.03	-108.3	20.1	1.67	5.85	1.84	2.1	74.1	3.5	20.8	0.19	64742		SV-1	Spring	329	05/21/06
The Cedars	38.93537	-114.41800	19.9	7.56	8	-14.97	-109.4	20.1	1.78	5.43	0.75	2.1	72.1	3.6	20.8	0.18	65369		SV-1	Spring	329	08/30/06
The Cedars	38.93537	-114.41800	18.4	8.25	7.83	-15.05	-109.9	20.0	1.68	5.67	0.82	2.0	72.9	3.4	20.6	0.20	65660		SV-1	Spring	329	10/29/06
The Cedars	**38.93537**	**-114.41800**	**18.7**	**8.0**	**8.0**	**-15.02**	**-108.9**	**20.0**	**1.7**	**5.7**	**1.0**	**2.0**	**63.6**	**13.5**	**20.7**	**0.2**				**Spring**	**329**	
CE-DT-4	36.79556	-114.89222	34.0	3.5	7.4	-13.00	-102.5	46.0	19.0	84.0	11.0	35.0	294.0	110.0	33.0	1.9	138		GS52	Well	78	12/23/80
CE-DT-4	**36.79556**	**-114.89222**	**34.0**	**3.5**	**7.4**	**-13.00**	**-102.5**	**46.0**	**19.0**	**84.0**	**11.0**	**35.0**	**294.0**	**110.0**	**33.0**	**1.9**	**138**	**1**	**GS52**	**Well**	**78**	**12/23/80**
CE-DT-6 Well	36.76778	-114.78694				-13.10	-99.0										130.2	1	DRI	Well	72	09/28/86
CE-DT-6 Well	36.76778	-114.78694	33.5	3.7	7.2	-12.95	-97.0	58.0	25.0	88.0	11.0	53.0	272.0	160.0	30.0	2.1	130	1	GS47	Well	72	09/28/86
CE-DT-6 Well	36.76778	-114.78694	**33.5**	**3.7**	**7.2**	**-13.03**	**-98.0**	**58.0**	**25.0**	**88.0**	**11.0**	**53.0**	**272.0**	**160.0**	**30.0**	**2.1**		**1**		**Well**	**72**	
CE-VF-2 Well	36.87500	-114.94556				-12.95	-101.0										155	1	USGS	Well	81	02/05/86
CE-VF-2 Well	36.87500	-114.94556	34.0	2.9	7.4	-13.10	-101.0	47.0	21.0	81.0	11.0	34.0	303.0	90.0	34.0	1.7	156	1	USGS	Well	81	01/06/88
CE-VF-2 Well	36.87500	-114.94556	**34.0**	**2.9**	**7.4**	**-13.10**	**-101.0**	**47.0**	**21.0**	**81.0**	**11.0**	**34.0**	**303.0**	**90.0**	**34.0**	**1.7**		**2.0**		**Well**	**81**	
Chicken Spring	39.23885	-115.38886	8.3	5.7	6.6	-16.17	-122.0									--	62715		DRI-WP-10	Spring	330	06/07/05
Chicken Spring	**39.23885**	**-115.38886**	**8.3**	**5.7**	**6.6**	**-16.17**	**-122.0**									**--**	**62715**	**1**	**DRI-WP-10**	**Spring**	**330**	**06/07/05**
Chimney Rock Spring	38.83528	-114.88417	13.0	1.4	6.8	-14.30	-109.0	56.0	6.8	12.0		5.4	207.0	21.0	56.0	0.2	425	1	GS205	Spring	219	08/01/85
Chimney Rock Spring	38.83528	-114.88417	12.8	0.88	6.73	-14.74	-112.0	39.3	5.51	14.0	8.38	3.3	171	10.7	61.1	0.17	65052	1	ER-26	Spring	443	07/13/06
Chimney Rock Spring	**38.83528**	**-114.88417**	**12.9**	**1.1**	**6.8**	**-14.52**	**-110.5**	**47.7**	**6.2**	**13.0**	**8.4**	**4.4**	**189.0**	**15.9**	**58.6**	**0.2**	**425**	**2**	**GS205**	**Spring**	**219**	**08/01/85**
Circle Wash Spring	39.12170	-115.36929	7.6	7.1	6.2	-15.30	-114.5									--	62710		DRI-WP-5	Spring	331	06/06/05
Circle Wash Spring	**39.12170**	**-115.36929**	**7.6**	**7.1**	**6.2**	**-15.30**	**-114.5**									**--**	**62710**	**1**	**DRI-WP-5**	**Spring**	**331**	**06/06/05**
Clover Creek Valley Well 232	37.50500	-114.27600	21.5		7.8	-11.70	-84.0	60.0	6.0	8.0	3.0	26.0	180.0	13.0		0.4	232		E29	Well	114	07/18/75
Clover Creek Valley Well 232	**37.50500**	**-114.27600**	**21.5**		**7.8**	**-11.70**	**-84.0**	**60.0**	**6.0**	**8.0**	**3.0**	**26.0**	**180.0**	**13.0**		**0.4**	**232**	**1**	**E29**	**Well**	**114**	**07/18/75**
Clover Creek Valley Well 246	37.58470	-114.25980	26.0		7.8	-12.40	-89.0	41.0	6.0	10.0	5.0	17.0	166.0	4.0			246		E28	Well	120	07/18/75
Clover Creek Valley Well 246	**37.58470**	**-114.25980**	**26.0**		**7.8**	**-12.40**	**-89.0**	**41.0**	**6.0**	**10.0**	**5.0**	**17.0**	**166.0**	**4.0**			**246**		**E28**	**Well**	**120**	**07/18/75**
Cold Spring	37.71370	-115.41016	--	--	--	-12.98	-98.9	49.7	12.1	22.8	1.5	19.4	208.0	22.6	50.7	--	60841	1		Spring	288	06/25/04
Cold Spring	**37.71370**	**-115.41016**	**--**	**--**	**--**	**-12.98**	**-98.9**	**49.7**	**12.1**	**22.8**	**1.5**	**19.4**	**208.0**	**22.6**	**50.7**	**--**	**60841**	**1**		**Spring**	**288**	**06/25/04**
Cold Spring, Preston	38.91800	-115.06680	22.0	3.0	7.2	-15.80	-121.0	39.0	19.0	12.0	3.1	13.0		39.0	20.0	0.3	446		GS221	Spring	230	07/16/81
Cold Spring, Preston	38.91800	-115.06680	21.5	3.0	7.8	-15.80	-126.0	43.0	20.0	13.0	2.9	14.0	190.0	37.0	20.0	0.4	447		GS222	Spring	230	06/16/83
Cold Spring, Preston	**38.91800**	**-115.06680**	**21.8**	**3.0**	**7.5**	**-15.80**	**-123.5**	**41.0**	**19.5**	**12.5**	**3.0**	**13.5**	**190.0**	**38.0**	**20.0**	**0.4**				**Spring**	**230**	
Connor Spring	37.90165	-114.56023	8.4	7.7	7.7	-13.84	-100.6	72.3	25.8	1.5	0.6	2.0	348.0	3.8	8.7	--	60838	1		Spring	283	06/24/04
Connor Spring	**37.90165**	**-114.56023**	**8.4**	**7.7**	**7.7**	**-13.84**	**-100.6**	**72.3**	**25.8**	**1.5**	**0.6**	**2.0**	**348.0**	**3.8**	**8.7**	**--**	**60838**	**1**		**Spring**	**283**	**06/24/04**
Corn Creek Spring South	36.43890	-115.35775	21.4	4.0	7.4	-12.88	-95.0	51.0	48.2	9.8	3.0	9.1	401.0	25.1	28.7	--	58503	1		Spring	307	01/17/04
Corn Creek Spring South	36.43890	-115.35775	21.1	3.3	7.3	-12.89	-95.0	47.4	33.7	6.4	2.1	6.9	288.0	18.5	19.5	--	60852	1		Spring	307	06/30/04
Corn Creek Spring South	36.43890	-115.35775	**21.1**	**3.3**	**7.3**	**-12.89**	**-95.0**	**47.4**	**33.7**	**6.4**	**2.1**	**6.9**	**288.0**	**18.5**	**19.5**	**#DIV/0!**		**2**		**Spring**	**307**	
Corral Spring (Unnamed Spring)	36.37056	-114.46000	17.0	6.2	7.3	-12.10	-91.5										28		PL13	Spring	19	02/07/96
Corral Spring (Unnamed Spring)	**36.37056**	**-114.46000**	**17.0**	**6.2**	**7.3**	**-12.10**	**-91.5**										**28**		**PL13**	**Spring**	**19**	**02/07/96**
Cottonwood Spring (Fairview)	38.31204	-114.63476	13.1	4.6	--	-13.40	-102.2	33.8	4.9	17.8	0.8	6.1	161.0	4.7	38.0	--	60848	1		Spring	274	06/29/04
Cottonwood Spring (Fairview)	**38.31204**	**-114.63476**	**13.1**	**4.6**	**--**	**-13.40**	**-102.2**	**33.8**	**4.9**	**17.8**	**0.8**	**6.1**	**161.0**	**4.7**	**38.0**	**--**	**60848**	**1**		**Spring**	**274**	**06/29/04**
Cottonwood Spring (Black Mtns.)	36.20333	-114.64361	12.6	6.5	7.8	-10.80	-80.0	524.0	220.0	209.0	10.7	63.6	205.0	2410.0	17.4		13		PL17	Spring	8	02/06/96
Cottonwood Spring (Black Mtns.)	**36.20333**	**-114.64361**	**12.6**	**6.5**	**7.8**	**-10.80**	**-80.0**	**524.0**	**220.0**	**209.0**	**10.7**	**63.6**	**205.0**	**2410.0**	**17.4**		**13**		**PL17**	**Spring**	**8**	**02/06/96**
Cottonwood Spring (Delamar)	37.53418	-114.74636	15.5	2.3	7.1	-12.87	-96.9	80.0	9.3	29.5	0.7	17.3	311.0	18.7	48.7	--	59698	1		Spring	265	03/26/04
Cottonwood Spring (Delamar)	**37.53418**	**-114.74636**	**15.5**	**2.3**	**7.1**	**-12.87**	**-96.9**	**80.0**	**9.3**	**29.5**	**0.7**	**17.3**	**311.0**	**18.7**	**48.7**	**--**	**59698**	**1**		**Spring**	**265**	**03/26/04**

Cow Camp Spring	36.58361	-115.30722	14.5		7.6	-12.60	-90.5	48.0	31.0	21.0	0.7	28.0	290.0	23.0	16.0	0.2	75		GS19	Spring	47	10/28/81
Cow Camp Spring	36.58361	-115.30722	10.0	5.9	7.6	-12.60	-93.0	50.0	35.0	25.0	0.6	29.0		29.0	15.0	0.2	77		GS21	Spring	47	05/10/83
Cow Camp Spring	36.58361	-115.30722	16.8	5.1	7.3	-12.46	-92.0	48.9	35.6	26.9	0.6	23.5	312.0	24.6	17.6	--	61105	1		Spring	47	07/27/04
Cow Camp Spring	36.58361	-115.30722	10.1	8.4	7.0	-12.47	-91.9	52.0	38.0	38.9	0.3	39.9	298.0	48.6	15.1	--	62399		DRI-SR-4	Spring	47	04/28/05
Cow Camp Spring	36.58361	-115.30722	**12.9**	**6.5**	**7.4**	**-12.53**	**-91.9**	**49.7**	**34.9**	**28.0**	**0.5**	**30.1**	**300.0**	**31.3**	**15.9**	**0.2**				**Spring**	**47**	
Coyote Spring	38.03186	-114.86219	13.3	4.7	6.8	-12.26	-95.2	75.1	11.4	55.5	10.7	31.7	246.0	105.0	82.7	--	62409		DRI-DL-1	Spring	169	05/01/05
Coyote Spring	38.03186	-114.86219				-12.80	-95.0										330		Kirk1017	Spring	169	--
Coyote Spring	38.03186	-114.86219	**13.3**	**4.7**	**6.8**	**-12.53**	**-95.1**	**75.1**	**11.4**	**55.5**	**10.7**	**31.7**	**246.0**	**105.0**	**82.7**	**#DIV/0!**				**Spring**	**169**	
Crystal Springs	37.53144	-115.23364					-109.0												Win	Spring	116	08/01/68
Crystal Springs	37.53144	-115.23364					-110.0												Win	Spring	116	01/01/69
Crystal Springs	37.53144	-115.23364					-109.0												Win	Spring	116	03/01/70
Crystal Springs	37.53144	-115.23364	27.5	1.8	7.3	-14.30	-109.0	43.0	21.0	22.0	5.0	8.9		34.0	25.0	0.3	235		GS87	Spring	116	07/20/81
Crystal Springs	37.53144	-115.23364	26.5		7.4	-14.38	-108.4	44.0	22.0	24.0	5.4	8.6	248.0	32.0	24.0	0.3	238		GS90	Spring	116	08/16/94
Crystal Springs	37.53144	-115.23364	28.0		7.7	-14.39	-106.9	44.2	22.6	23.8	4.8	9.6	255.0	34.7	24.7	0.4	239		IT120	Spring	116	08/07/95
Crystal Springs	37.531618	-115.233635				-14.32	-108.0										USGS			Spring		6/3/2003
Crystal Springs	37.53144	-115.23364	27.3	5.1	7.3	-14.36	-109.2	43.1	22.2	23.6	5.3	8.7	255.0	32.3	26.4	--	61106			Spring	116	07/30/04
Crystal Springs	37.53144	-115.23364	27.3	1.3	7.6	-14.41	-109.0	45.3	22.4	24.2	5.3	9.1	240.0	33.6	26.6	--	61618			Spring	116	10/20/04
Crystal Springs	37.53144	-115.23364	27.2	1.3	7.5	-14.35	-109.4	45.6	22.0	24.1	5.2	8.8	247.0	33.2	25.2	--	61971			Spring	116	01/24/05
Crystal Springs	37.53144	-115.23364	27.1	1.3	7.3	-14.44	-107.3									--	62622		DRI-PV-2	Spring	116	05/18/05
Crystal Springs	37.53144	-115.23364	27.0	1.3	6.9	-14.46	-109.3										63229		DRI-PV-2	Spring	116	08/14/05
Crystal Spring	37.53144	-115.23364	27.1	1.28	7.38	-14.42	-110.1	45.7	22.2	23.8	5.10	9.3	248	33.1	25	0.33	63574			Spring	116	9-Nov-05
Crystal Spring	37.531810	-115.233830	27.1	1.43	7.43	-14.47	-108.5	45.1	22.1	23.6	5.13	9.3	245	33.9	24.7	0.33	65655		PV-2	Spring	116	10/28/06
Crystal Springs	37.531810	-115.233830	27.1	1.26	7.44	-14.53	-108.8	46.3	22.5	24.2	5.35	9.5	247	33.8	24.7	0.35	64168		PV-2	Spring	116	02/17/06
Crystal Springs	37.531810	-115.233830	27.2	1.16	7.51	-14.47	-109.5	45.5	21.9	24.0	5.72	9.5	247	35.1	25.4	0.35	64746		PV-2	Spring	116	05/22/06
Crystal Springs	37.531810	-115.233830	27.10	1.32	7.42	-14.49	-108.8	45.9	22.6	21.2	4.36	9.07	239	34.8	25.0	0.33	65290		PV-2	Spring	116	08/23/06
Crystal Springs	37.53144	-115.23364	**27.2**	**1.7**	**7.4**	**-14.41**	**-108.8**	**44.9**	**22.1**	**23.5**	**5.1**	**9.1**	**247.1**	**33.7**	**25.2**	**0.3**				**Spring**	**116**	
CSV-2 Well	36.78056	-114.72222	27.0	4.0	7.4	-12.85	-98.0	60.0	27.0	100.0	10.0	61.0	276.0	160.0	30.0	2.3	135		GS51	Well	76	01/26/86
CSV-2 Well	36.78056	-114.72222				-12.99	-97.7										USGS			Well		7/8/2003
CSV-2 Well	**36.78056**	**-114.72222**	**27.0**	**4.0**	**7.4**	**-12.92**	**-97.9**	**60.0**	**27.0**	**100.0**	**10.0**	**61.0**	**276.0**	**160.0**	**30.0**	**2.3**	**135**		**GS51**	**Well**	**76**	**01/26/86**
CSV-3 Well	36.69083	-114.92500	41.0		7.4	-10.35	-75.0	51.0	25.0	38.0	10.0	26.0	239.0	54.0	24.0	1.2	104		GS38	Well	60	10/07/87
CSV-3 Well	**36.69083**	**-114.92500**	**41.0**		**7.4**	**-10.35**	**-75.0**	**51.0**	**25.0**	**38.0**	**10.0**	**26.0**	**239.0**	**54.0**	**24.0**	**1.2**	**104**		**GS38**	**Well**	**60**	**10/07/87**
Davies Spring	36.96556	-114.50194	14.3			-12.50	-89.0										177		GS64	Spring	90	02/06/84
Davies Spring	**36.96556**	**-114.50194**	**14.3**			**-12.50**	**-89.0**										**177**		**GS64**	**Spring**	**90**	**02/06/84**
Deadman Spring (Highland)	37.91861	-114.54139	9.5		7.1	-13.30	-99.0	98.0	41.0	5.0	0.9	4.2	506.0	8.3	19.0	0.1	319		GS119	Spring	162	04/07/85
Deadman Spring (Highland)	37.91861	-114.54139	27.9	4.9	9.7	-10.83	-90.9	12.2	40.1	4.1	0.4	2.5	143.0	5.4	2.1	--	60837	1		Spring	162	06/24/04
Deadman Spring (Highland)	37.91861	-114.54139	**18.7**	**4.9**	**8.4**	**-12.07**	**-95.0**	**55.1**	**40.6**	**4.6**	**0.7**	**3.4**	**324.5**	**6.9**	**10.6**	**0.1**		**2**		**Spring**	**162**	
Decathon Spring	38.80738	-114.27884	7.6	7.1	6.9	-14.60	-107.0	111.0	7.6	2.9	0.5	3.4	11.4	325.0	11.3	0.11	62914		SN-5	Spring	381	07/14/05
Decathon Spring	**38.80738**	**-114.27884**	**7.6**	**7.1**	**6.9**	**-14.60**	**-107.0**	**111.0**	**7.6**	**2.9**	**0.5**	**3.4**	**11.4**	**325.0**	**11.3**	**0.11**	**62914**		**SN-5**	**Spring**	**381**	**07/14/05**
Deer Spring (White Pine)	38.99498	-115.39136	--	--	--	-15.87	-118.9	--	--	--	--	--	--	--	--	--	JThomas-032304-4	1	WP-4	Spring	322	10/12/03
Deer Spring (White Pine)	38.99498	-115.39136	9.4	6.3	6.9	-15.87	-119.6									--	62822		WP-4	Spring	322	06/28/05
Deer Spring (White Pine)	38.99498	-115.39136	**9.4**	**6.3**	**6.9**	**-15.87**	**-119.3**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**				**Spring**	**322**	
Deer Spring (Butte)	39.48683	-115.27559	12.3	6.4	6.3	-14.74	-114.1									--	62704		DRI-BT-6	Spring	332	06/04/05
Deer Spring (Butte)	39.48683	-115.27559	**12.30**	**6.35**	**6.30**	**-14.74**	**-114.1**									**--**	**62704.00**		**DRI-BT-6**	**Spring**	**332.00**	
Delmues Spring (Unnamed Spring)	37.86000	-114.32222	18.0		7.7	-13.40	-104.0	47.0	6.7	30.0	6.3	24.0	180.0	18.0	64.0	0.6	302		GS111	Spring	149	04/08/85
Delmues Spring (Unnamed Spring)	**37.86000**	**-114.32222**	**18.0**		**7.7**	**-13.40**	**-104.0**	**47.0**	**6.7**	**30.0**	**6.3**	**24.0**	**180.0**	**18.0**	**64.0**	**0.6**	**302**		**GS111**	**Spring**	**149**	
Desert Valley (Dry Lake) Well #1	36.95306	-115.19750	19.0	2.8	8.0	-13.10	-98.0	22.0	27.0	35.0	5.7	8.9	413.0	48.0	49.0	0.6	171		GS61	Well	87	03/18/87
Desert Valley (Dry Lake) Well #1	**36.95306**	**-115.19750**	**19.0**	**2.8**	**8.0**	**-13.10**	**-98.0**	**22.0**	**27.0**	**35.0**	**5.7**	**8.9**	**413.0**	**48.0**	**49.0**	**0.6**	**171**		**GS61**	**Well**	**87**	
Dipping Tank Spring	39.775222	-114.475117	12	7.77	6.83	-15.74	-119.8	47.5	8.37	16.2	2.01	18	167	14.6	30.7	0.10	63280	1		Spring	398	25-Aug-05
Dipping Tank Spring	**39.775222**	**-114.475117**	**12**	**7.77**	**6.83**	**-15.74**	**-119.8**	**47.5**	**8.37**	**16.2**	**2.01**	**18**	**167**	**14.6**	**30.7**	**0.10**	**63280**	**1**		**Spring**	**398**	**25-Aug-05**
DLLLC Hidden Valley	36.49340	-114.92657				-12.90	-97.0										999		HV-1	Well	37	06/05/00
DLLLC Hidden Valley	**36.49340**	**-114.92657**				**-12.90**	**-97.0**										**999**		**HV-1**	**Well**	**37**	
Dodge Well	38.24444	-114.54250	17.0			-14.20	-107.0										350		GS137	Well	185	06/07/85
Dodge Well	**38.24444**	**-114.54250**	**17.0**			**-14.20**	**-107.0**										**350**		**GS137**	**Well**	**185**	
Dry Lake Valley Well	36.45500	-114.84389	29.0	2.0	7.3	-13.30	-97.5	110.0	48.0	120.0	13.0	170.0	210.0	360.0	21.0	2.1	64		GS17	Well	34	07/01/85
Dry Lake Valley Well	**36.45500**	**-114.84389**	**29.0**	**2.0**	**7.3**	**-13.30**	**-97.5**	**110.0**	**48.0**	**120.0**	**13.0**	**170.0**	**210.0**	**360.0**	**21.0**	**2.1**	**64**	**1**	**GS17**	**Well**	**34**	**07/01/85**
East Settling Spring	37.37315	-114.23282	--	--	--	-12.76	-92.2	--	--	--	--	--	--	--	--	--	61100B	1		Spring	248	07/31/04
East Settling Spring	**37.37315**	**-114.23282**	**--**	**--**	**--**	**-12.76**	**-92.2**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**61100B**	**1**		**Spring**	**248**	**07/31/04**
Easter Spring	39.04120	-115.34883	11.1	6.7	7.3	-15.56	-119.4										62823		WP-23	Spring	365	06/29/05
Easter Spring	**39.04120**	**-115.34883**	**11.1**	**6.7**	**7.3**	**-15.56**	**-119.4**										**62823**		**WP-23**	**Spring**	**365**	**06/29/05**
EH-3 Weiser Wash	36.69222	-114.52556	24.1		7.8	-12.70	-91.0	511.0	201.0	170.0	22.0	194.0	123.0	2100.0	15.0			GS999	4	Well	61	averages
EH-3 Weiser Wash	**36.69222**	**-114.52556**	**24.1**		**7.8**	**-12.70**	**-91.0**	**511.0**	**201.0**	**170.0**	**22.0**	**194.0**	**123.0**	**2100.0**	**15.0**			**GS999**	**4**	**Well**	**61**	**averages**
EH-4 Weiser Wash	36.70639	-114.71611	22.8	0.0	8.3	-13.00	-98.0	49.0	30.0	90.0	12.0	57.0	245.0	171.0	28.0	0.0	AVG	1		Well	63	averages
EH-4 Weiser Wash	**36.70639**	**-114.71611**	**22.8**	**0.0**	**8.3**	**-13.00**	**-98.0**	**49.0**	**30.0**	**90.0**	**12.0**	**57.0**	**245.0**	**171.0**	**28.0**	**0.0**	**AVG**	**1**		**Well**	**63**	**averages**
EH-6 Weiser Wash	36.68167	-114.57000	24.8	0.0	7.7	-13.90	-99.5	341.0	131.0	274.0	31.0	41.0	178.0	1800.0	13.0	0.0	AVG	1		Well	59	averages
EH-6 Weiser Wash	**36.68167**	**-114.57000**	**24.8**	**0.0**	**7.7**	**-13.90**	**-99.5**	**341.0**	**131.0**	**274.0**	**31.0**	**41.0**	**178.0**	**1800.0**	**13.0**	**0.0**	**AVG**	**1**		**Well**	**59**	**averages**

EH-7	36.67056	-114.53139	21.0		7.3	-12.45	-91.0	470.0	190.0	170.0	20.0	65.0		2000.0	15.0	0.9	99		GS35	Well	56	03/19/87
EH-7	**36.67056**	**-114.53139**	**21.0**		**7.3**	**-12.45**	**-91.0**	**470.0**	**190.0**	**170.0**	**20.0**	**65.0**		**2000.0**	**15.0**	**0.9**	**99**		**GS35**	**Well**	**56**	**03/19/87**
EH-8 Weiser Wash	36.67389	-114.57583	0.0	0.0	7.6	-13.70	-96.5	375.0	104.0	416.0	22.0	233.0	162.0	1780.0	26.0	0.0	AVG	1		Well	57	averages
EH-8 Weiser Wash	**36.67389**	**-114.57583**	**0.0**	**0.0**	**7.6**	**-13.70**	**-96.5**	**375.0**	**104.0**	**416.0**	**22.0**	**233.0**	**162.0**	**1780.0**	**26.0**	**0.0**	**AVG**	**1**		**Well**	**57**	**averages**
Eightmile Spring	37.46466	-115.06440	17.9	6.7	7.2	-13.12	-96.7	45.0	9.2	13.2	1.5	10.6	189.0	8.9	43.2	--	61103	1		Spring	295	07/30/04
Eightmile Spring	37.46466	-115.06440	14.4	6.7	7.4	-13.06	-94.4	52.2	9.9	17.8	1.1	16.2	195.0	14.8	37.6	--	61106C		DRI-PR-11	Spring	295	04/30/05
Eightmile Spring	37.46466	-115.06440	**16.2**	**6.7**	**7.3**	**-13.09**	**-95.6**	**48.6**	**9.5**	**15.5**	**1.3**	**13.4**	**192.0**	**11.9**	**40.4**	**#DIV/0!**				**Spring**	**295**	
Eight Mile Spring (Snake Range)	39.388297	-114.28433	11.1	7.65	7.02	-15.53	-116.3	77.8	18.3	5.74	0.86	4.7	307	9.5	12.6	<.05	63284	1	SN-32	Spring	402	26-Aug-05
Eight Mile Spring (Resample)	39.388280	-114.284365	11	7.1	7.31	-15.38	-114.8	79.7	18.5	5.28	0.76	4.9	306	9.6	12.4	0.05	65421	1	SN-32	Spring	496	09/17/06
Eight Mile Spring (Snake Range)	**39.388297**	**-114.28433**	**11.05**	**7.375**	**7.165**	**-15.46**	**-115.6**	**78.75**	**18.4**	**5.51**	**0.81**	**4.78**	**306.5**	**9.545**	**12.5**	**0.05**	**63284**	**2**	SN-32	**Spring**	**402**	
Ella Spring	37.49072	-114.44835	7.5	3.6	7.7	-12.56	-95.8	44.2	8.6	11.1	1.8	7.0	170.0	8.8	27.1	--	59702	1		Spring	251	03/27/04
Ella Spring	**37.49072**	**-114.44835**	**7.5**	**3.6**	**7.7**	**-12.56**	**-95.8**	**44.2**	**8.6**	**11.1**	**1.8**	**7.0**	**170.0**	**8.8**	**27.1**	**--**	**59702**	**1**		**Spring**	**251**	**03/27/04**
Emigrant Spring	38.62500	-115.04778	19.5	5.2	7.1	-14.50	-108.0	67.0	24.0	5.3	1.6	2.9	300.0	14.0	13.0	0.2	410		GS188	Spring	207	07/18/81
Emigrant Spring	38.62500	-115.04778	20.1				-107.5										411		GS189	Spring	207	01/17/84
Emigrant Spring	**38.62500**	**-115.04778**	**19.8**	**5.2**	**7.1**	**-14.50**	**-107.8**	**67.0**	**24.0**	**5.3**	**1.6**	**2.9**	**300.0**	**14.0**	**13.0**	**0.2**				**Spring**	**207**	
Fence Spring	38.17978	-114.71593	--	--	--	-12.55	-97.4	--	--	--	--	--	--	--	--	--	--	1		Spring	278	06/29/04
Fence Spring	**38.17978**	**-114.71593**	**--**	**--**	**--**	**-12.55**	**-97.4**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**278**	**06/29/04**
Flag Spring #3	38.42139	-115.02222	22.8		7.5	-14.30	-105.0	50.0	21.0	10.0	3.4	6.6	270.0	12.0	26.0	0.2	380		GS161	Spring	201	01/17/84
Flag Spring #3	**38.42139**	**-115.02222**	**22.8**		**7.5**	**-14.30**	**-105.0**	**50.0**	**21.0**	**10.0**	**3.4**	**6.6**	**270.0**	**12.0**	**26.0**	**0.2**	**380**		**GS161**	**Spring**	**201**	**01/17/84**
Flatnose Spring (Unnamed Spring)	37.89611	-114.22583	25.0		8.0	-13.40	-101.0	26.0	3.5	34.0	5.6	10.0	146.0	18.0	55.0	1.3	306		GS113	Spring	153	04/08/85
Flatnose Spring (Unnamed Spring)	**37.89611**	**-114.22583**	**25.0**		**8.0**	**-13.40**	**-101.0**	**26.0**	**3.5**	**34.0**	**5.6**	**10.0**	**146.0**	**18.0**	**55.0**	**1.3**	**306**		**GS113**	**Spring**	**153**	**04/08/85**
Forest Home Spring (Unnamed Spring)	38.37750	-115.37528	14.0	5.3	7.6	-14.50	-108.5	62.0	26.0	9.9		6.9	309.0	19.0	14.0	<.1	368		GS152	Spring	195	07/24/85
Forest Home Spring (Unnamed Spring)	**38.37750**	**-115.37528**	**14.0**	**5.3**	**7.6**	**-14.50**	**-108.5**	**62.0**	**26.0**	**9.9**		**6.9**	**309.0**	**19.0**	**14.0**	**<.1**	**368**		**GS152**	**Spring**	**195**	**07/24/85**
Four Mile Spring	39.307241	-114.298032	9.4	6.5	7.23	-14.75	-112.5	85.5	33.7	8.88	1.18	7.5	375	40.2	15.8	0.10	65413		SN-25	Spring	488	09/16/06
Four Mile Spring	**39.307241**	**-114.298032**	**9.4**	**6.5**	**7.23**	**-14.75**	**-112.5**	**85.5**	**33.7**	**8.88**	**1.18**	**7.5**	**375**	**40.2**	**15.8**	**0.10**	**65413**		**SN-25**	**Spring**	**488**	**09/16/06**
Fox Cabin	38.16267	-114.65034	--	--	--	-13.59	-103.5	--	--	--	--	--	--	--	--	--	--	1		Spring	273	06/29/04
Fox Cabin	**38.16267**	**-114.65034**	**--**	**--**	**--**	**-13.59**	**-103.5**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**273**	**06/29/04**
Fugro CV Deep Well CE-DT-5	36.79556	-114.89222	35.5	2.3	7.2	-12.90	-99.5	46.0	20.0	78.0	11.0	34.0	300.0	100.0	33.0	1.9	139		GS53	Well	77	07/22/81
Fugro CV Deep Well CE-DT-5	36.79556	-114.89222				-12.99	-99.6										USGS			Well		5/28/2003
Fugro CV Deep Well CE-DT-5	36.79556	-114.89222				-12.99	-99.6										USGS			Deep Well		2/16/2005
Fugro CV Deep Well CE-DT-5	**36.79556**	**-114.89222**	**35.5**	**2.3**	**7.2**	**-12.96**	**-99.6**	**46.0**	**20.0**	**78.0**	**11.0**	**34.0**	**300.0**	**100.0**	**33.0**	**1.9**	**139**		**GS53**	**Well**	**77**	**07/22/81**
Fugro Dry Lake V Deep Well	38.14583	-114.89333	27.5	3.2	7.1	-14.20	-108.0	73.0	29.0	20.0	6.9	6.2		27.0	25.0	0.5	343		GS133	Well	179	12/10/80
Fugro Dry Lake V Deep Well	38.14583	-114.89333				-14.11	-107.0										USGS			Well		6/19/2003
Fugro Dry Lake V Deep Well	**38.14583**	**-114.89333**	**27.5**	**3.2**	**7.1**	**-14.16**	**-107.5**	**73.0**	**29.0**	**20.0**	**6.9**	**6.2**		**27.0**	**25.0**	**0.5**	**343**		**GS133**	**Well**	**179**	**12/10/80**
Fugro Steptoe V Deep Well	38.92000	-114.84528	11.0	5.5	7.5	-14.90	-117.0	66.0	14.0	15.0	4.4	12.0		57.0	28.0	0.4	443		GS218	Well	228	01/19/81
Fugro Steptoe V Deep Well	**38.92000**	**-114.84528**	**11.0**	**5.5**	**7.5**	**-14.90**	**-117.0**	**66.0**	**14.0**	**15.0**	**4.4**	**12.0**		**57.0**	**28.0**	**0.4**	**443**		**GS218**	**Well**	**228**	**01/19/81**
Garden Spring	37.26425	-114.28869	8.8	6.5	7.1	-11.54	-87.0	--	--	--	--	--	--	--	--	--	58500	1		Spring	246	01/15/04
Garden Spring	**37.26425**	**-114.28869**	**8.8**	**6.5**	**7.1**	**-11.54**	**-87.0**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**58500**	**1**		**Spring**	**246**	**01/15/04**
Geyser Spring	38.68000	-114.66556	12.5		7.8	-14.50	-105.0										419		E1	Spring	213	04/03/85
Geyser Spring	**38.68000**	**-114.66556**	**12.5**		**7.8**	**-14.50**	**-105.0**										**419**		**E1**	**Spring**	**213**	**04/03/85**
Gourd Spring	36.95861	-114.29167	E16.			-10.60	-77.5										175		GS63	Spring	89	02/06/84
Gourd Spring	**36.95861**	**-114.29167**	**E16.**			**-10.60**	**-77.5**										**175**		**GS63**	**Spring**	**89**	**02/06/84**
GP Apex Well	36.34111	-114.92667				-13.35	-97.5										999		Jim	Well	17	09/29/86
GP Apex Well	36.34111	-114.92667	31.0	5.5	7.0	-13.45	-98.0	120.0	47.0	130.0	13.0	200.0		380.0	23.0	1.4	24		PLC23	Well	17	09/30/86
GP Apex Well	36.34111	-114.92667				-13.80	-96.0						226.0				25		GS8	Well	17	09/30/86
GP Apex Well	36.34111	-114.92667	**31.0**	**5.5**	**7.0**	**-13.53**	**-97.2**	**120.0**	**47.0**	**130.0**	**13.0**	**200.0**	**226.0**	**380.0**	**23.0**	**1.4**				**Well**	**17**	
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	27.0	492.0	7.2	-15.83	-119.6	49.8	16.8	29.3	3.9	23.9	245.0	22.1	23.1	--	61482			Spring	333	09/24/04
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.9	6.3	7.7	-15.88	-120.0	50.7	17.1	29.1	3.9	23.6	236.0	22.6	22.8	--	61963	2		Spring	333	01/22/05
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707				-15.83	-119.4										62623			Spring	333	05/23/05
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707				-15.93	-119.8	49.9	16.4	28.4	3.9	23.6	22.2	240.0	22.3	0.23	63224		SU-1	Spring	333	08/12/05
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.6	4.9	7.52	-15.90	-122.8	47.3	17.0	28.5	3.91	22.8	235	22.5	22.7	0.6	63568			Spring	333	8-Nov-05
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.8	5.5	7.58	-15.96	-119.5	50.8	16.2	28.2	3.89	23.7	236	22.8	22.5	0.65	64237		SU-1	Spring	333	02/25/06
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	27.3	5.75	7.55	-16.00	-121.2	50.4	16.6	28.8	4.92	24.2	236	23.5	23.0	0.63	64740		SU-1	Spring	333	05/21/06
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.70	5.75	7.59	-15.88	-120.4	51.2	17.0	24.1	3.01	24.4	247	22.8	21.8	0.62	65292		SU-1	Spring	333	08/25/06
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.9	5.74	7.56	-15.91	-120.3	51.1	17.1	28.6	3.85	24.1	233	22.7	22.4	0.58	65658		SU-1	Spring	333	10/29/06
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	**26.9**	**75.1**	**7.5**	**-15.90**	**-120.3**	**50.2**	**16.8**	**28.1**	**3.9**	**23.8**	**211.3**	**49.9**	**22.6**	**0.6**				**Spring**	**333**	
Granite Spring	38.562713	-114.916582	11.8	5.84	6.83	-13.32	-103.4	44.6	10.9	16.6	2.92	12.6	186	17.2	57.3	0.17	65049		ER-23	Spring	440	07/13/06
Granite Spring	**38.562713**	**-114.916582**	**11.8**	**5.84**	**6.83**	**-13.32**	**-103.4**	**44.6**	**10.9**	**16.6**	**2.92**	**12.6**	**186**	**17.2**	**57.3**	**0.17**	**65049**		**ER-23**	**Spring**	**440**	**07/13/06**
Grapevine Spring (KSV-2)	37.12988	-114.70972				-11.60	-88.0										183		Kirk1028	Spring	93	--
Grapevine Spring (KSV-2)	37.12988	-114.70972	18.5		7.3	-12.00	-87.5	75.0	22.0	17.0	2.3	27.0	280.0	40.0	22.0	0.9	185		GS69	Spring	93	02/03/84
Grapevine Spring (KSV-2)	37.12988	-114.70972	18.2	2.4	7.6	-11.90	-88.6	77.2	17.3	20.2	2.9	31.4	236.0	44.5	28.3	--	62396		DRI-MM-1	Spring	93	04/27/05
Grapevine Spring (KSV-2)	37.12988	-114.70972				-11.95	-85.2	77.5	17.9	18.7	2.38	32.7	245.0	46.7	27.3	0.27	63223		DRI-MM-1	Spring	93	08/16/05
Grapevine Spring (KSV-2)	37.12988	-114.70972	18.3	5.7	7.71	-11.89	-87.7	79.2	17.6	18.1	2.62	30.1	244	42.8	26.8	0.68	63573			Spring	93	9-Nov-05
Grapevine Spring WR7	37.12988	-114.70972	12.1	4.86	7.5	-12.00	-87.3	76.3	18.0	18.0	1.95	32.1	228	44.8	24.2	0.66	64171		MM-1	Spring	93	02/16/06
Grapevine Spring WR7	37.12988	-114.70972	18.8	1.33	7.3	-11.92	-87.3	76.7	17.7	16.8	2.55	28.0	248	40.0	26.7	0.71	64745		MM-1	Spring	93	05/22/06

Grapevine Spring WR7	37.12988	-114.70972	20.70	2.56	7.14	-12.00	-87.4	73.4	18.5	16.7	1.96	31.0	233	45.6	24.8	0.67	65288		MM-1	Spring	93	08/23/06
Grapevine Spring WR7	37.12988	-114.70972	17.3	2.92	7.28	-11.93	-87.2	74.0	18.5	18.1	2.05	29.6	228	44.7	24.1	0.66	65665		MM-1	Spring	93	10/30/06
Grapevine Spring WR7	37.12988	-114.70972	-	-	-	-12.03	-87.5	-	-	-	-	-	-	-	-	-	-	-	MM-1	Spring	-	5/9/2007
Grapevine Spring (KSV-2)	37.12988	-114.70972	**17.7**	**3.3**	**7.4**	**-11.92**	**-87.4**	**76.2**	**18.4**	**18.0**	**2.3**	**30.2**	**242.8**	**43.6**	**25.5**	**0.7**				**Spring**	**93**	
Grass Valley Springs	39.713209	-114.233004	9.2	6	6.35	-16.72	-124.7	18.0	3.26	12.3	0.94	5.9	81.0	5.1	26.6	0.09	63274			Spring	392	23-Aug-05
Grass Valley Springs	**39.713209**	**-114.233004**	**9.2**	**6**	**6.35**	**-16.72**	**-124.7**	**18.0**	**3.26**	**12.3**	**0.94**	**5.9**	**81.0**	**5.1**	**26.6**	**0.09**	**63274**			**Spring**	**392**	**23-Aug-05**
Grassy Spring	37.54107	-114.79174	13.0	6.5	7.4	-10.90	-85.0	85.2	15.3	30.8	0.7	36.9	269.0	58.0	33.0		241		K7	Spring	117	01/14/85
Grassy Spring	37.54107	-114.79174	14.2	5.3	7.5	-11.23	-90.9	111.0	19.2	51.0	0.6	57.0	339.0	54.0	36.4	--	59700	1		Spring	117	03/26/04
Grassy Spring	37.54107	-114.79174	13.6	5.7	7.0	-11.10	-90.1	116.0	20.7	39.9	0.9	70.7	330.0	69.0	36.8	--	62402		DRI-DR-20	Spring	117	04/27/05
Grassy Spring	**37.54107**	**-114.79174**	**13.6**	**5.8**	**7.3**	**-11.08**	**-88.7**	**104.1**	**18.4**	**40.6**	**0.7**	**54.9**	**312.7**	**60.3**	**35.4**	**--**				**Spring**	**117**	
Gubler Canyon Creek Spring (Unnamed Spring in Gubler Canyon)	39.13389	-114.96139	12.5			-14.90	-111.0					2.4					457		GS243	Spring	235	06/16/83
Gubler Canyon Creek Spring (Unnamed Spring in Gubler Canyon)	**39.13389**	**-114.96139**	**12.5**			**-14.90**	**-111.0**					**2.4**					**457**		**GS243**	**Spring**	**235**	**06/16/83**
Hackberry Spring	36.91778	-114.43778	10.0			-12.30	-87.0										162		GS58	Spring	84	02/05/84
Hackberry Spring	**36.91778**	**-114.43778**	**10.0**			**-12.30**	**-87.0**										**162**		**GS58**	**Spring**	**84**	**02/05/84**
Haggerty Spring	38.66930	-114.90482	11.9	5.98	6.85	-14.78	-109.6	69.7	13.0	3.94	0.76	2.8	259	7.0	10.6		62979		ER-9	Spring	387	07/31/05
Haggerty Spring	**38.66930**	**-114.90482**	**11.9**	**5.98**	**6.85**	**-14.78**	**-109.6**	**69.7**	**13.0**	**3.94**	**0.76**	**2.8**	**259**	**7.0**	**10.6**		**62979**		**ER-9**	**Spring**	**387**	**07/31/05**
Halfway Spring (RS)	38.964420	-115.311490	12.9	2.6	7.8	-13.35	-108.4	Iso Only	-	-	-	-	-	-	-	-	--		WP-14	Spring	429	07/11/06
Halfway Spring	38.964420	-115.311490	16.5	0.85	6.93	-13.68	-109.0	100	21.2	37.6	1.9	14.7	448	21.1	56.6	-	--		WP-14	Spring	429	06/29/05
Halfway Spring (RS)	**38.964420**	**-115.311490**	**14.7**	**1.725**	**7.365**	**-13.52**	**-108.7**		**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**--**		**WP-14**	**Spring**	**429**	**07/11/06**
Hamilton Spring	37.93572	-114.88764	14.4	6.8	7.2	-11.76	-93.1	66.9	10.8	29.4	7.2	22.9	260.0	25.5	69.4	--	59686	1		Spring	298	03/23/04
Hamilton Spring	**37.93572**	**-114.88764**	**14.4**	**6.8**	**7.2**	**-11.76**	**-93.1**	**66.9**	**10.8**	**29.4**	**7.2**	**22.9**	**260.0**	**25.5**	**69.4**	**--**	**59686**	**1**		**Spring**	**298**	**03/23/04**
Headwaters Spring WR5	38.36575	-114.31935	9.6	6.5	7.0	-14.65	-106.9	10.4	2.4	4.5	1.3	4.5	37.1	4.7	19.1	--	60311			Spring	309	05/19/04
Headwaters Spring WR5	38.36575	-114.31935	--	--	--	-14.67	-108.7	--	--	--	--	--	--	--	--	--	60311B	4		Spring	309	07/18/04
Headwaters Spring WR5	38.36575	-114.31935	8.2	7.1	6.9	-14.67	-108.8	11.2	2.5	4.8	1.2	4.2	37.2	4.4	20.4	--	61481			Spring	309	09/23/04
Headwaters Spring WR5	38.36575	-114.31935				-15.01	-110.4										62970			Spring	309	07/27/05
Headwaters Spring WR5	38.36575	-114.31935				-14.99	-109.6	11.8	2.5	4.9	1.2	4.7	3.4	44.3	21.1	0.20	63221		WC-1	Spring	309	08/13/05
Headwaters Spring WR5	38.36575	-114.31935	9.5	5.97	6.36	-14.71	-107.8	13.8	3.00	5.43	1.34	6.2	46.9	4.4	21.4	0.06	63565	1		Spring	309	7-Nov-05
Headwaters Spring WR5	38.365750	-114.319350	9.3	6.25	6.54	-14.52	-106.3	11.4	2.57	5.21	1.27	3.7	45.0	3.7	22.0	0.08	64737		WC-1	Spring	309	05/23/06
Headwaters Spring WR5	38.365750	-114.319350	12.1	6.14	6.37	-14.59	-107.7	10.7	2.46	5.04	1.29	4.5	43.2	4.1	21.2	0.06	65370		WC-1	Spring	309	08/31/06
Headwaters Spring WR5	38.365750	-114.319350	8.9	7.09	6.50	-14.47	-107.3	11.5	2.68	5.28	1.30	4.4	41.1	4.0	21.5	0.07	65744		WC-1	Spring	309	11/16/06
WR 5 Autosampler	38.365750	-114.319350	-	-	-	-14.61	-107.6	-	-	-	-	-	-	-	-	-	DRI-65370-9		WC-1	Spring	309	12/01/05
WR 5 Autosampler	38.365750	-114.319350	-	-	-	-14.70	-108.6	-	-	-	-	-	-	-	-	-	DRI-65370-12		WC-1	Spring	309	01/01/06
WR 5 Autosampler	38.365750	-114.319350	-	-	-	-14.52	-107.7	-	-	-	-	-	-	-	-	-	DRI-65370-14		WC-1	Spring	309	02/01/06
WR 5 Autosampler	38.365750	-114.319350	-	-	-	-14.34	-105.7	-	-	-	-	-	-	-	-	-	DRI-65370-16		WC-1	Spring	309	03/01/06
WR 5 Autosampler	38.365750	-114.319350	-	-	-	-14.36	-105.5	-	-	-	-	-	-	-	-	-	DRI-65370-20		WC-1	Spring	309	05/01/06
WR5 Autosample 1	38.365750	-114.319350	-	-	-	-14.53	-105.7	-	-	-	-	-	-	-	-	-	65744Auto1		WC-1	Spring	309	09/01/06
WR5 Autosample 5	38.365750	-114.319350	-	-	-	-14.10	-105.4	-	-	-	-	-	-	-	-	-	65744Auto5		WC-1	Spring	309	11/01/06
Headwaters Spring WR5	38.365750	-114.319350	8.5	NA	6.24	-14.24	-105.0	10.6	2.41	4.62	1.24	3.1	41.8	3.5	19.4	0.08	65744		WC-1	Spring	309	5/7/2007
Headwaters Spring WR5	38.36575	-114.31935	**9.4**	**6.5**	**6.6**	**-14.57**	**-107.3**	**11.4**	**2.6**	**5.0**	**1.3**	**4.4**	**37.0**	**9.1**	**20.8**	**0.1**		17	WC-1	**Spring**	**309**	
Hells Acres Gulch Spring (Unnamed Spring in Hells Acres Gulch)	37.46028	-115.12472	13.0		8.3	-12.30	-93.0	45.2	9.0	20.7	2.4	8.2	198.0	19.9	39.0		211		K9	Spring	109	01/14/85
Hells Acres Gulch Spring(Unnamed Spring in Hells Acres Gulch)	**37.46028**	**-115.12472**	**13.0**		**8.3**	**-12.30**	**-93.0**	**45.2**	**9.0**	**20.7**	**2.4**	**8.2**	**198.0**	**19.9**	**39.0**		**211**		**K9**	**Spring**	**109**	**01/14/85**
Henry Spring	37.68990	-115.37391	--	--	--	-12.77	-97.4	--	--	--	--	--	--	--	--	--	--	1		Spring	287	06/25/04
Henry Spring	**37.68990**	**-115.37391**	**--**	**--**	**--**	**-12.77**	**-97.4**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**287**	**06/25/04**
High Springs	39.130125	-114.950408	7.4	6.49	7.5	-15.43	-113.4	66.2	10.1	3.65	0.91	0.8	232	17.9	10.4	0.12	65042		ER-16	Spring	433	07/12/06
High Springs	**39.130125**	**-114.950408**	**7.4**	**6.49**	**7.5**	**-15.43**	**-113.4**	**66.2**	**10.1**	**3.65**	**0.91**	**0.8**	**232**	**17.9**	**10.4**	**0.12**	**65042**		**ER-16**	**Spring**	**433**	**07/12/06**
Highland Spring	37.92110	-114.54923	10.0		7.2	-13.30	-98.5	86.0	36.0	4.7	1.0	4.4	474.0	8.1	15.0	0.1	320		GS120	Spring	163	04/07/85
Highland Spring	37.92110	-114.54923	11.6	5.8	7.4	-13.49	-99.6	77.1	35.9	3.7	0.7	3.7	413.0	6.2	15.3	--	60839	1		Spring	163	06/24/04
Highland Spring	37.92110	-114.54923	10.2	7.3	6.8	-13.30	-99.3	82.9	35.1	4.3	0.6	3.4	403.0	5.9	16.1	--	62408		DRI-HR-1	Spring	163	05/01/05
Highland Spring	37.92110	-114.54923	**10.6**	**6.6**	**7.1**	**-13.36**	**-99.1**	**82.0**	**35.7**	**4.3**	**0.8**	**3.8**	**430.0**	**6.7**	**15.5**	**0.1**				**Spring**	**163**	
Hiko Spring	37.59833	-115.21444				-13.80	-109.0										249		PLC12	Spring	122	--
Hiko Spring	37.59833	-115.21444					-110.5										254		IT127	Spring	122	08/01/68
Hiko Spring	37.59833	-115.21444					-109.5										255		IT128	Spring	122	01/01/69
Hiko Spring	37.59833	-115.21444					-109.5										256		IT129	Spring	122	03/01/70
Hiko Spring	37.59833	-115.21444				-15.30	-110.0										251		IT124	Spring	122	01/14/85
Hiko Spring	37.59833	-115.21444				-14.00	-105.0										257		IT130	Spring	122	01/14/85
Hiko Spring	37.59833	-115.21444	26.5		7.7	-14.45	-107.7	46.4	23.3	25.6	6.6	46.3	273.0	38.1	33.1	0.5	252		IT125	Spring	122	08/07/95
Hiko Spring	37.59833	-115.21444	**26.5**	**#DIV/0!**	**7.7**	**-14.39**	**-108.7**	**46.4**	**23.3**	**25.6**	**6.6**	**46.3**	**273.0**	**38.1**	**33.1**	**0.5**				**Spring**	**122**	
Hole in the Bank Spring	38.84915	-114.89566	6.9	7.9	6.6	-15.37	-114.9	43.7	11.0	12.4	2.95	5.1	195	10.5	50.6	0.13	62977		ER-8	Spring	386	07/31/05
Hole in the Bank Spring	**38.84915**	**-114.89566**	**6.9**	**7.9**	**6.6**	**-15.37**	**-114.9**	**43.7**	**11.0**	**12.4**	**2.95**	**5.1**	**195**	**10.5**	**50.6**	**0.13**	**62977**		**ER-8**	**Spring**	**386**	**07/31/05**
Horse Spring (Morman)	36.94139	-114.44639				-12.70	-89.0										167		GS59	Spring	85	02/05/84
Horse Spring (Morman)	**36.94139**	**-114.44639**				**-12.70**	**-89.0**										**167**		**GS59**	**Spring**	**85**	**02/05/84**
Horse Spring (Grant)	38.32951	-115.38580	14.7	7.2	7.1	-12.86	-99.5										62829		GR-3	Spring	370	06/30/05
Horse Spring (Grant)	**38.32951**	**-115.38580**	**14.7**	**7.2**	**7.1**	**-12.86**	**-99.5**										**62829**		**GR-3**	**Spring**	**370**	**06/30/05**
Horsethief Spring	38.02649	-114.24511	11.7	1.6	6.9	-12.73	-96.3	56.6	8.0	16.5	1.2	18.6	206.0	13.0	50.1	--	60314	1		Spring	314	05/20/04
Horsethief Spring	38.02649	-114.24511	9.7	1.9	6.4	-12.62	-97.6	76.5	10.6	27.6	0.5	19.5	293.0	13.5	60.3	--	62406		DRI-WC-6	Spring	314	05/01/05
Horsethief Spring	38.02649	-114.24511	**10.7**	**1.8**	**6.7**	**-12.68**	**-97.0**	**66.6**	**9.3**	**22.1**	**0.9**	**19.1**	**249.5**	**13.3**	**55.2**	**#DIV/0!**				**Spring**	**314**	
Hot Creek Campground Well	38.38833	-115.13278	19.0			-15.30	-118.0										374		GS155	Well	198	07/19/81
Hot Creek Campground Well	**38.38833**	**-115.13278**	**19.0**			**-15.30**	**-118.0**										**374**		**GS155**	**Well**	**198**	**07/19/81**

Hot Creek Springs	38.38251	-115.15451	32.5	1.0	7.2	-15.50	-118.0	59.0	21.0	24.0	5.5	10.0		46.0	28.0	0.9	372		GS153	Spring	197	07/19/81
Hot Creek Springs	38.38251	-115.15451	31.8	1.3	7.2	-15.71	-120.5	57.9	22.1	24.9	4.8	10.1	282.0	43.9	28.2	--	61484			Spring	197	09/25/04
Hot Creek Springs	38.38251	-115.15451	31.3	1.4	7.3	-15.66	-119.0	59.0	22.2	25.0	5.3	10.0	272.0	45.5	27.8	--	61972	2		Spring	197	01/24/05
Hot Creek Springs	38.38251	-115.15451	31.2	1.6	7.1	-15.66	-118.6									--	62624		DRI-WV-2	Spring	197	05/18/05
Hot Creek Springs	38.38251	-115.15451	31.3	1.6	6.8	-15.70	-117.4										63228		DRI-WV-2	Spring	197	08/14/05
Hot Creek Spring	38.38251	-115.15451	30.9	1.52	7.33	-15.73	-119.1	59.7	22.4	24.3	5.03	10	273	45.1	27.7	1.02	63564			Spring	197	11/6/05
Hot Creek Spring	38.382510	-115.154510	31.3	1.87	7.32	-15.77	-119.2	58.7	22.1	24.5	5.22	10.2	269	45.4	27.8	1.02	65656		WV-2	Spring	197	10/28/06
Hot Creek Springs	38.382510	-115.154510	31.3	1.06	7.29	-15.75	-118.4	59.5	21.5	24.3	5.14	10.1	271	45.2	28.8	1.04	64234		WV-2	Spring	197	02/17/06
Hot Creek Springs	38.382510	-115.154510	31.7	1.54	7.36	-15.67	-120.1	59.6	21.6	25.2	5.15	10.6	269	47.0	28.4	1.02	64736		WV-2	Spring	197	05/22/06
Hot Creek Springs	38.382510	-115.154510	31.4	1.32	7.3	-15.75	-119.0	59.3	22.3	22.3	4.53	10.1	268	46.0	27.7	1.00	65367		WV-2	Spring	197	08/29/06
Hot Creek Springs	38.38251	-115.15451	**31.5**	**1.4**	**7.2**	**-15.69**	**-118.9**	**59.1**	**21.9**	**24.3**	**5.1**	**10.1**	**272.0**	**45.5**	**28.1**	**1.0**				**Spring**	**197**	
Indian Spring (Butte)	39.44040	-115.31884	11.3	7.9	7.1	-15.31	-119.1									--	62709		DRI-BT-8	Spring	334	06/05/05
Indian Spring (Butte)	**39.44040**	**-115.31884**	**11.3**	**7.9**	**7.1**	**-15.31**	**-119.1**									**--**	**62709**		**DRI-BT-8**	**Spring**	**334**	**06/05/05**
Indian Springs	38.64160	-114.44957				-14.16	-106.3	26.3	4.10	12.7	4.56	9.4	114.0	6.7	72.8	0.10	62974		FO-1	Spring	375	07/29/05
Indian Springs	**38.64160**	**-114.44957**				**-14.16**	**-106.3**	**26.3**	**4.10**	**12.7**	**4.56**	**9.4**	**114.0**	**6.7**	**72.8**	**0.10**	**62974**		**FO-1**	**Spring**	**375**	**07/29/05**
Iverson's Spring	36.71028	-114.71194					-97.0										111		PLC18	Spring	65	--
Iverson's Spring	**36.71028**	**-114.71194**					**-97.0**										**111**		**PLC18**	**Spring**	**65**	**--**
Jenson Well	37.18417	-114.46444	18.0		7.7	-11.60	-88.5	55.0	14.0	100.0	7.2	45.0	340.0	80.0	56.0	2.1	187		GS70	Well	95	04/10/85
Jenson Well	**37.18417**	**-114.46444**	**18.0**		**7.7**	**-11.60**	**-88.5**	**55.0**	**14.0**	**100.0**	**7.2**	**45.0**	**340.0**	**80.0**	**56.0**	**2.1**	**187**		**GS70**	**Well**	**95**	**04/10/85**
John Wadsworth	37.76861	-114.40694	14.5		7.5	-12.90	-101.0	120.0	47.0	150.0	9.5	88.0	601.0	200.0	76.0	6.5	286		GS101	Well	140	06/04/85
John Wadsworth	**37.76861**	**-114.40694**	**14.5**		**7.5**	**-12.90**	**-101.0**	**120.0**	**47.0**	**150.0**	**9.5**	**88.0**	**601.0**	**200.0**	**76.0**	**6.5**	**286**		**GS101**	**Well**	**140**	**06/04/85**
Johnson Spring	39.92319	-114.98923	10.2	9.0	7.5	-15.94	-123.4									--	62625		DRI-CC-1	Spring	335	05/24/05
Johnson Spring	**39.92319**	**-114.98923**	**10.2**	**9.0**	**7.5**	**-15.94**	**-123.4**									**--**	**62625**		**DRI-CC-1**	**Spring**	**335**	**05/24/05**
Jones Spring Pumphouse	36.71116	-114.71694	27.2	5.3	7.4	-12.99	-98.9	63.4	27.4	95.7	11.1	63.1	252.0	178.0	29.5	--	62033	1		Spring	293	02/10/05
Jones Spring Pumphouse	36.71116	-114.71694	32.00	3.90	7.00	-12.99	-97.80	63.70	27.30	96.00	11.20	61.90	256.00	174.00	31.40	2.18	62034		DRI-MV-6	Spring	293	06/08/05
Jones Spring Pumphouse	36.711160	-114.716940	31.7	3.67	7.36	-13.07	-97.7	63.8	27.4	96.3	10.9	61.8	254	178	29.4	2.20	64175		MV-5	Spring	292	02/16/06
Jones Spring Pumphouse	36.711160	-114.716940	32.2	4.36	7.27	-13.07	-97.9	62.6	27.1	93.1	11.2	62.6	254	181	29.7	2.19	64902		MV-5	Spring	292	06/21/06
Jones Spring Pumphouse	36.711160	-114.716940	32.20	4.05	7.30	-13.10	-97.3	63.7	27.8	84.5	9.32	62.2	269	179	29.3	2.13	65285		MV-5	Spring	292	08/23/06
Jones Spring Pumphouse	36.711160	-114.716940	31.7	3.14	7.35	-13.09	-98.0	64.6	27.2	95.0	11.1	60.7	252	176	29.2	2.2	65661		MV-5	Spring	292	10/30/06
Jones Spring Pumphouse	**36.71116**	**-114.71694**	**31.2**	**4.1**	**7.3**	**-13.05**	**-97.9**	**63.6**	**27.4**	**93.4**	**10.8**	**62.1**	**256.2**	**177.7**	**29.8**	**2.2**				**Spring**	292	
Juanita Spring	36.63694	-114.24750	26.0		7.3	-11.65	-87.0	130.0	43.0	25.0	5.3	15.0		370.0	29.0	1.0	90		GS30	Spring	50	01/25/86
Juanita Spring	**36.63694**	**-114.24750**	**26.0**		**7.3**	**-11.65**	**-87.0**	**130.0**	**43.0**	**25.0**	**5.3**	**15.0**		**370.0**	**29.0**	**1.0**	**90**		**GS30**	**Spring**	**50**	**01/25/86**
Kalamazoo Spring WR6	39.56648	-114.59594	12.1	6.8	7.3	-16.22	-121.6	47.2	15.5	2.5	0.7	2.1	208.0	10.6	10.5	--	60962			Spring	336	07/20/04
Kalamazoo Spring WR6	39.56648	-114.59594	12.3	6.7	7.3	-16.22	-118.5	46.8	16.0	3.2	0.9	1.9	196.0	11.0	11.7	--	61348A			Spring	336	09/21/04
Kalamazoo Spring WR6	39.56648	-114.59594	11.9	6.9	7.4	-16.28	-121.6	48.6	16.5	3.5	0.8	1.8	209.0	12.1	11.4	--	61966	3		Spring	336	01/23/05
Kalamazoo Spring WR6	39.56648	-114.59594				-16.13	-118.6										62636			Spring	336	05/23/05
Kalamazoo Spring WR6	39.56648	-114.59594				-16.18	-119.2	49.6	15.2	3.0	0.7	1.8	11.4	214.0	11.5	0.13	63222A		SC-3	Spring	336	08/12/05
Kalamazoo Spring WR6	39.56648	-114.59594	11.9	7.33	7.47	-16.17	-121.0	49.1	17.5	3.46	0.74	1.9	219	12.8	12.4	<.05	63567			Spring	336	8-Nov-05
Kalamazoo Spring WR6	39.566480	-114.595940	11.7	7.14	7.6	-16.22	-119.3	49.3	16.6	3.42	0.79	2.0	213	12.8	12.1	<.1	64236		SC-3	Spring	336	02/25/06
Kalamazoo Spring WR6	39.566480	-114.595940	9.8	8.1	7.51	-16.06	-118.0	50.0	11.0	2.65	0.55	1.4	191	7.4	9.6	<.05	64739		SC-3	Spring	336	05/21/06
Kalamazoo Spring WR6	39.566480	-114.595940	-	-	-	-16.16	-120.1	-	-	-	-	-	-	-	-	-	--		SC-3	Spring	336	08/02/06
Kalamazoo Spring WR6	39.566480	-114.595940	11.9	7.3	7.55	-16.24	-119.7	50.0	17.1	2.87	0.60	2.0	230	12.4	12.0	<.05	65368		SC-3	Spring	336	08/30/06
Kalamazoo Spring WR6	39.566480	-114.595940	12.0	6.50	7.52	-16.11	-120.5	50.2	17.3	3.51	0.82	1.5	216	12.5	12.4	<.05	65657		SC-3	Spring	336	10/29/06
Kalamazoo Spring WR6	39.566480	-114.595940	11.3	NA	7.6	-16.19	-120.4	48.7	16.3	3.67	0.76	1.5	220	11.7	12.4	0.05	65657		SC-3	Spring		5/8/2007
Kalamazoo Spring WR6	39.56648	-114.59594	**11.7**	**7.1**	**7.5**	**-16.18**	**-119.9**	**49.0**	**15.9**	**3.2**	**0.7**	**1.8**	**191.3**	**31.7**	**11.6**	**0.1**				**Spring**	**336**	
Kane Springs (KSV-3)	37.24611	-114.70584				-12.60	-87.0										193		Kirk1025	Spring	97	--
Kane Springs (KSV-3)	37.24611	-114.70584	16.4		7.2	-11.90	-86.5	44.0	13.0	20.0	5.9	17.0	210.0	14.0	60.0	2.8	195		GS72	Spring	97	02/02/84
Kane Springs (KSV-3)	37.24611	-114.70584	14.8	5.2	7.0	-11.88	-87.0	49.0	13.6	20.3	1.4	17.6	214.0	15.1	64.5	--	58490	1		Spring	97	01/13/04
Kane Springs (KSV-3)	**37.24611**	**-114.70584**	**15.6**	**5.2**	**7.1**	**-12.13**	**-86.8**	**46.5**	**13.3**	**20.2**	**3.6**	**17.3**	**212.0**	**14.6**	**62.3**	**2.8**				**Spring**	**97**	
Kershaw-Ryan Spring #1	37.59028	-114.52010	20.0	6.5	8.4	-13.11	-95.1	24.2	2.7	26.5	4.4	6.3	140.0	4.4	46.1	--	59701	1		Spring	250	03/27/04
Kershaw-Ryan Spring #1	**37.59028**	**-114.52010**	**20.0**	**6.5**	**8.4**	**-13.11**	**-95.1**	**24.2**	**2.7**	**26.5**	**4.4**	**6.3**	**140.0**	**4.4**	**46.1**	**--**	**59701**	**1**		**Spring**	**250**	**03/27/04**
Kiln Spring	37.805098	-114.164229	11.5	2.43	7.11	-12.34	-91.9	93.5	22.9	34.8	0.53	51.2	320	56.9	27.4	0.24	64904		MG-1	Spring	418	06/21/06
Kiln Spring	**37.805098**	**-114.164229**	**11.5**	**2.43**	**7.11**	**-12.34**	**-91.9**	**93.5**	**22.9**	**34.8**	**0.53**	**51.2**	**320**	**56.9**	**27.4**	**0.24**	**64904**		**MG-1**	**Spring**	**418**	**06/21/06**
Lake Mead Base Well #3	36.23917	-115.00444				-13.80	-101.5										19		PLC35	Well	12	--
Lake Mead Base Well #3	**36.23917**	**-115.00444**				**-13.80**	**-101.5**										**19**		**PLC35**	**Well**	**12**	**--**
Lake Valley Well	38.35556	-114.58917	18.0		8.1	-14.70	-111.0	61.0	9.7	22.0	2.1	68.0	121.0	25.0	25.0	0.2	365		GS147	Well	193	06/07/85
Lake Valley Well	**38.35556**	**-114.58917**	**18.0**		**8.1**	**-14.70**	**-111.0**	**61.0**	**9.7**	**22.0**	**2.1**	**68.0**	**121.0**	**25.0**	**25.0**	**0.2**	**365**		**GS147**	**Well**	**193**	**06/07/85**
Lamb Spring	36.94500	-115.10583	13.5			-13.15	-92.5	37.0	41.0	8.7	0.6	8.6		24.0	12.0	0.2	168			Spring	86	05/19/88
Lamb Spring	**36.94500**	**-115.10583**	**13.5**			**-13.15**	**-92.5**	**37.0**	**41.0**	**8.7**	**0.6**	**8.6**		**24.0**	**12.0**	**0.2**	**168**			**Spring**	**86**	**05/19/88**
Lester Mathews Well	37.79361	-114.39972	20.0		8.1	-13.30	-103.0	73.0	21.0	140.0	10.0	44.0		170.0	64.0	3.1	289		GS104	Well	142	06/04/85
Lester Mathews Well	**37.79361**	**-114.39972**	**20.0**		**8.1**	**-13.30**	**-103.0**	**73.0**	**21.0**	**140.0**	**10.0**	**44.0**		**170.0**	**64.0**	**3.1**	**289**		**GS104**	**Well**	**142**	**06/04/85**
Lime Spring	37.91467	-114.54022	21.0		8.3	-12.90	-97.0	55.0	31.0	3.8	0.9	4.1	290.0	8.9	14.0	0.1	315		GS118	Spring	160	04/07/85
Lime Spring	37.91467	-114.54022	15.1	0.4	7.4	-13.41	-99.9	76.1	40.6	3.3	1.1	3.6	433.0	6.4	14.1	--	60840	1		Spring	160	06/24/04
Lime Spring	37.91467	-114.54022	**18.1**	**0.4**	**7.8**	**-13.16**	**-98.5**	**65.6**	**35.8**	**3.5**	**1.0**	**3.9**	**361.5**	**7.7**	**14.1**	**0.1**				**Spring**	**160**	
Lion Spring	38.25863	-114.13032	9.8	8.2	7.8	-14.11	-103.4	37.0	7.0	17.2	3.8	36.1	124.0	15.3	56.6	--	60317	1		Spring	318	05/21/04
Lion Spring	**38.25863**	**-114.13032**	**9.8**	**8.2**	**7.8**	**-14.11**	**-103.4**	**37.0**	**7.0**	**17.2**	**3.8**	**36.1**	**124.0**	**15.3**	**56.6**	**--**	**60317**	**1**		**Spring**	**318**	**05/21/04**

Lion Spring (Egan Range)	39.180372	-114.984442	12.5	5.07	7.28	-15.34	-114.8	64.5	13.2	13.7	4.61	15.4	237	28.7	42.3	0.10	65039		ER-13	Spring	430	07/12/06
Lion Spring (Egan Range)	**39.180372**	**-114.984442**	**12.5**	**5.07**	**7.28**	**-15.34**	**-114.8**	**64.5**	**13.2**	**13.7**	**4.61**	**15.4**	**237**	**28.7**	**42.3**	**0.10**	**65039**		**ER-13**	**Spring**	**430**	**07/12/06**
Little Ash Spring (Ash Spring)	37.46389	-115.19167	37.0		7.4	-14.20	-107.2	45.3	15.4	29.8	7.3	9.5	250.0	35.0	31.5	0.8	229		IT33	Spring	111	08/08/95
Little Ash Spring (Ash Spring)	**37.46389**	**-115.19167**	**37.0**		**7.4**	**-14.20**	**-107.2**	**45.3**	**15.4**	**29.8**	**7.3**	**9.5**	**250.0**	**35.0**	**31.5**	**0.8**	**229**		**IT33**	**Spring**	**111**	**08/08/95**
Little Boulder Spring	37.71330	-114.95217	12.0	6.4	7.1	-13.06	-97.2	21.8	5.9	8.0	2.9	4.9	101.0	7.8	44.8	--	59690	1		Spring	301	03/24/04
Little Boulder Spring	**37.71330**	**-114.95217**	**12.0**	**6.4**	**7.1**	**-13.06**	**-97.2**	**21.8**	**5.9**	**8.0**	**2.9**	**4.9**	**101.0**	**7.8**	**44.8**	**--**	**59690**	**1**		**Spring**	**301**	**03/24/04**
Little Currant Creek	38.83444	-115.35806	10.5			-15.00	-113.0													Surface	217	08/23/83
Little Currant Creek	**38.83444**	**-115.35806**	**10.5**			**-15.00**	**-113.0**													**Surface**	**217**	**08/23/83**
Little Spring (Grant Range)	38.33197	-115.36050	14.7	1.7	6.9	-12.48	-99.4										62828	1		Spring	369	06/30/05
Little Spring (Grant Range)	**38.33197**	**-115.36050**	**14.7**	**1.7**	**6.9**	**-12.48**	**-99.4**										**62828**	**1**		**Spring**	**369**	**06/30/05**
Little Springs (Clover Mts)	37.53418	-114.35607	18.5	5.3	7.6	-12.78	-93.0	30.2	5.1	11.2	2.8	9.7	137.0	4.8	56.5	--	61096	1		Spring	254	07/31/04
Little Springs (Clover Mts)	37.53418	-114.35607	17.1	6.7	6.8	-12.84	-93.5	29.6	4.7	10.8	2.5	8.6	112.0	5.0	46.6	--	62403		DRI-CR-7	Spring	254	04/30/05
Little Springs (Clover Mts)	37.53418	-114.35607	**17.8**	**6.0**	**7.2**	**-12.81**	**-93.3**	**29.9**	**4.9**	**11.0**	**2.6**	**9.2**	**124.5**	**4.9**	**51.6**	**#DIV/0!**				**Spring**	**254**	
Little Cut Spring	37.69653	-115.37810	--	--	--	-12.93	-98.4	68.8	19.7	21.1	2.6	22.2	295.0	30.6	55.9	--	60844	1		Spring	286	06/25/04
Little Cut Spring	37.69653	-115.37810	10.4	4.8	6.8	-12.76	-98.2	75.0	21.0	22.8	2.3	21.1	302.0	33.1	52.2	--	62410		DRI-MI-1	Spring	286	05/02/05
Little Cut Spring	37.69653	-115.37810	**10.4**	**4.8**	**6.8**	**-12.85**	**-98.3**	**71.9**	**20.4**	**22.0**	**2.4**	**21.7**	**298.5**	**31.9**	**54.1**	**#DIV/0!**				**Spring**	**286**	
Little Tom Plain Spring	39.08092	-115.37152	8.0	7.2	6.7	-15.87	-121.8									--	62712		DRI-WP-7	Spring	337	06/06/05
Little Tom Plain Spring (RS)	39.081026	-115.371715	8.9	5.74	7.13	-15.85	-120.1	66.8	5.61	19.3	2.63	14.7	231	19.8	47.3	0.25	65037		WP-12	Spring	427	07/11/06
Little Tom Plain Spring	**39.08092**	**-115.37152**	**8.5**	**6.4**	**6.9**	**-15.86**	**-121.0**	**66.8**	**5.6**	**19.3**	**2.6**	**14.7**	**231.0**	**19.8**	**47.3**	**0.3**	**62712**		**DRI-WP-7**	**Spring**	**337**	**06/06/05**
Littlefield Spring	38.23125	-114.70223	14.9	5.0	7.0	-12.73	-98.5	67.1	13.3	16.3	2.8	22.5	254.0	20.9	47.5	--	60847	1		Spring	275	06/26/04
Littlefield Spring	**38.23125**	**-114.70223**	**14.9**	**5.0**	**7.0**	**-12.73**	**-98.5**	**67.1**	**13.3**	**16.3**	**2.8**	**22.5**	**254.0**	**20.9**	**47.5**	**--**	**60847**	**1**		**Spring**	**275**	**06/26/04**
Lone Pine Spring	38.89556	-114.89944	--	--	--	-14.98	-109.2	--	--	--	--	--	--	--	--	--	--	1		Spring	223	10/13/03
Lone Pine Spring	38.89556	-114.89944	8.0	7.4	7.5	-14.95	-111.5	67.0	4.2	3.5		1.6	224.0	3.7	17.0	<.1	434		GS214	Spring	223	08/01/85
Lone Pine Spring	38.89556	-114.89944	7	7.09	7.44	-14.77	-110.0	72.5	3.80	4.35	1.27	2.3	220	6.0	27.6	0.05	65053		ER-27	Spring	444	07/13/06
Lone Pine Spring	38.89556	-114.89944	**7.5**	**7.2**	**7.5**	**-14.90**	**-110.2**	**69.8**	**4.0**	**3.9**	**1.3**	**2.0**	**222.0**	**4.9**	**22.3**	**0.1**				**Spring**	**223**	
Lower Chokecherry Spring	37.53721	-114.69709	6.4	7.3	7.7	-12.98	-98.4	73.2	15.2	26.7	1.6	19.4	296.0	25.0	53.4	--	59694	1		Spring	261	03/25/04
Lower Chokecherry Spring	**37.53721**	**-114.69709**	**6.4**	**7.3**	**7.7**	**-12.98**	**-98.4**	**73.2**	**15.2**	**26.7**	**1.6**	**19.4**	**296.0**	**25.0**	**53.4**	**--**	**59694**	**1**		**Spring**	**261**	**03/25/04**
Lower Fairview	38.17573	-114.65551	--	--	--	-12.39	-97.5	--	--	--	--	--	--	--	--	--	--	1		Spring	281	06/29/04
Lower Fairview	**38.17573**	**-114.65551**	**--**	**--**	**--**	**-12.39**	**-97.5**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**281**	**06/29/04**
Lower Indian Spring	37.45006	-114.65730	21.4	3.6	8.3	-12.62	-96.0	1.9	0.2	95.1	0.8	12.1	221.0	10.4	56.2	--	58498	1		Spring	267	01/14/04
Lower Indian Spring	**37.45006**	**-114.65730**	**21.4**	**3.6**	**8.3**	**-12.62**	**-96.0**	**1.9**	**0.2**	**95.1**	**0.8**	**12.1**	**221.0**	**10.4**	**56.2**	**--**	**58498**	**1**		**Spring**	**267**	**01/14/04**
Lower Little Cherry Cr Spring	38.16722	-115.65333		8.0	7.6	-13.90	-103.0						268.0				346		GS135	Spring	182	07/31/85
Lower Little Cherry Cr Spring	**38.16722**	**-115.65333**		**8.0**	**7.6**	**-13.90**	**-103.0**						**268.0**				**346**		**GS135**	**Spring**	**182**	**07/31/85**
Lower Pony Spring	38.31972	-114.60722	20.0			-13.20	-101.0										359		GS142	Spring	190	07/23/81
Lower Pony Spring	38.31972	-114.60722	14.0		7.9	-13.30	-101.0	45.0	2.0	36.0	1.1	10.0	202.0	8.2	47.0	0.1	360		GS143	Spring	190	04/05/85
Lower Pony Spring	38.31972	-114.60722	**17.0**	**#DIV/0!**	**7.9**	**-13.25**	**-101.0**	**45.0**	**2.0**	**36.0**	**1.1**	**10.0**	**202.0**	**8.2**	**47.0**	**0.1**				**Spring**	**190**	
Unnamed Spring in Snow Creek	40.07837	-114.91138				-16.24	-120.9									--	62629B		DRI-CC-3	Spring	338	05/24/05
Unnamed Spring in Snow Creek	**40.07837**	**-114.91138**				**-16.24**	**-120.9**									**--**	**62629B**		**DRI-CC-3**	**Spring**	**338**	**05/24/05**
Lund Spring	38.85000	-115.00250	19.0	5.7	7.5	-15.40	-113.0	56.0	23.0	3.8	0.9	2.8	270.0	11.0	11.0	0.1	429		GS210	Spring	221	04/27/82
Lund Spring	38.85000	-115.00250	**19.0**	**5.7**	**7.5**	**-15.40**	**-113.0**	**56.0**	**23.0**	**3.8**	**0.9**	**2.8**	**270.0**	**11.0**	**11.0**	**0.1**				**Spring**	**221**	
M-8 Spring (Unnamed Spring)	36.72083	-114.72750				-12.75	-99.0										119		PLC15	Spring	68	10/30/85
M-8 Spring (Unnamed Spring)	**36.72083**	**-114.72750**				**-12.75**	**-99.0**										**119**		**PLC15**	**Spring**	**68**	**10/30/85**
M-9 Spring (Unnamed Spring)	36.72583	-114.72722				-12.45	-96.5										126		PLC16	Spring	70	10/30/85
M-9 Spring (Unnamed Spring)	**36.72583**	**-114.72722**				**-12.45**	**-96.5**										**126**		**PLC16**	**Spring**	**70**	**10/30/85**
Maynard Lake Spring (Unnamed Spring)	37.19167	-115.03389	9.6		7.9	-12.30	-94.0	43.0	23.0	114.0	14.0	30.0	405.0	88.0			186		IT136	Spring	94	01/14/85
Maynard Lake Spring (Unnamed Spring)	**37.19167**	**-115.03389**	**9.6**		**7.9**	**-12.30**	**-94.0**	**43.0**	**23.0**	**114.0**	**14.0**	**30.0**	**405.0**	**88.0**			**186**		**IT136**	**Spring**	**94**	**01/14/85**
McDermitt Spring	38.25914	-114.63164				-11.21	-94.3													Spring	323	06/26/04
McDermitt Spring	**38.25914**	**-114.63164**				**-11.21**	**-94.3**													**Spring**	**323**	**06/26/04**
Meadow Valley Wash, Cal.	37.63581	-114.51357	5.0		7.8	-13.10	-97.0	58.0	25.0	94.6	15.4	59.1	387.0	66.2	59.0	2.0	271		E27	Surface	130	12/00/79
Meadow Valley Wash, Cal.	**37.63581**	**-114.51357**	**5.0**		**7.8**	**-13.10**	**-97.0**	**58.0**	**25.0**	**94.6**	**15.4**	**59.1**	**387.0**	**66.2**	**59.0**	**2.0**	**271**		**E27**	**Surface**	**130**	**12/00/79**
Meloy Spring	38.25181	-114.70497	14.4	6.9	7.2	-12.75	-99.8	68.1	12.2	16.4	4.4	24.9	248.0	18.1	54.2	--	60845	1		Spring	276	06/26/04
Meloy Spring	**38.25181**	**-114.70497**	**14.4**	**6.9**	**7.2**	**-12.75**	**-99.8**	**68.1**	**12.2**	**16.4**	**4.4**	**24.9**	**248.0**	**18.1**	**54.2**	**--**	**60845**	**1**		**Spring**	**276**	**06/26/04**
Merril's Camp #39	38.18825	-113.866363	8.4	6.27	7.21	-14.13	-102.1	41.8	5.69	8.36	0.38	6.5	156	5.4	15.5	0.09	63597	1		Spring	410	19-Nov-05
Merril's Camp #39	**38.18825**	**-113.866363**	**8.4**	**6.27**	**7.21**	**-14.13**	**-102.1**	**41.8**	**5.69**	**8.36**	**0.38**	**6.5**	**156**	**5.4**	**15.5**	**0.09**	**63597**	**1**		**Spring**	**410**	**19-Nov-05**
Mesquite Wtr Bunkerville 1	36.77528	-114.11806	23.0		7.5	-13.51	-102.5	54.0	28.0	39.0	8.1	31.0	198.0	120.0	25.0	0.9	132		GS49	Well	74	08/17/94
Mesquite Wtr Bunkerville 1	**36.77528**	**-114.11806**	**23.0**		**7.5**	**-13.51**	**-102.5**	**54.0**	**28.0**	**39.0**	**8.1**	**31.0**	**198.0**	**120.0**	**25.0**	**0.9**	**132**		**GS49**	**Well**	**74**	**08/17/94**
Mesquite Wtr Bunkerville 2	36.77417	-114.12889	23.0		7.6	-13.51	-102.1	38.0	20.0	50.0	7.5	13.0	220.0	89.0	21.0	1.4	131		GS48	Well	73	08/18/94
Mesquite Wtr Bunkerville 2	**36.77417**	**-114.12889**	**23.0**		**7.6**	**-13.51**	**-102.1**	**38.0**	**20.0**	**50.0**	**7.5**	**13.0**	**220.0**	**89.0**	**21.0**	**1.4**	**131**		**GS48**	**Well**	**73**	**08/18/94**
Mesquite Wtr Virgin Vly 5	36.77806	-114.08417	26.5		7.4	-13.78	-103.3	110.0	54.0	100.0	7.6	100.0	145.0	440.0	22.0	0.3	133		GS50	Well	75	08/17/94
Mesquite Wtr Virgin Vly 5	**36.77806**	**-114.08417**	**26.5**		**7.4**	**-13.78**	**-103.3**	**110.0**	**54.0**	**100.0**	**7.6**	**100.0**	**145.0**	**440.0**	**22.0**	**0.3**	**133**		**GS50**	**Well**	**75**	**08/17/94**

Mesquite Wtr Virgin Vly 25	36.80833	-114.07250	23.0		7.6	-12.85	-98.9	55.0	34.0	210.0	9.3	160.0	210.0	300.0	28.0	1.2	152		GS54	Well	79	08/18/94
Mesquite Wtr Virgin Vly 25	**36.80833**	**-114.07250**	**23.0**		**7.6**	**-12.85**	**-98.9**	**55.0**	**34.0**	**210.0**	**9.3**	**160.0**	**210.0**	**300.0**	**28.0**	**1.2**	**152**		**GS54**	**Well**	**79**	**08/18/94**
Moapa Well	36.53139	-114.79667				-13.40	-99.0										999		TH-1	Well	41	04/07/00
Moapa Well	**36.53139**	**-114.79667**				**-13.40**	**-99.0**										**999**		**TH-1**	**Well**	**41**	**04/07/00**
Mike's Spring	39.643701	-114.2049	10.7	6.4	6.77	-15.89	-121.1	61.9	18.9	31.8	1.81	29.2	246	34.8	27.5	0.35	63272			Spring	390	23-Aug-05
Mike's Spring	**39.643701**	**-114.2049**	**10.7**	**6.4**	**6.77**	**-15.89**	**-121.1**	**61.9**	**18.9**	**31.8**	**1.81**	**29.2**	**246**	**34.8**	**27.5**	**0.35**	**63272**			**Spring**	**390**	**23-Aug-05**
Mirant	36.418611	-114.9575				-13.23	-96.8										USGS		618	Well	622	6/4/2003
Mirant	36.418611	-114.9575				-13.23	-96.8										USGS		618	Well	622	6/4/2003
Monitoring Spring WR1	38.94903	-115.41008	5.7	8.7	7.5	-15.58	-111.2	56.7	10.0	2.5	0.6	1.1	229.0	4.3	7.4	--	57694			Spring	320	10/12/03
Monitoring Spring WR1	38.94903	-115.41008	6.0	8.5	7.5	-15.32	-113.3	76.0	7.7	2.7	0.7	1.1	259.0	3.3	9.0	--	59578			Spring	320	03/23/04
Monitoring Spring WR1	38.94903	-115.41008	6.7	9.7	8.0	-15.62	-114.0	60.5	9.9	2.1	0.5	1.0	219.0	3.8	7.8	--	60784			Spring	320	06/21/04
Monitoring Spring WR1	38.94903	-115.41008	7.3	10.1	7.4	-15.51	-115.7	60.8	10.9	3.2	1.0	1.2	231.0	4.2	7.5	--	61478			Spring	320	09/22/04
Monitoring Spring WR1	38.94903	-115.41008	5.0	8.6	8.1	-15.58	-115.1	62.0	10.7	2.8	0.8	1.3	227.0	4.5	7.4	--	61962	5		Spring	320	01/21/05
Monitoring Spring WR1	38.94903	-115.41008	6.4	9.4	6.6	-15.55	-112.3									--	62632A		DRI-WP-1	Spring	320	05/21/05
Monitoring Spring WR1	38.94903	-115.41008	5.9	9.4	6.8	-15.63	-113.2	59.1	9.81	2.38	0.63	1.1	224.0	4.3	7.6	0.52	63218		DRI-WP-1	Spring	320	08/14/05
Monitoring Spring WR1	38.94903	-115.41008	5.7	9.79	7.2	-15.65	-113.8	57.2	10.1	2.34	0.58	1.2	211	4.5	7.4	0.11	63561			Spring	320	5-Nov-05
Monitoring Spring WR1	38.949510	-115.408980	5.7	8.11	7.51	-15.69	-113.8	55.7	9.83	2.45	0.64	1.2	208	4.7	7.3	<.1	64235		WP-1	Spring	320	02/24/06
Monitoring Spring WR1	38.949510	-115.408980	5.9	9.22	7.38	-15.38	-111.8	59.1	6.32	1.89	0.49	1.0	199	2.4	7.8	0.05	64733		WP-1	Spring	320	05/20/06
Monitoring Spring WR1	38.949510	-115.408980	-	-	-	-15.63	-114.1	-	-	-	-	-	-	-	-	-	--		WP-1	Spring	320	07/11/06
Monitoring Spring WR1	38.949510	-115.408980	5.7	8.36	7.12	-15.64	-114.7	56.2	10.1	2.41	0.58	1.3	217	4.8	7.39	0.05	65365		WP-1	Spring	320	08/29/06
Monitoring Spring WR1	38.949510	-115.408980	5.6	8.31	7.20	-15.67	-114.5	56.0	10.2	2.48	0.62	1.2	209	4.6	7.28	0.06	65743		WP-1	Spring	320	11/15/06
Monitoring Spring WR1	38.949510	-115.408980	5.9	NA	7.24	-15.61	-114.6	64.9	8.57	2.36	0.61	0.9	244	3.6	7.1	0.06	65743		WP-1	Spring	320	5/6/2007
Monitoring Spring WR1	38.94903	-115.41008	**6.0**	**9.0**	**7.4**	**-15.58**	**-113.7**	**60.4**	**9.5**	**2.5**	**0.6**	**1.2**	**223.1**	**4.1**	**7.6**	**0.1**		**14**	WP-1	**Spring**	**320**	
Moon River Spring	38.35167	-115.18083	32.5	2.3	7.4	-15.80	-120.0	55.0	22.0	22.0	4.4	9.3	260.0	44.0	25.0	1.2	362		GS145	Spring	192	04/27/82
Moon River Spring	**38.35167**	**-115.18083**	**32.5**	**2.3**	**7.4**	**-15.80**	**-120.0**	**55.0**	**22.0**	**22.0**	**4.4**	**9.3**	**260.0**	**44.0**	**25.0**	**1.2**	**362**		**GS145**	**Spring**	**192**	**04/27/82**
Moorman Spring	38.59472	-115.13833	37.0	1.7	7.0	-15.70	-119.0	58.0	19.0	24.0	5.9	9.9		47.0	27.0	1.3	405		GS185	Spring	205	07/18/81
Moorman Spring	**38.59472**	**-115.13833**	**37.0**	**1.7**	**7.0**	**-15.70**	**-119.0**	**58.0**	**19.0**	**24.0**	**5.9**	**9.9**		**47.0**	**27.0**	**1.3**	**405**		**GS185**	**Spring**	**205**	**07/18/81**
Mormon Well Spring	36.64389	-115.09778	11.5		7.3	-12.90	-92.5	81.0	40.0	11.0	0.4	24.0			16.0	0.1	94		GS32	Spring	53	10/27/81
Mormon Well Spring	36.64389	-115.09778	10.0	5.1	7.6	-12.50	-91.0	65.0	41.0	12.0	1.0	12.0	395.0	21.0	16.0	0.1	95		GS33	Spring	53	05/09/83
Mormon Well Spring	36.64389	-115.09778	12.0		7.4	-12.60	-92.0	84.0	44.0	13.0	0.5	12.0		23.0	17.0	0.2	96		GS34	Spring	53	10/07/87
Mormon Well Spring	36.64389	-115.09778	**11.2**	**5.1**	**7.4**	**-12.67**	**-91.8**	**76.7**	**41.7**	**12.0**	**0.6**	**16.0**	**395.0**	**22.0**	**16.3**	**0.1**				**Spring**	**53**	
Mud Spring (Buck Mts)	39.73587	-115.57036	11.6	9.4	6.9	-15.21	-117.6									--	62705		DRI-BK-1	Spring	339	06/05/05
Mud Spring (Buck Mts)	**39.73587**	**-115.57036**	**11.6**	**9.4**	**6.9**	**-15.21**	**-117.6**									**--**	**62705**		**DRI-BK-1**	**Spring**	**339**	**06/05/05**
Mud Sp Barcass 34 (Snake Range)	39.325706	-114.26714	6.9	7.51	7.13	-15.43	-117.1	73.4	14.5	3.02	0.64	2.5	287	5.4	10.0	<.05	63528	1		Spring	404	25-Oct-05
Mud Sp Barcass 34 (Snake Range)	**39.325706**	**-114.26714**	**6.9**	**7.51**	**7.13**	**-15.43**	**-117.1**	**73.4**	**14.5**	**3.02**	**0.64**	**2.5**	**287**	**5.4**	**10.0**	**<.05**	**63528**	**1**		**Spring**	**404**	**25-Oct-05**
Mud Spring	39.081603	-114.972414	12.4	5.02	7.31	-14.53	-111.0	62.4	11.2	14.1	0.57	8.6	235	18.4	15.2	0.11	65055		ER-29	Spring	446	07/13/06
Mud Spring	**39.081603**	**-114.972414**	**12.4**	**5.02**	**7.31**	**-14.53**	**-111.0**	**62.4**	**11.2**	**14.1**	**0.57**	**8.6**	**235**	**18.4**	**15.2**	**0.11**	**65055**		**ER-29**	**Spring**	**446**	**07/13/06**
Murphy Spring	38.33973	-115.44937	10.6	8.7	6.7	-15.40	-114.5										62833			Spring	373	07/02/05
Murphy Spring	**38.33973**	**-115.44937**	**10.6**	**8.7**	**6.7**	**-15.40**	**-114.5**										**62833**			**Spring**	**373**	**07/02/05**
Mustang Spring	37.73553	-114.92166	10.0	3.4	7.0	-12.60	-91.0	111.0	8.0	17.3	6.5	11.4	346.0	58.0	58.0		277		K6	Spring	135	01/14/85
Mustang Spring	37.73553	-114.92166	13.4	6.2	6.8	-12.37	-90.0	105.0	7.8	18.4	6.8	9.9	319.0	61.6	62.1	--	59691	1		Spring	135	03/24/04
Mustang Spring	37.73553	-114.92166	**11.7**	**4.8**	**6.9**	**-12.49**	**-90.5**	**108.0**	**7.9**	**17.9**	**6.6**	**10.7**	**332.5**	**59.8**	**60.1**	**#DIV/0!**				**Spring**	**135**	
Mustang Spring (Snake)	38.86257	-114.27179	4.3	8.4	7.1	-15.30	-111.0	68.0	4.6	1.3	0.4	0.8	5.5	218.0	5.7	2.18	62915		SN-6	Spring	382	07/14/05
Mustang Spring (Snake)	**38.86257**	**-114.27179**	**4.3**	**8.4**	**7.1**	**-15.30**	**-111.0**	**68.0**	**4.6**	**1.3**	**0.4**	**0.8**	**5.5**	**218.0**	**5.7**	**2.18**	**62915**		**SN-6**	**Spring**	**382**	**07/14/05**
MVW above Eagle Canyon	38.02778	-114.18583	19.0		8.2	-12.00	-93.0										328		E6	Surface	168	04/09/85
MVW above Eagle Canyon	**38.02778**	**-114.18583**	**19.0**		**8.2**	**-12.00**	**-93.0**										**328**		**E6**	**Surface**	**168**	**04/09/85**
Narrow Canyon Spring	37.36729	-114.67807	9.9	5.8	7.2	-12.47	-92.5	61.9	12.7	17.7	1.9	17.9	228.0	20.8	47.2	--	59683	1		Spring	257	03/22/04
Narrow Canyon Spring	**37.36729**	**-114.67807**	**9.9**	**5.8**	**7.2**	**-12.47**	**-92.5**	**61.9**	**12.7**	**17.7**	**1.9**	**17.9**	**228.0**	**20.8**	**47.2**	**--**	**59683**	**1**		**Spring**	**257**	**03/22/04**
Nellis AFB #4	36.24889	-115.00417				-13.20	-95.0										20		PLC36	Well	13	--
Nellis AFB #4	**36.24889**	**-115.00417**				**-13.20**	**-95.0**										**20**		**PLC36**	**Well**	**13**	**--**
Nellis AFB Well #13	36.21222	-115.05000				-13.80	-98.0										18		PLC34	Well	11	--
Nellis AFB Well #13	**36.21222**	**-115.05000**				**-13.80**	**-98.0**										**18**		**PLC34**	**Well**	**11**	**--**
Newels Spring	37.902479	-114.032021	21.5	7.17	7.74	-12.48	-96.0	88.0	16.9	22.6	2.39	39	289	36.5	36.1	0.46	64909		MG-6	Spring	423	06/22/06
Newels Spring	**37.902479**	**-114.032021**	**21.5**	**7.17**	**7.74**	**-12.48**	**-96.0**	**88.0**	**16.9**	**22.6**	**2.39**	**39**	**289**	**36.5**	**36.1**	**0.46**	**64909**		**MG-6**	**Spring**	**423**	**06/22/06**
Nicholas Spring	38.91062	-115.06142	22.0	3.4	7.8	-16.10	-124.0	42.0	19.0	13.0	3.3	24.0	180.0	40.0	20.0	0.6	440		GS219	Spring	227	04/27/82
Nicholas Spring	**38.91062**	**-115.06142**	**22.0**	**3.4**	**7.8**	**-16.10**	**-124.0**	**42.0**	**19.0**	**13.0**	**3.3**	**24.0**	**180.0**	**40.0**	**20.0**	**0.6**	**440**		**GS219**	**Spring**	**227**	**04/27/82**
North Creek Spring	38.71056	-114.73056	8.5		6.9	-14.60	-105.0	9.1	1.6	2.2	0.9	1.3	25.0	3.8	12.0	0.4	420		GS198	Spring	214	04/03/85
North Creek Spring	**38.71056**	**-114.73056**	**8.5**		**6.9**	**-14.60**	**-105.0**	**9.1**	**1.6**	**2.2**	**0.9**	**1.3**	**25.0**	**3.8**	**12.0**	**0.4**	**420**		**GS198**	**Spring**	**214**	**04/03/85**
North Lee Well	37.82444	-114.38444	22.0		8.0	-13.30	-101.0	59.0	12.0	44.0	9.9	48.0	220.0	33.0	54.0	1.0	299		GS109	Well	147	06/04/85
North Lee Well	**37.82444**	**-114.38444**	**22.0**		**8.0**	**-13.30**	**-101.0**	**59.0**	**12.0**	**44.0**	**9.9**	**48.0**	**220.0**	**33.0**	**54.0**	**1.0**	**299**		**GS109**	**Well**	**147**	**06/04/85**
North Spring	39.15611	-114.96306	5.5			-15.00	-113.0					4.2					459		GS245	Spring	237	06/17/83
North Springs	39.154903	-114.962777	6.3	7.14	7.42	-15.21	-111.7	54.3	9.63	3.44	0.52	1.4	201	10.7	9.3	0.10	65041		ER-15	Spring	432	07/12/06
North Spring	**39.15551**	**-114.96292**	**5.90000**	**7.14000**	**7.42000**	**-15.11**	**-112.4**	**54.30000**	**9.63000**	**3.44000**	**0.52000**	**2.80000**	**201.00000**	**10.70000**	**9.30000**	**0.10000**	**459**		**GS245**	**Spring**	**237**	**06/17/83**

Oak Spring	37.60547	-114.71015	10.5	7.1	7.1	-11.87	-90.0	84.9	16.5	64.1	2.0	41.1	355.0	34.2	56.5	--	58502	1		Spring	269	01/16/04
Oak Spring	**37.60547**	**-114.71015**	**10.5**	**7.1**	**7.1**	**-11.87**	**-90.0**	**84.9**	**16.5**	**64.1**	**2.0**	**41.1**	**355.0**	**34.2**	**56.5**	**--**	**58502**	**1**		**Spring**	**269**	**01/16/04**
Ox Valley Spring	37.970526	-114.059658	8.8	6.03	7.02	-13.95	-100.0	37.5	6.97	5.23	0.50	4.6	118	25.0	12.4	0.63	64908		MG-5	Spring	422	06/22/06
Ox Valley Spring	**37.970526**	**-114.059658**	**8.8**	**6.03**	**7.02**	**-13.95**	**-100.0**	**37.5**	**6.97**	**5.23**	**0.50**	**4.6**	**118**	**25.0**	**12.4**	**0.63**	**64908**		**MG-5**	**Spring**	**422**	**06/22/06**
Oxborrow Well	37.88611	-114.30472	11.5		7.9	-11.80	-92.0	130.0	22.0	65.0	11.0	140.0	351.0	63.0	58.0	0.8	303		GS112	Well	150	06/05/85
Oxborrow Well	**37.88611**	**-114.30472**	**11.5**		**7.9**	**-11.80**	**-92.0**	**130.0**	**22.0**	**65.0**	**11.0**	**140.0**	**351.0**	**63.0**	**58.0**	**0.8**	**303**		**GS112**	**Well**	**150**	**06/05/85**
Pahroc Spring	37.66466	-114.98065	16.0	0.8	7.6	-12.50	-89.0	30.9	8.3	12.3	5.6	11.7	135.0	11.4	59.0		272		K5	Spring	131	01/14/85
Pahroc Spring	37.66466	-114.98065	14.4	5.7	7.4	-12.65	-94.0	25.6	6.7	40.1	5.7	13.1	169.0	12.9	66.8	--	58494	1		Spring	131	01/16/04
Pahroc Spring	37.66466	-114.98065	16.0	7.3	6.6	-12.79	-93.5	31.3	8.3	12.7	5.2	12.6	134.0	12.8	62.1	--	61106C		DRI-PR-1	Spring	131	04/30/05
Pahroc Spring	37.66466	-114.98065	**15.5**	**4.6**	**7.2**	**-12.65**	**-92.2**	**29.3**	**7.8**	**21.7**	**5.5**	**12.5**	**146.0**	**12.4**	**62.6**	**#DIV/0!**				**Spring**	**131**	
Panaca Spring	37.80754	-114.38086	29.0	5.6	7.8	-13.90	-106.0	32.0	9.8	36.0	6.8	15.0		29.0	45.0	1.6	294		GS107	Spring	144	04/26/84
Panaca Spring	37.80754	-114.38086	29.5		7.9	-14.00	-108.0	34.0	10.0	38.0	7.1	16.0		25.0	50.0	1.5	292		GS105	Spring	144	04/08/85
Panaca Spring	37.80754	-114.38086	28.5	6.2	7.8	-14.20	-106.5	33.0	10.0	37.0	6.7	17.0		27.0	48.0	1.4	293		GS106	Spring	144	11/11/86
Panaca Spring	37.80754	-114.38086					-107.0										293		DRI	Spring	144	11/11/86
Panaca Spring	37.80754	-114.38086	28.4	4.0	7.8	-14.11	-107.4	32.4	10.4	38.0	7.4	17.8	176.0	30.4	52.4	--	61619			Spring	144	10/20/04
Panaca Spring	37.80754	-114.38086	28.6	5.4	7.7	-14.25	-107.9	32.6	10.3	37.9	7.2	17.3	177.0	29.3	49.7	--	61969	2		Spring	144	01/24/05
Panaca Spring	37.80754	-114.38086	28.3	4.7	7.0	-14.15	-107.1									--	62626		DRI-MW-1	Spring	144	05/20/05
Panaca Spring	37.80754	-114.38086	28.9	4.4	7.0	-14.17	-106.4										63231		DRI-MW-1	Spring	144	08/16/05
Panaca Spring	37.80754	-114.38086	28.7	4.6	7.6	-14.18	-106.8	30.0	10.3	37.6	7.00	17.4	179	29.1	49.0	1.42	63571			Spring	144	9-Nov-05
Panaca Spring	37.80754	-114.38086	28.8	4.15	7.71	-14.20	-105.8	34.2	10.2	37.9	6.97	17.9	178	29.7	48.8	1.50	64169		MW-1	Spring	144	02/17/06
Panaca Spring	37.80754	-114.38086	28.8	5.9	7.8	-14.17	-107.1	32.6	9.97	37.0	9.66	18.2	180	30.7	50.2	1.48	64743		MW-1	Spring	144	05/22/06
Panaca Spring	37.80754	-114.38086	29.10	5.85	7.67	-14.24	-107.0	32.6	10.2	34.6	6.06	17.8	184	30.5	49.8	1.51	65289		MW-1	Spring	144	08/23/06
Panaca Spring	37.80754	-114.38086	28.9	4.43	7.62	-14.14	-106.9	32.7	10.0	37.0	1.74	17.3	175	29.8	49.9	1.52	65654		MW-1	Spring	144	10/28/06
Panaca Spring	37.80754	-114.38086	**28.8**	**5.0**	**7.6**	**-14.14**	**-106.9**	**32.6**	**10.1**	**37.1**	**6.7**	**17.2**	**178.4**	**29.1**	**49.3**	**1.5**				**Spring**	**144**	
Panaca Town Well	37.79722	-114.39917	29.5		7.9	-14.00	-106.0	45.0	1.0	47.0	8.3	19.0	203.0	68.0	58.0	1.8	291		E16	Well	143	06/04/85
Panaca Town Well	**37.79722**	**-114.39917**	**29.5**		**7.9**	**-14.00**	**-106.0**	**45.0**	**1.0**	**47.0**	**8.3**	**19.0**	**203.0**	**68.0**	**58.0**	**1.8**	**291**		**E16**	**Well**	**143**	**06/04/85**
Parsnip Spring	38.14944	-114.26250	19.0		7.7	-12.80	-93.5	16.0	3.0	12.0	2.2	7.5	70.0	9.1	41.0	0.1	344		GS134	Spring	180	06/05/85
Parsnip Spring	**38.14944**	**-114.26250**	**19.0**		**7.7**	**-12.80**	**-93.5**	**16.0**	**3.0**	**12.0**	**2.2**	**7.5**	**70.0**	**9.1**	**41.0**	**0.1**	**344**		**GS134**	**Spring**	**180**	**06/05/85**
Patterson Pass Spring WR3	38.60280	-114.71481	12.0	6.0	6.6	-14.91	-106.5	58.4	9.0	22.4	0.3	10.6	230.0	23.2	17.5	--	57755			Spring	305	10/30/03
Patterson Pass Spring WR3 (duplicate sample)	38.60280	-114.71481	--	--	--	-14.94	-109.2	--	--	--	--	--	--	--	--	--	57755	5		Spring	305	10/30/03
Patterson Pass Spring WR3	38.60280	-114.71481	11.8	3.6	6.1	-16.25	-114.4	19.5	3.8	2.0	1.4	0.9	68.6	9.6	10.8	--	59579		DRI-SC-2	Spring	305	03/24/04
Patterson Pass Spring WR3	38.60280	-114.71481	11.5	6.2	7.1	-14.84	-109.1	19.8	4.6	3.0	1.5	1.2	67.0	9.8	11.1	--	60786		DRI-SC-2	Spring	305	06/23/04
Patterson Pass Spring WR3	38.60280	-114.71481	12.0	5.9	7.5	-14.79	-107.9	18.5	3.9	1.9	1.4	0.9	66.5	9.4	10.2	--	61480		DRI-SC-2	Spring	305	09/23/04
Patterson Pass Spring WR3	38.60280	-114.71481	11.7	5.5	6.8	-14.77	-108.3	20.5	4.1	2.2	1.5	1.2	71.6	9.8	10.5	--	61967		DRI-SC-2	Spring	305	01/23/05
Patterson Pass Spring WR3	38.60280	-114.71481	11.4	6.0	6.7	-14.71	-106.8									--	61481		DRI-SC-2	Spring	305	05/20/05
Patterson Pass Spring WR3	38.60280	-114.71481				-14.83	-107.6	18.8	3.66	1.89	1.41	1.0	65.5	8.7	10.1	0.73	63220		DRI-SC-2	Spring	305	08/15/05
Patterson Pass Spring WR3	38.60280	-114.71481	12.1	6.08	6.97	-14.87	-107.5	19.3	3.74	1.90	1.35	1.1	63.8	8.7	10.0	0.44	63566			Spring		11/07/05
Patterson Pass Spring WR3	38.602800	-114.714880	11.8	7.09	6.78	-14.91	-108.1	19.6	3.82	1.86	1.23	1.1	65.9	9.1	10.2	0.46	65371		SC-2	Spring	305	08/31/06
Patterson Pass Spring WR3	38.602800	-114.714880	12.2	6.80	6.87	-14.89	-108.4	19.2	3.81	2.07	1.43	1.0	66.3	8.8	10.1	0.47	65653		SC-2	Spring	305	10/28/06
Patterson Pass Spring WR3	38.602800	-114.714880	11.9	6.38	6.52	-14.90	-106.9	19.4	3.68	1.86	1.42	1.2	65.0	8.8	10.1	0.46	64239		SC-2	Spring	305	02/26/06
Patterson Pass Spring WR3	38.602800	-114.714880	11.7	7.47	6.95	-14.86	-108.5	19.2	3.80	2.2	1.20	1.2	67.2	9.1	10.2	0.47	64738		SC-2	Spring	305	05/23/06
Patterson Pass Spring WR3	38.602800	-114.714880	-	-	-	-14.86	-107.9	-	-	-	-	-	-	-	-	-	--		SC-2	Spring	305	07/14/06
Patterson Pass Spring WR3	38.602800	-114.714880	11.7	NA	6.6	-14.96	-108.5	19.9	3.82	1.99	1.40	1.0	69.0	8.4	9.59	0.47	65653		SC-2	Spring	305	5/7/2007
Patterson Pass Spring WR3	38.60280	-114.71481	**11.8**	**6.1**	**6.8**	**-14.95**	**-108.4**	**22.7**	**4.3**	**3.8**	**1.3**	**1.9**	**66.9**	**10.3**	**10.9**	**0.5**				**Spring**	**305**	
Peach Spring	36.95444	-114.28972	15.1			-10.40	-76.5										173		GS62	Spring	88	02/06/84
Peach Spring	**36.95444**	**-114.28972**	**15.1**			**-10.40**	**-76.5**										**173**		**GS62**	**Spring**	**88**	**02/06/84**
Pederson's East	36.70933	-114.71556	32.0	2.4	7.3	-12.92	-97.0	64.3	28.5	96.4	11.6	66.1	255.0	178.0	30.3	--	58497		DRI-MV-2	Spring	290	01/12/04
Pederson's East	36.70933	-114.71556	31.9	2.7	7.4	-12.92	-97.0	64.6	27.6	94.2	11.1	61.4	264.0	181.0	29.1	--	60307		DRI-MV-2	Spring	290	05/18/04
Pederson's East	36.70933	-114.71556				-12.98	-98.4	68.2	28.3	94.0	11.3	61.5	257.0	178.0	31.2	--	61613		DRI-MV-2	Spring	290	10/19/04
Pederson's East	36.70933	-114.71556	31.2	3.2	7.4	-12.89	-98.3	64.4	27.7	95.6	11.2	62.0	253.0	181.0	29.5	--	62032	4	DRI-MV-2	Spring	290	02/10/05
Pederson's East	36.70933	-114.71556	32.0	3.0	6.8	-12.96	-98.3									--	62033		DRI-MV-2	Spring	290	06/08/05
Pederson East	36.709330	-114.715560	31.6	2.7	7.32	-13.00	-97.5	64.8	27.7	95.7	10.1	61.0	254	180	29.1	2.19	64173		MV-2	Spring	290	02/16/06
Pederson East	36.709330	-114.715560	31.7	2.65	7.28	-13.02	-97.7	63.4	27.3	92.7	11.1	61.7	253	182	29.4	2.19	64901		MV-2	Spring	290	06/21/06
Pederson East	36.709330	-114.715560	32.00	2.76	7.25	-13.06	-97.4	64.8	28.1	86.0	9.64	61.8	257	183	29.1	2.16	65287		MV-2	Spring	290	08/23/06
Pederson East	36.709330	-114.715560	31.9	2.63	7.30	-13.03	-98.7	63.9	27.8	93.3	11.0	59.3	253	179	29.0	2.20	65663		MV-2	Spring	290	10/30/06
Pederson's East	36.70933	-114.71556	**31.8**	**2.8**	**7.3**	**-12.98**	**-97.8**	**64.8**	**27.9**	**93.5**	**10.9**	**61.9**	**255.8**	**180.3**	**29.6**	**2.2**				**Spring**	**290**	
Pederson's Warm Spring (M-13)	36.70958	-114.71594					-98.0										113.2		jim	Spring	67	1/00/69
Pederson's Warm Spring (M-13)	36.70958	-114.71594					-97.0										113.2		jim	Spring	67	3/00/70
Pederson's Warm Spring (M-13)	36.70958	-114.71594	32.5		7.2	-12.90	-96.5	66.0	26.0	96.0	10.0	61.0	270.0	190.0	62.1	2.1	113		IT249	Spring	67	07/22/81
Pederson's Warm Spring (M-13)	36.70958	-114.71594				-12.75	-97.0										118		PLC17	Spring	67	10/30/85
Pederson's Warm Spring (M-13)	36.70958	-114.71594				-13.05	-99.0										115		IT251	Spring	67	01/07/88
Pederson's Warm Spring (M-13)	36.70958	-114.71594				-12.85	-96.9										USGS			spring		7/30/2003
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.6	2.2	7.3	-12.91	-97.2	65.3	28.4	99.2	11.4	67.7	261.0	189.0	28.4	--	58488		DRI-MV-1	Spring	67	01/12/04
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.1	3.8	7.4	-12.85	-97.5	65.4	27.8	97.2	10.9	65.9	265.0	184.0	29.2	--	60306		DRI-MV-1	Spring	67	05/18/04
Pederson's Warm Spring (M-13)	36.70958	-114.71594				-12.92	-97.4	64.5	27.8	97.2	11.0	63.0	257.0	183.0	30.6	--	61617		DRI-MV-1	Spring	67	10/19/04
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.2	3.0	7.3	-12.91	-98.0	64.8	27.4	98.8	10.9	63.2	256.0	186.0	29.8	--	62031	4	DRI-MV-1	Spring	67	02/10/05
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.9	3.6	7.0	-12.91	-97.6									--	62032		DRI-MV-1	Spring	67	06/08/05
Pederson's Warm Spring (M-13)	36.709580	-114.715940	31.3	2.65	7.34	-13.02	-97.2	66.6	27.7	99.2	10.6	62.4	255	185	29.4	2.20	64172		MV-1	Spring	67	02/16/06
Pederson's Warm Spring (M-13)	36.709580	-114.715940	31.6	4.3	7.39	-12.98	-98.1	64.1	27.2	95.2	10.9	62.9	255	186	29.1	2.18	64900		MV-1	Spring	67	06/21/06
Pederson's Warm Spring (M-13)	36.709580	-114.715940	31.80	2.92	7.24	-13.01	-97.7	65.3	28.2	90.0	9.3	63.7	251	187	29.2	2.15	65286		MV-1	Spring	67	08/23/06
Pederson's Warm Spring (M-13)	36.709580	-114.715940	31.5	2.33	7.35	-13.04	-97.3	64.8	27.8	97.0	10.9	61.3	254	184	28.8	2.23	65664		MV-1	Spring	67	10/30/06
Pederson's Warm Spring (M-13)	36.70958	-114.71594	**31.6**	**3.1**	**7.3**	**-12.93**	**-97.5**	**65.2**	**27.6**	**96.6**	**10.7**	**63.5**	**258.2**	**186.0**	**33.0**	**2.2**		**9**		**Spring**	**67**	
Perry Sp Barcass 37	38.332851	-114.975864	12.1	4.81	7.06	-15.04	-107.7	78.9	20.9	24.1	2.64	19.1	333	25.1	27.9	0.22	63531	1		Spring	408	27-Oct-05
Perry Sp Barcass 37	**38.332851**	**-114.975864**	**12.1**	**4.81**	**7.06**	**-15.04**	**-107.7**	**78.9**	**20.9**	**24.1**	**2.64**	**19.1**	**333**	**25.1**	**27.9**	**0.22**	**63531**	**1**		**Spring**	**408**	**27-Oct-05**

SE ROA 46790

Pine Spring	37.90800	-114.55132	4.5			-13.40	-99.0										312	1	GS116	Spring	157	04/07/85
Pine Spring	37.90800	-114.55132	--	--	--	-13.33	-99.0	--	--	--	--	--	--	--	--	--	--	1		Spring	157	06/24/04
Pine Spring	**37.90800**	**-114.55132**	**4.5**	**#DIV/0!**	**#DIV/0!**	**-13.37**	**-99.0**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**		**2**		**Spring**	**157**	
Pine Springs (Egan Range)	39.117546	-114.944249	8.7	7.9	7.9	-15.71	-116.0	71.1	9.58	3.69	0.46	0.7	246	13.9	10.9	0.10	65043		ER-17	Spring	434	07/12/06
Pine Springs (Egan Range)	**39.117546**	**-114.944249**	**8.7**	**7.9**	**7.9**	**-15.71**	**-116.0**	**71.1**	**9.58**	**3.69**	**0.46**	**0.7**	**246**	**13.9**	**10.9**	**0.10**	**65043**		**ER-17**	**Spring**	**434**	**07/12/06**
Preston Big Spring	38.93331	-115.08222	21.0	3.1	7.7	-15.60	-126.0	44.0	20.0	13.0	2.9	14.0	185.0	36.0	20.0	0.4	450		GS224	Spring	231	06/16/83
Preston Big Spring	38.93331	-115.08222	22.0	3.1	7.7	-15.90	-123.0	45.0	20.0	13.0	3.0	15.0		38.0	19.0	0.4	452		GS226	Spring	231	06/26/84
Preston Big Spring	38.93331	-115.08222	21.2	2.6	7.3	-15.87	-122.6	40.7	19.4	13.6	3.1	15.9	182.0	37.7	19.9	--	61483		DRI-WV-1	Spring	231	09/25/04
Preston Big Spring	38.93331	-115.08222	20.8	3.1	7.6	-15.89	-122.4	41.9	19.8	13.0	3.2	16.0	176.0	38.1	19.9	--	61968	2	DRI-WV-1	Spring	231	01/24/05
Preston Big Spring	38.93331	-115.08222	21.1	3.1	7.5	-15.86	-120.0									--	62627		DRI-WV-1	Spring	231	05/21/05
Preston Big Spring	38.93331	-115.08222	21.1	3.0	7.0	-15.88	-121.2										63227		DRI-WV-1	Spring	231	08/14/05
Preston Big Spring	38.93331	-115.08222	20.9	2.6	7.77	-15.86	-120.4	41.9	19.6	12.6	3.08	15.8	174	38.1	20.0	0.34	63563			Spring	231	6-Nov-05
Preston Big Spring	38.933310	-115.082220	21.3	3.79	7.66	-15.95	-121.8	41.6	19.2	13.2	3.16	16.5	175	39.9	20.4	0.36	64735		WV-1	Spring	231	05/20/06
Preston Big Spring	38.933310	-115.082220	-	-	-	-15.98	-121.7	-	-	-	-	-	-	-	-	-	--		WV-1	Spring	231	07/12/06
Preston Big Spring	38.933310	-115.082220	21	2.7	7.54	-15.96	-121.6	42.0	19.7	12.5	2.94	16.1	183	39.6	19.9	0.35	65366		WV-1	Spring	231	08/29/06
Preston Big Spring	38.933310	-115.082220	21.0	3.04	7.66	-15.88	-120.9	41.8	19.6	12.7	3.16	15.6	174	39.0	19.8	0.36	65652		WV-1	Spring	231	10/27/06
Preston Big Spring	38.93331	-115.08222	**21.1**	**3.0**	**7.6**	**-15.88**	**-122.0**	**42.4**	**19.7**	**13.0**	**3.1**	**15.6**	**178.4**	**38.3**	**19.9**	**0.4**				**Spring**	**231**	
Quaking Aspen Spring	37.37563	-114.24255	9.6	3.2	6.2	-12.98	-93.6	13.8	3.7	11.4	1.5	4.1	83.3	2.1	49.6	--	61100	1		Spring	255	07/31/04
Quaking Aspen Spring	**37.37563**	**-114.24255**	**9.6**	**3.2**	**6.2**	**-12.98**	**-93.6**	**13.8**	**3.7**	**11.4**	**1.5**	**4.1**	**83.3**	**2.1**	**49.6**	**--**	**61100**	**1**		**Spring**	**255**	**07/31/04**
Rabbit Brush	39.18383	-114.27363	--	--	--	-15.50	-117.1											1.00		Spring	412	26-Oct-05
Rabbit Brush	**39.18383**	**-114.27363**	**--**	**--**	**--**	**-15.50**	**-117.1**											**1.00**		**Spring**	**412**	**26-Oct-05**
Railroad Well	37.35111	-114.53389	16.0		7.6	-11.60	-86.0	42.0	14.0	98.0	8.8	42.0	300.0	60.0	51.0	2.3	204		GS77	Well	103	01/31/84
Railroad Well	**37.35111**	**-114.53389**	**16.0**		**7.6**	**-11.60**	**-86.0**	**42.0**	**14.0**	**98.0**	**8.8**	**42.0**	**300.0**	**60.0**	**51.0**	**2.3**	**204**		**GS77**	**Well**	**103**	**01/31/84**
Railroad Well (Farrier, NV)	36.81361	-114.65389	22.8		8.0	-12.50	-97.5	84.0	31.0	150.0	19.0	52.0	64.0	550.0	23.0	1.6	154		USGS	Well	80	02/04/84
Railroad Well (Farrier, NV)	**36.81361**	**-114.65389**	**22.8**		**8.0**	**-12.50**	**-97.5**	**84.0**	**31.0**	**150.0**	**19.0**	**52.0**	**64.0**	**550.0**	**23.0**	**1.6**	**154**		**USGS**	**Well**	**80**	**02/04/84**
Raised Sp Barcass 36	38.972591	-114.370414	10.8	7.62	6.07	-13.54	-103.7	7.01	1.77	2.38	0.66	1.0	31.2	2.4	11.4	0.05	63532	1		Spring	407	27-Oct-05
Raised Sp Barcass 36	**38.972591**	**-114.370414**	**10.8**	**7.62**	**6.07**	**-13.54**	**-103.7**	**7.01**	**1.77**	**2.38**	**0.66**	**1.0**	**31.2**	**2.4**	**11.4**	**0.05**	**63532**	**1**		**Spring**	**407**	**27-Oct-05**
Ram. Res. Wtr Supply Well	39.74333	-115.45111	11.9	50.0	8.0	-16.75	-129.5						155.0				470		GS261	Well	244	07/19/85
Ram. Res. Wtr Supply Well	**39.74333**	**-115.45111**	**11.9**	**50.0**	**8.0**	**-16.75**	**-129.5**						**155.0**				**470**		**GS261**	**Well**	**244**	**07/19/85**
Ramone Mathews Well	37.52667	-114.24417	18.5		7.8	-12.30	-92.0	42.0	6.3	20.0	5.9	15.0	171.0	12.0	61.0	0.3	233		GS86	Well	115	06/03/85
Ramone Mathews Well	**37.52667**	**-114.24417**	**18.5**		**7.8**	**-12.30**	**-92.0**	**42.0**	**6.3**	**20.0**	**5.9**	**15.0**	**171.0**	**12.0**	**61.0**	**0.3**	**233**		**GS86**	**Well**	**115**	**06/03/85**
Randono Well	37.32389	-114.50222	17.2		7.6	-11.70	-87.5	46.0	14.0	100.0	8.4	44.0	350.0	63.0	54.0	2.3	200		GS75	Well	100	02/03/84
Randono Well	**37.32389**	**-114.50222**	**17.2**		**7.6**	**-11.70**	**-87.5**	**46.0**	**14.0**	**100.0**	**8.4**	**44.0**	**350.0**	**63.0**	**54.0**	**2.3**	**200**		**GS75**	**Well**	**100**	**02/03/84**
Rattlesnake Spring	37.82624	-114.93012	14.1	7.4	7.8	-12.65	-97.3	47.6	7.5	27.6	5.2	16.5	199.0	19.3	52.5	--	59692	1		Spring	302	03/24/04
Rattlesnake Spring	**37.82624**	**-114.93012**	**14.1**	**7.4**	**7.8**	**-12.65**	**-97.3**	**47.6**	**7.5**	**27.6**	**5.2**	**16.5**	**199.0**	**19.3**	**52.5**	**--**	**59692**	**1**		**Spring**	**302**	**03/24/04**
Red Rock Spring	37.56698	-114.75320	10.0	--	7.3	-12.30	-95.0	85.4	13.3	28.4	2.4	15.7	332.0	16.3	41.1	--	58495	1		Spring	256	01/10/04
Red Rock Spring	**37.56698**	**-114.75320**	**10.0**	**--**	**7.3**	**-12.30**	**-95.0**	**85.4**	**13.3**	**28.4**	**2.4**	**15.7**	**332.0**	**16.3**	**41.1**	**--**	**58495**	**1**		**Spring**	**256**	**01/10/04**
Reed Spring	37.55731	-115.41800	--	--	--	-14.24	-98.4	49.6	14.2	13.7	2.8	17.3	199.0	18.9	43.9	--	60843	1		Spring	289	06/25/04
Reed Spring	**37.55731**	**-115.41800**	**--**	**--**	**--**	**-14.24**	**-98.4**	**49.6**	**14.2**	**13.7**	**2.8**	**17.3**	**199.0**	**18.9**	**43.9**	**--**	**60843**	**1**		**Spring**	**289**	**06/25/04**
Ripgut Sp #40	38.248018	-114.039204	18.7	5.67	6.95	-14.38	-106.4	25.2	4.58	18.2	8.17	17.0	116	6.4	63.5	0.15	63598	1		Spring	411	19-Nov-05
Ripgut Sp #40	**38.248018**	**-114.039204**	**18.7**	**5.67**	**6.95**	**-14.38**	**-106.4**	**25.2**	**4.58**	**18.2**	**8.17**	**17.0**	**116**	**6.4**	**63.5**	**0.15**	**63598**	**1**		**Spring**	**411**	**19-Nov-05**
Robison Spring	38.21273	-114.70636	--	--	--	-12.34	-97.9	--	--	--	--	--	--	--	--	--	--	1		Spring	279	06/29/04
Robison Spring	**38.21273**	**-114.70636**	**--**	**--**	**--**	**-12.34**	**-97.9**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**279**	**06/29/04**
Robbers Roost #2 Spring (Butte)	39.49596	-115.28046	12.7	1.3	6.2	-14.39	-112.0									--	62703		DRI-BT-5	Spring	340	06/04/05
Robbers Roost #2 Spring (Butte)	**39.49596**	**-115.28046**	**12.7**	**1.3**	**6.2**	**-14.39**	**-112.0**									**--**	**62703**		**DRI-BT-5**	**Spring**	**340**	**06/04/05**
Robbers Roost Spring (Schell Ck)	38.77051	-114.78331				-14.75	-109.7	58.8	27.9	11.2	0.56	7.2	304.0	21.7	14.3	0.10	62978		SC-5	Spring	389	07/31/01
Robbers Roost Spring (Schell Ck)	**38.77051**	**-114.78331**				**-14.75**	**-109.7**	**58.8**	**27.9**	**11.2**	**0.56**	**7.2**	**304.0**	**21.7**	**14.3**	**0.10**	**62978**		**SC-5**	**Spring**	**389**	**07/31/01**
Rock Springs	39.859787	-114.472767	9.4	5.1	6.05	-15.17	-118.4	50.0	8.01	12.5	0.91	5.8	188	15.7	38.2	0.05	63281	1		Spring	399	25-Aug-05
Rock Springs	**39.859787**	**-114.472767**	**9.4**	**5.1**	**6.05**	**-15.17**	**-118.4**	**50.0**	**8.01**	**12.5**	**0.91**	**5.8**	**188**	**15.7**	**38.2**	**0.05**	**63281**	**1**		**Spring**	**399**	**25-Aug-05**
Rogers Spring	36.37750	-114.44389	30.5	2.3	7.0	-12.20	-92.0	410.0	140.0	280.0	21.0	330.0		1600.0	18.0	1.3	35		GS10	Spring	21	07/21/81
Rogers Spring	36.37750	-114.44389	30.0		7.5	-12.40	-92.0	423.0	143.0	291.0	22.7	327.0	161.0	1620.0	16.8	1.4	33		PL11	Spring	21	03/19/92
Rogers Spring	36.37750	-114.44389	30.0	2.6	7.0	-12.40	-91.0										32		PL11	Spring	21	02/08/96
Rogers Spring	36.37750	-114.44389	**30.2**	**2.5**	**7.2**	**-12.33**	**-91.7**	**416.5**	**141.5**	**285.5**	**21.9**	**328.5**	**161.0**	**1610.0**	**17.4**	**1.4**		**2**		**Spring**	**21**	
Ryans Spring D 38	38.331207	-113.928551	8	2.2	7.07	-13.68	-103.5	80.8	8.31	24.9	0.91	41.5	264	22.8	33.3	0.09	63596			Spring	409	19-Nov-05
Ryans Spring D 38	**38.331207**	**-113.928551**	**8**	**2.2**	**7.07**	**-13.68**	**-103.5**	**80.8**	**8.31**	**24.9**	**0.91**	**41.5**	**264**	**22.8**	**33.3**	**0.09**	**63596**			**Spring**	**409**	**19-Nov-05**
Rye Patch Spring	36.57967	-115.30586	9.7	8.1	7.5	-12.31	-89.3	49.5	24.2	16.0	2.0	17.5	218.0	22.0	13.7	--	62397		DRI-SR-5	Spring	341	04/28/05
Rye Patch Spring	**36.57967**	**-115.30586**	**9.7**	**8.1**	**7.5**	**-12.31**	**-89.3**	**49.5**	**24.2**	**16.0**	**2.0**	**17.5**	**218.0**	**22.0**	**13.7**	**--**	**62397**		**DRI-SR-5**	**Spring**	**341**	**04/28/05**
Saddle Spring (White Pine)	38.97541	-115.40023				-15.00	-116.0					3.1					438	1	GS217	Spring	225	06/15/83
Saddle Spring (White Pine)	38.97541	-115.40023	7.6	6.9	6.2	-15.66	-118.6										62820	1	WP-2	Spring	357	06/28/05
Saddle Spring (White Pine)	38.97541	-115.40023	--	--	--	-15.70	-115.7	--	--	--	--	--	--	--	--	--		1	WP-2	Spring	357	10/12/03
Saddle Spring (White Pine)	38.97541	-115.40023	**7.6**	**6.9**	**6.2**	**-15.45**	**-116.8**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**		**3**		**Spring**	**357**	

Sage Hen Spring	39.11533	-115.39212	7.7	7.0	6.2	-14.76	-112.4									--	62714		DRI-WP-9	Spring	342	06/06/05
Sage Hen Spring	**39.11533**	**-115.39212**	**7.7**	**7.0**	**6.2**	**-14.76**	**-112.4**									**--**	**62714**		**DRI-WP-9**	**Spring**	**342**	**06/06/05**
Sand Spring	39.33056	-115.45500	13.0			-16.20	-123.0										465		GS250	Spring	239	07/14/81
Sand Spring	**39.33056**	**-115.45500**	**13.0**			**-16.20**	**-123.0**										**465**		**GS250**	**Spring**	**239**	**07/14/81**
Sammy Spring	39.43597	-115.32453	11.6	6.9	6.9	-15.30	-117.6									--	62628		DRI-BT-2	Spring	343	05/24/05
Sammy Spring	**39.43597**	**-115.32453**	**11.6**	**6.9**	**6.9**	**-15.30**	**-117.6**									**--**	**62628**		**DRI-BT-2**	**Spring**	**343**	**05/24/05**
Sandstone Spring	36.21111	-114.55667	11.0	2.0	7.0	-10.50	-79.0	209.0	79.2	21.9	5.0	16.9	249.0	725.0	13.8		17		PL16	Spring	10	02/07/96
Sandstone Spring	**36.21111**	**-114.55667**	**11.0**	**2.0**	**7.0**	**-10.50**	**-79.0**	**209.0**	**79.2**	**21.9**	**5.0**	**16.9**	**249.0**	**725.0**	**13.8**		**17**		**PL16**	**Spring**	**10**	**02/07/96**
Sawmill Spring (Sheep)	36.68056	-115.17611				-12.85	-92.0	12.0	29.0	1.8	0.6	2.1		5.9	6.1	0.2	101		GS36	Spring	58	05/19/88
Sawmill Spring (Sheep)	**36.68056**	**-115.17611**				**-12.85**	**-92.0**	**12.0**	**29.0**	**1.8**	**0.6**	**2.1**		**5.9**	**6.1**	**0.2**	**101**		**GS36**	**Spring**	**58**	**05/19/88**
Sawmill Spring (Delamar Range)	37.36762	-114.69708	10.3	10.3	6.9	-12.58	-88.7	56.2	10.4	18.9	2.2	16.6	220.0	19.0	41.7	--	59685	1		Spring	259	03/22/04
Sawmill Spring (Delamar Range)	**37.36762**	**-114.69708**	**10.3**	**10.3**	**6.9**	**-12.58**	**-88.7**	**56.2**	**10.4**	**18.9**	**2.2**	**16.6**	**220.0**	**19.0**	**41.7**	**--**	**59685**	**1**		**Spring**	**259**	**03/22/04**
Sawmill Spring West	37.36734	-114.69749	9.7	6.6	6.5	-12.86	-91.8	33.9	4.6	12.1	2.0	7.4	146.0	7.0	36.8	--	59684	1		Spring	258	03/22/04
Sawmill Spring West	**37.36734**	**-114.69749**	**9.7**	**6.6**	**6.5**	**-12.86**	**-91.8**	**33.9**	**4.6**	**12.1**	**2.0**	**7.4**	**146.0**	**7.0**	**36.8**	**--**	**59684**	**1**		**Spring**	**258**	**03/22/04**
Scirpus Spring (No spring on Map)	36.37694	-114.44917	17.0	0.7	7.1	-12.00	-90.0	513.0	186.0	350.0	25.3	386.0	266.0	2040.0	20.4		30		PL12	Spring	20	02/07/96
Scirpus Spring (No spring on Map)	**36.37694**	**-114.44917**	**17.0**	**0.7**	**7.1**	**-12.00**	**-90.0**	**513.0**	**186.0**	**350.0**	**25.3**	**386.0**	**266.0**	**2040.0**	**20.4**		**30**		**PL12**	**Spring**	**20**	**02/07/96**
Scotty Spring	38.16479	-114.68374	14.2	1.9	7.1	-12.73	-98.9	67.3	12.6	23.0	1.4	30.7	254.0	21.1	44.6	--	60846	1		Spring	272	06/26/04
Scotty Spring	**38.16479**	**-114.68374**	**14.2**	**1.9**	**7.1**	**-12.73**	**-98.9**	**67.3**	**12.6**	**23.0**	**1.4**	**30.7**	**254.0**	**21.1**	**44.6**	**--**	**60846**	**1**		**Spring**	**272**	**06/26/04**
Seaman Spring	37.86120	-115.19877	--	--	--	-13.13	-99.0	--	--	--	--	--	--	--	--	--	--	1		Spring	306	06/25/04
Seaman Spring	**37.86120**	**-115.19877**	**--**	**--**	**--**	**-13.13**	**-99.0**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**306**	**06/25/04**
Second Sawmill Spring	38.87583	-114.89861	6.5			-14.70	-110.0										431		GS212	Spring	222	08/01/85
Second Sawmill Spring	**38.87583**	**-114.89861**	**6.5**			**-14.70**	**-110.0**										**431**		**GS212**	**Spring**	**222**	**08/01/85**
Secret Spring	38.83889	-115.28972				-14.00	-110.0					11.0					427		GS208	Spring	220	06/16/83
Secret Spring	**38.83889**	**-115.28972**				**-14.00**	**-110.0**					**11.0**					**427**		**GS208**	**Spring**	**220**	**06/16/83**
Sheep Spring (Clover)	37.40063	-114.27779	10.0		6.8	-12.00	-87.0	24.0	5.0	9.8	1.3	7.9	96.0	7.0	33.0	0.7	209.5		Jim	Spring	108	06/03/85
Sheep Spring (Clover)	37.40063	-114.27779	18.5	1.1	6.9	-12.06	-90.5	32.7	6.5	11.8	2.0	9.8	143.0	5.1	45.5	--	61097	1	DRI-CR-9	Spring	108	07/31/04
Sheep Spring (Clover)	37.40063	-114.27779	**14.3**	**1.1**	**6.9**	**-12.03**	**-88.8**	**28.4**	**5.7**	**10.8**	**1.7**	**8.9**	**119.5**	**6.1**	**39.3**	**0.7**	**209.5**			**Spring**	**108**	
Sheep Spring (Schell Ck)	38.67611	-114.77667	14.0	6.7	6.6	-13.70	-99.5	8.0	2.1	2.8		1.5	46.0	4.1	14.0	<.1	418		GS194	Spring	212	08/02/85
Sheep Spring (Schell Ck)	**38.67611**	**-114.77667**	**14.0**	**6.7**	**6.6**	**-13.70**	**-99.5**	**8.0**	**2.1**	**2.8**		**1.5**	**46.0**	**4.1**	**14.0**	**<.1**	**418**		**GS194**	**Spring**	**212**	**08/02/85**
Sheep Spring (Sheep Range)	36.89500	-115.11472	15.0	6.5	7.8	-13.35	-96.0	31.0	40.0	7.9	1.1	7.1		13.0	13.0	0.2	159		GS57	Spring	83	05/19/88
Sheep Spring (Sheep Range)	**36.89500**	**-115.11472**	**15.0**	**6.5**	**7.8**	**-13.35**	**-96.0**	**31.0**	**40.0**	**7.9**	**1.1**	**7.1**		**13.0**	**13.0**	**0.2**			**GS57**	**Spring**	**83**	**05/19/88**
Shellback Spring	39.13197	-115.38436	7.7	8.8	6.5	-16.54	-123.6									--	62719		DRI-WP-14	Spring	344	06/07/05
Shellback Spring	**39.13197**	**-115.38436**	**7.7**	**8.8**	**6.5**	**-16.54**	**-123.6**									**--**			**DRI-WP-14**	**Spring**	**344**	**06/07/05**
Shingle Spring	38.53972	-114.93472	15.0			-13.25	-103.5										388		GS168	Spring	203	08/03/85
Shingle Spring	38.539585	-114.935526	15.2	4.34	7.15	-13.41	-103.8	61.7	18.8	15.6	2.51	16.2	260	23.3	44.8	0.17	65048		ER-22	Spring	439	07/13/06
Shingle Spring	**38.53972**	**-114.93472**	**15.1**	**4.3**	**7.2**	**-13.33**	**-103.7**	**61.7**	**18.8**	**15.6**	**2.5**	**16.2**	**260.0**	**23.3**	**44.8**	**0.2**			**GS168**	**Spring**	**203**	**08/03/85**
Sidehill Spring	38.41596	-114.79613	13.0			-13.05	-100.0										377		GS160	Spring	200	08/02/85
Sidehill Spring	38.41596	-114.79613	12.6	6.3	6.8	-13.37	-100.8	50.9	16.6	12.5	1.14	6.9	242.0	11.9	51.4	0.08	62981			Spring	200	08/01/05
Sidehill Spring	38.41596	-114.79613	**12.8**	**6.3**	**6.8**	**-13.21**	**-100.4**	**50.9**	**16.6**	**12.5**	**1.1**	**6.9**	**242.0**	**11.9**	**51.4**	**0.1**			**GS160**	**Spring**	**200**	
Silver Spring	38.81085	-114.88121	9.3	7.84	6.72	-14.74	-111.9	80.6	5.42	5.40	0.66	3.5	261	10.3	12.5	0.09	62975		ER-7	Spring	385	07/29/05
Silver Spring (RS)	38.810613	-114.881175	9	8.25	7.43	-14.68	-110.8	79.9	5.50	5.45	0.59	3.1	255	10.7	12.6	0.07	65051		ER-25	Spring	442	07/13/06
Silver Spring	**38.81085**	**-114.88121**	**9.15**	**8.045**	**7.075**	**-14.71**	**-111.4**	**80.25**	**5.46**	**5.425**	**0.625**	**3.3**	**258**	**10.5**	**12.55**	**0.08**	**62975**		**ER-7**	**Spring**	**385**	**07/29/05**
Sixmile Spring	37.49222	-115.08806	22.0		7.9	-13.06	-93.4	45.2	10.6	16.9	1.3	3.2	207.0	11.7	49.6	0.1	230		IT151	Spring	112	08/08/95
Sixmile Spring	**37.49222**	**-115.08806**	**22.0**		**7.9**	**-13.06**	**-93.4**	**45.2**	**10.6**	**16.9**	**1.3**	**3.2**	**207.0**	**11.7**	**49.6**	**0.1**			**IT151**	**Spring**	**112**	**08/08/95**
SK-10	38.75000	-115.17000					-119.0					16.3					423		Kirk110	Well	218	--
SK-10	**38.75000**	**-115.17000**					**-119.0**					**16.3**					**423**		**Kirk110**	**Well**	**218**	**--**
SK-18	37.71000	-114.80000					-95.0					11.3					276		Kirk130	Well	134	--
SK-18	**37.71000**	**-114.80000**					**-95.0**					**11.3**					**276**		**Kirk130**	**Well**	**134**	**--**
Snow Creek Spring (Unnamed Spring in Snow Creek)	40.07837	-114.91138	7.9	9.3	7.2	-16.22	-120.7									--	62629A		DRI-CC-2	Spring	345	05/24/05
Snow Creek Spring (Unnamed Spring in Snow Creek)	**40.07837**	**-114.91138**	**7.9**	**9.3**	**7.2**	**-16.22**	**-120.7**									**--**	**62629A**		**DRI-CC-2**	**Spring**	**345**	**05/24/05**
Snowmelt Below Duckwater Peak	38.90056	-115.38250	10.0			-14.10	-105.0					0.6					437		GS216	Surface	224	06/15/83
Snowmelt Below Duckwater Peak	**38.90056**	**-115.38250**	**10.0**			**-14.10**	**-105.0**					**0.6**					**437**		**GS216**	**Surface**	**224**	**06/15/83**
South Monument Spring	38.25586	-114.11651	9.1	5.8	7.1	-14.23	-102.3	25.5	5.6	12.6	5.8	22.5	101.0	8.6	55.5	--	60318	1		Spring	319	05/21/04
South Monument Spring	**38.25586**	**-114.11651**	**9.1**	**5.8**	**7.1**	**-14.23**	**-102.3**	**25.5**	**5.6**	**12.6**	**5.8**	**22.5**	**101.0**	**8.6**	**55.5**	**--**	**60318**	**1**		**Spring**	**319**	**05/21/04**
South Spring (Egan)	39.14556	-114.97000	7.0			-15.00	-111.0					3.0					458		GS244	Spring	236	06/17/83
South Springs	39.145258	-114.972867	6.8	8.83	7.8	-15.23	-111.9	46.6	10.9	5.15	0.53	2.3	190	11.2	9.5	0.11	65040		ER-14	Spring	431	07/12/06
South Spring (Egan)	**39.14556**	**-114.97000**	**6.9**	**8.8**	**7.8**	**-15.12**	**-111.5**	**46.6**	**10.9**	**5.2**	**0.5**	**2.7**	**190.0**	**11.2**	**9.5**	**0.1**	**458**		**GS244**	**Spring**	**236**	**06/17/83**
South Spring (Snake)	38.80405	-114.17588	9.7	5.7	6.9	-14.70	-108.0	66.3	28.8	2.2	0.5	2.6	3.4	343.0	7.6	0.18	62917		SN-7	Spring	383	07/14/05
South Spring (Snake)	**38.80405**	**-114.17588**	**9.7**	**5.7**	**6.9**	**-14.70**	**-108.0**	**66.3**	**28.8**	**2.2**	**0.5**	**2.6**	**3.4**	**343.0**	**7.6**	**0.18**	**62917**		**SN-7**	**Spring**	**383**	**07/14/05**

Spencer Well	37.39500	-115.18028	19.0		7.7	-13.68	-104.1	53.8	44.0	119.4	14.5	45.9	466.0	158.0	59.8	1.6	206		IT155	Well	106	08/06/95
Spencer Well	**37.39500**	**-115.18028**	**19.0**		**7.7**	**-13.68**	**-104.1**	**53.8**	**44.0**	**119.4**	**14.5**	**45.9**	**466.0**	**158.0**	**59.8**	**1.6**	**206**		**IT155**	**Well**	**106**	**08/06/95**
Spring Creek Spring	38.90935	-114.11295	12.9	8.1	7.3	-15.40	-113.0	64.2	7.9	6.9	1.2	6.7	12.5	227.0	11.5	1.51	62916		SN-8	Spring	384	07/16/05
Spring Creek Spring	**38.90935**	**-114.11295**	**12.9**	**8.1**	**7.3**	**-15.40**	**-113.0**	**64.2**	**7.9**	**6.9**	**1.2**	**6.7**	**12.5**	**227.0**	**11.5**	**1.51**	**62916**		**SN-8**	**Spring**	**384**	**07/16/05**
Unnamed Spring below Currant Mtn	38.89417	-115.38278	18.0			-14.00	-107.0					11.0					439		GS213	Spring	226	06/15/83
Unnamed Spring below Currant Mtn	**38.89417**	**-115.38278**	**18.0**			**-14.00**	**-107.0**					**11.0**					**439**		**GS213**	**Spring**	**226**	**06/15/83**
Unnamed Spring nr Redd's Cabin Summit	38.12512	-114.06920	8.0		7.9	-12.50	-95.0	92.0	19.0	26.0	2.4	23.0		25.0	23.0	0.3	334		GS128	Spring	173	04/09/85
Unnamed Spring nr Redd's Cabin Summit	38.12512	-114.06920	15.9	7.7	7.9	-12.37	-93.7	93.1	21.3	30.9	1.3	26.9	374.0	31.6	25.5	--	60315	1	WM-3	Spring	173	05/21/04
Unnamed Spring nr Redd's Cabin Summit	**38.12512**	**-114.06920**	**12.0**	**7.7**	**7.9**	**-12.44**	**-94.4**	**92.6**	**20.2**	**28.5**	**1.9**	**25.0**	**374.0**	**28.3**	**24.3**	**0.3**				**Spring**	**173**	
Unnamed Spring in Schell Creek Range	38.51851	-114.74229	--	--	--	-14.40	-108.1	17.6	3.8	1.9	1.2	0.9	67.9	9.5	10.8	--	57756			Spring	304	10/29/03
Unnamed Spring in Schell Creek Range	38.51851	-114.74229	--	--	--	-14.46	-105.8	--	--	--	--	--	--	--	--	--	57756	2		Spring	304	10/29/03
Unnamed Spring in Schell Creek Range	38.51851	-114.74229	10.7	6.47	7.22	-14.61	-106.9	56.0	8.70	23.2	0.34	11.8	210	26.2	16.2	0.15	62976	1	SC-4	Spring	374	07/30/05
Unnamed Spring in Schell Creek Range	38.51851	-114.74229	11	3.76	7.41	-14.45	-108.3	55.6	8.58	21.4	<.1	11.5	210	25.0	15.4	0.13	65058		SC-9	Spring	449	07/14/06
Unnamed Spring in Schell Creek Range	**38.51851**	**-114.74229**	**10.9**	**5.1**	**7.3**	**-14.48**	**-107.3**	**43.1**	**7.0**	**15.5**	**0.8**	**8.1**	**162.6**	**20.2**	**14.1**	**0.1**				**Spring**	**304**	
Indian Spring near Steward Ranch	38.31056	-114.65028	8.0		7.0	-13.60	-102.0	38.0	5.9	17.0	0.6	7.9	161.0	12.0	46.0	0.2	357		GS141	Spring	188	04/05/85
Indian Spring near Steward Ranch	**38.31056**	**-114.65028**	**8.0**		**7.0**	**-13.60**	**-102.0**	**38.0**	**5.9**	**17.0**	**0.6**	**7.9**	**161.0**	**12.0**	**46.0**	**0.2**	**357**		**GS141**	**Spring**	**188**	**04/05/85**
Stock Well (Delamar Wash)	37.34944	-114.75833					-88.0										1000		GS999	Well	101	--
Stock Well (Delamar Wash)	**37.34944**	**-114.75833**					**-88.0**										**1000**		**GS999**	**Well**	**101**	**--**
Stove Spring	39.09486	-115.36359	9.1	7.1	6.4	-15.71	-114.5									--	62711		DRI-WP-6	Spring	347	06/06/05
Stove Spring	**39.09486**	**-115.36359**	**9.1**	**7.1**	**6.4**	**-15.71**	**-114.5**									**--**	**62711**		**DRI-WP-6**	**Spring**	**347**	**06/06/05**
Summit Spring	39.55109	-115.23000	7.7	6.4	6.5	-15.94	-120.8									--	62702		DRI-BT-4	Spring	348	06/04/05
Summit Spring	**39.55109**	**-115.23000**	**7.7**	**6.4**	**6.5**	**-15.94**	**-120.8**									**--**	**62702**		**DRI-BT-4**	**Spring**	**348**	**06/04/05**
Summit Spring (Mahogany Mts.)	37.749840	-114.153585	13.2	2.08	7.07	-12.04	-92.1	107	24.4	57.1	2.74	59.4	422	40.8	55.0	0.38	64905		MG-2	Spring	419	06/21/06
Summit Spring (Mahogany Mts.)	**37.749840**	**-114.153585**	**13.2**	**2.08**	**7.07**	**-12.04**	**-92.1**	**107**	**24.4**	**57.1**	**2.74**	**59.4**	**422**	**40.8**	**55.0**	**0.38**	**64905**		**MG-2**	**Spring**	**419**	**06/21/06**
Teaspoon Spring	38.34509	-115.41189	11.9	4.8	7.0	-13.26	-100.0										62830			Spring	371	06/30/05
Teaspoon Spring	**38.34509**	**-115.41189**	**11.9**	**4.8**	**7.0**	**-13.26**	**-100.0**										**62830**			**Spring**	**371**	**06/30/05**
The Seeps (Spring)	37.73944	-115.57556	9.0		7.5	-13.30	-98.0	110.0	25.9	53.0	3.9	41.7	455.0	53.4	55.0		281		K10	Spring	136	01/15/85
The Seeps (Spring)	**37.73944**	**-115.57556**	**9.0**		**7.5**	**-13.30**	**-98.0**	**110.0**	**25.9**	**53.0**	**3.9**	**41.7**	**455.0**	**53.4**	**55.0**		**281**		**K10**	**Spring**	**136**	**01/15/85**
Thirty Mile Spring	39.55556	-115.21806	8.5		8.0	-16.40	-126.0	29.0	4.6	13.0	2.8	5.5	140.0	7.9	43.0	0.2	468		GS256	Spring	242	08/23/83
Thirty Mile Spring	**39.55556**	**-115.21806**	**8.5**		**8.0**	**-16.40**	**-126.0**	**29.0**	**4.6**	**13.0**	**2.8**	**5.5**	**140.0**	**7.9**	**43.0**	**0.2**	**468**		**GS256**	**Spring**	**242**	**08/23/83**
Tippet Spring	39.876915	-114.37348	21.4	2.76	6.8	-16.24	-121.9	54.8	30.2	7.65	1.08	7.1	279	26.0	12.0	0.05	63276	1		Spring	394	24-Aug-05
Tippet Spring	**39.876915**	**-114.37348**	**21.4**	**2.76**	**6.8**	**-16.24**	**-121.9**	**54.8**	**30.2**	**7.65**	**1.08**	**7.1**	**279**	**26.0**	**12.0**	**0.05**	**63276**	**1**		**Spring**	**394**	**24-Aug-05**
Tobe Spring	38.00609	-114.08980	19.8	8.0	8.7	-13.04	-100.0	49.6	7.8	25.3	3.2	20.9	89.1	20.5	45.6	--	60312	1		Spring	315	05/20/04
Tobe Spring	**38.00609**	**-114.08980**	**19.8**	**8.0**	**8.7**	**-13.04**	**-100.0**	**49.6**	**7.8**	**25.3**	**3.2**	**20.9**	**89.1**	**20.5**	**45.6**	**--**	**60312**	**1**		**Spring**	**315**	**05/20/04**
Tobe Spring 2	38.00675	-114.08969	13.7	4.0	7.2	-12.09	-93.6	38.2	5.7	17.1	3.4	14.8	157.0	7.0	47.0	--	60313	1		Spring	316	05/20/04
Tobe Spring 2	**38.00675**	**-114.08969**	**13.7**	**4.0**	**7.2**	**-12.09**	**-93.6**	**38.2**	**5.7**	**17.1**	**3.4**	**14.8**	**157.0**	**7.0**	**47.0**	**--**	**60313**	**1**		**Spring**	**316**	**05/20/04**
Trough Spring	38.36971	-114.96316	--	--	--	-13.56	-103.6											1		Spring	413	28-Oct_05
Trough Spring	**38.36971**	**-114.96316**	**--**	**--**	**--**	**-13.56**	**-103.6**											**1**		**Spring**	**413**	**28-Oct_05**
Tunnel Spring	39.35142	-115.44964	10.4	5.5	7.0	-15.02	-118.3										62832			Spring	366	07/01/05
Tunnel Spring	**39.35142**	**-115.44964**	**10.4**	**5.5**	**7.0**	**-15.02**	**-118.3**										**62832**			**Spring**	**366**	**07/01/05**
Twin Spring	37.46996	-115.02371	16.9	7.0	7.2	-13.24	-97.4	40.9	9.5	17.2	2.2	10.4	190.0	8.8	48.6	--	61104	1		Spring	294	07/30/04
Twin Spring	**37.46996**	**-115.02371**	**16.9**	**7.0**	**7.2**	**-13.24**	**-97.4**	**40.9**	**9.5**	**17.2**	**2.2**	**10.4**	**190.0**	**8.8**	**48.6**	**--**	**61104**	**1**		**Spring**	**294**	**07/30/04**
Unnamed Chokecherry Spring	37.53905	-114.70312	11.8	6.2	7.2	-12.54	-98.1	23.9	5.9	9.3	1.4	3.5	109.0	7.9	48.6	--	59696	1		Spring	263	03/25/04
Unnamed Chokecherry Spring	**37.53905**	**-114.70312**	**11.8**	**6.2**	**7.2**	**-12.54**	**-98.1**	**23.9**	**5.9**	**9.3**	**1.4**	**3.5**	**109.0**	**7.9**	**48.6**	**--**	**59696**	**1**		**Spring**	**263**	**03/25/04**
Unnamed Hayden Canyon Spring	39.15147	-115.39264	6.9	6.0	7.0	-15.69	-120.9									--	62718		DRI-WP-13	Spring	350	06/07/05
Unnamed Hayden Canyon Spring	**39.15147**	**-115.39264**	**6.9**	**6.0**	**7.0**	**-15.69**	**-120.9**									**--**	**62718**		**DRI-WP-13**	**Spring**	**350**	**06/07/05**
Unnamed Near Little Willow Spring	39.72235	-115.60986	9.4	8.4	7.2	-17.04	-125.9									--	62707		DRI-BK-3	Spring	351	06/05/05
Unnamed Near Little Willow Spring	**39.72235**	**-115.60986**	**9.4**	**8.4**	**7.2**	**-17.04**	**-125.9**									**--**	**62707**		**DRI-BK-3**	**Spring**	**351**	**06/05/05**
Unnamed Shellback Ridge Spring	39.14038	-115.38952	7.0	0.3	4.9	-16.18	-123.6									--	62720		DRI-WP-15	Spring	352	06/07/05
Unnamed Shellback Ridge Spring	**39.14038**	**-115.38952**	**7.0**	**0.3**	**4.9**	**-16.18**	**-123.6**									**--**	**62720**		**DRI-WP-15**	**Spring**	**352**	**06/07/05**
Unnamed Spring (Unnamed Combs Creek Spring)	39.50919	-114.99298				-15.63	-118.9									--	62630		DRI-ER-6	Spring	353	05/24/05
Unnamed Spring (Unnamed Combs Creek Spring)	**39.50919**	**-114.99298**				**-15.63**	**-118.9**									**--**	**62630**		**DRI-ER-6**	**Spring**	**353**	**05/24/05**
Unnamed Spring #3 (Snake)	38.73321	-114.33335	11.7	6.5	6.8	-14.10	-109.0	104.0	21.4	44.7	1.7	90.1	70.0	283.0	114.0	0.16	62920		SN-3	Spring	379	07/13/05
Unnamed Spring #3 (Snake)	**38.73321**	**-114.33335**	**11.7**	**6.5**	**6.8**	**-14.10**	**-109.0**	**104.0**	**21.4**	**44.7**	**1.7**	**90.1**	**70.0**	**283.0**	**114.0**	**0.16**	**62920**		**SN-3**	**Spring**	**379**	**07/13/05**
Unnamed Spring #4 (Snake)	38.83515	-114.19643	6.1	4.98	6.43	-14.65	-107.2	131	22.3	6.06	1.02	6.6	474	17.9	11.0	0.05	62972		SN-1	Spring	376	07/28/05
Unnamed Spring #4 (Snake)	**38.83515**	**-114.19643**	**6.1**	**4.98**	**6.43**	**-14.65**	**-107.2**	**131**	**22.3**	**6.06**	**1.02**	**6.6**	**474**	**17.9**	**11.0**	**0.05**	**62972**		**SN-1**	**Spring**	**376**	**07/28/05**
Unnamed Spring #5 (Snake)	38.85148	-114.17036	11.9	5.84	6.97	-14.04	-106.7	58.4	30.8	9.34	1.22	9.2	322	9.2	10.9	0.08	62973		SN-2	Spring	377	07/28/05
Unnamed Spring #5 (Snake)	**38.85148**	**-114.17036**	**11.9**	**5.84**	**6.97**	**-14.04**	**-106.7**	**58.4**	**30.8**	**9.34**	**1.22**	**9.2**	**322**	**9.2**	**10.9**	**0.08**	**62973**		**SN-2**	**Spring**	**377**	**07/28/05**
Unnamed Spring #1 (White Pine)	38.96778	-115.39900	8.3	8.9	6.5	-15.36	-114.8										62818	1		Spring	359	06/28/05

Unnamed Spring #1 (White Pine)	**38.96778**	**-115.39900**	**8.3**	**8.9**	**6.5**	**-15.36**	**-114.8**										**62818**	**1**		**Spring**	**359**	**06/28/05**
Unnamed Spring #2 (Mahogany Mts)	37.943211	-114.068416	13.4	6.27	7.35	-13.47	-100.7	64.1	8.94	12.1	0.89	10.2	210	23.6	21.6	0.67	64907		MG-4	Spring	421	06/22/06
Unnamed Spring #2 (Mahogany Mts)	**37.943211**	**-114.068416**	**13.4**	**6.27**	**7.35**	**-13.47**	**-100.7**	**64.1**	**8.94**	**12.1**	**0.89**	**10.2**	**210**	**23.6**	**21.6**	**0.67**	**64907**		**MG-4**	**Spring**	**421**	**06/22/06**
Unnamed Spring #1(White Rock Mts)	38.303410	-114.160379	10.4	8.01	7.35	-15.05	-109.6	47.2	8.85	15.9	0.98	45.5	128	14.0	35.5	0.08	64897		WM-8	Spring	415	06/19/06
Unnamed Spring #1(White Rock Mts)	**38.303410**	**-114.160379**	**10.4**	**8.01**	**7.35**	**-15.05**	**-109.6**	**47.2**	**8.85**	**15.9**	**0.98**	**45.5**	**128**	**14.0**	**35.5**	**0.08**	**64897**		**WM-8**	**Spring**	**415**	**06/19/06**
Unnamed Spring #2 (White Rock Mts)	38.195394	-114.105820	11.1	2.82	6.67	-13.00	-97.0	29.1	7.85	10.4	0.52	3.3	130	8.3	40.7	0.15	64899		WM-10	Spring	417	06/19/06
Unnamed Spring #2 (White RockMts)	**38.195394**	**-114.105820**	**11.1**	**2.82**	**6.67**	**-13.00**	**-97.0**	**29.1**	**7.85**	**10.4**	**0.52**	**3.3**	**130**	**8.3**	**40.7**	**0.15**	**64899**		**WM-10**	**Spring**	**417**	**06/19/06**
Unnamed Spring #1(Egan)	39.068946	-114.918846	7	6.9	7.11	-15.14	-112.2	82.6	9.14	4.46	0.94	1.6	277	20.9	11.2	0.12	65044		ER-18	Spring	435	07/12/06
Unnamed Spring #1(Egan)	**39.068946**	**-114.918846**	**7**	**6.9**	**7.11**	**-15.14**	**-112.2**	**82.6**	**9.14**	**4.46**	**0.94**	**1.6**	**277**	**20.9**	**11.2**	**0.12**	**65044**		**ER-18**	**Spring**	**435**	**07/12/06**
Unnamed Spring #2 (White Pine)	38.97696	-115.40065	8.7	5.9	5.7	-15.66	-114.9										62819	1		Spring	360	06/28/05
Unnamed Spring #2 (White Pine)	**38.97696**	**-115.40065**	**8.7**	**5.9**	**5.7**	**-15.66**	**-114.9**										**62819**	**1**		**Spring**	**360**	**06/28/05**
Unnamed Spring #2 (Egan Range)	39.045766	-114.924576	4.1	7.62	7.5	-15.14	-110.0	50.7	5.87	3.95	0.68	1.0	182	5.8	9.2	0.08	65045		ER-19	Spring	436	07/12/06
Unnamed Spring #2 (Egan Range)	**39.045766**	**-114.924576**	**4.1**	**7.62**	**7.5**	**-15.14**	**-110.0**	**50.7**	**5.87**	**3.95**	**0.68**	**1.0**	**182**	**5.8**	**9.2**	**0.08**	**65045**		**ER-19**	**Spring**	**436**	**07/12/06**
Unnamed Spring #3 (White Pine)	38.98418	-115.39037	9.8	2.9	6.1	-14.96	-113.1										62821	1		Spring	361	06/28/05
Unnamed Spring #3 (White Pine)	**38.98418**	**-115.39037**	**9.8**	**2.9**	**6.1**	**-14.96**	**-113.1**										**62821**	**1**		**Spring**	**361**	**06/28/05**
Unnamed Spring #3 (Egan Range)	39.056771	-114.926784	4.8	8.75	7.5	-15.07	-110.2	66.9	4.69	3.98	0.69	0.9	221	5.5	10.2	0.10	65046		ER-20	Spring	437	07/12/06
Unnamed Spring #3 (Egan Range)	**39.056771**	**-114.926784**	**4.8**	**8.75**	**7.5**	**-15.07**	**-110.2**	**66.9**	**4.69**	**3.98**	**0.69**	**0.9**	**221**	**5.5**	**10.2**	**0.10**	**65046**		**ER-20**	**Spring**	**437**	**07/12/06**
Unnamed Spring #4 (White Pine)	39.03633	-115.39347	8.1	3.7	6.9	-15.01	-116.3										62824	1		Spring	362	06/29/05
Unnamed Spring #4 (White Pine)	**39.03633**	**-115.39347**	**8.1**	**3.7**	**6.9**	**-15.01**	**-116.3**										**62824**	**1**		**Spring**	**362**	**06/29/05**
Unnamed Spring #4 (Egan Range)	39.085308	-114.921879	6.7	8.65	7.43	-15.37	-114.0	65.1	10.1	3.38	0.78	1.3	229	11.9	11.5	0.11	65047		ER-21	Spring	438	07/12/06
Unnamed Spring #4 (Egan Range)	**39.085308**	**-114.921879**	**6.7**	**8.65**	**7.43**	**-15.37**	**-114.0**	**65.1**	**10.1**	**3.38**	**0.78**	**1.3**	**229**	**11.9**	**11.5**	**0.11**	**65047**		**ER-21**	**Spring**	**438**	**07/12/06**
Unnamed Spring #5 (White Pine)	39.00631	-115.39043	9.0	7.0	7.0	-16.01	-120.4										62825	1	WP-13	Spring	363	06/29/05
Unnamed Spring #5 (White Pine)	39.00631	-115.39043				-14.04	-106.7										62973		WP-13	Spring	363	07/28/01
Unnamed Spring #5(RS, White Pine)	39.006300	-115.390430	8.9	6.83	7.12	-16.02	-120.8	62.5	5.30	14.8	1.16	6.9	224	10.6	30.5	0.16	65038		WP-13	Spring	428	07/11/06
Unnamed Spring #5 (White Pine)	39.00631	-115.39043	**9.0**	**6.9**	**7.1**	**-15.36**	**-116.0**	**62.5**	**5.3**	**14.8**	**1.2**	**6.9**	**224.0**	**10.6**	**30.5**	**0.2**		**3**	WP-13	**Spring**	**363**	
Unnamed Spring #5 (Egan Range)	38.903097	-114.923433	7.3	7.13	7.04	-14.72	-109.6	93.1	18.3	4.39	0.92	3.3	331	32.4	14.0	0.06	65054		ER-28	Spring	445	07/13/06
Unnamed Spring #5 (Egan Range)	**38.903097**	**-114.923433**	**7.3**	**7.13**	**7.04**	**-14.72**	**-109.6**	**93.1**	**18.3**	**4.39**	**0.92**	**3.3**	**331**	**32.4**	**14.0**	**0.06**	**65054**		**ER-28**	**Spring**	**445**	**07/13/06**
Unnamed Spring #6 (White Pine)	38.99300	-115.37519	9.1	0.5	6.8	-14.98	-115.1										62826	1		Spring	364	06/29/05
Unnamed Spring #6 (White Pine)	**38.99300**	**-115.37519**	**9.1**	**0.5**	**6.8**	**-14.98**	**-115.1**										**62826**	**1**		**Spring**	**364**	**06/29/05**
Unnamed Spring #7 (Quinn)	38.16152	-115.64159	7.4	6.1	6.7	-14.23	-105.9										62834	1		Spring	367	07/02/05
Unnamed Spring #7 (Quinn)	**38.16152**	**-115.64159**	**7.4**	**6.1**	**6.7**	**-14.23**	**-105.9**										**62834**	**1**		**Spring**	**367**	**07/02/05**
Unnamed Spring #8 (Quinn)	38.05659	-115.66484	11.5	0.3	6.5	-14.18	-104.4										62835	1		Spring	368	07/02/05
Unnamed Spring #8 (Quinn)	**38.05659**	**-115.66484**	**11.5**	**0.3**	**6.5**	**-14.18**	**-104.4**										**62835**	**1**		**Spring**	**368**	**07/02/05**
Unnamed Spring #7(Kern MTS)	39.680719	-114.190886	10.2	0.06	6.32	-15.80	-116.3	51.5	11.0	25.7	0.82	14.9	232	14.1	36.0	0.40	63273			Spring	391	23-Aug-05
Unnamed Spring #7(Kern MTS)	**39.680719**	**-114.190886**	**10.2**	**0.06**	**6.32**	**-15.80**	**-116.3**	**51.5**	**11.0**	**25.7**	**0.82**	**14.9**	**232**	**14.1**	**36.0**	**0.40**	**63273**			**Spring**	**391**	**23-Aug-05**
Unnamed Spring #8 (Antelope Range)	39.987784	-114.433412	9.2	2.9	6.13	-15.85	-121.4	35.9	6.98	12.8	1.89	11.1	130	22.1	44.9	0.13	63277	1		Spring	395	24-Aug-05
Unnamed Spring #8 (Antelope Range)	**39.987784**	**-114.433412**	**9.2**	**2.9**	**6.13**	**-15.85**	**-121.4**	**35.9**	**6.98**	**12.8**	**1.89**	**11.1**	**130**	**22.1**	**44.9**	**0.13**	**63277**	**1**		**Spring**	**395**	**24-Aug-05**
Unnamed Spring #9 (Antelope Range)	39.993636	-114.420708	8.3	5.6	6.16	-16.41	-123.0	32.8	6.25	8.86	3.03	14.8	109	14.9	44.4	0.10	63278	1		Spring	396	25-Aug-05
Unnamed Spring #9 (Antelope Range)	**39.993636**	**-114.420708**	**8.3**	**5.6**	**6.16**	**-16.41**	**-123.0**	**32.8**	**6.25**	**8.86**	**3.03**	**14.8**	**109**	**14.9**	**44.4**	**0.10**	**63278**	**1**		**Spring**	**396**	**25-Aug-05**
Unnamed Spring #10 (Antelope Range)	39.937971	-114.360742	12.9	1.29	6.59	-15.95	-122.0	92.0	49.2	34.1	1.19	35.5	329	175	19.3	0.16	63279	1		Spring	397	25-Aug-05
Unnamed Spring #10 (Antelope Range)	**39.937971**	**-114.360742**	**12.9**	**1.29**	**6.59**	**-15.95**	**-122.0**	**92.0**	**49.2**	**34.1**	**1.19**	**35.5**	**329**	**175**	**19.3**	**0.16**	**63279**	**1**		**Spring**	**397**	**25-Aug-05**
Unnamed Springs #11(Snake Range)	39.484774	-114.310317	8.9	7.85	6.71	-15.65	-117.1	60.1	11.4	11.4	1.56	8.3	231	11.1	19.1	0.06	63283	1		Spring	401	26-Aug-05
Unnamed Springs #11(Snake Range)	**39.484774**	**-114.310317**	**8.9**	**7.85**	**6.71**	**-15.65**	**-117.1**	**60.1**	**11.4**	**11.4**	**1.56**	**8.3**	**231**	**11.1**	**19.1**	**0.06**	**63283**	**1**		**Spring**	**401**	**26-Aug-05**
Unnamed Spring #12 (Snake Range)	39.307465	-114.216096	7.6	6.54	7.24	-15.89	-116.6	39.1	3.53	4.78	0.64	2.4	130	4.2	11.9	0.07	63527	1		Spring	403	25-Oct-05
Unnamed Spring #12 (Snake Range)	**39.307465**	**-114.216096**	**7.6**	**6.54**	**7.24**	**-15.89**	**-116.6**	**39.1**	**3.53**	**4.78**	**0.64**	**2.4**	**130**	**4.2**	**11.9**	**0.07**	**63527**	**1**		**Spring**	**403**	**25-Oct-05**
Unnamed Sp Silver Cr Canyon	39.22899	-114.26075	9.2	3.12	7.39	-15.38	-115.7	71.3	30.4	8.93	0.75	6.6	322	35.4	12.6	0.08	63529	1		Spring	405	26-Oct-05
Unnamed Sp Silver Cr Canyon	**39.22899**	**-114.26075**	**9.2**	**3.12**	**7.39**	**-15.38**	**-115.7**	**71.3**	**30.4**	**8.93**	**0.75**	**6.6**	**322**	**35.4**	**12.6**	**0.08**	**63529**	**1**		**Spring**	**405**	**26-Oct-05**
Unnamed Spring 13 (Snake Range)	39.177792	-114.286862	9.9	6.17	7.48	-14.76	-114.3	79.1	94.7	67.8	1.14	83.6	437	234	19.6	0.15	63530	1		Spring	406	26-Oct-05
Unnamed Spring 13 (Snake Range)	**39.177792**	**-114.286862**	**9.9**	**6.17**	**7.48**	**-14.76**	**-114.3**	**79.1**	**94.7**	**67.8**	**1.14**	**83.6**	**437**	**234**	**19.6**	**0.15**	**63530**	**1**		**Spring**	**406**	**26-Oct-05**
Unnamed Stone Cabin Spring	39.15911	-115.39892	8.5	8.2	6.8	-15.31	-114.2									--	62717		DRI-WP-12	Spring	354	06/07/05
Unnamed Stone Cabin Spring	39.15911	-115.39892	9.2	7.22	7.31	-15.47	-118.2	66.7	11.7	14.3	0.92	7.9	248	13.0	16.8	0.23	65036		WP-11	Spring	426	07/11/06
Unnamed Stone Cabin Spring	**39.15911**	**-115.39892**	**8.9**	**7.7**	**7.1**	**-15.39**	**-116.2**	**66.7**	**11.7**	**14.3**	**0.9**	**7.9**	**248.0**	**13.0**	**16.8**	**0.2**			**DRI-WP-12**	**Spring**	**354**	**06/07/05**
Unnamed Spring (Clover)	37.27654	-114.30744	3.3	4.9	7.1	-12.20	-88.0	126.0	22.6	56.6	1.5	14.8	401.0	157.0	35.4	--	58501	1		Spring	249	01/15/04
Unnamed Spring (Clover)	**37.27654**	**-114.30744**	**3.3**	**4.9**	**7.1**	**-12.20**	**-88.0**	**126.0**	**22.6**	**56.6**	**1.5**	**14.8**	**401.0**	**157.0**	**35.4**	**--**	**58501**	**1**		**Spring**	**249**	**01/15/04**
Unnamed Spring	37.49917	-114.45250	10.0			-11.60	-86.5										231		GS85	Spring	113	06/03/85
Unnamed Spring	**37.49917**	**-114.45250**	**10.0**			**-11.60**	**-86.5**										**231**		**GS85**	**Spring**	**113**	**06/03/85**
Unnamed Spring in dry creek bed (White Pine Range)	38.89546	-115.38372	--	--	--	-15.31	-113.6	--	--	--	--	--	--	--	--	--	--	1		Spring	321	10/12/03
Unnamed Spring in dry creek bed (White Pine Range)	**38.89546**	**-115.38372**	**--**	**--**	**--**	**-15.31**	**-113.6**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**321**	**10/12/03**

Unnamed Spring in Miller Canyon	38.32738	-114.24383	--	--	--	-14.27	-103.7	--	--	--	--	--	--	--	--	--	--	1		Spring	313	05/19/04
Unnamed Spring in Miller Canyon	**38.32738**	**-114.24383**	**--**	**--**	**--**	**-14.27**	**-103.7**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**1**		**Spring**	**313**	**05/19/04**
Unnamed Spring in Road (South Pahroc Range)	37.53638	-115.10651	28.4	4.5	6.4	-13.07	-96.7	42.6	10.0	16.1	1.5	8.8	193.0	8.7	49.7	--	61098	1		Spring	303	07/30/04
Unnamed Spring in Road(South Pahroc Range)	**37.53638**	**-115.10651**	**28.4**	**4.5**	**6.4**	**-13.07**	**-96.7**	**42.6**	**10.0**	**16.1**	**1.5**	**8.8**	**193.0**	**8.7**	**49.7**	**--**	**61098**	**1**		**Spring**	**303**	**07/30/04**
Unnamed Spring nr Clover Creek	37.61461	-114.45061	16.2	0.9	7.0	-11.96	-89.7	67.4	9.1	29.9	6.8	20.3	299.0	11.1	55.6	--	61102	1		Spring	252	07/31/04
Unnamed Spring nr Clover Creek	**37.61461**	**-114.45061**	**16.2**	**0.9**	**7.0**	**-11.96**	**-89.7**	**67.4**	**9.1**	**29.9**	**6.8**	**20.3**	**299.0**	**11.1**	**55.6**	**--**	**61102**	**1**		**Spring**	**252**	**07/31/04**
Unnamed Spring nr Six Mile seep	37.49680	-115.09102	--	--	--	-12.62	-94.5	--	--	--	--	--	--	--	--	--	61106A	1		Spring	296	07/30/04
Unnamed Spring nr Six Mile seep	**37.49680**	**-115.09102**	**--**	**--**	**--**	**-12.62**	**-94.5**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**61106A**	**1**		**Spring**	**296**	**07/30/04**
Unnamed Spring--nr Blackrock	37.91689	-114.91859	9.2	7.1	7.4	-11.90	-94.3	45.9	9.3	25.8	6.1	23.7	184.0	23.1	69.2	--	59688	1		Spring	299	03/23/04
Unnamed Spring--nr Blackrock	**37.91689**	**-114.91859**	**9.2**	**7.1**	**7.4**	**-11.90**	**-94.3**	**45.9**	**9.3**	**25.8**	**6.1**	**23.7**	**184.0**	**23.1**	**69.2**	**--**	**59688**	**1**		**Spring**	**299**	**03/23/04**
Unnamed Well (Longdale)	36.59000	-114.48000			7.8	-13.20	-103.0	29.0	2.2	35.0	5.2	6.0	135.0	26.0	132.7	1.0	78		IT174	Well	48	03/04/74
Unnamed Well (Longdale)	**36.59000**	**-114.48000**			**7.8**	**-13.20**	**-103.0**	**29.0**	**2.2**	**35.0**	**5.2**	**6.0**	**135.0**	**26.0**	**132.7**	**1.0**	**78**		**IT174**	**Well**	**48**	**03/04/74**
Unnamed Well (Near Dry Lake Range)	36.38278	-114.91667	26.5	0.5	7.3	-13.70	-96.0	123.0	46.0	140.0	16.0	190.0	230.0	360.0	21.0	1.6	41		GS12	Well	24	04/26/82
Unnamed Well (Near Dry Lake Range)	**36.38278**	**-114.91667**	**26.5**	**0.5**	**7.3**	**-13.70**	**-96.0**	**123.0**	**46.0**	**140.0**	**16.0**	**190.0**	**230.0**	**360.0**	**21.0**	**1.6**	**41**		**GS12**	**Well**	**24**	**04/26/82**
South Fox Well	38.77222	-114.52667	12.0	3.3	7.8	-15.00	-113.0	34.0	21.0	7.1	1.6	6.0		8.0	15.0	0.3	422		GS201	Well	216	07/06/83
South Fox Well	**38.77222**	**-114.52667**	**12.0**	**3.3**	**7.8**	**-15.00**	**-113.0**	**34.0**	**21.0**	**7.1**	**1.6**	**6.0**		**8.0**	**15.0**	**0.3**	**422**		**GS201**	**Well**	**216**	**07/06/83**
Unnamed, Kaolin Wash	36.48722	-114.46667	14.1	6.0	8.5	-11.30	-88.0	48.9	25.9	77.6	21.3	46.5	213.0	168.0	19.1		67		PL3	Spring	35	02/09/96
Unnamed, Kaolin Wash	**36.48722**	**-114.46667**	**14.1**	**6.0**	**8.5**	**-11.30**	**-88.0**	**48.9**	**25.9**	**77.6**	**21.3**	**46.5**	**213.0**	**168.0**	**19.1**		**67**		**PL3**	**Spring**	**35**	**02/09/96**
Upper Burnt Canyon Spring	38.287295	-114.200492	14.8	3.00	6.80	-12.83	-97.6	65.9	15.3	11.5	0.57	17.3	251	6.7	50.4	0.18	64898		WM-9	Spring	416	06/19/06
Upper Burnt Canyon Spring	**38.287295**	**-114.200492**	**14.8**	**3.00**	**6.80**	**-12.83**	**-97.6**	**65.9**	**15.3**	**11.5**	**0.57**	**17.3**	**251**	**6.7**	**50.4**	**0.18**	**64898**		**WM-9**	**Spring**	**416**	**06/19/06**
Upper Burnt Canyon Spring #2	38.287295	-114.200492	-	-	-	-13.66	-103.6	-	-	-	-	-	-	-	-	-	--		WM-9b	Spring	416	06/19/06
Upper Burnt Canyon Spring #2	**38.287295**	**-114.200492**	**-**	**-**	**-**	**-13.66**	**-103.6**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**--**		**WM-9b**	**Spring**	**416**	**06/19/06**
Upper Chokecherry Spring	37.53746	-114.69833	9.3	7.3	8.0	-12.96	-98.9	53.0	10.6	23.2	1.2	13.6	219.0	16.7	50.0	--	59695	1		Spring	262	03/25/04
Upper Chokecherry Spring	**37.53746**	**-114.69833**	**9.3**	**7.3**	**8.0**	**-12.96**	**-98.9**	**53.0**	**10.6**	**23.2**	**1.2**	**13.6**	**219.0**	**16.7**	**50.0**	**--**	**59695**	**1**		**Spring**	**262**	**03/25/04**
Upper Conner Spring	37.90278	-114.56056	8.0	8.2	7.4	-13.85	-100.0	73.0	26.0	2.2	0.5	2.1	351.0	5.4	8.5	<.1	310		GS115	Spring	156	11/11/86
Upper Conner Spring	37.90278	-114.56056	9.2	8.1	7.7	-13.88	-102.3	76.9	27.6	1.6	0.6	1.9	368.0	3.6	8.5	--	60836	1		Spring	156	06/24/04
Upper Conner Spring	37.90278	-114.56056	**8.6**	**8.2**	**7.6**	**-13.87**	**-101.2**	**75.0**	**26.8**	**1.9**	**0.5**	**2.0**	**359.5**	**4.5**	**8.5**	**<.1**	**310**		**GS115**	**Spring**	**156**	**11/11/86**
Upper Fairview	38.18657	-114.66620	18.0	1.8	7.2	-12.66	-97.7	60.2	10.6	28.1	2.6	23.6	259.0	14.5	48.4	--	60850	1		Spring	280	06/29/04
Upper Fairview	**38.18657**	**-114.66620**	**18.0**	**1.8**	**7.2**	**-12.66**	**-97.7**	**60.2**	**10.6**	**28.1**	**2.6**	**23.6**	**259.0**	**14.5**	**48.4**	**--**	**60850**	**1**		**Spring**	**280**	**06/29/04**
Upper Illipah Crk	39.28167	-115.39000				-16.00	-124.0												GS999	Surface	238	06/13/83
Upper Illipah Crk	39.28167	-115.39000				-16.20	-123.0												GS999	Surface	238	08/23/83
Upper Illipah Crk	**39.28167**	**-115.39000**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**-16.10**	**-123.5**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**				**Surface**	**238**	
Upper Indian Spring	37.45202	-114.65831	11.7	3.6	7.3	-11.46	-88.0	68.0	19.3	23.9	0.3	9.1	319.0	13.0	53.4	--	58499	1		Spring	268	01/14/04
Upper Indian Spring	**37.45202**	**-114.65831**	**11.7**	**3.6**	**7.3**	**-11.46**	**-88.0**	**68.0**	**19.3**	**23.9**	**0.3**	**9.1**	**319.0**	**13.0**	**53.4**	**--**	**58499**	**1**		**Spring**	**268**	**01/14/04**
Unnamed Spring near Pony Spring	38.32139	-114.64222	11.5			-12.90	-99.0										361		GS144	Spring	191	07/23/81
Unnamed Spring near Pony Spring	**38.32139**	**-114.64222**	**11.5**			**-12.90**	**-99.0**										**361**		**GS144**	**Spring**	**191**	**07/23/81**
Upper Riggs Spring WR4	37.36833	-114.64778															477			Spring	105	--
Upper Riggs Spring WR4	37.36833	-114.64778	10.8			-11.90	-88.0										207		GS78	Spring	105	02/02/84
Upper Riggs Spring WR4	37.36833	-114.64778	10.1	4.4	7.3	-11.90	-87.0	64.7	15.9	19.4	0.0	17.5	274.0	12.0	57.8	--	58492			Spring	105	01/13/04
Upper Riggs Spring WR4	37.36833	-114.64778	16.9	10.9	8.0	-11.95	-87.3	57.6	15.9	17.6	3.4	16.5	256.0	12.7	48.8	--	60082			Spring	105	04/29/04
Upper Riggs Spring WR4	37.36833	-114.64778	13.2	0.7	7.4	-11.55	-86.2	63.4	16.6	18.8	4.2	16.4	277.0	8.7	57.2	--	61614			Spring	105	10/19/04
Upper Riggs Spring WR4	37.36833	-114.64778	6.0	6.8	7.1	-12.46	-87.0	35.5	8.8	11.6	2.0	7.2	153.0	8.1	42.0	--	62035	4		Spring	105	02/10/05
Upper Riggs Spring WR4	37.36833	-114.64778	**11.4**	**5.7**	**7.4**	**-11.95**	**-87.1**	**55.3**	**14.3**	**16.9**	**2.4**	**14.4**	**240.0**	**10.4**	**51.5**	**#DIV/0!**		**5**		**Spring**	**105**	
Upper Terrace Spring WR2	39.08664	-114.92565	--	--	--	-15.43	-111.3	39.7	10.9	4.1	0.7	2.1	173.0	7.3	11.9	--	57696			Spring	270	10/13/03
Upper Terrace Spring WR2	39.08664	-114.92565	8.2	5.1	7.1	-15.43	-114.9	39.8	11.0	4.1	0.7	2.1	172.0	7.3	12.1	--	57697			Spring	270	10/15/03
Upper Terrace Spring WR2	39.08664	-114.92565	7.6	--	7.9	-15.44	-111.8	40.5	10.8	4.3	0.8	2.1	172.0	7.1	9.2	--	60080			Spring	270	04/26/04
Upper Terrace Spring WR2	39.08664	-114.92565	8.0	8.0	7.5	-15.40	-115.6	40.4	10.7	3.6	0.7	2.4	169.0	7.4	11.8	--	60785			Spring	270	06/23/04
Upper Terrace Spring WR2	39.08664	-114.92565	8.2	7.1	6.9	-15.35	-114.4	41.6	11.3	4.3	0.8	2.4	177.0	7.3	11.8	--	61479			Spring	270	09/22/04
Upper Terrace Spring WR2	39.08664	-114.92565	7.2	8.3	7.8	-15.41	-114.6	40.3	10.7	4.2	0.8	2.3	168.0	7.7	11.1	--	62030	6		Spring	270	02/09/05
Upper Terrace Spring WR2	39.08664	-114.92565				-15.24	-113.7									--	62633A		DRI-ER-1	Spring	270	05/21/05
Upper Terrace Spring WR2	39.08664	-114.92565				-15.43	-113.4	41.8	10.5	4.14	0.76	2.3	173.0	7.9	11.2	<.05	63219		DRI-ER-1	Spring	270	08/14/05
Upper Terrace Spring WR2	39.08664	-114.92565	7.7	8.05	7.77	-15.41	-113.7	41.3	10.8	4.06	0.74	2.2	167	7.5	11.3	0.1	63562			Spring	270	6-Nov-05
Upper Terrace Spring WR2	39.086640	-114.925650	7.5	8.26	7.87	-15.41	-114.5	40.5	10.7	4.23	1.10	2.3	164	7.7	11.5	0.11	64734		ER-1	Spring	270	05/24/06
Upper Terrace Spring WR2	39.086640	-114.925650	-	-	-	-15.43	-114.1	-	-	-	-	-	-	-	-	-	--		ER-1	Spring	270	07/12/06
Upper Terrace Spring WR2	39.086640	-114.925650	7.9	7.55	7.68	-15.48	-114.1	41.4	10.9	3.65	0.61	2.1	166	7.6	11.2	0.09	65364		ER-1	Spring	270	08/29/06
Upper Terrace Spring WR2	39.086640	-114.925650	7.7	7.09	7.80	-15.50	-115.2	41.1	10.9	4.34	0.92	1.4	169	7.2	11.2	0.10	65651		ER-1	Spring	270	10/27/06
Upper Terrace Spring WR2	39.086640	-114.925650	7.5	NA	7.87	-15.46	-114.2	40.3	10.7	4.07	0.76	1.9	173	6.5	10.6	0.11	65651		ER-1	Spring		5/8/2007
Upper Terrace Spring WR2	39.08664	-114.92565	**7.8**	**7.4**	**7.6**	**-15.42**	**-114.0**	**40.7**	**10.8**	**4.1**	**0.8**	**2.1**	**170.0**	**7.4**	**11.2**	**0.1**				**Spring**	**270**	
Upper Tower Spring	38.12049	-114.33344	--	--	--	-12.30	-93.3	20.2	3.3	16.3	6.2	7.6	104.0	7.2	45.8	--	60081	1		Spring	312	04/28/04
Upper Tower Spring	**38.12049**	**-114.33344**	**--**	**--**	**--**	**-12.30**	**-93.3**	**20.2**	**3.3**	**16.3**	**6.2**	**7.6**	**104.0**	**7.2**	**45.8**	**--**	**60081**	**1**		**Spring**	**312**	**04/28/04**
US Lime Well (Genstar)	36.39139	-114.90389	24.0	4.8	7.4	-12.75	-97.0	120.0	47.0	140.0	1.3	180.0	226.0	370.0	23.0	1.6	52		GS16	Well	27	03/31/86
US Lime Well (Genstar)	**36.39139**	**-114.90389**	**24.0**	**4.8**	**7.4**	**-12.75**	**-97.0**	**120.0**	**47.0**	**140.0**	**1.3**	**180.0**	**226.0**	**370.0**	**23.0**	**1.6**	**52**		**GS16**	**Well**	**27**	**03/31/86**
USGS CSV-1	36.76694	-114.86194	29.5			-13.55	-103.0	260.0	93.0	160.0	30.0	39.0		1300.0	19.0	1.2	127		GS45	Well	71	05/18/88
USGS CSV-1	**36.76694**	**-114.86194**	**29.5**			**-13.55**	**-103.0**	**260.0**	**93.0**	**160.0**	**30.0**	**39.0**		**1300.0**	**19.0**	**1.2**	**127**		**GS45**	**Well**	**71**	**05/18/88**

USGS-MX C.V. Well (CV-DT-1)	38.13778	-115.33861	23.0	3.4	7.2	-14.60	-110.0	37.0	19.0	20.0	4.6	5.7	253.0	26.0	36.0	0.4	338		GS130	Well	176	10/15/81
USGS-MX C.V. Well (CV-DT-1)	38.13778	-115.33861				-14.52	-108.0										USGS			Well		6/25/2003
USGS-MX C.V. Well (CV-DT-1)	**38.13778**	**-115.33861**	**23.0**	**3.4**	**7.2**	**-14.56**	**-109.0**	**37.0**	**19.0**	**20.0**	**4.6**	**5.7**	**253.0**	**26.0**	**36.0**	**0.4**	**338**		**GS130**	**Well**	**176**	**10/15/81**
USGS-MX CE, VF-1	36.87528	-114.94528	28.0		7.0	-12.65	-94.0	41.0	7.5	34.0	1.2	42.0	156.0	20.0	14.0	0.5	157		GS56	Well	82	01/06/88
USGS-MX CE, VF-1	**36.87528**	**-114.94528**	**28.0**		**7.0**	**-12.65**	**-94.0**	**41.0**	**7.5**	**34.0**	**1.2**	**42.0**	**156.0**	**20.0**	**14.0**	**0.5**	**157**		**GS56**	**Well**	**82**	**01/06/88**
Valley of Fire Well	36.42250	-114.54778	28.0		7.4	-10.60	-82.0	118.0	53.0	39.0	8.2	21.0	164.0	449.0	8.3	0.2	58		PLC33	Well	31	06/24/85
Valley of Fire Well	**36.42250**	**-114.54778**	**28.0**		**7.4**	**-10.60**	**-82.0**	**118.0**	**53.0**	**39.0**	**8.2**	**21.0**	**164.0**	**449.0**	**8.3**	**0.2**	**58**		**PLC33**	**Well**	**31**	**06/24/85**
VF Spring 1	36.40139	-114.40194	23.0	5.0	7.1	-11.20	-88.0										53		PL7	Spring	28	02/09/96
VF Spring 1	**36.40139**	**-114.40194**	**23.0**	**5.0**	**7.1**	**-11.20**	**-88.0**										**53**		**PL7**	**Spring**	**28**	**02/09/96**
VF Spring 2	36.40528	-114.43056	13.5	3.9	7.8	-11.80	-92.0										55		PL6	Spring	29	03/07/96
VF Spring 2	**36.40528**	**-114.43056**	**13.5**	**3.9**	**7.8**	**-11.80**	**-92.0**										**55**		**PL6**	**Spring**	**29**	**03/07/96**
VF Spring 3	36.40583	-114.44389	15.0	5.3	7.6	-12.20	-93.0	537.0	208.0	295.0	51.1	278.0	169.0	2290.0	12.4		57		PL5	Spring	30	03/07/96
VF Spring 3	**36.40583**	**-114.44389**	**15.0**	**5.3**	**7.6**	**-12.20**	**-93.0**	**537.0**	**208.0**	**295.0**	**51.1**	**278.0**	**169.0**	**2290.0**	**12.4**		**57**		**PL5**	**Spring**	**30**	**03/07/96**
Wamp Spring	36.64167	-115.07000	7.0		8.2	-10.60	-81.0	71.0	13.0	10.0	2.1	4.9	585.0	8.4	24.0	0.2	91		GS31	Spring	52	03/20/87
Wamp Spring	**36.64167**	**-115.07000**	**7.0**		**8.2**	**-10.60**	**-81.0**	**71.0**	**13.0**	**10.0**	**2.1**	**4.9**	**585.0**	**8.4**	**24.0**	**0.2**	**91**		**GS31**	**Spring**	**52**	**03/20/87**
Water Canyon	38.98816	-114.96032	11.0			-15.00	-115.0										1033		GS999	Surface	233	06/14/83
Water Canyon	38.98816	-114.96032	9.0			-15.50	-117.0										1033		GS999	Surface	233	08/23/83
Water Canyon	**38.98816**	**-114.96032**	**10.0**	**#DIV/0!**	**#DIV/0!**	**-15.25**	**-116.0**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**				**Surface**	**233**	
Water Canyon at USGS gage	38.98700	-114.95500	--	--	--	-15.41	-109.5	--	--	--	--	--	--	--	--	--	--			Spring	271	10/24/03
Water Canyon at USGS gage (duplicate sample)	38.98700	-114.95500	--	--	--	-15.43	-112.7	--	--	--	--	--	--	--	--	--	--	2		Spring	271	10/24/03
Water Canyon at USGS gage	**38.98700**	**-114.95500**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**-15.42**	**-111.1**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**				**Spring**	**271**	
Water Canyon Spring	39.00691	-114.91063	8.9	7.9	7.3	-15.60	-114.4	40.1	11.0	4.0	0.7	7.3	180.0	1.6	12.0	--	57695	1		Spring	358	10/14/03
Water Canyon Spring	**39.00691**	**-114.91063**	**8.9**	**7.9**	**7.3**	**-15.60**	**-114.4**	**40.1**	**11.0**	**4.0**	**0.7**	**7.3**	**180.0**	**1.6**	**12.0**	**--**	**57695**	**1**		**Spring**	**358**	**10/14/03**
Water Canyon Spring (Mahogany)	37.956621	-114.064936	11.1	2.21	7.11	-13.68	-100.4	81.9	11.8	9.44	1.12	5.1	210	84.1	17.2	1.58	64906		MG-3	Spring	420	06/22/06
Water Canyon Spring (Mahogany)	**37.956621**	**-114.064936**	**11.1**	**2.21**	**7.11**	**-13.68**	**-100.4**	**81.9**	**11.8**	**9.44**	**1.12**	**5.1**	**210**	**84.1**	**17.2**	**1.58**	**64906**		**MG-3**	**Spring**	**420**	**06/22/06**
Water Tank 0.4mi West of Sixmile	37.49119	-115.09605	--	--	--	-12.44	-93.8	--	--	--	--	--	--	--	--	--	61106C	1		Spring	297	07/30/04
Water Tank 0.4mi West of Sixmile	**37.49119**	**-115.09605**	**--**	**--**	**--**	**-12.44**	**-93.8**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**61106C**	**1**		**Spring**	**297**	**07/30/04**
Weaver Well	37.74472	-114.43070	17.0		7.7	-13.10	-101.0	100.0	42.0	110.0	14.0	110.0	430.0	180.0	73.0	2.9	283		GS100	Well	137	06/04/85
Weaver Well	**37.74472**	**-114.43070**	**17.0**		**7.7**	**-13.10**	**-101.0**	**100.0**	**42.0**	**110.0**	**14.0**	**110.0**	**430.0**	**180.0**	**73.0**	**2.9**	**283**		**GS100**	**Well**	**137**	**06/04/85**
Well at Alligator Ridge	39.73735	-115.51432	34.0	4.1	7.2	-16.60	-127.0	60.0	23.0	19.0	6.5	6.7		52.0	26.0	1.0	469		GS260	Well	243	04/24/84
Well at Alligator Ridge	**39.73735**	**-115.51432**	**34.0**	**4.1**	**7.2**	**-16.60**	**-127.0**	**60.0**	**23.0**	**19.0**	**6.5**	**6.7**		**52.0**	**26.0**	**1.0**	**469**		**GS260**	**Well**	**243**	**04/24/84**
White Rock Spring (Sheep)	36.70791	-115.23942	19.9	1.7	7.0	-9.96	-84.8	41.8	35.1	18.2	11.9	10.8	326.0	12.7	57.7	--	61095	1		Spring	64	07/27/04
White Rock Spring (Sheep)	36.70791	-115.23942	10.2	3.8	6.5	-10.38	-86.1	39.8	35.2	16.8	10.5	10.3	303.0	12.5	46.5	--	62398		DRI-SR-3	Spring	64	04/28/05
White Rock Spring (Sheep)	36.70791	-115.23942	**15.1**	**2.7**	**6.8**	**-10.17**	**-85.5**	**40.8**	**35.2**	**17.5**	**11.2**	**10.6**	**314.5**	**12.6**	**52.1**	**#DIV/0!**				**Spring**	**64**	
White Rock Spring (Butte)	40.06079	-115.16385	9.4	6.0	6.4	-15.36	-119.2									--	62631		DRI-BT-3	Spring	355	05/24/05
White Rock Spring (Butte)	**40.06079**	**-115.16385**	**9.4**	**6.0**	**6.4**	**-15.36**	**-119.2**									**--**	**62631**		**DRI-BT-3**	**Spring**	**355**	**05/24/05**
White Rock Well	38.12557	-114.17027	14.5		7.9	-13.10	-101.0	68.0	10.0	11.0	4.0	51.0	168.0	20.0	61.0	0.6	336		E4	Well	175	07/24/75
White Rock Well	**38.12557**	**-114.17027**	**14.5**		**7.9**	**-13.10**	**-101.0**	**68.0**	**10.0**	**11.0**	**4.0**	**51.0**	**168.0**	**20.0**	**61.0**	**0.6**	**336**		**E4**	**Well**	**175**	**07/24/75**
White Rock Spring (Seaman Range)	37.89630	-115.01970				-12.10	-90.0										308		Kirk1019	Spring	154	01/13/85
White Rock Spring (Seaman Range)	**37.89630**	**-115.01970**				**-12.10**	**-90.0**										**308**		**Kirk1019**	**Spring**	**154**	**01/13/85**
Wildhorse Spring (Fairview)	38.19722	-114.60861	8.0		7.6	-11.70	-92.5										348		GS136	Spring	183	04/06/85
Wildhorse Spring (Fairview)	**38.19722**	**-114.60861**	**8.0**		**7.6**	**-11.70**	**-92.5**										**348**		**GS136**	**Spring**	**183**	**04/06/85**
Wild Horse Spring (White Pine)	39.33361	-115.44333	17.5			-16.80	-129.0										466		GS251	Spring	240	07/14/81
Wild Horse Spring (White Pine)	**39.33361**	**-115.44333**	**17.5**			**-16.80**	**-129.0**										**466**		**GS251**	**Spring**	**240**	**07/14/81**
Warm Spring (White Pine Range)	38.94778	-115.22806	53.0	1.0	9.3	-15.80	-118.0	1.6	<.12	61.0	0.6	9.4		16.0	56.0	13.0	453		GS204	Spring	232	04/29/82
Warm Spring (White Pine Range)	**38.94778**	**-115.22806**	**53.0**	**1.0**	**9.3**	**-15.80**	**-118.0**	**1.6**	**<.12**	**61.0**	**0.6**	**9.4**		**16.0**	**56.0**	**13.0**	**453**		**GS204**	**Spring**	**232**	**04/29/82**
Willow Spring (KSV-1)	37.09483	-114.83096				-11.90	-86.5										180		Kirk1026	Spring	92	--
Willow Spring (KSV-1)	37.09483	-114.83096															476			Spring	92	--
Willow Spring (KSV-1)	37.09483	-114.83096	17.4		7.5	-11.60	-88.0	20.0	2.7	56.0	4.6	22.0	140.0	34.0	65.0	1.1	182		GS67	Spring	92	02/03/84
Willow Spring (KSV-1)	37.09483	-114.83096	9.3	8.3	7.5	-11.57	-88.0	18.2	3.2	55.9	2.2	21.3	131.0	33.5	67.3	--	58489	1		Spring	92	01/12/04
Willow Spring (KSV-1)	37.09483	-114.83096	16.7	1.6	7.4	-11.63	-89.1	19.9	4.3	9.9	1.7	6.5	84.9	6.3	37.2	--	62395		DRI-DR-2	Spring	92	04/27/05
Willow Spring (KSV-1)	37.09483	-114.83096	**14.5**	**5.0**	**7.5**	**-11.60**	**-88.4**	**19.4**	**3.4**	**40.6**	**2.9**	**16.6**	**118.6**	**24.6**	**56.5**	**1.1**				**Spring**	**92**	
Willow Spring 2 (So.of Oak Sps.summit)	37.55653	-114.69773	13.7	2.5	7.4	-11.69	-91.2	59.4	14.7	25.5	1.8	13.6	274.0	15.2	55.7	--	59693	1		Spring	260	03/25/04
Willow Spring 2 (So.of Oak Sps.summit)	**37.55653**	**-114.69773**	**13.7**	**2.5**	**7.4**	**-11.69**	**-91.2**	**59.4**	**14.7**	**25.5**	**1.8**	**13.6**	**274.0**	**15.2**	**55.7**	**--**	**59693**	**1**		**Spring**	**260**	**03/25/04**
Wilson Creek	38.31806	-114.40333	17.0		8.0	-13.20	-97.5	21.0	3.3	11.0	2.9	7.0	77.0	11.0	39.0	0.3	358		E2	Surface	189	04/05/85
Wilson Creek	**38.31806**	**-114.40333**	**17.0**		**8.0**	**-13.20**	**-97.5**	**21.0**	**3.3**	**11.0**	**2.9**	**7.0**	**77.0**	**11.0**	**39.0**	**0.3**	**358**		**E2**	**Surface**	**189**	**04/05/85**
Wiregrass Spring (Sheep)	36.63325	-115.20842	9.5		7.3	-12.80	-94.0	69.0	32.0	2.7	1.1	3.0		5.0	12.0	0.1	82		GS22	Spring	49	10/28/81
Wiregrass Spring (Sheep)	36.63325	-115.20842	6.5	6.1	7.3	-12.70	-96.0	68.0	32.0	3.2	1.1	3.2		9.0	12.0	0.1	83		GS23	Spring	49	05/11/83
Wiregrass Spring (Sheep)	36.63325	-115.20842				-12.85	-94.0										83.5		JIM	Spring	49	10/09/86
Wiregrass Spring (Sheep)	36.63325	-115.20842	4.0		7.3	-12.80	-91.5	71.0	34.0	2.8	1.1	3.4	374.0	6.9	12.0	0.1	84		GS24	Spring	49	03/20/87
Wiregrass Spring (Sheep)	36.63325	-115.20842	13.0			-12.55	-92.0	70.0	33.0	2.8	1.5	2.9		7.1	12.0	0.2	85		GS25	Spring	49	06/17/87

Wiregrass Spring (Sheep)	36.63325	-115.20842	14.0	5.4	7.3	-12.75	-94.0	68.0	33.0	3.1	1.0	2.9	372.0	7.3	12.0	0.2	86		GS26	Spring	49	08/04/87
Wiregrass Spring (Sheep)	36.63325	-115.20842	4.0	5.0	7.3	-12.85	-97.0	72.0	34.0	3.1	5.7	3.8		7.7	12.0	0.2	87		GS27	Spring	49	01/05/88
Wiregrass Spring (Sheep)	36.63325	-115.20842	8.0	5.0	7.4	-12.95	-95.5	72.0	34.0	2.8	1.0	2.6		7.3	12.0	0.2	88		GS28	Spring	49	04/06/88
Wiregrass Spring (Sheep)	36.63325	-115.20842	7.0		7.3	-12.85	-94.5	69.0	36.0	3.1	1.1	2.7		7.3	12.0	0.1	89		GS29	Spring	49	12/12/88
Wiregrass Spring (Sheep)	36.63325	-115.20842	8.2	2.3	7.3	-12.87	-94.0	--	--	--	--	--	--	--	--	--	58487			Spring	49	01/17/04
Wiregrass Spring (Sheep)	36.63325	-115.20842	9.9	2.5	6.9	-13.12	-96.8	67.8	33.2	2.5	1.0	3.7	367.0	6.0	14.4	--	60851	2		Spring	49	06/30/04
Wiregrass Spring (Sheep)	36.63325	-115.20842	8.3	4.0	6.6	-13.76	-101.2	74.4	40.6	3.9	1.3	3.9	404.0	5.4	14.8	--	62400		DRI-SR-2	Spring	49	04/29/05
Wiregrass Spring (Sheep Range)	36.63325	-115.20842	-	-	-	-13.19	-95.6	-	-	-	-	-	-	-	-	-	--		SH-2	Spring	49	04/29/06
Wiregrass Spring (Sheep)	36.63325	-115.20842	**8.4**	**4.3**	**7.2**	**-12.93**	**-95.1**	**70.1**	**34.2**	**3.0**	**1.6**	**3.2**	**379.3**	**6.9**	**12.5**	**0.2**				**Spring**	**49**	
Wiregrass Spring (Grant)	38.35211	-115.42693	14.3	4.3	7.5	-13.29	-101.4										62831			Spring	372	06/30/05
Wiregrass Spring (Grant)	**38.35211**	**-115.42693**	**14.3**	**4.3**	**7.5**	**-13.29**	**-101.4**										**62831**			**Spring**	**372**	**06/30/05**
Woodchuck Spring	39.72453	-115.57297	7.5	6.9	6.8	-15.55	-119.6									--	62706		DRI-BK-2	Spring	356	06/05/05
Woodchuck Spring	**39.72453**	**-115.57297**	**7.5**	**6.9**	**6.8**	**-15.55**	**-119.6**									**--**	**62706**		**DRI-BK-2**	**Spring**	**356**	**06/05/05**
180W501	38.592009	-114.840798				-14.12	-105.6										SNWA			Deep Well	600	5/17/2006
180W501	**38.592009**	**-114.840798**				**-14.12**	**-105.6**										**SNWA**			**Deep Well**	**600**	**5/17/2006**
180W902	38.363315	-114.827504				-14.12	-104.7										SNWA			Deep Well	601	5/18/2006
180W902	**38.363315**	**-114.827504**				**-14.12**	**-104.7**										**SNWA**			**Deep Well**	**601**	**5/18/2006**
181M1	37.911628	-114.855283				-13.67	-105.0										SNWA			Deep Well	603	5/31/2006
181M1	**37.911628**	**-114.855283**				**-13.67**	**-105.0**										**SNWA**			**Deep Well**	**603**	**5/31/2006**
181W909M	37.695999	-114.746389				-13.50	-104.6										SNWA			Deep Well	604	6/5/2006
181W909M	**37.695999**	**-114.746389**				**-13.50**	**-104.6**										**SNWA**			**Deep Well**	**604**	**6/5/2006**
182M-1	37.34683	-114.957963				-14.07	-109.6										SNWA			Deep Well	606	5/23/2006
182M-1	**37.34683**	**-114.957963**				**-14.07**	**-109.6**										**SNWA**			**Deep Well**	**606**	**5/23/2006**
182W906M	37.326909	-114.854631				-13.33	-100.3										SNWA			Deep Well	607	9/2/2005
182W906M	**37.326909**	**-114.854631**				**-13.33**	**-100.3**										**SNWA**			**Deep Well**	**607**	**9/2/2005**
209M-1	37.643513	-114.989498				-13.53	-104.7										SNWA			Deep Well	608	6/14/2006
209M-1	**37.643513**	**-114.989498**				**-13.53**	**-104.7**										**SNWA**			**Deep Well**	**608**	**6/14/2006**
CSI-1	36.797679	-114.914709				-13.08	-102.6										SNWA			Well	609	5/31/2005
CSI-1	**36.797679**	**-114.914709**				**-13.08**	**-102.6**										**SNWA**			**Well**	**609**	**5/31/2005**
CSI-2	36.797681	-114.914709				-12.90	-100.2										SNWA			Well	610	9/30/2005
CSI-2	**36.797681**	**-114.914709**				**-12.90**	**-100.2**										**SNWA**			**Well**	**610**	**9/30/2005**
CSI-3	36.825539	-114.916667				-13.03	-99.6										SNWA			Well	611	9/13/2006
CSI-3	**36.825539**	**-114.916667**				**-13.03**	**-99.6**										**SNWA**			**Well**	**611**	**9/13/2006**
CSVM-2	36.661822	-114.923053				-13.14	-97.7										SNWA			Well	612	1/10/2006
CSVM-2	**36.661822**	**-114.923053**				**-13.14**	**-97.7**										**SNWA**			**Well**	**612**	**1/10/2006**
CSVM-3	37.052496	-114.983361				-13.10	-98.0										SNWA			Well	613	1/6/2006
CSVM-3	**37.052496**	**-114.983361**				**-13.10**	**-98.0**										**SNWA**			**Well**	**613**	**1/6/2006**
CSVM-4	36.991061	-114.886481				-13.41	-102.5										SNWA			Well	614	1/16/2006
CSVM-4	**36.991061**	**-114.886481**				**-13.41**	**-102.5**										**SNWA**			**Well**	**614**	**1/16/2006**
CSVM-5	36.747576	-114.980445				-12.67	-95.0										SNWA			Well	615	1/8/2006
CSVM-5	**36.747576**	**-114.980445**				**-12.67**	**-95.0**										**SNWA**			**Well**	**615**	**1/8/2006**
CSVM-6	36.832502	-114.909164				-12.97	-100.7										SNWA			Well	616	1/11/2006
CSVM-6	**36.832502**	**-114.909164**				**-12.97**	**-100.7**										**SNWA**			**Well**	**616**	**1/11/2006**
CSVM-7	37.047013	-114.995714				-12.51	-93.6										SNWA			Well	617	1/23/2006
CSVM-7	**37.047013**	**-114.995714**				**-12.51**	**-93.6**										**SNWA**			**Well**	**617**	**1/23/2006**
KPW-1						-14.00	-104.0										SNWA			Well	618	12/15/05
KPW-1						**-14.00**	**-104.0**										**SNWA**			**Well**	**618**	**12/15/05**

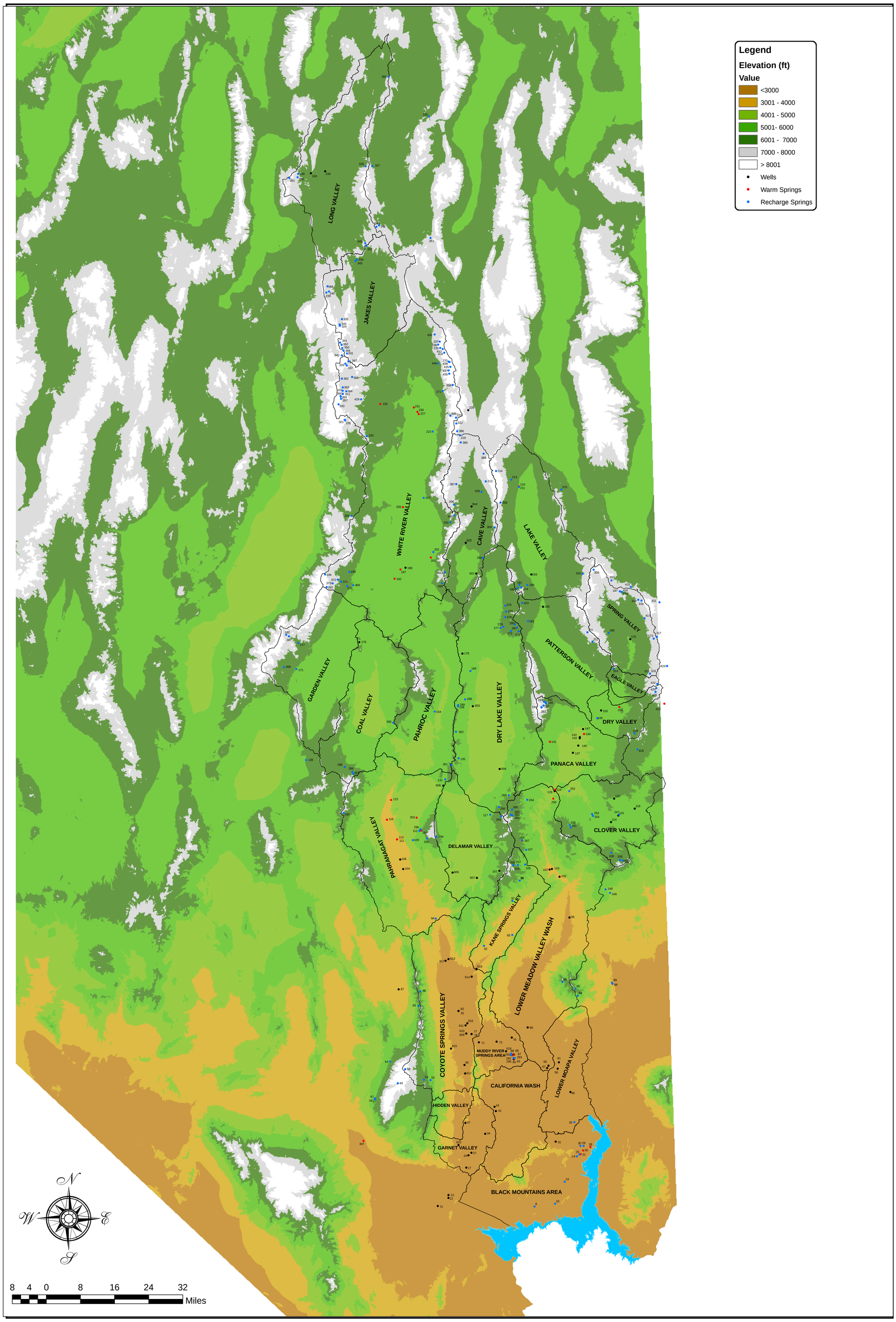

Plate 1. Site locations with site numbers which refer to the sites in the water chemistry appendix (Appendix 3) and on Plate 2.

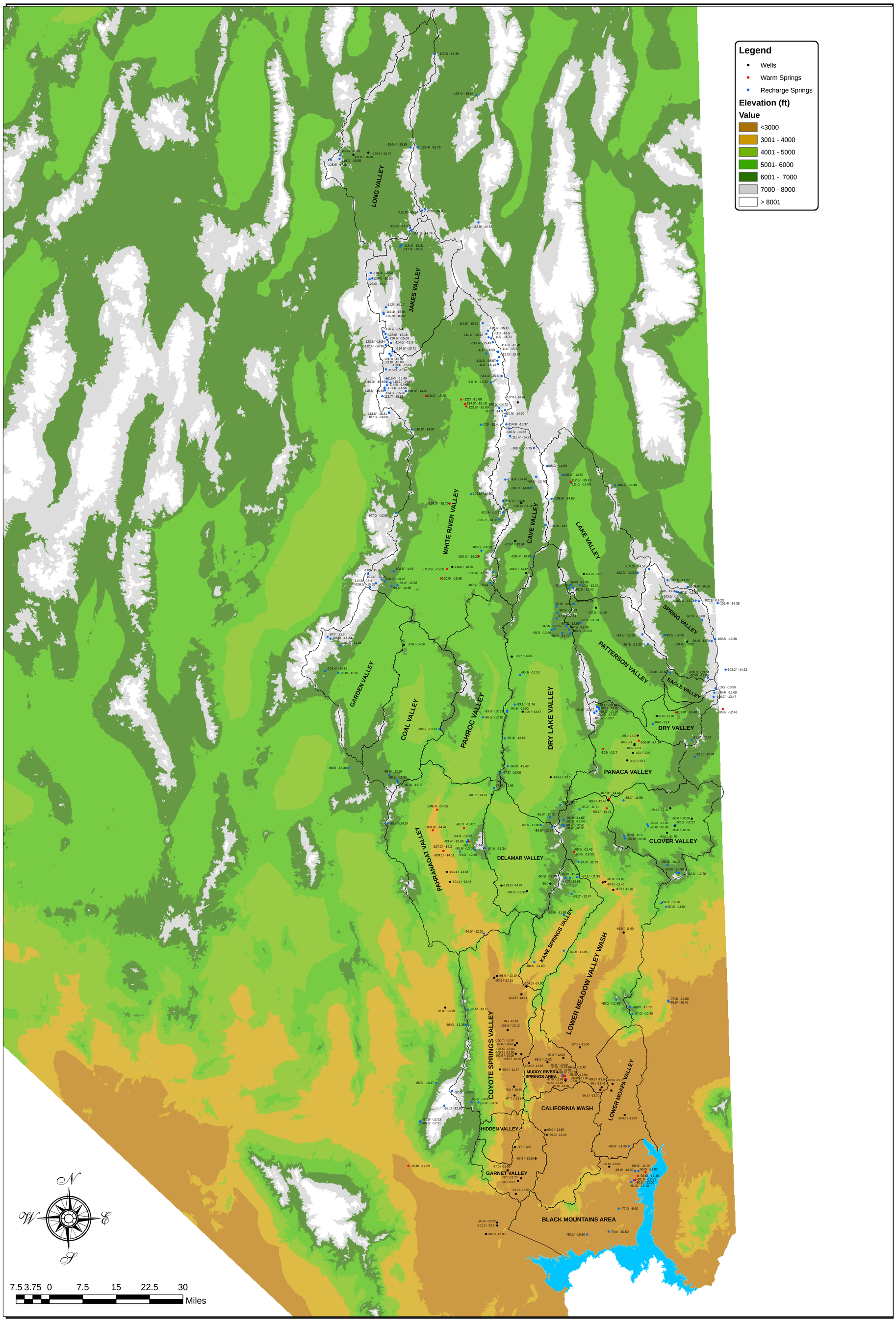

Plate 2. Deuterium and oxygen-18 data for all sites in the study area. If a site has more than one stable isotope analyses, the average value is shown on the plate. The data the plate was made from are given in Appendix 3.

Evaluation of Groundwater Origins, Flow Paths, and Ages in East-Central and Southeastern Nevada

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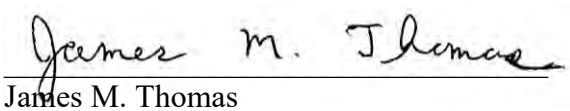

James M. Thomas
Desert Research Institute

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EXECUTIVE SUMMARY

This report evaluates groundwater sources and flow paths in the Delamar, Dry Lake, and Cave valleys (DDC) area using deuterium (δD) and oxygen-18 ($\delta^{18}O$) data combined with hydrogeologic information. The DDC area is part of the larger White River Flow System (WRFS), so this report also evaluates groundwater flow from the DDC area to other adjacent valleys in the WRFS. Carbon-14 corrected groundwater ages were also estimated for the regional warm spring areas of the WRFS to provide information on recharge timing and groundwater travel times within the WRFS.

Evaluation of isotopic variability of recharge area springs and regional warm springs shows that variability is small over a period of several years up to 40 years, for samples collected throughout all four seasons. Variability of four recharge area monitoring springs have standard deviations that range from 0.7 to 1.1 permil (‰) and 0.07 to 0.11‰ (except for one site with a value of 0.33), for δD and $\delta^{18}O$, respectively. This range in variability is for flows ranging from about 100 to 5,000 gallons per minute and with one site having 7 years of data and two of the three sites having 6 years of data. Isotopic variability of 10 regional warm springs had a standard deviation ranging from 0.5 to 1.9‰ for δD and 0.05 to 0.21‰ (except for one site with a value of 0.67) for $\delta^{18}O$. Spatial variability of recharge area sites was larger than the temporal variation, with standard deviations ranging from 1.8 to 4.2‰ and 0.35 to 0.70‰ for δD and $\delta^{18}O$, respectively. Thus, this low variability of δD and $\delta^{18}O$ groundwater data shows that they are an appropriate tool to evaluate sources and flow paths of groundwater in eastern and southeastern Nevada.

The δD and $\delta^{18}O$ data combined with mountain block recharge rates show that groundwater in the DDC area is supplied by local recharge from the mountain block recharge areas of the valleys. There is little, if any, interbasin flow into the most upgradient of these three valleys, Cave Valley. Groundwater flows out of Cave Valley into southeastern White River Valley and northeastern Pahroc Valley. Potentially a small amount (up to 2,000 acre-feet per year) of groundwater may flow into northwest Dry Lake Valley from northeast Pahroc Valley. Groundwater in Dry Lake Valley flows south into Delamar Valley. Groundwater flows south, or southwest, out of Delamar Valley to Coyote Springs Valley, although some groundwater may flow through the very southern part of Pahranagat Valley along the Pahranagat Valley Shear Zone before entering Coyote Springs Valley.

Isotopic data show that groundwater originating in the DDC area supplies little, if any, water to the warm springs in southern White River Valley. These data also show that groundwater discharging from warm springs in Pahranagat Valley are a mixture of waters recharged in numerous valleys north of Pahranagat Valley, which likely includes Cave Valley.

The δD and $\delta^{18}O$ data, tritium data, and carbon-14 corrected groundwater ages show that groundwater in the WRFS, which includes Delamar, Dry Lake, and Cave valleys, is recharged under current climatic conditions. Carbon-14 corrected groundwater ages also show that it can take thousands of years for groundwater from mountainous recharge areas to flow through numerous basins and discharge in warm spring areas throughout the WRFS.

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1. Site locations with site numbers which refer to the sites in Appendix 1.
2. Deuterium and oxygen-18 data for all sites used in this study and some additional sites in eastern and southern Nevada. If a site has more than one stable isotope analyses, the average value is shown on the plate. The data the plate was made from are given in Appendix 1.

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INTRODUCTION

This report focuses on groundwater flow through the Delamar, Dry Lake, and Cave valleys (DDC) area in east central Nevada. These three valleys are part of the larger White River Flow System (WRFS), which is a regional groundwater flow system in east-central Nevada (Figure 1). The primary objectives of this report are to: 1) evaluate groundwater sources and flow paths of the DDC area, with particular interest in potential flow from the DDC area to springs in adjacent valleys of the WRFS, primarily regional warm springs in White River and Pahranagat valleys; and 2) evaluate recharge timing to the WRFS, which also provides information on groundwater travel times within the WRFS.

This report is based on the Thomas and Mihevc (2007) report, but includes significant revisions. The revisions include: (1) the inclusion of new data collected since the 2007 report and additional data from the SNWA geochemical and isotopic database; (2) the addition of the calculation of carbon-14 corrected groundwater ages, which provides information on recharge timing and groundwater travel times within the WRFS; and (3) this report only focuses on groundwater sources and flow paths for the DDC area, so the isotope mass-balance model for the WRFS presented by Thomas and Mihevc (2007) was not updated or included in this study. Although this report focuses on the DDC area and does not include a discussion of the entire WRFS, carbon-14 corrected groundwater ages are presented for the regional warm springs in White River, Pahranagat, and Upper Moapa valleys of the WRFS.

The stable isotopes deuterium ($^{2}H/^{1}H$) and oxygen-18 ($^{18}O/^{16}O$), reported as δD and $\delta^{18}O$ in permil (parts per thousand; ‰), respectively, are used to evaluate groundwater sources and flow paths for the DDC area. This evaluation includes potential groundwater flow from the DDC area to adjacent valleys within the WRFS. δD and $\delta^{18}O$ are ideal natural tracers to evaluate water sources and flow paths of groundwater because they are part of the water molecule, rather than being dissolved in the water like all other potential tracers. Thus, δD and $\delta^{18}O$ values are only affected by physical processes, such as evaporation, and are unchanged under low to moderate temperatures by geochemical processes such as dissolution or precipitation, which affects other potential groundwater tracers. The ratio of the mass difference of ^{2}H as compared to ^{1}H (2/1) is significantly greater than that of ^{18}O to ^{16}O (18/16), so the change in deuterium values is greater than the change in oxygen-18 values during physical processes. Water that has undergone any significant evaporation is easily identified because of this mass-ratio difference. A change in δD and $\delta^{18}O$ values that result from the mass differences during physical processes is called isotopic fractionation. This fractionation is known and can be easily calculated for physical processes.

The timing of groundwater recharge and the travel time of groundwater along flow paths in the WRFS were evaluated using: (1) stable isotopes of water that is recharged and discharged all along the WRFS from its headwaters in Long Valley to the Muddy Springs discharge area in Upper Moapa Valley (Thomas and Mihevc, 2007); and (2) carbon-13 and carbon-14 data for dissolved inorganic carbon in groundwater of the WRFS. δD and $\delta^{18}O$ data provide information on the timing of recharge to the WRFS, as indicated by both recharge and regional spring isotopic values. Carbon-14 and carbon-13 data are used to estimate groundwater ages that are corrected for reactions involving solid and gas phases that contain carbon [such as calcite ($CaCO_3$) with no carbon-14 (rock sources) or atmospheric or soil zone CO_2 gas with modern or elevated carbon-14 values].

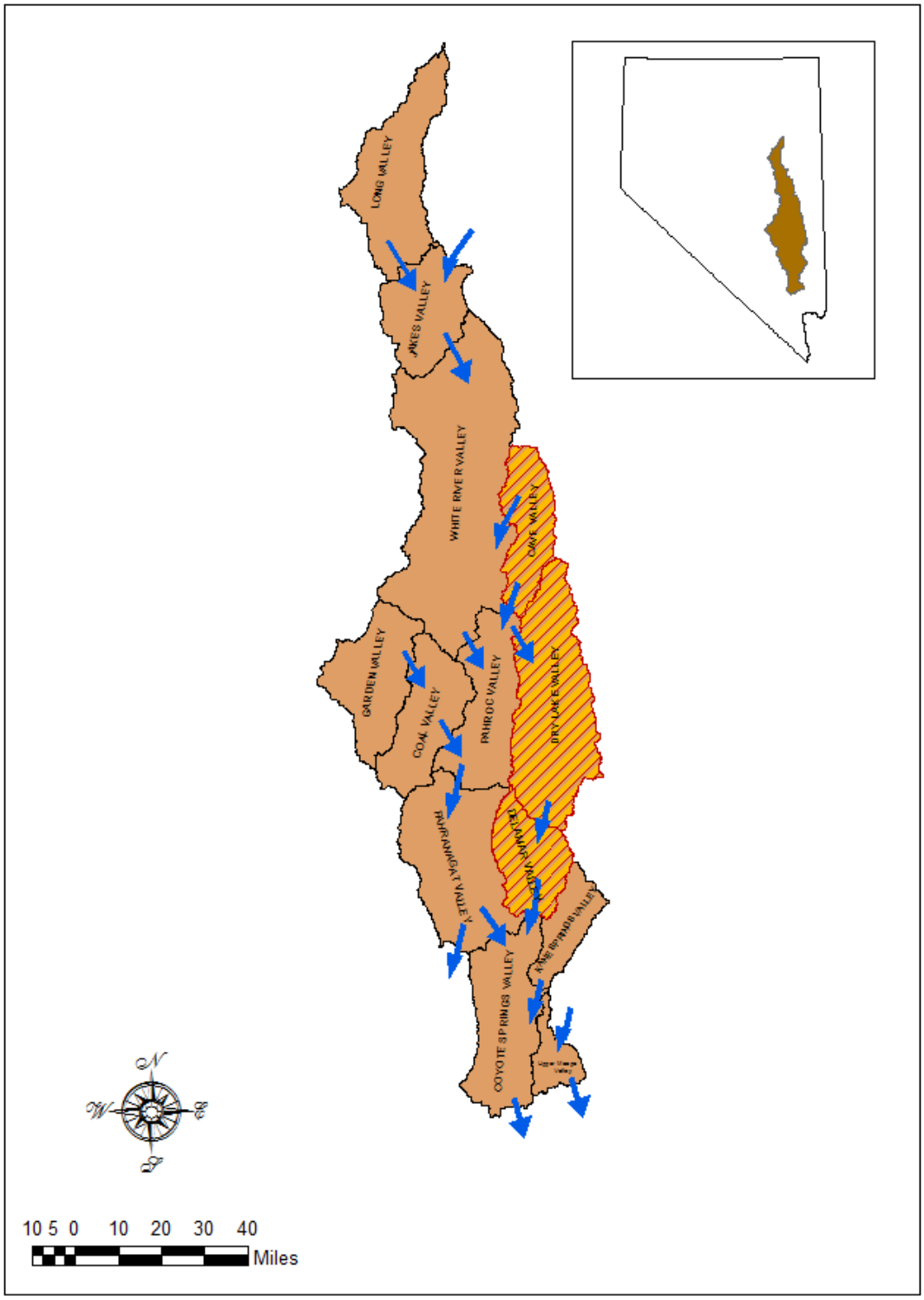

Figure 1. Study area location showing the White River Flow System (WRFS), which includes Delamar, Dry Lake, and Cave valleys (DDC area is shaded). General groundwater flow directions are from Burns and Drici (2011) and are shown by arrows.

Study Area Description

The focus area of this project is the DDC area, but it also includes the WRFS because groundwater flows from the DDC area to other valleys of the WRFS (Figure 1). The regional WRFS extends from Long Valley in the north to the Muddy River Springs area in Upper Moapa Valley in the south, with the DDC valleys located in the eastern middle part of the WRFS. A groundwater hydraulic gradient extends from Long Valley in the north to the Muddy River Springs area of Upper Moapa Valley in the south (Eakin, 1966; Mifflin, 1968; Thomas et al. 1986; 1996; 2001; Kirk and Campana, 1990; Thomas and Mihevc, 2007). Groundwater flow directions for the entire WRFS, including the DDC area, are shown in Figure 1.

Groundwater flows from north to south down the WRFS primarily in carbonate rock aquifers that underlie the area (Eakin, 1966; Mifflin, 1968; Thomas et al. 1986; 1996; Kirk and Campana, 1990; Plume and Carlton, 1988; Plume, 1996; Welch et al., 2007). Groundwater flows between valleys along the hydraulic gradient, and this interbasin flow is discharged from regional warm (> 20^{o}C) springs in White River, Pahranagat, and Upper Moapa valleys (Eakin, 1966; Mifflin, 1968; Kirk and Campana, 1990; Thomas et al., 1996; 2001; Thomas and Mihevc, 2007). Groundwater is recharged in mountains of the WRFS, which are generally along the eastern and western sides of the valleys, and this local recharge mixes with interbasin flow as it passes from one topographic valley to the next. Groundwater is discharged from local springs supplied by water from the adjacent mountain block recharge areas and from regional warm spring areas that include a mixture of groundwater from many recharge areas and valleys. Groundwater is also discharged in phreatophytic areas in some valleys of the WRFS, some of which are associated with warm spring discharge areas and others that are not part of the regional warm spring discharge areas but instead are supplied by recharge to that valley.

Water Chemistry and Isotope Data

Most of the water chemistry and isotopic data used in this report were collected by Desert Research Institute (DRI), U.S. Geological Survey (USGS), and Southern Nevada Water Authority (SNWA) personnel. Most of the water chemistry samples were analyzed at the DRI Water Quality Laboratory, in Reno, Nevada, or the USGS Central Water Quality Laboratory, in Denver, Colorado. Recent δD and $\delta^{18}O$ samples were analyzed at the University of Nevada, Reno Isotope Laboratory. Historic δD and $\delta^{18}O$ data used in this report are from samples analyzed at the DRI Isotope Laboratory in Las Vegas, Nevada; the USGS Isotope Laboratories in Reston, Virginia and Menlo Park, California; and the Waterloo Isotope Laboratory in Waterloo, Canada. Recent carbon-13 and carbon-14 isotopic data are from samples analyzed at the University of Arizona Accelerator Facility in Tucson, Arizona. Historic carbon isotope data are from samples analyzed at the DRI Isotope Laboratory in Las Vegas, Nevada, and the USGS Isotope Laboratories in Reston, Virginia and Menlo Park, California. All data used in this report are provided in Appendix 1. Appendix 1 was developed for isotopic and chemical studies for east-central and southeastern Nevada, so it also contains data outside of the area of this study that were not used in this report.

USING STABLE ISOTOPE DATA TO EVALUATE GROUNDWATER SOURCES AND FLOW PATHS

δD and $\delta^{18}O$ have been used to evaluate groundwater sources and flow paths because they are part of the water molecule. Once water recharges an aquifer, its isotopic signature (δD and $\delta^{18}O$ values) travels with the water and remains unchanged unless the water mixes with water from another source(s) with different δD and $\delta^{18}O$ values, or the groundwater undergoes evaporation (Kirk and Campana, 1990; Thomas et al., 1996; 2001; Clark and Fritz, 1997; Lundmark et al., 2007; Thomas and Mihevc, 2007). Thus, if the isotopic values of the recharge waters are known, and they differ for different recharge areas, then the source(s) of water in an aquifer can be identified. δD and $\delta^{18}O$ are conservative, so that they can also be used to evaluate amounts of groundwater mixing from different sources along a groundwater flow path.

In this study, the stable isotopes of water (δD and $\delta^{18}O$) are used to evaluate sources of groundwater in Delamar, Dry Lake, and Cave valleys and groundwater discharging from springs in adjacent valleys of the WRFS. As noted above, the δD and $\delta^{18}O$ values change only during evaporation and are not involved in chemical reactions that could change their values. Any groundwater that has undergone significant evaporation is not included in the isotope evaluations of water sources and flow paths and is not included in Appendix 1. A groundwater sample is assumed to have undergone significant evaporation if the predicted δD value as calculated from the measured $\delta^{18}O$ value of the sample is 10‰, or more, positive than the measured deuterium value. These samples are easily identified on a δD versus $\delta^{18}O$ plot because they plot 10‰ below (to the right of) of the global meteoric water line defined by the equation $\delta D = 8\delta^{18}O + 10$ (Craig, 1961). The global meteoric water line is a regression line that represents un-evaporated precipitation from all over the world, ranging from the equator to the Arctic and Antarctica. A local meteoric water line is sometimes developed for studies in Nevada, but these lines generally include groundwater samples that have undergone some evaporation or sublimation prior to recharge, thus they are highly influenced by the evaporated less negative samples. A study of isotopic values of precipitation in southern Nevada showed that precipitation values plot close to the global meteoric line, except for the lightest storms (<0.25 cm) which were highly evaporated, and snow samples plot along the global meteoric water line (Benson and Klieforth, 1989).

Groundwater sources and flow paths were evaluated by calculating the average δD and $\delta^{18}O$ values of mountain block recharge areas in a valley. Valleys in east-central and southeastern Nevada generally have two main recharge areas, a mountain block on the east side and a mountain block on the west side of the valley. However, no matter if there are two, or more than two, recharge areas within a topographic basin (valley), they are treated separately and assigned their own average δD and $\delta^{18}O$ values. δD and $\delta^{18}O$ values are assigned to recharge areas by taking the average stable isotope values of all the springs sampled in a recharge area. If a spring site contains more than one sample, then the average δD and $\delta^{18}O$ values for the site is used in calculating the average stable isotope value of the recharge area.

Recharge-area springs are used to represent the isotopic composition of groundwater recharge to a mountain block because they represent an integration of many recharge events and generally integrate recharge over large areas. Recharge-area springs are great integrators

and represent precipitation that becomes groundwater recharge because they: (1) average the isotopic composition of all precipitation events that become recharge, (2) do not contain water, and its isotopic signature, that is lost by sublimation, evaporation, and transpiration, and (3) represent a larger area than a single measurement point, such as precipitation collected at a single location.

The δD and $\delta^{18}O$ values of groundwater discharging from springs, or in wells, on the valley floor can be used to evaluate the source(s) of water supplying them. Springs and wells on valley floors that contain cool (< 20°C) groundwater can be used to evaluate sources of water recharging a basin. The source(s) of this cool water is generally local recharge to the adjacent mountain blocks, as indicated by the average isotopic composition of springs in mountain-block recharge areas weighted by the amount of recharge to each individual mountain block. If the δD and $\delta^{18}O$ values of water in a spring or well on a valley floor are similar to the average δD and $\delta^{18}O$ values of the recharge to the valley (within 2‰ δD and 0.2‰ $\delta^{18}O$) then the most likely groundwater source(s) is the local recharge to the mountain blocks within the valley. If the groundwater isotopic values are significantly different than the average recharge values, then the groundwater may include interbasin flow from an upgradient valley(s). Springs and wells on valley floors that contain warm groundwater [> 20°C, which represents an average flow depth of several thousand feet (Acheampong et al., 2005)] can be used to evaluate water sources and interbasin flow. The warm springs usually include flow from an upgradient basin(s) that flows at depth into the valley. The δD and $\delta^{18}O$ values of groundwater flowing out of an upgradient basin(s), along with δD and $\delta^{18}O$ values of local recharge, are used to identify the source(s) of groundwater discharging from warm spring areas. All four warm spring areas in White River, Pahranagat, and Upper Moapa valleys of the WRFS are isotopically much lighter (more negative) than local recharge in the adjacent mountain block recharge areas, supporting interbasin groundwater flow to these springs from upgradient basins (Plate 2; Appendix 1).

Deuterium and Oxygen-18 Variability

An important consideration in using δD and $\delta^{18}O$ values to evaluate the source(s) of water discharging from valley springs, or in wells, is their natural variability. This variability includes; (1) changes in recharge area spring isotopic values over time; (2) potential stable isotope differences with altitude in recharge areas; (3) the spatial distribution of stable isotope values of springs in mountain block recharge areas; and (4) changes in regional warm spring isotopic values over time. Ideally, isotopic variability will be small so that isotope values for springs in recharge areas and for springs and wells on the valley floor do not have a large uncertainty associated with them. If uncertainty of isotopic values for these springs and wells is small, then the measured isotopic values are appropriate indicators for determining present day recharge sources, as well as, historic recharge sources for springs and wells on valley floors. The analytical (measurement) precision for δD is +/– 1.0‰ and for $\delta^{18}O$ is +/– 0.10‰. (Analytical precision values represent one standard deviation; Simon Poulson, University of Nevada, Reno Isotope Laboratory, oral communication, 2007.)

Isotopic Variability Over Time of Springs in Recharge Areas

A large amount of isotopic data has been collected in recharge areas of the WRFS, including the DDC area (Figure 1; Plates 1 and 2; Appendix 1). Three springs in major

recharge areas of the WRFS [Monitoring Spring WR1 in the White Pine Range (site 320), Upper Terrace Spring WR2 in the Egan Range (site 270), and Patterson Pass Spring WR3 in the Schell Creek Range (site 305)] have been continuously monitored for flow, water temperature, and electrical conductance. These springs have also been sampled on an approximately quarterly basis (access permitting) for δD, $\delta^{18}O$, pH, and major-ion chemistry from October of 2003 to November 2009, with WR1 also having a sample collected in June 2010. In addition, one recharge area spring [Upper Riggs Spring, WR4 in the Delamar Mountains (site 105)] was monitored and sampled from April 2004 to February 2005 until the monitoring site was destroyed by a flood. This monitoring site also has a sample from February 1984. Bulk precipitation amount was also measured at the spring monitoring sites and precipitation samples were collected for δD and $\delta^{18}O$ analysis. These data are presented in Appendix 2. Numerous recharge-area springs were also sampled for stable isotopes and major-ion chemistry to provide information for recharge areas that had little or no isotopic data in the Thomas et al. (2001) study and to provide more data for all recharge areas throughout the WRFS (Plates 1 and 2; Appendix 1).

Continuous flow and approximately quarterly deuterium data for recharge-area monitoring springs are shown in Figures 2, 3, and 4 ($\delta^{18}O$ is not shown on the plots because it is strongly correlated with δD and follows the same trend as δD). As is observed in all three figures, the δD composition of the springs varies little with change in flow or season. For example, δD values for Monitoring Spring WR1 in the White Pine Range only varies between -116.2 and -111.2‰ for a range in flow of about 100 to 5,000 gallons per minute and for the time period October 2003 to June 2010 (Figure 2; Table 1). Oxygen-18 for these same samples varies between -15.90 and -15.32‰. During this period, 25 samples were collected with an average δD value of -114.0‰ and a standard deviation of 1.1‰ and an average $\delta^{18}O$ value of -15.63‰ with a standard deviation of 0.11‰ (Table 1). A similar pattern is observed for the other three recharge-area monitoring springs in the WRFS (Figures 3 and 4; Table 1). Table 1 presents a summary of the data in Figures 2, 3, and 4 and data for the shorter record at Upper Riggs Spring WR4 in the Delamar Range, with minimum, maximum, median, mean, and standard deviation values for the isotopic data for all four recharge area monitoring sites. The greatest range in δD values that was observed for all four sites is 5.0‰ for the Monitoring Spring WR1 in the White Pine Range and the smallest range is 1.8‰ for five samples for the Upper Riggs Spring WR4 monitoring site in the Delamar Mountains (Table 1). All of the standard deviations of the spring δD data are about 1‰ with the highest standard deviation being 1.1‰ for Monitoring Spring WR1 and the lowest being 0.7‰ for Upper Riggs Spring. $\delta^{18}O$ data follows a similar pattern with the standard deviation ranging from 0.07 to 0.11‰ (except for Upper Riggs Spring with a value of 0.33‰) for the four recharge-area monitoring sites (Table 1). These standard deviations are about the same as the analytical uncertainty of the δD and $\delta^{18}O$ water analysis.

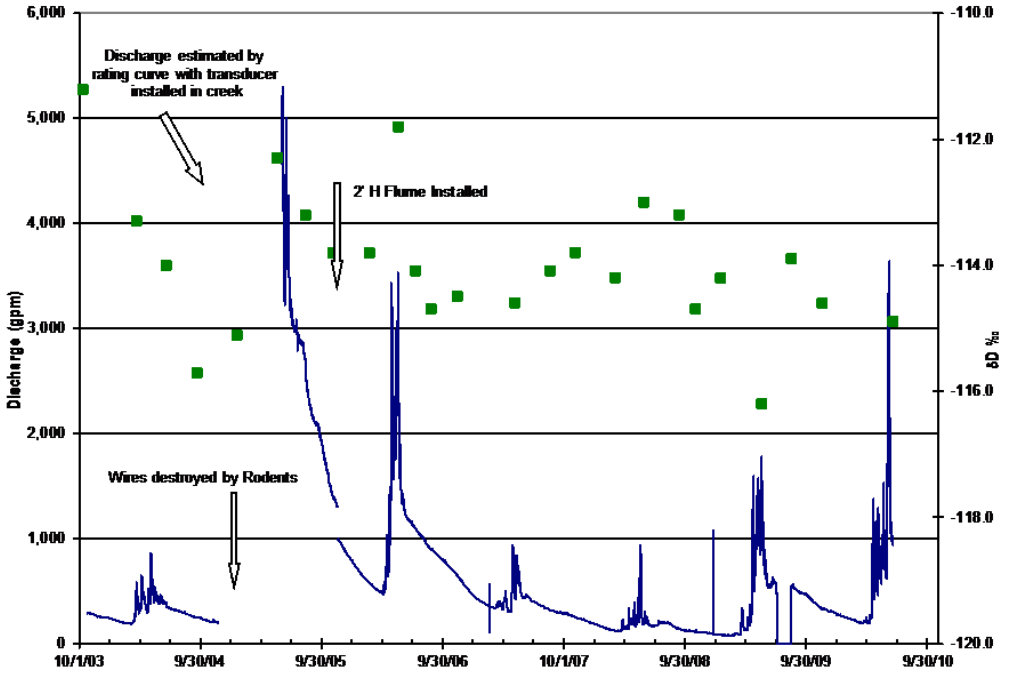

Figure 2. Deuterium and flow data for Monitoring Spring WR1 in the White Pine Range in northwestern White River Valley. Green squares are the deuterium data, which have an analytical uncertainty of +/- 1.0‰. Blue line is spring flow. The high spring flows in the spring of 2005 are estimated from a rating curve developed from continuous stream-height data and flow measurements (flow exceeded the flume capacity).

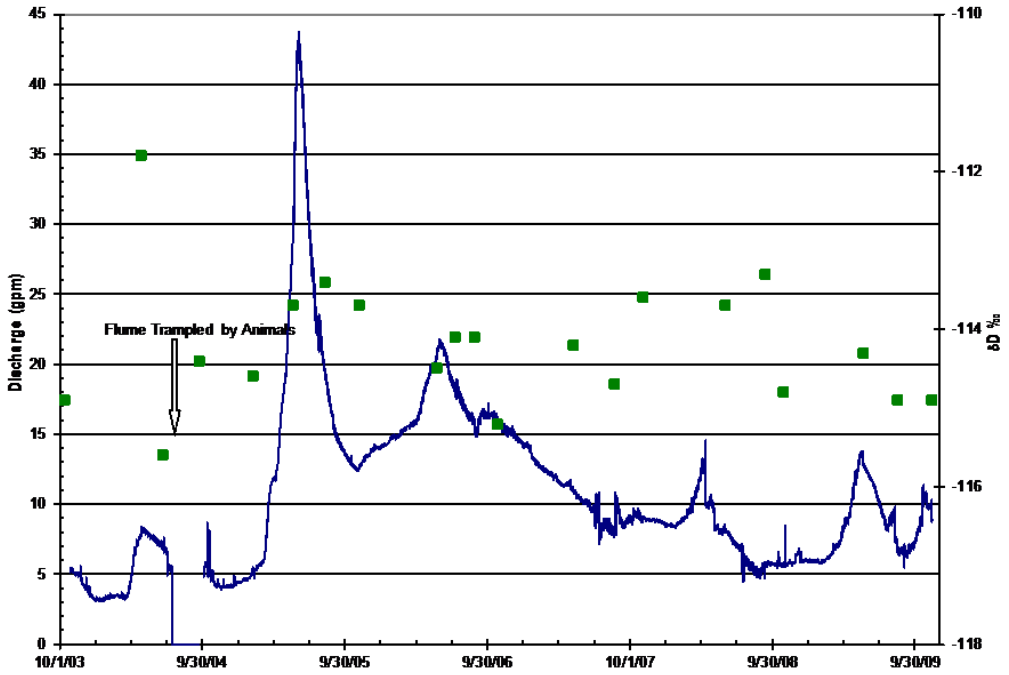

Figure 3. Deuterium and flow data for Upper Terrace Spring WR2 in the Egan Range in northeastern White River Valley. Green squares are the deuterium data, which have an analytical uncertainty of +/- 1.0‰. Blue line is spring flow.

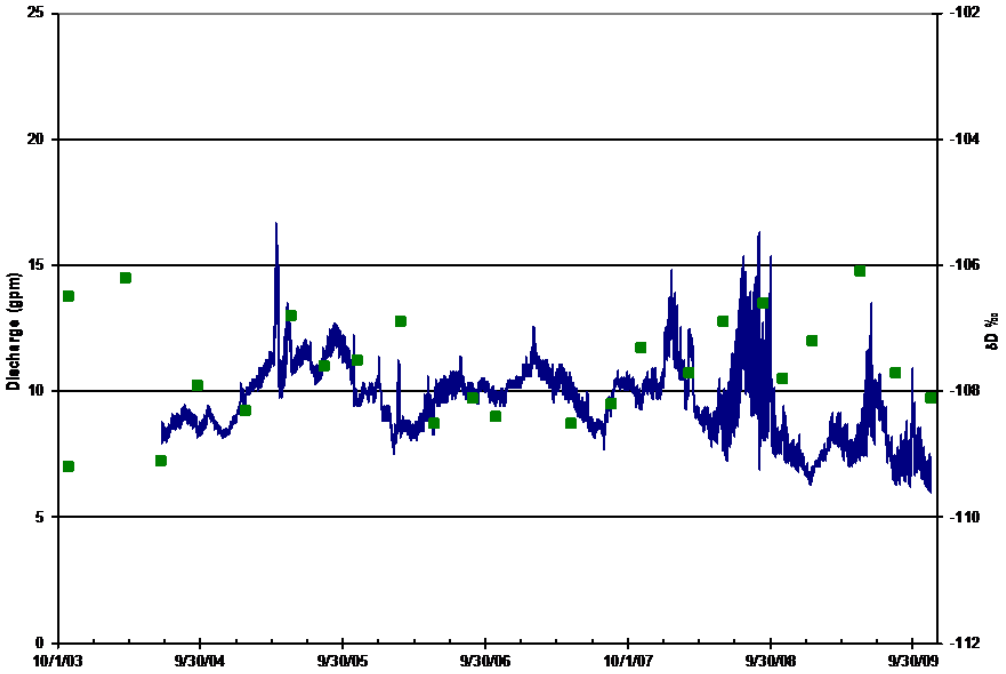

Figure 4. Deuterium and flow data for Patterson Pass Spring WR3 in the Schell Creek Range in western Lake Valley. Green squares are the deuterium data, which have an analytical uncertainty of +/- 1.0‰. Blue line is spring flow.

Table 1. Variability of δD and $\delta^{18}O$ in recharge-area springs of the WRFS. Values are reported in permil.

Site Name		Number of Samples	Minimum	Maximum	Median	Mean	Standard Deviation
			White Pine Range				
Monitoring Spring WR1	δD	25	-116.2	-111.2	-114.1	-114.0	1.1
Monitoring Spring WR1	$\delta^{18}O$	25	-15.90	-15.32	-15.64	-15.63	0.11
			Egan Range				
Upper Terrace Spring WR2	δD	21	-115.6	-111.8	-114.3	-114.2	0.8
Upper Terrace Spring WR2	$\delta^{18}O$	21	-15.64	-15.24	-15.46	-15.45	0.08
			Schell Creek Range				
Patterson Pass Spring WR3	δD	24	-109.1	-106.1	-107.8	-107.6	0.8
Patterson Pass Spring WR3	$\delta^{18}O$	24	-14.96	-14.71	-14.90	-14.88	0.07
			Delamar Mountains				
Upper Riggs Spring WR4	δD	5	-88.0	-86.2	-87.0	-87.0	0.7
Upper Riggs Spring WR4	$\delta^{18}O$	5	-12.46	-11.55	-11.90	-11.95	0.33

Isotopic Variability with Altitude of Springs in Recharge Areas

The potential for variability of stable isotope values with altitude also needs to be considered, because if stable isotope values become more depleted (more negative) with increasing altitude in the recharge areas, this would need to be accounted for in assigning average stable isotope values to recharge areas (the amount of precipitation and the percent of precipitation that becomes recharge increases with increasing altitude). The altitudes of the springs were used in these evaluations, although the average recharge altitude of the source of the spring water would be a better altitude value to use than the spring altitude (Russell et al., 2007). One could estimate the average altitude of recharge represented by the spring using the methods of Russell et al. (2007), or by simply taking the average altitude of the catchment above the spring because according to Russell et al. (2007), page 48 –Uncertainty in the actual elevation of the recharge basin tended to pull the mean elevation toward the middle of that slope." In the Russell et al. (2007) report –that slope" was the slope between the spring and the highest point in the watershed above the spring. However, this approach was not taken in this study because of the unknown source of recharge to the springs (they could be derived from recharge to the mountain block anywhere above the spring) and precipitation amounts for the elevation gradients within the watershed would have to be known to correctly estimate the average recharge altitude based on a precipitation weighted altitude relationship (because of the increase in precipitation with altitude in mountainous recharge areas of Nevada). Finally, using the average altitude of the spring catchment would have little effect on the trends of the plots presented in Figures 5 through 8, and any effect would likely be to increase the lower-spring altitudes relative to the higher-spring altitudes (since many of the springs would have a similar ridge line altitude for their catchments). Incorporating average recharge altitudes for springs would likely reduce any potential altitude-stable isotope relationship.

The relationship between δD and altitude was evaluated for four major recharge areas in the study area that contained 14, or more, springs. In the northern part of the WRFS, the White Pine Range and Central Egan Range δD data were plotted as a function of altitude (Figures 5 and 6). There are very weak relationships (R^2 values of 0.066 and 0.018) of δD as a function of altitude in these plots and the strongest relationship, which is for the White Pine Range, shows a negative slope for δD as a function of altitude (δD values increase with increasing altitude). In the central and southern part of the WRFS, δD data were plotted as a function of altitude for the Fairview and Bristol Ranges and the Delamar Mountains (Figures 7 and 8). There is a very weak relationship of δD with altitude for the Fairview and Bristol Ranges (R^2 value of 0.026). There is a stronger observed relationship for the Delamar Range (R^2 value of 0.366) than the other three recharge areas, with δD values becoming more positive with decreasing altitude (Figures 5-8). Using the average value of all the springs may result in a more positive δD recharge value for the Delamar Range than the actual δD recharge value, so this relationship could shift the average isotopic recharge value for the Delamar Range to an isotopic value that is 2 to 3‰ more negative. This shift would have no effect on the interpretations in this report. Although a decrease in δD values with increasing altitude is observed on the western side of the Sierra Nevada, as storm tracks originating from the Pacific Ocean move inland and ascend to the Sierra crest (Smith et al., 1979), this effect is not assumed to occur in eastern and southeastern Nevada because cloud

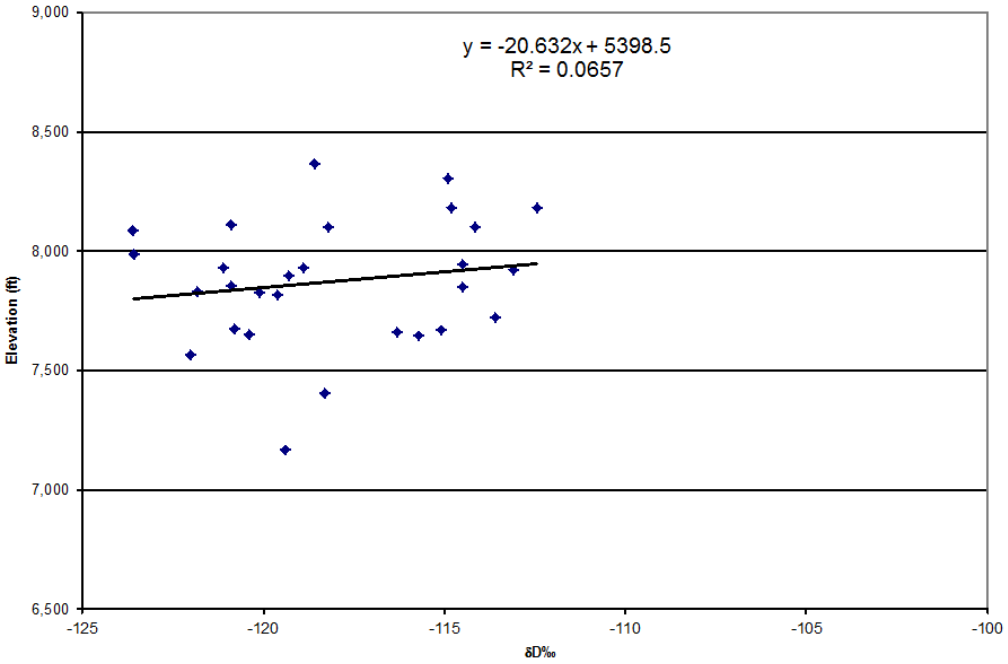

Figure 5. Deuterium as a function of altitude in the White Pine Range. δD data have an analytical uncertainty of +/- 1.0‰.

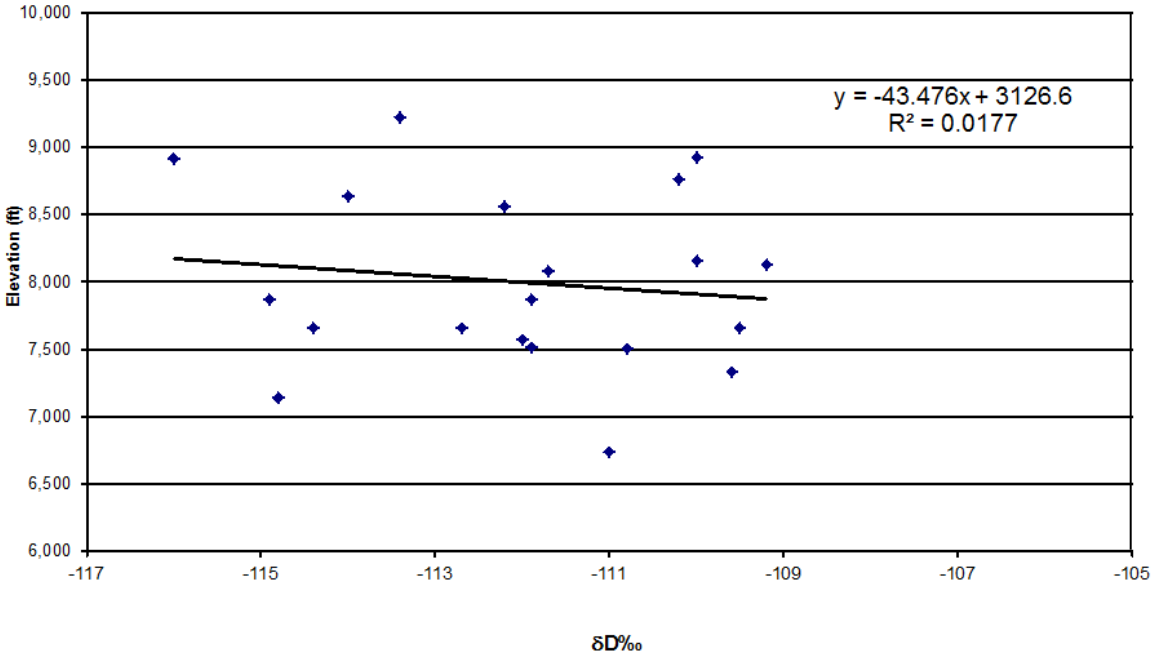

Figure 6. Deuterium as a function of altitude in the Central Egan Range. δD data have an analytical uncertainty of +/- 1.0‰.

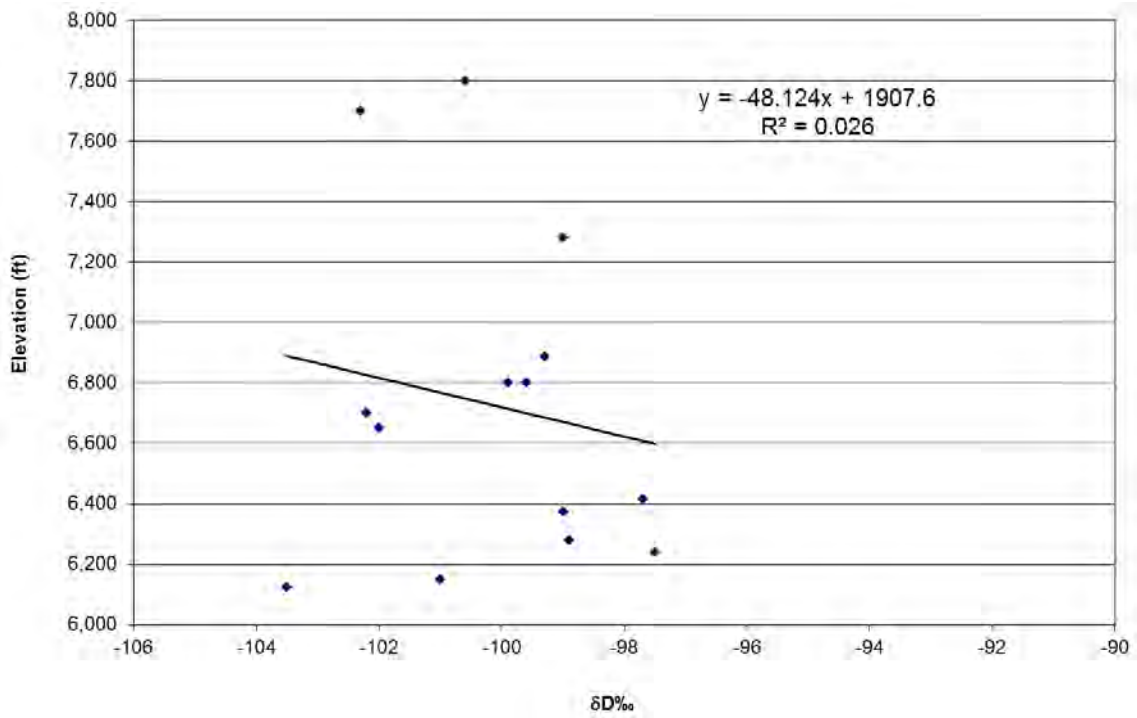

Figure 7. Deuterium as a function of altitude in the Highland and Fairview Ranges. δD data have an analytical uncertainty of +/- 1.0‰.

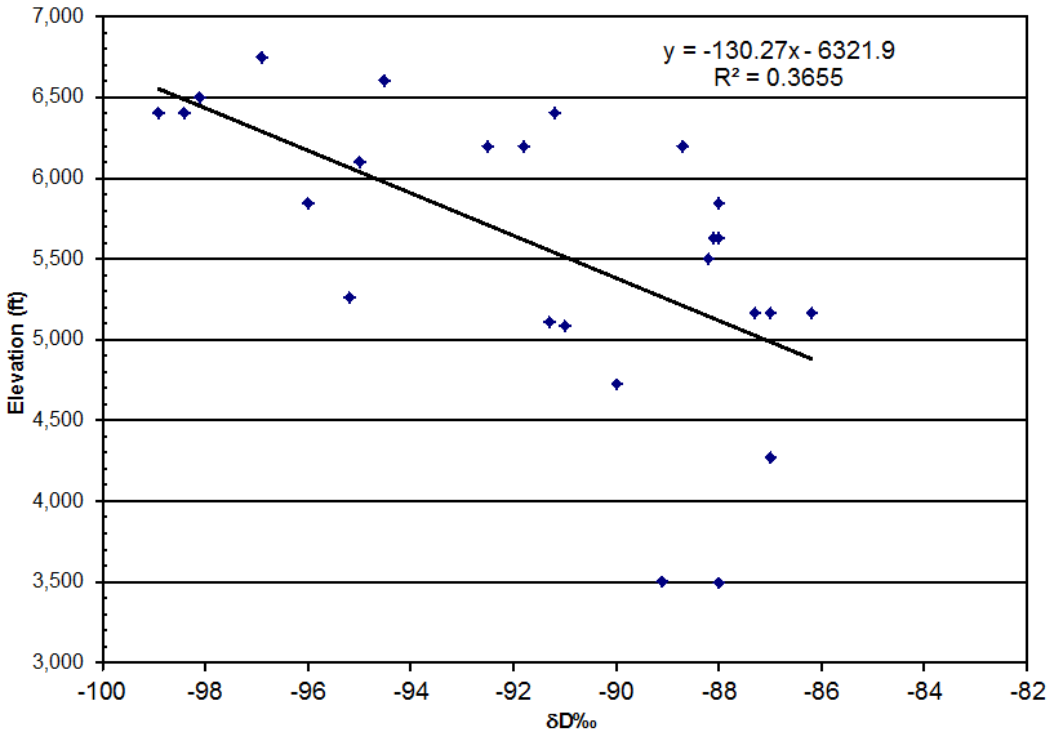

Figure 8. Deuterium as a function of altitude in the Delamar Mountains. δD data have an analytical uncertainty of +/- 1.0‰.

base levels may be similar across the Great Basin. The lack of an apparent δD with altitude relationship in all but the Delamar Range in the four WRFS recharge areas is consistent with the results of Thomas et al. (1996; Figure 21) for the Spring Mountains in southern Nevada. They found no δD-altitude relationship for samples ranging in altitude from about 4,400 to 10,300 feet in the Spring Mountains. The significance of a lack of a δD-altitude relationship is that isotopic values in recharge areas can simply be averaged to obtain the recharge isotopic signature for a mountain block recharge area.

Spatial Isotopic Variability of Springs in Recharge Areas

The spatial variability of δD values in recharge areas is presented in Table 2. The range in δD values for the recharge areas is 4.8 to 11.9‰ and the standard deviations of these recharge area springs range from 1.8 to 4.2‰ (Table 2). These ranges in δD and standard deviation values are greater than the range in spring δD temporal values presented in Table 1. Given that δD values of groundwater in valleys adjacent to these recharge areas, that have cool temperatures (< 20°C) and variable flow rates indicating that they are derived from local recharge, have similar δD values to that of the average value of springs in the adjacent recharge areas indicates that they are appropriate values to represent recharge in the mountain block recharge areas (see discussion later in this report in section titled "Isotopic Evaluation of Groundwater Sources and Flow Paths"). This similarity of the average δD value of springs in recharge areas with that of locally derived groundwater in adjacent valleys, combined with the small variability of spring δD values over time and large flow fluctuations, shows that springs in mountain block recharge areas provide good representative δD values for DDC recharge areas.

Isotopic Variability of Regional Warm Springs

Regional warm (> 20°C) springs in the WRFS have consistent isotopic values and flow rates over time, have average flow depths of several thousand feet (Acheampong et al., 2005), and contain significantly more negative isotopic values than local recharge to the basin that they are in, so they provide valuable information needed to evaluate interbasin groundwater flow in the WRFS. Thus, it is important that isotopic variability of these springs is known, and if this variability is large, then the water sources supplying regional warm springs would need to be considered under transient, rather than steady-state, conditions. Table 3 presents minimum, maximum, median, mean, and standard deviation values for δD and $\delta^{18}O$ for the warm spring provinces (discharge areas) of the WRFS. Analysis of data are presented for individual springs within a warm spring province if three or more analyses are available and for the average of all warm springs in a warm spring province (Table 3). For example, in northern White River Valley, Preston Big Spring (Appendix 1 and Plate 1; site 231) is a warm spring in the Preston warm spring province that has 13 samples, so the variability of stable isotopic data for this spring was analyzed. Additionally, there are two other warm springs in the warm spring province, Nicholas (Appendix 1 and Plate 1; site 227) and Cold (Appendix 1 and Plate 1; site 230) springs. Cold Spring is a warm (21.8°C) spring despite its name. So, the statistical values for Preston Big Spring data and also for the average values of the three springs in the Preston warm spring

Table 2. Spatial variability of δD and $\delta^{18}O$ in mountain block recharge areas of the DDC area. Values are reported in permil. NA: not applicable.

Site Name		Number of Samples	Minimum	Maximum	Median	Mean	Standard Deviation
			Cave Valley				
South Schell Creek Range	δD	6	-109.5	-99.5	-106.2	-105.0	4.0
South Schell Creek Range	$\delta^{18}O$	6	-14.88	-13.17	-14.47	-14.21	0.64
South Egan Range	δD	8	-111.4	-103.4	-106.6	-106.9	3.3
South Egan Range	$\delta^{18}O$	8	-15.04	-13.32	-14.21	-14.15	0.70
			Dry Lake Valley				
South Schell Creek Range	δD	1	-100.9	-100.9	-100.9	-100.9	NA
South Schell Creek Range	$\delta^{18}O$	1	-13.17	-13.17	-13.17	-13.17	NA
North Pahroc Range	δD	8	-97.3	-90.5	-94.1	-94.3	2.4
North Pahroc Range	$\delta^{18}O$	8	-13.06	-11.76	-12.43	-12.39	0.42
Fairview Range	δD	13	-103.5	-97.4	-98.9	-99.5	2.0
Fairview Range	$\delta^{18}O$	13	-13.60	-12.34	-12.73	-12.88	0.44
Bristol and Highland Ranges	δD	6	-101.2	-95.0	-99.1	-98.9	2.2
Bristol and Highland Ranges	$\delta^{18}O$	6	-13.87	-12.07	-13.36	-13.28	0.66
Chief Range	δD	9	-98.9	-88.2	-95.0	-94.6	3.9
Chief Range	$\delta^{18}O$	9	-12.98	-11.69	-12.32	-12.36	0.52
			Delamar Valley				
Delamar Range	δD	17	-98.9	-87.0	-91.8	-92.4	4.2
Delamar Range	$\delta^{18}O$	17	-12.98	-11.46	-12.47	-12.32	0.49
South Pahroc Range	δD	8	-97.4	-92.6	-94.2	-94.6	1.8
South Pahroc Range	$\delta^{18}O$	8	-13.24	-12.30	-12.84	-12.81	0.35

Table 3. Variability of δD and $\delta^{18}O$ of regional warm (> 20°C) springs in the WRFS. Values are reported in permil.

Site Name		Number of Samples	Minimum	Maximum	Median	Mean	Standard Deviation
			North White River Valley				
Preston Big Spring	δD	13	-126.0	-120.0	-121.8	-122.0	1.5
Preston Big Spring	$\delta^{18}O$	13	-15.99	-15.60	-15.88	-15.87	0.12
North White River Valley	δD	3	-124.0	-121.8	-123.5	-123.1	1.2
North White River Valley	$\delta^{18}O$	3	-16.10	-15.80	-15.88	-15.93	0.16
			South White River Valley				
Hot Creek Springs	δD	12	-120.5	-117.4	-119.1	-119.1	0.9
Hot Creek Springs	$\delta^{18}O$	12	-15.82	-15.50	-15.71	-15.69	0.10
South White River Valley	δD	4	-120.0	-118.0	-119.4	-119.2	0.9
South White River Valley	$\delta^{18}O$	4	-15.80	-15.30	-15.65	-15.60	0.21
			Pahranagat Valley				
Crystal Springs	δD	18	-111.0	-106.9	-109.0	-109.0	1.0
Crystal Springs	$\delta^{18}O$	15	-14.53	-14.23	-14.41	-14.40	0.08
Hiko Spring	δD	7	-110.5	-105.0	-109.5	-108.7	1.9
Hiko Spring	$\delta^{18}O$	4	-15.30	-13.80	-14.23	-14.39	0.67
Ash Springs	δD	6	-112.0	-107.0	-108.7	-109.1	1.8
Ash Springs	$\delta^{18}O$	3	-14.20	-14.03	-14.10	-14.11	0.09
Pahranagat Valley	δD	4	-109.1	-107.2	-108.9	-108.5	0.9
Pahranagat Valley	$\delta^{18}O$	4	-14.40	-14.11	-14.29	-14.27	0.14

Table 3. Variability of δD and $\delta^{18}O$ of regional warm (> 20°C) springs in the WRFS (continued).

Site Name		Number of Samples	Minimum	Maximum	Median	Mean	Standard Deviation
Upper Moapa Valley (Muddy Springs area)							
Baldwin Spring	δD	9	-98.6	-96.3	-97.9	-97.6	0.8
Baldwin Spring	$\delta^{18}O$	9	-13.05	-12.91	-12.95	-12.97	0.05
Big Muddy Spring	δD	6	-99.0	-96.5	-98.0	-97.9	0.8
Big Muddy Spring	$\delta^{18}O$	5	-13.05	-12.75	-12.89	-12.89	0.11
Jones Spring Pumphouse	δD	6	-98.9	-97.3	-97.9	-97.9	0.5
Jones Spring Pumphouse	$\delta^{18}O$	6	-13.10	-12.99	-13.07	-13.05	0.05
Pederson's East	δD	9	-98.7	-97.0	-97.7	-97.8	0.6
Pederson's East	$\delta^{18}O$	9	-13.06	-12.89	-12.98	-12.98	0.06
Pederson's Warm Spring (M-13)	δD	15	-99.0	-96.5	-97.4	-97.5	0.6
Pederson's Warm Spring (M-13)	$\delta^{18}O$	13	-13.05	-12.75	-12.91	-12.93	0.09
Upper Moapa Valley	δD	9	-99.0	-96.5	-97.8	-97.7	0.7
Upper Moapa Valley	$\delta^{18}O$	8	-13.05	-12.45	-12.94	-12.87	0.19

province are presented in Table 3. δD values for Preston Big Spring range from -126.0 to -120.0‰, with a mean value of -122.0‰ and a standard deviation of 1.5‰. δD values range from -124.0 to -121.8‰, with a standard deviation of 1.2‰ for the average values of the three springs in the Preston warm spring province. In general, the standard deviations for the individual warm spring δD data and for the average values of all springs with isotopic data in a warm spring province are about 1‰ (Table 3). $\delta^{18}O$ data follow a similar pattern, with standard deviations ranging from 0.05 to 0.21‰ (except for one site with a standard deviation of 0.67‰). The variability of the warm spring isotopic data is similar to the analytical uncertainly of δD (1.0‰) and $\delta^{18}O$ (0.1‰). This low variability of the stable isotopic data shows that the stable isotopic composition of regional warm springs provides an appropriate means for evaluating groundwater sources and flow paths for the springs.

It is important to understand that the small degree of isotopic variation in some samples from warm springs is over a period lasting from 20 to 40 years. For example, isotopic data was first collected for Big Muddy Spring, in Upper Moapa Valley, in March 1970 and six samples from 1970 to 2004 have a range of only -99.0 to -96.5‰. Similarly, Hiko, Crystal, and Ash springs in Pahranagat Valley have isotopic data that were first collected in 1968. For all three springs during the time period of 1968 to 2006, δD only varied by 5.5‰. Preston Big Spring in northern White River Valley and Hot Creek Spring in southern White River Valley have samples that span 24 and 26 year periods with a range in δD values of 6.0 and 3.1‰, respectively (Table 3).Summary of Isotopic Variability

The small range in isotopic values and standard deviations of the recharge area and regional warm spring data shows that δD and $\delta^{18}O$ are appropriate tracers of groundwater in the WRFS that can be used to evaluate sources and flow paths. If temporal variability of δD and $\delta^{18}O$ of recharge area monitoring springs and regional warm springs had been high, then the uncertainty associated with using them to evaluate water sources and flow paths in regional flow systems would have also been high.

Isotopic Evaluation of Groundwater Sources and Flow Paths

The WRFS shown in Figure 1 and Plate 1 has a hydraulic gradient that extends from Long Valley in the north to Upper Moapa Valley (Muddy River Springs) in the south (Eakin, 1966; Mifflin, 1968; Kirk and Campana, 1990; Thomas et al., 1996; 2001; Thomas and Mihevc, 2007). Groundwater in this regional flow system flows primarily through carbonate-rock aquifers (Eakin, 1966; Mifflin, 1968; Thomas et al. 1986; 1996; Plume and Carlton, 1988; Kirk and Campana, 1990; Plume, 1996; Welch et al., 2007), although volcanic rocks are also present as is observed for parts of the DDC area of the White River Flow System (Plume and Carlton, 1988; Plume, 1996; Rowley and Dixon, 2011).

If δD and $\delta^{18}O$ data are going to be used to evaluate groundwater sources and flow paths, including interbasin flow, then these data have to be significantly different for the different recharge areas and for groundwater within each valley. Thomas and Mihevc (2007) showed that the δD and $\delta^{18}O$ values of groundwater in the northern part of the WRFS were 50 and 6.5‰ more negative, respectively, than groundwater in the southern part of the WRFS. Although the DDC area only extends through the middle and eastern part of the WRFS (Figure 1), δD and $\delta^{18}O$ data for the DDC area have a range of 24.4 and 3.35‰, respectively, from northern Cave Valley to southern Delamar Valley (Figure 9). Since, the

analytical uncertainty of δD is +/- 1‰ and $\delta^{18}O$ is +/- 0.1‰, these differences in δD and $\delta^{18}O$ values observed for the DDC area are significant, so δD and $\delta^{18}O$ values can be used to evaluate sources and flow paths of groundwater in the DDC area and potential flow to adjacent valleys.

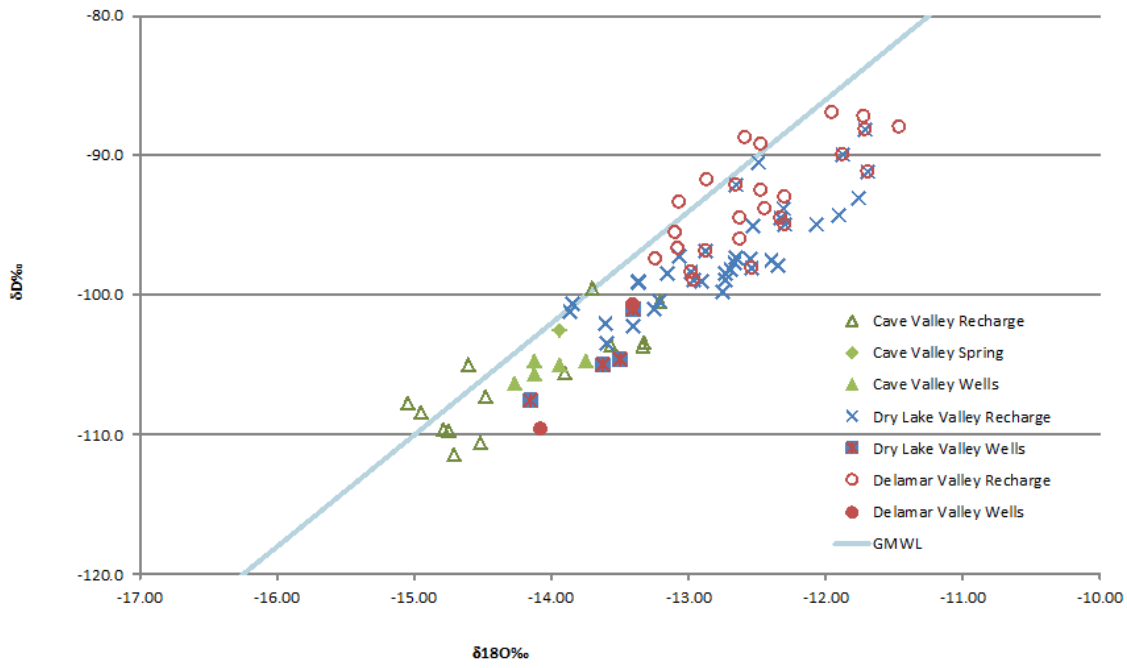

Figure 9. Plot of deuterium versus oxygen-18 for samples in the DDC area. GMWL is the Global Meteoric Water Line from Craig (1961).

Groundwater discharging from springs and in wells on the valley floors outside of recharge areas can be used to evaluate groundwater sources and flow paths. Two types of springs exist in the WRFS: (1) cool (< 20°C) springs that receive recharge from adjacent mountain block recharge areas surrounding a valley; and (2) warm (> 20°C) springs that have deep groundwater flow (thousands of feet below the land surface; Acheampong et al., 2005) and generally have interbasin flow as part, if not all, of their discharge. In the DDC area, cool springs and wells on the valley floors are present, but there are no warm springs in this area. However, regional warm springs are present in valleys adjacent to the DDC area, so isotopic data for warm springs in White River and Pahranagat valleys are used to evaluate potential groundwater flow from the DDC area to these regional warm springs.

Delamar, Dry Lake, and Cave Valleys

The DDC area has groundwater flow primarily in carbonate-rock aquifers underlying the three valleys and unconsolidated basin-fill aquifers within the valleys (Burns and Drici, 2011). There are also areas of volcanic rock in the DDC area that may contain local aquifers (Plume, 1996; Rowley and Dixon, 2011). A hydraulic gradient extends from Cave Valley (highest water level elevations) to Dry Lake Valley to Delamar Valley (lowest water level

elevations; Figure 1 and Plate 1; Burns and Drici, 2011). Thus, potentially groundwater could flow from Cave to Dry Lake to Delamar valleys from north to south down the hydraulic gradient. However, due to geologic and structural controls in the central and southern parts of Cave Valley, groundwater in northwestern Cave Valley is thought to flow toward the southwest into southeastern White River Valley (along the Shingle Pass Fault system) and groundwater in northeastern and southern Cave Valley is thought to flow toward the southwest into northeastern Pahroc Valley (Eakin, 1966; Kirk and Campana, 1990; Thomas and Mihevc, 2007; Burns and Drici, 2011; Rowley and Dixon, 2011). Hydrogeologic data indicates that groundwater does flow from northern Dry Lake Valley to the south through Dry Lake Valley and into northern Delamar Valley. Groundwater in northern Delamar Valley flows to the south and eventually out of the southern end of the valley into Coyote Springs Valley. Groundwater in southern Delamar Valley also potentially flows to the southwest along the Pahranagat Valley Shear Zone and into the very southern end of Pahranagat Valley and northern Coyote Springs Valley (Eakin, 1966; Kirk and Campana, 1990; Thomas and Mihevc, 2007; Burns and Drici, 2011).

The δD and $\delta^{18}O$ data of mountain block recharge areas can be used with recharge estimates, evapotranspiration (ET) estimates, and groundwater flow directions to evaluate the sources, flow paths, and mixing of groundwater in the DDC area. Recharge to the southern Egan and southern Schell Creek ranges provide recharge to Cave Valley aquifers (Figure 10). The southern Egan Range recharge has average δD and $\delta^{18}O$ values of -106.9 and -14.15‰, respectively (Tables 2 and 4). The southern Schell Creek Range has average δD and $\delta^{18}O$ values of -105.0 and -14.21‰, respectively (Tables 2 and 4). The mixture of these two recharge sources to Cave Valley produces an average annual recharge to the valley of 13,700 acre-feet per year (afy) with an average isotopic composition of -105.9 and -14.18‰ (Table 4). There is an estimated 1,300 afy of groundwater lost by ET from shallow groundwater in Cave Valley (Burns and Drici, 2011). Thus, 12,400 afy of groundwater flows out of Cave Valley to southeastern White River Valley and northeastern Pahroc Valley. This groundwater has an isotopic signature of -105.9 and -14.18‰ for δD and $\delta^{18}O$, respectively.

The δD and $\delta^{18}O$ data for groundwater in springs and wells located on the valley floor of Cave Valley are used to evaluate the sources of groundwater supplying the aquifers of Cave Valley. If the mixture of water from the two main recharge areas is the only source supplying groundwater to Cave Valley aquifers, then groundwater in the valley should have similar δD and $\delta^{18}O$ values as the mixture of recharge waters. Groundwater discharging from Cave Spring (Appendix 1; plates 1 and 2; site 209) has average δD and $\delta^{18}O$ values of -102.5 and -13.94‰, respectively, for four samples. Groundwater in five wells (Appendix 1; plates 1 and 2; sites 600, 601, 620, 625, 627) have δD values ranging from -106.3 to -104.7‰ and $\delta^{18}O$ values ranging from -14.27 to -13.75‰, respectively (Plates 1 and 2; Appendix 1). Ideally, δD and $\delta^{18}O$ values would be within 2.0 and 0.2‰, respectively, of the proposed sources of water for the valley aquifers if these are the sources supplying all of the water to the valley aquifers (Thomas et al., 2001; Thomas and Mihevc, 2007). The average δD value of water flowing from Cave Spring is 3.4‰ more positive, and the average $\delta^{18}O$ value is 0.24‰ more positive, than that of the average recharge values. These Cave Spring values are 1.4 and 0.04‰ more positive than the ideal range of δD and $\delta^{18}O$ values, respectively, for supporting local recharge water as the sole source of water for the spring. However, these values are within the range of spring values in the Cave Valley recharge areas (Figure 9). In

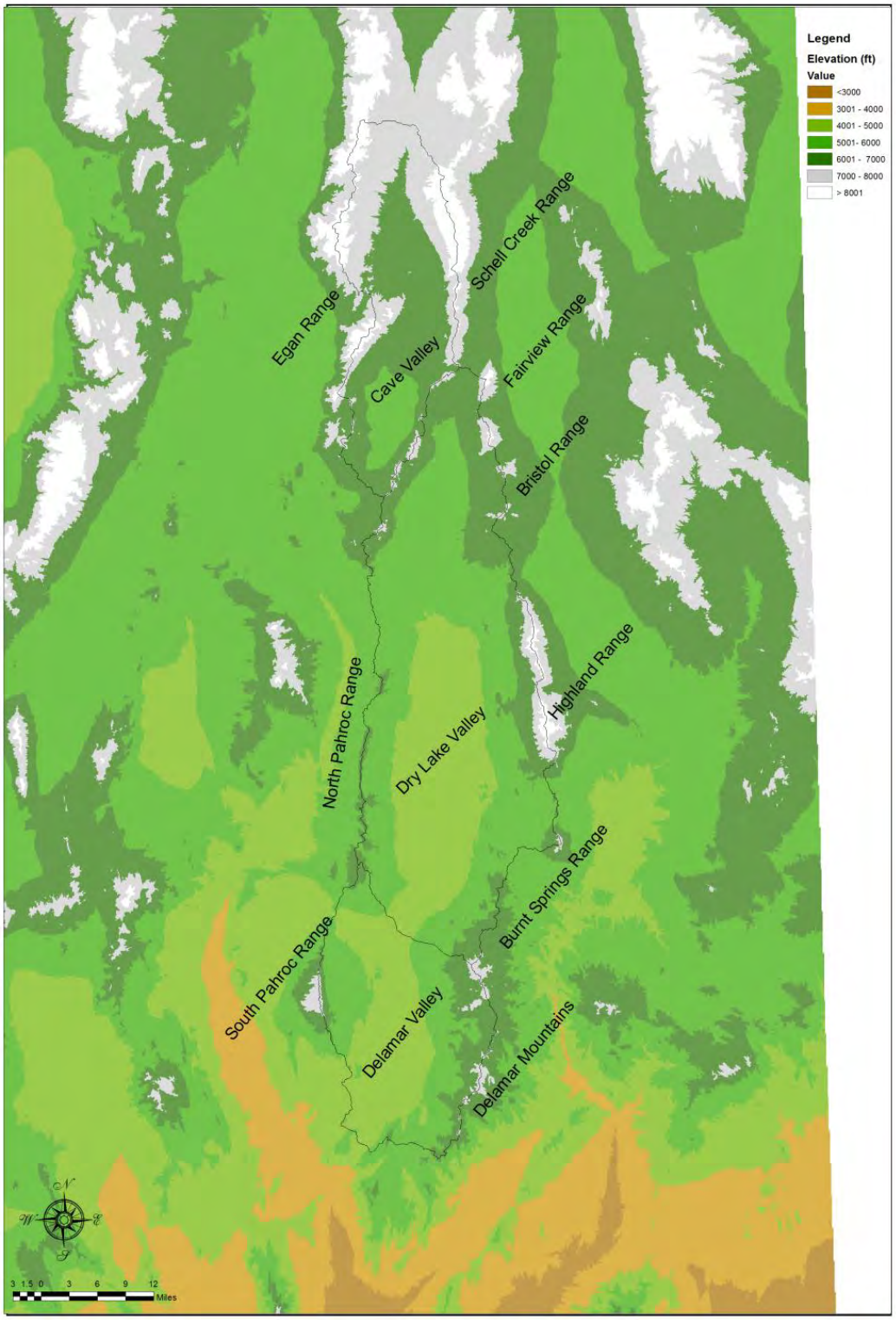

Figure 10. DDC area showing the mountain ranges that comprise the mountain block recharge areas for the three valleys.

Table 4. DDC area average isotopic values for mountain block recharge areas, valley groundwaters, and inflows and outflows to the valleys; and estimated recharge and evapotranspiration (ET) average annual rates, and outflow and inflow rates to valleys. δD and $\delta^{18}O$ values are in permil and recharge and ET values are in acre-feet per year. Recharge and ET values are from Burns and Drici (2011).

Site Name	δD	$\delta^{18}O$	Recharge/ET
Cave Valley			
South Schell Creek Range	-105.0	-14.21	6,800
South Egan Range	-106.9	-14.15	6,900
Recharge to Cave Valley	-105.9	-14.18	13,700
ET from Cave Valley	-105.9	-14.18	1,300
Flow out of Cave Valley to southeastern White River Valley and northeastern Pahroc Valley	-105.9	-14.18	12,400
Dry Lake Valley			
South Schell Creek Range	-100.9	-13.17	2,200
North Pahroc Range	-94.3	-12.39	1,000
Fairview Range	-99.5	-12.88	3,700
Bristol and Highland Ranges	-98.9	-13.28	7,600
Chief and Burnt Spgs Ranges	-94.6	-12.36	1,800
Recharge to Dry Lake Valley	-98.6	-13.02	16,300
Inflow to Dry Lake Valley from NE Pahroc Valley	-105.9	-14.18	2,000
ET from Dry Lake Valley			0
Flow out of Dry Lake Valley to Delamar Valley	-99.4	-13.15	18,300
Delamar Valley			
Delamar Range	-92.4	-12.32	5,600
South Pahroc Range	-94.6	-12.81	1,000
Recharge to Delamar Valley	-92.8	-12.39	6,600
Inflow to Delamar Valley	-99.4	-13.15	18,300
ET from Delamar Valley			0
Flow out of Delamar Valley to Coyote Springs Valley	-97.6	-12.95	24,900

comparison, δD of groundwater for the five wells are within 2‰ of the average δD value of recharge to the valley and the values only vary by 1.6‰, although these values represent only one sample per well so the variability of groundwater isotopic values in these wells over time is not known. The $\delta^{18}O$ values of these wells varies by 0.52‰ and the most positive value is 0.43‰ more positive than the average recharge value, but all values fall within the range of recharge area spring values. Thus, although some of the groundwater δD and $\delta^{18}O$ values in Cave Valley fall outside the ideal range of recharge values, the isotopic data support local

recharge from the mountain block recharge areas as the source of water in aquifers of the valley.

Although all available δD and $\delta^{18}O$ sample values are reported for wells drilled by SNWA in Appendix 1, if more than one sample is reported in Appendix 1 only the most recent sample is used in the evaluation of groundwater sources and flow paths. The most recent value is used instead of an average value, because a large amount of water from outside the valley was used to drill most of the wells and well development was likely not sufficient to remove this water in order to obtain representative isotopic values of groundwater in the aquifers (Jim Watrus, SNWA Hydrogeologist, oral communication, 2011). The most recent sample would have been collected after the most water had been pumped from the well and this sample would also have allowed time for any flushing of the well by water in the aquifer flowing through the well. These wells were drilled as observation wells to monitor groundwater levels rather than as potential production wells, so they were not extensively developed (Jim Watrus, SNWA Hydrogeologist, oral communication, 2011).

Lundmark et al. (2007), using a discrete-state compartment (DSC) model with δD as a calibration parameter, and based on the ability of Cave Valley's northern geologic boundary to allow groundwater flow between valleys (Welch et al., 2007), showed that Cave Valley could potentially receive groundwater flow from southern Steptoe Valley (the valley directly north of Cave Valley on Plates 1 and 2). However, the isotopic data presented in this report shows that little, if any interbasin flow enters Cave Valley from Steptoe Valley (Appendix 1 and Plate 2). If some groundwater does flow from southern Steptoe Valley to Cave Valley, then there would be water in addition to the local recharge in Cave Valley aquifers. Since the same mountain block recharge areas of Cave Valley extend north to form the western and eastern mountain block recharge areas of southernmost Steptoe Valley, recharge to these mountain blocks could have a similar isotopic composition as that of groundwater recharging Cave Valley. However, the average isotopic composition of groundwater recharging southern Steptoe Valley would be similar to groundwater recharging northern White River Valley because the two valleys receive recharge from the same part of the Egan Range. The average isotopic composition of this recharge is -112.3 and -15.15‰ for δD and $\delta^{18}O$, respectively (Thomas and Mihevc, 2007). These recharge isotopic values are 6.4 and 0.97‰ more negative than recharge to Cave Valley and Cave Valley groundwaters are slightly more positive than Cave Valley recharge. Thus, although recharge-area isotopic data do not preclude recharge to southernmost Steptoe Valley from flowing into Cave Valley, the amount of interbasin flow would be very limited based on the isotopic data.

Groundwater in Dry Lake Valley is derived from local recharge and potentially a small volume of flow (up to 2,000 afy) from northeast Pahroc Valley into northwest Dry Lake Valley (Burns and Drici, 2011). Recharge to Dry Lake Valley aquifers is received from the southern Schell Creek, north Pahroc, Fairview, Bristol, Highland, Chief, and Burnt Springs ranges (Plate 1 and Figure 10; Thomas and Mihevc, 2007; Burns and Drici, 2011). The total amount of recharge from the six mountain block recharge areas is 16,300 afy (Burns and Drici, 2011) with average δD and $\delta^{18}O$ values of -98.0 and -12.97‰, respectively. These recharge weighted average δD and $\delta^{18}O$ values are obtained by multiplying the average isotopic values for the recharge areas (Table 2) by the amount of recharge, adding up these values, and then dividing by the total amount of recharge to the valley (Table 4).

There are four wells in Dry Lake Valley that have been sampled for isotope analysis that can be used to evaluate the sources of groundwater for Dry Lake Valley aquifers. Along the northwest boundary of Dry Lake Valley that adjoins Pahroc Valley, the Fugro Dry Lake Valley Deep Well (Appendix 1 and Plate 1; site 179) was drilled and extensively developed by Fugro (a company that drilled the well for the proposed MX missile program). This well contains groundwater with average δD and $\delta^{18}O$ values of -107.5 and -14.16‰, respectively (Appendix 1). This groundwater contains significantly more negative isotopic values than the local recharge to northern Dry Lake Valley from the adjacent southern Schell Creek Range (Table 2; -100.9 and -13.17‰). The isotopic values of this groundwater are similar (within 2.0‰ δD and 0.2‰ $\delta^{18}O$) to that of groundwater flowing out of southwest Cave Valley to northeastern Pahroc Valley (-105.9 and -14.18‰). This similarity in δD and $\delta^{18}O$ values supports the hydrogeologic interpretation that groundwater flows from southwestern Cave Valley into northeastern Pahroc Valley. The hydrogeologic framework also supports groundwater flow from southern White River Valley to northern Pahroc Valley (Burns and Drici, 2011), so this could also be a source of groundwater flow from northeastern Pahroc Valley to northwestern Dry Lake Valley. However, any contribution of this flow reaching northern Dry Lake Valley would be limited because Thomas and Mihevc (2007) calculated groundwater flowing out of southern White River Valley would have an isotopic content of -113.6 and -15.04‰, which is significantly more negative than water in the Fugro well. The Fugro well in Dry Lake Valley (Appendix 1 and Plate 1; site 179) is located near the Dry Lake Valley-Pahroc Valley topographic divide (Plate 1), so groundwater in this area may continue to flow to the southwest into northeast Pahroc Valley or some (up to 2,000 afy) may flow southeast into central Dry Lake Valley.

Two wells located in central Dry Lake Valley, one on the east side of the valley (Vidler well PW-1; Appendix 1 and Plate 1; site 636) and one on the west side of the valley (SNWA well 181M-1; Appendix 1 and Plate 1; site 603) contain groundwater with δD and $\delta^{18}O$ values of -101 and -13.4‰ and -105.0 and -13.62‰, respectively. The hydrogeology indicates that these wells should receive most of their water from the southern Schell Creek, Fairview, Bristol, and Highland ranges (Burns and Drici, 2011). The recharge weighted average δD and $\delta^{18}O$ values for these four mountain block recharge areas is -99.4 and -13.15‰, respectively (Table 4). The isotopic values of water in the Vidler PW-1 well are very similar to the recharge values (1.6 and 0.25‰ different in δD and $\delta^{18}O$, respectively), so the isotopic data support the source of this water being local recharge. In contrast, the isotopic data for the SNWA well does not support local recharge as the main source of this water because the values are 5.4 and 0.47‰ more negative than the local recharge water. Local recharge to the adjacent northern Pahroc Range is even more positive than for the four northern recharge areas (Table 4), so this is not the source of the majority of water in this well either. This water may represent interbasin flow in the carbonate-rock aquifer. The δD value of this groundwater is only 0.9‰ more positive than groundwater inflow from northeast Pahroc Valley, but the $\delta^{18}O$ value is 0.56‰ more positive so only the δD value would support this groundwater being interbasin flow. Because this well is a new SNWA well that has not been extensively developed (Jim Watrus, SNWA Hydrogeologist, oral communication, 2011), the water in this well may contain mostly water used in drilling the well rather than primarily native groundwater in the aquifer.

SNWA well 181W909M and well SK-18 (Appendix 1 and Plate 1; sites 604 and 134) are located in the southern part of Dry Lake Valley, so their isotopic data can be used to evaluate the source(s) and flow paths of water in this part of the valley. The δD and $\delta^{18}O$ values for SNWA well 181W909M are -104.6 and -13.50‰, respectively. These values are significantly less than average recharge values for Dry Lake Valley (Table 4), so this sample may represent interbasin flow in the carbonate-rock aquifer (1.3 and 0.68‰ more positive in δD and $\delta^{18}O$, respectively, as compared to inflow from northeastern Pahroc Valley). The groundwater in this well has similar isotopic values of that of SNWA well 181M-1, so like groundwater in well 181M-1 the δD value would support interbasin flow, but the $\delta^{18}O$ value does not. This well also has not been extensively developed so the water in this well likely contains mostly water used in drilling the well rather than primarily native groundwater in the aquifer. Water in well SK-18 has a δD value of -95‰ (Kirk and Campana, 1990). Unfortunately, this sample does not have a $\delta^{18}O$ value, so it cannot be determined if groundwater in this well is significantly evaporated. If this groundwater has not undergone significant evaporation, then it is similar to the δD value of the average recharge to the valley and almost the same as recharge to the Chief, Burnt Springs and North Pahroc ranges in the southern part of the valley (Table 4). Thus, this sample indicates that local recharge to Dry Lake Valley is the primary source of groundwater in this part of the valley.

The hydrogeology of the DDC area indicates that groundwater in Delamar Valley is derived from interbasin flow from Dry Lake Valley and local recharge (Thomas and Mihevc, 2007; Burns and Drici, 2011). There are two wells with isotopic data that are available to evaluate groundwater sources and flow paths in Delamar Valley. These wells are SNWA well 182M1 (Appendix 1 and Plate 1; site 606) with δD and $\delta^{18}O$ values of -109.6 and -14.07‰, respectively, and SNWA well 182W906M (Appendix 1 and Plate 1; site 607) with δD and $\delta^{18}O$ values of -100.7 and -13.40‰, respectively. The water in well 182W906M is isotopically similar to the mixture of inflow from Dry Lake Valley with local recharge to Delamar Valley, but it is 3.1 and 0.45‰ more negative in δD and $\delta^{18}O$, respectively (Table 4), than the mixture of water in Delamar Valley. Thus, the isotopic data of groundwater in this well supports a mixture of local recharge and interbasin flow from Dry Lake Valley as the main source of water in this well. The slightly more negative isotope values may indicate more interbasin flow than local recharge reaches this well as presented in Table 4, or more likely that water used to drill the well has not been completely removed from the aquifer. The water in well 182M1 is likely almost all water used in drilling the well, since the isotopic data is similar to the isotopic values of the water used in drilling this well (Pahranagat Valley water) and the well has undergone little development because it is a low yielding well drilled for water level observation rather than water production (Jim Watrus, SNWA Hydrogeologist, oral communication, 2011).

In summary, δD and $\delta^{18}O$ data show that groundwater in the DDC area is supplied by local recharge from the mountain block recharge areas of the valleys. There is little, if any, interbasin flow from Steptoe Valley to the north into the most upgradient of these three valleys, Cave Valley. Groundwater in Cave Valley is derived from local recharge to the valley. Groundwater flows out of Cave Valley into southeastern White River Valley and northeastern Pahroc Valley. All of the groundwater in Dry Lake Valley is derived from local recharge to the valley, except for the potential of up to 2,000 afy of inflow to northwest Dry Lake Valley from northeast Pahroc Valley. All groundwater in Dry Lake Valley flows down

gradient to the south to Delamar Valley. Delamar Valley aquifers also receive groundwater recharge from mountain block recharge areas in the valley that mixes with the groundwater flowing into the valley from Dry Lake Valley. All groundwater in the valley flows south out of southern Delamar Valley to northern Coyote Springs Valley. Although, some groundwater may flow southwest out of Delamar Valley along the Pahranagat Valley Shear Zone into the very southern part of Pahranagat Valley before flowing into northern Coyote Springs Valley (Burns and Drici, 2011). Potential groundwater flow from the DDC area to adjacent valleys is described in more detail in following sections of this report.

Potential Groundwater Flow from the DDC Area to White River Valley

The WRFS (Figure 1) was originally described by Eakin (1966). Eakin postulated that some of the water discharging from the Muddy River Springs area in Upper Moapa Valley originated more than 200 miles north of the spring area and that this regional interbasin flow system included 13 valleys. Eakin reached these conclusions on the basis of "preliminary appraisals of the distribution and quantities of the estimated groundwater recharge and discharge within the region, the uniformity of discharge of the principal springs, the compatibility of the potential hydraulic gradient with regional groundwater movement, the relative hydrologic properties of the major rock groups in the region, and to a limited extent, the chemical character of water issuing from the principal springs." The main conclusions of his study were: (1) Paleozoic carbonate rocks form the regional aquifer of the WRFS, (2) recharge and discharge estimates balance within the flow system, and (3) the principal discharging springs (warm springs in this report) have a uniform discharge rate, indicating a regional rather than local water source.

As noted earlier in this report, based on structural and geologic controls, groundwater in northwestern Cave Valley flows southwest into southeastern White River Valley (Burns and Drici, 2011; Rowley and Dixon, 2011). In southeastern White River Valley, three springs—Emigrant (site 207), Butterfield (site 202), and Flag #3 (site 201)—are located along the range-bounding fault on the east side of the valley (Plate 1). Flag Spring #3 has a water temperature of 22.8°C; but because of its location, and similar isotopic and water chemistry content to that of Emigrant and Butterfield springs (Appendix 1); it is included with the other two cool springs along the range- bounding fault in our analysis. These three springs have isotopic values that range from -107.8 to -105.0‰ for δD and -14.50 to -14.20‰ for $\delta^{18}O$. These values are similar to the average isotopic composition of recharge to the southern Egan Range in southern White River Valley and western Cave Valley, δD and $\delta^{18}O$ of -106.9 and -14.15‰, respectively (Table 4; Appendix 1; Thomas and Mihevc, 2007). Thus, the southern Egan Range is the most likely source of water supplying these springs (Plates 1 and 2; Figure 10). This includes recharge from the Egan Range to northwestern Cave Valley which could flow into southeastern White River Valley along the Shingle Pass fault system. Thus, outflow from northwestern Cave Valley could supply some of the flow observed at Emigrant, Butterfield and Flag #3 springs in southeastern White River Valley.

Two warm springs in southern White River Valley, Hot Creek Spring (site 197) and Moon River Spring (site 192) (Appendix 1; Plates 1 and 2), could potentially contain groundwater from Cave Valley since there is outflow from northwestern Cave Valley to southeastern White River Valley. The isotopic composition of these two warm springs ranges from -120.0 to -118.9‰ for δD and -15.80 to -15.69‰ for $\delta^{18}O$. Since the average isotopic

composition of northwestern Cave Valley groundwater outflow (recharge to the southern Egan Range) is -106.9‰ for δD and -14.15‰ for $\delta^{18}O$, little, if any, Cave Valley groundwater could be supplying flow to these two warm springs. Additionally, local recharge to southern White River Valley from the southern Egan and Grant Ranges has average δD values ranging from -106.9 to -106.5‰ and $\delta^{18}O$ values ranging from -14.23 to -14.15‰ (Thomas and Mihevc, 2007), so this also is not a source of water for the regional warm springs. Thus, the source of the southern White River Valley warm springs is groundwater from the north of this area that has more negative isotopic values (Thomas and Mihevc, 2007; Appendix 1 and Plate 2 this report).

Potential Groundwater Flow from the DDC Area to Pahranagat Valley

The regional warm springs in Pahranagat Valley discharge interbasin flow from several valleys. Pahroc Valley is the valley directly upgradient from Pahranagat Valley and it receives inflow from Cave, White River (which receives inflow from Jakes, Long, and southern Butte valleys), and Coal (which receives inflow from Garden Valley) valleys (Figure 1; Thomas and Mihevc, 2007). Thus, some of the groundwater discharging from Hiko (site 122), Crystal (site 116), Ash (site 110), and Little Ash (site 111) warm springs in Pahranagat Valley (Plate 1) likely originates in Cave Valley. Groundwater flow from northwestern Cave Valley to southeastern White River Valley is discharged by cool springs along the range-bounding fault of the Egan Range and is lost by evapotranspiration in the valley, so little, if any, of this groundwater would flow into Pahranagat Valley. Groundwater flow from southwestern Cave Valley that enters northeastern Pahroc Valley likely becomes part of the mixture of regional groundwater flow in the WRFS that contributes to groundwater inflow into Pahranagat Valley. Part of the groundwater inflow to Pahranagat Valley discharges from Pahranagat Valley warm springs, although the sources and flow paths of groundwater supplying the Pahranagat Valley warm springs are not well understood (Thomas and Mihevc, 2007). Groundwater flowing out of southwest Cave Valley has δD and $\delta^{18}O$ values of -105.9 and -14.18‰, respectively (Table 4). These values fall within the range of δD values -112.0 to -105.0‰ and $\delta^{18}O$ values -15.30 to -13.80‰ for the Pahranagat Valley warm springs and are similar to the average values of -108.5 and -14.27‰ for these springs (Table 3). Thus, the isotopic data indicate that some of the groundwater flowing out of southwestern Cave Valley likely contributes to Pahranagat Valley warm spring discharge. Some groundwater originating in Cave Valley likely flows south past the Pahranagat Valley warm springs as part of the mixture of regional groundwater flow in the WRFS.

RECHARGE TIMING AND GROUNDWATER TRAVEL TIMES

Understanding the timing of recharge to springs in the mountain block recharge areas and the time it takes groundwater to flow (travel time) from recharge areas to valleys and between valleys (interbasin flow) is important for determining if δD and $\delta^{18}O$ data in the WRFS represent current climatic conditions or past cooler and wetter climatic conditions. If groundwater discharging from regional warm springs contains a significant amount of groundwater recharged during a past cooler climate then the δD and $\delta^{18}O$ data used for determining sources and flow paths would need to be adjusted to account for more negative recharge isotopic values during this time.

Recharge Timing Based on Stable Isotope and Tritium Data

δD and $\delta^{18}O$ data for regional groundwater flow systems can be used to evaluate recharge timing irrespective of whether a regional flow system is responding to current climatic conditions or past climatic conditions. If recharge and discharge rates and flow directions are known for a regional groundwater flow system, then δD and $\delta^{18}O$ data can be used to evaluate if a flow system contains a significant amount of groundwater flowing through it that was recharged during a past (i.e., different) climatic condition. For the WRFS, the most recent past climatic condition that would have significantly different δD and $\delta^{18}O$ recharge values than present day conditions would be the cooler and wetter last glacial period, which ended about 12,000 to 16,000 years ago in southern Nevada. If the four main regional warm spring areas of the WRFS were discharging a significant amount of water from the last glacial period, then the isotopic composition of the springs would be at a minimum 10 and 1.2‰ more negative in δD and $\delta^{18}O$ composition, respectively, than present day recharge (Winograd et al., 1992; 2006), and could be as much as 16 and 2.0‰ more negative (Benson and Klieforth, 1989). Thus, if any significant portion of groundwater in the WRFS was recharged during the last glacial period, regional warm springs would be 10 to 20‰ more negative in δD and 1.0 to 2.0‰ more negative in $\delta^{18}O$ than present day values.

δD and $\delta^{18}O$ groundwater data for the WRFS combined with recharge and ET estimates (Thomas and Mihevc, 2007; Burns and Drici, 2011) show that the WRFS is responding to current climate conditions and not a past wetter and cooler climate. This is supported by the fact that if warm springs in the WRFS were discharging a significant amount of groundwater recharged under a cooler and wetter climate than the current climate, the isotopic values of the regional spring discharge would be significantly more negative than is currently measured. These regional warm springs are supported by interbasin flow that has groundwater with isotopically more negative values than the local recharge (Thomas and Mihevc, 2007). Thus, regional warm springs would have significantly more negative values than is measured today. Even during wetter climatic periods, there would not be sufficient local recharge to Pahranagat and Upper Moapa valleys to supply the warm spring discharge in these valleys, so interbasin flow would be needed to maintain even current flow conditions at these regional spring discharge areas, much less the increased flow expected for a cooler and wetter climate.

Tritium can be used to determine if recharge area springs are representative of present day climate conditions and also if present day recharge is entering valley aquifers. Groundwater that contains measureable tritium indicates that the water is less than about 60 years old and thus would represent present day climatic conditions. Tritium may also indicate mixing of young (< 60 year old) groundwater with older groundwater. Tritium data for groundwater in the WRFS shows that springs in mountain block recharge areas are discharging groundwater that was recharged within the last 60 years, because they contain measurable tritium (Thomas et al. 1996; Hershey et al., 2007). Lund, Butterfield, and Emigrant springs on the valley floor along the eastern side of White River Valley and Cave Spring in Cave Valley contain 1.2 to 17.4 tritium units (TU) of tritium (Table 5; Hershey et al., 2007), indicating that mountain block recharge that is < 60 years old is entering the valley aquifers. In contrast, none of the regional warm springs has tritium above 1.0 tritium units, indicating that all of the water discharging from regional warm springs was recharged before the early 1950s (Table 5).

Table 5. Tritium and carbon isotope data (when more than one sample is used to obtain a value, the number of samples is shown in parentheses and the reported value is an average value for all the samples and for the warm springs is weighted by the flow rates) and saturation indices for calcite, dolomite, and gypsum calculated in NETPATH. Mineral saturation indices (SI) values are negative for under saturation (mineral will dissolve) and positive for over saturation (mineral will precipitate from the water).

Site Name	Tritium (TU)	Carbon-13 (permil)	Carbon-14 (pmc)	Calcite (SI)	Dolomite (SI)	Gypsum (SI)
Recharge Groundwaters						
Lund Spring	1.9	-8.1	41.6	0.14	0.16	-2.62
Emigrant Spring	17.4	-9.2	55.7	-0.14	-0.45	-2.46
Butterfield Spring	1.2	-8.5	30.3	-0.18	-0.46	-2.81
Ave spring recharge	6.8 (3)	-8.60 (3)	42.5 (3)	-0.06	-0.24	-2.61
Northern White River Valley Warm Springs						
Preston Big Spring	<1	-5.7	11.2	-0.08	-0.19	-2.18
Nichols Spring	NA	-5.7	6.5	0.13	-0.23	-2.17
Preston Cold Spring	NA	-5.6	2.2	-0.11	-0.22	-2.20
Ave N. WRV warm Springs	<1 (1)	-5.69 (3)	9.2 (3)	0.00	-0.02	-2.18
Southern White River Valley Warm Springs						
Hot Creek Spring	<1	-4.26 (2)	5.0 (2)	0.02	0.03	-2.03
Moon River Spring	NA	-5.0	6.4	0.18	0.38	-2.06
Ave S. WRV warm springs	<1 (1)	-4.42 (2)	5.3 (2)	0.01	0.01	2.03
Pahranagat Valley Warm Springs						
Hiko Spring	<1	-6.45 (2)	6.1 (2)	0.23	0.52	-2.18
Crystal Spring	<1	-6.57 (4)	7.3 (3)	0.01	0.09	-2.24
Ash Spring	<1	-6.70 (2)	6.3 (3)	0.04	-0.10	-2.24
Ave Pahranagat V warm springs	<1 (3)	-6.61 (3)	6.6 (3)	-0.02	0.01	-2.23
Upper Moapa Valley Warm Springs						
Big Muddy Spring	<1 (2)	-5.90 (2)	8.2 (2)	0.00	0.03	-1.47

Carbon-14 Corrected Groundwater Ages and Travel Times

Cave, Dry Lake, and Delamar valleys are located within the larger WRFS and contribute to the overall groundwater resources of the WRFS. Understanding the time it takes groundwater to flow from recharge areas to valleys and between valleys (interbasin flow) within the WRFS is important for managing these groundwater resources. To estimate the time it takes groundwater to flow through aquifers in the WRFS, groundwater ages corrected for geochemical reactions and physical processes were determined by geochemical modeling using major ion chemistry and carbon-13 and carbon-14 isotopic data. The computer model NETPATH (Plummer et al., 1994; El-Kadi et al., 2010) was used to calculate carbon-14 corrected groundwater ages. Determining groundwater travel times in a regional flow system like the WRFS is complicated because every valley in the WRFS has local groundwater recharge that mixes with interbasin flow as groundwater flows from north to south down the

WRFS. Thus, groundwater travel times represent a central tendency of the actual recharge time for each recharge event. To evaluate groundwater travel times in the WRFS, carbon-14 corrected groundwater ages were determined for the four main warm spring discharge areas of the WRFS (see Thomas et al., 1996 and Hershey et al. 2007, for a detailed description of how carbon-14 corrected ages are calculated). Calculating carbon-14 corrected ages for regional warm springs is an effective way to evaluate groundwater travel times because these warm springs represent a mixture of up-gradient groundwaters that have traveled both a long distance -- generally tens of miles -- and to great depth -- generally thousands of feet -- before being discharged from the spring.

Groundwater carbon-14 data, reported as percent modern carbon (pmc), needs to be corrected for geochemical reactions and physical processes involving carbon in order to determine a realistic groundwater age. Some laboratories report carbon-14 ages for carbon-14 groundwater values, but these ages should never be used as groundwater ages because they do not account for reactions and processes that affect carbon-14 concentrations in the groundwater. For example, warm springs discharging from regional carbonate-rock aquifers in Ash Meadows in southern Nevada contain only 2 to 4 pmc carbon-14 (with one spring reaching 11 pmc), but these groundwaters are at most several thousand years old and could be as young as 1,000 years old (Winograd et al. 1992; 2006; Thomas et al., 1996). Thus, low carbon-14 values (< 15 pmc) in regional warm spring waters of the WRFS, which could indicate that these waters are more than 20,000 years old (Table 5; Thomas et al., 1996; Hershey et al., 2007), need to be corrected for geochemical reactions and physical processes in order to obtain realistic groundwater ages.

To obtain realistic groundwater ages using carbon isotope data (carbon-14 corrected ages), the dissolution of calcite and dolomite that comprise the carbonate-rock aquifers, dissolution or outgassing of CO_2, and adsorption and diffusion processes that remove carbon-14 from groundwater must be considered. Dissolution of calcite and dolomite add carbon to the water that contains no carbon-14. CO_2 may outgas or dissolve depending on the conditions near the spring area, but once water passing through the unsaturated zone (water will react with CO_2 gas in the unsaturated zone) reaches the saturated zone (i.e., the water table of an aquifer) there should be no additional dissolution or outgassing of CO_2 along a flow path, until the groundwater is discharged at the spring where some CO_2 may exsolve (degas from the water). Adsorption and diffusion processes can remove carbon-14 from groundwater (Hershey and Howcroft, 1998; Hershey et al., 2003; 2007). These reactions and processes involving phases that contain carbon (and carbon-13 and carbon-14 isotopes), need to be accounted for to obtain carbon-14 corrected groundwater ages. Regional warm springs in the WRFS are a mixture of flow that is contributed all along the regional flow system from many different recharge areas and valleys, so the age of water discharging from warm springs is an average age. Thus, a small percent of the water discharging from regional warm springs could have been recharged during the last glacial (or similar) period when the climate was cooler and wetter. However, the δD and $\delta^{18}O$ data; recharge and discharge estimates; and interbasin flow supported by the hydrogeologic framework for the WRFS do not support any significant amount of recharge from a cooler and wetter climate (this report; and Thomas et al., 1996, 2001; Thomas and Mihevc, 2007; Hershey et al., 2007).

Carbon-14 and carbon-13 isotopes of inorganic carbon dissolved in groundwater can be used to estimate groundwater ages by using geochemical models that account for all

reactions and processes involving carbon from a recharge area to a sample location along a flow path. The change in isotopic composition between phases, such as differences in carbon-13 and carbon-14 values between carbon dissolved in water and calcite precipitated from water, is called isotopic fractionation. Groundwater ages calculated using geochemical models that account for changes in water chemistry and isotopic fractionations along a flow path, and from mixing of waters with different chemistries, are called carbon-14 corrected ages. These model calculated ages are called carbon-14 corrected ages because they account for the addition or removal of carbon (and carbon-14) to the groundwater and the changes (fractionations) of the isotope values as they change from one phase to another. Geochemical models that calculate carbon-14 corrected groundwater ages are only valid if the modeled carbon-13 value matches the carbon-13 value measured in the groundwater sample at the end of the flow path. Carbon-14 is radioactive and naturally decays over time, whereas carbon-13 is stable and does not decay (change) over time. The only way that a carbon-13 concentration can change is by mixing two, or more, waters with different carbon-13 values or by geochemical reactions that add or remove carbon to or from the water. Carbon-13 will fractionate as it reacts and moves from one phase to another; for example carbon dissolved in water can precipitate as calcite, and this can easily and accurately be accounted for if the pH, temperature and dissolved carbon content of the water sample is known (Deines et al., 1974; Wigley et al., 1978; Mook, 1980; Plummer et al., 1983; 1994).

Carbon-14 corrected groundwater ages and travel times have been previously calculated by Thomas et al. (1996) and Hershey et al. (2007) for groundwater discharging from regional warm springs in the WRFS. Thomas et al. (1996) and Hershey et al. (2007) used the same approach as was used in this report for calculating groundwater ages. Groundwater ages calculated for regional warm springs in Pahranagat and Upper Moapa valleys ranged from 4,800 to 8,500 years (Thomas et al., 1996; Table 18 model 3 and Figure 26). Groundwater travel time from the warm springs in northern White River Valley to the warm springs in southern White River Valley, based on groundwater ages calculated for a mixture of water containing 40 to 60 percent recharge water (with modern carbon-14 values of about 100 pmc) with northern White River Valley warm spring water, produced an average groundwater travel time for this mixture of water of 12,000 to 16,000 years (Hershey et al., 2007).

The NETPATH models used in this study are based on the same assumptions as those used by Thomas et al. (1996) and Hershey et al. (2007). The only difference in the NETPATH models used in this study, besides any new data that would be included in Table 3 and Appendix 1, is a simpler model using only calcite, dolomite, CO_2 gas, and gypsum. This simpler model was used because the goal of this study was to determine the carbon-14 corrected groundwater age and not to explain all major ion chemistry changes in the water along flow paths of the WRFS. Gypsum was included in this simple carbon model to account for calcium added to the water by gypsum dissolution, which can result in more calcite precipitation and dolomite dissolution. This process of gypsum dissolution producing more calcite precipitation and dolomite dissolution is called dedolomitization (Back et al., 1983). The water chemistry data used for NETPATH modeling is the average water chemistry for a site using the data presented in Appendix 1. The carbon isotope data used for the NETPATH modeling is presented in Table 5 and is from USGS, DRI, and SNWA sample collection and analysis at USGS, DRI, and the University of Arizona isotope laboratories.

Carbon-14 age dating model results are presented in Table 6. Columns two through five in the table present the mass transfer of calcite, dolomite, gypsum, and CO_2 gas needed to produce the water chemistry for the regional warm springs from an initial carbonate recharge water (see next paragraph for a description of this water). Minerals that are under saturated in the water [negative saturation indices (SI) values in Table 5] should dissolve, and those that are saturated (positive SI values) should precipitate from the water. The NETPATH model results in Table 6 are supported by the SI values in Table 5. Similar to the modeling approach used by Thomas et al. (1996) and Hershey et al. (2007), if carbon is added to the water along a flow path (a positive CO_2 mass transfer value > 0.30 millimoles per liter) this amount of carbon was added to the recharge water. The reason this CO_2 carbon is added to the recharge water is because once the water becomes isolated from the unsaturated zone, there should be little, or no, interaction with unsaturated zone CO_2 gas, and a previous study has shown that there is likely CO_2 outgassing in some of the recharge spring areas (Thomas et al., 1996). Column six in Table 6 shows the amount of calcite that is exchanged between the water and the aquifer (calcite dissolved and precipitated due to temperature and pressure changes as groundwater flows through the regional aquifers) to obtain modeled carbon-13 values that match measured values.

Table 6. NETPATH model results showing the mass transfer of calcite, dolomite, gypsum, and CO_2 gas in millimoles per liter (positive values indicate that the phase is entering the water and negative values indicate that the phase is being removed from the water). The carbon-14 corrected age is the age calculated after correcting for all carbon entering or leaving the water along the flow path and the fractionations associated with these reactions. All flow paths use the recharge waters listed in Table 3 as the initial water chemistry for a flow path. The final water along the flow path is listed in this table. A carbon-14 corrected age that is modern is less than about 1,000 years old.

Final Flow Path Site	Calcite (mmoles/L)	Dolomite (mmoles/L)	Gypsum (mmoles/L)	CO_2 (mmoles/L)	Calcite cycled (mmoles/L)	Corrected Carbon-14 age (years)
Northern White River Warm Springs	-0.51	-0.14	0.29	-1.15	1.3	10,000
Southern White River Warm Springs	-0.27	-0.05	0.36	0.24	>10	modern
Pahranagat Valley Warm Springs	-0.41	-0.12	0.24	0.20	4.2	8,700
Big Muddy Warm Spring	-1.82	0.16	1.85	0.00[a]	6.5	3,300

a—The original NETPATH model for Big Muddy Warm Spring had 1.25 mmoles/L of CO_2 being added to the water along the flow path. So in following the Thomas et al. (1996) and Hershey et al. (2007) modeling approach, this amount of CO_2 was added to the recharge waters so that the amount of CO_2 mass transfer along the flow path is 0.00 mmoles/L.

All of the NETPATH models assume that the water chemistry and isotope values of Lund, Emigrant, and Butterfield springs (Table 5), which are located along the eastern side of White River Valley, are representative of present day recharge to carbonate aquifers of the WRFS. These springs were chosen to represent groundwater recharging the carbonate rock aquifers of the WRFS because: 1) they occur along the eastern range-bounding fault of White River Valley so they represent recharge from the carbonate rock-dominated Egan Range that flows from the mountain block into the carbonate rock aquifers of the WRFS; 2) all three springs contain measureable tritium (Table 5), indicating that these groundwaters have been recharged since the 1950s; 3) they have carbon-14 and carbon-13 values in the ranges expected for recharging groundwaters that have been isolated from atmospheric CO_2 gas, and dissolved calcite and dolomite; 4) they have δD and δ18O values that represent local recharge to the adjacent Egan Range; and 5) groundwater flow from these springs, at least for Lund Spring, is highly variable indicating that they respond to local recharge from the adjacent mountains.

The carbon-14 corrected groundwater ages range from modern (< 1,000 years old) to 10,000 years old. These ages represent the average age of groundwater discharging from the regional warm springs. The discharge-weighted average carbon-14 values of the four regional warm springs in the WRFS range only from 5.3 to 9.2 pmc, but carbon-13 values range from -6.61 to -4.42 permil. This range in carbon-13 values for groundwaters that have similar chemistries results in this about 10,000 year range of groundwater ages. Of note, it is the more positive carbon-13 values of the southern White River Valley warm spring waters (Table 5), as compared to the other warm spring area groundwaters, which result in this warm spring area having a carbon-14 corrected age that is modern. It is important to consider that these carbon-14 corrected groundwater ages likely overestimate the age of the groundwater flowing from the regional warm springs because they do not account for diffusion processes which have been shown to be important in carbonate rock aquifers in southern Nevada (Hershey and Howcroft, 1998; Hershey et al., 2003; 2007). Correcting the model ages for diffusion processes is beyond the scope of this report.

If groundwater flowed from northern White River Valley warm springs to Big Muddy Springs in Upper Moapa Valley without any recharge being added along this flow path then the difference in groundwater ages of these springs could be used to determine groundwater travel times in the WRFS. However, local recharge water within each basin mixes with interbasin flow between warm spring discharge areas. This is observed by water balance studies and supported by the fact that δD and $\delta^{18}O$ values become more positive in WRFS warm springs as groundwater flows from north to south down the WRFS (Thomas and Mihevc, 2007). Thus, carbon-14 corrected groundwater ages represent the mixture of recharge and interbasin flow groundwater at a regional warm spring and provide a range for the time that it takes groundwater to flow from recharge areas to regional warm springs and for interbasin flow from one warm spring area to another within the WRFS.

SUMMARY AND CONCLUSIONS

Deuterium and oxygen-18 data were used to evaluate groundwater sources and flow paths in the DDC area. In order to use δD and $\delta^{18}O$ data for groundwater source and flow path evaluations they need to; (1) show a range throughout the study area so that different recharge areas have different isotopic signatures; (2) have little variability within a recharge

area; and (3) the isotopic signature in recharge areas has to be similar to the signature of the past. Temporal and spatial isotopic variability were evaluated in this study.

Temporal isotopic variability of four recharge area monitoring springs within the WRFS was relatively small with standard deviations of δD and $\delta^{18}O$ data ranging from 0.7 to 1.1‰ and 0.07 to 0.11‰ (except for one site with a value of 0.33‰), respectively. The range in standard deviation for the four sites is for samples taken quarterly throughout all four seasons; and with one site having 7 years of data and two of the three sites having 6 years of data. The isotopic composition of these springs varied little from season to season even though spring flow ranged from about 100 to 5,000 gallons per minute. This lack of temporal isotopic variability of recharge area springs is important because recharge area springs are used to determine the sources of groundwater in the DDC area.

Temporal isotopic variability of 10 regional warm springs in the WRFS is relatively small with the standard deviation of δD and $\delta^{18}O$ data ranging from 0.5 to 1.9‰ and 0.05 to 0.21‰ (except for one site with a standard deviation of 0.67‰), respectively. This range in values is for samples taken throughout all four seasons, with some regional warm spring data extending over 40 years and a significant number of springs having data that spans 20 to 25 years. This lack of temporal isotopic variability of regional warm springs is important for evaluating potential groundwater flow from the DDC area to the Hot Creek Spring area in southern White River Valley and regional warm springs in Pahranagat Valley.

Spatial isotopic variability within the mountain block recharge areas of the DDC area shows that the spatial variability is greater than the temporal variability. The range in standard deviation of spring isotopic values for nine mountain block recharge areas is 1.8 to 4.2‰ for δD and 0.35 to 0.70‰ for $\delta^{18}O$.

The relationship of stable isotopes with altitude was evaluated for four major recharge areas in the study area with 14, or more, springs. These four recharge areas include the White Pine and Central Egan ranges in the northern part of the study area, the Fairview and Bristol ranges in the central part of the study area, and the Delamar Mountains in the southern part of the study area. There is only very weak relationships of δD with altitude in three of the four recharge areas (R^2 values of 0.066, 0.018, and 0.026), and the strongest correlation (0.066) was for an increase in isotopic values with increasing altitude (the opposite relationship is expected, that is more negative δD values with increasing altitude). The southernmost and lowest altitude recharge area, the Delamar Range, showed a correlation of more negative δD with increasing altitude with an R^2 value of 0.366. This lack of a relationship between isotopic values and altitude in recharge areas, for most of the recharge areas, is important because the average isotopic composition of all sites in a recharge area can be used to determine the isotopic signature for a recharge area.

The average δD and $\delta^{18}O$ values for recharge areas, weighted by the amount of recharge for each individual mountain block, were calculated to determine the average isotopic values of local recharge to a valley. These average values were compared with valley groundwater values to evaluate sources and flow paths of groundwater in the DDC area and to adjacent valleys. δD and $\delta^{18}O$ data show that groundwater in the DDC area is supplied by local recharge from the mountain block recharge areas of the valleys. There is little, if any, interbasin flow into the most upgradient of these three valleys, Cave Valley. Groundwater flows out of Cave Valley into southeastern White River Valley and

northeastern Pahroc Valley. Potentially a small amount (up to 2,000 acre-feet per year) of groundwater may flow into northwest Dry Lake Valley from northeast Pahroc Valley. All of the groundwater in Dry Lake Valley is derived from local recharge to the valley, except for the potential of up to 2,000 afy of inflow to northwest Dry Lake Valley. There is no groundwater ET in Dry Lake Valley (Burns and Drici, 2011), so all groundwater in Dry Lake Valley flows down gradient to the south to Delamar Valley. Delamar Valley aquifers also receive groundwater recharge from mountain block recharge areas in the valley that mixes with the groundwater flowing into the valley from Dry Lake Valley. There is no groundwater ET in Delamar Valley (Burns and Drici, 2011), so all groundwater in the valley flows south out of southern Delamar Valley to northern Coyote Springs Valley. Although, some groundwater may flow southwest out of Delamar Valley along the Pahranagat Valley Shear Zone into the very southern part of Pahranagat Valley before flowing into northern Coyote Springs Valley.

Isotopic data show that groundwater originating in the DDC area supplies little, if any, water to the warm springs in southern White River Valley. These data also show that groundwater discharging from warm springs in Pahranagat Valley are a mixture of waters recharged in numerous valleys north of Pahranagat Valley, which likely includes Cave Valley.

Deuterium and oxygen-18 data, tritium data, and carbon-14 corrected groundwater ages, show that groundwater in the White River Flow System, which includes Delamar, Dry Lake, and Cave valleys, is recharged under current climatic conditions. Carbon-14 corrected groundwater ages also show that it can take thousands of years for groundwater from mountainous recharge areas to flow through numerous basins and discharge in warm spring areas throughout the WRFS. Carbon-14 corrected groundwater ages of the four regional warm spring areas in the White River Flow system range from modern (<1,000 years) to 10,000 years. None of the regional warm springs has tritium above 1.0 tritium units, indicating that all of the water discharging from regional warm springs was recharged before the early 1950s.

REFERENCES

Acheampong, S.Y., J.M. Thomas, and C.A. Cooper, 2005. Estimation of circulation depths of some low temperature thermal springs in east-central, Nevada. Nevada Water Resources Association 2005 Conference, Reno, Nevada.

Back, W.B., B. Hanshaw, L.N. Plummer, P.H. Rahn, C.T. Rightmire and M. Rubin, 1983. Process and rate of dedolomitization—Mass transfer and ^{14}C dating in a regional carbonate aquifer. *Geological Society of America Bulletin*, 94: 1415-1429.

Benson, L.V. and H. Klieforth, 1989. Stable isotopes in precipitation and ground water in the Yucca Mountain region, southern Nevada—Paleoclimatic implications, *in* Peterson, D.H., *ed.*, Aspects of climate variability in the Pacific and the western Americas: Geophysical Monograph 55, p. 41-59.

Burns A.G. and W. Drici, 2011. Hydrology and water resources of Spring, Cave, Dry Lake, and Delamar valleys, Nevada and vicinity: Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada.

Clark, I. and P. Fritz, 1997. Environmental Isotopes in Hydrogeology. Lewis Publishers, NewYork, New York.

Craig, H., 1961. Isotopic variations in meteoric waters. *Science*, 133: 1702-1703.

Deines, P., D. Langmuir, and R.S. Harmon, 1974. Stable carbon isotope ratios and the existence of a gas phase in the evolution of carbonate ground waters. *Geochimica et Cosmochimica Acta*, 38: 1147-1164.

Eakin, T.E., 1966. A regional interbasin ground-water system in the White River area, southeastern Nevada. *Water Resources Research*, 2: 251-271.

El-Kadi, A.I., L.N. Plummer and P. Aggarwal, 2010. NETPATH-WIN: an interactive user version of the mass-balance model, NETPATH. *Groundwater*, doi:10.111/j.1745-6584.2010.00779.x.

Hershey, R.L. and W.D. Howcroft, 1998. Laboratory experiments evaluating carbon-14 retardation in a carbonate aquifer. Geological Society of America, Abstracts with Programs, Vol. 30, No. 7, p. A-278.

Hershey, R.L., W. Howcroft, and P.W. Reimus, 2003. Laboratory experiments to evaluate diffusion of ^{14}C into Nevada Test Site carbonate aquifer matrix. Desert Research Institute Publication No. 45180.

Hershey, R.L., D.L. Decker, S. Earman, J. Ryu, P. Reimus and E.S. Garcia, Jr., 2007. Laboratory experiments of carbon-14 uptake on calcite and dolomite. The 233rd American Chemical Society National Meeting, March 25-29, 2007, Chicago, IL, Abstract # NUCL 135 (http://oasys2.confex.com/acs/233nm/techprogram/).

Hershey, R.L., V.M. Heilweil, P. Gardner, B.F. Lyles, S. Earman, J.M. Thomas and K.W. Lundmark, 2007. Ground-water chemistry interpretations supporting the Basin and Range Regional Carbonate-Rock Aquifer System (BARCAS) study, eastern Nevada and Western Utah. Desert Research Institute Publication no. 41230.

Kirk, S.T. and M.E. Campana, 1990. A deuterium-calibrated groundwater flow model of a regional carbonate-alluvial system. *Journal of Hydrology*, 119: 357-388.

Lundmark, K.W., G.M. Pohll and R.W.H. Carroll, 2007. A steady-state water budget accounting model for the carbonate aquifer system in White Pine County, Nevada, and adjacent areas in Nevada and Utah. Desert Research Institute Publication no. 41235.

Mifflin, M.D., 1968. Delineation of ground-water flow systems in Nevada. Desert Research Institute Publication no. 42004.

Mook, W.G., 1980. Carbon-14 in hydrogeological studies. New York, Elsevier Scientific Publishing Company.

Plume, R.W., 1996. Hydrogeologic framework of the Great Basin region of Nevada, Utah, and adjacent states. U.S. Geological Survey Professional Paper 1409-B.

Plume, R.W. and S.M. Carlton, 1988. Hydrogeology of the Great Basin region of Nevada, Utah, and adjacent states. U.S. Geological Survey Hydrologic Investigations Atlas HA-694-A, scale 1:1,000,000.

Plummer, L.N., D.L. Parkhurst and D.C. Thorstenson, 1983. Development of reaction models for ground-water systems. *Geochimica et Cosmochimica Acta*, 47: 665-686.

Plummer, L.N., E.C. Prestermon and D.L. Parkhurst, 1994. An interactive code (NETPATH) for modeling net geochemical reactions along a flow path, Version 2.0. U.S. Geological Survey Water Resources Investigations Report 94-4169.

Rowley, P.D. and G.L. Dixon, 2011. Geology and Geophysics of Spring, Cave, Dry Lake, and Delamar valleys, White Pine and Lincoln Counties and adjacent areas, Nevada and Utah: The geologic framework of regional groundwater flow systems: Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada.

Russell, C.E., S.A. Mizell and T.B. Minor, 2007. Estimation of ground water recharge in Steptoe Valley, Nevada, by the elevation-dependent chloride mass-balance approach. Desert Research Institute Publication no. 41241.

Smith, G.I., I. Friedman, H. Klieforth and K. Hardcastle, 1979. Areal distribution of deuterium in eastern California precipitation, 1968-1969. *Applied Meteorology*, 18:172-188.

Thomas, J.M., J.L. Mason and J.D. Crabtree, 1986. Ground-water levels in the Great Basin Region of Nevada, Utah, and adjacent states. U.S. Geological Survey Hydrologic Investigations Atlas HA-694-B: 2 plates, scale 1:1,000,000.

Thomas, J.M., 1996. Geochemical and isotopic interpretation of groundwater flow, geochemical processes, and age dating of groundwater in the carbonate-rock aquifers of the southern Basin and Range: University of Nevada, Reno, Ph.D. dissertation.

Thomas, J.M., A.H. Welch and M.D. Dettinger, 1996. Geochemistry and isotope hydrology of representative aquifers in the Great Basin Region of Nevada, Utah, and adjacent states. U.S. Geological Survey Professional Paper 1409-C.

Thomas, J.M., S.C. Calhoun and W.B. Apambire, 2001. A deuterium mass-balance interpretation of groundwater sources and flows in southeastern Nevada: Desert Research Institute Publication No. 41169.

Thomas, J.M. and T. Mihevc, 2007. Stable isotope evaluation of water budgets for the White River and Meadow Valley Wash regional groundwater flow systems in east central and southeastern Nevada. Desert Research Institute Letter Report.

Welch, A.H., D.J. Bright and L.A. Knochenmus, eds., 2007. Water resources of the Basin and Range carbonate-rock aquifer system, White Pine County, Nevada and adjacent areas in Nevada and Utah. U.S. Geological Survey Scientific Investigations Report 2007-5261.

Wigley, T.M.L., L.N. Plummer and F.J. Pearson, Jr., 1978. Mass transfer and carbon isotope evolution in natural water systems. *Geochimica et Cosmochimica Acta,* 42: 1117-1139.

Winograd, I.J., T.B. Coplen, J.M. Landwehr, A.C. Riggs, K.R. Ludwig, BJ. Szabo, P.T. Kolesar and KM. Revesz, 1992. Continuous 500,000-year climate record from vein calcite in Devils Hole, Nevada. *Science,* 258: 255-260.

Winograd, I.J., J.M. Landwehr, T.B. Coplen, W.D. Sharp, A.C. Riggs, K.R. Ludwig and P.T. Kolesar, 2006. Devils Hole, Nevada, $\delta^{18}O$ record extended to the mid-Holocene. *Quaternary Research,* 66: 202-212.

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA.

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Abandoned Spring	37.49914	-114.72889	10.2	7.7	7.80	-12.32	-94.5	81.00	20.00	50.00	2.26	35.20	357.00	41.80	27.80	--	59699	--	Spring	266	03/26/04
Acoma Well	37.54861	-114.17306	17.0	--	7.70	-12.60	-95.0	38.00	5.30	21.00	7.00	17.00	149.00	10.00	54.00	0.3	244	GS91	Well	118	06/03/85
Adaven Spring	38.13861	-115.60139	12.5	6.9	7.54	-13.95	-103.0	63.00	25.00	14.00	2.20	4.80	324.00	18.00	28.00	0.2	341	GS131	Spring	177	07/31/85
Adaven Spring	38.13861	-115.60139	9.9		7.10	-14.07	-107.6	--	--	--	--	--	358.00	--	--	--	340	IT115	Spring	177	02/03/97
Alamo City Well #7	37.36222	-115.16833	18.5	--	7.57	-13.46	-101.1	61.42	56.00	96.30	13.73	54.60	454.00	188.00	59.13	1.3	205	IT116	Well	104	08/08/95
Albert Spring	38.56833	-115.36167	14.5	--	--	-13.95	-107.0	--	--	--	--	--	--	--	--	--	403	GS182	Spring	204	07/24/85
APCAR	36.71099	-114.71682	--	--	--	-12.94	-98.2	62.90	27.20	95.00	11.20	62.10	257.00	176.00	31.60	--	61616	--	Spring	292	10/19/04
Arrow Canyon	36.73421	-114.74778	--	--	--	-12.91	-99.4	--	--	--	--	--	--	--	--	--	SNWA	--	Well	619	02/01/06
Ash Springs	37.46361	-115.19250	--	--	--	--	-107.0	--	--	--	--	--	--	--	--	--	222	IT27	Spring	110	08/01/68
Ash Springs	37.46361	-115.19250	--	--	--	--	-109.0	--	--	--	--	--	--	--	--	--	223	IT28	Spring	110	01/01/69
Ash Springs	37.46361	-115.19250	--	--	--	--	-112.0	--	--	--	--	--	--	--	--	--	224	IT29	Spring	110	03/01/70
Ash Springs	37.46361	-115.19250	36.0	2.3	7.04	-14.10	-108.0	43.00	14.00	27.00	7.40	8.50	259.00	34.00	30.00	0.8	225	GS81	Spring	110	07/20/81
Ash Springs	37.46356	-115.19252	--	--	--	-14.03	-110.0	--	--	--	--	--	--	--	--	--	SNWA	--	Spring	--	05/24/04
Ash Springs	37.46361	-115.19250	34.0	1.6	7.42	-14.20	-108.4	46.40	16.80	28.40	7.26	8.60	248.00	32.80	32.70	--	61099	--	Spring	110	07/30/04
Aspen Springs South	39.21629	-115.39800	6.9	9.4	7.00	-16.02	-120.9	--	--	--	--	--	--	--	--	--	62721	DRI-WP-16	Spring	324	06/07/05
Aspen Springs North	39.22100	-115.39905	6.9	7.7	6.50	-15.84	-119.3	--	--	--	--	--	--	--	--	--	62716	DRI-WP-11	Spring	349	06/07/05
Bailey Spring (Fairview)	38.17593	-114.72829	18.9	7.0	7.77	-12.68	-98.5	86.40	21.40	29.80	2.10	48.30	331.00	26.60	32.40	--	60849	--	Spring	277	06/29/04
Bailey Spring (Fairview)	38.17593	-114.72829	10.7	6.0	6.99	-12.70	-97.9	96.20	25.80	42.40	1.66	70.30	327.00	49.70	33.10	--	62407	DRI-FR-5	Spring	277	05/01/05
Bailey Spring (Wilson Ck)	38.35295	-114.36718	17.9	6.4	7.84	-12.93	-102.0	45.00	9.43	18.50	2.06	40.60	135.00	16.10	36.70	--	60310	--	Spring	310	05/18/04
Baldwin Spring	36.72035	-114.72415	31.9	2.6	7.30	-12.95	-96.3	63.80	28.10	96.30	11.60	63.80	260.00	180.00	32.00	--	58496	DRI-MV-3	Spring	291	01/12/04
Baldwin Spring	36.72035	-114.72415	32.0	3.0	7.48	-12.93	-96.8	63.70	27.60	94.70	11.10	64.10	263.00	180.00	29.20	--	60309	DRI-MV-3	Spring	291	05/18/04
Baldwin Spring	36.72035	-114.72415	--	--	--	-12.96	-98.6	62.80	27.40	95.00	11.20	61.40	258.00	174.00	32.10	--	61620	DRI-MV-3	Spring	291	10/19/04
Baldwin Spring	36.72035	-114.72415	31.8	2.7	7.30	-12.94	-98.1	63.10	27.40	95.70	11.20	61.70	252.00	178.00	29.60	--	62034	DRI-MV-3	Spring	291	02/10/05
Baldwin Spring	36.72035	-114.72415	32.0	2.8	6.80	-12.94	-97.2	--	--	--	--	--	--	--	--	--	62035	DRI-MV-3	Spring	291	06/08/05
Baldwin Spring	36.72035	-114.72415	31.8	2.6	7.32	-13.05	-98.0	63.50	27.20	96.80	10.90	61.10	253.00	176.00	29.60	2.2	64174	DRI-MV-3	Spring	291	02/16/06
Baldwin Spring	36.72035	-114.72415	30.2	5.3	7.35	-13.03	-98.2	71.10	22.10	93.40	11.20	63.40	254.00	180.00	30.40	2.2	64903	DRI-MV-3	Spring	291	06/21/06
Baldwin Spring	36.72035	-114.72415	32.3	4.8	7.29	-13.03	-97.1	64.50	28.00	83.90	9.35	61.70	259.00	178.00	29.10	2.2	65284	DRI-MV-3	Spring	291	08/23/06
Baldwin Spring	36.72035	-114.72415	31.7	4.3	7.33	-12.91	-97.9	61.80	27.40	93.50	11.20	60.00	251.00	175.00	29.50	2.2	65662	DRI-MV-3	Spring	291	10/30/06
Barrel Spring	38.13105	-114.05505	9.8	6.2	7.72	-13.36	-100.5	55.70	6.12	16.50	0.52	18.80	193.00	10.70	22.90	--	60316	--	Spring	317	05/21/04
Bennett Spring	37.78417	-114.52806	24.0	--	7.50	-13.70	-103.0	56.00	26.00	6.50	1.50	7.90	318.00	6.90	14.00	<.1	288	GS103	Spring	141	04/10/85
Big Muddy Spring	36.72196	-114.71682	--	--	--	--	-98.0	--	--	--	--	--	--	--	--	--	121.2	--	Spring	69	3/00/70
Big Muddy Spring	36.72196	-114.71682	32.5	3.0	7.24	-12.90	-96.5	66.00	26.00	96.00	10.00	61.00	270.00	190.00	29.00	2.1	122	GS42	Spring	69	07/22/81
Big Muddy Spring	36.72196	-114.71682	--	--	--	-12.75	-98.0	--	--	--	--	--	--	--	--	--	125	--	Spring	69	10/30/85
Big Muddy Spring	36.72196	-114.71682	--	--	--	-13.05	-99.0	--	--	--	--	--	--	--	--	--	124	GS44	Spring	69	01/07/88
Big Muddy Spring	36.72196	-114.71682	31.0	--	--	-12.84	-98.4	64.40	27.60	99.90	10.90	64.20	270.00	198.00	29.90	--	60308	--	Spring	69	05/18/04
Big Muddy Spring	36.72196	-114.71682	--	--	--	-12.89	-97.6	63.40	27.00	99.10	10.90	64.50	255.00	178.00	32.60	--	61615	--	Spring	69	10/19/04

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Big Spring (Clover)	37.52781	-114.35258	17.2	7.4	7.32	-12.89	-94.2	27.30	4.26	9.50	2.58	7.30	111.00	3.90	48.20	--	61094	--	Spring	253	07/31/04
Big Spring (Clover)	37.52781	-114.35258	17.0	7.1	7.44	-12.89	-92.9	30.20	4.46	11.10	2.55	9.00	114.00	4.80	45.80	--	62401	DRI-CR-6	Spring	253	04/30/05
Big Spring (Egan)	38.59947	-114.91624	14.0	5.4	6.79	-13.85	-106.0	34.00	5.80	13.00		4.20	156.00	7.20	50.00	0.1	408	GS187	Spring	206	08/03/85
Big Spring (Egan)	38.59947	-114.91624	13.0	5.8	6.50	-13.92	-104.2	--	--	--	--	--	--	--	--	--	--	--	Spring	206	10/14/03
Big Spring (Egan)	38.59947	-114.91624	12.9	5.2	6.11	-13.98	-106.1	34.70	5.78	12.40	2.36	3.80	152.00	7.10	51.70		62980	ER-4	Spring	206	07/31/05
Big Spring (Egan)	38.59947	-114.91624	12.8	5.4	6.76	-13.86	-105.8	34.10	5.83	12.60	2.38	3.90	146.00	7.00	52.10	0.1	65050	ER-24	Spring	441	07/13/06
Big Spring (Grant)	38.37056	-115.48111	12.5	--	8.10	-15.20	-112.0	78.00	7.00	4.90	--	2.10	268.00	13.00	9.50	<.1	366	GS151	Spring	194	07/24/85
Big Spring Snake Valley	38.69892	-114.13223	17.2	5.3	7.54	-15.14	-112.2	47.80	20.30	5.50	1.51	5.10	228.00	8.50	12.60	--	61964	--	Spring	325	01/22/05
Big Spring Snake Valley	38.69892	-114.13223	--	--	--	-15.22	-112.2	48.30	19.50	5.28	1.54	5.50	8.50	234.00	12.70	0.1	63226	SU-2	Spring	325	08/13/05
Big Spring Snake Valley	38.69892	-114.13223	17.2	4.9	7.50	-15.10	-110.3	42.90	20.20	5.34	1.51	5.80	229.00	8.50	12.70	0.1	63569	--	Spring	--	11/08/05
Big Spring Snake Valley	38.69892	-114.13223	16.8	5.2	7.61	-15.17	-111.6	47.50	19.60	5.32	1.50	5.50	229.00	8.60	12.50	0.1	64238	SU-2	Spring	325	02/25/06
Big Spring Snake Valley	38.69892	-114.13223	17.2	5.3	7.43	-15.10	-112.6	49.00	20.30	6.18	2.61	7.30	232.00	9.30	12.80	0.1	64741	SU-2	Spring	325	05/21/06
Big Spring Snake Valley	38.69892	-114.13223	17.3	5.4	7.49	-15.15	-111.8	47.70	20.40	5.20	1.42	5.33	232.00	8.84	12.70	0.1	65291	SU-2	Spring	325	08/24/06
Big Spring Snake Valley	38.69892	-114.13223	17.0	4.8	7.44	-15.20	-111.1	49.70	20.30	5.93	1.45	6.10	232.00	8.50	12.90	0.1	65659	SU-2	Spring	325	10/29/06
Big Spring North	38.65611	-114.63306	20.5	--	7.60	-15.10	-112.0	49.00	19.00	5.30	2.10	6.00	240.00	12.00	21.00	0.2	416	GS193	Spring	211	04/04/85
Big Spring South	38.65417	-114.63306	18.5	--	7.50	-14.80	-111.0	45.00	18.00	5.40	1.90	5.60	200.00	12.00	18.00	0.2	415	GS192	Spring	210	04/04/85
Bishop Spring	37.41854	-114.64169	--	--	--	-11.70	-85.5	--	--	--	--	--	--	--	--	--	208	GS80	Spring	107	02/02/84
Bishop Spring	37.41854	-114.64169	17.5	6.3	7.04	-11.67	-88.0	68.00	24.10	17.10	0.92	13.40	332.00	14.50	54.80	--	58493	--	Spring	107	01/14/04
Bishop Spring	37.41854	-114.64169	18.4	4.6	6.93	-11.78	-88.1	--	--	--	--	--	--	--	--	--	62618	DRI-DR-6	Spring	107	05/20/05
Bitter Spring	36.28500	-114.51417	17.2	4.8	7.58	-9.90	-77.0	--	--	--	--	--	--	--	--	--	22	PL15	Spring	14	02/06/96
Black Rock Spring	37.91204	-114.91906	--	--	--	-12.25	-94.0	--	--	--	--	--	--	--	--	--	313	GS117	Spring	158	03/22/88
Black Rock Spring	37.91204	-114.91906	12.1	8.3	7.60	-12.36	-93.6	36.70	7.98	16.10	4.62	13.90	146.00	15.90	63.60	--	59687	--	Spring	158	03/23/04
Blue Point Spring	36.39000	-114.43306	--	--	--	-12.40	-93.0	--	--	--	--	--	--	--	--	--	49	PL8	Spring	26	06/24/85
Blue Point Spring	36.39000	-114.43306	--	--	--	-12.35	-92.5	--	--	--	--	--	--	--	--	--	47.5	USGS	Spring	26	07/01/85
Blue Point Spring	36.39000	-114.43306	30.0	--	7.80	-12.50	-93.5	470.00	160.00	330.00	23.00	400.00	160.00	1900.00	16.00	1.5	48	GS15	Spring	26	07/01/85
Blue Point Spring	36.39000	-114.43306	29.6	2.7	7.05	-12.30	-91.0	--	--	--	--	--	--	--	--	--	47	PL8	Spring	26	02/08/96
Blue Point Springs	36.39000	-114.43306	--	--	--	-12.47	-93.0	--	--	--	--	--	--	--	--	--	USGS	--	spring	--	06/05/03
Blue Rock Spring	38.15344	-114.35401	--	--	--	-12.68	-93.4	--	--	--	--	--	--	--	--	--	--	--	Spring	311	04/28/04
Boulder Spring (KSV-4)	37.31436	-114.67261	--	--	--	-12.00	-87.5	--	--	--	--	--	--	--	--	--	196	Kirk1027	Spring	98	--
Boulder Spring (KSV-4)	37.31436	-114.67261	16.8	--	7.90	-12.60	-87.0	21.00	4.90	12.00	2.30	7.80	100.00	6.00	41.00	1.7	198	GS74	Spring	98	02/02/84
Boulder Spring (KSV-4)	37.31436	-114.67261	5.0	8.8	7.36	-12.60	-91.0	19.40	4.46	11.40	0.26	6.60	88.90	5.70	42.80	--	58491		Spring	98	01/13/04
Boulder Spring (KSV-4)	37.31436	-114.67261	13.6	7.7	7.59	-12.66	-91.3	21.20	3.78	55.20	4.08	25.00	138.00	34.80	65.30	--	62394	DRI-DR-3	Spring	98	04/27/05
Big Tom Plain Spring	39.08701	-115.37737	7.4	6.1	6.70	-15.92	-121.1	--	--	--	--	--	--	--	--	--	62713	DRI-WP-8	Spring	326	06/06/05
Bradshaw Well	37.34917	-114.54389	14.8	--	7.30	-11.40	-88.5	85.00	28.00	120.00	11.00	52.00	550.00	76.00	63.00	2.3	202	GS76	Well	102	02/01/84
Brady Spring	38.32746	-115.47509	10.3	--	--	-15.38	-108.5	82.80	8.45	2.90	1.01	0.80	292.00	2.90	13.80	--	57754	--	Spring	282	10/28/03
Brady Spring (duplicate sample)	38.32746	-115.47509	--	--	--	-15.38	-110.4	--	--	--	--	--	--	--	--	--	57754	--	Spring	282	10/28/03
Buckboard Spring	37.58886	-114.63111	14.7	7.1	7.70	-11.71	-88.2	45.10	8.31	17.30	2.05	13.90	182.00	10.60	45.50	--	59697	--	Spring	264	03/26/04
Burnt Canyon Spring (Unnamed Spring in Burnt Canyon)	38.28944	-114.20889	11.0	--	7.60	-12.30	-93.0	35.00	7.70	8.10	0.50	5.20	140.00	8.20	38.00	0.1	356	GS140	Spring	187	06/05/85

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Butcher Spring	38.03035	-114.01531	10.1	7.6	7.10	-14.22	-103.2	25.50	5.44	10.80	1.01	18.10	78.30	10.90	26.90	0.2	64910	MG-7	Spring	424	06/23/06
Butte Spring	39.75816	-115.24246	13.7	7.4	6.89	-15.79	-120.4	--	--	--	--	--	--	--	--	--	62619	DRI-BT-1	Spring	327	05/24/05
Byron Well	36.58368	-114.64163	--	--	--	-13.27	-97.1	--	--	--	--	--	--	--	--	--	108503	SNWA	Well	623	01/28/05
Butterfield Spring	38.43972	-115.01083	16.5	6.1	7.31	-14.20	-105.0	47.00	22.00	6.00	2.50	4.70	260.00	8.00	23.00	0.1	384	GS163	Spring	202	07/19/81
Caliente City Well	37.61583	-114.51333	14.3	--	--	-12.40	-89.0	--	--	--	--	--	--	--	--	--	263	GS95	Well	124	01/31/84
Cabin Spring	39.75790	-115.27245	11.0	8.7	7.00	-15.89	-124.4	--	--	--	--	--	--	--	--	--	62708	DRI-BT-7	Spring	328	06/05/05
Cain Springs	39.54258	-114.22588	14.9	4.5	6.92	-10.85	-98.4	191.00	53.60	117.00	0.85	352.00	322.00	162.00	34.70	0.3	63282	--	Spring	400	08/26/05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	45.0	--	7.80	-14.50	-109.0	37.00	7.30	49.00	19.00	13.00	222.00	34.00	130.00	1.4	270	GS99	Spring	129	04/10/85
Caliente Hot Springs (Hotel)	37.62111	-114.51042	40.7	4.4	8.17	-14.52	-106.4	35.00	7.34	50.10	18.70	14.50	213.00	37.20	128.00	--	61621	--	Spring	129	10/20/04
Caliente Hot Springs (Hotel)	37.62111	-114.51042	40.4	4.1	8.06	-14.29	-109.3	35.60	7.17	51.80	19.00	14.50	208.00	44.80	119.00	--	61970	--	Spring	129	01/24/05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	41.0	4.0	7.52	-14.43	-107.0	--	--	--	--	--	--	--	--	--	62620	DRI-MW-2	Spring	129	05/19/05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	40.1	2.8	7.62	-14.47	-109.0	--	--	--	--	--	--	--	--	--	63230	DRI-MW-2	Spring	129	08/16/05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	41.5	3.1	7.71	-14.47	-107.2	35.00	7.36	51.20	18.80	13.70	214.00	39.10	122.00	1.5	63572		Spring	129	11/09/05
Caliente Hot Springs (Hotel)	37.62111	-114.51042	39.7	4.5	7.91	-14.42	-107.7	38.40	7.61	52.20	18.90	17.30	215.00	43.60	119.00	1.4	64170	MW-2	Spring	129	02/17/06
Caliente Hot Springs (Hotel)	37.62111	-114.51042	39.9	3.3	7.98	-14.38	-107.3	39.00	7.93	53.60	21.10	18.50	224.00	46.50	118.00	1.4	64744	MW-2	Spring	129	05/22/06
Calpine Test Well 1a	36.54611	-114.80194	30.5	--	--	-13.50	-99.0	--	--	--	--	--	--	--	--	--	999	ECP-1a	Well	43	04/07/00
Camp Creek	38.24361	-114.25222	9.0	--	7.90	-14.00	-102.0	--	--	--	--	--	--	--	--	--	349	E3	Surface	184	04/09/85
Carpenter Spring	38.05000	-115.61167	16.0	--	--	-11.85	-95.0	--	--	--	--	--	--	--	--	--	332	GS126	Spring	171	07/31/85
Cave Spring (Cave Valley)	38.64111	-114.79583	12.0	8.4	7.41	-13.85	-100.0	16.00	2.20	3.10		1.00	62.00	4.50	14.00	<.1	414	GS191	Spring	209	08/02/85
Cave Spring (Cave Valley)	38.64111	-114.79583	--	--	--	-14.16	-104.9	--	--	--	--	--	--	--	--	--	68110	SNWA	Spring	209	08/06/03
Cave Spring (Cave Valley)	38.64111	-114.79583	--	--	--	-13.54	-102.7	--	--	--	--	--	--	--	--	--	88485	SNWA	Spring	209	06/21/04
Cave Spring (Cave Valley)	38.64111	-114.79583	11.7	7.6	7.20	-14.20	-102.2	15.40	2.04	2.57	0.68	1.00	55.40	2.60	16.00	0.1	65057	SC-8	Spring	209	07/14/06
Cave Spring (Clover)	37.52979	-114.24092	18.7	4.7	7.00	-12.21	-90.8	47.80	9.12	26.40	8.41	20.00	219.00	10.80	57.40	--	61101	--	Spring	247	07/31/04
Cave Spring (Clover)	37.52979	-114.24092	18.7	4.7	7.00	-12.53	-94.7	--	--	--	--	--	--	--	--	--	61101B	--	Spring	247	07/31/04
Cave Valley MX	38.46859	-114.86944	--	--	--	-13.94	-105.0	--	--	--	--	--	--	--	--	--	--	USGS	Deep Well	620	07/10/03
Cave Valley Seedling Well	38.58298	-114.79334	--	--	--	-13.75	-104.7	--	--	--	--	--	--	--	--	--	112271	SNWA	Well	625	07/25/05
Cedar Spring	39.77309	-114.21140	14.4	2.8	7.20	-15.52	-121.5	104.00	50.60	16.50	1.60	42.90	208.00	262.00	14.60	0.5	63275	--	Spring	393	08/23/05
Cedar Cabin Spring	38.79689	-114.22339	9.6	9.0	7.55	-14.10	-106.0	62.30	20.20	5.45	1.04	5.00	5.70	272.00	12.00	<.04	62913	SN-4	Spring	380	07/13/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
The Cedars	38.93537	-114.41800	18.7	8.0	8.03	-15.02	-110.3	20.00	1.70	5.88	0.85	2.00	74.90	3.20	20.70	--	61965	--	Spring	329	01/22/05
The Cedars	38.93537	-114.41800	18.9	8.4	7.97	-15.03	-108.1	--	--	--	--	--	--	--	--	--	62621	DRI-SV-1	Spring	329	05/20/05
The Cedars	38.93537	-114.41800	--	--	--	-15.00	-108.6	19.80	1.68	5.85	0.86	2.00	3.30	74.20	20.60	0.3	63225	SV-1	Spring	329	08/12/05
The Cedars	38.93537	-114.41800	18.3	7.3	7.95	-15.00	-108.2	20.10	1.69	5.71	0.82	2.00	73.10	3.30	20.70	0.2	63570		Spring	329	11/08/05
The Cedars	38.93537	-114.41800	18.2	7.7	8.10	-15.02	-108.4	20.10	1.59	5.60	0.84	2.10	74.80	3.40	20.50	0.2	64240	SV-1	Spring	329	02/26/06
The Cedars	38.93537	-114.41800	18.8	8.5	7.90	-15.03	-108.3	20.10	1.67	5.85	1.84	2.10	74.10	3.50	20.80	0.2	64742	SV-1	Spring	329	05/21/06
The Cedars	38.93537	-114.41800	19.9	7.6	8.00	-14.97	-109.4	20.10	1.78	5.43	0.75	2.07	72.10	3.55	20.80	0.2	65369	SV-1	Spring	329	08/30/06
The Cedars	38.93537	-114.41800	18.4	8.3	7.83	-15.05	-109.9	20.00	1.68	5.67	0.82	2.00	72.90	3.40	20.60	0.2	65660	SV-1	Spring	329	10/29/06
CE-DT-4	36.79556	-114.89222	34.0	3.5	7.35	-13.00	-102.5	46.00	19.00	84.00	11.00	35.00	294.00	110.00	33.00	1.9	138	GS52	Well	78	12/23/80
CE-DT-6 Well	36.76778	-114.78694	--	--	--	-13.10	-99.0	--	--	--	--	--	--	--	--	--	130.2	DRI	Well	72	09/28/86
CE-DT-6 Well	36.76778	-114.78694	33.5	3.7	7.16	-12.95	-97.0	58.00	25.00	88.00	11.00	53.00	272.00	160.00	30.00	2.1	130	GS47	Well	72	09/28/86
CE-VF-2 Well	36.87500	-114.94556	--	--	--	-12.95	-101.0	--	--	--	--	--	--	--	--	--	155	USGS	Well	81	02/05/86
CE-VF-2 Well	36.87500	-114.94556	34.0	2.9	7.40	-13.10	-101.0	47.00	21.00	81.00	11.00	34.00	303.00	90.00	34.00	1.7	156	USGS	Well	81	01/06/88
Chicken Spring	39.23885	-115.38886	8.3	5.7	6.60	-16.17	-122.0	--	--	--	--	--	--	--	--	--	62715	DRI-WP-10	Spring	330	06/07/05
Chimney Rock Spring	38.83528	-114.88417	13.0	1.4	6.78	-14.30	-109.0	56.00	6.80	12.00		5.40	207.00	21.00	56.00	0.2	425	GS205	Spring	219	08/01/85
Chimney Rock Spring	38.83528	-114.88417	12.8	0.9	6.73	-14.74	-112.0	39.30	5.51	14.00	8.38	3.30	171.00	10.70	61.10	0.2	65052	ER-26	Spring	219	07/13/06
Circle Wash Spring	39.12170	-115.36929	7.6	7.1	6.20	-15.30	-114.5	--	--	--	--	--	--	--	--	--	62710	DRI-WP-5	Spring	331	06/06/05
Clover Creek Valley Well 232	37.50500	-114.27600	21.5	--	7.80	-11.70	-84.0	60.00	6.00	8.00	3.00	26.00	180.00	13.00	--	0.4	232	E29	Well	114	07/18/75
Clover Creek Valley Well 246	37.58470	-114.25980	26.0	--	7.80	-12.40	-89.0	41.00	6.00	10.00	5.00	17.00	166.00	4.00	--	--	246	E28	Well	120	07/18/75
Cold Spring	37.71370	-115.41016	--	--	--	-12.98	-98.9	49.70	12.10	22.80	1.50	19.40	208.00	22.60	50.70	--	60841	--	Spring	288	06/25/04
Cold Spring, Preston	38.91800	-115.06680	22.0	3.0	7.20	-15.80	-121.0	39.00	19.00	12.00	3.10	13.00	190.00	39.00	20.00	0.3	446	GS221	Spring	230	07/16/81
Cold Spring, Preston	38.91800	-115.06680	21.5	3.0	7.80	-15.80	-126.0	43.00	20.00	13.00	2.90	14.00	190.00	37.00	20.00	0.4	447	GS222	Spring	230	06/16/83
Connor Spring	37.90165	-114.56023	8.4	7.7	7.68	-13.84	-100.6	72.30	25.80	1.48	0.59	2.00	348.00	3.80	8.70	--	60838	--	Spring	283	06/24/04
Corn Creek Spring South	36.43890	-115.35775	21.4	4.0	7.44	-12.88	-95.0	51.00	48.20	9.81	3.02	9.10	401.00	25.10	28.70	--	58503	--	Spring	307	01/17/04
Corn Creek Spring South	36.43890	-115.35775	21.1	3.3	7.26	-12.89	-95.0	47.40	33.70	6.44	2.11	6.90	288.00	18.50	19.50	--	60852	--	Spring	307	06/30/04
Corral Spring (Unnamed Spring)	36.37056	-114.46000	17.0	6.2	7.31	-12.10	-91.5	--	--	--	--	--	--	--	--	--	28	PL13	Spring	19	02/07/96
Cottonwood Spring (Fairview)	38.31204	-114.63476	13.1	4.6	--	-13.40	-102.2	33.80	4.87	17.80	0.80	6.10	161.00	4.70	38.00	--	60848	--	Spring	274	06/29/04
Cottonwood Spring (Black Mtns.)	36.20333	-114.64361	12.6	6.5	7.81	-10.80	-80.0	524.00	220.00	209.00	10.70	63.60	205.00	2410.00	17.40	--	13	PL17	Spring	8	02/06/96
Cottonwood Spring (Delamar)	37.53418	-114.74636	15.5	2.3	7.10	-12.87	-96.9	80.00	9.32	29.50	0.70	17.30	311.00	18.70	48.70	--	59698	--	Spring	265	03/26/04
Cow Camp Spring	36.58361	-115.30722	14.5	--	7.60	-12.60	-90.5	48.00	31.00	21.00	0.70	28.00	290.00	23.00	16.00	0.2	75	GS19	Spring	47	10/28/81
Cow Camp Spring	36.58361	-115.30722	10.0	5.9	7.60	-12.60	-93.0	50.00	35.00	25.00	0.60	29.00	--	29.00	15.00	0.2	77	GS21	Spring	47	05/10/83
Cow Camp Spring	36.58361	-115.30722	16.8	5.1	7.26	-12.46	-92.0	48.90	35.60	26.90	0.55	23.50	312.00	24.60	17.60	--	61105		Spring	47	07/27/04
Cow Camp Spring	36.58361	-115.30722	10.1	8.4	6.96	-12.47	-91.9	52.00	38.00	38.90	0.29	39.90	298.00	48.60	15.10	--	62399	DRI-SR-4	Spring	47	04/28/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Coyote Spring	38.03186	-114.86219	--	--	--	-12.04	-97.2	--	--	--	--	--	--	--	--	--	88474	SNWA	Spring	169	06/21/04
Coyote Spring	38.03186	-114.86219	13.3	4.7	6.76	-12.26	-95.2	75.10	11.40	55.50	10.70	31.70	246.00	105.00	82.70	--	62409	DRI-DL-1	Spring	169	05/01/05
Coyote Spring	38.03186	-114.86219	--	--	--	-12.80	-95.0	--	--	--	--	--	--	--	--	--	330	Kirk1017	Spring	169	--
Crystal Springs	37.53144	-115.23364	--	--	--	--	-109.0	--	--	--	--	--	--	--	--	--	--	Win	Spring	116	08/01/68
Crystal Springs	37.53144	-115.23364	--	--	--	--	-110.0	--	--	--	--	--	--	--	--	--	--	Win	Spring	116	01/01/69
Crystal Springs	37.53144	-115.23364	--	--	--	--	-109.0	--	--	--	--	--	--	--	--	--	--	Win	Spring	116	03/01/70
Crystal Springs	37.53144	-115.23364	27.5	1.8	7.34	-14.30	-109.0	43.00	21.00	22.00	5.00	8.90	260.00	34.00	25.00	0.3	235	GS87	Spring	116	07/20/81
Crystal Springs	37.53144	-115.23364	26.5	--	7.40	-14.38	-108.4	44.00	22.00	24.00	5.40	8.60	248.00	32.00	24.00	0.3	238	GS90	Spring	116	08/16/94
Crystal Springs	37.53144	-115.23364	28.0	--	7.74	-14.39	-106.9	44.16	22.56	23.84	4.83	9.60	255.00	34.70	24.74	0.4	239	IT120	Spring	116	08/07/95
Crystal Springs	37.53162	-115.23363	--	--	--	-14.32	-108.0	--	--	--	--	--	--	--	--	--	USGS	--	Spring	116	06/03/03
Crystal Springs	37.53144	-115.23364	--	--	--	-14.23	-111.0	--	--	--	--	--	--	--	--	--	84392	SNWA	Spring	116	05/24/04
Crystal Springs	37.53144	-115.23364	27.3	5.1	7.25	-14.36	-109.2	43.10	22.20	23.60	5.26	8.70	255.00	32.30	26.40	--	61106	--	Spring	116	07/30/04
Crystal Springs	37.53144	-115.23364	27.3	1.3	7.59	-14.41	-109.0	45.30	22.40	24.20	5.28	9.10	240.00	33.60	26.60	--	61618	--	Spring	116	10/20/04
Crystal Springs	37.53144	-115.23364	27.2	1.3	7.50	-14.35	-109.4	45.60	22.00	24.10	5.18	8.80	247.00	33.20	25.20	--	61971	--	Spring	116	01/24/05
Crystal Springs	37.53144	-115.23364	27.1	1.3	7.26	-14.44	-107.3	--	--	--	--	--	--	--	--	--	62622	DRI-PV-2	Spring	116	05/18/05
Crystal Springs	37.53144	-115.23364	27.0	1.3	6.92	-14.46	-109.3	--	--	--	--	--	--	--	--	--	63229	DRI-PV-2	Spring	116	08/14/05
Crystal Spring	37.53144	-115.23364	27.1	1.3	7.38	-14.42	-110.1	45.70	22.20	23.80	5.10	9.30	248.00	33.10	25.00	0.3	63574	--	Spring	116	11/09/05
Crystal Spring	37.53181	-115.23383	27.1	1.4	7.43	-14.47	-108.5	45.10	22.10	23.60	5.13	9.30	245.00	33.90	24.70	0.3	65655	PV-2	Spring	116	10/28/06
Crystal Springs	37.53181	-115.23383	27.1	1.3	7.44	-14.53	-108.8	46.30	22.50	24.20	5.35	9.50	247.00	33.80	24.70	0.4	64168	PV-2	Spring	116	02/17/06
Crystal Springs	37.53181	-115.23383	27.2	1.2	7.51	-14.47	-109.5	45.50	21.90	24.00	5.72	9.50	247.00	35.10	25.40	0.4	64746	PV-2	Spring	116	05/22/06
Crystal Springs	37.53181	-115.23383	27.1	1.3	7.42	-14.49	-108.8	45.90	22.60	21.20	4.36	9.07	239.00	34.80	25.00	0.3	65290	PV-2	Spring	116	08/23/06
CSV-2 Well	36.78056	-114.72222	27.0	4.0	7.40	-12.85	-98.0	60.00	27.00	100.00	10.00	61.00	276.00	160.00	30.00	2.3	135	GS51	Well	76	01/26/86
CSV-2 Well	36.78056	-114.72222	--	--	--	-12.99	-97.7	--	--	--	--	--	--	--	--	--	USGS	--	Well	76	07/08/03
CSV-3 Well	36.69083	-114.92500	41.0	--	7.35	-10.35	-75.0	51.00	25.00	38.00	10.00	26.00	239.00	54.00	24.00	1.2	104	GS38	Well	60	10/07/87
CSV-3 Well	36.69083	-114.92500	--	--	--	-10.30	-75.8	--	--	--	--	--	--	--	--	--	121722	SNWA	Well	60	01/26/06
Davies Spring	36.96556	-114.50194	14.3	--	--	-12.50	-89.0	--	--	--	--	--	--	--	--	--	177	GS64	Spring	90	02/06/84
Deadman Spring (Highland)	37.91861	-114.54139	9.5	--	7.10	-13.30	-99.0	98.00	41.00	5.00	0.90	4.20	506.00	8.30	19.00	0.1	319	GS119	Spring	162	04/07/85
Deadman Spring (Highland)	37.91861	-114.54139	27.9	4.9	9.68	-10.83	-90.9	12.20	40.10	4.11	0.43	2.50	143.00	5.40	2.10	--	60837	--	Spring	162	06/24/04
Decathon Spring	38.80738	-114.27884	7.6	7.1	6.89	-14.60	-107.0	111.00	7.58	2.88	0.54	3.40	11.40	325.00	11.30	0.1	62914	SN-5	Spring	381	07/14/05
Deer Spring (White Pine)	38.99498	-115.39136	--	--	--	-15.87	-118.9	--	--	--	--	--	--	--	--	--	JThomas-032304-4	WP-4	Spring	322	10/12/03
Deer Spring (White Pine)	38.99498	-115.39136	9.4	6.3	6.90	-15.87	-119.6	--	--	--	--	--	--	--	--	--	62822	WP-4	Spring	322	06/28/05
Deer Spring (Butte)	39.48683	-115.27559	12.3	6.4	6.30	-14.74	-114.1	--	--	--	--	--	--	--	--	--	62704	DRI-BT-6	Spring	332	06/04/05
Delmues Spring (Unnamed Spring)	37.86000	-114.32222	18.0	--	7.70	-13.40	-104.0	47.00	6.70	30.00	6.30	24.00	180.00	18.00	64.00	0.6	302	GS111	Spring	149	04/08/85
Desert Valley (Dry Lake) Well #1	36.95306	-115.19750	19.0	2.8	7.97	-13.10	-98.0	22.00	27.00	35.00	5.70	8.90	413.00	48.00	49.00	0.6	171	GS61	Well	87	03/18/87
Dipping Tank Spring	39.77522	-114.47512	12.0	7.8	6.83	-15.74	-119.8	47.50	8.37	16.20	2.01	18.00	167.00	14.60	30.70	0.1	63280	--	Spring	398	08/25/05
DLLLC Hidden Valley	36.49340	-114.92657	--	--	--	-12.90	-97.0	--	--	--	--	--	--	--	--	--	999	HV-1	Well	37	06/05/00
Dodge Well	38.24444	-114.54250	17.0	--	--	-14.20	-107.0	--	--	--	--	--	--	--	--	--	350	GS137	Well	185	06/07/85
Douglas Spring	38.85003	-115.14867	--	--	--	-13.01	-106.4	--	--	--	--	--	--	--	--	--	112274	SNWA	Spring	626	07/26/05
Dry Lake Valley Well	36.45500	-114.84389	29.0	2.0	7.27	-13.30	-97.5	110.00	48.00	120.00	13.00	170.00	210.00	360.00	21.00	2.1	64	GS17	Well	34	07/01/85

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
East Settling Spring	37.37315	-114.23282	--	--	--	-12.76	-92.2	--	--	--	--	--	--	--	--	--	61100B	--	Spring	248	07/31/04
Easter Spring	39.04120	-115.34883	11.1	6.7	7.30	-15.56	-119.4	--	--	--	--	--	--	--	--	--	62823	WP-23	Spring	365	06/29/05
EH-3 Weiser Wash	36.69222	-114.52556	24.1	--	7.80	-12.70	-91.0	511.00	201.00	170.00	22.00	194.00	123.00	2100.00	15.00	--	--	4	Well	61	averages
EH-4 Weiser Wash	36.70639	-114.71611	22.8	0.0	8.30	-13.00	-98.0	49.00	30.00	90.00	12.00	57.00	245.00	171.00	28.00	0.0	AVG	--	Well	63	averages
EH-6 Weiser Wash	36.68167	-114.57000	24.8	0.0	7.70	-13.90	-99.5	341.00	131.00	274.00	31.00	41.00	178.00	1800.00	13.00	0.0	AVG	--	Well	59	averages
EH-7	36.67056	-114.53139	21.0	--	7.33	-12.45	-91.0	470.00	190.00	170.00	20.00	65.00	--	2000.00	15.00	0.9	99	GS35	Well	56	03/19/87
EH-8 Weiser Wash	36.67389	-114.57583	0.0	0.0	7.60	-13.70	-96.5	375.00	104.00	416.00	22.00	233.00	162.00	1780.00	26.00	0.0	AVG	--	Well	57	averages
Eightmile Spring	37.46466	-115.06440	17.9	6.7	7.23	-13.12	-96.7	45.00	9.15	13.20	1.49	10.60	189.00	8.90	43.20	0.0	61103	--	Spring	295	07/30/04
Eightmile Spring	37.46466	-115.06440	14.4	6.7	7.35	-13.06	-94.4	52.20	9.90	17.80	1.07	16.20	195.00	14.80	37.60	0.0	61106C	DRI-PR-11	Spring	295	04/30/05
Eight Mile Spring (Snake Range)	39.38830	-114.28433	11.1	7.7	7.02	-15.53	-116.3	77.80	18.30	5.74	0.86	4.70	307.00	9.50	12.60	<.05	63284	SN-32	Spring	402	08/26/05
Eight Mile Spring (Snake Range)	39.38830	-114.28433	11.0	7.1	7.31	-15.38	-114.8	79.70	18.50	5.28	0.76	4.86	306.00	9.59	12.40	0.1	65421	SN-32	Spring	402	09/17/06
Eight Mile Spring (Snake Range)	39.38830	-114.28433	11.5	7.5	7.36	-15.40	-114.3	80.20	18.70	5.79	0.81	4.81	333.00	8.96	11.40	0.1	68482	SN-32	Spring	496	06/02/08
Eight Mile Spring (Snake Range)	39.38830	-114.28433	11.4	6.9	7.39	-15.46	-112.0	78.40	18.70	5.76	0.83	4.61	330.00	9.02	12.00	0.0	68915	SN-32	Spring	496	09/12/08
Eight Mile Spring (Snake Range)	39.38830	-114.28433	11.4	7.5	7.31	-15.39	-115.7	78.90	18.80	5.78	0.84	4.65	322.00	8.87	11.60	0.1	69146	SN-32	Spring	496	11/01/08
Eight Mile Spring (Snake Range)	39.38830	-114.28433	--	--	--	-15.30	-114.8	79.70	18.50	5.58	0.73	4.74	316.00	8.43	12.20	0.1	69867	SN-32	Spring	496	08/15/09
Eight Mile Spring (Snake Range)	39.38830	-114.28433	--	--	--	-15.45	-115.6	77.90	17.70	5.79	0.82	4.93	329.00	9.01	11.50	0.0	70617	SN-32	Spring	496	11/17/09
Ella Spring	37.49072	-114.44835	7.5	3.6	7.70	-12.56	-95.8	44.20	8.55	11.10	1.84	7.00	170.00	8.80	27.10	--	59702	--	Spring	251	03/27/04
Emigrant Spring	38.62500	-115.04778	19.5	5.2	7.14	-14.50	-108.0	67.00	24.00	5.30	1.60	2.90	300.00	14.00	13.00	0.2	410	GS188	Spring	207	07/18/81
Emigrant Spring	38.62500	-115.04778	20.1	--	--	--	-107.5	--	--	--	--	--	--	--	--	--	411	GS189	Spring	207	01/17/84
Fence Spring	38.17978	-114.71593	--	--	--	-12.55	-97.4	--	--	--	--	--	--	--	--	--	--	--	Spring	278	06/29/04
Flag Spring #3	38.42139	-115.02222	22.8	-	7.50	-14.30	-105.0	50.00	21.00	10.00	3.40	6.60	270.00	12.00	26.00	0.2	380	GS161	Spring	201	01/17/84
Flatnose Spring (Unnamed Spring)	37.89611	-114.22583	25.0	--	8.00	-13.40	-101.0	26.00	3.50	34.00	5.60	10.00	146.00	18.00	55.00	1.3	306	GS113	Spring	153	04/08/85
Forest Home Spring (Unnamed Spring)	38.37750	-115.37528	14.0	5.3	7.63	-14.50	-108.5	62.00	26.00	9.90	--	6.90	309.00	19.00	14.00	<.1	368	GS152	Spring	195	07/24/85
Four Mile Spring	39.30724	-114.29803	9.4	6.5	7.23	-14.75	-112.5	85.50	33.70	8.88	1.18	7.49	375.00	40.20	15.80	0.1	65413	SN-25	Spring	488	09/16/06
Fox Cabin	38.16267	-114.65034	--	--	--	-13.59	-103.5	--	--	--	--	--	--	--	--	--	--	--	Spring	273	06/29/04
Fugro CV Deep Well CE-DT-5	36.79556	-114.89222	35.5	2.3	7.15	-12.90	-99.5	46.00	20.00	78.00	11.00	34.00	300.00	100.00	33.00	1.9	139	GS53	Well	77	07/22/81
Fugro CV Deep Well CE-DT-6	36.79556	-114.89222	--	--	--	-13.16	-100.1	--	--	--	--	--	--	--	--	--	65461	SNWA	Well	77	04/08/03
Fugro CV Deep Well CE-DT-5	36.79556	-114.89222	--	--	--	-12.99	-99.6	--	--	--	--	--	--	--	--	--	USGS	--	Well	77	05/28/03
Fugro CV Deep Well CE-DT-5	36.79556	-114.89222	--	--	--	-12.99	-99.6	--	--	--	--	--	--	--	--	--	USGS	--	Deep Well	77	02/16/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Fugro Dry Lake V Deep Well	38.14583	-114.89333	27.5	3.2	7.08	-14.20	-108.0	73.00	29.00	20.00	6.90	6.20	--	27.00	25.00	0.5	343	GS133	Well	179	12/10/80
Fugro Dry Lake V Deep Well	38.14583	-114.89333	--	--	--	-14.11	-107.0	--	--	--	--	--	--	--	--	--	USGS	--	Well	179	06/19/03
Fugro Steptoe V Deep Well	38.92000	-114.84528	11.0	5.5	7.50	-14.90	-117.0	66.00	14.00	15.00	4.40	12.00	--	57.00	28.00	0.4	443	GS218	Well	228	01/19/81
Garden Spring	37.26425	-114.28869	8.8	6.5	7.06	-11.54	-87.0	--	--	--	--	--	--	--	--	--	58500	--	Spring	246	01/15/04
Geyser Spring	38.68000	-114.66556	12.5	--	7.80	-14.50	-105.0	--	--	--	--	--	--	--	--	--	419	E1	Spring	213	04/03/85
Gourd Spring	36.95861	-114.29167	E16.	--	--	-10.60	-77.5	--	--	--	--	--	--	--	--	--	175	GS63	Spring	89	02/06/84
GP Apex Well	36.34111	-114.92667	--	--	--	-13.35	-97.5	--	--	--	--	--	--	--	--	--	999	Jim	Well	17	09/29/86
GP Apex Well	36.34111	-114.92667	31.0	5.5	6.96	-13.45	-98.0	120.00	47.00	130.00	13.00	200.00		380.00	23.00	1.4	24	PLC23	Well	17	09/30/86
GP Apex Well	36.34111	-114.92667	--	--	--	-13.80	-96.0	--	--	--	--	--	226.00	--	--	--	25	GS8	Well	17	09/30/86
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	27.0	492.0	7.23	-15.83	-119.6	49.80	16.80	29.30	3.94	23.90	245.00	22.10	23.10	--	61482	--	Spring	333	09/24/04
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.9	6.3	7.71	-15.88	-120.0	50.70	17.10	29.10	3.92	23.60	236.00	22.60	22.80	--	61963	--	Spring	333	01/22/05
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	--	--	--	-15.83	-119.4	--	--	--	--	--	--	--	--	--	62623	--	Spring	333	05/23/05
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	--	--	--	-15.93	-119.8	49.90	16.40	28.40	3.86	23.60	22.20	240.00	22.30	0.2	63224	SU-1	Spring	333	08/12/05
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.6	4.9	7.52	-15.90	-122.8	47.30	17.00	28.50	3.91	22.80	235.00	22.50	22.70	0.6	63568	--	Spring	333	11/08/05
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.8	5.5	7.58	-15.96	-119.5	50.80	16.20	28.20	3.89	23.70	236.00	22.80	22.50	0.7	64237	SU-1	Spring	333	02/25/06
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	27.3	5.8	7.55	-16.00	-121.2	50.40	16.60	28.80	4.92	24.20	236.00	23.50	23.00	0.6	64740	SU-1	Spring	333	05/21/06
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.7	5.8	7.59	-15.88	-120.4	51.20	17.00	24.10	3.01	24.40	247.00	22.80	21.80	0.6	65292	SU-1	Spring	333	08/25/06
Gandy Warm Spring (Warm Spring Near Gandy)	39.46000	-114.03707	26.9	5.7	7.56	-15.91	-120.3	51.10	17.10	28.60	3.85	24.10	233.00	22.70	22.40	0.6	65658	SU-1	Spring	333	10/29/06
Granite Spring	38.56271	-114.91658	11.8	5.8	6.83	-13.32	-103.4	44.60	10.90	16.60	2.92	12.60	186.00	17.20	57.30	0.2	65049	ER-23	Spring	440	07/13/06
Grapevine Spring (KSV-2)	37.12988	-114.70972	--	--	--	-11.60	-88.0	--	--	--	--	--	--	--	--	--	183	Kirk1028	Spring	93	--
Grapevine Spring (KSV-2)	37.12988	-114.70972	18.5	--	7.30	-12.00	-87.5	75.00	22.00	17.00	2.30	27.00	280.00	40.00	22.00	0.9	185	GS69	Spring	93	02/03/84
Grapevine Spring (KSV-2)	37.12988	-114.70972	18.2	2.4	7.56	-11.90	-88.6	77.20	17.30	20.20	2.90	31.40	236.00	44.50	28.30	--	62396	DRI-MM-1	Spring	93	04/27/05
Grapevine Spring (KSV-2)	37.12988	-114.70972	--	--	--	-11.95	-85.2	77.50	17.90	18.70	2.38	32.70	245.00	46.70	27.30	0.3	63223	DRI-MM-1	Spring	93	08/16/05
Grapevine Spring (KSV-2)	37.12988	-114.70972	18.3	5.7	7.71	-11.89	-87.7	79.20	17.60	18.10	2.62	30.10	244.00	42.80	26.80	0.7	63573	--	Spring	93	11/09/05
Grapevine Spring WR7	37.12988	-114.70972	12.1	4.9	7.50	-12.00	-87.3	76.30	18.00	18.00	1.95	32.10	228.00	44.80	24.20	0.7	64171	MM-1	Spring	93	02/16/06
Grapevine Spring WR7	37.12988	-114.70972	18.8	1.3	7.30	-11.92	-87.3	76.70	17.70	16.80	2.55	28.00	248.00	40.00	26.70	0.7	64745	MM-1	Spring	93	05/22/06
Grapevine Spring WR7	37.12988	-114.70972	20.7	2.6	7.14	-12.00	-87.4	73.40	18.50	16.70	1.96	31.00	233.00	45.60	24.80	0.7	65288	MM-1	Spring	93	08/23/06
Grapevine Spring WR7	37.12988	-114.70972	17.3	2.9	7.28	-11.93	-87.2	74.00	18.50	18.10	2.05	29.60	228.00	44.70	24.10	0.7	65665	MM-1	Spring	93	10/30/06
Grapevine Spring WR7	37.12988	-114.70972	--	--	--	-12.03	-87.5	--	--	--	--	--	--	--	--	--	--	MM-1	Spring	93	05/09/07
Grass Valley Springs	39.71321	-114.23300	9.2	6.0	6.35	-16.72	-124.7	18.00	3.26	12.30	0.94	5.90	81.00	5.10	26.60	0.1	63274		Spring	392	08/23/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Gubler Canyon Creek Spring (Unnamed Spring in Gubler Canyon)	39.13389	-114.96139	12.5	--	--	-14.90	-111.0	--	--	--	--	2.40	--	--	--	--	457	GS243	Spring	235	06/16/83
Hackberry Spring	36.91778	-114.43778	10.0	--	--	-12.30	-87.0	--	--	--	--	--	--	--	--	--	162	GS58	Spring	84	02/05/84
Haggerty Spring	38.66930	-114.90482	11.9	6.0	6.85	-14.78	-109.6	69.70	13.00	3.94	0.76	2.80	259.00	7.00	10.60	--	62979	ER-9	Spring	387	07/31/05
Headwaters Spring WR5	38.36575	-114.31935	9.6	6.5	7.00	-14.65	-106.9	10.40	2.41	4.47	1.31	4.50	37.10	4.70	19.10	--	60311	--	Spring	309	05/19/04
Headwaters Spring WR5	38.36575	-114.31935	--	--	--	-14.67	-108.7	--	--	--	--	--	--	--	--	--	60311B	--	Spring	309	07/18/04
Headwaters Spring WR5	38.36575	-114.31935	8.2	7.1	6.85	-14.67	-108.8	11.20	2.51	4.79	1.21	4.20	37.20	4.40	20.40	--	61481	--	Spring	309	09/23/04
Headwaters Spring WR5	38.36575	-114.31935	--	--	--	-15.01	-110.4	--	--	--	--	--	--	--	--	--	62970	--	Spring	309	07/27/05
Headwaters Spring WR5	38.36575	-114.31935	--	--	--	-14.99	-109.6	11.80	2.54	4.88	1.21	4.70	3.40	44.30	21.10	0.2	63221	WC-1	Spring	309	08/13/05
Headwaters Spring WR5	38.36575	-114.31935	9.5	6.0	6.36	-14.71	-107.8	13.80	3.00	5.43	1.34	6.20	46.90	4.40	21.40	0.1	63565		Spring	309	11/07/05
Headwaters Spring WR5	38.36575	-114.31935	9.3	6.3	6.54	-14.52	-106.3	11.40	2.57	5.21	1.27	3.70	45.00	3.70	22.00	0.1	64737	WC-1	Spring	309	05/23/06
Headwaters Spring WR5	38.36575	-114.31935	12.1	6.1	6.37	-14.59	-107.7	10.70	2.46	5.04	1.29	4.48	43.20	4.08	21.20	0.1	65370	WC-1	Spring	309	08/31/06
Headwaters Spring WR5	38.36575	-114.31935	8.9	7.1	6.50	-14.47	-107.3	11.50	2.68	5.28	1.30	4.41	41.10	4.03	21.50	0.1	65744	WC-1	Spring	309	11/16/06
WR 5 Autosampler	38.36575	-114.31935	--	--	--	-14.61	-107.6	--	--	--	--	--	--	--	--	--	DRI-65370-9	WC-1	Spring	309	12/01/05
WR 5 Autosampler	38.36575	-114.31935	--	--	--	-14.70	-108.6	--	--	--	--	--	--	--	--	--	DRI-65370-12	WC-1	Spring	309	01/01/06
WR 5 Autosampler	38.36575	-114.31935	--	--	--	-14.52	-107.7	--	--	--	--	--	--	--	--	--	DRI-65370-14	WC-1	Spring	309	02/01/06
WR 5 Autosampler	38.36575	-114.31935	--	--	--	-14.34	-105.7	--	--	--	--	--	--	--	--	--	DRI-65370-16	WC-1	Spring	309	03/01/06
WR 5 Autosampler	38.36575	-114.31935	--	--	--	-14.36	-105.5	--	--	--	--	--	--	--	--	--	DRI-65370-20	WC-1	Spring	309	05/01/06
WR5 Autosample 1	38.36575	-114.31935	--	--	--	-14.53	-105.7	--	--	--	--	--	--	--	--	--	65744 Auto1	WC-1	Spring	309	09/01/06
WR5 Autosample 5	38.36575	-114.31935	--	--	--	-14.10	-105.4	--	--	--	--	--	--	--	--	--	65744 Auto5	WC-1	Spring	309	11/01/06
Headwaters Spring WR5	38.36575	-114.31935	8.5	NA	6.24	-14.24	-105.0	10.60	2.41	4.62	1.24	3.10	41.80	3.50	19.40	0.1	65744	WC-1	Spring	309	05/07/07
Headwaters Spring WR5	38.36575	-114.31935	--	--	--	-14.33	-105.2	--	--	--	--	--	--	--	--	--	67249A	WC-1	Spring	309	06/01/07
Headwaters Spring WR5	38.36575	-114.31935	--	--	--	-14.21	-104.5	--	--	--	--	--	--	--	--	--	67249B	WC-1	Spring	309	07/01/07
Headwaters Spring WR5	38.36575	-114.31935	12.8	4.3	6.30	-14.32	-106.4	10.30	2.35	5.37	1.39	3.64	43.80	3.71	19.60	<.1	67249	WC-1	Spring	309	08/20/07
Headwaters Spring WR5	38.36575	-114.31935	10.1	5.5	6.40	-14.32	-105.3	10.30	2.33	4.81	1.18	3.80	40.80	3.60	18.90	0.1	67507	WC-1	Spring	309	11/02/07
Headwaters Spring WR5	38.36575	-114.31935	9.2	5.5	6.29	-14.30	-105.4	9.72	2.28	4.46	1.16	3.40	38.20	3.58	19.40	0.1	68475	WC-1	Spring	309	05/30/08
Headwaters Spring WR5	38.36575	-114.31935	11.5	6.4	6.32	-14.44	-104.9	9.94	2.40	4.53	1.26	3.72	38.70	3.72	20.30	0.1	68912	WC-1	Spring	309	09/11/08
Headwaters Spring WR5	38.36575	-114.31935	10.1	6.8	6.24	-14.44	-106.4	10.10	2.38	4.48	1.32	3.75	47.00	3.61	19.20	0.1	69143	WC-1	Spring	309	10/30/08
Headwaters Spring WR5	38.36575	-114.31935	9.0	7.3	6.17	-13.98	-103.4	10.10	2.42	4.51	1.29	3.47	40.30	3.70	19.00	0.1	69859	WC-1	Spring	309	05/18/09
Headwaters Spring WR5	38.36575	-114.31935	--	--	--	-14.14	-103.8	10.20	2.36	4.54	1.29	3.85	39.60	3.72	20.30	0.1	69859	WC-1	Spring	309	08/17/09
Headwaters Spring WR5	38.36575	-114.31935	--	--	--	-14.27	-104.7	9.70	2.25	4.52	1.20	4.08	38.20	3.75	18.60	0.1	70611	WC-1	Spring	309	11/14/09
Hells Acres Gulch Spring (Unnamed Spring in Hells Acres Gulch)	37.46028	-115.12472	13.0	--	8.30	-12.30	-93.0	45.20	9.03	20.70	2.38	8.20	198.00	19.90	39.00	--	211	K9	Spring	109	01/14/85
Henry Spring	37.68990	-115.37391	--	--	--	-12.77	-97.4	--	--	--	--	--	--	--	--	--	--	--	Spring	287	06/25/04
High Springs	39.13012	-114.95041	7.4	6.5	7.50	-15.43	-113.4	66.20	10.10	3.65	0.91	0.80	232.00	17.90	10.40	0.1	65042	ER-16	Spring	433	07/12/06
Highland Spring	37.92110	-114.54923	10.0	--	7.20	-13.30	-98.5	86.00	36.00	4.70	1.00	4.40	474.00	8.10	15.00	0.1	320	GS120	Spring	163	04/07/85
Highland Spring	37.92110	-114.54923	11.6	5.8	7.35	-13.49	-99.6	77.10	35.90	3.71	0.71	3.70	413.00	6.20	15.30	--	60839	--	Spring	163	06/24/04
Highland Spring	37.92110	-114.54923	10.2	7.3	6.79	-13.30	-99.3	82.90	35.10	4.34	0.64	3.40	403.00	5.90	16.10	--	62408	DRI-HR-1	Spring	163	05/01/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Hiko Spring	37.59833	-115.21444	--	--	--	-13.80	-109.0	--	--	--	--	--	--	--	--	--	249	PLC12	Spring	122	--
Hiko Spring	37.59833	-115.21444	--	--	--	--	-110.5	--	--	--	--	--	--	--	--	--	254	IT127	Spring	122	08/01/68
Hiko Spring	37.59833	-115.21444	--	--	--	--	-109.5	--	--	--	--	--	--	--	--	--	255	IT128	Spring	122	01/01/69
Hiko Spring	37.59833	-115.21444	--	--	--	--	-109.5	--	--	--	--	--	--	--	--	--	256	IT129	Spring	122	03/01/70
Hiko Spring	37.59833	-115.21444	26.0	--	7.40	-15.30	-110.0	49.0	23.00	26.00	7.40	11.00	282.00	37.00	30.00	0.6	251	IT124	Spring	122	01/14/85
Hiko Spring	37.59833	-115.21444	--	--	--	-14.00	-105.0	--	--	--	--	--	--	--	--	--	257	IT130	Spring	122	01/14/85
Hiko Spring	37.59833	-115.21444	26.5	--	7.73	-14.45	-107.7	46.40	23.33	25.57	6.63	11.00	273.00	38.10	33.08	0.5	252	IT125	Spring	122	08/07/95
Hole in the Bank Spring	38.84915	-114.89566	6.9	7.9	6.64	-15.37	-114.9	43.70	11.00	12.40	2.95	5.10	195.00	10.50	50.60	0.1	62977	ER-8	Spring	386	07/31/05
Horse Spring (Morman)	36.94139	-114.44639	--	--	--	-12.70	-89.0	--	--	--	--	--	--	--	--	--	167	GS59	Spring	85	02/05/84
Horse Spring (Grant)	38.32951	-115.38580	14.7	7.2	7.10	-12.86	-99.5	--	--	--	--	--	--	--	--	--	62829	GR-3	Spring	370	06/30/05
Horsethief Spring	38.02649	-114.24511	11.7	1.6	6.92	-12.73	-96.3	56.60	7.96	16.50	1.22	18.60	206.00	13.00	50.10	--	60314	--	Spring	314	05/20/04
Horsethief Spring	38.02649	-114.24511	9.7	1.9	6.39	-12.62	-97.6	76.50	10.60	27.60	0.50	19.50	293.00	13.50	60.30	--	62406	DRI-WC-6	Spring	314	05/01/05
Hot Creek Campground Well	38.38833	-115.13278	19.0	--	--	-15.30	-118.0	--	--	--	--	--	--	--	--	--	374	GS155	Well	198	07/19/81
Hot Creek Springs	38.38251	-115.15451	32.5	1.0	7.22	-15.50	-118.0	59.00	21.00	24.00	5.50	10.00	--	46.00	28.00	0.9	372	GS153	Spring	197	07/19/81
Hot Creek Springs	38.38251	-115.15451	--	--	--	-15.82	-120.0	--	--	--	--	--	--	--	--	--	68113	SNWA	Spring	197	08/08/03
Hot Creek Springs	38.38251	-115.15451	--	--	--	-15.51	-120.1	--	--	--	--	--	--	--	--	--	88477	SNWA	Spring	197	06/23/04
Hot Creek Springs	38.38251	-115.15451	31.8	1.3	7.17	-15.71	-120.5	57.90	22.10	24.90	4.82	10.10	282.00	43.90	28.20	--	61484	--	Spring	197	09/25/04
Hot Creek Springs	38.38251	-115.15451	31.3	1.4	7.33	-15.66	-119.0	59.00	22.20	25.00	5.28	10.00	272.00	45.50	27.80	--	61972	--	Spring	197	01/24/05
Hot Creek Springs	38.38251	-115.15451	31.2	1.6	7.05	-15.66	-118.6	--	--	--	--	--	--	--	--	--	62624	DRI-WV-2	Spring	197	05/18/05
Hot Creek Springs	38.38251	-115.15451	31.3	1.6	6.77	-15.70	-117.4	--	--	--	--	--	--	--	--		63228	DRI-WV-2	Spring	197	08/14/05
Hot Creek Spring	38.38251	-115.15451	30.9	1.5	7.33	-15.73	-119.1	59.70	22.40	24.30	5.03	10.00	273.00	45.10	27.70	1.0	63564	--	Spring	197	11/06/05
Hot Creek Spring	38.38251	-115.15451	31.3	1.9	7.32	-15.77	-119.2	58.70	22.10	24.50	5.22	10.20	269.00	45.40	27.80	1.0	65656	WV-2	Spring	197	10/28/06
Hot Creek Springs	38.38251	-115.15451	31.3	1.1	7.29	-15.75	-118.4	59.50	21.50	24.30	5.14	10.10	271.00	45.20	28.80	1.0	64234	WV-2	Spring	197	02/17/06
Hot Creek Springs	38.38251	-115.15451	31.7	1.5	7.36	-15.67	-120.1	59.60	21.60	25.20	5.15	10.60	269.00	47.00	28.40	1.0	64736	WV-2	Spring	197	05/22/06
Hot Creek Springs	38.38251	-115.15451	31.4	1.3	7.30	-15.75	-119.0	59.30	22.30	22.30	4.53	10.10	268.00	46.00	27.70	1.0	65367	WV-2	Spring	197	08/29/06
Indian Spring (N Jakes V)	39.44040	-115.31884	--	--	--	-15.25	-118.4	--	--	--	--	--	--	--	--	--	92573	SNWA	Spring	334	07/27/04
Indian Spring (N Jakes V)	39.44040	-115.31884	11.3	7.9	7.10	-15.31	-119.1	--	--	--	--	--	--	--	--	--	62709	DRI-BT-8	Spring	334	06/05/05
Indian Springs (S Springs V)	38.64160	-114.44957	--	--	--	-14.16	-106.3	26.30	4.10	12.70	4.56	9.40	114.00	6.70	72.80	0.1	62974	FO-1	Spring	375	07/29/05
Iverson's Spring	36.71028	-114.71194	--	--	--	--	-97.0	--	--	--	--	--	--	--	--	--	111	PLC18	Spring	65	--
Jenson Well	37.18417	-114.46444	18.0	--	7.70	-11.60	-88.5	55.00	14.00	100.00	7.20	45.00	340.00	80.00	56.00	2.1	187	GS70	Well	95	04/10/85
John Wadsworth	37.76861	-114.40694	14.5	--	7.50	-12.90	-101.0	120.00	47.00	150.00	9.50	88.00	601.00	200.00	76.00	6.5	286	GS101	Well	140	06/04/85
Johnson Spring	39.92319	-114.98923	10.2	9.0	7.54	-15.94	-123.4	--	--	--	--	--	--	--	--	--	62625	DRI-CC-1	Spring	335	05/24/05
Jones Spring Pumphouse	36.71116	-114.71694	27.2	5.3	7.44	-12.99	-98.9	63.40	27.40	95.70	11.10	63.10	252.00	178.00	29.50	--	62033		Spring	293	02/10/05
Jones Spring Pumphouse	36.71116	-114.71694	32.0	3.9	7.00	-12.99	-97.8	63.70	27.30	96.00	11.20	61.90	256.00	174.00	31.40	2.2	62034	DRI-MV-6	Spring	293	06/08/05
Jones Spring Pumphouse	36.71116	-114.71694	31.7	3.7	7.36	-13.07	-97.7	63.80	27.40	96.30	10.90	61.80	254.00	178.00	29.40	2.2	64175	MV-5	Spring	292	02/16/06
Jones Spring Pumphouse	36.71116	-114.71694	32.2	4.4	7.27	-13.07	-97.9	62.60	27.10	93.10	11.20	62.60	254.00	181.00	29.70	2.2	64902	MV-5	Spring	292	06/21/06
Jones Spring Pumphouse	36.71116	-114.71694	32.2	4.1	7.30	-13.10	-97.3	63.70	27.80	84.50	9.32	62.20	269.00	179.00	29.30	2.1	65285	MV-5	Spring	292	08/23/06
Jones Spring Pumphouse	36.71116	-114.71694	31.2	4.1	7.29	-13.05	-97.9	63.63	27.37	93.43	10.80	62.05	256.17	177.67	29.75	2.2	--	--	Spring	292	--

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Juanita Spring	36.63694	-114.24750	26.0	--	7.30	-11.65	-87.0	130.00	43.00	25.00	5.30	15.00	--	370.00	29.00	1.0	90	GS30	Spring	50	01/25/86
Kalamazoo Spring WR6	39.56648	-114.59594	12.1	6.8	7.33	-16.22	-121.6	47.20	15.50	2.46	0.71	2.10	208.00	10.60	10.50	--	60962	SC-3	Spring	336	07/20/04
Kalamazoo Spring WR6	39.56648	-114.59594	12.3	6.7	7.32	-16.22	-118.5	46.80	16.00	3.20	0.87	1.90	196.00	11.00	11.70	--	61348A	SC-3	Spring	336	09/21/04
Kalamazoo Spring WR6	39.56648	-114.59594	11.9	6.9	7.42	-16.28	-121.6	48.60	16.50	3.49	0.79	1.80	209.00	12.10	11.40	--	61966	SC-3	Spring	336	01/23/05
Kalamazoo Spring WR6	39.56648	-114.59594	--	--	--	-16.13	-118.6	--	--	--	--	--	--	--	--	--	62636	SC-3	Spring	336	05/23/05
Kalamazoo Spring WR6	39.56648	-114.59594	--	--	--	-16.18	-119.2	49.60	15.20	3.03	0.71	1.80	214.00	11.40	11.50	0.1	63222A	SC-3	Spring	336	08/12/05
Kalamazoo Spring WR6	39.56648	-114.59594	11.9	7.3	7.47	-16.17	-121.0	49.10	17.50	3.46	0.74	1.90	219.00	12.80	12.40	<.05	63567	SC-3	Spring	336	11/08/05
Kalamazoo Spring WR6	39.56648	-114.59594	11.7	7.1	7.60	-16.22	-119.3	49.30	16.60	3.42	0.79	2.00	213.00	12.80	12.10	<.1	64236	SC-3	Spring	336	02/25/06
Kalamazoo Spring WR6	39.56648	-114.59594	9.8	8.1	7.51	-16.06	-118.0	50.00	11.00	2.65	0.55	1.40	191.00	7.40	9.60	<.05	64739	SC-3	Spring	336	05/21/06
Kalamazoo Spring WR6	39.56648	-114.59594	--	--	--	-16.16	-120.1	--	--	--	--	--	--	--	--	--	--	SC-3	Spring	336	08/02/06
Kalamazoo Spring WR6	39.56648	-114.59594	11.9	7.3	7.55	-16.24	-119.7	50.00	17.10	2.87	0.60	2.02	230.00	12.40	12.00	<.05	65368	SC-3	Spring	336	08/30/06
Kalamazoo Spring WR6	39.56648	-114.59594	12.0	6.5	7.52	-16.11	-120.5	50.20	17.30	3.51	0.82	1.50	216.00	12.50	12.40	<.05	65657	SC-3	Spring	336	10/29/06
Kalamazoo Spring WR6	39.56648	-114.59594	11.3		7.60	-16.19	-120.4	48.70	16.30	3.67	0.76	1.45	220.00	11.70	12.40	0.1	65657	SC-3	Spring	336	05/08/07
Kalamazoo Spring WR7	39.56648	-114.59594	12.4	5.7	7.51	-16.22	-120.4	47.90	16.40	3.21	0.72	1.26	225.00	12.00	10.90	<.1	67250	SC-3	Spring	336	08/21/07
Kalamazoo Spring WR8	39.56648	-114.59594	12.0	4.2	7.67	-16.28	-120.7	50.10	17.40	3.35	0.77	1.40	227.00	12.30	11.30	<.05	67513	SC-3	Spring	336	11/04/07
Kalamazoo Spring WR9	39.56648	-114.59594	11.8	6.9	7.50	-16.30	-121.3	45.70	16.20	3.15	0.68	1.79	225.00	12.60	11.40	0.1	67947	SC-3	Spring	336	03/02/08
Kalamazoo Spring WR10	39.56648	-114.59594	11.7	6.9	7.67	-16.20	-120.4	48.20	16.40	3.44	0.78	1.79	220.00	12.10	11.50	0.0	68478	SC-3	Spring	336	05/31/08
Kalamazoo Spring WR11	39.56648	-114.59594	12.4	7.3	7.52	-16.37	-120.0	48.20	17.20	3.17	0.74	1.84	222.00	12.00	11.10	0.0	68917	SC-3	Spring	336	09/13/08
Kalamazoo Spring WR12	39.56648	-114.59594	12.3	7.0	7.55	-16.32	-121.4	47.90	17.30	3.38	0.92	1.80	218.00	12.00	11.00	0.1	69148	SC-3	Spring	336	11/01/08
Kalamazoo Spring WR13	39.56648	-114.59594	11.9	6.9	7.58	-16.36	-121.6	48.50	16.90	3.25	0.76	1.70	213.00	11.60	11.50	0.0	69427	SC-3	Spring	336	01/16/09
Kalamazoo Spring WR14	39.56648	-114.59594	10.3	7.6	7.57	-16.23	-118.9	46.90	12.00	3.27	0.70	1.46	195.00	8.91	11.30	0.0	69866	SC-3	Spring	336	05/21/09
Kalamazoo Spring WR15	39.56648	-114.59594	--	--	--	-16.21	-120.3	47.90	15.80	3.11	0.69	1.90	209.00	10.70	11.40	0.0	69866	SC-3	Spring	336	08/15/09
Kalamazoo Spring WR16	39.56648	-114.59594	--	--	--	-16.32	-121.1	48.00	16.50	3.28	0.82	1.97	225.00	11.50	10.80	0.0	70615	SC-3	Spring	336	11/15/09
Kane Springs (KSV-3)	37.24611	-114.70584	--	--	--	-12.60	-87.0	--	--	--	--	--	--	--	--	--	193	Kirk1025	Spring	97	--
Kane Springs (KSV-3)	37.24611	-114.70584	16.4	--	7.20	-11.90	-86.5	44.00	13.00	20.00	5.90	17.00	210.00	14.00	60.00	2.8	195	GS72	Spring	97	02/02/84
Kane Springs (KSV-3)	37.24611	-114.70584	14.8	5.2	7.04	-11.88	-87.0	49.00	13.60	20.30	1.36	17.60	214.00	15.10	64.50	--	58490	--	Spring	97	01/13/04
Kershaw-Ryan Spring #1	37.59028	-114.52010	20.0	6.5	8.40	-13.11	-95.1	24.20	2.66	26.50	4.38	6.30	140.00	4.40	46.10	--	59701	--	Spring	250	03/27/04
Kiln Spring	37.80510	-114.16423	11.5	2.4	7.11	-12.34	-91.9	93.50	22.90	34.80	0.53	51.20	320.00	56.90	27.40	0.2	64904	MG-1	Spring	418	06/21/06
Lake Mead Base Well #3	36.23917	-115.00444	--	--	--	-13.80	-101.5	--	--	--	--	--	--	--	--	--	19	PLC35	Well	12	--
Lake Valley Well	38.35556	-114.58917	18.0	--	8.10	-14.70	-111.0	61.00	9.70	22.00	2.10	68.00	121.00	25.00	25.00	0.2	365	GS147	Well	193	06/07/85
Lamb Spring	36.94500	-115.10583	13.5	--	--	-13.15	-92.5	37.00	41.00	8.70	0.60	8.60	--	24.00	12.00	0.2	168	--	Spring	86	05/19/88
Lester Mathews Well	37.79361	-114.39972	20.0	--	8.10	-13.30	-103.0	73.00	21.00	140.00	10.00	44.00	--	170.00	64.00	3.1	289	GS104	Well	142	06/04/85
Lime Spring	37.91467	-114.54022	21.0	--	8.30	-12.90	-97.0	55.00	31.00	3.80	0.90	4.10	290.00	8.90	14.00	0.1	315	GS118	Spring	160	04/07/85
Lime Spring	37.91467	-114.54022	15.1	0.4	7.35	-13.41	-99.9	76.10	40.60	3.27	1.09	3.60	433.00	6.40	14.10	--	60840	--	Spring	160	06/24/04
Lion Spring	38.25863	-114.13032	9.8	8.2	7.77	-14.11	-103.4	37.00	7.04	17.20	3.84	36.10	124.00	15.30	56.60	--	60317	--	Spring	318	05/21/04
Lion Spring (Egan Range)	39.18037	-114.98444	12.5	5.1	7.28	-15.34	-114.8	64.50	13.20	13.70	4.61	15.40	237.00	28.70	42.30	0.1	65039	ER-13	Spring	430	07/12/06
Little Ash Spring (Ash Spring)	37.46389	-115.19167	37.0	--	7.36	-14.20	-107.2	45.27	15.40	29.80	7.30	9.50	250.00	35.00	31.54	0.8	229	IT33	Spring	111	08/08/95
Little Boulder Spring	37.71330	-114.95217	12.0	6.4	7.10	-13.06	-97.2	21.80	5.88	7.99	2.91	4.90	101.00	7.80	44.80	--	59690	--	Spring	301	03/24/04
Little Currant Creek	38.83444	-115.35806	10.5	--	--	-15.00	-113.0	--	--	--	--	--	--	--	--	--	--	--	Surface	217	08/23/83

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Little Spring (Grant Range)	38.33197	-115.36050	14.7	1.7	6.90	-12.48	-99.4	--	--	--	--	--	--	--	--	--	62828	--	Spring	369	06/30/05
Little Springs (Clover Mts)	37.53418	-114.35607	18.5	5.3	7.56	-12.78	-93.0	30.20	5.11	11.20	2.77	9.70	137.00	4.80	56.50	--	61096	--	Spring	254	07/31/04
Little Springs (Clover Mts)	37.53418	-114.35607	17.1	6.7	6.81	-12.84	-93.5	29.60	4.73	10.80	2.45	8.60	112.00	5.00	46.60	--	62403	DRI-CR-7	Spring	254	04/30/05
Little Cut Spring	37.69653	-115.37810	--	--	--	-12.93	-98.4	68.80	19.70	21.10	2.57	22.20	295.00	30.60	55.90	--	60844		Spring	286	06/25/04
Little Cut Spring	37.69653	-115.37810	10.4	4.8	6.77	-12.76	-98.2	75.00	21.00	22.80	2.30	21.10	302.00	33.10	52.20	--	62410	DRI-MI-1	Spring	286	05/02/05
Little Tom Plain Spring	39.08092	-115.37152	8.0	7.2	6.70	-15.87	-121.8	--	--	--	--	--	--	--	--	--	62712	DRI-WP-7	Spring	337	06/06/05
Little Tom Plain Spring (RS)	39.08103	-115.37172	8.9	5.7	7.13	-15.85	-120.1	66.80	5.61	19.30	2.63	14.70	231.00	19.80	47.30	0.3	65037	WP-12	Spring	337	07/11/06
Littlefield Spring	38.23125	-114.70223	14.9	5.0	7.02	-12.73	-98.5	67.10	13.30	16.30	2.75	22.50	254.00	20.90	47.50	--	60847	--	Spring	275	06/26/04
Littlefield Spring	38.23125	-114.70223	--	--	--	-12.40	-98.0	--	--	--	--	--	--	--	--	--	112272	SNWA	Spring	275	07/25/05
Lone Pine Spring	38.89556	-114.89944	--	--	--	-14.98	-109.2	--	--	--	--	--	--	--	--	--	--	--	Spring	223	10/13/03
Lone Pine Spring	38.89556	-114.89944	8.0	7.4	7.50	-14.95	-111.5	67.00	4.20	3.50		1.60	224.00	3.70	17.00	<.1	434	GS214	Spring	223	08/01/85
Lone Pine Spring	38.89556	-114.89944	7.0	7.1	7.44	-14.77	-110.0	72.50	3.80	4.35	1.27	2.30	220.00	6.00	27.60	0.1	65053	ER-27	Spring	223	07/13/06
Lower Chokecherry Spring	37.53721	-114.69709	6.4	7.3	7.70	-12.98	-98.4	73.20	15.20	26.70	1.55	19.40	296.00	25.00	53.40	--	59694	--	Spring	261	03/25/04
Lower Fairview	38.17573	-114.65551	--	--	--	-12.39	-97.5	--	--	--	--	--	--	--	--	--	--	--	Spring	281	06/29/04
Lower Indian Spring	37.45006	-114.65730	21.4	3.6	8.30	-12.62	-96.0	1.90	0.17	95.10	0.80	12.10	221.00	10.40	56.20	--	58498	--	Spring	267	01/14/04
Lower Little Cherry Cr Spring	38.16722	-115.65333	--	8.0	7.55	-13.90	-103.0	--	--	--	--	--	268.00	--	--	--	346	GS135	Spring	182	07/31/85
Lower Pony Spring	38.31972	-114.60722	20.0	--	--	-13.20	-101.0	--	--	--	--	--	--	--	--	--	359	GS142	Spring	190	07/23/81
Lower Pony Spring	38.31972	-114.60722	14.0	--	7.90	-13.30	-101.0	45.00	2.00	36.00	1.10	10.00	202.00	8.20	47.00	0.1	360	GS143	Spring	190	04/05/85
Unnamed Spring in Snow Creek	40.07837	-114.91138	--	--	--	-16.24	-120.9	--	--	--	--	--	--	--	--	--	62629B	DRI-CC-3	Spring	338	05/24/05
Lund Spring	38.85000	-115.00250	19.0	5.7	7.49	-15.40	-113.0	56.00	23.00	3.80	0.90	2.80	270.00	11.00	11.00	0.1	429	GS210	Spring	221	04/27/82
Lund Spring	38.85000	-115.00250	--	--	--	-15.37	-117.1	--	--	--	--	--	--	--	--	--	68109	SNWA	Spring	221	08/06/03
Lund Spring	38.85000	-115.00250	--	--	--	-14.97	-115.3	--	--	--	--	--	--	--	--	--	88478	SNWA	Spring	221	06/24/04
M-8 Spring (Unnamed Spring)	36.72083	-114.72750	--	--	--	-12.75	-99.0	--	--	--	--	--	--	--	--	--	119	PLC15	Spring	68	10/30/85
M-9 Spring (Unnamed Spring)	36.72583	-114.72722	--	--	--	-12.45	-96.5	--	--	--	--	--	--	--	--	--	126	PLC16	Spring	70	10/30/85
Maynard Lake Spring (Unnamed Spring)	37.19167	-115.03389	9.6	--	7.90	-12.30	-94.0	43.00	23.00	114.00	14.00	30.00	405.00	88.00	--	--	186	IT136	Spring	94	01/14/85
McDermitt Spring	38.25914	-114.63164	--	--	--	-11.21	-94.3	--	--	--	--	--	--	--	--	--	--	--	Spring	323	06/26/04
Meadow Valley Wash, Cal.	37.63581	-114.51357	5.0	--	7.80	-13.10	-97.0	58.00	25.00	94.60	15.40	59.10	387.00	66.20	59.00	2.0	271	E27	Surface	130	12/00/79
Meloy Spring	38.25181	-114.70497	14.4	6.9	7.15	-12.75	-99.8	68.10	12.20	16.40	4.40	24.90	248.00	18.10	54.20	--	60845	--	Spring	276	06/26/04
Merril's Camp #39	38.18825	-113.86636	8.4	6.3	7.21	-14.13	-102.1	41.80	5.69	8.36	0.38	6.50	156.00	5.40	15.50	0.1	63597	--	Spring	410	11/19/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Mesquite Wtr Bunkerville 1	36.77528	-114.11806	23.0	--	7.50	-13.51	-102.5	54.00	28.00	39.00	8.10	31.00	198.00	120.00	25.00	0.9	132	GS49	Well	74	08/17/94
Mesquite Wtr Bunkerville 2	36.77417	-114.12889	23.0	--	7.60	-13.51	-102.1	38.00	20.00	50.00	7.50	13.00	220.00	89.00	21.00	1.4	131	GS48	Well	73	08/18/94
Mesquite Wtr Virgin Vly 5	36.77806	-114.08417	26.5	--	7.40	-13.78	-103.3	110.00	54.00	100.00	7.60	100.00	145.00	440.00	22.00	0.3	133	GS50	Well	75	08/17/94
Mesquite Wtr Virgin Vly 25	36.80833	-114.07250	23.0	--	7.60	-12.85	-98.9	55.00	34.00	210.00	9.30	160.00	210.00	300.00	28.00	1.2	152	GS54	Well	79	08/18/94
Moapa Well	36.53139	-114.79667	--	--	--	-13.40	-99.0	--	--	--	--	--	--	--	--	--	999	TH-1	Well	41	04/07/00
Mike's Spring	39.64370	-114.20490	10.7	6.4	6.77	-15.89	-121.1	61.90	18.90	31.80	1.81	29.20	246.00	34.80	27.50	0.4	63272	--	Spring	390	08/23/05
Mirant	36.41861	-114.95750	--	--	--	-13.23	-96.8	--	--	--	--	--	--	--	--	--	USGS	618	Well	622	06/04/03
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.7	8.7	7.50	-15.58	-111.2	56.70	10.00	2.48	0.61	1.10	229.00	4.30	7.40	--	57694	WP-1	Spring	320	10/12/03
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	6.0	8.5	7.46	-15.32	-113.3	76.00	7.73	2.68	0.70	1.10	259.00	3.30	9.00	--	59578	WP-1	Spring	320	03/23/04
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	6.7	9.7	8.00	-15.62	-114.0	60.50	9.88	2.09	0.54	1.00	219.00	3.80	7.80	--	60784	WP-1	Spring	320	06/21/04
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	7.3	10.1	7.41	-15.51	-115.7	60.80	10.90	3.17	1.00	1.20	231.00	4.20	7.50	--	61478	WP-1	Spring	320	09/22/04
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.0	8.6	8.14	-15.58	-115.1	62.00	10.70	2.83	0.77	1.30	227.00	4.50	7.40	--	61962	WP-1	Spring	320	01/21/05
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	6.4	9.4	6.61	-15.55	-112.3	--	--	--	--	--	--	--	--	--	62632A	WP-1	Spring	320	05/21/05
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.9	9.4	6.80	-15.63	-113.2	59.10	9.81	2.38	0.63	1.10	224.00	4.30	7.60	0.5	63218	WP-1	Spring	320	08/14/05
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.7	9.8	7.20	-15.65	-113.8	57.20	10.10	2.34	0.58	1.20	211.00	4.50	7.40	0.1	63561	WP-1	Spring	320	11/05/05
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.7	8.1	7.51	-15.69	-113.8	55.70	9.83	2.45	0.64	1.20	208.00	4.70	7.30	<.1	64235	WP-1	Spring	320	02/24/06
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.9	9.2	7.38	-15.38	-111.8	59.10	6.32	1.89	0.49	1.00	199.00	2.40	7.80	0.1	64733	WP-1	Spring	320	05/20/06
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	--	--	--	-15.63	-114.1	--	--	--	--	--	--	--	--	--	--	WP-1	Spring	320	07/11/06
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.7	8.4	7.12	-15.64	-114.7	56.20	10.10	2.41	0.58	1.28	217.00	4.77	7.39	0.1	65365	WP-1	Spring	320	08/29/06
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.6	8.3	7.20	-15.67	-114.5	56.00	10.20	2.48	0.62	1.21	209.00	4.55	7.28	0.1	65743	WP-1	Spring	320	11/15/06
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.9	--	7.24	-15.61	-114.6	64.90	8.57	2.36	0.61	0.88	244.00	3.57	7.10	0.1	65743	WP-1	Spring	320	05/06/07
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	6.0	6.3	7.19	-15.64	-114.1	56.40	10.30	2.46	0.60	0.80	228.00	4.71	6.97	<.1	67246	WP-1	Spring	320	08/19/07
Monitoring Spring WR1 (White Pine Range)	38.94951	115.40898	5.7	6.11	7.27	-15.68	-113.8	59.4	10.6	2.31	0.56	1	231	4.6	6.76	0.06	67509	WP-1	Spring	320	11/03/07
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.8	8.1	6.67	-15.70	-114.2	54.10	9.74	2.43	0.61	1.10	224.00	4.85	6.86	0.1	67950	WP-1	Spring	320	03/03/08
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.9	7.3	7.40	-15.59	-113.0	65.10	9.03	2.42	0.63	1.09	244.00	3.74	7.20	0.1	68483	WP-1	Spring	320	05/29/08
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	6.6	9.7	7.48	-15.69	-113.2	59.80	10.80	2.42	0.58	1.16	235.00	4.66	7.19	0.1	68918	WP-1	Spring	320	09/14/08
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	6.0	8.6	7.22	-15.68	-114.7	60.20	10.90	2.54	0.68	1.04	235.00	4.64	7.00	0.0	69149	WP-1	Spring	320	10/31/08
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.9	8.6	7.39	-15.66	-114.2	61.00	10.70	2.55	0.66	1.00	228.00	4.50	7.00	0.1	69428	WP-1	Spring	320	01/15/09
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	5.9	9.2	7.23	-15.90	-116.2	62.60	3.09	1.78	0.54	0.85	217.00	2.09	6.15	0.0	69861	WP-1	Spring	320	05/19/09
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	--	--	--	-15.69	-113.9	59.70	10.40	2.04	0.52	1.06	222.00	4.10	7.41	0.0	69861	WP-1	Spring	320	08/16/09
Monitoring Spring WR1 (White Pine Range)	38.94903	-115.41008	--	--	--	-15.71	-114.6	58.90	10.40	2.39	0.64	1.14	236.00	4.33	6.85	0.1	70616	WP-1	Spring	320	11/16/09
Monitoring Spring WR1 (White Pine Range)	38.94951	115.40898	--	--	--	-15.69	-114.9	63.5	9.16	2.37	0.54	1.2	235	3.4	7.3	0.06	70616	WP-1	Spring	320	06/18/10

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Moon River Spring	38.35167	-115.18083	32.5	2.3	7.38	-15.80	-120.0	55.00	22.00	22.00	4.40	9.30	260.00	44.00	25.00	1.2	362	GS145	Spring	192	04/27/82
Moorman Spring	38.59472	-115.13833	37.0	1.7	7.03	-15.70	-119.0	58.00	19.00	24.00	5.90	9.90	--	47.00	27.00	1.3	405	GS185	Spring	205	07/18/81
Moorman Spring	38.59472	-115.13833	--	--		-15.54	-120.2	--	--	--	--	--	--	--	--	--	88479	SNWA	Spring	205	06/23/04
Mormon Well Spring	36.64389	-115.09778	11.5	--	7.26	-12.90	-92.5	81.00	40.00	11.00	0.40	24.00	--	--	16.00	0.1	94	GS32	Spring	53	10/27/81
Mormon Well Spring	36.64389	-115.09778	10.0	5.1	7.60	-12.50	-91.0	65.00	41.00	12.00	1.00	12.00	395.00	21.00	16.00	0.1	95	GS33	Spring	53	05/09/83
Mormon Well Spring	36.64389	-115.09778	12.0	--	7.36	-12.60	-92.0	84.00	44.00	13.00	0.50	12.00	--	23.00	17.00	0.2	96	GS34	Spring	53	10/07/87
Mud Spring (Buck Mts)	39.73587	-115.57036	11.6	9.4	6.90	-15.21	-117.6	--	--	--	--	--	--	--	--	--	62705	DRI-BK-1	Spring	339	06/05/05
Mud Sp Barcass 34 (Snake Range)	39.32571	-114.26714	6.9	7.5	7.13	-15.43	-117.1	73.40	14.50	3.02	0.64	2.50	287.00	5.40	10.00	<.05	63528	--	Spring	404	10/25/05
Mud Spring	39.08160	-114.97241	12.4	5.0	7.31	-14.53	-111.0	62.40	11.20	14.10	0.57	8.60	235.00	18.40	15.20	0.1	65055	ER-29	Spring	446	07/13/06
Murphy Spring	38.33973	-115.44937	10.6	8.7	6.70	-15.40	-114.5	--	--	--	--	--	--	--	--	--	62833	--	Spring	373	07/02/05
Mustang Spring	37.73553	-114.92166	10.0	3.4	7.00	-12.60	-91.0	111.00	7.98	17.30	6.49	11.40	346.00	58.00	58.00	--	277	K6	Spring	135	01/14/85
Mustang Spring	37.73553	-114.92166	13.4	6.2	6.80	-12.37	-90.0	105.00	7.77	18.40	6.77	9.90	319.00	61.60	62.10	--	59691	--	Spring	135	03/24/04
Mustang Spring (Snake)	38.86257	-114.27179	4.3	8.4	7.09	-15.30	-111.0	68.00	4.58	1.32	0.36	0.80	5.50	218.00	5.70	2.2	62915	SN-6	Spring	382	07/14/05
MVW above Eagle Canyon	38.02778	-114.18583	19.0	--	8.20	-12.00	-93.0	--	--	--	--	--	--	--	--	--	328	E6	Surface	168	04/09/85
Narrow Canyon Spring	37.36729	-114.67807	9.9	5.8	7.20	-12.47	-92.5	61.90	12.70	17.70	1.87	17.90	228.00	20.80	47.20	--	59683		Spring	257	03/22/04
Nellis AFB #4	36.24889	-115.00417	--	--	--	-13.20	-95.0	--	--	--	--	--	--	--	--	--	20	PLC36	Well	13	--
Nellis AFB Well #13	36.21222	-115.05000	--	--	--	-13.80	-98.0	--	--	--	--	--	--	--	--	--	18	PLC34	Well	11	--
Newels Spring	37.90248	-114.03202	21.5	7.2	7.74	-12.48	-96.0	88.00	16.90	22.60	2.39	39.00	289.00	36.50	36.10	0.5	64909	MG-6	Spring	423	06/22/06
Nicholas Spring	38.91062	-115.06142	22.0	3.4	7.75	-16.10	-124.0	42.00	19.00	13.00	3.30	24.00	180.00	40.00	20.00	0.6	440	GS219	Spring	227	04/27/82
North Creek Spring	38.71056	-114.73056	8.5	--	6.90	-14.60	-105.0	9.10	1.60	2.20	0.90	1.30	25.00	3.80	12.00	0.4	420	GS198	Spring	214	04/03/85
North Lee Well	37.82444	-114.38444	22.0	--3	8.00	-13.30	-101.0	59.00	12.00	44.00	9.90	48.00	220.00	33.00	54.00	1.0	299	GS109	Well	147	06/04/85
North Spring	39.15611	-114.96306	5.5	--	--	-15.00	-113.0	--	--	--	--	4.20	--	--	--	--	459	GS245	Spring	237	06/17/83
North Springs	39.15490	-114.96278	6.3	7.1	7.42	-15.21	-111.7	54.30	9.63	3.44	0.52	1.40	201.00	10.70	9.30	0.1	65041	ER-15	Spring	237	07/12/06
Oak Spring	37.60547	-114.71015	10.5	7.1	7.05	-11.87	-90.0	84.90	16.50	64.10	1.97	41.10	355.00	34.20	56.50	--	58502	--	Spring	269	01/16/04
Ox Valley Spring	37.97053	-114.05966	8.8	6.0	7.02	-13.95	-100.0	37.50	6.97	5.23	0.50	4.60	118.00	25.00	12.40	0.6	64908	MG-5	Spring	422	06/22/06
Oxborrow Well	37.88611	-114.30472	11.5	--	7.90	-11.80	-92.0	130.00	22.00	65.00	11.00	140.00	351.00	63.00	58.00	0.8	303	GS112	Well	150	06/05/85
Pahroc Spring	37.66466	-114.98065	16.0	0.8	7.60	-12.50	-89.0	30.90	8.28	12.30	5.63	11.70	135.00	11.40	59.00	--	272	K5	Spring	131	01/14/85
Pahroc Spring	37.66466	-114.98065	14.4	5.7	7.40	-12.65	-94.0	25.60	6.69	40.10	5.72	13.10	169.00	12.90	66.80	--	58494		Spring	131	01/16/04
Pahroc Spring	37.66466	-114.98065	--	--	--	-12.55	-93.9	--	--	--	--	--	--	--	--	--	111191/120746	SNWA	Spring	131	04/05/05
Pahroc Spring	37.66466	-114.98065	16.0	7.3	6.61	-12.79	-93.5	31.30	8.33	12.70	5.16	12.60	134.00	12.80	62.10	--	61106C	DRI-PR-1	Spring	131	04/30/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Panaca Spring	37.80754	-114.38086	29.0	5.6	7.80	-13.90	-106.0	32.00	9.80	36.00	6.80	15.00	--	29.00	45.00	1.6	294	GS107	Spring	144	04/26/84
Panaca Spring	37.80754	-114.38086	29.5	--	7.90	-14.00	-108.0	34.00	10.00	38.00	7.10	16.00	--	25.00	50.00	1.5	292	GS105	Spring	144	04/08/85
Panaca Spring	37.80754	-114.38086	28.5	6.2	7.79	-14.20	-106.5	33.00	10.00	37.00	6.70	17.00	--	27.00	48.00	1.4	293	GS106	Spring	144	11/11/86
Panaca Spring	37.80754	-114.38086	--	--	--	--	-107.0	--	--	--	--	--	--	--	--	--	293	DRI	Spring	144	11/11/86
Panaca Spring	37.80754	-114.38086	28.4	4.0	7.83	-14.11	-107.4	32.40	10.40	38.00	7.43	17.80	176.00	30.40	52.40	--	61619	--	Spring	144	10/20/04
Panaca Spring	37.80754	-114.38086	28.6	5.4	7.68	-14.25	-107.9	32.60	10.30	37.90	7.19	17.30	177.00	29.30	49.70	--	61969	--	Spring	144	01/24/05
Panaca Spring	37.80754	-114.38086	28.3	4.7	7.04	-14.15	-107.1	--	--	--	--	--	--	--	--	--	62626	DRI-MW-1	Spring	144	05/20/05
Panaca Spring	37.80754	-114.38086	28.9	4.4	7.04	-14.17	-106.4	--	--	--	--	--	--	--	--	--	63231	DRI-MW-1	Spring	144	08/16/05
Panaca Spring	37.80754	-114.38086	28.7	4.6	7.60	-14.18	-106.8	30.00	10.30	37.60	7.00	17.40	179.00	29.10	49.00	1.4	63571	--	Spring	144	11/09/05
Panaca Spring	37.80754	-114.38086	28.8	4.2	7.71	-14.20	-105.8	34.20	10.20	37.90	6.97	17.90	178.00	29.70	48.80	1.5	64169	MW-1	Spring	144	02/17/06
Panaca Spring	37.80754	-114.38086	28.8	5.9	7.80	-14.17	-107.1	32.60	9.97	37.00	9.66	18.20	180.00	30.70	50.20	1.5	64743	MW-1	Spring	144	05/22/06
Panaca Spring	37.80754	-114.38086	29.1	5.9	7.67	-14.24	-107.0	32.60	10.20	34.60	6.06	17.80	184.00	30.50	49.80	1.5	65289	MW-1	Spring	144	08/23/06
Panaca Spring	37.80754	-114.38086	28.9	4.4	7.62	-14.14	-106.9	32.70	10.00	37.00	1.74	17.30	175.00	29.80	49.90	1.5	65654	MW-1	Spring	144	10/28/06
Panaca Town Well	37.79722	-114.39917	29.5	--	7.90	-14.00	-106.0	45.00	1.00	47.00	8.30	19.00	203.00	68.00	58.00	1.8	291	E16	Well	143	06/04/85
Parsnip Spring	38.14944	-114.26250	19.0	--	7.70	-12.80	-93.5	16.00	3.00	12.00	2.20	7.50	70.00	9.10	41.00	0.1	344	GS134	Spring	180	06/05/85
Patterson Pass Spring WR3	38.60280	-114.71481	12.0	6.0	6.60	-14.91	-106.5	--	--	--	--	--	--	--	--	--	57755	SC-2	Spring	305	10/30/03
Patterson Pass Spring WR3 (duplicate sample)	38.60280	-114.71481	--	--	--	-14.94	-109.2	--	--	--	--	--	--	--	--	--	57755	SC-2	Spring	305	10/30/03
Patterson Pass Spring WR3	38.60280	-114.71481	11.8	3.6	6.07	-14.75	-106.2	19.50	3.83	1.99	1.42	0.90	68.60	9.60	10.80	--	59579	SC-2	Spring	305	03/24/04
Patterson Pass Spring WR3	38.60280	-114.71481	11.5	6.2	7.10	-14.84	-109.1	19.80	4.62	3.00	1.46	1.20	67.00	9.80	11.10	--	60786	SC-2	Spring	305	06/23/04
Patterson Pass Spring WR3	38.60280	-114.71481	12.0	5.9	7.45	-14.79	-107.9	18.50	3.86	1.94	1.39	0.90	66.50	9.40	10.20	--	61480	SC-2	Spring	305	09/23/04
Patterson Pass Spring WR3	38.60280	-114.71481	11.7	5.5	6.82	-14.77	-108.3	20.50	4.14	2.20	1.46	1.20	71.60	9.80	10.50	--	61967	SC-2	Spring	305	01/23/05
Patterson Pass Spring WR3	38.60280	-114.71481	11.4	6.0	6.66	-14.71	-106.8	--	--	--	--	--	--	--	--	--	61481	SC-2	Spring	305	05/20/05
Patterson Pass Spring WR3	38.60280	-114.71481	--	--	--	-14.83	-107.6	18.80	3.66	1.89	1.41	1.00	65.50	8.70	10.10	0.7	63220	SC-2	Spring	305	08/15/05
Patterson Pass Spring WR3	38.60280	-114.71481	12.1	6.1	6.97	-14.87	-107.5	19.30	3.74	1.90	1.35	1.10	63.80	8.70	10.00	0.4	63566	SC-2	Spring	305	11/07/05
Patterson Pass Spring WR3	38.60280	-114.71481	11.8	7.1	6.78	-14.91	-108.1	19.60	3.82	1.86	1.23	1.12	65.90	9.10	10.20	0.5	65371	SC-2	Spring	305	08/31/06
Patterson Pass Spring WR3	38.60280	-114.71481	12.2	6.8	6.87	-14.89	-108.4	19.20	3.81	2.07	1.43	1.00	66.30	8.80	10.10	0.5	65653	SC-2	Spring	305	10/28/06
Patterson Pass Spring WR3	38.60280	-114.71481	11.9	6.4	6.52	-14.90	-106.9	19.40	3.68	1.86	1.42	1.20	65.00	8.80	10.10	0.5	64239	SC-2	Spring	305	02/26/06
Patterson Pass Spring WR3	38.60280	-114.71481	11.7	7.5	6.95	-14.86	-108.5	19.20	3.80	2.20	1.20	1.20	67.20	9.10	10.20	0.5	64738	SC-2	Spring	305	05/23/06
Patterson Pass Spring WR3	38.60280	-114.71481	--	--	--	-14.86	-107.9	--	--	--	--	--	--	--	--	--	--	SC-2	Spring	305	07/14/06
Patterson Pass Spring WR3	38.60280	-114.71481	11.7	--	6.60	-14.96	-108.5	19.90	3.82	1.99	1.40	0.95	69.00	8.37	9.59	0.5	65653	SC-2	Spring	305	05/07/07
Patterson Pass Spring WR3	38.60280	-114.71481	12.0	5.1	6.80	-14.87	-108.2	19.30	3.81	1.97	1.38	0.97	71.00	9.16	9.72	0.1	67248	SC-2	Spring	305	08/20/07
Patterson Pass Spring WR3	38.60280	-114.71481	12.2	3.3	6.79	-14.90	-107.3	20.10	3.93	2.09	1.39	1.00	70.00	9.10	9.50	0.5	67508	SC-2	Spring	305	11/02/07
Patterson Pass Spring WR3	38.60280	-114.71481	11.8	5.2	6.39	-14.94	-107.7	18.20	3.67	2.03	1.40	1.00	71.50	9.16	9.34	0.5	67951	SC-2	Spring	305	03/04/08
Patterson Pass Spring WR3	38.60280	-114.71481	11.7	5.1	6.83	-14.93	-106.9	18.70	3.91	2.05	1.37	1.04	69.50	9.22	9.40	0.5	68476	SC-2	Spring	305	05/30/08
Patterson Pass Spring WR3	38.60280	-114.71481	12.0	6.2	6.90	-14.95	-106.6	18.80	3.91	1.90	1.30	1.03	71.70	9.44	9.92	0.5	68911	SC-2	Spring	305	09/11/08
Patterson Pass Spring WR3	38.60280	-114.71481	12.2	5.7	6.51	-14.95	-107.8	19.40	3.95	2.03	1.47	0.93	72.70	9.45	9.52	0.5	69142	SC-2	Spring	305	10/31/08
Patterson Pass Spring WR3	38.60280	-114.71481	12.1	6.1	6.82	-14.96	-107.2	19.80	3.94	2.06	1.45	0.90	77.50	9.00	9.80	0.5	69423	SC-2	Spring	305	01/14/09
Patterson Pass Spring WR3	38.60280	-114.71481	11.6	5.9	6.76	-14.87	-106.1	19.30	3.90	2.05	1.36	0.90	69.10	9.41	9.54	0.5	69860	SC-2	Spring	305	05/18/09
Patterson Pass Spring WR3	38.60280	-114.71481	--	--	--	-14.93	-107.7	17.90	3.83	1.85	1.36	0.86	68.60	9.19	10.00	0.5	69860	SC-2	Spring	305	08/17/09
Patterson Pass Spring WR3	38.60280	-114.71481	--	--	--	-14.95	-108.1	19.50	3.91	2.00	1.75	1.04	72.30	9.52	9.47	0.5	70613	SC-2	Spring	305	11/15/09

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Peach Spring	36.95444	-114.28972	15.1	--	--	-10.40	-76.5	--	--	--	--	--	--	--	--	--	173	GS62	Spring	88	02/06/84
Pederson's East	36.70933	-114.71556	32.0	2.4	7.31	-12.92	-97.0	64.30	28.50	96.40	11.60	66.10	255.00	178.00	30.30	--	58497	DRI-MV-2	Spring	290	01/12/04
Pederson's East	36.70933	-114.71556	31.9	2.7	7.38	-12.92	-97.0	64.60	27.60	94.20	11.10	61.40	264.00	181.00	29.10	--	60307	DRI-MV-2	Spring	290	05/18/04
Pederson's East	36.70933	-114.71556	--	--	--	-12.98	-98.4	68.20	28.30	94.00	11.30	61.50	257.00	178.00	31.20	--	61613	DRI-MV-2	Spring	290	10/19/04
Pederson's East	36.70933	-114.71556	31.2	3.2	7.37	-12.89	-98.3	64.40	27.70	95.60	11.20	62.00	253.00	181.00	29.50	--	62032	DRI-MV-2	Spring	290	02/10/05
Pederson's East	36.70933	-114.71556	32.0	3.0	6.80	-12.96	-98.3	--	--	--	--	--	--	--	--	--	62033	DRI-MV-2	Spring	290	06/08/05
Pederson East	36.70933	-114.71556	31.6	2.7	7.32	-13.00	-97.5	64.80	27.70	95.70	10.10	61.00	254.00	180.00	29.10	2.2	64173	MV-2	Spring	290	02/16/06
Pederson East	36.70933	-114.71556	31.7	2.7	7.28	-13.02	-97.7	63.40	27.30	92.70	11.10	61.70	253.00	182.00	29.40	2.2	64901	MV-2	Spring	290	06/21/06
Pederson East	36.70933	-114.71556	32.0	2.8	7.25	-13.06	-97.4	64.80	28.10	86.00	9.64	61.80	257.00	183.00	29.10	2.2	65287	MV-2	Spring	290	08/23/06
Pederson East	36.70933	-114.71556	31.9	2.6	7.30	-13.03	-98.7	63.90	27.80	93.30	11.00	59.30	253.00	179.00	29.00	2.2	65663	MV-2	Spring	290	10/30/06
Pederson's Warm Spring (M-13)	36.70958	-114.71594	--	--	--	--	-98.0	--	--	--	--	--	--	--	--	--	113.2	jim	Spring	67	1/00/69
Pederson's Warm Spring (M-13)	36.70958	-114.71594	--	--	--	--	-97.0	--	--	--	--	--	--	--	--	--	113.2	jim	Spring	67	3/00/70
Pederson's Warm Spring (M-13)	36.70958	-114.71594	32.5	--	7.20	-12.90	-96.5	66.00	26.00	96.00	10.00	61.00	270.00	190.00	62.06	2.1	113	IT249	Spring	67	07/22/81
Pederson's Warm Spring (M-13)	36.70958	-114.71594	--	--	--	-12.75	-97.0	--	--	--	--	--	--	--	--	--	118	PLC17	Spring	67	10/30/85
Pederson's Warm Spring (M-13)	36.70958	-114.71594	--	--	--	-13.05	-99.0	--	--	--	--	--	--	--	--	--	115	IT251	Spring	67	01/07/88
Pederson's Warm Spring (M-13)	36.70958	-114.71594	--	--	--	-12.85	-96.9	--	--	--	--	--	--	--	--	--	USGS	--	spring	67	07/30/03
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.6	2.2	7.29	-12.91	-97.2	65.30	28.40	99.20	11.40	67.70	261.00	189.00	28.40	--	58488	DRI-MV-1	Spring	67	01/12/04
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.1	3.8	7.42	-12.85	-97.5	65.40	27.80	97.20	10.90	65.90	265.00	184.00	29.20	--	60306	DRI-MV-1	Spring	67	05/18/04
Pederson's Warm Spring (M-13)	36.70958	-114.71594	--	--	--	-12.92	-97.4	64.50	27.80	97.20	11.00	63.00	257.00	183.00	30.60	--	61617	DRI-MV-1	Spring	67	10/19/04
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.2	3.0	7.31	-12.91	-98.0	64.80	27.40	98.80	10.90	63.20	256.00	186.00	29.80	--	62031	DRI-MV-1	Spring	67	02/10/05
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.9	3.6	7.00	-12.91	-97.6	--	--	--	--	--	--	--	--	--	62032	DRI-MV-1	Spring	67	06/08/05
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.3	2.7	7.34	-13.02	-97.2	66.60	27.70	99.20	10.60	62.40	255.00	185.00	29.40	2.2	64172	MV-1	Spring	67	02/16/06
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.6	4.3	7.39	-12.98	-98.1	64.10	27.20	95.20	10.90	62.90	255.00	186.00	29.10	2.2	64900	MV-1	Spring	67	06/21/06
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.8	2.9	7.24	-13.01	-97.7	65.30	28.20	90.00	9.30	63.70	251.00	187.00	29.20	2.2	65286	MV-1	Spring	67	08/23/06
Pederson's Warm Spring (M-13)	36.70958	-114.71594	31.5	2.3	7.35	-13.04	-97.3	64.80	27.80	97.00	10.90	61.30	254.00	184.00	28.80	2.2	65664	MV-1	Spring	67	10/30/06
Perry Sp Barcass 37	38.33285	-114.97586	12.1	4.8	7.06	-15.04	-107.7	78.90	20.90	24.10	2.64	19.10	333.00	25.10	27.90	0.2	63531	--	Spring	408	10/27/05
Pine Spring	37.90800	-114.55132	4.5	--	--	-13.40	-99.0	--	--	--	--	--	--	--	--	--	312	GS116	Spring	157	04/07/85
Pine Spring	37.90800	-114.55132	--	--	--	-13.33	-99.0	--	--	--	--	--	--	--	--	--	--	--	Spring	157	06/24/04
Pine Springs (Egan Range)	39.11755	-114.94425	8.7	7.9	7.90	-15.71	-116.0	71.10	9.58	3.69	0.46	0.70	246.00	13.90	10.90	0.1	65043	ER-17	Spring	434	07/12/06
Preston Big Spring	38.93331	-115.08222	21.0	3.1	7.70	-15.60	-126.0	44.00	20.00	13.00	2.90	14.00	185.00	36.00	20.00	0.4	450	GS224	Spring	231	06/16/83
Preston Big Spring	38.93331	-115.08222	22.0	3.1	7.65	-15.90	-123.0	45.00	20.00	13.00	3.00	15.00	--	38.00	19.00	0.4	452	GS226	Spring	231	06/26/84
Preston Big Spring	38.93331	-115.08222	--	--	--	-15.99	-121.8	--	--	--	--	--	--	--	--	--	68111	SNWA	Spring	231	08/06/03
Preston Big Spring	38.93331	-115.08222	--	--	--	-15.66	-123.1	--	--	--	--	--	--	--	--	--	88482	SNWA	Spring	231	06/24/04
Preston Big Spring	38.93331	-115.08222	21.2	2.6	7.32	-15.87	-122.6	40.70	19.40	13.60	3.11	15.90	182.00	37.70	19.90	--	61483	DRI-WV-1	Spring	231	09/25/04
Preston Big Spring	38.93331	-115.08222	20.8	3.1	7.64	-15.89	-122.4	41.90	19.80	13.00	3.23	16.00	176.00	38.10	19.90	--	61968	DRI-WV-1	Spring	231	01/24/05
Preston Big Spring	38.93331	-115.08222	21.1	3.1	7.52	-15.86	-120.0	--	--	--	--	--	--	--	--	--	62627	DRI-WV-1	Spring	231	05/21/05
Preston Big Spring	38.93331	-115.08222	21.1	3.0	7.04	-15.88	-121.2	--	--	--	--	--	--	--	--	--	63227	DRI-WV-1	Spring	231	08/14/05
Preston Big Spring	38.93331	-115.08222	20.9	2.6	7.77	-15.86	-120.4	41.90	19.60	12.60	3.08	15.80	174.00	38.10	20.00	0.3	63563	--	Spring	231	11/06/05
Preston Big Spring	38.93331	-115.08222	21.3	3.8	7.66	-15.95	-121.8	41.60	19.20	13.20	3.16	16.50	175.00	39.90	20.40	0.4	64735	WV-1	Spring	231	05/20/06
Preston Big Spring	38.93331	-115.08222	-	-	-	-15.98	-121.7	-	-	-	-	-	-	-	-	-	--	WV-1	Spring	231	07/12/06
Preston Big Spring	38.93331	-115.08222	21.0	2.7	7.54	-15.96	-121.6	42.00	19.70	12.50	2.94	16.10	183.00	39.60	19.90	0.4	65366	WV-1	Spring	231	08/29/06
Preston Big Spring	38.93331	-115.08222	21.0	3.0	7.66	-15.88	-120.9	41.80	19.60	12.70	3.16	15.60	174.00	39.00	19.80	0.4	65652	WV-1	Spring	231	10/27/06

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Quaking Aspen Spring	37.37563	-114.24255	9.6	3.2	6.18	-12.98	-93.6	13.80	3.68	11.40	1.48	4.10	83.30	2.10	49.60	--	61100	--	Spring	255	07/31/04
Rabbit Brush	39.18383	-114.27363	--	--	--	-15.50	-117.1	--	--	--	--	--	--	--	--	--	--	--	Spring	412	10/26/05
Railroad Well	37.35111	-114.53389	16.0	--	7.60	-11.60	-86.0	42.00	14.00	98.00	8.80	42.00	300.00	60.00	51.00	2.3	204	GS77	Well	103	01/31/84
Railroad Well (Farrier, NV)	36.81361	-114.65389	22.8	--	8.00	-12.50	-97.5	84.00	31.00	150.00	19.00	52.00	64.00	550.00	23.00	1.6	154	USGS	Well	80	02/04/84
Raised Sp Barcass 36	38.97259	-114.37041	10.8	7.6	6.07	-13.54	-103.7	7.01	1.77	2.38	0.66	1.00	31.20	2.40	11.40	0.1	63532	--	Spring	407	10/27/05
Ram. Res. Wtr Supply Well	39.74333	-115.45111	11.9	50.0	8.02	-16.75	-129.5	--	--	--	--	--	155.00	--	--	--	470	GS261	Well	244	07/19/85
Ramone Mathews Well	37.52667	-114.24417	18.5	--	7.80	-12.30	-92.0	42.00	6.30	20.00	5.90	15.00	171.00	12.00	61.00	0.3	233	GS86	Well	115	06/03/85
Randono Well	37.32389	-114.50222	17.2	--	7.60	-11.70	-87.5	46.00	14.00	100.00	8.40	44.00	350.00	63.00	54.00	2.3	200	GS75	Well	100	02/03/84
Rattlesnake Spring	37.82624	-114.93012	14.1	7.4	7.80	-12.65	-97.3	47.60	7.50	27.60	5.16	16.50	199.00	19.30	52.50	--	59692	--	Spring	302	03/24/04
Red Rock Spring	37.56698	-114.75320	10.0	--	7.32	-12.30	-95.0	85.40	13.30	28.40	2.40	15.70	332.00	16.30	41.10	--	58495	--	Spring	256	01/10/04
Reed Spring	37.55731	-115.41800	--	--	--	-14.24	-98.4	49.60	14.20	13.70	2.78	17.30	199.00	18.90	43.90	--	60843	--	Spring	289	06/25/04
Ripgut Sp #40	38.24802	-114.03920	18.7	5.7	6.95	-14.38	-106.4	25.20	4.58	18.20	8.17	17.00	116.00	6.40	63.50	0.2	63598	--	Spring	411	11/19/05
Robison Spring	38.21273	-114.70636	--	--	--	-12.34	-97.9	--	--	--	--	--	--	--	--	--	--	--	Spring	279	06/29/04
Robbers Roost #2 Spring (Butte)	39.49596	-115.28046	12.7	1.3	6.20	-14.39	-112.0	--	--	--	--	--	--	--	--	--	62703	DRI-BT-5	Spring	340	06/04/05
Robbers Roost Spring (Schell Ck)	38.77051	-114.78331	--	--	--	-14.75	-109.7	58.80	27.90	11.20	0.56	7.20	304.00	21.70	14.30	0.1	62978	SC-5	Spring	389	07/31/01
Robbers Roost Spring (Schell Ck)	38.77051	-114.78331	--	--	--	-14.15	-109.2	--	--	--	--	--	--	--	--	--	68116	SNWA	Spring	389	08/06/03
Rock Springs	39.85979	-114.47277	9.4	5.1	6.05	-15.17	-118.4	50.00	8.01	12.50	0.91	5.80	188.00	15.70	38.20	0.1	63281	--	Spring	399	08/25/05
Rogers Spring	36.37750	-114.44389	30.5	2.3	7.02	-12.20	-92.0	410.00	140.00	280.00	21.00	330.00	--	1600.00	18.00	1.3	35	GS10	Spring	21	07/21/81
Rogers Spring	36.37750	-114.44389	30.0	--	7.48	-12.40	-92.0	423.00	143.00	291.00	22.70	327.00	161.00	1620.00	16.80	1.4	33	PL11	Spring	21	03/19/92
Rogers Spring	36.37750	-114.44389	30.0	2.6	7.03	-12.40	-91.0	--	--	--	--	--	--	--	--	--	32	PL11	Spring	21	02/08/96
Ryans Spring D 38	38.33121	-113.92855	8.0	2.2	7.07	-13.68	-103.5	80.80	8.31	24.90	0.91	41.50	264.00	22.80	33.30	0.1	63596	--	Spring	409	11/19/05
Rye Patch Spring	36.57967	-115.30586	9.7	8.1	7.54	-12.31	-89.3	49.50	24.20	16.00	1.98	17.50	218.00	22.00	13.70	--	62397	DRI-SR-5	Spring	341	04/28/05
Saddle Spring (White Pine)	38.97541	-115.40023	--	--	--	-15.00	-116.0	--	--	--	--	3.10	--	--	--	--	438	GS217	Spring	357	06/15/83
Saddle Spring (White Pine)	38.97541	-115.40023	7.6	6.9	6.20	-15.66	-118.6	--	--	--	--	--	--	--	--	--	62820	WP-2	Spring	357	06/28/05
Saddle Spring (White Pine)	38.97541	-115.40023	--	--	--	-15.70	-115.7	--	--	--	--	--	--	--	--	--	--	WP-2	Spring	357	10/12/03
Sage Hen Spring	39.11533	-115.39212	7.7	7.0	6.20	-14.76	-112.4	--	--	--	--	--	--	--	--	--	62714	DRI-WP-9	Spring	342	06/06/05
Sand Spring	39.33056	-115.45500	13.0	--	--	-16.20	-123.0	--	--	--	--	--	--	--	--	--	465	GS250	Spring	239	07/14/81
Sammy Spring	39.43597	-115.32453	11.6	6.9	6.93	-15.30	-117.6	--	--	--	--	--	--	--	--	--	62628	DRI-BT-2	Spring	343	05/24/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Sandstone Spring	36.21111	-114.55667	11.0	2.0	7.03	-10.50	-79.0	209.00	79.20	21.90	4.96	16.90	249.00	725.00	13.80	--	17	PL16	Spring	10	02/07/96
Sawmill Spring (Sheep)	36.68056	-115.17611	--	--	--	-12.85	-92.0	12.00	29.00	1.80	0.60	2.10	--	5.90	6.10	0.2	101	GS36	Spring	58	05/19/88
Sawmill Spring (Delamar Range)	37.36762	-114.69708	10.3	10.3	6.90	-12.58	-88.7	56.20	10.40	18.90	2.18	16.60	220.00	19.00	41.70	--	59685	--	Spring	259	03/22/04
Sawmill Spring West	37.36734	-114.69749	9.7	6.6	6.50	-12.86	-91.8	33.90	4.55	12.10	2.00	7.40	146.00	7.00	36.80	--	59684	--	Spring	258	03/22/04
Scirpus Spring (No spring on Map)	36.37694	-114.44917	17.0	0.7	7.13	-12.00	-90.0	513.00	186.00	350.00	25.30	386.00	266.00	2040.00	20.40	--	30	PL12	Spring	20	02/07/96
Scotty Spring	38.16479	-114.68374	14.2	1.9	7.07	-12.73	-98.9	67.30	12.60	23.00	1.36	30.70	254.00	21.10	44.60	--	60846		Spring	272	06/26/04
Seaman Spring	37.86120	-115.19877	--	--	--	-13.13	-99.0	--	--	--	--	--	--	--	--	--	--	--	Spring	306	06/25/04
Second Sawmill Spring	38.87583	-114.89861	6.5	--	--	-14.70	-110.0	--	--	--	--	--	--	--	--	--	431	GS212	Spring	222	08/01/85
Secret Spring	38.83889	-115.28972	--	--	--	-14.00	-110.0	--	--	--	--	11.00	--	--	--	--	427	GS208	Spring	220	06/16/83
Sheep Spring (Clover)	37.40063	-114.27779	10.0	--	6.80	-12.00	-87.0	24.00	5.00	9.80	1.30	7.90	96.00	7.00	33.00	0.7	209.5	Jim	Spring	108	06/03/85
Sheep Spring (Clover)	37.40063	-114.27779	18.5	1.1	6.90	-12.06	-90.5	32.70	6.46	11.80	2.01	9.80	143.00	5.10	45.50	--	61097	DRI-CR-9	Spring	108	07/31/04
Sheep Spring (Schell Ck)	38.67611	-114.77667	14.0	6.7	6.63	-13.70	-99.5	8.00	2.10	2.80	--	1.50	46.00	4.10	14.00	<.1	418	GS194	Spring	212	08/02/85
Sheep Spring (Sheep Range)	36.89500	-115.11472	15.0	6.5	7.75	-13.35	-96.0	31.00	40.00	7.90	1.10	7.10	--	13.00	13.00	0.2	159	GS57	Spring	83	05/19/88
Shellback Spring	39.13197	-115.38436	7.7	8.8	6.50	-16.54	-123.6	--	--	--	--	--	--	--	--	--	62719	DRI-WP-14	Spring	344	06/07/05
Shingle Spring	38.53972	-114.93472	15.0	--	--	-13.25	-103.5	--	--	--	--	--	--	--	--	--	388	GS168	Spring	203	08/03/85
Shingle Spring	38.53958	-114.93553	15.2	4.3	7.15	-13.41	-103.8	61.70	18.80	15.60	2.51	16.20	260.00	23.30	44.80	0.2	65048	ER-22	Spring	203	07/13/06
Sidehill Spring	38.41596	-114.79613	13.0	--	--	-13.05	-100.0	--	--	--	--	--	--	--	--	--	377	GS160	Spring	200	08/02/85
Sidehill Spring	38.41596	-114.79613	--	--	--	-13.10	-101.8	--	--	--	--	--	--	--	--	--	88483	SNWA	Spring	200	06/21/04
Sidehill Spring	38.41596	-114.79613	12.6	6.3	6.76	-13.37	-100.8	50.90	16.60	12.50	1.14	6.90	242.00	11.90	51.40	0.1	62981	--	Spring	200	08/01/05
Silver Spring	38.81085	-114.88121	9.3	7.8	6.72	-14.74	-111.9	80.60	5.42	5.40	0.66	3.50	261.00	10.30	12.50	0.1	62975	ER-7	Spring	385	07/29/05
Silver Spring (RS)	38.81061	-114.88117	9.0	8.3	7.43	-14.68	-110.8	79.90	5.50	5.45	0.59	3.10	255.00	10.70	12.60	0.1	65051	ER-25	Spring	385	07/13/06
Sixmile Spring	37.49222	-115.08806	22.0	--	7.85	-13.06	-93.4	45.19	10.58	16.90	1.30	3.20	207.00	11.70	49.58	0.1	230	IT151	Spring	112	08/08/95
SK-10	38.75000	-115.17000	--	--	--	--	-119.0	--	--	--	--	16.30	--	--	--	--	423	Kirk110	Well	218	--
SK-18	37.71000	-114.80000	--	--	--	--	-95.0	--	--	--	--	11.30	--	--	--	--	276	Kirk130	Well	134	--
Snow Creek Spring (Unnamed Spring in Snow Creek)	40.07837	-114.91138	7.9	9.3	7.21	-16.22	-120.7	--	--	--	--	--	--	--	--	--	62629A	DRI-CC-2	Spring	345	05/24/05
Snowmelt Below Duckwater Peak	38.90056	-115.38250	10.0	--		-14.10	-105.0	--	--	--	--	0.60	--	--	--	--	437	GS216	Surface	224	06/15/83
South Monument Spring	38.25586	-114.11651	9.1	5.8	7.10	-14.23	-102.3	25.50	5.59	12.60	5.78	22.50	101.00	8.60	55.50	--	60318	--	Spring	319	05/21/04
South Spring (Egan)	39.14556	-114.97000	7.0	--	---	-15.00	-111.0	--	--	--	--	3.00	--	--	--	--	458	GS244	Spring	236	06/17/83

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
South Springs (Egan)	39.14526	-114.97287	6.8	8.8	7.80	-15.23	-111.9	46.60	10.90	5.15	0.53	2.30	190.00	11.20	9.50	0.1	65040	ER-14	Spring	236	07/12/06
South Spring (Snake)	38.80405	-114.17588	9.7	5.7	6.87	-14.70	-108.0	66.30	28.80	2.23	0.54	2.60	3.40	343.00	7.60	0.2	62917	SN-7	Spring	383	07/14/05
Spencer Well	37.39500	-115.18028	19.0	--	7.69	-13.68	-104.1	53.76	43.97	119.40	14.50	45.90	466.00	158.00	59.81	1.6	206	IT155	Well	106	08/06/95
Spring Creek Spring	38.90935	-114.11295	12.9	8.1	7.26	-15.40	-113.0	64.20	7.85	6.94	1.22	6.70	12.50	227.00	11.50	1.5	62916	SN-8	Spring	384	07/16/05
Unnamed Spring nr Redd's Cabin Summit	38.12512	-114.06920	8.0	--	7.90	-12.50	-95.0	92.00	19.00	26.00	2.40	23.00	--	25.00	23.00	0.3	334	GS128	Spring	173	04/09/85
Unnamed Spring nr Redd's Cabin Summit	38.12512	-114.06920	15.9	7.7	7.85	-12.37	-93.7	93.10	21.30	30.90	1.32	26.90	374.00	31.60	25.50	--	60315	WM-3	Spring	173	05/21/04
Unnamed Spring in Schell Creek Range	38.51851	-114.74229	--	--	--	-14.40	-108.1	17.60	3.77	1.87	1.16	0.90	67.90	9.50	10.80	--	57756	--	Spring	304	10/29/03
Unnamed Spring in Schell Creek Range	38.51851	-114.74229	--	--	--	-14.46	-105.8	--	--	--	--	--	--	--	--	--	57756	--	Spring	304	10/29/03
Unnamed Spring in Schell Creek Range	38.51851	-114.74229	10.7	6.5	7.22	-14.61	-106.9	56.00	8.70	23.20	0.34	11.80	210.00	26.20	16.20	0.2	62976	SC-4	Spring	304	07/30/05
Unnamed Spring in Schell Creek Range	38.51851	-114.74229	11.0	3.8	7.41	-14.45	-108.3	55.60	8.58	21.40	<.1	11.50	210.00	25.00	15.40	0.1	65058	SC-9	Spring	304	07/14/06
Indian Spring near Steward Ranch	38.31056	-114.65028	8.0	--	7.00	-13.60	-102.0	38.00	5.90	17.00	0.60	7.90	161.00	12.00	46.00	0.2	357	GS141	Spring	188	04/05/85
Stock Well (Delamar Wash)	37.34944	-114.75833	--	--	--	--	-88.0	--	--	--	--	--	--	--	--	--	1000	GS999	Well	101	--
Stove Spring	39.09486	-115.36359	9.1	7.1	6.40	-15.71	-114.5	--	--	--	--	--	--	--	--	--	62711	DRI-WP-6	Spring	347	06/06/05
Summit Spring	39.55109	-115.23000	7.7	6.4	6.50	-15.94	-120.8	--	--	--	--	--	--	--	--	--	62702	DRI-BT-4	Spring	348	06/04/05
Summit Spring (Mahogany Mts.)	37.74984	-114.15359	13.2	2.1	7.07	-12.04	-92.1	107.00	24.40	57.10	2.74	59.40	422.00	40.80	55.00	0.4	64905	MG-2	Spring	419	06/21/06
Teaspoon Spring	38.34509	-115.41189	11.9	4.8	7.00	-13.26	-100.0	--	--	--	--	--	--	--	--	--	62830	--	Spring	371	06/30/05
The Seeps (Spring)	37.73944	-115.57556	9.0	--	7.50	-13.30	-98.0	110.00	25.90	53.00	3.88	41.70	455.00	53.40	55.00	--	281	K10	Spring	136	01/15/85
Thirty Mile Spring	39.55556	-115.21806	8.5	--	8.00	-16.40	-126.0	29.00	4.60	13.00	2.80	5.50	140.00	7.90	43.00	0.2	468	GS256	Spring	242	08/23/83
Tippet Spring	39.87691	-114.37348	21.4	2.8	6.80	-16.24	-121.9	54.80	30.20	7.65	1.08	7.10	279.00	26.00	12.00	0.1	63276	--	Spring	394	08/24/05
Tobe Spring	38.00609	-114.08980	19.8	8.0	8.70	-13.04	-100.0	49.60	7.84	25.30	3.21	20.90	89.10	20.50	45.60	--	60312	--	Spring	315	05/20/04
Tobe Spring 2	38.00675	-114.08969	13.7	4.0	7.20	-12.09	-93.6	38.20	5.72	17.10	3.44	14.80	157.00	7.00	47.00	--	60313	--	Spring	316	05/20/04
Trough Spring	38.36971	-114.96316	--	--	--	-13.56	-103.6	--	--	--	--	--	--	--	--	--	--	--	Spring	413	28-Oct_05
Tunnel Spring	39.35142	-115.44964	10.4	5.5	7.00	-15.02	-118.3	--	--	--	--	--	--	--	--	--	62832	--	Spring	366	07/01/05
Twin Spring	37.46996	-115.02371	16.9	7.0	7.23	-13.24	-97.4	40.90	9.48	17.20	2.15	10.40	190.00	8.80	48.60	--	61104	--	Spring	294	07/30/04
Unnamed Chokecherry Spring	37.53905	-114.70312	11.8	6.2	7.20	-12.54	-98.1	23.90	5.86	9.31	1.43	3.50	109.00	7.90	48.60	--	59696	--	Spring	263	03/25/04

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Unnamed Hayden Canyon Spring	39.15147	-115.39264	6.9	6.0	7.00	-15.69	-120.9	--	--	--	--	--	--	--	--	--	62718	DRI-WP-13	Spring	350	06/07/05
Unnamed Near Little Willow Spring	39.72235	-115.60986	9.4	8.4	7.20	-17.04	-125.9	--	--	--	--	--	--	--	--	--	62707	DRI-BK-3	Spring	351	06/05/05
Unnamed Shellback Ridge Spring	39.14038	-115.38952	7.0	0.3	4.90	-16.18	-123.6	--	--	--	--	--	--	--	--	--	62720	DRI-WP-15	Spring	352	06/07/05
Unnamed Spring (Unnamed Combs Creek Spring)	39.50919	-114.99298	--	--	--	-15.63	-118.9	--	--	--	--	--	--	--	--	--	62630	DRI-ER-6	Spring	353	05/24/05
Unnamed Spring #3 (Snake)	38.73321	-114.33335	11.7	6.5	6.78	-14.10	-109.0	104.00	21.40	44.70	1.70	90.10	70.00	283.00	114.00	0.2	62920	SN-3	Spring	379	07/13/05
Unnamed Spring #4 (Snake)	38.83515	-114.19643	6.1	5.0	6.43	-14.65	-107.2	131.00	22.30	6.06	1.02	6.60	474.00	17.90	11.00	0.1	62972	SN-1	Spring	376	07/28/05
Unnamed Spring #5 (Snake)	38.85148	-114.17036	11.9	5.8	6.97	-14.04	-106.7	58.40	30.80	9.34	1.22	9.20	322.00	9.20	10.90	0.1	62973	SN-2	Spring	377	07/28/05
Unnamed Spring #1 (White Pine)	38.96778	-115.39900	8.3	8.9	6.50	-15.36	-114.8	--	--	--	--	--	--	--	--	--	62818	--	Spring	359	06/28/05
Unnamed Spring #2 (Mahogany Mts)	37.94321	-114.06842	13.4	6.3	7.35	-13.47	-100.7	64.10	8.94	12.10	0.89	10.20	210.00	23.60	21.60	0.7	64907	MG-4	Spring	421	06/22/06
Unnamed Spring #1(White Rock Mts)	38.30341	-114.16038	10.4	8.0	7.35	-15.05	-109.6	47.20	8.85	15.90	0.98	45.50	128.00	14.00	35.50	0.1	64897	WM-8	Spring	415	06/19/06
Unnamed Spring #2 (White Rock Mts)	38.19539	-114.10582	11.1	2.8	6.67	-13.00	-97.0	29.10	7.85	10.40	0.52	3.30	130.00	8.30	40.70	0.2	64899	WM-10	Spring	417	06/19/06
Unnamed Spring #1(Egan)	39.06895	-114.91885	7.0	6.9	7.11	-15.14	-112.2	82.60	9.14	4.46	0.94	1.60	277.00	20.90	11.20	0.1	65044	ER-18	Spring	435	07/12/06
Unnamed Spring #2 (White Pine)	38.97696	-115.40065	8.7	5.9	5.70	-15.66	-114.9	--	--	--	--	--	--	--	--	--	62819	--	Spring	360	06/28/05
Unnamed Spring #2 (Egan Range)	39.04577	-114.92458	4.1	7.6	7.50	-15.14	-110.0	50.70	5.87	3.95	0.68	1.00	182.00	5.80	9.20	0.1	65045	ER-19	Spring	436	07/12/06
Unnamed Spring #3 (White Pine)	38.98418	-115.39037	9.8	2.9	6.10	-14.96	-113.1	--	--	--	--	--	--	--	--	--	62821		Spring	361	06/28/05
Unnamed Spring #3 (Egan Range)	39.05677	-114.92678	4.8	8.8	7.50	-15.07	-110.2	66.90	4.69	3.98	0.69	0.90	221.00	5.50	10.20	0.1	65046	ER-20	Spring	437	07/12/06
Unnamed Spring #4 (White Pine)	39.03633	-115.39347	8.1	3.7	6.90	-15.01	-116.3	--	--	--	--	--	--	--	--	--	62824	--	Spring	362	06/29/05
Unnamed Spring #4 (Egan Range)	39.08531	-114.92188	6.7	8.7	7.43	-15.37	-114.0	65.10	10.10	3.38	0.78	1.30	229.00	11.90	11.50	0.1	65047	ER-21	Spring	438	07/12/06
Unnamed Spring #5 (White Pine)	39.00631	-115.39043	9.0	7.0	7.00	-16.01	-120.4	--	--	--	--	--	--	--	--	--	62825	WP-13	Spring	363	06/29/05
Unnamed Spring #5 (White Pine)	39.00631	-115.39043	--	--	--	-14.04	-106.7	--	--	--	--	--	--	--	--	--	62973	WP-13	Spring	363	07/28/01
Unnamed Spring #5 (RS, White Pine)	39.00630	-115.39043	8.9	6.8	7.12	-16.02	-120.8	62.50	5.30	14.80	1.16	6.90	224.00	10.60	30.50	0.2	65038	WP-13	Spring	363	07/11/06
Unnamed Spring #5 (Egan Range)	38.90310	-114.92343	7.3	7.1	7.04	-14.72	-109.6	93.10	18.30	4.39	0.92	3.30	331.00	32.40	14.00	0.1	65054	ER-28	Spring	445	07/13/06

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Unnamed Spring #6 (White Pine)	38.99300	-115.37519	9.1	0.5	6.80	-14.98	-115.1	--	--	--	--	--	--	--	--	--	62826	--	Spring	364	06/29/05
Unnamed Spring #7 (Quinn)	38.16152	-115.64159	7.4	6.1	6.70	-14.23	-105.9	--	--	--	--	--	--	--	--	--	62834	--	Spring	367	07/02/05
Unnamed Spring #8 (Quinn)	38.05659	-115.66484	11.5	0.3	6.50	-14.18	-104.4	--	--	--	--	--	--	--	--	--	62835	--	Spring	368	07/02/05
Unnamed Spring #7 (Kern MTS)	39.68072	-114.19089	10.2	0.1	6.32	-15.80	-116.3	51.50	11.00	25.70	0.82	14.90	232.00	14.10	36.00	0.4	63273	--	Spring	391	08/23/05
Unnamed Spring #8 (Antelope Range)	39.98778	-114.43341	9.2	2.9	6.13	-15.85	-121.4	35.90	6.98	12.80	1.89	11.10	130.00	22.10	44.90	0.1	63277	--	Spring	395	08/24/05
Unnamed Spring #9 (Antelope Range)	39.99364	-114.42071	8.3	5.6	6.16	-16.41	-123.0	32.80	6.25	8.86	3.03	14.80	109.00	14.90	44.40	0.1	63278	--	Spring	396	08/25/05
Unnamed Spring #10 (Antelope Range)	39.93797	-114.36074	12.9	1.3	6.59	-15.95	-122.0	92.00	49.20	34.10	1.19	35.50	329.00	175.00	19.30	0.2	63279	--	Spring	397	08/25/05
Unnamed Springs #11(Snake Range)	39.48477	-114.31032	8.9	7.9	6.71	-15.65	-117.1	60.10	11.40	11.40	1.56	8.30	231.00	11.10	19.10	0.1	63283	--	Spring	401	08/26/05
Unnamed Spring #12 (Snake Range)	39.30746	-114.21610	7.6	6.5	7.24	-15.89	-116.6	39.10	3.53	4.78	0.64	2.40	130.00	4.20	11.90	0.1	63527	--	Spring	403	10/25/05
Unnamed Sp Silver Cr Canyon	39.22899	-114.26075	9.2	3.1	7.39	-15.38	-115.7	71.30	30.40	8.93	0.75	6.60	322.00	35.40	12.60	0.1	63529	--	Spring	405	10/26/05
Unnamed Spring 13 (Snake Range)	39.17779	-114.28686	9.9	6.2	7.48	-14.76	-114.3	79.10	94.70	67.80	1.14	83.60	437.00	234.00	19.60	0.2	63530	--	Spring	406	10/26/05
Unnamed Stone Cabin Spring	39.15911	-115.39892	8.5	8.2	6.80	-15.31	-114.2	--	--	--	--	--	--	--	--	--	62717	DRI-WP-12	Spring	354	06/07/05
Unnamed Stone Cabin Spring	39.15911	-115.39892	9.2	7.2	7.31	-15.47	-118.2	66.70	11.70	14.30	0.92	7.90	248.00	13.00	16.80	0.2	65036	WP-11	Spring	354	07/11/06
Unnamed Spring (Clover)	37.27654	-114.30744	3.3	4.9	7.09	-12.20	-88.0	126.00	22.60	56.60	1.51	14.80	401.00	157.00	35.40	--	58501	--	Spring	249	01/15/04
Unnamed Spring	37.49917	-114.45250	10.0	--	--	-11.60	-86.5	--	--	--	--	--	--	--	--	--	231	GS85	Spring	113	06/03/85
Unnamed Spring in dry creek bed (White Pine Range)	38.89546	-115.38372	--	--	--	-15.31	-113.6	--	--	--	--	--	--	--	--	--	--		Spring	321	10/12/03
Unnamed Spring in Miller Canyon	38.32738	-114.24383	--	--	--	-14.27	-103.7	--	--	--	--	--	--	--	--	--	--		Spring	313	05/19/04
Unnamed Spring in Road (South Pahroc Range)	37.53638	-115.10651	28.4	4.5	6.37	-13.07	-96.7	42.60	10.00	16.10	1.53	8.80	193.00	8.70	49.70	--	61098	--	Spring	303	07/30/04
Unnamed Spring nr Clover Creek	37.61461	-114.45061	16.2	0.9	6.99	-11.96	-89.7	67.40	9.05	29.90	6.83	20.30	299.00	11.10	55.60	--	61102	--	Spring	252	07/31/04
Unnamed Spring nr Six Mile seep	37.49680	-115.09102	--	--	--	-12.62	-94.5	--	--	--	--	--	--	--	--	--	61106A	--	Spring	296	07/30/04
Unnamed Spring--nr Blackrock	37.91689	-114.91859	9.2	7.1	7.40	-11.90	-94.3	45.90	9.28	25.80	6.14	23.70	184.00	23.10	69.20	--	59688	--	Spring	299	03/23/04
Unnamed Well (Longdale)	36.59000	-114.48000	--	--	7.80	-13.20	-103.0	29.00	2.20	35.00	5.20	6.00	135.00	26.00	132.68	1.0	78	IT174	Well	48	03/04/74

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Unnamed Well (Near Dry Lake Range)	36.38278	-114.91667	26.5	0.5	7.33	-13.70	-96.0	123.00	46.00	140.00	16.00	190.00	230.00	360.00	21.00	1.6	41	GS12	Well	24	04/26/82
South Fox Well	38.77222	-114.52667	12.0	3.3	7.80	-15.00	-113.0	34.00	21.00	7.10	1.60	6.00	--	8.00	15.00	0.3	422	GS201	Well	216	07/06/83
Unnamed, Kaolin Wash	36.48722	-114.46667	14.1	6.0	8.46	-11.30	-88.0	48.90	25.90	77.60	21.30	46.50	213.00	168.00	19.10	--	67	PL3	Spring	35	02/09/96
Upper Burnt Canyon Spring	38.28729	-114.20049	14.8	3.0	6.80	-12.83	-97.6	65.90	15.30	11.50	0.57	17.30	251.00	6.70	50.40	0.2	64898	WM-9	Spring	416	06/19/06
Upper Burnt Canyon Spring #2	38.28729	-114.20049	--	--	--	-13.66	-103.6	--	--	--	--	--	--	--	--	--	--	WM-9b	Spring	416	06/19/06
Upper Chokecherry Spring	37.53746	-114.69833	9.3	7.3	8.00	-12.96	-98.9	53.00	10.60	23.20	1.23	13.60	219.00	16.70	50.00	--	59695	--	Spring	262	03/25/04
Upper Conner Spring	37.90278	-114.56056	8.0	8.2	7.43	-13.85	-100.0	73.00	26.00	2.20	0.50	2.10	351.00	5.40	8.50	<.1	310	GS115	Spring	156	11/11/86
Upper Conner Spring	37.90278	-114.56056	9.2	8.1	7.74	-13.88	-102.3	76.90	27.60	1.58	0.59	1.90	368.00	3.60	8.50	--	60836	--	Spring	156	06/24/04
Upper Fairview	38.18657	-114.66620	18.0	1.8	7.23	-12.66	-97.7	60.20	10.60	28.10	2.64	23.60	259.00	14.50	48.40	--	60850	--	Spring	280	06/29/04
Upper Illipah Crk	39.28167	-115.39000	--	--	--	-16.00	-124.0	--	--	--	--	--	--	--	--	--	--	GS999	Surface	238	06/13/83
Upper Illipah Crk	39.28167	-115.39000	--	--	--	-16.20	-123.0	--	--	--	--	--	--	--	--	--	--	GS999	Surface	238	08/23/83
Upper Illipah Crk	39.28167	-115.39000	--	--	--	-15.95	-120.9	--	--	--	--	--	--	--	--	--	68119	SNWA	Surface	238	08/05/03
Upper Indian Spring	37.45202	-114.65831	11.7	3.6	7.31	-11.46	-88.0	68.00	19.30	23.90	0.34	9.10	319.00	13.00	53.40	--	58499		Spring	268	01/14/04
Unnamed Spring near Pony Spring	38.32139	-114.64222	11.5	--	--	-12.90	-99.0	--	--	--	--	--	--	--	--	--	361	GS144	Spring	191	07/23/81
Upper Riggs Spring WR4	37.36833	-114.64778	10.8	--	--	-11.90	-88.0	--	--	--	--	--	--	--	--	--	207	GS78	Spring	105	02/02/84
Upper Riggs Spring WR4	37.36833	-114.64778	10.1	4.4	7.30	-11.90	-87.0	64.70	15.90	19.40	0.02	17.50	274.00	12.00	57.80	--	58492	--	Spring	105	01/13/04
Upper Riggs Spring WR4	37.36833	-114.64778	16.9	10.9	7.99	-11.95	-86.6	57.60	15.90	17.60	3.36	16.50	256.00	12.70	48.80	--	60082	--	Spring	105	04/29/04
Upper Riggs Spring WR4	37.36833	-114.64778	13.2	0.7	7.37	-11.55	-86.2	63.40	16.60	18.80	4.16	16.40	277.00	8.70	57.20	--	61614	--	Spring	105	10/19/04
Upper Riggs Spring WR4	37.36833	-114.64778	6.0	6.8	7.08	-12.46	-87.0	35.50	8.79	11.60	2.04	7.20	153.00	8.10	42.00	--	62035	--	Spring	105	02/10/05
Upper Terrace Spring WR2	39.08664	-114.92565	--	--	--	--	--	39.70	10.90	4.09	0.72	2.10	173.00	7.30	11.90	--	57696	ER-1	Spring	270	10/13/03
Upper Terrace Spring WR2	39.08664	-114.92565	8.2	5.1	7.10	-15.43	-114.9	39.80	11.00	4.07	0.72	2.10	172.00	7.30	12.10	--	57697	ER-1	Spring	270	10/15/03
Upper Terrace Spring WR2	39.08664	-114.92565	7.6	--	7.90	-15.44	-111.8	40.50	10.80	4.25	0.80	2.10	172.00	7.10	9.20	--	60080	ER-1	Spring	270	04/26/04
Upper Terrace Spring WR2	39.08664	-114.92565	8.0	8.0	7.51	-15.40	-115.6	40.40	10.70	3.60	0.71	2.40	169.00	7.40	11.80	--	60785	ER-1	Spring	270	06/23/04
Upper Terrace Spring WR2	39.08664	-114.92565	8.2	7.1	6.85	-15.35	-114.4	41.60	11.30	4.29	0.75	2.40	177.00	7.30	11.80	--	61479	ER-1	Spring	270	09/22/04
Upper Terrace Spring WR2	39.08664	-114.92565	7.2	8.3	7.82	-15.41	-114.6	40.30	10.70	4.24	0.81	2.30	168.00	7.70	11.10	--	62030	ER-1	Spring	270	02/09/05
Upper Terrace Spring WR2	39.08664	-114.92565	--	--	--	-15.24	-113.7	--	--	--	--	--	--	--	--	--	62633A	ER-1	Spring	270	05/21/05
Upper Terrace Spring WR2	39.08664	-114.92565	--	--	--	-15.43	-113.4	41.80	10.50	4.14	0.76	2.30	173.00	7.90	11.20	<.05	63219	ER-1	Spring	270	08/14/05
Upper Terrace Spring WR2	39.08664	-114.92565	7.7	8.1	7.77	-15.41	-113.7	41.30	10.80	4.06	0.74	2.20	167.00	7.50	11.30	0.1	63562	ER-1	Spring	270	11/06/05
Upper Terrace Spring WR2	39.08664	-114.92565	7.5	8.3	7.87	-15.41	-114.5	40.50	10.70	4.23	1.10	2.30	164.00	7.70	11.50	0.1	64734	ER-1	Spring	270	05/24/06
Upper Terrace Spring WR2	39.08664	-114.92565	--	--	--	-15.43	-114.1	--	--	--	--	--	--	--	--	--	--	ER-1	Spring	270	07/12/06
Upper Terrace Spring WR2	39.08664	-114.92565	7.9	7.6	7.68	-15.48	-114.1	41.40	10.90	3.65	0.61	2.13	166.00	7.61	11.20	0.1	65364	ER-1	Spring	270	08/29/06
Upper Terrace Spring WR2	39.08664	-114.92565	7.7	7.1	7.80	-15.50	-115.2	41.10	10.90	4.34	0.92	1.40	169.00	7.20	11.20	0.1	65651	ER-1	Spring	270	10/27/06
Upper Terrace Spring WR2	39.08664	-114.92565	7.5		7.87	-15.46	-114.2	40.30	10.70	4.07	0.76	1.89	173.00	6.47	10.60	0.1	65651	ER-1	Spring	270	05/08/07

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
Upper Terrace Spring WR2	39.08664	-114.92565	8.2	6.2	7.70	-15.46	-114.7	39.80	10.70	4.07	0.82	1.25	178.00	6.92	10.80	--	67247	ER-1	Spring	270	08/23/07
Upper Terrace Spring WR2	39.08664	-114.92565	8.0	5.9	7.83	-15.46	-113.6	41.70	11.20	4.00	0.75	1.90	176.00	6.70	10.50	0.1	67510	ER-1	Spring	270	11/03/07
Upper Terrace Spring WR2	39.08664	-114.92565	7.8	8.2	7.84	-15.48	-113.7	39.90	11.00	4.08	0.77	2.00	176.00	6.66	10.40	0.1	68479	ER-1	Spring	270	06/01/08
Upper Terrace Spring WR2	39.08664	-114.92565	8.4	8.2	7.78	-15.54	-113.3	38.80	10.70	3.95	0.67	2.07	178.00	6.82	11.00	0.1	68910	ER-1	Spring	270	09/10/08
Upper Terrace Spring WR2	39.08664	-114.92565	8.3	7.9	7.86	-15.50	-114.8	40.10	11.00	4.11	0.88	1.95	184.00	6.75	10.50	0.1	69141	ER-1	Spring	270	10/29/08
Upper Terrace Spring WR2	39.08664	-114.92565	7.9	8.1	7.85	-15.55	-114.3	39.60	10.80	4.00	0.75	1.97	168.00	6.61	10.40	0.1	69862	ER-1	Spring	270	05/19/09
Upper Terrace Spring WR2	39.08664	-114.92565	--	--	--	-15.47	-114.9	40.80	10.90	4.08	0.69	2.04	172.00	6.42	11.20	0.1	69862	ER-1	Spring	270	08/15/09
Upper Terrace Spring WR2	39.08664	-114.92565	--	--	--	-15.64	-114.9	40.80	11.00	4.12	0.77	2.07	182.00	6.58	10.50	0.1	70610	ER-1	Spring	270	11/13/09
Upper Tower Spring	38.12049	-114.33344	--	--	--	-12.30	-93.3	20.20	3.33	16.30	6.15	7.60	104.00	7.20	45.80	--	60081	--	Spring	312	04/28/04
US Lime Well (Genstar)	36.39139	-114.90389	24.0	4.8	7.40	-12.75	-97.0	120.00	47.00	140.00	1.30	180.00	226.00	370.00	23.00	1.6	52	GS16	Well	27	03/31/86
USGS CSV-1	36.76694	-114.86194	29.5	--	--	-13.55	-103.0	260.00	93.00	160.00	30.00	39.00	--	1300.00	19.00	1.2	127	GS45	Well	71	05/18/88
USGS-MX C.V. Well (CV-DT-1)	38.13778	-115.33861	23.0	3.4	7.20	-14.60	-110.0	37.00	19.00	20.00	4.60	5.70	253.00	26.00	36.00	0.4	338	GS130	Well	176	10/15/81
USGS-MX C.V. Well (CV-DT-1)	38.13778	-115.33861	--	--		-14.52	-108.0	--	--	--	--	--	--	--	--	--	USGS	--	Well	--	06/25/03
USGS-MX CE, VF-1	36.87528	-114.94528	28.0	--	7.03	-12.65	-94.0	41.00	7.50	34.00	1.20	42.00	156.00	20.00	14.00	0.5	157	GS56	Well	82	01/06/88
Valley of Fire Well	36.42250	-114.54778	28.0	--	7.40	-10.60	-82.0	118.00	53.00	39.00	8.20	21.00	164.00	449.00	8.30	0.2	58	PLC33	Well	31	06/24/85
VF Spring 1	36.40139	-114.40194	23.0	5.0	7.10	-11.20	-88.0	--	--	--	--	--	--	--	--	--	53	PL7	Spring	28	02/09/96
VF Spring 2	36.40528	-114.43056	13.5	3.9	7.76	-11.80	-92.0	--	--	--	--	--	--	--	--	--	55	PL6	Spring	29	03/07/96
VF Spring 3	36.40583	-114.44389	15.0	5.3	7.61	-12.20	-93.0	537.00	208.00	295.00	51.10	278.00	169.00	2290.00	12.40	--	57	PL5	Spring	30	03/07/96
Wamp Spring	36.64167	-115.07000	7.0	--	8.15	-10.60	-81.0	71.00	13.00	10.00	2.10	4.90	585.00	8.40	24.00	0.2	91	GS31	Spring	52	03/20/87
Water Canyon	38.98816	-114.96032	11.0	--	--	-15.00	-115.0	--	--	--	--	--	--	--	--	--	1033	GS999	Surface	233	06/14/83
Water Canyon	38.98816	-114.96032	9.0	--	--	-15.50	-117.0	--	--	--	--	--	--	--	--	--	1033	GS999	Surface	233	08/23/83
Water Canyon at USGS gage	38.98700	-114.95500	--	--	--	-15.41	-109.5	--	--	--	--	--	--	--	--	--	--	--	Spring	271	-- 10/24/03
Water Canyon at USGS gage (duplicate sample)	38.98700	-114.95500	--	--	--	-15.43	-112.7	--	--	--	--	--	--	--	--	--	--	--	Spring	271	10/24/03
Water Canyon Spring	39.00691	-114.91063	8.9	7.9	7.30	-15.60	-114.4	40.10	11.00	4.04	0.72	7.30	180.00	1.64	12.00	--	57695	--	Spring	358	10/14/03
Water Canyon Spring (Mahogany)	37.95662	-114.06494	11.1	2.2	7.11	-13.68	-100.4	81.90	11.80	9.44	1.12	5.10	210.00	84.10	17.20	1.6	64906	MG-3	Spring	420	06/22/06
Water Tank 0.4mi West of Sixmile	37.49119	-115.09605	--	--	--	-12.44	-93.8	--	--	--	--	--	--	--	--	--	61106C	--	Spring	297	07/30/04
Weaver Well	37.74472	-114.43070	17.0	--	7.70	-13.10	-101.0	100.00	42.00	110.00	14.00	110.00	430.00	180.00	73.00	2.9	283	GS100	Well	137	06/04/85
Well at Alligator Ridge	39.73735	-115.51432	34.0	4.1	7.20	-16.60	-127.0	60.00	23.00	19.00	6.50	6.70	--	52.00	26.00	1.0	469	GS260	Well	243	04/24/84
White Rock Spring (Sheep)	36.70791	-115.23942	19.9	1.7	7.02	-9.96	-84.8	41.80	35.10	18.20	11.90	10.80	326.00	12.70	57.70	--	61095	--	Spring	64	07/27/04
White Rock Spring (Sheep)	36.70791	-115.23942	10.2	3.8	6.51	-10.38	-86.1	39.80	35.20	16.80	10.50	10.30	303.00	12.50	46.50	--	62398	DRI-SR-3	Spring	64	04/28/05

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
White Rock Spring (Butte)	40.06079	-115.16385	9.4	6.0	6.38	-15.36	-119.2	--	--	--	--	--	--	--	--	--	62631	DRI-BT-3	Spring	355	05/24/05
White Rock Well	38.12557	-114.17027	14.5	--	7.90	-13.10	-101.0	68.00	10.00	11.00	4.00	51.00	168.00	20.00	61.00	0.6	336	E4	Well	175	07/24/75
White Rock Spring (Seaman Range)	37.89630	-115.01970	--	--	--	-12.10	-90.0	--	--	--	--	--	--	--	--	--	308	Kirk1019	Spring	154	01/13/85
Wildhorse Spring (Fairview)	38.19722	-114.60861	8.0	--	7.60	-11.70	-92.5	--	--	--	--	--	--	--	--	--	348	GS136	Spring	183	04/06/85
Wild Horse Spring (White Pine)	39.33361	-115.44333	17.5	--	--	-16.80	-129.0	--	--	--	--	--	--	--	--	--	466	GS251	Spring	240	07/14/81
Warm Spring (White Pine Range)	38.94778	-115.22806	53.0	1.0	9.25	-15.80	-118.0	1.60	<.12	61.00	0.60	9.40	--	16.00	56.00	13.0	453	GS204	Spring	232	04/29/82
Warm Spring (White Pine Range)	38.94778	-115.22806	--	--	--	-14.37	-114.8	--	--	--	--	--	--	--	--	--	112273	SNWA	Spring	232	07/26/05
Willow Spring (KSV-1)	37.09483	-114.83096	--	--	--	-11.90	-86.5	--	--	--	--	--	--	--	--	--	180	Kirk1026	Spring	92	--
Willow Spring (KSV-1)	37.09483	-114.83096	17.4	--	7.50	-11.60	-88.0	20.00	2.70	56.00	4.60	22.00	140.00	34.00	65.00	1.1	182	GS67	Spring	92	02/03/84
Willow Spring (KSV-1)	37.09483	-114.83096	9.3	8.3	7.52	-11.57	-88.0	18.20	3.17	55.90	2.24	21.30	131.00	33.50	67.30	--	58489		Spring	92	01/12/04
Willow Spring (KSV-1)	37.09483	-114.83096	16.7	1.6	7.44	-11.63	-89.1	19.90	4.25	9.85	1.74	6.50	84.90	6.30	37.20	--	62395	DRI-DR-2	Spring	92	04/27/05
Willow Spring 2 (So.of Oak Sps.summit)	37.55653	-114.69773	13.7	2.5	7.40	-11.69	-91.2	59.40	14.70	25.50	1.79	13.60	274.00	15.20	55.70	--	59693	--	Spring	260	03/25/04
Wilson Creek	38.31806	-114.40333	17.0	--	8.00	-13.20	-97.5	21.00	3.30	11.00	2.90	7.00	77.00	11.00	39.00	0.3	358	E2	Surface	189	04/05/85
Wiregrass Spring (Sheep)	36.63325	-115.20842	9.5	--	7.30	-12.80	-94.0	69.00	32.00	2.70	1.10	3.00	--	5.00	12.00	0.1	82	GS22	Spring	49	10/28/81
Wiregrass Spring (Sheep)	36.63325	-115.20842	6.5	6.1	7.30	-12.70	-96.0	68.00	32.00	3.20	1.10	3.20	--	9.00	12.00	0.1	83	GS23	Spring	49	05/11/83
Wiregrass Spring (Sheep)	36.63325	-115.20842	--	--	--	-12.85	-94.0	--	--	--	--	--	--	--	--	--	83.5	JIM	Spring	49	10/09/86
Wiregrass Spring (Sheep)	36.63325	-115.20842	4.0	--	7.32	-12.80	-91.5	71.00	34.00	2.80	1.10	3.40	374.00	6.90	12.00	0.1	84	GS24	Spring	49	03/20/87
Wiregrass Spring (Sheep)	36.63325	-115.20842	13.0	--	--	-12.55	-92.0	70.00	33.00	2.80	1.50	2.90	--	7.10	12.00	0.2	85	GS25	Spring	49	06/17/87
Wiregrass Spring (Sheep)	36.63325	-115.20842	14.0	5.4	7.34	-12.75	-94.0	68.00	33.00	3.10	1.00	2.90	372.00	7.30	12.00	0.2	86	GS26	Spring	49	08/04/87
Wiregrass Spring (Sheep)	36.63325	-115.20842	4.0	5.0	7.32	-12.85	-97.0	72.00	34.00	3.10	5.70	3.80	--	7.70	12.00	0.2	87	GS27	Spring	49	01/05/88
Wiregrass Spring (Sheep)	36.63325	-115.20842	8.0	5.0	7.41	-12.95	-95.5	72.00	34.00	2.80	1.00	2.60	--	7.30	12.00	0.2	88	GS28	Spring	49	04/06/88
Wiregrass Spring (Sheep)	36.63325	-115.20842	7.0	--	7.30	-12.85	-94.5	69.00	36.00	3.10	1.10	2.70	--	7.30	12.00	0.1	89	GS29	Spring	49	12/12/88
Wiregrass Spring (Sheep)	36.63325	-115.20842	8.2	2.3	7.34	-12.87	-94.0	--	--	--	--	--	--	--	--	--	58487	--	Spring	49	01/17/04
Wiregrass Spring (Sheep)	36.63325	-115.20842	9.9	2.5	6.89	-13.12	-96.8	67.80	33.20	2.48	0.98	3.70	367.00	6.00	14.40	--	60851	--	Spring	49	06/30/04
Wiregrass Spring (Sheep)	36.63325	-115.20842	8.3	4.0	6.55	-13.76	-101.2	74.40	40.60	3.92	1.27	3.90	404.00	5.40	14.80	--	62400	DRI-SR-2	Spring	49	04/29/05
Wiregrass Spring (Sheep)	36.63325	-115.20842	--	--	--	-13.19	-95.6	--	--	--	--	--	--	--	--	--	--	SH-2	Spring	49	04/29/06
Wiregrass Spring (Grant)	38.35211	-115.42693	14.3	4.3	7.50	-13.29	-101.4	--	--	--	--	--	--	--	--	--	62831	--	Spring	372	06/30/05
Woodchuck Spring	39.72453	-115.57297	7.5	6.9	6.80	-15.55	-119.6	--	--	--	--	--	--	--	--	--	62706	DRI-BK-2	Spring	356	06/05/05
180W501	38.59201	-114.84080	--	--	--	-14.12	-105.6	--	--	--	--	--	--	--	--	--	--	SNWA	Well	600	05/17/06
180W902M	38.36331	-114.82750	--	--	--	-13.99	-107.1	--	--	--	--	--	--	--	--	--	120738	SNWA	Well	601	10/19/05
180W902M	38.36331	-114.82750	--	--	--	-14.12	-104.7	--	--	--	--	--	--	--	--	--	--	SNWA	Well	601	05/18/06
181M1	37.91163	-114.85528	--	--	--	-13.57	-104.9	--	--	--	--	--	--	--	--	--	120739	SNWA	Well	603	08/30/05
181M1	37.91163	-114.85528	--	--	--	-13.67	-105.0	--	--	--	--	--	--	--	--	--	--	SNWA	Well	603	05/31/06
181W909M	37.69600	-114.74639	--	--	--	-13.70	-106.4	--	--	--	--	--	--	--	--	--	120737	SNWA	Well	604	04/27/05
181W909M	37.69600	-114.74639	--	--	--	-13.50	-104.6	--	--	--	--	--	--	--	--	--	--	SNWA	Well	604	06/05/06
182M-1	37.34683	-114.95796	--	--	--	-14.07	-109.6	--	--	--	--	--	--	--	--	--	--	SNWA	Well	606	05/23/06

APPENDIX 1. ISOTOPIC, FIELD PARAMETER, AND WATER CHEMISTRY DATA FOR ALL SITES USED IN THIS STUDY AND SOME ADDITIONAL SITES IN EASTERN AND SOUTHERN NEVADA (CONTINUED).

Name	Latitude Degrees	Longitude Degrees	Water Temp. (°C)	DO (mg/L)	pH	$\delta^{18}O$ (‰)	δD (‰)	Ca (mg/L)	Mg (mg/L)	Na (mg/L)	K (mg/L)	Cl (mg/L)	HCO_3 (mg/L)	SO_4 (mg/L)	SiO_2 (mg/L)	F (mg/L)	Sample #	REF_ID	Site Type	Site #	Date
182W906M	37.32691	-114.85463	--	--	--	-12.89	-103.6	--	--	--	--	--	--	--	--	--	120743	SNWA	Well	607	03/19/05
182W906M	37.32691	-114.85463	--	--	--	-13.40	-100.7	--	--	--	--	--	--	--	--	--	120741	SNWA	Well	607	09/02/05
209M-1	37.64351	-114.98950	--	--	--	-13.00	-99.7	--	--	--	--	--	--	--	--	--	120742	SNWA	Well	608	08/04/05
209M-1	37.64351	-114.98950	--	--	--	-13.53	-104.7	--	--	--	--	--	--	--	--	--	--	SNWA	Well	608	06/14/06
CSI-1	36.79768	-114.91471	--	--	--	-13.08	-102.6	--	--	--	--	--	--	--	--	--	--	SNWA	Well	609	05/31/05
CSI-2	36.79768	-114.91471	--	--	--	-12.90	-100.2	--	--	--	--	--	--	--	--	--	--	SNWA	Well	610	09/30/05
CSI-3	36.82554	-114.91667	--	--	--	-13.03	-99.6	--	--	--	--	--	--	--	--	--	--	SNWA	Well	611	09/13/06
CSI-4	36.84998	-114.95452	--	--	--	-12.68	-98.6	--	--	--	--	--	--	--	--	--	174086	SNWA	Well	628	12/05/07
CSVM-1	36.79118	-114.88621	--	--	--	-13.13	-99.3	--	--	--	--	--	--	--	--	--	65462	SNWA	Well	632	02/27/03
CSVM-2	36.66182	-114.92305	--	--	--	-13.13	-96.3	--	--	--	--	--	--	--	--	--	65453	SNWA	Well	612	02/23/03
CSVM-2	36.66182	-114.92305	--	--	--	-13.14	-97.7	--	--	--	--	--	--	--	--	--	--	SNWA	Well	612	01/10/06
CSVM-3	37.05250	-114.98336	--	--	--	-12.86	-98.4	--	--	--	--	--	--	--	--	--	65456	SNWA	Well	613	05/19/03
CSVM-3	37.05250	-114.98336	--	--	--	-13.10	-98.0	--	--	--	--	--	--	--	--	--	--	SNWA	Well	613	01/06/06
CSVM-4	36.99106	-114.88648	--	--	--	-13.37	-102.7	--	--	--	--	--	--	--	--	--	65455	SNWA	Well	614	03/26/03
CSVM-4	36.99106	-114.88648	--	--	--	-13.41	-102.5	--	--	--	--	--	--	--	--	--	--	SNWA	Well	614	01/16/06
CSVM-5	36.74758	-114.98045	--	--	--	-12.82	-94.0	--	--	--	--	--	--	--	--	--	65452	SNWA	Well	615	02/06/03
CSVM-5	36.74758	-114.98045	--	--	--	-12.67	-95.0	--	--	--	--	--	--	--	--	--	--	SNWA	Well	615	01/08/06
CSVM-6	36.83250	-114.90916	--	--	--	-12.94	-100.2	--	--	--	--	--	--	--	--	--	65454	SNWA	Well	616	03/20/03
CSVM-6	36.83250	-114.90916	--	--	--	-12.97	-100.7	--	--	--	--	--	--	--	--	--	--	SNWA	Well	616	01/11/06
CSVM-7	37.04701	-114.99571	--	--	--	-12.47	-93.9	--	--	--	--	--	--	--	--	--	65457	SNWA	Well	617	05/04/03
CSVM-7	37.04701	-114.99571	--	--	--	-12.51	-93.6	--	--	--	--	--	--	--	--	--	--	SNWA	Well	617	01/23/06
KPW-1	--	--	--	--	--	-13.63	-105.0	--	--	--	--	--	--	--	--	--	120744	SNWA	Well	618	12/15/05
RW-1	36.45565	-114.84709	--	--	--	-13.19	-100.9	--	--	--	--	--	--	--	--	--	112270	SNWA	Well	624	07/20/05
CAV6002X	38.36281	-114.82736	--	--	--	-14.27	-106.3	--	--	--	--	--	--	--	--	--	174083	SNWA	Well	627	12/03/07
CSV3009X	36.98363	-114.96546	--	--	--	-13.48	-100.2	--	--	--	--	--	--	--	--	--	200044	SNWA	Well	629	12/08/08
CSV3011X	36.98195	-114.93191	--	--	--	-12.83	-90.4	--	--	--	--	--	--	--	--	--	200046	SNWA	Well	630	12/16/08
CSV3011X	36.98195	-114.93191	--	--	--	-12.87	-94.0	--	--	--	--	--	--	--	--	--	200045	SNWA	Well	630	12/20/08
UMVM-1 (MRS1009M)	36.75808	-114.82324	--	--	--	-13.15	-98.9	--	--	--	--	--	--	--	--	--	65460	SNWA	Well	631	06/14/03
GV-1	36.43506	-114.95859	--	--	--	-13.15	-98.8	--	--	--	--	--	--	--	--	--	79439	SNWA	Well	634	01/15/04
GV-2	36.35828	-114.92445	--	--	--	-13.46	-96.8	--	--	--	--	--	--	--	--	--	69559	SNWA	Well	635	09/25/03
PW-1	37.89546	114.71828	24.4	-	-	-13.4	-101	37	19	37	3.9	15	190	32	--	--	SNWA	DL-2	Well	636	1/21/10

APPENDIX 2. AMOUNT OF PRECIPITATION AND ISOTOPIC COMPOSITION FROM BULK STORAGE GAUGES AT WR1 IN THE WHITE PINE RANGE, WR2 IN THE EGAN RANGE, WR3 IN THE SCHELL CREEK RANGE, AND WR4 IN THE DELAMAR MOUNTAINS.

Site	Start Date	End Date	Precipitation (in)	$\delta^{18}O$	δD
WR1 - Altitude 8,012 ft	10/23/03	3/23/04	7.10	-17.13	-124.1
	3/23/04	4/26/04	9.60	-16.19	-116.4
	4/26/04	6/21/04	1.32	--	--
	6/21/04	9/22/04	2.76	-11.95	-87.8
	9/22/04	1/21/05	12.96	--	--
	1/21/05	5/21/05	15.36	-16.19	-112.9
	5/21/05	8/14/05	0.60	-11.79	-82.1
	8/14/05	11/5/05	0.96	-8.95	-58.5
	11/5/05	2/24/06	6.00	--	--
	2/24/06	5/20/06	9.36	-15.12	-107.8
	5/20/06	8/29/06	3.00	-7.11	-48.4
	8/29/06	11/15/06	2.40	-13.59	-96.8
	11/15/06	5/6/07	8.40	-17.42	-126.7
	5/6/07	8/19/07	2.76	-10.82	-79.8
	8/19/07	11/3/07	1.44	-11.70	-83.1
	11/3/08	3/3/08	8.04	-16.82	-122.2
	3/3/08	5/29/08	0.96	-16.58	-121.3
	5/29/08	9/14/08	2.88	-9.82	-70.0
	9/14/08	10/31/08	0.96	-10.09	-68.1
	10/31/08	1/15/09	4.32	-18.32	-132.1
	1/15/09	5/19/09	10.32	-16.36	-119.0
	5/19/09	8/16/09	4.20	-10.64	-75.3
	8/16/09	11/16/09	2.52	-16.97	-122.9
WR2 - Altitude 8,747 ft	10/15/03	4/26/04	13.32	-16.93	-119.8
	4/26/04	6/23/04	1.8	--	--
	6/23/04	9/22/04	1.68	-13.15	-93.5
	9/22/04	2/9/05	14.04	-16.53	-117.7
	2/9/05	5/21/05	21.24	-17.59	-127.6
	5/21/05	7/26/05	1.32	--	--
	7/26/05	8/11/05	0.36	--	--
	8/11/05	11/7/05	2.4	-11.70	-79.1
	11/7/05	5/24/06	16.92	-16.30	-116.4
	5/24/06	8/29/06	3.96	-9.28	-60.2

APPENDIX 2. AMOUNT OF PRECIPITATION AND ISOTOPIC COMPOSITION FROM BULK STORAGE GAUGES AT WR1 IN THE WHITE PINE RANGE, WR2 IN THE EGAN RANGE, WR3 IN THE SCHELL CREEK RANGE, AND WR4 IN THE DELAMAR MOUNTAINS (CONTINUED).

Site	Start Date	End Date	Precipitation (in)	$\delta^{18}O$	δD
	8/29/06	10/27/06	2.4	-13.82	-94.9
	10/27/06	5/8/07	9.84	-18.04	-131.5
	5/8/07	8/23/07	2.28	-13.46	-95.0
	8/23/07	11/3/07	1.68	-13.87	-94.2
	11/3/07	6/1/08	9.6	-18.22	-132.2
	6/1/08	9/10/08	1.8	-14.84	-105.8
	9/10/08	10/29/08	1.2	-13.20	-88.2
	10/29/08	5/19/09	9.72	-17.45	-124.7
	5/19/09	8/16/09	4.08	-11.91	-82.3
	8/16/09	11/13/09	2.88	-12.18	-82.2
WR3 – Altitude 7,484 ft	10/30/03	3/24/04	7.92	-16.25	-114.4
	3/24/04	4/27/04	3.72	-15.37	-104.3
	4/27/04	6/23/04	1.32	--	--
	6/23/04	9/23/04	2.64	-9.53	-69.3
	9/23/04	1/23/05	16.80	--	--
	1/23/05	5/20/05	13.20	-15.57	-110.5
	5/20/05	8/15/05	1.86	-7.12	-50.3
	8/15/05	11/7/05	2.76	-11.11	-74.9
	11/7/05	2/26/06	3.12	-13.77	-97.3
	2/26/06	5/23/06	6.60	-14.99	-105.6
	5/23/06	8/31/06	2.28	-8.88	-62
	8/31/06	10/28/06	2.16	-11.97	-84.5
	10/28/06	5/7/07	4.92	-17.49	-127.9
	5/7/07	8/20/07	2.04	-8.87	-63.4
	8/20/07	11/2/07	1.32	-11.32	-80.8
	11/2/07	3/4/08	7.56	-15.27	-109.2
	3/4/08	5/30/08	0.84	-16.96	-123
	5/30/08	9/11/08	0.84	-10.71	-81.3
	9/11/08	10/31/08	0.72	-10.87	-72.9
	10/31/08	1/14/09	3.41	-17.64	-126.1
	1/14/09	5/19/09	7.38	-15.33	-108
	5/19/09	8/17/09	4.08	-9.75	-67.3
	8/17/09	11/15/09	0.96	-9.34	-62.9
WR4 – Altitude 5,163 ft	04/29/04	10/19/04	2.88	-8.12	-61.8
	10/19/04	02/10/05	13.68	-11.86	-85.6
	02/10/05	05/19/05	8.04	-12.03	-87.3

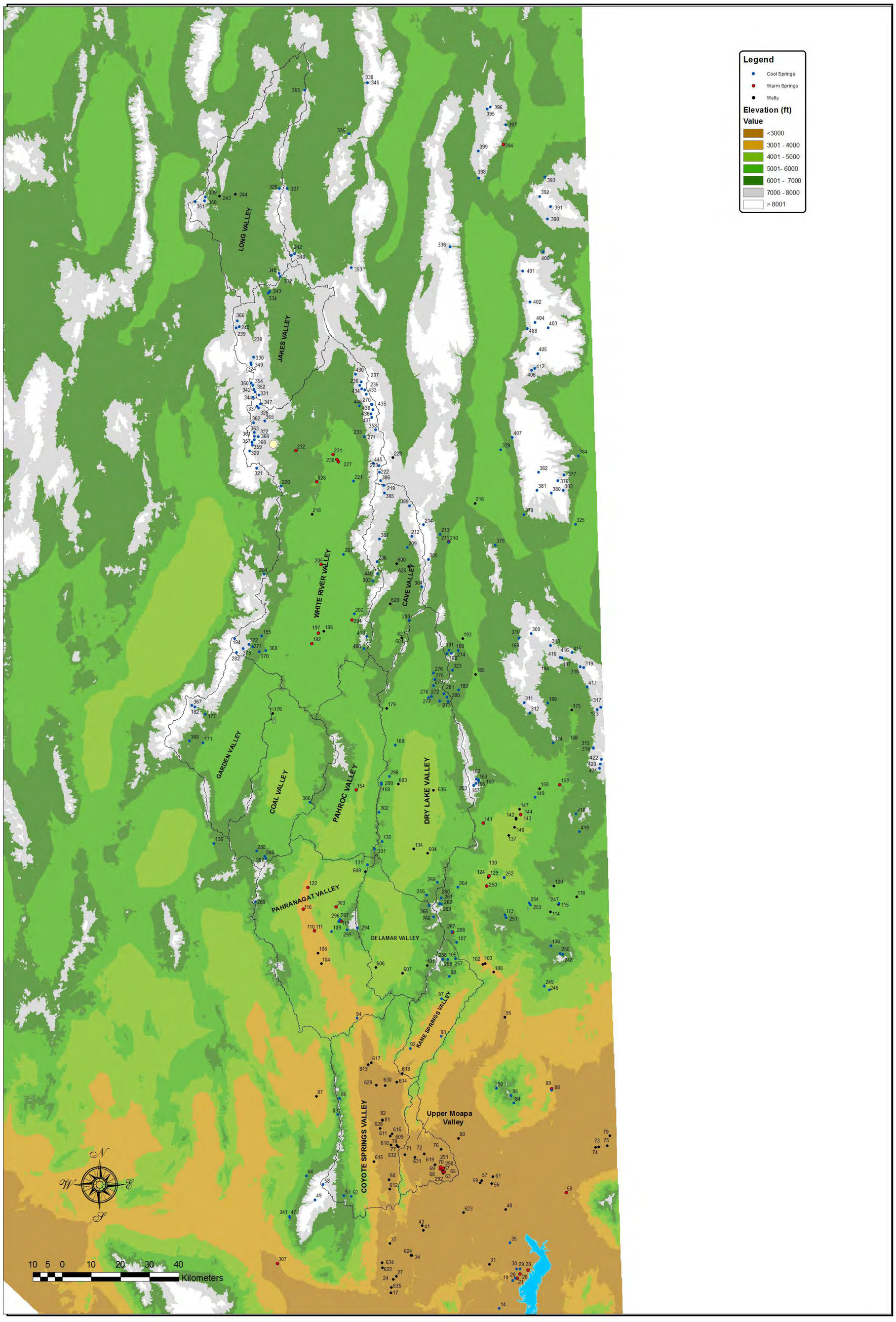

Plate 1. Site locations with site numbers which refer to the sites in the water chemistry appendix (Appendix1) and on Plate 2.

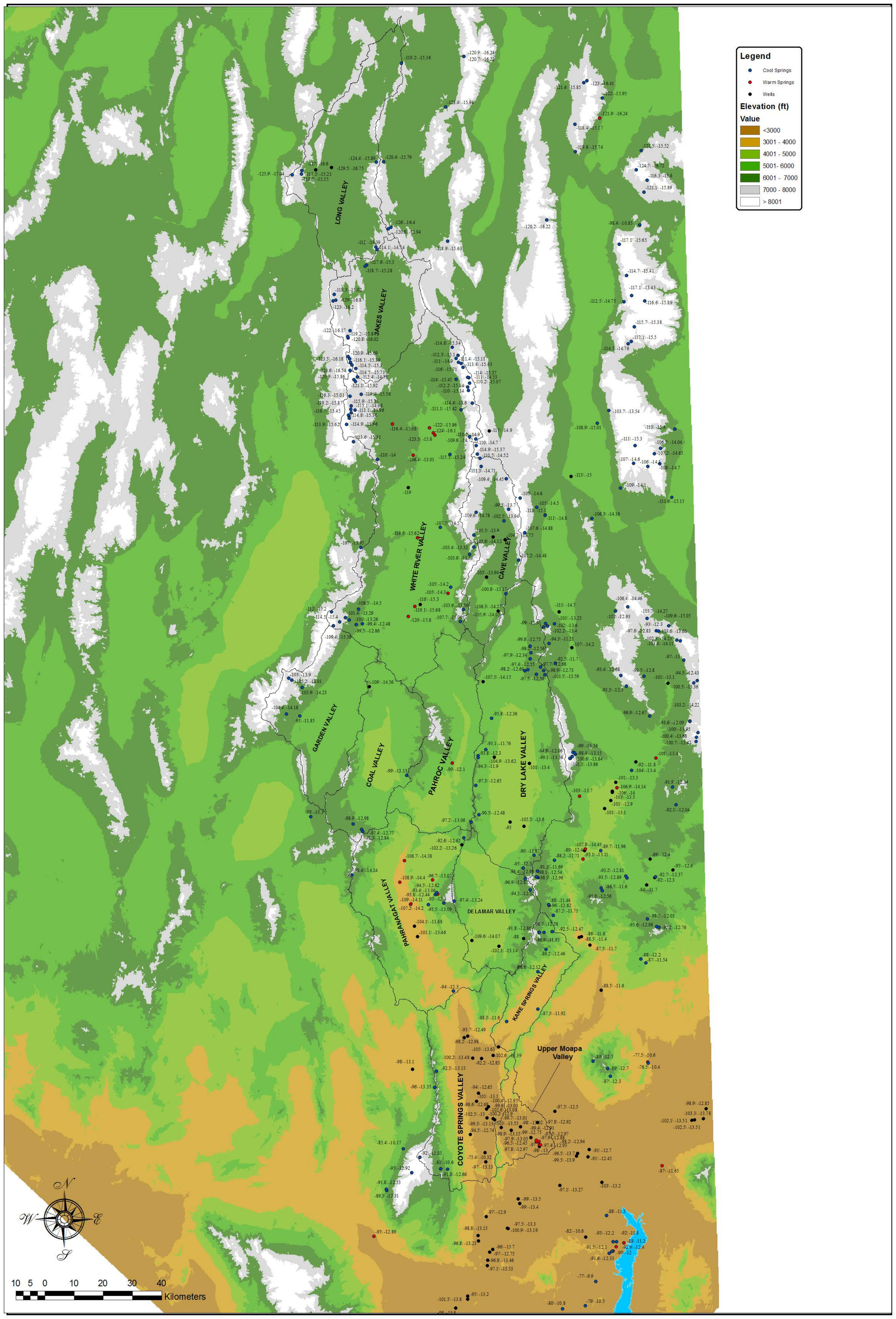

Plate 2. Deuterium and oxygen-18 data for all sites in the study area. If a site has more than one stable isotope analyses, the average value is shown on the plate. The data the plate was made from are given in Appendix 1.

The relative contributions of summer and cool-season precipitation to groundwater recharge, Spring Mountains, Nevada, USA

Isaac J. Winograd · Alan C. Riggs
Tyler B. Coplen

Abstract A comparison of the stable-isotope signatures of spring waters, snow, snowmelt, summer (July thru September) rain, and cool season (October thru June) rain indicates that the high-intensity, short-duration summer convective storms, which contribute approximately a third of the annual precipitation to the Spring Mountains, provide only a small fraction (perhaps 10%) of the recharge to this major upland in southern Nevada, USA. Late spring snowmelt is the principal means of recharging the fractured Paleozoic-age carbonate rocks comprising the central and highest portion of the Spring Mountains. Daily discharge measurements at Peak Spring Canyon Creek during the period 1978–94 show that snowpacks were greatly enhanced during El Niño events.

Résumé La comparaison des signatures isotopiques stables des eaux de sources, de neige, de fonte de neige, des pluies d'été (juillet à septembre) et de saison froide (octobre à juin) montre que les précipitations convectives d'été de forte intensité et de courte durée, apportant un tiers des précipitations annuelles reçues par les Monts Spring, ne participent que pour une faible part (10%) à la recharge de cette importante zone d'altitude du sud du Nevada (États-Unis). La fonte tardive de la neige au printemps constitue l'essentiel de la recharge des roches carbonatées fracturées d'âge paléozoïque formant la partie centrale et la plus haute des Monts Spring. Les données journalières de débit sur la rivière du canyon de Peak Spring, entre 1978 et 1994, montrent que les hauteurs de neige ont été plus élevées pendant les événements El Niño.

Resumen La comparación entre las marcas isotópicas de aguas de manantiales, nieve, deshielo, lluvias de verano (julio a septiembre) y resto de lluvias (octubre a junio) indican que las tormentas de verano, de corta duración y gran intensidad, las cuales suponen alrededor de un tercio de la precipitación total anual en las Spring Mountains, proporcionan sólo una fracción pequeña (alrededor del 10%) de la recarga en esta zona al sur de Nevada (EE.UU.). El deshielo de finales de la primavera es la principal fuente de recarga de las rocas carbonatadas fracturadas de edad Paleozoica que forman las partes central y superior de las Spring Mountains. Las medidas de descarga diarias en el Desfiladero de Peak Spring Canyon durante 1978–94 muestran que los espesores de nieve aumentaron coincidiendo con los fenómenos de El Niño.

Key words USA · stable isotopes · groundwater recharge/water budget · hydrochemistry

Introduction

In a pioneering paper, Eugene Simpson, David Thorud, and Irving Friedman (1972) were the first to demonstrate that the isotopic signatures of winter and summer precipitation in southern Arizona (USA) were different, and that the differences can be used to determine the seasonality of groundwater recharge. They observed that winter precipitation from Pacific Ocean frontal systems was approximately 20 per mill depleted in deuterium compared with summer convective precipitation, derived from the Gulf of Mexico. (For expressing isotopic results, we use "per mill" herein, as recommended by ISO 1992.) A comparison of these precipitation data with the deuterium content of groundwater led Simpson et al. (1972) to conclude that winter precipitation is the dominant source of recharge to the Tucson groundwater basin. The innovative study by Simpson et al. (1972) prompted the work described herein for the Spring Mountains in southern Nevada (USA).

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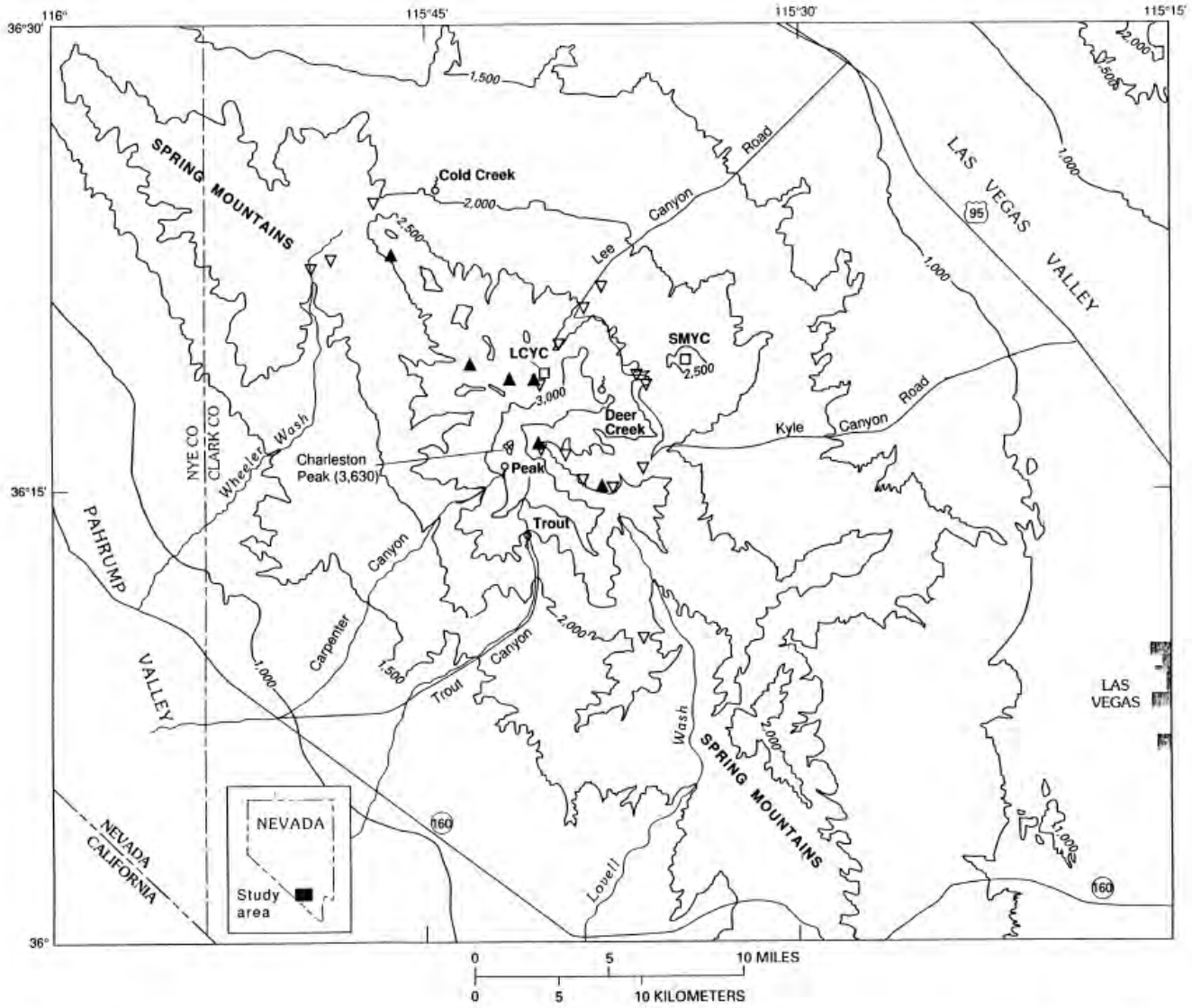

Fig. 1 Location and topography of the Spring Mountains (Nevada, USA) showing locations of springs and other data stations. *Solid triangles* denote location of snow courses; *open triangles*, snowmelt samples; *squares*, precipitation stations at Spring Mountains Youth Camp (*SMYC*) and at Lee Canyon Youth Camp (*LCYC*); contours show altitude in meters above sea level, generalized from 1:100,000-scale metric topographic map, Las Vegas, Nevada–California quadrangle)

The Spring Mountains, the highest (~3630 m) mountain range in southern Nevada, are the principal recharge area for the flanking Pahrump, Las Vegas, and other groundwater basins; locations are shown in *Figure 1*. The central and highest portion of this range is composed of structurally complex Paleozoic-age carbonate rocks aggregating several thousand meters in thickness (Longwell 1965). Average annual precipitation ranges from approximately 200 mm in the foothills, at an altitude of approximately 1800 m, to more than 600 mm at the crest of this rugged upland (Winograd and Thordarson 1975, their Fig. 3). Late fall through spring precipitation, usually associated with areally extensive low-pressure systems containing moisture of Pacific Ocean origin, forms approximately two thirds of the annual precipitation (Houghton 1969). Summer precipitation, in contrast, occurs predominantly as high-intensity, short-duration convective storms that vary in location from one storm to the next. The summer moisture is derived from the Gulf of California, and possibly also the Gulf of Mexico.

Using the approach introduced by Simpson et al. (1972), Winograd and Riggs (1984) and Hershey et al. (1991) reached markedly different conclusions regarding the importance of summer rain as a source of recharge to the Spring Mountains. Hershey et al. (1991) concluded that summer rain contributes ~40% of annual recharge. In contrast, Winograd and Riggs (1984) concluded, as did Simpson et al. (1972) for the Tucson basin, that such precipitation contributes negligibly to recharge. In an attempt to reconcile this difference of

opinion, we present and analyze deuterium (δD) and oxygen-18 (δ^{18}O) data for spring waters, snow, snowmelt, late-fall through spring rain, and summer rain collected intermittently in the Spring Mountains during 1968–88 by the authors, as well as data collected subsequently by Hershey (1989), Hershey et al. (1991), and Thomas et al. (1991, 1996).

Isotopic Composition of Spring Waters

Maxey and Jameson (1948) and Hughes (1966) both noted that in late summer and fall many of the springs in the Spring Mountains were either dry or had discharges of only a few gallons a minute. Accordingly, we studied two springs, Trout and Cold Creek (*Fig. 1*), which, from historical measurements, were likely to be perennial. Recognizing from Waring's (1921) measurements of Trout and other springs (reproduced in Fig. 8 of Maxey and Jameson 1948) that snowmelt was likely to be an important component of the water discharging from upland springs, we attempted to sample Trout and Cold Creek Springs at least twice yearly, once during the late spring to determine the isotopic composition of snowmelt-induced discharge, and again in late fall or early winter to sample baseflow. We also discuss two other springs (Peak Spring and Deer Creek Spring) from which pertinent data were collected by others.

We do not attempt to define the hydrogeologic boundaries of the catchment areas feeding these four upland springs. Such an exercise would be incomplete at best, and probably misleading due to: (a) the likely presence of major undetected hydrogeologic discontinuities, including karst conduits, common to the complex structural geology of the Spring Mountains (Longwell 1965; Birchfiel et al. 1974); (b) the absence of wells that might permit mapping of the local potentiometric surface tributary to each spring; and (c) the likelihood, based on three decades of studies of groundwater flow in Paleozoic-age carbonate rocks of southern Nevada (Winograd 1962; Eakin 1965; Mifflin 1969; Winograd and Thordarson 1975; Hess and Mifflin 1978, Dettinger et al. 1995), that the topographic (i.e., surface water) and hydrogeologic (i.e., groundwater) boundaries tributary to these springs are not coincident.

Trout Spring

Trout Spring (*Fig. 1*) flows from a ~760-m-long subhorizontal cave at an altitude of ~2360 m on the southwestern slopes of the Spring Mountains (*Fig. 1*). For most of its length, this tortuous cavern, developed in the Bird Spring Formation of Carboniferous age, is too low to walk through (McLane 1975, 1977). McLane (1977) noted that the principal source of the spring discharge is water upwelling along a fracture at the end of the cavern. McLane named this spring and cavern Deer Spring and Deer Spring Cave, names not to be confused with Deer Creek Spring located on the northeastern slopes of the Spring Mountains (*Fig. 1*). We retain the name Trout Spring, which has been on U.S. Geological Survey topographic maps and in the literature at least since 1916. Trout Spring was visited periodically between 1970 and 1989. Data obtained from the samples collected, and measurements made during these visits, are presented in *Table 1* and in *Figure 2*.

Trout Spring water samples, collected at the mouth of the cave, are representative of the groundwater upwelling ~760 m from the mouth, as shown by analyses of stable isotopes and chemical constituents of samples collected at the entrance and at ~75, ~150, and ~200 m into the cave on 16 February 1976 by Jack Hess of the Desert Research Institute (Nevada). These data, reproduced below, show no change in the isotopic or chemical parameters as the water traversed the outermost 200 m of the cavern. (Stable-isotope data are from T. B. Coplen; see *Table 1* for standards and precision. Chemical data are from J. Chemerys, U.S. Geological Survey, Reston, VA.)

Distance from entrance (m)	δD (VSMOW, per mill)	δ^{18}O	Ca (mg/L)	Mg
0	−100	−14.1	40	11
~ 75	− 99	−13.9	41	11
~150	− 99	−14.1	36	9.2
~200	−101	−14.0	41	11

Given the likely 100% humidity in this cavern and the low temperature (6.5–8.5 °C; see *Table 1*) of the waters flowing through it, it is unlikely that the isotopic composition of the water changed during the ~560-m passage from the fracture source (at 760 m) to the innermost sampling station 200 m from the cavern entrance.

The deuterium (δD) and discharge measurements from Trout Spring are plotted in *Figure 2*. Deuterium varied less than 5 per mill between 1970 and 1989, even as spring discharge varied by an order of magnitude. The values chosen to bracket the δD ordinate (–110 to

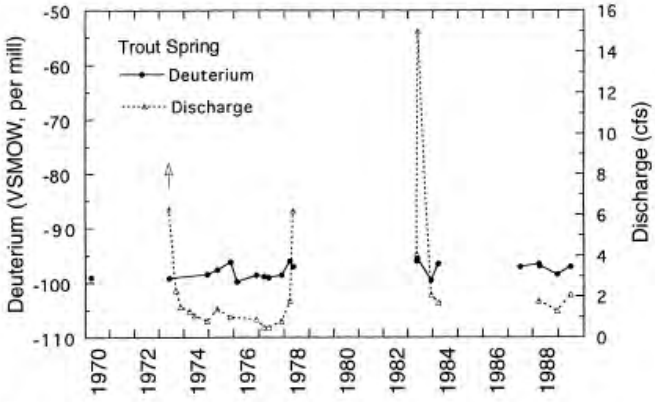

Fig. 2 Discharge and deuterium (δD) content of Trout Spring water, 1970–89. Precisions of δD and of discharge measurements are given in *Table 1*; *arrow* denotes that discharge exceeded the value measured, as explained in *Table 1*. *cfs*, cubic feet per second

Table 1 Stable isotopic, discharge, and other data for Trout Spring, Spring Mountains, Nevada (Location: NE1/4, NW1/4, SW1/4 section 10, T.20S., R.56E.; altitude, ~2360 m; precision of δD and δ^{18}O measurements by T. B. Coplen are ±1 and ±0.15 per mill, respectively; ^{3}H measurements by T. Wyerman, USGS, Reston, VA; discharge measurements considered accurate to ±20 percent. Data from T. Wyerman, U.S. Geological Survey (written communs., 1977, 1979, and 1980)

Date	Isotopic content (per mill)		Temperature (°C)	Tritium (T.U.)	Discharge (cfs)
	Deuterium	Oxygen-18			
3/28/1970	−99.0	–	8.3	–	–
6/4/1973	−99.1	−14.1	6.5	85±4	6.3
9/7/1973	–	−13.8	8.0	85±4	2.3
11/14/1973	–	−13.8	8.0	90±7	1.5
3/25/1974	–	−13.7	8.5	85±7	1.3
6/4/1974	–	–	7.0	85±7	1.1
12/8/1974	−98.4	−13.8	8.2	83±6	0.80
5/1/1975	−97.6	−13.3	7.5	70±2	1.4
11/11/1975	−96.2	−13.4	8.1	69±7	1.0
2/16/1976	−99.8	−14.0	–	–	–
11/17/1976	−98.6	−13.9	8.5	68±4	0.90
3/8/1977	−98.8	−14.1	8.2	66±3	0.50
5/13/1977	−99.0	−14.1	8.0	72±6	0.50
11/19/1977	−98.6	−13.4	8.0	78±6	0.80
3/21/1978	−96.0	−12.8	8.0	45±5	1.8
5/8/1978	−97.0	−12.9	7.4	52±4	6.2
5/4/1983	−96.0	−13.2	8.0	–	4.1
5/16/1983	−95.5	−13.0	7.5	–	15
11/30/1983	−99.5	−13.6	7.5	–	2.1
3/19/1984	−96.5	−13.6	7.5	–	1.7
6/30/1987	−97.0	−13.7	6.9	–	–
3/24/1988	−96.5	−13.7	8.5	–	1.8
4/4/1988	−96.9	−13.7	–	–	–
12/11/1988	−98.4	−13.7	–	–	1.3
6/21/1989	−97.0	−13.6	–	–	2.1

[1] The δD contents are expressed on a scale normalized such that the δD value of SLAP reference water is -428 exactly per mill relative to VSMOW reference water. The δ^{18}O values are expressed on a scale normalized such that δ^{18}O of SLAP reference water is −55.5 per mill exactly relative to VSMOW reference water

[2] δD content of sample collected on 3/28/70 is from Winograd and Friedman (1972). Their value was multiplied by 0.97 to account for a systematic difference between the I. Friedman and T.B. Coplen laboratories

[3] Discharge on 6/4/73 was measured in arroyo, ~30 m downstream from cave mouth and did not include flow in 15-cm pipe; it is, therefore, a minimum value. All subsequent discharge measurements were made several meters inside the cave and included all discharge. Discharge was measured using the float measurement method, which has an accuracy of ±20 percent (Fenwick 1994)

[4] Data for 2/16/76 are average of measurements on samples collected at mouth of and ~75, ~150, and ~200 m inside the cave from which Trout Spring emerges. See discussion and table in text

[5] Conversion factor: 1 cfs = 28.32 L/s

–50 per mill) are the highest and lowest median values of possible sources of the spring water, as discussed below. Thus, compared with the spread of 60 per mill in the median source values, the δD content of Trout Spring water (*Fig. 2*) is essentially constant.

Cold Creek Spring

Cold Creek Spring emerges from a dissected alluvial fan bordering the Spring Mountains on the north (*Fig. 1*). Hughes (1966) suggested that a pediment surface on carbonate rocks may underlie the alluvium and host the spring. If Hughes (1966) is correct, the geologic mapping of Longwell (1965, Plate I) suggests that the Bird Spring Formation may (like Trout Spring) be the aquifer feeding this spring. The spring orifice is at an altitude of ~1930 m.

Deuterium and discharge data for Cold Creek Spring for 1968–88 are given in *Table 2* and are shown in *Figure 3*. As at Trout Spring, the δD varied narrowly (6 per mill) despite large variations in spring discharge.

Data from Trout Spring and Cold Creek Spring, though spanning as much as two decades, contain large gaps in coverage (*Figs. 2, 3*) and include no data on short-term (i.e., daily to weekly) variations in discharge and isotopic content of spring waters in the Spring Mountains. We now examine two detailed short-term records from Peak Spring and Deer Creek Spring.

Peak Spring

Peak Spring discharges from the Bird Spring Formation (Hershey 1989) near the crest of the Spring Mountains at an altitude of ~3260 m (*Fig. 1*). This spring is only approximately 4.5 km north–northwest of Trout Spring but is approximately 900 m higher. Because of the remoteness of the spring, all but one of the water samples

Table 2 Stable-isotope, discharge, and other data for Cold Creek Spring, Spring Mountains, Nevada (Location: SW1/4, NE1/4, SE1/4, section 1, T.18 S., R.55 E.; altitude, ~1930 m; precision of δD and $\delta^{18}O$ measurements given in *Table 1*; discharge measurements, made using pygmy current meter, considered accurate to ±10 percent)

Date	Isotopic content (per mill)		Temperature (°C)	Tritium (T.U.)	Discharge (cfs)
	Deuterium	Oxygen-18			
8/24/1968	– 97.0	–	–	–	–
1/27/1969	–102	–	10	–	–
3/30/1970	–103	–	10	–	–
5/31/1973	– 99.1	–14.1	9.0	47±4	5.4
8/29/1973	– 98.4	–14.2	10	32±2	5.2
11/13/1973	–	–13.8	10	25±1	2.4
4/4/1974	–	–13.9	10	21±1	1.0
6/1/1974	–	–	10	21±1	0.70
12/9/1974	–100	–13.8	10	18±1	1.1
4/28/1975	–100	–13.8	10	21±1	1.3
11/10/1975	– 98.0	–13.3	10	21±1	1.5
9/17/1976	–	–	10	16±1	1.1
11/16/1976	–100	–14.0	10	–	1.0
2/17/1977	–101	–14.2	10	18±1	1.0
5/12/1977	–102	–14.2	10	16±1	0.9
11/18/1977	–102	–13.8	12	14±1	0.8
3/20/1978	– 99.5	–13.2	10	14±1	0.9
5/6/1978	– 98.5	–13.2	9.5	36±2	4.1
12/4/1982	–102	–14.0	–	–	–
5/2/1983	–100	–13.8	10	–	1.1
5/15/1983	–100	–13.6	9.5	–	2.2
12/12/1983	– 99.5	–13.8	11	–	2.2
3/31/1987	– 99.0	–13.8	10	–	–
4/5/1988	–100	–13.8	11	–	–

[1] δD data for 1968–70, from Winograd and Friedman (1972), multiplied by 0.97 to account for a systematic difference between the I. Friedman and T.B. Coplen laboratories

[2] Conversion factor: 1 cfs = 28.32 L/s

(for isotopic analyses) were collected at the end of an access road approximately 4 km downstream from and ~1200 m lower than the spring, at a gaging station designated by Thomas et al. (1991) as Peak Spring Canyon Creek. No other springs occur in the canyon between the gaging station and Peak Spring (J.M. Thomas, pers. commun.). Between 27 September 1986 and 16 November 1989, this spring was sampled for stable-isotope analysis 17 times at this location; data are shown in *Table 3*. Only on 23 June 1987 was the spring sampled at its source, by Hershey (1989). A plot of δD data superimposed on daily discharge measurements for calendar years 1986–1989 is given in *Figure 4*. As at Trout and Cold Creek Springs, the range of δD was narrow (between ca. –101 and –92 per mill). During the prominent discharge pulse of April–June 1988, when discharge varied by nearly an order of magnitude, δD varied only ~6 per mill.

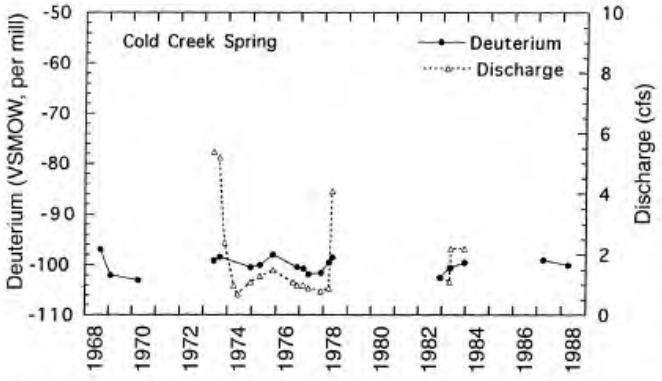

Fig. 3 Discharge and δD content of Cold Creek Spring water, 1968–88. Precisions of δD and of discharge measurements are given in *Tables 1* and *2*)

That the waters sampled at the gaging station ~4 km downstream from Peak Spring may yield representative values of δD at the source is indicated by the measurement made on a water sample collected at the spring on 23 June 1987. The δD of this sample (arrow, *Fig. 4*) is within 2 per mill of values obtained from samples taken downstream on 9 June and 3 August 1987 (*Table 3*). At these times, discharge was low and summer temperatures high, conditions that favor maximum isotopic enrichment. Given the 1-per-mill precision of the δD measurements, no demonstrable difference is shown in δD between the samples taken at and 4 km downstream from the spring on these three dates. On the other hand, an inverse relation exists between δD and discharge during March thru May 1988. We show later that when δD is weighted for discharge, it is approximately 2.5 per mill lighter than the median δD of samples collected at the gaging station. Thus, we must leave open the possibility of a small (2–3 per mill) en-

Table 3 Stable-isotope and discharge data for Peak Spring Canyon Creek and Peak Spring, Spring Mountains, Nevada. Peak Spring, located at SW1/4, SW1/4, SE1/4, section 28, T. 19 S., R. 56 E. at an altitude of ~3260 m, was sampled only on 6/23/87 by Hershey (1989); all other data from Peak Spring Canyon Creek gaging station, ~4 km downstream of, and ~1200 m lower than, Peak Spring; Peak Spring Canyon Creek data are from Thomas et al. (1991, 1996), from J.M. Thomas (USGS, Carson City, NV, written communication, 1996) or from T.B. Coplen (USGS, Reston, VA, written communication, 1997). Conversion factor: 1 cfs = 28.32 L/s

Date	Isotopic content (per mill)		Discharge (cfs)
	Deuterium	Oxygen-18	
9/27/1986	– 92.5	–13.1	0.44
4/7/1987	– 93.5	–13.4	0.55
6/9/1987	– 92.0	–13.0	2.0
6/23/1987	– 94.0	–13.1	1.0
8/3/1987	– 92.5	–13.0	0.64
11/10/1987	– 97.5	–13.6	0.91
3/8/1988	– 98.0	–13.7	1.8
4/5/1988	–101	–13.8	2.8
5/17/1988	– 98.5	–13.8	14
6/23/1988	– 95.5	–13.6	1.9
9/6/1988	– 95.5	–13.2	1.1
10/18/1988	– 94.5	–13.3	0.71
11/25/1988	– 94.5	–13.4	0.65
5/26/1989	– 95.0	–13.2	1.1
7/5/1989	– 96.0	–13.2	0.49
7/26/1989	– 94.5	–12.9	0.30
10/19/1989	– 91.5	–13.1	0.40
11/16/1989	– 93.0	–13.2	0.26

richment of the δD of Peak Spring water as it moves 4 km to the Peak Spring Canyon Creek gaging and δD sampling station.

Deer Creek Spring

Deer Creek Spring emerges from fractured Paleozoic-age carbonate rock (Ordovician-age Pogonip Group) at an altitude of 2870 m (Hershey 1989) on the northeastern side of the Spring Mountains (*Fig. 1*). Hershey (1989) measured the discharge at this site every 5 min; hourly averages of these data form the spring-discharge hydrographs in *Figure 5* (from Fig. 25 of Hershey 1989). Deuterium values from Appendix D in Hershey (1989) have been added above these hydrographs, which otherwise are unaltered. In addition to the isotopic data added to this figure, Hershey's (1989) Appendix D also indicates that on 28 June 1985 the δD was –97 per mill.

R.L. Hershey has continued periodic measurements at Deer Creek Spring since publication of his M.A. thesis in 1989. The stable-isotope content of the spring water varied between –101 and –96 per mill between 1987 and 1991 (Hershey et al. 1991); the post-1988 data have not yet been published and are not included in this paper.

Isotopic Composition of Precipitation

A brief overview of the synoptic climatology of southern Nevada is given prior to presenting the stable-isotope composition of snow, snowmelt, and rain in the Spring Mountains. Houghton et al. (1975, pp 14–19) note three storm types – Pacific fronts, Great Basin lows, and summer thunderstorms of monsoonal origin – that bring moisture into southern Nevada at different times of the year. We discuss each in turn.

Eastward-moving fronts, associated with the Aleutian Low, bring maritime moisture into the Great Basin from October through June (Houghton 1969; Houghton et al. 1975, Fig. 11), with the heaviest Pacific frontal precipitation occurring from December through February. Great Basin lows develop along cold fronts that move inland from the Pacific. They are most common from April through June, and least common from July through September (Houghton et al. 1975, Fig. 12). Houghton et al. (1975, p. 16) state: "While Great Basin lows occur less often than Pacific types, these storms are more likely to cause precipitation over most of Nevada because the low is directly over the region. They

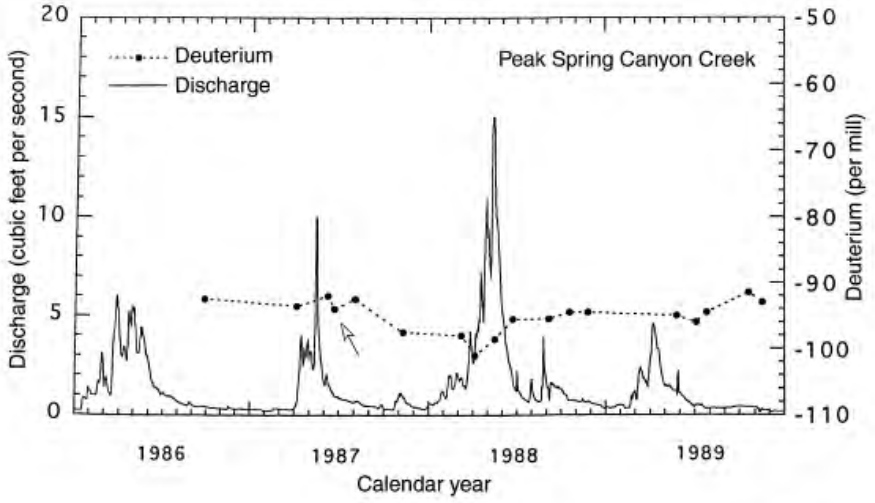

Fig. 4 Daily discharge and periodic δD content of Peak Spring Canyon Creek, 1986–89. *Arrow* identifies δD content of water collected at Peak Spring on 23 June 1987, approximately 4 km up-canyon from the Peak Spring Canyon Creek gaging station. Discharge data from U.S. Geological Survey, Carson City, Nevada

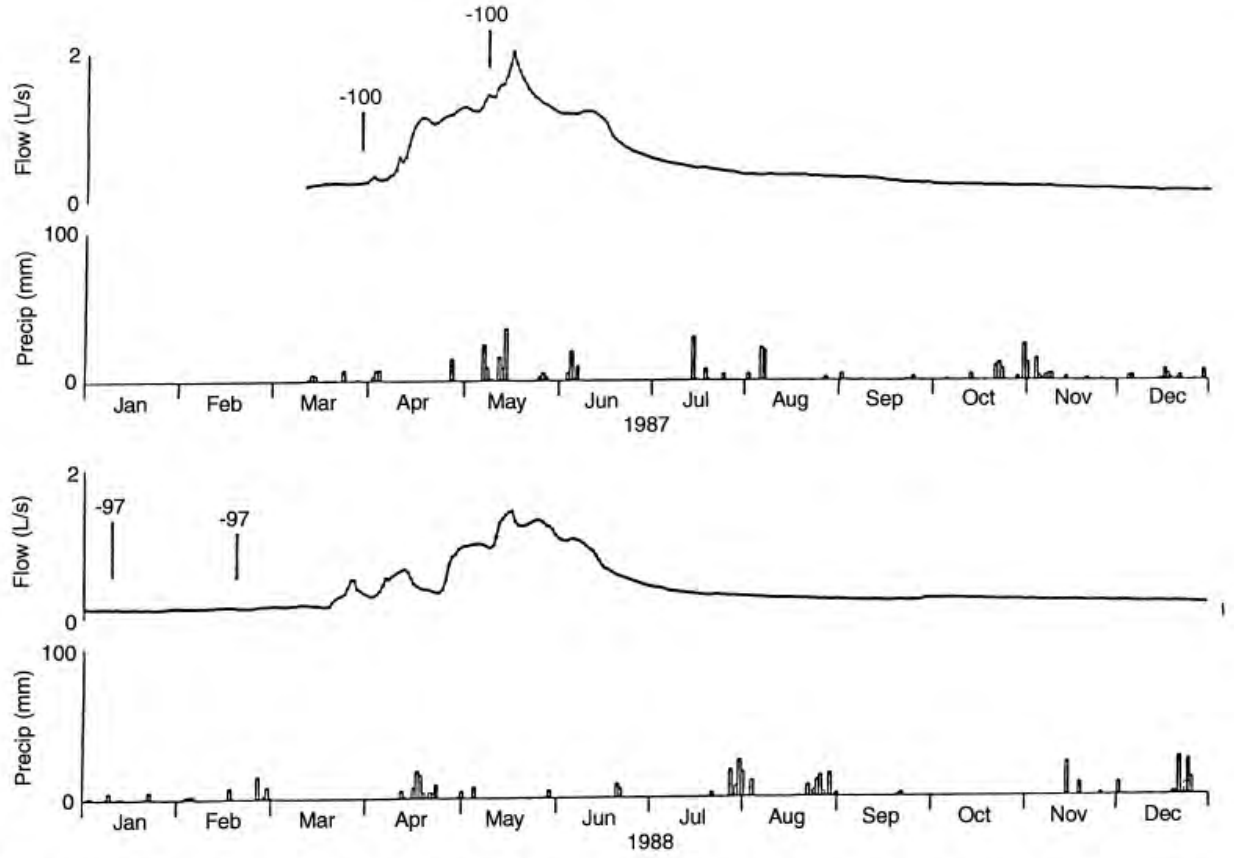

Fig. 5 Discharge of, and precipitation at, Deer Creek Spring, 1987–88 (from Hershey 1989, Fig. 25). *Numbers* above hydrographs are δD content of spring water, as given in Appendix D of Hershey (1989)

are the chief sources of precipitation over the central and eastern parts of the state." Moisture derived from such lows comes from the Pacific Ocean. Together, the Pacific frontal storms and Great Basin lows generate approximately two thirds of the annual precipitation in southern Nevada (Houghton 1969, Fig. 64B).

The third storm type described by Houghton et al. (1975, Fig. 13) – summer thunderstorms – occur chiefly in July through September, delivering moisture advected from either or both the Gulf of Mexico and the Gulf of California. Hales (1972, 1974) and Brenner (1974) consider such storms to be of monsoonal origin, deriving their moisture principally from the Gulf of California. An origin from the tropical Pacific Ocean, via the Gulf of California, has recently been strongly documented by Douglas et al. (1993).

Since publication of Houghton's (1969) monograph on Nevada precipitation, the major effect of El Niño events on precipitation and stream flow in the southwestern United States has become apparent (Cayan and Webb 1992; Schonher and Nicholson 1989). During El Niño events, which occur at irregular 2- to 5-year intervals, warm central tropical Pacific waters extend eastward toward South America and then spread south and north, reaching to and beyond California. It is beyond the scope of this report to discuss the origins of El Niño, which itself is the warm phase of a larger coupled atmospheric-oceanic phenomenon referred to as ENSO (El Niño/Southern Oscillation). An excellent overview of ENSO is presented by Diaz and Kiladis (1992), and a discussion of various definitions of El Niño, with a listing of El Niño occurrences since 1951, is presented by Trenberth (1997). During some (but not all) El Niño events, precipitation in the deserts of southern California is as much as 185% of the mean (Schonher and Nicholson 1989), with significant increases in stream flow throughout the western states (Cayan and Webb 1992).

With the above cursory introduction to the synoptic climatology of southern Nevada, we discuss the stable-isotope composition of cool-season precipitation (i.e., precipitation of Pacific Ocean origin that fell between October through June) and summer rain (i.e., rain of Gulf of California origin that fell between July through September). Winograd and Riggs (1984) and Hershey et al. (1991) used slightly different definitions of these two precipitation periods. They both defined "cool-season" precipitation as that occurring between November through May, and "warm-season" precipitation as that occurring between June and October. The definitions of cool season and summer precipitation used in this report are based on Houghton's (1969) and Houghton et al.'s (1975) description of the synoptic climatology of Nevada.

Snow Cores

In February and March of each year from 1975 through 1978, Robert L. Speck and his colleagues in the Agricultural Research Service measured the snowpack on the Spring Mountains by coring along six snow courses, shown in *Figure 1*. Their measurements of average snow depth and average water content along each snow course is given in *Table 4*, together with the $\delta^{18}O$ and δD of the melted snow cores. A δD–$\delta^{18}O$ plot of these data is shown in *Figure 6*, together with isotopic data for 26 additional snow cores, from various locations in the central Spring Mountains, collected in the winter of 1987–88 by R.L. Hershey (1989, Appendix D). The location of Hershey's snow cores are not shown in *Figure 1*, but his stable-isotope data are reproduced in our *Table 4*. Hershey (1989) provides no snow-depth or water-content data for his sampling stations, though we are told that he collected an integrated sample of existing snow surveys of 1975–78 by R.L. Speck (Agricultural Research Service Las Vegas, NV, written communication, 1975, 1976, 1977, and 1978); location and average altitude of snow courses given in Footnote. Snow-core samples designated "spm" are from Appendix D in Hershey (1989) and were analyzed at Desert Research Institute, Las Vegas, Nevada; these stable-isotope results are also reported relative to the VSMOW standard. Hershey's samples collected on 1/7/88 and 1/26/88 are described as "Snow (from near surface)." Conversion factor: 1 inch = 25.4 mm

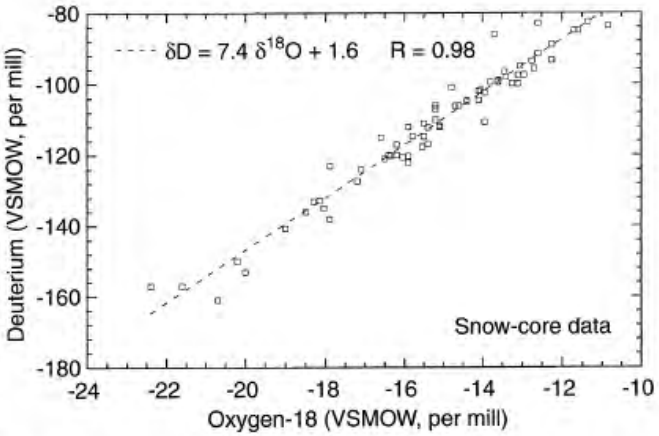

Fig. 6 Deuterium (δD) and oxygen-18 ($\delta^{18}O$) of snow from the Spring Mountains snow-course surveys of 1975–78, plus the snow data of Hershey (1989, Appendix D)

Table 4 Stable-isotope, water-content, and other data for snow cores, Spring Mountains, Nevada. Data from cores obtained dur-

Location/ sample no.	Date	Average snow depth (in.)	Average water content (in.)	Isotopic content (per mill)		Station altitude (m)
				Deuterium	Oxygen-18	
Clark Canyon #1	2/26/1975	15	4.2	−118	−15.6	2600
	3/25/1975	27	8.3	−112	−15.1	
	2/27/1976	20	6.0	−120	−15.9	
	3/30/1976	12	4.5	−141	−19.0	
	3/1/1977	2.0	0.6	− 97.4	−13.0	
	3/2/1978	56	16	− 95.0	−13.0	
	3/28/1978	50	20	− 85.0	−11.7	
Trough Springs	2/26/1975	9.0	2.8	−115	−15.5	2500
	2/27/1975	25	7.0	−135	−18.0	
	2/27/1976	12	3.8	−127	−17.2	
	3/30/1976	4.0	1.3	−133	−18.2	
	3/1/1977	2.6	1.0	− 83.6	−10.8	
	3/28/1978	46	19	− 93.5	−12.8	
Kyle Canyon #2	2/27/1975	9.0	2.3	−110	−14.0	2600
	3/24/1975	25	7.1	−105	−14.4	
	2/26/1976	22	7.8	− 98.1	−13.4	
	3/29/1976	14	5.8	− 99.5	−13.6	
	2/28/1977	4.2	1.5	− 93.4	−12.2	
	3/1/1978	65	21	− 99.0	−13.6	
	3/29/1978	56	25	− 85.0	−11.6	
Rainbow Canyon #2	2/27/1975	18	4.9	−112	−15.1	2400
	3/24/1975	37	10.4	−112	−15.4	
	2/26/1976	29	9.3	− 91.5	−12.6	
	3/29/1976	27	11	−106	−14.6	
	2/28/1977	9.8	3.4	− 96.6	−13.4	
	3/1/1978	80	26	− 82.5	−11.4	
	3/29/1978	78	32	− 89.0	−12.2	
Lee Canyon #2	2/27/1975	18	4.6	−121	−16.0	2800
	3/24/1975	26	8.7	−120	−16.4	
	2/26/1976	30	8.9	− 99.9	−13.2	
	3/29/1976	16	6.2	−115	−15.8	
	2/28/1977	5.2	1.5	− 95.7	−12.7	
	3/3/1978	73	22	−102	−14.0	
	3/29/1978	57	24	− 99.5	−13.8	

Table 4 Continued

Location/ sample no.	Date	Average snow depth (in.)	Average water content (in.)	Isotopic content (per mill)		Station altitude (m)
				Deuterium	Oxygen-18	
Lee Canyon #3	2/27/1975	10	2.6	−122	−15.9	2600
	3/24/1975	24	7.7	−117	−15.4	
	2/26/1976	21	7.0	− 99.1	−13.6	
	3/29/1976	11	4.9	−106	−14.7	
	2/28/1977	3.0	1.0	−102	−14.0	
	3/3/1978	58	17.5	−104	−14.1	
	3/29/1978	45	19.6	− 97.5	−13.1	
spm-1-sn	1/14/1987	–	–	−120	−16.2	1677
spm-2-sn	1/14/1987	–	–	−111	−15.5	1804
spm-3-sn	1/14/1987	–	–	−106	−15.2	1878
spm-4-sn	1/14/1987	–	–	−100	−13.1	1768
spm-5-sn	1/14/1987	–	–	−107	−15.2	2073
spm-6-sn	1/14/1987	–	–	−102	−14.1	1707
spm-8-sn	1/15/1987	–	–	−110	−15.2	2073
spm-10-sn	1/21/1987	–	–	−124	−17.1	2268
spm-11-sn	1/21/1987	–	–	−120	−16.4	2780
spm-12-sn	1/21/1987	–	–	−150	−20.2	2438
spm-13-sn	2/25/1987	–	–	− 86.0	−13.7	2073
spm-14-sn	2/25/1987	–	–	− 83.0	−12.6	2377
spm-15-sn	2/25/1987	–	–	−101	−14.8	2780
spm-16-sn	2/25/1987	–	–	−123	−17.9	2700
spm-17-sn	2/25/1987	–	–	−112	−15.9	2338
spm-21-sn	3/24/1987	–	–	−115	−16.6	1980
spm-23-sn	3/24/1987	–	–	−136	−18.5	2080
spm-24-sn	3/24/1987	–	–	−133	−18.3	2625
spm-26-sn	3/30/1987	–	–	−117	−16.2	2871
spm-31-sn	5/7/1987	–	–	−138	−17.9	3099
spm-32-sn	5/7/1987	–	–	−105	−14.4	2770
spm-50-sn	12/26/1987	–	–	−153	−20.0	1930
spm-51-sn	12/30/1987	–	–	−157	−22.4	2871
spm-53-sn	1/7/1988	–	–	−161	−20.7	2871
spm-54-sn	1/7/1988	–	–	−157	−21.6	2871
spm-55-sn	1/26/1988	–	–	−121	−16.5	2871

Station	Location	Approximate altitude (m)
Clark Canyon #1	NW1/4, section 8, T. 19 S., R. 56 E.	2600
Trough Springs	NW1/4, section 23, T. 18 S., R. 55 E.	2500
Kyle Canyon #2	NE1/4, section 27, T. 19 S., R. 56 E.	2600
Rainbow Canyon #2	SW1/4, section 31, T. 19 S., R. 57 E.	2400
Lee Canyon #2	SE1/4, section 9, T. 19 S., R. 56 E.	2800
Lee Canyon #3	SE1/4, section 10, T. 19 S., R. 56 E.	2600

ing snow accumulation at each snow bank visited. The slope (~7.4) of the $\delta^{18}O$–δD snow-core data shown in *Figure 6*, is nearly equal to that of the meteoric water line (~8), indicating minimal post-precipitation, or post-collection, isotopic enrichment.

The stable-isotope content of the snow cores shows little correlation with altitude. The snow cores analyzed by Hershey (1989, Appendix D) ranged in altitude from ~1680 to ~3100 m (*Table 4*). The equation relating altitude (x) and δD (y) for his data is $y = -74.96 - 0.019x$, with a correlation coefficient $(r) = 0.40$. Five of the six snow courses sampled by R.L. Speck were within a narrow altitude range (*Table 4*) and are therefore poorly suited for correlations between altitude and stable isotopic.

We are aware that the snow-core stable-isotope data presented in *Table 4* provide no information on the isotopic variations within a snowpack, variations resulting from multiple snowfalls, and "aging" of the snow due to recrystallization, sublimation, and melting (e.g., see Stichler et al. 1981; Friedman et al. 1991). Each of the measurements (*Table 4*) is a weighted average of the water from each snow-course survey, an average that, in turn, would presumably be reflected in snowmelt (discussed below) and, subsequently, in recharge to the fractured Paleozoic-age carbonate rocks, which ultimately transmit it to the spring discharge points.

Snowmelt

As part of this study, 20 samples of snowmelt were collected at various locations in the central Spring Mountains between 1976 and 1978, and four more samples were collected in 1987 by Hershey (1989, Appendix D).

Table 5 Stable-isotope data for snowmelt, Spring Mountains, Nevada. Precision of δD and δ^{18}O measurements given in *Table 1*; station altitudes estimated to ±10 m from USGS topographic maps, scale 1:62500; data for stations designated "spm" are from Appendix D of Hershey (1989)

Station number	Location	Date	Isotopic content (per mill)		Altitude (m)
			Deuterium	Oxygen-18	
Hess #2	Rainbow Canyon	3/19/1976	− 93.5	−12.6	2390
Hess #12	W. side Wheeler Pass	3/20/1976	−107	−14.3	2020
Hess #5	Along Deer Creek Rd.	3/19/1976	− 79.8	−10.6	2480
Hess #11	W. side Wheeler Pass	3/20/1976	− 95.9	−12.6	2110
Hess #8	Along Lee Canyon Rd.	3/19/1976	− 99.2	−12.9	2330
Hess #11a	W. side Wheeler Pass	3/20/1976	− 93.0	−12.5	2110
Hess #13	Lovell Summitt	3/20/1976	− 66.8	− 9.5	2070
Hess #10	Wheeler Pass	3/20/1976	− 97.8	−13.2	2050
Hess #9	FS Boundary	3/19/1976	− 94.9	−12.2	2220
Hess #7	1 mi. Girl Scout camp	3/19/1976	−108	−14.4	2460
Hess #1	Kyle Canyon-Decrck	3/19/1976	− 85.9	−11.2	2200
Hess #3	Mary Jane Falls	3/19/1976	− 88.9	−11.9	2550
Hess #6	McWilliams Campground.	3/19/1976	−112	−15.4	2620
Hess #4	Mt. Charleston Lodge	3/19/1976	− 89.2	−12.2	2340
IJW #3	NE1/4SE1/4Sec26T19SR	3/27/1978	− 80.5	− 9.9	2410
IJW #2	Near Hess #1	3/27/1978	− 84.5	−11.2	2090
IJW #1	Angel Peak turnoff	3/27/1978	− 89.0	−12.2	2550
Hess #7	1 mi. Girl Scout camp	3/27/1978	− 96.5	−13.2	2460
Hess #6	McWilliams Campground.	3/27/1978	− 95.0	−12.8	2620
IJW #1	Angel peak turnoff	5/3/1978	−111	−14.6	2550
spm-7-mw	Wood Canyon	1/14/1987	− 87.0	−11.6	1707
spm-18-mw	Switchback Spring	3/24/1987	− 92.0	−12.8	1680
spm-19-sm	Switchback Spring	3/24/1987	−110	−14.0	1798
spm-20-mw	Switchback Spring	3/24/1987	− 99.0	−12.7	1780

Many of the sample locations are shown in *Figure 1*; the isotopic contents of these samples and other pertinent data are given in *Table 5*. An δD–δ^{18}O plot of these data is given in *Figure 7*. The slope of the data (~7.4) is identical to that for the snow cores (*Fig. 6*).

As with the snow cores, little or no relation exists between δD (y) and altitude (x) of the snowmelt collection site, despite altitude differences greater than 900 m. The regression line of δD of snowmelt vs altitude is y = –87.98–0.003x, with a correlation coefficient (r) = 0.073.

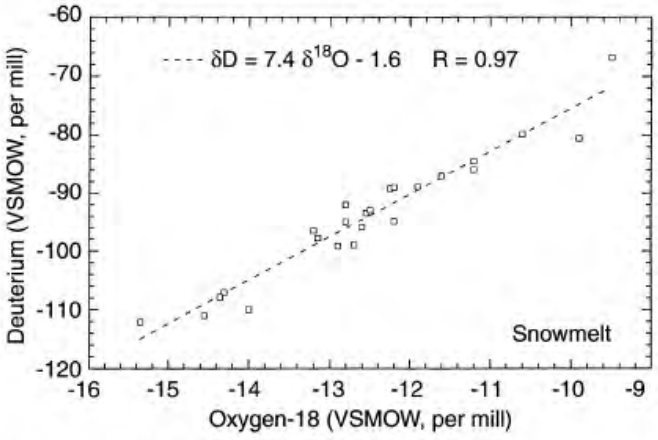

Fig. 7 δD and δ^{18}O of Spring Mountains snowmelt

Cool-Season (October thru June) Rain

Table 6 presents the stable-isotope data for 24 samples of rain collected during the months of October though June in 1976–78 and 1987–88. The 1976–78 samples were collected within 24 h of the precipitation event. The 1987–88 samples are those collected and reported by Hershey (1989; *Table 5*); they include samples that are representative of several days of rain. Because Hershey (1989) used a heated rain gage, some of his data probably represent melted snow. A δD–δ^{18}O plot of these data is given in *Figure 8*. The slope of the data (8.0) is identical to that of the global meteoric water line.

We make no attempt to correlate the δD of rain with altitude of collection station, because the two stations with the bulk of the data (Spring Mountain Youth Camp and Deer Creek Spring) are with 300 m altitude of each other (*Table 6*).

Summer (July thru September) Rain

Table 7 presents the stable-isotope data for 27 samples of rain collected during the months of July though September 1976, 1987, and 1988. A δD–δ^{18}O plot is given in *Fig. 9*. The slope of these data (~6) is considerably lower than that for the meteoric water line, a finding also observed for Mojave Desert summer precipitation by Friedman et al. (1992; *Fig. 8*). They note δD–δ^{18}O slopes of 5–6, which they believe were caused by evap-

Table 6 Stable-isotope data for cool-season (October–June) rain, Spring Mountains, Nevada. Precision of δD and $\delta^{18}O$ measurements given in *Table 1*. $\delta^{18}O$ value for sample of 1/6/78 was computed using a regression equation for the δD-$\delta^{18}O$ data set for the Spring Mountain Youth Camp (altitude ~2550 m); Lee Canyon Youth Camp at altitude of ~2580 m; Kyle Canyon sample at ~2340 m. Data for Deer Creek Spring #1 (altitude ~2870 m) from Hershey (1989, Table 5)

Location	Date	Rainfall amount (mm)	Isotopic content (per mill)	
			Deuterium	Oxygen-18
Lee Canyon Youth Camp	5/7/1976	17.0	– 46.4	– 7.65
Kyle Canyon	11/15/1976	–	–153	–20.1
Spring Mtn. Youth Camp	5/17/1977	3.00	– 93.4	–12.9
	5/26/1977	5.00	–199	–25.4
	6/8/1977	10.0	– 50.4	– 7.95
	12/30/1977	3.00	– 87.5	–10.6
	1/6/1978	14.6	–132	–17.3
	3/9/1978	20.2	– 92.5	–12.2
	3/31/1978	12.2	– 84.5	–11.8
	4/10/1978	4.10	–112	–15.0
	5/2/1978	11.1	– 98.5	–13.4
	10/20/1978	10.0	– 96.5	–14.2
	11/13/1978	5.00	– 71.0	–11.0
Deer Creek Spring #1	10/1987	65.8	–107	–15.5
	11/87	15.7	–107	–15.5
	11/87	17.3	– 82.0	–11.8
	12/87	7.10	–135	–15.6
	12/87	30.2	–157	–22.4
	1/88	3.00	–159	–21.2
	1/88	15.2	–121	–16.5
	4/88	69.1	– 92.0	–12.3
	5/88	5.80	– 92.0	–12.3
	5/88	12.7	– 83.0	–12.2
	6/88	16.5	– 79.0	–11.0

oration during transit from the cloud base to the ground surface.

Discussion

As mentioned previously, we do not know the hydrogeologic boundaries of the groundwater basins tributary to each of the four springs sampled; nor do we know the isotopic content of rain, snow, snowmelt, and soil waters in the immediate vicinity of each spring. Additionally, the data we do have is disparate in type, time, and geographic location. Keeping these limitations in mind, we present below some tentative observations drawn from our data.

Snowmelt Recharge

All four springs discussed above (Trout, Cold Creek, Peak, and Deer Creek; *Figs. 2–5*) had peak discharges in the late spring months, declining to base-flow levels in the late fall and winter. This pattern, best seen in

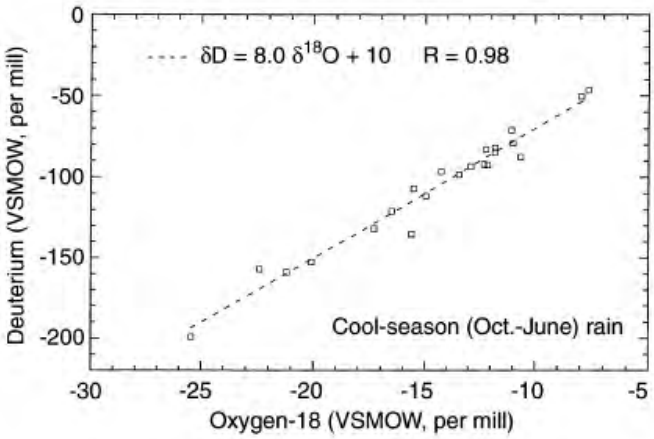

Fig. 8 δD and $\delta^{18}O$ of cool-season (October thru June) rain, Spring Mountains, Nevada

Table 7 Stable-isotope data for summer (July–September) rain, Spring Mountains, Nevada. Precision of δD and $\delta^{18}O$ measurements given in *Table 1*; at Lee Canyon Youth Camp the first of the two samples reported for 7/27/76 was collected after initial hour of rain, and the second sample at end of second hour; the first sample reported for 7/30/76 was collected at start of rain, and the second sample after 50 minutes. Samples from Deer Creek Spring #1 from Table 5 of Hershey (1989); Hershey's data, listed by month, presumably represent composite of several precipitation events

Location and sample no.	Date	Rainfall amount (mm)	Isotopic content (per mill)	
			Deuterium	Oxygen-18
Spring Mtn. Youth Camp	7/16/1976	2.80	– 50.2	– 7.50
	7/26/1976	5.80	– 29.6	– 2.45
	7/27/1976	4.10	– 38.2	– 6.10
	7/30/1976	2.50	– 34.5	– 5.15
	7/30/1976	2.80	– 29.9	– 5.60
	9/7/1976	8.60	– 60.0	– 9.45
	9/9/1976	10.9	–139	–19.2
	9/10/1976	23.8	– 82.8	–12.2
	9/25/1976	25.0	– 85.9	–12.9
	9/6/1978	24.0	– 39.0	– 4.10
Lee Canyon Youth Camp	7/15/1976	3.00	– 48.8	– 6.85
	7/16/1976	24.0	– 39.2	– 6.50
	7/25/1976	30.0	– 32.8	– 1.10
	7/26/1976	17.0	– 51.8	– 9.20
	7/27/1976	19.0	– 59.0	–10.0
	7/27/1976	–	– 73.5	–11.4
	7/28/1976	35.0	– 48.2	– 7.60
	7/30/1976	–	– 46.9	– 7.70
	7/30/1976	–	– 35.3	– 5.60
	9/5/1976	21.5	– 83.8	–12.4
	9/24/1976	10.0	– 93.0	–12.6
	9/26/1976	14.5	– 91.3	–13.7
Deer Creek Spr. #1	8/87	4.80	– 74.0	–10.7
	8/87	43.4	– 79.0	–11.9
	9/87	5.30	– 46.0	– 6.80
	9/87	4.10	– 40.0	– 5.40
	8/88	74.4	– 75.0	–11.3

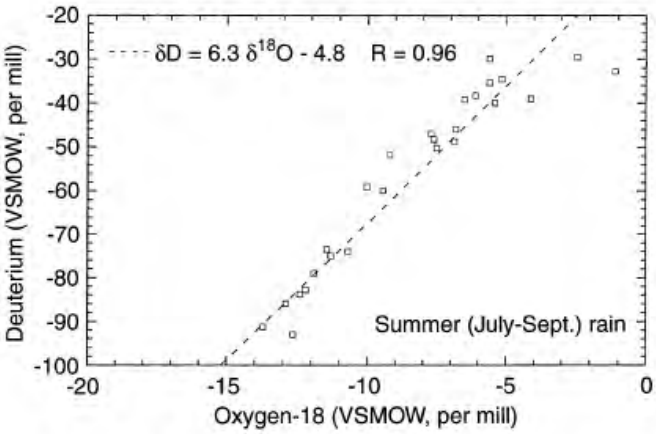

Fig. 9 δD and δ^{18}O of summer (July thru September) rain, Spring Mountains, Nevada

those springs measured daily (*Figs. 4, 5*), presumably reflects snowmelt recharge to the groundwater basins feeding the springs. Some years, for example 1974, 1975, and 1977 at Trout and Cold Creek Springs (*Figs. 2, 3*), appear to have had minimal snowmelt recharge, consistent with the snowpack data described below.

Snowmelt Recharge and El Niño Events

The high discharges in the spring months of 1973, 1978, and 1983 at Trout Spring (*Fig. 2*; *Table 1*) and in 1973 and 1978 at Cold Creek Spring (*Fig. 3*; *Table 2*) followed the winters within the El Niño events of 1972–73, 1977–78, and 1982–83 (Trenberth, 1997). To see whether this apparent relation has any validity, we show in *Figure 10* the daily discharge hydrograph for Peak Spring Canyon Creek for calendar (as opposed to water) years 1978–94. This record contains only two breaks, one extending from the fall of 1983 to the fall of 1984, and the second from the fall of 1993 to the summer of 1994. The approximate mid-point middle of the El Niño events that occurred between 1977 and 1994 are marked above the hydrograph by the vertical lettering (EN 77–78, EN 79–80, etc.). The exact duration of each El Niño (as given in Table 2 of Trenberth, 1997) and its relation to the month of maximum discharge at Peak Spring Canyon Creek is given in *Table 8*. Seven of eight times that discharge equaled or exceeded 10 cubic feet per second (cfs; ~283 L/s; *Fig. 10*) occurred within or in the snowmelt months immediately following an El Niño event. Furthermore, the peak discharge (~35 cfs, ~990 L/s), during the spring months of 1983, occurred within the largest El Niño of the century, the 1982–83 event. Although this relation of Peak Spring Canyon Creek discharge to El Niño events is intriguing, we need to keep in mind Cayan and Webb's (1992) cautionary remarks regarding El Niño events and western United States stream flow. They stated "the occurrence of El Niño conditions alone is not sufficient to explain increased flood frequency; instead, large floods appear to occur during a small subset of years associated with El Niño conditions." As an example of this cautionary note, the average water content of the snow cores collected during the Spring Mountains snow-course surveys of February and March of 1978 (*Table 4*) was ~14 times that in 1977, although 1977 was associated with the El Niño event of 1976–77 (Table 2; Trenberth, 1997).

Near Constancy of δD and δ^{18}O of Spring Waters

A characteristic that is common to all four springs is the near constancy of δD (or of δ^{18}O, had we elected to plot these data) with time, despite as much as an order-

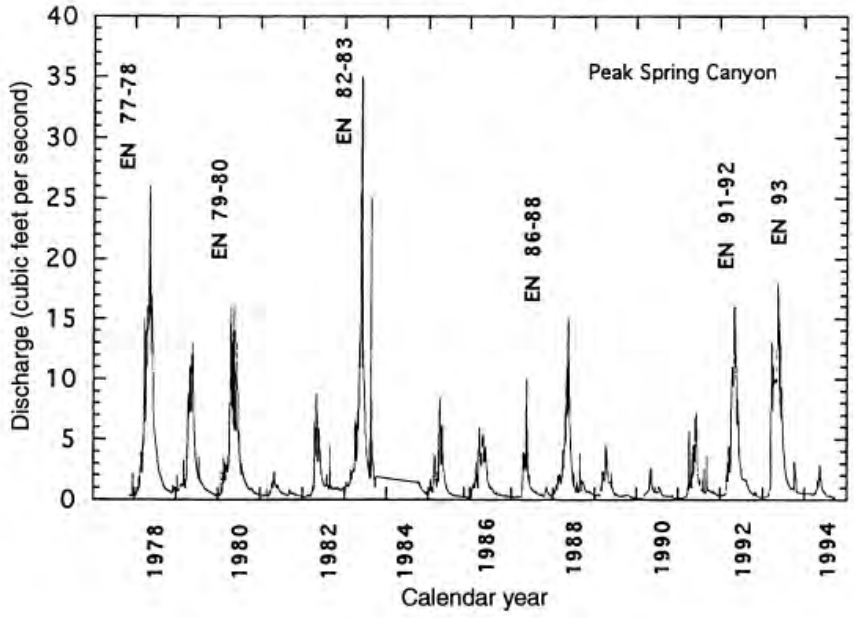

Fig. 10 Daily discharge at Peak Spring Canyon Creek and El Niño events, 1978–94. The *vertical lettering* is centered over the mid-points of each El Niño event; the exact duration of each event is given in *Table 8*. Discharge data from U.S. Geological Survey, Carson City, Nevada

Table 8 El Niño events and maximum discharge at Peak Spring Canyon Creek, Spring Mountains, Nevada. Entries in first three columns from Trenberth (1997, Table 2)

Time of El Niño event			Month and year of maximum discharge
Years	Start	End	
1977–1978	7/77	1/78	5/78
1979–1980	10/79	4/80	4/80
1982–1983	4/82	7/83	5/83
1986–1988	8/86	2/88	5/87, 5/88
1991–1992	3/91	7/92	4/92
1993	2/93	9/93	5/93

Table 9 Median, mean, and weighted mean δD content of spring waters, snow, snowmelt, and summer (July–Sept.) and cool-season (Oct.–June) rains. Except for spring waters, the data are grouped by year(s) of collection. The weighted mean δD values were computed using the volumetric data, i.e., discharge, precipitation amount, or water-content data, in *Tables 1–7*

Data grouping	δD (per mill)		
	Median	Mean	Weighted mean
Trout Spring	– 97.6	– 97.7	– 96.9
Cold Creek Spring	–100	–100	– 99.4
Peak Spring Canyon[1]	– 94.5	– 95.0	– 97.0
Snow cores 1975	–116	–116	–116
Snow cores 1976	–106	–111	–107
Snow cores 1977	– 96.1	– 94.8	– 95.1
Snow cores 1978	– 95.0	– 93.9	– 93.2
Snow cores 1987–88	–118	–121	[2]
Snowmelt 1976–78	– 94.2	– 93.4	[2]
Snowmelt 1987	– 95.5	– 97.0	[2]
Rain (Oct.–June) 1976–78	– 93.4	–101	– 91.4
Rain (Oct.–June) 1987–88	–107	–110	–106
Rain (July–Sept.) 1976	– 49.5	– 58.7	– 61.7
Rain (July–Sept.) 1987–88	– 74.0	– 62.8	– 74.0

[1] Peak Spring Canyon Creek values were computed including the single δD measurement for water collected at Peak Spring. Exclusion of this value changes the weighted mean by 0.1 per mill; the median and mean are unaffected

[2] Weighted mean δD's could not be calculated for these groupings in absence of volumetric data

of-magnitude variation in discharge (*Figs. 2–4*). At Trout Spring, δD varied <5 per mill between 1970 and 1989 (*Fig. 2*; *Table 1*); at Cold Creek, ~6 per mill between 1968 and 1988 (*Fig. 3*; *Table 2*); and at Peak Spring, ~9 per mill between mid-1986 and mid-1989 (*Fig. 4*; *Table 3*). At Deer Creek Spring, Hersey et al. (1991) reported a variation of 5 per mill between 1987 and 1991. These variations are a fraction of the variation of 170 per mill that was measured in the potential recharge sources discussed above and summarized below.

Absence of Variation of δD (or of $\delta^{18}O$) with Altitude

That the stable-isotope content of precipitation varies markedly (and inversely) with the altitude of the sampling station has been shown for many regions. In the Sierra Nevada, for example, Smith et al. (1979, their Table 6) observed that δD decreased from 20–45 per mill per 1000 m increase in station altitude during nine different storms, with a mean value of –33 per mill per 1000 m. Friedman et al. (1992) report a gradient of –20 per mill per 1000 m for precipitation in the Transverse and Peninsular Ranges of southern California. The decrease in the δD of precipitation with altitude is caused by the adiabatic uplifting of moist air masses (as they cross a mountain range), with condensation occurring at successively lower temperatures with increasing altitude (Smith et al. 1979). The lower the condensation temperature, the greater the isotopic fractionation, and the greater the depletion of δD in the next parcel of moisture to condense.

In the Spring Mountains, the snow and snowmelt δDs show no variation of δD with altitude, despite station-altitude differences of as much as 1400 m (see *Tables 4, 5*). Major differences in the altitude of the springs also has little influence on the mean δD content of spring discharge, as seen in the following table (data from *Tables 1–3*, and from Hershey 1989).

Spring	Altitude (m)	Discharge weighted δD (VSMOW, per mill)
Cold Creek	1,930	–99.4
Trout	2,360	–96.9
Deer Creek	2,870	–98 (average of 5)
Peak Spring	3,260	< –97.0

As mentioned in the discussion of Peak Spring, the δD values measured at the Peak Spring Canyon Creek gaging station (~1200 m lower than Peak Spring) might be a few per mill more positive than δD of water at the spring, i.e., the spring water δD might be more negative than –97.0 by a few per mill. The value given for Deer Creek is unweighted, being an average of five measurements reported by Hershey (1989).

The absence of an isotopic-altitudinal gradient in the Spring Mountains is not unique. Coplen (1993, p. 234) noted that "the altitude effect is often not seen (1) on mountains interior to a continent ..., (2) for precipitation of snow, and (3) on the lee side of mountains."

Age of the Spring Waters

Included in *Tables 1* and *2* are tritium (^3H) data for Trout and Cold Creek Springs. These data yield diverse interpretations, especially when used in conjunction with the spring-discharge and water-temperature data; with International Atomic Energy Agency (IAEA 1992) data for ^3H in precipitation at Albuquerque (New Mexico), Salt Lake City (Utah), or Menlo Park (California); and with sparse ^3H data for southern Nevada precipitation. They can be used to argue that Trout Spring waters are at most a few years old, and that Cold Creek Spring base flow might be a few decades old, or perhaps (using the sparse Nevada data)

vice versa. In the absence of weighted annual ^3H data for southern Nevada precipitation, an unequivocal interpretation of the ^3H data appears unlikely, especially in view of large differences between the ^3H content of Menlo Park precipitation and that at Albuquerque and Salt Lake City (IAEA 1992). Nevertheless, we include the ^3H data in *Tables 1* and *2*; perhaps they will someday be of use to other workers. The presence of more than 10 TU (tritium units) in the springs unequivocally attests to water ages less than 50 years old (Mazor 1997, p. 202).

Our hydrogeologic intuition suggests that the water discharging from the three upland springs (Trout, Peak, and Deer Creek) is at the most a few years old, whereas the base flow at Cold Creek Spring (located at the foot of the Spring Mountains) is an admixture of waters, some of which may be several times older than those discharging from the upland springs. For example, it is difficult to believe that the residence time of Peak Spring water is more than a year or two, given (a) the location of Peak Spring (~400 m below the crest of the Spring Mountains), (b) the relatively high fracture transmissivity and low effective porosity of the dense Paleozoic-age carbonate-rock aquifers of southern Nevada (Winograd and Thordarson 1975), and (c) the shape of daily-discharge hydrograph at Peak Spring Canyon Creek (*Fig. 10*).

Magnitude of Summer Recharge to the Spring Mountains

We return to the question that initiated this study. Do the dramatic summer convective storms contribute recharge to the Spring Mountains? Specifically, during the period of our records (1968–89), did summer precipitation make up a significant percentage of the total spring discharge? In a reconnaissance study of the stable-isotope content of precipitation and spring waters in the Spring Mountains, Winograd and Riggs (1984) concluded that "recharge occurs primarily from cool season precipitation; infiltration from the dramatic summer convective storms seldom reaches the water table." In contrast, Hershey (1989, Tables 5–7, pp 61–75) concluded, on the basis of the stable-isotope content of precipitation events in 1987 and 1988, that summer rains did provide recharge to Deer Creek Spring, although he did not quantify his statement. Subsequently, in an abstract summarizing data collected between 1987 and 1991, Hershey et al. (1991) maintained that 40% of the spring discharge was derived from warm-season precipitation, which they defined as encompassing the months of June to October.

Figures 11 and *12* summarize all of the data presented in this paper, including those published by Hershey (1989) and Thomas et al. (1991, 1996). *Figure 11* gives the median value of 14 different groupings of the data given in *Tables 1–7*. The groupings were chosen to highlight the annual variability in isotopic content of summer and cool-season precipitation. Because the snowmelt data (*Table 5*) and some snow-core data (*Table 4*) do not permit volumetric weighting of the isotopic values, we elected to utilize median values in constructing this illustration. Median δD values are nearly identical with weighted δD values, as seen in *Table 9*, which compares medians, means, and weighted means for these 14 groupings of data. For 10 of 11 categories that could be weighted, the weighted mean and the median δD values agree within 2.5 per mill; for 7 of 11, the agreement is within 1 per mill. The first feature of interest in *Figure 11* is that the median values yield a δD–δ^{18}O linear correlation with a slope of ~7.8, which is nearly equivalent to the global meteoric water line (slope ~8) of Craig (1961). The second feature of interest in *Figure 11* is, as mentioned, the wide scatter of δD–δ^{18}O contents of summer rain, cool-season rain, snow cores, and snowmelt from year to year. For example, approximately 23 per mill δD separates the median values of snow cores sampled in 1978 and 1987–88, and approximately 24 per mill separates the summer-rain

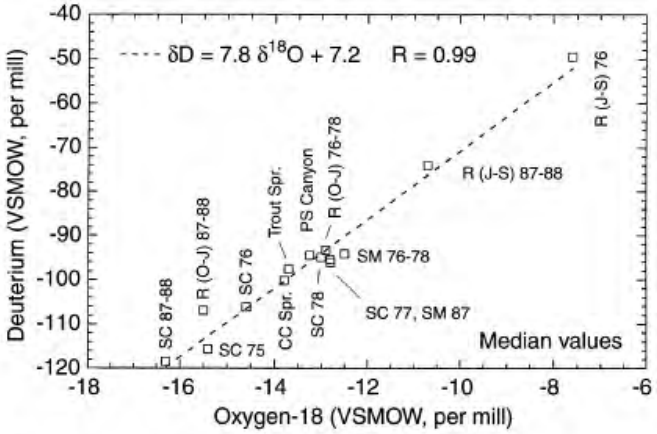

Fig. 11 Median δD and δ^{18}O for spring waters, snow, snowmelt, and rain, Spring Mountains, Nevada. *SC*, snow; *SM*, snowmelt; *R (O-J)*, cool-season rain; *R (J-S)*, summer rain; *CC Spr*, Cold Creek Spring; *PS Canyon*, Peak Spring Canyon Creek; *numbers next to letters* indicate year(s) in which samples were collected

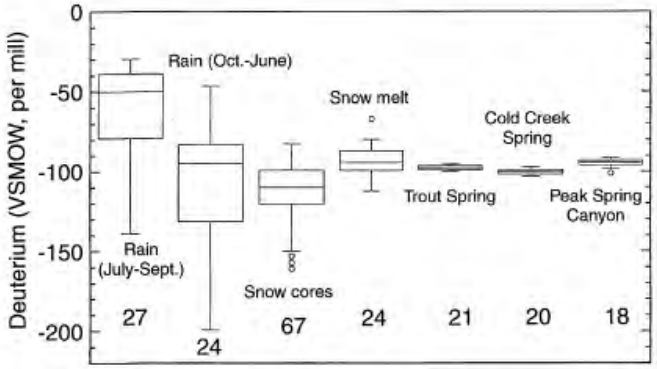

Fig. 12 Box plot of δD concentration in spring waters, snow, snowmelt, and rain, Spring Mountains, Nevada. See text for explanation of plot

samples collected in 1976 vs that in 1987–88. Thirdly, the δD and δ^{18}O values for Trout Spring, Cold Creek Spring, and Peak Spring Canyon Creek occur well within some of the groupings representing cool-season precipitation, but they are ~20 per mill more negative in δD (and 2.5 per mill more negative in δ^{18}O) than the most negative value for summer rain.

Figure 12 presents the δD data in a box plot. Such plots permit a qualitative comparison of the δD (or of δ^{18}O) of the five major types of data, i.e., summer rain, cool-season rain, snow cores, snowmelt, and spring discharge. A more sophisticated statistical analysis does not appear warranted, given the uneven temporal sampling of each data type and the numerous physical processes affecting the δD of each type. Each box encloses 50% of ranked δD data for the specified data type, with the median shown by the horizontal line within each box. That is, the base of each box marks the upper bound of the lower quartile (LQ) of the ranked data, and the top of the box is the lower bound of the upper quartile (UQ). The lines extending below and above each box mark the minimum and maximum values of the ranked data, except for a few outliers that are shown by circles. Outliers are defined as values that are more than 1.5 x (UQ–LQ) distant from the inner bounds of the upper or lower quartile; outliers are included in the ranked data. The numbers just above the lower margin of the figure represent the total number of samples in each population. For example, the graphical depiction for snow cores is based on 67 samples. The median value is –110 per mill, with an LQ and UQ of –120 and –100 per mill, respectively. The remaining data, with the exception of three outliers, are between –150 and –82 per mill. A box plot of the δ^{18}O data also was prepared; it provides no additional information and is therefore not shown.

In *Figure 12*, the range of δD values (both within the boxes and between the vertical lines) decreases from left to right in the plot. Such a reduction is not unexpected in that the snow data represent the weighted averages of several precipitation events, whereas the rain data are for individual storms. The snowmelt data, in turn, apparently represent further homogenization of the isotopic content of the snow pack, though substantially fewer measurements of snowmelt δD values (24) exist than of snow (67). Finally, the spring waters have very uniform isotopic contents, as mentioned previously. This uniformity presumably represents further homogenization of the isotopic input of recharge during passage through the soil zone and the local groundwater basin that is tributary to each spring.

As indicated by the median values and by the central 50% of the ranked data, *Figure 12* also shows that the waters of Trout Spring, Cold Creek Spring, and Peak Spring Canyon Creek approximate cool-season (October thru June) precipitation. Specifically, the median δD values of the spring waters (–95 to –100 per mill) are between the medians for snow cores (–110 per mill), and snowmelt (–94 per mill). In contrast, the median for summer rain is –50 per mill, or 45–50 per mill heavier than that of the spring waters. The box denoting the central values for the summer rains does not overlap the boxes for any of the other population. Thus, *Figure 12* provides qualitative evidence that cool-season precipitation (snow and rain) is likely to be the major contributor to water discharging from Trout Spring, Cold Creek Spring, and Peak Spring.

Additional qualitative evidence suggestive of minimal summer recharge comes from the hydrographs of discharge from Deer Creek Spring (*Fig. 5*). As mentioned previously, these hydrographs (reproduced from Hershey 1989) are based on discharge measurements recorded every 5 min and averaged over a 1-hr period (Hershey 1989, p. 42). Hershey notes (1989, pp 108–109) that "most summer precipitation occurs in concentrated time periods of several days allowing the thin soil zones to become saturated and for precipitation to recharge through fractures. Considering trends of increasing precipitation and decreased temperatures with increased elevation, along with decreased plant density and decreased soil depth with increased elevations, precipitation from events of several days duration should infiltrate the soil zones and enter fractures at higher elevations." However, despite significant summer rainfall in both 1987 and 1988 (*Fig. 5*), Hershey's (1989) hourly hydrographs (*Fig. 5*) fail to show any evidence of summer (July thru September) recharge reversing the slow decrease in spring discharge to fall–winter base flow.

Using the weighted δD values given in *Table 9*, we present a mass-balance computation as an indicator of the relative contribution of summer rains and cool-season precipitation to the spring discharge at Trout Spring, Cold Creek Spring, and Peak Spring. We used the average of the δD-weighted averages of these springs to represent the δD of spring discharge, obtaining a value of –97.8 per mill. To represent cool-season precipitation, we used the average of the six weighted values in *Table 9* for cool-season precipitation (specifically, the data for snow cores for 1975–78, plus the entries for 1976–78 and 1987–88 rain), obtaining a value of –101.5 per mill. The two weighted entries for summer rain were averaged, yielding a value of –67.8 per mill. Letting the spring discharge have a value of 1, and the respective contributions of cool-season and summer precipitation values of X and 1-X, respectively, we computed the relative contibutions of the two precipitation sources to spring discharge as follows:

$$X(-101.5) + (1\text{-}X)(-67.8) = 1(-97.8)$$

Solving the formula yields a value of X (i.e., cool-season precipitation) = 0.89, and a value of 1-X (i.e., summer rain) = 0.11. Alternatively, using the median values in *Table 9*, so that we might include the snowmelt and snow-core data that we were unable to weigh, we obtained nearly identical values (0.88 and 0.12) for the fraction of spring discharge that came from cool-season and summer precipitation, respectively.

Implicit in such a mass balance are several assumptions, the first being that our disparate precipitation data are, to a first approximation, representative of average isotopic content of precipitation that fell on the hydrogeologic basins feeding Trout Spring, Cold Creek Spring, and Peak Spring during 1975–88. Given the large differences in stable-isotope content of rain, snow, and snowmelt from year to year (*Fig. 11*; *Table 9*), this assumption is open to question. At the same time, the near-constancy of δD between springs (see unnumbered table above), and with discharge at each spring (*Figs. 2–5*) over two decades, suggests a relatively uniform δD of precipitation events leading to Spring Mountains recharge. Another assumption is that the residence time of the groundwater emerging from these springs is relatively short, approximately a few years rather than a decade or more. We consider this assumption valid for the highest altitude springs (Trout Spring, Peak Spring, and Deer Creek Spring), but leave open the possibility that the base flow at Cold Creek might be a mixture of waters of various ages. A third assumption is that little isotopic enrichment of precipitation occurs during recharge. Thus, refinement of the above mass balance will require additional data, especially of cool-season and summer precipitation during El Niño events.

In summary, both qualitative (*Fig. 12*) and semi-quantitative analyses of the data indicate that cool-season precipitation is the dominant source of recharge to the Paleozoic-age carbonate-rock aquifer within the highest portions of the Spring Mountains.

Conclusion

A comparison of the stable-isotope signature of spring waters, snow, snowmelt, summer (July thru September) rain, and cool-season (October thru June) rain indicates that the high-intensity/short-duration summer convective storms, which contribute approximately one third of the annual precipitation to the Spring Mountains, provide only a small fraction (perhaps 10%) of the recharge to this major southern Nevada upland. Late spring snowmelt is the principal means of recharging the fractured Paleozoic carbonate rocks that form the central and highest portion of the Spring Mountains. Daily discharge measurements at Peak Spring Canyon Creek during 1978–94 show that snowpacks were greatly enhanced during El Niño events.

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References

Brenner IS (1974) A surge of maritime tropical air: Gulf of California to the southwestern United States. Monthly Weather Rev 102:375–389

Burchhfiel BC, Fleck RJ, Secor DT, Vincelette RR, Davis GA (1974) Geology of the Spring Mountains, Nevada. Bull Geol Soc Am 85:1013–1022

Cayan DR, Webb RH (1992) El Niño/Southern Oscillation and streamflow in the western United States. In: Diaz HF, Markgraf V (eds) El Niño, historical and paleoclimatic aspects of the Southern Oscillation. Cambridge University Press, Cambridge, pp 29–68

Coplen TB (1993) Uses of environmental isotopes. In: Alley WB (ed) Regional ground-water quality. Van Nostrand Reinhold, New York

Craig H (1961) Isotopic variations in natural waters. Science 133:1702–1703

Dettinger MD, Harrill JR, Schmidt DL, Hess JW (1995) Distribution of carbonate-rock aquifers and the potential for their development, southern Nevada and adjacent parts of California, Arizona, and Utah. US Geol Surv Water-Resour Invest Rep 91–4146:100 pp

Diaz HF, Kiladis GN (1992) Atmospheric teleconnections associated with the extreme phases of the Southern Oscillation. In: Diaz HF, Markgraf V (eds) El Niño, historical and paleoclimatic aspects of the Southern Oscillation. Cambridge University Press, Cambridge, pp 7–28

Douglas MW, Maddox RA, Howard K, Reyes S (1993) The Mexican monsoon. J Climate 6:1665–1677

Eakin TE (1966) A regional interbasin ground-water system in the White River area, southeastern Nevada. Water Resour Res 2:251–271

Fenwick JK (1994) Hydrologists field manual. National Institute of Water and Atmospheric Research Ltd, New Zealand. NIWA Science and Technology Series no. 5, chap 4.5, pp 4-11 to 4-23

Friedman I, Benson C, Gleason J (1991) Isotopic changes during snow metamorphism. In: Taylor HP Jr, O'Neil JR, Kaplan IR (eds) Stable isotope geochemistry: a tribute to Samuel Epstein. Geochem Soc Spec Publ 3:211–221

Friedman I, Smith GI, Gleason JD, Warden A, Harris JM (1992) Stable isotope composition of waters in southeastern California. 1. Modern precipitation. J Geophys Res 97 (D5): 5795–5812

Hales JE Jr (1972) Surges of maritime tropical air northward over the Gulf of California. Monthly Weather Rev 100:298–306

Hales JE Jr (1974) Southwestern United States summer monsoon source: Gulf of Mexico or Pacific Ocean? J Appl Meteorol 13:331–342

Hershey RL (1989) Hydrogeology and hydrogeochemistry of the Spring Mountains, Clark County, Nevada. Master's Thesis, University of Nevada, Las Vegas, 236 pp

Hershey RL, Lyles BF, Hess JW (1991) Stable-isotopic evidence of warm-season recharge to the Spring Mountains, southern Nevada. Geol Soc Am (abstracts with programs) 23 (5): A381

Hess JW, Mifflin MD (1978) A feasibility study of water production from deep carbonate aquifers in Nevada. University of Nevada, Desert Research Institute Publication 41054, 125 pp

Houghton JG (1969) Characteristics of rainfall in the Great basin. Desert Research Institute, University of Nevada, Reno, 205 pp

Houghton JG, Sakamoto CM, Gifford RO (1975) Nevada's weather and climate. Nevada Bureau Mines Geol Spec Publ 2:1–78

Hughes JL (1966) Some aspects of the hydrogeology of the Spring Mountains and Pahrump Valley, Nevada, and environs, as determined by spring evaluation. Master's Thesis, University of Nevada, Reno, 116 pp

International Atomic Energy Agency (1992) Statistical treatment of data on environmental isotopes in precipitation. International Atomic Energy Agency,Vienna, Technical Reports Series no. 331, 781 pp
ISO (1992) ISO 31–0, Quantities and Units, Part 0, General Principles, subclause 2.3.3. International Organization for Standardization
Longwell CR, Pampeyan EH, Boyer B, Roberts RJ (1965) Geology and mineral deposits of Clark County, Nevada. Nevada Bureau Mines Bull 62:1–218
Maxey GB, Jameson CH (1948) Geology and water resources of Las Vegas, Pahrump, and Indian Springs Valleys, Clark and Nye Counties, Nevada. Nevada Water Resour Bull 5:1–121
Mazor E (1997) Chemical and isotopic groundwater hydrology. Dekker, New York
McLane A (1975) Deer Spring Cave: Nevada's toughest. Great Basin Grotto Cave Lights 19:7–11
McLane A (1977) Deer Spring Cave: to the end. Great Basin Grotto Cave Lights 26:4–6
Mifflin MD (1968) Delineation of ground-water flow systems in Nevada. Desert Research Institute, Technical Report Series H-W. Hydrol Water Resour Publ 4:1–110
Schonher T, Nicholson SE (1989) The relationship between California rainfall and ENSO events. J Climate 2:1258–1269
Simpson ES, Thorud DB, Friedman I (1972) Distinguishing seasonal recharge to groundwater by deuterium analysis in southern Arizona. In: World water balance. Proc Reading Symp 1970. International Association of Scientific Hydrology-UNESCO-WMO, pp 623–633
Smith GI, Friedman I, Klieforth H, Hardcastle K (1979) Areal distribution of deuterium in eastern California precipitation, 1968–1969. J Appl Meteorol 18:172–188
Stichler W, Rauert W, Martinec J (1981) Environmental isotope studies of an alpine snowpack. Nordic Hydrol 12:297–308
Thomas JM, Lyles BF, Carpenter LA (1991) Chemical and isotopic data for water from wells, springs, and streams in carbonate-rock terrane of southern and eastern Nevada and southeastern California, 1985–88. US Geol Surv Open-File Rep 89–422:1–24
Thomas JM, Welch AH, Dettinger MD (1996) Geochemistry and isotope hydrology of representative aquifers in the Great basin region of Nevada, Utah, and adjacent states. US Geol Surv Prof Pap 1409-C: C76
Trenberth KE (1997) The definition of El Niño. Bull Am Meteorol Soc 78:2771–2777
Waring GA (1921) Ground water in Pahrump, Mesquite, and Ivanpah Valleys, Nevada and California. US Geol Surv Water-Supply Pap 450-C
Winograd IJ (1962) Interbasin movement of ground water at the Nevada Test Site, Nevada. US Geol Surv Prof Pap 450-C: 108–111
Winograd IJ, Friedman I (1972) Deuterium as a tracer of regional ground-water flow, southern Great basin, Nevada and California. Bull Geol Soc Am 83:3691–3708
Winograd IJ, Thordarson W (1975) Hydrogeologic and hydrochemical framework south-central Great basin, Nevada–California, with special reference to the Nevada Test Site. US Geol Surv Prof Pap 712-C: 1–126
Winograd IJ, Riggs AC (1984) Recharge to the Spring Mountains, Nevada: isotopic evidence. Geol Soc Am (abstracts with programs) 16 (6): 698

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An Ecohydraulic Model to Identify and Monitor Moapa Dace Habitat

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Abstract

Moapa dace (*Moapa coriacea*) is a critically endangered thermophilic minnow native to the Muddy River ecosystem in southeastern Nevada, USA. Restricted to temperatures between 26.0 and 32.0°C, these fish are constrained to the upper two km of the Muddy River and several small tributaries fed by warm springs. Habitat alterations, nonnative species invasion, and water withdrawals during the 20th century resulted in a drastic decline in the dace population and in 1979 the Moapa Valley National Wildlife Refuge (Refuge) was created to protect them. The goal of our study was to determine the potential effects of reduced surface flows that might result from groundwater pumping or water diversions on Moapa dace habitat inside the Refuge. We accomplished our goal in several steps. First, we conducted snorkel surveys to determine the locations of Moapa dace on three warm-spring tributaries of the Muddy River. Second, we conducted hydraulic simulations over a range of flows with a two-dimensional hydrodynamic model. Third, we developed a set of Moapa dace habitat models with logistic regression and a geographic information system. Fourth, we estimated Moapa dace habitat over a range of flows (plus or minus 30% of base flow). Our spatially explicit habitat models achieved classification accuracies between 85% and 91%, depending on the snorkel survey and creek. Water depth was the most significant covariate in our models, followed by substrate, Froude number, velocity, and water temperature. Hydraulic simulations showed 2–11% gains in dace habitat when flows were increased by 30%, and 8–32% losses when flows were reduced by 30%. To ensure the health and survival of Moapa dace and the Muddy River ecosystem, groundwater and surface-water withdrawals and diversions need to be carefully monitored, while fully implementing a proactive conservation strategy.

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Introduction

Anthropogenic factors negatively affect aquatic communities in the southwestern U.S. Specifically, in the Southern Xeric Basin and Range ecoregion [1], 82% of sampled stream reaches have disturbed riparian zones, 73% contain non-native vertebrates, 53% have serious streambed stability issues, 42% have mercury in fish, and 33% have reduced habitat complexity [2]. Aggravating this situation is the higher than average human growth rate in the arid southwest, contributing to the 15–60 m declines in groundwater levels region-wide, depending on location [3]. Thus it is no surprise that the desert southwest has an inordinate number of federally listed fishes, including Moapa dace *Moapa coriacea* [4]. Further complicating this picture is the looming threat of climate change, which will likely result in warmer air and water temperatures, reduced winter snowpack, and lower summer streamflows [5,6]. Collectively, these conditions make it imperative that wise water management practices are implemented to conserve the native aquatic biota in the arid southwest.

The Moapa dace is a thermophilic minnow endemic to the Muddy River, Clark County, Nevada [7]. Inhabiting water temperatures between 26.0 and 32.0°C, Moapa dace is restricted to the upper reaches of the Muddy River ecosystem where the river originates from thermal springs emanating from a deep carbonaceous aquifer [8,9]. The Moapa dace occurs only in the upper reaches of the Muddy River ecosystem (a.k.a. Warm Springs Area) because its water cools in a downstream direction [10]. In addition, seven other aquatic species of special concern inhabit the Muddy River ecosystem (three fish, two snails, and two insects), with each species having a unique life history and habitat preferences [11]. The Moapa White River springfish *Crenichthys baileyi moapae* is a cohabitating endemic thermophile that occurs in similar locations as Moapa dace. Virgin River chub *Gila seminuda* were known to occur throughout the main stem Muddy River, while speckled dace *Rhinichthys osculus moapae* inhabited the river downstream of the Warm Springs Area.

Moapa dace habitat was altered with the development of spring discharge in the Warm Springs Area for agricultural and recreational use [11,12]. The introduction of western mosquitofish *Gambusia affinis* by the 1930s and shortfin molly *Poecilia mexicana* in the 1960s also contributed to Moapa dace decline [13,14]. To insure persistence of Moapa dace and the Moapa White River springfish, the Moapa Valley National Wildlife Refuge (hereafter

"Refuge") was established in 1979 and subsequently expanded [11]. The Refuge is now comprised of three spring provinces (i.e., groups of springs) representing less than 10% of the two endemic's historic habitat. Still, the Refuge has been important to native fish persistence, especially Moapa dace and White River springfish. Moapa dace reproduce in the spring-fed tributaries to the Muddy River in water temperatures between 30 and 32°C [12].

The Refuge was instrumental in averting the extinction of Moapa dace after the 1995 invasion of blue tilapia *Oreochromis aureus* into the Warm Springs Area. Following the invasion, the two thermal endemic species were extirpated from about 90% of their former range [15,16], including critical adult foraging habitat in the mainstem Muddy River. While tilapias were prevented from accessing the Refuge by installation of temporary barriers, they have nonetheless temporarily severed the connectivity between springbrook and mainstem habitats. Readers may view a video of Moapa dace and Moapa White River springfish foraging and feeding in the Refuge (see Video S1).

Repatriation of Moapa dace to its historic range (i.e., Muddy River) is important because fragmented populations have a much greater chance of extinction [17,18]. The largest, oldest, and most fecund Moapa dace occurred in the larger water volume of the main stem Muddy River [12] - life history traits which enhance the species' probability of persistence [19]. In 2005 the primary water purveyor for Clark County, Southern Nevada Water Authority [20], purchased the Warm Springs Area for the protection of the area's biota, which provided the opportunity for tilapia extirpation from the Warm Springs Area.

With the establishment of Refuge and the Warm Springs Natural Area (WSNA), a substantial portion of the Moapa dace historic habitat is now under protection. However, in recent years there has been concern as to the sustainability of springs feeding the Muddy River [21]. Specifically, there has been pumping from the Muddy River's ground-water source, which may increase further, translating into decreased spring discharge [21]. To manage Moapa dace populations on the Refuge and WSNA, while sustaining the seven other sensitive aquatic species, managers need to understand the effect reduced streamflow has on the dace population and the larger Muddy River ecosystem.

In this paper we examine the potential effects of surface-water reductions on the availability of Moapa dace habitat by simulating an increase or decrease in the three primary Refuge springbrooks by 30% relative to baseflow. While Moapa dace are more sensitive to flow reduction than some species (e.g., Moapa White River springfish) [14], our results have implications for all aquatic species in the Warm Springs and Muddy River ecosystem. By providing a methodology that couples fine-grain hydrodynamic data, GIS, and habitat use observations, our approach can be applied to any aquatic ecosystem, large or small, provided the necessary physical and biological data are available.

Materials and Methods

Study Site

The Moapa Valley National Wildlife Refuge is situated near the southern edge of the Warm Springs Area (Fig. 1). Approximately 47 hectares, the Refuge contains three spring provinces - each of which feed a springbrook - referred to herein as the Plummer, Pedersen, and Apcar springbrooks. The three springbrooks eventually converge to form the Refuge Springbrook, a tributary to the Muddy River. Just prior to their acquisition, the Plummer and Pedersen properties were public resorts with their springbrooks feeding large and small swimming pools. In contrast, Apcar Springbrook had been altered to provide water for local municipal and irrigation purposes. At the time of each acquisition, no Moapa dace and few to no Moapa White River springfish occurred on each of the three properties. Following acquisition by the U.S. Fish and Wildlife Service, substantial habitat rehabilitation was undertaken at each of the three spring provinces aimed at creating suitable native fish habitat. Major rehabilitation modifications included channel realignment, removal of hundreds of nonnative fan palms *Wahingtonia filifera*, and channel excavation. Other rehabilitation actions included riparian vegetation planting, in-stream log placement, and cattail *Tyha* sp. removal [20].

The Pedersen Springbrook system was the first U.S. Fish and Wildlife Service acquisition (1979 and 1984), and habitat modification on that system began in the mid-1980s. This springbrook is fed by the highest springs within the Warm Springs Area and they are suspected to be the most sensitive to ground-water pumping [21]. Of the seven springs feeding the Pedersen Springbrook, two of the highest are equipped with flow gages, as is the Pedersen Springbrook where it leaves the Refuge 200 m downstream from the convergences of the spring tributaries (Fig. 1). The Pedersen Springbrook is also distinguished by the absence of western mosquitofish and shortfin molly; a small barrier prevents nonnative fishes access to the Refuge reach of the springbrook.

Purchased in 2001, hundreds of fan palms were removed from the Apcar system in 2007 and the springbrook rerouted to what was judged to be its historic course in 2009. Moapa dace began colonizing the newly excavated 163-m-long springbrook within months after its construction, but density was low at the time of our study and probably below carrying capacity. Streamflow in the Apcar Springbrook had the greatest potential for fluctuation in discharge due to water diversion for municipal use.

The Plummer Springbrook was used in the development and testing of our habitat models because it harbored the greatest density of Moapa dace during our five years of study (unpublished survey data, U.S. Fish and Wildlife Service, Las Vegas Field Office). The Plummer Springbrook has three tributaries converging 45 m upstream from where the springbrook leaves the Refuge at Warm Springs Road. With the assistance of The Nature Conservancy this property and spring province was acquired by the U.S. Fish and Wildlife Service in the late 1990s and a major rehabilitation of the spring province and springbrook occurred in 2006 and 2007. The rehabilitated springbrook is composed of small pools, riffles, glides, and small falls; it also has a public viewing chamber and is the focus of the Refuge's visitor center.

Hydrodynamic Modeling

We simulated the hydraulic conditions in the three Refuge springbrooks with River2D [22], a two-dimensional (2D), depth-averaged model [23]. Developed for streams and rivers, River2D has been extensively verified [24–26]. One of River2D's strengths is its variable-size mesh that can be optimized to obtain fine-scale details in areas of interest. Given the small size of the Refuge springbrooks, we constructed a mesh with 8–12 cm resolution to accurately discern hydraulic features associated with Moapa dace. We avoided one- and three-dimensional models because they produce data too coarse- (1-D) or fine-scale (3-D) to efficiently model Moapa dace foraging habitat (i.e., <1 m^2), while providing the flexibility to map and compare habitat across the entire Refuge [27]. Three products output by River2D are depth-averaged velocity, water depth, and Froude number, calculated at each intersection (node) of a triangulated irregular mesh, for a given flow. The Froude number is a dimensionless hydraulic variable that can objectively identify pool, riffle, and glide features [28,29].

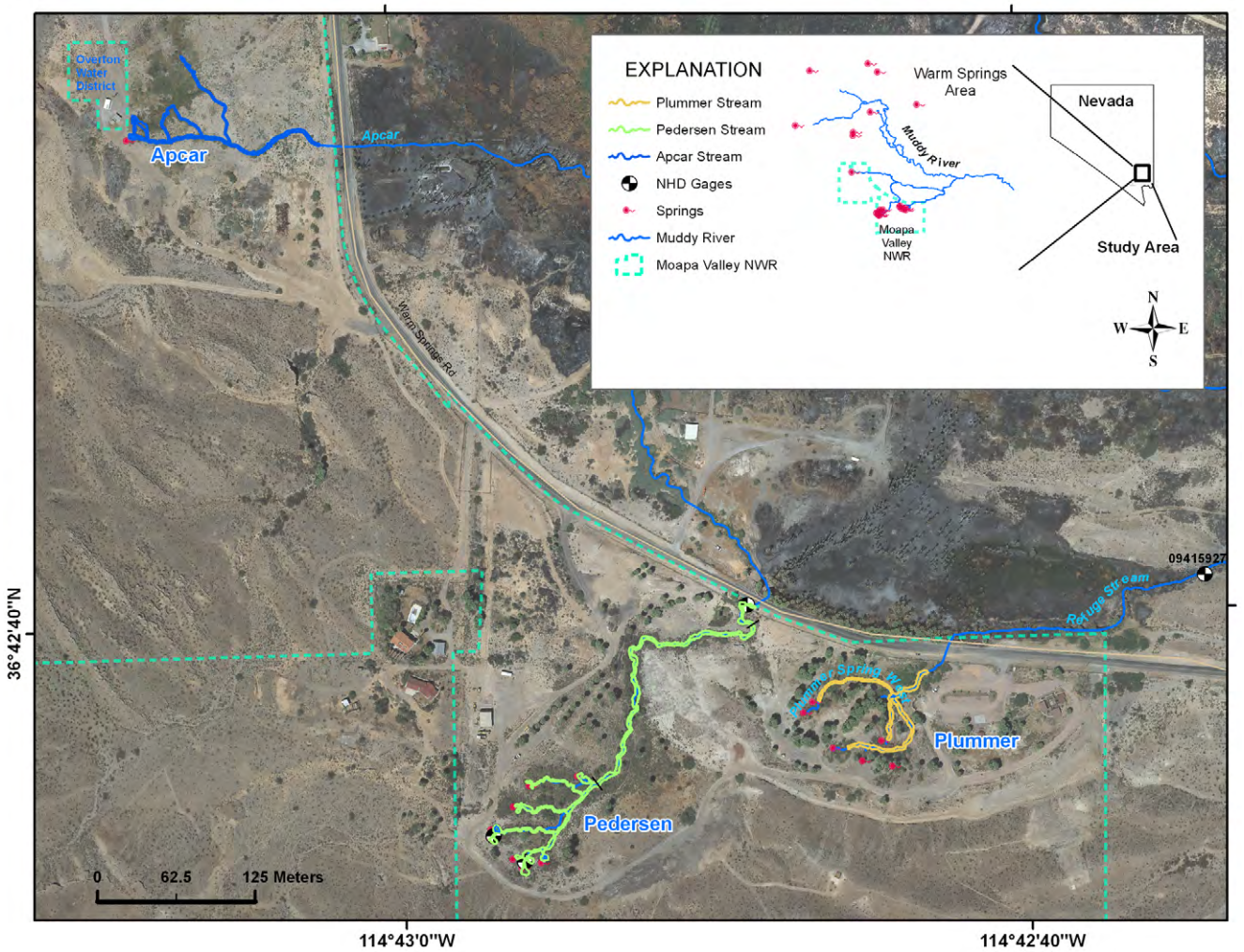

Figure 1. A map of the project area with the three spring-fed creeks displayed inside the Refuge boundary. Culverts route the springbrooks under the road located on the Refuge boundary.
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To insure confidence in the predictability of our 2-D-hydrodynamic model, we followed the methodology and steps in the on-line manual http://www.river2d.ualberta.ca and real-life applications [30,31]. Refer to File S1 for details related to bathymetry, substrate, or water temperature; File S2 for hydrodynamic boundary conditions; and File S3 for a calibration chart of Plummer Creek (0.071 cms). We could not verify simulations that were higher or lower than the baseflows for each springbrook since their flows were unwavering during and proceeding the study period. Nor could we manually change the inflows at each springhead for verification purposes due to the endangered status of Moapa dace. Thus, we relied exclusively on the calibration of the baseflow simulations and the depth-averaged St.Venant equations [22] to reach equilibrium (inflow equals outflow) for each flow simulation (see Hydrodynamic and Habitat Modeling Accuracies section in Discussion for details as to how this may affect our simulations).

Snorkel Surveys

Three snorkel surveys were conducted during the spring of 2009 on Plummer Springbrook between April 20 and May 28. Spaced approximately two weeks apart, snorkel surveys covered the entire Plummer Springbrook from the spring head to the culvert, located at the Refuge boundary (Fig. 1). Snorkel surveys began at the downstream of the springbrook as it left the Refuge and the snorkeler crawled upstream until a subject Moapa dace was sighted. After it was judged the fish was unaffected by the snorkeler's presence, its location was marked on a map as accurately as possible. Fish habitat use is influenced by size and life stage [32] and for our model we used dace ranging from about 40 to 85 mm fork length (FL), the largest observed on the Plummer Springbrook. Fish 40 mm FL were in the late juvenile stage [12], but used the same habitat as adults. For model construction, we drew polygons around dace locations to create occupied patch boundaries, with larger dace clusters producing the biggest patch boundaries. All locations outside of occupied patch boundaries were considered empty since no dace were observed in the snorkel surveys. A map of Moapa dace habitat was completed by joining the presence-absence polygons into one continuous surface representing Plummer Springbrook from the spring head to the Refuge boundary, with no areas unsurveyed.

Three follow-up snorkel surveys were conducted in the next 18 months: January 30, 2010; August 10, 2010; and January 30, 2011. The last survey date was unique because all three Refuge springbrooks were surveyed, while only Plummer Springbrook was surveyed on the other two dates. Thus, the first two snorkel surveys

were used to calibrate and verify the habitat model in Plummer Springbrook, while the third survey was used to verify the model on Pedersen and Apcar springbrooks following extrapolation of the model. This approach allowed us to perform an independent verification of the habitat model over both space and time.

Environmental Database

We constructed an environmental database for habitat modeling by georeferencing all data to a common coordinate system (UTM, Zone 11, NAD83), with each variable rendered as a grid with 12X12-cm (0.014 m^2) resolution (Table 1). Five predictor variables were created from River2D and field surveys for each springbrook; the principal variables were water depth (DEP), velocity (VEL), Froude number (FRD), substrate (SUB3), and water temperature (TMP). Additional variables were created for modeling purposes through the aggregation of substrate and Froude values into different size classes. Specifically, Froude number was reclassified into pool, riffle, and glide classes with FRD thresholds (pool: Fr <0.18; riffle >0.41; with glide intermediate) [29], while six substrate classes (fines, small gravel, medium gravel, large gravel, cobble, boulder) were aggregated into three classes (fines, gravels, cobble/boulder). Lastly, higher-order terms (e.g., quadratic, cubed) were created for each continuous variable for curvilinear model testing.

Habitat Modeling

We used cell-based (raster) modeling [33] and logistic regression [34] to build and test numerous Moapa dace habitat models for Plummer Springbrook. We employed logistic regression because it is well suited for the examination of the relationship between a binary response (i.e., presence or absence) and various explanatory variables [34,35]. We constructed a set of candidate habitat models for comparison and hypothesis testing with presence/absence snorkel data (spring 2009), physical variables (2D hydrodynamic data and substrate maps), logistic regression, and cell-based modeling. We used ArcGIS (version 9x; Redlands, CA) for database construction, SPSS (Chicago, Ill) for logistic regression, and ARC/INFO GRID (ESRI, 1992) for cell-based modeling.

A couple of challenges we faced when developing a model were spatial errors in the observations ($\sim$ 0.5–1 m) and an uneven distribution of dace, reflecting habitat preferences at certain locations. We dealt with spatial errors by randomly generating locations inside of occupied patch boundaries, reasoning that the fish were moving and feeding at the time of observation. We preserved the unequal distribution of dace by generating the same number of random points in each patch as the mean number observed in the snorkel surveys. Lastly, we characterized the larger, unused (background) portion of Plummer Springbrook by generating more absences than presences [36,37], with a minimum spacing of 12 cm (309 absences versus 141 presences; Fig. 2). Our approach reduced spatial autocorrelation by ensuring that no cell was sampled twice and that its neighboring cells were empty, while capturing habitat preferences through the unequal allocation of random points that were informed by snorkel abundance data. Following the compilation of random points, we attributed each location with its respective environmental features (e.g., velocity, depth) with a GIS.

We evaluated the predictive capability of combinations of covariates on dace occurrence with multivariate logistic regression. Given the field work that had been conducted to date on the Refuge, we held an a priori assumption that a combination of geomorphic features and hydraulic conditions was important for Moapa dace (Table 1). We used backward elimination and the likelihood-ratio test to identify significant covariates, starting with a full model and then progressively removing one or more variables and examining the change in Akaike's information criterion (AIC) [38]. We checked for nonlinearity between the logit and a continuous variable with quadratic, cubic, and log terms [39]. We evaluated 11 candidate models, comparing their performance with AIC model weights [38], Nagelkerke's pseudo-R^2 [40], Hosmer–Lemeshow goodness-of-fit statistic $\hat{C}$ [34], a binary classification table [41], and a Receiver Operating Characteristic (ROC) area-under-the-curve (AUC) [42].

Model Application and Verification

We generated spatially explicit maps of predicted Moapa dace habitat in Plummer Springbrook with cell-based modeling techniques [33], populating each model with its respective predictor variables (grids). We examined model accuracy with snorkel data described previously. We focused only on presence locations for verification purposes since the differences in Moapa dace numbers ($\sim$4X, this paper) on the three Refuge springbrooks were large, reflecting the recent history of habitat modifications and enhancement on each stream, versus the quality of habitat, making a comparison of model commission meaningless among streams.

We constructed a binary habitat map for each model by applying a probability cutpoint (threshold) of 0.3, which we obtained through trial and error during the model development and testing phase on Plummer Springbrook, balancing omission and commission errors [37]. Specifically, grid cells with a probability >0.3 were assigned a value of 1 (habitat), while cells with probabilities ≤ 0.3 were converted to zero (non-habitat). We used a GIS to overlay dace locations and habitat maps, calculating accuracy as the percentage of dace locations that fell within predicted suitable areas. Since there was some error in assigning locations of dace observed in the field to a map, we considered any

Table 1. Predictor variables used for Moapa dace habitat modeling.

Variable	Type	Description
VEL	Continuous	Depth-averaged velocity (m/s) obtained from 2D hydrodynamic model
DEP	Continuous	Water depth (m) obtained from 2D boundary conditions
FRD	Continuous	Froude values greater than 1 are super-critical flow; values <1 are sub-critical flow
SUB3	Categorical	Three substrate classes: 1 = fines, 2 = gravels, 3 = cobbles/boulders
SUB7	Categorical	Seven substrate classes: the three groups (SUB3) are further subdivided by size
TMP	Continuous	Temperature °C

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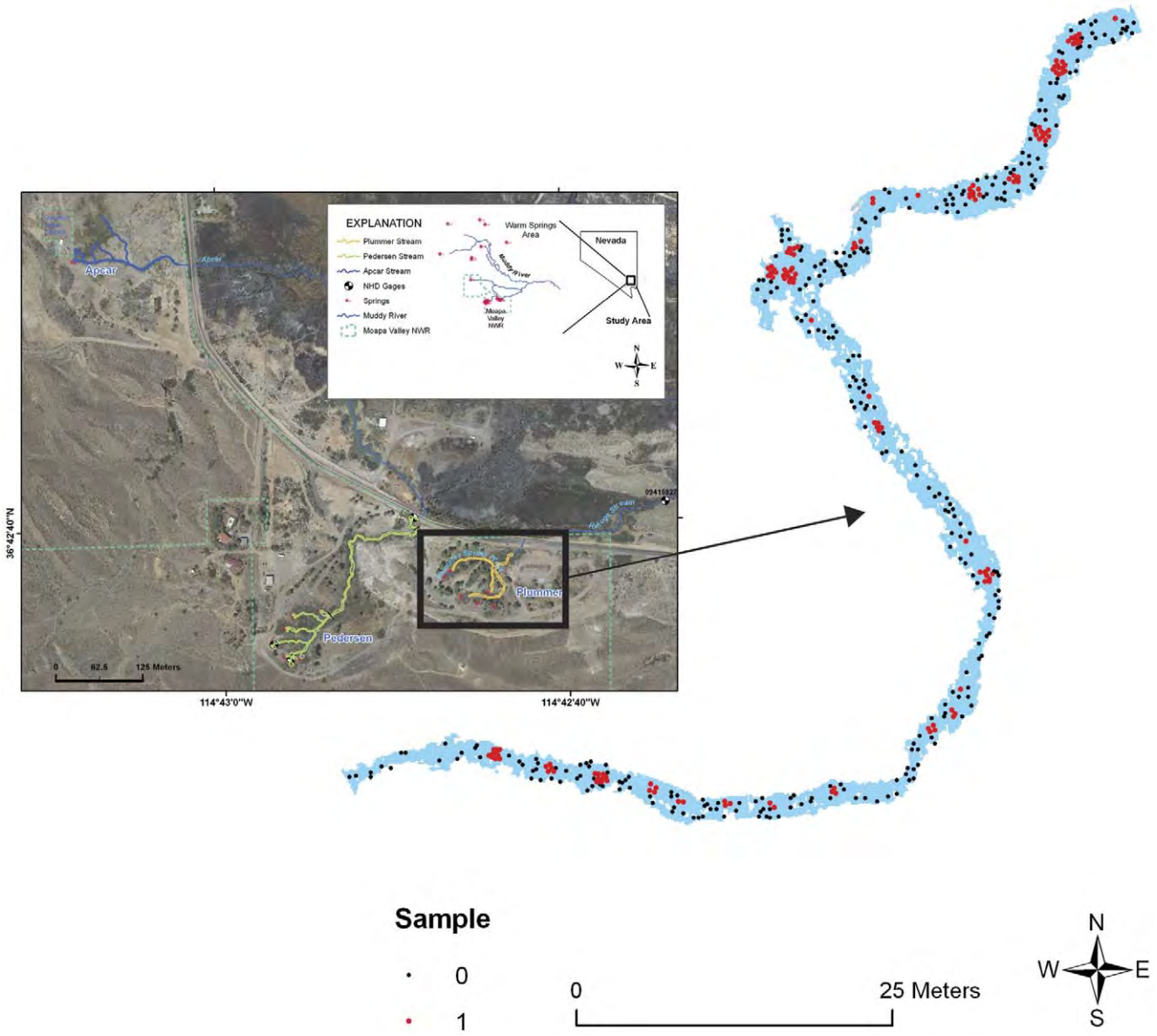

Figure 2. Random sample locations used for model development inside and outside of occupied dace patches in Plummer Springbrook. Snorkel surveys in the spring of 2009 were conducted to determine the locations of Moapa dace (shown in red), while absence locations were generated randomly outside of known dace sites with a GIS (309 absences and 141 presences).
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dace that fell within two cells (~24 cm) of an occupied patch to be a correct classification.

We assessed model fit by examining the density of presence locations found within discrete probability classes [31,37]. Specifically, we created 20% interval classes from the continuous probabilities output from the habitat model, overlaid dace locations, and calculated the density of dace within each probability class (number of dace/cell/probability class). A good fit to the model should be demonstrated by an increasing number of dace locations inside of higher probability classes.

Extrapolating the models to Apcar and Pedersen springbrooks required that we not change the model coefficients or probability threshold that were obtained on Plummer Springbrook, only the predictor grids (substrate, velocity, depth, Froude number). Applying the Plummer Springbrook habitat model to Plummer, Apcar, and Pedersen springbrooks ensured a true test of our habitat model in a spatial and temporal perspective.

Hydraulic Habitat Simulations

We conducted habitat simulations over a range of flows by ramping up or drawing down the flow in each Refuge springbrook by 30% relative to its baseflow, in 10% increments, calculating the amount of habitat at each flow with the habitat model. We tabulated the amount of predicted dace habitat for each flow simulation and displayed the results in bar graphs. Due to different reach lengths and base flows of the three springbrooks, we standardized our results for comparison purposes in two ways. First, we divided the amount of predicted habitat for each habitat-flow simulation by the length of springbrook, resulting in the amount of predicted habitat per-linear-meter of channel. Second, we divided the difference between each habitat-flow simulation

from its base-flow habitat estimate, producing the magnitude of change relative to its baseflow.

Results

Hydrodynamic Modeling

Two-dimensional hydraulic simulations for Plummer, Pedersen, and Apcar springbrooks achieved velocity and depth accuracies from 74%–91% (RMSE) and 84%–92%, respectively (see File S3). Each 2D springbrook simulation produced distinct patterns in depths and velocities, with pools and riffles easily discerned by their shapes and profiles (see File S4). Applying Froude thresholds to velocity and depth data revealed that Plummer Springbrook was comprised of 70% pools, 18% glides, and 12% riffles (baseflow = 0.071 cms). In contrast, Pedersen Springbrook was comprised of 50% pools, 33% glides, and 17% riffles (baseflow = 0.108 cms). Lastly, Apcar was comprised of 67% pools, 15% glides, and 18% riffles (baseflow = 0.066 cms).

Snorkel Surveys

Snorkel surveys in Plummer Springbrook (20 April through 28 May, 2009) revealed that dace were located at similar locations in different surveys, but moved significantly between sites (CV ~ 60%). However, overall abundance changed little between surveys (<5%), with an average of 141 dace, or 1.1 fish per-linear-meter of stream channel inside the Refuge. The two follow-up snorkel surveys in Plummer Springbrook detected 127 dace on 30 Jan 2010 (0.96 fish/m) and 161 dace on 30 Jan 2011 (1.2 fish/m). In contrast, only 62 dace were detected on Pedersen Springbrook on 30 Jan 2011 (0.26 fish/m) and 34 dace on Apcar Springbrook (0.21 fish/m). Thus, Plummer Springbrook had ~4 times the number of dace per-linear-meter of springbrook than the other two refuge streams.

Habitat Modeling

We saw distinct differences in velocity and depth conditions selected by Moapa dace, as compared to random background locations, in Plummer Springbrook at a baseflow of 0.071 cms (Fig. 3A), and a small difference in temperature (Fig. 3B). The further apart each group's medians, the stronger the evidence for habitat selectivity, while the closer the quartiles are within a group (i.e., 0 or 1), the smaller (more specific) the niche. The largest differences in median values between each sample group, listed in descending order of importance, were water depth, Froude number, stream temperature, and velocity. For the categorical variable substrate (Fig. 3C), the largest number of absence locations occurred inside cobble/boulder areas, while the largest number of presence locations occurred inside gravel areas.

Univariate logistic regression revealed that water depth had the closest association with dace locations during the spring of 2009 (Table 2; baseflow = 0.071 cms), followed in descending order of importance by substrate (3 classes), Froude number (continuous), velocity, and water temperature. Water depth obtained a good fit across 10 probability deciles ($\hat{C} = 0.5$), explained 37% of the variability, achieved 75.1% overall classification accuracy (binary; probability threshold = 0.3), and achieved an AUC of 0.82. The next closest univariate was substrate, with an AUC of 0.71. Of the univariables, only temperature had a non-significant AUC.

Of the 13 models we tested (Table 2) the top performer (according to AIC) contained a depth and substrate variable, plus a Froude variable (Model 1). Model 2 was also strongly supported by AIC ($\Delta AIC = 1.78$), but contained a velocity variable in place of the Froude variable. We could not pair velocity into most models that contained Froude due to high colinearity, but we could pair

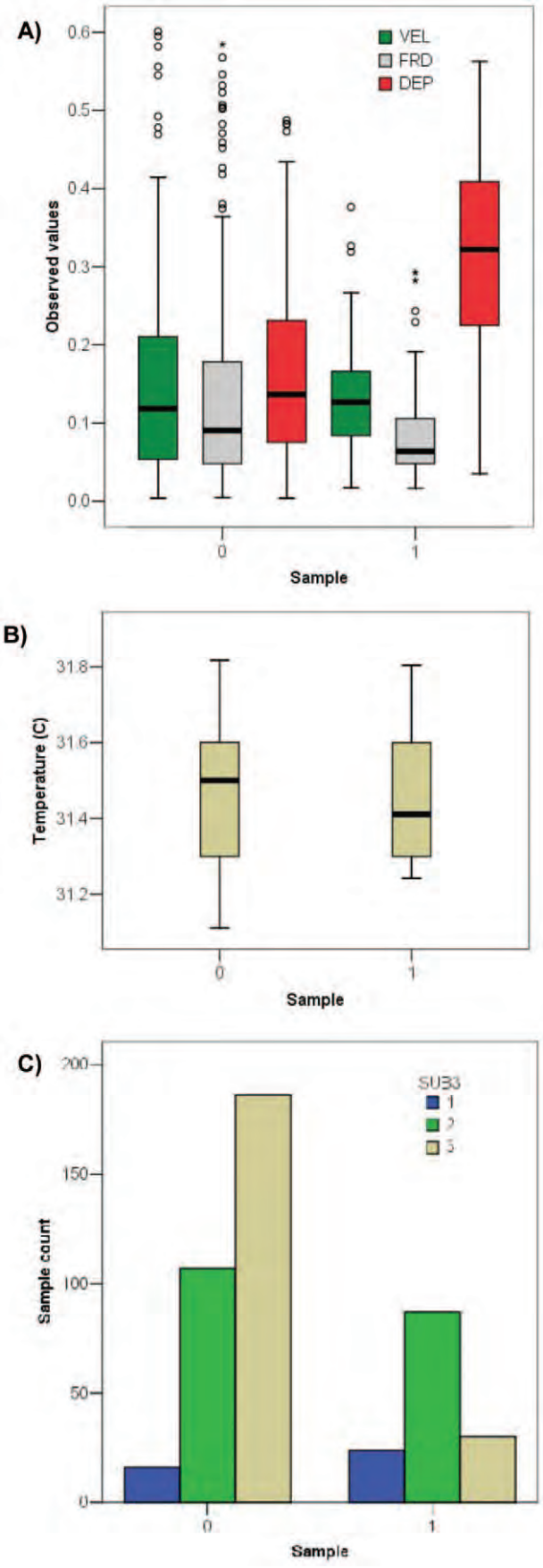

Figure 3. Box-and-whisker plots and bar graphs display the range of environmental values found at 450 sample locations in Plummer Springbrook (see Fig. 2). Panel A displays the distribution of velocity (m/sec), depth (m), and Froude values; panel B shows temperature values; panel C portrays the number of presence or absence sample locations found within three substrate classes (1 = fines, 2 = gravels, 3 = cobble/boulder).
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depth with Froude - even though Froude incorporates depth into its computation. There was moderate support for Models 3–7 (ΔAIC between 3 and 6), with no support for the remaining six models (ΔAIC >79). The critical variable that resulted in the large gap in AIC scores between Models 1 thru 7 and Models 8 thru 13 was depth. Whenever depth was in a model, it was either strongly (Models 1,2) or moderately (Models 3–7) supported. No other covariate influenced the multivariate models to the magnitude of depth, with substrate a distant second, followed by Froude number, velocity, and temperature. Depth was also the best univariate model (Model 6), achieving equal model-fit statistics as the top five models, with the exception of its AIC score (ΔAIC = 4.455). The two temperature models (5 and 7) were only moderately supported by AIC, but Model 5 achieved the best overall model fit ($\hat{C} = 0.821$) and tied model 1 for best R^2 (0.403) and AUC (0.838), while Model 7 obtained the best overall classification accuracy (76.6%), indicating temperature played a small role in dace habitat selection in Plummer Springbrook.

We selected Model 2 for model extrapolation into Apcar and Pedersen springbrooks, and for hydraulic-habitat simulations (i.e., ramping up and drawing down flows), because it was strongly supported by AIC, achieved a reasonably good model fit ($\hat{C} = 0.608$), and velocity is easier to interpret than the Froude number. We also found little difference in performance between these two models from an accuracy or spatially explicit perspective (model parameters for Models 1 and 2 are listed in Table 3). We retained covariates in Models 1 or 2 if they improved the overall fit

Table 3. Model parameters and coefficients for Model 1 (top) and Model 2 (bottom): outputs were obtained from multiple logistic regression on Plummer Creek, with samples collected in the spring of 2009 ($n = 450$; 309 absences and 141 presences).

Model 1					
Variable	***B***	**S.E.**	**Wald**	**df**	**Sig.**
DEP	12.745	4.402	8.383	1	0.004
DEP_2	−8.956	7.822	1.311	1	0.252
FRD	4.778	6.065	0.621	1	0.431
FRD_2	−22.941	20.594	1.241	1	0.265
SUB3 (reference)			10.44	2	0.005
SUB3 (class 1)	1.134	0.442	6.595	1	0.01
SUB3 (class 2)	0.8	0.282	8.031	1	0.005
Constant	−3.838	0.626	37.634	1	0
Model 2					
DEP	13.935	4.426	9.913	1	0.002
DEP_2	−10.923	7.746	1.989	1	0.158
SUB3 (reference)			10.272	2	0.006
SUB (class 1)	1.126	0.447	6.345	1	0.012
SUB (class 2)	0.796	0.282	7.979	1	0.005
vel252b	4.238	5.135	0.681	1	0.409
vel252b_2	−15.174	14.272	1.13	1	0.288
Constant	−4.047	0.604	44.914	1	0

See Table 1 for variable definitions; variables with an underscore (e.g., Dep_2) are squared terms.
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Table 2. Model results for univariate and multivariate logistic regression, listed from best to worst according to AIC score ($n = 450$; 309 absences and 141 presences).

Model	LL	NPar	AIC	ΔAIC	w	$\hat{C}$	R^2	OA	AUC	Variables
1	407.461	8	423.461	0.000	0.484	0.685	0.403	76.20	0.838	*DEP, FRD, SUB3
2	409.241	8	425.241	1.780	0.199	0.608	0.399	76.20	0.835	*DEP, VEL, SUB3
3	421.035	3	427.035	3.574	0.081	0.499	0.372	75.70	0.826	*DEP, FRD
4	419.037	4	427.037	3.576	0.081	0.797	0.377	75.05	0.826	*DEP, VEL, FRD
5	407.284	10	427.284	3.828	0.072	0.821	0.403	76.30	0.838	*DEP,FRD,TMP,SUB3
6	421.916	3	427.916	4.455	0.052	0.499	0.370	75.10	0.823	DEP
7	408.963	10	428.963	5.502	0.031	0.488	0.400	76.55	0.835	*DEP,VEL,TMP,SUB3
8	494.787	4	502.787	79.326	0.000	NA	0.188	69.45	0.708	SUB3
9	491.44	8	507.440	83.979	0.000	NA	0.197	68.65	0.724	SUB7
10	519.993	2	523.993	100.532	0.000	0.040	0.118	59.50	0.664	FRD
11	522.173	3	528.173	104.712	0.000	0.247	0.112	61.65	0.670	VEL
12	527.814	4	535.814	112.353	0.000	NA	0.096	59.60	0.598	FRD3
13	559.568	1	561.568	138.107	0.000	0.000	0.000	54.90	0.500	TMP

Statistics presented are twice the negative log-likelihood value (−2L), the number of parameters (NPar), change in AIC score when compared to the best model (ΔAIC), AIC model weight (w), Hosmer-Lemeshow goodness-of-fit statistic ($\hat{C}$), Nagelkerke pseudo R-squared (R^2), overall classification accuracy (OA), ROC area-under-the-curve (AUC), and the principal variables in each model (higher-order terms not shown. For variable descriptions, see Table 1; * denotes the variable that had the greatest influence on the model's log likelihood. Quadratic terms are not shown in the Variables field.
doi:10.1371/journal.pone.0055551.t002

of the model ($\hat{C}$), regardless of statistical significance (Table 3). While quadratic terms improved the fit of both models, indicating non-linear relationships, logarithmic and cubic functions failed to improve model fit.

Interpretation of the odds ratios (exp β) and model coefficients for Models 1 or 2 provided information about the habitat preferences of dace. Specifically, dace were approximately three times as likely to occur on sandy substrates as a cobble-boulder substrate, and approximately two times as likely on a gravel surface. Interpretation of the squared terms revealed that in small springbrooks dace about 40 to 85 mm FL preferred water depths between 0.64 and 0.71 m, a Froude value of 0.1 (non-stagnant pool), and a velocity of 0.14 m/s. These values changed slightly when other models were examined, but they were not as well supported by AIC as Models 1 or 2.

Model Application and Verification

Model 2 produced a mean probability for dace habitat in Plummer Springbrook of 0.21 (baseflow 0.071 cms), with a maximum of 0.83 and a minimum of 0. Applying a habitat probability threshold of 0.3, 26.8% (0.007 ha) of Plummer Springbrook was predicted to be dace habitat at a baseflow of 0.069 cms (see File S4). Model 2 achieved 88% accuracy in August 2010 when challenged with independent snorkel data (22 out of 25 sites correct), 90.5% accuracy in January 2010 (19 of 21), and 91.1% in January 2011 (41 out of 45).

Model 2 obtained a good fit when we examined dace density per probability class in Plummer Springbrook, using snorkel data in the spring of 2009 (Fig. 4). For this analysis we merged probability classes 4 and 5 since the model's probabilities topped out at 84%, producing too few cells or fish observations in class 5 to stand alone. Thus, we calculated dace densities inside four probability classes: 0–20%, 20.1–40%, 40.1–60%, and >60%. The following equation describes the relationship between dace density and the four probability classes in Plummer Springbrook.

$$D = 0.009X - 0.0077.$$

where D is the density of dace per cell (0.0144 m^2) for a given probability class. Our density estimate for Plummer Springbrook appeared to represent future dace conditions too since the numbers of dace in the two future snorkel surveys bracketed the numbers observed in the spring of 2009, with the locations approximately the same.

The mean probability of dace occurrence in Pedersen Springbrook, using Model 2, was 22.2% (baseflow 0.108 cms), with a maximum probability of 85.3%, and a minimum of 0%. Applying a 30% probability threshold resulted in 29.3% (0.013 ha) of the springbrook predicted to be dace habitat (see File S4). When we challenged the habitat model to independent snorkel data collected in January 2011, the model achieved 84.6% accuracy (22 of 26 sites correctly classified). The mean model probability for Apcar Springbrook, using Model 2, was 30.8% (baseflow 0.066 cms), with a maximum probability of 86% and a minimum of 0%. Applying a 30% probability threshold resulted in 42.7% (0.013 ha) of Apcar Springbrook predicted to be dace habitat (see File S4). When we challenged the habitat model to independent snorkel data collected in January 2011, the model achieved 90% accuracy (18 of 20 sites).

Hydraulic Habitat Simulations

When we supplied the habitat model with seven flows, starting at a 30% increase over baseflow and then descending in 10% increments - until a 30% reduction was achieved - habitat (per-linear-meter of stream channel) appeared to decrease steadily in Plummer and Apcar springbrooks (Fig. 5A). This pattern was not the same for Pedersen Springbrook, where the maximum habitat was obtained at a 10% increase over baseflow, before leveling out. The amount of predicted habitat per-linear-meter of springbrook revealed that Apcar Springbrook is expected to produce the most dace habitat over the range of flows. The slope of the increase for Plummer Springbrook appeared similar to Apcar, but the amount of predicted habitat per-linear-meter of channel was approximately 30% less. In contrast, Plummer and Pedersen springbrooks had different slopes (reactions), but the amount of predicted habitat per-linear-meter of springbrook was similar at the top and bottom of the flow simulations. However, Pedersen Springbrook appeared more responsive to flows between minus 20% and plus 20% compared with Plummer Springbrook. When we simulated how dace habitat in each springbrook would change in relation to its baseflow prediction (Fig. 5B), Plummer Springbrook appeared the most sensitive, with potential losses of approximately 30% and increases of 10%. Pedersen Springbrook appeared to be the second most sensitive to flow modifications, with potential habitat losses of 15% and gains of 2%. In contrast, Apcar Springbrook gained or lost approximately 5% of its predicted dace habitat in relation to its baseflow, indicating it was least sensitive to flow alteration.

Discussion

Hydrodynamic and Habitat Modeling Accuracies

The accuracy rate of our 2D hydrodynamic flow simulations ranged from 73–91%, under baseflow conditions, which is consistent with other 2D studies on large and small streams [26,30,43]. We were unable to calibrate or validate non-baseflow simulations given the unvarying springheads over the study period. Calibration typically involves changing mesh configuration or roughness values to achieve closer agreement between simulated and measured water surface elevations and velocities [23,30]. Thus, our flow simulations may have bias that could affect habitat classification, but the baseflow had good verification results and it was the midrange of our flow simulations. To our knowledge these are some of the smallest streams where 2D fish-habitat modeling has been conducted and we are satisfied given the 85–91% accuracies Model 2 achieved with temporally and spatially independent snorkel-survey data. Furthermore, the excellent linear fit between the model's probability classes and dace densities demonstrated that the model provided useful information about the quality of dace habitat (i.e., higher dace numbers informed the model of preferred hydrogeomorphic conditions).

Habitat-flow Simulations

Plummer and Apcar springbrooks produced proportionately more habitat as flows increased, while Pedersen springbrook reached a plateau after a 10% increase, suggesting a geomorphic constraint. In contrast, Plummer and Apcar springbrooks appeared relatively unconstrained by geomorphology and thus dace might benefit from increased flows. Conversely, habitat simulations consistently showed in each springbrook that reduced flows produce less Moapa dace habitat. A reduction in habitat is typically followed by a reduction in population number, thus the information in this study is important when considering population dynamics in relation to streamflow [44].

Because Refuge springbrooks are close to spring heads, Refuge habitat experienced a very narrow temperature range and our analysis garnered only moderate support for the two temperature

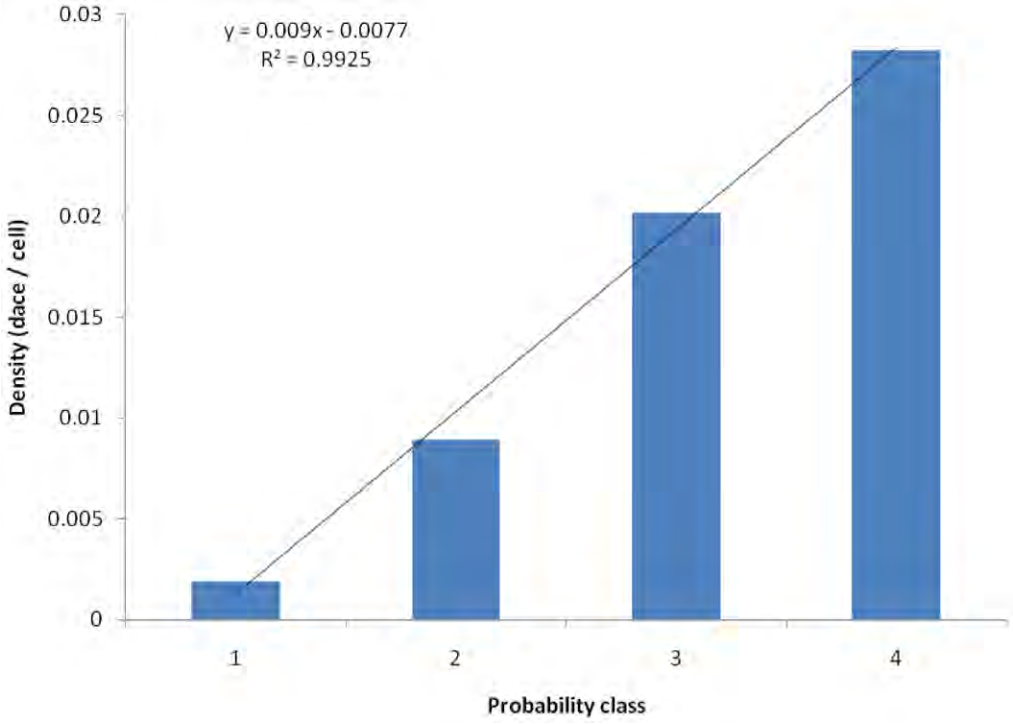


Figure 4. The relationship between Moapa dace density and four probability classes in Plummer Creek, as output by Model 2. Probability classes are 1 (0–20%), 2 (20.1–40%, 3 (40.1–60%), and 4 (>60%). Dace densities were obtained by averaging three back-to-back snorkel surveys (spring of 2009), counting the number of dace within each probability class, and dividing by the number of cells (0.0144 m^2) found within each probability class.
doi:10.1371/journal.pone.0055551.g004

models (Table 2, Models 5,7). Had we had the opportunity to study Moapa dace in its historic range in the Muddy River, where waters are cooler, the influence of temperature in our models would likely be greater because larger, older fishes frequently inhabit cooler water [45,46]; a phenomena previously observed in Moapa dace [12]. A reduction in springflows on the Refuge or Muddy River could result in stream cooling [47], which may reduce the area currently suitable for rearing, foraging, and spawning (26°−32°C).

Detection

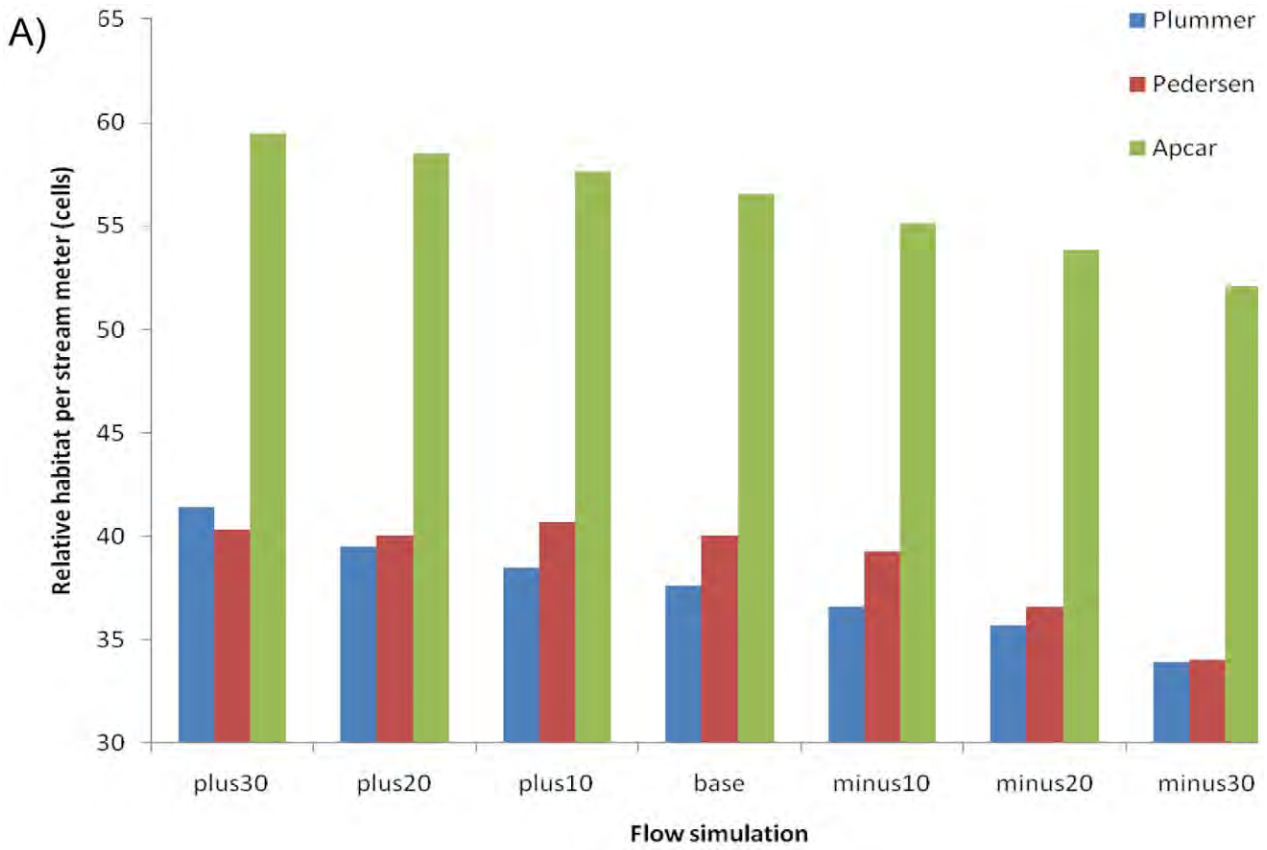
Moapa dace have patchy distribution and congregate in predictable hydraulic conditions, as defined by our model. Foraging primarily upon drift [12], Moapa dace presumably select hydraulic conditions that promote optimal foraging [48], hence their patchy distribution. They are also quite transient, frequently moving among patches [14], with an average movement of 68 m between bi-monthly sampling events, and ~30% leaving the refuge entirely (Mark Hereford, USGS Biologist, personal communication). As more information is gathered through tagging and genetic analysis, we will gain a better understanding of dace migration rates on and off the refuge, particularly at finer temporal and spatial scales. Until this occurs, we chose not to incorporate detection probabilities into our modeling approach [49].

Habitat selection can be density dependent with only higher quality habitat used when population numbers are low [50,51]. The Plummer Springbrook was inhabited by well over 50% of the Moapa dace population during the period of our study and presumably virtually all available habitats were occupied during our snorkel surveys. We are confident based upon our extrapolation tests (temporally and spatially) that the habitat model we developed for Plummer Springbrook, and extrapolated to Pedersen and Apcar springbrooks, captured the essential features that comprise dace habitat. Namely, water depth, substrate composition, Froude number, and velocity, with temperature a distant last.

Habitat Restoration-Rehabilitation

Habitat rehabilitation in the three Refuge springbrooks was crudely modeled on sites observed to support congregations of foraging Moapa dace before they became restricted to the Refuge (Unpublished report: G. Gary Scoppettone). Most sites were in the upper Muddy River where the catchment basin intermittently floods, producing flows well beyond the historic 1.1 m^3/s attributed solely to thermal springs [9]. The cut and fill alluviation produced by intermittent flooding most likely built and destroyed Moapa dace habitat in the main-stem Muddy River in a dynamic process that has occurred for thousands of years. These dynamic flooding-erosion processes generally decrease in an upstream direction [52], thus catchments with smaller or reduced drainage areas are not as dynamic. The Refuge springbrooks have all been cut off from their respective sub- catchment basins and thus the quality of Moapa dace habitat will likely degrade in time due to emergent and submergent vegetation. Without intermittent flooding to maintain or generate new dace habitat, the Refuge springbrooks will need to be continually monitored for habitat quality, with habitat restoration conducted on an as-needed basis.

Our habitat models provide targets and thresholds for managers in the development, evaluation, and monitoring of dace habitat. For example, the amount of predicted habitat from our models can be used as an indicator of the effectiveness of a restoration or



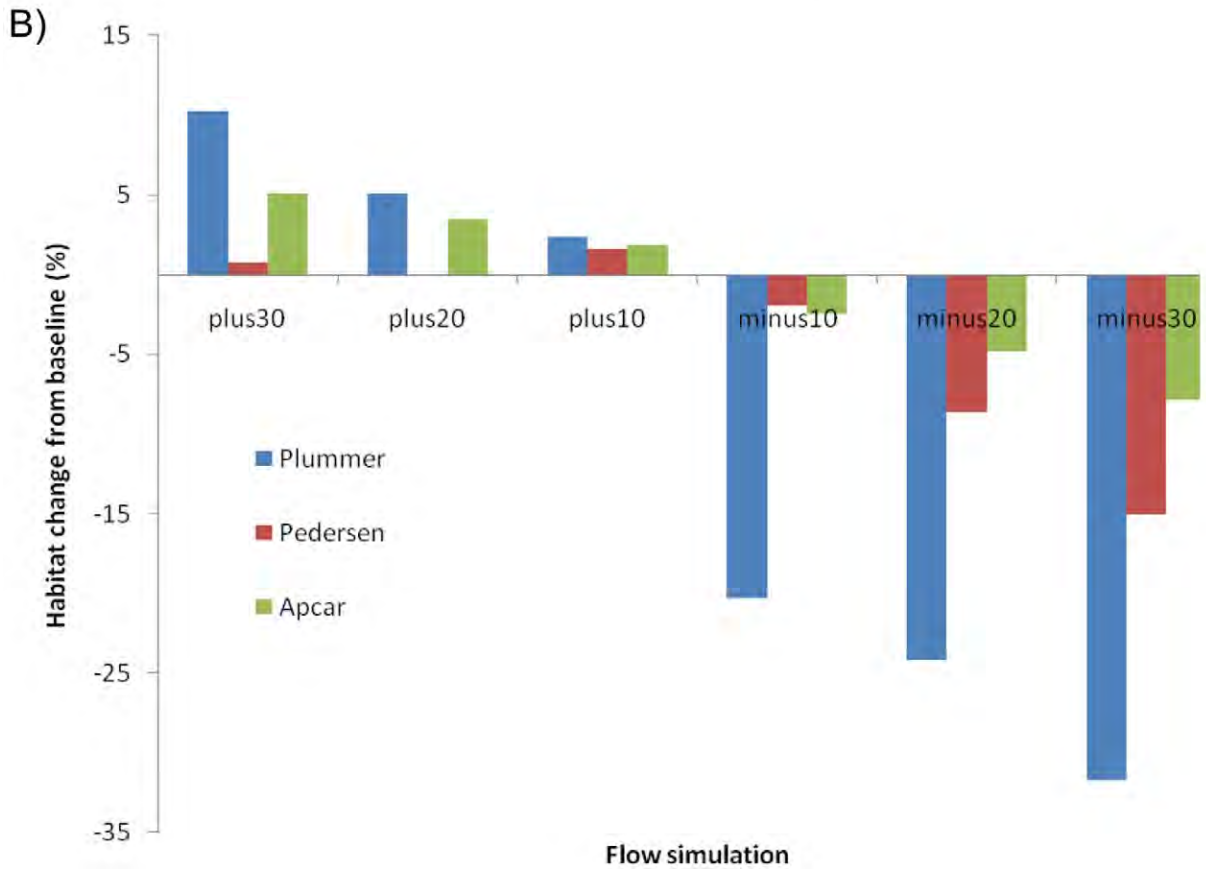


Figure 5. Habitat-discharge relations among Plummer, Pedersen, and Apcar creeks, in 10% flow increments. In panel A, the amount of predicted habitat by flow is presented after standardizing the data by stream length. In panel B, the relative change in habitat in relation to baseflow was calculated in 10% flow increments.
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enhancement activity. In addition, changes in habitat quantity or quality could be assessed by calculating habitat prior to and after a restoration or enhancement activity, calculating the mean probability for a given reach, or habitat quantity through application of a probability threshold (30% for our models). It is also possible to use the habitat models to simulate the benefits of a given restoration or enhancement activity before committing the funds for on-the-ground efforts to implement the proposal. Simulating an enhancement activity would involve modifying the bathymetry, rerunning the 2D hydraulic model, and recomputing habitat. One could compare multiple scenarios when determining the most optimum use of resources for the restoration or enhancement of dace habitat. The final evaluation criterion for any project should be the number of dace observed prior to and following a restoration or enhancement activity, with the models providing guidance on the achievement and monitoring of dace habitat over space and time.

Conclusion

This study indicates that a reduction in spring discharge within Moapa Valley National Wildlife Refuge will cause a reduction in important refugial habitat for Moapa dace, and may exacerbate native-nonnative interactions [53,54]. The Muddy River's carbonate aquifer is being closely monitored to prevent breaching its sustainability (personal communication, Lee Simons, U.S. Fish and Wildlife Service, Las Vegas, Nevada). However, there are concerns that pumping from the aquifer may cause an unintended overdraft and a reduction in spring discharge [21]. Another looming threat to sustaining the Muddy River's carbonate aquifer is global climate change. The southwest is expected to get warmer and drier in the next century, with spring and summer streamflows predicted to be significantly reduced [5,6]. While it is unknown how climate change will affect the groundwater in the vicinity of the Refuge, it will probably decrease as the climate warms and dries. Our model provides important information to managers charged with protecting and recovery of Moapa dace in an era of potential reduction in thermal spring discharge feeding the Muddy River.

The focus of this study was Moapa dace, but our results have implications for seven other aquatic species listed as sensitive in the Muddy River ecosystem [11]. Each species has its own specific habitat requirements, by life stage, but they all share the Muddy River ecosystem and a threat to one species is a concern for all. We have shown that reduced flows on the Refuge will threaten Moapa dace habitat, while increased flows would provide benefits. Until we know more about the habitat preferences of all aquatic species in the Muddy River ecosystem, a water conservation strategy that minimizes any net loss in habitat is desirable.

Supporting Information

File S1 Background information on substrate and bathymetric surveys.
(DOC)

File S2 Detailed boundary conditions for River2D hydraulic simulations.
(DOC)

File S3 2D hydrodynamic model calibration and verification charts for each springbrook.
(DOC)

File S4 2D hydrodynamic model output and habitat maps for each springbrook.
(DOC)

Video S1 A typical sandy-bottom plunge-pool habitat selected by Moapa dace. Identified by their fusiform body and deeply forked tail with black spot at its base, Moapa dace are actively working the water column for drift items. Also in the video are Moapa White River springfish identified by their square tail. Both species are thermal endemic, typically occurring in water temperatures from 26 to 32°C and are restricted to the headwaters of the Muddy River, Clark County, Nevada where the river originates from a series of thermal springs. Video provided by Pete Rissler (U.S. Geological Survey).
(MP4)

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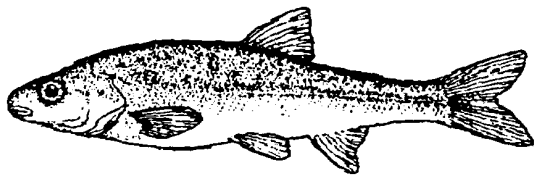
Author Contributions

Performed snorkel and habitat surveys: GGS CJD. Conceived and designed the experiments: JRH. Performed the experiments: JRH TRB. Analyzed the data: JRH TRB GGS CJD. Wrote the paper: JRH GGS TRB.

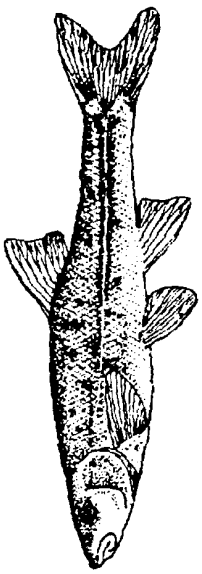
References

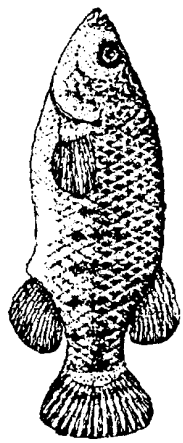
1. Omernik JM (1987) Ecoregions of the conterminous United States. Annals of the Association of American Geographers 77, 118–125.
2. Stoddard JL, Peck DV, Paulsen SG, Van Sickle J, Hawkins CP, et al. (2005) An Ecological Assessment of Western Streams and Rivers. EPA 620/R-05/005, U.S. Environmental Protection Agency, Washington, DC. Available: http://www.epa.gov/emap/west/html/docs/wstriv.html. Accessed 2012 Nov 24.
3. Stonestrom DA, Harrill JR (2007) Ground-water recharge in the arid and semiarid southwestern United States-climatic and geologic framework. U.S. Geological Survey Professional Paper 1703-A, 27 p. Available: http://pubs.usgs.gov/pp/pp1703/a/pp1703a.pdf. Accessed 2012 Nov 24.
4. Minckley WL, Deacon JE (1991) Battle against extinction: native fish management in the American West. Tucson: University of Arizona Press. 517 p.
5. Seager R, Ting MF, Held I, Kushnir Y, Lu J, et al. (2007) Model projections of an imminent transition to a more arid climate in southwestern North America. Science 316: 1181–1184.
6. Subhrendu G, Pruitt T (2011) West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface Water Projections. Technical Memorandum No. 86-68210-2011-01. U.S. Department of the Interior, Bureau of Reclamation, Technical Service Center, Denver, Colorado. Available: http://www.usbr.gov/WaterSMART/docs/west-wide-climate-risk-assessments.pdf. Accessed 2012 Jul 6.

7. U.S. Department of the Interior (1973) Threatened wildlife of the United States. U.S. Bureau of Sport Fisheries and Wildlife Resources Publication 114.
8. Hubbs CL, Miller RR (1948) Two new relict genera of cyprinid fishes from Nevada. Occas pap Mus Zool. Univ. Mich 507: 1–30.
9. Eakin TE (1966) A regional interbasin groundwater system in the White River Area, southeastern Nevada. Water Resour Res 2: 251–271.
10. Garside LJ, Schilling JH (1979) Thermal waters of Nevada. Nevada Bureau of Mines and Geology. Bulletin 91. Reno: Mackay School of Mines and Geology, University of Nevada. 163 p.
11. U.S. Fish and Wildlife Service (1995) Recovery plan for the rare aquatic species of the Muddy River ecosystem. Portland, Oregon. 60 pp. Available: http://water.nv.gov/hearings/past/dry/browseable/exhibits%5CUSFWS/Exhibit%20601%20recovery%20plan%20for%20aquatic%20spp%20MRS.pdf. Accessed 2012 Jul 6.
12. Scoppettone GG, Burge HL, Tuttle PL (1992) Life history, abundance, and distribution of Moapa dace (*Moapa coriacea*). Great Basin Nat 52: 216–225.
13. Deacon JE, Bradley WG (1972) Ecological distribution of fishes of Moapa (Muddy) River in Clark County, Nevada. Trans Am Fish Soc 101: 408–419.
14. Scoppettone GG (1993) Interactions between native and nonnative fishes of the upper Muddy River, Nevada. Trans Am Fish Soc 122: 599–608.
15. Scoppettone GG, Rissler PH, Nielsen MB, Harvey JE (1998) The status of *Moapa coriacea* and *Gila seminude* and status information on other fishes of the Muddy River, Clark County, Nevada. Southwest Nat 43: 115–122.
16. Scoppettone GG, Salgado JA, Nielsen MB (2005) Blue tilapia (*Oreochromis aureus*) predation on fishes in the Muddy River system, Clark County, Nevada. West N Am Nat 65: 410–414.
17. Groom MJ, Meffe GK, Carroll CR (2006) Principles of Conservation Biology, 3rd Edition. Sunderland: Sinauer Associates 793 p.
18. Fahrig L (2002) Effect of habitat fragmentation on the extinction threshold: a synthesis. Ecol Appl 12: 346–353.
19. Stearns SC (1992) The evolution of life histories. New York: Oxford University Press. 249 p.
20. Galati L (2011) Warm Springs Natural Area Stewardship Plan. Southern Nevada Water Authority, Las Vegas, NV. Available: http://www.snwa.com/env/wsna_stewardship.html. Accessed 2012 Jul 2.
21. Mayer TD, Congdon RD (2008) Evaluating climate variability and pumping effects in statistical analyses. Ground Water 46: 212–227.
22. Ghanem AH, Steffler PM, Hicks FE, Katopodis C (1996) Two dimensional finite element flow modeling of physical fish habitat. Regul River 12: 185–200.
23. Steffler P, Blackburn J (2002) River2D. Two-Dimensional Depth Averaged Model of River Hydrodynamics and Fish Habitat. Introduction to Depth Averaged Modeling and User's Manual. University of Alberta. September, 2002. 119 pp. Available: http://www.river2d.ualberta.ca/Downloads/documentation/River2D.pdf. Accessed 2012 Jul 6.
24. Ghanem AH, Steffler PM, Hicks FE, Katopodis C (1995) Dry area treatment for two dimensional finite element shallow flow modeling. Proceedings of the 12th Canadian Hydrotechnical Conference, Ottawa, Ontario.
25. Waddle T, Steffler PM, Ghanem A, Katopodis C, Locke A (1996) Comparison of one and two dimensional hydrodynamic models for a small habitat stream. Ecohydraulics 2000 Conference, Quebec City, June. 10 p.
26. Hatten JR, Batt TR (2010) Hydraulic alterations resulting from hydropower development in the Bonneville Reach of the Columbia River. Northwest Sci 84: 207–222.
27. Lane SN, Mould DC, Carbonneau PE, Hardy RJ, Bergeron NE (2006) Fuzzy modelling of habitat suitability using 2D and 3D hydrodynamic models : biological challenges., in River Flow 2006 : International Conference on Fluvial Hydraulics, Lisbon, Portugal, 6–8 September 2006; proceedings. London: Taylor & Francis, 2043–2054.
28. Jowett IG, Richardson J, Biggs BJF, Hickey CW, Quinn JM (1991) Microhabitat preferences of benthic invertebrates and the development of generalized *Deleatidium* spp. habitat suitability curves, applied to four New Zealand rivers. New Zeal J Mar Fresh 25: 187–199.
29. Jowett IG (1993) A method for objectively identifying pool, run, and riffle habitats from physical measurements. New Zeal J Mar Fresh 27: 241–248.
30. Tiffan KF, Garland RD, Rondorf DW (2002) Quantifying flow-dependent changes in subyearling fall chinook salmon rearing habitat using two-dimensional spatially explicit modeling. N Am J Fish Manage 22: 713–726.
31. Hatten JR, Tiffan KF, Anglin DR, Haeseker SL, Skalicky JJ, et al. (2009) A spatial model to assess the effects of hydropower operations on Columbia River fall Chinook salmon spawning habitat. N Am J Fish Manage 29: 1379–1405.
32. Lobb MD III, Orth DJ (1991) Habitat use by an assemblage of fish in a warmwater stream. Trans. Am. Fish. Soc. 120: 65–78.
33. Environmental Systems Research Institute (ESRI) (1992) Cell-based Modeling with GRID, 2nd ed. Redlands: ESRI. 267 p.
34. Hosmer DW, Lemeshow S (2000) Applied logistic regression. New York: John Wiley & Sons. 373 p.
35. Keating KA, Cherry S (2004) Use and interpretation of logistic regression in habitat selection studies. J Wildl. Manage 68: 774–789.
36. Kvamme L (1985) Determining empirical relationships between the natural environment and prehistoric site locations: a hunter-gatherer example. Pages 208–238 *in* C. Carr, editor. For concordance in archaeological analysis. Westport Publishers, Kansas City, Kansas, USA.
37. Hatten JR, Paradzick CE (2003) A multiscaled model of Southwestern Willow Flycatcher breeding habitat. J. Wildl. Manage. 67: 774–788.
38. Burnham KP, Anderson DR (2002) Model selection and multimodel inference: a practical information theoretic approach, 2nd edition. New York: Springer. 488 p.
39. Box GEP, Tidwell PW (1962) Transformation of the independent variables. Technometrics 4: 531–550.
40. Nagelkerke NJD (1991) A note on general definition of the coefficient of determination. Biometrika 78: 691–692.
41. Story M, Congalton RG (1986) Accuracy assessment: a user's perspective. Photogramm Eng Remote Sens. 52: 397–399.
42. Egan JP (1975) Signal detection theory and ROC analysis. New York: Academic Press. 277 p.
43. Waddle T (2010) Field evaluation of a two-dimensional hydrodynamic model near boulders for habitat calculation. River Res Appl 26: 730–741.
44. Williams BK, Nichols JD, Conroy MJ (2002) Analysis and management of animal populations. San Diego: Academic Press. 817p.
45. Ricker WE (1979) Growth rates and models. Pages 677–743 *in* W.S. Hoar, D. J. Randall, and J.R. Brett, editors. Fish Physiology; Bioenergetics and Growth. VIII. Academic Press, New York, San Francisco, London.
46. Glencross BD, Felsing M (2006) Influence of fish size and water temperature on the metabolic demand by barranmundi, *Lates calcarifer* (Bloch), in freshwater. Aquac Res 37: 1055–1062.
47. Hauer FR, Hill WR (2006) Temperature, light and oxygen. Pages 103–119 in Hauer FR and Lamberti GA, editors, Methods in stream ecology. Amsterdam, Boston, Heidelberg, London: Academic Press. 877 p.
48. Grossman G D, Rincon PA, Farr MD, Ratazcjczak RE (2002) A new optimal foraging model predicts habit use by drift-feeding stream minnows. Ecol Freshw Fish 11: 2–10.
49. MacKenzie DI, Nichols JD, Royle JA, Pollock KH, Bailey LL, et al. (2006) Occupancy estimation and modeling: Inferring patterns and dynamics of species occurrence. San Diego: Academic Press. 344 p.
50. Guthric CG, Moorhead DL (2002) Density-dependent habitat selection: evaluating isoleg theory with a Lotka-Volterra model. Oikos 97: 184–194.
51. Lindberg WJ, Frazer TK, Portier KM, Vose F, Loftin J, et al. (2006) Density-dependent habitat selection and performance by a large mobile reef fish. Ecol Appl 16: 731–746.
52. Hauer FR, Lamberti GA (2006) Methods in stream ecology. Amsterdam, Boston, Heidelberg, London: Academic Press. 877 p.
53. Scoppettone GG, Rissler PH, Gourley C, Martinez C (2005) Habitat restoration as a means of controlling non-native fish in a Mojave Desert Oasis. Restor Ecol 13: 247–256.
54. Lamouroux N, Cattaneo F (2006) Fish assemblages and stream hydraulics: consistent relations across spatial scales and regions. River Res Appl 22: 727–737.



RECOVERY PLAN
FOR THE
RARE AQUATIC SPECIES
OF THE
MUDDY RIVER ECOSYSTEM

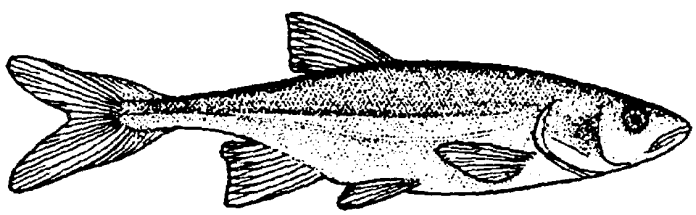




U.S. Fish and Wildlife Service

Region 1

Portland, Oregon



RECOVERY PLAN

FOR THE RARE AQUATIC SPECIES OF

THE MUDDY RIVER ECOSYSTEM

First Revision
(Original Approved: February 14, 1983)

Prepared by
Selena J. Werdon

for
U.S. Fish and Wildlife Service
Region 1
Portland, Oregon

Approved: _____ Michael J. Spear
Regional Director, U.S. Fish and Wildlife Service

Date: 5/16/96

This Recovery Plan covers one federally listed species (Moapa dace) and seven species of special concern in the Muddy River ecosystem.

DISCLAIMER

Recovery plans delineate reasonable actions believed to be required to recover and/or protect listed species. Plans published by the U.S. Fish and Wildlife Service or National Marine Fisheries Service are sometimes prepared with the assistance of recovery teams, contractors, State agencies, and other affected and interested parties. Recovery teams serve as independent advisors to the Services. Plans are reviewed by the public and submitted to additional peer review before they are adopted by the Services. Objectives of the plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific tasks and may not represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service/National Marine Fisheries Service. They represent the official position of the National Marine Fisheries Service/ U.S. Fish and Wildlife Service only after they have been signed by the Assistant Administrator/Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

By approving this document, the Director/Regional Director/Assistant Administrator certifies that the data used in its development represents the best scientific and commercial data available at the time it was written. Copies of all documents reviewed in development of the plan are available in the administrative record, located at the Nevada State Office of the U.S. Fish and Wildlife Service, Reno, Nevada.

Literature Citation of this document should read as follows:

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Fees for recovery plans vary depending on the number of pages.

EXECUTIVE SUMMARY OF THE RECOVERY PLAN FOR THE RARE AQUATIC SPECIES OF THE MUDDY RIVER ECOSYSTEM

Current Species Status: The Moapa dace (*Moapa coriacea*) was listed as endangered on March 11, 1967 (32 Federal Register 4001). It occupies approximately 9.5 kilometers (6 miles) of stream habitat in five thermal headwater spring systems and the main stem of the upper Muddy (= Moapa) River, Clark County, Nevada. Critical habitat has not been designated. A range-wide survey documented 3,841 adult Moapa dace in August 1994. The Muddy River ecosystem is also inhabited by seven aquatic species of special concern (three fish, two snails, and two insects).

Habitat Requirements and Limiting Factors: Adult Moapa dace inhabit the main stem Muddy River, but only successfully reproduce in tributary thermal spring outflows (30-32° Celsius; 86-89.6° Fahrenheit). Larval and juvenile dace occur in low- to moderate-velocity areas in the spring outflows. Moapa dace are omnivorous drift feeders. Principle threats to the species are habitat alterations which have eliminated access to and/or destroyed spawning, nursery, and foraging areas; water loss; impoundments; and introductions of nonnative fishes and parasites.

Recovery Objective: Delisting.

Recovery Criteria: Moapa dace will be considered for reclassification from endangered to threatened when: 1) Existing instream flows and historical habitat in three of the five occupied spring systems (Apcar, Baldwin, Cardy Lamb, Muddy Spring, Refuge) and the upper Muddy River have been protected through conservation agreements, easements, or fee title acquisitions; 2) 4,500 adult Moapa dace are present among the five spring systems and the upper Muddy River; and 3) the Moapa dace population is comprised of three or more age-classes, and reproduction and recruitment are documented from three spring systems.

Moapa dace will be considered for delisting provided that all reclassification criteria have been met and when: 1) 6,000 adult Moapa dace are present among the five spring systems and the upper Muddy River for 5 consecutive years; 2) 75 percent of the historical habitat in the five spring systems and the upper Muddy River provides Moapa dace spawning, nursery, cover, and/or foraging habitat; and 3) nonnative fishes and parasites no longer adversely affect the long-term survival of Moapa dace. These recovery criteria are preliminary and may be revised on the basis of new information (including research specified as recovery tasks).

Actions Needed:

1. Protect instream flows and historical habitat within the upper Muddy River and tributary spring systems.
2. Conduct restoration/management activities.
3. Monitor Moapa dace population.
4. Research population health.
5. Provide public information and education.

Implementation Participants:

The Nevada Division of Wildlife and National Biological Service will be assisting the U.S. Fish and Wildlife Service in implementing recovery tasks. For activities occurring on private land, landowner participation is also needed.

Total Estimated Cost of Recovery (1996-2008): ($1,000's)

Year	Need 1	Need 2	Need 3	Need 4	Need 5	Total
1996	51	51	11	0	19	132
1997	TBD	15+TBD	11	7	21	54+TBD
1998	TBD	15+TBD	11	0	6	32+TBD
1999	TBD	15+TBD	11	0	6	32+TBD
2000	TBD	15+TBD	11	0	6	32+TBD
Total	51+TBD	126+TBD	132	7	106	422+TBD

Date of Recovery: Reclassification of Moapa dace from endangered to threatened could be initiated in 2000, if recovery criteria for threatened status are met. Delisting could be initiated in 2009, if reclassification to threatened status occurs as scheduled.

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I. INTRODUCTION

A. Brief Overview

The Muddy (= Moapa) River is located in northeastern Clark County, Nevada (Figure 1). The river originates from numerous thermal springs [30-32° Celsius (°C), 86-89.6° Fahrenheit (°F)] in an area known as Warm Springs. Historically, the river flowed 48.4 kilometers (km) [30 miles (mi)] into the Virgin River, a Colorado River tributary. However, when Hoover Dam was completed in 1935, the lower 8 km (5 mi) of the Muddy River were subsequently flooded by Lake Mead. The remaining riverine habitat has an average gradient of 1.6 meters (m) per kilometer [8.45 feet (ft) per mile] (Cross 1976).

Total discharge from the headwater springs is nearly constant at approximately 1.3 cubic meters per second (m^3/sec) [45.9 cubic feet per second (cfs)] (Eakin 1964). However, flow in the main stem Muddy River varies with precipitation events, seasonal water diversions, groundwater recharge, vegetation transpiration, evaporation, and irrigation return flows. Before reaching Lake Mead, nearly 75 percent of the annual inflow is lost to diversions, evaporation, and transpiration [Soil Conservation Service (SCS) 1993].

Streams in the Moapa Valley were originally bordered by willow (*Salix* spp.) and screwbean mesquite (*Prosopis pubescens*) (Longwell 1928, Harrington 1929). However, nonnative palm trees are now the dominant riparian tree species along spring systems in the Warm Springs area, and they are increasing in abundance along the upper Muddy River. Salt cedar (*Tamarix* spp.), another nonnative species, is currently the most common riparian species along the middle and lower river.

The Muddy River ecosystem supports eight rare, endemic aquatic species,

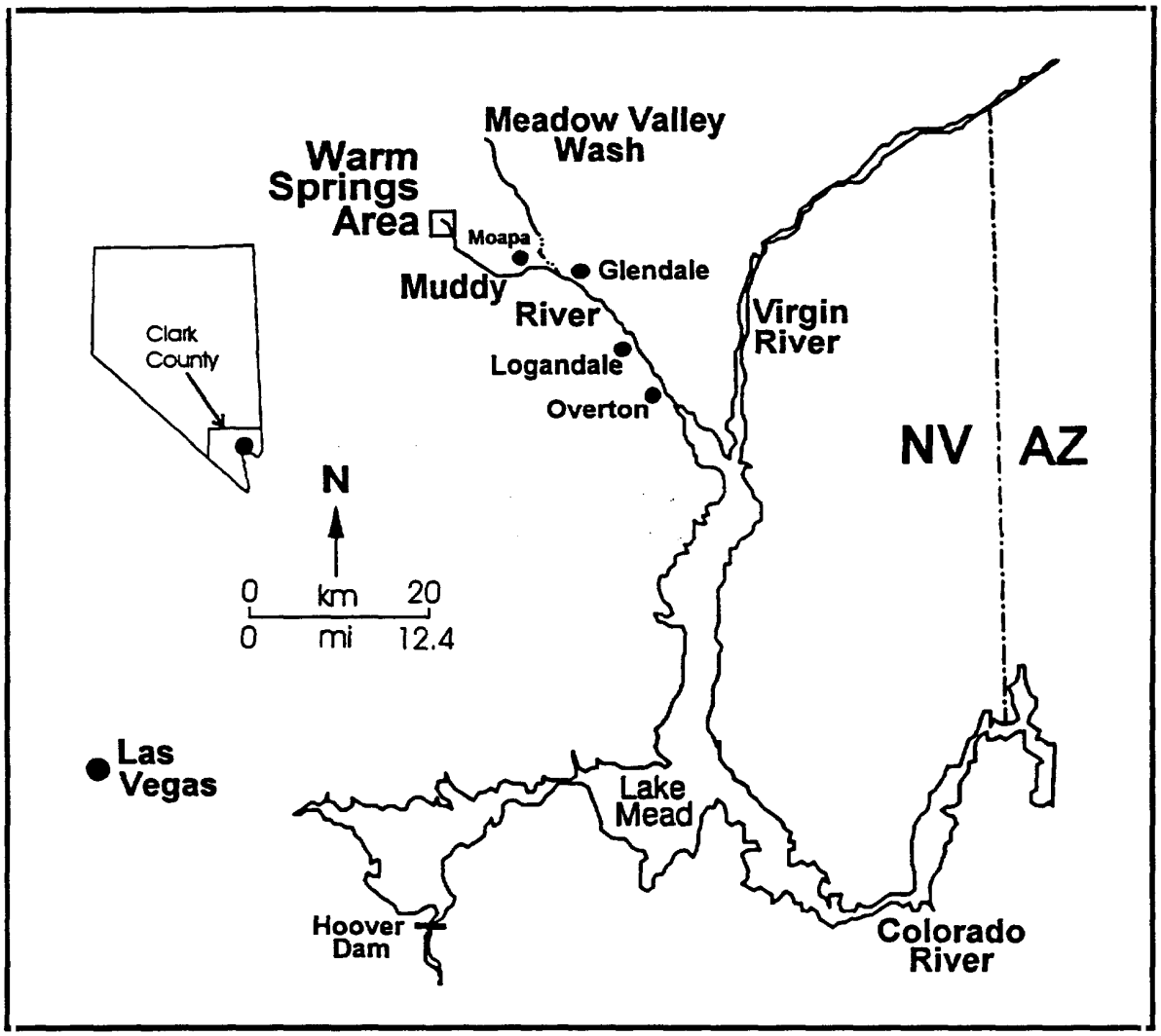

Figure 1. Geographic location of the Muddy River and the Warm Springs area, Clark County, Nevada.

including one endangered fish. The Moapa dace (*Moapa coriacea*) was federally listed as endangered under the Endangered Species Preservation Act of 1966 on March 11, 1967 (32 Federal Register 4001), and has been afforded the protection of the Endangered Species Act (ESA) since its inception in 1973. The U.S. Fish and Wildlife Service (USFWS) assigned Moapa dace a recovery priority of 1 [each listed species is ranked from 1 (highest) to 12] because it is the only species within the genus *Moapa*, there is a high degree of threat to its continued existence, and it has a high potential for recovery.

The USFWS prepared a recovery plan for Moapa dace in 1983, which specified research-related tasks to guide recovery. This document is a revision of the 1983 recovery plan and incorporates recent research data and addresses the species' current status, threats, and recovery needs. It also addresses the current status, threats, and recovery needs of the seven other rare aquatic species (three fish, two snails, and two insects) which occur with Moapa dace in the Muddy River ecosystem and are species of special concern. These species may warrant listing as either threatened or endangered, but status data are not conclusive at the present time. Implementation of recovery tasks included in this plan should reduce the threats to these species and may make listing unnecessary.

B. Species Description

The Moapa dace (Figure 2) was first collected in 1938 and was described by Hubbs and Miller (1948). Key identification characteristics are a black spot at the base of the tail and small, embedded scales, which create a smooth leathery appearance. Coloration is olive-yellow above with indistinct blotches on the sides; the belly is white. A diffuse, golden-brown side stripe may also be present. Maximum size is approximately 120 millimeters (mm) [4.7 inches (in)] fork length (FL; measured from the tip of the snout to the base of the fork in the tail),

and the oldest specimen recorded is over 4 years old (Scoppettone et al. 1992). Technical descriptions of Moapa dace appear in Hubbs and Miller (1948) and La Rivers (1962).

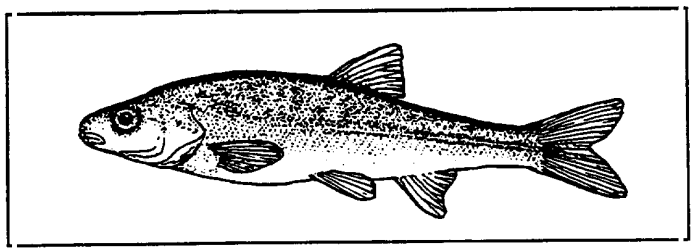

Figure 2. Moapa dace (*Moapa coriacea*).

Among North American minnows (Family: Cyprinidae), *Moapa* is regarded as being most closely related to the dace genera *Rhinichthys* (speckled dace) and *Agosia* (longfin dace) (Coburn and Cavender 1992). These three dace genera, along with the genera *Gila* (chub), *Lepidomeda* (spinedace), *Meda* (spikedace), and *Plagopterus* (woundfin), developed from a single ancestral type (monophyletic) and are only associated with the Colorado River Basin (Dr. Robert R. Miller, University of Michigan, pers. comm.).

C. Distribution

Moapa dace are endemic to the upper Muddy River and tributary thermal spring systems within the Warm Springs area. Historically, they may have inhabited as many as 25 individual springs and up to 16 km (10 mi) of stream habitat (Ono et al. 1983). Cooler water temperatures in the middle and lower Muddy River were likely a natural barrier to downstream movement of Moapa dace (La Rivers 1962).

Moapa dace currently inhabit approximately 9.5 km (5.9 mi) of stream habitat within five spring systems and the upper Muddy River (Figure 3). In the Muddy

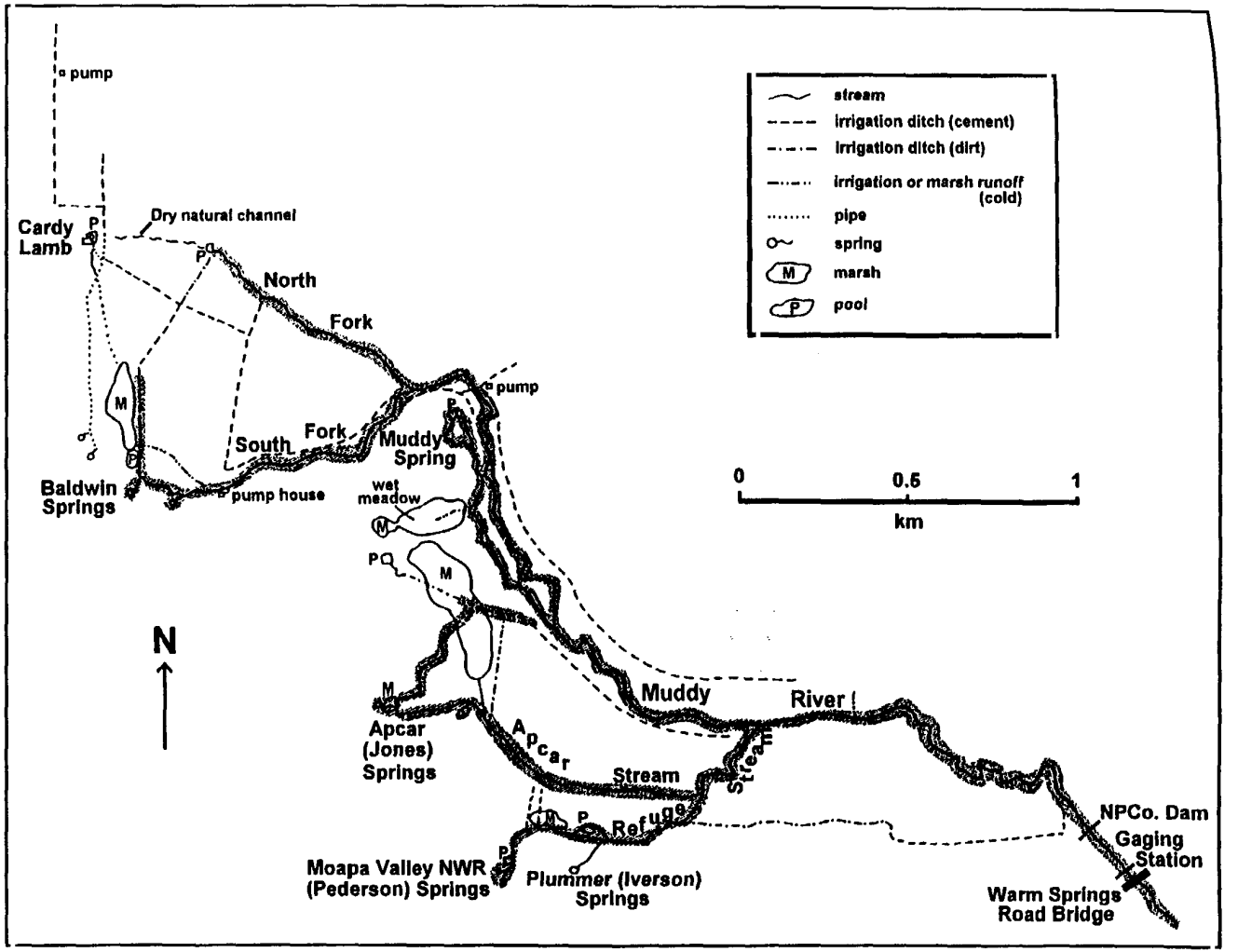

Figure 3. Distribution of Moapa dace (*Moapa coriacea*) (shaded) in the Warm Springs area, Clark County, Nevada. (Modified from: Scoppettone et al. 1987, 1992)

River, their range extends to approximately 300 m (1,000 ft) downstream of the Warm Springs Road bridge. Occupied habitat in the upper Muddy River and four spring systems (Apcar, Baldwin, Cardy Lamb, and Muddy Spring) is entirely on private land. The fifth spring system originates on Moapa Valley National Wildlife Refuge (NWR), but the outflow (Refuge stream) flows through private land before reaching the Muddy River.

D. **Habitat and Life History**

Habitat - Moapa dace occupy a variety of habitats in the Warm Springs area, including spring pools, tributaries (spring outflows), and the main stem Muddy River. Habitat use varies among larval, juvenile, and adult life stages. Larval dace are found only in the upper reaches of tributaries and occur most frequently in slack water. Juveniles occur throughout tributaries and occupy habitats with increasing flow velocities as they grow. Adult dace inhabit both tributaries and the main stem Muddy River, but occur more often in the river except during spawning (Scoppettone et al. 1987, 1992). Larger adults are typically associated with higher-velocity flows [0.8-0.9 meter per second (m/sec); 2.6-3.0 feet per second (ft/sec)] (Cross 1976), and the largest adults occur in the river (Scoppettone et al. 1987).

Aquatic plants such as *Chara* and other algae, spike rush (*Eleocharis* spp.), water nymph (*Najas* spp.), watercress (*Nasturtium* spp.), pondweed (*Potamogeton* spp.), and nonnative eel grass (*Vallisneria* spp.) are abundant in most spring pools and other slack water areas. Such vegetation is nearly absent from swift water areas inhabited by adult Moapa dace. Fibrous roots from nonnative palm trees (*Washingtonia filifera* and *Phoenix dactylifera*) also provide structure in spring pools and outflows, but negatively alter stream hydraulics for native fishes. General water quality characteristics within Moapa dace habitat are as follows:

Temperature 19.5-32°C (67-89.6°F) (USFWS 1983); dissolved oxygen 3.4-8.4 milligrams per liter (mg/L) [1 mg/L = 1 part per million (ppm)] (La Rivers 1962, Deacon and Bradley 1972, Scoppettone et al. 1992); total dissolved solids 606-867 mg/L (ppm) (USFWS 1983); and pH 7.1-7.9 (Deacon and Bradley 1972, Cross 1976). Turbidity is highly variable and increases with distance from the spring orifices; 39.7 Nephelometric Turbidity Units have been recorded during heavy agricultural run-off (Scoppettone et al. 1987). Spring pools typically contain pebble or organic silt substrates, while tributaries and the Muddy River have various combinations of clay, sand, pebble, and cobble substrates (USFWS 1983).

Reproductive Biology - Moapa dace spawn year-round; however, peak spawning activity occurs in the spring, with lesser activity in autumn (Scoppettone et al. 1992). Sexual maturity occurs at 1 year of age, at approximately 38-45 mm (1.5-1.75 in) FL (Hubbs and Miller 1948; Scoppettone et al. 1987, 1992). Fecundity is related to fish size; egg counts range from 60 in a 45 mm (1.75 in) FL dace to 772 in a 90 mm (3.5 in) FL dace (Scoppettone et al. 1992).

Moapa dace have only been found to successfully reproduce in water temperatures of 30-32°C (86-89.6°F). Therefore, sexually mature Moapa dace must migrate upstream from the Muddy River into thermal tributaries to spawn successfully (Scoppettone et al. 1987). Moapa dace have never been observed spawning; however, redds (nests) believed to be those of Moapa dace were found approximately 150 m (500 ft) downstream from a spring orifice (Scoppettone et al. 1992). The redds were in sandy-silt substrate at depths of 15-19 centimeters (cm) (5.9-7.5 in) and near-bed water velocities of 3.7-7.6 cm/sec (1.5-3.0 in/sec).

The duration of egg incubation is unknown, but is likely relatively short because of the high water temperatures. Emigration of young-of-the-year Moapa dace from

the Refuge stream peaks in May (Scoppettone et al. 1987), and dispersal is likely similar in other tributaries with comparable water temperatures. Mortality rates have been estimated at 68 percent for the first year (juveniles) and 65 percent the second year (adults) (Scoppettone et al. 1987).

Food Habits - Moapa dace are omnivorous, as indicated by: Pharyngeal teeth (located in the throat) with both cutting and grinding surfaces (Hubbs and Miller 1948, La Rivers 1962); a gut length of 96 percent of body length (Scoppettone et al. 1987); and stomach contents. Stomach contents of Moapa dace include: Beetles, moths and butterflies, true flies, leaf hoppers, true bugs, caddisflies, mayflies, damsel and dragonflies, worms, scuds, crustaceans, snails, filamentous algae, vascular plants, detritus, and sand (Scoppettone et al. 1987, 1992).

Visual observations of Moapa dace have revealed that they feed primarily on drift items, but adults forage from the substrate as well. Larval dace feed on plankton in the upper water column, in areas with little or no current, and juvenile dace feed at mid-water level [Mr. G. Gary Scoppettone, National Biological Service (NBS), pers. comm.; Scoppettone et al. 1992]. Schools of 30 or more dace have been observed congregating at drift stations to feed (Scoppettone et al. 1987). They often use sites where cover is provided by overhanging vegetation or depth (Dr. Donald W. Sada, Aquatic Ecology and Conservation Consulting, pers. comm.). Drift stations are also located in reaches of low- to moderate-water velocity adjacent to depressions in the substrate. These depressions may be located downstream of a pebble riffle which creates turbulent flows. Moapa dace actively feed 24 hours a day, but peak feeding occurs around dawn and dusk (Scoppettone et al. 1987).

Species of Special Concern

In addition to Moapa dace, three other endemic minnows are present in the Muddy River ecosystem: Virgin River chub (*Gila seminuda*), Moapa speckled dace (*Rhinichthys osculus moapae*), and Moapa White River springfish (*Crenichthys baileyi moapae*). Also endemic to the Warm Springs area are the Moapa pebblesnail (*Fluminicola avernalis*), grated tryonia (*Tryonia clathrata*), Moapa Warm Spring riffle beetle (*Stenelmis moapa*), and Amargosa naucorid (*Pelocoris shoshone shoshone*). These seven species of special concern are discussed below.

Virgin River Chub

Virgin River chub (Figure 4) are silvery colored with olive shading on the back. Their fins are sometimes a pale yellow-orange. Scales on the back and belly are unusually small and deeply embedded; in some individuals they are missing entirely. These fish appear streamlined, and their tails are deeply forked. Their mouth is trout-like, and their diet consists of a variety of aquatic insects, algae, and crustaceans. Maximum size is approximately 46 cm (18 in).

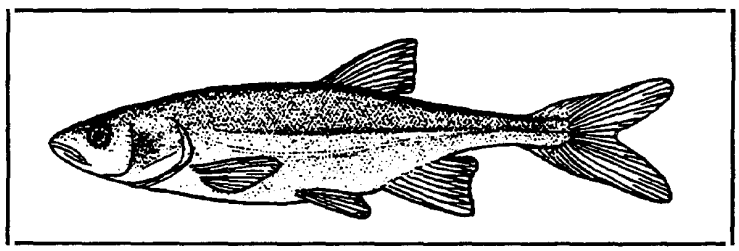

Figure 4. Virgin River chub (*Gila seminuda*).

Chub have been collected in water temperatures of 15-30°C (59-86°F) (Deacon and Bradley 1972, Cross 1976). They are typically found in deep channels and pools with sandy bottoms where there is cover in the form of large rocks,

overhanging streambanks, or tree roots (Scoppettone unpubl. data). Virgin River chub apparently avoid shallow riffles (Cross 1976).

Virgin River chub in the Muddy River were formerly considered a unique subspecies of roundtail chub [Moapa roundtail chub (*G. robusta* ssp.)] (Holden and Stalnaker 1970, Minckley 1973, Smith et al. 1979). However, genetic research has shown these fish to be the same species as the federally endangered Virgin River chub in the Virgin River (DeMarais et al. 1992). No movement of chub between these two rivers has been documented since Lake Mead filled (Allan and Roden 1978), and these populations are considered distinct (DeMarais et al. 1992, 60 Federal Register 37866). The recovery needs of the listed Virgin River population are covered in the Virgin River Fishes Recovery Plan (USFWS 1995); therefore, only the Muddy River population is considered in this document. Virgin River chub have been collected throughout the Muddy River, but were historically most abundant between the Warm Springs area and Logandale (Deacon and Bradley 1972, Cross 1976). During a 1994 population census, 8,251 chub were observed in the upper Muddy River and the five tributary spring systems (Scoppettone unpubl. data). In subsequent trap netting surveys during 1994 and 1995, 973 chub were captured in the Muddy River between the confluence with the Refuge stream and the Warm Springs Road bridge, 854 between the Warm Springs Road bridge and White Narrows, 1,915 between White Narrows and Reid-Gardner Station, and 717 between Reid-Gardner Station and Interstate 15 (Figures 3 and 5) (Scoppettone unpubl. data). The chub population in the main stem Muddy River between the confluence with the Refuge stream and Interstate 15 was estimated at 20,593 (confidence interval ±7,339; adjusted Petersen method) (Scoppettone unpubl. data). Chub are rarely captured downstream of Interstate 15 and have been extirpated downstream of Wells Siding Diversion (Scoppettone unpubl. data; Mr. Jim Heinrich, Nevada

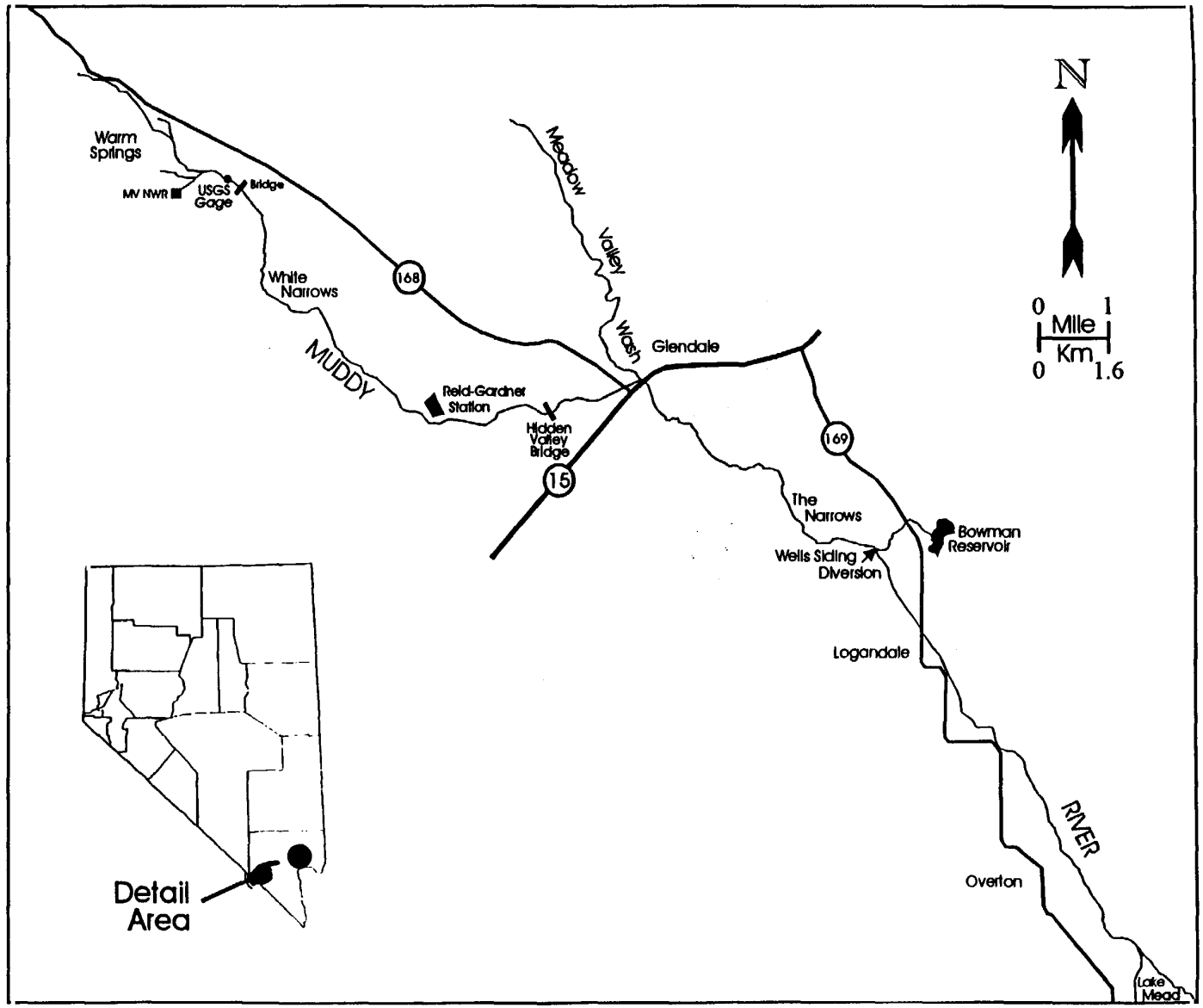

Figure 5. Geographic features of Moapa Valley, Clark County, Nevada.

Division of Wildlife, unpubl. data; Deacon and Bradley 1972; Cross 1976).

A decline in chub abundance in the Muddy River was first documented in the 1960's (Wilson et al. 1966, Deacon and Bradley 1972). By 1964, the abundance of chub at a 1938 collection site had decreased more than 83 percent; a similar decrease (approximately 92 percent) was documented at a 1942 collection site (Wilson et al. 1966). Between 1964 and 1968, Deacon and Bradley (1972) noted an upstream shift in chub distribution. By 1974-1975, the chub had been eliminated from the lower Muddy River and were further reduced in abundance in the middle portion of the river (Cross 1976). The species' decline may have been related to cumulative effects of changes in water quality and quantity, and substrate (Deacon and Bradley 1972, Cross 1976); channelization (Cross 1976); nonnative fish species (Deacon et al. 1964, Hubbs and Deacon 1964, Deacon and Bradley 1972, Cross 1976); and parasitism (Wilson et al. 1966).

Moapa Speckled Dace

Moapa speckled dace (Figure 6) are generally olive or tan colored on the back with faint darker specks. The lower sides and belly are yellowish or cream colored. They have a rounded, elongate body with a somewhat pointed head. Their tail is deeply forked, and all other fins are large and sickle shaped. During the spawning season, males may develop orange-red coloration on the mouth, gill covers, and fins. Maximum size is approximately 10 cm (4 in), and they typically live 3 years or less. Moapa speckled dace are considered most closely related to Pahranagat speckled dace (*R. o. velifer*) and Virgin River speckled dace (*R. o. yarrowi*).

These fish typically live on the bottom in shallow, cobble riffles, hiding in low flow velocity areas behind rocks (Cross 1976). Spawning habitat consists of

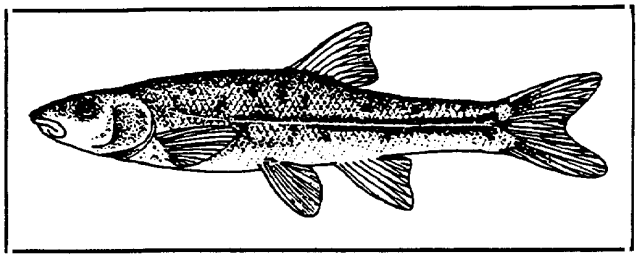

Figure 6. Moapa speckled dace (*Rhinichthys osculus moapae*).

small patches of bare rocks and pebbles which are cleared of debris by the males. Larval speckled dace remain down in the pebbles for a short time and then move into lower velocity areas. Young speckled dace feed primarily on plankton, while adults feed primarily on aquatic insects and algae.

Moapa speckled dace historically have occurred in relatively low numbers, primarily in the middle Muddy River (Deacon and Bradley 1972, Cross 1976). Moapa dace may exclude Moapa speckled dace from the upper river and spring systems because speckled dace are typically abundant in similar clear, thermal water habitats (Deacon and Bradley 1972). Lake Mead is a barrier to downstream dispersal because the habitat is unsuitable (Miller 1952, Williams 1978).

Speckled dace currently inhabit approximately 16.7 km (10.4 mi) of the Muddy River. In a 1994 survey, a total of 706 Moapa speckled dace were captured and released in the main stem Muddy River (Scoppettone unpubl. data). Of these, 28 percent were captured between the Warm Springs Road bridge and White Narrows, 64 percent between White Narrows and Reid-Gardner Station, and 8 percent between Reid-Gardner Station and Interstate 15 (Figure 5). Only one speckled dace was caught downstream of the Interstate 15 bridge. No estimate of total population size is available.

Deacon and Bradley (1972) noted that the distribution of Moapa speckled dace

shifted upstream between 1964 and 1967, as did the Virgin River chub. Speckled dace have likely also been adversely affected by reductions in water quality and quantity, habitat modifications, parasites, and competition and/or predation by nonnative fish species.

Moapa White River Springfish

Moapa White River springfish (Figure 7) are generally olive colored on the back, while the lower sides and belly fade to almost white. The bases of the tail and the pectoral fins are yellow-orange. Two horizontal rows of black spots are present on the sides. The colors of female fish are not as intense as those of the males. Springfish are deep-bodied, and maximum length is approximately 5-7.6 cm (2-3 in). They typically live 3 to 4 years. Moapa White River springfish differ from the four other subspecies of White River springfish (*C. b. albivallis, C. b. baileyi, C. b. grandis,* and *C. b. thermophilus*) in body shape, numbers of fin rays, and coloration (Williams and Wilde 1981).

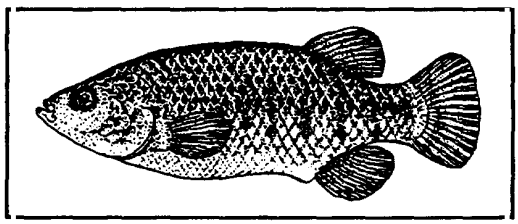

Figure 7. Moapa White River springfish (*Crenichthys baileyi moapae*).

Moapa White River springfish occur in five spring systems (Apcar, Baldwin, Cardy Lamb, Muddy Spring, Refuge) and the upper Muddy River, but are most abundant in the spring systems (Deacon and Bradley 1972, Cross 1976, Scoppettone et al. 1987, Sada pers. comm.). Springfish are extremely tolerant of high water temperatures and low dissolved oxygen levels. They typically live at or near the

springheads and in pools and backwaters along spring outflow streams and the upper Muddy River until water temperatures become too cold in downstream reaches. However, springfish have historically (1941) been collected in the Muddy River as far downstream as the Hidden Valley Road bridge (Figure 5) (Deacon and Bradley 1972). Springfish were also documented downstream of the Hidden Valley Road bridge in an artificial pond near the river in 1986 (Scoppettone et al. 1987). Springfish primarily eat filamentous algae, but also eat aquatic insects.

Summer surveys in 1984 produced a springfish population estimate of nearly 25,000 fish from the spring systems; springfish in the upper Muddy River were not surveyed (Scoppettone et al. 1987). Threats to Moapa White River springfish are water loss, habitat modifications, and competition and predation by nonnative fishes.

Moapa Pebblesnail

Moapa pebblesnail shells are cone-shaped, but broad (Figure 8). They are sometimes called turban snails. The shells are less than 3.5 mm (0.14 in) long and 3.1 mm (0.12 in) wide (Landye 1973). The operculum (lid) is amber in color. Moapa pebblesnails are members of the Family Hydrobiidae.

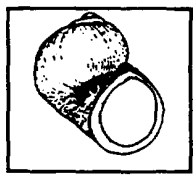

Figure 8. Moapa pebblesnail (*Fluminicola avernalis*).

Moapa pebblesnails have been collected at the Apcar, Refuge, and Plummer Springs, at springs on Warm Springs Ranch (likely the Baldwin, Cardy Lamb,

and/or Muddy Spring systems), and at a number of other unnamed springs in the Warm Springs area. These snails occur on pebbles, cobbles, concrete surfaces, and submerged vegetation. In 1973, they were considered locally abundant in the Apcar spring system and springs on Warm Springs Ranch with approximately 5 snails per square centimeter (cm^2) [32 per square inch (in^2)]; other springs had fewer than 1/cm^2 (7/in^2) (Landye 1973). No declines in abundance were noted because no baseline data were available. However, declines associated with recreational development of the springs were believed to have occurred, and further declines were anticipated due to the introduction of an Oriental snail (*Melanoides turberculatum*) (Landye 1973). Current population size and status are unknown.

Grated Tryonia

Grated tryonia shells are cone-shaped and less than 5 mm (0.2 in) long (Figure 9) (Landye 1973). Prominent ridges run the length of the shells, and finer growth lines can be seen between the ridges. Grated tryonia are members of the Family Hydrobiidae. This snail occurs most often in detritus and algae. In 1973, they were considered locally abundant in spring systems associated with the Muddy River (Landye 1973). Sada (pers. comm.) collected tryonia at Muddy and Cardy Lamb Springs in 1992. They also occur in spring systems to the north in the Pahranagat and White River Valleys, Nevada. Declines have been noted associated with the introduction of *M. turberculatum*, and habitat modification is

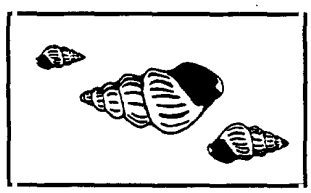

Figure 9. Grated tryonia (*Tryonia clathrata*).

also likely a threat. However, current population size and status are unknown.

Moapa Warm Spring Riffle Beetle

Moapa Warm Spring riffle beetles (Figure 10) are cylindrical and approximately 3.5 mm (0.14 in) long and 1 mm (0.04 in) wide (Schmude 1992). Their backs are reddish-brown, and the legs have a greenish tint. A dark stripe runs down the middle of the head. Although these beetles have wings they are undeveloped, and the beetles are flightless.

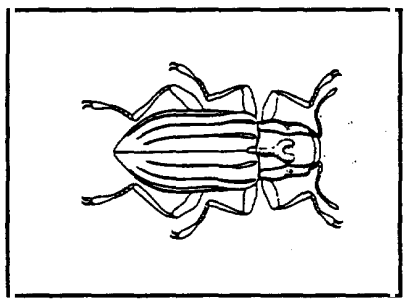

Figure 10. Moapa Warm Spring riffle beetle (*Stenelmis moapa*).

Adult riffle beetles typically occur in outflow streams immediately downstream of the spring sources in swift, shallow water on pebbles, algae-covered rocks within sand-pebble areas, aquatic vegetation, and especially bare tree roots (Schmude 1992). They have also been documented from the upper Muddy River and in marsh habitats connected to the spring systems, where the beetles live on submerged grass and under overhanging grassy streambanks. They may also live within submerged limestone (travertine) deposits. These beetles can live in water as warm as 31.7°C (89°F) and feed on algae.

As many as 149 riffle beetles have been collected at one time from the Plummer spring system (Schmude 1992). In 1986, adult beetles were abundant there, but

uncommon in the Muddy River upstream of the confluence with the Refuge stream. Prior development of the Plummer spring system for recreation and modifications to other occupied habitats are the greatest threats to the species. Current population size and status are unknown. Moapa Warm Spring riffle beetles were once thought to occur in Ash Springs and Hiko Spring in the Pahranagat Valley (La Rivers 1949, 1950), but these specimens were likely *S. occidentalis* (Schmude 1992).

Amargosa Naucorid

Amargosa naucorids are oval shaped, flattened bugs with front legs that form pincers (Figure 11). The middle and back legs are modified for swimming. Many naucorid species have fully developed flight wings, but flight is rarely observed. Colors are variable and range from a blackish brown to yellow brown and even green or gray. Body size is approximately 8-9 mm (0.31-0.35 in) long and 5 mm (0.2 in) wide. The Amargosa naucorid is consistently smaller and has different coloration than the one other *Pelocoris shoshone* subspecies (*P. s. amargosus*) found in the Amargosa River system in southwestern Nevada and Death Valley, California (La Rivers 1956, Usinger 1956).

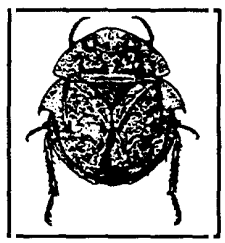

Figure 11. Amargosa naucorid (*Pelocoris shoshone shoshone*).

Naucorids eat various aquatic organisms including dragonfly, midge, and mosquito larvae; water boatmen; and mollusks. They carry a small air bubble under water

with them to maximize diving time. In the Warm Springs area, Amargosa naucorids typically live among aquatic plants in pools and lower velocity stream reaches, often under overhanging banks associated with marshy habitats. Current population status is unknown, but habitat modification is likely the most significant threat.

Other Species

Two other endemic species present in the Warm Springs area are a naucorid (*Usingerina moapensis*) and a water strider (*Rhagovelia becki*). *Usingerina moapensis* occurs in pebble beds in stream habitats with water temperatures between 23.9-31.7°C (75-89°F) (Usinger 1956). *Rhagovelia* are typically around 4 mm (0.16 in) in length. They have six legs with tufts of hairs on the ends, which enable them to live on water without breaking through the surface. In general, these water striders inhabit swift riffle reaches (Usinger 1956). The current population size, distribution, and potential threats to these two species are unknown.

E. Reasons for Listing

Change in Abundance - Moapa dace were "rather common" throughout the Warm Springs area when discovered in 1938, inhabiting spring pools, tributaries, and the main stem Muddy River (Hubbs and Miller 1948). La Rivers (1962) considered Moapa dace a common species only until 1950. However, collections by Hubbs and Miller indicate that Moapa dace were still relatively abundant in the Warm Springs area as of 1959 (UMMZ 1994).

A decline in Moapa dace abundance was first noted shortly after the introduction of nonnative shortfin mollies (*Poecilia mexicana*) in 1963 (Deacon and Bradley

1972, Cross 1976). Except for an increase in abundance at two historical collection sites on the upper Muddy River in 1967, Moapa dace continued to decline in both the spring systems and the upper river in subsequent years (Deacon and Bradley 1972). Deacon and Bradley (1972) attributed the 1967 increase to Moapa dace temporarily overcoming the detrimental effects of the molly introduction. However, these data could reflect natural population level fluctuations, migration of dace between the spring systems and the main stem river, or unidentified environmental changes.

In 1969, the International Union for Conservation of Nature and Natural Resources (IUCN) estimated the Moapa dace population at 500-1,000 individuals (Ono et al. 1983), however, the basis for this population estimate is unknown. Field surveys of historical collection sites during 1974-75 documented substantial declines in Moapa dace abundance since the 1964-68 surveys (Cross 1976). The IUCN estimated only a few hundred Moapa dace remained by 1977 (Ono et al. 1983). When the original Moapa Dace Recovery Plan was written in 1983, the Moapa dace population was estimated to consist of less than 1,000 individuals, restricted to three springs and less than 3.2 km (2 mi) of tributary and main stem Muddy River habitat (USFWS 1983).

During 1984-87, USFWS's Seattle National Fisheries Research Center (NFRC, now part of the NBS) extensively surveyed historical Moapa dace habitat and estimated the adult dace population at 2,600 to 2,800 individuals (Scoppettone et al. 1992). This population estimate represented the most accurate data on abundance and distribution ever gathered on the species. The apparent increase in the Moapa dace population in the 1980's may have been related to differences in survey techniques between NFRC and previous researchers. NFRC estimated the Moapa dace population by snorkeling habitats within the Warm Springs area and counting the number of dace observed. Earlier surveys were done with seines or

by electrofishing, methods which provide estimates of relative abundance, but are less reliable for estimating the size of the Moapa dace population (Scoppettone pers. comm.). A portion of the apparent population increase was also likely related to increased spawning habitat due to restoration of spring outflows on Moapa Valley NWR.

NBS resurveyed Moapa dace habitat in 1994, and a total of 3,841 adult dace were observed (Scoppettone unpubl. data). The number of dace would likely have been approximately 500 fish higher, if not for a catastrophic fire in June 1994 which nearly extirpated Moapa dace in the entire Refuge spring system (Scoppettone pers. comm.).

Habitat Alteration - Alteration of Moapa dace habitat in the Warm Springs area began before the species was discovered, primarily for irrigation purposes (Scrugham 1920). The spring systems and the upper Muddy River have since been developed for recreational, industrial, and municipal uses as well.

Natural spring pools in both the Plummer (Desert Oasis Warm Springs Resort) and Refuge (7-12 Warm Springs Resort; later Moapa Valley NWR) spring systems were enlarged and lined with concrete and/or gravel to create public swimming pools. Water discharging from these springs was chlorinated, as required by State regulations for public use; and aquatic vegetation was mechanically and/or chemically (copper sulfate) removed. Moapa dace were eliminated from both spring systems prior to 1979. Total discharge from the Refuge stream includes 100.5 L/sec (3.55 cfs) from the Refuge springs (USGS 1993), 64 L/sec (2.26 cfs) from the Plummer springs (Eakin 1964), and 83.2 L/sec (2.94 cfs) from the Apcar spring system (Eakin 1964) for a total potential discharge of 247.7 L/sec (8.75 cfs) at the confluence with the Muddy River.

One spring in the Apcar system has been enlarged and concreted to make a private swimming pool. Water rights from other springs in the Apcar system and approximately 0.26 hectare (ha) [0.64 acre (A)] of surrounding land (T. 14 S., R. 65 E., sec. 16, SE¼) were sold to the Moapa Valley Water District (MVWD). MVWD has channelized and piped these springs (since 1959) for local municipal use. Another outflow stream in the Apcar system flows through a culvert under Warm Springs Road and into dirt and cement irrigation ditches on Warm Springs Ranch.

At least two spring systems (Baldwin, Cardy Lamb) on Warm Springs Ranch were historically channelized and diverted for irrigation. Cardy Lamb (T. 14 S., R. 65 E., sec. 9, SW¼) discharges into a cement swimming pool, which overflows into an irrigation ditch. Flow from the Cardy Lamb system was 130.5 L/sec (4.61 cfs) in 1963 at the confluence with the Muddy River (Eakin 1964). Another swimming pool was constructed on Warm Springs Ranch in an overflow channel from the Muddy Spring stream (T. 14 S., R. 65 E., sec. 16, NE¼) in 1992. The 29 ha (72 A) of land surrounding this pool were set aside for private recreational use. Flows from the Muddy Spring system were 235.6 L/sec (8.32 cfs) in 1963 (Eakin 1964). Springs in the Baldwin system (T. 14 S., R. 65 E., sec. 16, NW¼ and sec. 15, NW¼) are currently piped by MVWD, and together with the Apcar spring system diversions, represent approximately 50 percent of MVWD's water supply. In 1963, flows from the Baldwin system into the Muddy River totaled 261 L/sec (9.21 cfs) (Eakin 1964)

Previously, irrigation return flows and runoff from fields on Warm Springs Ranch greatly increased turbidity and sediment loads in the spring outflows and upper Muddy River. Agricultural activity on Warm Springs Ranch has decreased in recent years, as the ranch is no longer operated as a church welfare farm. However, portions of the ranch are currently leased for horse and cattle grazing

and alfalfa production. The landowner has indicated that no agricultural pesticides are being used on the property. A surface water right totaling approximately 56 L/sec (1.98 cfs) from springs near the southern and western property boundaries has been retained by the landowner for ranch use.

The main stem Muddy River is a vital component of Moapa dace habitat, especially for the larger and more fecund adults. It typically supports approximately 50 percent of the dace population (Scoppettone et al. 1987). Moapa dace move between the river and tributaries for spawning and to avoid periodically unfavorable water quality conditions in the river (i.e., high turbidity). Moapa dace habitat in the Muddy River has been adversely modified by human activities directly affecting the river and also indirectly by activities affecting the river's headwater springs, tributaries, and floodplain.

In addition to spring water leased from MVWD and groundwater leased from at least three wells on Warm Springs Ranch, Nevada Power Company (NPC) diverts water directly from the upper Muddy River (T. 14 S., R. 65 E., sec. 15, SE¼) for use at Reid-Gardner Station, an electrical generating facility near Moapa, Nevada. Diversions at this site have occurred since 1968, and current diversion rates are up to 260 L/sec (9.2 cfs) during the months of October through May and up to 50 L/sec (1.77 cfs) during the remainder of the year. Instream flow at the USGS gaging station immediately downstream averages 1,212 L/sec (42.8 cfs) (Eakin 1964, USGS 1993).

The existing NPC diversion dam on the Muddy River was constructed in 1988-89. It impounds approximately 140 m (450 ft) of the upper Muddy River and has reduced the overall suitability of this habitat for Moapa dace. Several riffles and drift feeding stations were likely eliminated by the impoundment, thereby reducing foraging opportunities for adult dace. Decreased flow velocities upstream of the

dam have also increased silt deposition and promoted establishment of extensive beds of nonnative eel grass, both of which cover vital sand, pebble, and cobble substrates. Nonnative fish species, including shortfin mollies and mosquitofish (*Gambusia affinis*), are well established in this habitat. The dam also inhibits upstream movement of Moapa dace which are downstream of the structure, preventing access to spring systems for spawning. Sada (pers. comm.) has observed over 100 Moapa dace in the 300-m (1,000-ft) reach immediately downstream of the dam. These dace are lost to the reproductive population. NPC is preparing to replace the diversion dam with an intake specifically designed to not impound the river or restrict Moapa dace movement.

In 1944, the U.S. Bureau of Reclamation constructed a Cipoletti weir gaging station on the Muddy River at the Warm Springs Road bridge. The concrete weir is over 3 m (10 ft) high and impounds approximately 45 m (150 ft) of Moapa dace habitat in the upper Muddy River immediately downstream of NPC's diversion dam. It likely affects flows, substrate, aquatic vegetation, and fish species composition, but to a lesser extent than the NPC dam. The weir is a physical barrier to upstream movements of all fishes in the middle and lower Muddy River. The present range of Moapa dace extends downstream of this structure, and these dace are lost to the reproductive population as well.

Introduced Species - Through stocking, nonnative mosquitofish became established in the Muddy River system by 1938, but typically occupied pool habitats and did not appear to substantially impact the Moapa dace population. There is little spatial overlap between adult Moapa dace and mosquitofish; overlap with larval and juvenile dace is approximately 22-26 percent (Deacon and Bradley 1972, Scoppettone 1993).

Shortfin mollies were introduced into the Muddy River ecosystem in the early 1960's and had a much greater impact on Moapa dace than did mosquitofish. Shortfin mollies were common in the Muddy River by autumn 1963 (Hubbs and Deacon 1964), but were not the predominant species in the headwater spring systems until January 1965 (Deacon and Bradley 1972). The concurrent decline in the abundance of Moapa dace during these years was likely related to interactions between these two species.

Habitat use by mollies is similar to that of Moapa dace (Deacon and Bradley 1972, Scoppettone et al. 1987). Deacon and Bradley (1972) estimated spatial overlap between Moapa dace and shortfin mollies at 68 percent; Scoppettone (1993) estimated spatial overlap between adult shortfin mollies and larval and juvenile Moapa dace at 44-45 percent. Laboratory experiments have demonstrated that shortfin mollies are fish larvae predators (Scoppettone 1993), and this may have been the mechanism effecting the decline in Moapa dace abundance.

In addition to mosquitofish and shortfin mollies, numerous other nonnative fish species have been collected in the Muddy River. Common carp (*Cyprinus carpio*) were first collected in 1938; channel catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*), and green sunfish (*Lepomis cyanellus*) were collected in 1942 (UMMZ 1994). Deacon and Bradley (1972) collected several additional nonnative fish species in the Muddy River during 1963-68 including: Red shiner (*Cyprinella lutrensis*), fathead minnow (*Pimephales promelas*), and black bullhead (*Ameiurus melas*). Two additional nonnative fishes present during 1974-75 collections by Cross (1976) were golden shiners (*Notemigonus crysoleucas*) and a single rainbow trout (*Oncorhynchus mykiss*). Historically, nonnative fishes other than mosquitofish, mollies, and common carp have been collected only from the middle and lower Muddy River.

More recent additions to the Muddy River's fish fauna include blue tilapia (*Tilapia aurea*) and Koi (*C. carpio* domestic var.), discovered in 1991 and 1992, respectively (Sada 1992 *in litt.*). Limited numbers of both species were found upstream of the weir, but below the NPC dam. Weir passage was likely facilitated by human intervention. The blue tilapia population downstream of the weir has been estimated at over 200 fish, with documented reproduction in 1992 (Heinrich pers. comm.). Blue tilapia can increase turbidity, reduce the abundance of algae and aquatic vegetation, and alter natural forage bases (plankton) (Taylor et al. 1984). Thus, this nonnative species has the potential to cause substantial negative impacts to Moapa dace habitat as well as habitats of other native species in the Muddy River ecosystem.

The effects of nonnative fishes on Moapa dace have not been studied, other than those of mosquitofish and shortfin mollies. However, in addition to direct effects such as predation, prior nonnative fish introductions have introduced fish parasites including tapeworms (*Bothriocephalus acheilognathi*), nematodes (*Contracaecum* spp.), and anchor worms (*Lernaea* spp.) which have adversely affected native fishes of the Muddy River (Wilson et al. 1966, Heckman 1988). The anchor worm (*Lernaea* spp.) has been identified as a Moapa dace parasite (Wilson et al. 1966), however, the current extent of Moapa dace infestation by this copepod and other parasites is unknown. Anchor worm infestations cause tissue damage and blood loss and expose fish to secondary infections from bacteria, fungi, and viruses. Heavy infestations may cause reduced longevity, reduced fecundity, and even direct mortality. Tapeworms may cause fish to become listless, lose weight, or become sterile; severe infections may cause the abdomen to become distended and block the intestine (USFWS 1986). Nematodes may encyst in fish muscle tissue with detrimental effects on overall fish health (Wilson et al. 1966).

Adverse effects to Moapa dace from nonnative species other than fishes include

predation by bullfrogs (*Rana catesbeiana*) and spiny soft-shelled turtles (*Trionyx spiniferus*) (USFWS 1989). The nonnative snail, *M. tuberculatum*, is extremely abundant in the spring systems, but their impact on Moapa dace, if any, is unknown.

F. Conservation Measures

Conservation measures for Moapa dace were initiated when the species was federally listed as endangered in 1967. The State of Nevada classified the species as rare in 1970, increasing recognition of its legal protection [General Register No. 1(8), 501.110 Nevada Revised Statute, 3-6-78]. Currently, the State of Nevada lists Moapa dace as endangered (Nevada Administrative Code 503.065-.06, 1988).

1. Refugia - A refugium is a natural or artificial habitat where an isolated population of a species is established and protected. Refugia populations can be used to restock a species into its historical habitat in the event the species is extirpated. Because Moapa dace were believed in danger of extinction in their historical habitat, attempts were made to establish new refugia populations. In September 1972, 20 juvenile and adult Moapa dace were transported to Shoshone Ponds, a U.S. Bureau of Land Management facility for endangered fish species located near Ely, Nevada. This transplant failed after a month for unknown reasons. A later transplant of Moapa dace to Hot Creek Springs, located approximately 322 km (200 mi) north of Las Vegas, Nevada, also failed possibly due to water quality differences or other habitat limitations (USFWS 1979, unpubl. data). In the 1970's, data on the life history and habitat requirements of Moapa dace were limited, thus, efforts to establish refugia populations failed. These data have since been collected, but no suitable refugia sites have been identified. There are currently no Moapa dace in refugia.

2. Moapa Valley National Wildlife Refuge - Essential habitat (36.4 ha; 90 A) for Moapa dace was described in an Environmental Assessment (EA) for land acquisition by the USFWS in the Warm Springs area (USFWS 1979). The EA identified four parcels of private land as essential habitat, which together contained six spring systems and the upper Muddy River. USFWS purchased one parcel (7-12 Warm Springs Resort) and associated water rights in September 1979 for the appraised value. Moapa Valley NWR was established on the property and initially consisted of 4.86 ha (12 A), with three distinct spring orifices. However, no Moapa dace were present due to habitat alterations and chlorination associated with prior resort operations.

The USFWS prepared an Aquatic Habitat Management Plan (HMP) to guide aquatic habitat development and restoration on Moapa Valley NWR. To increase available habitat on the refuge, a 320-m (1,050-ft) long artificial stream channel was constructed in 1980. Substrates and cover were strategically placed within this concrete channel to create pool, riffle, and run habitats. The artificial stream was first stocked with 50 Moapa dace in February 1981. Additional dace were placed in pool habitat on Moapa Valley NWR during July 1981 and again in February 1982. However, only 17 Moapa dace remained on Moapa Valley NWR by December 1983 (Scoppettone pers. comm.), indicating the marginal success of the transplants and the need for additional research on habitat requirements. Other activities performed under the HMP included filling an olympic swimming pool and modifying other smaller pools to provide more suitable habitat. Habitat within spring outflows was also restored to more natural conditions, and fish barriers were constructed at various sites to inhibit the upstream movement of nonnative fishes.

To protect Moapa Valley NWR's water supply and provide long-term protection of additional Moapa dace habitat, an adjacent land parcel (8.77 ha; 21.7 A) and

water rights to two springs were purchased by the USFWS in October 1983. Acquisition of this habitat was a priority 1 task (an action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future) in the 1983 recovery plan because approximately 50 percent of the surface water on Moapa Valley NWR originated from the two springs on the adjoining property. With this addition to Moapa Valley NWR, the USFWS's water rights totaled approximately 12.5 percent of the tributary inflows to the upper Muddy River. In April 1984, the newly acquired habitat was chemically treated to eradicate nonnative fishes. Adult and juvenile Moapa dace were then stocked into the artificial stream; 120 individuals were in residence by January 1986 (Scoppettone et al. 1992).

Root masses from palm trees were encroaching into Moapa dace spawning, nursery, and adult foraging habitats and also constricting spring outflow channels on Moapa Valley NWR in the early 1980's. Channel constrictions produce increased flow velocities, which also affect the suitability of spawning and nursery habitats downstream. A limited number of nonnative palm trees were removed from riparian areas on Moapa Valley NWR in 1983-84, and 35 more were removed in 1990. The palm trees selected for removal were those immediately adjacent to or within the spring pools and outflow streams. Evapotranspiration by these trees was likely a significant source of water loss from the Moapa Valley NWR spring system. Their removal opened the overstory canopy, allowing more sunlight to reach the water, thereby increasing primary production within the spring system. This increased primary production likely increased the abundance of food items for Moapa dace. Moapa Valley NWR's draft Landscape Plan specified that approximately one-third of the remaining mature [height > 3 m (10 ft)] palm trees be removed from riparian areas on the refuge to benefit the dace (USFWS 1991).

On June 26, 1994, a fire originating on an adjacent resort property spread to the palm grove on Moapa Valley NWR. Although the fire passed quickly through the refuge due to high winds, the intense heat likely caused water temperatures in the spring system to reach levels lethal to fish, except at the spring orifices and in deep, artificial pools. Also, up to 1 m (3.3 ft) of ash and debris from burning palm fronds filled the spring pools and outflow streams, depleting dissolved oxygen and increasing the acidity of the water. NBS and USFWS biologists surveyed the refuge spring system on June 28 and July 5-6, 1994, and only 15 Moapa dace were observed (Scoppettone pers. comm.). The refuge was previously inhabited by as many as 500 adult Moapa dace; the number of larval and juvenile Moapa dace lost due to the fire is unknown. Once habitat conditions in the refuge spring system have stabilized, Moapa dace obtained from nearby spring systems and/or the Muddy River will be used to restock the refuge.

Since the fire, debris deposited throughout the spring system has been manually removed, and natural flows have flushed out ash and other fine particulates. Approximately 200 burned palm trees were removed from riparian areas to prevent future catastrophic fires and to improve stream and pool habitats. Native and nonnative riparian plants have reestablished themselves along the spring system. Additional native vegetation will be planted to protect the spring system from excess sedimentation from the barren uplands and to hinder repopulation of palm trees and invasion by salt cedar. Also, leaves from native deciduous trees will provide a source of nutrients through decomposition and will increase productivity of the spring system.

3. Recovery Plan - A recovery plan for Moapa dace was written in 1983 by USFWS, in cooperation with the Nevada Division of Wildlife. The primary objective of the 1983 plan was to "protect and rehabilitate adequate habitat within the historical range of the Moapa dace to delist the species" (USFWS 1983). It

identified five priority research and recovery needs for Moapa dace: 1) Determine characteristics of a self-sustaining population, 2) rehabilitate habitats to support Moapa dace, 3) reintroduce Moapa dace, 4) monitor populations, and 5) protect habitat. The recovery plan provided a means whereby Federal agencies could fund and/or perform recovery actions identified in the plan. In the years immediately following publication of the recovery plan, much effort was directed toward restoring habitat on Moapa Valley NWR and reintroducing Moapa dace.

4. Research - Hubbs and Miller (1948) were first to report on the distribution, habitat, morphometrics (body size measurements), and meristics (i.e., scale counts) of Moapa dace, as well as associated species in the Muddy River ecosystem. Limited additional research was performed with regard to Moapa dace until they were listed in 1967. Deacon et al. (1964) reported on the introductions of nonnative fishes to the Muddy River and their effects on native fishes; Wilson et al. (1966) studied the incidence of parasitism; and Deacon and Bradley (1972) examined fish species composition, distributions, changes in abundance, and habitat use. Deacon and Bradley's 1964-68 study was repeated in 1974-75 by Cross (1976).

Completion of the 1983 recovery plan created a new Federal research initiative. NFRC completed many research tasks specified in the 1983 Plan, including studies during 1984-89 on Moapa dace life history, abundance and distribution, food habits, age and growth, habitat use, movement patterns, population dynamics, and inter- and intraspecific interactions (USFWS 1984, Scoppettone et al. 1987, 1992). This key research identified the need for habitat continuity between thermal spring systems and the Muddy River for the survival of Moapa dace.

5. Other Conservation Actions - Moapa Valley residents have formed a committee to develop a conservation strategy for the Muddy River ecosystem.

This committee, known as the Muddy River Regional Environmental Impact Alleviation Committee (MRREIAC), is identifying actions to restore and manage aquatic and riparian habitats to benefit endemic fish and wildlife and local residents. The USFWS is assisting MRREIAC by providing biological information on Moapa dace and the species of special concern, as well as data on general environmental conditions. This recovery plan should serve as a guide for MRREIAC in developing conservation actions benefitting rare aquatic species.

G. Recovery Strategy

The strategy for recovery that is detailed in the following stepdown narrative begins with the protection and management of Moapa dace habitat including existing instream flows. Recovery will be accomplished by protecting Moapa dace habitat from adverse physical, chemical, and biological modifications through the development of conservation agreements with private landowners. Comprehensive management plans for these areas will be developed to guide habitat restoration efforts. Nonnative fish removal is one priority restoration measure.

A monitoring program is proposed that will collect and analyze baseline data necessary for assessing population trends and habitat conditions. A research project is also recommended to study the prevalence of parasitic organisms and to determine their effects on the Moapa dace population. Public information and education outreach programs will be necessary to keep interested and affected parties informed of recovery activities and to create an avenue for their involvement.

II. RECOVERY ANALYSIS

A. Objective and Criteria - The objective of this Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem is to improve the status of Moapa dace so that it may be delisted and to improve the status of seven associated aquatic species of special concern. Moapa dace only occupy the unique habitats of the Warm Springs area, and recovery tasks are focused on habitats within their historical range. However, recovery tasks that would benefit species of special concern throughout the Muddy River ecosystem are also included. All recovery criteria are preliminary and may be revised on the basis of new information (including research specified as recovery tasks). The estimated dates for reclassification of Moapa dace to threatened status and delisting are 2000 and 2009, respectively.

Moapa dace will be considered for reclassification from endangered to threatened when:

1) Existing instream flows* and historical habitat in three of the following five occupied spring systems and the upper Muddy River have been protected through conservation agreements, easements, or fee title acquisitions:

> **Apcar** - from the spring orifices to the confluence with the Refuge spring system [stream length of 1.08 km (0.67 mi)].
>
> **Baldwin** - from the spring orifices to the confluence with the North Fork of the Muddy River [stream length of 1.02 km (0.63 mi)].
>
> **Cardy Lamb** - from the spring orifices to the confluence with the South Fork of the Muddy River [stream length of 0.8 km (0.5 mi)].

Muddy Spring - from the spring orifices to the confluence with the Muddy River [stream length of 0.8 km (0.5 mi)].

Refuge - from the spring orifices on Moapa Valley NWR to the confluence with the Muddy River [stream length of 1.39 km (0.86 mi)].

Upper Muddy River - from the confluence of the North Fork and South Fork to approximately 300 m (1,000 ft) downstream of the Warm Springs Road bridge [stream length of 3.33 km (2.07 mi)].

* - Existing instream flow data are unavailable for four of the five spring systems, and thus, flows are not quantified here.

2) 4,500 adult Moapa dace are present among the five spring systems and the upper Muddy River; and

3) the Moapa dace population is comprised of three or more age-classes, and reproduction and recruitment is documented from three spring systems.

Moapa dace will be considered for delisting provided that all reclassification criteria have been met and when:

1) 6,000 adult Moapa dace are present among the five spring systems and the upper Muddy River for 5 consecutive years;

2) 75 percent of the historical habitat in the five spring systems and the upper Muddy River provides Moapa dace spawning, nursery, cover, and/or foraging habitat; and

3) nonnative fishes and parasites no longer adversely affect the long-term survival of Moapa dace.

Actions taken to recover Moapa dace and restore the upper Muddy River ecosystem will give due consideration to the needs of all species of special concern. One stated purpose of the ESA is to conserve ecosystems upon which endangered and threatened species depend. Actions taken to improve the status of Moapa dace should improve the status of the entire riverine ecosystem. Although not a criterion for reclassification or delisting of Moapa dace, the distribution and abundance of the seven species of special concern within their historical habitats in the Warm Springs area should be used as an indicator of overall ecosystem health and stability. Prior to implementing any task identified in this Plan, the lead agency must comply with all applicable provisions of the ESA, as well as the National Environmental Policy Act of 1966.

B. Narrative Outline for Recovery Actions Addressing Threats

1. Protect and restore Moapa dace habitat

Moapa dace are naturally restricted in distribution to the Warm Springs area. Because of their specific habitat requirements and limited distribution, habitat within the Warm Springs area needs to be protected and restored to recover the species. This habitat includes the upper Muddy River and five tributary spring systems, which together provide spawning, rearing, feeding, and cover habitat. Migration corridors between tributary spawning habitat and the main stem Muddy River are also an important component of Moapa dace habitat.

Moapa dace habitat in the upper Muddy River and tributary spring systems has been physically, chemically, and biologically modified, such that extensive restoration will be required to achieve delisting. Restoration needs for Moapa dace habitat are known; however, site specific restoration planning in coordination with the landowners is needed. Measures undertaken to restore habitat in the spring systems and the upper Muddy River for Moapa dace should benefit associated species of special concern and possibly eliminate the need for future listings of these species.

11. Develop and implement habitat protection agreements

Moapa dace habitat on Moapa Valley NWR is ensured long-term protection from adverse modifications by virtue of its Federal refuge status. However, the majority of habitat currently occupied by Moapa dace is on private property, and no protective measures are in place. Actions by private landowners are not subject to all of the same Federal regulations pertaining to endangered species as are actions funded, permitted, or performed by Federal agencies. Therefore, obtaining the cooperation and support of the landowners is essential to protect these

habitats. Future adverse modifications (physical, chemical, and/or biological) to Moapa dace habitat on private land can be minimized or avoided through landowner coordination and participation. Similarly, actions to restore such habitat can only be accomplished with the cooperation of the landowners.

Long-term protection for Moapa dace habitat in at least three spring systems and the upper Muddy River is a criterion for reclassifying and delisting the species. Such habitat/species protection agreements, typically called conservation agreements, can cover a period as short as 5 years, but can extend into perpetuity depending upon the terms of the agreement reached with each individual landowner. Long-term agreements (i.e., 30 years) are most desirable for delisting purposes.

Conservation agreements should be negotiated with willing private landowners. These agreements are always voluntary on the part of the landowner. Conservation agreements could include access rights for management activities such as nonnative species eradication and Moapa dace population monitoring, maintenance of existing instream flow and habitat, habitat restoration activities, and any other appropriate measures. Monitoring implementation and success of agreed upon tasks would be part of the conservation effort.

Land acquisition and/or water rights acquisition from willing sellers at fair market value are other options to provide long-term protection to Moapa dace habitat. Purchasing privately owned Moapa dace habitat and associated water rights may permit more extensive habitat restoration than conservation agreements. If funding and willing sellers are available, Moapa dace habitat and associated water rights could be acquired and

incorporated into Moapa Valley NWR. Refuge status would ensure long-term protection and management. Any water right ownership transfers from willing sellers would be subject to Nevada water law.

12. Minimize nonnative fish impacts

Nonnative fishes represent a serious threat to recovery and survival of Moapa dace. Surveys have documented the presence of shortfin mollies and/or mosquitofish within all occupied Moapa dace habitat (except within a portion of the Refuge spring system on Moapa Valley NWR protected by a fish barrier). Their continued presence may preclude delisting Moapa dace due to adverse effects on reproduction and recruitment. The invasion of blue tilapia throughout Moapa dace habitat appears imminent, and adverse effects are highly probable.

Wherever feasible, all nonnative fishes should be removed from Moapa dace habitat. Restoration of habitat to natural conditions will facilitate nonnative fish removal by reducing the availability and suitabililty of habitat for these species. Physical removal of nonnative fishes (e.g., trapping, seining, etc.) should be used whenever possible to minimize effects on Moapa dace and other aquatic species of special concern. However, chemical eradication (e.g., rotenone) might be necessary in some reaches where flows, depth, and/or cover make physical removal infeasible. All rare native aquatic species in the Warm Springs area should benefit by reducing or eliminating interactions with nonnative fishes.

The USGS weir is currently acting as a fish barrier and is restricting further unaided upstream movement of blue tilapia and other nonnative fishes into the upper Muddy River and subsequently into the spring

systems. Monitoring of this gaging station is being discontinued by the USGS due to funding constraints. The weir should be evaluated for use as a permanent fish barrier, and responsibility for maintenance of the barrier would be assumed by USFWS. Any modifications to the weir must be designed to minimize debris accumulation, to not impound water, and to withstand frequent small-scale flood events without compromising barrier integrity. However, if the weir is compromised and tilapia become established in the Warm Springs area, strong consideration should be given to removing the weir in its entirity.

13. Develop and implement habitat restoration/management plans

Habitat restoration/management plans should be developed in cooperation with landowners for all occupied habitats (Apcar, Baldwin, Cardy Lamb, Muddy Spring, and Refuge spring systems and the upper Muddy River). The five spring systems will benefit most from restoration work as they have experienced more perturbations. The restoration work will be guided by available data on historical biological, physical, and chemical habitat conditions in these reaches.

Restoration and management needs vary among the spring systems and the river, but may include: Restoring natural hydrologic regimes (i.e., restore flows to dewatered, low flow, or intermittent tributary reaches, remove artificial impoundment structures, etc.); creating spawning and nursery habitats in the spring systems, and drift feeding stations in the spring systems and the upper river; improving water quality, particularly in reaches associated with agricultural land; removing nonnative aquatic and terrestrial vegetation encroaching into spring outflow channels; fire cleanup on the Refuge spring system and fire prevention measures throughout riparian areas associated with occupied habitat (i.e., palm tree

thinning, revegetation with native species, etc.); and creating contiguous Moapa dace habitat from spawning areas near spring orifices to the upper Muddy River. Any restoration activities involving changes in water use would be of a non-consumptive nature (to maintain or increase instream flows).

2. Monitor Moapa dace population

Most earlier Moapa dace monitoring efforts have been sporadic and have not covered the entire range of the species, and monitoring techniques have varied. Monitoring should be performed annually by snorkeling all historical Moapa dace habitat and recording the individuals observed. Surveys should occur during the winter because of improved fish visibility (less turbidity and aquatic vegetation) and because spawning activity is reduced. This monitoring protocol will be used to develop a reliable long-term data set.

Monitoring data are necessary to determine whether or not recovery criteria for reclassification and delisting have been met. These criteria set requirements for Moapa dace abundance, population structure, and distribution. Monitoring will also provide data to evaluate the effectiveness of habitat restoration and management and nonnative species eradication measures. Also, potential problems such as nonnative species reinvasions can be identified in a timely manner during routine population monitoring.

3. Determine extent of parasitism in Moapa dace population

Parasites and disease-causing organisms are typically present in any environment; however, outbreaks among fish can frequently be linked to some form of stress, which increases their susceptibility. In the Muddy River, nonnative fishes have acted as vectors for new parasites including anchor worms, nematodes, and Asian fish tapeworms (Wilson et al. 1966, Heckman

1988). Wilson et al. (1966) suggested that the high incidence of parasitism in native fishes of the Muddy River was due to habitat deterioration. Moapa dace may also be experiencing some form of stress from interactions with increasing populations of nonnative fishes.

Moapa dace parasites should be identified and their impacts on Moapa dace health, reproduction, and recruitment should be determined. If documented as having a negative impact on Moapa dace, control and/or preventative measures should be developed. These measures may be linked to nonnative fish eradication activities and habitat restoration.

4. Provide public information and education

An outreach plan for public information and education regarding Moapa dace and other aquatic species of special concern should be developed. Outreach activities have a focal point in Moapa Valley NWR, but should cover recovery actions both on and off the refuge. Significant future recovery actions such as habitat restoration, conservation agreements, and even monitoring data will provide specific opportunities for public outreach. Press releases, feature articles, fact sheets, interviews, field trips, presentations, and brochures may be used to reach the local, regional, and scientific communities. Outreach materials such as fact sheets and brochures should be made available on site at Moapa Valley NWR and at local USFWS offices for distribution to the public.

Outreach activities must be directed at landowners with Moapa dace habitat, but should also involve the general public where appropriate. Public support for recovery efforts will be especially vital in limiting future adverse modifications to Moapa dace habitat, including reintroductions of nonnative fish species. Public information and education is also needed to prevent aerial, surface, and groundwater transport of pesticides and herbicides from

agricultural or residential land into nearby Moapa dace habitat.

A self-guided, interpretive trail and corresponding exhibits are proposed for the spring system at Moapa Valley NWR. Due to their endangered status, Moapa dace will likely be the primary focus of such exhibits; however, information regarding other rare endemic fishes and invertebrates would be included to emphasize interrelationships among ecosystem components.

C. Literature Cited

Allan, R.C., and D.L. Roden. 1978. Fish of Lake Mead and Lake Mohave - Base fisheries data Boulder Canyon to Davis Dam. Biological Bulletin No. 7. Nevada Department of Wildlife, Reno. 105 pp.

Coburn, M.M., and T.M. Cavender. 1992. Interrelationships of North American cyprinid fishes. Pages 328-373 *in* Systematics, Historical Ecology, and North American Freshwater Fishes. R.L. Mayden (ed.). Stanford University Press, Stanford, California.

Cross, J.N. 1976. Status of the native fish fauna of the Moapa River (Clark County, Nevada). Transactions of the American Fisheries Society 105(4):503-508.

Deacon, J.E., C.L. Hubbs, and B.J. Zahuranec. 1964. Some effects of introduced fishes on the native fish fauna of southern Nevada. Copeia 1964:384-388.

Deacon, J.E., and W.G. Bradley. 1972. Ecological distribution of fishes of Moapa (Muddy) River in Clark County, Nevada. Transactions of the American Fisheries Society 101(3):408-419.

DeMarais, B.D., T.E. Dowling, M.E. Douglas, W.L. Minckley, and P.C. Marsh. 1992. Origin of *Gila seminuda* (Teleostei: Cyprinidae) through introgressive hybridization: Implications for evolution and conservation. Proceedings of the National Academy of Science 89:2747-2751.

Eakin, T.E. 1964. Groundwater appraisal of Coyote Spring and Kane Spring Valleys and Muddy River Springs area, Lincoln and Clark Counties, Nevada. U.S. Geological Survey, Groundwater Resources-Reconnaissance Series Report No. 25. 40 pp.

Harrington, M.R. 1929. Archaeological explorations in Southern Nevada. South West Museum Papers No. 4. Reprint 1970:1-126.

Heckman, R.A. 1988. Presence of the Asian fish tapeworm, (*Bothriocephalus acheilognathi*), in the Moapa-Muddy River area, Nevada. Brigham Young University, Provo, Utah. 6 pp.

Holden, P.B., and C.B. Stalnaker. 1970. Systematic studies of the Cyprinid genus *Gila*, in the Upper Colorado River Basin. Copeia 1970(3):409-420.

Hubbs, C.L., and R.R. Miller. 1948. Two new, relict genera of cyprinid fishes from Nevada. University of Michigan Museum of Zoology Occasional Paper 507:1-30.

Hubbs, C.L., and J.E. Deacon. 1964. Additional introductions of tropical fishes into southern Nevada. Southwestern Naturalist 9(4):249-251.

Landye, J.J. 1973. Status of the inland aquatic and semi-aquatic mollusks of the American Southwest. Report prepared by the Lower Colorado River Basin Research Laboratory, Arizona State University, Tempe. Submitted to the Bureau of Sport Fisheries and Wildlife, Washington, D.C. p. 14.

La Rivers, I. 1949. A new subspecies of *Stenelmis* from Nevada. Entomological Society Washington Proceedings 51(5):218-224.

La Rivers, I. 1950. The meeting point of *Ambrysus* and *Pelocoris* in Nevada (Hemiptera: Naucoridae). Pan-Pacific Entomologist 26(1):19-21.

La Rivers, I. 1956. A new subspecies of *Pelocoris shoshone* from the Death Valley Drainage (Naucoridae: Hemiptera). Wasmann Journal of Biology 14(1):155-158.

La Rivers, I. 1962. Fishes and fisheries of Nevada. Nevada Fish and Game Commission, Reno. 782 pp.

Longwell, C.R. 1928. Geology of the Muddy Mountains, Nevada, with a section through the Virgin Range to the Grand Wash Cliffs, Arizona. U.S. Geological Survey Bulletin 798. p. 14-15.

Miller, R.R. 1952. Bait fishes of the lower Colorado River from Lake Mead, Nevada, to Yuma, Arizona, with a key for their identification. California Fish and Game 38(1):7-42.

Minckley, W.L. 1973. Fishes of Arizona. Arizona Game and Fish Department, Phoenix. 293 pp.

Ono, R.D., J.D. Williams, and A. Wagner. 1983. Vanishing fishes of North America. Stone Wall Press, Washington, D.C. 257 pp.

Schmude, K.L. 1992. Revision of the riffle beetle genus *Stenelmis* (Coleoptera: Elmidae) in North America, with notes on bionomics. Ph.D. Dissertation. University of Wisconsin, Madison. p. 45-46.

Scoppettone, G.G. 1993. Interactions between native and nonnative fishes of the upper Muddy River, Nevada. Transactions of the American Fisheries Society 122:599-608.

Scoppettone, G.G., H.L. Burge, P.L. Tuttle, M. Parker, and N.K. Parker. 1987. Life history and status of the Moapa dace (*Moapa coriacea*). U.S. Fish and Wildlife Service, National Fisheries Research Center, Seattle, Washington. 77 pp.

Scoppettone, G.G., H.L. Burge, and P.L. Tuttle. 1992. Life history, abundance, and distribution of Moapa dace (*Moapa coriacea*). Great Basin Naturalist 52(3):216-225.

Scrugham, J.G. 1920. Order of determination of relative rights to the Muddy River and its tributaries. Judgement and Decree, Case No. 377. State Engineer, Carson City, Nevada. 23 pp. + exhibits.

Smith, G.R., R.R. Miller, and W.D. Sable. 1979. Species relationships among fishes of the genus *Gila* in the upper Colorado River drainage. Pages 613-623 *in* Proceedings of the First Conference on Scientific Research in the National Parks. R.M. Linn (ed.). National Park Service Transactions and Proceedings Series No. 5. Washington, D.C.

Soil Conservation Service. 1993. Salinity Control Plan and Final Environmental Impact Statement. Moapa Valley Unit, Nevada. Colorado River Salinity Control Program. Nevada State Office, Reno. 105 pp. + appendices.

Taylor, J.N., W.R. Courtenay, Jr., and J.A. McCann. 1984. Known impacts of exotic fishes in the continental United States. Pages 322-373 *in* Distribution, Biology, and Management of Exotic Fishes. W.R. Courtenay, Jr. and J.R. Stauffer, Jr. (eds.). Johns Hopkins University Press, Baltimore, Maryland.

University of Michigan Museum of Zoology (UMMZ). 1994. Collection records of the Division of Fishes. Ann Arbor, Michigan.

U.S. Fish and Wildlife Service. 1979. Environmental Impact Assessment, Land Acquisition Ascertainment Report, Moapa Dace (*Moapa coriacea*). Portland, Oregon. 88 pp.

U.S. Fish and Wildlife Service. 1983. Moapa Dace Recovery Plan. Portland, Oregon. 32 pp.

U.S. Fish and Wildlife Service. 1984. Life history and ecological requirements of the Moapa dace (*Moapa coriacea*). Endangered Species Recovery Plan Research Project. National Fisheries Research Center, Seattle, Washington. 40 pp.

U.S. Fish and Wildlife Service. 1986. Some parasites and diseases of warmwater fishes. Research and Development Fish and Wildlife Leaflet 6. Fish Farming Experimental Station, Stuttgart, Arkansas. 22 pp.

U.S. Fish and Wildlife Service. 1989. Wildlife Inventory Plan, Moapa Valley National Wildlife Refuge. Desert National Wildlife Refuge Complex, Las Vegas, Nevada. 4 pp.

U.S. Fish and Wildlife Service. 1991. Draft Landscape Plan, Moapa Valley National Wildlife Refuge. Desert National Wildlife Refuge Complex, Las Vegas, Nevada. 16 pp.

U.S. Fish and Wildlife Service. 1995. Virgin River Fishes Recovery Plan. Denver, Colorado. 45 pp.

U.S. Geological Survey. 1993. Water Resources Data, Nevada, Water Year 1993. Water-Data Report NV-93-1. 596 pp.

Usinger, R.L. 1956. Aquatic insects of California with keys to North American genera and Calilfornia species. University of California Press, Berkeley. 508 pp.

Williams, J.E. 1978. Taxonomic status of *Rhinichthys osculus* (Cyprinidae) in the Moapa River, Nevada. Southwestern Naturalist 23(3):511-518.

Williams, J.E., and G.R. Wilde. 1981. Taxonomic status and morphology of isolated populations of the White River springfish, *Crenichthys baileyi* (Cyprinodontidae). Southwestern Naturalist 25(4):485-503.

Wilson, B.L., J.E. Deacon, and W.G. Bradley. 1966. Parasitism in the fishes of the Moapa River, Clark County, Nevada. Transactions of the California-Nevada Section of the Wildlife Society 1966:12-23.

III. IMPLEMENTATION SCHEDULE

This Implementation Schedule outlines actions and estimated costs for the Muddy River ecosystem recovery program. It is a guide for meeting the recovery objective discussed in Part II of this Plan. This schedule indicates task priorities, task numbers, task descriptions, duration of tasks, the responsible agencies, and lastly, estimated costs. These actions, when accomplished, should bring about the recovery of Moapa dace. It should be noted that the estimated monetary needs for all parties involved in recovery are identified and; therefore, Part III reflects the total estimated financial requirements for the recovery of this species.

Priorities in Column 1 of the following Implementation Schedule are assigned as follows:

Priority 1 - A short-term action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2 - A long-term action that must be taken to prevent a significant decline in species population/habitat quality, or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to meet the recovery objectives.

Recovery Plan Implementation Schedule

Priority Number	Task No.	Task Description	Task Duration (Years)	Responsible Parties	Total Cost ($1,000's) 1996-2008	Cost Estimates ($1,000's) FY 1996	FY 1997	FY 1998	FY 1999	FY 2000
NEED 1 - PROTECT INSTREAM FLOWS AND HISTORICAL HABITAT WITHIN THE UPPER MUDDY RIVER AND TRIBUTARY SPRING SYSTEMS										
1	11	Develop (FY 1996) and implement habitat protection agreements	6	FWS* NDOW	45+TBD 6+TBD	45 6	TBD TBD	TBD TBD	TBD TBD	TBD TBD
NEED 2 - CONDUCT RESTORATION/MANAGEMENT ACTIVITIES										
1	12	Minimize nonnative fish impacts	6	NDOW* FWS NBS	30 30 30	5 5 5	5 5 5	5 5 5	5 5 5	5 5 5
2	13	Develop (FY 1996) and implement habitat restoration/management plans	12	FWS* NDOW NBS	18+TBD 6+TBD 12+TBD	18 6 12	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD	TBD TBD TBD
NEED 3 - MONITOR MOAPA DACE POPULATION										
2	2	Monitor Moapa dace population	12	NBS* FWS NDOW	96 24 12	8 2 1	8 2 1	8 2 1	8 2 1	8 2 1
NEED 4 - RESEARCH POPULATION HEALTH										
3	3	Determine extent of parasitism in Moapa dace population	1	NBS*	7	0	7	0	0	0
NEED 5 - PROVIDE PUBLIC INFORMATION AND EDUCATION										
1	4	Provide public information and education	Continual	FWS* NDOW	91 15	16 3	20 1	5 1	5 1	5 1

Definitions for terms and acronyms used in Implementation Schedule:
Continual = Task will be implemented on an annual basis once it is begun and will continue until no longer required for recovery.
To Be Determined (TBD) = Cost will be determined at a later date.
Total Cost = Projected cost of task from start to task completion.

Responsible Parties (* = Lead Agency):
FWS = Fish and Wildlife Service
NBS = National Biological Service
NDOW = Nevada Division of Wildlife

IV. APPENDICES

A. PUBLIC/PEER REVIEW

The draft recovery plan was made available to the public for comment as required by the 1988 amendments to the Endangered Species Act of 1973. The public comment period was announced in the Federal Register on October 5, 1993 and closed on December 6, 1993. Prior to the closing, numerous landowners requested additional time to comment on the plan. Therefore, the comment period was reopened in the Federal Register on December 29, 1993 and closed on February 14, 1994. Copies of the draft plan were provided to qualified members of the academic and scientific community for peer review. The U.S. Fish and Wildlife Service (Service) solicited and/or received comments on the document from the academic and scientific community, private individuals, industry representatives, and Federal, State, and local agencies listed below. Before completion of this final recovery plan, the Service received a total of 296 response letters, as indicated by an asterisk (*). The comments provided in these letters were considered in preparation of this final recovery plan and incorporated, as appropriate. Other significant comments are addressed by the Service in Appendix B. All letters of comment on the plan are on file at the Service's Nevada State Office in Reno.

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B. SIGNIFICANT PUBLIC COMMENTS AND SERVICE RESPONSES

This section consolidates, summarizes, and provides the Fish and Wildlife Service's (Service) response to *significant* comments *not* addressed by changes in the text. Specific comments that reoccurred in the letters are addressed only once.

Comment (C): The Service is in violation of the Endangered Species Act of 1973, as amended (ESA) [section 4.(a)(3)(A) and section 4.(b)(6)(C)(ii)], because critical habitat has not been designated for Moapa dace.

Response (R): Moapa dace were listed in 1967 under the Endangered Species Preservation Act of 1966 (ESPA). The ESPA did not require critical habitat designation. When Congress passed the ESA in 1973, it incorporated ESPA listed species such as Moapa dace. Critical habitat designation was not required until the 1978 amendment to the ESA and was not retroactive.

C: This recovery plan contains a "defacto" designation of critical habitat, without public notice, review, or consideration of economic impacts.

R: Recovery plans do not propose or designate critical habitat. However, the ESA requires that these plans are as specific as possible in identifying recovery tasks, including site-specific management actions. While five spring systems and the upper Muddy River were identified as areas for implementation of various recovery tasks, these areas are not being designated as critical habitat.

C: The Service has failed to comply with the National Environmental Policy Act of 1969 (NEPA) by not preparing an Environmental Impact Statement (EIS) for this Plan.

R: The Service is not required to comply with NEPA in development of recovery plans since they are only planning documents suggesting potential actions by the Service, other Federal agencies, State and local governments, the private sector, or a combination of the above. Recovery plans impose no obligations on any agency, entity, or persons to implement the various tasks. Implementation of recovery actions will be subject to NEPA compliance, as appropriate, at the time they are actually "proposed" and an environmental assessment or EIS would be completed at that time.

C: The Service should recover Moapa dace on Moapa Valley NWR instead of private land.

R: Moapa dace, as a species, cannot achieve recovery on Moapa Valley NWR alone. This spring system comprises only a fraction of Moapa dace historical habitat. In particular, the spring system does not provide foraging habitat suitable for larger adult Moapa dace, such as is found in the upper Muddy River. Also, Moapa dace must be distributed throughout their historical range in order to prevent a catastrophic event from causing the extinction of the species. This recovery plan, therefore, recommends actions that will recover the species across its historical range.

C: The draft recovery plan advocates flooding on the Muddy River which could impact private property.

R: The flooding that was mentioned in the draft plan is a frequent, periodic **natural** occurrence on the Muddy River. Impacts to private property in the floodplain do occasionally occur as a result of these natural events. The discussion in the draft recovery plan was merely to present information on how these natural flood events are beneficial to the riverine ecosystem. In particular, Moapa dace habitat benefits from sediment transport and nutrient inputs, nonnative aquatic vegetation removal, and creation of new spawning and foraging habitat. Also, nonnative fishes are typically unable to tolerate these high flow events as well as native species and their abundance and distribution may be reduced.

C: The Service has failed to comply with Executive Order 12630.

R: Executive Order 12630 requires Federal government agencies to carefully evaluate the effect of their administrative, regulatory, and legislative actions on constitutionally protected property rights to ensure that any potential taking must be subjected to an analysis known as a Takings Implication Assessment (TIA). However, in the Order, "policies that have takings implications" for which a TIA would be required do not include "studies or similar efforts or planning activities." Recovery plans are merely planning documents and, therefore, are exempted from a TIA. The Service would comply with all relevant regulations in implementing tasks in this recovery plan.

C: The Service has failed to comply with Executive Order 12291.

Executive Order 12291 requires Federal agencies to prepare regulatory impact analyses for any "major rule." A major rule is defined as any regulation that is likely to result in: (1) An annual effect on the economy of $100 million or more; (2) a major increase in costs or prices for consumers, individual industries, Federal,

State, or local government agencies, or geographic regions; or (3) significant or adverse effects on competition, employment, investment, productivity, innovation, or on the ability of United States-based enterprises to compete with foreign-based enterprises in domestic or export markets (46 Federal Register 13193). A recovery plan does not meet the definition of a regulation or rule as set forth in the Order. Therefore, the Service is not obligated to prepare a regulatory impact analysis for this plan. The Service would comply with all relevant regualtions in implementing tasks in this recovery plan.

C: The recovery plan does not address effects of Service purchases of land and/or water rights on the local economy and downstream water users.

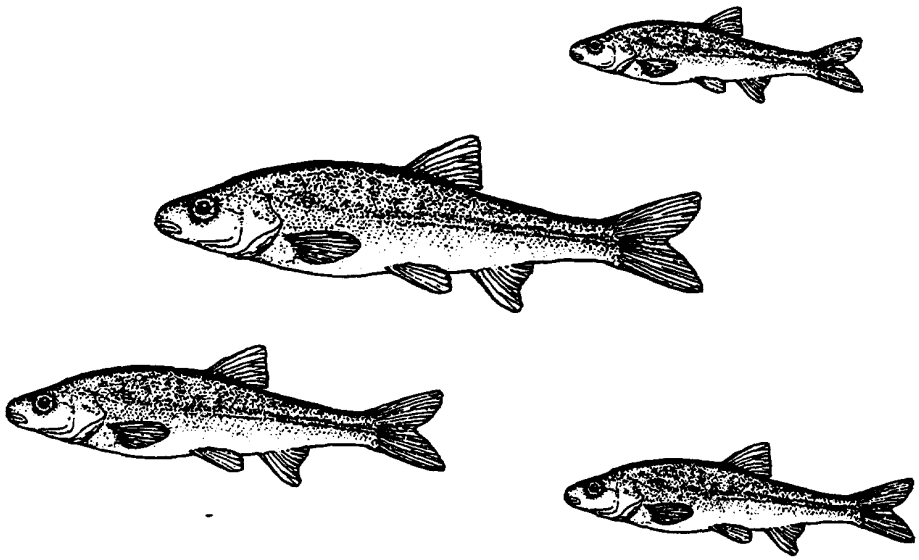
R: Any water right (or land) acquisitions would be from willing sellers at fair market value, therefore, the owners would not experience adverse economic effects. In addition, any water rights acquired or leased by the Service would be used to provide instream flows for Moapa dace and other endemic aquatic species, which would be a nonconsumptive water use with no adverse effect upon existing water diversions. Indeed, Muddy River flows downstream might actually increase, for example, if water in the Warm Springs area was converted from private agricultural use to instream flow use. Acquisitions by the Service would be subject to NEPA at the time they are actually proposed and an environmental assessment or EIS would be completed at that time. These documents would address any potential local economic impacts or effects on downstream water users. Land sold to the Service would result in loss of private property in the local tax base which could impact the local economy, but the Service makes payments in lieu of taxes on refuge lands to minimize these impacts. The Service is also interested in developing conservation agreements with willing landowners rather than purchasing property or water rights. With a conservation agreement, the landowner would retain ownership of the property and/or water rights, while allowing activities benefitting Moapa dace. Conservation agreements would minimize the potential for any adverse economic effects.

C: The Moapa dace population should be monitored before the recovery plan is implemented; it may currently be self-sustaining.

R: Funding to develop and implement a monitoring plan is not currently available. Identification of monitoring as a recovery task in the plan will assist the Service and other participating agencies in obtaining necessary funding for population status surveys.

C: Is the Service proposing to list any other species mentioned in the recovery plan?

R: The plan discusses seven species of special concern inhabiting the Muddy River ecosystem, specifically, three fish species and four invertebrate species. Implementation of tasks in this recovery plan should reduce threats to these species and may improve their status such that listing is not necessary to provide for their long-term protection.



"Conservation is sometimes perceived as stopping everything cold, as holding whooping cranes in higher esteem than people. It is up to science to spread the understanding that the choice is not between wild places or people. Rather, it is between a rich or an impoverished existence for man."

Thomas E. Lovejoy - Conservation Biology 1980

ARIZONA COOPERATIVE FISH AND WILDLIFE RESEARCH UNIT December 2014

Spawning Ecology and Captive Husbandry of Endangered Moapa Dace

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Spawning Ecology and Captive Husbandry of Endangered Moapa Dace

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Executive Summary

- Moapa Dace *Moapa coriacea* is an endangered cyprinid endemic to the Warm Springs area of the Muddy River in Clark County, southeastern Nevada.
- Moapa Dace were listed as federally endangered because of their limited range, low abundance, habitat alterations, and threats from non-native species.
- Spawning by Moapa Dace has not been documented prior to this study; consequently the conditions required for this critical aspect of their life history are unknown.
- Information about Moapa Dace reproduction will be important for managers to utilize in habitat improvement projects and to identify factors that induce spawning in captivity.
- Twelve underwater cameras were deployed in the uppermost reach of Plummer Stream. Camera sites were selected systematically to assess the variety of environmental conditions available.
- We quantified the available environment by dividing the field of view in front of each camera into a grid and estimated size and embeddedness of substrate, depth, stream velocity, and categorized cover.
- Video was recorded from March through May 2012. From over 4,000 10-min video clips selected for analysis, 13 spawning events were identified. Moapa Dace displayed behaviors consistent with broadcasting cyprinids.
- For spawning, Moapa Dace selected depths ranging from 30-34 cm, water velocities from 0.11-0.17 m/sec, cobble substrate, and instream overhead cover. We could not find that they selected for embeddedness, open water, instream velocity shelter, instream overhead cover, or above stream overhead cover.

- To aid in initial efforts to breed Moapa dace in captivity, we replicated conditions observed to be associated with spawning in the field.
- Conservation of Moapa Dace could benefit from a captive propagation program in three ways: fish in captivity can provide research specimens that are difficult to obtain otherwise; a captive population can preserve this unique species if something catastrophic impacts the wild population; and a captive stock could be used to supplement the wild population if it falls below a critical threshold.
- Prior to this work, Moapa Dace had never been successfully held in captivity for any length of time.
- To develop a protocol for rearing and propagating Moapa Dace in captivity, 40 fish were collected in February 2013, and an additional group of 30 fish were collected in January 2014. These fish were immediately transported to the Fish Propagation Facility at the University of Arizona's College of Agriculture.
- We successfully transported and reared Moapa Dace employing slow acclimation and aggressive prophylactic treatment; feeding adults with a combination of live and frozen invertebrates and commercially available pelleted foods; and providing an artificial stream environment to them.
- Moapa Dace proved to be difficult to propagate. We were unable to propagate Moapa Dace through 13 different treatments. Different types of cover and different sized substrates were introduced; photoperiod, water chemistry, and temperature were manipulated; and a hormone bath and injection were applied.
- Moapa Dace were successfully propagated in one treatment. This treatment was left ongoing, with minimal disturbance, for over three months. It occurred in an artificial

stream and incorporated 14 broodstock from the second capture period, an additional submersible pump to direct an increased velocity along gravel and cobble substrate, and a variety of substrate sizes and artificial plants.

- Initial information suggests that to successfully rear and captively propagate Moapa Dace, biologists should take great care with acclimating Moapa Dace, and provide as similar conditions (e.g. subsurface flow, artificial stream, variety of substrate including cobble, water temperatures, cover) as possible to those experienced by the fish in the wild. Sufficient brood stock should be available to use in spawning attempts. Small numbers of brood fish will likely limit chances of success.
- Because spawning occurred after the end of the initial study period, an addendum to this report will be provided at a later date to specify, in more detail, the conditions that led to successful spawning by Moapa dace, including any associated information, such as reproductive ecology, available as a result of this success.

Chapter 1.

Environmental Conditions Utilized by Moapa Dace While Spawning

Abstract.--Moapa Dace *Moapa coriacea* is an endangered cyprinid endemic to the Warm Springs area of the Muddy River in Clark County, southeastern Nevada. Moapa Dace are listed as federally endangered because of their limited range, low abundance, and adverse impacts from habitat alterations and nonnative species. Spawning by Moapa Dace has never been documented; consequently environmental conditions required for this critical aspect of their life history are unknown. Knowledge of Moapa Dace spawning ecology provides vital data for managers to manage habitat and to identify factors that induce spawning in captivity. Twelve underwater cameras were deployed in the uppermost reach of Plummer Stream in an attempt to capture Moapa Dace spawning activity. Camera sites were selected systematically to represent the variety of conditions available. We quantified the available environment by dividing the field of view in front of each camera into a grid and estimating size and embeddedness of substrate, depth, stream velocity, and cover categories in each cell of every grid. Video was recorded from March through May 2012 and then watched to identify locations of spawning and their associated characteristics. From over 4,000 10-min video clips selected for analysis, 13 spawning events were identified. Moapa Dace displayed behaviors consistent with broadcasting cyprinids. Nonparametric contingency table analyses were utilized to ascertain whether or not Moapa Dace selected specific conditions to spawn. For spawning, Moapa Dace selected depths ranging from 30 to 34 cm, water velocities from 0.11 to 0.17 m/s, and cobble substrate. We could not find that they selected for any category of embeddedness or cover (i.e., open water, instream velocity shelter, instream overhead cover, or above stream overhead cover. This

information furthers the understanding of Moapa Dace spawning ecology in the wild. Moreover, replicating these conditions in captivity will aid in efforts to breed Moapa Dace.

Introduction

Many native fishes of the arid southwestern United States are declining, threatened, endangered, or extinct (Minckley and Deacon 1991; Scoppettone et al. 1998; Hatten et al. 2013). Interactions with invasive species, habitat loss and degradation, barriers to movement, groundwater pumping, management for sport fishing, and wildfire are contributing to the demise of these vulnerable organisms (Cross 1976; Minckley and Deacon 1991).

Moapa Dace *Moapa coriacea*, a cyprinid endemic to the Muddy (Moapa) River system of Clark County, Nevada (Hubbs and Miller 1948; Cross 1976) was first collected and identified in 1938 (Hubbs and Miller 1948; Miller et al. 1991). Historically, Moapa Dace were found in 16 km of the upper Muddy River and its tributaries, known as the Warm Springs area (Figure 1; U.S. Fish and Wildlife Service 1996). The Warm Springs area is comprised of over 20 thermal, constant-temperature, springs within a 2-km radius, coming together to form the Muddy River (Cross 1976; Scoppettone et al. 1992). The water is about 32°C to 33°C at the springs and cools as it flows downstream (Scoppettone et al. 1992; Scoppettone et al. 1998). Moapa Dace are thermophilic, meaning they prefer warmer water, living primarily in temperatures from 26°C to 32°C. Water temperature presumably limits their distribution downstream (Cross 1976; Scoppettone et al. 1992).

The Muddy River contains three native fishes in addition to Moapa Dace: Virgin River Chub *Gila seminuda*, Moapa Speckled Dace *Rhinichthys osculus moapae*, and Moapa White River Springfish *Crenichthys baileyi moapae* (Scoppettone et al. 1998). By the time Moapa

Dace were discovered in 1938, Western Mosquitofish *Gambusia affinis* had invaded the Warm Springs area, and in the early 1960s, Shortfin Molly *Poecilia mexicana* were also present (Scoppettone et al. 1992; Scoppettone 1993). As a result of their limited range, low abundance, and presence of invasive species, Moapa Dace were listed as federally endangered within 30 years of being described (U.S. Office of the Federal Register 1967).

In June 1994, a fire swept across one of the tributaries of the Muddy River and reduced numbers of Moapa Dace from 500 to 34 individuals in that reach (Scoppettone et al. 1998). Shortly after the fire, Blue Tilapia *Oreochromis aureus* began invading the Warm Springs area (Scoppettone et al. 1998; Scoppettone and Goodchild 2009). From 1994 to 1997, the total population of Moapa Dace, in all tributaries, dropped from 3,800 to less than 1,600 adults (Scoppettone et al. 1998; Scoppettone and Goodchild 2009), and led to the IUCN designation of critically endangered (Gimenez 1996). Recent population estimates, based on snorkel surveys, have been as low as 459 dace in February 2008 and up to 2,248 dace in August 2014 (U.S. Fish and Wildlife Service unpublished data).

Knowledge of the spawning ecology of endangered species can be a powerful tool in the preservation of evolutionarily important populations (Johnston 1999); however, spawning of Moapa Dace in the wild has not been observed, and factors correlated with this behavior have never been documented. The objective of this work was to attempt to observe Moapa Dace spawning in the wild, and evaluate environmental factors correlated with their spawning activity. This information will aid in managing spawning habitat and help predict the conditions likely to promote spawning in captivity.

Methods

Study Site

Fish were monitored for spawning in the furthest upstream reach of Plummer Stream, located in Moapa Valley National Wildlife Refuge (Figure 1). This approximately 120-m spring-fed section of stream is a northeasterly flowing tributary of the Muddy River. It is situated in the Mojave Desert approximately 70 km NE of Las Vegas, Nevada at about 540 m above sea level. The site was chosen because it was close to a power source for videography equipment and had consistently supported the highest concentrations of Moapa Dace for the five years immediately prior to this study (U.S. Fish and Wildlife Service unpublished data).

Plummer Stream's riparian zone was primarily made up of arrowweed *Pluchea sericea*, willow *Salix spp*., screwbean mesquite *Prosopis pubescens* and stands of nonnative salt-cedar *Tamarix spp.* and palm trees *Washingtonia filifera* and *Phoenix dactylifera* (U.S. Fish and Wildlife Service 1996). The aquatic macrophyte community of Plummer Stream was mostly comprised of green algae *Chara spp.*, spike rush *Eleocharis spp.*, water nymph *Najas spp.*, watercress *Nasturtium spp.*, pondweed *Potamogeton spp.*, and nonnative eel grass *Vallisneria spp*. (U.S. Fish and Wildlife Service 1996).

Camera Arrangement

We used 12 IP-66 weatherproof-rated security cameras (model LBC6050, Lorex Technologies, Toronto, Ontario) to monitor behavior of Moapa Dace. Cameras were bullet-shaped, 8 cm wide x 15 cm long, and reinforced at all seams with silicone caulk for underwater

deployment. Cameras were equipped with 8.5-mm (1/3-in) Sony Super HAD II image sensors and 47 infrared light-emitting diodes to capture nighttime and daytime activity. Cameras had a 60 degree diagonal field-of-view and a horizontal resolution of 600 TV lines. Systematically installed 10 m apart, cameras were attached to two, 1 m long by 10 mm thick, pieces of rebar driven into the substrate. Cameras were placed approximately 2 to 10 cm under the water surface and angled approximately 10 to 30 degrees toward the stream bottom to maximize clarity and field-of-view. Coaxial camera cables were placed inside rubber garden hoses slit down the side and zip tied shut, to discourage terrestrial rodents from chewing. For added protection, the 2 m of garden hose-covered coaxial cables closest to the cameras were also covered by plastic corrugated tubing, to prevent muskrats *Ondatra zibethicus* from chewing.

Video was recorded by connecting four cameras to each of three digital video recorders (DVRs) (model ECOR264-4X1, EverFocus Electronics Corporation, Duarte, California). Digital video recorders were set to record continuously from March through May 2012, the time of greatest larval Moapa Dace abundance (Scoppettone et al. 1992). Digital video recorders were housed in metal storage chests (model 2032-OS, RIDGID, Crystal Lake, Illinois) along Plummer Stream. Storage chests were modified with two holes cut in the bottoms, one for a 120-mm exhaust fan (model A2368, Thermaltake Technology, City of Industry, California) to cool the unit and another to accommodate the power and coaxial cables. In addition, we painted the storage chests a desert-sand color so they were camouflaged and to minimize heat absorption.

Quantification of Available Environmental Conditions

To identify available habitat at each underwater camera, four small colorful pieces of tile were placed in each corner of the underwater field-of-view and photos were taken from above

water, down vertically, using another camera. The photos were opened in Microsoft Paint and a grid was attached to each field-of-view. The photos were then used as guides, in the field, to sample environmental parameters in each cell of every grid. Dominant substrate size was quantified by visually estimating which size category covered the greatest area within a cell. As suggested by Bain (1999), a code was assigned based on the modified Wentworth scale (i.e., 5 = boulder, > 256 mm diameter; 4 = cobble, 64-256 mm; 3 = pebble, 16-63 mm; 2 = gravel, 2-15 mm; 1 = sand, 0.06-1 mm; 0 = silt and clay, < 0.059 mm). Substrate embeddedness, the percent of space between larger substrate sizes filled by smaller ones, was estimated to the nearest quartile and assigned a value from one to four (i.e., 0-25% embedded was assigned a 1; 2 = 26-50%; 3 = 51-75%; 4 = 76-100%; Bovee 1986). Depth was measured at the center of each cell using a 1.2-m USGS top setting wading rod (model 105-001, Rickly Hydrological Company, Columbus, Ohio). Flow was estimated at the center of each cell by measuring mean column velocity at 60% of the water depth, from the water surface, using a USGS pygmy meter (model 6205, Rickly Hydrological Company, Columbus, Ohio) mounted to the wading rod. A flow computer (AquaCalc Pro model 102-010, Rickly Hydrological Company Columbus, Ohio) was mounted to the top of the wading rod to calculate mean flow. Cover was categorized into four groups: instream velocity shelter, instream overhead cover, above stream overhead cover, or open water. Instream velocity shelter was assigned to a cell when an object (e.g., cobble, boulder, or submerged log) that was at least 6 cm wide, extended at least 6 cm above the stream bottom, and existed at the upstream end of a cell. A cell was classified as having instream overhead cover when an object, typically a downed log, was positioned in the water column directly above the cell, had a diameter of at least 10 cm, and at least three-fourths of the diameter overlapped the cell. Turbulence (e.g., whitewater) in the water column, obstructing the view of

underlying fish, was classified as instream overhead cover as well. Above stream overhead cover was classified in the same way as instream overhead cover except the cover (e.g., downed log or tree with overhanging branches) was elevated above the surface of the water. If none of the above types of cover could be applied to a cell, it was classified as open water. Open water was the only classification that was mutually exclusive; there could be any combination of the first three types assigned to any given cell. One temperature logger (HOBO Pendant Temperature and Light Data Logger model UA-002-64, Onset Computer Corporation, Bourne, Massachusetts) was installed on the mount, with each camera, to record temperature every ten minutes throughout the duration of video recording. Macrohabitat was classified as pool, glide, run, and riffle based on descriptions from Arend (1999). Temperature was the only variable measured continuously; all others were estimated once and then assumed to remain constant due to the highly stable nature of this spring-fed system. To confirm this assumption, stream discharge was monitored at a USGS flume-gauge (site number: 9415927) approximately 400 m downstream of the most downstream site in this study.

Monitoring of Spawning Events

A total of 4,488 10-min video clips from March 17, 2012 through April 19, 2012 were selected for analyses. This was about 11 percent of the video recorded during that time period. To sub-sample in a representative fashion, the entire video sequence was subdivided into 24-h days. Each day was further subdivided into 144 10-min clips. Lastly, an online random sequence generator (http://www.random.org/sequences/, Randomness and Integrity Services, Dublin, Ireland) was used to select 16 10-min video clips, from each 24-h day, for analysis. While watching each clip, all fish observed were identified and counted. All behaviors displayed by Moapa Dace were noted. Behaviors were defined as (1) *passing by* when fish swam through

the field-of-view with no obvious intent to stay; (2) *stationary swimming* when fish maintained their position in current; (3) *random swimming* when fish changed their position in the stream with no apparent purpose but stayed within the field-of-view; (4) *feeding* when fish actively pursued prey items; (5) *chasing* when a fish approached another in an aggressive manner causing it to relocate; (6) *courting* when two fish swam closely alongside one another very intently but did not vibrate or twirl around each other; and (7) *spawning* when two or more fish vibrated against or gyrated around one another in a similar fashion to the behavior described for two close relatives, Longfin Dace *Agosia chrysogaster* and Speckled Dace *Rhinichthys osculus* (John 1963; Minckley and Barber 1971).

To assign environmental variables to a spawning location, the event was assessed in comparison to the overhead pictures and grid of cells for that field-of-view. Based on the position of fish in the video, in relation to landmarks, the event was assigned to a particular cell. Frequently (8 of 13 events) spawning was carried across multiple cells but the event was only assigned to the location of where it started.

Data Analysis

We used plot analyses to identify the range of conditions Moapa Dace used for spawning (Bonar et al. 2010) and nonparametric contingency table analyses to ascertain whether or not Moapa Dace selected specific conditions to spawn (Bovee 1986; Thomas and Bovee 1993; Bovee et al. 1998). To identify use, ranges of conditions from cells where spawning occurred were noted and presented in frequency plots for easy visualization. To evaluate spawning site selectivity, cells in all camera locations were placed into one of four categories to build a 2x2 contingency table. These four categories depended on whether environmental variables were

continuous (e.g., depth and velocity), nonbinomial discrete (e.g., substrate and embeddedness), or binomial (presence of a cover type or not). For continuous and nonbinomial discrete variables, the four cell categories were (a) preferred for spawning and spawning occurred in the cell; (b) not preferred for spawning and spawning occurred in the cell; (c) preferred for spawning and no spawning occurred in the cell; (d) not preferred for spawning and no spawning occurred in the cell (Figure 2). First, a range of values was identified as "preferred" and "not preferred" for each variable. To make this designation, values from cells, which spawning occurred in, were sorted in numerical order and then the range of values occupying the central 50% of spawning observations was labeled "preferred" (Thomas and Bovee 1993; K. D. Bovee, USGS Mid-Continent Ecological Science Center, personal communication), while values outside this range were labelled "not preferred." All cells were then classified as preferred or not preferred with respect to the value for each variable. For binomial variables, such as presence of specific cover types, no predesignation was made for the preference of cells. Cells were placed into one of four categories as before, however, categories were (a) cover type present and spawning occurred; (b) cover type absent and spawning occurred; (c) cover type present and no spawning occurred; (d) cover type absent and no spawning occurred. Once a contingency table was generated, the test statistic:

$$T_1 = \frac{N^{0.5}(ad-bc)}{[(a+b)(c+d)(a+c)(b+d)]^{0.5}}$$

was produced. T_1 is approximately normally distributed; therefore, it is compared with a standard normal distribution to determine the level of significance (Conover 1980). This is a one-sided test of the null hypothesis that sites with a parameter within the "preferred" range were utilized in an equal or smaller proportion than sites outside the "preferred" range. To add a

multivariate aspect to these analyses, a contingency table was built in a similar manner as above except the left column only included counts of cells that fell within the "preferred" range for all significant parameters, from univariate analyses, at the same time (Thomas and Bovee 1993). The null hypothesis for the multivariate analysis was that fish used cells with any significant variables outside of the "preferred" range in an equal or greater proportion than cells containing all the significant variables inside the "preferred" range. As a result of the extraordinarily rare nature of Moapa Dace spawning, and to reduce the risk of overlooking conditions important to Moapa Dace reproduction, we rejected each null hypothesis in this study at a 0.10 level of significance.

Results

Quantification of Available Environmental Conditions

The following summary statistics are means followed by an associated standard error in parentheses. The field-of-view in front of each camera was slightly different depending on the camera's angle toward the bottom, stream depth, and stream width at that location. The mean area within the 12 camera's fields-of-view was 0.32 (0.086) m^2, ranging from 0.04 to 1.18 m^2. The number of cells per field-of-view ranged from 21 to 30 with a mean area of 0.01 (0.00083) m^2 per cell. There were a total of 280 cells or sampling sites. Mean dominant substrate size (modified Wentworth scale) for all sites was 2.7 (0.099) (i.e., between gravel and pebble) and ranged from 0 (silt) to 5 (boulder); however, a majority of the sites were dominated by cobble (Table 1; Figure 3). Embeddedness ranged from 1 to 4 with a mean of 2.4 (0.069) (Table 1). About a third of the sampling sites were categorized in the first, second, and fourth quartiles each, with only a few in the third quartile of embeddedness (Figure 3). Mean depth for all

sampling sites was 28 (0.060) cm and ranged from 9 to 53 cm (Table 1). A range of 0 to 0.62 m/s mean column velocity was observed, with a mean of 0.17 (0.0074) m/s (Table 1). Mean temperature recorded among all camera sites throughout the duration of time that video was analyzed was 31.7 (0.014)°C and ranged from 31.0°C to 32.8°C (Table 1). Approximately 20 percent of sampling sites had instream velocity shelter, about 35 percent had instream overhead cover, about 60 percent had above stream overhead cover, and about 20 percent were open water (Figure 3). Macrohabitat of camera sites consisted of three sites classified as pool, three sites classified as glide, four sites classified as run, and two sites classified as riffle. Discharge throughout the duration of time that cameras were installed in Plummer Stream, at the USGS gauge downstream of the sampling sites, ranged from 0.12 to 0.14 m^3/s with a mean of 0.13 (0.000034) m^3/s.

Monitoring of Spawning Events

The most frequently observed fish species was Moapa White River Springfish, occurring in 86% of video segments and Moapa Dace were identified in 43%. Two nonnative species: Shortfin Molly and Western Mosquitofish were observed in 9% and 2% of clips, respectively.

Moapa Dace were feeding in about two-thirds of the video segments when observed and were passing by in a little less than one-third of observations; all other behaviors were identified in only a small fraction of clips. Spawning, one of the less frequently observed behaviors, was identified 13 times. Over the 13 events, the average length of time Moapa Dace spent spawning was 2 s, with a range from 1 to 4 s.

Spawning was observed to occur primarily (12 times) between two dace. One spawning event involved a group of about 10 individuals. During spawning, two or more fish came

together near the surface of the water and gyrated around one another as they drifted down toward the stream bottom. They never appeared to interact with the substrate intentionally and never displayed any kind of nest building behavior. Four of the spawning events began in the same location as a previous spawning event; consequently, there were only nine unique spawning sites utilized in selection analyses.

Spawning was recorded on March 19, March 31, April 1-5, April 8, April 11, and April 14 2012. Two spawning events were recorded in macrohabitat categorized as a run, six in a glide, and five in a pool. Spawning activity was only observed during daylight hours. Four spawning events occurred between 0700 hours and 0900 hours, one during the noon hour, and eight between 1400 hours and 2000 hours.

Data Analysis

For the nine spawning sites, a range of environmental conditions could be identified. Mean dominant substrate size (modified Wentworth scale) for all sites was 3.7 (0.33) (i.e. between pebble and cobble) and ranged from 0 (silt) to 5 (boulder); however, a large majority of spawning was in cobble (Table 2; Figure 3). Embeddedness ranged from 1 to 4 with a mean of 2.4 (0.38), which falls between the 26-50% and 51-75% quartiles (Table 2). Mean depth for all spawning sites was 33 (0.56) cm and ranged from 30 to 38 cm (Table 2). Velocity of spawning sites ranged from undetectable to 0.39 m/s, with a mean of 0.22 (0.040) m/s (Table 2). Mean temperature recorded at each spawning site, during the 10-min segment of video when each spawn occurred, was 31.7 (0.075)°C and ranged from 31.1°C to 32.0°C (Table 2). Approximately 10 percent of spawning sites were associated with instream velocity shelter,

about 55 percent had instream overhead cover, about 55 percent had above stream overhead cover, and about 20 percent did not have any cover (Figure 4).

Moapa Dace utilized certain conditions to spawn in Plummer Stream different from the availability of those conditions. They utilized areas with deeper than average water depth. They tend to spawn in water velocities that were slower to mid-range speed. Spawning occurred primarily over rocky substrates mostly comprised of the cobble size class. Embeddedness of the substrate, where spawning occurred, ranged widely, but the proportion of spawning over areas having the highest quartile was slightly larger than the proportion of that quartile available in the study reach. Cover at spawning locations seemed to follow the pattern of availability with few events observed behind velocity shelter or open water and more events observed beneath overhead cover; instream overhead cover is the only type used disproportionately more than it was available.

Moapa Dace selected certain conditions to spawn. Selections for specific depth, velocity, and substrate were all significant ($P < 0.10$; Table 3). The central 50% of the range Moapa Dace selected for spawning included depths from 30 to 34 cm, velocities from 0.11 to 0.17 m/s, and dominant substrate sizes within the cobble category (Table 3). The multivariate contingency table combining the central 50% of ranges for depth, velocity, and substrate also resulted in a significant test statistic (Table 3). Selection for presence of instream overhead cover was nearly significant ($T_1 = 1.26$, $P = 0.11$; Table 3). We could not identify that Moapa Dace selected for any category of embeddedness, open water, instream velocity shelter, or above stream overhead cover (Table 3, Figure 3).

Discussion

This study is the first to document spawning of endangered Moapa Dace in the wild. Moapa Dace spawning behavior fits into the broadcasting category of spawning modes, described by Johnston (1999) as the primitive mode where eggs and milt are released over an unaltered substrate and no parental care is provided. Broadcast spawning is exhibited by over 60% of North American cyprinids (Johnston 1999). Different species broadcast their gametes in varying ways. Some species group together in large spawning aggregations that can consist of up to hundreds of individuals (Moyle 2002), while others simply breed in pairs (Platania and Altenbach 1998). Some fishes release their spawn over rocky substrates while others use submerged aquatic vegetation (Moyle 2002). Some species spawn in lentic systems but others require flowing water (Johnston 1999). Eggs produced by broadcasting cyprinids can be demersal adhesive, demersal nonadhesive, and semibuoyant nonadhesive (Platania and Altenbach 1998; Johnston 1999).

We could not verify that spawning behavior, observed during this study, produced fertilized eggs because video was analyzed at a later date. Furthermore, fish were not close enough to the camera to provide the resolution necessary to observe gametes; however, the behaviors observed were very similar to spawning behaviors reported for other cyprinids of the desert Southwest. The type of eggs released by Moapa Dace is still unknown.

Moapa Dace live in a predominantly stable environment. Discharge remained steady throughout this study and there were no significant weather events to create disturbances to alter the environment. Therefore, unlike some species where spawning is triggered by wide fluctuations in environmental variables such as temperature (Kaya 1991; Rakes et al. 1999;

Archdeacon and Bonar 2009) or velocity (Mills 1980), triggers that stimulate Moapa Dace to spawn are probably subtle; or spawning might have been more prevalent if there were significant weather events.

Videography proved to be effective for learning about the spawning ecology of Moapa Dace; however, difficulties did exist. Ideally, studies such as this would have more observations of spawning than we were able to obtain. Thomas and Bovee (1993) suggest obtaining at least 55 occupied cells and at least 200 unoccupied cells when evaluating environmental selection. As the numbers of observations are reduced, the frequency of type II errors (false acceptance of null hypotheses) can be expected to increase rapidly (Thomas and Bovee 1993). Type I errors (false rejections of null hypotheses) can also be expected to occur more frequently as numbers of observations drop, but remain less common than Type II errors (Thomas and Bovee 1993). Type I errors are a more serious problem (concluding a significant result) so their relative rarity is good. More samples would have benefitted these analyses by increasing statistical power to obtain significant results.

Equipment limitations also provided challenges. The camera system needed to be located near a power source. The DVRs recorded video onto hard drives that filled quickly due to the continuous movement of fish, the water, and submerged vegetation. Hard drives needed to be replaced about every 10 days. Also, image quality of the video would occasionally deteriorate because algae grew on camera lenses and vegetation became wrapped around cameras, thus obscuring the view. These issues can be rectified with frequent monitoring. Furthermore, the large volume of video recorded, required substantial time to analyze. Increasing video speed to review fish behavior more rapidly was possible, but since Moapa Dace were frequently in the

field-of-view, the video often had to be watched more closely to identify behaviors. Other systems will likely have large gaps of time with no fish in front of the cameras, which will enable viewers to fast forward and analyze more video. Image analysis systems (e.g., Cooke and Bunt 2004) have been useful for the identification of spawning behavior of Largemouth Bass *Micropterus salmoides* (Cooke et al. 2001), feeding by Bluegill *Lepomis macrochirus* (Harrel and Dibble 2001), and captive spawning by other cyprinids (Platania and Altenbach 1998). An efficient image analysis system would allow more video to be analyzed, increasing the power of monitoring efforts.

Conclusion

Spawning in Moapa dace was documented 13 times during this study. Moapa Dace displayed behavior consistent with broadcasting cyprinids. For spawning, Moapa Dace selected depths ranging from 30 to 34 cm, water velocities from 0.11 to 0.17 m/s, and cobble substrate. We did not find that Moapa Dace selected for embeddedness, open water, instream velocity shelter, instream overhead cover, or above stream overhead cover. Additional examination of areas where these conditions align will be important to further the understanding of Moapa Dace spawning ecology. Moreover, replicating these conditions in captivity will aid Moapa Dace husbandry efforts.

References

Archdeacon, T. P., and S. A. Bonar. 2009. Captive breeding of endangered Mohave Tui Chub. North American Journal of Aquaculture 71:360-362.

Arend, K. K. 1999. Macrohabitat identification. Pages 95-103 *in* M. B. Bain, and N. J. Stevenson, editors. Aquatic habitat assessment: Common methods. American Fisheries Society, Bethesda, Maryland.

Bain, M. B. 1999. Substrate. Pages 95-103 *in* M. B. Bain, and N. J. Stevenson, editors. Aquatic habitat assessment: Common methods. American Fisheries Society, Bethesda, Maryland.

Bonar, S. A., N. Mercado-Silva, and D. Rogowski. 2010. Habitat use by the fishes of a Southwestern desert stream: Cherry Creek, Arizona. Arizona Cooperative Fish and Wildlife Research Report 02-10, Tucson.

Bovee, K. D., B. L. Lamb, J. M. Bartholow, C. B. Stalnaker, J. Taylor, and J. Henriksen. 1998. Stream habitat analysis using the instream flow incremental methodology. U.S. Geological Survey, Information and Technology Report USGS/BRD-1998-0004, Fort Collins, Colorado.

Bovee, K. D. 1986. Development and evaluation of habitat suitability criteria for use in the Instream Flow Incremental Methodology. Instream Flow Information Paper 21. U.S. Fish and Wildlife Service Biological Report 86(7).

Conover, W. J. 1980. Practical nonparametric statistics. John Wiley and Sons, New York.

Cooke, S. J., and C. M. Bunt. 2004. Construction of a junction box for use with an inexpensive, commercially available underwater video camera suitable for aquatic research. North American Journal of Fisheries Management 24:253-257.

Cooke, S. J., R. S. McKinley, D. P. Philipp. 2001. Physical activity and behavior of a centrarchid fish, *Micropterus salmoides* (Lacepede), during spawning. Ecology of Freshwater Fish 10:227-237.

Cross, J. N. 1976. Status of the native fish fauna of the Moapa River (Clark County, Nevada). Transactions of the American Fisheries Society 105:503-508.

Gimenez, D. M. 1996. *Moapa coriacea*. IUCN Red list of threatened species. www.iucnredlist.org. (September 2011).

Harrel, L. H., and E. D. Dibble. 2001. Foraging efficiency of juvenile bluegill, *Lepomis macrochirus,* among different vegetated habitats. Environmental Biology of Fishes 62:441-453.

Hatten, J. R., T. R. Batt, G. G. Scoppettone, C. J. Dixon. 2013. An ecohydraulic model to identify and monitor Moapa Dace habitat. Plos One 8(2).

Hubbs, C. L., and R. R. Miller. 1948. Two new, relict genera of cyprinid fishes from Nevada. University of Michigan Museum of Zoology Occasional Papers 507:1-35.

John, K. R. 1963. The effect of torrential rains on the reproductive cycle of *Rhinichthys osculus* in the Chiricahua Mountains, Arizona. Copeia 2:286-291.

Johnston, C. E. 1999. The relationship of spawning mode to conservation of North American minnows (*Cyprinidae*). Environmental Biology of Fishes 55:21-30.

Kaya, C. M. 1991. Laboratory spawning and rearing of Speckled Dace. Progressive Fish-Culturist 53:259-260.

Moyle, P. B. 2002. Inland fishes of California. University of California Press, Berkeley.

Miller, R. R., C. Hubbs, and F. H. Miller. 1991. Ichthyological exploration of the American West: The Hubbs-Miller era, 1915-1950. Pages 19-40 *in* W.L. Minckley, and J. E. Deacon, editors. Battle against extinction. University of Arizona Press, Tucson.

Mills, C. A. 1980. Spawning and rearing eggs of the dace *Leuciscus leuciscus*. Fish Management 11:67-72.

Minckley, W. L., and J. E. Deacon. 1991. Battle against extinction: Native fish management in the American West. University of Arizona Press, Tucson.

Minckley, W. L., and W. E. Barber. 1971. Some aspects of biology of the Longfin Dace, a cyprinid fish characteristic of streams in the Sonoran Desert. The Southwestern Naturalist 15:459-464.

Platania, S. P., and C. S. Altenbach. 1998. Reproductive strategies and egg types of seven Rio Grande basin cyprinids. Copeia 1998(3):559-569.

Rakes, P. L., J. R. Shute, and P. W. Shute. 1999. Reproductive behavior, captive breeding, and restoration ecology of endangered fishes. Environmental Biology of Fishes 55:31–42.

Scoppettone, G. G., H. L. Burge, and P. L. Turtle. 1992. Life history, abundance, and distribution of Moapa Dace *Moapa coriacea*. Great Basin Naturalist 52:216-225.

Scoppettone, G. G., P. H. Rissler, M. B. Nielsen, and J. E. Harvey. 1998. The status of *Moapa coriacea* and *Gila seminuda* and status information on other fishes of the Muddy River, Clark County, Nevada. The Southwestern Naturalist 43:115-122.

Scoppettone, G. G., and S. Goodchild. 2009. Threatened fishes of the world: *Moapa coriacea* Hubbs and Miller, 1948 (Cyprinidae). Environmental Biology of Fishes 86:339-340.

Thomas, J. A., and K. D. Bovee. 1993. Application and testing of a procedure to evaluate transferability of habitat suitability criteria. Regulated Rivers: Research and Management 8: 285-294.

U.S. Fish and Wildlife Service. 1996. Recovery plan for the rare aquatic species of the Muddy River ecosystem. USFWS, Portland, Oregon.

U.S. Office of the Federal Register. 1967. Native fish and wildlife, endangered species. Federal Register 32:48(11 March 1967):4001.

Table 1.1. Mean and standard error (SE) of selected environmental characteristics of sampling sites (n = 280) in Plummer Stream, Nevada. Temperature was not recorded in each individual cell, but at each of the 12 camera locations.

Variable	Mean	SE	Maximum	Minimum
Substrate (modified Wentworth scale)	2.7	0.099	5	0
Embeddedness (quartile)	2.4	0.069	4	1
Depth (cm)	28	0.59	53	9
Velocity (m/s)	0.17	0.0074	0.62	0.00
Temperature (°C)	31.7	0.0139	32.8	31.0

Table 1.2. Selected environmental characteristics of locations (n = 9) where Moapa Dace spawned in Plummer Stream, Nevada. SE is standard error. Note: temperature was not recorded in each individual cell; statistics reported are for temperatures logged at the cameras where spawning occurred, during the 10-min interval that spawning occurred.

Variable	Mean	SE	Maximum	Minimum
Substrate (modified Wentworth scale)	3.7	0.33	5	0
Embeddedness (quartile)	2.4	0.38	4	1
Depth (cm)	33	0.56	38	30
Velocity (m/s)	0.22	0.040	0.39	0.00
Temperature (°C)	31.7	0.0754	32.0	31.1

Table 1.3. Results from nonparametric contingency table tests to evaluate whether Moapa Dace selected for certain resources. T_1 is the test statistic produced in the one-sided tests and was compared with a standard normal distribution to determine the level of significance. The multivariate test incorporated each variable with a *P*-value less than 0.10 (i.e., depth, velocity, and substrate).

Variable	Preferred Range	T_1	*P*-value
Substrate (modified Wentworth scale)	4	1.35	<0.089
Embeddedness (quartile)	---	0.45	0.33
Depth (cm)	30-34	3.92	<0.0002
Velocity (m/s)	0.11-0.17	2.22	0.011
Instream Overhead Cover	Present	1.26	0.11
Open Water	---	0.03	0.49
Above Stream Overhead Cover	---	-0.32	0.63
Instream Velocity Shelter	---	-0.46	0.67
Multivariate Test	---	3.29	0.0005

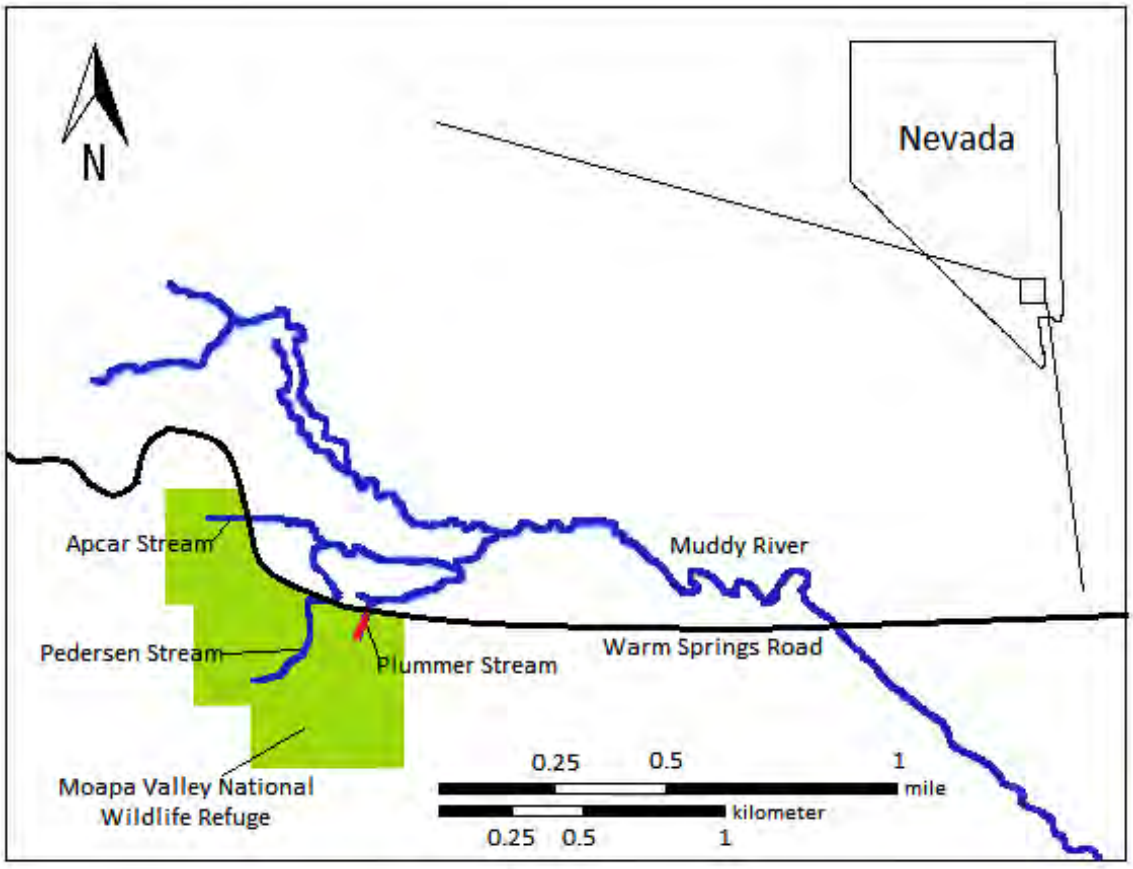

Figure 1.1. Map of the Warm Springs area in southeastern Nevada, where Moapa Dace occur in the wild. Section of Plummer Stream highlighted in red is the reach that was used for this study.

	Preferred	Not Preferred	TOTAL
Spawning Occurred	*a*	*b*	*a* + *b*
No Spawning Occurred	*c*	*d*	*c* + *d*
TOTAL	*a* + *c*	*b* + *d*	*N*

Figure 1.2. Contingency table format used in the one-sided test of the null hypothesis that each individual environmental parameter, within the "preferred" range, is utilized less than or equal to the proportion of its availability.

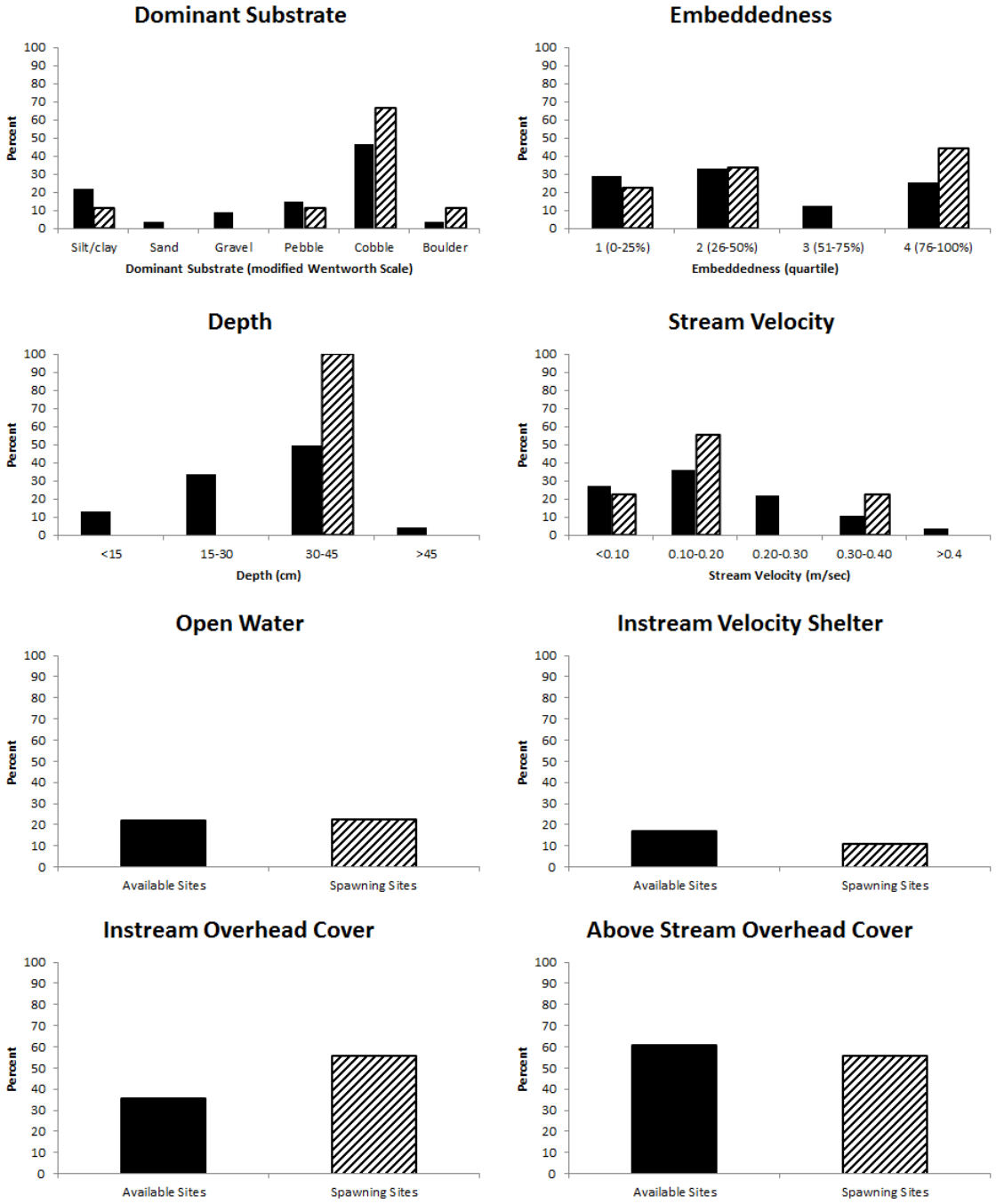

Figure 1.3. Percent of available sites (n = 280; solid bars) versus spawning sites (n = 9; patterned bars) within categories for dominant substrate size, embeddedness, depth, velocity, and several cover parameters.

Chapter 2.

Captive Rearing and Propagation of Endangered Moapa Dace

Abstract.--Moapa Dace *Moapa coriacea* is a critically endangered cyprinid endemic to the Warm Springs area of Clark County, Nevada. Moapa Dace are listed as federally endangered because of their limited range, low abundance, habitat alteration, and negative impacts from introduced species. Prior to this work, Moapa Dace had never been successfully held in captivity for any length of time. In an effort to develop a protocol for rearing and propagating Moapa Dace in captivity, 40 fish were collected in February 2013, and an additional group of 30 fish were collected in January 2014. We were able to successfully transport and rear Moapa Dace employing slow acclimation and aggressive prophylactic treatment; feeding adults with a combination of live and frozen invertebrates and commercially available pelleted foods; and providing an artificial stream environment to them. In an attempt to spawn Moapa Dace, we applied 14 different treatments, including introduction of different types of cover and different sized substrates; manipulations of photoperiod, water chemistry, and temperature; and application of hormone baths and injections. Moapa Dace were successfully propagated in one treatment left ongoing for over three months. This treatment occurred in an artificial stream and incorporated 14 broodstock from the second capture period, an additional submersible pump to direct an increased velocity along gravel and cobble substrate, and a variety of substrate sizes and artificial plants. Further tests are necessary to fine tune the understanding of what triggered the fish to spawn but initial information suggests that to successfully rear and captively propagate Moapa Dace, biologists should take great care with acclimation and provide an environment similar to that experienced by fish in the wild, incorporating stream conditions and minimal human disturbance.

Introduction

Little is known about the spawning mode of many imperiled minnows and even less is known about rearing them in captivity (Johnston 1999). One such example is critically endangered Moapa Dace *Moapa coriacea*, a cyprinid endemic to the Muddy (Moapa) River system of Clark County, Nevada (Hubbs and Miller 1948; Cross 1976) first collected and identified in 1938 (Hubbs and Miller 1948; Miller et al. 1991). Historically, Moapa Dace were found in 16 km of the upper Muddy River and its tributaries, known as the Warm Springs area (Figure 1; U.S. Fish and Wildlife Service 1996). The Warm Springs area is comprised of over 20 thermal, constant-temperature, springs within a 2-km radius, coming together to form the Muddy River (Cross 1976; Scoppettone et al. 1992). The water is about 32°C to 33°C at the springs and cools as it flows downstream (Scoppettone et al. 1992; Scoppettone et al. 1998). Moapa Dace are thermophilic, meaning they prefer warmer water, living primarily in temperatures from 26°C to 32°C. Water temperature presumably limits their distribution downstream (Cross 1976; Scoppettone et al. 1992). Moapa Dace have been reported to inhabit water containing 3.4 to 8.4 mg/L dissolved oxygen and pH ranging from 7.1 to 7.9 (U.S. Fish and Wildlife Service 1996).

The predicament of low abundance and restricted distribution that makes Moapa Dace vulnerable to extinction is exacerbated by numerous threats. Nonnative Shortfin Molly *Poecilia mexicana* may be consuming larval Moapa Dace in areas where they have access to larval nurseries (Scoppettone 1993). Nonnative Blue Tilapia *Oreochromis aureus* prey upon Moapa Dace (Scoppettone et al. 2005), but have recently been removed from the Warm Springs area; however, they still exist downstream, so potential for their reintroduction remains high. Red Shiners *Cyprinella lutrensis* have been introduced to the nearby Virgin River, coinciding with a

decline of endangered Woundfin *Plagopterus argentissimus* (Rinne 1995) and could also threaten Moapa Dace. Wildfire is unpredictable and has devastated Moapa Dace in the past (Scoppettone et al. 1998). Groundwater pumping in the Warm Springs area, which is approaching the limits of sustainability, may further endanger Moapa Dace by reducing available habitat (Mayer and Congdon 2008; Hatten et al. 2013).

Prior to this work, Moapa Dace were never successfully held in captivity. The status of this unique fish may be more secure with an established captive population. Captive rearing and propagation has a threefold benefit to imperiled fishes: it is easier to justify the use of research specimens if they are already in captivity; captive populations provide a refuge if catastrophic events affect wild populations; and captive populations provide a source for reintroduction if wild populations fall below a minimum viable level (Echelle 1991). In order to maintain a population in captivity, the fish need to reproduce successfully in a captive setting. Many fishes can be triggered to spawn in captivity by replicating the natural conditions (e.g., access to spawning substrate, change of temperature, change of day length, and rain) that stimulate them to spawn in the wild (De Silva et al. 2008). Hormone injections are typically utilized to successfully spawn fishes that are particularly difficult to spawn in an artificial setting.

The objectives of this project were: 1) investigate factors necessary for maintenance of Moapa Dace in captivity, 2) design and construct facilities for captive Moapa Dace, 3) rear Moapa Dace in captivity, and 4) propagate Moapa Dace in captivity.

Methods

Fish Collection and Transport

Wild fish were captured during two different sampling events (U.S. Fish and Wildlife Service Recovery Permit TED86593-2). We obtained 40 Moapa Dace on February 16, 2013 during the first sampling event. Fish were captured using aluminum mesh minnow traps in Pederson Stream and Plummer Stream (Figure 1). Traps were placed in areas that high numbers of dace were noted during the biannual snorkel survey held a few days prior. Traps were set at approximately 0500 hours and fish were removed from 0730 hours to 0900 hours the same morning. Once captured, fish with PIT tags were released immediately and only adults (fish measuring greater than 40 mm total length [TL]) were kept. These fish ranged from approximately 50 to 100 mm TL. The second collection occurred on January 15, 2014. Thirty additional Moapa Dace were captured by snorkelers using dip nets. To minimize handling this time, fish were not scanned for PIT tags and were visually estimated to be greater than 40 mm TL. Fish ranged from approximately 50 mm to 80 mm TL.

Fish were transported to propagation facilities at the University of Arizona's College of Agriculture in Tucson, Arizona, immediately following capture. We used four cube-shaped 45-L coolers, each equipped with an aerator and a heater (50-W Ebo-jager, Eheim, Montreal, Quebec), set at 30°C, to transport the fish via truck to Tucson. On the first trip, ten dace were transported in each cooler. To minimize effects of stress caused by transport and handling, we added 200 g (0.6% solution) of non-iodized salt (All Natural Solar Salt Crystals, Morton Salt, Chicago, Illinois) and 5 mL water conditioner (Stress Coat, Aquarium Pharmaceuticals, Chalfont, Pennsylvania) to each cooler that had been filled three-fourths full with Muddy River water. For

the second transport, two coolers were used to carry eight dace each and the other two coolers were used to hold seven dace each. We filled each cooler three-fourths full with Muddy River water and added 135 g (0.4% solution) of Morton non-iodized salt and 5 mL Stress Coat water conditioner.

Rearing

Equipment and location.--Two quarantine systems and four artificial streams were designed to captively rear Moapa Dace. Each quarantine system consisted of a 240-L acrylic aquarium to hold fish and a 60-L glass aquarium that served as a sump (Figure 2). The bottom, ends, and back of the aquariums were made of black nontransparent acrylic and the front was the only clear wall. We drilled a hole in an end of the acrylic tank, 4 cm from the top, and installed a 3.8-cm (1.5-in) diameter double threaded bulkhead fitted with an overflow strainer. We plumbed the bulkhead with 3.8-cm (1.5-in) diameter polyvinyl chloride (PVC) pipe so water would overflow and drain into the sump. The sump was filled with 20 L of 2.5-cm (1-in) plastic floating bio-balls (CBB1-F, Pentair Aquatic Eco-Systems, Apopka, Florida) as a medium for biological filtration. We installed a Pondmaster Magnetic Drive Utility Pump (model 5, Danner Manufacturing, Islandia, New York) in the sump. The pump forced water through 2.5-cm (1-in) diameter flexible braided PVC tubing into an ultraviolet sterilizer (model QL-40, Lifegard Aquatics, Cerritos, California) and back into the acrylic tank through a 1.9-cm (3/4-in) diameter PVC pipe. The pump also created a current in the tank. To maintain stable temperatures, we installed one 250-W Ebo-jager heater in each aquarium and sump.

For the artificial streams, we used an approximately 800-L rectangular fiberglass tank for the fish and a 1,200-L cylindrical fiberglass tank as a sump (Figure 3). The fiberglass tanks

came with a circular port at one end, through which we were able to pass a piece of 10-cm (4-in) diameter PVC. We set the fill level of the artificial streams with the height of the overflow PVC pipe exiting. Once water level reached that height, it overflowed and fed into the sump by gravity. In the sump, we hung two 18.95-L (5-gal) plastic buckets, each were filled with 2.5-cm (1-in) plastic bio-balls, topped with filter pads (Blue Bonded Filter Pads, Pentair Aquatic Eco-Systems, Apopka, Florida), and had about fifteen 10-mm holes drilled in the bottom. Two recirculating pumps (Rio 1100, Taam, Camarillo, California) pumped water from the sump through 1.9-cm (3/4-in) diameter vinyl tubing into the top of the bucket filters, through which it filtered and then drained back into the sump via gravity. Also in the sump, we installed a submersible Pondmaster model 12 magnetic drive utility pump that pushed water through 1.9-cm (3/4-in) diameter PVC pipe, into an ultraviolet sterilizer (Lifegard Aquatics model QL-40, Cerritos, California), through 2.5-cm (1-in) diameter braided PVC tubing, then back into the tank through a 1.9-cm (3/4-in) diameter PVC pipe. The pump also created a current in the artificial stream; velocity ranged from below detectable levels to 1.2 m/s at the inflow. Artificial streams were 268 cm long x 68.5 cm wide and water depth ranged from 32 to 40 cm. To maintain stable temperatures, we installed three 300-W Ebo-jager heaters in the fiberglass tanks and two 300-W ViaAqua heaters (Commodity Axis, Camarillo, California) in the sumps.

Originally, the artificial streams were set up in a greenhouse and received ambient Tucson, Arizona sunlight but later they were brought indoors to have better control over temperature and photoperiod. Once indoors, operations and components were the same, with the exception that 220-L glass aquaria were then used as sumps. These sumps were filled with approximately 28 L of 2.5-cm (1-in) plastic floating bio-balls, as a medium for biological filtration.

Prior to stocking fish into either system, they were disinfected and cycled to establish biological filtration. Each system was filled with water then a chlorine powder pool shock (Leslie's Power Powder Plus, Leslie's Swimming Pool Supplies, Phoenix, Arizona) was dosed at 4.93 mL (1 tsp) per 152 L (40 gal) of water. This was allowed to circulate through the system for 4-5 d until the chlorine bubbled off and reached undetectable levels. Next, we performed a 25% water change and then to provide a nitrogen source for nitrifying bacteria, we added 1.75 g ammonium chloride per 190 L of water and allowed it to disperse throughout the system. Each system was inoculated with 30 mL (1 oz) nitrifying bacteria starter culture (StartSmart Complete, TLC Products, Cleveland, Ohio) per 37.9 L (10 gal) of water. Lastly, 0.62 mL (1/8 tsp) of dry fish food was added to the sump to aid in establishment of heterotrophic bacteria.

We used well water from the agricultural center during acclimation and propagation treatments for the first group of fish brought into captivity. Disinfected Muddy River water was used during acclimation for the second group of fish and to perform water chemistry treatments in an attempt to trigger them to spawn. We obtained approximately 12,000 L of Muddy River water via tanker trailer to replace Tucson well water. The polyethylene hauling tanks were disinfected prior to water collection; water was collected from Jones Spring, at the head of Apcar Stream, and transported back to Tucson. Before water was used to rear fish, it was treated using 4.93 mL (1 tsp) Leslie's chlorine powder per 152 L (40 gal) of water and it was allowed to bubble off for about 5 d until chlorine was undetectable.

Acclimation and Prophylactic Treatment.--Fish prophylaxis began immediately upon arrival to Tucson. For the first batch of fish from February 2013, we performed a treatment for external parasites by removing half of the water volume in the coolers, adding 1 mL of 10% buffered formalin per 4 L (1 gal) of water, and continuing aeration. After 10 min, 4 L (1 gal) of

water were added from the designated quarantine tanks to the coolers and this was repeated every 10 min until the coolers were full, drained halfway again and filled once more. This process allowed the fish to be exposed to prophylaxis and slowly acclimate to new water conditions. Once treatments were complete, Moapa Dace were transferred into quarantine tanks in no particular order, 20 in each.

Quarantine aquaria were held at 28°C with a 200-W Ebo-jager heater and water was maintained at a 0.3% solution of non-iodized salt to aid in acclimation. Starting on the second day in quarantine, fish were fed small semi-floating pellets (Hikari Tropical Micro Pellets, Hikari Sales U.S.A., Hayward, California) by hand, twice daily. We performed approximately 20% to 30% water changes daily unless water quality deteriorated or antibiotic bath treatments were used, then 40% to 90% changes were performed. When fish showed signs of disease, we treated them using the appropriate medicine as directed by manufacturers. Bacterial infections (e.g., lethargy and lack of appetite) were treated with antibiotics, (Fish Sulfa Forte, Thomas Laboratories, Tolleson, Arizona; Chloramphenicol, EMD Millipore, Billerica, Massachusetts; and Kanaplex, Seachem Laboratories, Madison, Georgia); and parasite infections (e.g., rapid ventilation of infected gills and lethargy) were treated using a formalin and malachite green product (Rid Ich Plus, Kordon LLC, Hayward, California), an increased salt concentration to 0.6%, and chloroquine phosphate (Fishman Chemical, Tavernier, Florida).

The second group of fish obtained in January 2014 was treated somewhat differently. We performed a 1-hour prophylactic bath, to eliminate external parasites, by adding 1 mL of malachite green and formalin solution (solution contained 0.05 ppm malachite green and 25 ppm formalin, Southwestern Native Aquatic Resources and Recovery Center, Dexter, New Mexico) to each 45-L cooler filled three-fourths full of water, and maintaining aeration. After 1 hour,

one-half of the water volume was removed from each cooler and then water was slowly siphoned through an approximately 1.5-m long airline hose, with a 4.76-mm (3/16-in) inside diameter, from the respective artificial stream into the coolers, until they were full. Coolers were then immediately drained halfway, and slowly filled again. This process allowed fish to be exposed to prophylaxis and acclimate to the new water conditions. Once complete, all 30 dace were transferred directly into an artificial stream instead of the quarantine aquaria.

During quarantine, artificial streams were maintained at 29°C to 30°C with two 300-W Ebo-jager heaters in the fiberglass tanks and one 300-W ViaAqua heater in the sumps. On the first day, we performed a 70% water change and approximately 20% to 30% water changes daily after that, unless prophylactic treatments were performed, then water was flushed from artificial streams to achieve a nearly 100% water change. After 24 h in captivity, fish were fed Hikari Micro Pellets, by hand, twice daily and frozen invertebrates (i.e., Hikari Blood Worms and Hikari Brine Shrimp) once daily, alternating between the two each day. The malachite green and formalin solution was applied prophylactically at a concentration of 26 ppt (1 mL per 38 L of water) for 1 hour on the third and seventh day in captivity. Oxytetracycline (Pennox 343, Pennfield Animal Health, Omaha, Nebraska) treatments were applied at a concentration of 10 ppm for 7 h on days five and ten. During formalin and antibiotic treatments, the recirculating pump in the sump was turned off to isolate the therapeutant with the fish and protect the biofilter. A submersible model 5 Pondmaster magnetic drive utility pump was placed in each artificial stream along with aeration to maintain appropriate water conditions for the fish during these treatments. A liquid praziquantel therapeutant (PraziPro, Hikari Sales U.S.A., Hayward, California) was administered at a rate of 1 mL PraziPro per 15 L of water on day 18 to circulate

through the system for 3 d and again on day 26 to circulate for 7 d before water changes. PraziPro does not affect nitrifying bacteria so biofilters were not isolated during its application.

Feeding, General Care, Water Quality.--Through quarantine, fish were reared over one and a half months before propagation treatments began. Care of fish was as follows:

After close inspection of results from hand feeding, we installed an automatic feeder (Fish Mate F14 Aquarium Fish Feeder, Ani Mate, Conroe, Texas) on each artificial stream, which delivered three feedings per day. We continued feeding frozen invertebrates to the fish once daily, alternating between brine shrimp *Artemia* spp. and bloodworms *Chironomus* spp. In addition, we placed a leaf of organic romaine lettuce *Lactuca sativa* var. *longifolia* in each artificial stream approximately once every two months. Temperature was monitored daily using an ISO calibrated thermometer. Water quality (pH, ammonia, nitrite, nitrate, alkalinity, and hardness) was monitored daily until parameters stabilized subsequent to the initial stocking of fish and then weekly thereafter. Approximately 10% water changes were made weekly after parameters stabilized as well. Gravel substrate was siphoned monthly to remove waste.

Investigation of Different Treatments to Trigger Spawning

Preliminarily, we performed a videography study to monitor spawning behavior in the wild. We identified 13 spawning events. From this project (Chapter 1) we concluded that Moapa Dace are broadcast spawners. Based on comparing proportions of used resources with proportions of resources available, they preferred depths from 30 to 34 cm, stream velocities from 0.11 to 0.17 m/s, and rocky substrate to spawn. Based on those field observations and techniques used to successfully spawn other fishes, we tested 14 different treatments to captively breed Moapa Dace (Table 1). The fish were given at least two weeks to spawn after each

treatment was initiated, with the exception of hormone injections, after which fish were monitored for three days. Throughout tests, artificial streams were visually checked daily for spawning behavior, eggs, and larvae. After treatments ended, we vacuumed the substrate to see if any young were hiding in crevices. The following treatments were conducted from March, 2013, through August, 2014:

Static treatment.--The water temperature and hydrograph for the Warm Springs area did not fluctuate substantially during our field study (chapter 1) and Moapa Dace larvae are found year-round; as a consequence, we believed they would spawn in captivity by providing a depth between 30 and 40 cm, a range of velocities including 0.11 to 0.17 m/s, some cover, and some gravel to incubate and protect eggs. Each artificial stream was provided with a 3.1-mm to 6.3-mm gravel and pebble substrate (Pure Water Pebbles Nutty Pebbles, World Wide Imports, Fort Lauderdale, Florida) two boulders, two 61-cm artificial *Elodea* plants (Tetra Water Wonders Anacharis Aquarium Plant, United Pet Group, Blacksburg, Virginia) and two 30-cm artificial *Eleocharis* plants (12-in Aqua Gardens Hairgrass, Imagine Gold LLC, South Hackensack, New Jersey). This test was performed on 12 fish, five in one artificial stream and seven in another, from April 1, 2013 to April 19, 2013.

Additional Macrophyte Cover 1. --We doubled the macrophyte cover by adding two more 61-cm Tetra Water Wonders *Elodea* plants, each anchored to an 18-cm (7-in) terra cotta pot, and two more 30-cm Aqua Gardens *Eleocharis* plants. This test was performed on 11 fish, five in one artificial stream and six in another, from April 20, 2013 to May 10, 2013.

Additional Macrophyte Cover 2.--We increased macrophyte cover still more by adding two 45-cm (18-in) artificial *Ambulia* plants (Marineland Ambulia, United Pet Group,

Blacksburg, Virginia), each anchored to a 10-cm (4-in) terra cotta pot, two 30-cm (12-in) artificial Marineland *Ambulia* plants, one 23-cm (9-in) artificial Marineland *Cabomba* plant, and one 15-cm (6-in) artificial Marineland *Cabomba* plant. This test was performed on 11 fish, five in one artificial stream and six in another, from May 11, 2013 to May 31, 2013.

Addition of Overhead Cover.--We installed a 3.7-m by 4.9-m tarp (ACE 12' x 16' Blue/Brown Polyethylene Tarp, ACE Hardware Corporation, Oak Brook, Illinois) approximately 1.5 m above the water surface of each artificial stream, to simulate overhead cover provided by trees. This test was performed on 11 fish, five in one artificial stream and six in another, from June 1, 2013 to June 15, 2013.

Addition of Cobble Substrate.--We added three approximately 400 cm^2 oval-shaped patches of cobble (Extra Large River Rock, Natural Stone Manufacturing, Phoenix, Arizona) to provide larger substrate. This test was performed on 11 fish, five in one artificial stream and six in another, from June 16, 2013 to July 5, 2013.

Addition of Sand Substrate.--Silica sand (Commercial Grade Medium, The Quikrete Companies, Atlanta, Georgia) was placed in two shoebox-size plastic storage bins and one smaller square plastic container (18x18 cm) cut to 3 cm high. The two shoebox size bins were placed on the bottom of the artificial stream and the small container was placed on top of a boulder, as a shallow shelf. This test was performed on 11 fish, five in one artificial stream and six in another, from July 6, 2013 to July 26, 2013.

Manipulation of Photoperiod.--After these simple additions to the environment failed to trigger spawning, we attempted more advanced manipulations. We built a 2x17-m enclosure around the two artificial streams with 1.9-cm thick (3/4-in) polystyrene insulation (R-TECH,

Insulfoam, Puyallup, Washington). We installed one 1.2-m (4-ft) two-light fluorescent bulb fixture (Lithonia Shoplight, Lithonia Lighting, Conyers, Georgia) approximately one meter above each artificial stream. The lights were plugged into a timer (TN311, Intermatic Incorporated, Spring Grove, Illinois) to control photoperiod. To simulate the transition from summer through the following spring, we applied the following photoperiod regime, each photoperiod was applied for 2 weeks: 14 h light : 10 h dark; 12 h light : 12 h dark; 10 h light : 14 h dark; 12 h light : 12 h dark; 14 h light : 10 h dark. This regime incorporates a similar maximum and minimum day length experienced in Moapa, Nevada (National Oceanic and Atmospheric Administration 2014) and was successfully used to stimulate spawning in another Mojave Desert cyprinid (Archdeacon and Bonar 2009). This test was performed on 11 fish, five in one artificial stream and six in another, from July 27, 2013 to September 16, 2013.

Rain simulation.--We sprayed approximately 40 L of 26°C reverse osmosis filtered soft water over the surface of each artificial stream to simulate rainfall. This dropped the water temperature from 30°C to 29°C in each. Heaters remained set at 30°C so the water temperature returned after a couple hours. This was performed twice, over two days. We waited another week and then performed larger rain simulations, in the same manner (twice over two days) as the smaller simulations, using approximately 80 L of filtered water (25°C). Immediately prior to adding the filtered water, we also drained the biofilters into the system to create slight turbidity. This larger rain event lowered the water temperature from 30°C to 28°C on the first day, and following the rain event, we set heaters to maintain this 28°C water temperature. On the second day, the rain event lowered the temperature from 28°C to 26°C and following this, we set heaters to maintain water temperature at 26°C. We kept the temperature at 26°C overnight and then raised it one degree each day over the next four consecutive days to reach the initial 30°C

temperature. This test was performed on 11 fish, five in one artificial stream and six in another, from September 17, 2013 to October 6, 2013.

Addition of Silt substrate.--Silt was filled to 3 cm high in the bottom of a square 18x18-cm 2-L plastic container and one container was placed in each artificial stream. Sediment was obtained from a dry portion of Black Draw, Arizona and sifted through a 425-µm sieve. Sediment was sterilized prior to use by heating it in a drying oven to 200˚C for 24 h. This test was performed on 11 fish, five in one artificial stream and six in another, from October 7, 2013 to October 25, 2013.

Photoperiod and Temperature Manipulation Combined.--We performed another photoperiod adjustment but this time it was at the same time as a temperature change. Photoperiod was first dropped from 14 h light : 10 h dark to 10 h light : 14 h dark. Water temperature began at 30°C. By adjusting the heaters, we lowered the water temperature 1°C every three days until it reached 26°C and then we increased the water temperature 1°C every two days until it reached 30°C again. The day after water temperature reached 30°C, we adjusted the photoperiod back to 14 h light : 10 h dark. This test was performed on 11 fish, five in one artificial stream and six in another, from October 26, 2013 to December 7, 2013.

Temperature, Water Chemistry, Photoperiod, Light Intensity, and Food Manipulation Combined.--Fish were removed from Tucson well water at 28°C and placed in another artificial stream with 30°C Muddy River water, blended with approximately 25% reverse osmosis filtered well water. Fish were transferred in an 18.95-L (5-gal) bucket filled halfway with water from the originating system and then slowly acclimated to new water conditions over 1.5 h. Acclimation was carried out by siphoning the blended water, from the new artificial stream, into the bucket

until it was full, immediately drained halfway, and filled once more. Water was siphoned through an approximately 1.5-m long 4.76-mm (3/16-in) inside diameter airline hose. The room the fish originated from had a 10 h light: 14 h dark photoperiod and the new room was at 14 h light : 10 h dark. An extra set of fluorescent lights were placed over the breeding tank to increase light intensity. Live food (Grindal worms *Enchytraeus buchholzi* and daphnia *Daphnia magna*) were fed to fish daily for one week prior to treatment through one week into treatment. This test was performed on 30 fish, 10 from the initial capture in one artificial stream and 20 new fish in another, from March 5, 2014 to March 21, 2014.

Hormone Bath.--We chose to treat the 10 fish captured in 2013 with a hormone bath treatment because they were larger and several looked gravid. Ova RH (synthetic analogue of salmonid GnRH, Syndel Laboratories, Nanaimo, British Columbia) was placed in a bucket with 15 L of water at a concentration of 16 µg of Ova RH per kg of water. The 10 fish were placed in the aerated bath for 3 h and then treated as above with the change in water chemistry and increase in temperature, day length and light intensity. All fish were placed in one artificial stream and treatment took place from April 25, 2014 to May 9, 2014.

Water Velocity.--Temperature, water chemistry, photoperiod, light intensity, and food manipulation were performed once again as above, but in this treatment, we increased water velocity in a section of artificial stream. This was achieved by placing a submersible Model 5 Pondmaster magnetic drive utility pump on the artificial stream bottom, midway down the length of the tank, with flow directed parallel to the substrate. This test was performed on 14 fish, all in one artificial stream, from May 1, 2014 to August 30, 2014.

Hormone Injection.--Seven days after the hormone bath was applied, we injected four of the ten fish that received the hormone bath treatment, with carp pituitary extract. The injections were supervised by personnel from Southwestern Native Aquatic Resources and Recovery Center (Dexter, New Mexico) experienced in providing injections to desert cyprinids. Ten mg carp pituitary (Pituitary Acetone Powder from Carp, Sigma-Aldrich, Saint Louis, Missouri) were mixed with 10 mL sterile saline solution and allowed to dissolve for 30 minutes. Prior to injection, the abdomen of each fish was gently depressed to determine sex if they were ripe enough to express gametes. No gametes were expressed by depressing the abdomen; therefore, a best guess was made at pairing two males with two females. Fish presumed to be females had larger abdomens and were a lighter golden brown overall (Figure 4 a). Fish presumed to be males had flatter abdomens and darker brown coloration with dark barring patterns dorsally (Figure 4 b). We performed the intraperitoneal injections with 0.1 mL of extract just behind the left pelvic fin of each fish. These fish ranged from 76 to 119 mm TL. The four fish were all placed in one artificial stream that contained similar conditions to those in the one from which they originated. Based on past experience, fish typically show spawning behavior within 24 h of injection (M. E. Ulibarri, USFWS Southwestern Native Aquatic Resources and Recovery Center, personal communication). After three days, we attempted to express gametes from them by gently depressing on their abdomens. Stress from this handling and disruption of their slime coat leaves the fish susceptible to bacterial infection (M. E. Ulibarri, USFWS Southwestern Native Aquatic Resources and Recovery Center, personal communication); consequently, fish were treated with oxytetracycline at a concentration of 10 ppm for seven hours, same as during quarantine. This test was performed on four fish, all in one artificial stream, from May 2, 2014 to May 5, 2013.

Results

Fish Collection and Transport

The use of minnow traps to collect Moapa Dace was less labor intensive, quicker, and enabled the capture of larger fish than snorkeling with aquarium nets. There were no mortalities during capture or transport using either method.

Rearing

Acclimation and Prophylactic Treatment.--No mortalities occurred during initial prophylactic treatments. Fish that were captured with minnow traps and initially stocked into acrylic aquaria with Tucson municipal water experienced high mortality after the first week in quarantine. Twenty eight fish out of 40 died during the 1.5 months in quarantine aquaria. When placed in aquaria, the fish were not calm. Their behavior alternated between continuous escape attempts through the clear viewing wall and periods of time staying close to the bottom. None of the therapeutic treatments seemed to slow the mortality rate of one or two fish per day. When placed in artificial streams, the fish were calmer and did not appear to be continuously trying to find a way out, and mortality rates dropped to nearly zero. Fish captured with aquarium nets and stocked immediately into artificial streams with Muddy River water experienced 0% mortality during quarantine.

Feeding, General Care, Water Quality.--Except during the disease outbreak in the initial group of fish, fish fed aggressively in both systems. Moapa Dace did not eat floating flake food but began feeding on small sinking pellets at the first attempt to feed them after 24 h in captivity. Fish nibbled at lettuce when it was available. They did not feed well at temperatures below 27°C. Water quality did not differ substantially between aquaria and artificial streams; pH was

typically 7.8 and ranged from 7.5 to 8.3, ammonia spiked to 1 ppm soon after stocking the fish but never went above 0 ppm after biofilters acclimated to the load of fish, nitrite spiked to 3 ppm initially but also remained at 0 ppm after acclimating. Nitrate (0-40 ppm), alkalinity (80-120 ppm), and hardness (75-200 ppm) were within normal ranges.

Investigation of Different Treatments to Trigger Spawning

Thirteen of the fourteen treatments utilized to trigger Moapa Dace to produce young in captivity were unsuccessful. During the static treatment, fish behavior was similar to that in slow water velocity sections in the wild; they swam slowly in random patterns, probably searching for food. This searching behavior was alternated by time spent hiding in terra cotta pots and under boulders. Placing additional plants in artificial streams did not appear to affect their behavior. Providing additional overhead cover decreased the amount of time fish spent hiding during the day. Manipulation of substrate did not affect their behavior aside from occasional forays into the silt container that agitated the fish when they encountered the container's sides. Adjusting the photoperiod by itself did not have a noticeable effect on behavior. Rain simulations caused an immediate increase in activity with fish schooling up and swimming around the artificial streams rapidly, followed by a decrease in activity a few hours later. In addition, when the temperature of the artificial streams fell below 27°C, following the addition of cool water, fish did not feed well. Photoperiod and temperature manipulation together resulted in behaviors similar to that when they were manipulated independently. Fish did not feed well below 27°C once again. However, unlike the rain event, here temperature was changed gradually and the water surface was not disturbed because heaters were used to adjust the temperature. This minimal amount of disturbance was associated with no sudden burst of fish activity, unlike what was observed during rain simulations. The combination of

temperature, water chemistry, photoperiod, light intensity, and food manipulation did not appear to alter fish behavior. Increased water velocity resulted in fish occasionally swimming to maintain a stationary position mid-channel in the faster flowing water, similar to their drift feeding behavior in the wild. Both the hormone bath and injection seemed to have a similar effect on the fish. They became substantially more aggressive toward one another and a few displayed apparent courtship behavior (i.e., two fish would continuously swim intently side by side for a period of time). After gently depressing on their abdomens, we was unable to express any gametes from fish that only received a hormone bath but the two injected fish, that we believed to be females, both released a clear gelatinous fluid and one released an egg (Figure 5).

Moapa Dace finally spawned during the velocity treatment, three months after it was initiated. This treatment occurred in an artificial stream that incorporated boulder, cobble, gravel, and sand substrates, along with artificial plants around the periphery. The treatment was initiated by temperature, water chemistry, photoperiod, light intensity, and velocity manipulation. A submersible pump was placed on the bottom to direct subsurface flow parallel to gravel and cobble. Fourteen broodstock from the second capture period were utilized. Furthermore, this treatment incorporated minimal disturbance (fish were not moved or handled and no new treatments were applied) for over three months. Approximately 200 fry were produced between August 1 and August 30, 2014.

Discussion

Acclimating wild fish to captivity is stressful to them. There exists a phenomenon, not well understood, known as delayed mortality syndrome (Noga 2010). Delayed mortality syndrome can occur anywhere from two days to a month after moving fish (Noga 2010).

Stressors such as trauma from capture, removal of slime from handling, overcrowding, poor water quality, acclimation to new water chemistry, and exposure to a new environment all contribute to compromising the immune system and may result in death (Noga 2010).

Delayed mortality syndrome experienced by fish from the first group was likely due to several factors. Each fish from the first lot was handled to check for PIT tags and obtain length measurements. In addition, these fish were first placed in quarantine aquaria, not the larger artificial streams, for quarantine. When placed in aquaria, the fish were stressed by continuously trying to escape. Therapeutic treatments were not isolated from biofilters, which may have negatively affected the nitrifying bacteria, resulting in the need for large daily water changes to maintain proper water quality. Although there was a spike of ammonia and nitrite when fish were stocked into both aquaria and artificial streams, the reduction of other stressors in the artificial streams likely enabled the fish to handle this stressor, while it may have contributed to mortality of fish in aquaria. With minimal cover in the aquaria, our presence likely added stress to those fish as well.

The group of fish captured in January, 2014 experienced better survival, probably because they were handled much less; were placed immediately into artificial streams with a more realistic environment; and were acclimated to captivity in Muddy River water. All of these helped to reduce stress, and the aggressive prophylactic treatments prevented infections. Moapa Dace did not appear very sensitive to formalin, malachite green, oxytetracycline, or praziquantel so these treatments are effective to eliminate parasites with a minimum of stress.

Moapa Dace have small, subterminal mouths so they appear to feed lower in the water column necessitating the use of the small sinking pellets. Scoppettone et al. (1992) found that

Moapa Dace are omnivores and they follow a similar feeding pattern in captivity. Their feeding preferences seemed to change periodically so a varied diet is recommended. Furthermore, maintaining water temperatures at 28°C seemed to result in calm behavior and uninterrupted feeding.

Both common and imperiled fishes have been propagated in captivity, but the difficulty of successful propagation varies widely. To spawn, fish need to sense a specific combination of environmental cues (e.g., change in photoperiod, change in temperature, change in water velocity, change in water chemistry, or presence of certain resources) that cause a cascade of physiological events (i.e., the hypothalamus is stimulated to produce releasing hormones that trigger the pituitary gland to release gonadotrophic hormones, resulting in gonads producing sex steroids that cause gametes to develop) (De Silva et al. 2008). Some species have spawned in aquaria with little more than providing water, and an appropriate temperature (Kaya 1991; Mattingly et al. 2003; Schultz and Bonar 2007; Bonar et al. 2011). Others require more environmental enrichment such as gravel, plants, and pottery along with a properly sequenced manipulation of photoperiod and temperature (Archdeacon and Bonar 2009; Kline and Bonar 2009). Many successful attempts to culture stream dwelling fishes have taken place in artificial streams (Buynak and Mohr 1981; Rakes et al. 1999; Bryan et al. 2005). Depending on their spawning mode, certain species require very specific substrate (e.g., plants, mound nests built by another species, crevices, or caves) to spawn (Buynak and Mohr 1981; Rakes et al. 1999; Bryan et al. 2005).

Moapa Dace only spawned successfully during 1 of 14 efforts despite trying numerous techniques that worked in other projects listed above and further methods based on observations of Moapa Dace spawning behavior in the wild (Chapter 1). They only spawned and produced

fry in the treatment incorporating an artificial stream with an additional submersible pump directing flow along the gravel and cobble substrate, a large number of broodfish from the second capture, and a variety of substrate and artificial aquatic plants. Larval production did not occur until three months after the initiation of the velocity treatment. The fact that they took so long to spawn leads us to believe that Moapa Dace may need a substantial amount of time to acclimate and require minimal human disturbance. Many attempts to breed other imperiled fishes (e.g., Devils Hole Pupfish *Cyprinodon diabolis* and Yaqui Catfish *Ictalurus pricei*) of the arid Southwest were also exceedingly difficult, and often unsuccessful and unpredictable (Deacon et al. 1995; M. E. Ulibarri, USFWS Southwestern Native Aquatic Resources and Recovery Center, personal communication). Other small cyprinids have also been notoriously difficult to breed in an artificial setting as well (Buynak and Mohr 1981). Moapa Dace seem to fit into that category of difficulty because they only spawned successfully after a considerable number of tests.

Precisely replicating environmental triggers found in wild populations is important for successful propagation. Missing environmental stimuli or stressors from captivity result in two common difficulties in propagation studies: females fail to undergo final oocyte maturation, or ovulation occurs but eggs are not released (De Silva 2008). Precise replication of conditions, including use of artificial streams finally resulted in the production of young. Use of hormone injections may help to bypass issues like missing stimuli or stressors (De Silva 2008; M. E. Ulibarri, USFWS Southwestern Native Aquatic Resources and Recovery Center, personal communication). Further testing of hormone injections may also be merited in future studies. The conservative dose of carp pituitary gland, we delivered, did not produce a successful spawn but it did trigger courtship behavior and the release of an egg with gentle pressure on the

abdomen of a fish three days after injection. Hormone injections have triggered fish to spawn in captivity with great success, even when fish are extremely difficult to propagate otherwise (Ball and Bacon 1954; Hamman 1981; Hamman 1982a, 1982b; Stoeckel 1993; Arabaci 2001; De Silva 2008). A dose of carp pituitary gland extract up to two or three times greater may be needed to successfully spawn Moapa Dace (A. V. Gonzalez, Universidad Autonoma de Nuevo Leon, personal communication). To increase the chances of success, a larger group of fish should be used because there are typically some fish that do not respond to the treatment (Hamman 1981; Hamman 1982a, 1982b).

Since successful spawning was documented in only one treatment at the end of the project, further tests are necessary to fine tune the understanding of what triggered the fish to spawn. Initial information suggests that to successfully rear and captively propagate Moapa Dace, biologists should take great care with acclimation and provide as similar conditions (e.g., flow, artificial stream, variety of substrate, water temperatures, and cover) as possible to those experienced by fish in the wild. Sufficient brood stock should be available to use in spawning attempts. Small numbers of brood fish limit chances of success.

Conclusion

We was able to successfully transport and rear Moapa Dace using 45-L coolers stocked with 10 or fewer fish and water conditioners for transportation; conducting slow acclimation with immediate prophylaxis; holding fish at 28°C to 30°C; feeding adults a combination of live and frozen invertebrates and commercially available pelleted foods; and holding them in an artificial stream environment. Moapa Dace were difficult to propagate, and young were produced during only 1 of 14 treatments. The successful treatment occurred in an artificial

stream and incorporated 14 broodstock from the second capture period, an additional submersible pump to direct an increased velocity along the gravel and cobble substrate, a variety of substrate sizes and artificial plants, and minimal human disturbance for a three month period. Initial information suggests that to successfully rear and captively propagate Moapa Dace, biologists should take great care with acclimating Moapa Dace, and provide as similar conditions (e.g., flow, artificial stream, variety of substrate, water temperatures, and cover) as possible to those experienced by fish in the wild. Sufficient brood stock should be available to use in spawning attempts. Small numbers of brood fish may limit chances of success.

References

Arabaci, M., H. Cagirgan, M. Sari. 2001. Induction of spawning in Common Carp *Cyprinus carpio* using LHRHa ([D-Ser (tBu)6, Pro9-NEt]-LHRH) combined with haloperidol: effects of different treatment time and determination of latency period dependence on temperature. Turkish Journal of Fisheries and Aquatic Sciences 1:1-5.

Archdeacon, T. P., and S. A. Bonar. 2009. Captive breeding of endangered Mohave Tui Chub. North American Journal of Aquaculture 71:360-362.

Ball, R. C., and E. H. Bacon. 1954. Use of pituitary materials in the propagation of minnows. Progressive Fish-Culturist 16:108-113.

Bonar, S. A., A. A. Schultz, and E. A. Sontz. 2011. Captive breeding and culture of Gila Chub *Gila intermedia*, Headwater Chub *Gila nigra* and Roundtail Chub *Gila robusta*. Arizona Cooperative Fish and Wildlife Research Report 01-11, Tucson.

Bryan, J. L., M. L. Wildhaber, and D. B. Noltie. 2005. Examining Neosho Madtom reproductive biology using ultrasound and artificial photothermal cycles. North American Journal of Aquaculture 67:221-230.

Buynak, G. L., and H. W. Mohr, Jr. 1981. Small-scale culture techniques for obtaining spawns from fish. Progressive Fish-Culturist 43:38–39.

Cross, J. N. 1976. Status of the native fish fauna of the Moapa River (Clark County, Nevada).Transactions of the American Fisheries Society 105:503-508.

Deacon, J. E., F. R. Taylor, and J. W. Pedretti. 1995. Egg viability and ecology of Devils Hole pupfish: insights from captive propagation. The Southwestern Naturalist 40:216-223.

De Silva, S. S., T. T. Nguyen, and B. A. Ingram. 2008. Fish reproduction in relation to aquaculture. Pages 535-575 *in* M. J. Rocha, A. Arukwe, and B. G. Kapoor, editors. Fish Reproduction. Science Publishers, Enfield, New Hampshire.

Echelle, A. A. 1991. Conservation genetics and genic diversity in freshwater fishes of western North America. Pages 141-153 *in* W. L. Minckley, and J. E. Deacon, editors. Battle against extinction. University of Arizona Press, Tucson.

Hamman, R. L. 1981. Hybridization of three species of chub in a hatchery. Progressive Fish-Culturist 43:140–141.

Hamman, R. L. 1982a. Induced spawning and culture of Bonytail Chub. Progressive Fish-Culturist 44:201–203.

Hamman, R. L. 1982b. Spawning and culture of Humpback Chub. Progressive Fish-Culturist 44:213–216.

Hatten, J. R., T. R. Batt, G. G. Scoppettone, C. J. Dixon. 2013. An ecohydraulic model to identify and monitor Moapa Dace habitat. Plos One 8(2).

Hubbs, C. L., and R. R. Miller. 1948. Two new, relict genera of cyprinid fishes from Nevada. University of Michigan Museum of Zoology Occasional Papers 507:1-35.

Johnston, C. E. 1999. The relationship of spawning mode to conservation of North American minnows (*Cyprinidae*). Environmental Biology of Fishes 55:21–30.

Kaya, C. M. 1991. Laboratory spawning and rearing of Speckled Dace. Progressive Fish-Culturist 53:259–260.

Kline, S. J., and S. A. Bonar. 2009. Captive breeding of endangered Yaqui Topminnow and Yaqui Chub for recovery purposes. North American Journal of Aquaculture 71:73-78.

Mattingly, H. T., J. Hamilton, and D. L. Galat. 2003. Reproductive ecology and captive breeding of the threatened Niangua Darter *Etheostoma nianguae*. American Midland Naturalist 149:376-383.

Mayer, T. D., and R. D. Congdon. 2008. Evaluating climate variability and pumping effects in statistical analyses. Ground Water 46:212–227.

Miller, R. R., C. Hubbs, and F. H. Miller. 1991. Ichthyological exploration of the American West: The Hubbs-Miller era, 1915-1950. Pages 19-40 *in* W. L. Minckley, and J. E. Deacon, editors. Battle against extinction. University of Arizona Press, Tucson.

National Oceanic and Atmospheric Administration. 2014. NOAA Solar Calculator (April 3). Available: http://www.esrl.noaa.gov/gmd/grad/solcalc/. (July 2014).

Noga, E. J. 2010. Fish disease: diagnosis and treatment, 2nd edition. John Wiley & Sons, Ames, Iowa.

Rakes, P. L., J. R. Shute, and P. W. Shute. 1999. Reproductive behavior, captive breeding, and restoration ecology of endangered fishes. Environmental Biology of Fishes 55:31–42.

Rinne, J. N. 1995. The effects of introduced fishes on native fishes: Arizona, Southwestern United States. Pages 149-159 *in* D. P. Phillip, J. M. Epifanio, J. A. Marsden, J. E. Claussen, and R. J. Wolotira Jr., editors. Protection of aquatic biodiversity: proceedings of the World Fisheries Congress, Theme 3.

Scoppettone, G. G. 1993. Interactions between native and nonnative fishes of the upper Muddy River, Nevada. Transactions of the American Fisheries Society 122:599-608.

Scoppettone, G. G., H. L. Burge, and P. L. Turtle. 1992. Life history, abundance, and distribution of Moapa Dace (*Moapa coriacea*). Great Basin Naturalist 52:216-225.

Scoppettone, G. G., J. A. Salgado, and M. B. Nielsen. 2005. Blue Tilapia *Oreochromis aureus* predation on fishes in the Muddy River system, Clark County, Nevada. Western North American Naturalist 65:410-414.

Scoppettone, G. G., P. H. Rissler, M. B. Nielsen, and J. E. Harvey. 1998. The status of *Moapa coriacea* and *Gila seminuda* and status information on other fishes of the Muddy River, Clark County, Nevada. The Southwestern Naturalist 43:115-122.

Stoeckel, J. N. 1993. Controlled cultivation techniques for the recovery of threatened fishes in Virginia. Doctoral dissertation. Virginia Polytechnic Institute and State University, Blacksburg.

U.S. Fish and Wildlife Service. 1996. Recovery plan for the rare aquatic species of the Muddy River ecosystem. USFWS, Portland, Oregon.

U.S. Office of the Federal Register. 1967. Native fish and wildlife, endangered species. Federal Register 32:48(11 March 1967):4001.

Table 2.1. Treatments to trigger Moapa Dace to spawn including: dates conducted, number of fish per artificial stream, total number of fish treatments were performed on, and sources of water used during each treatment.

Treatment	Date Applied	Number of fish per Artificial stream	Total Number of Fish	Water Source
Static treatment	4/1/13-4/19/13	7, 5	12	Tucson well water
Additional Macrophyte Cover 1	4/20/13-5/10/13	6, 5	11	Tucson well water
Additional Macrophyte Cover 2	5/11/13-5/31/13	6, 5	11	Tucson well water
Addition of Overhead Cover	6/1/13-6/15/13	6, 5	11	Tucson well water
Addition of Cobble Substrate	6/16/13-7/5/13	6, 5	11	Tucson well water
Addition of Sand Substrate	7/6/13-7/26/13	6, 5	11	Tucson well water
Manipulation of Photoperiod	7/27/13-9/16/13	6, 5	11	Tucson well water
Rain simulation	9/17/13-10/6/13	6, 5	11	Tucson well water and filtered well water
Addition of Silt substrate	10/7/13-10/25/13	6, 5	11	Tucson well water
Photoperiod and Temperature Manipulation Combined	10/26/13-12/7/13	6, 5	11	Tucson well water

Temperature, Water Chemistry, Photoperiod, Light Intensity, and Food Manipulation Combined	3/5/14-3/21/14	20, 10	30	Muddy River and filtered Tucson well water
Hormone (Ova RH) Bath	4/25/14-5/9/14	10	10	Muddy River and filtered Tucson well water
Water Velocity	5/1/14-8/30/14	14	14	Muddy River and filtered Tucson well water
Hormone (Carp Pituitary Extract) Injection	5/2/14-5/5/14	4	4	Muddy River and filtered Tucson well water

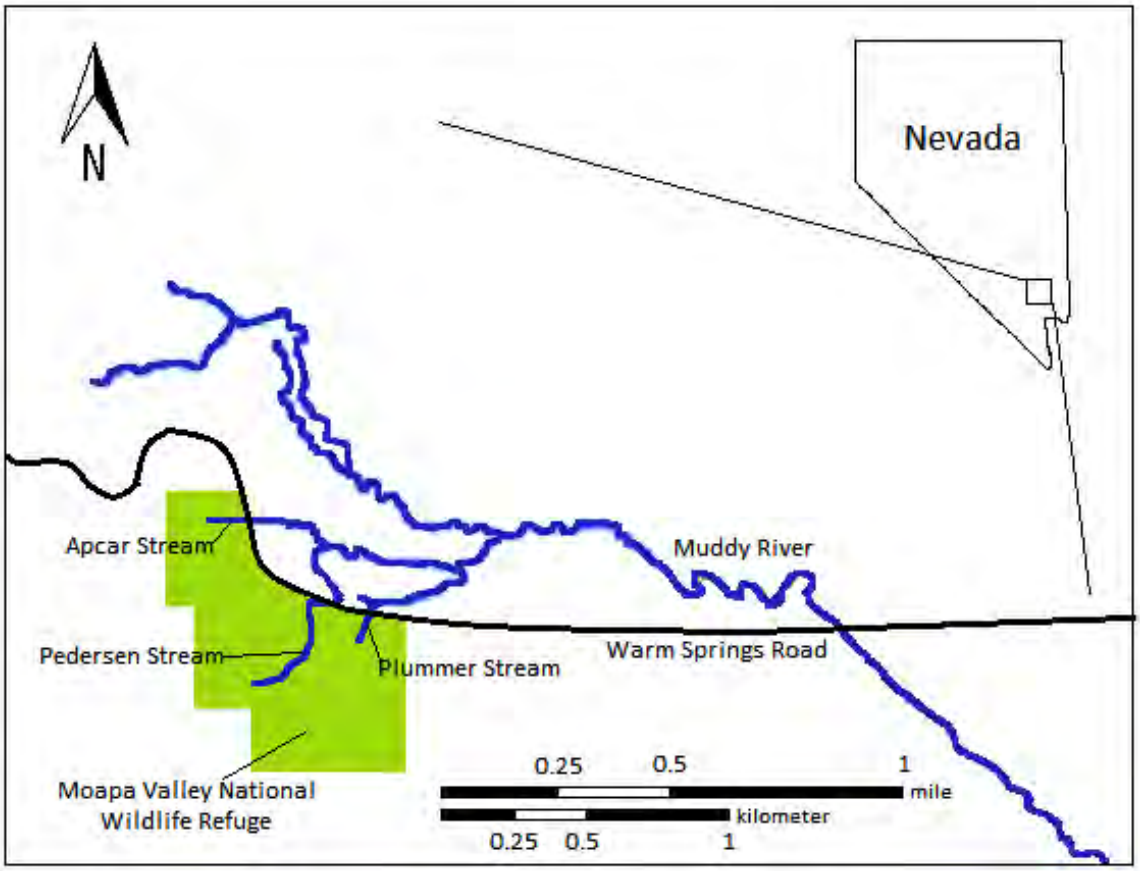

Figure 2.1. Map of the Warm Springs area in southeastern Nevada, where Moapa Dace occur in the wild.

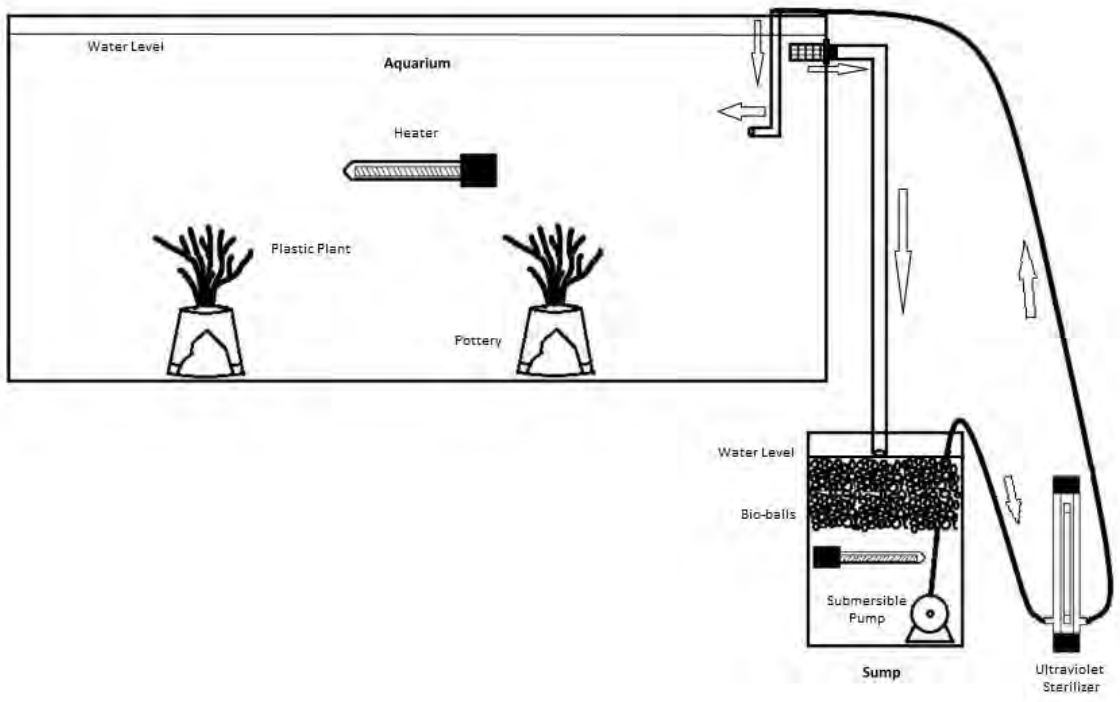

Figure 2.2. Diagram of aquarium system used, unsuccessfully, to quarantine Moapa Dace. A 240-L acrylic aquarium (top) was used to hold the fish. Pottery and plastic plants were provided as cover. A 60-L glass aquarium (bottom right) was used as a sump. The sump provided biological filtration and a submersible pump placed in the sump was used to circulate water through the ultraviolet sterilizer and back into the holding aquarium. Water overflowed into piping on right back into the sump. Plumbing signified by solid black lines was flexible vinyl tubing; open pipe was made of rigid polyvinyl chloride. Arrows show direction of water flow.

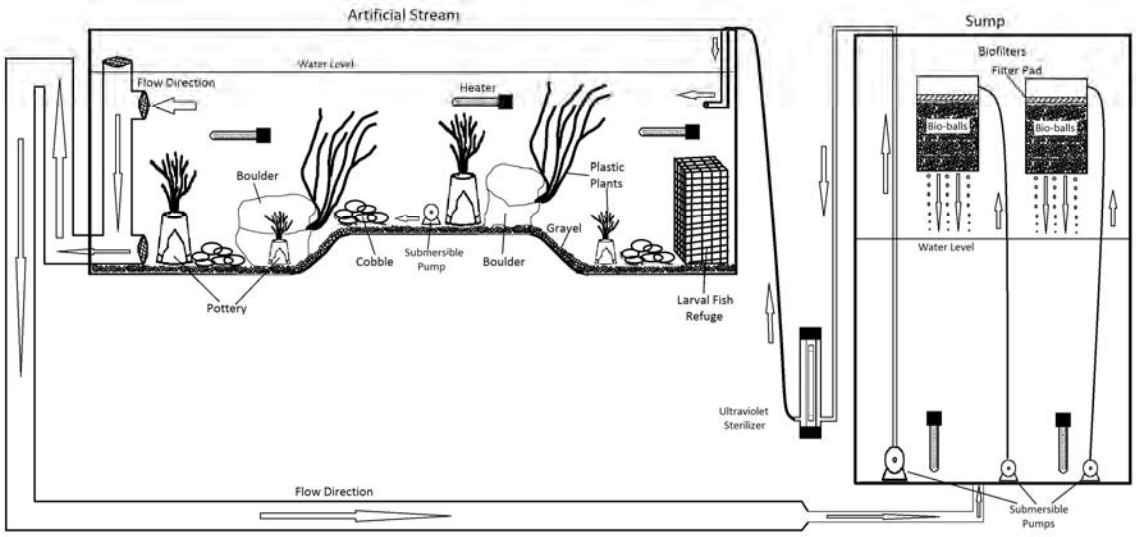

Figure 2.3. Diagram of system used to rear and propagate Moapa Dace. Fish were located in an 800-L fiberglass artificial stream (left). Silt and sand (not depicted) gravel, cobble, boulders, pottery, and plastic plants, were provided as substrate and cover. A 1,200-L cylindrical fiberglass tank was provided as a sump (right). For biological filtration, two 18.95-L plastic buckets were suspended above the water level in the sump. Submersible pumps forced water into the buckets and then it trickled through filter pads and bio-balls back into the sump. Another submersible pump in the sump circulated water through an ultraviolet sterilizer and back into the artificial stream. For the water velocity treatment, which ultimately led to successful spawning of Moapa Dace, a submersible pump was placed on the bottom of the artificial stream directing flow along the substrate. At the left end of the artificial stream, water would enter the pipes and overflow. Then the force of gravity would cause it to upwell through the bottom of the sump. Plumbing signified by solid black lines was flexible vinyl tubing; open pipe was made of rigid polyvinyl chloride. Arrows show direction of water flow.

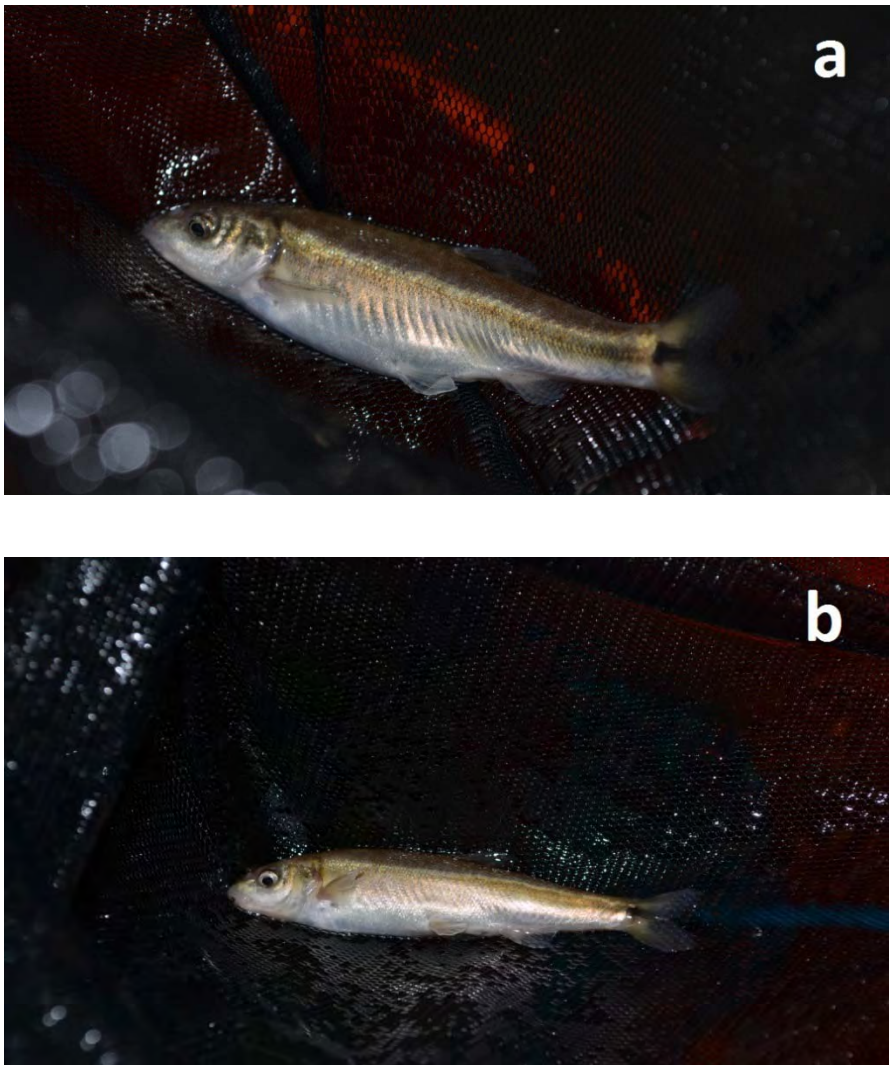

Figure 2.4. Fish presumed to be females had larger abdomens and were a lighter golden brown overall (a). Fish presumed to be males had flatter abdomens and darker brown coloration with dark barring patterns dorsally (b).

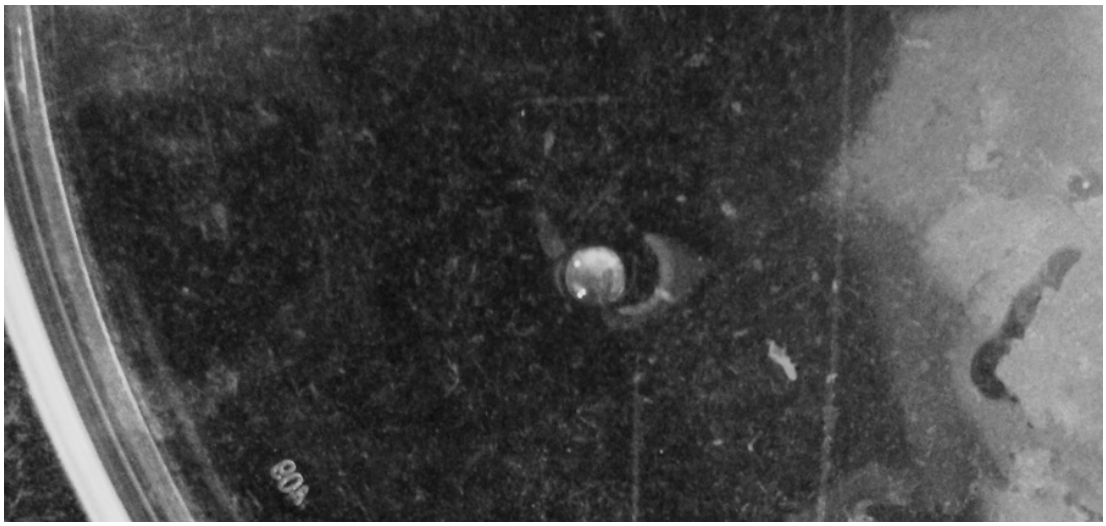

Figure 2.5. Egg expressed from female Moapa Dace after hormone injection.

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Prepared in cooperation with the U.S. Fish and Wildlife Service

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SE ROA 47345

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U.S. Geological Survey

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Conversion Factors

International System of Units to Inch/Pound

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
kilometer (km)	0.6214	mile (mi)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

A Stochastic Population Model to Evaluate Moapa Dace (*Moapa coriacea*) Population Growth Under Alternative Management Scenarios

By Russell W. Perry, Edward C. Jones, and G. Gary Scoppettone

Abstract

The primary goal of this research project was to evaluate the response of Moapa dace (*Moapa coriacea*) to the potential effects of changes in the amount of available habitat due to human influences such as ground water pumping, barriers to movement, and extirpation of Moapa dace from the mainstem Muddy River. To understand how these factors affect Moapa dace populations and to provide a tool to guide recovery actions, we developed a stochastic model to simulate Moapa dace population dynamics. Specifically, we developed an individual based model (IBM) to incorporate the critical components that drive Moapa dace population dynamics. Our model is composed of several interlinked submodels that describe changes in Moapa dace habitat as translated into carrying capacity, the influence of carrying capacity on demographic rates of dace, and the consequent effect on equilibrium population sizes. The model is spatially explicit and represents the stream network as eight discrete stream segments. The model operates at a monthly time step to incorporate seasonally varying reproduction. Growth rates of individuals vary among stream segments, with growth rates increasing along a headwater to mainstem gradient. Movement and survival of individuals are driven by density-dependent relationships that are influenced by the carrying capacity of each stream segment.

First, we calibrated the model to a historical time series of Moapa dace abundance estimates. The goal of the calibration was to estimate unknown parameters such as larval survival, carrying capacity of the tributary streams harboring the population of Moapa dace upstream of the gabion barrier, and carrying capacity of the mainstem Muddy River and tributaries. Based on historical abundance estimates, we found that the carrying capacity of the mainstem Muddy River was nearly twice the capacity of the tributary streams where Moapa dace have resided for the past 20 years.

Given the calibrated model, we then conducted simulations to assess (1) the effect of altering migration barriers that restrict upstream and downstream movement of dace, and (2) the effect of changes in carrying capacity on equilibrium population sizes. We found that barriers to upstream movement led to extinction of subpopulations upstream of the barriers when initial population sizes were small. The probability of one or more subpopulations going extinct over a 50-year time horizon was >0.80 at initial population sizes of 10 non-larval and 70 larval dace, and was >0.40 at initial population sizes of 50 non-larval and 350 larval dace. The probability of a subpopulation going extinct decreased to zero when the initial population size exceeded 100 non-larval dace. Removal of upstream migration barriers eliminated extinctions of subpopulations, even at low initial population sizes. Compensatory mechanisms such as density-dependent survival and movement acted to buffer against local extinctions because stream segments could be quickly repopulated by dispersal when fish could access all stream segments.

Providing access to the mainstem Muddy River through removal of a gabion barrier that restricted upstream and downstream movement increased total population size from about 875 to 3,000 individuals. Additionally, because of higher growth rates of individuals in the mainstem Muddy River, the size structure of the population shifted towards larger individuals with higher fecundity, thereby increasing reproductive capacity of the population.

Increasing or decreasing the total carrying capacity of all stream segments resulted in changes in equilibrium population size that were directly proportional to the change in capacity. However, changes in carrying capacity to some stream segments but not others could result in disproportionate changes in equilibrium population sizes by altering density-dependent movement and survival in the stream network. These simulations show how our IBM can provide a useful management tool for understanding the effect of restoration actions or reintroductions on carrying capacity, and, in turn, how these changes affect Moapa dace abundance. Such tools are critical for devising management strategies to achieve recovery goals.

Introduction

The Moapa dace (*Moapa coriacea*) is a thermophilic minnow native to the Muddy River system near Las Vegas, in southern Nevada. The range of Moapa dace is constrained to areas with water temperatures between 26.0 and 32.0 °C, which restrict them to the upper 2 km of the Muddy River and several small tributaries fed by warm springs. The general area where they occur is known as the Warm Springs Area. The Moapa dace was recognized as endangered in 1967 (Udall, 1967) and federally listed as such in 1973 due to its restricted range and population decline from historical levels (U.S. Department of the Interior, 1973). In 1995, exotic blue tilapia (*Oreochromis aureus*) invaded Warm Springs, and Moapa dace abundance declined shortly thereafter. Installation of a gabion barrier on the lower Plummer Stream (referred to as “Refuge Stream” in the associated Recovery Plan; U.S. Fish and Wildlife Service, 1996.) allowed blue tilapia to be eradicated upstream of this barrier. In 2014, these headwater streams harbored the remaining population of Moapa dace. Before introduction of blue tilapia, the Moapa dace population ranged from 3,000 to 5,000 fish, but since their habitat has been restricted to headwater streams upstream of the gabion barrier, their observed population has ranged from 439 to 1,727 individuals based on biannual snorkel counts through August 2013. Life history, abundance, and distribution information on Moapa dace are available in Scoppettone and others (1992) and Scoppettone (1993).

As a result of geothermal heating, water enters the Warm Springs pools at about 32 °C and cools as it flows downstream. Although water temperatures and flow rates in the Warm Springs Area show little seasonal variation, these stable environmental conditions may change because of human influences. Water removals from the Muddy River aquifer have been shown to reduce the volume of water entering the spring system, which will reduce the volume of water flowing into the headwater streams (Mayer and Congdon, 2008). Reduced spring flow has been shown to reduce the amount of suitable habitat available for the Moapa dace (Hatten and others, 2013). However, the effect of reduced spring flow on the thermal environment and the consequent effect on habitat suitability for Moapa dace is less certain. Changes in the amount of habitat available for Moapa dace owing to factors such as blue tilapia invasion or reduced spring flows will alter the carrying capacity of the environment to support Moapa dace. Declines in carrying capacity, in turn, may hamper efforts to restore or even maintain Moapa dace populations. Understanding how changes in carrying capacity influence population dynamics of Moapa dace is critical for devising strategies to meet recovery goals.

The primary goal of our project is to evaluate the response of the Moapa dace population to the potential effects of human influences such as ground water pumping, movement barriers, and reintroduction of Moapa dace to the mainstem Muddy River. To understand how these factors affect Moapa dace populations and to provide a tool to guide recovery actions, we developed a stochastic model to simulate Moapa dace population dynamics. Specifically, we developed an individual based model (IBM) to incorporate the critical components that drive Moapa dace population dynamics. Our model is composed of several interlinked submodels that describe changes in Moapa dace habitat as translated into carrying capacity, the influence of carrying capacity on demographic rates of dace, and the consequent effect on equilibrium population sizes.

Numerous important physiological, ecological, and behavioral characteristics of Moapa dace suggest that size structure is a critical component to include in a population dynamics model for dace. First, fecundity of Moapa dace increases with size, and thus larger individuals will contribute more recruits to the population than small individuals (Scoppettone and others, 1992). With size-dependent fecundity, the size structure of the population can be an important determinant of population growth rate. Prior to invasion of blue tilapia, Moapa dace up to 120 mm fork length (FL) commonly were observed in the mainstem Moapa River, but a FL of just 70 mm is near the upper end of the size distribution since their restriction to smaller headwater streams (Hereford, 2014b). Absence of highly fecund, large individuals, therefore, may affect how quickly the population recovers from population declines. Second, survival likely differs among life stages, particularly for larval (<25 mm FL) and non-larval dace (≥25 mm FL). For example, Scoppettone and Burge (1994) estimated survival of 32 percent during the first year of life (larvae to 45 mm FL), but observed 60 percent survival over the second year (45–55 mm FL). Therefore, an individual's growth rate will affect how long it remains within a given life stage, in turn influencing cumulative survival. These findings suggest that a population model for Moapa dace should include size-dependent growth, fecundity, and survival.

Size of Moapa dace also is correlated with temperature and the size of habitat units (depth, water velocity, and discharge), which may influence growth rates. Scoppettone and others (1992) observed that fish size increased with the range of water depth and volume used by Moapa dace. Size of Moapa dace generally appears to increase along a headwater-to-mainstem gradient. Moving along this gradient, water temperature decreases while water volume increases. It is unclear whether size of Moapa dace is organized along this gradient because of ontogenetic shifts in thermal preferenda or because of better ability to maintain feeding stations in higher velocity environments. We hypothesize that both mechanisms likely co-evolved to the tight linkage between water temperature and water volume in this system. For example, a hypothesis explaining the absence of large individuals in the restricted headwater population is that metabolic requirements at high temperatures reduce growth rates of larger individuals, thereby reducing their maximum attainable size (G. Scoppettone, U.S. Geological Survey, oral commun., 2010). These observations suggest that Moapa dace may require a diversity of channel size and water temperature for full expression of all possible size classes, which, in turn, may influence population growth rates owing to size-dependent fecundity. To incorporate these dynamics in our population model, we allow growth rates to vary among different stream segments that are represented in the model.

Movement behavior of Moapa dace, connectivity of the channel network in the Warm Springs Area, and current (2014) absence of dace from the mainstem Muddy River also are important features to include in the population dynamics model. Historically, the dace population appeared to move extensively throughout the channel network of headwater springs and Muddy River. For example, population counts varied little between 1986 and 1988, but the spatial distribution of the population varied considerably among years (Scoppettone and others, 1992). During these surveys, over one-half of

the population was observed in the mainstem Muddy River in one year, whereas only 16 percent were found in the mainstem in another year, with the balance of the population present each year in the headwater streams. Spawning is hypothesized to occur only in the higher water temperatures of headwater springs compared to the mainstem (Scoppettone and others, 1992), yet larger, more fecund individuals occupied mainstem channels. These findings indicate that high rates of movement throughout the channel network of the Muddy River system likely are an adaptive strategy that allows dace to capitalize on spatial variation in the environment (water temperature, volume, and velocity) in order to persist under such conditions. Thus, connectivity among channels and use of the mainstem Muddy River may be requisite for the long-term persistence of Moapa dace.

In the past, the channel network of the Warm Springs Area has been highly fragmented, with numerous barriers to upstream and downstream movement. Furthermore, Moapa dace have been extirpated from the mainstem Muddy River since the introduction of blue tilapia (Scoppettone and others, 2005). In 2012, however, movement barriers in headwater stream segments have been removed, and, since the occurrence of a large flood event in September 2014, some passage is allowed through the gabion barrier. When evaluating the population response of Moapa dace, we constructed a model that accounts for the spatial structure of the entire channel network that once was inhabited by the Moapa dace. This approach views the whole population (meta-population) as a collection of subpopulations with movement rates among subpopulations dictated by the spatial structure of the channel network.

Factors affecting the amount of available habitat or the ability of Moapa dace to move among habitats ultimately will influence the carrying capacity of the Warm Springs Area to support Moapa dace. These factors include changes in stream discharge, presence of invasive species, movement barriers, and extirpation from the mainstem Muddy River. Population trajectories over the past 30 years provide evidence that Moapa dace populations may have been constrained by carrying capacity and have responded to increases in carrying capacity. For example, snorkel surveys indicate that the population size in the area upstream of the gabion barrier remained relatively constant for more than 20 years (1985–2008), ranging from about 800 to 1,200 individuals. This long period of relative stability suggests that the population may have been at or near the capacity of the available habitat upstream of the gabion barrier. Although the population declined to only 439 observed individuals in 2008 for unknown reasons, the population has since rebounded to 1,727 fish as of August 2013. This increase is presumably owing to habitat restoration of the Pedersen and Apcar streams that likely increased carrying capacity upstream of the gabion barrier.

Density dependent processes, such as intraspecific competition, are weak controls on population growth rate when abundance is much less than carrying capacity, but act to decrease population growth rate as carrying capacity is approached. Therefore, populations tend to increase when abundance is much less than carrying capacity, but remain at a stable equilibrium when abundance is near carrying capacity. We explicitly incorporated density-dependent processes in our model in two ways. First, we used a density-dependent survival model that decreased survival as carrying capacity was approached, but increased survival when population size was much less than carrying capacity. Second, we used a density-dependent movement model based on ideal free distribution theory (Fretwell and Lucas, 1970), where individuals move to stream segments offering high profitability as measured in terms of survival. To estimate the carrying capacity of Warm Springs Area, we calibrated our IBM of Moapa dace by fitting it to the 30-year time series of snorkel counts. Given estimates of carrying capacity obtained through calibration, we then used the model to evaluate alternative scenarios relating to changes in carrying capacity, movement barriers, and access to the mainstem Muddy River.

To evaluate alternative scenarios, we compared equilibrium population sizes, population growth rates, life stage structure (larval, juvenile, and reproductive sized fish), and subpopulation extinction probabilities. Although we evaluated the probability of extinction for different subpopulations, our model predicted a very low probability that the entire population would go extinct because density-dependent mechanisms increased population growth rates at low population size, thereby reducing extinction risk. Although extinction probabilities are an important metric to consider, the minimum observed population abundance of Moapa dace (439 fish) is much greater than the level of abundance at which processes such as demographic stochasticity and allee effects would be expected to affect extinction probabilities. Nonetheless, the Moapa dace population is fragmented by movement barriers, occupies a small fraction of its historical range, and remains much less than recovery goals (6,000 fish; U.S. Fish and Wildlife Service, 1996). Therefore, although extinction of Moapa dace remains a concern, our population model is better suited to understanding how the amount of available habitat affects carrying capacity, and, in turn, population size. Additionally, our model is spatially explicit, incorporating linkages among different stream sections that allow movement barriers to be assessed. These attributes of our model provide fisheries managers with a quantitative tool for understanding how alternative management actions will affect recovery of the Moapa dace population.

Methods

Overview of Model Structure

Key characteristics of Moapa dace biology, the nature of the stream network structure, and relevant management questions dictated the type of population model we used to simulate Moapa dace biology. Based on these characteristics, we constructed an individual-based model (IBM). The key characteristics that required use of an IBM included:

- Growth rates vary among locations in the Warm Springs Area.
- Fecundity depends on size of individuals, which, in turn, depends on growth rate.
- Movement barriers restrict access to some locations.
- Survival is driven by carrying capacity of different stream segments.
- Survival differs among life stages (larvae, non-larvae), linked to growth rate.
- Management scenarios alter movement barriers or change carrying capacity.

An IBM is the ideal framework for incorporating these characteristics because the state of each individual at each time step is tracked throughout its life. In our model, these states include an individual's size, sex, location, and life stage (fig. 1). Demographic processes such as growth, reproduction, and survival then depend on the state of the individual, and the population structure (spatial distribution, size distribution, and abundance) arises as an emergent property of the collection of individuals (fig. 1).

An IBM is a stochastic model, meaning that the outcome of demographic processes arises probabilistically. This allowed us to incorporate effects such as demographic stochasticity, a process that can increase extinction probability at very low population sizes. Because the model is stochastic, there is a different outcome each time the model is run. This allowed us to examine not only the mean abundance through time, but how abundance varies over multiple model runs (referred to as "realizations" of the model).

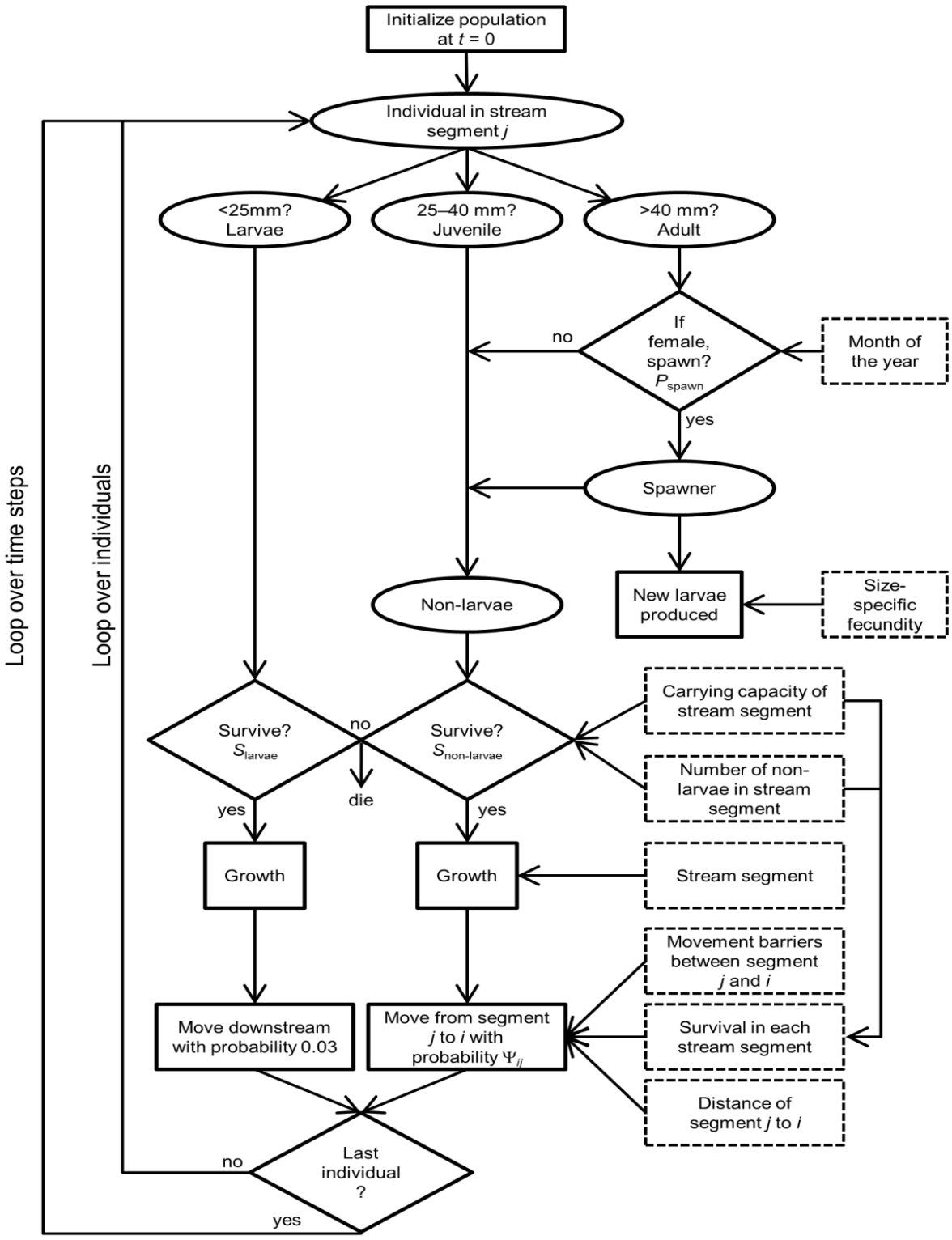

Figure 1. Flowchart of the individual-based population model for Moapa dace. Ovals represent the state of an individual, diamonds indicate a Bernoulli trial or a decision point, solid rectangles are model processes affecting the state of the individual, and dashed rectangles represent factors affecting model processes.

The IBM of Moapa dace is spatially explicit, allowing us to emulate processes such as location-dependent growth rate, movement barriers, and inhabitation of the mainstem Muddy River. We divided the stream network system into eight discrete stream segments based on location of historical movement barriers, confluences of different streams, and distinction between headwater spring segments and non-headwater segments (fig. 2). The seven stream segments upstream of the gabion barrier represent the primary remaining habitat harboring Moapa dace after the invasion by blue tilapia in 1995 until the recent (2014) flood event that damaged the gabion barrier. Segment 8 represents all available habitats downstream of the gabion barrier, which includes the mainstem Muddy River and other tributaries that harbored Moapa dace from 1985 to 1995, the period during which snorkel abundance estimates were available for calibration. Each stream segment had an associated carrying capacity, which was determined by calibrating the model to observed snorkel census data.

To incorporate seasonally varying dynamics, we constructed the model to run at a monthly time step. Thus, all demographic rates (growth, survival, and movement) are monthly rates. The choice of time step was dictated primarily by seasonally varying reproduction. Reproduction occurs year round, but with a clear peak in the spring (Scoppettone and others, 1992). Thus, because spawning was continuous and did not occur at a discrete time of the year, an annual time step could introduce considerable bias in the population dynamics.

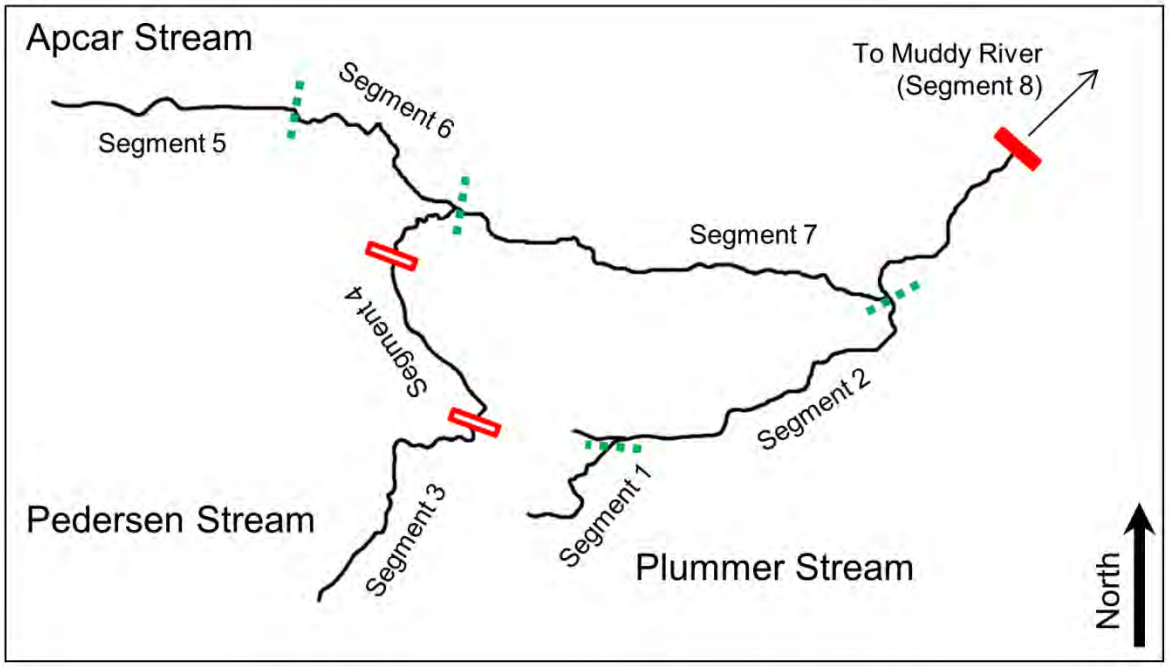

Figure 2. Schematic of tributary streams upstream of the gabion barrier (solid red bar) showing how the tributary streams were divided into seven stream segments in the individual-based model, Muddy River system, southern Nevada. Dotted green lines show where segments without movement barriers were divided. The two open bars indicate segments separated by barriers to upstream movement in Pedersen stream.

At each time step, individuals reproduce, survive, grow, and then move at the end of the time step (fig. 1). This sequence of events is an important component of the underlying structure of the model. Each event in the sequence is driven by an underlying submodel that determines how each demographic process is applied to fish of a given size and life stage in each stream segment. In the sections that follow, we describe in detail each of these sub-models used to simulate demographic processes, the procedures we used to calibrate the model, and given the calibrated model, the alternative scenarios we assessed to understand the potential response of the Moapa dace population to management actions that alter movement barriers or carrying capacity.

Description of Submodels

Reproduction and Larval Survival

Some aspects of Moapa dace reproductive ecology are well-known, but others are poorly understood. For example, a strong relation between fecundity and fish size has been well established (Scoppettone and others, 1992). Additionally, based on larvae counts during snorkel surveys, reproduction is known to occur year round, with distinct seasonal peaks during the spring (Scoppettone and others, 1992). However, less well known aspects of Moapa dace reproductive ecology include:

1. whether individuals spawn once or numerous times throughout the year;
2. fraction of total fecundity spawned during each spawning even;
3. probability of an egg hatching, given it has been laid;
4. monthly survival probability of larval-sized Moapa dace; and
5. how reproduction varies spatially throughout the Muddy River system.

For example, Scoppettone and others (1992) found that eggs skeins within Moapa dace were in different stages of development, indicating that only some fraction of the total fecundity is laid on a given spawning event, but this fraction remains unknown. Furthermore, larvae have been observed only near headwater tributaries (Scoppettone and others, 1992), but it is unclear whether this pattern results from spawning taking place everywhere with unsuccessful reproduction in lower segments, or whether individuals move upstream and spawn only in headwater segments.

To simulate reproduction of Moapa dace, we used historical information and datasets to parameterize the IBM. For example, our model incorporates size-dependent fecundity and seasonal reproduction. However, uncertainties in the reproductive ecology of Moapa dace required making a number of simplifying assumptions. The primary assumptions are (1) Moapa dace spawn once per year, (2) reproduction occurs everywhere, and (3) larval survival is constant across stream segments.

We used an allometric growth model to simulate the number of eggs produced by an individual Moapa dace as a function of length:

$$N_{\text{eggs},i} = \begin{cases} aL_i^b + \varepsilon_i & \text{if individual } i \text{ is female and } L_i \geq 40 \\ 0 & \text{if individual } i \text{ is male or } L_i < 40 \end{cases} \quad (1)$$

where

$N_{\text{eggs},I}$ is the number of eggs produced by the *i*th individual,
L_i is the fork length (mm) of the *i*th individual,
a and *b* are intercept and slope parameters, respectively, and
ε_i is normally distributed error with mean zero and standard deviation σ.

The parameters a=0.0026 (standard error [SE]=0.0015), b=2.783 (SE=0.135), and σ=40.94 (SE=5.67) were estimated from data provided by G. Scoppettone, which appeared in Scoppettone and others (1992). The slope parameter (b) close to 3 indicates that egg production (fecundity) increases nearly linearly with mass (fig. 3). We assumed a sex ratio of 0.5, and individuals were randomly assigned as male or female at birth. We set the minimum reproductive size at 40 mm because Scoppettone and others (1992) determined that eggs were just developing in a 41-mm female.

To simulate an individual's fecundity, first, the mean fecundity was determined as a function of that individual's length at the beginning of the time step. Next, a random variate was drawn from a normal distribution, with a mean of zero and standard deviation of σ=40.94 eggs, and then added to the mean fecundity. Therefore, on a given time step, an individual's fecundity could randomly vary from the mean fecundity by as much as ±82 eggs (i.e., 2 standard deviations about the mean).

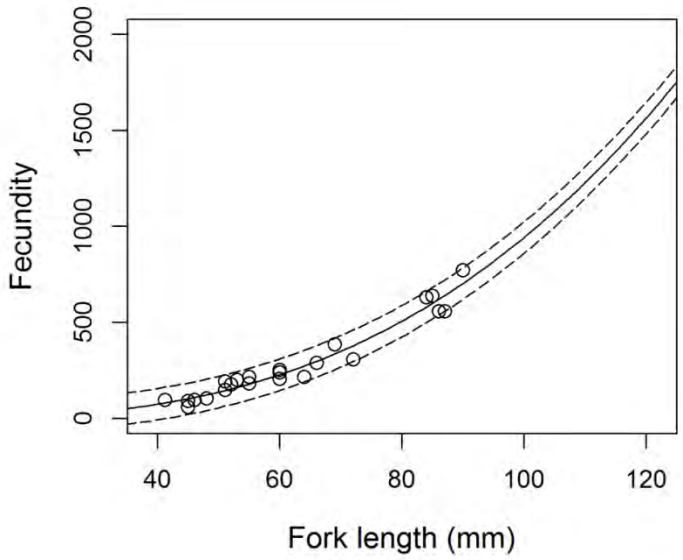

Figure 3. Graph showing relation of fork length (in millimeters [mm]) and fecundity of Moapa dace. Circles represent the observed measurements, solid line shows the predicted mean, and dashed lines show ±2 standard errors.

To simulate seasonally varying spawning, individual fish were randomly assigned a month of spawning at the beginning of each year, with the probability of spawning peaking in the spring. The probability of spawning in a given month was specified by using a truncated normal distribution with a mean spawning date of April 15 and standard deviation of 91.25 days (fig. 4). Females then spawned only if they survived to their randomly drawn month of spawning and only if at least one adult male (≥40 mm FL) was present within the same stream segment.

Given reproduction in a particular month, the number of larvae produced by an individual can be expressed as:

$$N_{\text{larvae},i} = N_{\text{eggs},i}\, p_{\text{laid}}\, p_{\text{hatch}} \tag{2}$$

where

$N_{\text{larvae},i}$ is the number of larvae produced by *i*th adult spawning female,
p_{laid} is the proportion of $N_{\text{eggs},i}$ laid, and
p_{hatch} is the probability of an egg hatching given it has been laid.

We assume that survival of larvae is density independent, and occurs at a constant monthly probability of S_{larvae} until larvae exceed 25 mm, at which point they become juveniles. At each time step, survival of individual larvae is determined by performing a Bernoulli trial with probability S_{larvae}. The probability of surviving from an egg to the juvenile stage is:

$$S_{\text{egg}\rightarrow\text{juvenile},i} = p_{\text{laid}}\, p_{\text{hatch}}\, S_{\text{larvae}}^{t} \tag{3}$$

where

$S_{\text{egg}\rightarrow\text{juvenile},i}$ is the total survival from the *i*th egg in a reproductive female until the time at which a larvae transitions to the juvenile stage *t* months later.

No information exists about the parameters p_{laid}, p_{hatch}, and S_{larvae}. Thus, we fixed p_{laid} and p_{hatch} to 1 and estimated S_{larvae} by calibration (see section, “Model Calibration,” for details). Using this approach, S_{larvae} in our model represents the monthly survival probability that accounts for the probability that an egg in a reproductive female is laid and hatched, and survives to the juvenile stage.

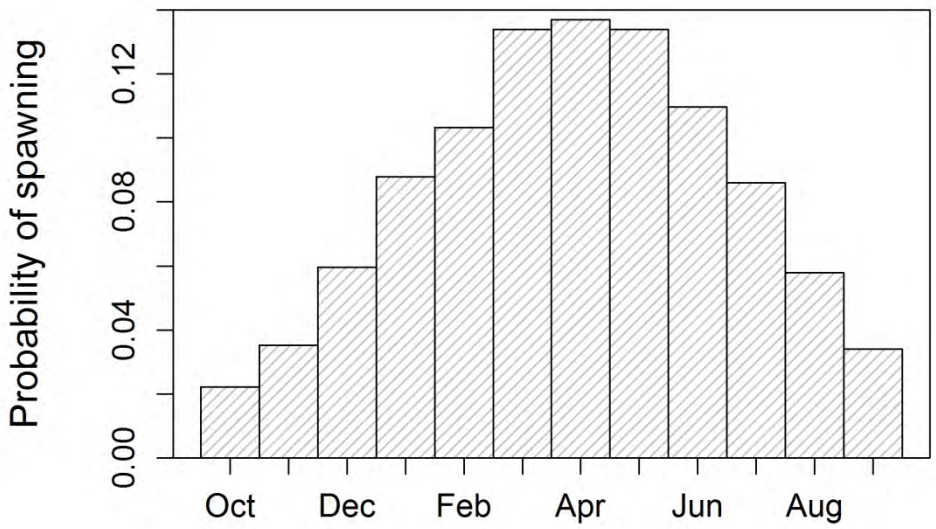

Figure 4. Graph showing monthly probability of spawning, used to simulate seasonally varying reproduction of Moapa dace.

Survival of Non-Larval Moapa Dace

Our individual-based model considers three key processes that influence survival: (1) demographic stochasticity, (2) process error, and (3) density dependence. Demographic stochasticity is the random chance that an individual lives or dies with given probability of survival. Demographic stochasticity is an important mechanism affecting extinction risk when populations are at very low levels. Process error is defined as temporal and spatial variation in the probability of surviving that is caused by fluctuations in the environment. Process error can increase risk of extinction when chance events cause simultaneous decreases in survival over space or when survival remains low over consecutive time periods. Last, competition among individuals for space or food can reduce survival as populations increase and approach the capacity of their environment. At low population levels, density-dependent factors can reduce extinction risk because survival increases in response to reduced competition for resources.

A key challenge in parameterizing a population model is estimating survival rates, particularly for small fish such as Moapa dace. For example, Hereford (2014a) found that bimonthly survival of Moapa dace ranged from about 0.70 to 0.96, and survival varied considerably among stream reaches, seasons, and years.

We used a multi-stage stock and recruitment model of Moussalli and Hilborn (1986) based on the Beverton and Holt (1957) model. For Moapa dace, this density-dependent model takes the form

$$N_{i,j,t+1} = \frac{N_{i,j,t}}{\frac{1}{S_{0,i,j,t\to t+1}} + \frac{N_{i,j,t}}{c_{i,j}}} \tag{4}$$

where

$N_{i,j,t}$ is the number of individuals in life stage *i* and stream segment *j* at time *t*,

$N_{i,j,t+1}$ is the number in stage *i* and segment *j* at time *t*+1,

$c_{i,j}$ is the carrying capacity of life stage *i* in segment *j*,

$S_{0,i,j,t\to t+1}$ is the density-independent survival from *t* to *t*+1 for life stage *i* in stream segment *j* that is approached as $N_{i,j,t}$ approaches zero.

The parameter $S_{0,i,j,t\to t+1}$ also is known as the productivity parameter (Moussalli and Hilborn, 1986).

For the Moapa dace IBM, we express this model in terms of survival from one time step to the next:

$$S_{i,j,t\to t+1} = \frac{N_{i,j,t+1}}{N_{i,j,t}} = \frac{1}{\frac{1}{S_{0,i,j,t\to t+1}} + \frac{N_{i,j,t}}{c_{i,j}}} \tag{5}$$

where $S_{i,j,t\to t+1}$ is the probability of surviving from *t* to *t*+1 for life stage *i* in stream segment *j*.

For this multistage model of density-dependent survival, carrying capacity has a temporal component such that it represents the number of individuals that can be supported by habitat over one time step of the model (1 month). For this reason, $c_{i,j}$ may be much higher than the equilibrium population size. Therefore, it is more natural to think of the cumulative capacity, $C_{i,j}$, which is the number of individuals that can be supported over some specified number of time steps, *n* (Moussalli and Hilborn, 1986):

$$C_{i,j} = \frac{\prod_{t=1}^{n} S_{0,i,j,t\to t+1}}{\sum_{t=1}^{n} \frac{S_{0,i,j,t\to t+1}}{c_{i,j}}} \tag{6}$$

For example, for density-independent survival of $S_{0,i,j,t\to t+1}$=0.98 per month and carrying capacity of $c_{i,j}$ =10,000, the cumulative capacity after 1 year is 744 individuals (fig. 5). This example illustrates how carrying capacity as estimated in our analysis will be much higher than the long-term population size at equilibrium. Furthermore, it illustrates how changes in carrying capacity might affect equilibrium population size in nonlinear and disproportionate ways.

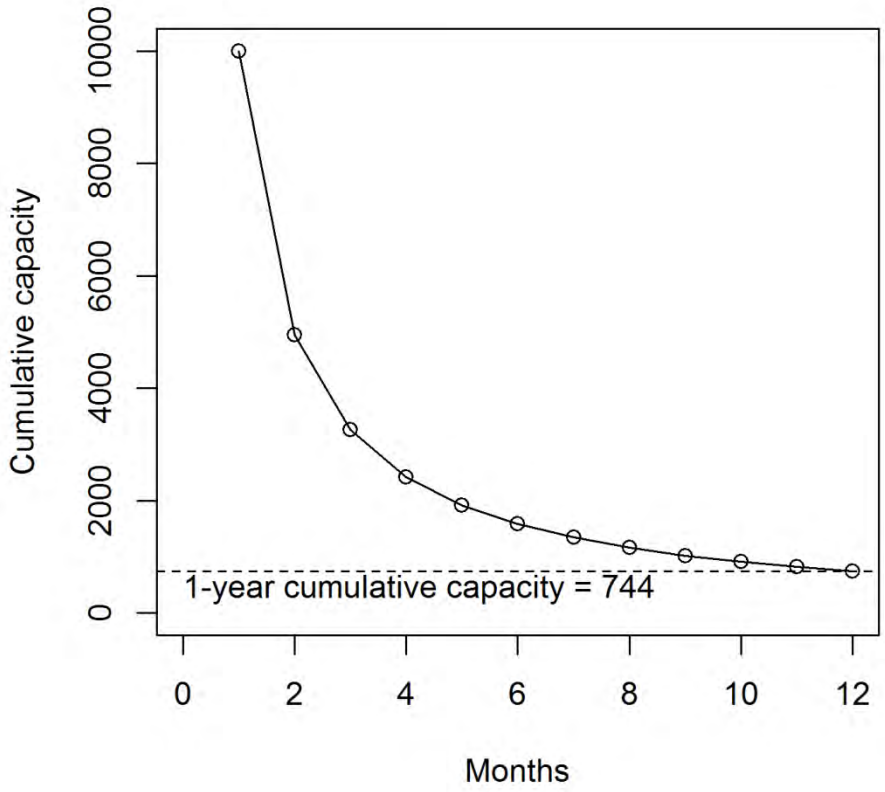

Figure 5. Graph showing cumulative capacity for a population with density-independent survival of 0.98 per month and a carrying capacity of 10,000 individuals per month.

We modeled survival separately for two life stages, *i*=larvae, or *i*=non-larval fish (subadults and adults). We assumed that survival of larvae was density independent such that $c_{i,j} = \infty$ and $S_{i,j,t \to t+1} = S_{0,i,j,t \to t+1}$. Larval survival and other reproductive parameters are unknown, and, therefore, were estimated through calibration (see sections, "Reproduction and Larval Survival" and "Model Calibration," for details). For non-larval fish, each discrete stream segment in the model was assigned a carrying capacity, which then allowed survival to vary among stream segments depending on segment-specific abundance and capacity. To determine the capacity of each segment, we first used calibration to estimate the carrying capacity of the mainstem Muddy River (stream segment 8) and the total capacity of all stream segments upstream of the gabion barrier (stream segments 1–7). Given an estimate of the total capacity upstream of the gabion barrier, we then used information about relative habitat quality and the length of each stream segment to determine the proportion of the total capacity assigned to each stream segment (table 1). Relative habitat quality was estimated by fitting an N-mixture model (Royle, 2004) to minnow trap catches to relate abundance of Moapa dace in each stream segment to habitat variables such as water depth, velocity, and substrate composition (R.W. Perry, U.S. Geological Survey, unpub. data, 2012). On average, site-specific estimates of habitat quality in stream segment 7 were lower than in other segments, but the greater size of this segment contributed to its overall larger capacity.

Table 1. Proportion of total carrying capacity upstream of the gabion barrier assigned to each stream segment.

	Stream segment						
	1	2	3	4	5	6	7
Proportion of capacity	0.069	0.190	0.105	0.117	0.062	0.151	0.306

Process error in monthly survival probability was estimated using data from a genetic mark-recapture study conducted on Moapa dace. Hereford (2014a) showed that Moapa dace survival varied among seasons, stream segments, and years. Our goal was to quantify this variation in terms of a mean monthly survival and standard deviation in monthly survival (i.e., the process error). We obtained capture histories of genetically tagged Moapa dace from Hereford (2014a), and used Program Mark (White and Burnham, 1999) to estimate the process error. A Cormack-Jolly-Seber survival model was fit to the capture histories representing 18 consecutive bimonthly sampling occasions in the seven distinct stream segments, and process error was estimated from a variance-components analysis of the fitted model following methods of Burnham and White (2002). We estimated that the process error owing to temporal and spatial variation in survival was 0.0399 per month (95-percent confidence interval=0.0349–0.0466).

Given estimated carrying capacity and process error, survival for each individual was simulated as follows. First, the mean survival probability for a given time step was determined based on segment-specific abundance using equation 5. Next, a normal random deviate with mean zero and standard deviation equal to the estimated process error was drawn, and then added to the mean survival probability. Thus, with process error=0.0399, mean monthly survival had a 95-percent probability of varying by ±6 percentage points each month. Last, given the monthly survival probability with process error, we then performed a Bernoulli trial to determine if the individual survived from one time step to the next.

Growth of Moapa Dace

Growth is an important aspect of Moapa dace population dynamics because fecundity is size specific. The size of individuals will influence their reproductive capacity, which, in turn, can affect population growth rates. Additionally, Scoppettone and others (1992) observed an increasing gradient in fish size from headwater springs to the mainstem Muddy River; the smallest fish were observed near headwater springs and the largest fish were observed in the mainstem. Since the population has been extirpated from the mainstem, large-sized, highly fecund fish were rare in the population restricted upstream of the gabion barrier.

To simulate growth of Moapa dace and to emulate the spatial dynamics, we used a von Bertalanffy growth model (Francis, 1988) that allowed for life stage- and location-specific growth rates. Furthermore, we assumed that individuals grow deterministically but that variation in growth rate arises from variation in growth parameters among individuals. We used a version of the von Bertalanffy growth model that describes growth rate as the change in length from one time step to the next:

$$L_{t+1} = L_t + \Delta L \tag{7}$$

$$\Delta L = \left(L_\infty - L_t\right)\left(1 - e^{-k}\right) \tag{8}$$

where

L_t and L_{t+1}	is the fork length at time t and t+1,
ΔL	is the change in fork length (mm) over one time step,
L_∞	is the asymptotic theoretical maximum fork length (mm), and
k	is a constant that determines how quickly length approaches L_∞.

The parameters L_∞ and k uniquely determine the growth trajectory, given length at time t (L_t). To drive individual growth trajectories, we assumed that these parameters were drawn from normal distributions for each individual:

$$L_\infty \sim \text{Normal}\left(\mu_{L_\infty}, \sigma_{L_\infty}\right) \tag{9}$$

$$k \sim \text{Normal}\left(\mu_k, \sigma_k\right) \tag{10}$$

where

μ_{L_∞} and μ_k	are the mean L_∞ and mean k, respectively, and
σ_{L_∞} and σ_k	are the standard deviation of L_∞ and k.

We developed four growth models that allowed individuals to grow at different rates, depending on their life stage (larvae or juveniles/adults) and their location in the Muddy River system (headwater springs, non-headwater springs, and the mainstem Muddy River). Where possible, existing data were analyzed to estimate μ_{L_∞} and μ_k. For larvae, we estimated μ_{L_∞} and μ_k from a study conducted in 1984 (Scoppettone and Burge, 1994), where 140 larval dace were transported to an isolated segment of upper Plummer Spring, and then their fork lengths were measured every 3 months for 3 years (table 2, appendix A). Growth of non-larval fish in this study might have been constrained by warm water temperatures or low dissolved oxygen concentrations in the upper Plummer Spring (Scoppettone and Burge, 1994). Therefore, we also analyzed size data obtained by Hereford (2014b), where juvenile and adult individuals were trapped with minnow traps over a 3-year period in all stream segments upstream of the gabion barrier. From this study, we analyzed 1,359 growth observations from 615 unique individuals ranging in size from 23 to 86 mm (Hereford, 2014b). We found evidence for lower growth rates (i.e., lower k) of juveniles and adults in headwater stream segments relative to downstream areas, which supports past observations of spatial differences in size distributions of Moapa dace (table 2, fig. 6, and appendix A).

Although our analyses provided estimates of total variation in observed size of Moapa dace, we did not measure variation in growth parameters among individuals because individuals either were not tracked (Scoppettone and Burge, 1994) or because recaptures of individuals were too sparse to estimate individual-specific parameters of the von Bertalanffy model (Hereford, 2014b). Therefore, to determine σ_{L_∞} and σ_k, we varied these parameters to match the observed variation in size of Moapa dace. We then set these parameters as constant across the four growth models (table 2, fig. 6).

Last, none of the growth models could reproduce the historically observed size distribution of fish in the Muddy River, where Moapa dace averaged 80 mm. Therefore, we hypothesized growth parameters for fish inhabiting the mainstem Muddy River that allowed them to obtain historically observed sizes (table 2, fig. 6).

Table 2. Life stage and segment-specific growth parameters used to simulate individual growth trajectories of Moapa dace.

Life stage	Segment description	Stream segment	μ_L	σ_L	μ_k	σ_k
Larvae (<25 mm)	All	1–8	56.9	5	0.120	0.015
Juveniles and adults	Headwater stream segments	1, 3, 5	67.6	5	0.046	0.015
Juveniles and adults	Non-headwater stream segments	2, 4, 6, 7	67.6	5	0.064	0.015
Juveniles and adults	Mainstem	8	105.0	5	0.050	0.015

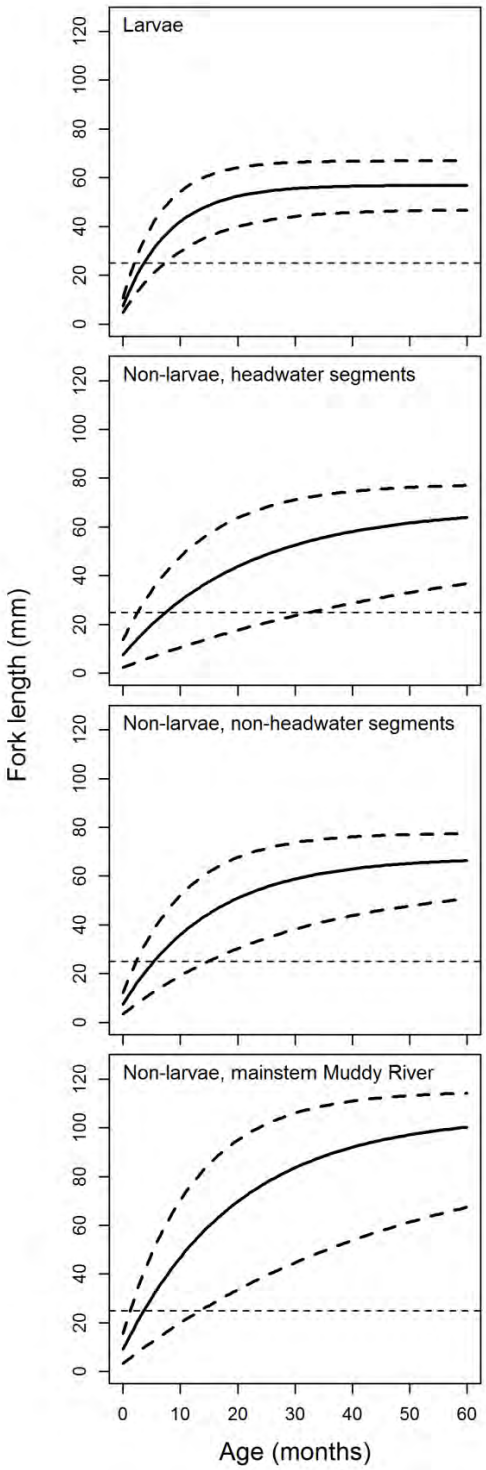

Figure 6. Graphs showing growth models of Moapa dace used to simulate individual growth trajectories. The solid line shows the von Bertalanffy model plotted at the mean value of the asymptotic theoretical maximum fork length (L_∞) and a constant that determines how quickly length approaches L_∞ (k), and thick dashed lines show the growth trajectory for the mean parameter values ± 2 standard deviations. The light dashed reference line at 25-millimeter (mm) marks the size at which individuals switch from larval to non-larval growth.

To simulate growth of an individual, a random deviate was drawn at birth for each growth parameter (L_∞ and k) from a normal distribution with mean zero and standard deviation of σ_{L_∞} and σ_k. This deviation measured the amount by which an individual's growth parameters were greater than or less than the mean for all life stages and locations. This approach allowed individuals to remain "fast growers" or "slow growers" as they switched from one growth curve to another, depending on life stage and location. The model for growth rate described in equation 7 requires an initial size at age 0, which we obtained from the age-specific von Bertalannfy model fit to size-at-age data from Scoppettone and Burge (1994; table A1, appendix A). Given size at age 0 and an individual's growth parameters, larvae in all locations grew following the same distribution of parameters. When an individual exceeded 25 mm and transitioned from larvae to juvenile, growth during a given time step then followed one of the three location-dependent growth curves (fig. 7). A juvenile or adult individual's growth rates thus depended on where they were located and changed as they moved among stream segments over time, with the constraint that growth was zero for any fish that exceeded L_∞ of a given stream segment.

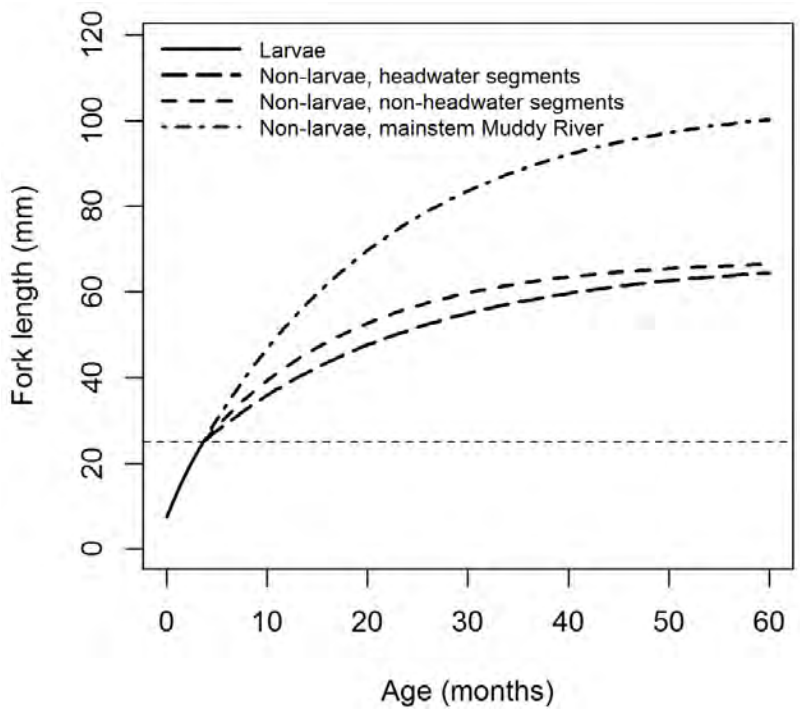

Figure 7. Graph showing example growth trajectory following the mean growth parameters for larval Moapa dace (less than 25 millimeters [mm]), and then changing to the mean growth trajectory of juveniles and adults for headwater stream segments, non-headwater segments, and the mainstem Muddy River.

Movement among Stream Segments

To simulate movement of non-larval fish (>25 mm FL) based on ecological theory, we used a fitness-based movement model based on the ideal free distribution. The ideal free distribution is a theory that assumes animals distribute among habitat patches proportionally to available resources (Fretwell and Lucas, 1970). Under this theory, animals are assumed to have knowledge of resources available in all patches, and redistribution among habitat patches will occur until the "payoff," as measured by resource intake rate, is equalized among all habitats. To implement a mechanistic model of movement, we modified the framework of Cressman and Křivan (2006), where animals currently in patch *j* move to patch *i* with probability Ψ_{ij}:

$$\Psi_{ij} = \begin{cases} \mu p_i \left(V_i - V_j\right) & \text{if } V_i > V_j,\ i \neq j \\ 0 & \text{if } V_i < V_j,\ i \neq j \\ 1 - \mu \sum_{V_i < V_\ell} p_\ell \left(V_\ell - V_i\right) & \text{if } i = j \end{cases} \tag{11}$$

where

p_i is the proportion of the population in patch *i* (i.e., stream segment),
V_i and V_j are the payoffs in patch *i* and *j*, and
μ is a parameter that scales the movement probability.

The first term above expresses the probability of moving from patch *j* to patch *i* as a function of difference in payoff between patches and the proportion of the population in patch *i*. The second term indicates that the probability of moving to patch *i* is zero if the payoff in patch *i* is less than the payoff in the currently inhabited patch, *j*. Because movement probabilities from patch *j* must sum to one, the last term expresses the probability of remaining in the currently occupied patch, *j*, as one minus the probability of moving out of patch *j* (i.e., the sum of the probabilities of moving to all other patches).

We used the density-dependent survival function (eqn. 5) as the measure of the payoff received in each stream segment. Using this approach, the probability of moving from stream segments *j* to *i* increases proportionally to the difference between S_i and S_j when survival in segment *i* is greater than the currently occupied segment, *j*. By using density-dependent survival as the payoff in the movement model, dace will have a higher probability of moving to segments where abundance is much less than carrying capacity, and conversely, will have a higher probability of leaving stream segments where abundance is close to carrying capacity, relative to other stream segments. These types of movement dynamics have been observed with Moapa dace (Hereford, 2014b).

We modified the model of Cressman and Křivan (2006) to better reflect likely movement behavior of Moapa dace. First, the model assumes that the difference in payoff among patches is independent of distance among patches. However, Moapa dace are more likely to move to nearby stream segments relative to distant stream segments over monthly timescales (Hereford, 2014b). Second, under this model, movement among patches continues until the payoff is equalized among all patches, at which point there is zero probability of moving. For Moapa dace, we expect there to be some low level of random movement among stream segments even when the payoff among segments is constant. To account for these factors, we first modified the model to discount the payoff as a function of distance between stream segments:

$$\Psi_{ij}^{*} = \begin{cases} \mu p_i \left(S_i^{d_{ij}} - S_j \right) & \text{if } S_i^{d_{ij}} > S_j,\ i \neq j \\ 0 & \text{if } S_i^{d_{ij}} < S_j,\ i \neq j \\ 1 - \mu \sum_{S_i < S_\ell} p_\ell \left(S_\ell^{d_{\ell j}} - S_i \right) & \text{if } i = j \end{cases} \tag{12}$$

where

Ψ_{ij}^{*} is the movement probability before allowing for random movement,
S_i and S_j are the probabilities of surviving in segment i and j, and
d_{ij} is the distance between stream segments measured in units of number of segments.

For adjacent segments, $d_{ij} = 1$, and the payoff is simply a function of the difference in survival between adjacent segments. For locations that are two or more stream segments away from the currently occupied segment ($d_{ij} \geq 2$), the cost of moving greater distance is accounted for by raising the survival probability to d_{ij}. For example, to have a higher probability of moving two segments away compared to an adjacent segment, the square of survival in the distant segment must be greater than survival in the adjacent segment. Thus, with equal survival among segments, dace will have a higher probability of moving to nearby segments, and only when survival in non-adjacent segments is considerably greater will they have a higher probability of moving.

Cressman and Křivan (2006) provide a modification to their model to allow for random movement unrelated to the difference in payoff among patches, which we modified to allow for a higher probability of random movement to adjacent segments relative to distant segments:

$$\Psi_{ij} = \frac{\varepsilon}{d_{ij}} + \left(1 - \sum_i \frac{\varepsilon}{d_{ij}} \right) \Psi_{ij}^{*} \tag{13}$$

where

ε is the probability of moving to an adjacent segment.

Here, when survival is equal among segments, $\Psi_{ij}^{*} = 0$, the probability of moving to an adjacent segment is ε, the probability of moving two segments away is $\varepsilon/2$, and the probability of moving three segments away is $\varepsilon/3$. Conversely, when $\Psi_{ij}^{*} \neq 0$, the probability of moving from segment j to segment i is a weighted average of the random movement probabilities with weights equal to $1/d_{ij}$.

To parameterize the model, we set μ=0.5 and ε=0.01, which resulted in a 1–3 percent probability of moving out of a given segment when survival was equal among stream segments. This level of movement approximates the movement probabilities observed based on genetic mark-recapture studies (Hereford, 2014b), although Hereford (2014b) examined movement distance over a bimonthly timescale rather than movement probabilities on a monthly timescale as implemented in our model. Barriers were represented in the model by setting the upstream and downstream movement probabilities to zero between segments separated by permanent barriers (for example, the gabion barrier). For the two barriers to upstream movements in the Pedersen system, upstream movement probabilities were set zero, but fish were allowed to move downstream of the upper and middle Pedersen segments (segments 3 and 4) according to the fitness-based movement model. However, during initial calibration of the model, we noted that populations in these segments always went extinct over the time horizon during which the population in these segments was known to persist. These findings indicated that simulated movement out of these reaches was higher than occurred in reality, suggesting that the upstream barriers in the Pedersen system also were likely impediments to downstream movement, an observation also supported by the findings of Hereford (2014b). Although genetic analysis identified the upper Pedersen population as genetically distinct, Hereford (2014a) also found evidence that individuals from upper Pedersen contributed to populations downstream of upper Pedersen, indicating that some downstream movement does occur. To reflect these patterns of movement, we reduced the random movement probability from upper and middle Pedersen by treating them as if they were separated by an additional stream segment. For example, for segments adjacent to upper and middle Pedersen, d_{ij} was increased from 1 to 2, and likewise for more distant segments.

Movement dynamics of larval Moapa dace (<25 mm FL) are completely unknown. Therefore, we used a simple movement model that assumed a low level of downstream dispersal but no upstream dispersal. We assigned an emigration probability of 3 percent per month from each stream segment and assumed that larvae could disperse by as much as two stream segments downstream per month. For stream segments that had only a single downstream segment, individuals had a 3-percent probability of moving to the downstream segment. For stream segments with two or more downstream segments, we assumed a 2-percent probability of moving to the adjacent downstream segment, and a 1-percent probability of dispersing downstream by two segments.

To implement this movement model in the stochastic IBM, we randomly drew the segment to which a fish moved by treating the stream segments as drawn from a multinomial distribution, with the probabilities of movement to each segment from a given segment forming the multinomial cell probabilities.

Model Calibration

Our IBM was constructed from a combination of empirically derived parameter estimates (for example, growth and survival), ecologically based theoretical models (for example, fitness-based movement), and assumed demographic parameters for life stages in which little is known (for example, reproduction and larval survival). Therefore, the goal of model calibration was to identify parameter values for the most uncertain model parameters that produced population trajectories consistent with the observed historical abundance of Moapa dace. The most uncertain model parameters driving population dynamics in our model were (1) the total carrying capacity of stream segments upstream of the gabion barrier (segments 1–7), (2) the carrying capacity of the mainstem Muddy River and associated tributaries downstream of the gabion barrier (segment 8), and (3) survival of larvae from an egg in a reproductive female to the point at which larvae transition to juveniles at 25 mm FL.

To calibrate the model, we varied carrying capacity and larval survival, ran the model for a 30-year period, and then evaluated the goodness of fit of simulated population sizes relative to the historical time series of population estimates based on annual and bi-annual snorkel censuses extending back to 1985. The snorkel surveys primarily count juvenile and adult dace. We eliminated larval counts where larvae were noted in the snorkel survey data owing to likely low detection probabilities of larvae. We then compared simulated non-larval abundance to the snorkel census data. Therefore, all population trajectories presented in this report exclude larvae and represent only abundance of juvenile and adult Moapa dace.

As our measure of goodness of fit to observed data, we used a negative log-likelihood function that assumed a multiplicative lognormal distribution of errors between observed and simulated abundance. First, we assumed the following model for the observed population size:

$$N_{\text{obs},t} = N_{\text{sim},t} \exp\left(\varepsilon_t\right), \qquad (14)$$
$$\ln\left(N_{\text{obs},t}\right) = \ln\left(N_{\text{sim},t}\right) + \varepsilon_y$$

where

$N_{\text{obs},t}$ is the observed number of non-larval Moapa dace at time *t* from the snorkel census,

$N_{\text{sim},t}$ is the simulated number of non-larval dace at time *t*, and

$\varepsilon_t \sim \text{Normal}\left(0, \sigma^2\right)$ is an additive error term on the logarithmic scale.

The negative log-likelihood for this model is:

$$-\ln L\left(\theta \mid N_{\text{obs},t}\right) = -\sum_t \ln\left[\frac{1}{\sigma\sqrt{2\pi}} \exp\left(-\frac{\left[\ln\left(N_{\text{obs},t}\right) - \ln\left(N_{\text{sim},t}\right)\right]^2}{2\sigma^2}\right)\right] \qquad (15)$$

where

$-\ln L\left(\theta \mid N_{\text{obs},t}\right)$ is the negative log-likelihood of the parameters (θ) given the observed data ($N_{\text{obs},t}$).

The residual standard deviation, σ, can be estimated analytically using:

$$\hat{\sigma} = \sqrt{\frac{1}{n}\sum_{y=1}^{n}\left[\ln\left(N_{\text{obs},t}\right) - \ln\left(N_{\text{sim},t}\right)\right]^2}\,. \qquad (16)$$

Because the IBM is a stochastic model that produces a different population trajectory on each run, we used the method of simulated maximum likelihood, which estimates the expected value of the likelihood over an ensemble of stochastic model runs (Gouriéroux and Monfort, 1997). In this case, the likelihood function (eqn. 15) is replaced with:

$$-\ln \hat{L}\left(\theta \mid N_{\text{obs},t}\right) = -\sum_{t} \ln \left[\frac{1}{S} \sum_{s=1}^{S} \left[\frac{1}{\sigma_s \sqrt{2\pi}} \exp\left(-\frac{\left[\ln\left(N_{\text{obs},t}\right) - \ln\left(N_{\text{sim},t,s}\right)\right]^2}{2\sigma_s^2} \right) \right] \right] \quad (17)$$

where

s = 1, …, S stochastic realizations of the IBM, and

$\hat{L}$ denotes that this function estimates the expected value of the likelihood function over S stochastic realizations.

We set S=100, meaning that we ran 100 stochastic realizations of the IBM for each set of parameter values, and calculated $-\ln \hat{L}\left(\theta \mid N_{\text{obs},t}\right)$ based on these 100 realizations.

We used the likelihood function described in equation 17 to evaluate the relative goodness of fit to observed data for alternative combinations of parameter values. Lower values of the negative log-likelihood function indicate parameter values that result in a better fit of the simulated population trajectories to observed data. Because all alternative parameter sets involved varying the same number of parameters, twice the negative log likelihood (hereafter referred to as "NLL") is equivalent to model selection criterion known as Akaike's Information Criterion (AIC; Burnham and Anderson, 2002). A difference of AIC ≤ 2 among models indicates competing models that fit the data equally well. Therefore, we interpreted differences of ≤ 1 NLL as parameter sets that fit the observed data equally well. Our goal then was to select sets of parameter values that were within one unit of the minimum NLL.

We performed model calibration in two stages. In the first stage, the goal was to estimate larval survival and the total carrying capacity of all stream segments upstream of the gabion barrier (segments 1–7). Therefore, we first fit the model to the time series of abundance estimates after the gabion had been installed by 1997 when movement of fish between the mainstem and tributaries upstream of the gabion was eliminated. Although the population upstream of the gabion barrier represented nearly the entire Moapa dace population, residual counts of dace downstream of the gabion barrier were subtracted so that the model was fit to the population size upstream of the gabion barrier. We selected three values of monthly larval survival (S_{larvae} = {0.25, 0.30, 0.35}). For each value of S_{larvae}, we ran the model over a range of total carrying capacity for all stream segments upstream of the gabion barrier. Total carrying capacity ranged from 4,200 to 11,000, a range that was wide enough to encompass the minimum NLL for each value of S_{larvae}. Because the probability of an egg being laid (p_{laid}) and hatched (p_{hatched}) was unknown, these parameters were set to 1. Therefore, S_{larvae} represents the average monthly probability that an egg in a reproductive female is laid, hatched, and survives to the juvenile stage, at which point it becomes available to be counted in the snorkel survey data to which the model is fit (see eqn. 3). We then selected a value of S_{larvae} and carrying capacity among all parameter sets that were within 1 unit of the minimum NLL.

For the second stage of calibration, the goal was to estimate the carrying capacity of the mainstem Muddy River and tributaries downstream of the gabion barrier (segment 8). Thus, we fit the model to the observed snorkel counts from 1985to 1995, the period before tilapia were introduced when Moapa dace inhabited the mainstem and moved freely between the mainstem and segments 1–7 upstream of the gabion barrier. For this calibration, we fixed S_{larvae} and carrying capacity upstream of the gabion barrier to the best-fit value from the first stage of calibration, and then estimated carrying capacity downstream of the gabion barrier (segment 8) by fitting the model to the total population abundance both upstream and downstream of the gabion barrier. We fit the model to the total population abundance rather than just abundance in segment 8 because presence of larger fish and movement of fish between the mainstem and tributaries could influence the total population size upstream and downstream of the gabion despite no change in capacity for segments 1–7. Therefore, fitting only to abundance estimates downstream of the gabion barrier may have underestimated its capacity. Carrying capacity of segment 8 ranged from 9,000 to 16,000. We then selected the carrying capacity for segment 8, which minimized the NLL of total population abundance. These values of S_{larvae} and total carrying capacity upstream and downstream of the gabion barrier were then used in all model runs to evaluate alternative scenarios.

Calibration also required that the population model attain a stable equilibrium before comparing simulated to observed data. To minimize the time required to reach equilibrium, we used an initial population of individuals that was sufficiently close to the equilibrium population structure. This initial population structure at time zero was obtained by (1) selecting parameter values that approximately matched observed population sizes, (2) running the model for 18 years to allow the population to attain equilibrium, and then (3) using the simulated population of individuals at year 18 as the initial population for all parameter sets in the calibration. We determined that a “burn in” of 5 years allowed population trajectories to reach equilibrium under a wide range of parameter values. Thus, simulated population trajectories were compared to observed abundances, beginning in year 6, after allowing population trajectories to reach equilibrium.

Alternative Scenarios

We ran a number of scenarios relating to migration barriers and changes to carrying capacity. For each scenario, we ran 100 stochastic realizations of the calibrated IBM over a 50-year time horizon. Initial populations for these scenarios were developed by running 100 realizations of the calibrated model, either with or without the gabion barrier in place, for a sufficiently long time horizon to attain an equilibrium population size, spatial distribution, and life stage structure. The population of individuals at the end of this time series was then used to form the initial populations for the 100 stochastic realizations for each scenario. Depending on the scenario, initial population size ranged from 10 to 500 non-larval individuals. Here, a specified number of non-larval individuals was randomly drawn from each of the 100 initial populations. Larval Moapa dace also were randomly drawn from the initial populations in proportion to the ratio of abundance of larval to non-larval dace. On average, there was a 7-to-1 ratio of larval to non-larval dace. Although we focus our analysis and calibration on non-larval abundance, an initial population size of 10 dace, for instance, indicates that 10 non-larval dace and 70 larval dace, on average, were drawn at random from each of the 100 initial populations.

Migration Barriers

Use of migration barriers has been an important management tool in the Warm Springs Area to manage the spread of invasive species, yet migration barriers also may negatively affect metapopulation dynamics of Moapa dace by restricting dispersal. Over the past 20 years, the primary migration barriers were the gabion barrier in the lower Plummer stream and two weirs that prevent upstream movement into Pedersen stream. The gabion barrier separates segments 7 and 8 (fig. 2) and eliminates upstream and downstream movement. The weirs on Pedersen stream separate segments 3 from 4 and 4 from 6, and are complete barriers to upstream movement and partial barriers to downstream movement (Hereford, 2014b; fig. 2). We evaluated the effect of four alternative migration barrier scenarios to understand how migration barriers influence population dynamics. These scenarios were comprised of:

A. Baseline—all barriers in place as the stream network system has been historically configured.
B. Gabion in, Pedersen weirs out—complete removal of Pedersen weirs allowing both upstream and downstream dispersal.
C. Gabion out, Pedersen weirs in—complete removal of gabion barrier allowing both upstream and downstream dispersal.
D. Gabion out, Pedersen weirs out—removal of all barriers to movement

Carrying Capacity

Many management actions and human influences affect carrying capacity. Habitat restoration increases capacity, whereas changes in spring discharge affect carrying capacity by altering the amount of suitable habitat for Moapa dace (Hatten and others, 2013). Because carrying capacity in our model has a temporal component representing monthly capacity (fig. 5), the population size that can be supported over the long term (i.e., the equilibrium population size) may not be directly proportional to carrying capacity. Furthermore, equilibrium population size will be a complex function of not only segment-specific capacity, but also of stream network structure, movement, growth, and survival.

To understand how changes in carrying capacity affect equilibrium population sizes, we ran a series of scenarios that both increased and decreased carrying capacity. These scenarios followed the approach of Hatten and others (2013), who simulated the amount of suitable habitat resulting from changes in discharge of -30 to +30 percent in headwater springs (segments 1, 3, and 5 in our model). Similarly, our approach was to vary the total carrying capacity upstream of the gabion barrier from -30 to +30 percent in increments of 10 percentage points. Changes in carrying capacity were performed under the baseline scenario, with the gabion barrier and Pedersen weirs in place and no Moapa dace in the mainstem Muddy River (segment 8). Our goal here was to understand how changes in carrying capacity from the historical state of the system could affect, either positively or negatively, the magnitude of the equilibrium population size that the system could support.

Results

Calibration and Model Behavior

The first stage of our model calibration exercise was informative about combinations of larval survival and carrying capacity upstream of the gabion barrier that best fit observed abundances of Moapa dace. For each value of larval survival, the negative log likelihood (NLL) followed a parabolic function of carrying capacity, with a clear range of values that were within 1 NLL of the minimum value (fig. 8). For example, for larval survival of 0.35, a carrying capacity of about 6,000 minimized the NLL, but values of capacity ranging from about 5,500 to 7,000 were within 1 NLL of the minimum value, indicating that a wide range of carrying capacity fit the observed data nearly as well. We also determined that, as larval survival decreased, a higher carrying capacity was required to obtain a similar fit to the data. For example, for monthly larval survivals of 0.25, 0.30, and 0.35, carrying capacities that were near the minimum NLL were 9,000, 7,200, and 6,000, respectively (fig. 8). Among the three values of larval survival, there was no clear global minimum. This finding indicates that larval survival was confounded with carrying capacity because alternative combinations of larval survival and carrying capacity fit the data nearly equally well. For this reason, we selected a larval survival of 0.30 at a carrying capacity of 7,200 upstream of the gabion barrier for the second stage of calibration and for simulation of all alternative scenarios.

For the second stage of calibration where we estimated capacity of the mainstem Muddy River and tributaries downstream of the gabion barrier (segment 8), we observed the minimum NLL at a carrying capacity of 13,800 (fig. 8). However, because we fit the model to only four abundance estimates that were available prior invasion of blue tilapia, there was more uncertainty in the best fit capacity, as indicated by the wide range of carrying capacities that were within 1 NLL of the minimum. Thus, carrying capacities from 11,500 to 15,500 also were plausible values. Given the selected values of larval survival (0.30) and carrying capacity (7,200 upstream of the gabion barrier and 13,800 downstream of the gabion barrier), our calibration indicated that the capacity of the mainstem Muddy River and tributaries downstream of the gabion barrier was nearly twice the capacity of the stream segments upstream of the gabion barrier.

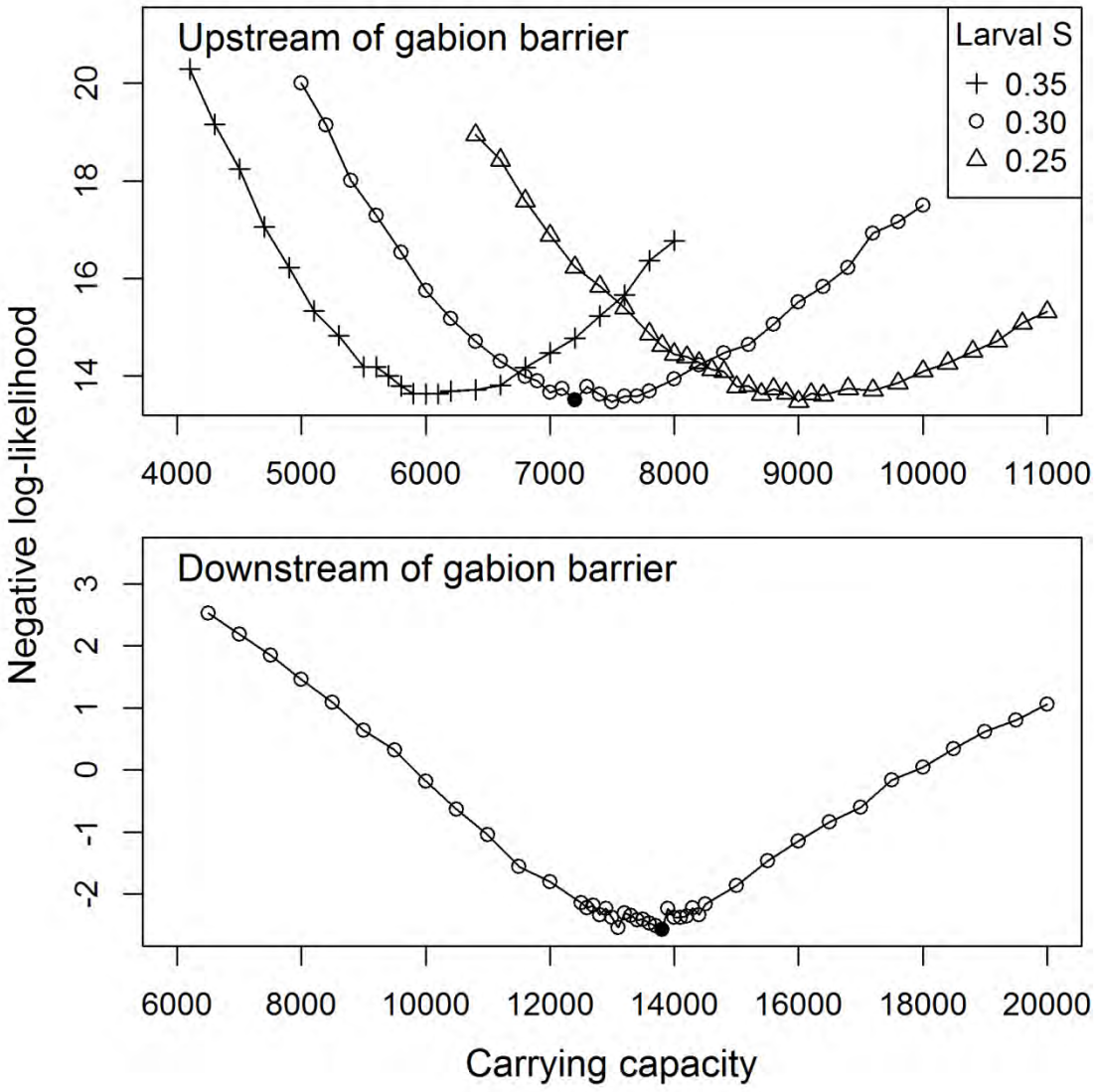

Figure 8. Negative log-likelihood profiles as a function of carrying capacity. The individual-based model was fit to abundance estimates, 1997–2014 (top panel) and 1985–1995 (bottom panel). Filled symbols indicate the parameter values that were selected for all subsequent simulations.

Given our selected parameters of larval survival and capacity, we examined the IBM's goodness of fit to total population abundance. For 1997–2014 when the gabion barrier was in place, the model captured the average abundance well, but failed to match the variation in observed abundance, particularly for the more recent abundance estimates after 2008 (fig. 9). Our model assumed that carrying capacity and larval survival were constant over the 20-year period, which is why the simulated trajectories fluctuate around a constant average value of about 875 individuals. However, substantial changes to the stream network occurred following 2008, including targeted removal of invasive fishes and numerous restoration activities. These actions likely had some influence on larval survival and carrying capacity. We expand on this topic in the section, "Discussion."

For 1985–1995, the simulated population trajectories matched the observed data well, particularly when considering the run-to-run variation observed among the 100 replicate simulations (fig. 9). For example, although the mean simulated abundance fluctuated from about 2,700 to 3,300 non-larval dace, the individual realizations ranged from about 2,300 to 4,000 individuals. The simulated range of abundance matched the observed variation in snorkel counts.

Comparing the observed to simulated abundance also reveals model behavior that is not apparent in the observed abundance estimates. Population trajectories show a seasonal cycle that is not seen in the observed abundance estimates. This seasonal cycle is driven by reproduction that peaks during spring and declines to a minimum during the winter. The peaks and troughs in non-larval abundance are driven by a combination of (1) seasonal recruitment of larvae that grow large enough to transition to juveniles (>25 mm FL), and (2) density-dependent survival that reduces survival when a large pulse of larvae recruit to juveniles and begin to compete for resources with non-larval dace. Cycles are not clearly evident in the observed data because snorkel surveys have been conducted at 6-month or longer intervals, making it difficult to observe fluctuations that occur at finer scales (for example, monthly).

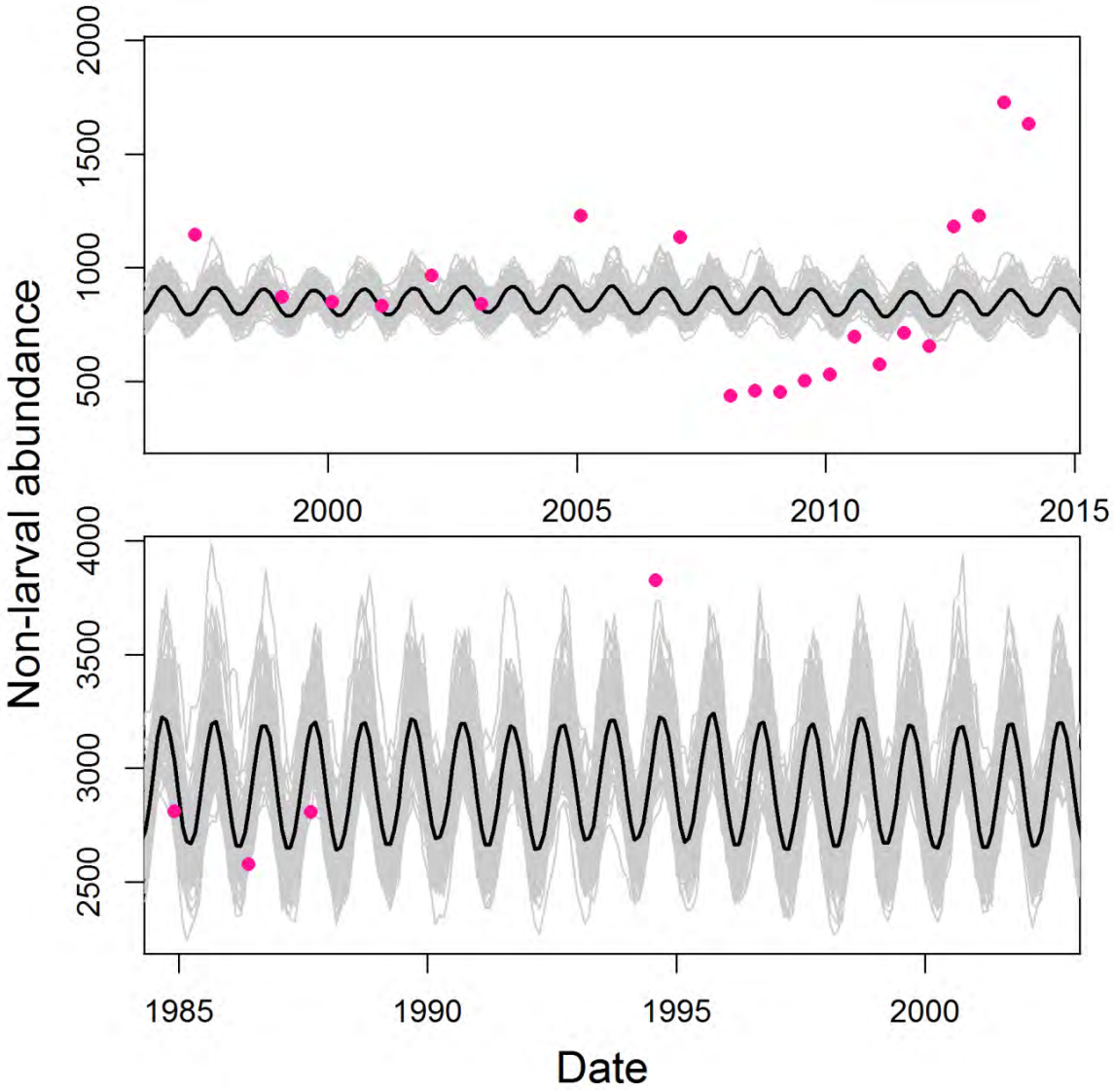

Figure 9. Graphs showing 100 population trajectories from the individual-based model (gray lines) and the mean abundance (black lines) shown against the observed snorkel counts (solid pink circles) using calibrated parameters with a larval survival rate of 0.30 at a carrying capacity of 7,200 upstream of gabion barrier and a carrying capacity of 13,800 downstream of gabion barrier. The upper panel is limited to the population upstream of the gabion barrier. The lower panel shows the total population upstream and downstream of the gabion barrier.

To further examine model behavior, we simulated the entire historical times series of the Moapa dace population using our best fit parameters of larval survival and carrying capacity, and then compared it to the observed data. For this simulation, we allowed fish to move freely between segments 1–7 and segment 8 until 1996. In 1996, we "installed the gabion barrier" by setting upstream and downstream movement probabilities to zero between segments 7 and 8. For the period after 1996, survival in segment 8 was set to zero to emulate the effect of the blue tilapia invasion. This simulation followed the observed population trajectory well, showing how the model can be used to simulate alternative scenarios such as past events that occurred in the Muddy River system (fig. 10).

Additionally, this simulation indicated that after the initial population decline owing to tilapia invasion, the simulated population continued to decline from about 1,200 to 800 individuals between 1996 and 2001. Our model hypothesized that fish inhabiting the mainstem Muddy River grew faster and attained larger size than fish in segments 1–7 upstream of the gabion barrier (fig. 7). Large fish that had moved from the mainstem into segments 1–7 were still present in the simulated population upstream of the gabion barrier at the time the barrier was installed in 1996. These large, highly fecund fish produced more larvae per individual, resulting in maintenance of a larger population size upstream of the gabion barrier. However, over time these larger fish died out, resulting in a gradual decline in the total population size as the population structure shifted to a population comprised of smaller adults that produced fewer larvae per individual.

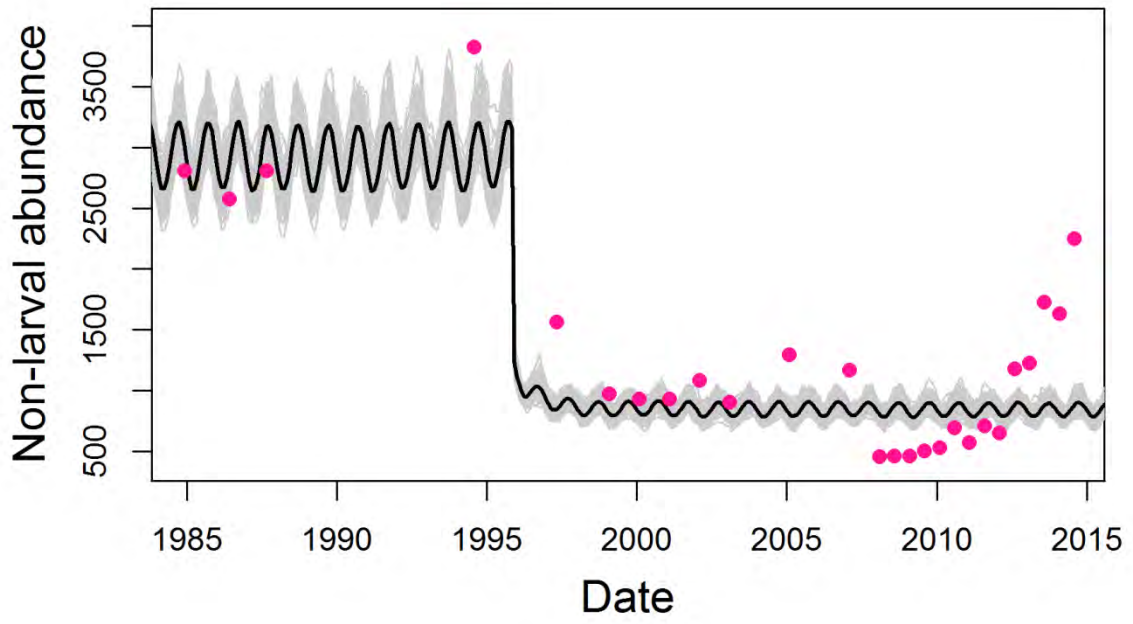

Figure 10. Graph showing 100 population trajectories from the individual-based model (gray lines) and mean abundance (black line) shown against the observed snorkel counts (solid pink circles) using calibrated parameters with a larval survival rate of 0.30 at a carrying capacity of 7,200 upstream of gabion barrier and a carrying capacity of 13,800 downstream of gabion barrier. This scenario simulated the invasion of blue tilapia and installation of the gabion barrier in 1996.

Migration Barrier Scenarios

The mean population size at equilibrium varied among the four migration barrier scenarios and depended on the initial population size for some scenarios. For the baseline scenario (Pedersen weirs and gabion barrier in place), the mean population size at equilibrium increased as initial population size increased from 10 to 50 to 500 individuals (figs. 11 and 12). This difference also was apparent for weirs in place with the gabion barrier removed, although the relative magnitude of this difference was less (figs. 11 and 12). In contrast, for the two scenarios where the Pedersen weirs were removed, we found no effect of initial population size on the equilibrium population size (figs. 11 and 12). The primary effect of removing the gabion barrier was to allow access between three springheads (collectively, segments 1–7 in this study) and the mainstem Muddy River downstream of the gabion, which increased the equilibrium population size considerably, as would be expected.

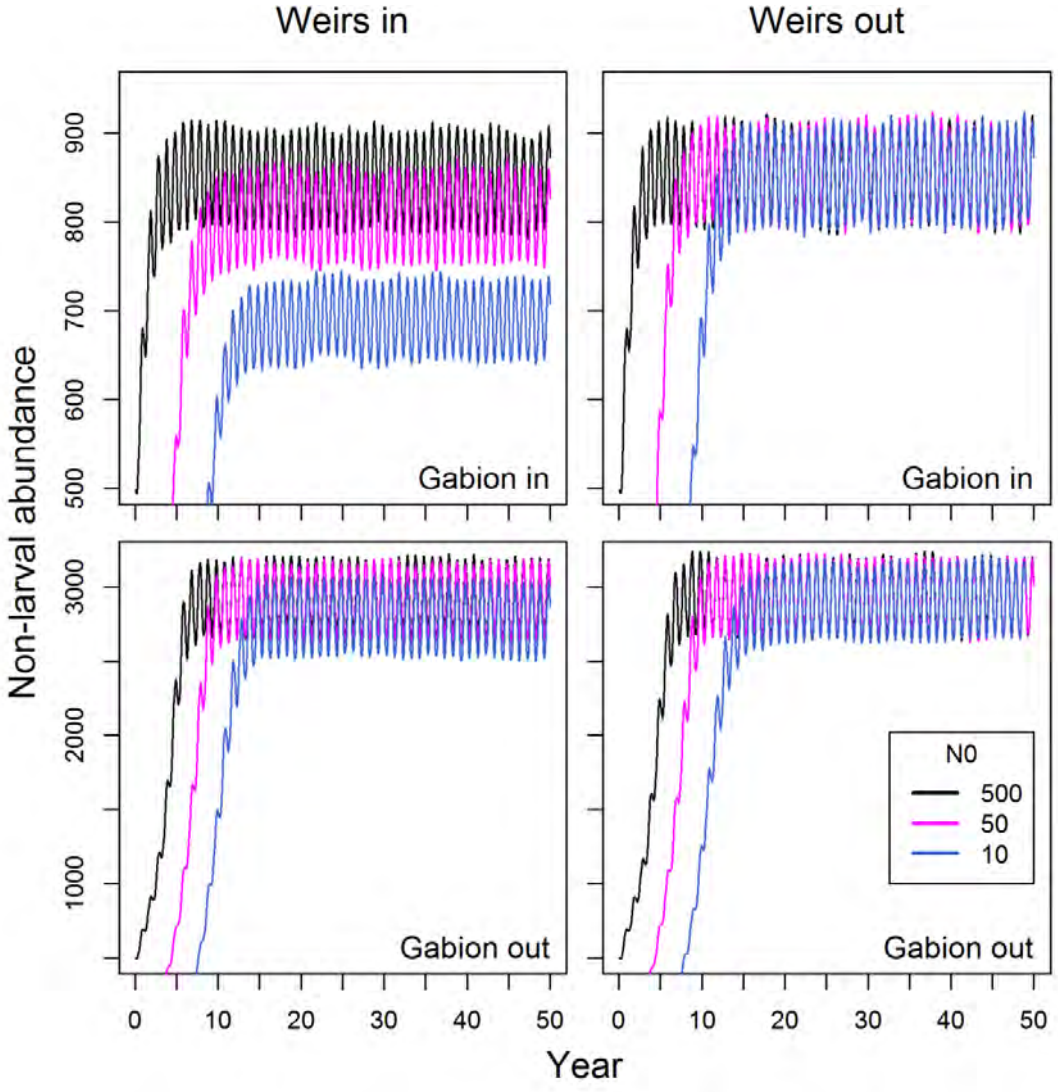

Figure 11. Time-series of mean monthly population abundance showing differences in the equilibrium population size among four alternative scenarios of migration barriers. Mean monthly abundance was computed from 100 simulations at three initial population sizes (N0=10, 50, and 500), for each of the alternative scenarios. The upper left panel shows the baseline scenario.

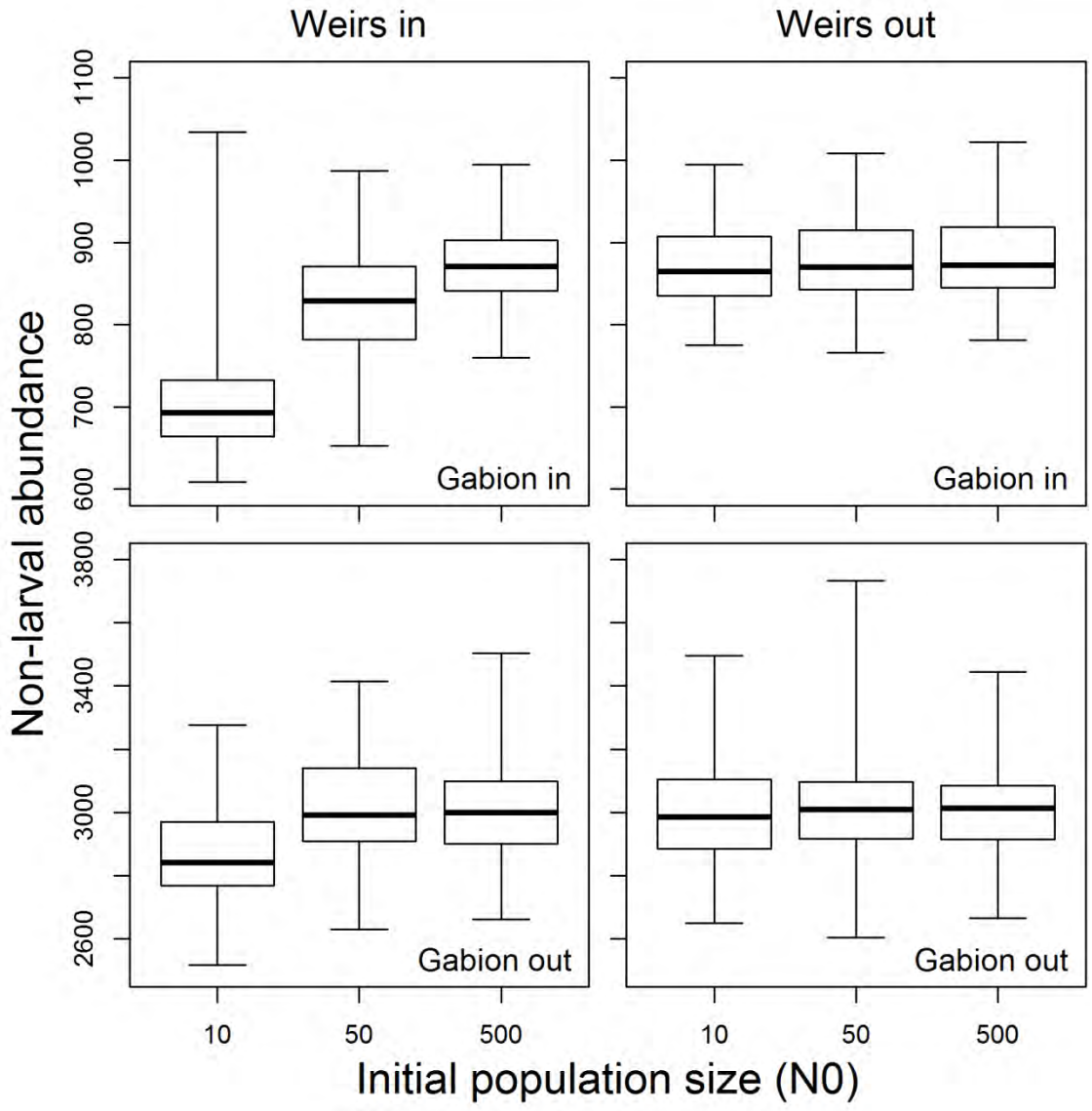

Figure 12. Boxplots showing differences among the distribution of simulated population abundance at the end of the 50-year time horizon for the four alternative scenarios of migration barriers at three initial population sizes (N0=10, 50, and 500). Thick black lines show the median, box hinges define the inter-quartile range, and whiskers bound the simulated range of abundance. The upper left panel shows the baseline scenario.

For scenarios with the Pedersen weirs in place, local extinctions of populations in the two Pedersen stream segments were the cause of the mean equilibrium population size declining with initial population abundance (fig. 13). For example, with an initial population size of 10 non-larval dace, the mean equilibrium population size was about 875 non-larval fish for model runs where zero local populations went extinct, which is similar to the equilibrium population size obtained for the calibration. However, mean equilibrium population size decreased to about 750 and 650 individuals, respectively, when either one or both populations in the Pedersen stream went extinct.

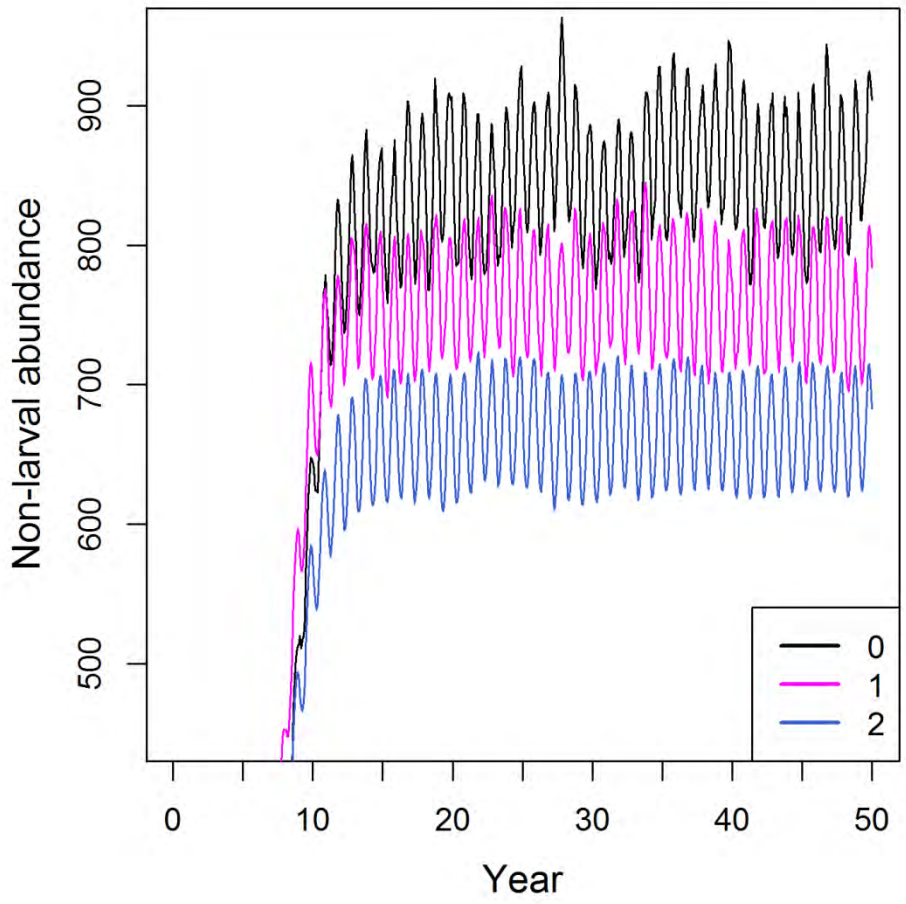

Figure 13. Time series of the mean monthly abundance for population realizations with 0, 1, and 2 local extinctions, simulated under the baseline scenario when Pedersen weirs and the gabion barrier were in place, starting with an initial population size of 10 fish.

We observed no local population extinctions with the Pedersen weirs removed, but a high probability of local extinctions at low initial population sizes when the weirs were in place. At an initial population size of 10 with weirs in place, the probability of local extinction was >80 percent (fig. 14). Even at an initial population size of 50 non-larval dace (and about 350 larval dace), the probability of at least one local extinction was about 40 percent. However, as initial population size increased to more than 100 non-larval dace, no further local extinctions were observed (fig. 14).

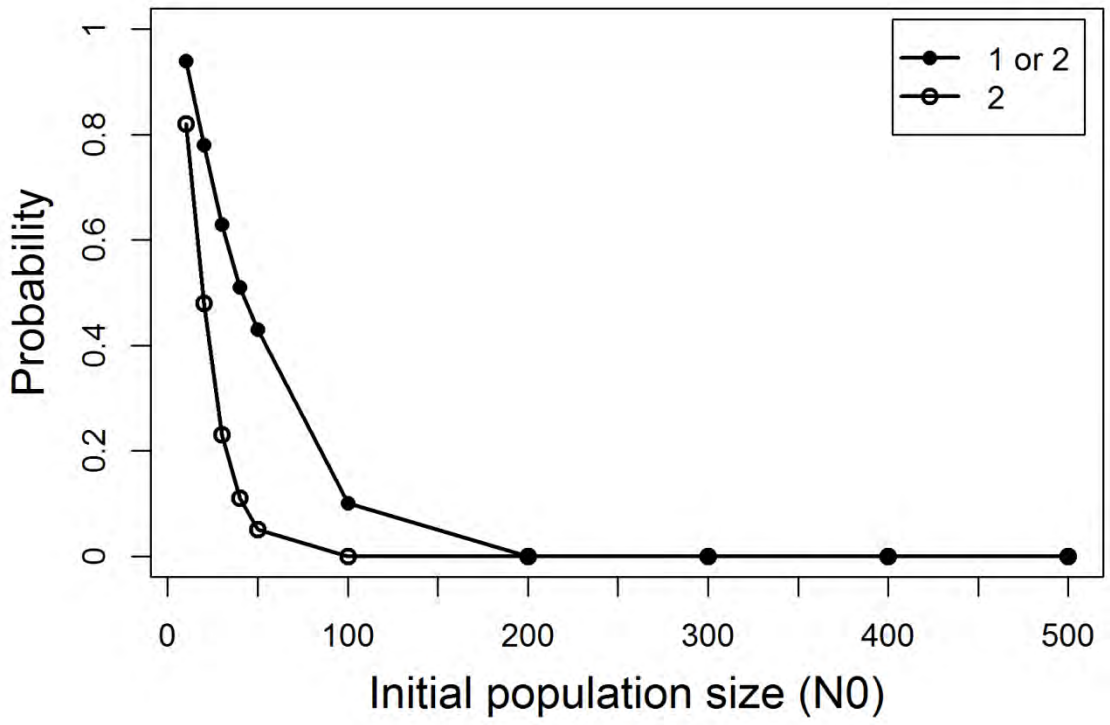

Figure 14. Probability of a local extinction as a function of initial population size. The two lines show the probability of one or more of the subpopulations in Pedersen stream going extinct compared to both segments going extinct.

Without the weirs, strong compensatory mechanisms act to buffer against local extinctions. First, at low initial population sizes, there is little intraspecific competition, which acts to increase survival. Second, even when stochastic events cause a sub-population to go extinct, the fitness-based movement function would act to increase the probability of an individual recolonizing a vacant segment, as long as individuals could freely move among segments. However, with barriers to upstream movement, once a population upstream of a barrier goes extinct, (natural) recolonization is impossible.

We also observed differences in the size and life-stage distributions among scenarios, particularly for scenarios with the gabion barrier in or out (tables 3 and 4). With access to the mainstem where fish grew faster and attained large size, the fraction of the population >65 mm FL increased (table 3), as did the abundance of fish >65 mm FL. The reproductive contribution of these large fish was disproportionate relative to their abundance. With the gabion barrier in place and no fish in the mainstem, there were about 7 larvae per adult, but this increased to about 10 larvae per adult with the gabion removed (table 4) when large fish could contribute to reproduction.

Table 3. Mean proportion of the population in each life stage in December of the last time step for four alternative scenarios of migration barriers.

[Mean standard deviation is shown in parentheses. Scenario:A, baseline with weirs in and gabion barrier in; B, weirs out and gabion barrier in; C, weirs in and gabion barrier out; D, weirs out and gabion barrier out. <, less than; >, greater than; mm, millimeter]

Scenario	Larvae (<25 mm FL)	Juvenile (25–40 mm FL)	Adult (40–65 mm FL)	Adult (>65 mm FL)
A	0.839 (0.0323)	0.041 (0.0095)	0.094 (0.0187)	0.026 (0.0052)
B	0.839 (0.0343)	0.041 (0.0102)	0.094 (0.0198)	0.026 (0.0056)
C	0.872 (0.0174)	0.042 (0.0064)	0.052 (0.0071)	0.034 (0.0046)
D	0.876 (0.0174)	0.041 (0.0064)	0.051 (0.0072)	0.032 (0.0044)

Table 4. Mean population abundance in each life stage in December of the last time step for four alternative scenarios of migration barriers.

[Mean standard deviation is shown in parentheses. Scenario: A, baseline with weirs in and gabion barrier in; B, weirs out and gabion barrier in; C, weirs in and gabion barrier out; and D weirs out and gabion barrier out. FL, fork length; ≤, less than or equal to; >, greater than]

Scenario	Larvae	Juvenile	Adult (≤ 65 mm FL)	Adult (>65 mm FL)	Larvae per adult
A	4,527 (1,088.221)	222 (22.367)	510 (30.786)	140 (11.827)	6.96 (1.597)
B	4,577 (1,023.136)	225 (25.901)	515 (29.624)	141 (14.607)	6.97 (1.464)
C	20,546 (3,169.803)	986 (74.115)	1,231 (74.263)	795 (43.652)	10.14 (1.486)
D	21,381 (,3350.573)	991 (68.610)	1,238 (73.613)	786 (53.158)	10.57 (1.581)

Carrying Capacity Scenarios

We observed that increasing or decreasing carrying capacity upstream of the gabion barrier resulted in concomitant changes in equilibrium population size (fig. 15). For example, decreasing carrying capacity by 30 percent reduced mean abundance from about 875 to 600 individuals, but increasing capacity by 30 percent increased mean abundance to about 1,150 individuals. These changes in abundance were directly proportional to the change in carrying capacity. For example, a 30-percent decrease in capacity lead to a 30-percent decrease in mean population size.

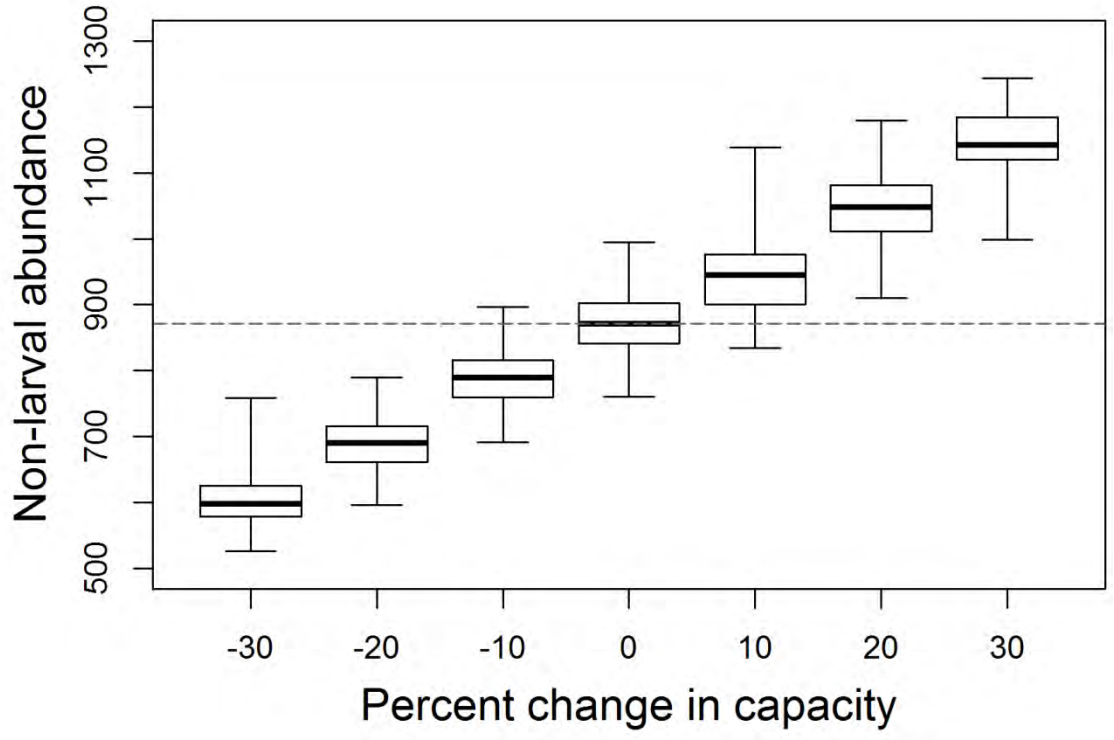

Figure 15. Boxplots showing distribution of population sizes at the end of 50-year simulations under the baseline scenario for 100 runs of the individual-based model. The baseline scenario consisted of the gabion barrier and Pedersen weirs in place. Carrying capacity varied in 10-percentage-point increments from the baseline carrying capacity of 7,200. Thick black lines show the median, box hinges define the inter-quartile range, and whiskers bound the simulated range of abundance.

Discussion

Our population model of Moapa dace proved a useful tool for understanding how dace populations might respond to changes in their habitat, such as alternative configuration of migration barriers and changes in carrying capacity. The IBM was constructed from a combination of empirically derived parameter estimates (for example, growth and survival), ecologically based theoretical models (for example, fitness-based movement), and assumed demographic parameters for life stages in which little is known (for example, reproduction and larval survival). Additionally, we calibrated the model to historical estimates of population abundance, which allowed us to assess scenarios that included reintroduction of dace to the mainstem Muddy River.

Because our model incorporates density-dependent processes that are driven by the capacity of available habitat to support Moapa dace, it is well suited to evaluate the potential effect of management actions that alter the amount of habitat. Changes to total capacity of tributary streams upstream of the gabion barrier led to changes in population abundance directly proportional to the change in capacity. However, we would not always expect population size to change in direct proportionality to carrying capacity. In our simulations, we simultaneously increased carrying capacity for all stream segments, which maintained the relative distribution of carrying capacity among stream segments. Because movement and survival in our model are intricately linked to the channel network structure and distribution of abundance by density-dependent relations, these relations remained unchanged when simultaneously changing capacity in all segments. However, if changes in carrying capacity had occurred disproportionately in some stream segments, we expect that the population dynamics would respond in such a way that the consequent change in total capacity could result in disproportionate changes to the total population size. Changing capacity in one segment but not others would influence the movement probabilities and the density-dependent survival relations. Thus, we should not always assume that population size would change in direct proportionality to carrying capacity. For this reason, our model could be a useful tool for examining where habitat restoration might yield higher or lower benefits to the population.

Although we examined how changes in capacity affect population size, we did not directly examine how specific factors, such as reduced spring discharge or habitat restoration, would influence population dynamics. The difficult link to make here is determining the amount by which carrying capacity would change in response to a change in spring discharge of a given magnitude. Hatten and others (2013) used detailed ecohydraulic models to show that the amount of suitable habitat for Moapa dace declined in response to reduced spring discharge of three headwater segments (segments 1, 3, and 5 in our model). However, to translate these effects to carrying capacity at the population level would require estimating how a change in spring discharge would affect the total amount of available habitat throughout all stream segments supporting the Moapa dace population. Thus, although our model is useful for understanding how changes in carrying capacity of a given magnitude might affect populations of Moapa dace, it remains a formidable challenge to mechanistically link specific types of changes in habitat (for example, reduced spring flows) to specific changes in carrying capacity.

In constructing our model, we were forced to make many simplifying assumptions because of the lack of knowledge about some aspects of Moapa dace biology. Chief among these assumptions was the reproductive biology of Moapa dace. We assumed that (1) individual Moapa dace spawn only once per year, (2) all eggs were laid when an individual spawned, (3) spawning occurred everywhere, and (4) larval survival was the same everywhere. All these assumptions are likely to be invalid to some extent. Anecdotal evidence based on observations of larvae suggests that successful reproduction occurs near headwater springs. However, reproduction of Moapa dace has never been observed in the wild. The frequency with which an individual spawns and how many eggs are spawned by an individual are unknown. However, by calibrating larval survival to allow the model to fit observed abundance estimates, we believe that our model captures the probability that an egg in a reproductive female survives to the juvenile stage. As more is learned about the reproductive biology of Moapa dace, we should be able to refine this aspect of the model.

Another important assumption was that growth rates of Moapa dace in the mainstem Muddy River were higher than in tributary streams. We have no direct evidence for higher growth rates except for historical observations showing that larger fish occupied the mainstem Muddy River but no longer exist in the population of Moapa dace upstream of the gabion barrier. It is possible that Moapa dace achieved larger size in the mainstem not owing to higher growth rates but because of higher survival rates that allowed them to live longer and achieve larger size. The 2014 flood event that washed out the gabion barrier offers an excellent opportunity to test these hypotheses once Moapa dace become established in their historical habitat.

Our model fit the average abundance upstream of the gabion barrier well, but clearly did not represent the magnitude of population fluctuations that occurred after 2008 (fig. 9). By estimating a single larval survival and carrying capacity, our analysis made the implicit assumption that carrying capacity and larval survival remained constant over the 20-year period. However, substantial changes to the stream network occurred following 2008. First, a sharp decline of the population to about 436 individuals occurred in 2008. To our knowledge, the cause of this decline has not been identified. Second, major restoration projects began around 2008. Upper Apcar stream was restored (segment 5), lower Pedersen stream was restored and redirected to its historical channel (segment 4), and the middle section of Apcar stream was restored (segment 6 and part of segment 7). Third, an extensive bimonthly trapping effort began in 2008 (Hereford, 2014a, 2014b) whereby invasive fishes were removed from the system, and larval dace are known to be consumed by invasive fish species (Scoppettone, 1993). Thus, carrying capacity of the stream network increased over time owing to restoration activities, and reduction of invasive fish populations may have increased larval survival and reduced competition with non-larval dace. It would have been difficult to represent the effects of these changes in our model because the ecosystem has been in a state of flux since 2008. The Moapa dace population appears to be responding positively to these recent activities. Should the population begin to stabilize at a new, higher equilibrium population size in the future, our model could be used to estimate the capacity of the stream network before and after restoration activities took place. Such an analysis could provide the basis for predicting the effects of habitat restoration in other locations, providing fisheries managers with an important tool for evaluating the effects of restoration actions on Moapa dace abundance.

Our simulations suggest that reintroducing Moapa dace to the mainstem Muddy River and increasing carrying capacity would result in substantial increases in Moapa dace abundance. However, our analyses suggest that these efforts alone will not be sufficient to achieve the recovery goal of 6,000 Moapa dace (U.S. Fish and Wildlife Service, 1996). Our estimate of carrying capacity for the mainstem Muddy River and tributaries represents the capacity of the system when dace abundance was estimated between 1985 and 1995. During 1985–1995, available habitat already was reduced, and the Muddy River and its tributaries likely have changed since 1995. To achieve the recovery goal, our analyses suggest that carrying capacity needs to be increased further by continued restoration of existing habitats and reintroductions to habitats from which dace have been extirpated. Our model could be a useful tool to help understand the magnitude of change in carrying capacity required to meet recovery goals. For example, it would be straightforward to explicitly represent other spring tributaries that connect to the mainstem Muddy River (for example, Cardy Lamb Springs). Based on our analysis of carrying capacity in other areas, we could hypothesize the increase in capacity achieved by reintroducing Moapa dace to additional headwater springs, and the consequent effect on the expected equilibrium abundance.

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References Cited

Beverton, R.J.H., and Holt, S.J., 1957, On the dynamics of exploited fish populations: London, Chapman and Hall, 533 p.

Burnham, K.P., and Anderson, D.R., 2002, Model selection and multimodel inference—A practical information-theoretic approach: New York, Springer, 488 p.

Burnham, K.P., and White, G.C., 2002, Evaluation of some random effects methodology applicable to bird ringing data: Journal of Applied Statistics, v. 29, p. 245–264.

Cressman, R., and Křivan, V., 2006, Migration dynamics for the ideal free distribution: The American Naturalist, v. 168, p. 384–397.

Francis, R.I.C.C., 1988, Maximum likelihood estimation of growth and growth variability from tagging data: New Zealand Journal of Fisheries and Aquatic Science, v. 22, p. 42–51.

Fretwell, D.S., and Lucas, 1970, On territorial behavior and other factors influencing habitat distribution in birds: Acta Biotheoretica, v. 19, p. 16–32.

Gouriéroux, C., and Monfort, A., 1997, Simulation-based econometric methods: Oxford, United Kingdom, Oxford University Press, 192 p.

Hatten, J.R., Batt, T.R., Scoppettone, G.G., and Dixon, C.J., 2013, An ecohydraulic model to identify and monitor Moapa dace habitat: PLoS ONE, v. 8, no.2, 12 p., doi:10.1371/journal.pone.0055551.

Hereford, M.E., 2014b, Home range, spatial dynamics, and growth of Moapa dace (*Moapa coriacea*); Reno, University of Nevada, Master's thesis, 70 p.

Hereford, D.M., 2014a, Population genetics and population dynamics of Moapa dace: Reno, University of Nevada, Master's thesis, 131 p.

Mayer T.D., and Congdon, R.D., 2008, Evaluating climate variability and pumping effects in statistical analyses: Ground Water, v. 46, p. 212–227.

Moussalli, E., and Hilborn, R., 1986, Optimal stock size and harvest rate in multistage life history models: Canadian Journal of Fisheries and Aquatic Sciences, v. 43, p. 135–141.

Quinn, T.J., and Deriso, R.B., 1999, Quantitative fish dynamics: New York, Oxford University Press, 542 p.

Royle, J.A., 2004, N-mixture models for estimating population size from spatially replicated counts: Biometrics v. 60, p. 108–115.

Scoppettone, G.G., 1993, Interactions between native and nonnative fishes of the upper Muddy River, Nevada: Transactions of the American Fisheries Society, v. 122, p. 599–608.

Scoppettone, G.G., and Burge, H.L., 1994, Growth and survivorship of Moapa dace (Osteichthys, Cyprinidae, *Moapa coriacea*) in an isolated stream reach on Moapa National Wildlife Refuge: Southwestern Naturalist, v. 39:, p. 92–195.

Scoppettone, G.G., Burge, H.L., and Tuttle, P.L., 1992, Life history, abundance, and distribution of Moapa dace (*Moapa coriacea*): Great Basin Naturalist, v. 52, p. 216–225.

Scoppettone ,G.G., Salgado, J.A., and Nielsen, M.B. ,2005, Blue tilapia (*Oreochromis aureus*) predation on fishes in the Muddy River system, Clark County, Nevada: Western North American Naturalist, v. 65, p. 410–414.

Udall, S.L., 1967, Native fish and wildlife—Endangered species: Federal Register, v. 32, no.48, p. 4,001.

U.S. Department of the Interior, 1973, Threatened wildlife of the United States: U.S. Bureau of Sport Fisheries and Wildlife Resources Publication 114.

U.S. Fish and Wildlife Service, 1996, Recovery plan for the rare aquatic species of the Muddy River ecosystem: U.S. Fish and Wildlife Service, Portland, Oregon, 60 p.

White, G.C., and Burnham, K.P., 1999, Program MARK—Survival estimation from populations of marked animals: Bird Study, v. 46, Supplement 001, p. 120–138.

Appendix A. Estimating Moapa Dace Growth Parameters

Growth of Larval Moapa Dace

To estimate larval growth, we obtained size-at-age from a study conducted in 1984 (Scoppettone and Burge, 1994). In this study, 140 larval dace were discovered in a concrete irrigation channel, and then transported to an isolated segment of Upper Plummer Spring where their fork lengths were measured every 3 months for 3 years. We estimated length at age t, $L(t)$, using the following form of the von Bertalanffy growth model (Quinn and Deriso, 1999):

$$L(t) = L_{\infty}\left(1 - e^{-k(t-t_0)}\right), \tag{A1}$$

where

t	is age in months,
L_{∞}	is the asymptotic theoretical maximum fork length (mm),
k	is a constant of the growth rate, and
t_0	is the hypothetical age when L=0.

For model fitting purposes, all fish were assumed to be 1 week old (t=0.25 month) at the time of first measurement. Parameter estimates were obtained by using a non-linear least-squares regression (table A1, fig. A1).

Table A1. Parameter estimates for the von Bertalanffy model fit to data from Scoppettone and Burge (1994).

Parameter	Estimate	Standard error
L_{∞}	56.85	1.175
k	0.120	0.007
t_0	-1.173	0.119

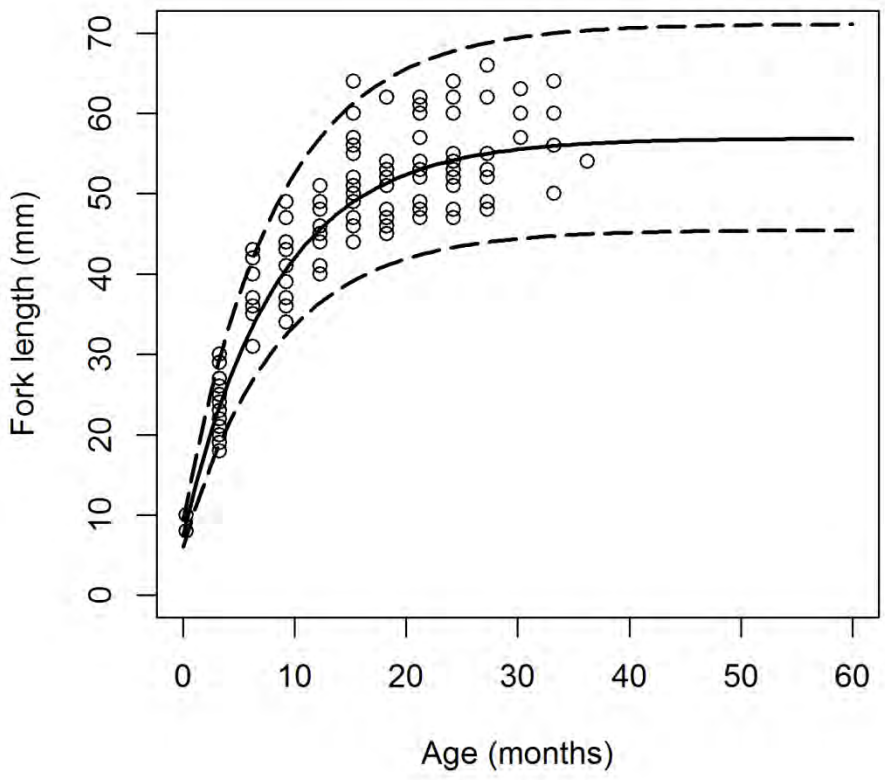

Figure A1. The von Bertalanffy growth model fit to size-at-age data from Scoppettone and Burge (1994). Dashed lines show 95-percent confidence intervals. Fork length in is millimeters (mm).

Growth of Juvenile and Adult Moapa Dace

We analyzed size data obtained by Hereford (2014b), where juvenile and adult individuals were trapped with minnow traps over a 3-year period in all stream segments upstream of the gabion barrier. We used the methods of Francis (1988) to fit a von Bertalannfy growth model where the response is the change in length as a function of initial length and time between recaptures:

$$\Delta L = \left(L_{\infty} - L_t\right)\left(1 - e^{-k\Delta t}\right) \quad \text{(A2)}$$

where

ΔL	is the change in fork length (mm) between recaptures,
L_t	is the initial fork length at time t,
Δt	is the time between recaptures (months),
L_{∞}	is the asymptotic theoretical maximum fork length (mm), and
k	is a constant of the growth rate.

This model was fit to 1,359 growth observations from 615 unique individuals ranging in size from 23 to 86 mm (Hereford, 2014b).

To determine whether fish in headwater spring segments (upper Plummer, upper Pedersen, and upper Apcar) had different growth rates than fish in downstream segments, we fit models that compared the following hypotheses:

Model 1—Both L_∞ and k differed between upper and lower segments.
Model 2—k differed between segments, but L_∞ was the same between segments.
Model 3—No difference in L_∞ or k for fish captured in upper and lower stream segments.

Fish were assigned to stream segments based on their location when initial length (L_t) was measured.

To fit this model to the data, we used maximum likelihood methods that assumed growth of fish was normally distributed with mean ΔL and standard deviation σ. However, negative growth values suggested the presence of measurement error associated with measuring fish length. Additionally, the growth data indicated that σ declined as ΔL declined. Therefore, we incorporated both measurement error and alternative structures for σ to identify a model that fit both the mean change in length and the variance in the observed change in length. The following model was assumed for the observations:

$$\Delta L_i = \Delta L_{\text{pred}} + \varepsilon_i \tag{A3}$$

where

ΔL_i is the ith growth observation,

ΔL_{pred} is the predicted growth based on eqn. A2, and

$\varepsilon_i = \Delta L_i - \Delta L_{\text{pred}}$ is the deviation between observed and predicted growth, which is assumed to follow a normal distribution with mean 0 and standard deviation σ.

Following the methods of Francis (1988), the total variance contributing to σ was expressed as a function of measurement error and ΔL:

$$\sigma = \sqrt{\sigma_i^2\left(\Delta L_{\text{pred}}\right) + s^2} \tag{A4}$$

where

s^2 is the measurement error, and

$\sigma_i^2\left(\Delta L_{\text{pred}}\right)$ is the variance for the ith growth observation expressed as a function of ΔL_{pred}.

To estimate measurement error, we assumed that negative growth in length was impossible and that all negative values of ΔL represented error in the measurement of the true length. We assumed that measurement error was normally distributed with mean zero and standard deviation s, and then estimated s by fitting a normal distribution truncated at zero to all negative observations of ΔL. The estimate of measurement error was s=1.86 mm (standard error=0.08), which appeared consistent with the data. Measurement error was set to this value in eqn. A3 when estimating the other parameters by maximum likelihood.

Next, we compared alternative models for the relation of σ_i with ΔL_{pred}, following the methods of Francis (1988). Alternative models were fit using the model structure that assumed both L_∞ and k differed between upper and lower stream segments (Model 1 referenced earlier in this section). We fit four alternative model structures:

Model 1a— $\sigma_i = \upsilon$

Model 1b) — $\sigma_i = \upsilon \Delta L_{\text{pred}}$

Model 1c— $\sigma_i = \tau\left(1 - e^{\upsilon \Delta L_{\text{pred}}}\right)$

Model 1d— $\sigma_i = \upsilon \Delta L_{\text{pred}}^{\tau}$

where υ and τ are parameters to be estimated by maximum likelihood. The first model is the null model that estimates σ_i as a constant, whereas the other models express σ_i as a linear, exponential, or power function of ΔL_{pred}.

We compared models using Akaike's Information Criterion (AIC; Burnham and Anderson, 2002) and selected the model with the lowest AIC score. We first selected among models fitting different variance structures (Models 1a–1d). Given the best fitting-model for the variance, we then compared Models 1–3 to assess whether growth parameters differed among stream segments.

The model expressing σ_i as a power function of length (Model 1d) fit the data considerably better than the other models. Given that ΔAIC > 10 are typically considered as having essentially no support relative to the best fitting model, we used Model 1d as the basis for comparing Models 1–3 (table A2). Relative to the full model (Model 1), a model with the same k but different L_∞ was not supported (ΔAIC=65.1), but the model with different k and the same L_∞ fit better than the full model (ΔAIC=1.7; table A3). The findings indicate that juvenile and adult Moapa dace upstream of the gabion barrier had the same asymptotic size (L_∞), but that non-larval fish in headwater stream segments grew at a slower rate than non-larval fish in stream segments downstream of the headwater segments (table A4, fig. A2).

Table A2. Model selection results for assessing alternative variance structures for growth of Moapa dace.

[NLL, Negative Log Likelihood; AIC, Akaike's Information Criterion; ΔAIC, the difference in AIC of each model relative to the lowest-AIC mode.]

Model	Number of parameters	NLL	AIC	ΔAIC
1a	5	3851.7	7,713.5	274.3
1b	5	3746.7	7,503.5	64.3
1c	6	3755.9	7,523.7	84.5
1d	6	3713.6	7,439.2	0.0

Table A3. Model selection results for alternative hypotheses of Moapa dace growth in upper and lower stream segments using the variance structure from Model 1d.

[NLL, Negative Log Likelihood; AIC, Akaike's Information Criterion; ΔAIC, the difference in AIC of each model relative to the lowest-AIC model]

Model	Number of parameters	NLL	AIC	ΔAIC
1	6	3,713.6	7,439.2	1.7
2	5	3,713.8	7,437.5	0.0
3	4	3,748.2	7,504.3	66.8

Table A4. Parameter estimates for the best-fit model of Moapa dace growth that uses Model 1d for the variance structure and Model 2 for difference in growth rates between upper and lower stream segments.

Parameter	Estimate	Standard error
$L\infty$	67.568	0.553
kupper	0.046	0.004
klower	0.064	0.003
υ	1.727	0.113
τ	0.613	0.040

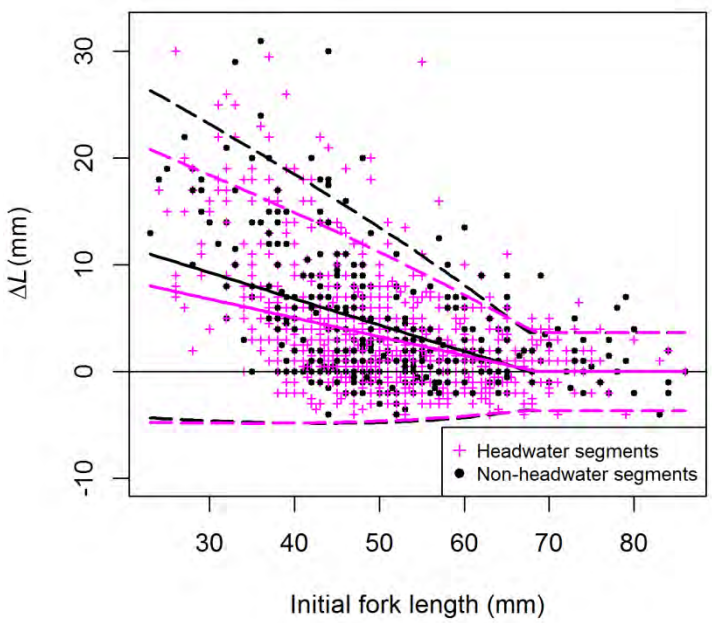

Figure A2. Graph showing the von Bertanlanffy growth model fit to the change in length (ΔL, in millimeters [mm]) between recaptures of Moapa dace in headwater and non-headwater stream segments. Solid lines show the best-fit model for headwater and non-headwater segments. Dashed lines show 95-percent confidence intervals.

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The Status of Moapa Coriacea and Gila Seminuda and Status Information on Other Fishes of the Muddy River, Clark County, Nevada

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THE STATUS OF *MOAPA CORIACEA* AND *GILA SEMINUDA* AND STATUS INFORMATION ON OTHER FISHES OF THE MUDDY RIVER, CLARK COUNTY, NEVADA

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ABSTRACT—*Moapa coriacea* is endemic to the headwaters (Warm Springs area) of the Muddy River, Clark County, Nevada. The Warm Springs area was snorkeled and *Moapa coriacea* and *Gila seminuda* enumerated in August 1994 after a fire, and in May 1997 after a diversion dam had been removed from the downstream end. *Gila seminuda* had been reported in greatest abundance downstream from the Warm Springs area and we estimated the population there through mark and recapture from January to March 1995. There was a dramatic reduction in native fishes in the Warm Springs area between 1994 and 1997, coinciding with the invasion of *Oreochromis aurea*. Downstream from the Warm Springs area *Gila seminuda* was the most frequently netted species while *O. aurea* was relatively scarce. The fish population (native and non-native) decreased in a downstream direction; the causative factor(s) have not been identified.

RESUMEN—*Moapa coriacea* es endémica de las aguas principales (área de manantiales) del río sucio en Clark County, Nevada. El área de manantiales fue buceada y *Moapa coriacea* y *Gila seminuda*, enumeradeas en agosto de 1994 después de un fuego y en mayo de 1997 después de la desviación de una presa, han sido removidas río abajo. *Gila seminuda* ha sido reportada en gran abundancia río abajo del área de los manantiales y hemos estimado la población a través de marcaje y recaptura de enero a marzo de 1995. Hubo una dramática reducción en peces nativos en al área de los manantiales entre 1994 y 1997, coincidiendo con la invasión de *Oreochromis aurea*. Rió abajo del área de los manantiales *Gila seminuda* fue la especie capturada con mayor frecuencia mientras que *O. aurea* fue relativamente escaza. La población de peces (nativos y no nativos) disminuyo en dirección rio abajo; el factor(es) causante no ha sido identificado.

The Muddy River (a.k.a Moapa River) is Nevada's only perennial tributary to the Colorado River. Yet, while connected to a large river system, its fish assemblage is characteristic of an isolated southwestern desert habitat, comprising few species, and harboring endemic forms. Contributing to species isolation is the thermal nature of the Muddy River (Hubbs and Miller, 1948; La Rivers, 1962), originating from a series of thermal springs emanating from a deep paleozoic carbonaceous aquifer (Eakin, 1964). Two of the river's four native fish species, *Moapa coriacea* (Moapa dace) and *Crenichthys baileyi moapae* (Moapa White River springfish), are thermophilic and endemic to the headwaters (Warm Springs area) typically in water temperatures ranging from 26.0 to 32.0°C (Hubbs and Miller, 1948). Because the Muddy River cools as it flows downstream, these fish are restricted to the Warm Springs area (Cross, 1976). *Rhinichthys osculus moapae* (Moapa speckled dace), also endemic (Williams, 1978), occupies the cooler water downstream from the Warm Springs area (Deacon and Bradley, 1972; Cross, 1976). The Moapa roundtail chub (*Gila robusta* sp.) was recently synonymized with Virgin River chub (*Gila seminuda*; DeMarais et al., 1992) and now it is the only one of the four natives not found exclusively in the Muddy River, but occurs in the Virgin River (Utah, Arizona, and Nevada) as well. In the Muddy River, *G. seminuda* does occur in the Warm Springs area, but its greatest concentration is downstream (Deacon and Bradley, 1972; Cross, 1976)

Symptomatic of fishes of the southwest desert, Muddy River native fish populations have declined due to habitat alteration and introduction of non-native fishes (Deacon and Bradley, 1972; Scoppettone, 1993). There have been previous Muddy River fish surveys (Dea-

con and Bradley, 1972; Cross, 1976; Scoppettone et al., 1992), but since then there have been additional habitat alterations and the introduction of at least one new fish species (*Oreochromis aurea*; blue tilapia), warranting an update in species status. *Moapa coriacea* is federally listed as endangered (U.S. Department of Interior, 1973), and *C. b. moapae* and *R. o. moapae* were category 2 species, considered for listing (U.S. Department of the Interior, 1991) until the designation was eliminated. *Gila seminuda* was federally listed as endangered in 1989 in the Virgin River (U.S. Fish and Wildlife Service, 1989), but listing of the Muddy River population is predicated, in part, upon its distribution and abundance (U.S. Fish and Wildlife Service, 1995). Thus, in this paper we investigate the status of *G. seminuda* and, additionally, *M. coriacea* because *M. coriacea* is the most susceptible to extinction and there had been recent perturbations to its very limited habitat. A flash fire swept through a tributary previously documented as containing almost one-third of the adult *M. coriacea* population. Also, a 1.5 m high dam was installed at the lower reach of the Warm Springs area, effectively impounding water to 1.5 km upstream. We surveyed the Warm Springs area in August 1994, six weeks after the fire and six years after the dam installation, and again in May 1997, two years after the dam had been removed.

Description of Area—More than 20 springs and seeps emerge within a 2 km radius and unite in the upper Moapa Valley to form the Muddy River (Fig. 1). Cumulative discharge is about 1.1 m^3/s (Eakin, 1964). Most springs are warm, between 32.0–33.0°C (Garside and Schilling, 1979). We define the stream systems upstream of a 0.6 m high concrete U.S. Geological Survey (USGS) gaging weir at Warm Springs Road (Fig. 1) as the "Warm Springs area." From its origin, here defined as the junction of the South and North forks, the Muddy River flows more than 40 km and discharges into the Overton Arm of Lake Mead. Despite its high mineral content, the Muddy River serves as a potable water source, is used to irrigate pasture and hay crops, and is a water source for a coal-fired power plant (Reid Gardner Station). Agricultural return flows add salt from mineral laden soils (U.S. Department of Agriculture, 1993); thus water conductivity increases markedly downstream (Deacon and Bradley, 1972).

The Muddy River system has been greatly altered by human activity. In the Warm Springs area, spring-fed tributaries have been excavated and natural channels replaced by concrete or earthen ditches. Approximately 30 m upstream of the USGS gaging weir, a 1.5 m high gabion dam was installed in 1988 to divert water to Reid Gardner Station, 9 km downstream. The dam was removed in February 1995 and replaced by a no-head diversion system. Several springs have been pooled for recreational purposes and others have been capped and pumped. Reaches of the main stem have been channelized and straightened. There are several concrete diversion dams along its course, which supply water for irrigation.

Native riparian vegetation is being replaced by non-native species. In the Warm Springs area, non-native fan palm (*Washingtonia filifera*) is the predominant riparian species along two small tributary streams, and has become established throughout watercourses of the upper Moapa Valley. Non-native tamarisk (*Tamarisk* sp.) is the predominant riparian vegetation occurring along the length of the river system, and patches of native mesquite (*Prosopis* sp.), arrow weed (*Pluchea sericea*) and ash (*Franzinua* sp.) persist along the upper to middle reaches.

In addition to four native fish species, 13 non-native fishes are known from the Muddy River (Deacon and Bradley, 1972; Cross, 1976). The most recent introduction *O. aurea*, native of Asia, was first observed immediately downstream from the high USGS gaging weir, in 1991 (Don Sada, Biological Consultant, Bishop, California, pers. comm.).

To protect *M. coriacea, C. b. moapae,* and Warm Springs area endemic invertebrates from the negative effects of non-native species and habitat destruction, the Moapa National Wildlife Refuge (MNWR) was established at one of the Warm Springs area spring provinces contributing to the flow of the Muddy River. Cumulative refuge spring flow was 0.09 m^3/s. About 500 m in length, the stream within the confines of the refuge has supported up to 500 *M. coriacea* and over 10,000 *C. b. moapae* adults with no non-native fishes (primary author, unpublished), and its native fish population is isolated by a 0.75 m high barrier. Downstream from the refuge the stream extends an addi-

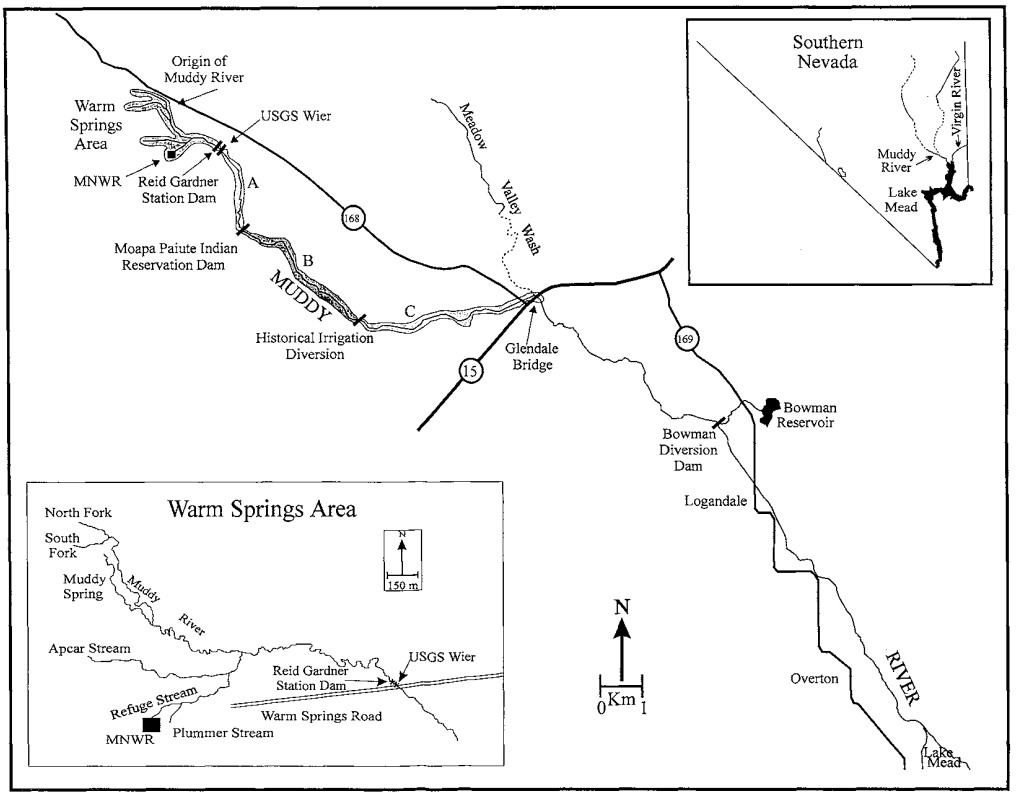

FIG. 1—Map of the Muddy River including Warm Springs area and three sections sampled with hoop nets.

tional 700 m before discharging into the Muddy River. The riparian corridor was predominated by fan palms downstream to the Apcar Stream and then deciduous trees predominated. In June 1994 a flash fire burned through the Refuge Stream to the Muddy River, leaving charred palms without fronds. The palms were not killed and sprouted fronds within several weeks.

MATERIALS AND METHODS—*Warm Springs Area Counts*—In the Warm Springs area, we used mask and snorkel to enumerate *M. coriacea* and *G. seminuda* greater than or equal to 40 mm FL. This method was used because the water generally runs clear and *M. coriacea* and *G. seminuda* (of this size) were in open water and patchy in distribution. *Crenichthys baileyi moapae* was much more numerous and more frequently associated with more complex habitat, so we estimated its relative abundance and distribution rather than conduct enumeration. Two surveys were made, each over a three-day period; one during August 9–11, 1994 and the other May 8–10, 1997. The snorkel survey began about 200 m downstream from the USGS weir at Warm Springs Road Bridge and continued upstream to include the main stem Muddy River and its five primary tributaries, a total distance of 5.9 km (Figure 1). Only *M. coriacea* was targeted for counting downstream of the USGS weir. Two pairs of snorkelers surveyed the mainstem, and one snorkeler the five tributaries.

In this paper, river kilometer (rk) is measured downstream from the Muddy River origin.

Downstream from Warm Springs Area-Mark and Recapture—Downstream from the Warm Springs area we used mark and recapture to estimate the *G. seminuda* population. Hoop nets were used for capture; they were 6.35 mm stretch- mesh, 1.60 m long, with a 0.66 m opening and set with the mouth oriented downstream.

We focused our efforts on the 17.1 km of stream immediately downstream from the Warm Springs are (rk 3.1–20.2), which had previously been documented as having the greatest concentration of *G. seminuda* (Deacon and Bradley, 1972; Cross, 1976; authors unpublished). We divided this reach into three sections, each defined by an impediment to

TABLE 1—Number of *Moapa coriacea* and *Gila seminuda* counted, and estimated number of *Oreochromis aurea* in the Warm Springs area.

	Moapa coriacea		*Gila seminuda*		*Oreochromis aurea*	
Location	1994	1997	1994	1997	1994	1997
North Fork	426	106	1,200	0	0	>40
South Fork	355	28	950	0	0	>30
Muddy Spring	236	28	346	0	0	2
Apcar Stream	407	528	871	1	0	>400
Refuge Stream	313	595	330	0	0	>200
Plummer Stream	0	20	0	0	0	0
Muddy River	2,088	260	4,359	1	0	>300
Total	3,841	1,565	8,056	2	0	>970

fish movement. Section A was 4.0 km long with the 0.6 m high USGS concrete weir upstream, and a 2.0 m high concrete diversion dam downstream. Section B began at the diversion dam and extended downstream 5.3 km to a 2.5 m high relic diversion dam at rk 12.4. Section C extended 7.8 km from the relic dam to Glendale Road Bridge (rk 20.2). There was no physical barrier at the downstream end of Section C.

To capture *G. seminuda* for marking, hoop nets were fished from January 17, 1995, to March 12, 1995. As many as 30 hoop nets were set at 40 m intervals; nets were fished overnight and then moved downstream, until the entire section had been sampled. For each net set, captured *G. seminuda* were measured, scanned for PIT (Passive Integrated Transponder) tag presence, and PIT-tagged in the abdominal cavity if the fish was ≥120 mm FL and had not been previously tagged. Five to seven days after marking had been completed, nets were set in the lower, mid, and upper reach of the section to sample for marked and unmarked *G. seminuda*. Population estimates were made using a modified Petersen estimator (Ricker, 1975), which is predicated upon a closed system, and fish randomly mixing. To test for random movement and whether fish remained within the section where they had been tagged, fish movement was tracked by giving each net an identification number and approximate location, using a Global Position System and scaled aerial photograph. A chi-square was used to test the hypothesis that recaptured fish would disperse upstream and downstream with equal frequency.

RESULTS—*Warm Springs Area Counts*—There was a reduction in the number of native fish between 1994 and 1997. Most notable the *G. seminuda* population dropped from over 8,000 to 2 individuals (Table 1). *Moapa coriacea* went from 3,800 to fewer than 1,600 adults. Although we did not enumerate *C. b. moapae,* in 1994 they were virtually 100% sympatric with *M. coriacea,* and they appeared numerous throughout the Warm Springs area. However, in 1997 *C. b. moapa* was rare in most of its range. Coinciding with native fish reduction in the Warm Springs area was the invasion of *O. aurea:* none were observed upstream of the USGS weir in 1994, but in 1997 more than 900 were sighted, many larger than 150 mm FL. *Oreochromis aurea* may have accessed the Warm Springs area when the Reid Gardner Station diversion dam was removed (April 1994) providing sufficient flow to allow passage over the USGS weir.

In 1997 over 65% of the remaining *M. coriacea* were in areas which *O. aurea* had apparently not invaded. In the Refuge Stream, 552 of its 595 *M. coriacea* were found upstream of a series of falls where *O. aurea* had not been sighted. Likewise, in the Apcar Stream, *M. coriacea* inhabited an area of dense *Vallisneria,* conditions which large (>70 mm FL) *O. aurea* appeared to avoid or not yet invaded. *Crenichthys baileyi moapae* followed a similar pattern of distribution and were most abundant in those areas where *M. coriacea* was most abundant and *O. aurea* were absent or few.

In our 1994 survey of the MNWR it was apparent that the flash fire had killed or cause to relocate almost all the fish inhabitants. Only 34 *M. coriacea* and fewer than 150 *C. b. moapae* were accounted for. Except for several shortfin molly (*Poecilia mexicana*), the Refuge Stream immediately downstream of MNWR was devoid of fish life downstream to the Apcar Stream. Most of the *M. coriacea* counted (296) along the Refuge Stream in 1994 were downstream from the Apcar Stream.

TABLE 2—Number and percent of total of fish of each species captured.

Species	Section A	Section B	Section C	Total
Gila seminuda	56.1% (806)	78.7% (1,921)	86.0% (671)	73.0% (3,398)
Rhinichthys osculus moapae	13.7% (197)	19.0% (457)	6.9% (54)	14.8% (708)
Moapa coriacea	0% (0)	0% (0)	0% (0)	0% (0)
Cyprinus carpio	0% (0)	0.2% (5)	0.5% (4)	0.9% (9)
Crenichthys baileyi moapae	0.7% (10)	0% (0)	0% (0)	0.3% (10)
Poecilia mexicana	21.1% (303)	0.8% (18)	0.5% (4)	6.8% (325)
Gambusia affinis	0% (0)	0% (0)	0% (0)	0% (0)
Oreochromis aurea	8.5% (122)	1.4% (33)	1.3% (10)	3.5% (165)
Ameiurus melas	0% (0)	0% (0)	4.7% (37)	0.8% (37)

Downstream from Warm Springs Area-Mark and Recapture—Gila seminuda was the most frequently netted species (3,398) representing 73.0% of the total captures, followed by *R. o. moapa* (708) representing 14.1%, and then *O. aurea* (Table 2). Fish captures declined in Section C. *Gila seminuda* captures dropped substantially at rk 16, and remaining consistently low at downstream net sets (Fig. 2). *Rhinichthys osculus moapae* captures were almost nil at and downstream from rk 14.

Movement of PIT-tagged *G. seminuda* indicated that they mixed randomly and did not leave the section in which they had been marked. Fish moved in Sections A, B, and C an average distance of 446, 927, and 993 m respectively, and there was no significant difference in directional movement ($x^2 = 1.03$, $P = 0.30$).

There was an estimated 15,684 *G. seminuda* along the 17.1 km reach sampled (Table 3). The most was in Section B (11,123) and the fewest in section C (2,234). Captured *G. seminuda* tended to be smallest ($\bar{X}$ = 115 mm FL; *SD* = 21 mm) in Section B and largest ($\bar{X}$ = 143 mm FL; *SD* = 25 mm) in Section C, and intermediate in length in Section A ($\bar{X}$ = 124 mm FL; *SD* = 24 mm).

DISCUSSION—*Oreochromis aurea* is the only non-native fish species to have become established in the Warm Springs area since *Poecilia mexicana* (short fin molly) in the early 1960s (Hubbs and Deacon, 1964), and we anticipate *O. aurea* will become a much greater threat to native fish persistence than have previous invaders. Where it has become established in Florida, *O. aurea* has replaced natives and become the predominant fish species (Shafland, 1979; Kohler and Courteney, 1986). Our 1997 survey suggested that in less than three years, *O. aurea* had already reduced the number and distribution of Warm Springs area natives. At the time of our survey *O. aurea* may still have been expanding in number and range, and the full negative effect on Warm Spring area native fish may not have occurred.

The invasion of *O. aurea* has elevated the importance of MNWR as a safe haven for the thermophilic *M. coriacea* and *C. b. moapae*, even though the June 1994 flash fire reduced the *M. coriacea* refuge population from about 500 individuals to 34. Fire, with abundant fuel, has been documented to kill fish and cause local extinction in small streams (Rinne, 1996; Rieman and Clayton, 1997). MNWR fish were probably killed by fire before they could escape. Dried palm fronds were an abundant, highly flammable fuel source, which cloaked the stream with ashes causing bank overflow. Within days after the fire, the remaining fish were concentrated near the spring source, and we speculate that they had survived by holding within spring sources at the time of the fire, and thus escaping the heat and chemical changes associated with highly fueled fires (Rinne, 1996; Rieman and Clayton, 1997). Our survey results prompted the removal of the highly flammable, albeit, fire resistant palms. Uprooting the large palms necessitated stream rehabilitation because hydraulic conditions conducive to all life stages of *M. coriacea* and *C. b. moapae* (Scoppettone et al., 1992; Scoppettone, 1993) were greatly reduced, and the documented invasion of *O. aurea* into the Warm Springs area required that this rehabilitation be expedited. Additional *M. coriacea* and *C. b. moapae* have already begun to be re-

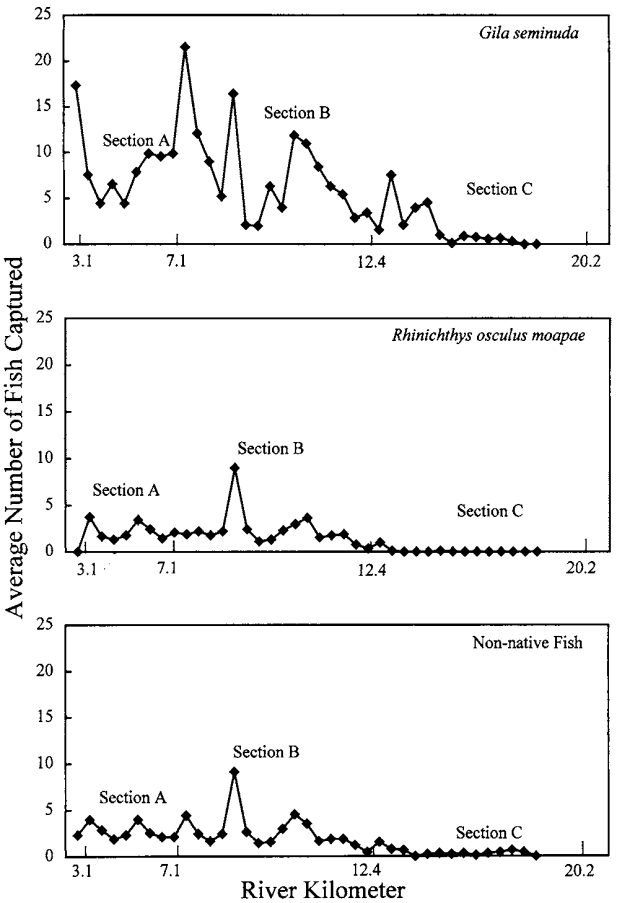

FIG. 2—The average number of fish captured at specific river kilometers throughout each of the three sample sections along the Muddy River.

leased onto the refuge from other parts of the Warm Springs area.

Before our 1994 survey, *G. seminuda* had been reported as less abundant than other fishes in the Warm Springs area, including *M. coriacea* (Hubbs and Miller, 1948; Deacon and Bradley, 1972; Cross, 1976; Scoppettone et al., 1986); for example, in 1986 only 415 were counted compared with over 2,800 *M. coriacea*. *Gila seminuda* distribution was also more localized than *M. coriacea* and was primarily confined to the main stem Muddy River; they were sympatric with *M. coriacea* in only about 50% of the *M. coriacea* range. In the summer of 1994, the *G. seminuda* population was greater than 8,000, most of which were <100 mm FL. It had spread to regions of the Warm Springs area where it had not been previously reported and sympatry incorporated about 90% of the *M. coriacea* range. We suspect that the impounded water created by the Reid Gardner Station power diversion dam encouraged the increase by creating suitable reproductive habitat. Whatever the cause, the increase of *G. sem-*

TABLE 3—Population estimates for *Gila seminuda* along a 17.1 km reach of the Muddy River, Nevada.

Section	Population estimate	95% confidence interval	
		Lower	Upper
A	2,327	1,481	3,173
B	11,123	7,219	15,027
C	2,234	2,186	2,283
Total	15,684	13,235	18,133

inuda in this vicinity probably contributed to downstream recruitment.

Results of our 1995 estimate indicated that *G. seminuda* was reasonably abundant downstream from the Warm Springs area. Catch rate in our hoop-nets suggested *G. seminuda* was much more numerous than *O. aurea,* which had established in the region by 1991. Although our hoop-nets were selective for larger fish, *R. o. moapa* was captured more frequently than *O. aurea.* Thus, *O. aurea* did not appear an immediate threat to replace native fishes downstream. We have renewed concerns, however, for *G. seminuda* and *R. o. moapa* since the Warm Springs area now probably contributes *O. aurea* rather than *G. seminuda* recruits. Such changes the Muddy River should be monitored. The environmental phenomena leading to a marked decline in fishes approximately 14 km downstream from the origin of the Muddy River also merits attention, since some of the apparently least disturbed and favorable native fish habitat harbored few or no fish. Deacon and Bradley (1972) found natives to decrease and non-native increase in a downstream direction, but we found a decrease in number of all species in a downstream direction. We conducted supplementary sampling three months prior to our hoop-net survey and found there were few fish downstream to Bowman Reservoir diversion dam (rk 25; Fig. 1), and the stream seasonally dry and without native fishes downstream of Bowman Reservoir.

Alteration of the Muddy River system has already greatly reduced native fish habitat, but now non-native species threaten to replace native fishes in the Warm Spring area, and the likelihood of fire from spread of fan palms in the basin is growing. Extraordinary measures may be needed to prevent extinction of the Muddy River native fishes.

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Literature Cited

Cross, J. N. 1976. Status of the native fish fauna of the Moapa River (Clark County, Nevada). Transactions of the American Fisheries Society 105: 503–508.

Deacon, J. E., and W. G. Bradley. 1972. Ecological distribution of fishes of Moapa (Muddy) River, in Clark County, Nevada. Transaction of the American Fisheries Society 101:408–419.

DeMarais, B. D., T. E. Dowling, M. E. Douglas, W. L. Minckley, and P. C. Marsh. 1992. Origin of *Gila seminuda* (Teleostei: Cyprinidae) through introgressive hybridization: implications for evolution and conservation. Evolution 89:2747–2751.

Eakin, T. E. 1964. Ground-water appraisal of Coyote Springs and Kane Spring valleys and Muddy River Springs Area, Lincoln and Clark counties, Nevada. Nevada Department of Conservation and Natural Resources, Ground-Water Resources Reconnaissance Series. Report 25.

Garside, L. J., and J. H. Schilling. 1979. Thermal waters of Nevada. Nevada Bureau of Mines and Geology, Bulletin 91. Mackay School of Mines and Geology, University of Nevada, Reno.

Hubbs, C. L., and R. R. Miller. 1948. The Great Basin with emphasis on glacial and postglacial times. II. The zoological evidence. University of Utah Bulletin 38:17–66.

Kohler, C. C., and W. R. Courteney. 1986. American Fisheries Society position on introductions of aquatic species. Fisheries (Bethesda) 11(2):39–42.

La Rivers, I. 1962. Fish and fisheries of Nevada. Nevada Fish and Game Commission. Reno Nevada.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Bulletin of the Fisheries Research Board of Canada Bulletin 191.

Rinne, J. N. 1996. Short-term effects of wildfire on fishes and aquatic macroinvertebrates in the southwestern United States. North American Journal of Fisheries Management 16:653–658.

Scoppettone, G. G., 1993. Interactions between native and non-native fishes of the Upper Muddy River, Nevada. Transactions of the American Fisheries Society 122:599–608.

Scoppettone, G. G., H. L. Burge, P. L. Tuttle, M. Parker, and N. Kanim Parker. 1986. Life history and status of the Moapa dace (*Moapa coriacea*). Unpublished report: U.S. Fish and Wildlife Service, National Fisheries Research Center, Washington, D.C.

Scoppettone, G. G., H. L. Burge, and P. L. Tuttle. 1992. Life history, abundance, and distribution of Moapa dace (*Moapa coriacea*). Great Basin Naturalist 52:216–225.

Shafland, P. L. 1979. Non-native fish introductions

with special reference to Florida. Fisheries (Bethesda) 4(3):18–24.

U.S. DEPARTMENT OF AGRICULTURE. 1993. Moapa Valley Unit Nevada; Colorado River Salinity Control Program. Final Environmental Impact Statement. Soil Conservation Service. Reno, Nevada.

U.S. DEPARTMENT OF THE INTERIOR. 1973. Threatened wildlife of the United States. U.S. Bureau of Sport Fisheries and Wildlife Resources Publication 114.

U.S. FISH AND WILDLIFE SERVICE. 1989. Endangered and Threatened Wildlife and Plants: Determination of Endangered Status for the Virgin River Chub, Federal Register 54:35305–35311.

U.S. FISH AND WILDLIFE SERVICE. 1991. Endangered and Threatened Wildlife and Plants; Animal Candidate Review for Listing as Endangered or Threatened Species, Proposed Rule 56:58804–58836.

U.S. FISH AND WILDLIFE SERVICE. 1995. Endangered and Threatened Wildlife and Plants; Proposed Change from Subspecies to Vertebrate Population Segment for Virgin River Chub in Virgin River and Notice of Status Review of Virgin River Chub in Muddy River, Federal Register 60:37866–37868.

WILLIAMS, J. E. 1978. Taxonomic status of *Rhinichthys osculus* (Cyprinidae) in the Moapa River, Nevada. Southwestern Naturalist 23:511–518.

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Blue tilapia (*Oreochromis aureus*) predation on fishes in the Muddy River system, Clark County, Nevada

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BLUE TILAPIA (*OREOCHROMIS AUREUS*) PREDATION ON FISHES IN THE MUDDY RIVER SYSTEM, CLARK COUNTY, NEVADA

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Key words: blue tilapia, predation, Muddy River, Moapa dace, Moapa White River springfish.

Blue tilapia (*Oreochromis aureus*), native to North Africa and the Middle East (Courtenay and Robins 1973, Fuller et al. 1999), has been introduced around the world as a human food source, for vegetation control, and as a game fish (Costa-Pierce and Riedel 2000). Blue tilapia has been particularly successful in establishing and spreading in North American waters where it has been reported to change fish community structure and cause native fish decline (Courtenay and Robins 1973, Fuller et al. 1999). Because of these detrimental effects, it is now generally considered an unwelcome introduction into North American waters (Dill and Cordone 1997, Fuller et al. 1999).

The 1st known introduction of blue tilapia in Nevada was in the Muddy River (a.k.a. Moapa River), Clark County, Nevada, and its arrival was followed by a decline in populations of native fishes (Scoppettone et al. 1998). The Muddy River is a 40-km-long tributary to the Colorado River system harboring 4 native fishes, 2 of which are endemic. Moapa dace (*Moapa coriacea*) and Moapa White River springfish (*Crenichthys baileyi moapae*) are known only from the headwaters of the Muddy River, referred to as the Warm Springs area. The river originates from over 20 thermal springs feeding 6 primary tributaries (Fig. 1). The native Virgin River chub (*Gila seminuda*) also occurs in the Warm Springs area but is considered thermal tolerant with greater abundance downstream, while native speckled dace occurs downstream from the Warm Springs area (Deacon and Bradley 1972, Cross 1976, Scoppettone 1993).

Blue tilapia was first observed in the Muddy River in 1991 immediately downstream from the Warm Springs area (Don Sada, Desert Research Institute, personal communication). It did not have access to the area, however, until February 1995 when a 1.5-m-high diversion dam was removed. Within 2 years of dam removal, blue tilapia had invaded 90% of the Warm Springs area, and there was a marked decline in native fishes (Scoppettone et al. 1998). By February 2001, snorkel surveys indicated that native fishes had been virtually eliminated from sections of the Warm Springs area accessible to and inhabited by blue tilapia (James Heinrich, Nevada Department of Wildlife, personal communication). Most of the remaining population of Moapa dace and Moapa White River springfish occurred in a tributary (Refuge Springs outflow) upstream of a natural barrier that had been enhanced to prevent blue tilapia movement upstream (Fig. 1). Endemic fish habitat was reduced from about 5.9 km of stream in the Warm Springs area prior to tilapia invasion to <600 m (upstream of a barrier) post-invasion. This development provides strong circumstantial evidence that blue tilapia was responsible for the decline of native fishes in the Warm Springs area.

In its native habitat blue tilapia is described as a filter-feeder, consuming zooplankton and phytoplankton as well as aquatic vegetation and some invertebrates (Spataru and Zorn 1978). In the Warm Springs area we observed aquatic vegetation declining after the blue tilapia invasion, following which tilapia persisted in robust numbers and native fishes declined. We hypothesized that after blue tilapia began to deplete aquatic vegetation, they switched to fish consumption, which would be extraordinary since piscivory has not been previously

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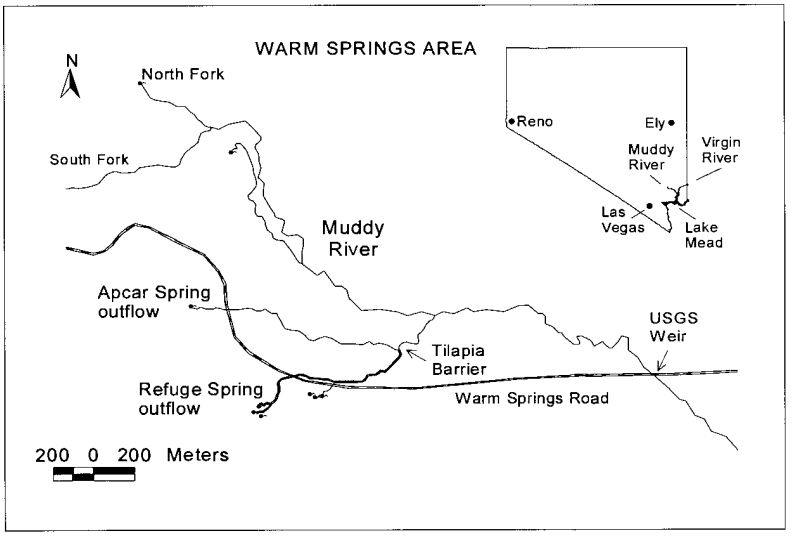

Fig. 1. Map of the Warm Springs area showing the Apcar Spring outflow and the Muddy River. Also shown is the Refuge Spring outflow and tilapia barrier. In bold is the 600 m of stream habitat haboring virtually all remaining Moapa dace and Moapa White River springfish in 2001. Inset shows the Muddy River system in relationship to State of Nevada and Lake Mead.

reported for blue tilapia. In this study we investigate blue tilapia fish predation in the Warm Springs area of the Muddy River.

The Warm Springs area spring systems and river channel had been greatly altered and were inhabited by nonnative mosquitofish (*Gambusia affinis*) and shortfin molly (*Poecilia mexicana*) for decades prior to blue tilapia (Hubbs and Miller 1948, Hubbs and Deacon 1964, Scoppettone et al. 1998). This was the case for the Apcar Spring outflow and the mainstem Muddy River, source locations for fish used in this investigation. The Apcar Spring outflow was 1.1 km in length and flowed at 0.06 $m^3 \cdot s^{-1}$, half of which was diverted for municipal and agricultural use at the upstream end. The stream channel was partially shaded by ash (*Fraxinus* sp.), cottonwood (*Populus* sp.), nonnative fan palm (*Washingtonia filifera*), and tamarisk (*Tamarix* sp.). Before blue tilapia introduction, approximately 90% of the stream bottom was covered with the macrophyte *Vallisneria.* In the Warm Springs area the Muddy River flowed in a deeply incised channel, and the predominant riparian vegetation was tamarisk and fan palms. Prior to tilapia entering the Warm Springs area, *Vallisneria* carpeted the main river channel almost 1 km upstream of Warm Springs. A 0.6-m-high weir (USGS weir) at Warm Springs Road approximated the beginning of the Warm Springs area (Fig. 1). Immediately upstream of the USGS weir, there was a 1.5-m-high gabion dam that served to divert water to the Reid-Gardner Power Plant until it was replaced with a no-head diversion system in February 1995.

We collected blue tilapia from the Apcar Spring outflow ($n = 161$) on 10 December 1998 following rotenone treatment for tilapia eradication (Fig. 1). Several weeks prior to treatment, we minnow-trapped Apcar Spring outflow to capture and relocate native fishes; 34 Moapa dace and several hundred Moapa White River springfish were relocated. We also collected blue tilapia ($n = 35$) along the Muddy River upstream of Warm Springs Road to the junction of the north and south forks, on 6 August 2000 using a 6.3-mm-mesh, 10.1-m-long, 1.2-m-wide seine. Captured blue tilapia were slit with a scalpel ventral to the digestive tract, fixed in 10% formalin, and stored in 45% ethanol. The Apcar blue tilapia were placed in formalin within 20 minutes of their exposure to rotenone, and Muddy River blue tilapia were placed in formalin immediately after seining. For each fish we measured standard length

TABLE 1. Items ingested by blue tilapia (*Oreochromis aureus*) in 2 tributaries of the Warm Springs area by frequency of occurrence (f) and percent by volume.

	Apcar Spring 2/10/98 (n = 128)		Muddy River 8/16/00 (n = 16)	
Food item	f	% volume	f	% volume
Mosquitofish	42	19.42	5	23.75
Shortfin molly	1	0.79	—	—
Moapa dace	5	1.25	—	—
Moapa White River springfish	9	2.89	1	3.75
Blue tilapia	—	—	1	5.63
Unidentified fish	44	19.52	—	—
Aquatic invertebrates	31	3.28	2	4.69
Terrestrial invertebrates	2	0.80	—	—
Plant	58	32.97	11	61.56
Digested matter	35	19.07	1	0.62

(SL) and total length (TL) to the nearest mm. Standard length was also taken of prey fishes retrieved from the gut that were sufficiently intact to obtain an approximate measurement. Stomach contents were examined and identified using a dissection microscope. Items consumed were quantified by frequency of occurrence and mean percent by volume (Windell 1971). Invertebrates were categorized as aquatic or terrestrial and fishes were identified to species. For those fishes that had been extensively digested, we used pharyngeal teeth, otoliths, and scales for identification. We correlated predator (i.e., blue tilapia) SL with SL of prey fish consumed. Significance of resulting correlation coefficients was tested using Table R in Rohlf and Sokal (1995).

Fish were found in guts of blue tilapia collected in the Apcar Spring outflow and the Muddy River. In the Apcar Spring outflow, fish were the predominant diet by frequency of occurrence and percent by volume. Of 161 blue tilapia collected, 128 had food items in the gut. Of these, 101 had consumed a total of 345 fish, accounting for 44% of the volume consumed. Five had consumed a total of 11 Moapa dace, and 9 had consumed a total of 14 Moapa White River springfish (Table 1). Mosquitofish were the predominant fish taken, with 163 found in 42 stomachs; a 150-mm-SL blue tilapia had consumed 25 mosquitofish. Measurable fish prey ranged from 11.0 to 38.7 mm SL, with Moapa dace the longest (Fig. 2). There was a significant (n = 64, r = 0.44, P = 0.01) positive correlation between blue tilapia SL and prey SL. Only 2 of 326 prey fish that could be identified were shortfin molly even though they were judged to represent over 50% of the Apcar fish population.

In the Muddy River, 16 of 35 blue tilapia collected had stomach contents: 33% by volume of the items consumed were fishes, 75% of which were mosquitofish (24% by volume; Table 1). Moapa White River springfish as prey ranged from 17 mm to 19 mm SL. Two young blue tilapia were part of the prey, accounting for 6% by volume of the items ingested.

This study adds predation to the list of mechanisms (competition for space, competition for food, and change in energy flow) by which blue tilapia can cause native fish decline (Gu et al. 1997, Moyle 2002). The long gut of this species is characteristic of herbivory (Costa-Pierce and Riedel 2000), but herbivory does not preclude the ability to digest animal protein (Hofer and Schiemer 1981). Blue tilapia is apparently a successful fish predator, with several consuming numerous fish, including small adult Moapa White River springfish and Moapa dace. We also documented 2 occurrences of cannibalism by the species.

Blue tilapia adjusts its feeding strategy to reflect the relative abundance and composition of available food (Gu et al. 1997), and we found this adjustment may include fish consumption. In the Apcar Spring outflow we assume that blue tilapia switched its diet from *Vallisneria*, after it was depleted, to fish. When blue tilapia were first observed in the Apcar Spring system in May 1997, over 400 were counted. At that time much of the stream was covered with *Vallisneria*, and the Moapa dace population was extensive (>500), similar to what had been counted in previous surveys

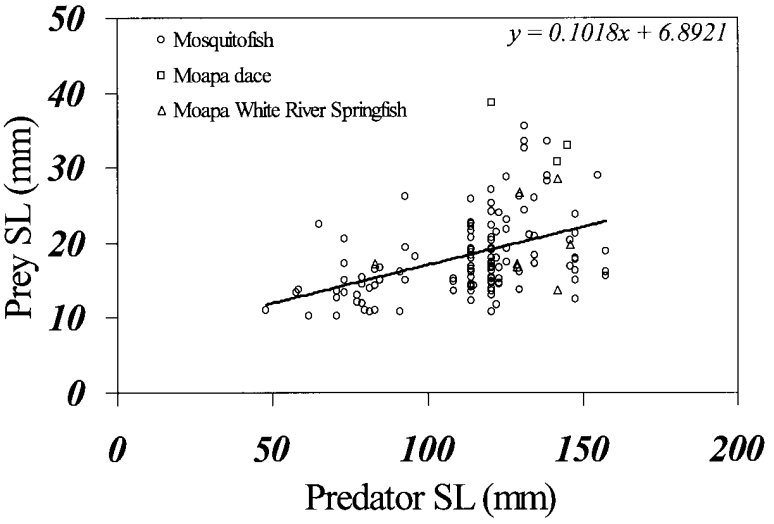

Fig. 2. Predator blue tilapia standard length (SL) in relation to SL of 3 prey species.

(Scoppettone et al. 1992, 1998). In June 1997, seven blue tilapia (140–240 mm fork length) were captured and were full of *Vallisneria* (James Heinrich personal communication), suggesting it was their primary food source. By 9 December 1998, the Apcar outflow was denuded and the Moapa dace population had collapsed from >500 to <70 (James Harvey personal communication). We collected fish samples from Apcar Spring outflow at a time when blue tilapia had switched diet but native fishes had not yet been extirpated. We were thus able to implicate blue tilapia piscivory as a contributor to native fish decline.

The high number of fish taken in the Apcar Spring outflow was not an artifact of rotenone application (i.e., blue tilapia taking dead and dying fish). First, with the application of rotenone, blue tilapia moved immediately to the water surface, gasping for air, with no indication of their preying on fish (James Heinrich personal communication). Second, many of the prey fish were in an advanced stage of digestion, indicating they had been taken before treatment. Lastly, blue tilapia seined from the Muddy River had also consumed fish, which was surprising since, other than blue tilapia and shortfin mollies, native fish were extremely rare when the Warm Springs area was snorkeled in February 2000 (James Harvey personal communication).

Blue tilapia has proven to be similar to Mozambique tilapia (*Oreochromis mossambicus*) in dietary plasticity (Maitipe and De Silva 1985) and ability to tolerate a broader range of temperature (Stauffer et al. 1988) than most tilapia. Since its introduction to the Muddy River system, it has spread from the warm water of the Muddy to seasonally cool waters of Lake Mead and the Virgin River (James Heinrich personal communication). Thus, its potential to spread into North American waters is greater than once believed. This study supports the suggestion that blue tilapia has had a detrimental effect in North American waters and the recommendation that its introduction and spread should be discouraged and existing populations extirpated whenever possible.

We thank Cynthia Martinez of the U.S. Fish and Wildlife Service for funding the project. Specimens were collected by M. Franz, S. Goodchild, J. Heinrich, and S. Reinbold. We also thank Tom Strekal, Walter T. Courtenay, Jr., Kristin Swaim, Misty Johnson, and Mark Fabes for reviewing the manuscript.

LITERATURE CITED

COSTA-PIERCE, B.A., AND R. RIEDEL. 2000. Fisheries ecology of the tilapias in subtropical lakes of the United States. Pages 1–20 *in* B.A. Costa-Pierce and J.E.

Rakocy, editors, Tilapia aquaculture in the Americas. Volume 2. World Aquaculture Society, Baton Rouge, LA.

COURTENAY, W.R., JR., AND C.R. ROBINS. 1973. Exotic aquatic organisms in Florida with emphasis on fishes: a review and recommendations. Transactions of the American Fisheries Society 102:1–12.

CROSS, J.N. 1976. Status of the native fish fauna of the Moapa River (Clark County, Nevada). Transactions of the American Fisheries Society 105:503–524.

DEACON, J.E., AND W.G. BRADLEY. 1972. Ecological distribution of fishes of Moapa (Muddy) River in Clark County, Nevada. Transactions of the American Fisheries Society 101:408–419.

DILL, W.A., AND A.J. CORDONE. 1997. History and status of introduced fishes in California. Fish Bulletin 178, Department of Fish and Game, State of California Resources Agency, Sacramento.

FULLER, P.L., L.G. NICO, AND J.D. WILLIAMS. 1999. Nonindigenous fishes introduced into inland waters of the United States. American Fisheries Society Special Publication 27, Bethesda, MD.

GU, B., C.L. SCHELSKE, AND M.V. HOYER. 1997. Intrapopulation feeding diversity in blue tilapia: evidence from stable-isotope analyses. Ecology 78:2263–2266.

HOFER, R., AND F. SCHIEMER. 1981. Proteolytic activity in the digestive tract of several species of fish with different feeding habits. Oecologia 48:342–345.

HUBBS, C., AND J.E. DEACON. 1964. Additional introductions of tropical fishes into southern Nevada. Southwestern Naturalist 9:249–251.

HUBBS, C.L., AND R.R. MILLER. 1948. Two relict genera of cyprinid fishes from Nevada. University of Michigan Museum of Zoology Occasional Papers 507:1–30.

MAITIPE, P., AND S.S. DE SILVA. 1985. Switches between zoophagy, phytophagy, and detritivory of *Sarotherodon mossambicus* (Peters) populations in twelve man-made Sri Lankan lakes. Journal of Fish Biology 26: 49–61.

MOYLE, P.B. 2002. Inland fishes of California. University of California Press, Berkeley.

ROHLF, F.J., AND R.R. SOKAL. 1995. Statistical tables. 3rd edition. W.H. Freeman and Company, Stony Brook, NY.

SCOPPETTONE, G.G. 1993. Interactions between native and nonnative fishes of the upper Muddy River, Nevada. Transaction of the American Fisheries Society 122: 599–608.

SCOPPETTONE, G.G., H.L. BURGE, AND P.L. TUTTLE. 1992. Life history, abundance, and distribution of Moapa dace (*Moapa coriacea*). Great Basin Naturalist 52: 216–225.

SCOPPETTONE, G.G., P.H. RISSLER, M.B. NIELSEN, AND J.E. HARVEY. 1998. The status of *Moapa coriacea* and *Gila seminuda* and status information on other fishes of the Muddy River, Clark County, Nevada. Southwestern Naturalist 43:115–122.

SPATARU, P., AND M. ZORN. 1978. Food and feeding habits of *Tilapia aurea* (Steindachner) (Cichlidae) in Lake Kinneret (Israel). Aquaculture 13:67–79.

STAUFFER, J.R., JR., S.E. BOLTZ, AND J.M. BOLTZ. 1988. Cold shock susceptibility of blue tilapia from Susquehanna River, Pennsylvania. North American Journal of Fisheries Management 8:329–332.

WINDELL, J.T. 1971. Food analysis and rate of digestion. Pages 215–226 *in* W.E. Ricker, editor, Methods for assessment of production in fresh waters. IBP Handbook 3. Blackwell Scientific Publications, Oxford and Edinburgh, UK.

Received 3 February 2004
Accepted 15 November 2004

FIRST AMENDMENT
TO
MOAPA TRANSMISSION SYSTEM
DESIGN, CONSTRUCTION, OPERATION AND MAINTENANCE
AGREEMENT

This First Amendment to the Moapa Transmission System Design, Construction, Operation and Maintenance Agreement ("Amendment") is entered into this 16th day of July, 2015, ("Execution Date") by and between the Moapa Valley Water District ("MVWD"), a political subdivision of the State of Nevada created by Chapter 477, Statutes of Nevada 1983, and the Southern Nevada Water Authority ("SNWA"), a political subdivision of the State of Nevada and a joint powers authority created on July 25, 1991, through a Cooperative Agreement entered into pursuant to Nevada Revised Statutes Chapter 277. MVWD and SNWA are sometimes herein collectively referred to as the "Parties" or individually as a "Party." Capitalized terms in this Amendment shall have the same meaning as defined in the August 20, 2009, Moapa Transmission System Design, Construction, Operation, and Maintenance Agreement.

RECITALS

A. On August 20, 2009, the Parties entered into the Moapa Transmission System Design, Construction, Operation, and Maintenance Agreement ("Agreement"). The Agreement delineates the ownership, design, construction, operational, and maintenance responsibilities of the Parties with regard to the Moapa Transmission System ("MTS"). The MTS treats and conveys groundwater from Coyote Spring Valley to MVWD's distribution system to facilitate the Order 1169 pump test and allow SNWA to convey the groundwater to Lake Mead.

B. The Order 1169 pump test began on November 15, 2010, and the Nevada State Engineer declared the pump test to be completed as of December 31, 2012, in Order 1169A. Although the pump test is complete, SNWA may continue to use the MTS as one part of its water resources portfolio, but there may be instances where SNWA does not need the MTS to operate on a full time basis.

C. Currently, the Agreement does not fully address the temporary suspension of operations and intermittent use of the MTS.

D. On April 20, 2006, SNWA, MVWD, CSI, the Moapa Band of Paiute Indians, and the United States Fish and Wildlife Service entered into a Memorandum of Agreement ("2006 MOA") regarding protection of the Moapa Dace and development of groundwater in and around the Coyote Spring Valley hydrographic basin. In the 2006 MOA, SNWA agreed to transfer 724 acre-feet per year ("afy") from Permit No. 49414 to MVWD to effectuate the dedication of in-stream flows in the Apcar Stream (a tributary of the Muddy River). In exchange, MVWD agreed to suspend diversion of MVWD's 724 acre-feet per year Jones Spring water right (Certificate No. 10060).

E. In the Agreement, "Substitute Water" is defined as 724 afy of Coyote Spring Valley groundwater from Permit No. 49414, which SNWA agreed to transfer to MVWD in the 2006 MOA to effectuate the dedication of in-stream flows in the Apcar Stream, to substitute for MVWD's suspension of utilization of its 724 afy Jones Spring water right.

F. Concurrently with execution of the 2006 MOA, MVWD entered into the Jones Spring Agreement with the Muddy Valley Irrigation Company and U.S. Fish and Wildlife Service. The Jones Spring Agreement provides that as long as MVWD is in full compliance with the

terms of the 2006 MOA, MVWD is able to resume use of Jones Spring water in the event Substitute Water from SNWA is unavailable or unusable to meet MVWD's municipal needs.

G. Currently, the Agreement does not address provision of Substitute Water in times when the MTS is not operating to produce Coyote Spring Valley groundwater for MVWD to use instead of MVWD's Jones Spring water right.

H. Due to the federal environmental permit requirements for the MTS and Coyote Spring Valley groundwater pumping, it is essential to the Parties that MVWD continue to refrain from diverting its Jones Spring water right, even in times when SNWA is unable to provide Substitute Water from Coyote Spring Valley.

I. The Parties intend to amend the Agreement to address temporary suspension of operations and intermittent use of the MTS, to allow for costs to be calculated on a fiscal year basis, and to add or clarify various other provisions in the Agreement.

NOW, THEREFORE, in consideration of the mutual promises and commitments described herein, the Parties agree as follows:

AGREEMENT

1. Section 1.38 is hereby deleted.

2. Section 1.39 is hereby deleted and replaced with the following Section 1.39:

> 1.39 "Year" means fiscal year, which begins on July 1st and ends on June 30th. It is the intent of the Parties that every time "Year" or "year" appears in the Agreement, it shall refer to a fiscal year and not a calendar year. Any reference to

the term "quarter" in this Agreement shall refer to a fiscal quarter (ie. July to September, October to December, January to March, April to June).

3. The fourth and fifth sentences in Section 4.2.1 of the Agreement are hereby deleted and replaced with the following sentences:

> Water entering the MVWD Distribution System will have a chlorine residual in the range of 0.2 mg/L to 1.0 mg/L. To monitor this, MVWD shall provide SNWA with chlorine residual readings taken once a month at the entry point to the MVWD 3MG Reservoir.

4. As described in Section 12.1 of the Agreement, the final repayment schedules for the SNWA Capital Facilities Costs and the MVWD Capital Facilities Costs are attached hereto and incorporated herein as Exhibit A to this Amendment.

5. The following sentence is hereby added to the end of Section 12.1.1:

> To the extent that the Parties owe each other payments for Annual Capital Facilities Costs for 2010, 2011, 2012, 2013, 2014, and 2015, the Parties hereby release each other from any obligation to pay any Annual Capital Facilities Costs for those years.

6. A new Section 12.1.3 is hereby added to the Agreement as follows:

> 12.1.3 In any year when SNWA conveys less than the full amount of Substitute Water through the MTS, SNWA shall be responsible for payment of 100% of the Parties' Annual Capital Facilities Costs.

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7. Section 12.3 is hereby deleted and replaced with the following Section 12.3:

12.3 Wheeling Fee. To the extent that a Wheeling Fee was due and payable for 2010, 2011, 2012, 2013, 2014, and 2015, MVWD hereby releases SNWA from any obligation to pay the Wheeling Fee for those years. No Wheeling Fee shall be paid by SNWA for the remaining term of this Agreement, as MVWD is being fully compensated by the other payments SNWA will make to MVWD pursuant to the terms of this Agreement.

8. The following three sentences are hereby added to Section 12.4 of the Agreement:

The Parties may agree during the annual meeting to adjust the first quarter payment of each Year to reflect payment for the invoice for additional funds due or a credit for the refund for overpayments in-lieu of a separate payment or refund. To the extent that the Parties owe each other additional payments for Annual O&M Costs for 2010, 2011, 2012, 2013, 2014, and 2015, the Parties hereby release each other from any obligation to pay any unpaid Annual O&M Costs for those years. In any year when SNWA conveys less than the full amount of Substitute Water through the MTS, SNWA shall pay 100% of the Parties' Annual O&M Costs which consist of the minimal maintenance costs necessary to keep facilities ready for future start up.

9. Section 13 of the Agreement is hereby deleted and replaced with the following Section 13:

13. Annual Meeting of the Parties. On or before March 15 of each year this Agreement is in effect, the Parties shall meet to discuss operation and maintenance of the Project for the coming year, including whether any water will be conveyed through the Project. Both Parties should also be prepared to discuss whether they anticipate needing to convey water through the Project anytime during the next five years. No later than 10 business days before the Annual

Meeting, each Party shall provide the other with its estimate of water deliveries for the coming year, if any; estimated quarterly and Annual O&M Costs; estimated funding needs for the O&M Emergency Reserve Funds (as defined in Section 16.1); and other information concerning the Project to ensure the Project is operated to the benefit of both Parties.

10. Section 16 of the Agreement is hereby deleted and replaced with the following Section 16:

16. Emergency Repair and Response. The Parties shall develop an Emergency Preparedness Plan for facilities each Party operates and maintains under this Agreement and shall make the plan available for review by the other Party. If an emergency occurs, each Party shall use its best efforts to deal with the emergency, make repairs, and to maintain or restore normal operations, and shall make every reasonable effort to contact the other Party to receive prior authorization for any needed emergency repairs and expenditures. If a Party is not available to authorize such emergency expenditures, the other Party may proceed without authorization, provided that that Party notifies the other Party within 24 hours of the occurrence and provided that the emergency expenditure is less than $10,000. Any emergency expenditure greater than $10,000 requires prior authorization by the other Party.

16.1 O&M Emergency Reserve Funds. The Parties shall establish and/or maintain their own O&M Emergency Reserve Funds to be used by the Parties only to fund emergency repairs when such repairs are needed to maintain or restore normal operations of Project facilities. At each Annual Meeting of the Parties held pursuant to Section 13, the Parties shall determine the yearly amount of funding to be contributed by the Parties to the O&M Emergency Reserve Funds.

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11. A new Section 28 is added to the Agreement as follows:

28. Jones Spring. Upon request by SNWA or for so long as the 2006 MOA or the federal environmental permit conditions for the MTS rights of way require it, MVWD agrees not to divert or use its Jones Spring water right (Certificate No. 10060) upstream of the Moapa gage. In any year when MVWD does not request the delivery of Substitute Water, and in exchange for MVWD's agreement not to use Jones Spring, SNWA agrees to pay MVWD $200,000 per year to cover MVWD's incremental costs of using other water sources instead of Jones Spring water or Substitute Water. The $200,000 per year payment also includes reimbursement to MVWD for performing the minimal maintenance necessary to keep the MTS facilities ready for future start up, as described on and attached hereto and incorporated herein as Exhibit B to this Amendment. MVWD agrees not to request delivery of Substitute Water before February 1, 2025, unless there is an unforeseen short term emergency need due to temporary constraints in the MVWD Distribution System. Each time MVWD requests delivery of Substitute Water a $50,000 start-up charge will be deducted from the $200,000 payment. Additionally, the $200,000 payment will be decreased by a pro-rated amount during any temporary emergency provision of Substitute Water based on the percentage of Substitute Water provided. For example, if 362 acre-feet of Substitute Water (50% of the 724 acre-feet) is delivered to MVWD, SNWA would pay MVWD $100,000 (50% of the $200,000 fee), less the $50,000 start-up charge. After February 1, 2025, MVWD may choose to request delivery of Substitute Water instead of receiving the $200,000 per year payment from SNWA. The first $200,000 payment will be made no later than 30 days after the Execution Date

of this Amendment. Future payments will be made before the new fiscal year begins, no later than June 30th of each year.

12. A new Section 29 is added to the Agreement as follows:

29. SNWA Reserved Capacity in MVWD Distribution System. While MVWD still agrees to accept 6,200 gpm (8.9 mgd) of SNWA Coyote Spring Groundwater into the MVWD Distribution System, based on the current capacity of the pump in the MX-5 well, SNWA currently may convey only 3,750 gpm (5.4 mgd) to the MVWD Distribution System. SNWA agrees that it will not use more than 3,750 gpm (5.4 mgd) of capacity in the MVWD Distribution System unless SNWA gives MVWD a minimum of two years prior notice. MVWD may issue new water commitments without regard to SNWA's reservation of 6,200 gpm (8.9 mgd) but will not issue new water commitments that would interfere with SNWA's ability to convey 3,750 gpm (5.4 mgd). Upon notice that SNWA intends to convey more than 3,750 gpm (5.4 mgd), the Parties will negotiate a separate agreement regarding provision of capacity to SNWA and how costs will be shared, if any new costs are necessary. In the event MVWD finds that the MVWD Distribution System capacity will need to be increased to accommodate both the actual demands of MVWD customers and SNWA's 3,750 gpm (5.4 mgd), MVWD will give SNWA two years prior written notice of the need for the capacity increase. At that time, the Parties will decide how best to increase the capacity in the MVWD Distribution System. However, rather than share in the cost to increase MVWD Distribution System Capacity, SNWA may choose, in its sole and absolute discretion, to reduce the amount of SNWA Coyote Spring Groundwater conveyed through the MVWD Distribution System.

13. Nothing in this Amendment shall be construed to amend the terms of the Jones Spring Agreement in any way, including but not limited to, MVWD's ability to resume use of Jones Spring as provided in the Jones Spring Agreement.

14. All other terms of the Agreement remain in full force and effect.

IN WITNESS HEREOF, each of the Parties has executed this Amendment as of the date and year first above written.

MOAPA VALLEY WATER DISTRICT

Joseph Davis, General Manager

Approved as to form:

Byron Mills, Esq., Counsel for MVWD

SOUTHERN NEVADA WATER AUTHORITY

John J. Entsminger, General Manager

Approved as to form:

Dana R. Walsh, Director of Legal Services

Moapa Transmission System - MVWD Capital Costs
25 Year Repayment Schedule

Capital Facilities Costs	$ 732,156.26
Interest and Finance Fees	5.20%
Payback Period in Years	25

Year	Interest	Principal	Annual Payment	Remaining Balance
1	$ 38,072.13	$ 14,922.34	$ 52,994.47	$ 717,233.92
2	$ 37,296.16	$ 15,698.31	$ 52,994.47	$ 701,535.61
3	$ 36,479.85	$ 16,514.62	$ 52,994.47	$ 685,020.99
4	$ 35,621.09	$ 17,373.38	$ 52,994.47	$ 667,647.61
5	$ 34,717.68	$ 18,276.79	$ 52,994.47	$ 649,370.82
6	$ 33,767.28	$ 19,227.19	$ 52,994.47	$ 630,143.63
7	$ 32,767.47	$ 20,227.00	$ 52,994.47	$ 609,916.63
8	$ 31,715.66	$ 21,278.81	$ 52,994.47	$ 588,637.83
9	$ 30,609.17	$ 22,385.30	$ 52,994.47	$ 566,252.52
10	$ 29,445.13	$ 23,549.34	$ 52,994.47	$ 542,703.18
11	$ 28,220.57	$ 24,773.90	$ 52,994.47	$ 517,929.28
12	$ 26,932.32	$ 26,062.15	$ 52,994.47	$ 491,867.13
13	$ 25,577.09	$ 27,417.38	$ 52,994.47	$ 464,449.75
14	$ 24,151.39	$ 28,843.08	$ 52,994.47	$ 435,606.67
15	$ 22,651.55	$ 30,342.92	$ 52,994.47	$ 405,263.75
16	$ 21,073.71	$ 31,920.75	$ 52,994.47	$ 373,342.99
17	$ 19,413.84	$ 33,580.63	$ 52,994.47	$ 339,762.36
18	$ 17,667.64	$ 35,326.83	$ 52,994.47	$ 304,435.53
19	$ 15,830.65	$ 37,163.82	$ 52,994.47	$ 267,271.71
20	$ 13,898.13	$ 39,096.34	$ 52,994.47	$ 228,175.37
21	$ 11,865.12	$ 41,129.35	$ 52,994.47	$ 187,046.02
22	$ 9,726.39	$ 43,268.08	$ 52,994.47	$ 143,777.94
23	$ 7,476.45	$ 45,518.02	$ 52,994.47	$ 98,259.93
24	$ 5,109.52	$ 47,884.95	$ 52,994.47	$ 50,374.97
25	$ 2,619.50	$ 50,374.97	$ 52,994.47	$ -
Total	$ 592,705.49	$ 732,156.26	$ 1,324,861.75	

SNWA

Moapa Transmission System - SNWA Capital Costs

25 Year Repayment Schedule

Capital Facilities Costs	$52,208,659
Interest and Finance Fees	5.20%
Payback Period in Years	25

Year	Interest ($)	Principal ($)	Annual Payment ($)	Remaining Balance ($)
1	2,714,850.27	1,064,083.76	3,778,934.03	51,144,575.24
2	2,659,517.91	1,119,416.11	3,778,934.03	50,025,159.13
3	2,601,308.27	1,177,625.75	3,778,934.03	48,847,533.37
4	2,540,071.74	1,238,862.29	3,778,934.03	47,608,671.08
5	2,475,650.90	1,303,283.13	3,778,934.03	46,305,387.95
6	2,407,880.17	1,371,053.85	3,778,934.03	44,934,334.10
7	2,336,585.37	1,442,348.65	3,778,934.03	43,491,985.45
8	2,261,583.24	1,517,350.78	3,778,934.03	41,974,634.66
9	2,182,681.00	1,596,253.02	3,778,934.03	40,378,381.64
10	2,099,675.85	1,679,258.18	3,778,934.03	38,699,123.46
11	2,012,354.42	1,766,579.61	3,778,934.03	36,932,543.85
12	1,920,492.28	1,858,441.75	3,778,934.03	35,074,102.10
13	1,823,853.31	1,955,080.72	3,778,934.03	33,119,021.39
14	1,722,189.11	2,056,744.91	3,778,934.03	31,062,276.47
15	1,615,238.38	2,163,695.65	3,778,934.03	28,898,580.82
16	1,502,726.20	2,276,207.82	3,778,934.03	26,622,373.00
17	1,384,363.40	2,394,570.63	3,778,934.03	24,227,802.37
18	1,259,845.72	2,519,088.30	3,778,934.03	21,708,714.06
19	1,128,853.13	2,650,080.90	3,778,934.03	19,058,633.17
20	991,048.92	2,787,885.10	3,778,934.03	16,270,748.06
21	846,078.90	2,932,855.13	3,778,934.03	13,337,892.94
22	693,570.43	3,085,363.59	3,778,934.03	10,252,529.34
23	533,131.53	3,245,802.50	3,778,934.03	7,006,726.84
24	364,349.80	3,414,584.23	3,778,934.03	3,592,142.61
25	186,791.42	3,592,142.61	3,778,934.03	0.00
Total	42,264,691.67	52,208,659.00	94,473,350.67	

EXHIBIT B

The following are the types of minimal maintenance activities MVWD agrees to perform in order to keep the MTS ready for future start up:

- Upkeep of electrical power to the site
- Upkeep of the fire protection system with water in the regulating tank or with Fire Department approval to disconnect
- Rodent protection
- Vandalism protection
- Pumping the well to waste on a regular basis

Preliminary Analysis of Effects of Reduced Discharge on Thermal Habitat of Pedersen Warm Springs Channel

Moapa Valley National Wildlife Refuge
Clark County, Nevada

Provisional Draft

Prepared for:

U.S. Department of Interior
U.S. Fish and Wildlife Service
Las Vegas, Nevada

Prepared by:

James T. Brock
Desert Research Institute
Reno, Nevada 89512

25 October 2004

Cover Image Courtesy of Otis Bay Environmental Consultants

Note: This preliminary report is intended to document progress and serve as a basis for discussion with staff at USFWS. In subsequent drafts the report text will be augmented and expanded. The data and results presented herein are provisional and subject to revision. The stream temperature model simulations have been completed but input has yet to double checked for accuracy. This working draft is provisional and should not be circulated externally in its present form.

Please contact me (jbrock@dri.edu or 208-395-0395) if there are questions related to usage or interpretation.

Jim Brock
25 Oct 2004

Introduction

The upper Muddy River (Clark County, Nevada) and tributary thermal spring systems are inhabited by several rare, endemic species including the Moapa dace (*Moapa coriacea*). Successful reproduction of Moapa dace has only been found in waters with a temperature range of 30-32° C, conditions which are limited to the upper reaches of five spring systems located in the Warm Springs area of Moapa Valley near Glendale, Nevada (Scoppetone et al. 1992). The Moapa Dace is Federally-listed as an endangered species, and a recovery plan stresses habitat alteration, predation by non-native fish, and flow reduction as factors that have adversely impacted survival of Moapa Dace populations (USFWS 1996).

The potential impacts of possible flow reductions in these thermal spring systems on Moapa dace and other aquatic species provided the impetus for the current study. Concern has been raised that regional ground water levels may be impacted by proposed expansion of groundwater pumping from wells. A lowered groundwater table could influence flows emanating from the thermal springs that create the Moapa dace's habitat (citation?).

The objectives of this study were to:

1) Calibrate and apply a water temperature model to a thermal spring channel known to provide suitable habitat for Moapa Dace.

2) Simulate water temperature conditions and characterize the thermal regime under scenarios of future flow conditions.

This report presents the initial results of monitoring and simulation modeling of water temperature for the Pedersen Warm Springs channel. Additional data collection is ongoing and subsequent analysis and simulation is planned once an entire year of data are available.

Study Site and Data Collection

A thermal spring system with one of the largest extant populations of Moapa dace is the Plummer - Pedersen (also spelled Pederson) warm springs complex, which originates on public land on the Moapa Valley National Wildlife Refuge (NWR). The Pedersen-Plummer springs complex was formerly operated as a "Warm Springs Resort" during which time the natural pools were enlarged and altered to create public bathing pools. Since acquiring the property in 19XX, the USFWS has been rehabilitating the channel in an effort to provide more natural habitat for the Moapa dace and other biota.

The Pedersen thermal spring system consists of several spring sources that emanate in close proximity to one another and combine to form a discrete channel with a flow of about 100 l/min (3.6 cfs). Pools are present at several of the spring sources and the two largest (Pedersen and Pedersen East) are equipped with weirs and level recording equipment maintained by USGS (see Table 1 for gage information). After

flowing northeast about 350 m the main Pedersen spring channel drops through a flume before entering a culvert that conveys it under Warm Springs Road. The slope of the channel within the Refuge is 0.033 m/m, with a drop of several meters occurring at a concrete-lined cascade that was constructed to obstruct passage of tilapia (non-native predators of Moapa dace).

Table 1. USGS Gaging Stations at Moapa Valley National Wildlife Refuge. Coordinates still to be entered.

USGS Station ID	Name	Latitude	Longitude
09415908	Pederson East Spring Near Moapa, Nevada		
09415910	Pederson Spring Near Moapa, Nevada		
09415920	Warm Springs West Near Moapa, Nevada		

Stream water temperature is most accurately simulated using numerical models when heat flux at the model boundaries is well quantified. Quantifying flow and temperature of thermal spring systems can be difficult, when, as is typically the case, there are numerous spring sources, including seepage of groundwater directly into the channel. Following an initial reconnaissance of the channel using a temperature and specific conductance probe, we selected a 220-m long segment of the Pedersen channel where there appeared to be minimal net accrual or loss of groundwater. Points for temperature monitoring were established and marked with rebar at eight points on the main channel as depicted in Figure 1.

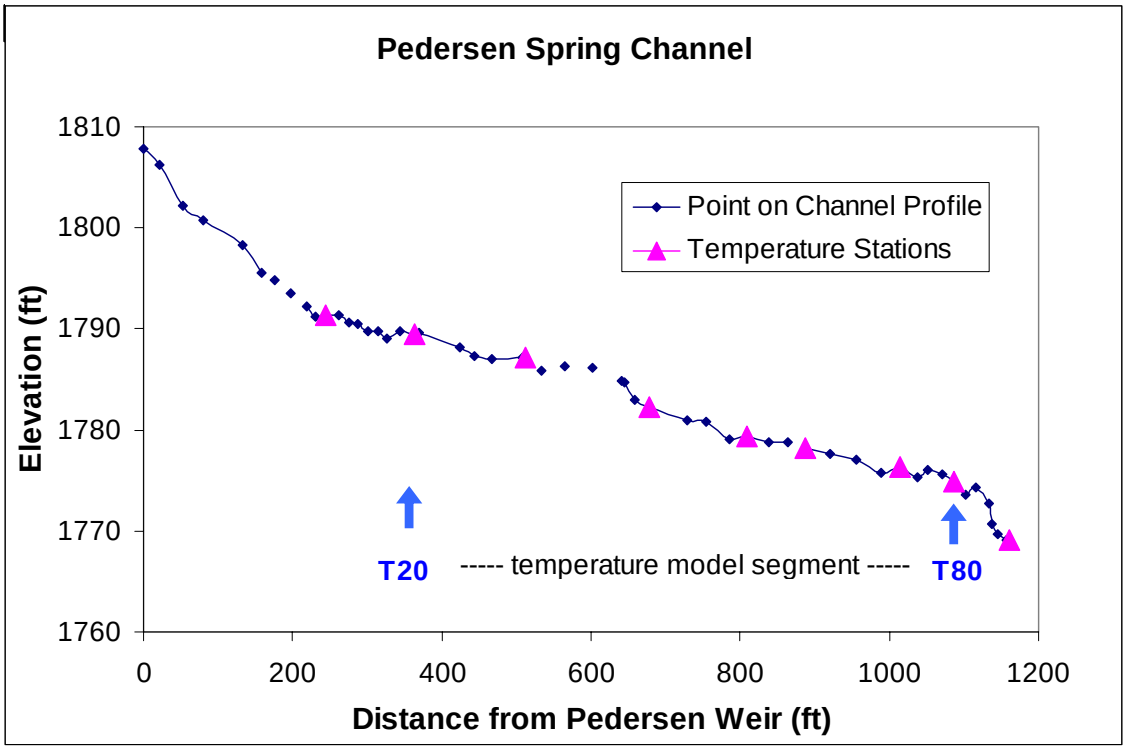

Figure 1. Longitudinal profile of Pedersen Spring Channel.

Figure 2 Aerial image of Moapa Valley Wildlife Refuge showing temperature monitoring stations on Pedersen Spring channel. Note: this image will be redone to incease font size and correct fuzziness.

Instantaneous measurements of water temperature were made using a YSI 600XL multiparameter sonde (accuracy +/- 0.15 °C). The sonde was also used to determine specific conductance. Water temperature was measured and logged on an hourly basis at four locations (T20, T30, T50, and T80) using Model 107 thermistors and either CR500 or CR10x data loggers (Campbell Scientific Inc).

Local meteorologic conditions were measured with sensors mounted on a tripod 1.5 m off the ground and 3 m from the spring channel at Station T30. Constituents included short wave radiation (Li-Cor Model LI200X), wind speed (RM Young Wing Sentry Anemometer), and air temperature/relative humidity (Vaisala HMP45C temperature/RH probe with self-aspirating radiation shield).

Meteorologic data were available as well from an ET station operated by USGS USGS on the Muddy River approximately _ km from the Pedersen Spring Channel (Muddy River Springs site latitude 36^{o} 41' 27''N, longitude 114^{o} 41' 16" W approximately 503 m (1650 ft) above sea level). Measurements from the lower (4 m) set of sensors (0.5 m above mesquite trees) included air and soil temperature, net irradiance, relative humidity, and wind speed (Guy DeMeo, Nevada District, written communication).

Supplemental shortwave irradiance data were obtained from the Desert Rock, Nevada SURFRAD station operated by NOAA (site latitude 36° 63' N, longitude 116°02' elevation 1007 m).

Figure 3. Meteorologic station at location T30.

The Stream Segment Temperature Model (SSTEMP; Bartholow 2002) was calibrated to the 220-m long segment of the Pedersen Spring channel between T20 and T80. Based on inputs of meteorology, stream geometery, riparian shading, and hydrology, SSTEMP simulates downstream water temperature in a discrete segment of a flowing stream channel over a 24-hr day. The program functions in steady state, and assumes that all inputs are mean daily values and are representative for the homogeneous segment modeled. SSTEMP simulates the various heat flux processes that determine temperature change. These physical processes include convection, conduction, evaporation, and flux (to and from the air) of short wave and longwave radiation. The SSTEMP model is based on the Stream Network Temperature Model (SNTEMP; Theurer et al. 1984).

Hydraulic characteristics of the Pedersen channel were obtained from a calibrated HEC RAS model (Otis Bay 2004). A channel profile was surveyed using a Topcon total station with control data obtained for the USGS gaging stations (Table 1).

Results

Discharge

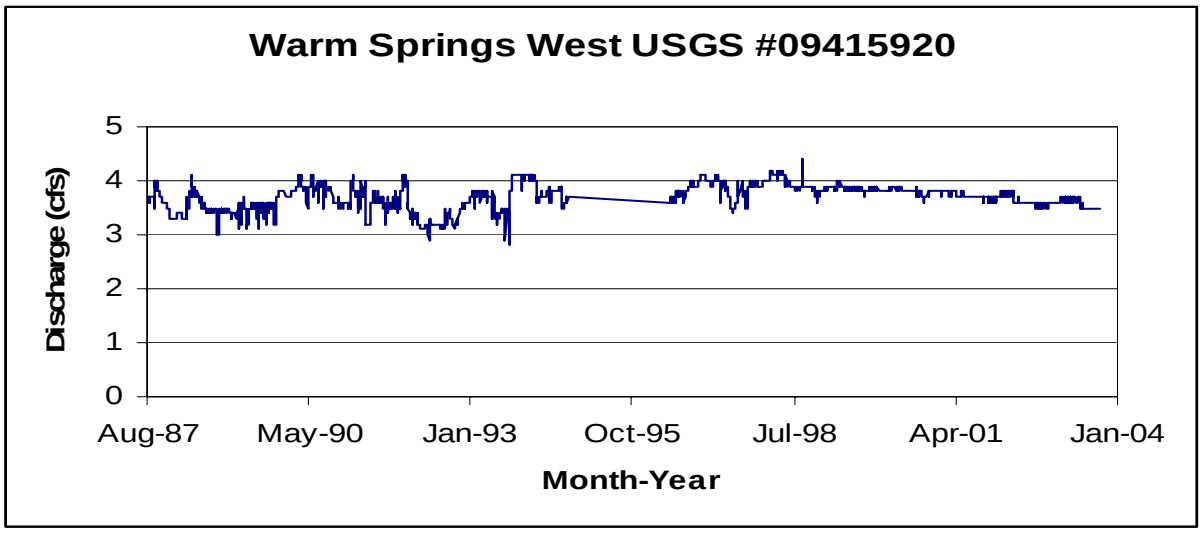

Figure 4. Discharge of Pedersen Spring Channel at Warm Springs West USGS Gage (#09415920)

Downstream Temperature Profiles.

Water temperature was measured at ten points on the channel profile from the Pedersen weir to the Warm Springs West flume (Table 2). In most cases the maximum water temperature occurred at location T20 (111 m) and consistently decreased downstream. The decreases downstream were relatively small and were maximum (0.7 C) during the coldest measurement period.

Table 2. Location of stations along channel with distance from Pedersen Spring weir

Description	DISTANCE (ft)	DISTANCE (m)	Notes
Pedersen Weir	0		
T10	244	75	
T20	364	111	Upstream Boundary of Temperature Model
T30	511	156	Weather Station
T40	677	206	
T50	810	247	
T60	887	270	
T70	1015	309	
T80	1087	331	Downstream Boundary of Temperature Model
flume	1161	354	

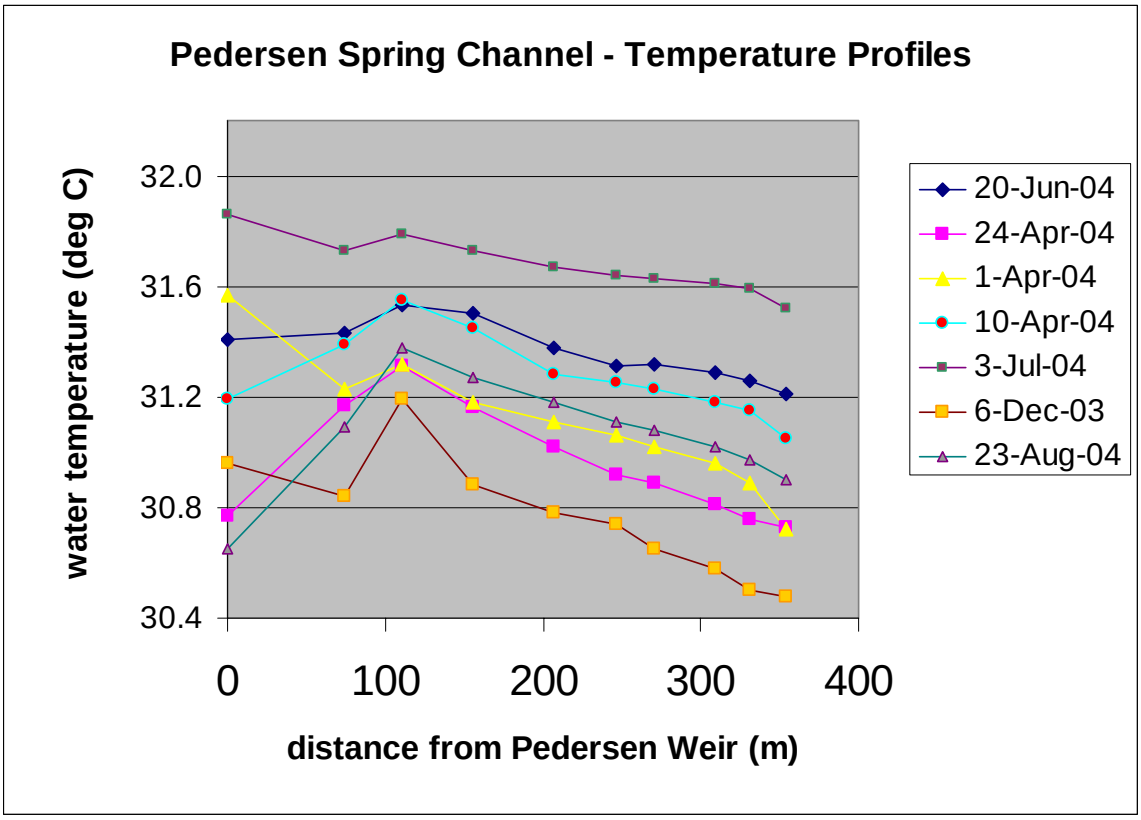

Figure 5. Temperature profiles of Pedersen Spring channel on 7 occasions (Dec 03 – Aug 04).

Meterology

A data record spanning an entire year was available for the Muddy River Springs ET site (30 July 2003 to 21 August 2004). Results for air temperature are given in Figure 6.

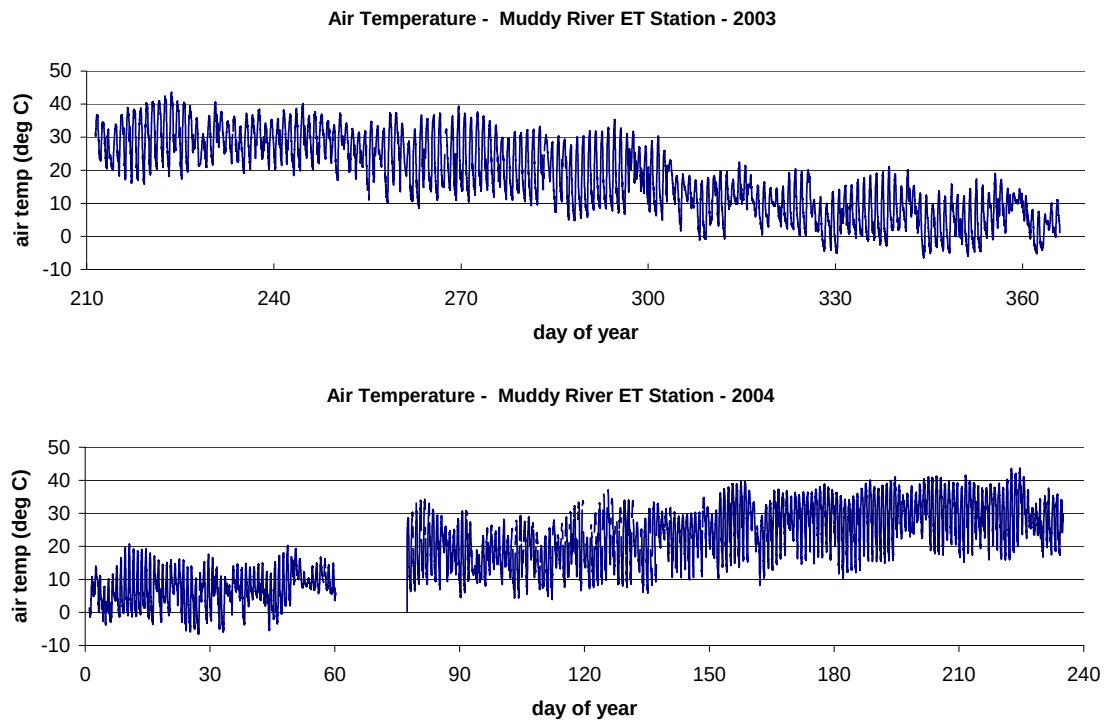

Figure 6. Air Temperature (4 m above ground) at Muddy River ET station. Provisional USGS Data.

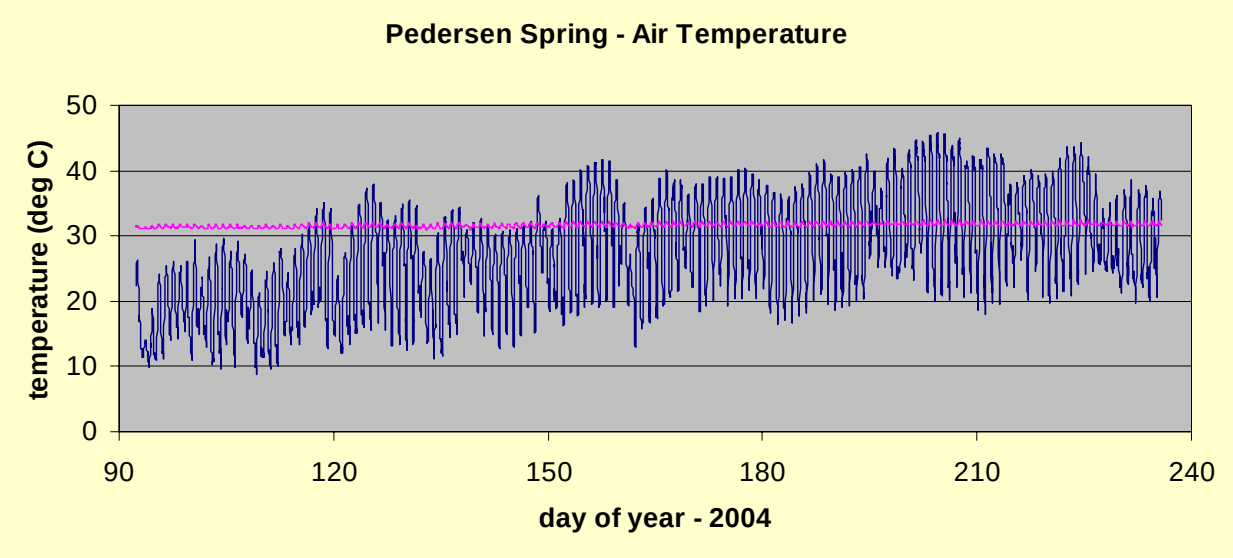

Figure 7. Air temperature (blue) and water temperature (pink) at Pedersen Spring T30 Station .

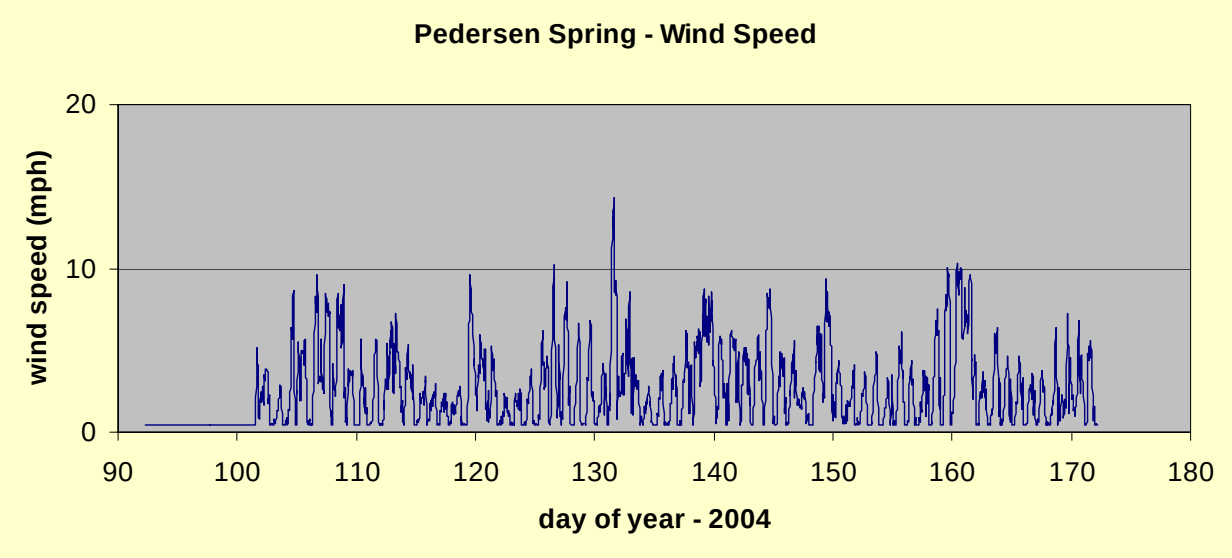

Figure 8. Wind speed at Pedersen Spring T30 Station.

The air temperature at the Pedersen T30 station is plotted against air temperature at the Muddy River Springs ET station (Figure 9). The Pedersen site tended to be slightly warmer than at Muddy River during the measurement period.

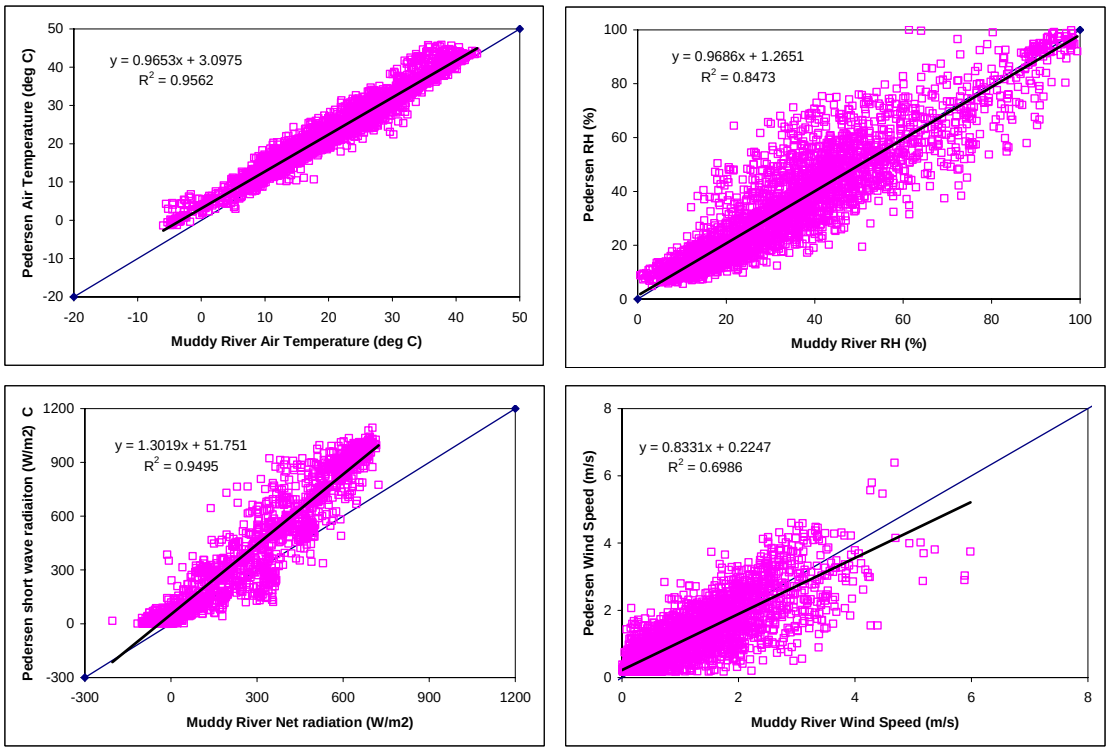

Figure 9. Correlation plots for Muddy River and Pedersen Station T30 for air temperature, wind speed, relative humidity and irradiance for data collected during period 6 – 16 2003 Dec and 1 Apr-21 Aug 2004.

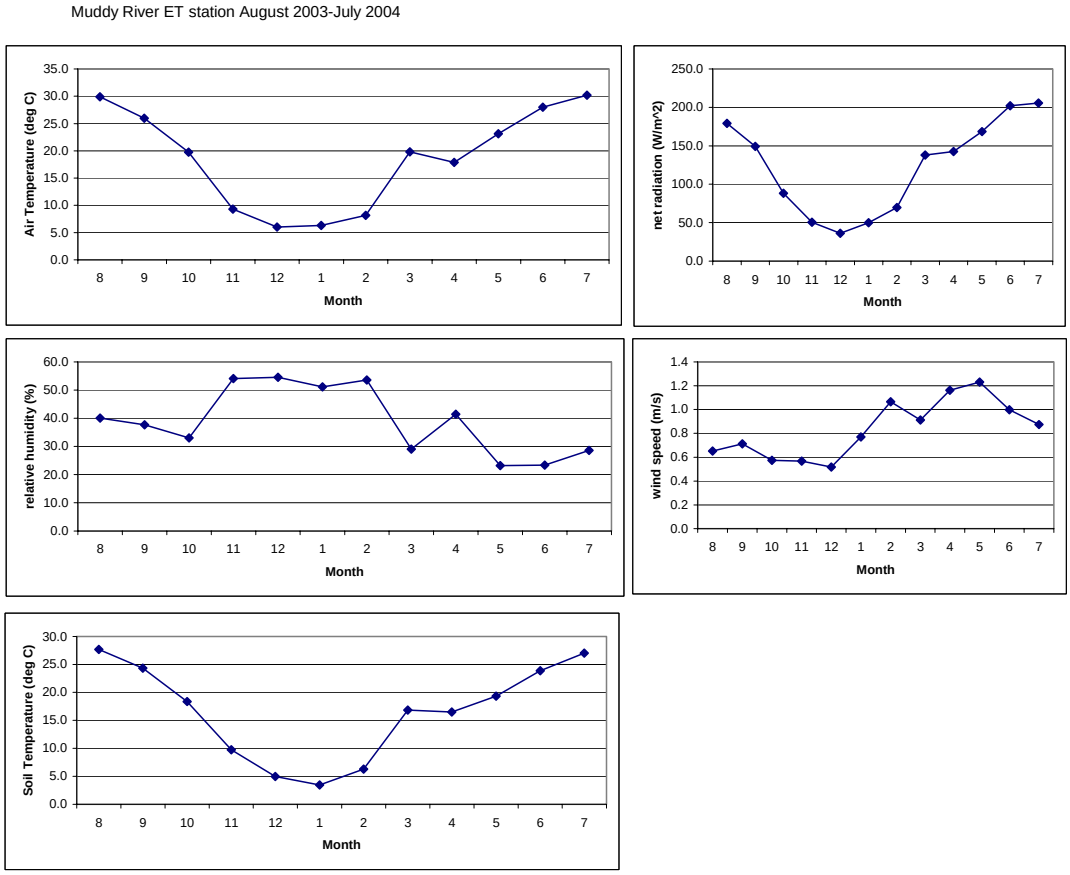

Figure 10. Monthly mean meteorologic conditions at Muddy River for period August 2003-July 2004. Source: USGS Provisional Data.

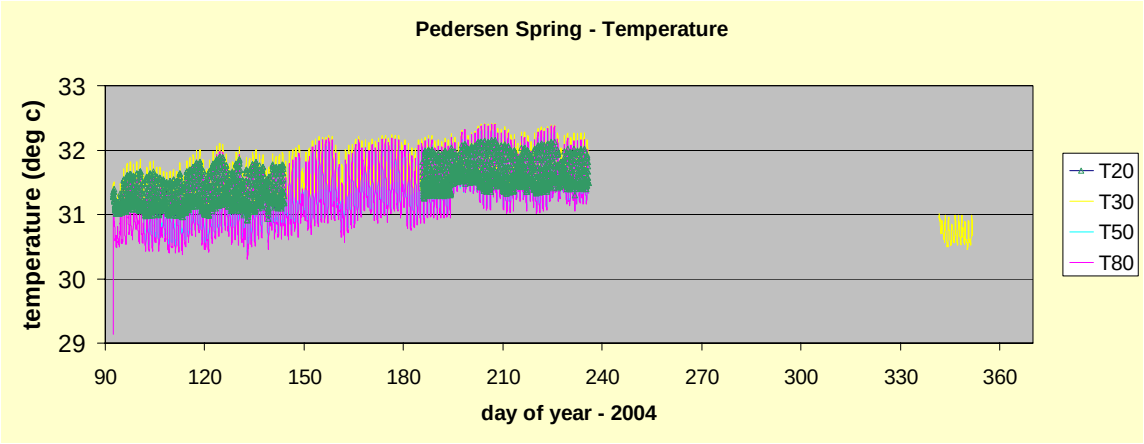

Figure 11. Pedersen Spring Channel temperature at stations T20, T30, T50 and T80.

The SSTEMP model simulates water temperature over a 24-hr day for a channel segment of homogeneous geometry. For this application of SSTEMP we selected a segment of the Pedersen Spring channel that is relatively homogeneous and lacks measurable accretion. The sources of input data used for the model are summarized in Table 3. A view of an example (in this case January) input screen for SSTEMP is provided in Figure 12.

Table 3 . Source of Input Data for SSTEMP Model for period August 2003-July 2004 of Pedersen Spring Channel Segment.

Category	Parameter	Description
Hydrology	Discharge	Discharge based on annual mean gage data for Warm Springs West station with additional assumed reductions based on scenarios
Geometry	Elevation Segment Length	field survey
	Mannings n and width hydraulic coefficients	HEC RAS results for pool (Otis Bay 2004)
Meteorology	Air temperature	Muddy River Springs mean monthly value adjusted for local conditions (see Table).
	Wind Speed, Relative Humidity, ground temperature	Muddy River Springs mean monthly value
	Short Wave Radiation	Desert Rock NOAA site
	Thermal Gradient	Used SSTEMP default
	Shade Factor	See Table

Table 4 Mean monthly air temperature at Muddy River Springs ET station with adjusted air temperature for conditions at Pedersen based on regression equation given in Figure 9.

Year	Month	Muddy River Mean (deg C)	Mean Adjusted to Pedersen (deg C)
2003	8	29.9	32.0
	9	26.0	28.2
	10	19.8	22.2
	11	9.3	12.1
	12	6.0	8.9
2004	1	6.3	9.2
	2	8.2	11.0
	3	19.8	22.2
	4	17.9	20.4
	5	23.1	25.4
	6	28.0	30.1
	7	30.2	32.2

Table 5 . Shade Factor used to attenuate unshaded solar radiation

Month	Shade Factor	Average SW Irradiance (Langleys/d)	Amount Transmitted to Water Surface (Langleys/d)
January	0.9	274	247
April	0.8	583	466
July	0.7	703	492
October	0.8	412	329

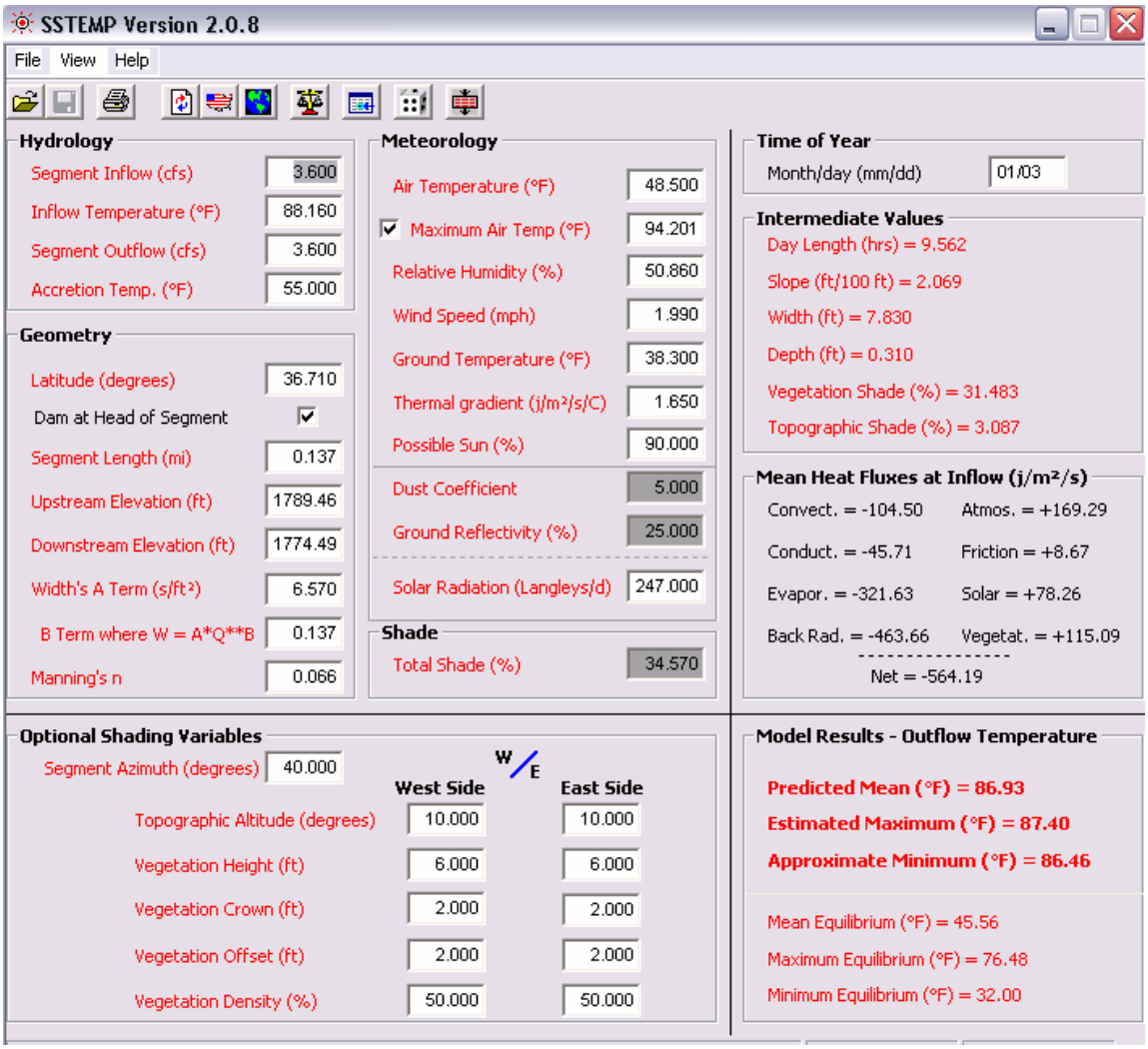

Figure 12 Screen Shot of SSTEMP model for simulation of January conditions of Pedersen Spring Channel.

Model Performance

The Pedersen Spring Segment SSTEMP model was calibrated to average conditions for the months January, April, July and October. These months were selected because they represented either typical (April and October) or extreme (January and July) temperatures for each season. Table 6 compares the simulated water temperature at the tail station (T80) of the modeled segment with the best available data that approximates observed conditions. The simulated temperatures for each season with available data are within 0.03 °C of the simulated value. A more rigorous assessment of closeness of fit between observed and simulated results will be possible once a full year of field data are collected. However, there is every indication that the water temperature simulation model is functioning as expected.

Table 6 . Observed compared with simulated values of water temperature at tail station (T80) of modeled Pedersen Spring Channel segment under full flow conditions (3.6 cfs).

Period	Observed instantaneous Temp (°C)	Simulated mean Temp (° C)
January (6 Dec 03)	30.50	30.52
April (1,24 Apr 04)	30.82	30.85
July (3 Jul 04)	31.59	31.62
October	-	30.79

Sensitivity Analysis

SSTEMP performs a standard sensitivity analysis in which the simulated temperature at the tail of the model segment is determined and compared with the original result based on a 10% increase or decrease in the magnitude of numerous variables. Results of the sensitivity analysis for January and July are presented in Figure 13. The variables that dominated the index of relative sensitivity were flow in and out of the segment and temperature of the inflow.

January

Sensitivity Analysis - SSTEMP (2.0.8)

Sensitivity for mean temperature values (10% variation) SSTEMP (2.0.8)
Original mean temperature = 30.52°C

Variable	Temperature change (°C) if variable is: Decreased	Increased	Relative Sensitivity
Segment Inflow (cms)	-0.03	+2.27	**********
Inflow Temperature (°C)	-2.98	+3.00	**********
Segment Outflow (cms)	+2.03	+0.03	**********
Accretion Temp. (°C)	0.00	0.00	
Width's A Term (s/m²)	+0.07	-0.07	*
B Term where W = A*Q**B	-0.02	+0.02	
Manning's n	0.00	0.00	
Air Temperature (°C)	-0.01	+0.01	
Relative Humidity (%)	-0.01	+0.01	
Wind Speed (mps)	+0.01	-0.01	
Ground Temperature (°C)	0.00	+0.00	
Thermal gradient (j/m²/s/C)	+0.01	-0.01	
Possible Sun (%)	+0.00	0.00	
Solar Radiation (j/m²/s)	-0.01	+0.01	
Segment Azimuth (radians)	+0.00	0.00	
West Side:			
Topographic Altitude (radians)	0.00	0.00	
Vegetation Height (m)	0.00	0.00	
Vegetation Crown (m)	0.00	0.00	
Vegetation Offset (m)	0.00	0.00	
Vegetation Density (%)	0.00	0.00	
East Side:			
Topographic Altitude (radians)	0.00	0.00	
Vegetation Height (m)	+0.00	0.00	
Vegetation Crown (m)	0.00	0.00	
Vegetation Offset (m)	0.00	+0.00	
Vegetation Density (%)	+0.00	0.00	
Maximum Air Temp (°C)	0.00	0.00	

July

Sensitivity Analysis - SSTEMP (2.0.8)

Sensitivity for mean temperature values (10% variation) SSTEMP (2.0.8)
Original mean temperature = 31.62°C

Variable	Temperature change (°C) if variable is: Decreased	Increased	Relative Sensitivity
Segment Inflow (cms)	-0.01	+2.33	**********
Inflow Temperature (°C)	-3.03	+3.05	**********
Segment Outflow (cms)	+2.13	+0.01	**********
Accretion Temp. (°C)	0.00	0.00	
Width's A Term (s/m²)	+0.02	-0.02	
B Term where W = A*Q**B	-0.01	+0.01	
Manning's n	0.00	0.00	
Air Temperature (°C)	-0.08	+0.07	*
Relative Humidity (%)	-0.02	+0.02	
Wind Speed (mps)	+0.01	-0.01	
Ground Temperature (°C)	-0.01	+0.01	
Thermal gradient (j/m²/s/C)	+0.00	0.00	
Possible Sun (%)	+0.00	0.00	
Solar Radiation (j/m²/s)	-0.02	+0.02	
Segment Azimuth (radians)	0.00	+0.00	
West Side:			
Topographic Altitude (radians)	+0.00	0.00	
Vegetation Height (m)	+0.00	0.00	
Vegetation Crown (m)	+0.00	0.00	
Vegetation Offset (m)	0.00	+0.00	
Vegetation Density (%)	+0.00	0.00	
East Side:			
Topographic Altitude (radians)	0.00	0.00	
Vegetation Height (m)	+0.00	0.00	
Vegetation Crown (m)	+0.00	0.00	
Vegetation Offset (m)	0.00	+0.00	
Vegetation Density (%)	+0.00	0.00	
Maximum Air Temp (°C)	0.00	0.00	

Figure 13. Sensitivity analysis results of SSTEMP for January and July conditions

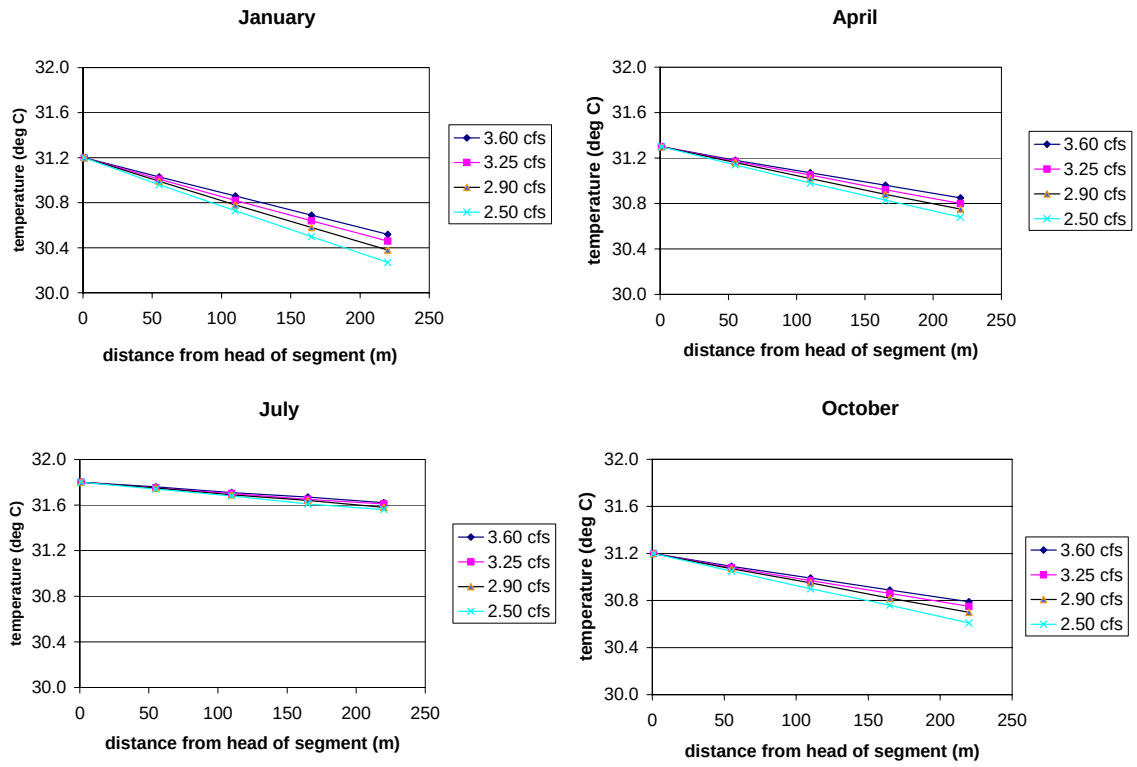

Figure 14. Results of SSTEMP simulations of Pedersen Spring Channel water temperature.

Table 6.

Table . Summary of SSTEMP simulations of mean monthly water temperature for Pedersen Spring channel segment

January

flow reduction (%)	67	30	20	10	0
cms	0.034	0.071	0.082	0.092	0.102
cfs	1.20	2.51	2.90	3.25	3.60

Distance (m)	Mean Temperature (deg C)				
1	31.19	31.20	31.20	31.20	31.20
55	30.75	30.96	30.99	31.01	31.03
110	30.32	30.73	30.78	30.82	30.86
165	29.89	30.50	30.58	30.64	30.69
220	29.47	30.27	30.38	30.46	30.52

April

flow reduction (%)	67	30	20	10	0
cms	0.034	0.071	0.082	0.092	0.102
cfs	1.20	2.51	2.90	3.25	3.60

Distance (m)	Mean Temperature (deg C)				
1	31.29	31.30	31.30	31.30	31.30
55	31.00	31.14	31.16	31.17	31.18
110	30.70	30.98	31.02	31.05	31.07
165	30.42	30.83	30.88	30.92	30.96
220	30.14	30.68	30.75	30.80	30.85

July

flow reduction (%)	67	30	20	10	0
cms	0.034	0.071	0.082	0.092	0.102
cfs	1.20	2.51	2.90	3.25	3.60

Distance (m)	Mean Temperature (deg C)				
1	31.80	31.80	31.80	31.80	31.80
55	31.68	31.74	31.75	31.75	31.76
110	31.56	31.68	31.69	31.70	31.71
165	31.45	31.61	31.64	31.65	31.67
220	31.33	31.56	31.58	31.61	31.62

October

flow reduction (%)	67	30	20	10	0
cms	0.034	0.071	0.082	0.092	0.102
cfs	1.20	2.51	2.90	3.25	3.60

Distance (m)	Mean Temperature (deg C)				
1	31.19	31.20	31.20	31.20	31.20
55	30.93	31.05	31.07	31.08	31.09
110	30.66	30.90	30.95	30.97	30.99
165	30.40	30.76	30.82	30.86	30.89
220	30.14	30.61	30.70	30.75	30.79

Table 7. SSTEMP simulation results for water temperature as a function of distance from head of modeled segment for four flow scenarios. Boxes highlight conditions with similar temperatures.

flow (cfs)	3.60	3.25	2.90	2.50
% reduction	0.00	10.00	20.00	30.00
Distance from head of segment	Water Temp (deg C)			
0	31.20	31.20	31.20	31.20
10	31.17	31.16	31.16	31.16
20	31.14	31.13	31.12	31.12
30	31.11	31.10	31.09	31.07
40	31.08	31.06	31.05	31.03
50	31.05	31.03	31.01	30.99
60	31.02	30.99	30.98	30.95
70	30.99	30.96	30.94	30.91
80	30.95	30.93	30.90	30.86
90	30.92	30.89	30.87	30.82
100	30.89	30.86	30.83	30.78
110	30.86	30.82	30.79	30.74
120	30.83	30.79	30.75	30.70
130	30.80	30.76	30.72	30.65
140	30.77	30.72	30.68	30.61
150	30.74	30.69	30.64	30.57
160	30.71	30.65	30.61	30.53
170	30.68	30.62	30.57	30.49
180	30.64	30.59	30.53	30.44
190	30.61	30.55	30.50	30.40
200	30.58	30.52	30.46	30.36
210	30.55	30.48	30.42	30.32
220	30.52	30.45	30.38	30.28
230	30.49	30.42	30.35	30.23
240	30.46	30.38	30.31	30.19
250	30.43	30.35	30.27	30.15
260	30.40	30.31	30.24	30.11
270	30.37	30.28	30.20	30.07
280	30.33	30.25	30.16	30.02
290	30.30	30.21	30.13	29.98
300	30.27	30.18	30.09	29.94
310	30.24	30.14	30.05	29.90
320	30.21	30.11	30.01	29.86
330	30.18	30.08	29.98	29.81
340	30.15	30.04	29.94	29.77
350	30.12	30.01	29.90	29.73
360	30.09	29.97	29.87	29.69
370	30.06	29.94	29.83	29.65
380	30.02	29.91	29.79	29.60
390	29.99	29.87	29.76	29.56
400	29.96	29.84	29.72	29.52
410	29.93	29.80	29.68	29.48

Discussion

Effect of Flow Reductions

In all 16 scenarios the simulated result of reductions in discharge of the spring was reduced water temperature (see Figure 14 and Table 6). The results followed what one would expect, with the greatest impact of flow reduction occurring during winter (December) when air temperature is coldest relative to the temperature of the thermal spring channel. In January, reduction in flow of 10%, 20%, 30% brought about a decrease respectively of 0.06 °C, 0.14°C , and 0.25 °C in the temperature of the spring channel at the end of the 220 m- long modeled segment.

Table 7 provides a means to scale these flow reductions into a change in thermal habitat for the aquatic biota. During December, the simulated temperature at T80, the tail of the modeled segment (220 m) was 30.52 °C. At a 10% reduction in flow, the model indicates indicate that the temperature of 30.52 °C would occur at a distance of 200 m. Similarly, at a 20% reduction in flow, the model indicates indicate that the temperature of 30.52 °C (actually 30.53 °C) would occur at a distance of 180 m. A similar relative effect of flow reduction occurs from 20 to 30% flow reduction. In general, for the Pedersen channel a 10% reduction in flow would result in a shift upstream of the base tail temperature by 20 meters.

The understanding of Moapa Dace reproductive biology is that the species has a minimum temperature requirement (= reproductive threshold) of 30 °C to support successful reproduction (Scoppettone et al. 1992). Simulation results indicate that these conditions would be met throughout the Pedersen temperature model segment on the FWR even under flow reduction of 30% during with the coldest annual conditions of December. It would take a flow reduction in excess of 50% to bring about a sub-threshold temperature condition (the scenario featuring 67% flow reduction resulted in a tail temperature of 29.47 °C). Although the subthreshold condition would not be expected to occur on the NWR at flow reductions of 30%, the amount of acceptable thermal habitat downstream from the refuge would be expected to be reduced at diminished flows. In Table 7 the highlighted boxes show the points at which the simulated temperature drops below 30 °C . Under current flow (3.60 cfs) conditions, the longitudinal extent of the channel above the 30 °C threshold is located a distance of 390 m. At 30% flow reduction this point has moved upstream to 290 m, a loss of 100 m of acceptable thermal habitat.

In summary, model results indicate that the flow reductions up to 30% of the Pedersen Spring Channel would not reduce the amount of habitat that meets the temperature requirements for Moapa dace on the Moapa Valley NWR, but would be expected to have an impact within a short distance (= a few hundred meters) downstream.

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References

Bartholow, J.M. 2002. SSTEMP for Windows: The Stream Segment Temperature Model (Version 2.0). U.S. Geological Survey computer model and documentation. Available on the internet at: http://www.fort.usgs.gov

Otis Bay Inc. 2004. Preliminary analysis of the effects of declining flows on channel characteristics and hydraulic habitat within the Pederson and Plummer Warm Springs Channels, Moapa Valley National Wildlife Refuge, Clark County, Nevada. Unpublished report prepared for U.S. Fish and Wildlife Service, Las Vegas, Nevada. 7 pp.

Scoppettone, G.G., H.L. Burge, and P.L. Tuttle. 1992. Life history, abundance, and distribution of Moapa dace (Moapa coriacea). Great Basin Naturalist 52(3):216-225.

Theurer, F.D., K.A. Voos, and W.J. Miller. 1984 Instream Water Temperature Model. Instream Flow Information Paper 16. Cooperative Instream Flow and Aquatic Ecosystem Group, U.S. Fish and Wildlife Service. Fort Collins, Colorado. approx 200 pp.

USFS 1996. Recovery plan for the rare aquatic species of the Muddy River Ecosystem. U.S. Fish and Wildlife Service, Region 1; Portland, Oregon. 60 pp.

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Preliminary Analysis of the Effects of Declining Flows on Channel Characteristics and Hydraulic Habitat within the Pedersen and Plummer Spring Channels of the Muddy River

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U.S. Fish and Wildlife Service
Clark County, Nevada

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Table of Contents

Preliminary Analysis of the Effects of Declining Flows on Channel Characteristics and Hydraulic Habitat within the Pedersen and Plummer Warm Springs Channels

Moapa Valley National Wildlife Refuge
Clark County, Nevada

1.0 Introduction

The relationship between the variables of width, depth, and velocity as a function of discharge is known as hydraulic geometry. The variation of these parameters can be viewed at both single cross sections (known as at-a-station hydraulic geometry) and along the length of a channel (known as downstream hydraulic geometry). The hydraulic characteristics (roughness, slope, etc.) of a given reach of channel or at a single cross section influence the observed width, depth, and velocity of water passing through the channel or cross section at varying levels of discharge. Channel topographical survey data were collected at representative sections of the Pederson and Plummer spring channels in order to estimate the changes in width, depth, and velocity associated with potentially declining spring flows.

This document discusses changes in width, depth, and velocity based on modeled decreases in discharge in the Pederson and Plummer channels. The results presented are based on the assumption that the overall shape of the channel cross section remains the same while a decrease in discharge occurs. Such an assumption yields results that more appropriately represent the near term changes in channel and hydraulic characteristics that would occur following a decrease in spring discharge. Therefore, this assumption results in a conservative estimate of the changes in width, depth, and velocity and does not address the additional changes in channel cross section that would likely occur following a decrease in discharge. Additional changes in channel cross section would likely occur due to decreased sediment transport capacity and vegetative encroachment.

2.0 Methods

Channel cross section and stream discharge data were obtained at representative channel locations on the Pederson and Plummer spring channels. Cross sections were surveyed at both riffles and pools. A series of channel cross sections were surveyed at two segments within each spring channel. Cross sections were surveyed both above (upstream segments) and below (downstream segments) primary confluences within each spring channel. Channel cross sections and discharge measurements were obtained from above and below the confluence of the Pederson and Pederson East channels and above and below the confluence of the two primary tributaries of the Plummer channel. Discharge measurements were taken within each set of cross sections in order to calibrate a HEC-RAS hydraulic model. Field discharge measurements were verified with gage records from the Pederson and Plummer spring gages.

A step backwater hydraulic model (HEC-RAS v. 3.1) was constructed for each series of surveyed cross sections, calibrated with observed water surface elevations and estimated roughness coefficients, and performed at a sequence of percent flow reductions in order to determine at-a-station changes in width, depth, and velocity. Reductions in width, depth, and velocity were determined at each cross section. The reduction of these parameters in select riffle-pool pairs in the upstream and downstream segments of both the Pederson and Plummer channels are presented. Percent reductions in width, depth, and velocity were calculated based on the difference between modeled initial width, depth, and velocity within respective segments and the modeled width, depth, and velocity associated with the percent reductions in discharge.

Reductions in habitat volume for riffles and pools were determined based on modeled wetted cross sectional area. Unit habitat volume loss was calculated by subtracting the reduced modeled cross sectional area from the initial modeled condition. Habitat volume loss was calculated based on 1) unit habitat volume loss and 2) a 100 feet long section of channel composed of 80% pool and 20 % riffle habitat. This approximation of relative riffle and pool abundance was based on average channel width and field observations.

The primary assumption made in the calculation of habitat volume loss is the assumed similarity of riffle and pool geometry throughout a 100 feet long representative channel segment.

3.0 Results

Declines in width, depth, and velocity associated with the modeled reduction of spring channel discharge at riffle-pool pairs in both the Pederson and Plummer channels are shown in Tables 1 and 2. Modeled hydraulic parameters (width, depth, and velocity) of select riffle-pool pairs within the upstream segments of the Pederson and Plummer spring channels and percent reductions of these variables with associated percent reductions in spring channel discharge are shown in Table 1. Modeled hydraulic parameters of select riffle-pool pairs within the downstream segments of the Pederson and Plummer spring channels and associated percent reductions of width, depth, and velocity are shown in Table 2. Habitat volume losses for riffle and pool habitat within the upstream and downstream segments of the spring channels are shown in Tables 3 and 4, respectively.

The field observed discharges of 1.23 cfs and 0.29 cfs were used as the initial discharge in the series of modeled discharge reductions in the upstream segments of the Pederson and Plummer channels, respectively. Similarly, the observed discharges of 3.59 cfs and 2.34 cfs were used as the initial discharge in the series of modeled discharge reductions in the downstream segments of the Pederson and Plummer channels, respectively. Because the exact loss of discharge in the spring channels due to a potential decline in groundwater elevation is presently unknown, the modeled 10% reduction in channel discharge will be described. This level of modeled discharge reduction within the downstream segment of the Pederson channel (3.2 cfs) also approximates the proposed minimum flow of 3.1 cfs at the Warm Springs West flume.

As shown in Table 1, the modeled 10 % reduction in discharge within the Pederson upstream segment results in 3.7 %, 9.5 %, and 0.4 % reductions in width, depth, and velocity within the selected riffle and 3.6 %, 1.8 %, and 4.4 % reduction in width, depth,

and velocity within the selected pool. Percent reductions in width, depth, and velocity in the selected Pederson downstream segment riffle are 1.8 %, 4.7 %, and 4.4 %, respectively while the percent reductions in the pool are 1.8 %, 3.4 %, and 5.9 %, as shown in Table 2.

As shown in Table 1, following the modeled 10 % reduction in discharge within the upstream segment of the Plummer channel, percent reductions of width, depth, and velocity at the riffle are 2.1 %, 3.7 %, and 2.2 %, respectively, while percent reductions at the pool are 0.6 %, 1.6 %, and 7.1 %, respectively. Within the downstream segment of the Plummer channel, width, depth, and velocity were reduced by 0.9 %, 5.4 %, and 4.0 % within the selected riffle and by 5.3 %, 1.4 %, and 3.8 % in the selected pool, as shown in Table 2.

Based on the modeled 10% reduction in discharge and associated decrease in wetted cross sectional area observed in the upstream segment of the Pederson channel, riffle and pool habitat volume loss within a 100 feet long section of channel would be 1.2 ft^3 and 12.0 ft^3, respectively, as shown in Table 3. Similarly, riffle and pool habitat volume loss within a 100 feet long channel segment would be 1.0 ft^3 and 4.0 ft^3, respectively, based on the decrease in cross sectional area observed in the upstream segment of the Plummer channel. The amount of habitat volume loss increases in the downstream direction due to increased discharge and channel cross sectional area. Therefore, as shown in Table 4, riffle and pool habitat volume loss within a 100 feet long section of channel was determined to be 5.8 ft^3 and 29.6 ft^3, based on the reduction of cross sectional area within the downstream segment of the Pederson channel following a 10% decrease in discharge. Riffle and pool habitat volume loss within a 100 feet long segment would be 5.8 ft^3 and 15.2 ft^3, respectively, based on the modeled 10% reduction in discharge within the downstream segment of the Plummer channel.

4.0 Discussion

Moapa dace occur throughout the Warm Springs area in spring pools, spring outflow channels, and the mainstem of the Muddy River and utilize these different habitat types during separate life stages. Therefore, a potential decline in spring discharge would have repercussions throughout all of the habitat types utilized by Moapa dace. Larval dace occur most frequently in low velocity backwater and only in the upper reaches of spring channels. Juvenile dace inhabit areas with a wider range of water velocity, but are primarily observed in the spring channels tributary to the Muddy River. Adult dace are found in both the spring channels and mainstem of the Muddy River, but are observed most often in the river. Dace commonly feed at drift stations located in reaches of low to moderate water velocity often occurring at pools maintained by channel scour below riffles (Scoppettone et al., 1987, 1992). Adult dace typically inhabit higher velocity water (3.6 to 3.0 ft/s) (Cross, 1976). Successful reproduction is only known to occur in the warm and low velocity water areas of the spring channels. Redds believed to be those of Moapa Dace have been observed in low velocity (0.125 to 0.25 ft/s) water within the spring channel (Scoppettone et al., 1992).

Model results yield a reduction in width, depth, and velocity in both riffles and pools. The primary effect of diminished flow within the spring channels will be a decrease in the diversity of hydraulic habitat. A decrease in velocity and depth within riffles could result in decreased invertebrate (food) production. Drift stations in pools are maintained by the scouring effect of turbulent flow. Scour will decrease in pools as water velocity and depth at the upstream end of the pool decreases. Perhaps the most prominent impact that could occur, due to a decrease in discharge and subsequent decrease in depth, is the reduction of overall water volume within the spring channels. Scoppettone et al. (1992) have demonstrated that overall dace size is scaled to water volume. Thus, larger water volumes provide the habitat necessary for increased food production and subsequently larger fish. Larger fish produce more eggs and aid in the preservation of the population.

A variety of hydraulic habitat is required throughout the life stages of the Moapa dace. The modeling of a range of decreased flows in the headwater spring channels of the upper Muddy River resulted in a decrease in the hydraulic parameters of width, depth, and velocity. Decreases in these parameters will likely have an adverse impact on the overall diversity and quantity of hydraulic habitat. Additional factors that will influence channel and hydraulic characteristics within the spring channels following a decline in spring discharge include, but may not be limited to, changes in sediment transport rates and the alteration of riffle and pool maintenance that is accomplished by the present rate of discharge in each spring channel. Additionally, vegetative encroachment and subsequent channel obstruction may also occur as the wetted cross sectional area of the individual channels decreases and new surfaces for vegetative growth are created.

5.0 References

Cross, J.N. 1976. Status of the native fish fauna of the Moapa River (Clark County, NV). Transactions of the American Fisheries Society 105 (4):503-508.

Scoppettone, G.G., H.L. Burge, P.L. Tuttle, M. Parker, and N.K. Parker. 1987. Life history and status of the Moapa dace (Moapa Coriacea). U.S. Fish and Wildlife Service, National Fisheries Research Center, Seattle, Washington. 77 pp.

Scoppettone, G.G., H.L. Burge, and P.L. Tuttle. 1992. Life history, abundance, and distribution of Moapa dace (Moapa coriacea). Great Basin Naturalist 52 (3):216-225.

Appendix A

Tables

Table 1. Modeled hydraulic parameters and associated percent reductions at riffle-pool pairs in upstream segments of Pederson and Plummer spring channels.

	Discharge (cfs)	Width (ft)	Depth (ft)	Velocity (ft/s)	Width Reduction (%)	Depth Reduction (%)	Velocity Reduction (%)
Pederson Riffle							
Upstream Segment CS 4	1.23	2.43	0.21	2.42	0.0	0.0	0.0
	1.11	2.34	0.19	2.41	3.7	9.5	0.4
	0.98	2.28	0.18	2.4	6.2	14.3	0.8
	0.86	2.21	0.17	2.34	9.1	19.0	3.3
	0.74	2.15	0.15	2.22	11.5	28.6	8.3
	0.62	2.07	0.14	2.13	14.8	33.3	12.0
	0.49	1.93	0.13	2.01	20.6	38.1	16.9
	0.37	1.72	0.11	1.9	29.2	47.6	21.5
	0.25	1.46	0.1	1.77	39.9	52.4	26.9
	0.12	1.09	0.07	1.52	55.1	66.7	37.2
Pederson Pool							
Upstream Segment CS 3	1.23	4.77	0.57	0.45	0.0	0.0	0.0
	1.11	4.6	0.56	0.43	3.6	1.8	4.4
	0.98	4.39	0.54	0.41	8.0	5.3	8.9
	0.86	4.17	0.53	0.39	12.6	7.0	13.3
	0.74	3.95	0.52	0.36	17.2	8.8	20.0
	0.62	3.71	0.51	0.33	22.2	10.5	26.7
	0.49	3.48	0.49	0.29	27.0	14.0	35.6
	0.37	3.31	0.46	0.25	30.6	19.3	44.4
	0.25	3.1	0.42	0.19	35.0	26.3	57.8
	0.12	2.81	0.36	0.12	41.1	36.8	73.3
Plummer Riffle							
Upstream Segment CS 4	0.29	2.34	0.27	0.46	0.0	0.0	0.0
	0.26	2.29	0.26	0.45	2.1	3.7	2.2
	0.23	2.23	0.24	0.43	4.7	11.1	6.5
	0.2	2.17	0.23	0.4	7.3	14.8	13.0
	0.17	2.1	0.21	0.38	10.3	22.2	17.4
	0.15	2.05	0.2	0.36	12.4	25.9	21.7
	0.12	1.98	0.18	0.33	15.4	33.3	28.3
	0.09	1.88	0.16	0.3	19.7	40.7	34.8
	0.06	1.78	0.14	0.25	23.9	48.1	45.7
	0.03	1.54	0.11	0.18	34.2	59.3	60.9
Plummer Pool							
Upstream Segment CS 3	0.29	3.14	0.64	0.14	0.0	0.0	0.0
	0.26	3.12	0.63	0.13	0.6	1.6	7.1
	0.23	3.09	0.62	0.12	1.6	3.1	14.3
	0.2	3.06	0.61	0.11	2.5	4.7	21.4
	0.17	3.04	0.59	0.09	3.2	7.8	35.7
	0.15	3.01	0.58	0.09	4.1	9.4	35.7
	0.12	2.98	0.57	0.07	5.1	10.9	50.0
	0.09	2.94	0.55	0.06	6.4	14.1	57.1
	0.06	2.89	0.53	0.04	8.0	17.2	71.4
	0.03	2.83	0.5	0.02	9.9	21.9	85.7

Table 2. Modeled hydraulic parameters and associated percent reductions at riffle-pool pairs in downstream segments of Pederson and Plummer spring channels.

	Discharge (cfs)	Width (ft)	Depth (ft)	Velocity (ft/s)	Width Reduction (%)	Depth Reduction (%)	Velocity Reduction (%)
Pederson Riffle							
Downstream Segment CS 5	3.59	6.22	0.64	0.9	0.0	0.0	0.0
	3.2	6.11	0.61	0.86	1.8	4.7	4.4
	2.8	6	0.56	0.83	3.5	12.5	7.8
	2.4	5.87	0.52	0.79	5.6	18.8	12.2
	2	5.73	0.47	0.75	7.9	26.6	16.7
	1.6	5.57	0.4	0.71	10.5	37.5	21.1
	1.2	5.38	0.33	0.68	13.5	48.4	24.4
	0.8	5.13	0.23	0.69	17.5	64.1	23.3
	0.4	2.82	0.18	0.81	54.7	71.9	10.0
Pederson Pool							
Downstream Segment CS 4	3.59	7.87	0.89	0.51	0.0	0.0	0.0
	3.2	7.73	0.86	0.48	1.8	3.4	5.9
	2.8	7.57	0.82	0.45	3.8	7.9	11.8
	2.4	7.4	0.78	0.41	6.0	12.4	19.6
	2	7.2	0.74	0.38	8.5	16.9	25.5
	1.6	6.98	0.69	0.33	11.3	22.5	35.3
	1.2	6.7	0.63	0.29	14.9	29.2	43.1
	0.8	6.35	0.54	0.23	19.3	39.3	54.9
	0.4	5.84	0.42	0.16	25.8	52.8	68.6
Plummer Riffle							
Downstream Segment CS 4	2.34	6.34	0.74	0.5	0.0	0.0	0.0
	2.11	6.28	0.7	0.48	0.9	5.4	4.0
	1.87	6.22	0.66	0.46	1.9	10.8	8.0
	1.64	6.07	0.56	0.48	4.3	24.3	4.0
	1.4	5.98	0.51	0.46	5.7	31.1	8.0
	1.17	5.84	0.45	0.45	7.9	39.2	10.0
	0.94	5.44	0.4	0.43	14.2	45.9	14.0
	0.7	5.18	0.33	0.41	18.3	55.4	18.0
	0.47	5.02	0.25	0.38	20.8	66.2	24.0
	0.23	4.8	0.13	0.36	24.3	82.4	28.0
Plummer Pool							
Downstream Segment CS 3	2.34	4.34	0.69	0.79	0.0	0.0	0.0
	2.11	4.11	0.68	0.76	5.3	1.4	3.8
	1.87	3.96	0.66	0.72	8.8	4.3	8.9
	1.64	3.57	0.61	0.76	17.7	11.6	3.8
	1.4	3.35	0.58	0.72	22.8	15.9	8.9
	1.17	3.12	0.55	0.68	28.1	20.3	13.9
	0.94	2.86	0.52	0.63	34.1	24.6	20.3
	0.7	2.63	0.47	0.56	39.4	31.9	29.1
	0.47	2.47	0.41	0.47	43.1	40.6	40.5
	0.23	2.26	0.32	0.32	47.9	53.6	59.5

Table 3. Modeled cross-sectional area and associated habitat volume loss based on riffle-pool pairs in upstream segments of Pederson and Plummer spring channels.

	Discharge (cfs)	Area (ft^2)	Area Reduction (%)	Unit Habitat Volume Loss* (ft^3)	Habitat Volume Loss ** (ft^3)
Pederson Riffle					
Upstream Segment CS 4	1.23	0.51	0.0	0.0	0.0
	1.11	0.45	11.8	0.1	1.2
	0.98	0.41	19.6	0.1	2.0
	0.86	0.37	27.5	0.1	2.8
	0.74	0.33	35.3	0.2	3.6
	0.62	0.29	43.1	0.2	4.4
	0.49	0.24	52.9	0.3	5.4
	0.37	0.19	62.7	0.3	6.4
	0.25	0.14	72.5	0.4	7.4
	0.12	0.08	84.3	0.4	8.6
Pederson Pool					
Upstream Segment CS 3	1.23	2.71	0.0	0.0	0.0
	1.11	2.56	5.5	0.2	12.0
	0.98	2.39	11.8	0.3	25.6
	0.86	2.22	18.1	0.5	39.2
	0.74	2.06	24.0	0.7	52.0
	0.62	1.89	30.3	0.8	65.6
	0.49	1.7	37.3	1.0	80.8
	0.37	1.5	44.6	1.2	96.8
	0.25	1.29	52.4	1.4	113.6
	0.12	1.02	62.4	1.7	135.2
Plummer Riffle					
Upstream Segment CS 4	0.29	0.63	0.0	0.0	0.0
	0.26	0.58	7.9	0.1	1.0
	0.23	0.54	14.3	0.1	1.8
	0.2	0.5	20.6	0.1	2.6
	0.17	0.45	28.6	0.2	3.6
	0.15	0.42	33.3	0.2	4.2
	0.12	0.36	42.9	0.3	5.4
	0.09	0.3	52.4	0.3	6.6
	0.06	0.24	61.9	0.4	7.8
	0.03	0.16	74.6	0.5	9.4
Plummer Pool					
Upstream Segment CS 3	0.29	2.01	0.0	0.0	0.0
	0.26	1.96	2.5	0.0	4.0
	0.23	1.91	5.0	0.1	8.0
	0.2	1.85	8.0	0.2	12.8
	0.17	1.8	10.4	0.2	16.8
	0.15	1.76	12.4	0.3	20.0
	0.12	1.69	15.9	0.3	25.6
	0.09	1.61	19.9	0.4	32.0
	0.06	1.53	23.9	0.5	38.4
	0.03	1.42	29.4	0.6	47.2

* Indicates decrease in riffle or pool volume per linear foot of channel.

** Indicates decrease in riffle or pool volume based on 100 feet of channel with 80 % pool habitat and 20% riffle habitat.

Table 4. Modeled cross-sectional area and associated habitat volume loss based on riffle-pool pairs in downstream segments of Pederson and Plummer spring channels.

	Discharge (cfs)	Area (ft^2)	Area Reduction (%)	Unit Habitat Volume Loss* (ft^3)	Habitat Volume Loss ** (ft^3)
Pederson Riffle					
Downstream Segment CS 5	3.59	4.00	0.0	0.0	0.0
	3.2	3.71	7.3	0.3	5.8
	2.8	3.39	15.3	0.6	12.2
	2.4	3.04	24.0	1.0	19.2
	2	2.67	33.3	1.3	26.6
	1.6	2.25	43.8	1.8	35.0
	1.2	1.77	55.8	2.2	44.6
	0.8	1.16	71.0	2.8	56.8
	0.4	0.50	87.5	3.5	70.0
Pederson Pool					
Downstream Segment CS 4	3.59	6.99	0.0	0.0	0.0
	3.2	6.62	5.3	0.4	29.6
	2.8	6.22	11.0	0.8	61.6
	2.4	5.79	17.2	1.2	96.0
	2	5.31	24.0	1.7	134.4
	1.6	4.79	31.5	2.2	176.0
	1.2	4.20	39.9	2.8	223.2
	0.8	3.46	50.5	3.5	282.4
	0.4	2.46	64.8	4.5	362.4
Plummer Riffle					
Downstream Segment CS 4	2.34	4.68	0.0	0.0	0.0
	2.11	4.39	6.2	0.3	5.8
	1.87	4.09	12.6	0.6	11.8
	1.64	3.43	26.7	1.3	25.0
	1.4	3.02	35.5	1.7	33.2
	1.17	2.61	44.2	2.1	41.4
	0.94	2.18	53.4	2.5	50.0
	0.7	1.71	63.5	3.0	59.4
	0.47	1.23	73.7	3.5	69.0
	0.23	0.64	86.3	4.0	80.8
Plummer Pool					
Downstream Segment CS 3	2.34	2.98	0.0	0.0	0.0
	2.11	2.79	6.4	0.2	15.2
	1.87	2.60	12.8	0.4	30.4
	1.64	2.17	27.2	0.8	64.8
	1.4	1.94	34.9	1.0	83.2
	1.17	1.71	42.6	1.3	101.6
	0.94	1.48	50.3	1.5	120.0
	0.7	1.24	58.4	1.7	139.2
	0.47	1.00	66.4	2.0	158.4
	0.23	0.72	75.8	2.3	180.8

* Indicates decrease in riffle or pool volume per linear foot of channel.

** Indicates decrease in riffle or pool volume based on 100 feet of channel with 80 % pool habitat and 20% riffle habitat.