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 27 OF 49

The Potential Impacts of Proposed Ground-Water Pumping in Coyote Spring Valley on the Water Resources of Lake Mead National Recreation Area

by

William P. Van Liew, P.E. and Jennifer T. Back

Hydrologists

United States Department of the Interior

National Park Service

Water Resources Division

Fort Collins, CO

July 11, 2001

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August 17, 2001

ERRATA TO:

The Potential Impacts of Proposed Ground-Water Pumping in Coyote Spring Valley on the Water Resources of Lake Mead National Recreation Area

by
William P. Van Liew, P.E. and *Jennifer T. Back*
United States Department of the Interior, National Park Service
July 11, 2001

1) **Summary Text Slides:** Fourth Slide

   Revision: Corrected Total Existing Rights to 16,300 afy from 16,500 afy.

2) **Figure 4.** Locations of springs in the Overton Arm of Lake Mead National Recreation Area.

   Revision: Addition of Muddy River Springs at upper part of map.

3) **Figure 8.** Locations of points of diversion of existing ground-water rights in Coyote Spring Valley.

   Revision: Removal of one point of diversion for a spring-water right.

4) **Figure 20.** Generalized hydrogeologic units in the study area.

   Revision: Inclusion of hydrogeologic units southeast of the Virgin River.

5) **Figure 21.** Major structural elements of the study area.

   Revision: Several minor typographical and drafting refinements.

6) **Figure 41.** Relationship between ground-water pumping from the Arrow Canyon Well and decline in water levels in the regional carbonate-rock aquifer.

   Revision: Correction to 4 water-level data points for well EH-4 between 1998 and 2000.

7) **Table 2.** Summary of information regarding existing ground-water rights in Coyote Spring Valley.

   Revision: Removal of information regarding a spring-water right, and correction of Total Existing Rights to 16,300 afy from 16,500 afy.

8) **Table 5.** Summary of annual discharge characteristics of regional springs.

   Revision: Addition of units, and notation that values are annual characteristics.

Outline of Presentation

- Water Resources of Lake Mead NRA
- GW Development in Coyote Spring Valley
- Overview of Regional Hydrologic System
- Regional Water-Resource Features
- Existing Impacts
- Water Available for Appropriation
- Conclusions

Water Resources of Lake Mead National Recreation Area

- Rogers and Blue Point Springs
- Other Regional Springs
- Muddy River
- Virgin River

Ground-Water Development in Coyote Spring Valley

- Existing Rights (TOTAL=16,300 afy)
  - Nevada Power Company
  - Coyote Springs Investment, LLC
  - Southern Nevada Water Authority
  - others

- Proposed Withdrawals (TOTAL=136,100)
  - Las Vegas Valley Water District (27,500 afy)
  - Coyote Springs Investment, LLC (108,600 afy)

Overview of Regional Hydrologic System

- The Great Basin Regional Aquifer System

- "The Colorado Regional Ground-Water Flow System of Nevada"

- The "Lower Colorado Flow System" (Study Area)

The Great Basin Regional Aquifer System

- The Carbonate-Rock Province
- Hydrographic Basins
- Aquifer System
  - Local basin-fill aquifers
  - Regional carbonate-rock aquifer

“The Colorado Regional Ground-Water Flow System of Nevada”

- Physical Setting
- Geologic Framework
- Hydrology and Hydraulics
  - Recharge
  - Ground-water movement
  - Discharge

The "Lower Colorado Flow System" (Study Area)

- Geologic Structural Features
- Interbasin Ground-water Movement
- Surface Water Features
  - Muddy River
  - Regional springs

Regional Water-Resource Features

- Characteristics of the Muddy River
- Characteristics of Rogers and Blue Point Springs

Characteristics of the Muddy River

- Discharge Characteristics
- Sources of Streamflow
  - Regional springs
  - Tributaries
- Gain and Loss Evaluation

Characteristics of Rogers and Blue Point Springs

- Discharge Characteristics
- Temperature
- Stable Isotopes
- Sources of Spring Discharge
  - Carbonate aquifer
  - Local recharge

Existing Impacts

- Muddy River
  - Discharge vs. time
  - Pumping vs. time
- Regional Carbonate-rock Aquifer
  - Water levels vs. time
  - Pumping vs. time

Water Available for Appropriation

- Regional Water Balance
  - Inflow
  - Outflow
- Existing Water Rights
  - Ground-water
  - Surface water
  - Springs

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Conclusions

- Rogers/Blue Point Springs Complex
  - Terminal discharge of regional carbonate-rock aquifer system
  - Local recharge component
- Water Available for Appropriation
  - "Lower Colorado Flow System" is already overappropriated; no water is available
- Existing Impacts
  - Decline in discharge of Muddy River
  - Decline in water levels of regional carbonate-rock aquifer

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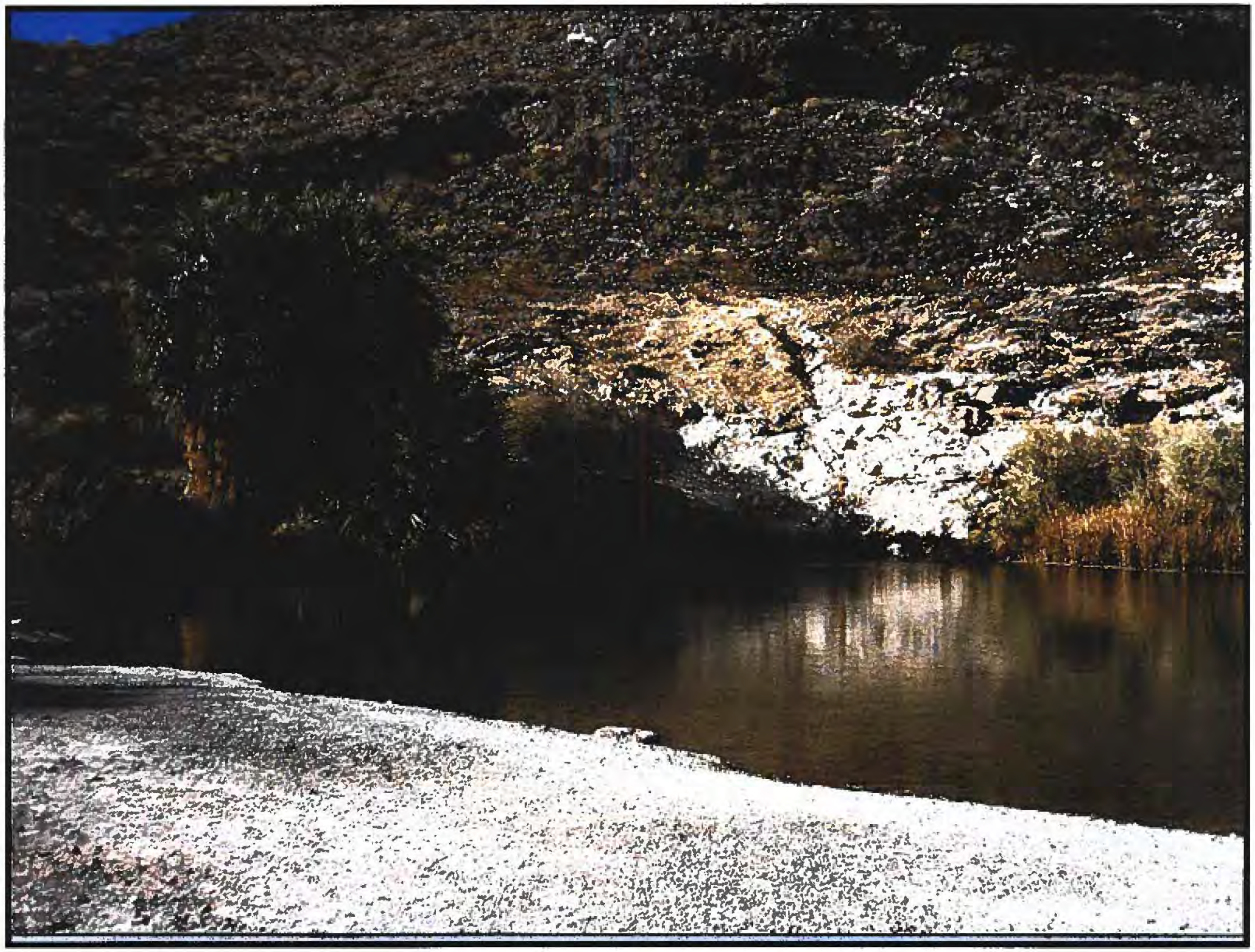


Figure 1. - Photograph of Rogers Spring and pond.

Figure 2. - Close-up photograph of Rogers Spring, showing ground-water discharge directly from Paleozoic carbonate rock.

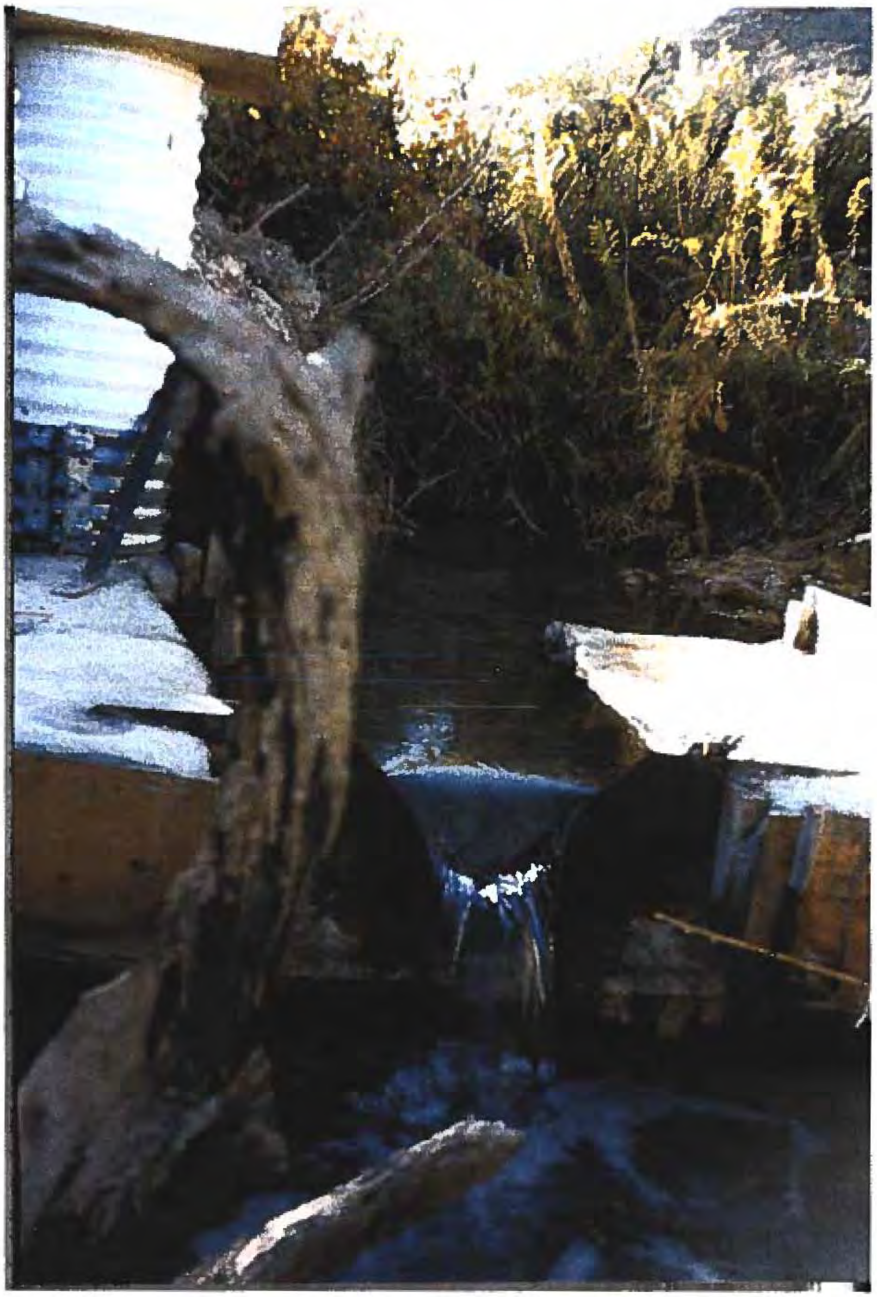


Figure 3. - Photograph of Blue Point Spring, showing discharge measurement gage.

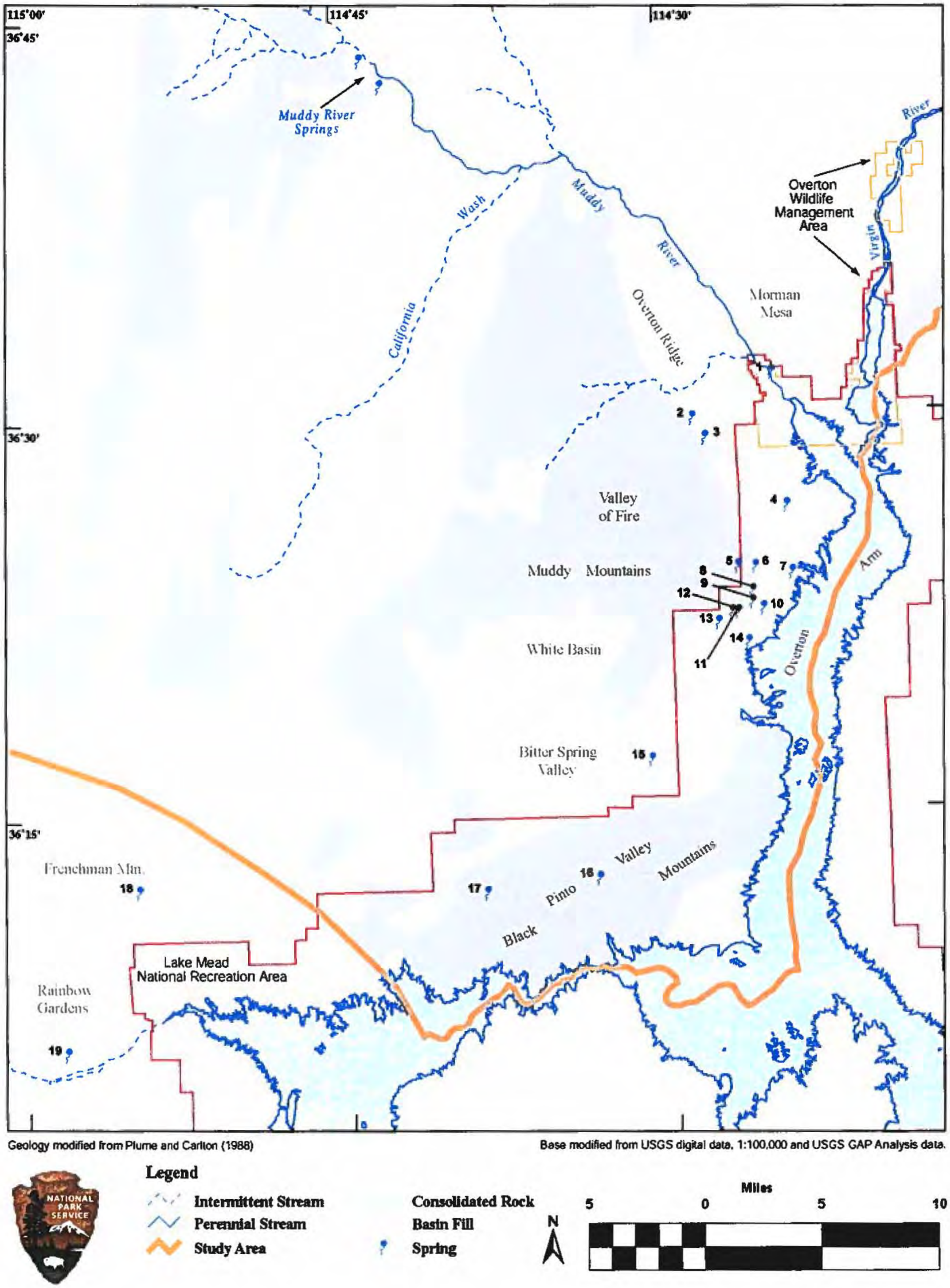


FIGURE 4.—Locations of springs in the Overton Arm area of Lake Mead National Recreation Area. See Table 1 for spring names and related information.

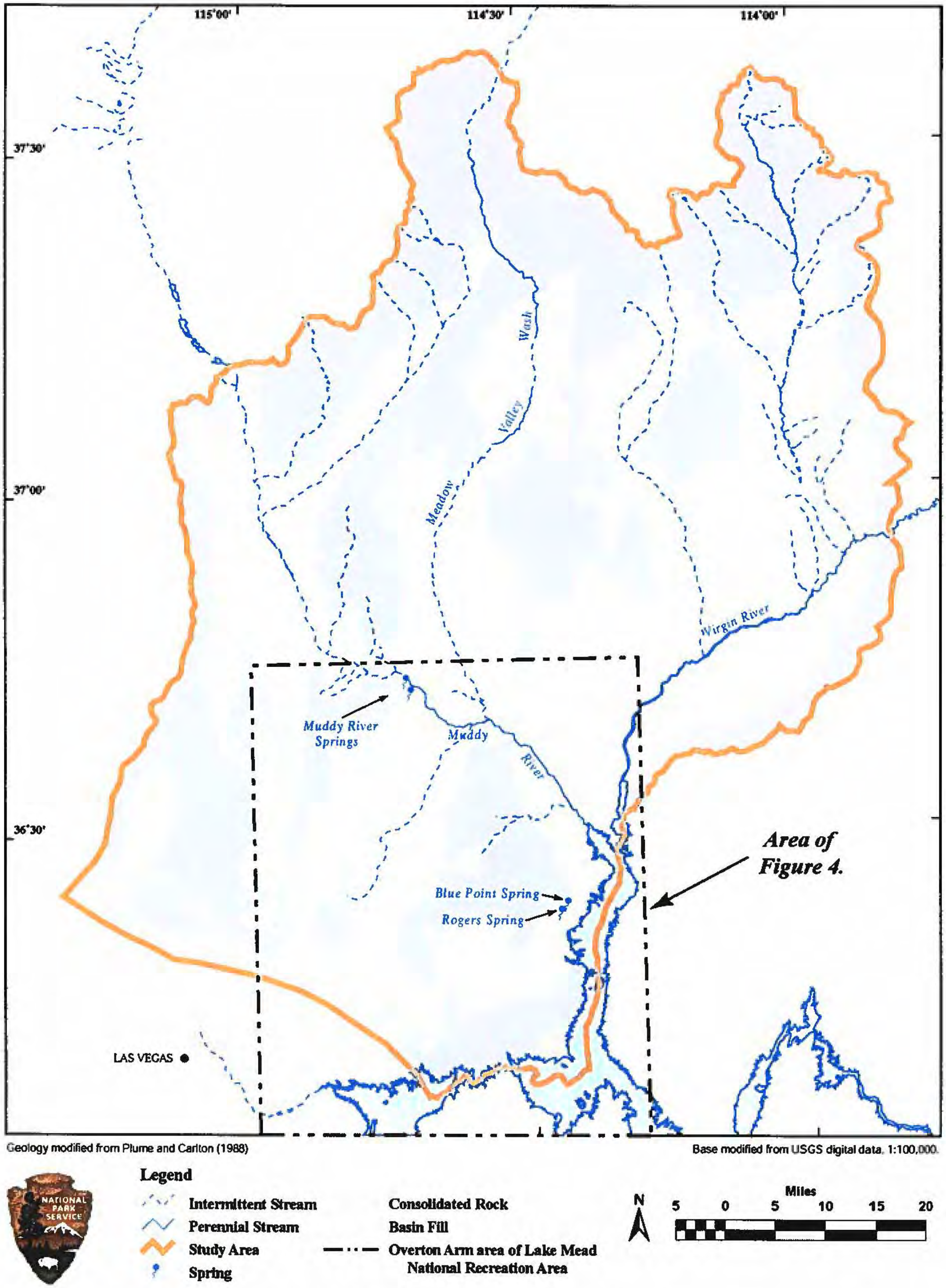


FIGURE 5.—Location of the Overton Arm area of Lake Mead National Recreation Area, as shown in Figure 4.

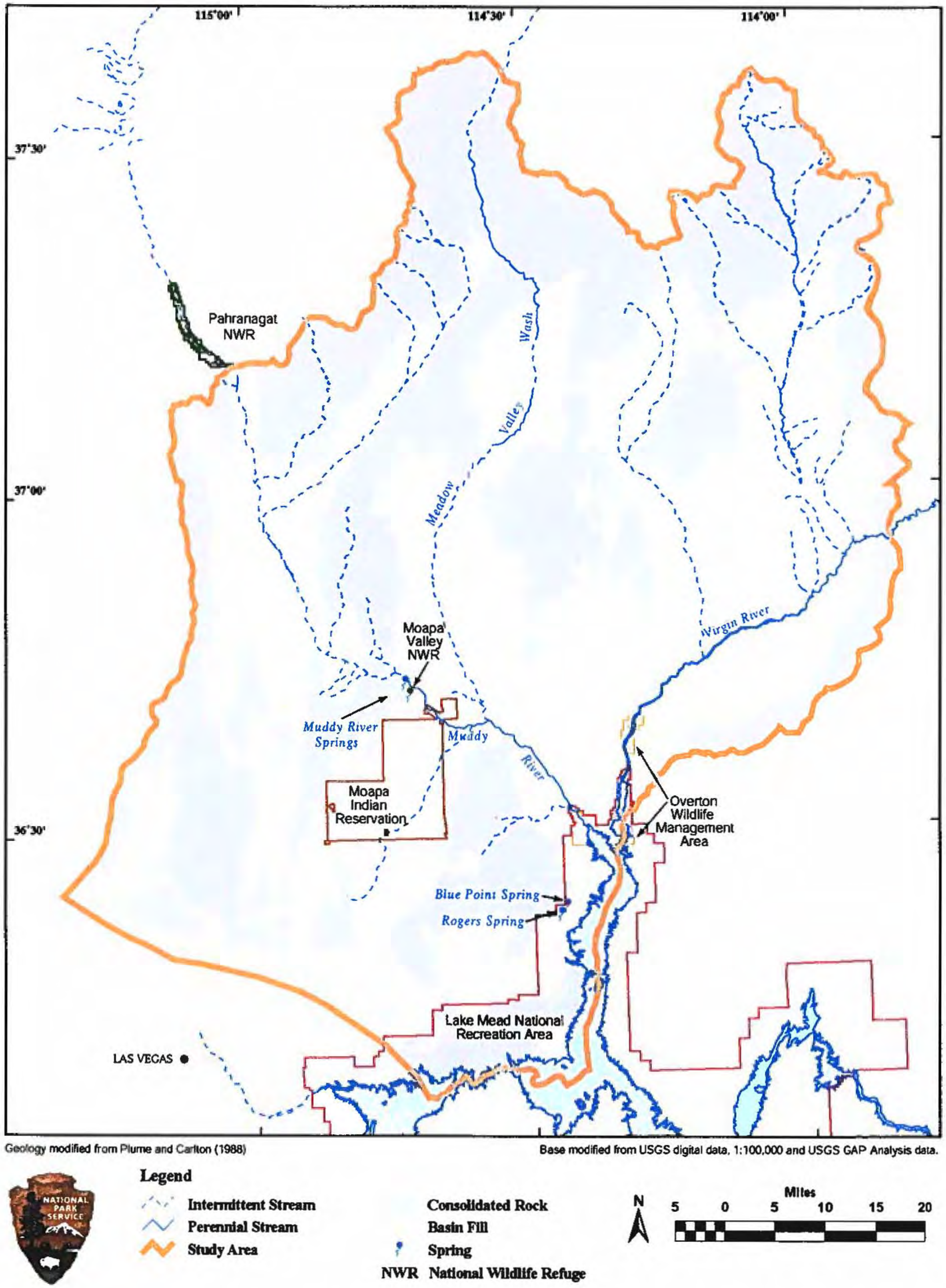


FIGURE 6.—Selected public land units of interest within the study area.

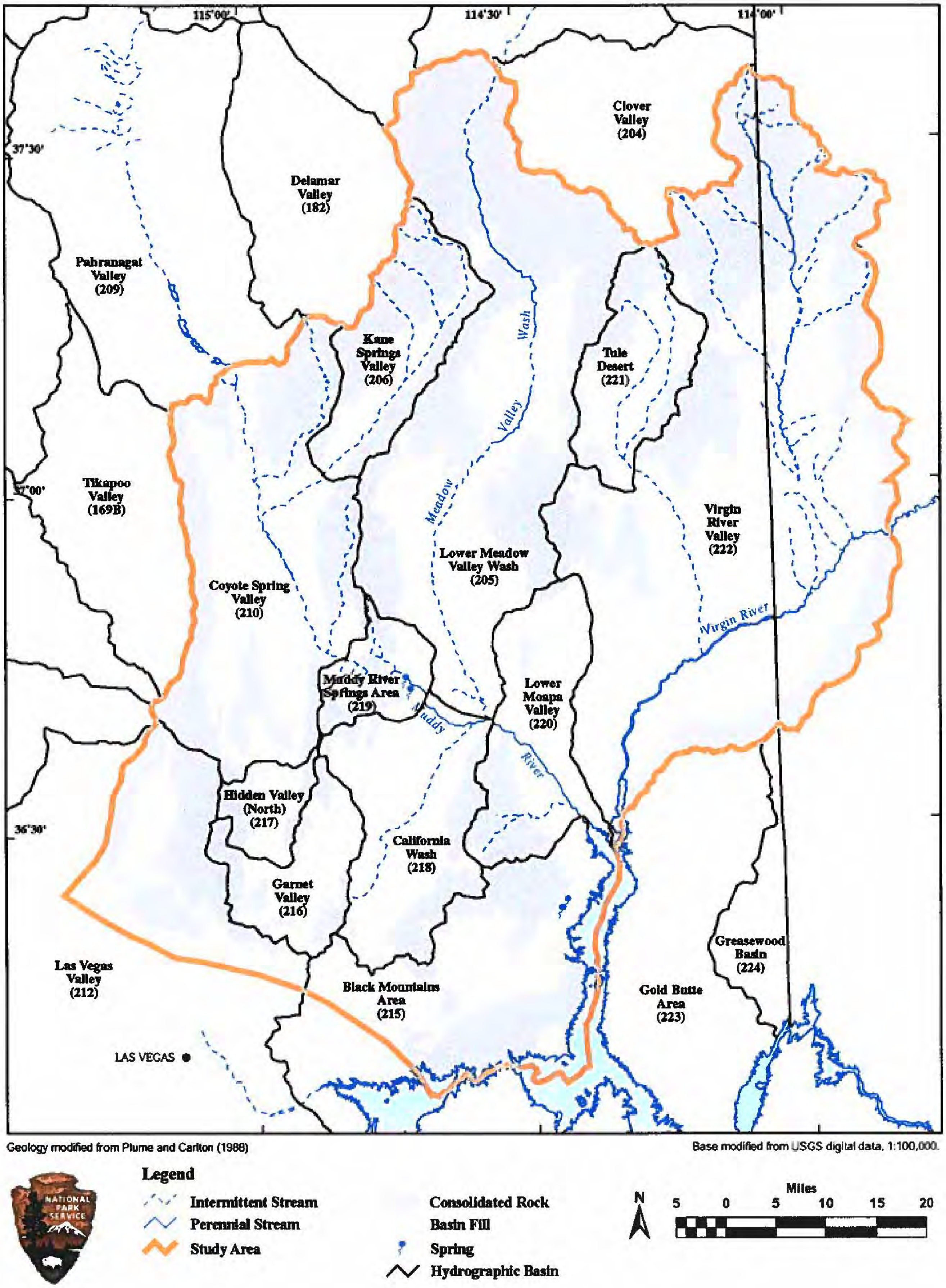
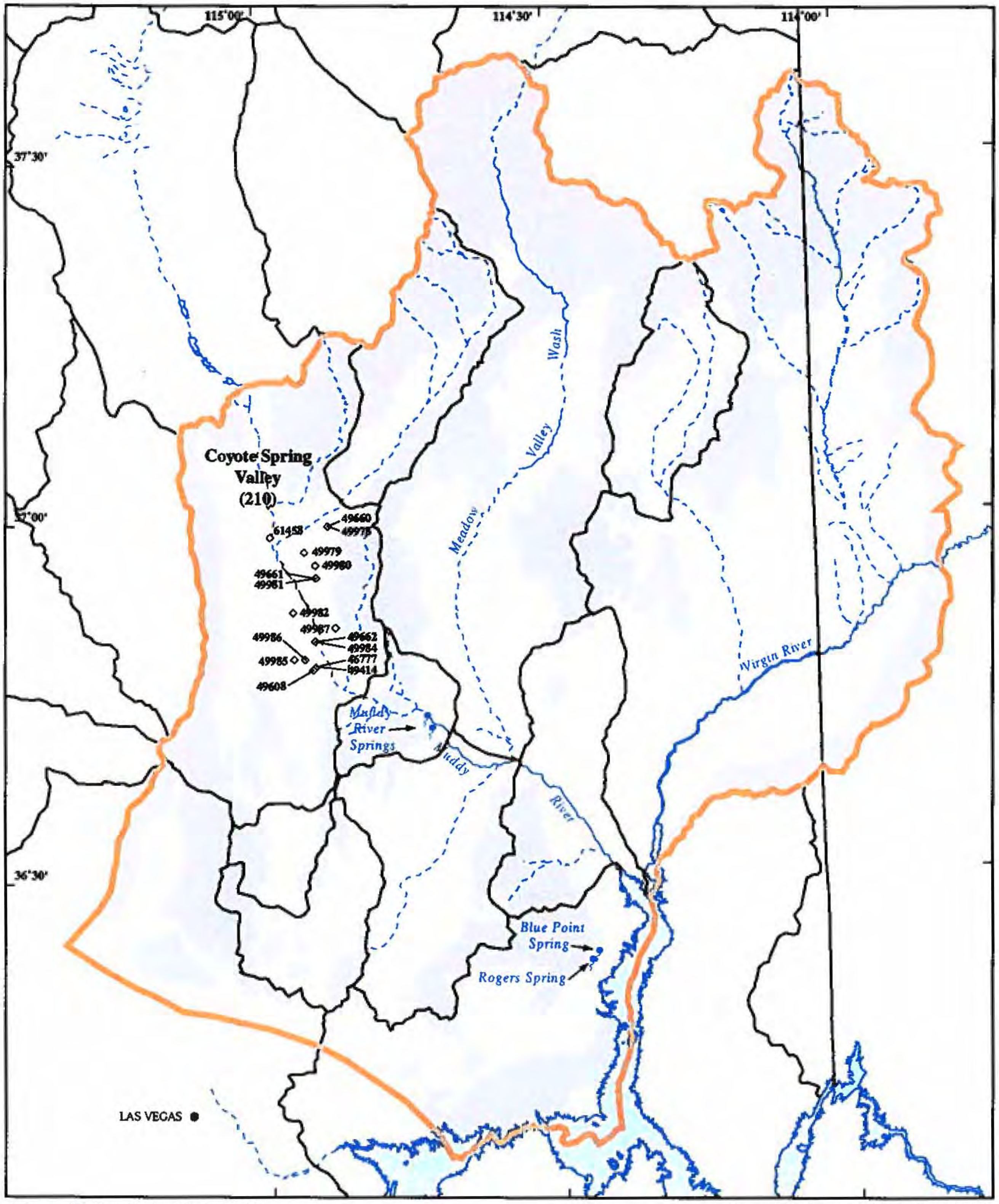


FIGURE 7.—Hydrographic basins within the study area and vicinity.



Geology modified from Plume and Carlton (1988)

Base modified from USGS digital data, 1:100,000.

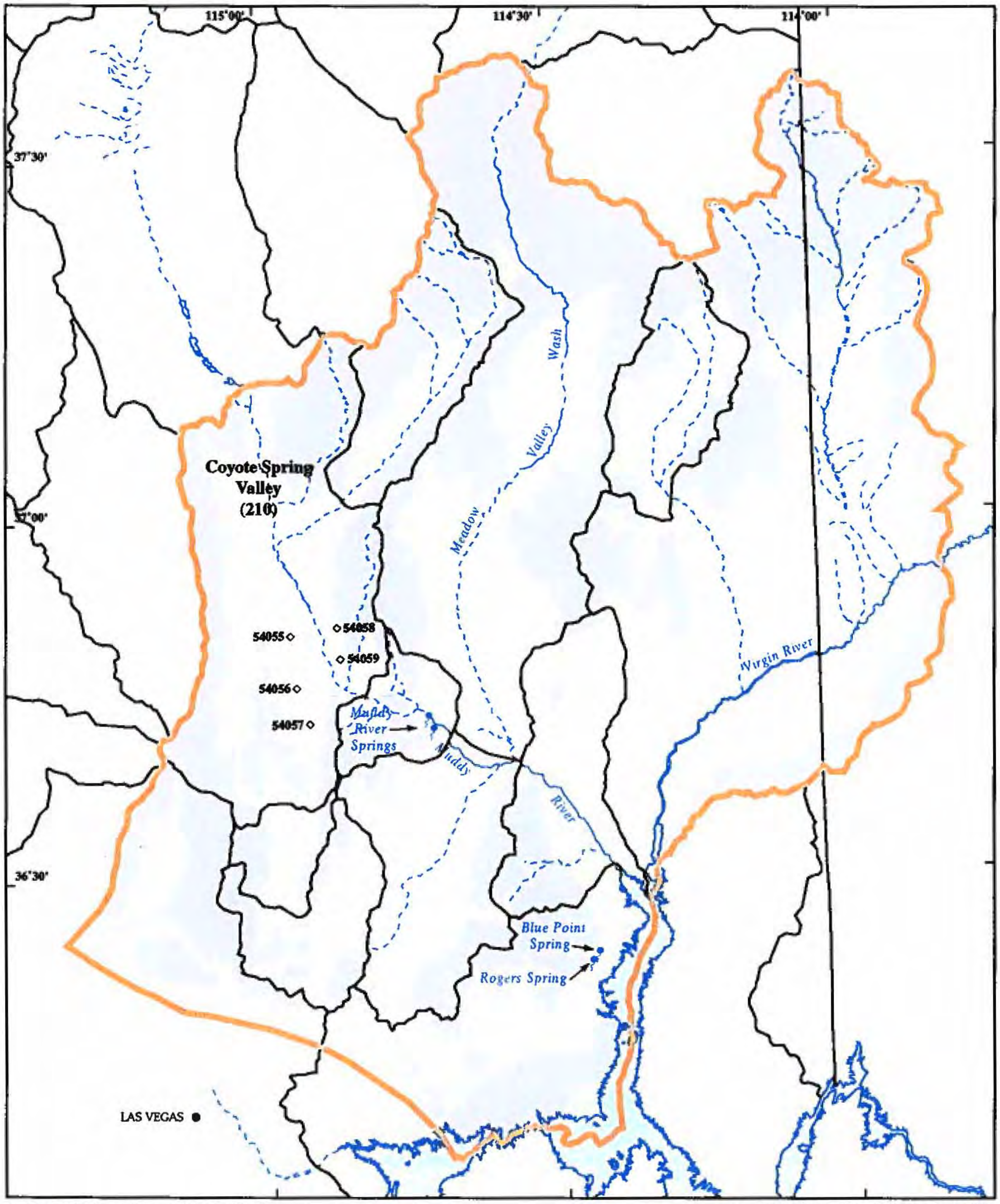
Legend

- Intermittent Stream
- Perennial Stream
- Study Area
- Existing Point of Diversion
- Consolidated Rock
- Basin Fill
- Spring
- Hydrographic Basin

N

Miles
5 0 5 10 15 20

FIGURE 8.—Locations of points of diversion of existing ground-water rights in Coyote Spring Valley. See Table 2 for permitted diversion rates and related information.



Geology modified from Plume and Carlton (1988)

Base modified from USGS digital data, 1:100,000.

Legend

Intermittent Stream
Perennial Stream
Study Area
Proposed Point of Diversion
Consolidated Rock
Basin Fill
Spring
Hydrographic Basin

N

Miles
5 0 5 10 15 20

FIGURE 9.—Locations of proposed ground-water withdrawals by LVVWD in Coyote Spring Valley. See Table 3 for proposed withdrawal rates and related information.

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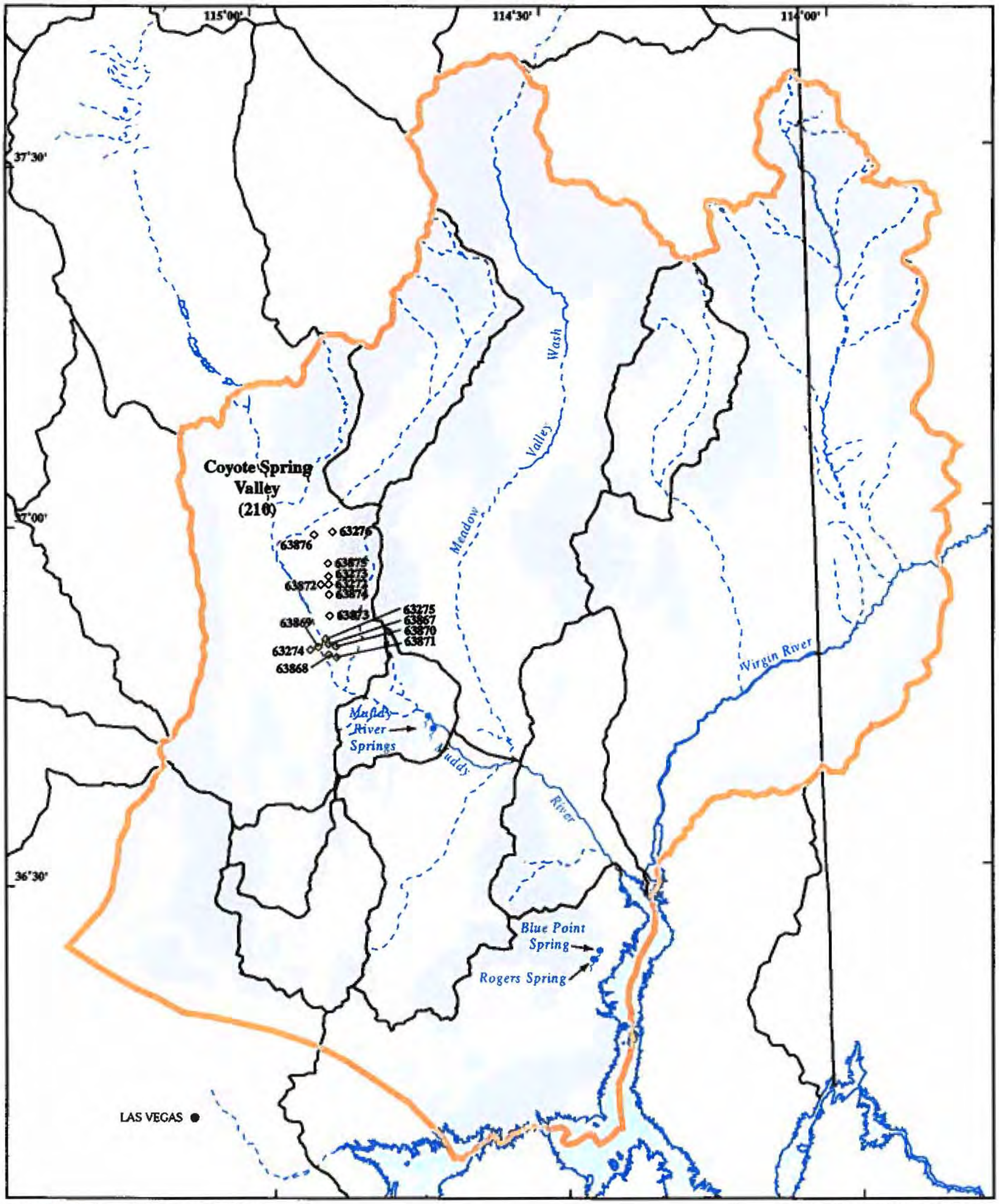

Geology modified from Plume and Carlton (1988)

Base modified from USGS digital data, 1:100,000.

Legend

- Intermittent Stream
- Perennial Stream
- Study Area
- Proposed Point of Diversion
- Consolidated Rock
- Basin Fill
- Spring
- Hydrographic Basin

N

Miles

5 0 5 10 15 20

FIGURE 10.—Locations of proposed ground-water withdrawals by Coyote Springs Investment, LLC, in Coyote Spring Valley. See Table 3 for proposed withdrawal rates and related information.

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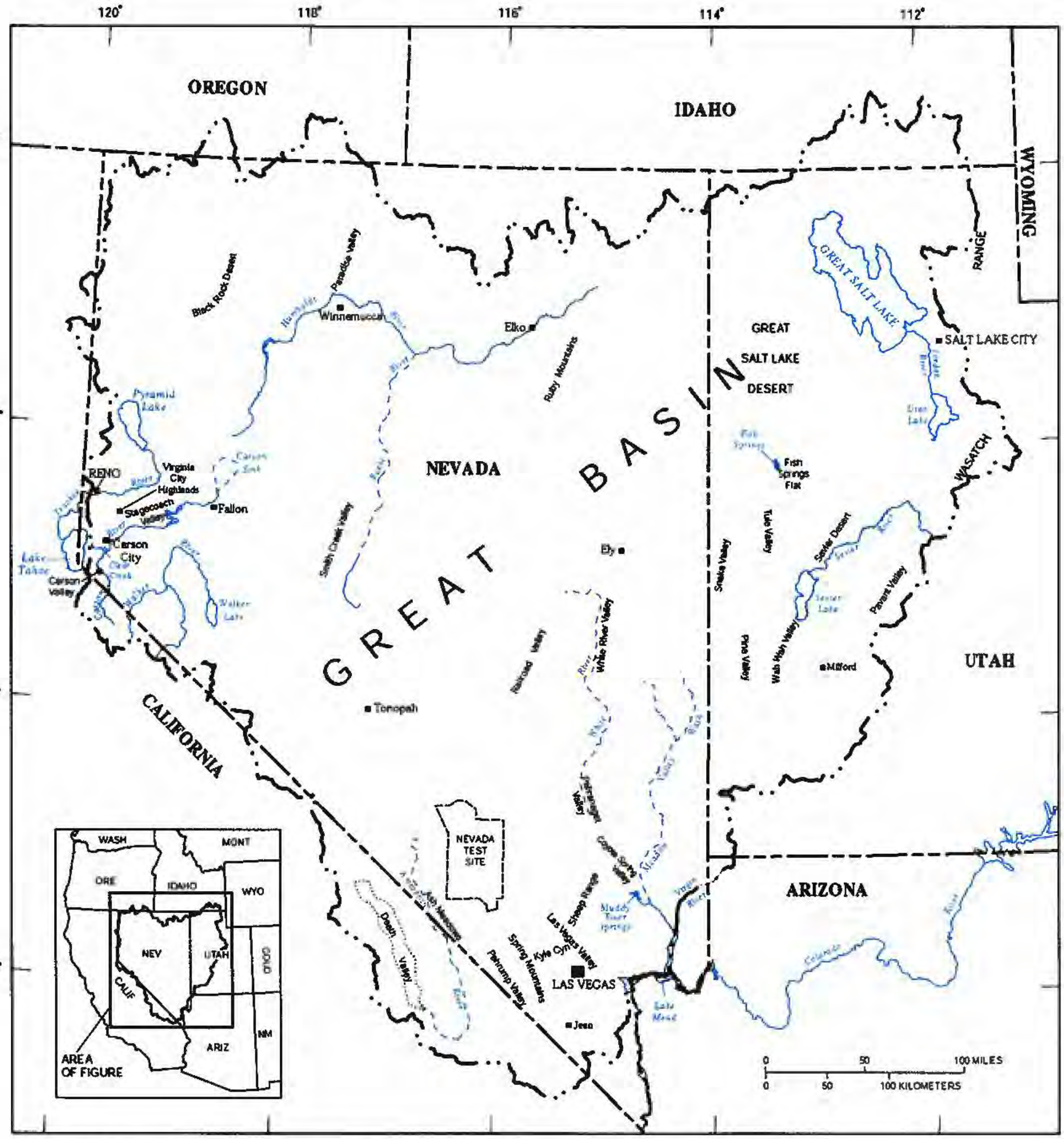

Base from U.S. Geological Survey digital data, 1:100,000, 1978-88, and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 114°00'

EXPLANATION

— · · — **Boundary of Great Basin Regional Aquifer System**

FIGURE 11.—Great Basin Regional Aquifer System. Modified from Harrill and Prudic (1998).

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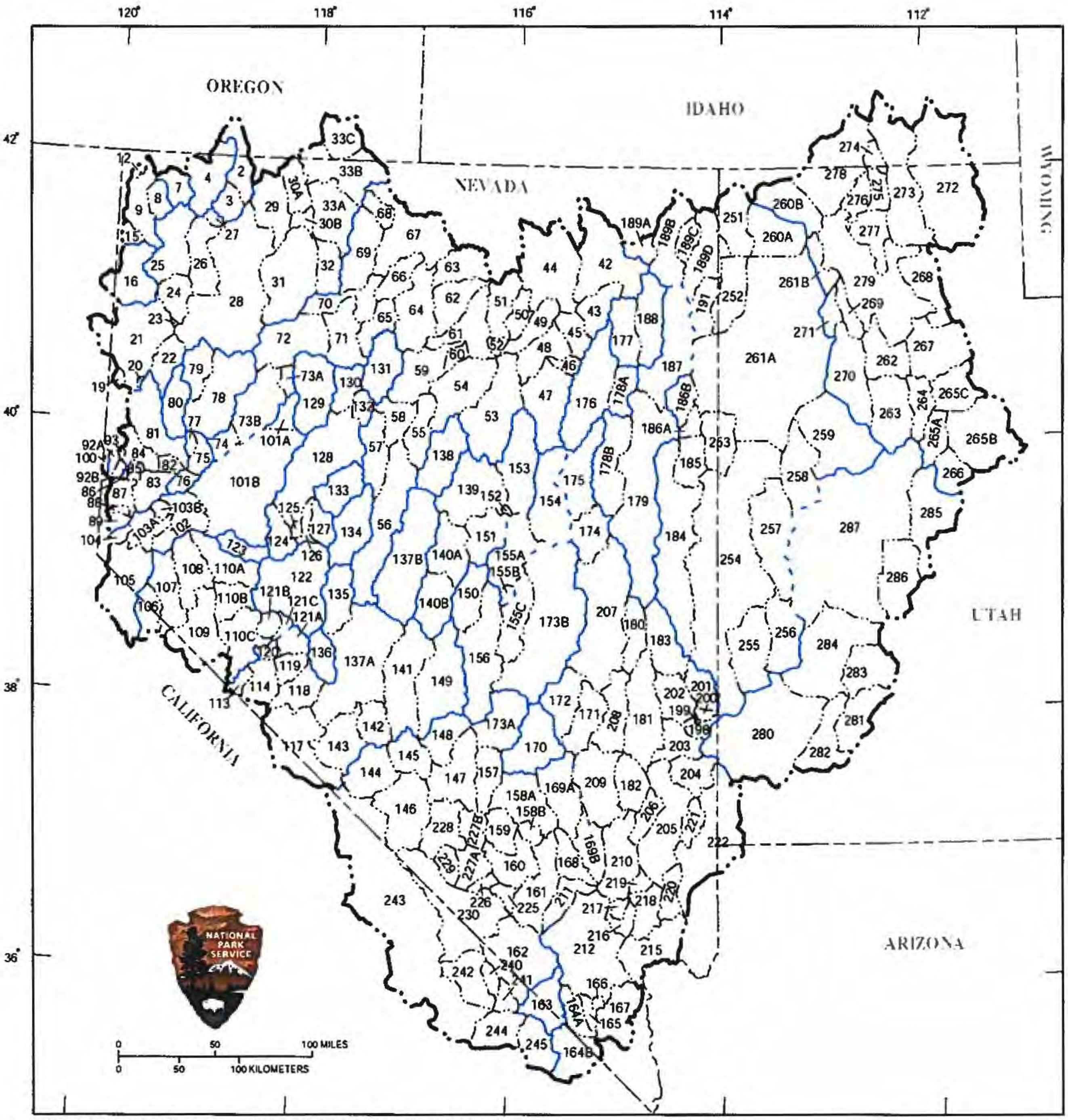
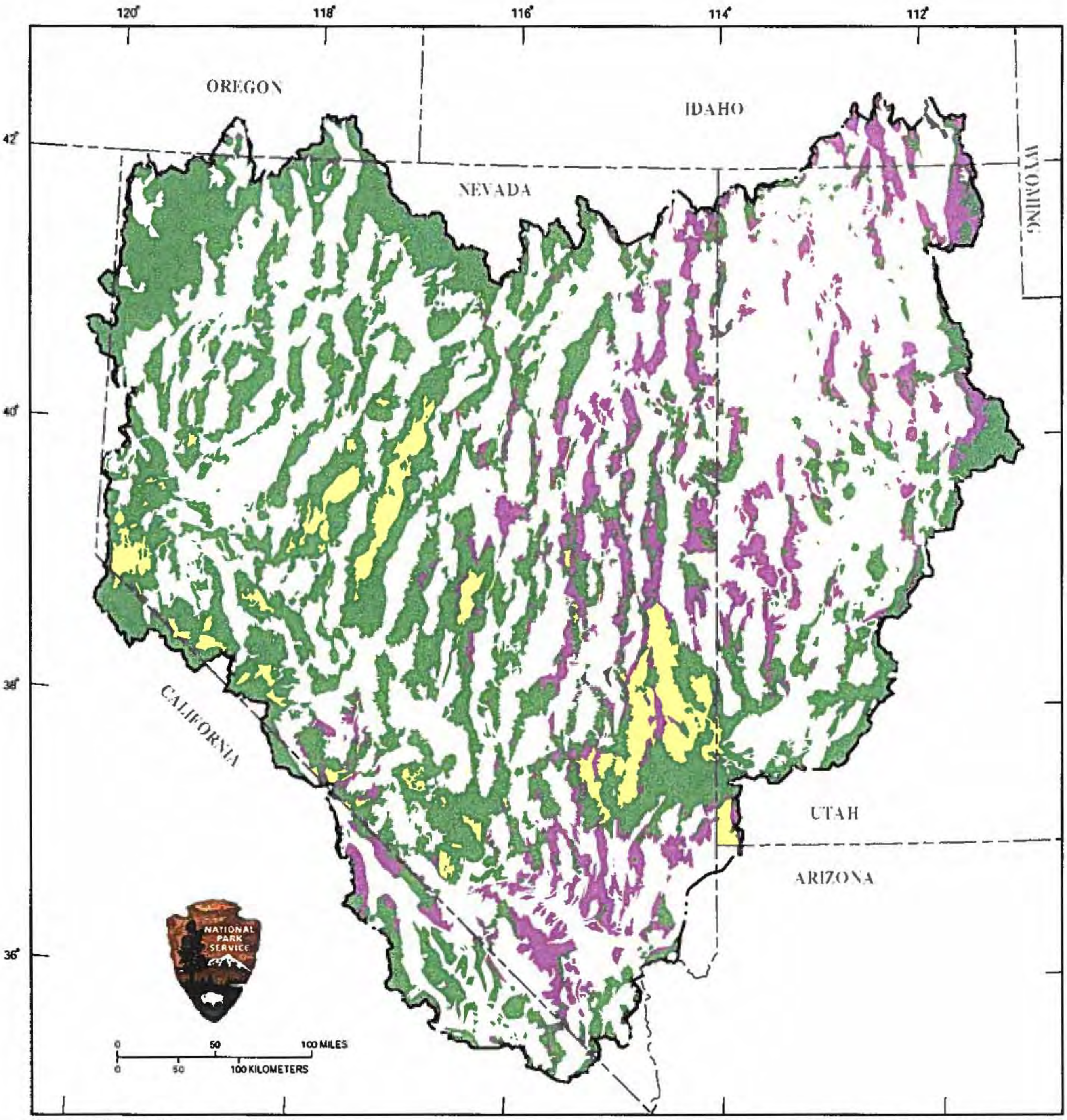


Base from U.S. Geological Survey digital data, 1:100,000, 1978-88, and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 114°00'

EXPLANATION

73B	**Hydrographic area or subarea**— Area shown by number only, subarea by number plus letter
	Boundary of Great Basin Regional Aquifer System
	Boundary of major flow system— Dashed where uncertain
	Boundary of hydrographic area or subarea

FIGURE 12.—Hydrographic areas and subareas of the Great Basin Regional Aquifer System. Modified from Harrill and Prudic (1998).



Geology modified from Plume and Carlton (1988)

Base from U.S. Geological Survey digital data, 1:100,000, 1978-88, and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 114°00'

EXPLANATION

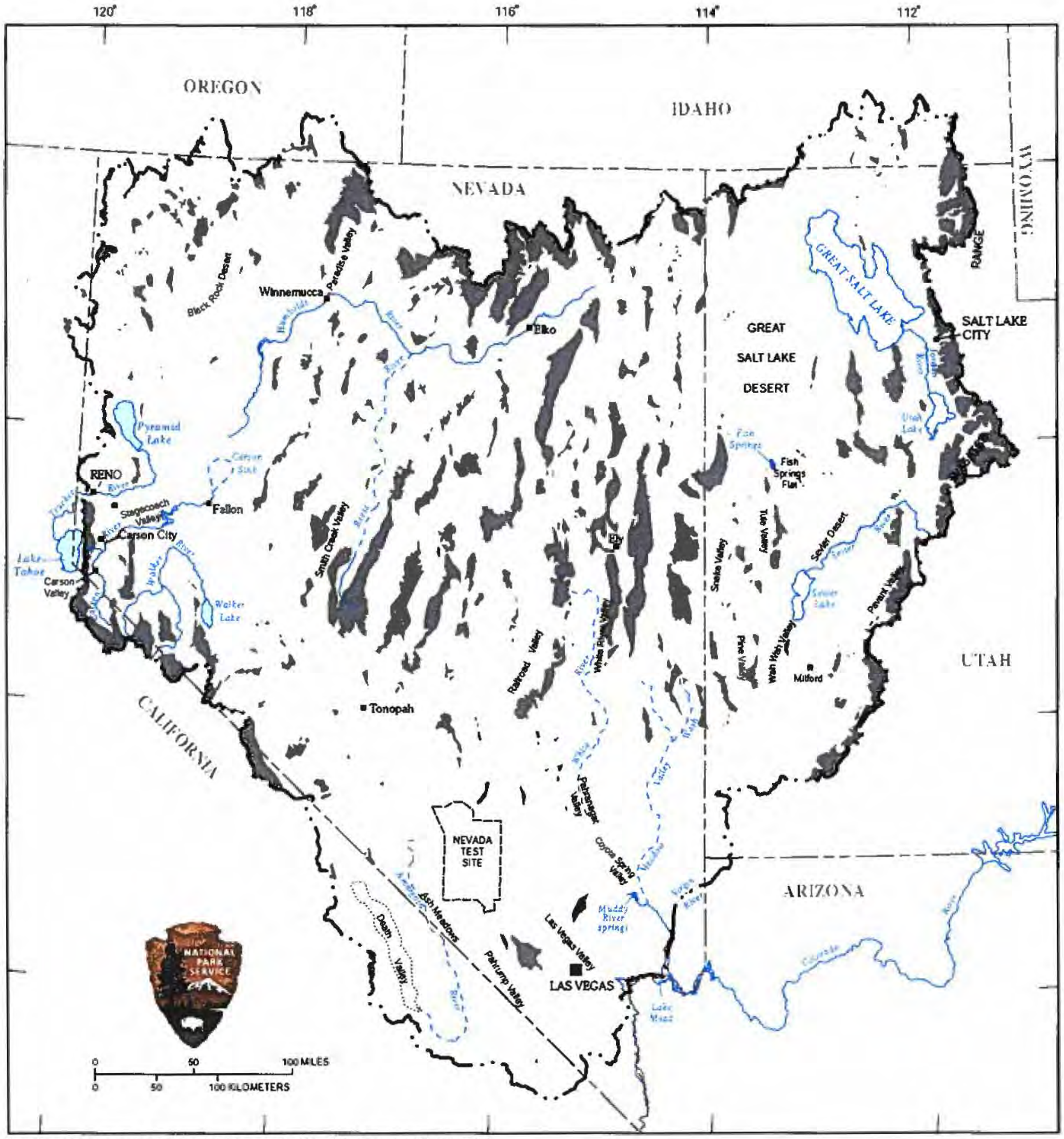
Basin fill— Mixed alluvial, colluvial, and lacustrine basin-fill deposits; some interbedded volcanic deposits. Most water pumped by wells is derived from deposits of gravel or sand or both. Forms basin-fill aquifers

Noncarbonate consolidated rocks— Fine-grained clastic rocks, metamorphic rocks, intrusive rocks, and most volcanic rocks. Generally function as relative barrier to ground-water flow. Stipple indicates very fractured volcanic rocks (some basalts and other flow rocks and some welded tuffs) that form highly permeable aquifers

Carbonate rocks— Sequences of permeable carbonate and clastic sedimentary rocks. Highest yielding aquifers are in areas of fractured carbonate rocks, where some fractures may have been enlarged by dissolution. Form carbonate-rock aquifers

Boundary of Great Basin Regional Aquifer System

FIGURE 13.—Generalized hydrogeologic units of the Great Basin Regional Aquifer System. Modified from Harrill and Prudic (1998).



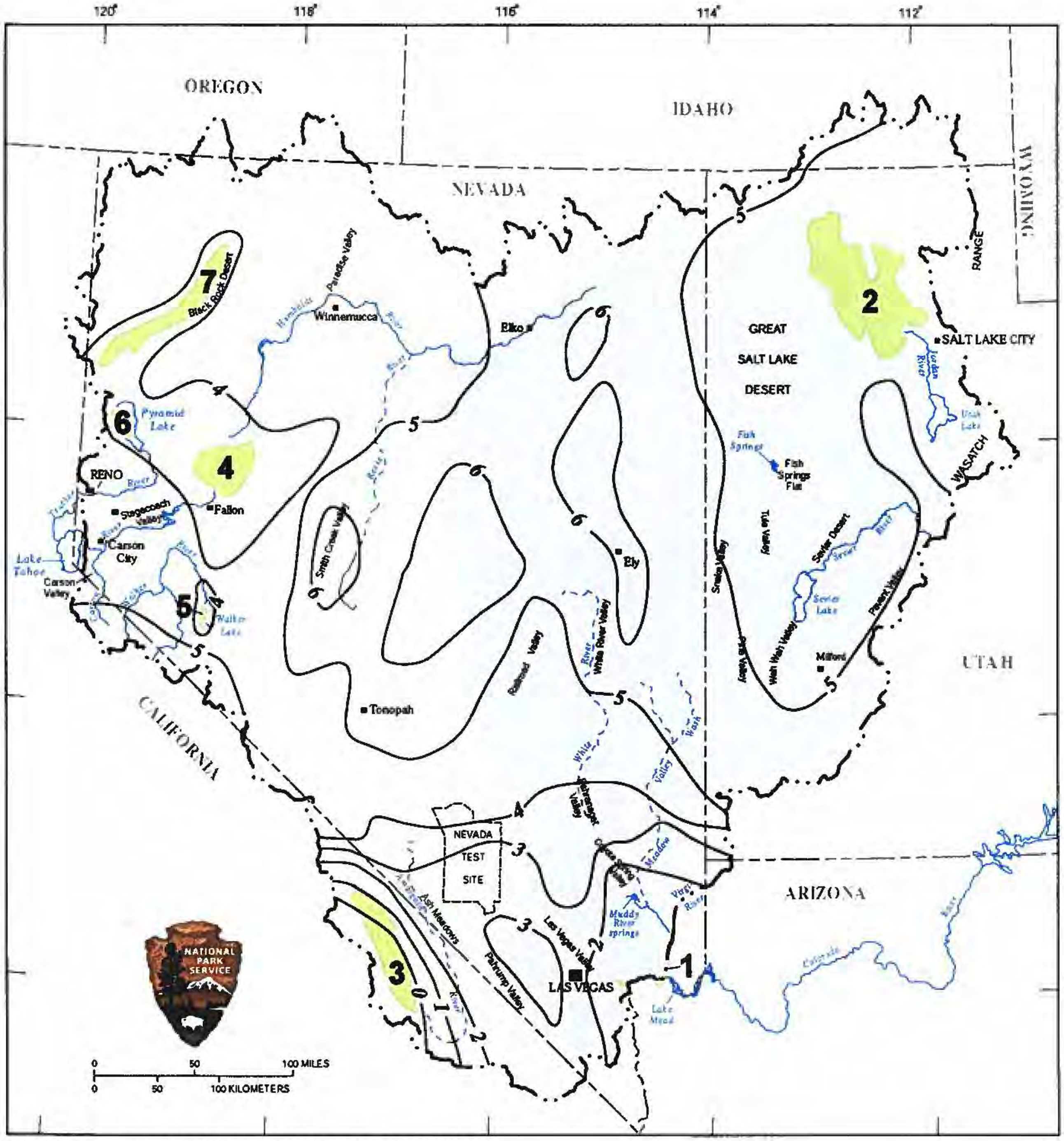
Base from U.S. Geological Survey digital data, 1:100,000, 1978-88, and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 114°00'

EXPLANATION

Major source area for ground-water recharge

Boundary of Great Basin Regional Aquifer System

FIGURE 14.—Major source areas of ground-water recharge in the Great Basin Regional Aquifer System. Modified from Harrill and Prudic (1998).



Base from U.S. Geological Survey digital data, 1:100,000, 1978-88, and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 114°00'

EXPLANATION

Carbonate-rock province

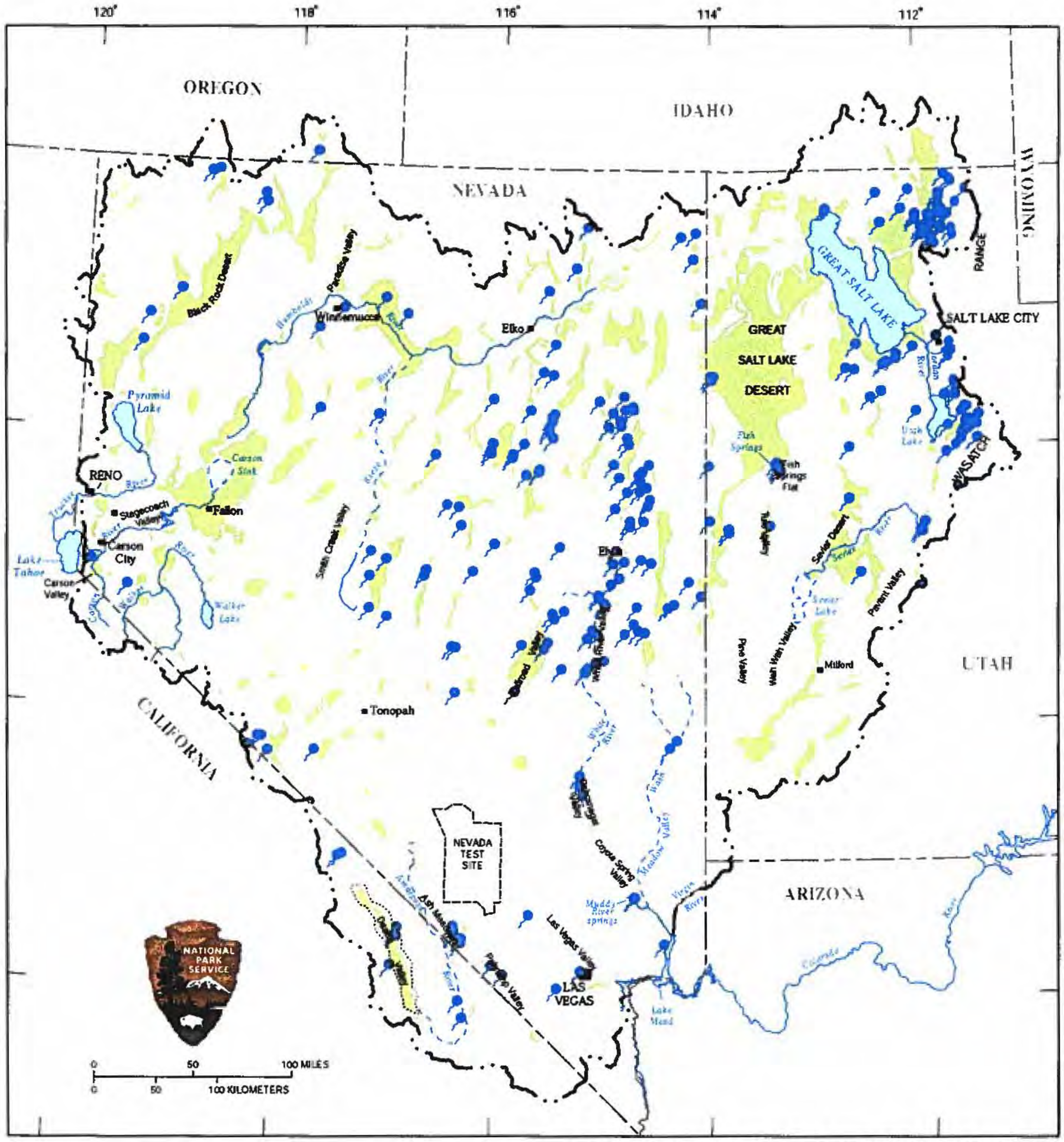
Regional-discharge area

1 Colorado River
2 Great Salt Lake
3 Death Valley
4 Carson Sink
5 Walker Lake
6 Pyramid Lake
7 Black Rock Desert

—3— **Line of equal regional-flow potential**— Number is altitude, in thousands of feet

— · · — **Boundary of Great Basin Regional Aquifer System**

FIGURE 15.—Regional ground-water flow potential in the Great Basin Regional Aquifer System. Modified from Harrill and Prudic (1998).



Base from U.S. Geological Survey digital data, 1:100,000, 1978-88, and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 114°00'

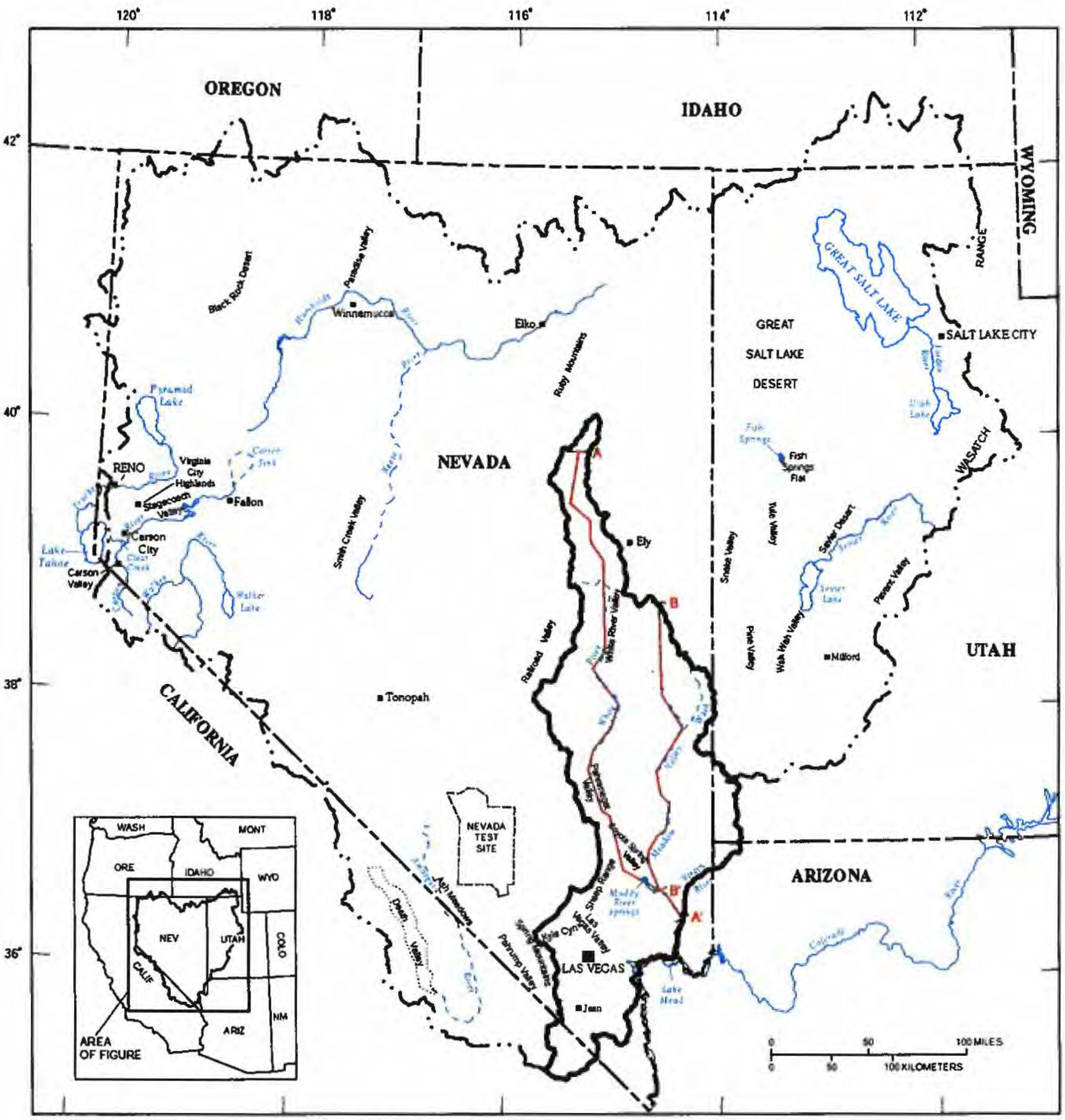
EXPLANATION

Area of shallow ground-water discharge by evapotranspiration

Boundary of Great Basin Regional Aquifer System

Large spring— In Utah and most of Nevada, springs having discharge generally greater than 1,000 gallons per minute; in more-arid parts of Nevada, Oregon, and California, regionally significant springs having discharges greater than 200 gallons per minute.

FIGURE 16.—Locations of large springs and areas of ground-water discharge by evapotranspiration in the Great Basin Regional Aquifer System. Modified from Harrill and Prudic (1998).



Base from U.S. Geological Survey digital data, 1:100,000, 1978-88, and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 114°00'

EXPLANATION

- Boundary of Great Basin Regional Aquifer System
- Colorado Regional Ground Water Flow System
- Trace of Cross Section

FIGURE 17.—Trace of cross sections A-A' and B-B'. See Figure 18 for cross-sectional views.

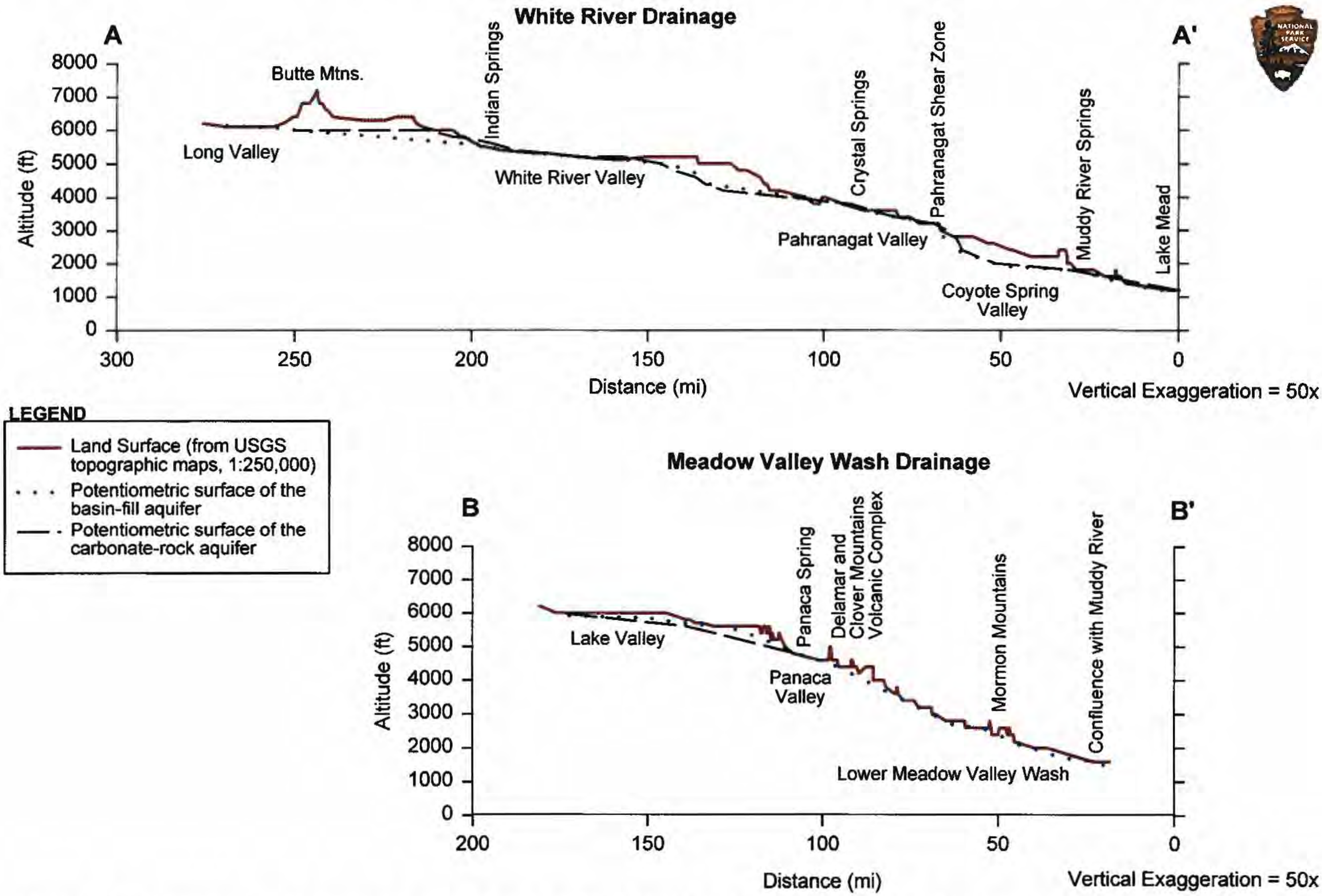


Figure 18a. - Longitudinal cross-sectional diagrams along the White River (A-A') and Meadow Valley Wash (B-B') drainages, showing the potentiometric surfaces of the basin-fill and carbonate-rock aquifers. See Figure 17 for locations of cross sections. Potentiometric-surface information taken from USGS HA-694-B (Thomas and others, 1986).

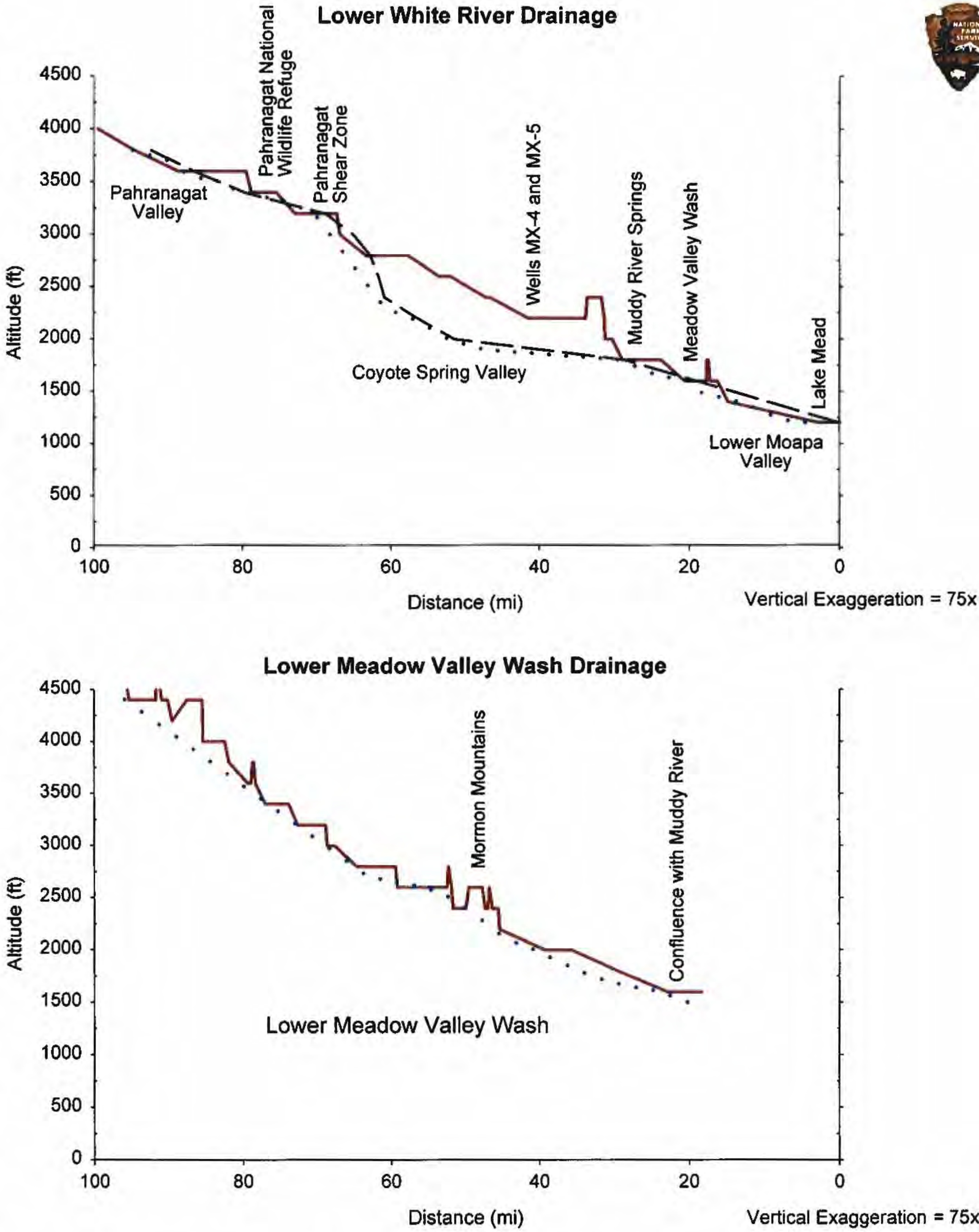
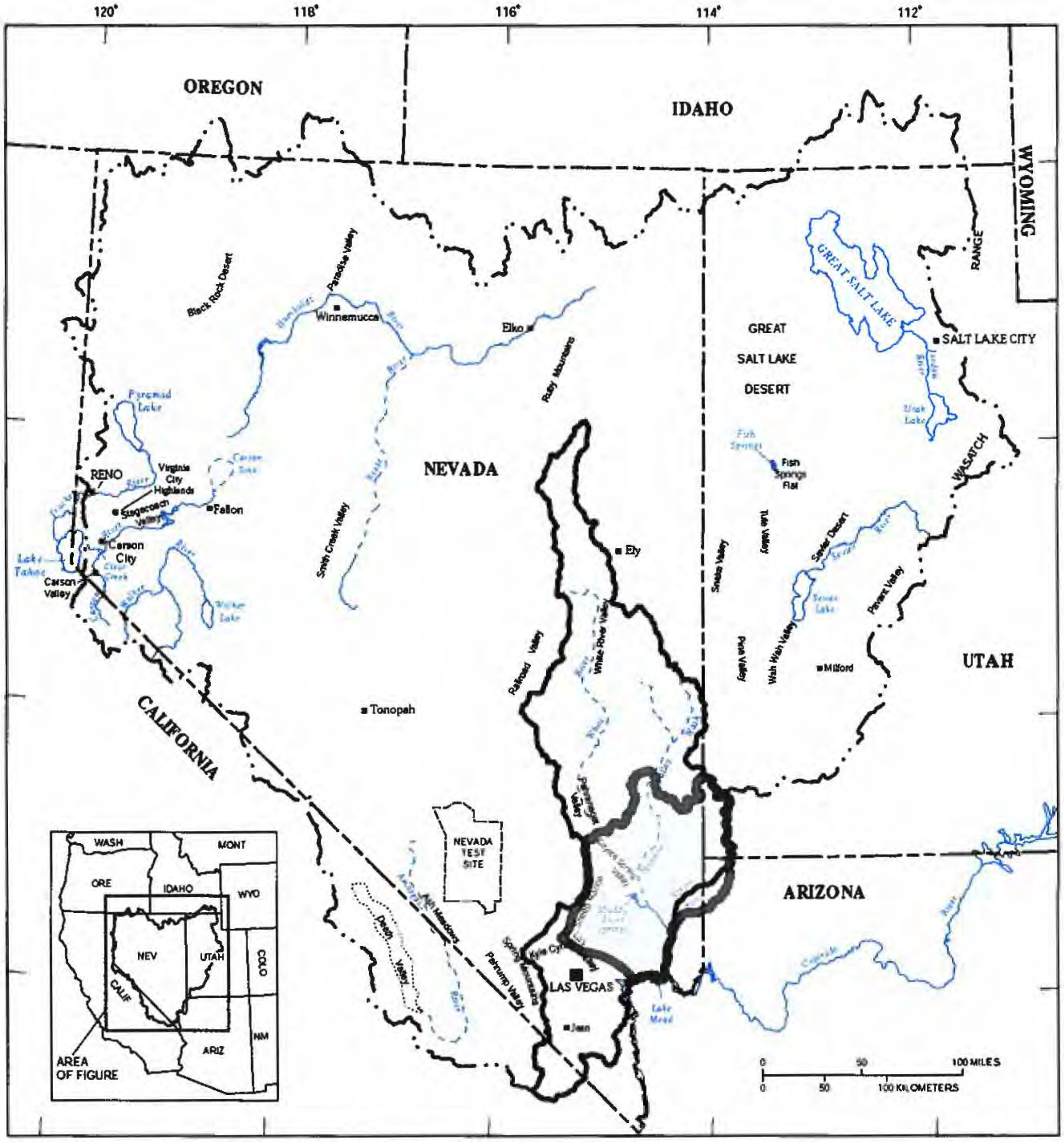


Figure 18b. - Enlarged longitudinal cross sections of the lower part of the White River and Meadow Valley Wash drainages, taken from Figure 18a.



Base from U.S. Geological Survey digital data, 1:100,000, 1978-88, and 1:250,000, 1987
Albers Equal-Area Conic projection
Standard parallels 29°30' and 45°30', central meridian 114°00'

EXPLANATION

- Boundary of Great Basin Regional Aquifer System
- Lower Colorado Flow System (Study Area)
- Colorado Regional Ground Water Flow System

FIGURE 19.—The Colorado Regional Ground-Water Flow System and the Lower Colorado Flow System within the Great Basin Regional Aquifer System. Modified from Harrill and Prudic (1998).

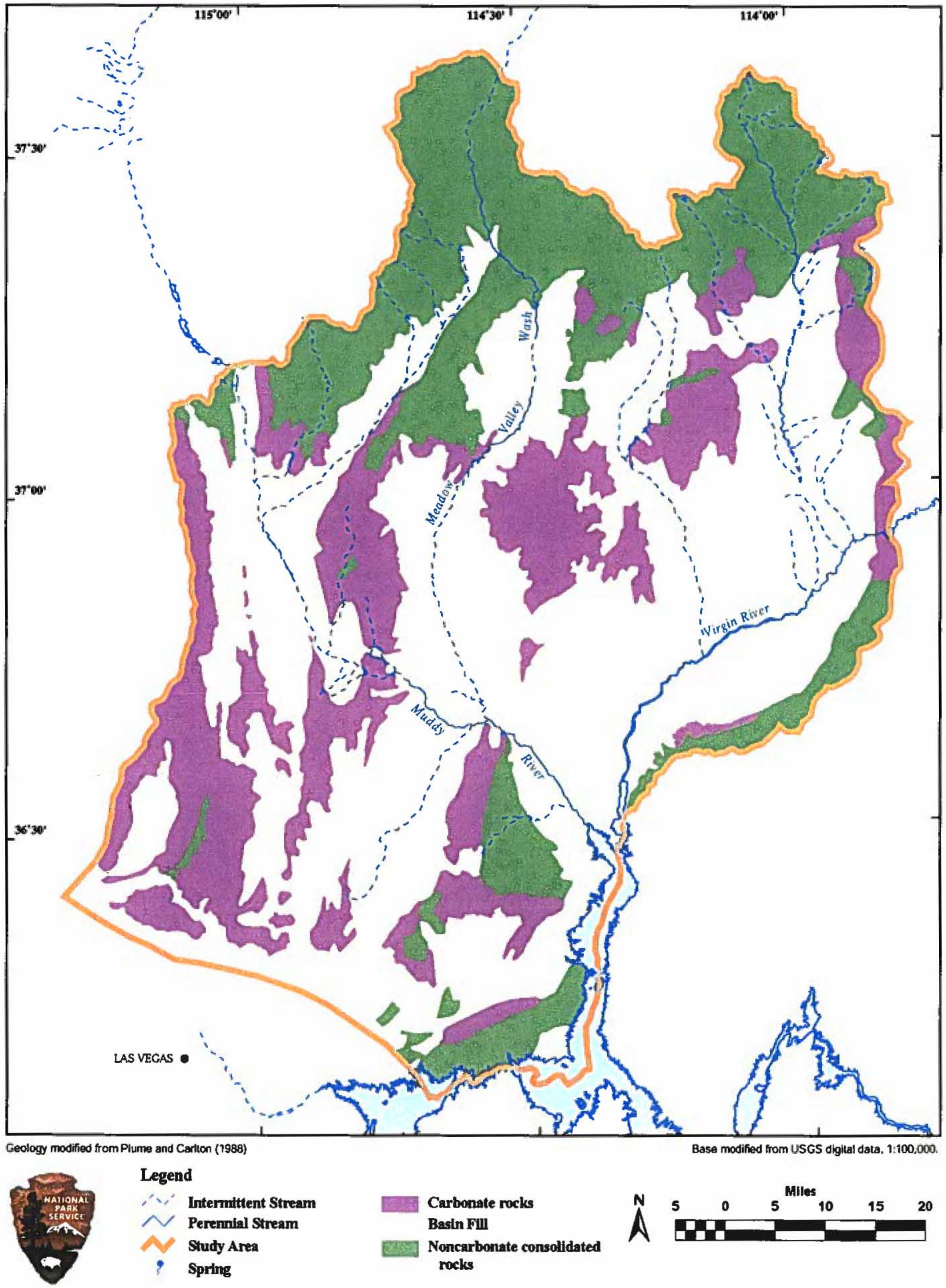


FIGURE 20.—Generalized hydrogeologic units in the study area. Modified from Harrill and Prudic, 1998.

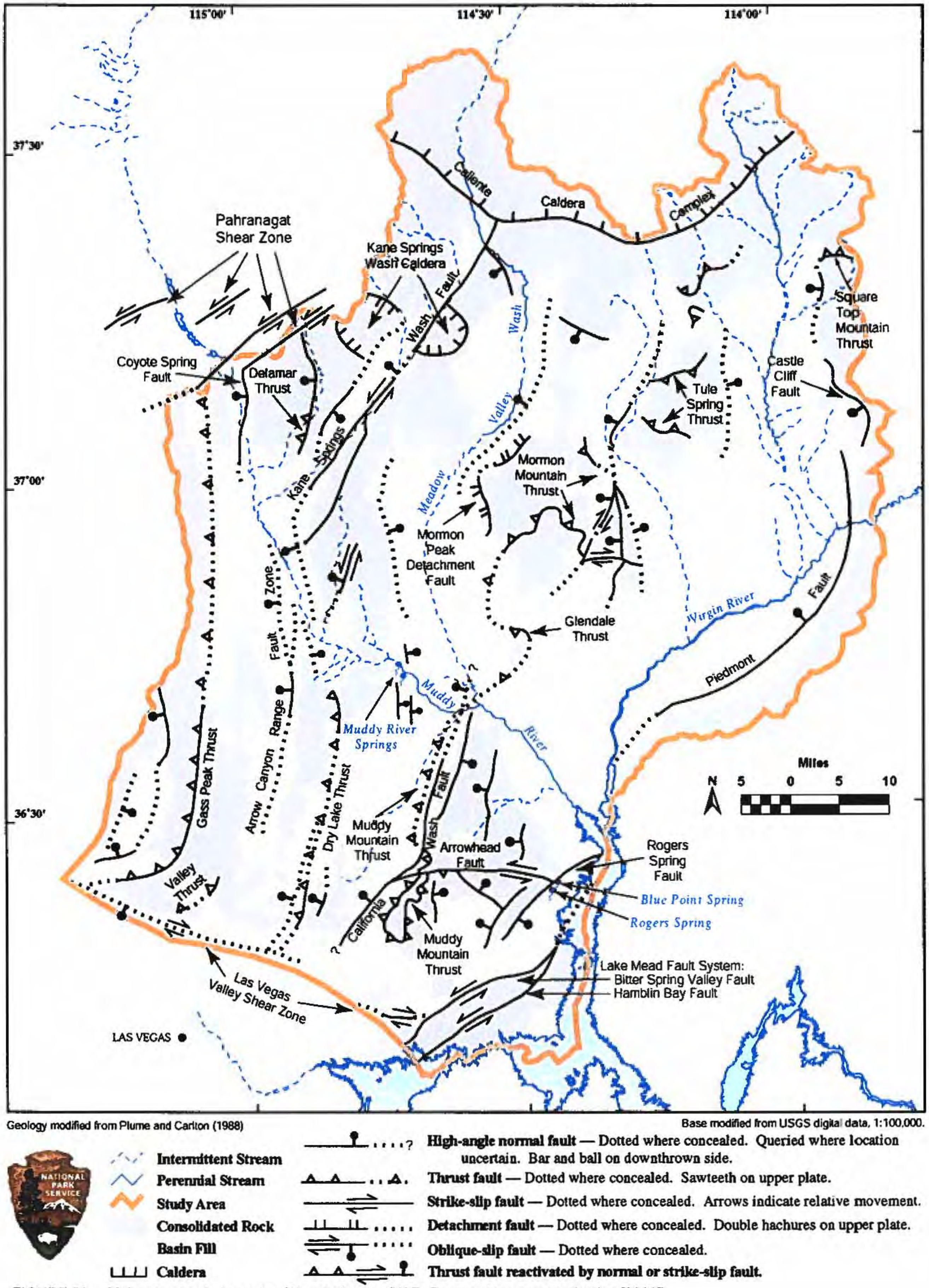


FIGURE 21.—Major structural elements of the study area (W.R. Page, written communication [2001]).

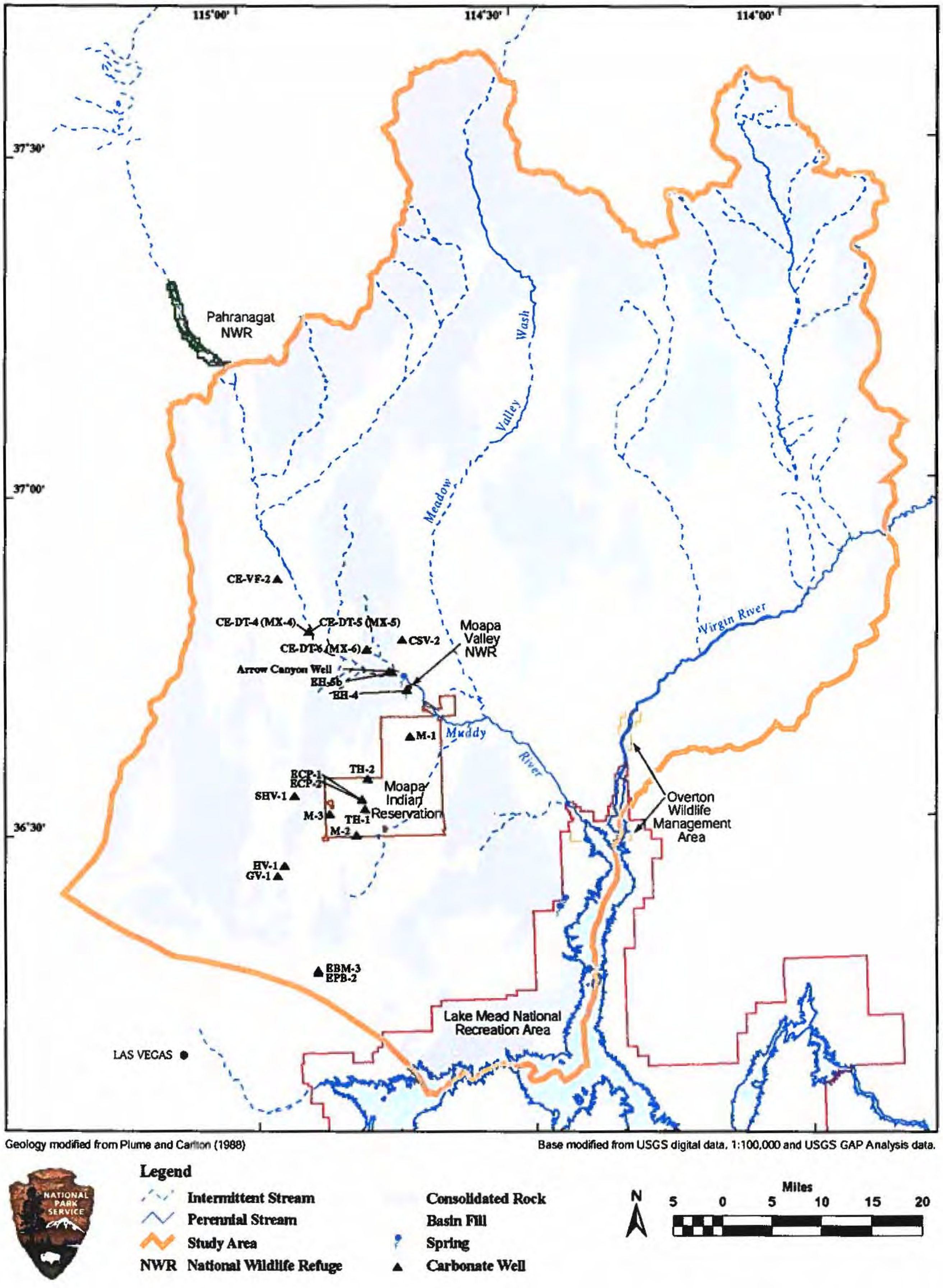


FIGURE 22.—Locations of wells within the study area that are completed in the regional carbonate-rock aquifer.

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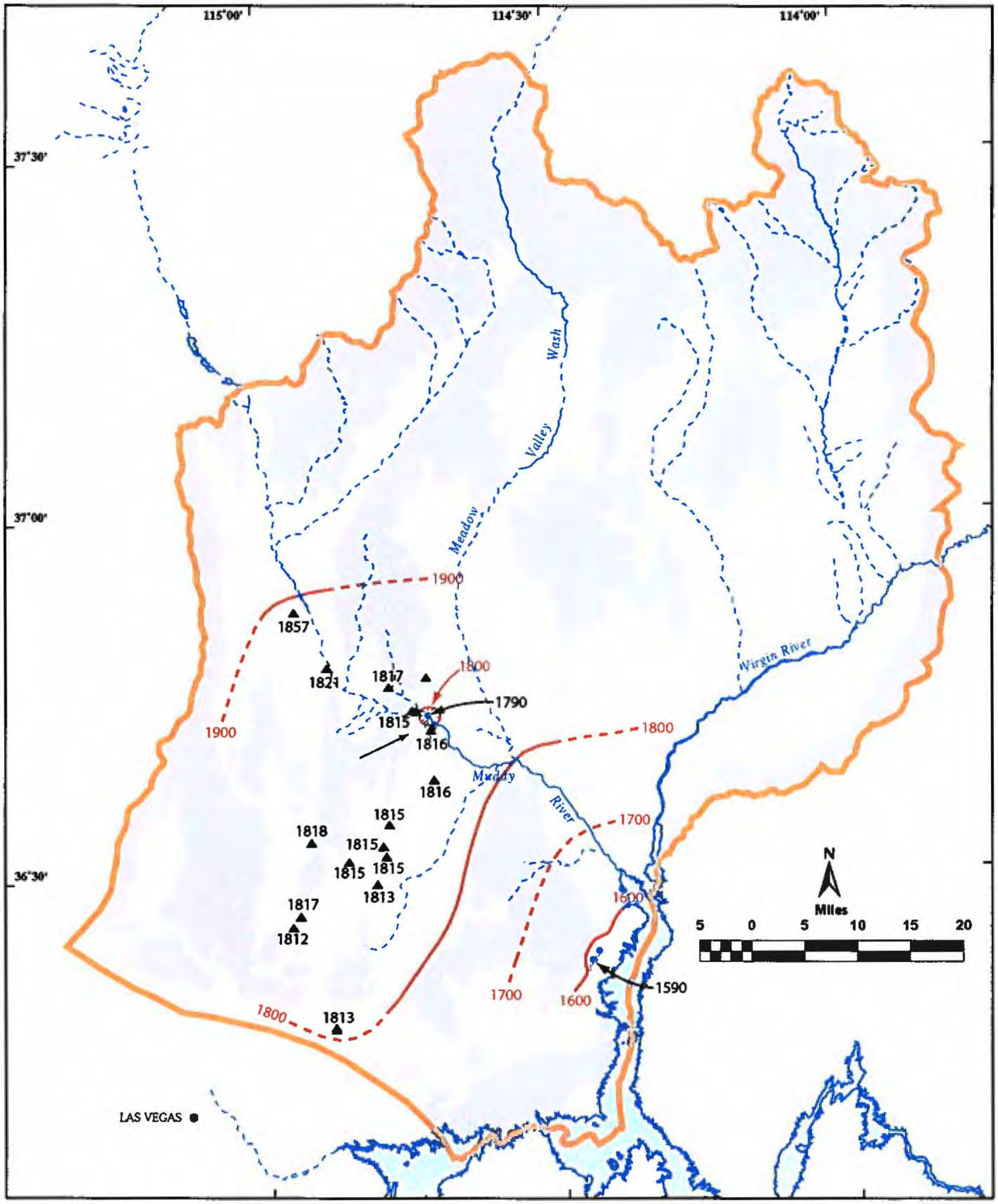


Geology modified from Plume and Carlton (1988)

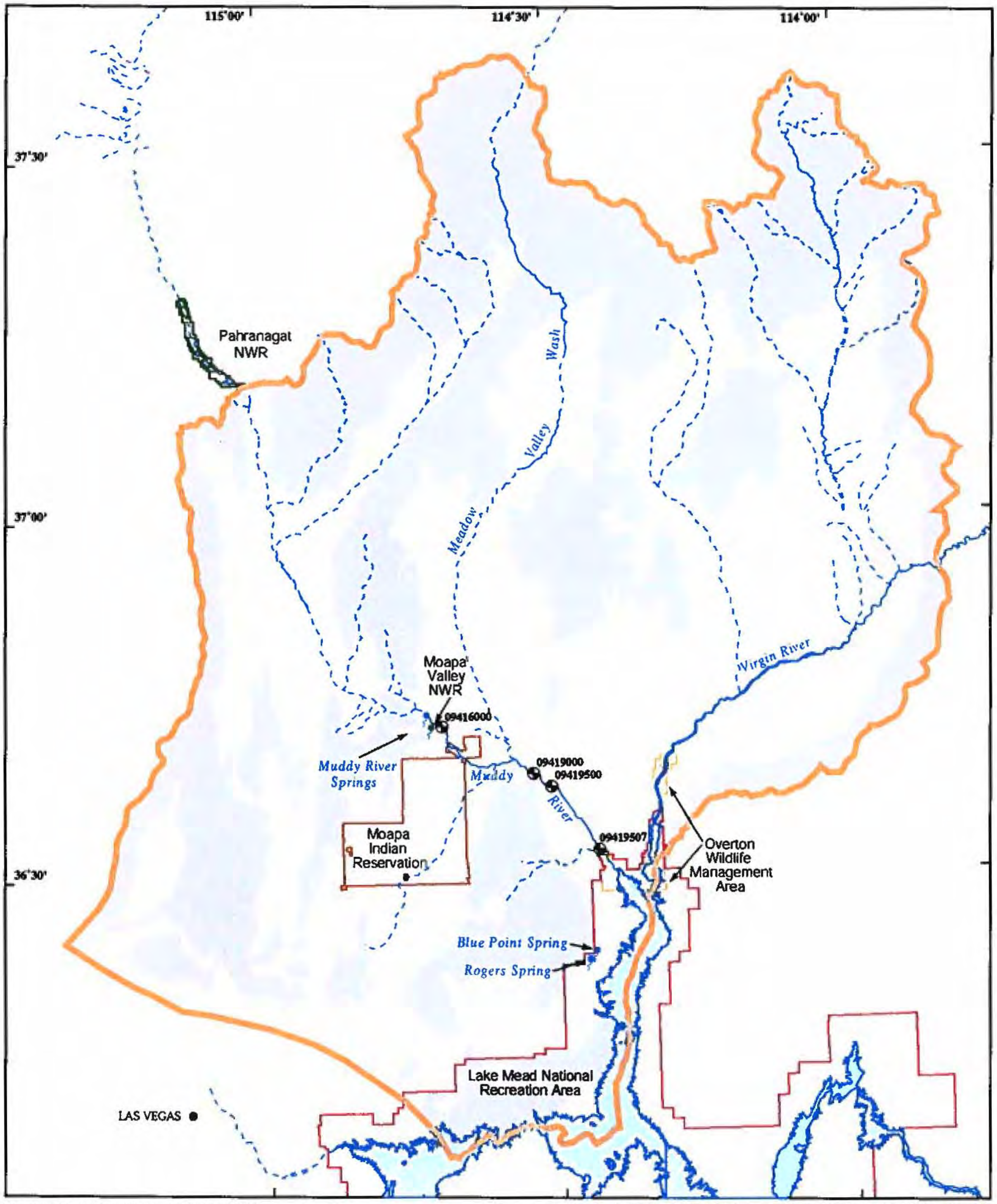
Base modified from USGS digital data. 1:100,000.

Legend

- Intermittent Stream
- Perennial Stream
- Study Area
- Spring
- Potentiometric - Surface Contour. Dashed where approximately located. Contour interval is 100 feet.
- Consolidated Rock
- Basin Fill
- 1812 Carbonate well with altitude of water level. Datum is sea level.

FIGURE 23.—Potentiometric surface of the regional carbonate-rock aquifer within the study area.

SE ROA 41430



Geology modified from Plume and Carlton (1988)

Base modified from USGS digital data, 1:100,000 and USGS GAP Analysis data.

Legend

	Intermittent Stream		Consolidated Rock
	Perennial Stream		Basin Fill
	Study Area		Spring
NWR	National Wildlife Refuge		USGS streamflow-gaging station

N

Miles

5 0 5 10 15 20

FIGURE 24.—Locations of USGS streamflow-gaging stations along the Muddy River.

SE ROA 41431

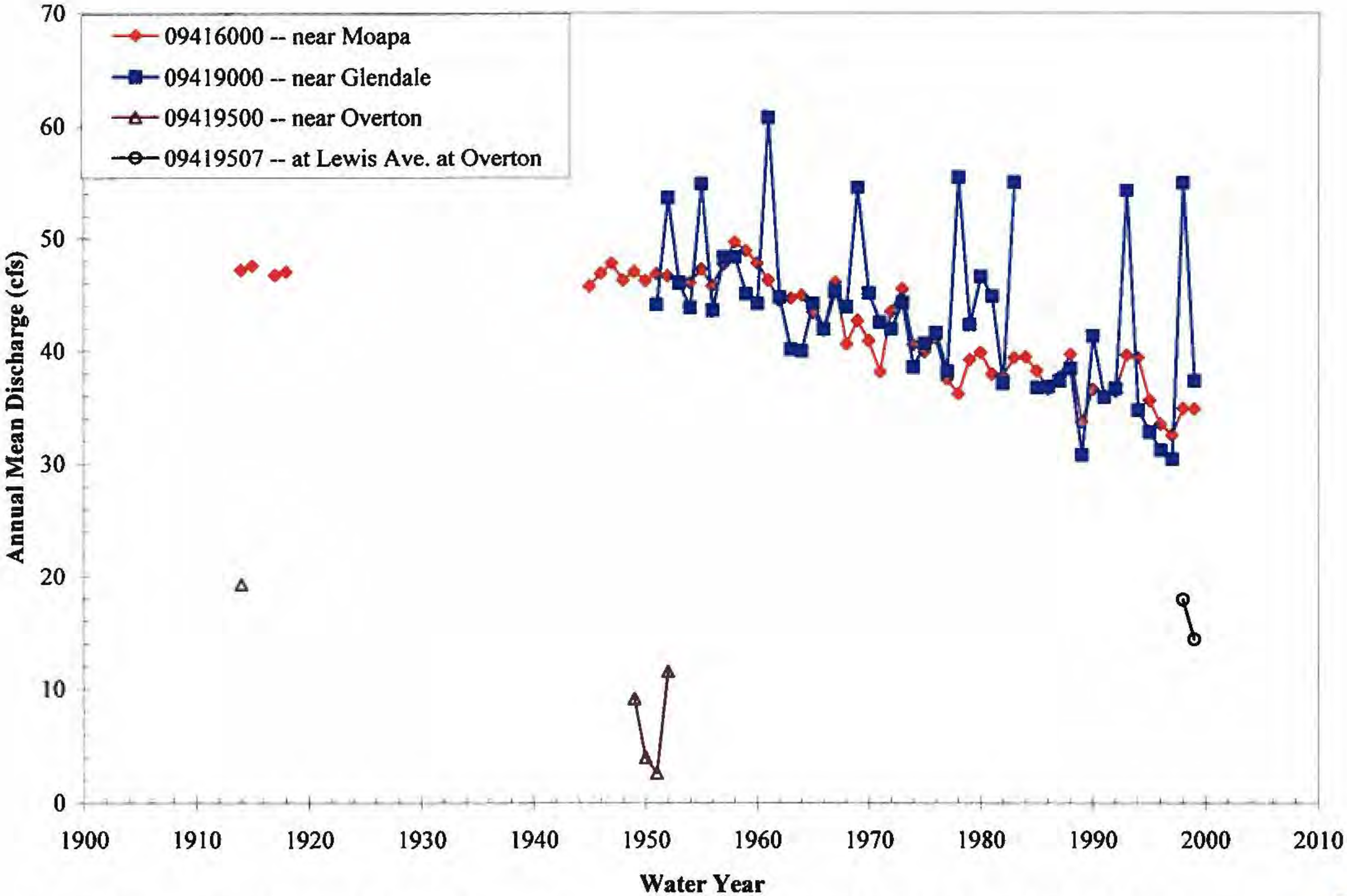


Figure 25. - Discharge vs. time at USGS streamflow-gaging stations along the Muddy River, 1914-2000. See Figure 24 for locations of gaging stations.

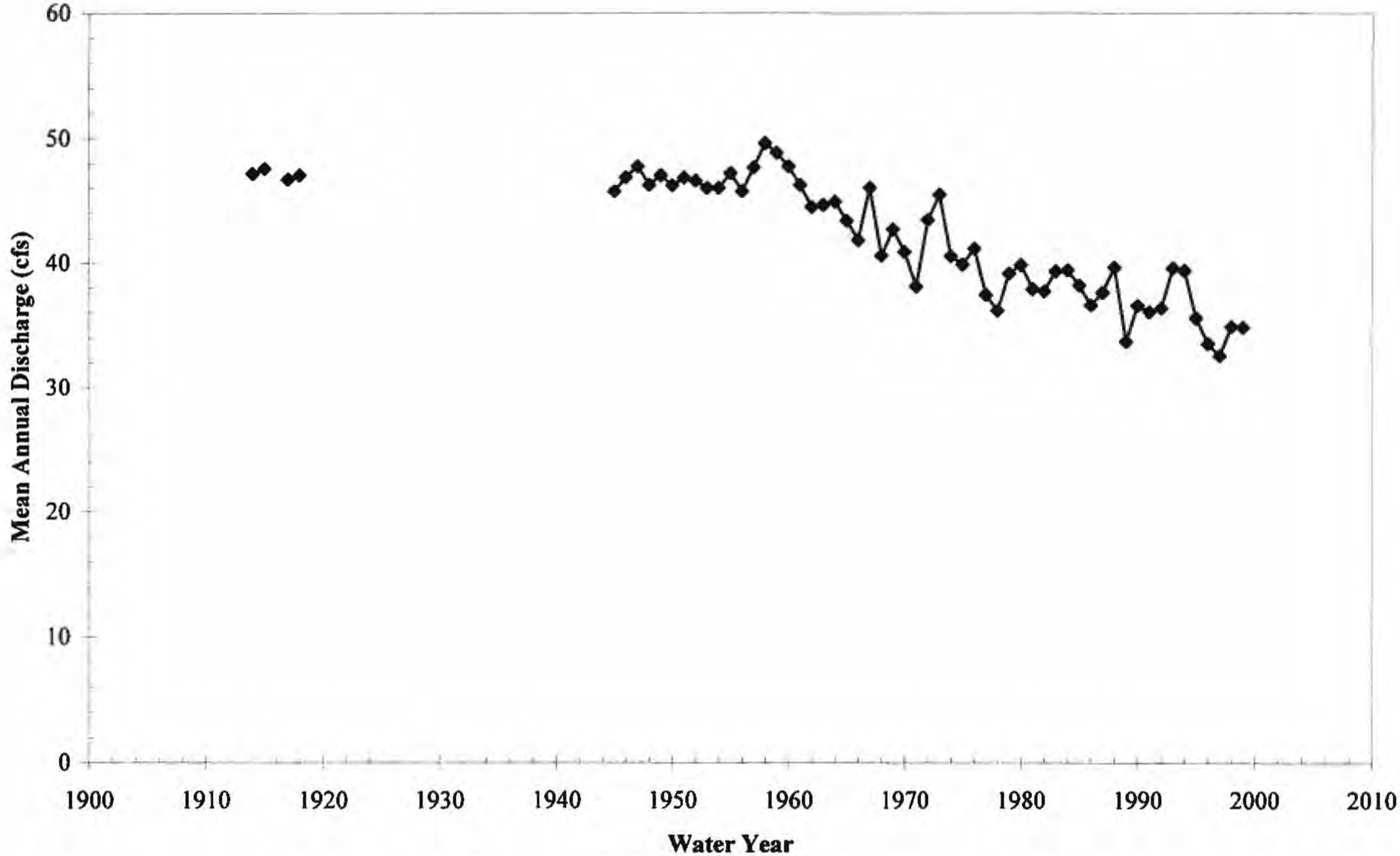


Figure 26. - Discharge vs. time at USGS streamflow-gaging station 09416000 (Muddy River near Moapa, Nevada), 1914-2000. See Figure 24 for location of gaging station.

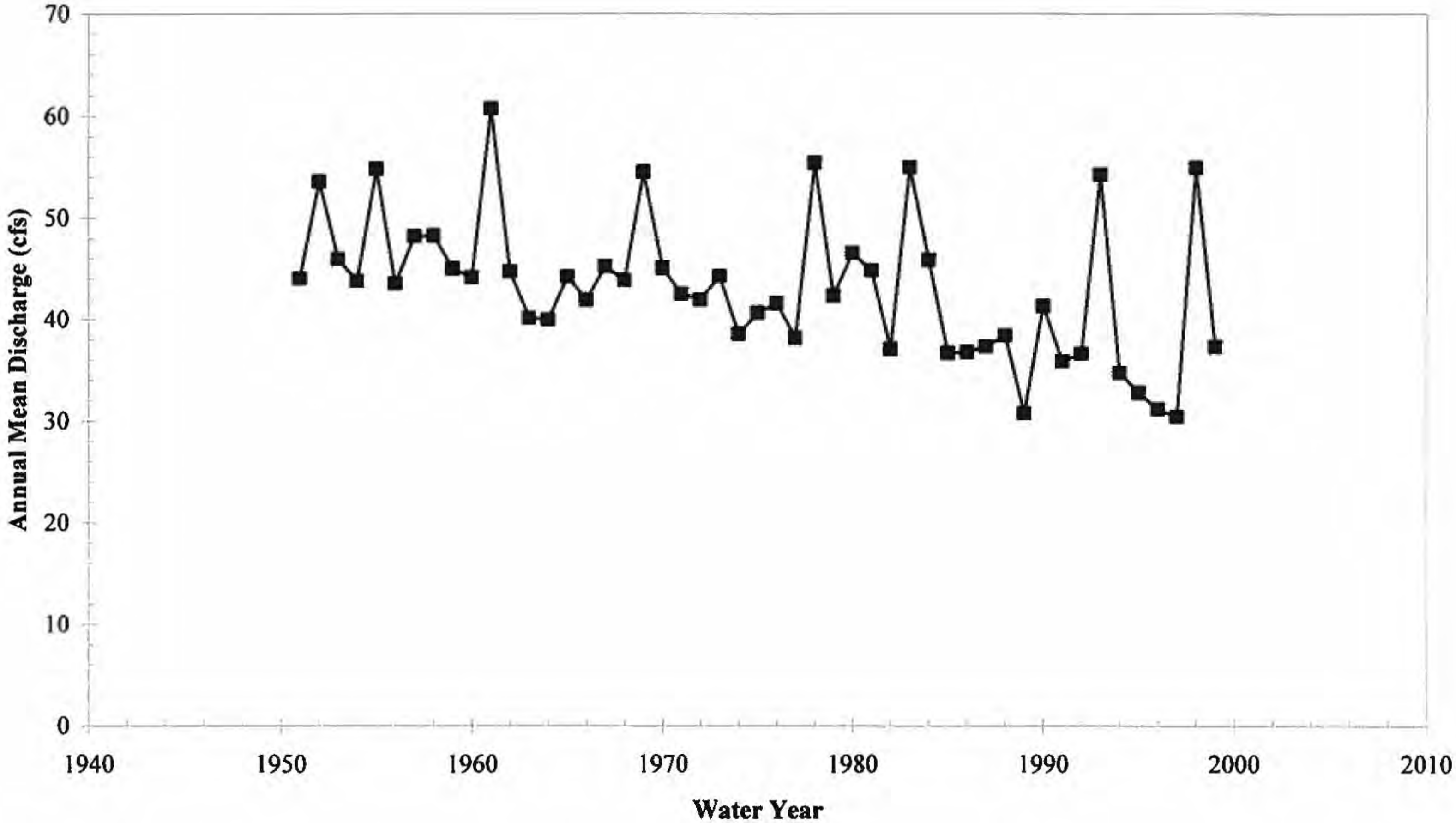


Figure 27. - Discharge vs. time at USGS streamflow-gaging station 09419000 (Muddy River near Glendale, Nevada), 1951-2000. See Figure 24 for location of gaging station. Note: 1984 value is an estimate.

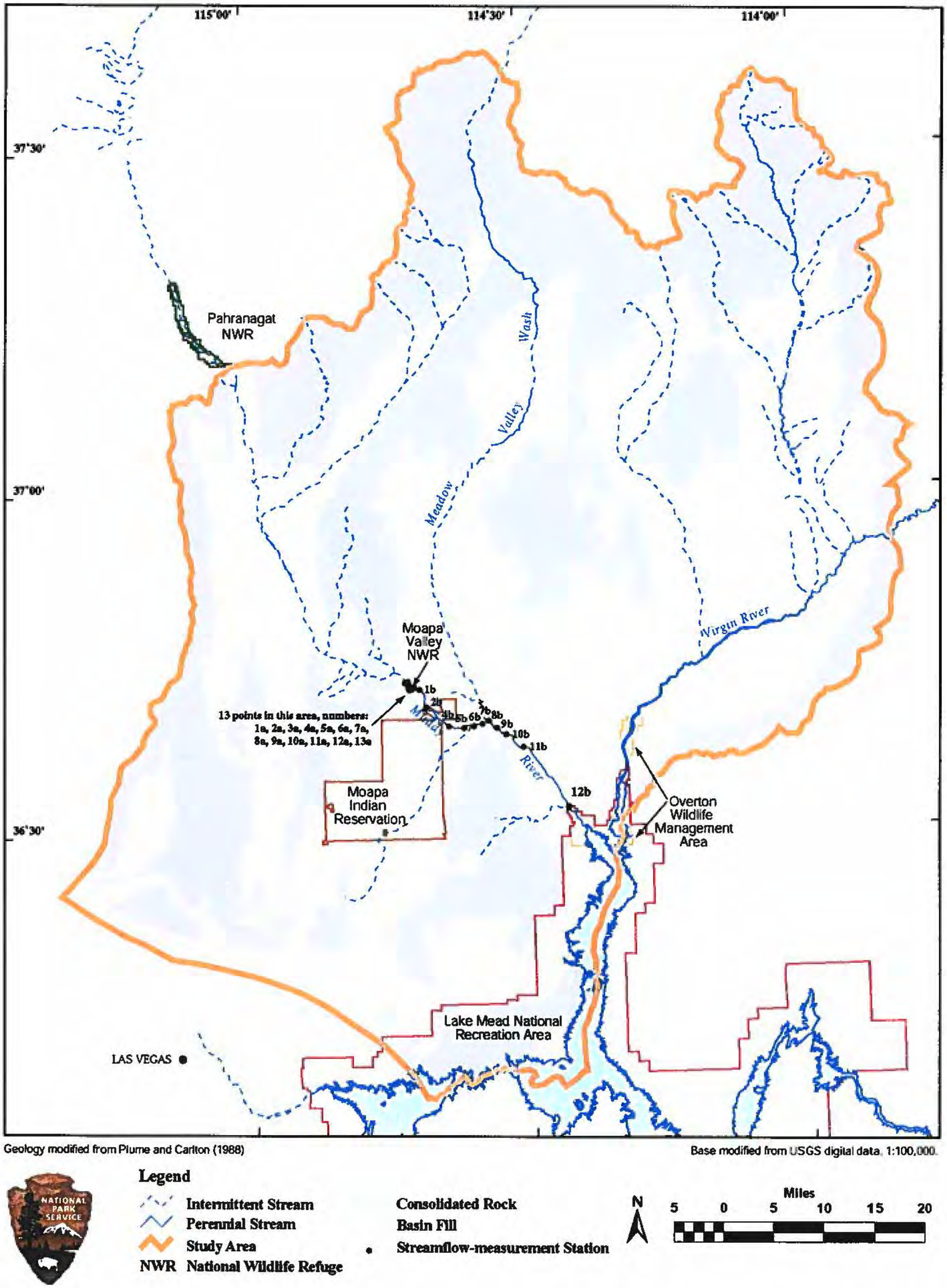


FIGURE 28.—Locations of streamflow-measurement stations along the Muddy River during the gain-and-loss run, February 7, 2001. See Table 4 for station names and related information.

SE ROA 41435

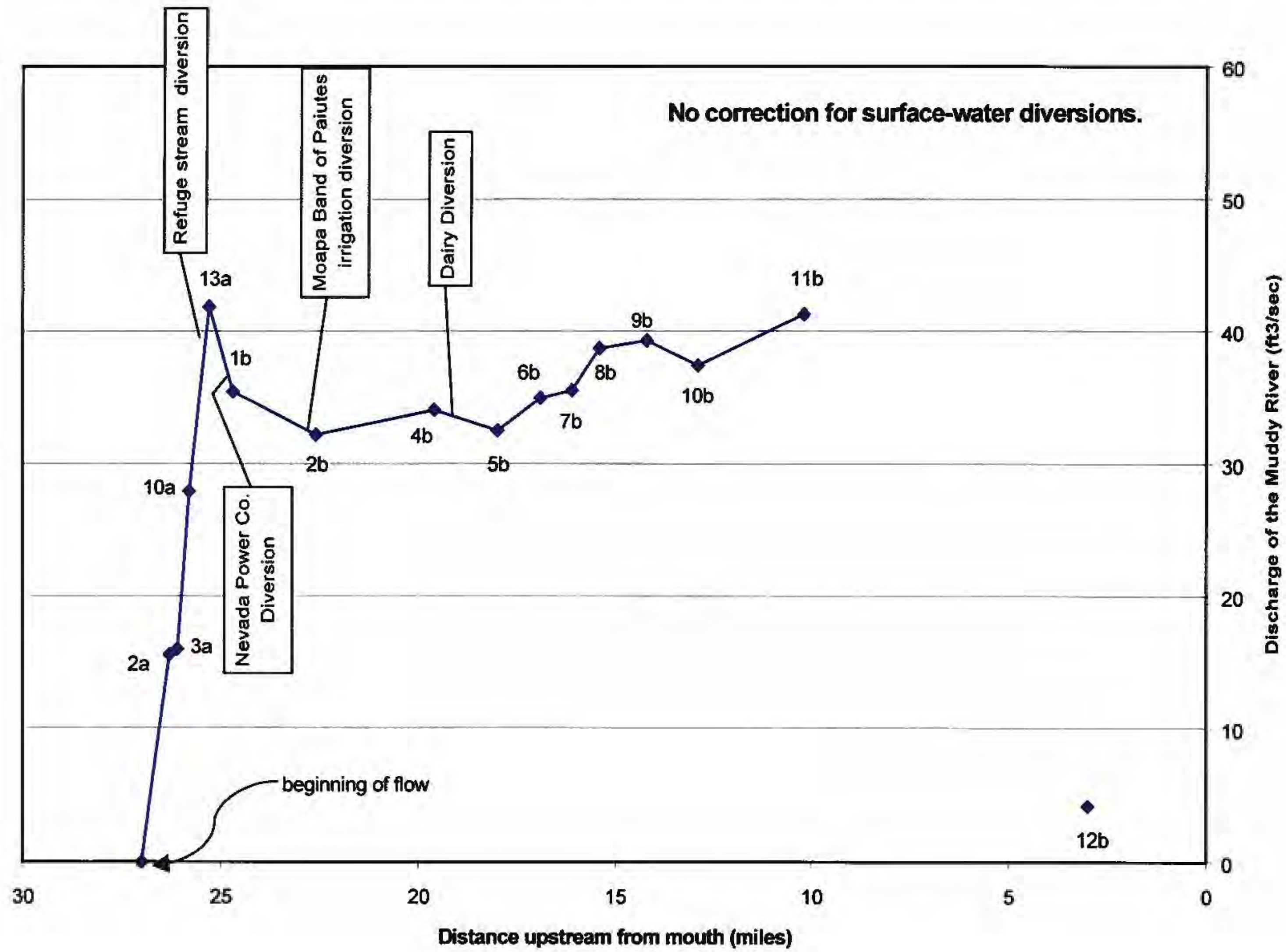


Figure 29a. - Discharge vs. distance along the Muddy River, February 7, 2001. See Figure 28 for locations of streamflow-measurement stations. See Table 3 for station names and related information.

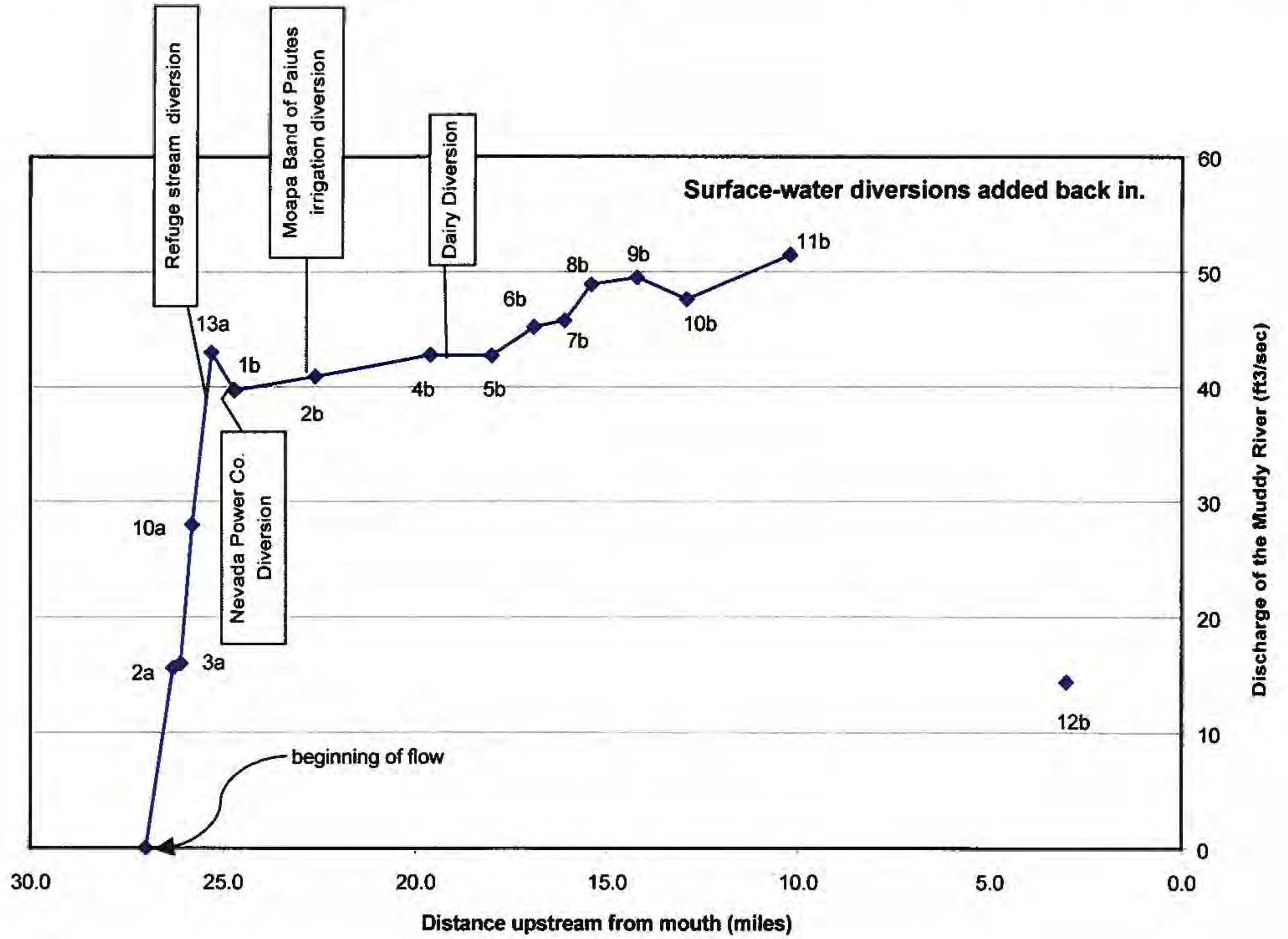


Figure 29b. - Discharge vs. distance along the Muddy River, February 7, 2001. See Figure 28 for locations of streamflow-measurement stations. See Table 3 for station names and related information.

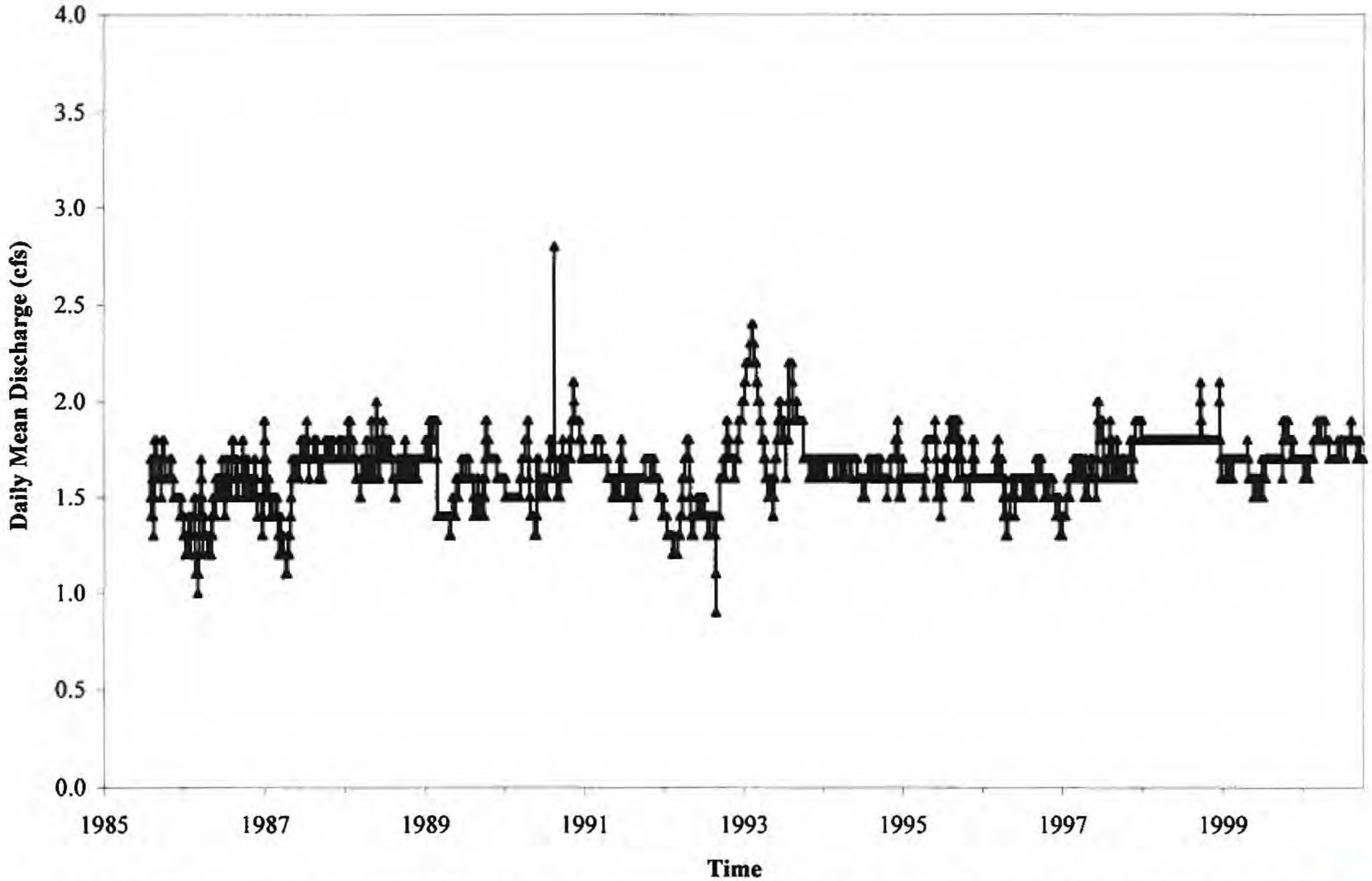


Figure 30. - Discharge vs. time at USGS gaging station 09419550 (Rogers Spring near Overton Beach, Nevada), 1985-2000. See Figures 4 through 6 for location of Rogers Spring.

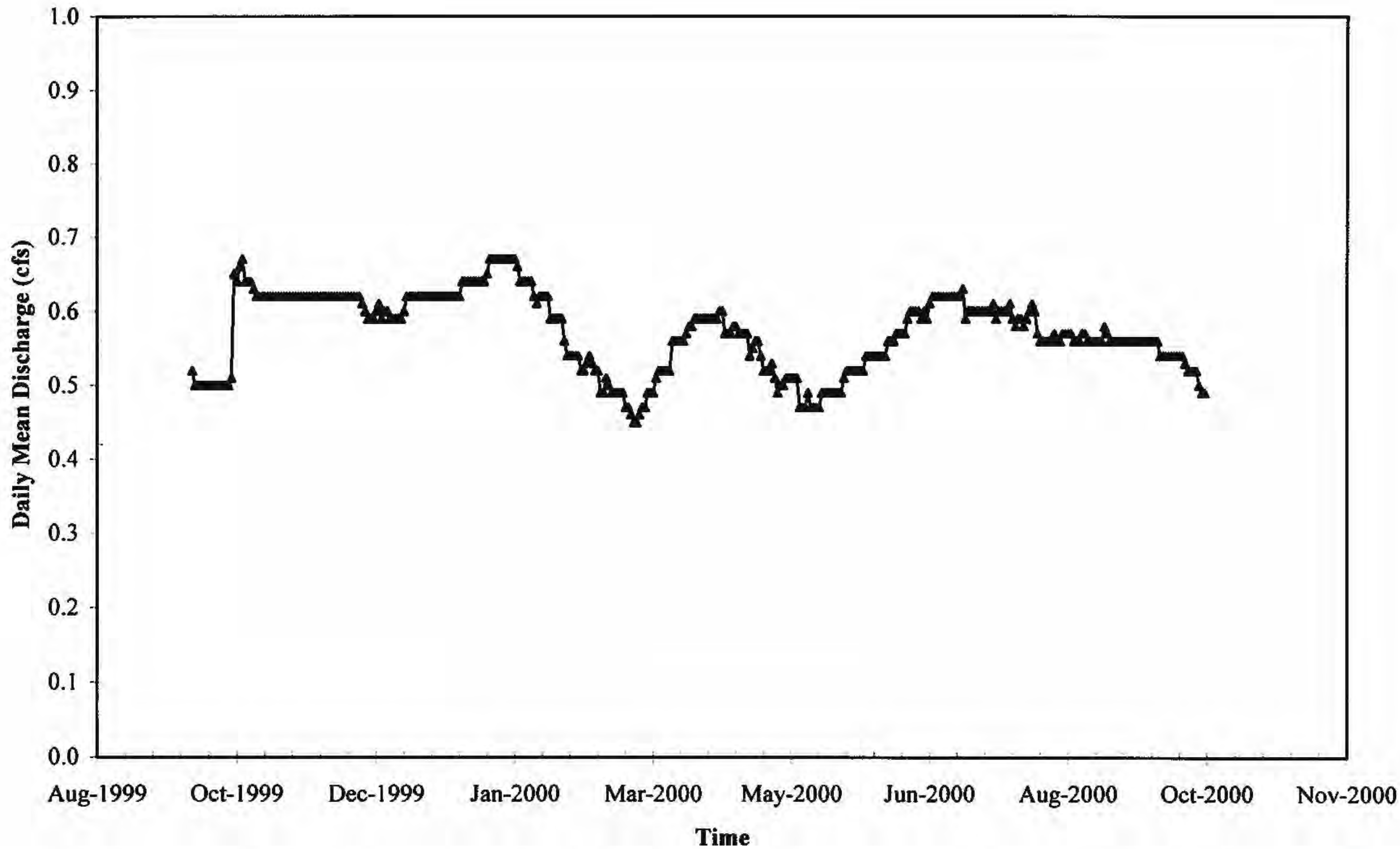


Figure 31. - Discharge vs. time at USGS gaging station 09419547 (Blue Point Spring near Valley of Fire State Park, Nevada), 1999-2000. See Figures 4 through 6 for location of Blue Point Spring.

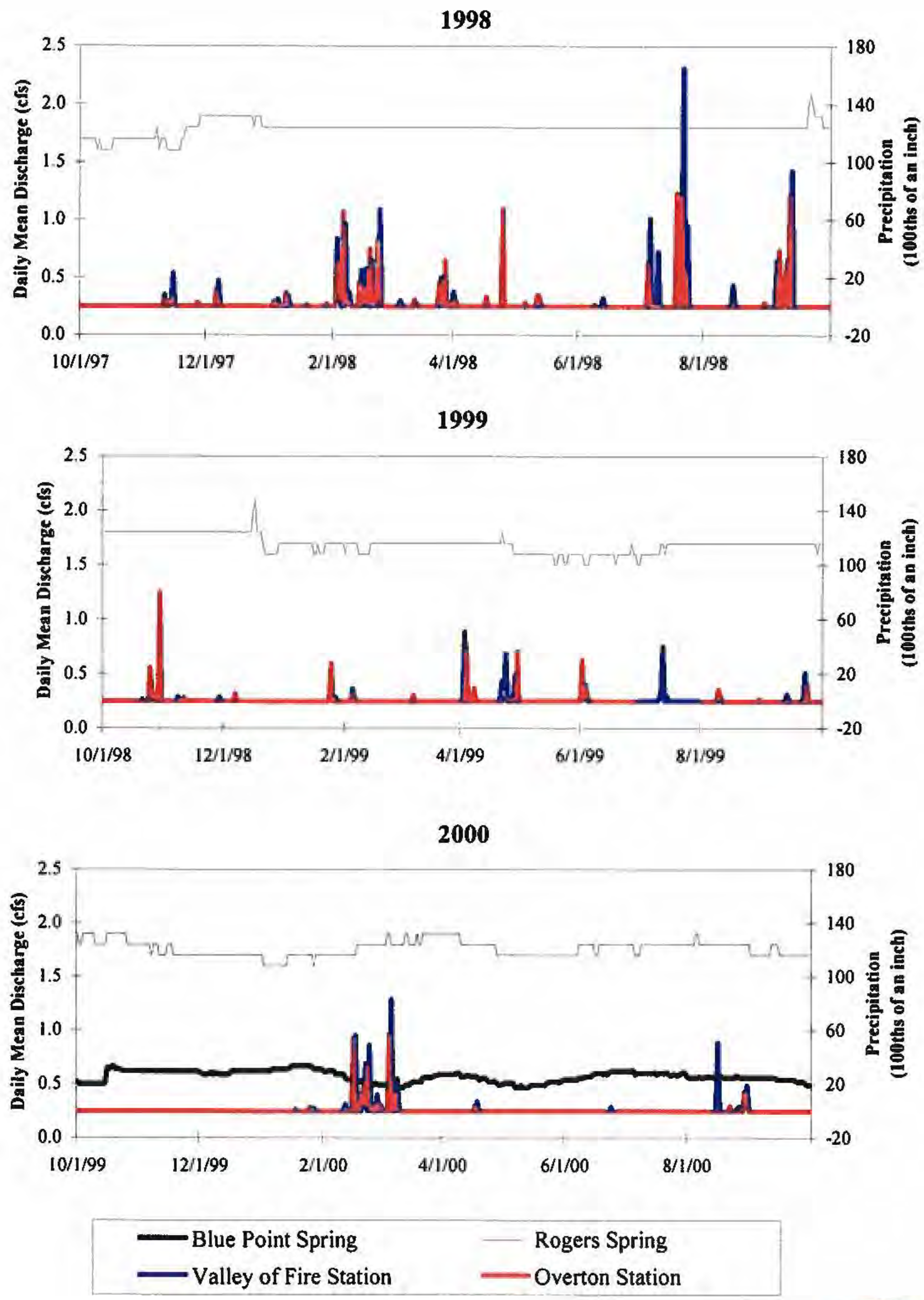


Figure 32. - Relationship between precipitation in the Muddy Mountains and discharge at Rogers and Blue Point Springs, 1998-2000.

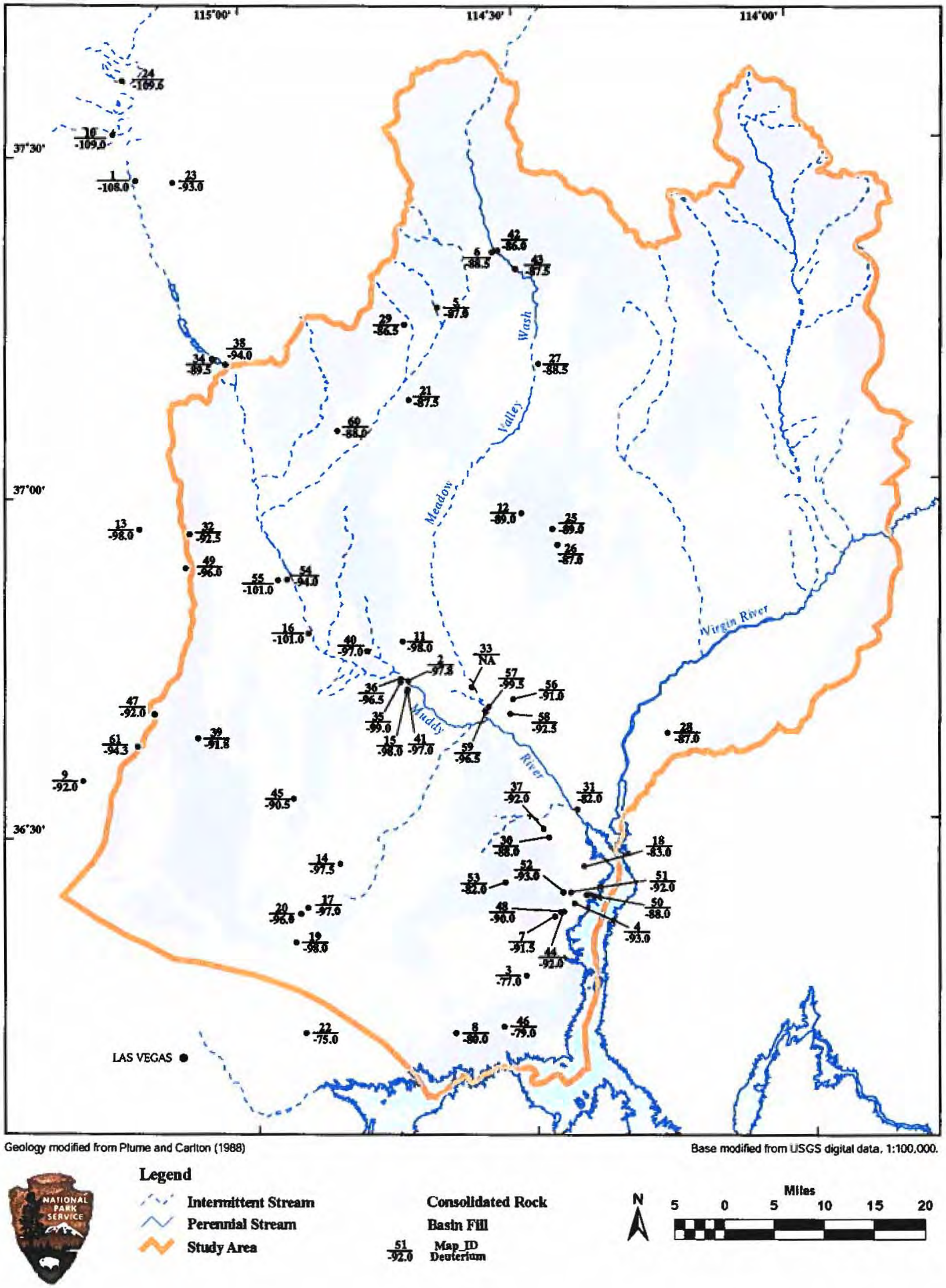


FIGURE 33.—Deuterium values of water samples in the study area and vicinity. See Table 7 for site names and related information.

SE ROA 41441

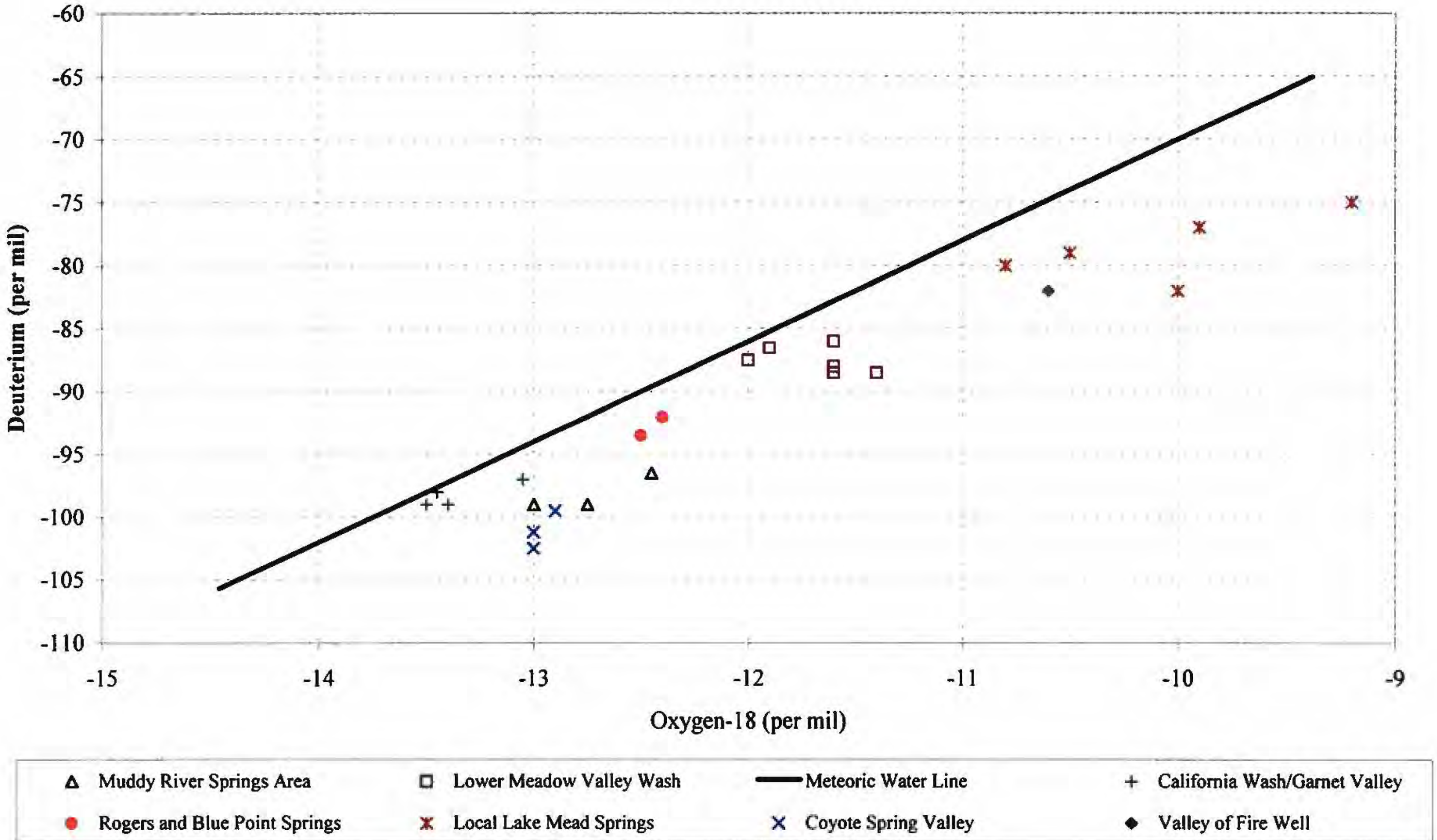


Figure 34. Deuterium and Oxygen-18 relationship for selected wells and springs in the study area.

SE ROA 41442

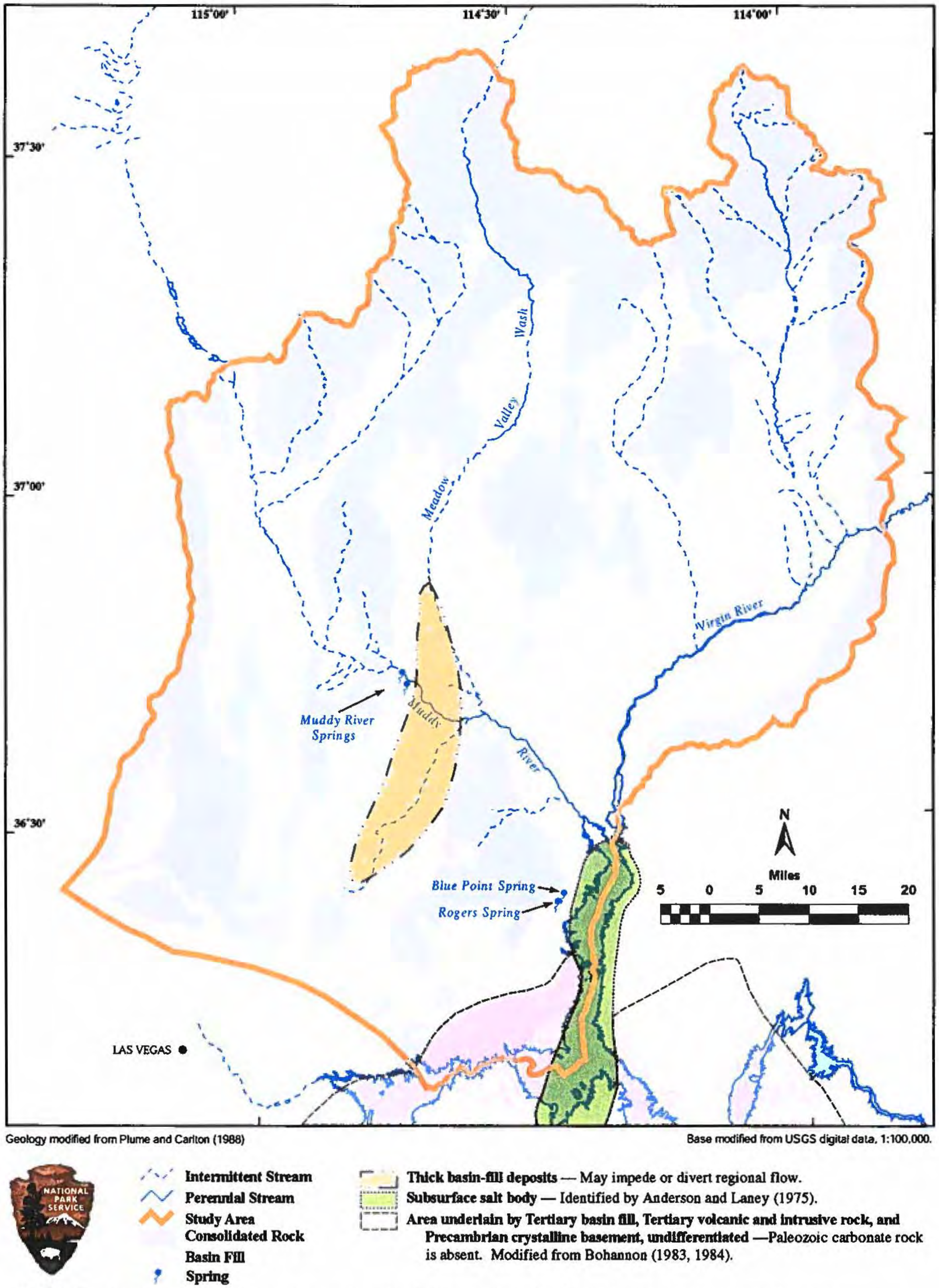


FIGURE 35.—Locations of relatively impervious rocks in the discharge region of the Colorado regional ground-water flow system. Modified from Dettinger and others (1995).

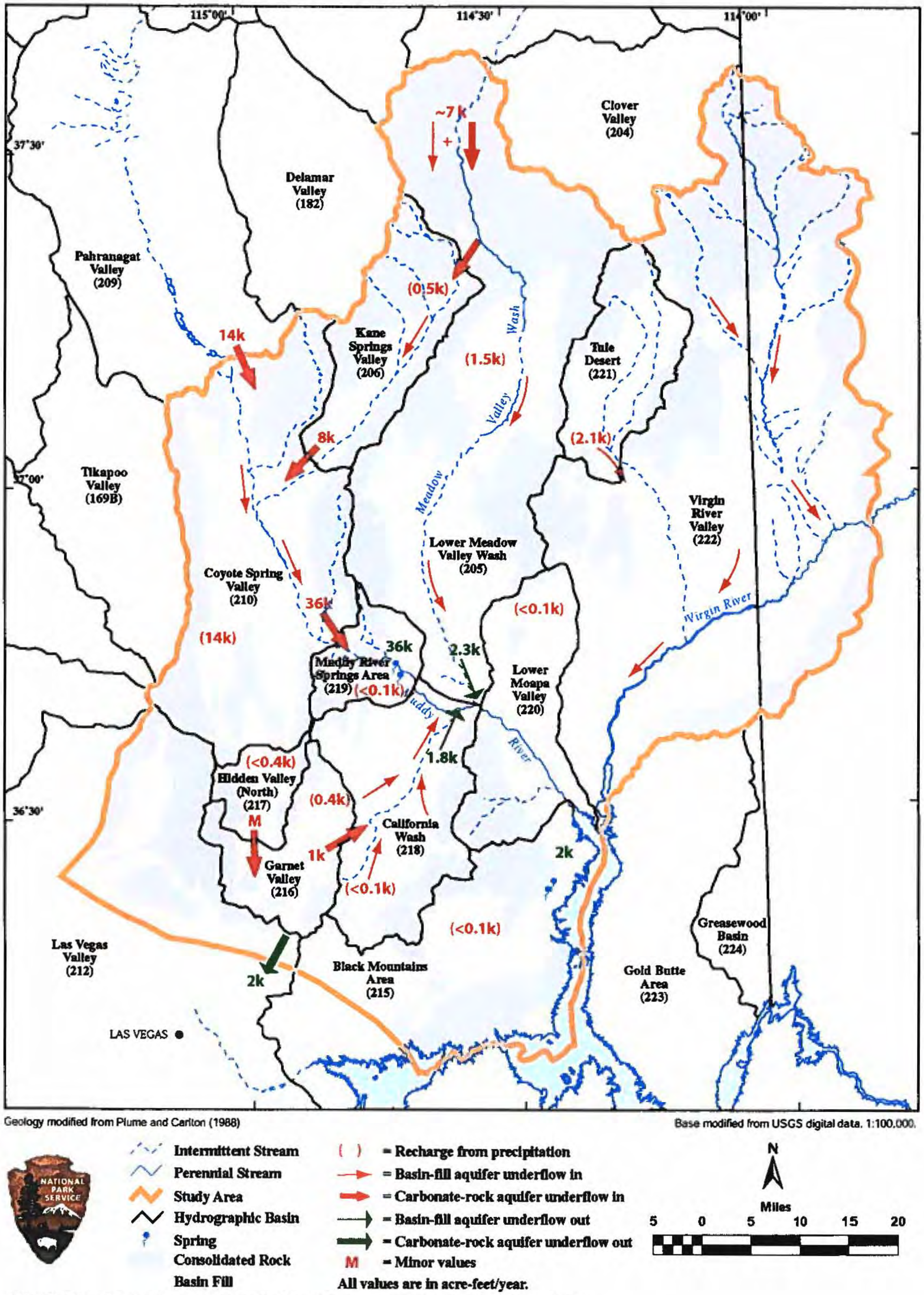


FIGURE 36.—Regional water balance for the study area, excluding the Virgin River Valley.

SE ROA 41444

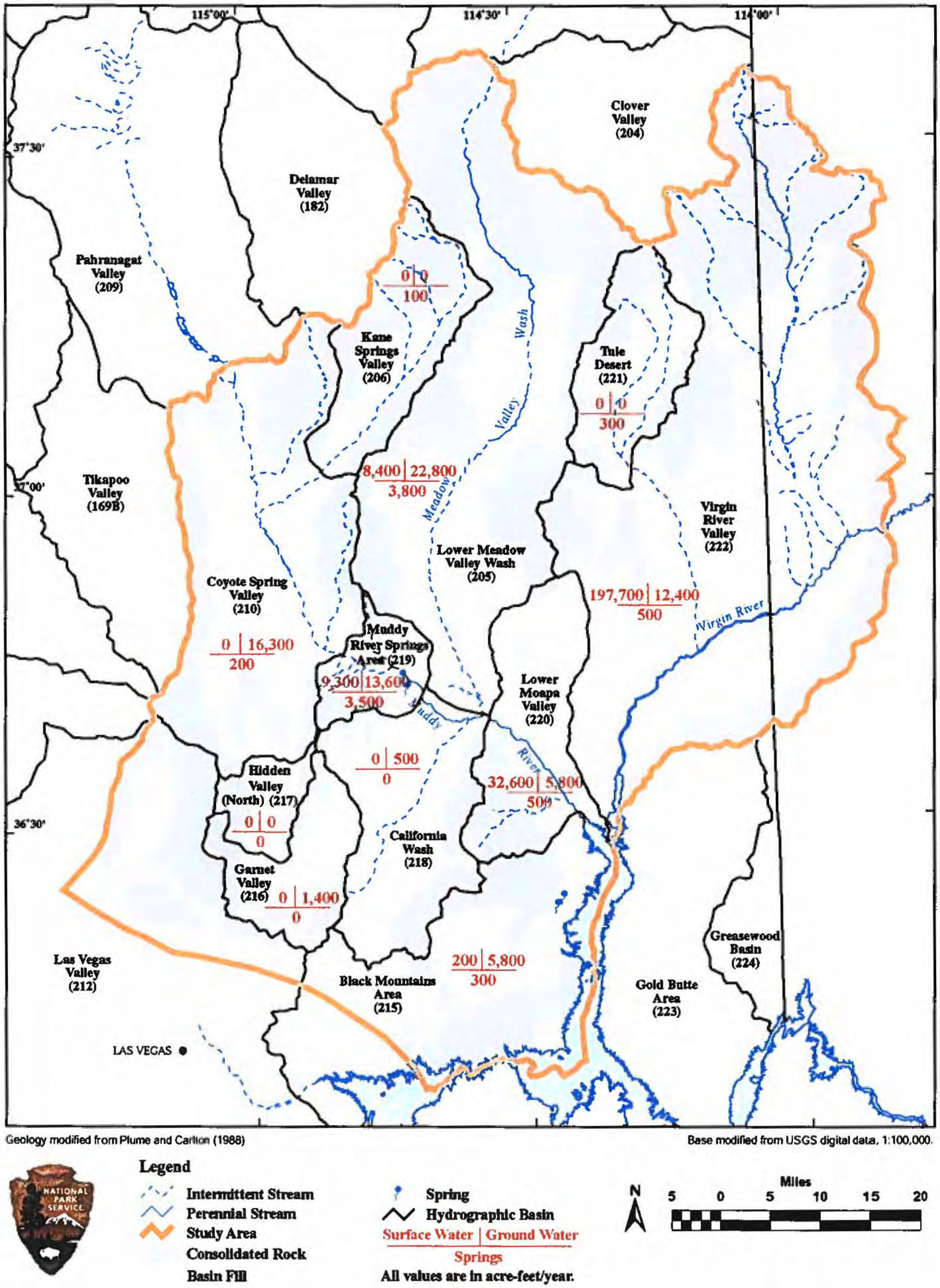
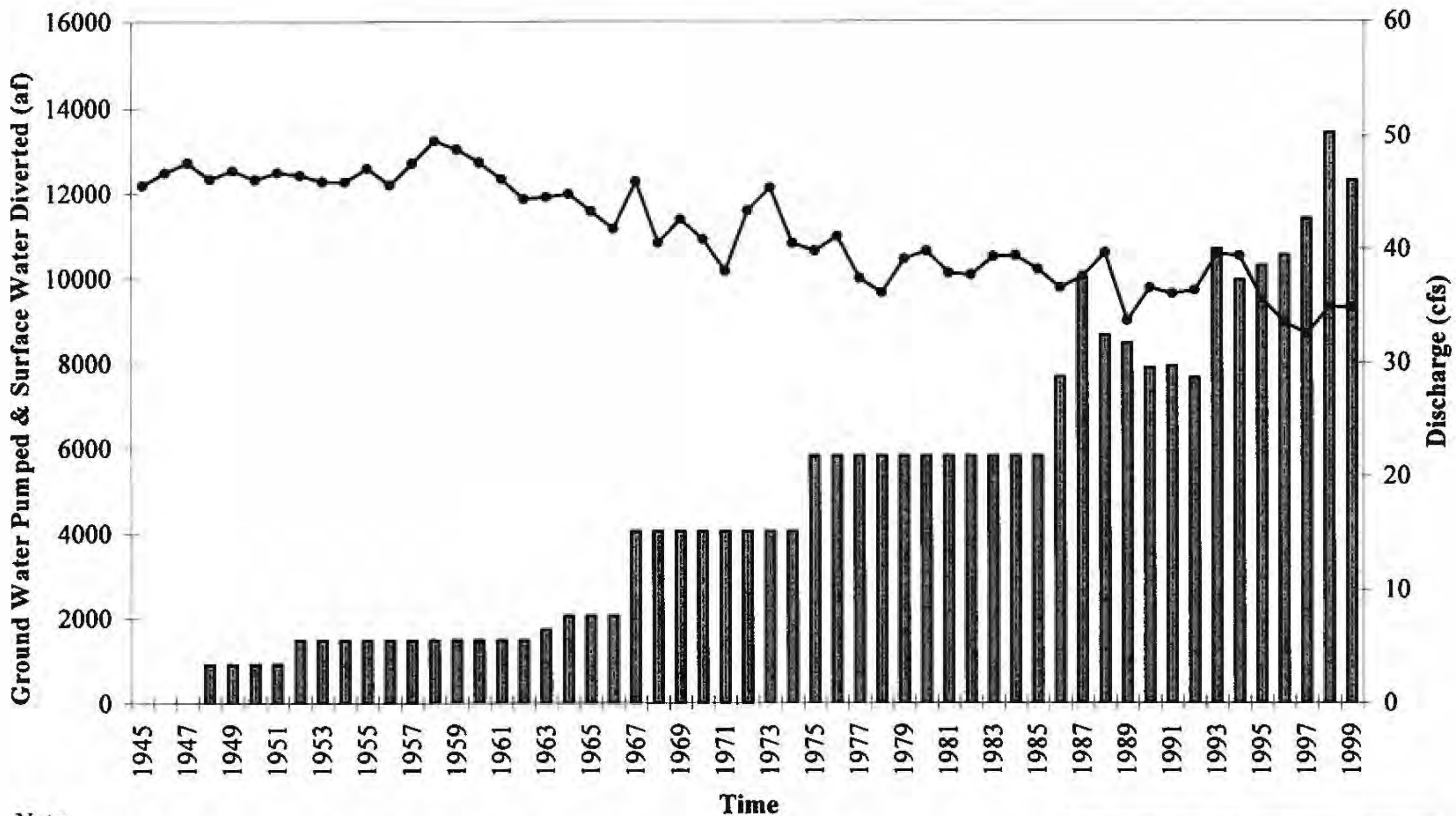


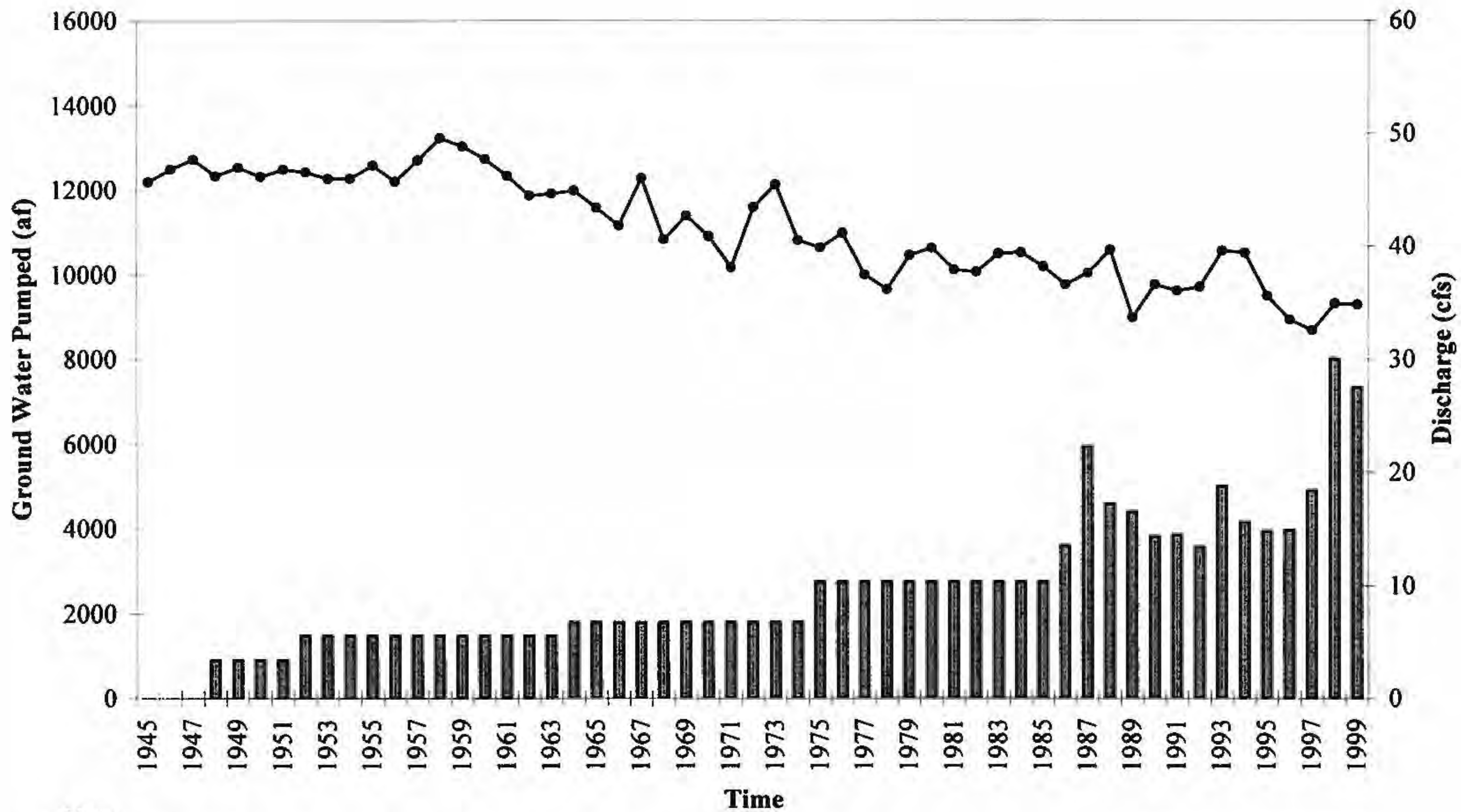
FIGURE 37.—Existing water rights in each hydrographic basin within the study area.

SE ROA 41445



Note:
1948 - 1963 based on permitted rights in Upper Muddy River area
1964 - 1986 based on testimony from David Barnaby (NPC), 1995
1987 - 1999 based on pumping records from NPC and MVWD

Figure 38. - Relationship between discharge at the "Muddy River near Moapa" gaging station and estimated water use in the Upper Muddy River Area.



Note:
1948 - 1963 based on permitted rights in Upper Muddy River area
1964 - 1986 based on testimony from David Barnaby, 1995
1987 - 1999 based on pumping records from NPC and MVWD

Figure 39. - Relationship between discharge at the "Muddy River near Moapa" gaging station and estimated ground-water withdrawals in the Upper Muddy River Area.

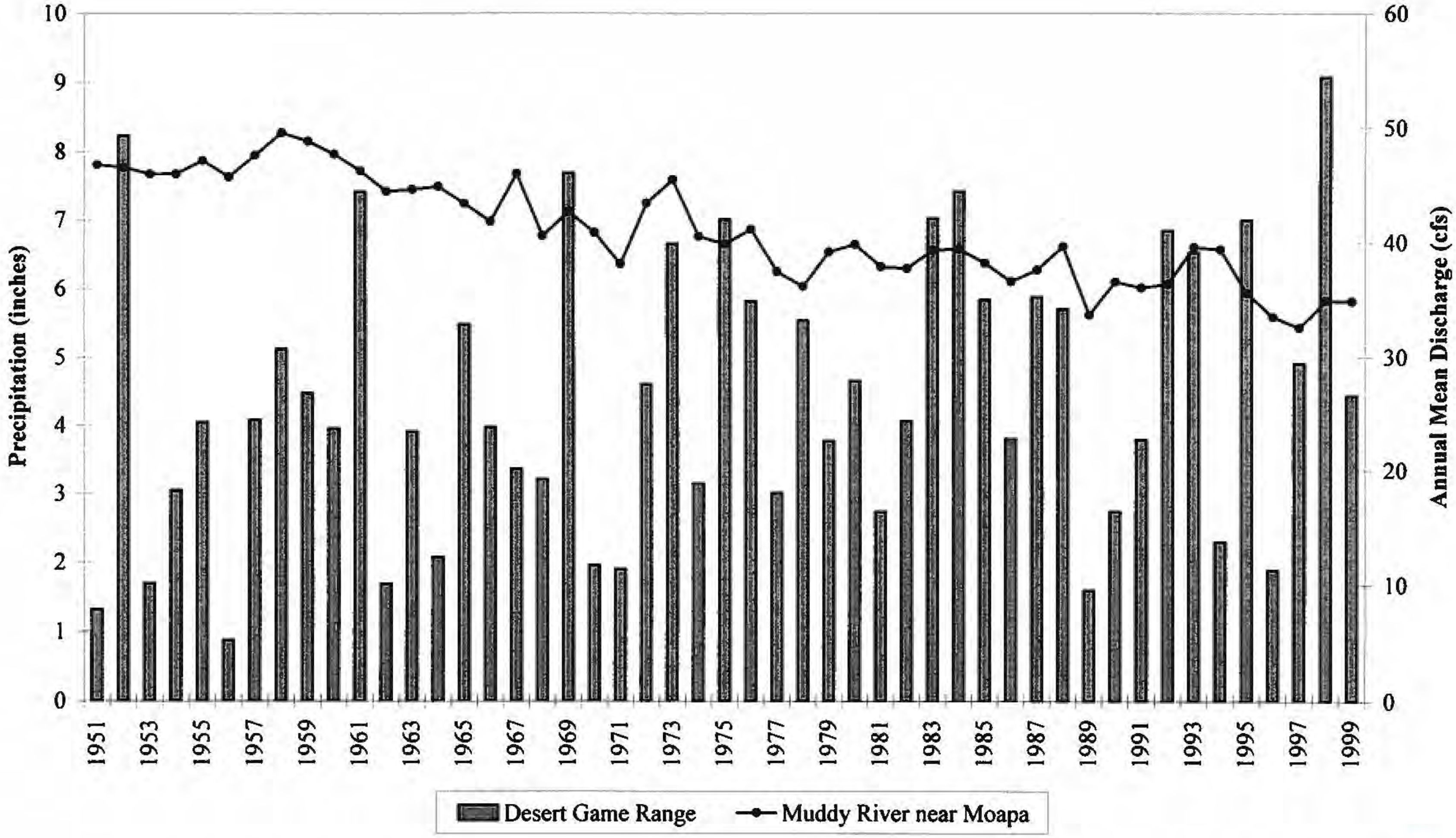


Figure 40. Relationship between discharge at the "Muddy River near Moapa" gaging station and precipitation at the Desert Game Range in the Sheep Mountains.

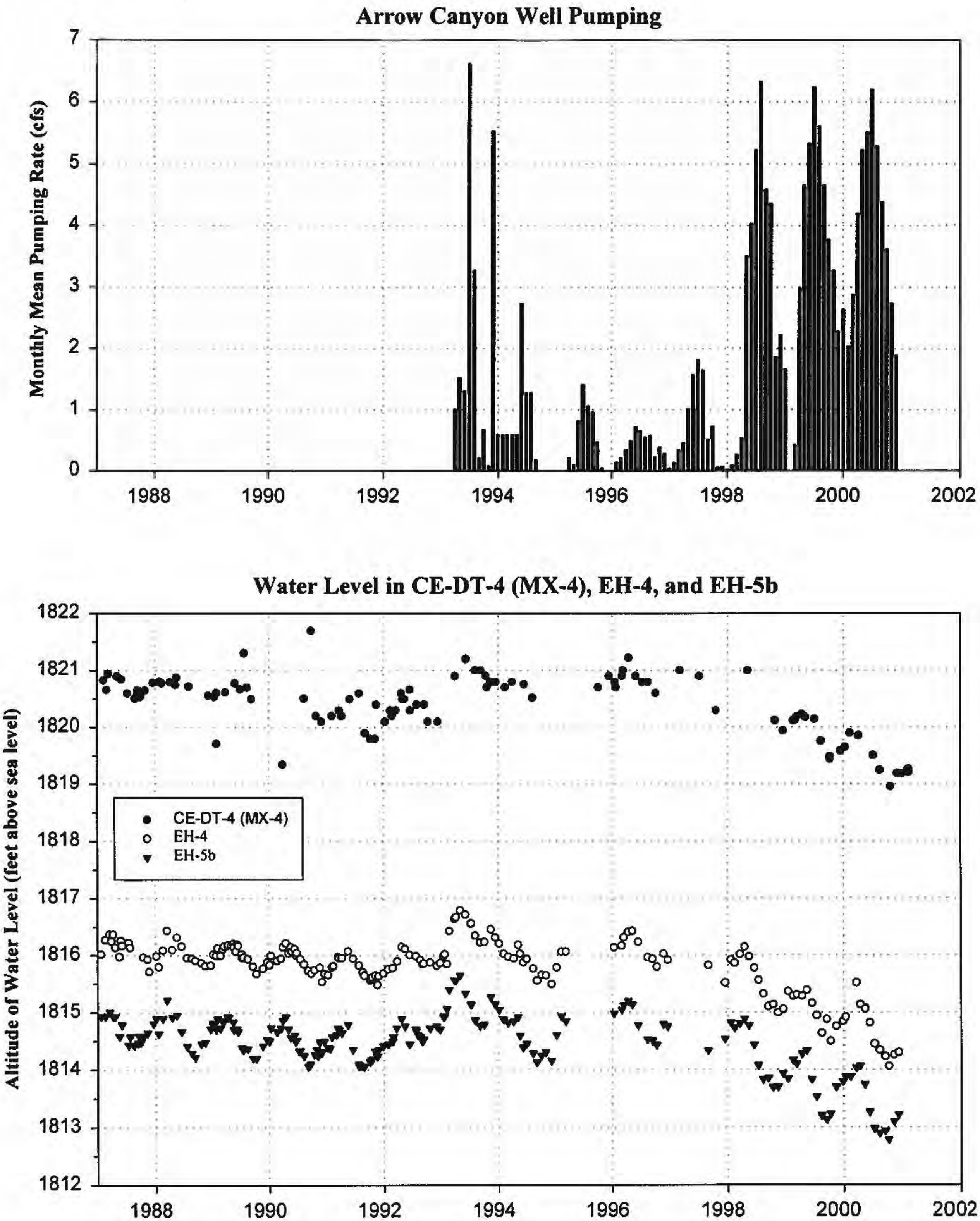


Figure 41. - Relationship between ground-water pumping from the Arrow Canyon Well and decline in water-levels in the regional carbonate-rock aquifer.

Geohydrologic Reconnaissance of Lake Mead National Recreation Area— Las Vegas Wash to Virgin River, Nevada

By R.L. LANEY and J.T. BALES

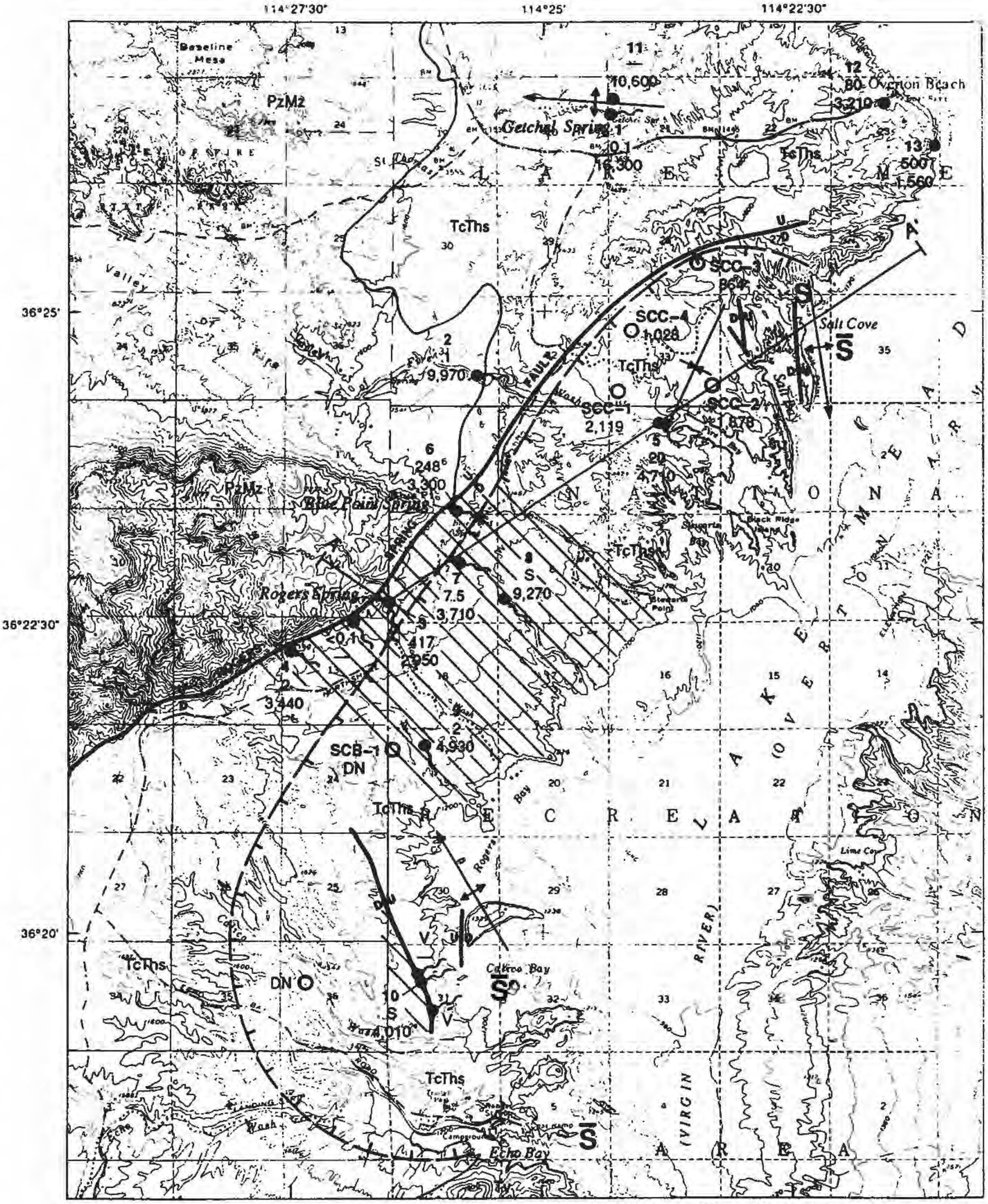
U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 96—4033

Prepared in cooperation with the
NATIONAL PARK SERVICE

Tucson, Arizona
1996

Figure 42. Laney and Bales, 1996.
Map and Cross-section.

SE ROA 41450 1/4



Base from U.S. Geological Survey Overton Beach 1:62,500, 1953

Geologic mapping and well and spring inventory by R.L. Laney and J.T. Bales, 1977–92. Geology modified from Bohannon (1983). Locations of test holes and extent of halite from Mannion (1963) and J.A. Rhodes, (Stauffer Chemical Company, written commun., 1986).

Figure 3. Generalized geology, extent of halite in the Muddy Creek Formation, and location of selected springs and exploratory test holes on the west side of Overton Arm, Lake Mead National Recreation Area.

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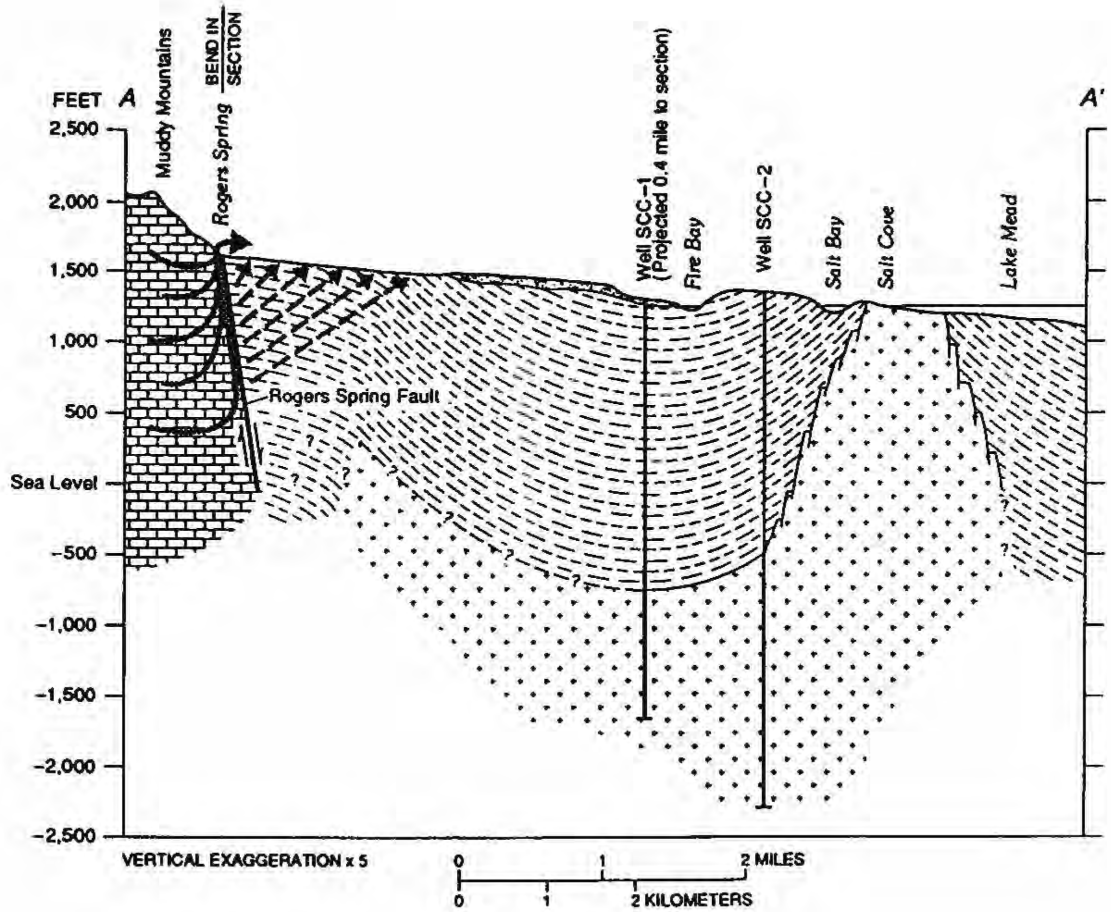
EXPLANATION

TcThs	MOSTLY FINE-GRAINED SEDIMENTARY ROCKS, EVAPORITE DEPOSITS, AND LOCALLY BASALT FLOWS OF THE MUDDY CREEK FORMATION—Locally, fine-grained sedimentary rocks and evaporite deposits of the Horse Spring Formation; overlying younger coarse-grained sedimentary deposits present in part of the area are not shown
Tv	INTERMEDIATE AND MAFIC LAVA FLOWS AND FLOW BRECCIA, FELSIC TUFF, AND MAFIC TO FELSIC INTRUSIVE ROCKS
PzMz	LIMESTONE AND DOLOMITE
	APPROXIMATE AREA WHERE SURFICIAL MATERIALS CONSIST LARGELY OF IMPURE GYPSUM AND OTHER PRECIPITATED SALTS—Surface may be composed of powdery clayey fluff lacking structure to coarsely crystalline gypsum, which, in places, may conform to the local surface topography, suggesting deposition at the land surface by springs and seeps; associated with ground-water discharge along the Rogers Spring Fault
	GEOLOGIC CONTACT
U D	FAULT—High-angle fault; U, upthrown side; D, downthrown side
	APPROXIMATE SUBSURFACE EXTENT OF HALITE IN THE MUDDY CREEK FORMATION—Teeth point toward the halite
A A'	TRACE OF GENERALIZED GEOLOGIC SECTION—In figure 4
	ANTICLINE—Showing approximate trace of crest plane and direction of plunge
	SYNCLINE—Showing approximate trace of trough plane and direction of plunge
S	HALITE OUTCROP
$\overline{S}$	HALITE OUTCROP NOW COVERED BY LAKE MEAD
SCC–1 O 2,119	TEST HOLE—Upper letter-number is identifier used by Stauffer Chemical Company; lower number is depth, in feet below land surface to the top of the halite in the Muddy Creek Formation; DN, indicates data not available
12 ● 80 3,210	WELL—Upper number is a site identifier used in figure 5; middle number is reported yield, in gallons per minute; lower number is dissolved-solids concentration, in milligrams per liter
4 2 ● 3,440	SPRING—Upper number is a site identifier used in figure 5; middle number is discharge, in gallons per minute; lower number is dissolved-solids concentration, in milligrams per liter; S, indicates a spring where discharge was too diffuse to make a discharge measurement or estimate; V, indicates presence of phreatophytes, but no visible discharge

Figure 3. Continued.



EXPLANATION

OLDER ALLUVIUM

Silty sand and gravel

MUDDY CREEK FORMATION

Clay, shale, siltstone, and gypsum

Halite

PALEOZOIC AND MESOZOIC SEDIMENTARY ROCKS, UNDIFFERENTIATED

Limestone and dolomite

GEOLOGIC CONTACT—Dashed where approximately located; queried where uncertain

FAULT—High-angle fault; arrows indicate direction of movement

DIRECTION OF GROUND-WATER MOVEMENT—Dashed arrow indicates diffuse upward leakage

Figure 4. Generalized geologic section between the Muddy Mountains and Lake Mead, Lake Mead National Recreation Area. Trace of section shown in figure 3 and on plate 1.

4/4

Table 1. - Summary of information regarding springs in the Overton Arm area of Lake Mead National Recreation Area. See Figure 4 for location of springs. Modified from Pohlmann and others (1998).

Map ID	Spring Name	Temperature (° F)	δ D (per mil)	Date Sampled	Comments
1	Kelsey Spring	72	-82	3/7/96	
2	Unnamed	52	-92	2/9/96	Located in Magnesite Wash
3	Unnamed	57	-88	2/9/96	Located in Kaolin Wash
4	Getchel Spring	51	-83	2/9/96	
5	Unnamed	59	-93	3/7/96	Uppermost Spring in Valley of Fire Wash
6	Unnamed	56	-92	3/7/96	Upper Spring in Valley of Fire Wash
7	Unnamed	73	-88	2/9/96	Lower Spring in Valley of Fire Wash
8	Blue Point Spring	85	-91	2/8/96	
9	Unnamed	63		2/8/96	Located 0.8 km south of Spring 8
10	Unnamed	59		2/8/96	Located 0.8 km southeast of Spring 9
11	Rogers Spring	86	-91	2/8/96	
12	Scirpus Spring	63	-90	2/7/96	
13	Corral Spring	63	-91.5	2/7/96	
14	Unnamed	63		2/8/96	Located northwest of Rogers Bay
15	Bitter Spring	63	-77	2/6/96	
16	Sandstone Spring	52	-79	2/7/96	
17	Cottonwood Spring	55	-80	2/6/96	
18	Gypsum Spring	60	-75	2/6/96	
19	Unnamed	60	-71	2/5/96	South of Rainbow Gardens

Table 2. - Summary of information regarding existing ground-water rights in Coyote Spring Valley. See Figure 8 for locations of points of diversion.

Application #	Filing Date	Status[1]	Source[2]	Type of Use	Owner	Rate (cfs)	Duty[3] (acre-ft./year)
46777	3/31/1983	PER	UG	Industrial	Coyote Springs Investment, LLC; Nevada Power Company	10.000	7,500
49414	9/27/1985	PER	UG	Industrial	Southern Nevada Water Authority	6.000	8,600
49608	12/30/1985	PER	UG	Industrial	Nevada Power	10.000	SUP to #46777
49660	1/27/1986	PER	UG	Industrial	Coyote Springs Investment, LLC	0.138	SUP to #49414
49661	1/27/1986	PER	UG	Industrial	Coyote Springs Investment, LLC	0.138	SUP to #49414
49662	1/27/1986	PER	UG	Industrial	Southern Nevada Water Authority	0.138	SUP to #49414
49978	7/15/1986	PER	UG	Industrial	Coyote Springs Investment, LLC	2.000	SUP to #49414
49979	7/15/1986	PER	UG	Industrial	Coyote Springs Investment, LLC	2.000	SUP to #49414
49980	7/15/1986	PER	UG	Industrial	Coyote Springs Investment, LLC	2.000	SUP to #49414
49981	7/15/1986	PER	UG	Industrial	Coyote Springs Investment, LLC	2.000	SUP to #49414
49982	7/15/1986	PER	UG	Industrial	Coyote Springs Investment, LLC	2.000	SUP to #49414
49984	7/15/1986	PER	UG	Industrial	Southern Nevada Water Authority	2.000	SUP to #49414
49985	7/15/1986	PER	UG	Industrial	Southern Nevada Water Authority	2.000	SUP to #49414
49986	7/15/1986	PER	UG	Industrial	Coyote Springs Investment, LLC; Southern Nevada Water Authority	2.000	SUP to #49414
49987	7/15/1986	PER	UG	Industrial	Coyote Springs Investment, LLC	2.000	SUP to #49414
61458	8/11/1995	PER	UG	Mining and Milling	Bedroc, Inc.	1.000	200
						Total	**16,300**

NOTE: Records as of January, 2001.
1 -- PER = Permitted
2 -- UG = Underground
3 -- SUP indicates supplemental, which, as used herein, indicates that the water right represents a portion of a combined duty.

Table 3. - Summary of information regarding proposed ground-water withdrawals by LVVWD and Coyote Springs Investment, LLC, in Coyote Spring Valley. See Figures 9 and 10 for locations of proposed withdrawals.

Application #	Filing Date	Status[1]	Source[2]	Type of Use	Owner	Rate (cfs)	Duty (acre-ft./year)
54055	10/17/89	RFP	UG	Municipal	Las Vegas Valley Water District	6.000	4,344
54056	10/17/89	RFP	UG	Municipal	Las Vegas Valley Water District	6.000	4,344
54057	10/17/89	RFP	UG	Municipal	Las Vegas Valley Water District	6.000	4,344
54058	10/17/89	RFP	UG	Municipal	Las Vegas Valley Water District	10.000	7,240
54059	10/17/89	RFP	UG	Municipal	Las Vegas Valley Water District	10.000	7,240
63272	7/24/97	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63273	7/24/97	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63274	7/24/97	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63275	7/24/97	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63276	7/24/97	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63867	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63868	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63869	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63870	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63871	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63872	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63873	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63874	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63875	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
63876	2/24/98	RFP	UG	Quasi-Municipal	Coyote Springs Investment, LLC	10.000	7,239
						Total	**136,098**

NOTE: Records as of January, 2001.
1 -- RFP = Ready-for-Action Protested
2 -- UG = Underground

Table 4. - Summary of gain-and-loss investigations along the Muddy River, February 7, 2001. See Figure 28 for locations of streamflow-measurement stations.

No correction for surface-water diversions.

STATION NUMBER	SITE NUMBER	STATION NAME	DISTANCE ALONG MUDDY RIVER (miles above mouth)	MAIN-STEM DISCHARGE (ft3/sec)	INCREMENTAL MAIN-STEM DISCHARGE GAIN OR LOSS (ft3/sec)	CUMULATIVE MAIN-STEM DISCHARGE CHANGE (ft3/sec)
		beginning of flow	27.0	0.00	0.00	0.00
9415880	2a	below Baldwin Springs	26.3	15.55	15.55	15.55
9415885	3a	near LDS farm (above Muddy Spring)	26.1	15.95	0.40	15.95
9415906	10a	below Muddy Spring; above Refuge Stream	25.8	27.97	12.02	27.97
9415955	13a	below Refuge Stream	25.3	41.85	13.88	41.85
09416000	1b	near Moapa (gage)	24.7	35.48	-6.37	35.48
09416500	2b	at White Narrows	22.6	32.22	-3.27	32.22
09417000	4b	nr RR crossing at power plant	19.6	34.08	1.87	34.08
09417270	5b	above California Wash	18.0	32.53	-1.55	32.53
09417380	6b	below California Wash	16.9	34.98	2.45	34.98
09417390	7b	above Meadow Valley Wash	16.1	35.57	0.58	35.57
09418890	8b	below Meadow Valley Wash	15.4	38.72	3.15	38.72
09418900	9b	near Lewis Ranch	14.2	39.30	0.58	39.30
09419000	10b	near Glendale (gage)	12.9	37.42	-1.88	37.42
09419490	11b	below Anderson Wash	10.2	41.28	3.86	41.28
09419507	12b	at Lewis Ave at Overton (gage)	3.0	4.17	-37.11	4.17

Surface-water diversions added back in.

STATION NUMBER	SITE NUMBER	STATION NAME	DIVERSION NAME	DISTANCE ALONG MUDDY RIVER (miles above mouth)	MAIN-STEM DISCHARGE (ft3/sec)	DIVERSION DISCHARGE (ft3/sec)	INCREMENTAL MAIN-STEM DISCHARGE GAIN OR LOSS (ft3/sec)	CUMULATIVE MAIN-STEM DISCHARGE CHANGE (ft3/sec)
		beginning of flow		27.0	0.00		0.00	0.00
9415880	2a	below Baldwin Springs		26.3	15.55		15.55	15.55
9415885	3a	near LDS farm (above Muddy Spring)		26.1	15.95		0.40	15.95
9415906	10a	below Muddy Spring; above Refuge Stream		25.8	27.97		12.02	27.97
9415925	9a		Refuge Stream	25.4		1.13		
9415955	13a	below Refuge Stream		25.3	41.85		15.01	42.98
			Nevada Power	24.7		3.07		
09416000	1b	near Moapa (gage)		24.7	35.48		-3.30	39.68
			Moapa Band irrigation	22.6		4.50		
09416500	2b	at White Narrows		22.6	32.22		1.23	40.91
09417000	4b	nr RR crossing at power plant		19.6	34.08		1.87	42.78
			Dairy	19.4		1.50		
09417270	5b	above California Wash		18.0	32.53		-0.05	42.73
09417380	6b	below California Wash		16.9	34.98		2.45	45.18
09417390	7b	above Meadow Valley Wash		16.1	35.57		0.58	45.76
09418890	8b	below Meadow Valley Wash		15.4	38.72		3.15	48.91
09418900	9b	near Lewis Ranch		14.2	39.30		0.58	49.50
09419000	10b	near Glendale (gage)		12.9	37.42		-1.88	47.61
09419490	11b	below Anderson Wash		10.2	41.28		3.86	51.48
09419507	12b	at Lewis Ave at Overton (gage)		3.0	4.17		-37.11	14.37

NOTE: Discharges are average of all measurements taken at each site on February 7, 2001.

Table 5. - Summary of annual discharge characteristics of regional springs (cfs).

Parameter	Muddy Spring	Pederson Spring	Warm Spring	Rogers Spring
Mean	7.29	0.21	3.67	1.65
Median	7.21	0.21	3.62	1.66
Standard Deviation	0.22	0.014	0.20	0.11
Sample Variance	0.05	0.0002	0.04	0.01
Range	0.73	0.05	0.58	0.41
Minimum	6.96	0.19	3.38	1.47
Maximum	7.69	0.24	3.96	1.88
Count	13	12	12	15
Coeff. of Variation	0.03	0.07	0.05	0.07

Table 6. - Summary of hydrogeochemical information for wells and springs in the region.

Site ID	TDS (mg/l)	Ca (mg/l)	Mg (mg/l)	Na (mg/l)	K (mg/l)	HCO_3 (mg/l)	SO_4 (mg/l)	Cl (mg/l)	δ D (per mil)	$\delta^{18}O$ (per mil)	Location
TH-1	917	110	49	110	15	180	240	130	-99.0	-13.40	Belly Tank Flat
ECP-1	901	120	52	110	17	200	290	150	-99.0	-13.50	Belly Tank Flat
Dry Lake Valley Well (DLV-1)	960	110	48	120	13	210	360	170	-97.5	-13.30	Coyote Spring Valley
VF-1 Well	230	41	7.5	34	1.2	156	20	42	-94.0	-12.60	Coyote Spring Valley
Desert Dry Lake Well	300	22	27	35	5.7	207	48	8.9	-98	-13.1	Coyote Spring Valley
ERTEC MX-4 and MX-5	480	46	20	81	11	295	105	34	-101.0	-13.00	Coyote Spring Valley
VF-2 Well	470	47	21	81	11	303	90	34	-101.0	-13.00	Coyote Spring Valley
Grace Petrol Arrow Canyon (Grace 1)	1000	120	46	140	16	230	360	190	-96.0	-13.70	Garnet Valley
GP Apex Well (GP1a)	1000	120	46	129	12	226	380	200	-98.0	-13.45	Garnet Valley
Genstar Well (Gen1)	1000	120	47	140	1.3	226	370	180	-97.0	-13.05	Garnet Valley
Hidden Valley Well (SHV-1)	470	33	30	86	12	245	90	64	-90.5	-11.2	Hidden Valley
Railroad Elgin Well	460	42	14	98	8.8	300	60	42	-86.0	-11.6	L. Meadow Valley Wash
Randono Well	500	46	14	100	8.4	350	63	44	-87.5	-11.7	L. Meadow Valley Wash
Jensen Well	520	55	14	100	7.2	340	80	45	-88.5	-11.6	L. Meadow Valley Wash
Sandstone Spring	1215	209	79.2	21.9	4.96	249	725	16.9	-79	-10.5	Lake Mead Local Springs
Kelsey Spring	2721	156	92.9	547	25.4	319	1180	332	-82	-10	Lake Mead Local Springs
Bitter Spring	3730	580	190	270	22	140	2400	160	-77	-9.9	Lake Mead Local Springs
Cottonwood Spring	3660	524	220	209	10.7	205	2410	63.6	-80	-10.8	Lake Mead Local Springs
Gypsum Spring	4253	532	308	231	21.5	146	2840	151	-75	-9.2	Lake Mead Local Springs
Rogers Spring	2900	450	140	300	20	160	1600	340	-92.0	-12.4	Lake Mead Regional Springs
Blue Point Spring	4000	500	160	340	24	160	1800	380	-93.5	-12.5	Lake Mead Regional Springs
Corral Spring	3440	510	160	340	23	180	1900	400	-91.5	-12.1	Lake Mead Regional Springs
Scirpus Spring	3787	513	186	350	25.3	266	2040	386	-90.0	-12.0	Lake Mead Regional Springs
Lewis Well	1300	107	76	203	12	321	560	121	na	na	Muddy River Springs
MX-6	560	58	25	87	10	271	159	53	-97	-12.95	Muddy River Springs area
Big Muddy Spring	610	66	26	96	10	270	190	61	-97.8	-12.90	Muddy River Springs area
Pederson's Warm Spring	640	75	26	110	8.8	280	190	59	-97.0	-12.75	Muddy River Springs area
CSV-2	590	60	27	100	10	276	160	61	-98	-12.85	Muddy River Springs area
EH-4	560	49	30	90	12	245	171	57	-98	-13	Muddy River Springs area
Ash Spring	290	46	15	29	7.7	259	33	8	-108	-14.1	Pahranagat Valley
Crystal Spring	290	44	22	22	5.3	258	33	8.7	-109	-14.3	Pahranagat Valley
Hiko Spring	320	49	23	26	7.4	282	37	11	-109.6	-14.65	Pahranagat Valley
Cow Camp Spring	310	49	33	23	0.6	290	19	29	-92.0	-12.60	Sheep Range
Sheep Spring	370	31	40	7.9	1.1	276	13	7.1	-96.0	-13.35	Sheep Range
Lamb Spring	270	37	41	8.7	0.6	289	24	8.6	-92.5	-13.15	Sheep Range
Weiser Wash EH-8	3100	375	104	416	22	162	1780	233	-96.5	-13.90	Weiser Wash
Weiser Wash EH-6	3300	341	131	274	31	178	1800	41	-99.5	-13.70	Weiser Wash
Weiser Wash EH-7	3000	481	198	163	24	124	1954	184	-92.5	-12.70	Weiser Wash
Weiser Wash EH-3	2700	511	201	170	22	123	2100	194	-91.0	-12.70	Weiser Wash

Table 7. - Isotopic data for selected sites shown on Figure 33.

Map ID	Site Name	δD (per mil)	$\delta^{18}O$ (per mil)	Source
1	Ash Spring	-108	-14.1	Thomas, et. al., 1996
2	Big Muddy Spring	-97.8	-12.90	Thomas, et. al., 1996
3	Bitter Spring	-77	-9.9	DRI-Pohlman, et. al., 1998
4	Blue Point Spring	-93.0	-12.4	Thomas, et. al., 1996
5	Boulder Spring	-87	-12.6	Thomas, et. al., 1996
6	Bradshaw Well	-88.5	-11.4	Thomas, et. al., 1996
7	Corral Spring	-91.5	-12.1	DRI-Pohlman, et. al., 1998
8	Cottonwood Spring	-80	-10.8	DRI-Pohlman, et. al., 1998
9	Cow Camp Spring	-92.0	-12.60	Thomas, et. al., 1996
10	Crystal Spring	-109	-14.3	Thomas, et. al., 1996
11	CSV-2	-98	-12.85	Thomas, et. al., 1996
12	Davies Spring	-89	-12.5	Thomas, et. al., 1996
13	Desert Dry Lake Well	-98	-13.1	Thomas, et. al., 1996
14	Dry Lake Valley Well	-97.5	-13.30	Thomas, et. al., 1996
15	EH-4	-98	-13	Thomas, et. al., 1996
16	ERTEC MX-4 and MX-5	-101.0	-13.00	Thomas, et. al., 1996
17	Genstar Well	-97.0	-13.05	Thomas, et. al., 1996
18	Getchel Spring	-83	-8.6	Thomas, et. al., 1996
19	GP Apex Well	-98.0	-13.45	Thomas, et. al., 1996
20	Grace Petrol. Arrow Canyon	-96.0	-13.70	Thomas, et. al., 1996
21	Grapevine Spring KSV-2	-87.5	-12	Thomas, et. al., 1996
22	Gypsum Spring	-75	-9.2	DRI-Pohlman, et. al., 1998
23	Hells Acre Gulch Spring	-93	-12.3	Thomas, et. al., 1996
24	Hiko Spring	-109.6	-14.65	Thomas, et. al., 1996
25	Horse Spring	-89	-12.7	Thomas, et. al., 1996
26	Hackberry Spring	-87	-12.3	Thomas, et. al., 1996
27	Jensen Well	-88.5	-11.6	Thomas, et. al., 1996
28	Juanita Spring	-87	-11.65	Thomas, et. al., 1996
29	Kane Spring	-86.5	-11.9	Thomas, et. al., 1996
30	Kaolin Wash	-88	-11.3	Thomas, et. al., 1996
31	Kelsey Spring	-82	-10	DRI-Pohlman, et. al., 1998
32	Lamb Spring	-92.5	-13.15	Thomas, et. al., 1996
33	B. Lewis Well	na	na	Thomas, et. al., 1996
34	Lone Tree Spring	-89.5	-10.9	Thomas, et. al., 1996
35	M-8 Spring	-99	-12.75	Thomas, et. al., 1996
36	M-9 Spring	-96.5	-12.45	Thomas, et. al., 1996
37	Magnesite Wash	-92	-11.5	Thomas, et. al., 1996
38	Maynard Lake Spring	-94	-12.3	Thomas, et. al., 1996
39	Mormon Well Spring	-91.8	-12.7	Thomas, et. al., 1996
40	MX-6	-97	-12.95	Thomas, et. al., 1996
41	Pederson's Warm Spring	-97.0	-12.75	Thomas, et. al., 1996
42	Railroad Elgin Well	-86.0	-11.6	Thomas, et. al., 1996
43	Randono Well	-87.5	-11.7	Thomas, et. al., 1996
44	Rogers Spring	-92	-12.2	Thomas, et. al., 1996
45	S. Hidden Valley Well	-90.5	-11.2	Thomas, et. al., 1996
46	Sandstone Spring	-79	-10.5	DRI-Pohlman, et. al., 1998
47	Sawmill Spring	-92	-12.85	Thomas, et. al., 1996
48	Scirpus Spring	-90.0	-12.0	DRI-Pohlman, et. al., 1998
49	Sheep Spring	-96.0	-13.35	Thomas, et. al., 1996
50	Valley of Fire Lower	-88	-11.2	Thomas, et. al., 1996
51	Valley of Fire Upper	-92	-11.8	Thomas, et. al., 1996
52	Valley of Fire Uppermost	-93	-12.2	Thomas, et. al., 1996
53	Valley of Fire Well	-82	-10.6	Thomas, et. al., 1996
54	VF-1 Well	-94.0	-12.60	Thomas, et. al., 1996
55	VF-2 Well	-101.0	-13.00	Thomas, et. al., 1996
56	Weiser Wash EH-3	-91.0	-12.70	Thomas, et. al., 1996
57	Weiser Wash EH-6	-99.5	-13.70	Thomas, et. al., 1996
58	Weiser Wash EH-7	-92.5	-12.70	Thomas, et. al., 1996
59	Weiser Wash EH-8	-96.5	-13.90	Thomas, et. al., 1996
60	Willow Spring KSV-1	-88	-11.6	Thomas, et. al., 1996
61	Wiregrass Spring	-94.3	-12.8	Thomas, et. al., 1996

Table 8. – Summary of regional water-balance information in the Lower Colorado System, excluding the Virgin River Valley.

(All values are in acre-feet/year.)

INFLOW:	
<u>"Underflow In" to Lower Colorado System:</u>	
Coyote Spring Valley[a]	14,000
Lower Meadow Valley Wash[b]	7,000
<u>Infiltration of Precipitation within the Lower Colorado System:</u>	
Coyote Spring Valley/Sheep Range[a,c]	14,000
Kane Springs Valley[d]	500
Lower Meadow Valley Wash[d]	1,500
Tule Desert[d]	2,100
Garnet Valley[d]	400
	+
TOTAL, REGIONAL INFLOW:	39,500
OUTFLOW:	
<u>Springflow:</u>	
Muddy River Springs	36,000
Rogers/Blue Point Spring complex[e]	2,000
<u>Ground-water discharge to Muddy River:</u>	
Lower Meadow Valley Wash[f]	2,300
California Wash[f]	1,800
<u>"Underflow Out" from Lower Colorado System:</u>	
Across Las Vegas Shear Zone[g]	2,000
	+
TOTAL, REGIONAL OUTFLOW:	44,100

Notes:

[a]From Harrill and Prudic (1998), based on hydrogeochemical analysis by Thomas and others (1996).

[b]From Rush (1964). This is a rough approximation of outflow in Lower Meadow Valley Wash, computed by the difference between estimated recharge and other estimated components of discharge.

[c]From Harrill and Prudic (1998), based on hydrogeochemical analysis by Thomas and others (1996). May include some recharge from the Sheep Mountains that originates outside Coyote Spring Valley.

[d]From Harrill and others (1988). Some or all of infiltration from Tule Desert may recharge the Virgin River Valley basin, as indicated by Harrill and others (1988), and as shown on Figure 36.

[e]From USGS discharge records and unpublished analysis by NPS personnel.

[f]From unpublished streamflow gain-and-loss run analysis by NPS personnel.

[g]From unpublished Darcy's Law calculation by NPS personnel.

Table 9. - Summary of existing water rights and pending applications in the study area.

	Ground Water		Springs		Surface Water		Total		Grand Total
Basin	Existing	Pending	Existing	Pending	Existing	Pending	Existing	Pending	
205	22,800	20,500	3,800	0	8,400	1,600	35,000	22,100	57,100
206	0	14,500	100	0	0	0	100	14,500	14,600
210	16,300	194,400	200	0	0	0	16,500	194,400	210,900
215	5,800	10,000	300	1,800	200	0	6,300	11,800	18,100
216	1,400	34,100	0	0	0	0	1,400	34,100	35,500
217	0	17,500	0	0	0	0	0	17,500	17,500
218	500	36,300	0	0	0	0	500	36,300	36,800
219	13,600	15,000	3,500	0	9,300	700	26,400	15,700	42,100
220	5,800	14,500	500	0	32,600	0	38,900	14,500	53,400
221	0	27,500	300	0	0	0	300	27,500	27,800
222	12,400	239,300	500	0	197,700	9,500	210,600	248,800	459,400
Total	78,600	623,600	9,200	1,800	248,200	11,800	336,000	637,200	973,200

(to the nearest 100 acre-feet per year; records as of January 2001)

Table 10. – Comparison of regional water-balance information with existing water rights in the study area, excluding the Virgin Valley.

(All values are in acre-feet/year)

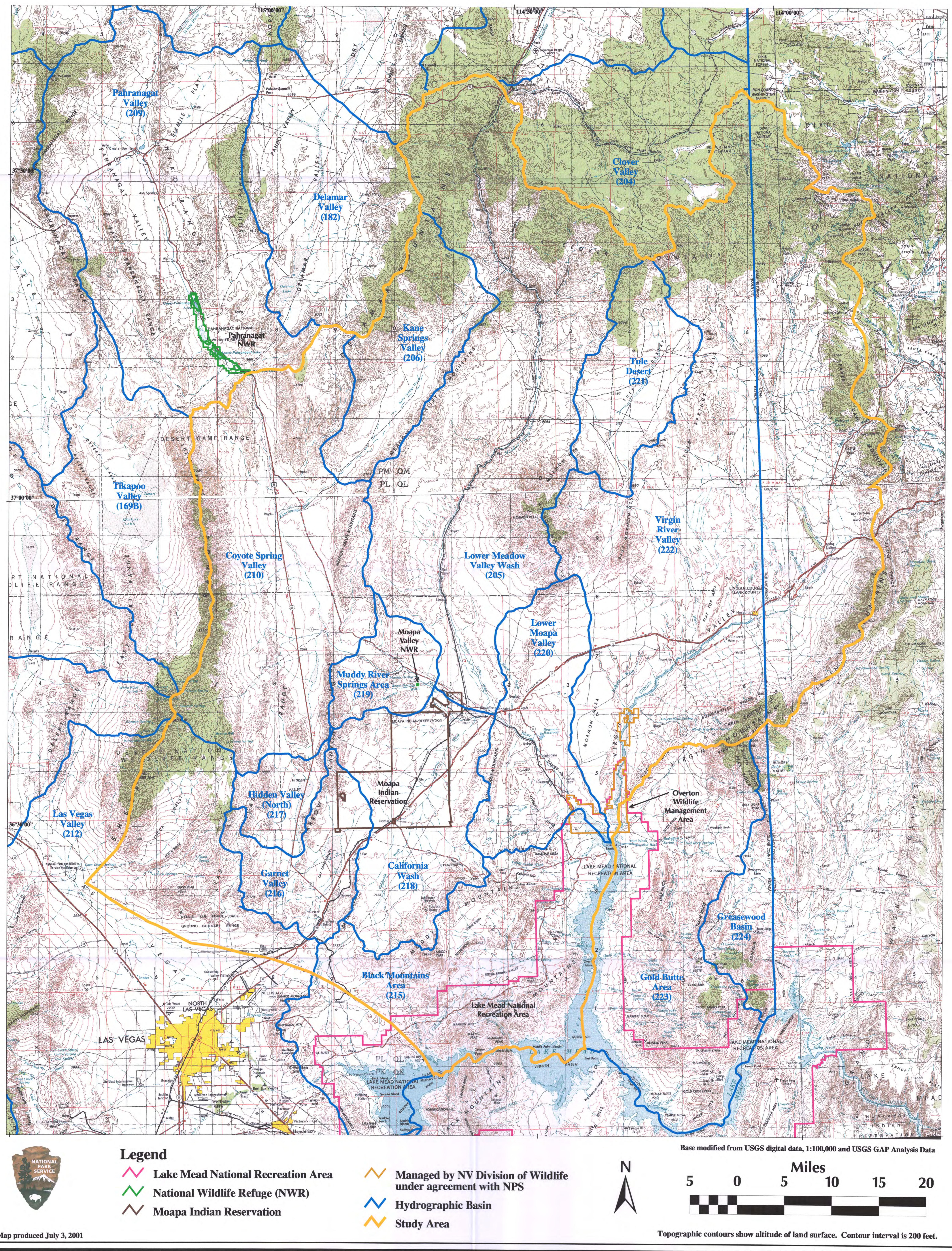
REGIONAL WATER BALANCE	***~44,000***

EXISTING WATER RIGHTS:

Surface Water:	
Muddy River:	42,100
Meadow Valley Wash:	8,400
TOTAL, existing surface-water rights	50,500
Springs:	
White River Flow Subsystem:	3,800
Meadow Valley Wash Flow Subsytem:	3,800
Other:	1,100
TOTAL, existing spring-water rights	8,700
Ground Water:	
White River Flow Subsystem:	29,900
Meadow Valley Wash Flow Subsytem:	22,800
Other:	13,500
TOTAL, existing ground-water rights	66,200

GRAND TOTAL, EXISTING WATER RIGHTS	***125,400***

Plate 1:
Map of Study Area



SE ROA 41464

JA_11761

ASSIGNED
No 54129

AMENDED

APPLICATION FOR PERMIT
TO APPROPRIATE THE PUBLIC WATERS OF THE STATE OF NEVADA

Date of filing in State Engineer's Office OCT 30 1989

Returned to applicant for correction DEC 07 1989

Corrected application filed JAN 31 1990

Map filed MAR 16 1990

The applicant Bonneville Nevada Corporation

257 East 200 South, Suite 800 (Street and No. or P.O. Box No.), of Salt Lake City, (City or Town),

Utah, 84111 (State and Zip Code No.), hereby make.... application for permission to appropriate the public waters of the State of Nevada, as hereinafter stated. (If applicant is a corporation, give date and place of incorporation; if a copartnership or association, give names of members.) December 2, 1988 with Secretary of State in Carson City, Nevada

1. The source of the proposed appropriation is an underground source (Name of stream, lake, spring, underground or other source)

2. The amount of water applied for is 2.3 cfs second-feet (One second-foot equals 448.83 gals. per min.)

   (a) If stored in reservoir give number of acre-feet n/a

3. The water to be used for Industrial (Cogeneration Power Plant) (Irrigation, power, mining, manufacturing, domestic, or other use. Must limit to one use.)

4. If use is for:

   (a) Irrigation, state number of acres to be irrigated n/a

   (b) Stockwater, state number and kinds of animals to be watered n/a

   (c) Other use (describe fully under "No. 12. Remarks") n/a

   (d) Power:

   (1) Horsepower developed 85 MW of electrical Power

   (2) Point of return of water to stream n/a

5. The water is to be diverted from its source at the following point within the NW¼ of the SW¼ of Section 7, T.20S., R.64E. M.D.B.&M. or at a point from which the Northwest (NW) corner of said Section 7 bears North 16°31'49" West a distance of 2861.12 feet. (Describe as being within a 40-acre subdivision of public survey, and by course and distance to a section corner. If on unsurveyed land, it should be so stated.)

6. Place of use Within a portion of the Southwest Quarter (SW¼) of the Northwest Quarter (NW¼), the Northwest Quarter (NW¼) of the Southwest Quarter (SW¼), and the Northeast Quarter (NE¼) of the the Southwest quarter (SW¼) of Section 7, Township 20 South, Ranger 64 East, M.D.B. & M., approximately fourteen and one half acres. (14½) (Describe by legal subdivision. If on unsurveyed land, it should be so stated.)

7. Use will begin about January 1st. (Month and Day) and end about December 31st (Month and Day), of each year.

8. Description of proposed works. (Under the provisions of NRS 535.010 you may be required to submit plans and specifications of your diversion or storage works.) drilled well with pump and motor (State manner in which water is to be diverted, i.e. diversion structure, ditches and flumes, drilled well with pump and motor, etc.)

9. Estimated cost of works $1,000,000.00

10. Estimated time required to construct works one (1) year
If well completed, describe works.

11. Estimated time required to complete the application of water to beneficial use eighteen (18) months

12. Remarks: For use other than irrigation or stock watering, state number and type of units to be served or annual consumptive use.

n/a

By s/Charles E. Cave
Charles E. Cave
2325 W. Charleston Blvd.
Las Vegas, Nv. 89102

Compared bc/se bp/se

Protested

APPROVAL OF STATE ENGINEER

This is to certify that I have examined the foregoing application, and do hereby grant the same, subject to the followng limitations and conditions:

This permit is issued subject to existing rights. It is understood that the amount of water herein granted is only a temporary allowance and that the final water right obtained under this permit will be dependent upon the amount of water actually placed to beneficial use. It is also understood that this right must allow for a reasonable lowering of the static water level. This well shall be equipped with a two (2) inch opening for measuring depth to water. If the well is flowing, a valve must be installed and maintained to prevent waste. A totalizing meter must be installed and maintained in the discharge pipeline near the point of diversion and accurate measurements must be kept of water placed to beneficial use. The totalizing meter must be installed before any use of water begins, or before the Proof of Completion of Work is filed. This source is located within an area designated by the State Engineer, pursuant to NRS 534.030. The State retains the right to regulate the use of the water herein granted at any and all times.

This Permit does not extend the permittee the right of ingress and egress on public, private or corporate lands.

The issuance of this permit does not waive the requirements that the permit holder obtain other permits from State, Federal and local agencies.

(CONTINUED ON PAGE 2)

The amount of water to be appropriated shall be limited to the amount which can be applied to beneficial use, and not to exceed 2.3 cubic feet per second, but not to exceed 1665 acre feet annually.

Work must be prosecuted with reasonable diligence and be completed on or before September 11, 1992

Proof of completion of work shall be filed on or before October 11, 1992

Application of water to beneficial use shall be made on or before September 11, 1995

Proof of the application of water to beneficial use shall be filed on or before October 11, 1995

Map in support of proof of beneficial use shall be filed on or before N/A

Completion of work filed

Proof of beneficial use filed

Cultural map filed

Certificate No. Issued

IN TESTIMONY WHEREOF, I R. MICHAEL TURNIPSEED, P.E. State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 11th day of September, A.D. 19 90

State Engineer

(O)-5314 (Rev.)
55269 1.15 cfs
Abrogated By 55270 1.15 cfs

(PERMIT TERMS CONTINUED)

This permit is issued under the provisions of NRS 534.120(2) as a preferred use.

A monthly report shall be submitted to the State Engineer within 10 days from the end of each month which shall include the amount of water pumped and the amount of water used for industrial purposes.

The total depth of the well drilled under Permit 54129 may not progress beyond the normal pool elevation of Lake Mead which is 1157 feet (mean sea level).

AMENDED

Serial No. ASSIGNED 55269

APPLICATION FOR PERMISSION TO CHANGE POINT OF DIVERSION, MANNER OF USE AND PLACE OF USE OF THE PUBLIC WATERS OF THE STATE OF NEVADA HERETOFORE APPROPRIATED

Date of filing in State Engineer's Office SEP 13 1990

Returned to applicant for correction OCT 24 1990

Corrected application filed DEC 07 1990 Map filed DEC 19 1990

The applicant Bonneville Nevada Corporation

257 East 200 South; Suite 800 of Salt Lake City
Street and No. or P.O. Box No. City or Town

Utah 84111 hereby make.... application for permission to change the
State and Zip Code No.

point of diversion and place of use of a portion
Point of diversion, manner of use, and/or place of use

of water heretofore appropriated under Permit 54129
Identify existing right by Permit, Certificate, Proof or Claim Nos. If Decreed, give title of Decree and identify right in Decree.

1. The source of water is underground
Name of stream, lake, underground spring or other source.

2. The amount of water to be changed 1.15 cfs
Second feet, acre feet. One second foot equals 448.83 gallons per minute.

3. The water to be used for Industrial (cogeneration power plant)
Irrigation, power, mining, industrial, etc. If for stock state number and kind of animals.

4. The water heretofore permitted for Industrial (cogeneration power plant)
Irrigation, power, mining, industrial, etc. If for stock state number and kind of animals.

5. The water is to be diverted at the following point within the SE¼ SE¼ Section 13, T.19S., R63E., M.D.B.&M. or at a point from which the S¼ corner of said Section 13 bears S. 48° 32' 19" W. a distance of 1779.15 feet
Describe as being within a 40-acre subdivision of public survey and by course and distance to a section corner. If on unsurveyed land, it should be stated.

6. The existing permitted point of diversion is located within NW¼ SW¼ Section 7, T.20S., R.64E., M.D.B.&M. or at a point from which the Northwest corner of said Section 7 bears North 16° 31' 49" West a distance of 2861.12 feet.
If point of diversion is not changed, do not answer.

7. Proposed place of use within a portion of SW¼ NW¼, NW¼ SW¼ and NE¼ SW¼ Section 7, T.20S., R.64E., M.D.B.&M., approximately 14.5 acre, and within a portion of SE¼ NE¼ and SW¼ NE¼ Section 34, T.18S., R.63E., M.D.B.&M., approximately 23.5 acres
Describe by legal subdivisions. If for irrigation state number of acres to be irrigated.

8. Existing place of use within a portion of SW¼ NW¼, NW¼ SW¼ and NE¼ SW¼ Section 7, T.20S., R.64E., M.D.B.&M. approximately 14.5 acres.
Describe by legal subdivisions. If permit is for irrigation, state number of acres irrigated. If changing place of use and/or manner of use of irrigation permit, describe acreage to be removed from irrigation.

9. Use will be from January 1st to December 31st of each year.
Month and Day Month and Day

10. Use was permitted from January 1st to December 31st of each year.
Month and Day Month and Day

11. Description of proposed works. (Under the provisions of NRS 535.010 you may be required to submit plans and specifications of your diversion or storage works.) drilled well with pump and motor, pipelines to places of use.
State manner in which water is to be diverted, i.e. diversion structure, ditches, pipes and flumes, or drilled well, etc.

12. Estimated cost of works $2,000,000.00

13. Estimated time required to construct works 2 years

SE ROA 41855

14. Estimated time required to complete the application of water to beneficial use 3 years

15. Remarks: For use other than irrigation or stock watering, state number and type of units to be served or annual consumptive use:

In addition to changing the point of diversion of 1.15 cfs appropriated under Permit 54129, the place of use is to include not only the 85 MW cogeneration plant in Black Mountain Area but also an 85 MW plant in Garnet Valley. The annual consumptive use is anticipated to be 2.3 cfs continuous flow or 1665 AF per year, under Applications 55269 and 55270.

By s/Roland D. Westergard
ROLAND D. WESTERGARD, P.E.
207 CARVILLE CIRCLE
CARSON CITY, NEVADA 89703

Compared bc/ bc am/se

Protested

APPROVAL OF STATE ENGINEER

This is to certify that I have examined the foregoing application, and do hereby grant the same, subject to the following limitations and conditions: This permit to change the point of diversion and place of use of a portion of the waters of an underground source as heretofore granted under Permit 54129 is issued subject to the terms and conditions imposed in said Permit 54129 and with the understanding that no other rights on the source will be affected by the change proposed herein. The well shall be equipped with a 2-inch opening and a totalizing meter must be installed and maintained in the discharge pipeline near the point of diversion and accurate measurements must be kept of water placed to beneficial use. The totalizing meter must be installed before any use of the water begins or before the proof of completion of work is filed. If the well is flowing, a valve must be installed and maintained to prevent waste. This source is located within an area designated by the State Engineer pursuant to NRS 534.030. The State retains the right to regulate the use of the water herein granted at any and all times.

This permit does not extend the permittee the right of ingress and egress on public, private or corporate lands.

The issuance of this permit does not waive the requirements that the permit holder obtain other permits from State, Federal and local agencies.

This permit is issued under the provisions of NRS 534.120(2) as a preferred use.

The total combined duty of water under Permits 55269 and 55270 shall not exceed 1,665 acre-feet annually.

A monthly report shall be submitted to the State Engineer within 10 days from the end of each month which shall include the amount of water pumped and the amount of water used for industrial purposes.

The amount of water to be changed shall be limited to the amount which can be applied to beneficial use, and not to exceed 1.15 cubic feet per second, but not to exceed 832.57 acre-feet annually.

Work must be prosecuted with reasonable diligence and be completed on or before September 11, 1992

Proof of completion of work shall be filed before October 11, 1992

Application of water to beneficial use shall be made on or before September 11, 1995

Proof of the application of water to beneficial use shall be filed on or before October 11, 1995

Map in support of proof of beneficial use shall be filed on or before N/A

Completion of work filed JUL 30 1992

Proof of beneficial use filed

Cultural map filed

Certificate No. Issued

IN TESTIMONY WHEREOF, I, R. MICHAEL TURNIPSEED, P.E. State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 5th day of July, A.D. 19 91

R. Michael Turnipseed, P.E.
State Engineer

(O)-1108 (Rev. 6-81)

Permit No. **55269** Certificate No. **17123** Book **81** Page **17123**

THE STATE OF NEVADA

CERTIFICATE OF APPROPRIATION OF WATER

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WHEREAS, Genevieve E. Marenco, Agent, has presented to the State Engineer of the State of Nevada, Proof of Application of Water to Beneficial Use, from an underground source, through a drilled well (Well EBP-2), pump and distribution system for industrial (power plant) purposes. The point of diversion of water from the source is as follows:

> **SE¼ SE¼ Section 13, T.19S., R.63E., M.D.B.&M., or at a point from which the S¼ corner of said Section 13 bears S. 48°32'19" W., a distance of 1,779.15 feet situated in Clark County, State of Nevada.**

NOW KNOW YE, That the State Engineer, under the provisions of NRS 533.425, has determined the date, source, purpose, amount of appropriation, and the place where such water is appurtenant, as follows:

Name of appropriator:	**Nevada Cogeneration Associates #1 and Nevada Cogeneration Associates #2**
Source:	**Underground (Well EBP-2)**
Manner of use:	**Industrial (Power Plant)**
Amount of appropriation:	***1.15 c.f.s., but not to exceed 96 acre-feet annually**
Period of use:	**January 1st to December 31st of each year**
Date of priority of appropriation:	****October 30, 1989**

Description of the works of diversion, manner and place of use:

Water is developed by means of a drilled well 1,214 feet deep, 12-inch diameter casing, equipped with a six stage Layne & Bowler pump with a 150 H.P. Franklin motor, thence through a distribution system to a 70,000 gallon storage tank serving an 85-megawatt power plant (Nevada Cogeneration Plant #1) located within a portion of the SW¼ NW¼, NW¼ SW¼, and NE¼ SW¼, Section 7, T.20S., R.64E., M.D.B.&M., approximately 14.5 acres being within Black Mountains Area; and serving an 85-megawatt power plant (Nevada Cogeneration #2) located within a portion of the SE¼ NE¼, and SW¼ NE¼, Section 34, T.18S., R.63E., M.D.B.&M., approximately 23.5 acres being within Garnet Valley.

***The total combined duty of water under Permit 55269, Certificate 17123; Permit 58031, Certificate 17124; and Permit 58032, Certificate 17125 shall not exceed 1,665 acre-feet annually.**

****This certificate changes the point of diversion and place of use of a portion of Permit 54129, therefore, the date of priority remains the same as Permit 54129.**

This certificate is issued subject to the terms of the permit.

The right to water hereby determined is limited to the amount which can be beneficially used, not to exceed the amount above specified, and the use is restricted to the place and for the purpose as set forth herein.

The right to water hereby determined is limited to the amount which can be beneficially used, not to exceed the amount above specified, and the use is restricted to the place and for the purpose as set forth herein.

IN TESTIMONY WHEREOF, I, **TRACY TAYLOR**, State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 15th day of December, A.D., **2008**.

KAKG/gkl

K. Hull P.E.
for State Engineer

ASSIGNED

AMENDED

Serial No. 55270

APPLICATION FOR PERMISSION TO CHANGE POINT OF DIVERSION, MANNER OF USE AND PLACE OF USE OF THE PUBLIC WATERS OF THE STATE OF NEVADA HERETOFORE APPROPRIATED

Date of filing in State Engineer's Office SEP 13 1990

Returned to applicant for correction JAN 25 1991

Corrected application filed MAR 26 1991 Map filed MAR 26 1991

The applicant Bonneville Nevada Corporation

257 East 200 South, Suite 800 of Salt Lake City
Street and No. or P.O. Box No. City or Town

Utah 84111 hereby makes application for permission to change the
State and Zip Code No.

Point of Diversion and place of use of a portion
Point of diversion, manner of use, and/or place of use

of water heretofore appropriated under Permit 54129
Identify existing right by Permit, Certificate, Proof or Claim Nos. If Decreed, give title of Decree and identify right in Decree.

1. The source of water is Underground
Name of stream, lake, underground spring or other source.

2. The amount of water to be changed 1.15 c.f.s.
Second feet, acre feet. One second foot equals 448.83 gallons per minute.

3. The water to be used for Industrial (cogeneration power plant)
Irrigation, power, mining, industrial, etc. If for stock state number and kind of animals.

4. The water heretofore permitted for Industrial (cogeneration power plant)
Irrigation, power, mining, industrial, etc. If for stock state number and kind of animals.

5. The water is to be diverted at the following point within NW¼ NE¼ Section 13, T.19S., R.63E., M.D.B.&M. or at a point from which the N¼ corner of said Section 13 bears North 55° 00' 00" West a distance of 114.00 feet.
Describe as being within a 40-acre subdivision of public survey and by course and distance to a section corner. If on unsurveyed land, it should be stated.

6. The existing permitted point of diversion is located within NW¼ SW¼ Section 7, T.20S., R.64E., M.D.B.&M. or at a point from which the Northwest corner of said Section 7 bears North 16° 31' 49" West a distance of 2861.12 feet.
If point of diversion is not changed, do not answer.

7. Proposed place of use within a portion of SW¼ NW¼, NW¼ SW¼ and NE¼ SW¼ Section 7, T.20S., R.64E., M.D.B.&M., approximately 14.5 acres, and within a portion of SE¼ NE¼ and SW¼ NE¼ Section 34, T.18S., R.63E., M.D.B.&M., approximately 23.5 acres.
Describe by legal subdivisions. If for irrigation state number of acres to be irrigated.

8. Existing place of use within a portion of SW¼ NW¼, NW¼ SW¼ and NE¼ SW¼ Section 7, T.20S., R.64E., M.D.B.&M., approximately 14.5 acres.
Describe by legal subdivisions. If permit is for irrigation, state number of acres irrigated. If changing place of use and/or manner of use of irrigation permit, describe acreage to be removed from irrigation.

9. Use will be from January 1st to December 31st of each year.
Month and Day Month and Day

10. Use was permitted from January 1st to December 31st of each year.
Month and Day Month and Day

11. Description of proposed works. (Under the provisions of NRS 535.010 you may be required to submit plans and specifications of your diversion or storage works.) drilled well with pump and motor, pipelines to places of use.
State manner in which water is to be diverted, i.e. diversion structure, ditches, pipes and flumes, or drilled well, etc.

12. Estimated cost of works $2,000,000.00

13. Estimated time required to construct works 2 years

SE ROA 41859

14. Estimated time required to complete the application of water to beneficial use 3 years

15. Remarks: For use other than irrigation or stock watering, state number and type of units to be served or annual consumptive use:

In addition to changing the point of diversion of 1.15 cfs. appropriated under Permit 54129, the place of use is to include not only the 85 MW cogeneration plant in Black Mountain Area but also an 85 MW plant in Garnet Valley. The annual consumptive use is anticipated to be 2.3 cfs continuous flow or 1665 AF per year, under Applications 55269 and 55270.

By s/Roland D. Westergard
Roland D. Westergard, P.E.
207 Carville Circle
Carson City, Nevada 89703

Compared bc/ bc am/se

Protested

APPROVAL OF STATE ENGINEER

This is to certify that I have examined the foregoing application, and do hereby grant the same, subject to the following limitations and conditions: This permit to change the point of diversion and place of use of a portion of the waters of an underground source as heretofore granted under Permit 54129 is issued subject to the terms and conditions imposed in said Permit 54129 and with the understanding that no other rights on the source will be affected by the change proposed herein. The well shall be equipped with a 2-inch opening and a totalizing meter must be installed and maintained in the discharge pipeline near the point of diversion and accurate measurements must be kept of water placed to beneficial use. The totalizing meter must be installed before any use of the water begins or before the proof of completion of work is filed. If the well is flowing, a valve must be installed and maintained to prevent waste. This source is located within an area designated by the State Engineer pursuant to NRS 534.030. The State retains the right to regulate the use of the water herein granted at any and all times.

This permit does not extend the permittee the right of ingress and egress on public, private or corporate lands.

The issuance of this permit does not waive the requirements that the permit holder obtain other permits from State, Federal and local agencies.

This permit is issued under the provisions of NRS 534.120(2) as a preferred use.

The total combined duty of water under Permits 55269 and 55270 shall not exceed 1,665 acre-feet annually.

A monthly report shall be submitted to the State Engineer within 10 days from the end of each month which shall include the amount of water pumped and the amount of water used for industrial purposes.

The amount of water to be changed shall be limited to the amount which can be applied to beneficial use, and not to exceed 1.15 cubic feet per second, but not to exceed 832.57 acre-feet annually.

Work must be prosecuted with reasonable diligence and be completed on or before September 11, 1992

Proof of completion of work shall be filed before October 11, 1992

Application of water to beneficial use shall be made on or before September 11, 1995

Proof of the application of water to beneficial use shall be filed on or before October 11, 1995

Map in support of proof of beneficial use shall be filed on or before N/A

Completion of work filed

Proof of beneficial use filed

Cultural map filed

Certificate No. Issued

Abrogated By 58130T 2-17-94 exp
58031 1.15

IN TESTIMONY WHEREOF, I, R. MICHAEL TURNIPSEED, P.E. State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 5th day of July, A.D. 1991

[signature] P.E.
State Engineer

(O)-1108 (Rev. 6-81)

SE ROA 41860

AMENDED

Nº 55271

ASSIGNED

APPLICATION FOR PERMIT
TO APPROPRIATE THE PUBLIC WATERS OF THE STATE OF NEVADA

Date of filing in State Engineer's Office SEP 13 1990

Returned to applicant for correction JAN 28 1991

Corrected application filed MAY 28 1991

Map filed MAY 28 1991

The applicant Bonneville Nevada Corporation

257 East 200 South, Suite 800 (Street and No. or P.O. Box No.), of Salt Lake City (City or Town),

Utah 84111 (State and Zip Code No.), hereby makes application for permission to appropriate the public waters of the State of Nevada, as hereinafter stated. (If applicant is a corporation, give date and place of incorporation; if a copartnership or association, give names of members.) December 2, 1988 with Secretary of State in Carson City, Nevada

1. The source of the proposed appropriation is an underground source (Name of stream, lake, spring, underground or other source)

2. The amount of water applied for is 2.3 cfs second-feet (One second-foot equals 448.83 gals. per min.)

   (a) If stored in reservoir give number of acre-feet

3. The water to be used for industrial (cogeneration power plant) (Irrigation, power, mining, manufacturing, domestic, or other use. Must limit to one use.)

4. If use is for:

   (a) Irrigation, state number of acres to be irrigated N/A

   (b) Stockwater, state number and kinds of animals to be watered N/A

   (c) Other use (describe fully under "No. 12. Remarks") N/A

   (d) Power:

      (1) Horsepower developed 170 MW (two 85 MW electrical power plants)

      (2) Point of return of water to stream N/A

5. The water is to be diverted from its source at the following point within SW¼ SE¼ Section 13, T.19S., R.63E., M.D.B.&M., or at a point from which the S¼ corner of said Section 13 bears S. 52° 06' 24" W. a distance of 1559.39 feet. (Describe as being within a 40-acre subdivision of public survey, and by course and distance to a section corner. If on unsurveyed land, it should be so stated.)

6. Place of use within a portion of SW¼ NW¼, NW¼ SW¼ and NE¼ SW¼ Section 7, T.20S., R.64E. M.D.B.&M. approximately 14.5 acres and within a portion of SE¼ NE¼ and SW¼ NE¼ Section 34, T.18S., R63E., M.D.B.&M., approximately 23.5 acres. (Describe by legal subdivision. If on unsurveyed land, it should be so stated.)

7. Use will begin about January 1st (Month and Day) and end about December 31st (Month and Day), of each year.

8. Description of proposed works. (Under the provisions of NRS 535.010 you may be required to submit plans and specifications of your diversion or storage works.) drilled well, pump & motor and pipelines to place of use (State manner in which water is to be diverted, i.e. diversion structure, ditches and flumes, drilled well with pump and motor, etc.)

9. Estimated cost of works $1,000,000.00

55271

10. Estimated time required to construct works 2 years
If well completed, describe works.

11. Estimated time required to complete the application of water to beneficial use 3 years

12. Remarks: For use other than irrigation or stock watering, state number and type of units to be served or annual consumptive use.

Two 85 MW cogeneration plants are to be served. This Application is for a well to serve as an emergency "backup" or alternative in the event of failure or other problems in obtaining necessary water from the primary water source.

By s/Roland D. Westergard
207 Carville Circle
Carson City, Nevada 89703

Compared bc/ bc am/se

Protested

APPROVAL OF STATE ENGINEER

This is to certify that I have examined the foregoing application, and do hereby grant the same, subject to the followng limitations and conditions:

This permit is issued subject to existing rights. It is understood that the amount of water herein granted is only a temporary allowance and that the final water right obtained under this permit will be dependent upon the amount of water actually placed to beneficial use. It is also understood that this right must allow for a reasonable lowering of the static water level. This well shall be equipped with a two (2) inch opening for measuring depth to water. If the well is flowing, a valve must be installed and maintained to prevent waste. A totalizing meter must be installed and maintained in the discharge pipeline near the point of diversion and accurate measurements must be kept of water placed to beneficial use. The totalizing meter must be installed before any use of water begins, or before the Proof of Completion of Work is filed. This source is located within an area designated by the State Engineer, pursuant to NRS 534.030. The State retains the right to regulate the use of the water herein granted at any and all times.

This permit does not extend the permittee the right of ingress and egress on public, private or corporate lands.

The total combined duty of water under Permits 54129, 55269, 55270 and 55271 shall not exceed 1665 acre-feet annually.

(CONTINUED ON PAGE 2)

The amount of water to be appropriated shall be limited to the amount which can be applied to beneficial use, and not to exceed 2.3 cubic feet per second, but not to exceed 1,665 acre-feet annually.

Work must be prosecuted with reasonable diligence and be completed on or before September 11, 1992

Proof of completion of work shall be filed on or before October 11, 1992

Application of water to beneficial use shall be made on or before September 11, 1995

Proof of the application of water to beneficial use shall be filed on or before October 11, 1995

Map in support of proof of beneficial use shall be filed on or before N/A

Completion of work filed

Proof of beneficial use filed

Cultural map filed

Certificate No. Issued

IN TESTIMONY WHEREOF, I R. MICHAEL TURNIPSEED, P.E. State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 18th day of November, A.D. 19 91

State Engineer

(O)-5314 (Rev.)

Abrogated By 58129T exp 2-17-94
58032 2.3

(PERMIT TERMS CONTINUED)

The issuance of this permit does not waive the requirements that the permit holder obtain other permits from State, Federal and local agencies.

This permit is issued under the provisions of NRS 534.120(2) as a preferred use.

ASSIGNED

SECOND AMENDED

Serial No. 58031

APPLICATION FOR PERMISSION TO CHANGE POINT OF DIVERSION, MANNER OF USE AND PLACE OF USE OF THE PUBLIC WATERS OF THE STATE OF NEVADA HERETOFORE APPROPRIATED

Date of filing in State Engineer's Office AUG 31 1992

Returned to applicant for correction OCT 05 1992

Corrected application filed DEC 03 1992 Map filed DEC 03 1992

The applicant Nevada Cogeneration Associates #1 and #2

420 N. Nellis Blvd., #A3-148 & #A3-117 of Las Vegas
Street and No. or P.O. Box No. City or Town

Nevada 89110 hereby make.... application for permission to change the
State and Zip Code No.

Point of Diversion
Point of diversion, manner of use, and/or place of use

of water heretofore appropriated under Permit No. 55270
Identify existing right by Permit, Certificate, Proof or Claim Nos. If Decreed, give title of Decree and identify right in Decree.

1. The source of water is Underground
Name of stream, lake, underground spring or other source.

2. The amount of water to be changed 1.15 C.F.S.
Second feet, acre feet. One second foot equals 448.83 gallons per minute.

3. The water to be used for Industrial (Cogeneration Power Plant)
Irrigation, power, mining, industrial, etc. If for stock state number and kind of animals.

4. The water heretofore permitted for Industrial (Cogeneration Power Plant)
Irrigation, power, mining, industrial, etc. If for stock state number and kind of animals.

5. The water is to be diverted at the following point Within a portion of the Northeast Quarter (NE¼) of the Southeast Quarter (SE¼) of Section 13, Township 19 South, Range 63 East, M.D.B. & M. or at a point from which the South Quarter (S¼) corner of said Section 13 bears South 40° 37' 41" W 3243.05 Feet.
Describe as being within a 40-acre subdivision of public survey and by course and distance to a section corner. If on unsurveyed land, it should be stated.

6. The existing permitted point of diversion is located within A portion of the Northwest Quarter (NW¼) of the Northeast Quarter (NE¼) of Section 13, Township 19 South, Range 63 East, M.D.B. & M. or at a point from which the North Quarter (N¼) of said Section 13 bears North 55° 00' 00" West a distance of 114.00 Feet.
If point of diversion is not changed, do not answer.

7. Proposed place of use Within a portion of the SW¼ NW¼, NW¼ SW¼, and NE¼ SW¼ of Section 7, Township 20 South, Range 64 East, M.D.B. & M. approximately 14.5 acres and within a portion of the SE¼ NE¼ and SW¼ NE¼ of Section 34, Township 18 South, Range 63 East, M.D.B. & M. approximately 23.5 acres.
Describe by legal subdivisions. If for irrigation state number of acres to be irrigated.

8. Existing place of use Same as proposed
Describe by legal subdivisions. If permit is for irrigation, state number of acres irrigated. If changing place of use and/or manner of use of irrigation permit, describe acreage to be removed from irrigation.

9. Use will be from January 1 to December 31 of each year.
Month and Day Month and Day

10. Use was permitted from January 1 to December 31 of each year.
Month and Day Month and Day

11. Description of proposed works. (Under the provisions of NRS 535.010 you may be required to submit plans and specifications of your diversion or storage works.) Drilled well with pump and motor, pipelines to place of use
State manner in which water is to be diverted, i.e. diversion structure, ditches, pipes and flumes, or drilled well, etc.

12. Estimated cost of works $2,000,000.00

13. Estimated time required to construct works 2 years

14. Estimated time required to complete the application of water to beneficial use 3 years

15. Remarks: For use other than irrigation or stock watering, state number and type of units to be served or annual consumptive use:

Anticipated 1.15 CFS continuous flow or 832.57 AF per year.

By s/Gary L. Haub
420 N. Nellis Blvd., #A3-148 & #A3-117
Las Vegas, NV 89110

Compared bk/se ab/se

Protested 2/12/93 byL Las Vegas Valley Water District
Pro. overruled 4/5/93;
Ruling No. 3950

APPROVAL OF STATE ENGINEER

This is to certify that I have examined the foregoing application, and do hereby grant the same, subject to the following limitations and conditions:

This permit to change the point of diversion of the waters of an underground source as heretofore granted under Permit 55270 is issued subject to the terms and conditions imposed in said Permit 55270 and with the understanding that no other rights on the source will be affected by the change proposed herein. The well shall be equipped with a 2-inch opening and a totalizing meter must be installed and maintained in the discharge pipeline near the point of diversion and accurate measurements must be kept of water placed to beneficial use. The totalizing meter must be installed before any use of the water begins or before the proof of completion of work is filed. If the well is flowing, a valve must be installed and maintained to prevent waste. This source is located within an area designated by the State Engineer pursuant to NRS 534.030. The State retains the right to regulate the use of the water herein granted at any and all times.

This permit does not extend the permittee the right of ingress and egress on public, private or corporate lands.

The total combined duty of water under Permits 55269, 58031 and 58032 shall not exceed 1665 acre-feet annually.

The issuance of this permit does not waive the requirements that the permit holder obtain other permits from State, Federal and local agencies.

This permit is issued subject to the State Engineer's Ruling No. 3950 dated April 5, 1993, with the exception that Item 5 of the ruling is hereby waived.

The issuance of Permit 58031 expires Permit 58130-T.

The amount of water to be changed shall be limited to the amount which can be applied to beneficial use, and not to exceed 1.15 cubic feet per second, but not to exceed 832.57 acre-feet annually.

Work must be prosecuted with reasonable diligence and be completed on or before September 11, 1993

Proof of completion of work shall be filed before October 11, 1993

Application of water to beneficial use shall be made on or before September 11, 1995

Proof of the application of water to beneficial use shall be filed on or before October 11, 1995

Map in support of proof of beneficial use shall be filed on or before N/A

Completion of work filed AUG 4 - 1993

Proof of beneficial use filed

Cultural map filed

Certificate No. Issued

IN TESTIMONY WHEREOF, I, R. MICHAEL TURNIPSEED, P.E. State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 28th day of May, A.D. 19 93

R. Michael Turnipseed P.E.
State Engineer

(O)-1108 (Rev. 6-81)

Permit No. **58031** Certificate No. **17124** Book **81** Page **17124**

THE STATE OF NEVADA

CERTIFICATE OF APPROPRIATION OF WATER

~ ~ ~ ~ ~

WHEREAS, Genevieve E. Marenco, Agent, has presented to the State Engineer of the State of Nevada, Proof of Application of Water to Beneficial Use, from an underground source, through a drilled well (Well EGV-3), pump and distribution system for industrial (power plant) purposes. The point of diversion of water from the source is as follows:

> **NE¼ SE¼ Section 13, T.19S., R.63E., M.D.B.&M., or at a point from which the S¼ corner of said Section 13 bears S. 40°37′41″ W., a distance of 3,243.05 feet, situated in Clark County, State of Nevada.**

NOW KNOW YE, That the State Engineer, under the provisions of NRS 533.425, has determined the date, source, purpose, amount of appropriation, and the place where such water is appurtenant, as follows:

Name of appropriator:	**Nevada Cogeneration Associates #1 and #2**
Source:	**Underground (Well EGV-3)**
Manner of use:	**Industrial (Power Plant)**
Amount of appropriation:	***1.15 c.f.s., but not to exceed 824 acre-feet annually**
Period of use:	**January 1st to December 31st of each year**
Date of priority of appropriation:	****October 30, 1989**

Description of the works of diversion, manner and place of use:

Water is developed by means of a drilled well, 955 feet deep, 12-inch diameter casing, equipped with a seven stage Layne & Bowler pump with a 200 H.P. Franklin motor, thence through a distribution system to a 70,000 gallon storage tank serving an 85-megawatt power plant (Nevada Cogeneration Plant #1) located within a portion of the SW¼ NW¼, NW¼ SW¼, and NE¼ SW¼, Section 7, T.20S., R.64E., M.D.B.&M., approximately 14.5 acres being within Black Mountains Area; and serving an 85-megawatt power plant (Nevada Cogeneration #2) located within a portion of the SE¼ NE¼, and SW¼ NE¼, Section 34, T.18S., R.63E., M.D.B.&M., approximately 23.5 acres being within Garnet Valley.

***The total combined duty of water under Permit 55269, Certificate 17123; Permit 58031, Certificate 17124; and Permit 58032, Certificate 17125 shall not exceed 1,665 acre-feet annually.**

***This certificate changes the point of diversion of Permit 55270, which changed the point of diversion and place of use of a portion of Permit 54129, therefore, the date of priority remains the same as Permit 54129.**

This certificate is issued subject to the terms of the permit.

The right to water hereby determined is limited to the amount which can be beneficially used, not to exceed the amount above specified, and the use is restricted to the place and for the purpose as set forth herein.

IN TESTIMONY WHEREOF, I, **TRACY TAYLOR**, State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 15th day of December, A.D., **2008**.

K. C. Hill P.E.
for State Engineer

KAKG/gkl

Serial No. 58032

APPLICATION FOR PERMISSION TO CHANGE POINT OF DIVERSION, MANNER OF USE AND PLACE OF USE OF THE PUBLIC WATERS OF THE STATE OF NEVADA HERETOFORE APPROPRIATED

Date of filing in State Engineer's Office AUG 31 1992

Returned to applicant for correction OCT 05 1992

Corrected application filed ________ Map filed DEC 03 1992

The applicant Nevada Cogeneration Associates No. 1 & 2

420 N. Nellis Blvd. A3-148 & 117 (Street and No. or P.O. Box No.) of Las Vegas (City or Town)

Nevada 89110 (State and Zip Code No.) hereby make.... application for permission to change the

Point of Diversion (Point of diversion, manner of use, and/or place of use)

of water heretofore appropriated under Permit No. 55271 (Identify existing right by Permit, Certificate, Proof or Claim Nos. If Decreed, give title of Decree and identify right in Decree.)

1. The source of water is Underground (Name of stream, lake, underground spring or other source.)

2. The amount of water to be changed 2.3 CFS (Second feet, acre feet. One second foot equals 448.83 gallons per minute.)

3. The water to be used for Industrial (Cogeneration Power Plant) (Irrigation, power, mining, industrial, etc. If for stock state number and kind of animals.)

4. The water heretofore permitted for Industrial (Cogeneration Power Plant) (Irrigation, power, mining, industrial, etc. If for stock state number and kind of animals.)

5. The water is to be diverted at the following point Within a portion of the Northeast Quarter (NE¼) of the Southeast Quarter (SE¼) of Section 13, Township 19 South, Range 63 East, M.D.B. & M. or at a point from which the South Quarter (S¼) corner of said Section 13 bears South 44° 16' 36" West 2657.10 Feet. (Describe as being within a 40-acre subdivision of public survey and by course and distance to a section corner. If on unsurveyed land, it should be stated.)

6. The existing permitted point of diversion is located within A portion of the Southwest Quarter (SW¼) of the Southeast Quarter (SE¼) of Section 13, Township 19 South, Range 63 East, M.D.B. & M. or at a point from which the South Quarter (S¼) corner of said Section 13 bears South 52° 06' 24" West a distance of 1559.39 Feet. (If point of diversion is not changed, do not answer.)

7. Proposed place of use Within a Portion of the SW¼ NW¼, NW¼ SW¼ and NE¼ SW¼ of Section 7, Township 20 South, Range 64 East, M.D.B. & M. approximately 14.5 acres and within a portion of the SE¼ NE¼ and SW¼ NE¼ of Section 34, Township 18 South, Range 63 East, M.D.B. & M. approximately 23.5 acres. (Describe by legal subdivisions. If for irrigation state number of acres to be irrigated.)

8. Existing place of use Same as proposed (Describe by legal subdivisions. If permit is for irrigation, state number of acres irrigated. If changing place of use and/or manner of use of irrigation permit, describe acreage to be removed from irrigation.)

9. Use will be from January 1 (Month and Day) to Decemeber 31 (Month and Day) of each year.

10. Use was permitted from January 1 (Month and Day) to December 31 (Month and Day) of each year.

11. Description of proposed works. (Under the provisions of NRS 535.010 you may be required to submit plans and specifications of your diversion or storage works.) Drilled well with pump and moter, Pipelines to place of use. (State manner in which water is to be diverted, i.e. diversion structure, ditches, pipes and flumes, or drilled well, etc.)

12. Estimated cost of works 2,000,000.00

13. Estimated time required to construct works 2 Years

SE ROA 41868

14. Estimated time required to complete the application of water to beneficial use 3 Years

15. Remarks: For use other than irrigation or stock watering, state number and type of units to be served or annual consumptive use:

Anticipated 2.3 CFS coninuous flow or 1665 AF per year.

By s/Gary L. Haub
~~420 N. Nellis Blvd #A3-148 & 117~~
Las Vegas, NV 89110

Compared bk/ se ab/se

Protested 2/12/93 by: Las Vegas Valley Water District

Pro. overruled 4/5/93;
Ruling No. 3950

APPROVAL OF STATE ENGINEER

This is to certify that I have examined the foregoing application, and do hereby grant the same, subject to the following limitations and conditions:

This permit to change the point of diversion of the waters of an underground source as heretofore granted under Permit 55271 is issued subject to the terms and conditions imposed in said Permit 55271 and with the understanding that no other rights on the source will be affected by the change proposed herein. The well shall be equipped with a 2-inch opening and a totalizing meter must be installed and maintained in the discharge pipeline near the point of diversion and accurate measurements must be kept of water placed to beneficial use. The totalizing meter must be installed before any use of the water begins or before the proof of completion of work is filed. If the well is flowing, a valve must be installed and maintained to prevent waste. This source is located within an area designated by the State Engineer pursuant to NRS 534.030. The State retains the right to regulate the use of the water herein granted at any and all times.

This permit does not extend the permittee the right of ingress and egress on public, private or corporate lands.

The total combined duty of water under Permits 55269, 58031 and 58032 shall not exceed 1665 acre-feet annually.

The issuance of this permit does not waive the requirements that the permit holder obtain other permits from State, Federal and local agencies.

This permit is issued subject to the State Engineer's Ruling No. 3950 dated April 5, 1993, with the exception that Item 5 of the ruling is hereby waived.

The issuance of Permit 58032 expires Permit 58129-T.

The amount of water to be changed shall be limited to the amount which can be applied to beneficial use, and not to exceed 2.3 cubic feet per second, but not to exceed 1665.0 acre-feet annually.

Work must be prosecuted with reasonable diligence and be completed on or before September 11, 1993

Proof of completion of work shall be filed before October 11, 1993

Application of water to beneficial use shall be made on or before September 11, 1995

Proof of the application of water to beneficial use shall be filed on or before October 11, 1995

Map in support of proof of beneficial use shall be filed on or before N/A

Completion of work filed AUG 4 - 1993

Proof of beneficial use filed

Cultural map filed

Certificate No. Issued

IN TESTIMONY WHEREOF, I, R. MICHAEL TURNIPSEED, P.E. State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 28th day of May, A.D. 19 93

R. Michael Turnipseed P.E.
State Engineer

(O)-1108 (Rev. 6-81)

Permit No. **58032** Certificate No. **17125** Book **81** Page **17125**

THE STATE OF NEVADA
CERTIFICATE OF APPROPRIATION OF WATER

~ ~ ~ ~ ~

WHEREAS, Genevieve E. Marenco, Agent, has presented to the State Engineer of the State of Nevada, Proof of Application of Water to Beneficial Use, from an underground source, through a drilled well (Well EBM-4), pump and distribution system for industrial (power plant) purposes. The point of diversion of water from the source is as follows:

NE¼ SE¼ Section 13, T.19S., R.63E., M.D.B.&M., or at a point from which the S¼ corner of said Section 13 bears S. 44°16'36" W., a distance of 2,657.10 feet situated in Clark County, State of Nevada.

NOW KNOW YE, That the State Engineer, under the provisions of NRS 533.425, has determined the date, source, purpose, amount of appropriation, and the place where such water is appurtenant, as follows:

Name of appropriator:	**Nevada Cogeneration Associates #1 and #2**
Source:	**Underground (Well EBM-4)**
Manner of Use:	**Industrial (Power Plant)**
Amount of appropriation:	***1.85 c.f.s., but not to exceed 826 acre-feet annually**
Period of use:	**January 1st to December 31st of each year**
Date of priority of appropriation:	****September 13, 1990**

Description of the works of diversion, manner and place of use:

Water is developed by means of a drilled well, 1,129 feet deep, 12 inch diameter casing, equipped with a seven stage Layne & Bowler pump with a 200 H.P. Franklin motor, thence through a distribution system to a 70,000 gallon storage tank serving an 85-megawatt power plant (Nevada Cogeneration Plant #1) located within a portion of the SW¼ NW¼, NW¼ SW¼, and NE¼ SW¼, Section 7, T.20S., R.64E., M.D.B.&M., approximately 14.5 acres being within Black Mountains Area; and serving an 85-megawatt power plant (Nevada Cogeneration #2) located within a portion of the SE¼ NE¼, and SW¼ NE¼, Section 34, T.18S., R.63E., M.D.B.&M., approximately 23.5 acres being within Garnet Valley.

***The total combined duty of water under Permit 55269, Certificate 17123; Permit 58031, Certificate 17124; and Permit 58032, Certificate 17125 shall not exceed 1,665 acre-feet annually.**

****This certificate changes the point of diversion of Permit 55271, therefore, the date of priority remains the same as Permit 55271.**

This certificate is issued subject to the terms of the permit.

The right to water hereby determined is limited to the amount which can be beneficially used, not to exceed the amount above specified, and the use is restricted to the place and for the purpose as set forth herein.

IN TESTIMONY WHEREOF, I, **TRACY TAYLOR**, State Engineer of Nevada, have hereunto set my hand and the seal of my office, this 15th day of December, A.D., **2008**.

K. Hull P.E.
for State Engineer

KAKG/gkl

IN THE OFFICE OF THE STATE ENGINEER
OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA	INTERIM ORDER #1303

Nevada Power Company
and Sierra Pacific Power Company
d/b/a NV Energy

AMENDED EXPERT WITNESS AND EXHIBIT LIST DISCLOSURE

Nevada Power Company d/b/a NV Energy ("Nevada Power") and Sierra Pacific Power Company d/b/a NV Energy ("Sierra" and together with Nevada Power, "NV Energy" or the "Companies") hereby files its exhibit and expert witness list pursuant to the State Engineer's August 23, 2019 Notice of Hearing.

EXPERT WITNESS

1. Richard A. Felling, PG
   rafelling@charter.net

Mr. Felling is an expert in Geology and Hydrogeology. Mr. Felling has been qualified as an expert for the Nevada State Engineer in hydrogeology in Nevada's Third Judicial District Court.

Mr. Felling's testimony will include support for NV Energy Rebuttal Report to State Engineer's Order 1303 Initial Reports by Respondents, which includes but is not limited to: (a) NV's position that the jointly-managed Lower White River Flow System (LWRFS) should consist of the five basins plus the northern portion of the Black Mountains Area as presently defined by the State Engineer; (2) Water level decline in the LWRFS was not due to drought, but rather recovery was complete approximately two to three years after completion of the test;

(3) steady state conditions are being reached in the Muddy River Springs Area under the current pumping regime, and (4) the movement of water rights between alluvial and carbonate wells.

EXHIBIT LIST

EXHIBIT	BATES NO.	EXHIBIT NAME
1.	NVE 1-12	NV Energy Rebuttal Report to State Engineer's Order 1303 Initial Reports by Respondents
2.	NVE 13-16	Curriculum Vitae of Richard A. Felling, PG

NV Energy incorporates the documents and records of the Nevada State Engineer listed in Exhibit A as documents and evidence that NV Energy desires the Nevada State Engineer to consider. NV Energy reserves the right to provide a demonstrative PowerPoint presentation during the September 23, 2019 hearing.

Dated this 6th day of September, 2019.

NV Energy

Justina Caviglia
Senior Attorney
Nevada Bar No. 9999
6100 Neil Road
Reno, Nevada 89511
775-834-3551
jcaviglia@nvenergy.com

Nevada Power Company
and Sierra Pacific Power Company
d/b/a NV Energy

CERTIFICATE OF SERVICE

Pursuant to NRCP 5(b), I hereby certify that I am an employee of NV Energy, and that on September 6th, 2019, I served the foregoing Notice of Appearance via direct email to the addresses indicated below:

8milelister@gmail.com ;
ablack@mcdonaldcarano.com ;
admin.mbop@moapabandofpaiutes.org ;
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Lori Petersen

Lori Petersen
Senior Legal Administrative Assistant
NV Energy

NV Energy Rebuttal Report to State Engineer's Order 1303 Initial Reports by Respondents

Richard A. Felling PG

August 16, 2019

NVEnergy offers the following rebuttal arguments to the five topics requested pursuant to State Engineer Order 1303.

The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System.

Contrary to the opinions of the Center for Biological Diversity (CBD), Lincoln-Vidler, Moapa Band of Paiutes (MBOP), Moapa Valley Water District (MVWD), City of North Las Vegas (CNLV), the Great Basin Water Network (GBWN), and the US Fish and Wildlife Service (USFWS), NV Energy believes the jointly-managed Lower White River Flow System (LWRFS) should consist of the five basins plus the northern portion of the Black Mountains Area as presently defined by the State Engineer. The reason for the current boundary is due to the fact recognized by most of the responding parties and the State Engineer that the basins share an extremely highly transmissive carbonate aquifer and water levels that move in lockstep throughout much of the area. It was demonstrated in the Order 1169 aquifer test that water development in one of the basins effects the remaining basins.

Submitted reports by the USFWS and the CBD argue for the inclusion of Kane Springs Valley into the LWRFS jointly managed area. Lincoln-Vidler and USFWS suggest adding the Lower Meadow Valley Wash to the LWRFS jointly managed area. Their arguments are similar. They are in agreement that subsurface water flows from the two basins into Coyote Spring Valley and the Muddy River Springs Area, respectively. That in itself is not sufficient for inclusion into the LWRFS jointly managed area. Those two basins have water levels that are significantly higher than the LWRFS carbonate aquifer and did not immediately respond during the Order 1169 aquifer test. If one were to add all basins whose groundwater flows into the LWRFS basins, then we would also need to add the entire White River Flow System as well as the Meadow Valley Flow System.

Most, if not all, of Nevada's Hydrographic basins have subsurface inflow or outflow to adjacent basins to some extent, but that does not mean joint management is warranted. The basins are best managed individually because the aquifers are separate and distinct, water budgets are easily distinguished between the basins, and management as individual hydrographic basins is straightforward and appropriate. The State Engineer should consider the water budgets of interconnected basins, but to require joint management at this late stage is unnecessary.

It also does not make sense to exclude from joint management those portions of the five plus basins whose groundwater levels differ from the central carbonate aquifer. If, for example, the northern portion of Coyote Spring Valley, as proposed by Lincoln-Vidler, or areas east of the Dry Lake Thrust in

California Wash, as proposed by CNLV, were excluded from joint management, how would the excluded areas be managed? As new hydrographic basins? Those areas are not basins, but portions of mountain block, alluvial fan, or valley floor. What would be the perennial yield of those partial basins when their recharge is already included in the groundwater supply of the basin as a whole and the LWRFS? The area as defined is acceptable.

The information obtained from the Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test.

NVEnergy does not agree that a significant portion of the water-level decline during and after the Order 1169 aquifer test was due to drought, as argued by MBOP. We agree with Southern Nevada Water Authority (SNWA) and MVWD that recovery was complete approximately two to three years after completion of the test. Full recovery to pre-test levels did not occur, and could not occur, because water levels regionally were still declining due to existing pumping as noted by SNWA. Contrary to the arguments made by SNWA and MBOP, NVEnergy argues that there is significant data to support the conclusion that the system is approaching steady state in the Muddy River Springs Area (MRSA) and other locations, and that water levels, spring flow, and the Muddy River are nearly equilibrated with the current carbonate pumping rate of 7,000 to 8,000 acre-feet annually.

The following hydrographs rebut their arguments, and display carbonate water levels at EH-4, located in the MRSA, Muddy River at Moapa gage flow, and carbonate pumpage. Figure 1 shows water levels in EH-4 and carbonate pumpage. The linear segments sketched and described on the hydrographs are self-explanatory. Note that since the recovery from the Order 1169 test, the hydrograph is nearly flat, indicating steady state conditions are almost present. Careful examination of the hydrograph since the middle of 2016 indicates that the water levels are no longer declining, and are perhaps even rising.

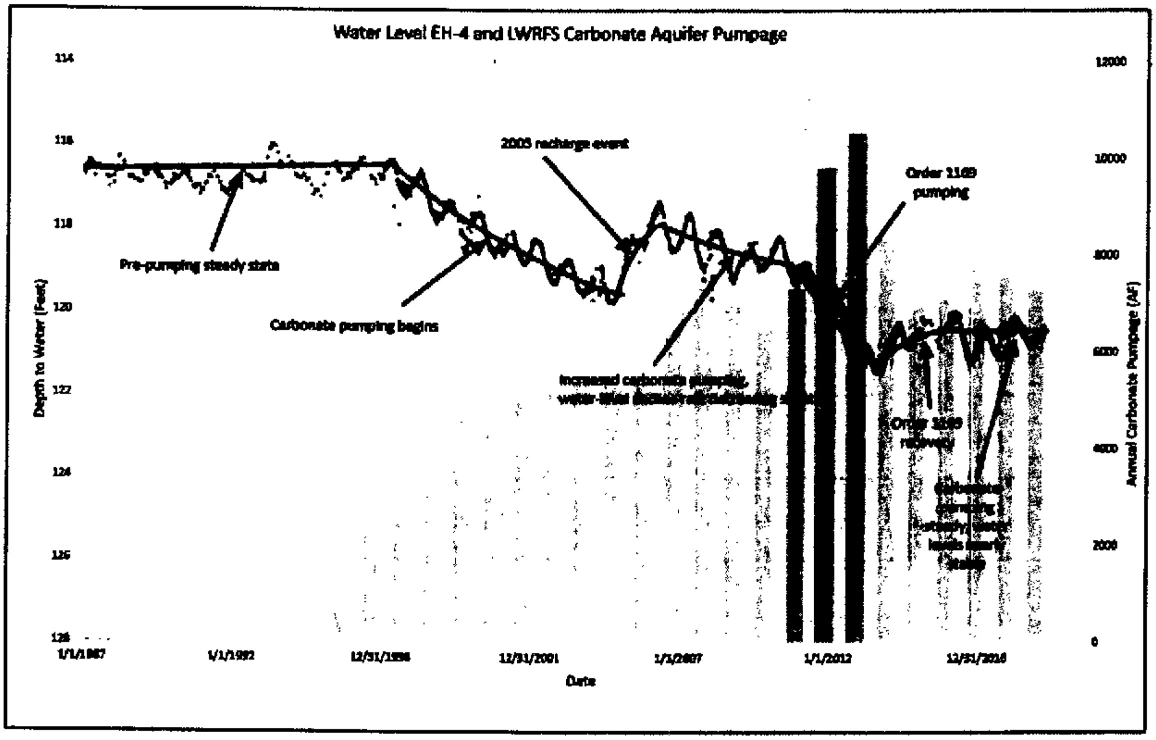

Figure 1. EH-4B hydrograph, annual carbonate aquifer pumpage in the LWRFS, and linear trend segments corresponding the various hydrologic stresses on the carbonate aquifer since 1987. Annual carbonate pumping from SNWA initial report, Table D-1. Water levels from State Engineer's website.

Figure 2 shows monthly flow at the Warm Springs West gage along with carbonate pumpage. The linear segments sketched on Figure 1 are unchanged and overlain on the Figure 2 hydrograph. The fit is not perfect, but is quite close. This comparison supports the findings of SNWA and the USFWS that spring flows are a direct function of groundwater levels.

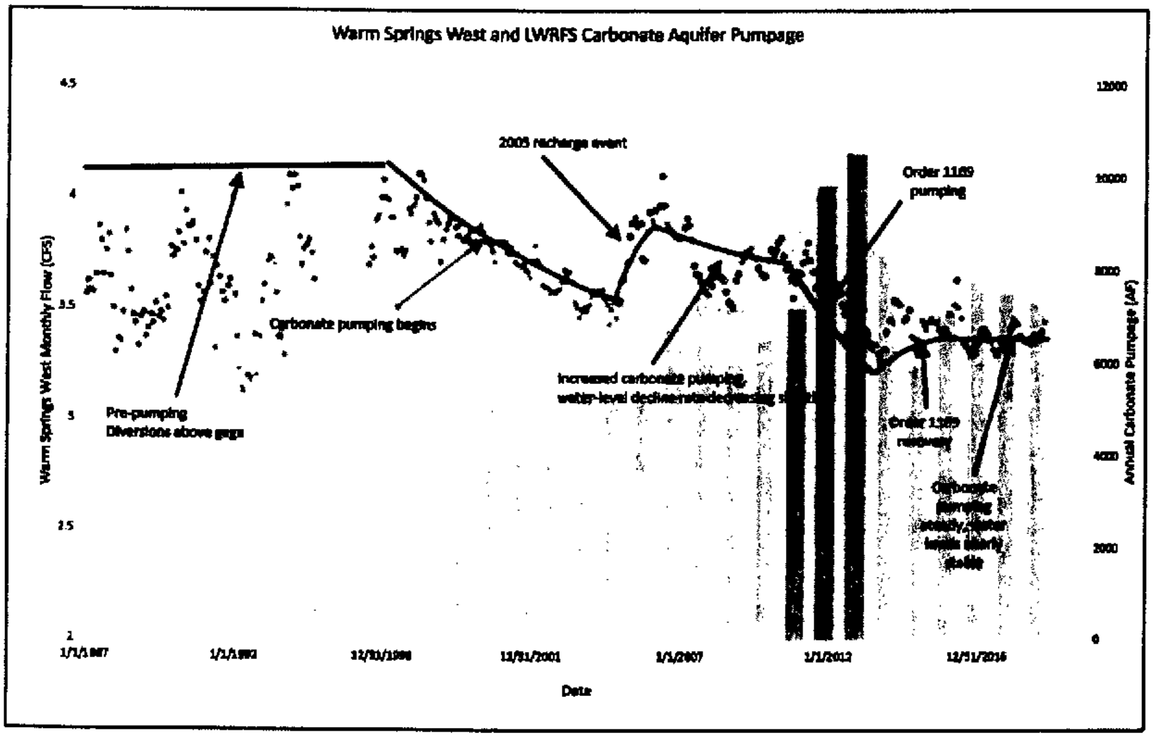

Figure 2. Monthly flow at Warm Springs West (grey dots) and annual carbonate pumpage in the LWRFS. The trendline segments from Figure 1 shown here for comparison purposes. Warm Springs West flow data from USGS website.

Figure 3 is a reconstructed hydrograph, displaying the segments of the hydrograph drafted in Figure 1, portraying their location as if they were not affected by the short-term stresses of the 2005 recharge event or the Order 1169 aquifer test. The declining portions of the hydrograph were simply copied and moved lower to indicate what the hydrograph might look like in the absence of those two stresses. In Figure 3 the hydrograph has not quite reached steady state, but is close. NVEnergy argues that this clear and empirical analysis rebuts those arguments by SNWA and MBOP that continued pumping at existing rates and locations will result in a significant and continued reduction in water levels and flows in the MRSA. Instead, future pumping at current rates and locations will result in minimal future water-level decline in the MRSA or significant decrease in the flow of Warm Springs West or the Muddy River.

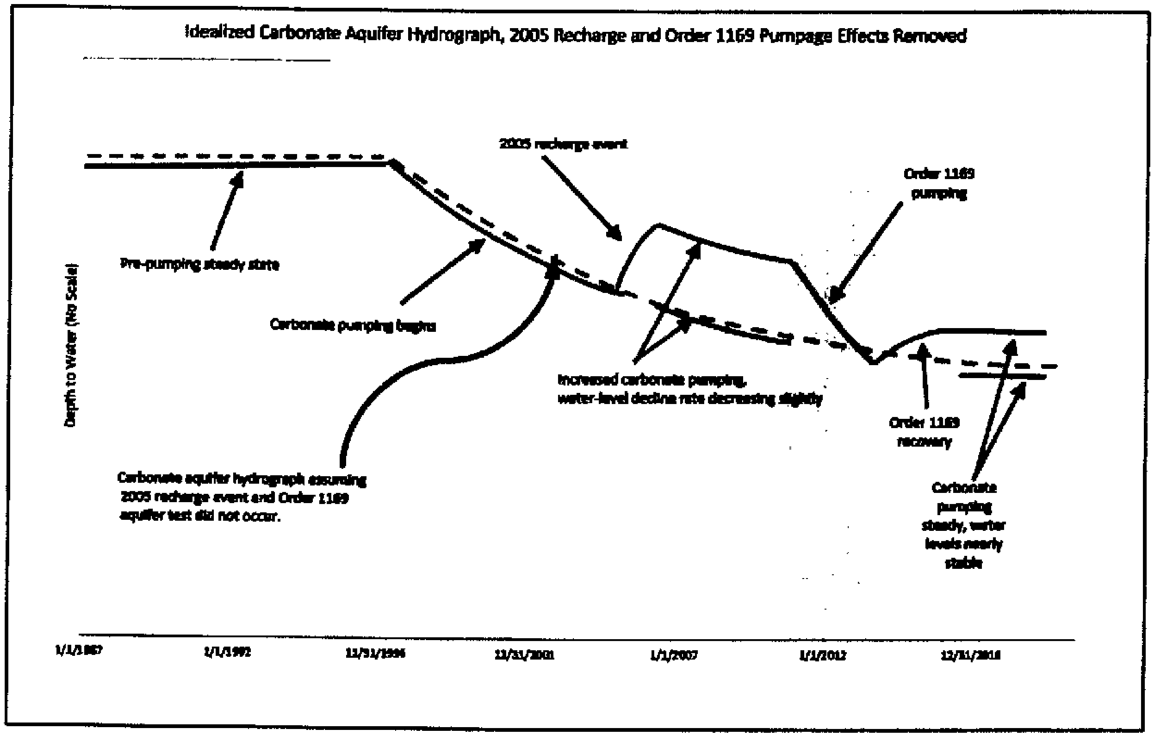

Figure 3. Hypothetical hydrograph of carbonate water levels and Warm Springs West flow (dashed blue line) in the absence of the 2005 recharge event and the Order 1169 aquifer test. Note the hydrograph is approaching steady state, contrary to the arguments of SNWA and MBOP.

SNWA's Figure 5-3 from their June report (Figure 4) shows that natural flows of the Muddy River at Moapa have increased since the Order 1169 pumping stress. The flow deficit since maximum recovery from the Order 1169 aquifer test in mid-2015 (per SNWA) is on the order of 2,300 to 3,750 afy, and is decreasing. The recovery of the Muddy River flow at Moapa further rebuts arguments for continued or increasing decline in the flow of the Muddy River, and supports the argument that the hydrologic system is reaching steady state under the present pumping regime.

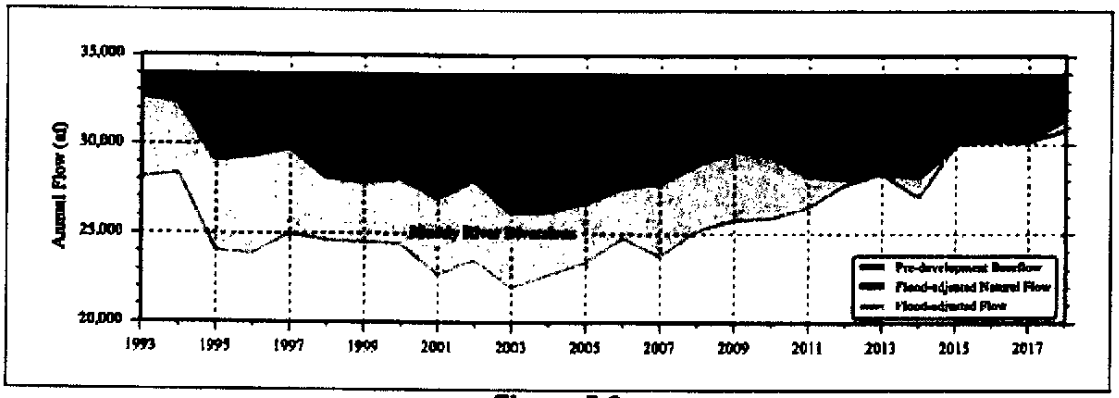

Figure 5-3
MR Flow Deficit (1993 - 2018)

Figure 4. Figure 5-3 from SNWA, June 2019 Assessment of Lower White River Flow System Water Resource Conditions and Aquifer Response report, submitted to the Nevada State Engineer pursuant to Order 1303.

Other areas in the LWRFS show a continuing decline in water levels as noted by several of the parties, but water levels also appear to levelling off in locations more distant from the center of the current pumping stress. Figure 5 shows the hydrograph for EH-4 in the Muddy River Springs Area and BM DL-2 at the southern end of the LWRFS in the Black Mountains Area. The total head tracks very closely through the end of the Order 1169 test, but diverge just a bit after the test pumping stopped. MBOP argues that drought alone could be responsible for 0.18 ft/yr of decline in the Apex area. It should be noted that pumping in the Apex area has increased in recent years, and could easily be responsible for the divergence.

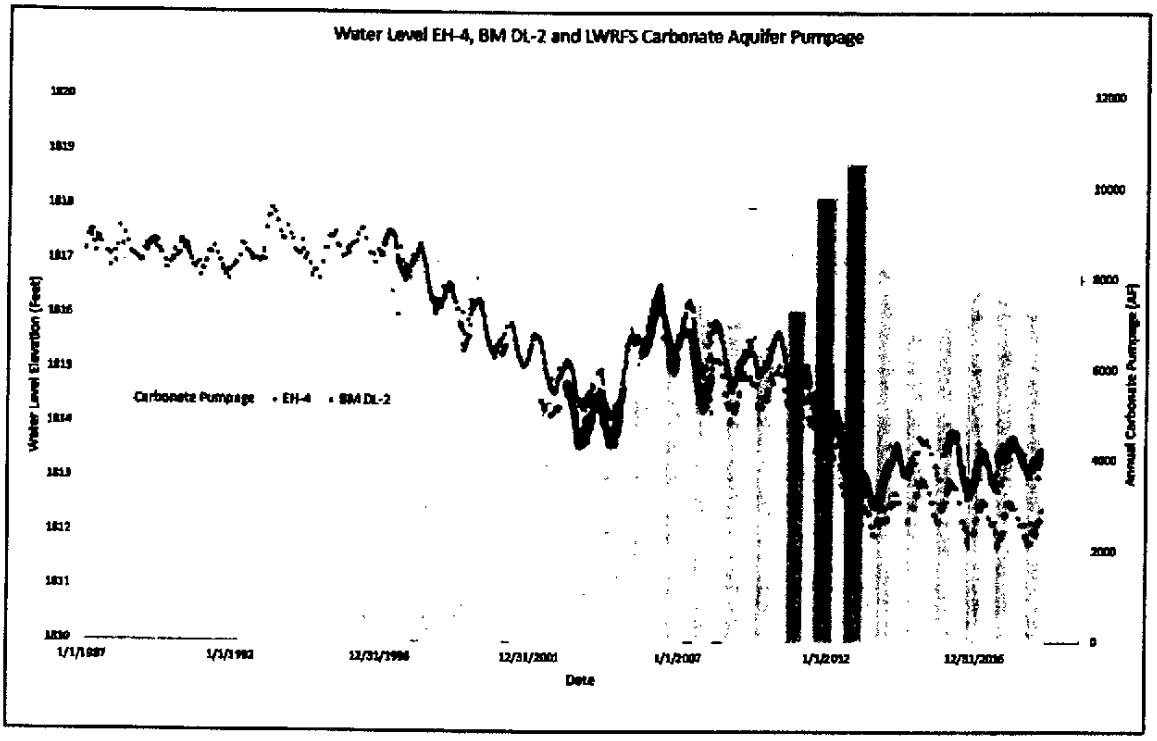

Figure 5. Hydrographs of EH-4 and BM DL-2 showing divergence since the end of Order 1169 pumping. Water-level data from NDWR website, pumping data from SNWA Table D-1.

The long-term annual quantity of groundwater that may be pumped from the LWRFS, including the relationships between the location of pumping on discharge of the Muddy River Springs and the capture of Muddy River flow.

Each of the parties appears to believe that they can pump their water rights without impacting the springs or the flow of the Muddy River, that is, it is always the other party's fault. In this case, NV Energy both agrees with and disagrees with the arguments of many of the parties. NVEnergy does not rebut the arguments of SNWA and USFWS that it is likely that all pumping in the LWRFS, and perhaps Kane Spring Valley and Lower Meadow Valley Wash, will ultimately impact the springs and the Muddy River. It is simply a matter of how much of an impairment and when will it occur. As discussed above, it is likely that the majority of impact for much of the pumping has already occurred.

In the 2011 State Engineer hearing on pending applications for groundwater in Delamar, Dry Lake and Cave Valleys, SNWA presented evidence and expert testimony in support of subsurface flow that bypassed the Muddy River and springs, flowing in the subsurface south from the Muddy River Springs Area to California Wash. The groundwater then exited the LWRFS somewhere along the southern or southeastern perimeter of the area. This amount was estimated to be 9,900 afy. The State Engineer accepted this evidence and expert testimony in Rulings 6254 through 6261. The source of that water was groundwater recharge distributed among all of the upgradient basins, including those basins in which SNWA had applications to appropriate groundwater. SNWA now argues that probably all of the groundwater in the LWRFS discharges to the Muddy River and springs, and that there is no bypass flow. NVEnergy disagrees.

Other respondents to Order 1303 information requests also believe that some amount of groundwater bypasses the Muddy River. The Moapa Band of Paiutes argue that perhaps up to 40,000 afy flows through Hidden and Garnet Valleys to the Las Vegas Valley. The City of North Las Vegas believes that there is some amount of subsurface discharge in the southeast portion of the LWRFS, but do not go so far as to estimate the amount. NV Energy agrees that there is some amount of groundwater that bypasses the Muddy River and springs. The amount is unclear, but SNWA argued in the 2011 hearing that the amount is 9,900 afy, and the State Engineer agreed. There is an approximately 40-mile perimeter east of California Wash and south of Garnet Valley and the Black Mountains Area where there is a potentiometric gradient to the east and south, away from the LWRFS. It seems impossible that the entire perimeter of the LWRFS is impermeable. Given the existing gradients, the thickness of the carbonate aquifer, and the length of the perimeter, it is possible that 10,000 afy could exit the LWRFS to the Las Vegas Valley or to the lower portions of the Black Mountains Area or Lake Mead.

The likelihood of subsurface flow bypassing the Muddy River and springs is important because that means that it is possible to capture groundwater discharge without causing a 1:1 depletion of the Muddy River or springs. The post-Order 1169 analyses discussed above show clear evidence that steady state conditions are being reached in the Muddy River Springs Area with 7,000 to 8,000 afy of carbonate pumping. The depletion of the Muddy River with this amount of pumping appears to be on the order of 2,300 to 3,750 afy, and is not increasing. Using these figures, impacts to the Muddy River appear to be on the order of 25% to 50% of the amount of groundwater pumped under the current pumping regime. NVEnergy agrees with respondents MBOP, North Las Vegas and others that groundwater pumping at locations further south, toward the southern boundary of the LWRFS, are likely to have less effect on the Muddy River and springs than pumping in Coyote Spring Valley or the Muddy River Springs Area.

The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River.

Respondents to Order 1303 generally agree that pumping from the alluvial aquifer in the Muddy River Springs Area impacts the Muddy River flows and deplete those flows on a near 1:1 ratio in a short period of time. SNWA also argues that carbonate pumping in the LWRFS will have a 1:1 effect on discharge from the springs and the Muddy River, but the time frame is longer for these effects to occur. NV Energy disagrees with SNWA that all pumping will ultimately deplete the Muddy River at a 1:1 ratio. As discussed above, water levels, spring flows, and the flow of the Muddy River at the Moapa gage have essentially stabilized under the current pumping regime. Depletion of the Muddy River at Moapa was 3,750 acre-feet in 2015, 3,598 acre-feet in 2016, 3,569 acre-feet in 2017, and decreased to about 2,300 acre-feet in 2018 (SNWA Fig 5-3 and Table 7-2), increases in flow that occurred during a time period that carbonate aquifer pumping was relatively stable. Furthermore, because there does appear to be groundwater underflow that bypasses the Muddy River and springs, some of that bypass flow could potentially be captured by pumping south of the Muddy River without impacting the river or springs.

Many of the parties that own water rights in California Wash and Garnet Valley argue that their pumping does not impact the Muddy River. That is likely true in part. However, many of the water rights in those areas have never been pumped. Nevada water law is based on two main tenants: prior appropriation and beneficial use. If the five plus basin area is managed as one, those parties with senior and certificated groundwater rights must be allowed the continued use of those rights over junior water rights that have never been put to beneficial use. That would be accomplished by changing some of these senior, certificated alluvial water rights to the carbonate aquifer in the southern LWRFS.

Any Other Matter believed to be relevant to the State Engineer's analysis.

Drought

Drought is not a significant cause for decreased water levels and spring flows in the LWRFS. MBOP argues that discharge at Big Muddy Spring correlates to discharge of the Humboldt River at Palisade, with a time lag of 12 to 22 years. It is not demonstrated by any scientific analysis that any water from the Humboldt River Basin contributes to the LWRFS, nor why any correlation between the two makes any sense. The preponderance of the water supply in the LWRFS is derived from groundwater recharge in NV Climate Division 3. Local recharge events in NV Climate Division 4, extreme southern Nevada, have been shown to almost immediately increase water levels and spring flows, as shown by SNWA. This occurred in 2005 and 2006 as a result of exceptional precipitation in 2005 (Figure 1 and Figure 6). The hydrograph of EH-4 in Figure 1 demonstrates that water levels are steady in the 10 years prior to significant carbonate pumping.

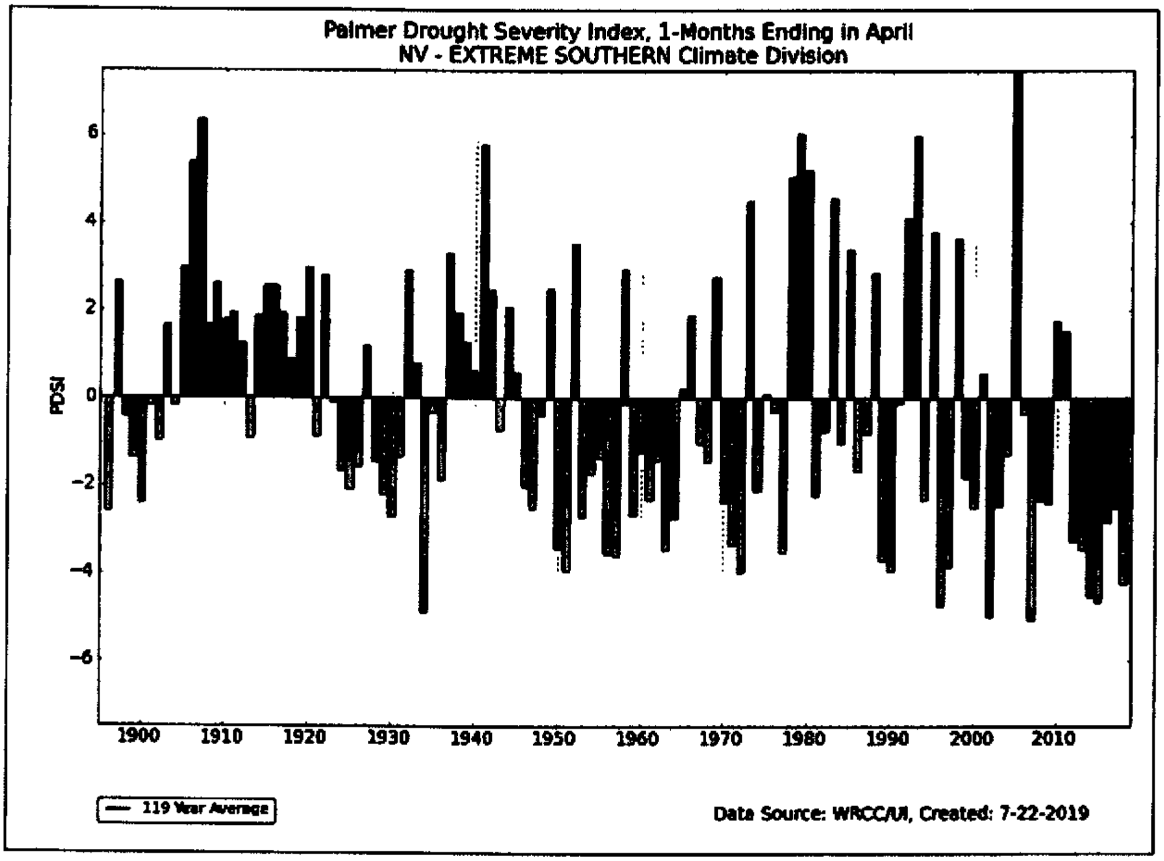

Figure 6. Palmer drought severity index, Extreme Southern Nevada, for 12-month periods ending in April. Note 2005 was extremely wet.

The subsurface flow into the LWRFS from upgradient basins is a function of the potentiometric gradient between Delamar Valley and Pahranagat Valley and Coyote Spring Valley. As documented by several of the respondents, water levels decline approximately 900 feet across the Pahranagat Shear Zone. The Delamar MX well (Figure 7), unaffected by groundwater pumping, shows steady or increasing water levels since 1982 even though there are significant drought periods in Climate Division 3 (Figure 8). SNWA monitor well 209-M1, east of Hiko and completed in carbonate, shows no change since its first measurements in 2008. These water levels in the source basins for the majority of the LWRFS groundwater supply show no evidence of drought. Perhaps the wells relied on by MBOP to demonstrate drought are in fact being affected by LWRFS pumping.

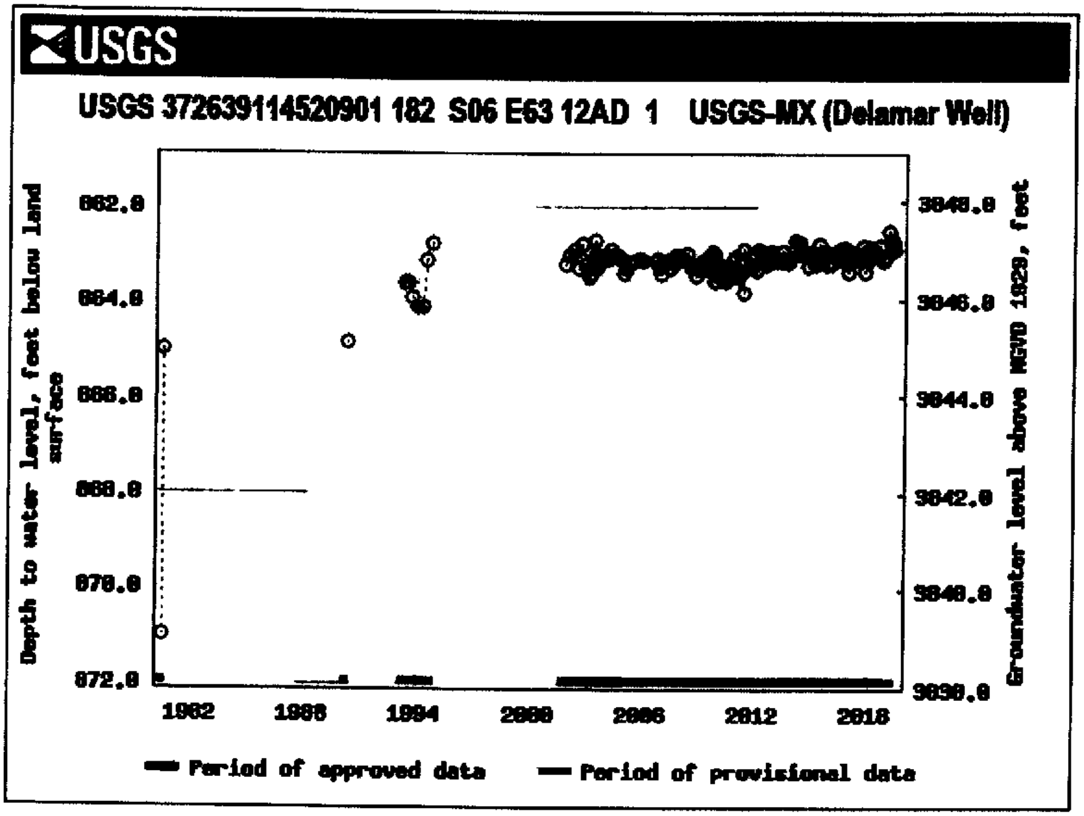

Figure 7. Hydrograph of USGS Delamar MX well. No evidence of drought or water-level decline.

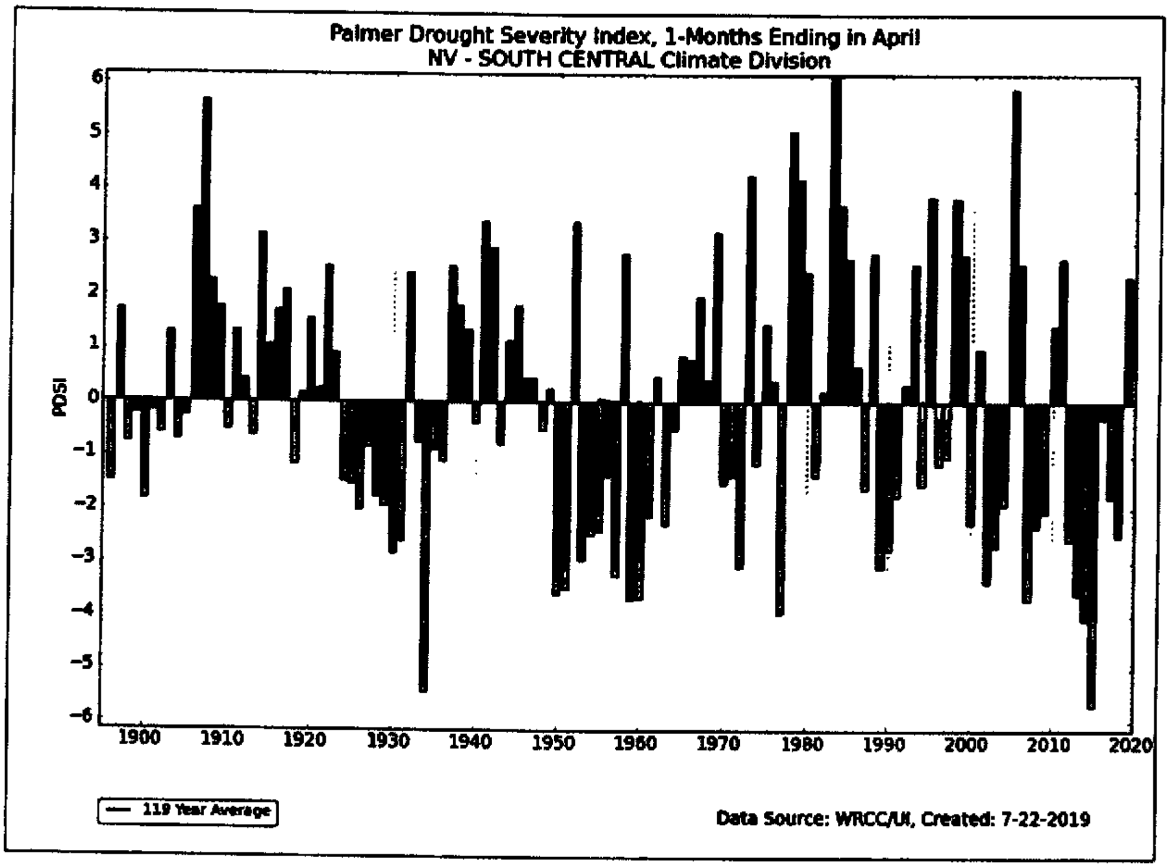

Figure 8. Palmer drought severity index for South Central Nevada climate division 3, the principal source of groundwater supply to the LWRFS.

<u>Suggested actions for consideration in a later phase</u>

It is highly unlikely that the water rights holders in the LWRFS can come to a voluntary agreement on a conjunctive management plan to manage surface water and groundwater in the LWRFS. Even assuming a majority could agree, those opposed would be under no obligation to abide by any such agreement. SNWA is claiming that groundwater use conflicts with their senior surface water rights, and is asking that all groundwater users mitigate their full water use on a 1:1 basis. A thorough analysis of the hydrologic data does not support this drop-for-drop depletion of Muddy River flow.

Two options are proposed. The first option would be for the State Engineer to officially combine the basins into a new hydrographic basin and to then declare the new basin a Critical Management Area pursuant to NRS 534.037 and 534.110. The water rights holders would then have 10 years to come up with a plan that would need approval by simple majority of water rights in the basin. The State Engineer would only approve the plan if it was equitable for all the parties.

The second option is for the State Engineer to take control of the process for creating a conjunctive management plan for the LWRFS. The State Engineer has authority to make rules for the administration of underground waters under NRS 534.020 and 534.120.

EXHIBIT LIST IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA HEARING DATE: September 23, 2019 through September 30, 2019, and October 1, 2019 through October 4, 2019			
		OFF.	AD.
	SOUTHERN NEVADA WATER AUTHORITY		
SNWA_EX_001	Exhibit List Evidentiary Exchange		
SNWA_EX_002	Summaries of Witnnesses' Testimony		
SNWA_EX_003	Resume of Andrew Burns		
SNWA_EX_004	Resume of Warda Drici		
SNWA_EX_005	Resume of Zane Marshall		
SNWA_EX_006	Resume of Robert Williams		
SNWA_EX_007	Burns, A., Drici, W., Collins, C., and Watrus, J., 2019, Assessment of Lower White River Flow System water resource conditions and aquifer response, Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada.		
SNWA_EX_008	Marshall, Z.L., and Williams, R.D., 2019, Assessment of Moapa dace and other groundwater-dependent special status species in the Lower White River Flow System, Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada		
SNWA_EX_009	Burns, A., Drici, W., and Marshall, Z.L., 2019, Response to stakeholder reports submitted to the Nevada State Engineer with regards to Interim Order 1303, Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada.		
SNWA_EX_010	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 50l-D, Pages Dl71-D176, Work done in cooperation with the Nevada Department of Conservation and Natural Resource, Carson City, Nev.		
SNWA_EX_011	Sauer, V.B. and R. W. Meyer, 1992, Determination of error in individual discharge measurements: U.S. Geological Survey Open-File Report 92-144, Norcross, Georgia.		
SNWA_EX_012	Grumbach, S. D. 1989, A Case Study of the Water Supply System at Nellis Air Force Base using Computer Simulation, Thesis No. AF IT/GEM/ENS/89S-9, Department of the Air Force Air University - Air Force Institude of Technology - Wright-Patterson Air Force Base, Ohio, 117 p.		
SNWA_EX_013	Helsel, D.R. and Hirsch, R.M., 2002, Statistical Methods, Techniques of Water-Resources Investigations of the United States Geological Survey - Book 4, Hydrologic Analysis and Interpretation, Chapter A3, U.S. Geological Survey, Water Resources.		

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SNWA_EX_014	Langenheim, V.E., Miller, J.J., Page, W.R., and Grow, J.A., 2001, Thickness and geometry of Cenozoic deposits in California Wash area, Nevada, based on gravity and seismic-reflection data: U.S. Geological Survey Open-File Report 01-393, 26 p.		
SNWA_EX_015	Loeltz, O. J., 1963, Contributions to the Hydrology of the United States - Geological Survey Water-Supply Paper 1669-Q, Prepared on behalf of the U.S. Department of Defense, United States Government Printing, Office - United States Department of the Interior: Washington, D.C., 21 p.		
SNWA_EX_016	MMB Apex Auction Well Survey Data		
SNWA_EX_017	NDWR Well Driller's Report for Apex Auction Well Log No. 131985.		
SNWA_EX_018	Page, W.R., Dixon, G.L., Rowley, P.D., and Brickey, D.W., 2005, Geologic map of parts of the Colorado, White River, and Death Valley groundwater flow systems-Nevada, Utah, and Arizona: Nevada Bureau of Mines and Geology Map 150, scale 1:250,000.		
SNWA_EX_019	Pampeyan, E.H., 1993, Geologic map of the Meadow Valley Mountains, Lincoln and Clark Counties, Nevada, Map I-2173, United States Geological Survey: 20 p.		
SNWA_EX_020	Pohlmann, K. F., Campagna, D., Chapman, J. B., Earman, S. B., 1998, Investigation of the Origin of Springs in the Lake Mead National Recreation Area, 51, DRI Report No. 41161.		
SNWA_EX_021	Rowley, P.D., Dixon, G.L., Burns, A.G., Pari, K.T., Watrus, J.M., and Ekren, E.B., 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.		
SNWA_EX_022	Rowley, P.D., Dixon, G.L., Mankinen, E.A., Pari, K.T., McPhee, D.K., McKee, E.H., Burns, A.G., Watrus, J.M., Ekren, E.B., Patrick, W.G., and Brandt, J.M., 2017, Geology and Geophysics of White Pine and Lincoln Counties, Nevada, and adjacent parts of Nevada and Utah: The geologic framework of regional Groundwater flow systems, Nevada Bureau of Mines and Geology Report 56, Prepared cooperatively by Geologic Mapping, Inc., New Harmony, Utah, U.S. Geological Survey, Menlo Park, California, Southern Nevada Water Authority, Las Vegas, Nevada and Private consultant, White Sulphur Springs, Montana.		
SNWA_EX_023	Southern Nevada Water Authority, 2008, Volume 3: Physical settings of springs in Clark, Lincoln, and White Pine Counties Groundwater Development Project, pp. 3-98 to 3-105.		
SNWA_EX_024	Southern Nevada Water Authority, 2009, Muddy River tributary conservation intentionally created surplus certification report calendar year 2008: Southern Nevada Water Authority, Las Vegas, Nevada, 225 p.		
SNWA_EX_025	Southern Nevada Water Authority, 2011, Muddy River tributary conservation intentionally created surplus certification report calendar year 2009: Southern Nevada Water Authority, Las Vegas, Nevada, 274 p.		
SNWA_EX_026	Southern Nevada Water Authority, 2012, Muddy River tributary conservation intentionally created surplus certification report calendar year 2010: Southern Nevada Water Authority, Las Vegas, Nevada, 98 p.		

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SNWA_EX_027	Southern Nevada Water Authority, 2012, Muddy River tributary conservation intentionally created surplus certification report calendar year 2011: Southern Nevada Water Authority, Las Vegas, Nevada, 104 p.		
SNWA_EX_028	Southern Nevada Water Authority, 2013, Muddy River tributary conservation intentionally created surplus certification report calendar year 2012: Southern Nevada Water Authority, Las Vegas, Nevada, 93 p.		
SNWA_EX_029	Southern Nevada Water Authority, 2015, Muddy River tributary conservation intentionally created surplus certification report calendar year 2013: Southern Nevada Water Authority, Las Vegas, Nevada, 90 p.		
SNWA_EX_030	Southern Nevada Water Authority, 2015c, Muddy River tributary conservation intentionally created surplus certification report calendar year 2014: Southern Nevada Water Authority, Las Vegas, Nevada, 84 p.		
SNWA_EX_031	Southern Nevada Water Authority, 2016, Muddy River tributary conservation intentionally created surplus certification report calendar year 2015: Southern Nevada Water Authority, Las Vegas, Nevada, 86 p.		
SNWA_EX_032	Thomas, J.M. and T. M. 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, Letter Report prepared by -Division of Hydrologic Sciences of Desert Research Institute - Nevada System of Higher Education in November 2007: Reno, Nevada, 189p.		
SNWA_EX_033	Thomas, J. M., Mihevc, T. 2011, Evaluation of Groundwater Origins, Flow Paths, and Ages in East-Central and Southeastern Nevada, Edition/Issue 41253, Desert Research Institute: Reno, Nevada, 67 p.		
SNWA_EX_034	Winograd, I. J., Riggs, A. C., Coplen, T. B. 1998. The Relative Contributions of Summer and Cool-Season Precipitation to Groundwater Recharge, Spring Mountains, Nevada, USA, Hydrogeology Journal, Volume 6 p. 77-93, New York, NY: Published by Springer - Verlag.		
SNWA_EX_035	National Oceanic and Atmospheric Administration, 2018, Climate Division 4 monthly precipitation and temperature data for period of record (1895-2019), accessed multiple times between September 2018 and March 2019. Webpage: https://www.ncdc.noaa.gov/cag/divisional/time-series.		
SNWA_EX_036	Affidavit, 2016, Affidavit to relinquish water rights regarding permit number 70430: Coyote Springs Investment LLC. Approved by the Nevada State Engineer. January 7.		
SNWA_EX_037	Agreement, 2006a, Water Supply Agreement: Moapa Band of Paiute Indians, Las Vegas Valley Water District, Southern Nevada Water Authority, Muddy Valley Irrigation Company, and Moapa Valley Water District. April 20.		
SNWA_EX_038	Agreement, 2006b, Jones Springs Agreement: Moapa Valley Water District, Muddy Valley Irrigation Company, and U.S. and Fish Wildlife Service. April 20.		
SNWA_EX_039	Agreement, 2009, Moapa Transmission System Design, Construction, Operation and Maintenance Agreement: Moapa Valley Water District and Southern Nevada Water Authority. August 20.		
SNWA_EX_040	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 8(2):e55551, doi:10.1371/journal.pone.0055551.		

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SNWA_EX_041	U.S. Fish and Wildlife Service, 2006a, Intra-service programmatic biological opinion for the proposed Muddy River Memorandum of Agreement regarding the groundwater withdrawal of 16,100 acre-feet per year from the regional carbonate aquifer in Coyote Spring Valley and California Wash basins, and establish conservation measures for the Moapa Dace, Clark County, Nevada. File No. 1-5-05 FW-536, January 30, 2006.		
SNWA_EX_042	U.S. Fish and Wildlife Service, 1996, Recovery plan for the rare aquatic species of the Muddy River ecosystem. First revision. Endangered Species Program, Region 1, Portland, Oregon.		
SNWA_EX_043	Ruggirello, J.E., Bonar, S.A., Feuerbacher, O.G., Simons, L., and Powers, C., 2014, Spawning ecology and captive husbandry of endangered Moapa dace. Arizona Cooperative Fish and Wildlife Research Unit, Fisheries Research Report 12-14.		
SNWA_EX_044	Perry, R.W., Jones, E.C., and Scoppettone, G.G., 2015, A stochastic population model to evaluate Moapa dace (*Moapa coriacea*) population growth under alternative management scenarios. Prepared in cooperation with the U.S. Fish and Wildlife Service. U.S. Geological Survey, Reston, Virginia, Open-File Report 2015-1126.		
SNWA_EX_045	Scoppettone, G.G., Rissler, P.H., Nielsen, M.B., and Harvey, J.E., 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(2):115–122.		
SNWA_EX_046	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 65(3):410-414.		
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SNWA_EX_048	Brock, J.T., 2004, 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. Desert Research Institute, Reno, Nevada. October. 22 p.		
SNWA_EX_049	Ellerton, C., 2019, SNWA holds event at Warm Springs Area, Moapa Valley Progress, Overton, Nevada. May 1. 2 p.		
SNWA_EX_050	Image demonstratives for Marshall testimony		
SNWA_EX_051	Otis Bay, 2003, 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: Moapa Valley National Wildlife Refuge, U.S. Fish and Wildlife Service, Clark County, Nevada. November. 13 p.		
SNWA_EX_052	Ruggirello, J.E., Bonar, S.A., Feuerbacher, O.G., Simons, L.H., and Powers, C., 2018, Propagation of endangered Moapa dace. Copeia 106(4):652-662.		
SNWA_EX_053	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 39(2):192-195.		

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SNWA_EX_054	Southern Nevada Water Authority, 2019b, Southwestern willow flycatcher and yellow-billed cuckoo surveys at the Warm Springs Natural Area, Clark County, Nevada, 2018. Prepared for the U.S. Fish and Wildlife Service. Southern Nevada Water Authority, Las Vegas, Nevada. January.		
SNWA_EX_055	Southern Nevada Water Authority, 2019c, Warm Springs Natural Area 2018 highlights. Southern Nevada Water Authority, Las Vegas, Nevada.		
SNWA_EX_056	U.S. Fish and Wildlife Service, 2006b, Biological Opinion for the proposed Coyote Springs Investment Development in Clark County, Nevada. File No. 1-5-05-FW-536-Tier 01, March 2, 2006.		
SNWA_EX_057	U.S. Fish and Wildlife Service, 2007, Proposed right-of-way permit and funding for a water conveyance system and associated groundwater pumping in the Coyote Spring Valley on the Warm Springs Area, Clark County, Nevada. File No. 1-5-05-FW-536-Tier 2, May 9, 2007.		
SNWA_EX_058	Permit 46777, 1983, Amended Application for Permit to Appropriate the Public Waters of the State of Nevada, Date of filing: Mar 31, 1983, Applicant: Nevada Power Company		
SNWA_EX_059	Change applications, 2003, Amended Application for Permission to Change Point of Diversion, Manner of Use and Place of Use of the Public Waters of the State of Nevada Heretofore Appropriated, No. 70429 & 70430, Date of filing Sep 24, 2003.		
SNWA_EX_060	Meeting minutes, 2006, Las Vegas Valley Water District Meeting October 17, 2006 & Board of County Commissioners Meeting October 16, 2006.		
SNWA_EX_061	Original Agreement, 2006, Coyote Springs Water and Wastewater Multi-Party Agreement. Dec 5, 2006.		
SNWA_EX_062	Coyote Springs Service Rules, 2007, Coyote Springs Water Resources General Improvement District Service Rules. Feb 6, 2007.		
SNWA_EX_063	Amended Agreement, 2015, Amended and Restated Coyote Springs Water and Wastewater Multi-Party Agreement. July 7, 2015.		
SNWA_EX_064	District's Letter dated April 19, 2017, Coyote Springs Infrastructure Status.		
SNWA_EX_065	District's Letter dated August 29, 2017, Long Term Coyote Spring Valley Water Supply.		
SNWA_EX_066	State Engineer's Letter dated May 16, 2018, Coyote Spring Valley Water Supply.		
SNWA_EX_067	District's Letter dated June 6, 2018, State Engineer May 16, 2018, Correspondence on Long Term Coyote Spring Valley Water Supply.		
SNWA_EX_068	State Engineer's Letter dated June 14, 2018, Public Workshop Regarding Existing Water Right Use and Groundwater Pumping in the Lower White River Flow System.		
SNWA_EX_069	State Engineer's PowerPoint Presentation, Water Use in the Lower White River Flow System.		
SNWA_EX_070	District's Letters dated August 20, 2018, Water Availability for Residential Subdivision Map.		
SNWA_EX_071	State Engineer's Letter dated September 7, 2018, Tentative Subdivision Review No. 13216-T Permit None.		
SNWA_EX_072	Nevada State Engineer, 1997, Ruling 4542.		
SNWA_EX_073	Request to Investigate Alleged Violation by Groundwater Users in LWRFS, July 3, 2019.		

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SNWA_EX_074	Las Vegas Valley (212) Hydrographic Abstract		
SNWA_EX_075	Reich Testimony, 2017, Transcript of Proceeding Public Hearing, Volume 7, Casron City, NV, October 3, 2017.		
SNWA_EX_076	Reich Testimony, 2017, Transcript of Proceeding Public Hearing, Volume 8, Casron City, NV, October 4, 2017.		
SNWA_EX_077	Burns, A.G., and Drici, W., 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.		
SNWA_EX_078	Nevada State Engineer, 1995, Ruling 4243.		
SNWA_EX_079	U.S. Fish and Wildlife Service, 1999, Letter to Moapa Valley Water District RE: Revised Trigger Levels for Moapa Valley National Wildlife Refuge Springs		
SNWA_EX_080	Moapa Valley Water District, 2002, Muddy Springs Area Monitoring Plan, Revision 1, September 2002.		
SNWA_EX_081	Order 1169 Aquifer Test Post-Recovery Trendline		
SNWA_EX_082	Head vs MX-4 SNWA and USGS Montly Data during Test Period (Lag 3)		
SNWA_EX_083	Protest, 1983, Nevada Department of Wildlife Protest to Application 46777, June 21, 1983.		
SNWA_EX_084	Protest, 1983, U.S. Fish and Wildlife Service Protest to Application 46777, June 29, 1983.		

IN THE OFFICE OF THE STATE ENGINEER OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA.	**LIST OF WITNESSES AND SUMMARY OF TESTIMONY**

The following are summaries of the proposed testimony of SNWA's witnesses.

1. **Andrew Burns.** Mr. Burns is the Water Resources Division Manager in the SNWA Water Resources Department and was previously the Senior Hydrologist at SNWA. Mr. Burns has been previously admitted to testify as an expert before the Nevada State Engineer as an expert in groundwater and surface water hydrology, hydrogeology, and related disciplines. Mr. Burns' Curriculum Vitae is included with SNWA's evidentiary disclosures as SNWA_EX_003, and he is qualified to give expert testimony in this matter as set forth in his Curriculum Vitae. Mr. Burns is qualified to testify as an expert because of his background and specialized knowledge, including his professional degrees and experience, years of working in the related field, and prior admittance an expert before the State Engineer. Mr. Burns' report includes topics and conclusions which he may provide expert testimony to accompany, and is included with SNWA's evidentiary disclosures as SNWA_EX_007. If he testifies, Mr. Burns may testify regarding the water resource assessment of the Lower White River Flow System as requested in Order 1303. Mr. Burns may give his opinion on the five separate questions posed by the State Engineer in Order 1303. These opinions may include, but are not limited to, the boundary of the LWRFS being correctly defined in Order 1303, his findings that minor changes in hydraulic

heads have resulted in significant changes in the discharges from high-elevation springs, his conclusion that climate variability is not a major contributor to the long-term declines of the Muddy River stream flows, the evidence demonstrating that groundwater production from alluvial reservoirs depletes Muddy River stream flows, the development of and findings from the Order 1169 aquifer stress test, and his determinations regarding the sustainable yield of the Lower White River Flow System being managed between 4,000 and 6,000 acre-feet per year to avoid impermissible conflicts. Additionally, Mr. Burns may testify regarding all related underlying evidence to these opinions and other opinions set forth in SNWA_EX_007. Mr. Burns, if he testifies, will also testify to his rebuttal opinions contained in SNWA_EX_009 and any further opinions he may make during the pendency of testimony and review of submitted evidence.

2. **Warda Drici.** Ms. Drici is a Hydrologist for the Water Resources Division in the SNWA Water Resources Department. If she testifies, Ms. Drici may testify regarding the analysis of groundwater data in support of the subject water right applications and water resource development. Ms. Drici has been previously admitted to testify as an expert before the Nevada State Engineer as an expert in groundwater hydrology, groundwater modeling, and related disciplines. Ms. Drici's Curriculum Vitae is included with SNWA's evidentiary disclosures as SNWA_EX_ 004, and she is qualified to give expert testimony in this matter as set forth in his Curriculum Vitae. Ms. Drici is qualified to testify as an expert because of her background and specialized knowledge, including prior admittance as an expert witness before the State Engineer and her professional and academic experience. Ms. Drici's report includes topics and conclusions which she may provide expert testimony to accompany, and is included with SNWA's evidentiary disclosures as SNWA_EX_007. Ms. Drici may testify about the aquifer properties, groundwater recharge, and boundary fluxes that are described in her report. Ms. Drici may also testify about the five conclusions that she made in her report responding to the State Engineer's five questions posed in Order 1303. These opinions may include, but are not limited to, the boundary of the LWRFS being correctly defined in Order 1303, her findings that minor

changes in hydraulic heads have resulted in significant changes in the discharges from high-elevation springs, her conclusion that climate variability is not a major contributor to the long-term declines of the Muddy River stream flows, the evidence demonstrating that groundwater production from alluvial reservoirs depletes Muddy River stream flows, the development of and findings from the Order 1169 aquifer stress test, and her determinations regarding the sustainable yield of the Lower White River Flow System being managed between 4,000 and 6,000 acre-feet per year to avoid impermissible conflicts. Additionally, Ms. Drici may testify regarding all related underlying evidence to these opinions and other opinions set forth in SNWA_EX_007. Ms. Drici, if she testifies, will also testify to her rebuttal opinions contained in SNWA_EX_009 and any further opinions she may make during the pendency of testimony and review of submitted evidence.

3. **Lisa Luptowitz.** Ms. Luptowitz is the Environmental Resources Division Manager in the SNWA Environmental Resources Department. Ms. Luptowitz may testify regarding the SNWA environmental compliance activities related to the Lower White River Flow System, including, but not limited to, activities associated with SNWA's duties and commitments regarding environmental resources in the Lower White River Flow System and related state and federal compliance procedures necessary for the Lower White River Flow System.

4. **Zane Marshall.** Mr. Marshall is the Director of Resources and Facilities in the SNWA Environmental Resources Department and previously a Senior Biologist. Mr. Marshall has been previously admitted to testify as an expert before the Nevada State Engineer as an expert in biologic resources and related disciplines. Mr. Marshall's Curriculum Vitae is included with SNWA's evidentiary disclosures as SNWA_EX_ 005, and he is qualified to give expert testimony in this matter as set forth in his Curriculum Vitae. Mr. Marshall is qualified to testify as an expert because of his background and specialized knowledge, including his prior admittance as an expert witness before the State Engineer and his professional and academic experience. Mr. Marshall may testify and provide expert opinion regarding environmental

resources in the Lower White River Flow System, conservation efforts to protect the Moapa dace, SNWA's conservations efforts under the 2006 Memorandum of Agreement ("MOA"), and to the contents of SNWA's report submitted to the State Engineer for the 2019 Interim Order 1303 hearing. Mr. Marshall's testimony, if given, will focus on the threats posed by groundwater production and reduced spring flows at the Warm Springs Area near the Muddy River to the Moapa dace. Mr. Marshall may also testify regarding related biologic concerns in the Lower White River Flow System as an effect from groundwater pumping and depletions of Muddy River streamflow, as outlined in SNWA_EX_008. Mr. Marshall may also testify to his rebuttal opinions included in SNWA_EX_009, and any further opinions he makes as a result of testimony or evidence submitted by other stakeholders.

5. Bob Williams. Mr. Williams is professional fishery biologist who has worked for thirty-two years in the implementation of and compliance with the Endangered Species Act ("ESA") and other environmental laws. Mr. Williams has previously worked as an Assistant Field Supervisor and Nevada State Supervisor for United States Fish and Wildlife Service (USFWS) for 18 years. Mr. Williams was intimately involved in the creation and implantation of the MOA during this period. Mr. Williams' Curriculum Vitae is included with the SNWA submissions as SNWA_EX_006. Mr. Williams has not testified as an expert witness before the State Engineer, but is qualified to give expert testimony in this matter as set forth in his Curriculum Vitae. Mr. Williams is qualified to testify as an expert because of his background and specialized knowledge, including his extensive work with the ESA, related environmental laws, and his professional positions. Mr. Williams may testify and provide expert opinion regarding environmental resources in the Lower White River Flow System, conservation efforts to protect the Moapa dace, SNWA's conservations efforts under the MOA, ongoing compliance with the MOA and the ESA, the contents of SNWA's report submitted to the State Engineer for the Order 1303 hearing included as SNWA_EX_008. His testimony if given will focus on the creation and implantation of the MOA and the current status of the Moapa dace under the ESA, as well as implications of groundwater pumping and reduced spring flows and Muddy River flows to ESA commitments. Mr. Williams may also testify to his rebuttal opinions included in SNWA_EX_009, and any further opinions he makes as a result of testimony or evidence submitted by other stakeholders.

6. **James Watrus.** Mr. Watrus is a Senior Hydrologist for the Water Resources Division in the SNWA Water Resources Department. Mr. Watrus, if he testifies, is expected testify to the collection, review, analysis, and outcomes of various lines of evidence, including ground composition studies, well data collection, and spring and stream data collection. Mr. Watrus may also testify regarding the aquifer properties described in the SNWA and similar expert reports. He may testify regarding the quantity of committed groundwater rights within Lower White River Flow System and adjacent related basins.

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7. **Colby N. Pellegrino.** Ms. Pellegrino is the Director for the Water Resources Department for SNWA and the Las Vegas Valley Water District. If she testifies, Ms. Pellegrino will testify as a representative of SNWA and may testify as a representative of the Las Vegas Valley Water District. Her testimony may include SNWA's outlooks and future plans for its water resources in the Lower White River Flow System, that resource's place in the overall SNWA water portfolio, SNWA's directive regarding water supplies for southern Nevada, the intentionally created surplus program and Lower White River Flow System water resource involvement therein, effects of groundwater pumping on the SNWA water portfolio, SNWA and the Las Vegas Valley Water District's obligations to other stakeholders in the Lower White River Flow System, and any rebuttal testimony she may give as a result of other stakeholders' testimony or evidence presented during this hearing.

DATED this 10 day of September, 2019.

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CERTIFICATE OF SERVICE

I hereby certify that I am an employee of TAGGART & TAGGART, LTD., and that on this day, I served, or caused to be served, a true and correct copy of the foregoing document via electronic delivery, addressed as follows:

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Assessment of Lower White River Flow System Water Resource Conditions and Aquifer Response

PRESENTATION TO THE OFFICE OF THE NEVADA STATE ENGINEER

Prepared by

SOUTHERN NEVADA WATER AUTHORITY

LAS VEGAS VALLEY WATER DISTRICT

PEOPLE LEADING THE WAY

June 2019

Suggested citation:
Burns, A., Drici, W., Collins, C., and Watrus, J., 2019, Assessment of Lower White River Flow System Water Resource Conditions and Aquifer Response, Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada.

Assessment of Lower White River Flow System Water Resource Conditions and Aquifer Response

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Pertaining to:
Nevada State Engineer
Interim Order 1303

June 2019

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TABLES

ACRONYMS

BLM	Bureau of Land Management
CSI	Coyote Springs Investment, LLC
CSV	Coyote Springs Valley
CSWR	Coyote Springs Water Resources
ET	Evapotranspiration
GID	General Improvement District
HA	Hydrographic Area
HRT	Hydrologic Review Team
ICS	Intentionally Created Surplus
LDS	The Church of Jesus Christ of Latter-day Saints
LIDAR	Light Detection and Ranging
LVVWD	Las Vegas Valley Water District
LVVSZ	Las Vegas Valley Shear Zone
LWRFS	Lower White River Flow System
MBOP	Moapa Band of Paiute Indians
METRIC	Mapping EvapoTranspiration at high Resolution with Internalized Calibration
MOA	Memorandum of Agreement
MRSA	Muddy River Springs Area
MR	Muddy River
MVIC	Muddy Valley Irrigation Company
MVWD	Moapa Valley Water District
NDWR	Nevada Division of Water Resources
NDVI	Normalized Difference Vegetation Index
NPS	National Park Service
NOAA	National Oceanic and Atmospheric Administration
NSE	Nevada State Engineer
NV	Nevada
NVE	Nevada Energy
NWIS	National Water Information System
PRISM	Parameter-elevation Regressions on Independent Slopes Model
PSZ	Pahranagat Shear Zone
SNWA	Southern Nevada Water Authority
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service
WRCC	Western Region Climate Center
WRFS	White River Flow System

ABBREVIATIONS (CONTINUED)

ºC	degrees Celsius
ºF	degrees Fahrenheit
af	acre-foot
afy	acre-feet per year
cfs	cubic feet per second
ft	foot [feet]
ft amsl	feet above mean sea level
ft bgs	feet below ground surface
ft/yr	foot per year [feet per year]
gpm	gallons per minute
in.	inch [inches]
Ma	million years ago

ABSTRACT

In response to Nevada State Engineer (NSE) Interim Order 1303, the Las Vegas Valley Water District (LVVWD) and Southern Nevada Water Authority (SNWA) conducted an assessment of the current water-resource conditions of the Lower White River Flow System (LWRFS), an administrative unit of six conjoined basins designated by the NSE. The LVVWD and SNWA have significant interests in the administration of water rights and management of water resources within the LWRFS. The LVVWD is the management entity for the Coyote Springs Water Resources General Improvement District located in Coyote Spring Valley. This means LVVWD will, effectively, be the water purveyor responsible for providing water to any community that is developed. SNWA owns substantial groundwater rights and owns or leases 1920 Muddy River Decree surface-water rights. SNWA also controls over 51 percent of the Muddy Valley Irrigation Company shares through ownership and lease agreements. SNWA interests in the groundwater and surface-water resources of the LWRFS total over 31,863 afy, and include points of diversion located in five of the six basins composing the LWRFS. Of particular interest to this assessment are Muddy River Tributary Intentionally Created Surplus (ICS) credits created and managed by SNWA. ICS is a critical component of the SNWA water-resource portfolio which is relied upon to supply current and future water demands of over 2 million Nevada residents and 40 million annual visitors.

As part of the assessment, an analysis was completed to evaluate hydrologic responses to natural and anthropogenic stresses observed at various locations of interest. The analysis considered time-series data for several variables that describe the historical conditions of the hydrologic system over a period of decades. The analysis focused on the historical behavior of the carbonate aquifer composing the LWRFS, the hydrology of the Muddy River Springs Area (MRSA), and responses of Muddy River streamflow to groundwater production.

The assessment yielded the following conclusions: (1) the carbonate rocks underlying the LWRFS basins are contiguous and form a single aquifer that is the source of spring discharge, subsurface inflow to the MRSA alluvial reservoir, and perennial streamflow; (2) hydrologic responses are highly correlated amongst LWRFS wells and springs sourced by the carbonate aquifer; (3) carbonate-aquifer groundwater production has impacted spring discharges; (4) groundwater production has depleted Muddy River streamflow and conflicted with senior Muddy River water rights; (5) the long-term average annual groundwater production from the carbonate aquifer must be limited to maintain specified flows at the Warm Springs West gage; and (6) since 2006, Muddy River streamflow depletions have reduced the volume of SNWA's ICS by about 12,000 acre-feet at a replacement cost of almost $2.3 million.

Based on the findings of this assessment, responses to NSE Interim Order 1303 are as follows: (a) the geographic boundary of the LWRFS as defined by the NSE is appropriate; (b) the data gathered during and after the Order 1169 aquifer test indicate that recovery of the LWRFS had attained its maximum by late 2015 - early 2016; (c) the data indicate that groundwater production from the MRSA alluvial reservoir or the carbonate aquifer simply cannot occur over the long-term without depleting spring and streamflows and conflicting with senior surface-water rights; (d) changing points of diversion to move groundwater production from the MRSA alluvial reservoir to locations sourced by the carbonate aquifer will not mitigate these conflicts, only delay their inevitable occurrence; and (e) groundwater production should not be permitted to continue without strict regulatory oversight and appropriate mitigation to affected senior water-right holders and adequate protections to ensure the Moapa dace are protected. If the conflicts with senior water-right holders are adequately addressed, the annual groundwater production from the carbonate aquifer should be managed between 4,000 – 6,000 afy over the long-term.

1.0 INTRODUCTION

This report was prepared on behalf of the Las Vegas Valley Water District (LVVWD) and Southern Nevada Water Authority (SNWA) in response to the Nevada State Engineer's (NSE) Interim Order 1303 (Order 1303) (NSE, 2019) concerning the Lower White River Flow System (LWRFS). The NSE defines the LWRFS as the hydrographic areas (HA) of Coyote Spring Valley (HA 210), Hidden Valley (HA 217), Garnet Valley (HA 216), California Wash (HA 218), Muddy River Springs Area (HA 219), and the northwest portion of the Black Mountains Area (HA 215) (NSE, 2019). Figure 1-1 depicts the boundary of the LWRFS, as designated by the NSE, and the adjacent Kane Springs Valley which is included in this assessment because it is tributary to the LWRFS and contributes to the local recharge.

The LVVWD and SNWA have significant interests in the administration of water rights and management of water resources within the LWRFS. LVVWD is the management entity for the Coyote Springs Water Resources General Improvement District (CSWR GID) located in Coyote Spring Valley (CSV). Within the LWRFS, SNWA owns substantial groundwater rights (11,200 afy) and owns or leases Muddy River surface-water rights (10,663 afy). SNWA also controls over 51 percent of the Muddy Valley Irrigation Company (MVIC) shares through ownership and lease agreements which for 2018 equated to approximately 10,000 af. SNWA interests in the groundwater and surface-water resources of the LWRFS total over 31,863 afy and include points of diversion located in five of the six hydrographic areas designated by the NSE.

This report presents data, technical analyses, and results to address issues raised in NSE Order 1303 concerning water-resource conditions and responses to groundwater production within the LWRFS. SNWA and the LVVWD urge the NSE to consider this report in issuing any temporary or final order concerning the administration of water rights and management of groundwater development in the LWRFS.

1.1 Background

In 1920, all waters of the Muddy River were decreed. The Muddy River plays an important role in the LWRFS because (1) it is the sole source of perennial streamflow; and (2) its headwaters constitute the main regional discharge from the flow system. In 1989, the LVVWD filed applications with the Nevada Division of Water Resources (NDWR) to appropriate groundwater in Coyote Spring Valley. The NSE held administrative hearings on these applications and other applications filed by Coyote Springs Investment, LLC (CSI) during 2001. Subsequent to these hearings, several NSE orders, stakeholder agreements, and NSE rulings were issued. The pertinent details of the relevant documents are summarized in the following sections.

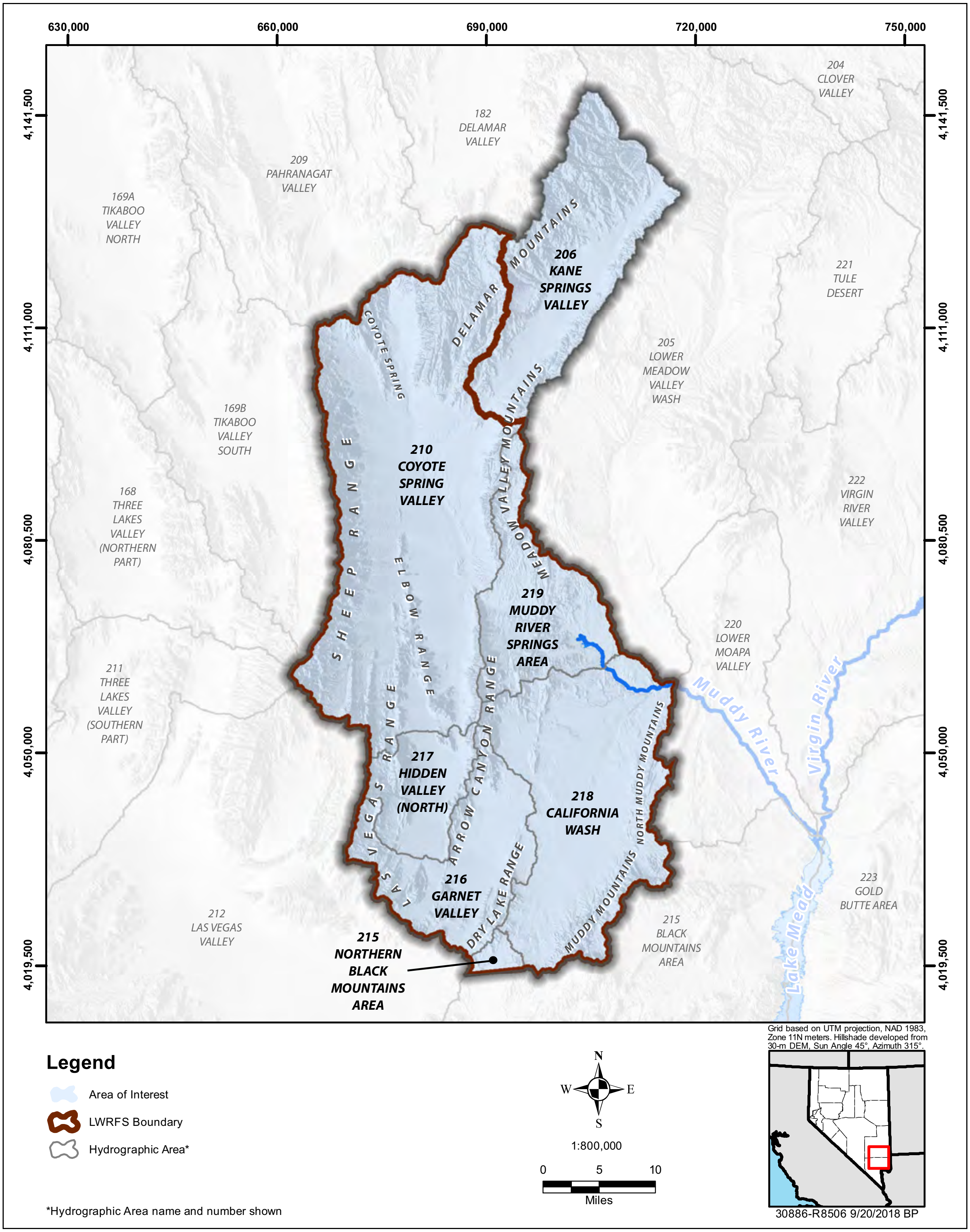

Figure 1-1
Boundary of the LWRFS

1.1.1 1920 Muddy River Decree

The Muddy River and the associated water rights were adjudicated and decreed in 1920 by the Tenth (now Eighth) Judicial District Court of the State of Nevada. The judgment and decree were in the case of Muddy Valley Irrigation Company et al. *v*. Moapa and Salt Lake Produce Company et al., *In the Matter of the Determination of the Relative Rights In and To the Waters of the Muddy River and its Tributaries in Clark County, State of Nevada*, dated March 12, 1920. The Muddy River Decree adjudicated the entire flow of the Muddy River including its tributaries, springs, headwaters, and other sources of supply. All of the decreed water rights are vested rights acquired by valid appropriation and beneficial use prior to March 1, 1905 and are considered as equal in rank without any party having any priority over another.

The decree specifies the entitlement to the waters of the Muddy River to several individuals and companies who were using the river prior to 1905 and maintained continuous use through the date of the decree. One of those companies is the Muddy Valley Irrigation Company (MVIC) who had certificated water rights in the Upper Muddy River but is, by the decree, entitled to the entire flow of the Muddy River except the flows granted to the other parties.

1.1.2 Order 1169

In 2002, the NSE issued Order 1169 holding in abeyance all pending and new applications for the appropriation of groundwater from the carbonate-rock aquifer (hereinafter referred to as the carbonate aquifer) underlying Coyote Spring, Hidden, Garnet, and Lower Moapa valleys, and the Muddy River Springs and Black Mountains areas. In addition, the NSE required a five-year study during which at least 50 percent of the existing groundwater rights in Coyote Spring Valley would be pumped for at least two consecutive years. The NSE stated the purpose of the study and aquifer test was to "*...determine if the pumping of those water rights will have any detrimental impacts on existing water rights or the environment.*" (NSE, 2002). The NSE directed the following entities to complete the study:

- LVVWD
- SNWA
- CSI
- Nevada Power Company (hereinafter referred to as Nevada Energy)
- Moapa Valley Water District (MVWD)

Order 1169 also instituted hydrologic monitoring and reporting requirements for the study participants and other water-right owners with points of diversion located in Garnet Valley and the Black Mountains Area. In April of 2002, the NSE granted requests by the Moapa Band of Paiutes (MBOP) and the U.S. Department of Interior to allow the Bureau of Indian Affairs, Fish and Wildlife Service (USFWS), and National Park Service (NPS) to participate in the study.

1.1.3 2006 Memorandum of Agreement

In 2006, to facilitate implementation of the Order 1169 study and aquifer test and to ensure protections of senior water rights and the endangered Moapa dace, the SNWA, CSI, USFWS, MBOP and MVWD entered into a Memorandum of Agreement (MOA) that instituted, among other things, Trigger Ranges associated with flows at the Warm Springs West near Moapa, Nevada gage under which pumping restrictions would apply (SNWA, 2006). These Trigger Ranges and the corresponding pumping restrictions are listed in Table 1-1.

Table 1-1
Trigger Ranges at Warm Springs West Gage and Corresponding Pumping Restrictions

	SNWA[/1]	CSI[/1]	MVWD[/2]	MBOP[/3]
Water Rights considered under MOA (afy)	9,000	4,600	--	2,500
Trigger Ranges (cfs)	**Pumping Restrictions (acre-feet per year [afy])**			
3.2 or less	Parties meet to discuss and interpret data and plan mitigation measures			
3.0 or less	SNWA & CSI take actions to redistribute pumping		--	--
3.0 to <2.9	< 8,050		--	--
2.9 to <2.8	< 6,000		--	< 2,000
2.8 to <2.7	< 4,000		--	< 1,700
≤ 2.7	< 724		--	< 1,250

[/1] SNWA and CSI production from wells MX-5, RW-2, CSI-1, CSI-2 and other CSI wells in Coyote Spring Valley
[/2] MVWD pumping restrictions were only for the duration of the NSE Order 1169 aquifer test
[/3] MBOP pumping under permit no. 54075

In addition, the MOA established a Hydrologic Review Team (HRT) composed of representatives of each MOA signatory. The HRT is tasked with analyzing hydrologic data and determining, on an annual basis, whether the pumping restrictions under each Trigger Range should be modified.

1.1.4 Order 1169 Aquifer Test and Order 1169A

Pumping associated with the aquifer test began in accordance with Order 1169 on November 15, 2010. The aquifer test was completed on December 31, 2012; however, production from SNWA's MX-5 well continued into April 2013.

During the test, pumping rates of the SNWA MX-5 well ranged from 3,300 to 3,800 gpm and constituted the single largest stress on the carbonate aquifer in the LWRFS. Equipment issues associated with the water treatment facility connected to the well resulted in periods of non-pumping during the test. Production volumes from the MX-5 well totaled 4,131 af and 3,961 af for calendar years 2011 and 2012, respectively. Combined with CSI pumping from wells CSI-1 through CSI-4, a total of 5,331 and 5,102 af were pumped in Coyote Spring Valley during calendar years 2011 and 2012, respectively. Additional production from the carbonate aquifer occurred during the test by MVWD in the Muddy River Springs Area (MRSA) and by several entities in Garnet Valley. A historical accounting of groundwater production in the LWRFS is presented in Section 4.0. Prior to and during the aquifer test, the study participants implemented a comprehensive hydrologic monitoring program under the direction of NDWR. Data collected under this program were submitted quarterly to NDWR in electronic form and made available to all study participants and the public.

The NSE issued amended Order 1169A on December 21, 2012 (NSE, 2012). In Order 1169A, the NSE declared the aquifer test completed as of December 31, 2012 and solicited information from the study participants regarding the test, impacts, and the availability of water pursuant to the pending applications held in abeyance by Order 1169. The reports submitted by the MOA signatories are summarized in Section 2.0.

1.1.5 NSE Rulings Nos. 6254 through 6261

In January 2014, the NSE issued Rulings 6254 through 6261 (NSE, 2014a through h). In these rulings the NSE denied all pending applications in the LWRFS and found that "*...the Order 1169 test measurably reduced flows in headwater springs of the Muddy River.*" The NSE also found that "*... the amount and location of groundwater that can be developed without capture of and conflict with senior water rights on the Muddy River and springs remains unclear, but the evidence is overwhelming that unappropriated water does not exist.*" Based on these findings, the NSE ruled that there is no unappropriated groundwater and that the applications would conflict with existing rights and threaten to prove detrimental to the public interest. The NSE also ruled that the basins composing the LWRFS would be jointly managed.

1.1.6 CSWR GID Letter to NSE

In a letter dated November 16, 2017, the LVVWD, acting in the capacity of the general manager of the CSWR GID, solicited an opinion from the NSE regarding whether Coyote Spring Valley groundwater could sustainably supply water for a project to develop 13,100 acres of land within Coyote Spring Valley. In the letter, LVVWD cited NSE Ruling 6255 in which the NSE concluded *"pumping under the Order 1169 test measurably reduced flows in the headwater Springs of the Muddy River...."* LVVWD further stated that while Ruling 6255 did not invalidate any existing water rights, LVVWD were not convinced that Coyote Spring Valley groundwater could sustainably support the project given the endangered species issues in the Muddy River and impacts to senior water rights. In addition, LVVWD solicited an opinion regarding the extent to which the NSE would be willing to execute subdivision maps for the project if the maps were predicated on the use of groundwater owned by the CSWR GID and developers of the project.

1.1.7 NSE Interim Order 1303

On January 11, 2019, the NSE issued Order 1303 designating the hydrographic areas composing the LWRFS as a joint administrative unit for the purpose of administering water rights. Order 1303 also held in abeyance any changes to existing groundwater rights and established a temporary moratorium on the review of final subdivision maps. In Order 1303, the NSE also requested input on the following issues from stakeholders with interests in the LWRFS that may be affected by water-rights development (NDWR, 2019):

(a) The geographic boundary of the hydrologically connected groundwater and surface-water systems comprising the Lower White River Flow System;

(b) The information obtained from the Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test;

(c) The long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including the relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow;

(d) The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River; and,

(e) Any other matter believed to be relevant to the State Engineer's analysis.

1.2 Purpose and Scope

The purpose of the work presented in this report is to summarize the current state of knowledge of the LWRFS, including spring discharge, the alluvial reservoir and perennial streamflow in the MRSA.

Specific objectives are to address the issues identified in Order 1303 by:

- evaluating hydrologic responses to the variable stress conditions affecting the LWRFS;
- evaluating the recovery responses associated with the cessation of the 2-year aquifer test;
- identifying trends in the behavior of key hydrologic variables;
- assessing the hydraulic connectivity between pumping centers and various points of interest;
- quantifying the average annual groundwater production from the carbonate aquifer that correspond to pre-selected spring discharge levels; and
- quantifying impacts to SNWA related to Muddy River streamflow depletions.

The scope of work includes a survey of the available information; compilation and analysis of time-series data; and the creation of various maps, tables, and charts to support the analyses and conclusions.

1.3 Approach

The objectives of this work were achieved by completing the following steps:

1. Performing a survey of the information available regarding the LWRFS, including hydrologic stress conditions and responses (Section 2.0).

2. Describing the flow system using the available information, including the interpretations derived from the data collected during the two-year aquifer test (Section 3.0).

3. Compiling and analyzing historical time-series data for natural and anthropogenic stresses affecting the hydrology of the LWRFS (Section 4.0).

4. Using historical time-series data to analyze the hydrologic responses of several variables that describe the historical conditions of the flow system over a period of decades (Section 5.0).

5. Qualitatively and quantitatively assessing the implications of changes in the hydraulic heads of the carbonate aquifer due to groundwater production in the LWRFS (Section 6.0).

6. Quantifying the impacts to SNWA related to Muddy River streamflow depletions caused by groundwater production in the LWRFS (Section 7.0)

7. Using the results of this assessment to respond to NSE requests for stakeholder input regarding several issues described in Order 1303 (Section 8.0).

2.0 SOURCES OF INFORMATION

This assessment required a review of the existing literature and the use of large quantities of data acquired from various sources. Depth to water measurements for wells and discharge measurements for the Muddy River and selected springs located in the LWRFS were assembled into an extensive database. These data were analyzed to evaluate current groundwater conditions, hydraulic gradients and flow directions, and aquifer responses to natural and anthropogenic stresses.

2.1 Previous Investigations

Previous investigations completed by SNWA, the LVVWD, and others that are relevant to this assessment are summarized in this section. Such investigations started with the reconnaissance studies initiated in the late 1940s and have continued since. Only relevant studies documented after the issuance of NSE's Order 1169A in December 2012 are summarized in this section.

2.1.1 Order 1169A Reports

In the months following the completion of the 2-year aquifer test mandated by NSE Order 1169, the various stakeholders, including the MOA signatories, evaluated the test results and documented their interpretations, conclusions, and recommendations in reports submitted to the NSE in June of 2013. These reports relied upon only a few months of recovery data that were influenced by the SNWA MX-5 well which continued pumping through mid-April 2013 (see Section 5.2.3 of this report for a more detailed explanation).

SNWA (2013b)

SNWA (2013b) presents the data collected before and during the test, as well as interpretations of aquifer responses and water availability. Based on their analysis of the pre-test and test data, the major conclusions made by SNWA (2013b) are as follows:

- Changes in groundwater levels are affected by both groundwater pumping from the carbonate aquifer and changes in prevailing hydrologic conditions before and after the aquifer test.

- The aquifer test confirmed that extensive hydraulic connectivity exists in the carbonate aquifer. However, the presence of boundaries and spatial variations in hydraulic conductivity affect the carbonate aquifer's response depending on location. For example, no discernible responses were observed north of the Kane Springs Fault and west of the MX-5 and CSI wells near the eastern front of the Las Vegas Range (note: the lack of responses cited in SNWA (2013b), referred to wells CSVM-3 and CSVM-5; see Sections 5.2.2 and 5.2.3 of this report for a more detailed explanation).

- Relatively minor declines in spring flow were observed at the highest elevation springs (Pederson and Pederson East springs) during the test. However, no changes were discerned in the flows of the Muddy River at the U.S. Geological Survey (USGS) Muddy River near Moapa, Nevada gage because the responses were relatively small compared to the large flows of the river and the impacts related to pumping within the MRSA.

- Pumping the existing groundwater rights in Coyote Spring Valley during the test did not result in an unreasonable lowering of the groundwater table. Furthermore, recovery began when pumping was reduced to pre-test levels.

- It remains unclear if additional resource development beyond existing permitted rights could take place in Coyote Spring Valley at selected locations.

USFWS, Bureau of Land Management (BLM), and NPS (2013)

The USFWS, BLM, and NPS prepared a similar report in 2013. Their analyses included a numerical groundwater flow model developed by Tetra Tech (2012a and b) and SeriesSEE analysis (Halford et al., 2012). They attempted to calibrate the model using the data from the 2-year aquifer test and used the resulting model to make predictions. The SeriesSEE analysis was conducted to segregate the drawdowns caused by the MX-5 pumping well from those caused by the other pumping wells. Their main conclusions are as follows:

- Pumping at MX-5 caused drawdowns of about the same magnitude in the portion of the carbonate aquifer underlying Coyote Spring Valley, the MRSA, Hidden and Garnet valleys, and California Wash at the end of the test.

- Using the results of the SeriesSEE analyses, USFWS et al. (2013) delineated the connected portion of the carbonate aquifer, which they state includes the source of the Muddy River Springs and majority source of the Muddy River.

- Based on these analyses, USFWS et al. (2013) concluded that pumping from the connected portion of the carbonate aquifer causes drawdowns of about the same magnitude throughout the delineated area.

- Based on previous information and the results of their analysis of the test data, they also concluded that no additional groundwater is available for appropriation.

Johnson and Mifflin (2013)

Johnson and Mifflin (2013) also prepared a report of the analysis of the 2-year aquifer test data. Based on their analysis, they found that (1) the portion of the WRFS located south of Pahranagat Valley consists of two separate flow fields, the northern and southern flow fields, that responded differently to the pumping in Coyote Spring Valley; and (2) the variations in the Muddy River baseflow caused by natural stresses are of the same order of magnitude as the pumping stresses in Coyote Spring Valley during the two-year aquifer test. Based on their analyses, they made the following four recommendations:

- At least four of the basins that include and extend upgradient from the MRSA should be combined into one water-management unit.
- The pending LVVWD water rights applications in this area should be denied on the grounds that they would impact senior rights by the full amount.
- The existing undeveloped permits located within the combined area must be mostly revoked, restricted, or very carefully managed to avoid periods of eliminated Muddy River base flows in the springs-area headwater reaches in the future.
- A large interim pumping test should be conducted in the northern portion of the Southern Flow Field to better evaluate the water-resource potential of this portion of the flow system.

CSI (2013)

CSI (2013) conducted a qualitative analysis of the 2-year aquifer test and concluded that the effects of pumping during the test generated a shallow drawdown cone that extends miles from the MX-5 well. Using the observations from the test and monitoring data collected by SNWA, CSI (2013) concluded the following:

- The Kane Spring fault acts as a groundwater barrier to groundwater flowing from north to south in Coyote Spring Valley and may also serve as a barrier to pumping from wells located north of the fault.
- Based on supporting information from SNWA's Annual Monitoring Reports, additional groundwater is available for appropriation in Coyote Spring Valley.
- Water-right applications submitted by CSI and SNWA should be fully or partly granted.

Myers (2013)

Myers (2013) describes an analysis of the 2-year aquifer test and a review of the groundwater flow model developed by Tetra Tech for the southern White River Flow System (WRFS) (Tetra Tech, 2012a and b). Myers (2013) concluded the following:

- The Order 1169 aquifer test data and the Tetra Tech groundwater flow model predictions indicate that pumping from existing groundwater rights in Coyote Springs Valley and the MRSA will cause the spring discharge to decrease to dangerous levels.
- Any additional water rights potentially granted in the future will cause the spring discharge to decrease further below the required target rates and may eventually dry up some or all of the springs in the MRSA.

2.1.2 Annual Data Reports (2013-2019)

This assessment relied upon the annual data reports prepared by the Order 1169 study participants and others who submit quarterly data to NDWR. Among these reports are the ones prepared by SNWA, MVWD, NVE and the HRT.

SNWA Annual Monitoring Reports

SNWA prepares and submits annual monitoring reports in satisfaction of water-right permit terms for groundwater and surface-water sites throughout the LWRFS. The reports of particular interest are the ones prepared after the completion of the aquifer test as they contain data characterizing the recovery responses to the pumping stresses imposed during the 2-year aquifer test (SNWA, 2013a; 2014; 2015a; 2016a; 2017a; 2018b and 2019).

HRT Annual Determination Reports

Also relevant to this assessment are the annual reports prepared by the HRT after the completion of the test (2013 through 2018). The MOA signatories collect and analyze data and share their findings to satisfy the objectives of the MOA. Since the MOA was signed in 2006, extensive data collection and analysis efforts have been performed, including those associated with the Order 1169 study. The HRT annual reports include descriptions of previous monitoring activities and interpretations prepared by the signatories and incorporated in the reports as appendices. Based on the findings of each year, the HRT makes recommendations about the action levels associated with the Trigger Ranges. As in all previous reports, HRT (2018) recommended that no changes be made to the existing pumping restrictions listed in the MOA (SNWA, 2006) and presented in Table 1-1.

2.1.3 Other Reports

A few other relevant reports have been issued since the completion of the Order 1169 aquifer test including the following:

Huntington et al. (2013)

Huntington et al. (2013) prepared a technical memorandum for SNWA containing estimates of evapotranspiration (ET) for the MRSA from 2001-2012. This work was part of a larger project designed to identify trends in ET over the period of 2001-2012 and the potential impacts that land management practices and vegetation changes may have on ET.

Rowley et al. (2017)

Rowley et al. (2017) published a comprehensive report describing the geology and geophysics of a large area including parts of eastern Nevada and western Utah, and the LWRFS. The report includes geologic maps at a scale of 1:250,000 based on various published and unpublished geologic maps, site studies and new local geologic maps. Their report includes 25 new geologic cross sections at the same scale and interpretations of new geophysical data collected by the USGS.

2.2 Data Sources

Data relevant to this assessment were obtained from many project-related sources as well as regional and national sources. Monitoring of hydrologic conditions and reporting of surface-water diversions and groundwater production has been on-going in the LWRFS for decades. Through the collective efforts of water-right owners, several monitoring programs have been implemented to comply with monitoring and reporting requirements associated with permit terms. In addition, the NDWR instituted comprehensive monitoring and reporting requirements associated with the Order 1169 study to ensure pertinent data were collected and reported in a timely manner. These data are summarized in annual data reports and are accessible on the NDWR website at http://water.nv.gov/Order1169Menu.aspx.

In addition, SNWA and NDWR participate in joint funding agreements with the USGS to fund operation and maintenance of several important surface-water and groundwater sites located within the LWRFS. These data are accessible through the USGS National Water Information System and Groundwater Site Inventory database (NWIS) (USGS, 2018). Additional data were compiled from the NDWR drillers log database (NDWR, 2018a), published reports documenting well completions or hydrologic studies. However, the majority of the data presented in this report were collected and reported by the 2006 MOA signatories and Order 1169 study participants.

Climate records spanning long periods were necessary for this assessment are not available for meteorological stations located within the LWRFS. Thus, climate data were obtained from the following agencies:

- Western Region Climate Center (WRCC) at https://wrcc.dri.edu/summary/Climsmnv.html
- National Oceanic and Atmospheric Administration (NOAA) at https://www.noaa.gov/climate
- Parameter-elevation Regressions on Independent Slopes Model (PRISM) at http://www.prism.oregonstate.edu/

3.0 LWRFS DESCRIPTION

The boundary of the LWRFS was initially described in NSE Rulings 6254 through 6261 (NSE, 2014a through h), inclusive, and a figure attached to the rulings that identified the Order 1169 basins. The boundary of the LWRFS is depicted in Figure 1-1. This section presents the physiography, climate, and hydrogeology of the LWRFS, and a description of the surface-water and groundwater hydrology.

3.1 Physiography

The LWRFS is within the Basin and Range physiographic province of the Great Basin, which is characterized by a series of parallel to sub-parallel, north-trending mountain ranges separated by elongated alluvial valleys (Fenneman, 1931). The western margin of the LWRFS is defined by the Sheep Range in the north and the Las Vegas Range in the south. The Sheep Range is the highest range in the LWRFS with peak elevations ranging from 7,000 to nearly 10,000 ft amsl. The eastern boundary of the LWRFS is defined by the Muddy and North Muddy mountains in the south and by the Meadow Valley and Delamar mountains in the north. Adjacent to the LWRFS, in Kane Springs Valley, elevations in the Delamar Mountains exceed 7,000 ft amsl. Included within the LWRFS are the Coyote Spring, Elbow, Arrow Canyon, and Dry Lake ranges all having elevations less than 6,000 ft amsl (Figure 1-1). During the Pleistocene Epoch, the White River flowed through Coyote Spring Valley entering the valley from southern Pahranagat Valley and traveling south and then southeast between the Arrow Canyon Range and the Meadow Valley Mountains where it continued along the present course of the Muddy River (Eakin, 1964). The elevations along this ancestral feature range from just above 3,000 ft amsl where it enters Coyote Spring Valley to 1,420 ft amsl where the river leaves California Wash near Glendale, Nevada.

3.2 Climate

The climate of the LWRFS is typical of southern Nevada ranging between arid and semi-arid conditions. This climate is characterized by small amounts of precipitation occurring mostly on the surrounding mountains, and high summer temperatures and evaporation rates. Winter-season precipitation occurs as snow at the higher elevations of the Sheep and Delamar Ranges and serves as the primary source of local recharge. During the summer months, precipitation occurs as a result of local storms. Air temperatures vary greatly on a daily and seasonal basis. Climate variations constitute natural stresses to the hydrologic system of the LWRFS and are discussed in more detail in Section 4.0.

3.3 Hydrogeology

The hydrogeology of the LWRFS is characterized by the complex geology of the area, which ranges in age from Precambrian siliciclastic rocks to Tertiary and Quaternary alluvial deposits that have been structurally deformed during several tectonic episodes (Rowley et al., 2017). Three tectonic episodes as well as extensive volcanism have affected the region. The Antler deformation and Sevier deformation resulted in east-verging thrust sheets in which Paleozoic carbonate rocks were placed over the top of each other as well as over younger rocks producing thick sequences of carbonate rocks in the region. The third tectonic episode is the middle Miocene to Holocene basin-range deformation that shaped the current topography of the Great Basin. In this episode, basin-range faulting produced horst and graben topography resulting in typically deep basins and relatively high mountain ranges that are generally oriented north-south (Rowley et al., 2017).

The following sections summarize the structural setting and hydrogeology of the LWRFS, with reference to the 1:250,000 scale hydrogeologic map of Rowley et al. (2011) presented in Figure 3-1. The map is based on a geologic map and cross sections for a region including portions of White Pine, Lincoln, and Clark counties in Nevada, and adjacent areas.

3.3.1 Structural Setting

Major structural episodes have caused faulting within the LWRFS. These episodes have influenced the distribution and thickness of geologic units and the geometry of the basins and ranges. Major fault structures within the area are described in the following sections.

Thrust Faults

Thrust faults within the LWRFS include the Muddy Mountain thrust in the Muddy Mountains, the Dry Lake thrust in the Dry Lake Range, and the Gass Peak thrust in the eastern Sheep Range (Figure 3-1). The importance of these faults is that they create very thick carbonate-rock sequences that, as a result of compression and transport, have significant fracture development and therefore increased permeabilities (Heilweil and Brooks, 2011; Page et al., 2005). In addition, these faults have juxtaposed the carbonate-rock sequence with low permeability rocks that are older (e.g. Gass Peak Thrust in the southern Sheep Range) or younger (e.g. Muddy Mountain Thrust). In these areas, this juxtaposition effectively truncates the extent of LWRFS. The thrust faults themselves may also act as barriers to groundwater flow (Page et al., 2005).

Strike-Slip Faults

The left-lateral strike-slip fault of the Pahranagat Shear Zone (PSZ) and the right-lateral strike-slip fault of the Las Vegas Valley Shear Zone (LVVSZ) occur just to the north and south of the LWRFS, respectively. Faults of the PSZ, provide a partial barrier to southward flow from southern Pahranagat and Delamar valleys into the LWRFS (Rowley et al., 2011). Groundwater likely flows south through the barrier into Coyote Spring Valley along north-trending normal faults and fractures (Rowley et al., 2011). The LVVSZ has been interpreted to be a barrier to southward groundwater flow (Heilweil and Brooks, 2011).

The Kane Springs Wash fault zone is a left-lateral and normal down-to-the-west oblique fault that occurs in Kane Springs Valley and the northern portion of Coyote Spring Valley (Figure 3-1). The oblique fault along with the Kane Springs Wash caldera complex and thrust faults likely prevent groundwater flow between Kane Springs Valley and Meadow Valley Wash (Rowley et al., 2011). In

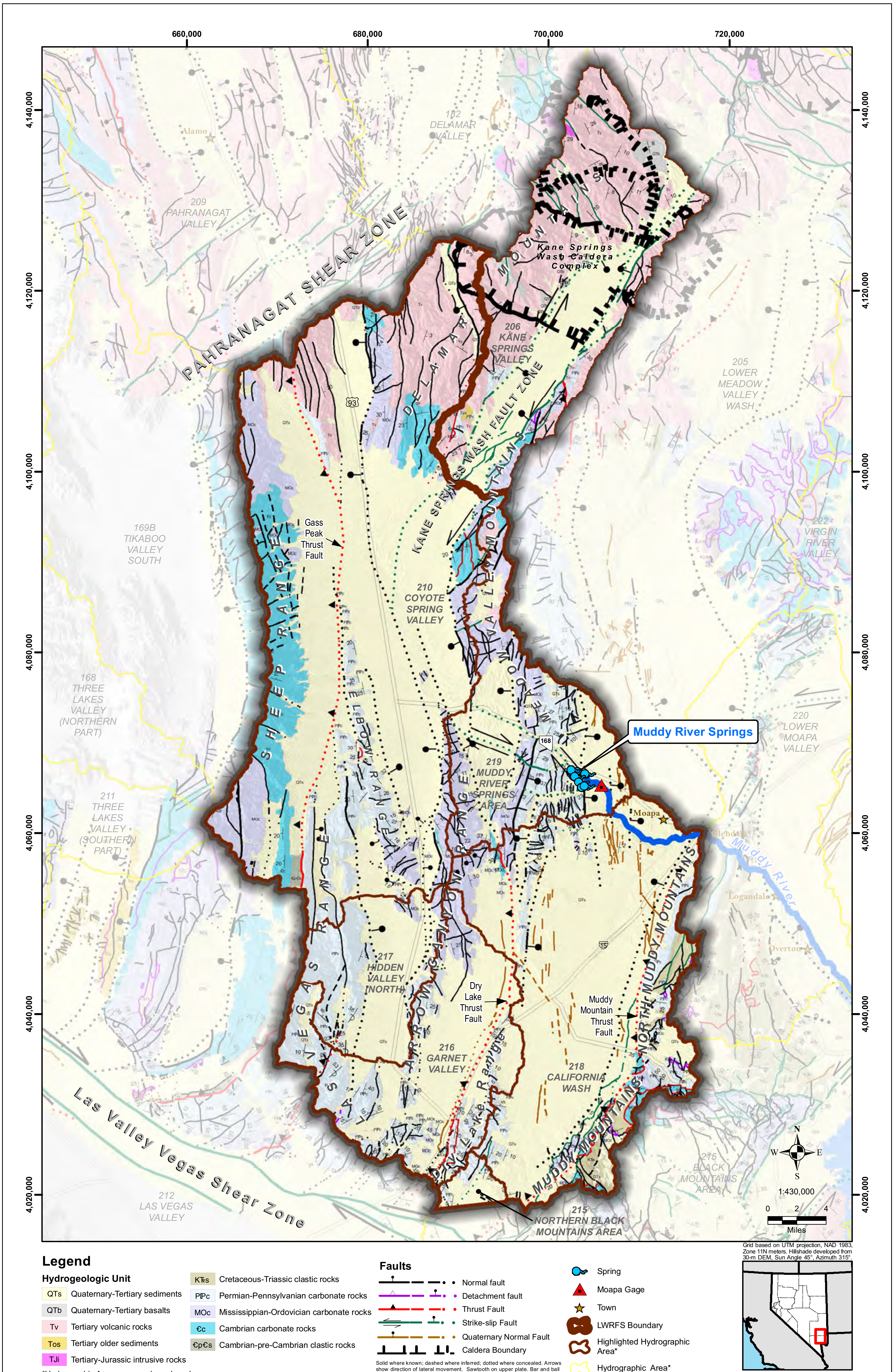

Figure 3-1
Hydrogeologic Map of the Lower White River Flow System

Coyote Spring Valley, the Kane Springs Wash fault zone may act as a partial barrier to flow, impeding flow across the fault from north to south.

Normal Faults

The main phase of Basin and Range deformation which began around 10 Ma, is characterized by steeply-dipping, north-striking, normal faulting (Rowley et al., 2017). This faulting is responsible for the formation of the present-day physiography of north-trending basins and ranges forming the LWRFS (Page et al., 2011). The many Basin and Range faults that underlie and define the sides of Coyote Spring Valley provide the pathways for southward groundwater flow (Harrill et al., 1988; Schmidt and Dixon, 1995). A major part of that groundwater flows southeast, between the northern end of the Arrow Canyon Range and the southwestern end of the Meadow Valley Mountains along what has been referred to as the east Arrow Canyon Range fault zone (Page et al., 2011; Rowley et al., 2011). East-striking faults intersect the north-striking faults likely increasing the permeability of carbonate rocks in the MRSA (Page et al., 2011; Rowley et al., 2017). The southeast-flowing groundwater is the principal source of many large springs in the MRSA, which currently create the perennial flow of the Muddy River (Schmidt and Dixon, 1995; Donovan et al., 2004; Buqo, 2007; Donovan, 2007; Johnson, 2007).

3.3.2 Hydrogeologic Setting

The hydrogeologic map presented in Figure 3-1 was constructed by grouping geologic units with similar hydrologic properties into hydrogeologic units. The following sections summarize the geology and hydrogeology of the mountain ranges within and at the boundaries of the LWRFS.

Delamar Mountains

The Delamar Mountains at the northern LWRFS boundary are dominated by Tertiary caldera complexes including the Kane Springs Wash caldera complex (Rowley et al., 1995; Scott and Swadley, 1995; Scott et al., 1996; Dixon et al., 2007). The main bounding fault of the Delamar Mountains is the down-to-the-west normal fault on the western side, which is joined from the southwest by several splays of the left-lateral and normal PSZ (Ekren et al., 1977). In Kane Springs Valley, the bounding fault is the oblique (left-lateral and normal down-to-the-west) Kane Springs Wash fault zone (Swadley et al., 1994). Tertiary caldera complexes forming the northern boundary of Kane Springs are effective barriers to groundwater flow. The calderas are barriers primarily because of their underlying intracaldera intrusions and both hydrothermal clays and contact-metamorphic rocks formed by emplacement of the intrusions into intracaldera tuffs (Rowley et al., 2011). Groundwater likely enters the LWRFS from southern Delamar Valley along the PSZ to Pahranagat Valley and then through the PSZ and along north-striking normal faults into Coyote Springs Valley (Figure 3-1).

Southern Sheep Range, Las Vegas Range, and Elbow Range

The southern Sheep Range is underlain by mostly Cambrian and Ordovician carbonate rocks that dip eastward (Guth, 1980). The range is a large tilt block uplifted along major north-striking, basin-range normal faults on its western side. The range is on the upthrown western side of the low-angle, west-dipping Gass Peak thrust. The thrust transported Neoproterozoic to Cambrian quartzite and

Cambrian to Devonian carbonate rocks eastward over Cambrian to Mississippian rocks (Dohrenwend et al., 1996).

The Las Vegas Range is defined by the Gass Peak thrust, which transported rocks as old as the Cambrian Wood Canyon Formation eastward over Mississippian, Pennsylvanian, and Permian carbonate rocks of the Bird Spring Formation (Maldonado and Schmidt, 1991). Most of the range is made up of folded Bird Spring limestone, with the Gass Peak thrust exposed along its western side (Maldonado and Schmidt, 1991; Page, 1998). The small Elbow Range, which bounds the Las Vegas Range on the northeast, is made up of thrusted and folded Bird Spring Formation that has been uplifted as a horst (Page and Pampeyan, 1996).

Meadow Valley Mountains

The Meadow Valley Mountains constitutes a narrow, generally low, north-northeast-trending range about 40-mi-long. The northern 30 mi of the range consists mostly of outflow ash-flow tuffs and part of the Kane Springs Wash caldera complex. The southern end of the Meadow Valley Mountains, just east of Coyote Spring Valley, is made up of mostly thrust-faulted and normally faulted Paleozoic rocks (Pampeyan, 1993; Swanson and Wernicke, 2017).

Arrow Canyon Range

The Arrow Canyon Range is a sharp, narrow, north-trending range consisting of a syncline of Cambrian to Mississippian carbonate rocks. It is uplifted along its western side by normal faults of the Arrow Canyon Range fault zone (Schmidt and Dixon, 1995; Page and Pampeyan, 1996; Page, 1998). The trace of the north-striking Dry Lake thrust, which carries Cambrian rocks over Silurian through Permian carbonate rocks, is exposed and projected north just east of the range (Page et al., 1992; Schmidt and Dixon, 1995; Beard et al., 2007).

North Muddy Mountains, Muddy Mountains, and Dry Lake Range

The southeastern corner of the LWRFS contains the Cretaceous-Triassic clastic rocks of the North Muddy Mountains and the Muddy Mountains (Bohannon, 1983). The Muddy Mountain thrust fault has placed the carbonate-rock sequence on top of these rocks, effectively truncating the LWRFS at this location. West of the Muddy Mountains and east of the Apex Industrial Park, is the small Dry Lake Range. This range is made up mostly of Bird Spring carbonate rocks. A narrow arm of bedrock extending west from Apex connects with the southern Arrow Canyon Range/Las Vegas Range. Basin-fill sediments to the northeast along the I-15 corridor (California Wash area) belong to an east-tilted half graben that reaches depths of 9,000 to 12,000 ft (Langenheim et al., 2001, 2010; Scheirer et al., 2006).

3.4 Hydrology

The hydrology of the LWRFS is presented in this section including descriptions of prominent surface-water features and associated time-series records of discharge; as well as descriptions of groundwater characteristics including aquifer types and conditions, and occurrence and movement. The sources of the data utilized in this section are described in Section 2.0.

3.4.1 Surface Water

The primary surface-water features of the LWRFS are located within the MRSA where five spring-complexes and numerous gaining stream reaches form the headwaters of the Muddy River, the only perennial stream within the LWRFS (Figure 3-2). There are additional small springs in Coyote Spring and Kane Springs valleys which discharge groundwater sourced from local recharge; however, these springs are not described in this report because their discharge is known to be minor (Eakin, 1964).

The regional carbonate aquifer is the source of water for the springs and the gaining stream reaches that form the headwaters of the Muddy River (Eakin, 1964; Rowley et al., 2017). Discharge from the springs coalesce with the gaining reaches to form the main channel of the Muddy River just above the USGS Muddy River near Moapa, Nevada (NV) gaging station. Figure 3-2 depicts the location of this gaging station and several other USGS gaging stations. Also depicted are the locations of metered surface-water diversions in the headwaters area. Table 3-1 lists the periods of record for each of the gaging stations.

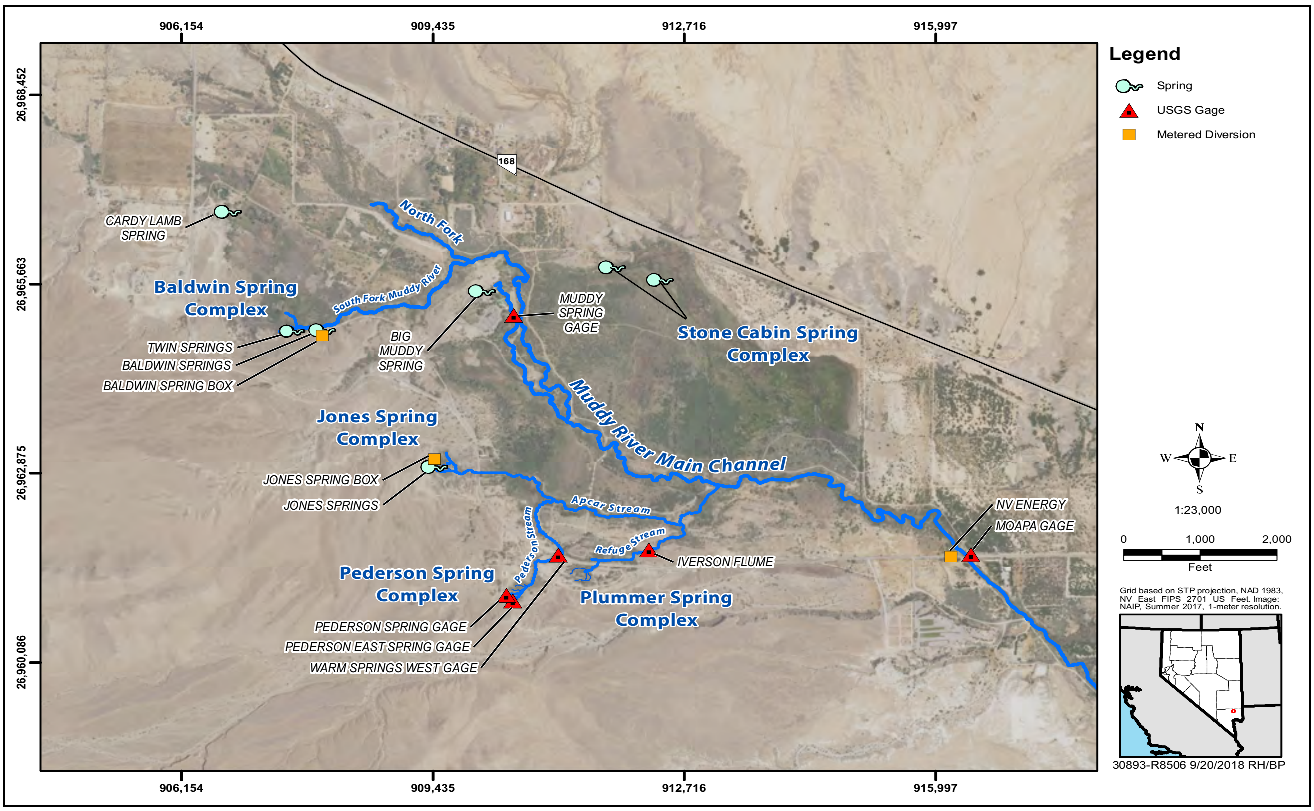

Figure 3-2
Spring Complexes, Streams, Diversions, and Gaging Stations within the Headwaters of the Muddy River

There are three gaging stations that are critical to the analyses presented in this report. Two are associated with the Pederson Spring Complex: Pederson Spring near Moapa, NV and Warm Springs

West near Moapa, NV. The Pederson Spring near Moapa, NV gage is important because it measures flow from the highest elevation spring within the MRSA representing groundwater discharge from the regional carbonate aquifer. The Warm Springs West gage is important because flow triggers have been established at the gage as part of the 2006 MOA (see Table 1-1). The third gaging station is the Muddy River near Moapa gage, which is important because it (1) measures the streamflow at this location, (2) provides the only basis for estimating the total discharge from the carbonate aquifer to the springs area, and (3) has the longest period of record. Details for each are presented in the following sections.

Table 3-1
USGS Gaging Stations in the Headwaters of the Muddy River

USGS Station Number	Gaging Station Name	Period of Record for Daily Average flow
09415900	Muddy Springs at LDS Farm near Moapa, NV (LDS gage)	August 1985 to Present
09415908	Pederson East Spring near Moapa, NV (Pederson East gage)	May 2002 to Present
09415910	Pederson Spring near Moapa, NV (Pederson gage)	October 1986 to Present[1]
09415920	Warm Springs West near Moapa, NV (Warm Springs West gage)	August 1985 to September 1994 June 1996 to Present[2]
09415927	Warm Springs Confluence at Iverson Flume near Moapa, NV (Iverson Flume gage)	October 2001 to Present
09416000	Muddy River near Moapa, NV (Moapa gage)	July 1913 to September 1915 May 1916 to September 1918 October 1944 to Present

Note: [1]Flow data in the latter half of 2003 through April 2004 reflects flows bypassing the gage through a leak in the weir. The weir was replaced in April 2004.
[2]Flow records prior to October 1997 were influenced by an agricultural diversion above the gage.

Pederson Spring Complex

The Pederson Spring near Moapa, NV gage (09415910) measures spring discharge from the highest elevation spring in the Muddy River headwaters area. The gage record begins in 1986, but is missing data from 1994 to 1996. The aluminum weir was found to be severely warped and it is speculated this happened when a fire burned through the area in 1994 (SNWA, 2008). In addition, the record includes underreported values from 2003 until April 2004 during which time discharge was observed bypassing the gage. The record from 1994 to April 2004 when the gage was replaced is considered poor quality. Figure 3-3 presents the flow record for the gage for the period 1986 to present. As the highest-elevation spring, it is considered to be the most sensitive to changes in groundwater conditions associated with the regional carbonate aquifer, and, therefore, a good indicator of how these changes affect spring discharge in the MRSA.

Warm Springs West near Moapa, NV Gage (09415920)

The Warm Springs West near Moapa, NV gage (09415920) is a parshall flume that measures the total discharge from the Pederson Spring complex. The period of the continuous record ranges from 1985 to present. Continuous gage records prior to October 1997 are considered unreliable because the flows were influenced by an unmetered agricultural diversion above the gage. Discrete measurements such as those made by Eakin (1964) are also available. These measurements are important because they provide valuable information prior to significant development in the area. Figure 3-4 presents

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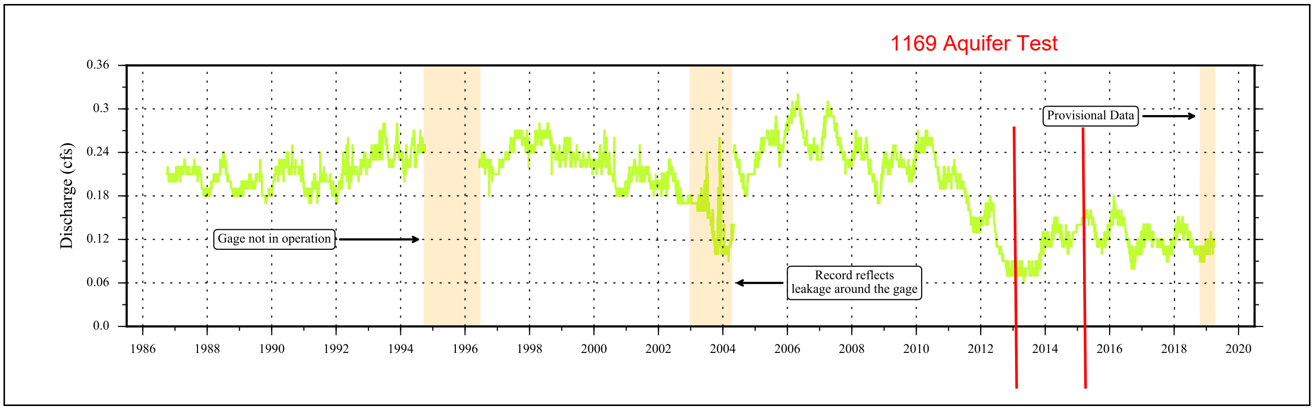

Figure 3-3
Pederson Spring near Moapa, NV - Daily Discharge Record (1986 to present)

the flow measured at the gage for the period of continuous record. The parties to the MOA established Trigger Ranges at various flow rates at the gage for the purpose of initiating water management actions to protect instream flow rights and habitat for the endangered Moapa dace. The first trigger has been established at 3.2 cfs.

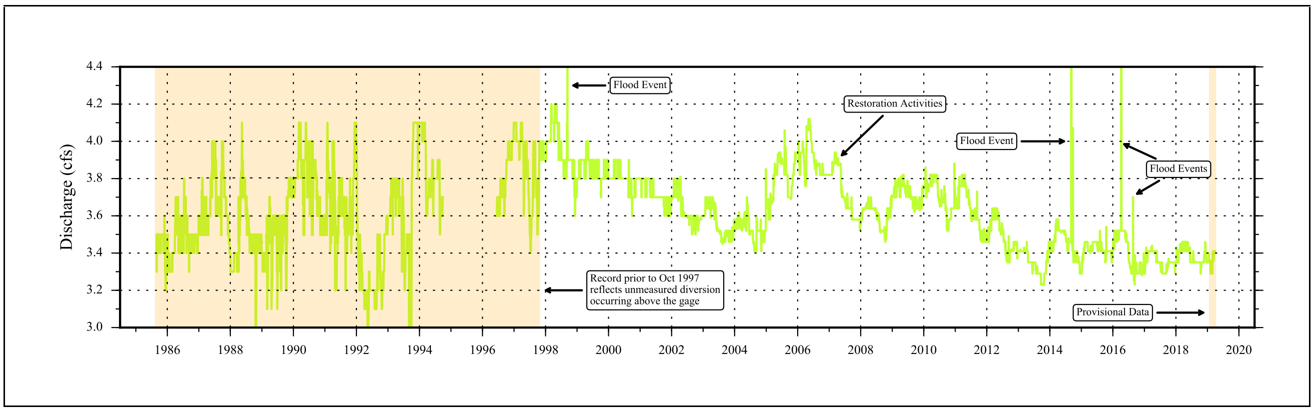

Figure 3-4
Warm Springs West near Moapa, NV - Daily Discharge Record (1985 to present)

Muddy River near Moapa, NV Gage (09416000)

The USGS Muddy River near Moapa, NV gage (Station No. 09416000; hereinafter referred to as the MR Moapa gage) measures the streamflow contributions from spring complexes, gaining reaches and intermittent flood flows. Streamflow is directly affected by surface-water diversions and ET occurring above the gage. Figure 3-5 presents a time-series chart of the annual streamflow measured at the MR Moapa gage for the period 1945 to 2018. Also presented on the chart is a record of these flows that has been adjusted to remove the influence of intermittent flood flows. These influences were removed from the mean daily flow record using a method that replaces the identified flood flow with the median monthly flow as described in Johnson (1999). The resulting flow record is more representative of actual baseflow conditions at the gage. The flood-adjusted flow record is used in the analyses presented in this report.

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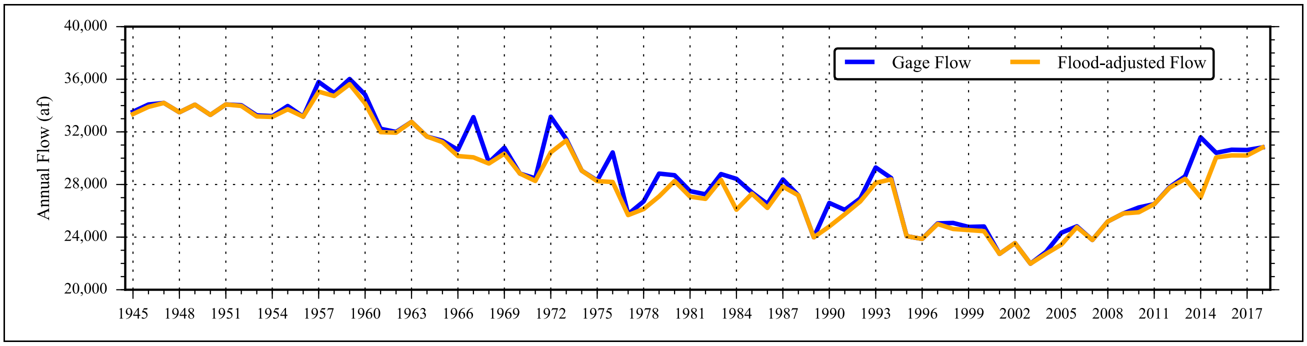

Figure 3-5
Muddy River near Moapa, NV (1945 to 2018)

The mean annual flow measured at the MR Moapa gage in 1946 was 46.8 cfs (33,900 af). This flow rate is considered the predevelopment baseflow because it predates municipal and industrial surface-water diversions and exports by NVE and MVWD, as well as groundwater development within the MRSA. This baseflow also matches the average mean annual flow when the gage was operated intermittently between 1913 and 1918. During two intervals covering 3-years (July 1, 1913 to June 30, 1915 and October 1, 1916 to September 30, 1917) the average flood-adjusted mean annual flow was 47.0 cfs (34,000 afy), a difference of 100 afy from the 1946 flow rate.

The 1946 pre-development baseflow also corresponds with information compiled by Eakin (1964). Eakin (1964) reported a 25-year average flood-adjusted mean annual flow of 46.4 cfs (33,600 afy) using intermittent data between 1914 and 1962. In addition, Eakin (1964) estimated that approximately 2,000 to 3,000 afy of spring flow was being consumed by phreatophytes between the spring orifices and the gage. Eakin and Moore (1964) examined the MRSA discharge in more detail and concluded that the January measurements of river flow at the MR Moapa gage are the most reliable estimates of discharge to the area as ET above the gage is practically zero during that month. They estimated the mean discharge to be 50.2 cfs, or about 36,000 afy, using data for a period spanning 1945 to 1962. As illustrated by Figure 3-5, the gage flow during pre-development conditions only varied by about 1,000 afy from 1945 to 1955. Starting in the early 1960s, Muddy River streamflow began to decline from the 33,900 afy pre-development baseflow. This decreasing trend continued, reaching a low of about 22,000 af in 2003. By this time, streamflow had declined by over one-third of the pre-development baseflow. Streamflow has since recovered, and by the end of 2018 the mean annual flood-adjusted flow was 30,800 af. The causes of this decline and subsequent recovery are analyzed in Section 5.0.

3.4.2 Groundwater

Descriptions of the groundwater characteristics of the LWRFS, including aquifer types and conditions and groundwater occurrence and movement are presented in this section.

3.4.2.1 Aquifer Types and Conditions

The hydrogeology described in Section 3.3 can be further simplified into a groundwater system composed of a regional carbonate aquifer interconnecting the basins of the LWRFS and one or more areas where saturated basin-fill is present. The regional carbonate aquifer is contiguous throughout the basins, while the saturated basin fill occurs primarily within the basin centers.

Regional Carbonate Aquifer

The identification of the regional carbonate aquifer was made by Eakin (1964, 1966) who noted that the large discharge from the springs located within the MRSA could not be supported by the relatively small local recharge. As a result, Eakin (1966) concluded that the springs were discharging groundwater originating from basins located upgradient. Eakin (1966) developed a water balance for thirteen basins located within south-eastern Nevada, ending with the MRSA. Based on the results, he concluded that recharge in these basins contributes to the discharge of the Muddy River springs and that the Paleozoic carbonate rocks must be the primary system that is transmitting water between these basins. Investigations conducted after Eakin (1966) revealed that the hydraulic connection of the carbonate aquifer extends to basins located south of the MRSA (SNWA, 2009; Burns and Drici, 2011; SNWA, 2013b).

The regional carbonate aquifer is predominantly composed of thick sequences of Paleozoic and Mesozoic carbonate rocks that have well-developed fracture networks (Heilweil and Brooks, 2011). As described in Section 3.3.2, thick sequences of carbonate rocks occur throughout the LWRFS as thrust faulting has placed carbonate-rock sequences on top of other carbonate rock sequences. The compressional and transport processes that are involved with thrusting may lead to significant fracture development (Heilweil and Brooks, 2011). Carbonate rocks typically have a low permeability but may have very high secondary permeabilities as result of fracturing and the dissolution of the carbonate minerals along faults, fractures, and bedding planes (Schaefer et al., 2005).

Basin-Fill Aquifers

Saturated basin fill may form aquifers in the LWRFS. Where they occur, these aquifers generally overlie the regional carbonate aquifer system and are typically separated from one another by mountain ranges composed of consolidated rocks (Schaefer et al., 2005). The aquifers are composed of Tertiary sediments consisting of eroded limestone, conglomerate, sandstones, as well as Quaternary alluvium, colluvium, playa deposits, and eolian deposits (Page et al., 2011). Basin fill can be composed of many sediment types with different grain sizes and levels of sorting, and, consequently, can have a large range of permeabilities (Heilweil and Brooks, 2011). Where present, basin-fill aquifers within the LWRFS occur at great depths above the carbonate aquifer, as perched, or as semi-perched systems.

MRSA Alluvial Reservoir

In the MRSA,the combination of permeable interbedded fine- and coarse-grained sediments on top of the low-permeability Muddy Creek Formation form a groundwater reservoir. Groundwater from the carbonate aquifer flows upwards through springs and seeps and recharges this reservoir. This

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reservoir acts as a highly transmissive shallow, local alluvial aquifer that comprises at least the top 125 ft of basin fill based on well-driller's reports. The water table of this shallow alluvial reservoir is generally within a few feet of land surface. Discharge from this reservoir occurs as ET and outflow to the Muddy River.

3.4.2.2 Occurrence and Movement

Figure 3-6 is a map presenting the current conceptualization of groundwater occurrence and movement within the LWRFS. The map depicts areas of potential local recharge and primary groundwater discharge, boundary flow, and current aquifer conditions based on water-level observations collected in January, February, or March of 2019, a period when pumping is at its lowest during the year. The areas of potential recharge were approximated by areas where normal precipitation is greater than 8 in. The PRISM 800-meter normal precipitation grid was used for this purpose (Daly et al., 1994, 1997, 1998, 2008). Aquifer conditions are represented by measurements of static or near-static water-level elevations on the map (Figure 3-6). Depth-to-water and water-level elevation data are presented in Table A-1 (Appendix A). The existing well data are insufficient for the development of potentiometric contour maps. Thus, the discussion is based on the well data presented in this section, supplemented by information from previous interpretive reports.

As stated above, within the LWRFS, groundwater occurs in basin-fill and carbonate-rock aquifers. Within many of the LWRFS basins, groundwater in the basin fill occurs at great depths, or as perched systems as is the case in the extreme northern area of Coyote Spring Valley (Eakin, 1964). The alluvial reservoir of the MRSA constitutes an exception in the LWRFS. Depth to water within the basin fill ranges between about 7 ft bgs (03/19/2019) at well LDS-East in the MRSA to about 751 ft bgs (02/06/2019) at the CSV3011M well in Coyote Spring Valley (Appendix A). The shallower depths to water occur within the alluvial reservoir, downgradient from the Muddy River springs. The greater depths to water in the basin fill occur in northern and southern Coyote Spring Valley. Groundwater also occurs at substantial depths in other basins of the LWRFS. For example, the Byron Well completed in the basin fill within California Wash basin has a depth to water of about 238 ft bgs (03/06/2019) (Appendix A).

Depth to groundwater within the carbonate aquifer varies significantly. In general, depth to water is near the surface in the MRSA and much deeper in the other basins. A better understanding of the deeper groundwater that occurs in the carbonate aquifer was developed based on the water-level responses, which are discussed in greater detail in Section 5.0. The responses depend on the relative locations of the wells with respect to the range-front faults located at the base of the mountain ranges (Figure 3-1). These faults have created structural basins where most of the wells are located.

Within the Coyote Spring Valley structural basin, water-level elevations are higher in the northern portion of the valley and decrease to the south. Wells located within the structural blocks of the mountain ranges are significantly higher (e.g., CSVM-3 and CSVM-5). Well CSVM-3, which has a depth to water of 445 ft bgs (02/06/2019), is located to the far north of the valley and within a different structural block composing the southern Delamar Mountains. Water-level elevations in this structural block are greater than 320-ft higher than those observed in wells CSVM-4 and KMW-1 to the southeast that are completed within the Kane Spring Wash fault zone. Well CSVM-5 is located high off the valley floor and within the structural block of the Sheep Range and has a depth to water

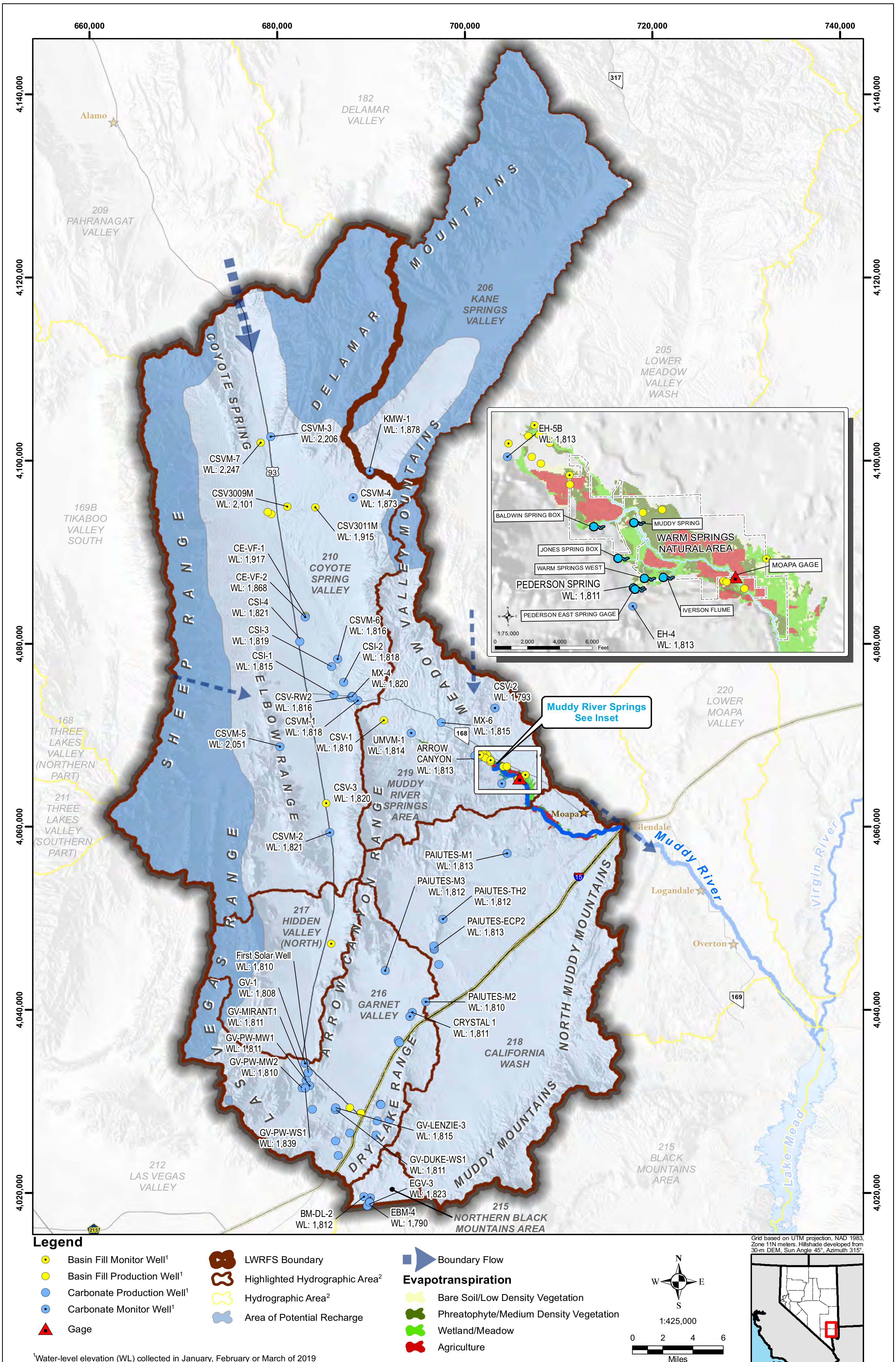

Figure 3-6
Conceptualization of the Lower White River Flow System

of 1,080 ft bgs (02/05/2019). At the CSVM-5 site, the Gass Peak thrust fault has influenced the geologic setting by causing the bedding orientation of the carbonate strata to be nearly vertical at the surface. Except for these two wells, water levels throughout the LWRFS respond in the same manner. This indicates a high-degree of hydraulic continuity between the structural basins of the LWRFS.

Based on the well data described in this section and presented in Figure 3-6 and Appendix A, the minimum depth to water measured within the connected portion of the carbonate aquifer was about 32 ft bgs (03/19/2019) measured at well EH-5B in the MRSA. The maximum depth to water of about 970 ft bgs (03/12/2019) was measured at well CSVM-4 in northern Coyote Springs Valley. Depth-to-water measurements in Garnet Valley range from about 261 to 884 ft bgs, all measured in early 2019. Despite the large differences in depth to water across the LWRFS, groundwater elevations in the carbonate aquifer near the center of the valleys only vary by approximately six feet between central Coyote Spring Valley, and Garnet Valley and Black Mountains Area to the south, and the MRSA and California Wash to the east. These minor differences in groundwater elevation across such a broad area are indicative of a high degree of hydraulic connection as demonstrated by the results of the NSE Order 1169 aquifer test.

In general, groundwater flows from areas of recharge at high elevations to discharge areas at lower elevations. The ssource of recharge to the carbonate aquifer underlying the LWRFS is a combination of regional groundwater inflow from the upper portion of the WRFS including Pahranagat, Delamar, and Kane Springs valleys; and from local recharge in the mountain ranges bounding the LWRFS (Figure 3-6). The potential areas of local recharge shown on the map are approximated by areas where annual precipitation is greater than 8 in. Such areas occur mainly on the higher elevations of the Delamar Mountains in Kane Springs Valley and northern Coyote Spring Valley, and the Sheep Range along the western boundary of Coyote Spring Valley. Within the LWRFS, natural groundwater discharge occurs through springs and seeps, ET from riparian and phreatophytic vegetation, leakage to gaining streams of the Muddy River, and by surface and subsurface outflow (Figure 3-6). Most of this natural discharge occurs within the MRSA where groundwater contributing to the headwaters of the Muddy River leaves the flow system in the form of surface water along this stream. A portion of the groundwater bypassing the MRSA rejoins the Muddy River below the MR Moapa Gage; whereas, any remainder likely flows to the Colorado River through the subsurface (SNWA, 2009a; Burns and Drici, 2011).

4.0 NATURAL AND ANTHROPOGENIC STRESSES

Groundwater levels, spring discharges, and perennial streamflow in the LWRFS are affected by many natural and anthropogenic stresses. The effects of these stresses depend on their magnitude, duration, and frequency, and can be classified as short- or long-term.

4.1 Natural Stresses

Natural stresses on a given hydrologic system include precipitation, air temperature, barometric pressure, earth tides, and earthquakes. Barometric pressure, earth tides, and earthquakes are short-term effects and are not given further consideration in this analysis. Air temperature, which is a controlling factor of ET, changes seasonally causing seasonal fluctuations in ET which may affect groundwater levels and discharge. In the LWRFS and its tributary basins, precipitation is the main source of recharge and is, therefore, the main driver of its hydrology. The LWRFS is within the Nevada Extreme Southern climate zone (Division 4) as defined by the National Oceanic and Atmospheric Administration's (NOAA) Climate Divisional Database (Figure 4-1).

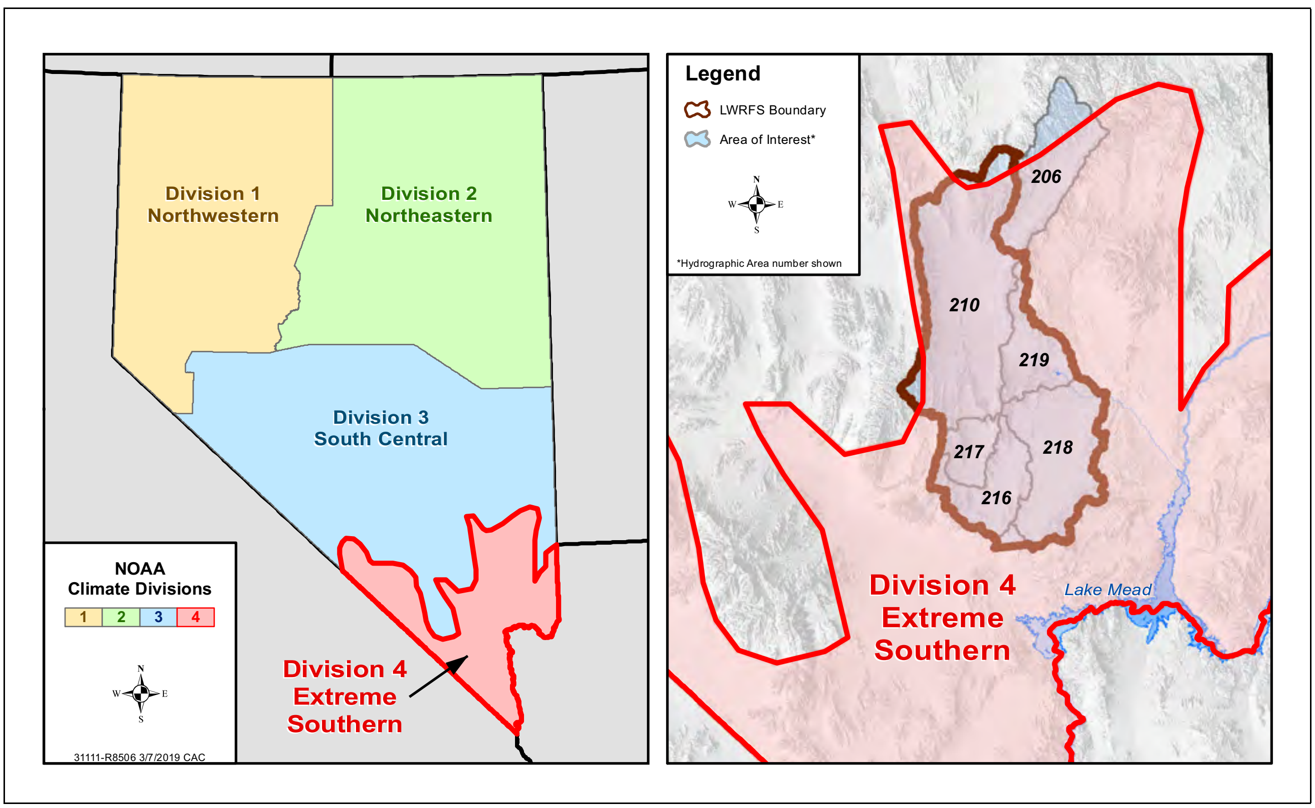

Figure 4-1
Nevada Division 4 Climate Zone

Divisional climate data are reported as average monthly values derived from daily climate observations within each climate division. Precipitation and air temperature data are of particular importance to the hydrology of the area of interest and were obtained from the on-line database (NOAA, 2019). Changes in precipitation can cause both short- and long-term effects in the groundwater levels and discharge from the area.

Annual precipitation data within Nevada Division 4 was compiled for the period 1895 to 2019. Winter precipitation in the LWRFS is understood to be the dominant source of local recharge. Winograd et al. (1998) demonstrated that winter precipitation (October through June) in the Spring Mountains of southern Nevada comprised two-thirds of the total precipitation for the area and was responsible for the majority of recharge to the hydrologic system, with summer precipitation comprising only a small fraction (perhaps 10 percent) of the recharge.

Division 4 winter-season precipitation, defined as the total precipitation occurring during the months of October through March, was used for the analyses presented in this report. These months were selected because most precipitation occurring during the warmer months (April through September) evaporates or is consumed by vegetation due to the high rates of potential ET, averaging 7.27 (ft/yr) from 2001 to 2012 at Overton, Nevada (Huntington et al., 2013). These rates are largely dependent upon air temperature. Based on the Division 4 period of record, the high temperatures for the months of April through September ranged from 64.1 to 104.4°F, averaging 89.9°F, while during the months of October through March, they ranged from 37.5 to 86.3°F, averaging 62.7°F. Figure 4-2 depicts the winter-season precipitation (October through March) from 1895 to 2019 with the data indicating a slight positive slope, or essentially no significant trend.

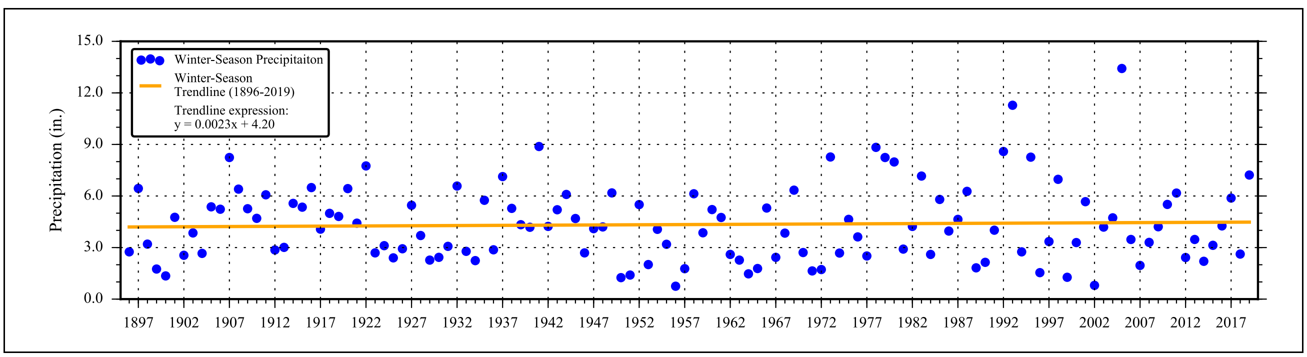

Figure 4-2
Climate Division 4 Precipitation with Trendline

Annual precipitation data were analyzed for the period 1990 to 2019, which is the period for which complete data sets are available for other LWRFS hydrologic and water-use records. Figure 4-3 presents the annual total precipitation as winter-season (October through March) and summer-season (April through September) totals. During this period, the winter- and summer-season precipitation averaged 4.60 and 2.58 in., respectively.

Precipitation data were evaluated by computing the annual percent of winter-season average for the period analyzed. These values are presented in Figure 4-3, with positive values (blue bars) representing above-average precipitation and negative values (red bars) representing below-average precipitation. There are several observations that can be made from Figure 4-3:

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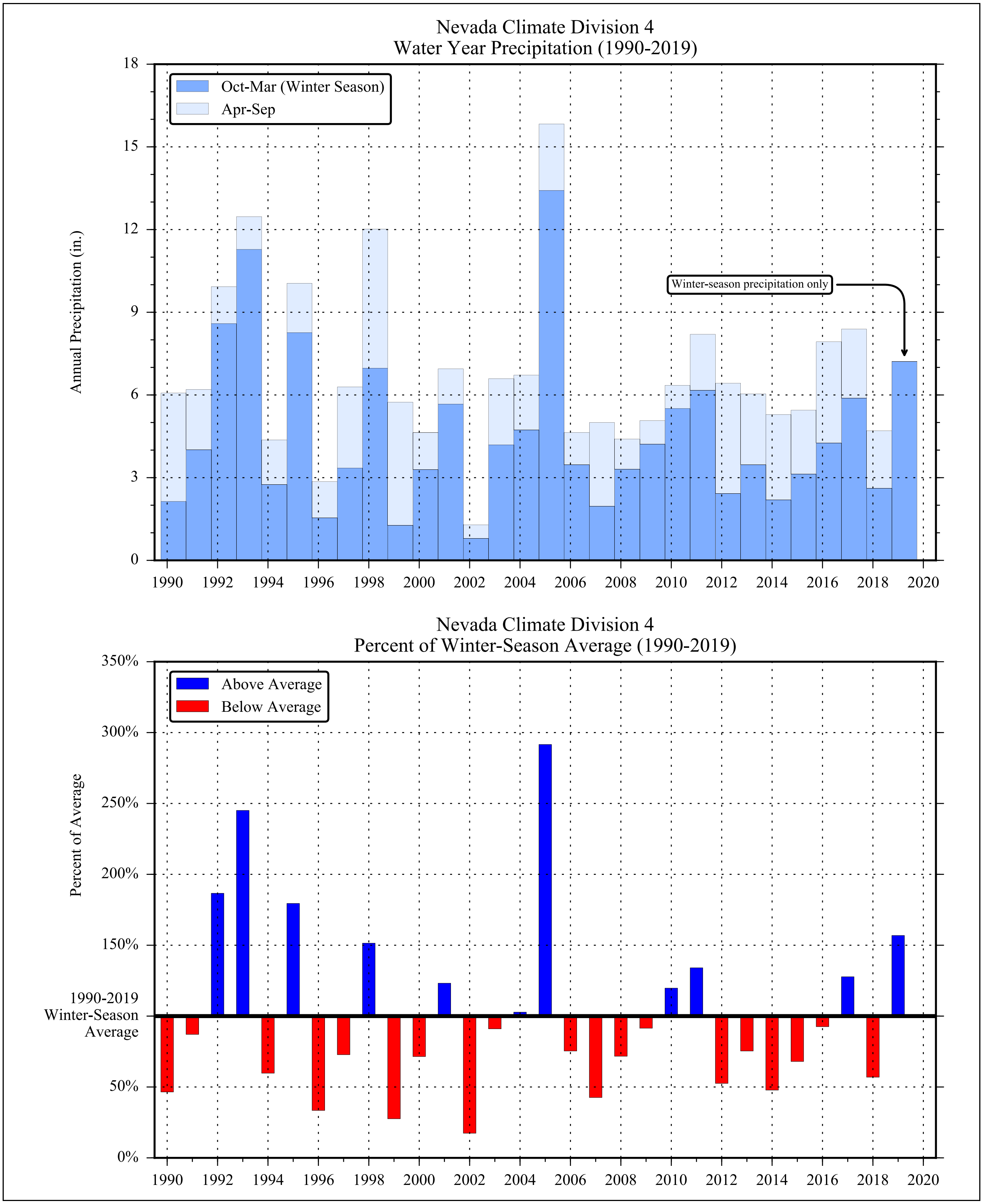

Figure 4-3
Nevada Climate Division 4 Precipitation

- Winter seasons of 1992, 1993, 1995, and 2005 were extraordinarily high, with values of 190, 250, 183 and 297 percent of average, respectively.
- Winter seasons of 1996, 1999, and 2002 were extraordinarily low, with values of 34, 28, and 18 percent of average, respectively.
- The period from 2006 through 2019 was mostly below average, with 10 of the 14 seasons below average.

4.2 Anthropogenic Stresses

The primary anthropogenic stresses that have influenced surface-water and groundwater conditions within the LWRFS include surface-water diversions above the MR Moapa gage, groundwater production from both the regional carbonate aquifer and MRSA alluvial reservoir, and land use. These stresses have occurred over different time periods and durations. Records of surface-water diversions, groundwater production, and groundwater levels were compiled from all available sources for the entire LWRFS. Historical information on MRSA land use and water development was assembled from the literature. The following sections present time-series data for MRSA surface-water diversions (see Figure 3-2 for locations) and groundwater production from the regional carbonate aquifer and the MRSA alluvial reservoir. The sources of data were described in Section 2.0.

4.2.1 Surface-Water Diversions above Muddy River near Moapa, NV Gage

There are three primary surface-water diversions above the MR Moapa gage that are of significance to this assessment. These are the MVWD diversions at the Pipeline-Jones and Baldwin springs, and the NVE Muddy River diversion directly above the gage. The locations of the diversions are depicted in Figure 3-2. The MVWD has diverted spring flow from the Pipeline-Jones and Baldwin springs since 1959 and 1975, respectively. Diversions by NVE began in 1968 when the agency started leasing decreed Muddy River water rights from the MVIC. The MVWD diversions supply water to users within the MVWD service area, primarily outside the MRSA. The NVE diversions were historically exported out of the MRSA to supply industrial uses at the Reid Gardner Generating Station in the California Wash basin. In addition, SNWA owns and leases surface-water rights above the gage, but water associated with the majority of these rights is not diverted and eventually flows into the Colorado River and Lake Mead for Tributary Conservation Intentionally Created Surplus (ICS) credits as discussed in detail in Section 7.0.

Detailed records of surface-water diversions by NVE and MVWD began in 1978 and 1992, respectively, and are provided in Table B-1 of Appendix B**.** Historically, these two entities have been the principal surface-water diverters above the MR Moapa gage. With the gradual closure of the Reid Gardner Generating Station, which began in 2014 and was completed in March 2017, NVE has not diverted surface water since 2015. There have been, and still are, minor diversions and uses of surface water above the gage by other water users. However, these diversions are small and no records exist to determine their quantity; therefore, they are not accounted for in this analysis. Figure 4-4 presents the historical surface-water diversions above the MR Moapa gage for the period in which records are available.

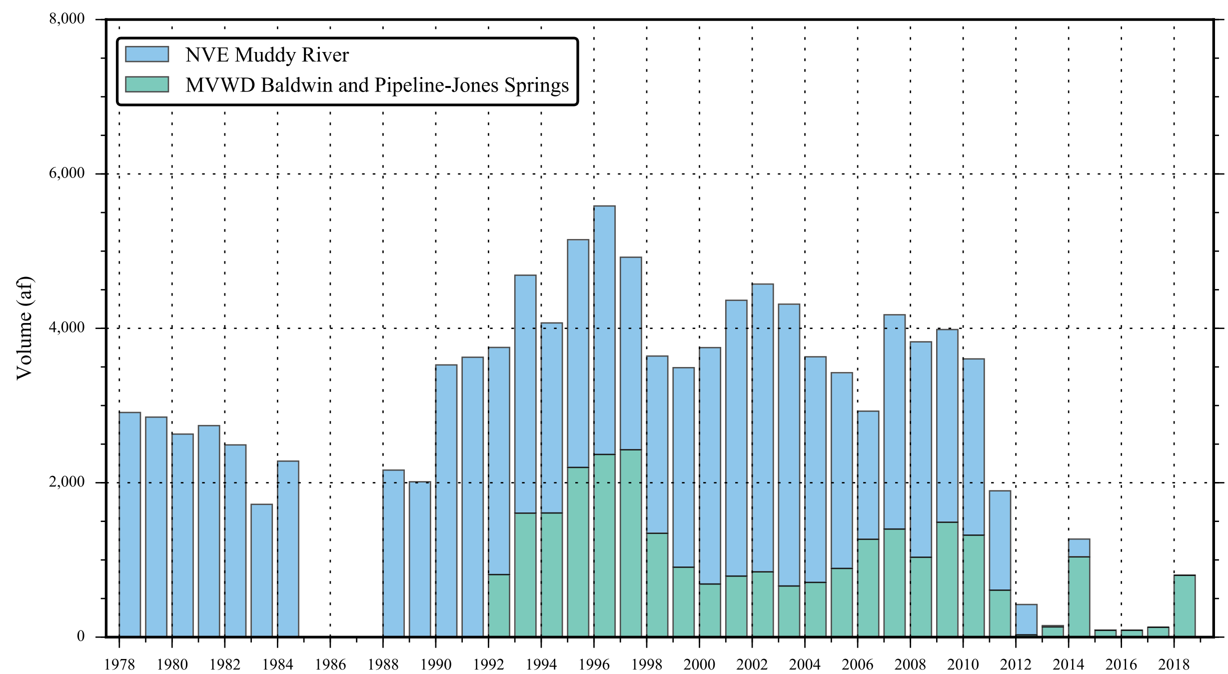

Figure 4-4
Surface-Water Diversions above the MR Moapa Gage

4.2.2 Groundwater Production

Groundwater is produced from two primary sources within the LWRFS: the MRSA alluvial reservoir and the regional carbonate aquifer underlying the six basins. As described in Section 3.4.2.2, the regional carbonate aquifer is also the source of water for the alluvial reservoir. Figure 4-5 depicts the locations of production wells within the LWRFS using symbology to differentiate between the sources (i.e., carbonate aquifer vs. basin fill). This section summarizes groundwater production from wells located within the MRSA and from wells located in the other LWRFS basins with completions in the carbonate aquifer.

4.2.2.1 Muddy River Springs Area

Groundwater production within the MRSA began around 1948 when the first well was constructed (Eakin, 1964; NDWR, 2018a). Eakin (1964) estimated groundwater production ranged from 2,000 to 3,000 af from about 12 wells completed in the alluvial reservoir as of 1964. The water was used for irrigation. Several of these wells (Lewis 1 through 5) were purchased by NVE and were used to supply water for the Reid Gardner Generating Station in the California Wash basin. NVE augmented the production from its Lewis well field using its Perkins and Behmer wells and by leasing water produced from three wells owned by the Corporation of the Presiding Bishop of the Church of Jesus Christ of Latter-Day Saints (LDS): LDS East, LDS Central, and LDS West. All of these production wells are completed to shallow depths in the alluvial reservoir ranging from 50 to 135 ft bgs. Well

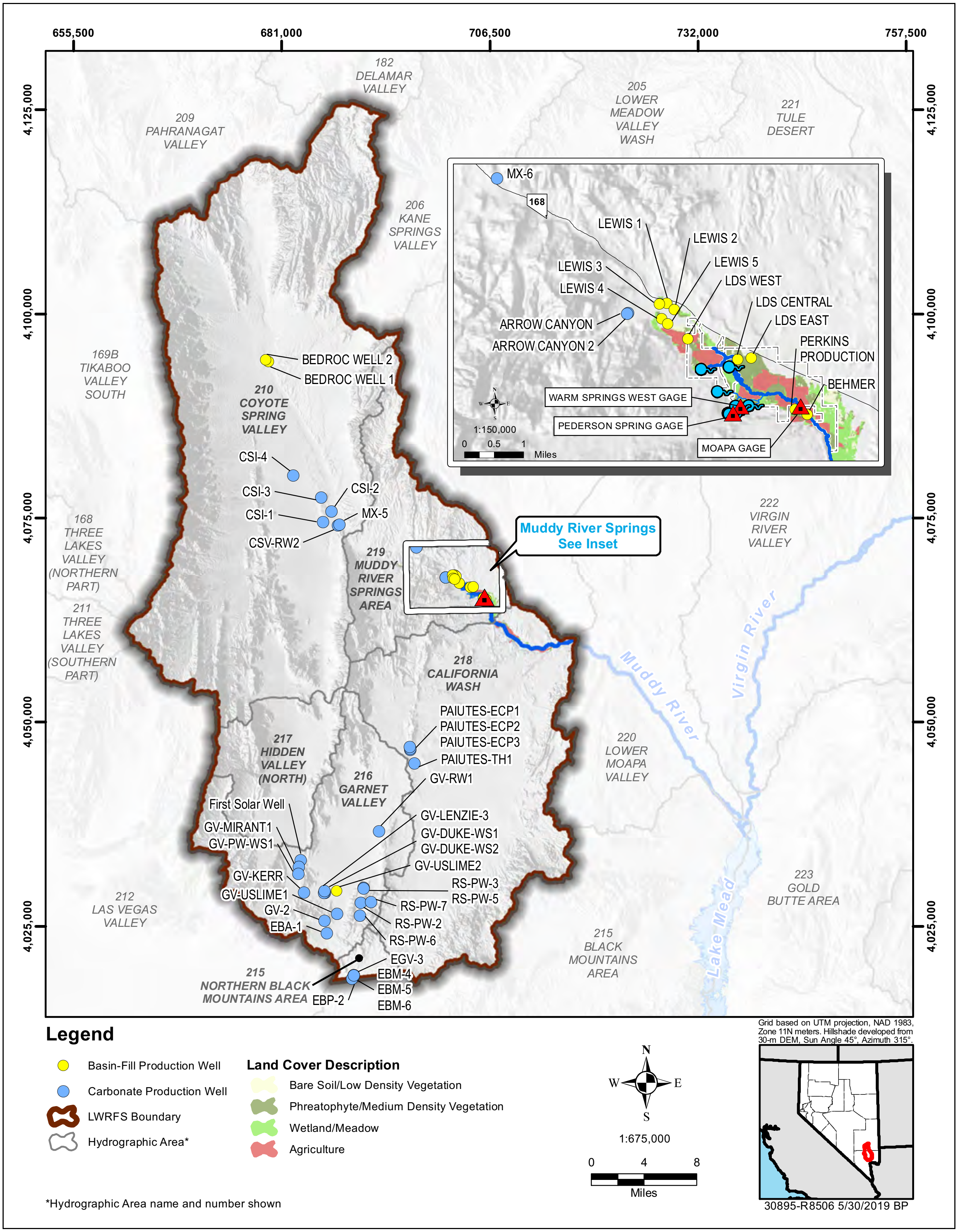

Figure 4-5
Locations of Production Wells in the LWRFS

construction details are provided in Table C-1 of Appendix C. NVE began reporting production data from these wells in 1987 (Table C-2 of Appendix C). Figure 4-6 presents the annual production from the wells grouped by well field (Lewis Wells, LDS Wells, and Perkins and Behmer wells).

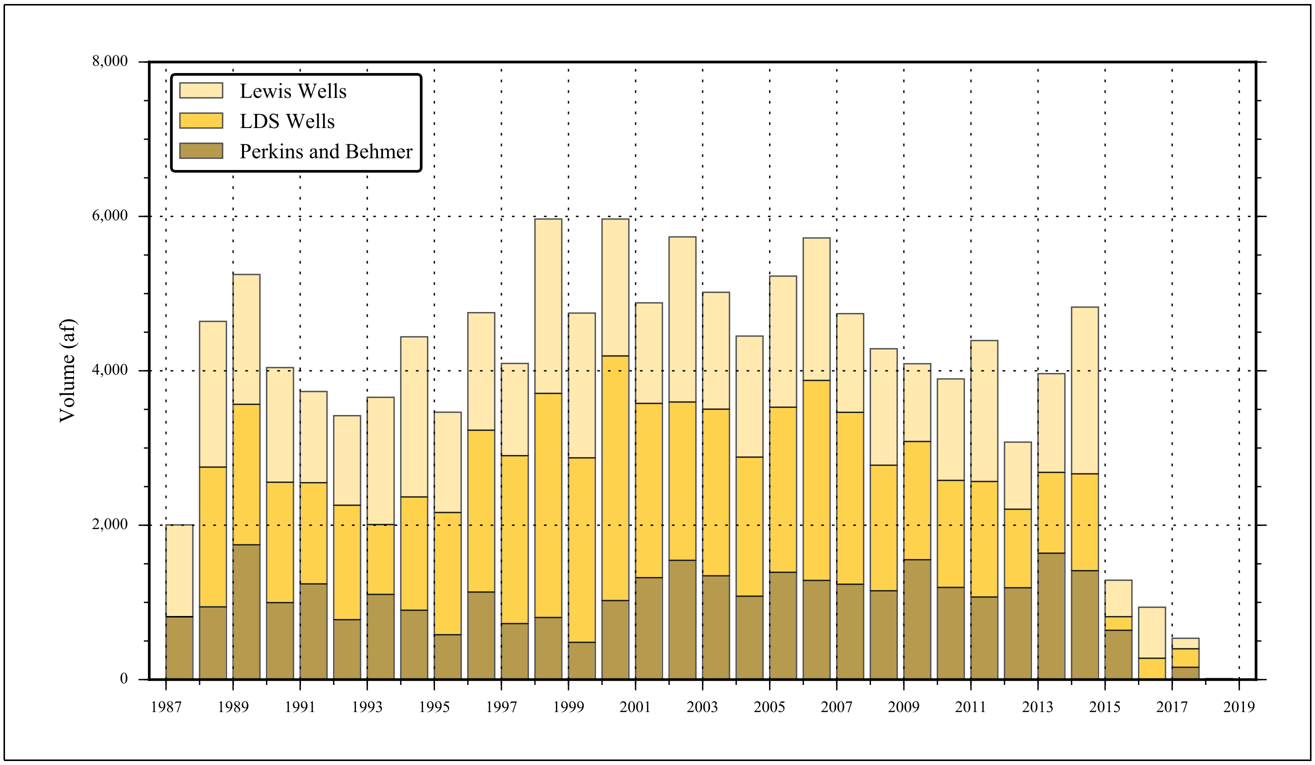

Figure 4-6
Annual Groundwater Production from the MRSA Alluvial Reservoir

Groundwater production by NVE constitutes the vast majority of production from the MRSA alluvial reservoir. However, there have been, and still are, other minor users within the area. These uses are small and no long-term records exist to determine their quantity; therefore, they were not accounted for in this analysis (2009c; 2011a and b; 2012a and b; 2013c; 2015b and c; 2016b; 2017b; 2018c; and NDWR, 2017; 2018b).

The MVWD produces groundwater from three wells completed in the regional carbonate aquifer within the MRSA. These wells, Arrow Canyon, Arrow Canyon 2, and MX-6, are located adjacent to and upgradient of the Muddy River headwaters (Figure 4-5). The wells are used to supply water for uses within the MVWD service area, primarily outside the MRSA. MVWD began reporting groundwater production totals from these wells in 1992 (Table C-2 of Appendix C). The groundwater production totals are presented in Figure 4-7 along with total production from the carbonate aquifer in the other LWRFS basins.

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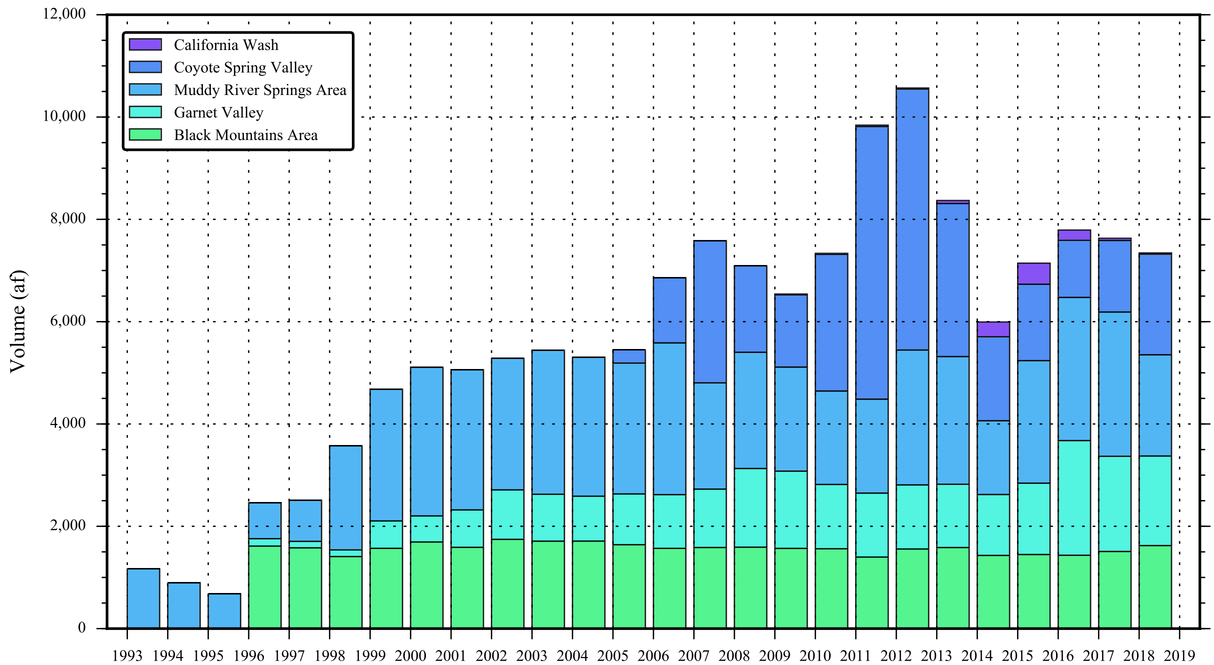

Figure 4-7
Carbonate-Aquifer Groundwater Production

4.2.2.2 Carbonate Aquifer

As described in Section 3.4.2.1, the LWRFS is defined by the interconnected nature of the underlying carbonate aquifer that provides hydraulic continuity between the basins. Production wells completed in the carbonate aquifer have some of the highest yields making it an attractive water-supply source. As a result, there has been significant development of the aquifer in various locations throughout the LWRFS. As stated in Section 1.0, one of the objectives of this assessment is to evaluate how the aquifer has responded to different stresses, in particular the long-term pumping stresses. This section summarizes annual groundwater production from the carbonate aquifer by LWRFS basin. The locations of the associated production wells are depicted in Figure 4-5. Site information and well construction data for these wells are provided in Table A-1 of Appendix A.

Coyote Spring Valley

Groundwater production started in 2005 when CSI began using water for construction purposes related to their Coyote Springs development. CSI has constructed four wells, CSI-1, CSI-2, CSI-3, and CSI-4, and has used them to support operation and maintenance of an 18-hole golf course and implementation of the NSE Order 1169 aquifer test. SNWA owns and operates the MX-5 well which was used as the primary production well during the NSE Order 1169 aquifer test. Annual production volumes for Coyote Spring Valley are provided in Table C-4 of Appendix C.

Garnet and Hidden Valleys

Groundwater production in Garnet Valley has predominantly been associated with mineral mining, electrical power generation, and industrial uses. There are several utility companies that lease groundwater rights owned by SNWA who have constructed production wells and operate them to supply water for industrial uses at their respective facilities. These entities report monthly production totals to SNWA who in turn reports them to NDWR on a quarterly basis. In addition, Republic Services operates several wells in support of their landfill operations in the southeast part of the valley, however, records are unavailable prior to 1999. Records for well EBA-1 are unverified for the period 1996 to 2000, and unavailable for wells GV-USLIME 1 and 2, Harvey, and GV-KERR prior to 1999. There has been no groundwater development in Hidden Valley. Annual production volumes for Garnet Valley are provided in Table C-4 of Appendix C.

Black Mountains Area

There are several wells completed in the carbonate aquifer in the northern portion of the Black Mountains Area that is a designated part of the LWRFS. Two of these wells, owned by Dry Lake Water, were constructed as production wells but have never been operational. The other wells, owned by Nevada Cogeneration Associates, have been used to supply water to a power generating station. Annual production volumes for the Black Mountains Area of the LWRFS are provided in Table C-4 of Appendix C.

California Wash

The MBOP has produced groundwater in the California Wash basin to supply municipal uses. Production has been relatively small as compared to other uses in the LWRFS. Annual production volumes for California Wash basin are provided in Table C-4 of Appendix C.

5.0 HYDROLOGIC RESPONSES

Using the time-series data compiled in Sections 3.0 and 4.0, hydrologic responses to natural and anthropogenic stresses were evaluated for the LWRFS. First, observed declines in Muddy River streamflow were evaluated. Second, responses to climate variability and carbonate-aquifer groundwater production were evaluated for representative wells in the LWRFS and high-elevation springs in the MRSA.

5.1 Evaluation of Muddy River Streamflow Declines

The Muddy River streamflow is measured near Moapa, NV as described in Section 3.4.1 and depicted in Figure 3-5. The flood-adjusted flow record was used in this analysis and compared to the average annual pre-development baseflow of 33,900 afy. By this comparison, a long-term trend of decreasing streamflow since the early 1960s was identified. The disparity between the pre-development baseflow and gage record indicates there have been factors impacting the flow over time. These may include one or more of the following: (1) climate variability, (2) changes in land use above the gage, (3) surface-water diversions above the gage, and (4) capture of spring and streamflows by production wells. These factors are evaluated in the following sections.

5.1.1 Climate Variability

To investigate the effects of climate variability on Muddy River streamflow, an evaluation of the historical precipitation record was performed. Only precipitation is considered in this analysis because it is the main climate variable affecting hydrology in the study area.

The winter-season precipitation record from 1895 to 2019 presented in Figure 4-2 was analyzed and a simple-linear regression indicated a positive slope, but essentially no trend. The precipitation record was also used to assess climate conditions before and after 1965. This year was selected to distinguish two periods of record for analysis that represented pre- and post-exports of water from the area, even though groundwater production in the MRSA had already been occurring since around 1947 (Eakin, 1964). Eakin (1964) reported that the groundwater production during this intervening period was relatively small, and had no discernible affect on the gage record.

The average annual winter-season precipitation was computed for each period and used as a metric to evaluate climate differences. The average annual winter-season precipitation was 4.17 and 4.50 in/yr, pre- and post-1965, respectively. Based on these values and because the post-1965 average is slightly higher, it is concluded that the historical trend in climate conditions have not been a primary factor causing the long-term trend of declining streamflow. The seasonal and annual variations in precipitation and temperature may, however, partly explain the short-term variability observed in the streamflow record.

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5.1.2 Historical Land Use in the MRSA

Pre-development ET within the MRSA was estimated to be between 2,000 and 3,000 afy (Eakin, 1964). Land-use changes presumably have some impact on the consumptive use of water due to an increase or decrease in vegetative cover. An increase in vegetative cover would increase consumptive use, making less water available in the system. Conversely, if vegetative cover decreased, consumptive use would also decrease, and more water would be available. Examples of land-use change include:

- replacing natural vegetation with agriculture lands
- fallowing agricultural lands
- restoring natural landscapes (e.g., removal of palm trees and replacing with natural vegetation)
- fires
- stream restoration

To evaluate conditions in the MRSA and the influence of land-use changes in the early 2000s, SNWA funded the Desert Research Institute to compile and analyze satellite imagery and associated vegetation indices to estimate ET for the period 2001 through 2012 (Huntington et al., 2013). The main objectives of the study were "*to identify trends in ET over the study period of 2001-2012 to identify potential impact on ET due to land management and vegetation changes (Huntigton et al., 2013)*". The study area encompassed the spring complexes, agricultural lands, and phreatophytes within the Muddy River headwaters, where most of the changes have occurred.

The study applied two methods to derive ET estimates. The first method used Mapping EvapoTranspiration at high Resolution with Internalized Calibration (METRIC), and the second used the Normalized Difference Vegetation Index (NDVI). Both methods relied upon Landsat multispectral data. Precipitation was subtracted from the ET estimates to yield results that are more comparable from one year to the next, and also allow for the evaluation of changes independent of precipitation influences.

The study results for each method are presented in Figure 5-1 which depicts the annual ET reduced by annual precipitation for the study period. High and low values are observed in the estimates from both methods and correspond with observed conditions that would be expected to have an impact on ET rates in the area. The high estimate of 2005 is associated with increased vegetation density due to above normal precipitation. Even though the precipitation falling directly on the ET area was subtracted from the ET volume, the effects of the extraordinarily large precipitation of 2005 can be seen in Figure 5-1. These effects are due to the increased recharge resulting from the extraordinary precipitation that raised groundwater levels; thereby, increasing water availability to vegetation in the area. During 2004-2005, precipitation was about 300 percent of the 2001-2012 average. The low estimate of 2010 is associated with a major fire that burned more than 600 acres. During the years analyzed, other more gradual and subtle changes occurred involving landscape restoration and the removal of palm trees and weeds in the Warm Springs Natural Area. These changes may have contributed to the decline observed over the analysis period.

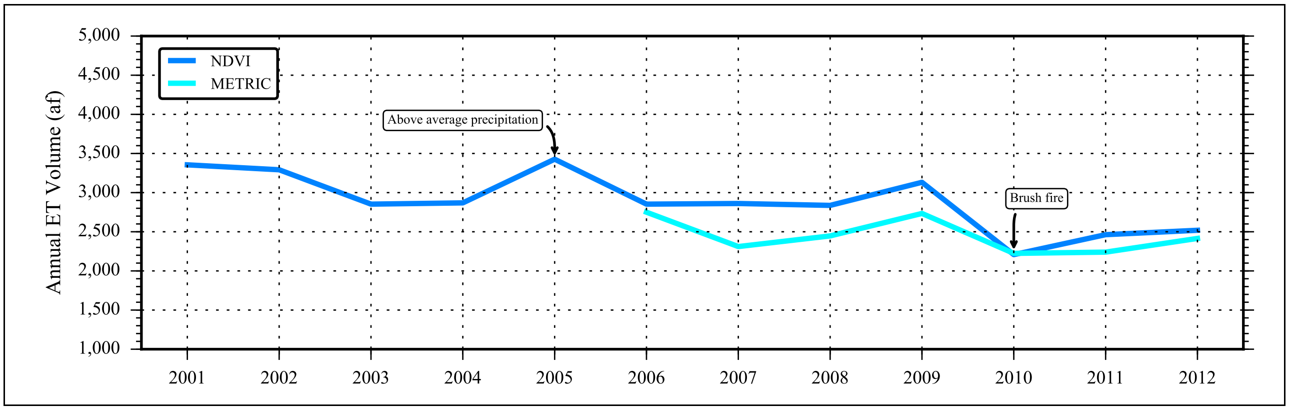

Figure 5-1
Annual ET Reduced by Precipitation for Muddy River Springs Area (2001 - 2012)

Although there were land-use changes observed during the years analyzed, the range of ET estimates closely aligns with the pre-development estimate of Eakin (1964). Estimates ranged from about 2,200 to 3,400 afy, and the estimates declined over the period of analysis by about 600 to 900 afy based on the METRIC and NDVI methods, respectively. These changes are relatively small compared to the measured flow of the Muddy River and appear to be within the range of seasonal variability observed during the period of pre-development baseflow from 1945 to 1955 (Figure 3-5).

5.1.3 MRSA Surface-Water Diversions

A natural-flow record was constructed for the period 1993 through 2018 by adding the total annual diversions above the MR Moapa gage to the flood-adjusted record (Figure 5-2). This period of record was selected because diversion data for the years prior to 1993 were incomplete or based on estimated values as opposed to metered records.

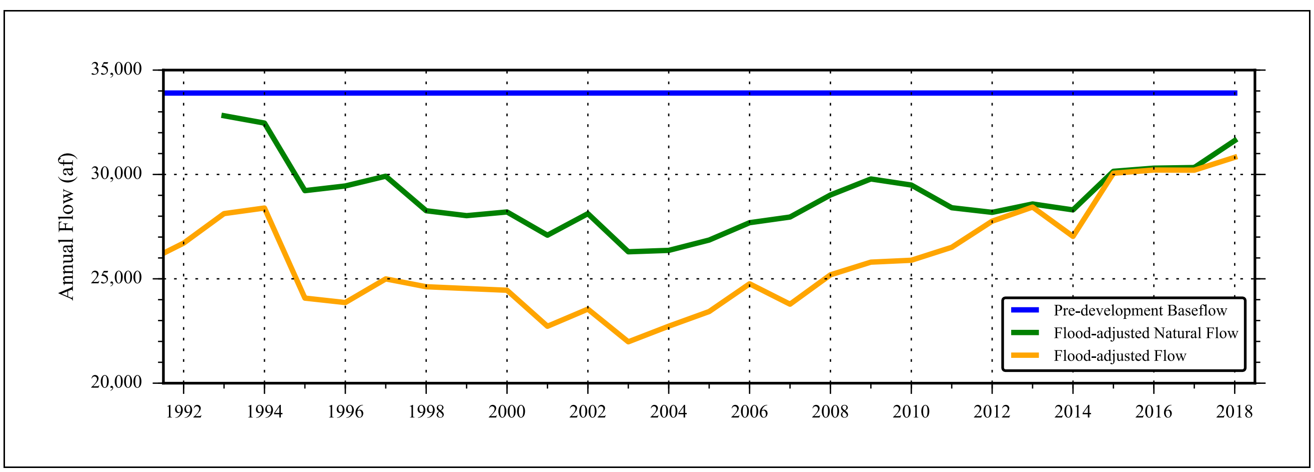

Figure 5-2
Natural Flow Record at MR Moapa Gage (1993 - 2018)

The diversion data used to construct the natural flow record include the MVWD diversions at Baldwin and Pipeline-Jones springs and the NVE diversion directly above the gage (Figure 4-4).

Water associated with these diversions was exported out of the basin to supply municipal uses within the MVWD service area and NVE industrial uses in California Wash basin. Figure 5-2 compares the natural flow record to the pre-development baseflow flow of 33,900 afy. Long-term climate variability and MRSA land-use were determined not to be primary factors causing the long-term trend of declining streamflow. Therefore, the difference between the pre-development baseflow and the natural flow record must be mostly associated with groundwater production within the MRSA.

5.1.4 MRSA Groundwater Production

MRSA groundwater production and its influence on Muddy River streamflow was evaluated by quantifying the difference between the pre-development baseflow, 33,900 afy, and the natural flow record (hereinafter referred to as the "MR Flow Deficit" depicted in Figure 5-3), and determining whether the difference and source of the deficit is equivalent to the annual groundwater production within the MRSA. Like the surface-water diversion data, groundwater-production records from 1993 through 2018 were used in the analysis.

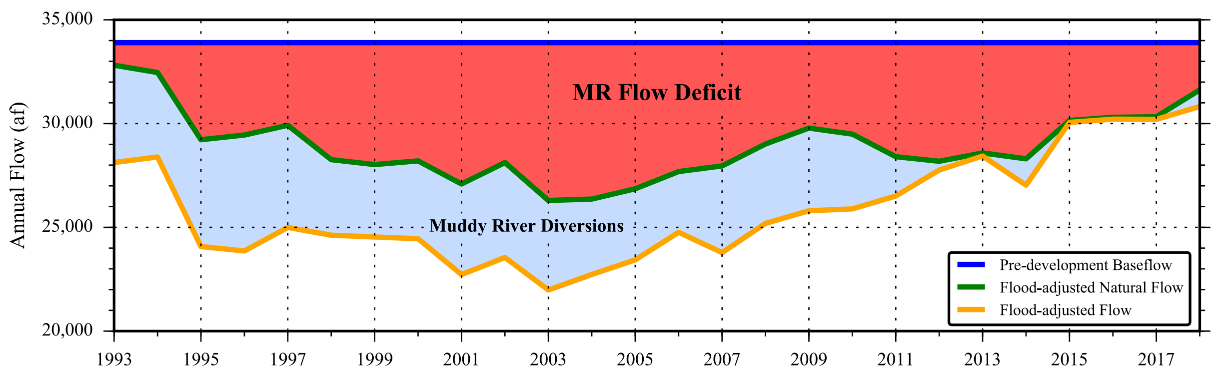

Figure 5-3
MR Flow Deficit (1993 - 2018)

As described in Section 4.2.2.1, there are several alluvial wells in the MRSA that are completed to shallow depths within the headwaters of the Muddy River. NVE has operated these wells to supply water for industrial uses in California Wash basin. Operation of the wells creates cones of depression that induce flow to the wells, capturing water from alluvial-reservoir storage, springs, and seeps on the valley floor, and gaining stream reaches above the gage. Conceptually, the wells capture water that would otherwise compose the flows measured at the gage during pre-development conditions. The locations of these wells and their historical production are presented in Figures 4-5 and 4-6, respectively.

In addition to the shallow alluvial wells operated by NVE, MVWD operates three municipal wells within the MRSA and northwest of the alluvial basin (i.e., Arrow Canyon, Arrow Canyon 2, and MX-6). These wells produce groundwater to supply municipal uses within the MVWD service area, but primarily to locations outside the MRSA. The locations of these wells and their historical production are presented in Figure 4-5 and 4-7, respectively.

Figure 5-4 presents a time-series chart of the annual MR Flow Deficit and MRSA groundwater production. Production from two wells, Perkins and Behmer, was excluded from the total because of their location in proximity to the MR Moapa gage. These wells are located downstream of the gage and are unlikely to influence the streamflow above the gage. As Figure 5-4 illustrates, groundwater production within the MRSA appears to fully account for the MR Flow Deficit observed for the period of analysis. Included on the chart is groundwater production by CSI and SNWA from production wells located farther away within Coyote Spring Valley and upgradient of the MRSA.

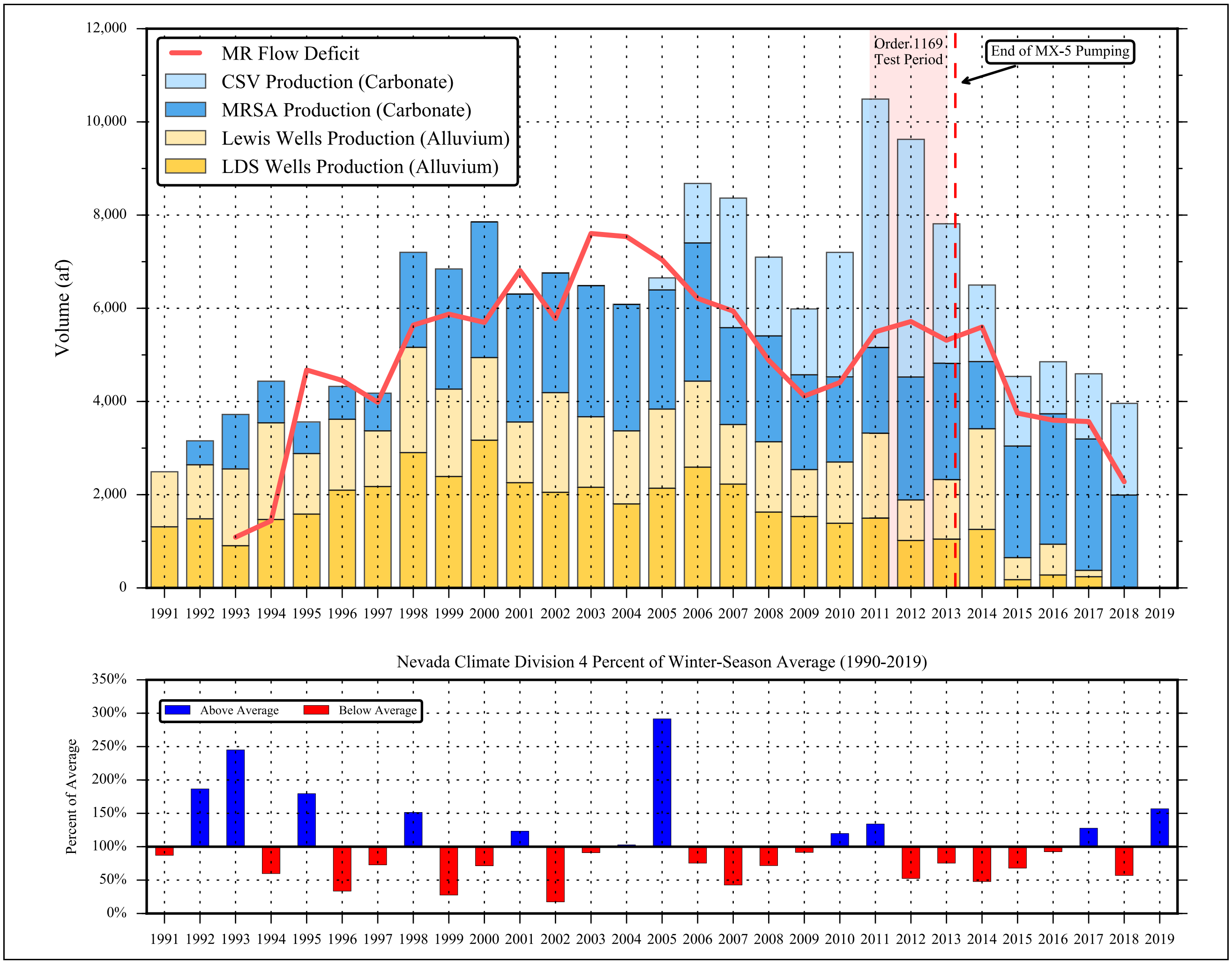

Figure 5-4
MR Flow Deficit and Coyote Spring Valley and MRSA Groundwater Production

There are certain years when the MR Flow Deficit appears to be too low (1993 and 1994) or too high (2003 and 2004) with respect to the annual groundwater production. This can be explained, in part, by the fluctuations in Muddy River streamflow caused by short-term variability in climate conditions as compared to the constant pre-development baseflow. During years of above average flow, the MR Deficit is apparently low because the difference between the pre-development baseflow and the above-average streamflow is smaller. Conversely, in years that the streamflow is below average, the MR Flow Deficit is apparently high because the difference is larger.

Regardless of the streamflow variability, the results of this analysis conclusively demonstrate the prominent impacts MRSA groundwater production has on MR streamflow. Groundwater production from the MRSA alluvial reservoir depletes MR streamflow on a 1:1 basis because the production wells are located within the MR headwaters and capture water that would otherwise flow into the river and past the MR Moapa gage. This is supported by the fact the production volumes fall beneath the MR Flow Deficit line as depicted in Figure 5-4. In similar fashion, MRSA production wells completed in the carbonate aquifer capture water that would otherwise replenish the alluvial reservoir through diffuse subsurface flow or contribute to MR streamflow via discrete springs. Capturing this groundwater ultimately depletes the source of supply to the alluvial reservoir and springs; thereby, depleting the MR streamflow. Based on the accounting depicted in Figure 5-4, the MRSA carbonate production wells have depleted MR streamflow approaching a 1:1 basis.

5.2 Carbonate-Aquifer Responses to Climate Variability and Pumping Stresses

Throughout the LWRFS, there are many groundwater sites that are monitored and provide information on groundwater conditions regarding the carbonate aquifer. These sites include production and monitor wells completed in the carbonate aquifer and various springs in the MRSA. In this section, a comparison of the hydrologic responses at selected wells and springs representative of the carbonate aquifer is presented. The comparison is followed by an analysis of the responses to climate variability and groundwater production.

5.2.1 Comparison of Hydrologic Responses

The comparison of the hydrologic responses at selected wells and springs representative of the carbonate aquifer was performed first by a visual examination of the hydrographs. Second, where correlations appear to exist, they were further analyzed, quantified and interpreted.

Time-series charts of water-level data for representative carbonate wells located in each of the basins composing the LWRFS were constructed and are presented in Figure 5-5 for wells CSVM-1, EH-4, PAIUTES-TH2, GV-1, and BM-DL-2. Based on a review of all of the data, most hydrographs exhibit very similar patterns. The only apparent exception is within Coyote Spring Valley for wells CSVM-3, CSVM-4, and CSVM-5, and within Kane Springs Valley for well KMW-1. Wells CSVM-3 and CSVM-5 are different because of their geologic setting and completion in the upthrown structural blocks of the southern Delamar Mountains and Sheep Range, respectively, as described in Section 3.4.2. Wells CSVM-4 and KMW-1 are completed within the Kane Springs fault zone. Time-series charts for these four wells are presented in Figure 5-6. The hydrograph for well CSVM-1 is included for comparison. As Figure 5-6 illustrates, the responses observed in CSVM-3 and CSVM-5 are distinctly different. The responses of wells CSVM-4 and KMW-1 are similar to those of other wells in the basin, but appear to be slightly attenuated by the Kane Springs fault.

Time-series charts of discharge data for springs located in the MRSA discharge area were constructed and evaluated. Records at the Pederson Spring and the Warm Springs West gage are used as indicators of how changes in aquifer conditions affect discharge from the regional springs in the area. These records are described in detail in Section 4.0 and are presented in Figure 5-7 with the percent of average winter-season precipitation and groundwater production from the carbonate aquifer. The

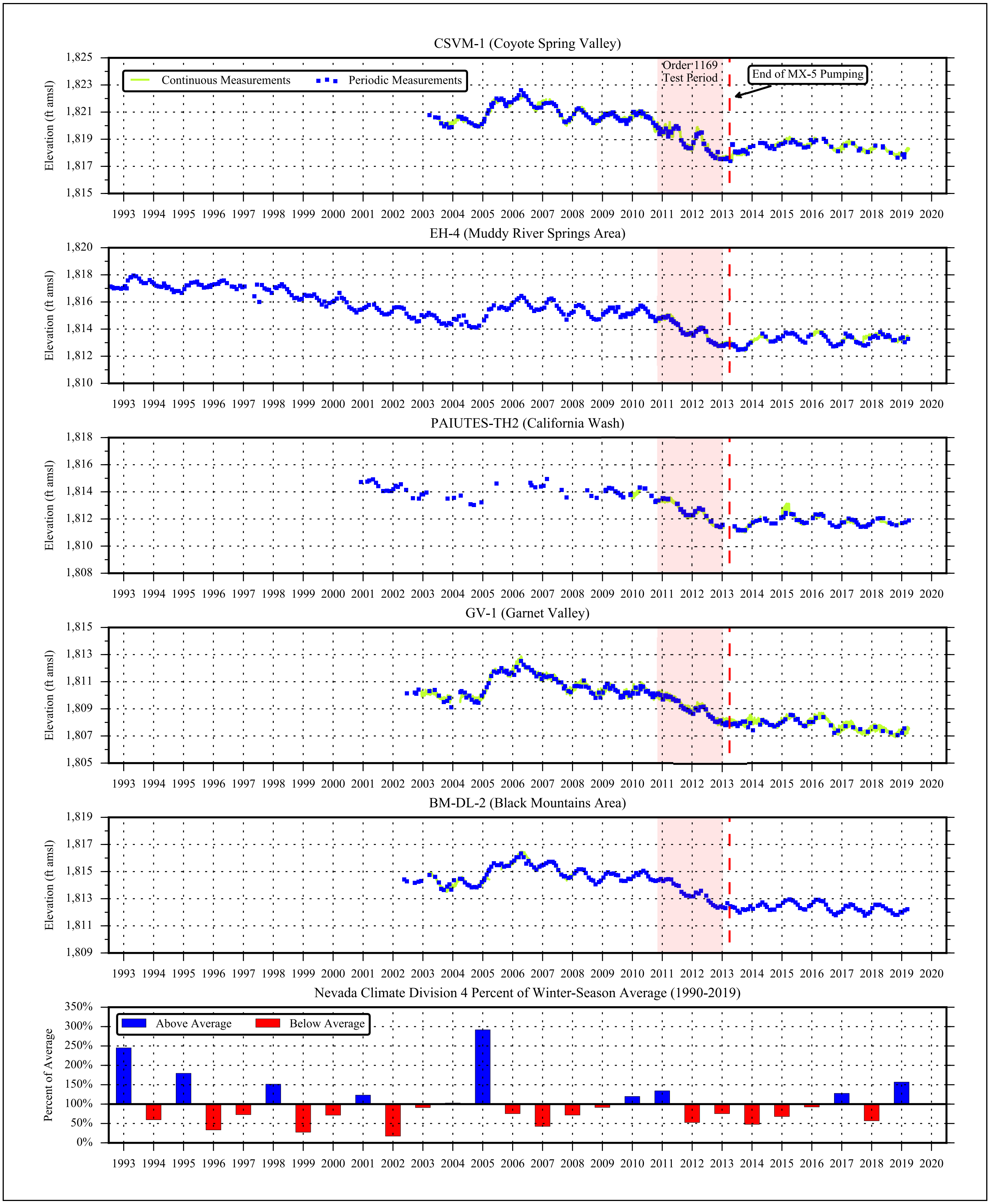

Figure 5-5
Water-Level Responses in Representative Carbonate Wells

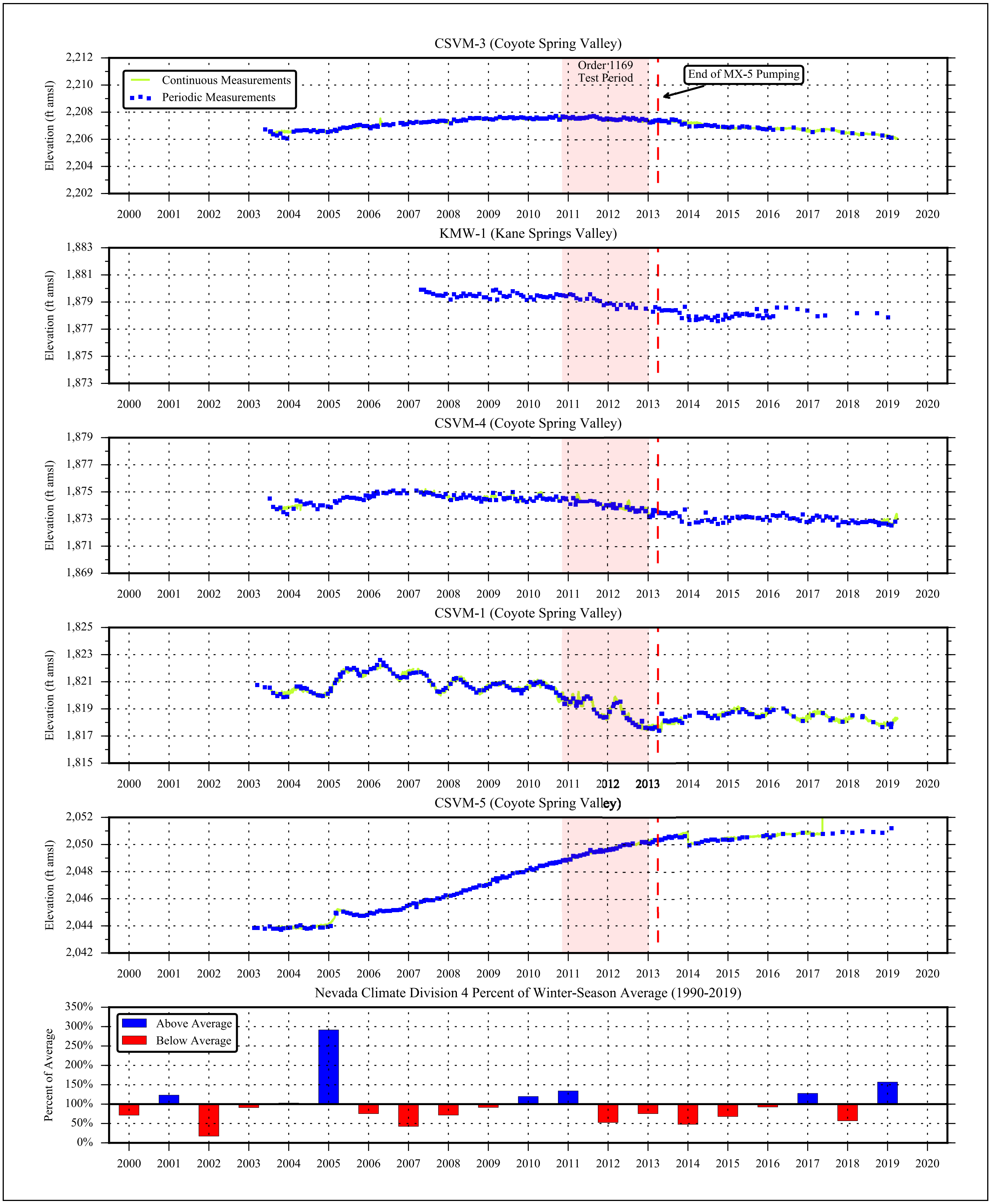

Figure 5-6
Water-Level Responses in Representative Carbonate Wells

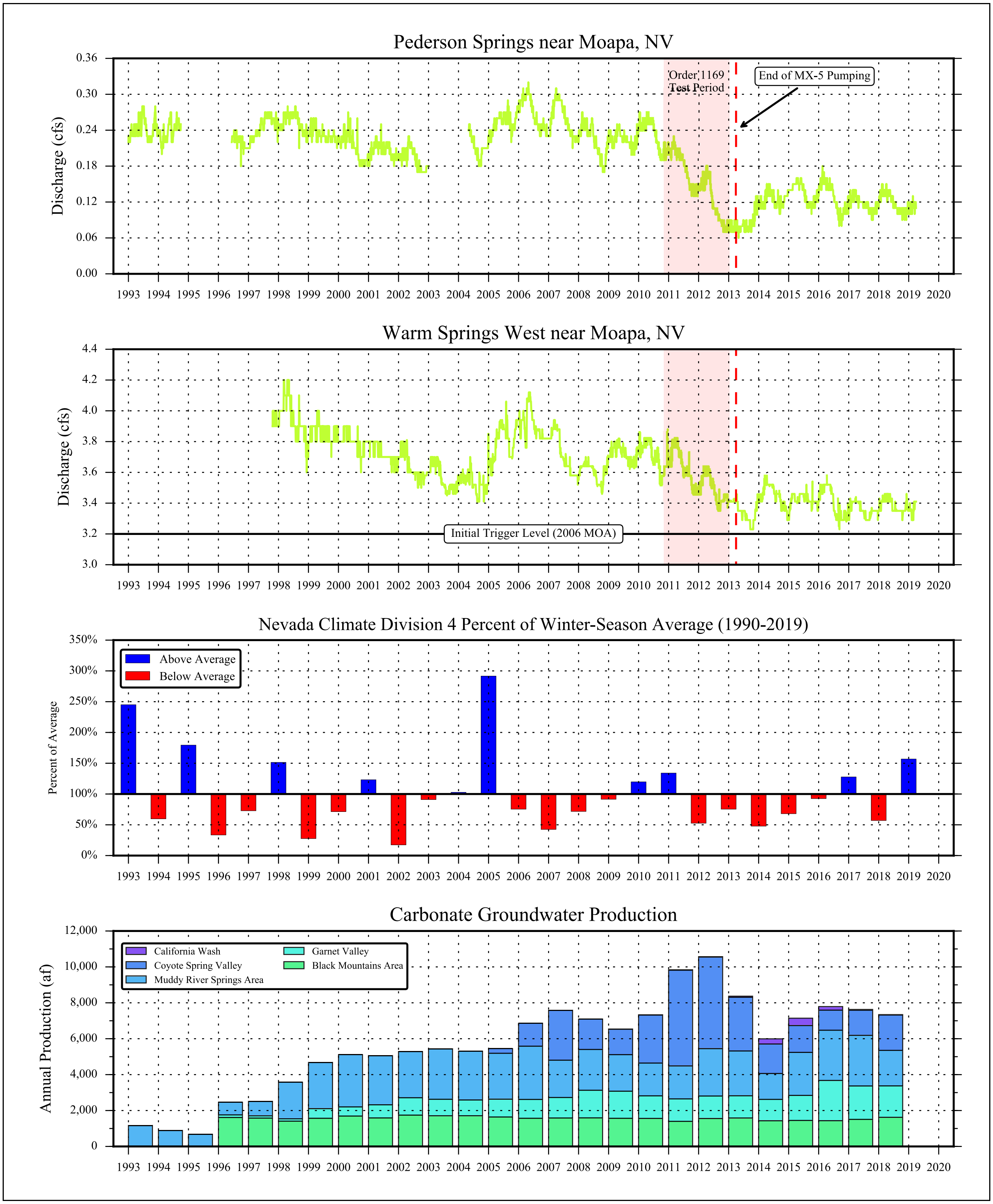

Figure 5-7
MRSA Spring Discharge and Carbonate-Aquifer Groundwater Production

gage records respond in the same manner as the interconnected carbonate-aquifer water levels shown in Figure 5-5. A similar response was expected because it is known that the carbonate aquifer is the source of the spring discharge. The connection was further confirmed by a quantifying the correlation between aquifer levels and spring discharge.

The correlation between the hydraulic head in the carbonate aquifer and spring discharge can easily be derived using the data available for selected wells and springs. Carbonate well EH-4 located in the MRSA was selected to represent the hydraulic head in the carbonate aquifer. Correlations between EH-4 water-level elevations (i.e., hydraulic head) and the discharge records from the Pederson Spring and Warm Springs West gages were analyzed. Using the continuous data records, average monthly values were derived for both the hydraulic head and discharge. For Pederson Spring, the period from 2004 to 2018 was used, excluding previous years during which the record was compromised as described in Section 3.4.1. For the Warm Springs West gage, the period from 1997 to 2018 was used. The discharge data were plotted against the hydraulic head data and the results are presented in Figures 5-8 and 5-9 for Pederson Spring and Warm Springs West gages, respectively. As expected, the relationships between discharge and carbonate head are linear with very high correlations, R^2=0.97 for Pederson Spring and R^2=0.89 for the Warm Springs West gage. The high correlations also confirm that the hydraulic head in the carbonate aquifer is the main driver of spring discharge for the selected springs. The scatter is most likely caused by measurement errors particularly in the spring discharge. The slopes of the straight lines indicate the correspondence between changes in EH-4 levels and spring discharge. A one-foot change in EH-4 level causes changes in discharge of about 0.058 cfs for Pederson Spring and about 0.16 cfs for the Warm Springs West gage.

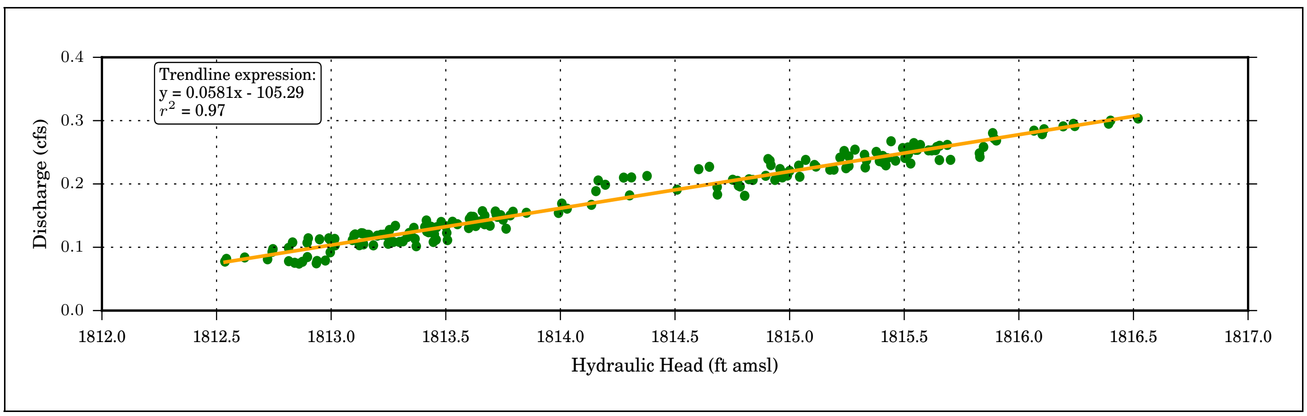

Figure 5-8
Correlation between Hydraulic Head at Well EH-4 and Discharge at Pederson Spring near Moapa, NV Gage

The USFWS developed the same relationships for Pederson Spring, Pederson East and the Warm Springs West gages using monthly data for 2002 to 2012 (USFWS et al., 2013). They separated the responses between 2 periods: 2002 to 2012 and the overlapping period of the 2-year aquifer test. The correlations they derived between spring discharge and the EH-4 hydraulic head were also very high, but also exhibited scatter most likely due to discharge measurement errors. The relationships developed using the 2-year aquifer test data had higher correlations because more accurate measurements of discharge were available for that time period (USFWS et al., 2013). These

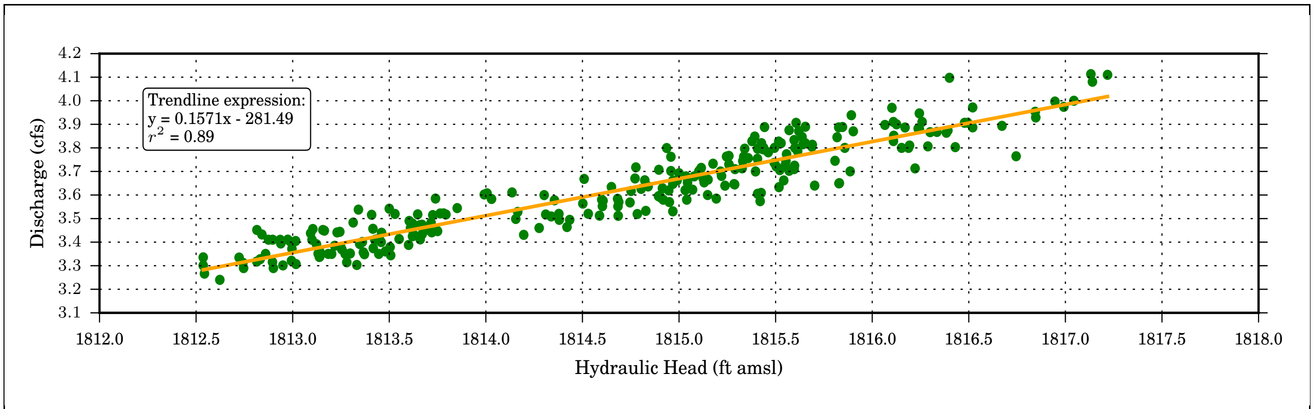

Figure 5-9
Correlation between Hydraulic Head at Well EH-4 and Discharge at Warm Springs West near Moapa Gage

relationships clearly demonstrate a direct connection between the carbonate head and spring flow for these specific sites.

Given that the EH-4/spring discharge correlations are high, it follows that the responses observed at carbonate wells could be correlated to that of EH-4 to assess if their responses are caused by the same stresses affecting the spring discharge. High correlation would also further confirm the hydraulic connectivity of the LWRFS. Correlations between water-level elevations of representative carbonate wells and well EH-4 were developed as follows. Average monthly values of hydraulic head were derived using water-level elevation records of the representative carbonate wells. The average monthly hydraulic heads of wells CSVM-1, BM-DL-2, PAIUTES-TH2, GV-1, CSVM-4 and MX-4 were plotted against EH-4 and the results are presented in Figure 5-10. EH-4 was selected as the focal carbonate well because of its long period of record, and its proximity to the MRSA discharge area. The periods used for the correlation analysis varied by well and were defined by the availability of data: PAIUTES-TH2 from 2000 to 2019, BM-DL-2 and GV-1 from 2002 to 2019, CSVM-1 from 2003 to 2019, CSVM-4 from 2003 to 2019, and MX-4 from 1987 to 2019. The relationships between the hydraulic head of carbonate wells in the LWRFS are linear and have very high correlations that range from R^2=0.82 to R^2=0.97. As these charts illustrate, groundwater levels respond in the same manner to natural and anthropogenic stresses throughout the LWRFS. The responses are indicative of a high degree of hydraulic connection within the aquifer and across all of the basins.

5.2.2 Responses to Climate Variability

Responses of selected wells and springs to climate variability were evaluated. As stated before, winter-season precipitation was the variable selected to represent climate because it is the main driver of natural recharge. The time-series charts shown in Figures 5-5, 5-6 and 5-7 are presented with precipitation data from the Nevada Division 4 as described in Section 4.1. In these figures, annual winter-season precipitation is represented as a percentage of average winter-season precipitation for the period 1990 through 2019.

The charts shown in Figures 5-5 and 5-6 illustrate the seasonal responses of groundwater levels to recharge pulses, with levels typically achieving their annual peak in April. The amplitudes of these

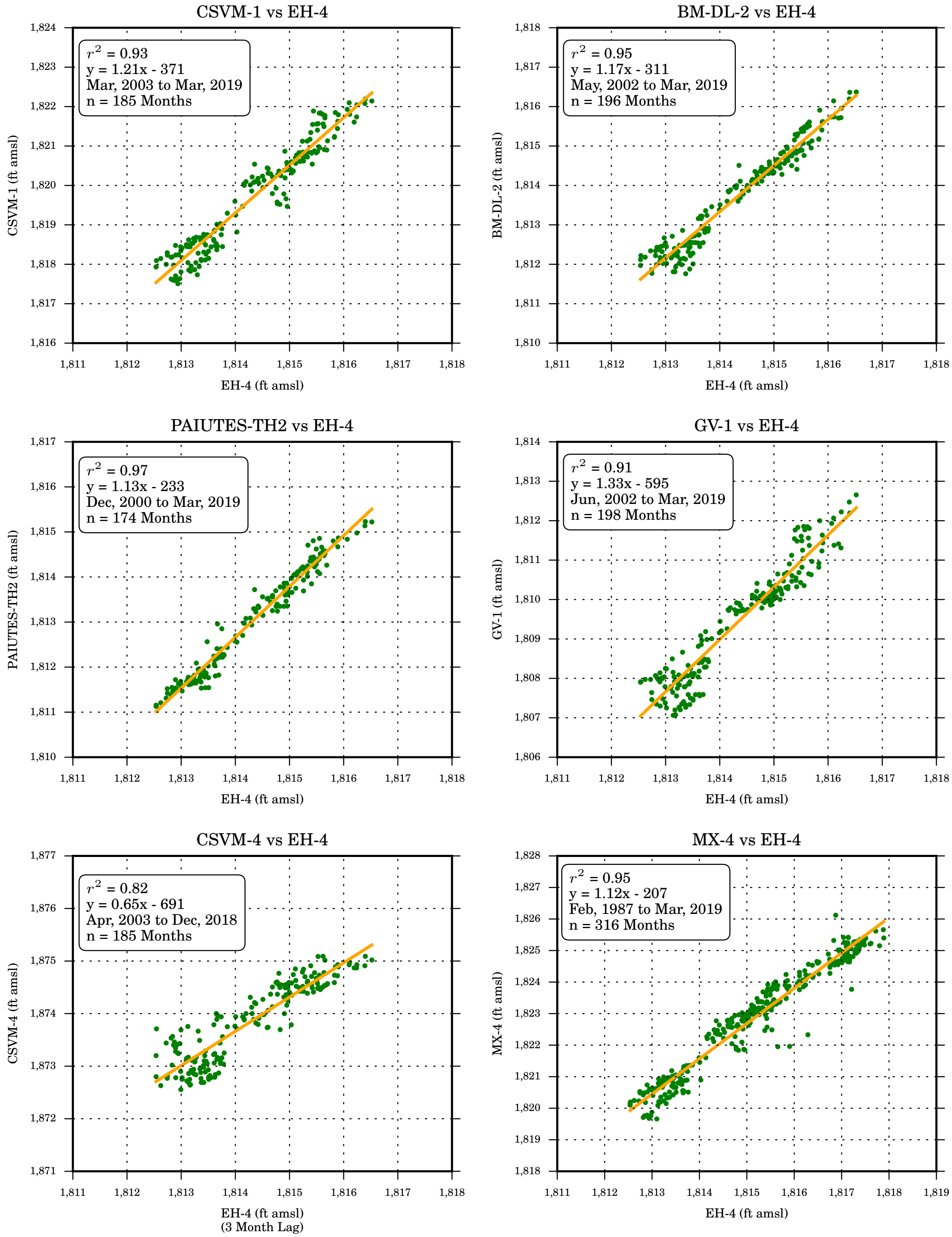

Figure 5-10
Correlation of Hydraulic Heads at Well EH-4 with Hydraulically Connected Carbonate Wells

seasonal fluctuations are generally consistent except for years when the percent of average precipitation is extraordinary, like in 2004-2005. For the winter months spanning October 2004 through March 2005, winter-season precipitation was nearly 300 percent of average, the highest percentage for the 1990 to 2019 period of record. Water levels in all carbonate wells increased accordingly in 2005, and by the spring of 2006 most wells reached their period of record high. After 2006, water levels declined and appeared to stabilize from 2008 through 2010, prior to the start of the NSE Order 1169 aquifer test.

As shown in Figure 5-7, in the MRSA, the Pederson Spring and the Warm Springs West gage records respond similarly, reaching peak discharge levels in the spring of 2006 after the extraordinary precipitation during 2004-2005. Like the groundwater levels, after 2006 the spring discharge declined, then stabilized prior to the start of the NSE Order 1169 aquifer test.

5.2.3 Groundwater Production - NSE Order 1169 Aquifer Test and Recovery

The responses to pumping stresses within the LWRFS, including the 2-year aquifer test, were analyzed using the records of carbonate-aquifer groundwater production described in Section 4.2.2.2 and presented by basin in Figure 4-7. Evaluations of the LWRFS responses during the aquifer test production and recovery periods are presented in the following sections.

5.2.3.1 Production Period

In general, regional responses to local pumping stresses are difficult to discern from natural stresses in the water-level records, which typically only vary about 6 ft throughout the entire LWFRS over the various periods of record. On an annual basis, the typical seasonal fluctuations associated with recharge pulses are less than 2 ft. These seasonal responses and longer-term trends associated with climate variability mask the subtle effects of gradual changes in the relatively consistent pumping regime. Only abrupt and significant changes to the pumping regime, such as those implemented as part of the NSE Order 1169 aquifer test, cause responses that are discernible in the water-level and spring-discharge records (Figures 5-11 through 5-13). These responses and interpretations of the test results are documented in several reports that were submitted to the NSE in 2013 and summarized in Section 2.0. In summary, water-levels in the carbonate aquifer declined from 1.0 to 2.5 ft throughout the LWRFS as a result of the stresses imposed during the aquifer test.

In general, responses to groundwater production are even more difficult to discern in the spring discharge records. The measurement accuracy of the Pederson and Warm Springs West gages and the variability of discharge due to seasonal fluctuations and long-term trends associated with the carbonate aquifer make it difficult to identify responses to pumping stresses. However, responses to pumping stresses imposed during the Order 1169 aquifer test were very apparent in these records. As Figure 5-7 illustrates, by the end of the 2-year aquifer test, discharge from Pederson Spring was reduced to about one-third of its pre-test flow, from 0.21 to 0.07 cfs. Discharge measured at the Warm Springs West gage declined about 8 percent, from 3.70 to 3.41 cfs. After the test, discharge at the Warm Springs West gage continued to decline and, had the test or operation of the MX-5 well continued, the initial trigger of 3.2 cfs at the Warm Springs West gage would have been reached before the end of 2014.

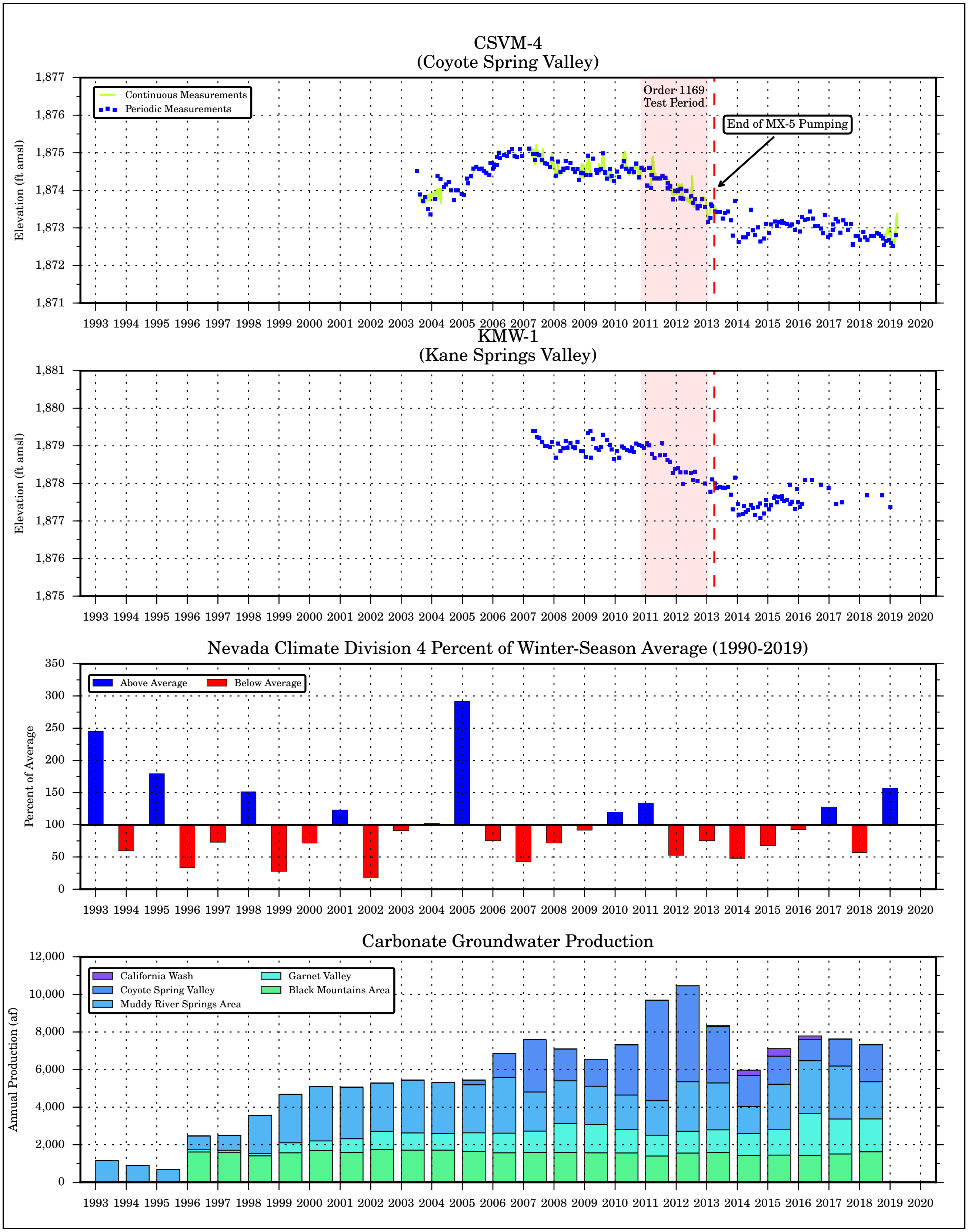

Figure 5-11
Carbonate-Aquifer Water Levels and Groundwater Production

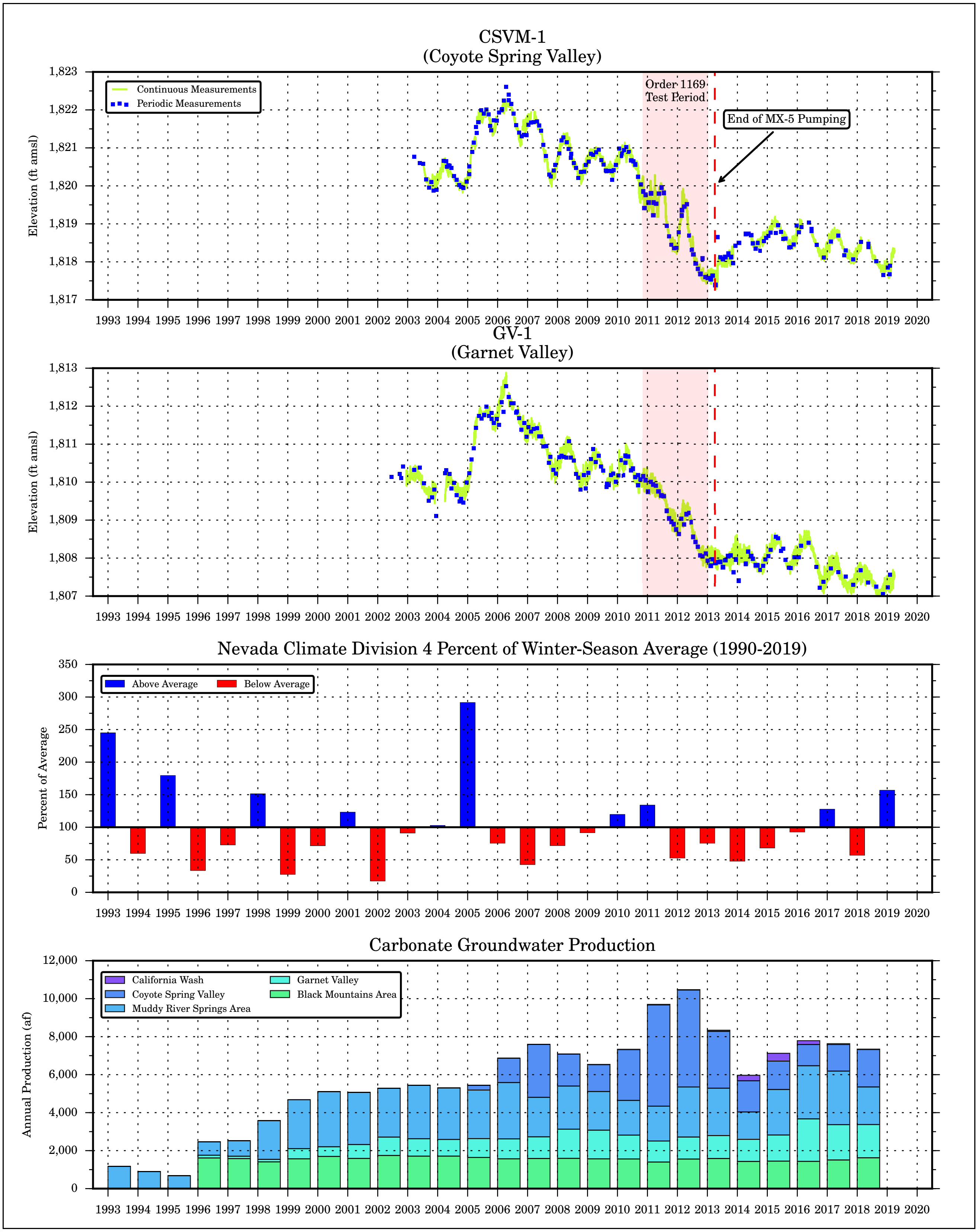

Figure 5-12
Carbonate-Aquifer Water Levels and Groundwater Production

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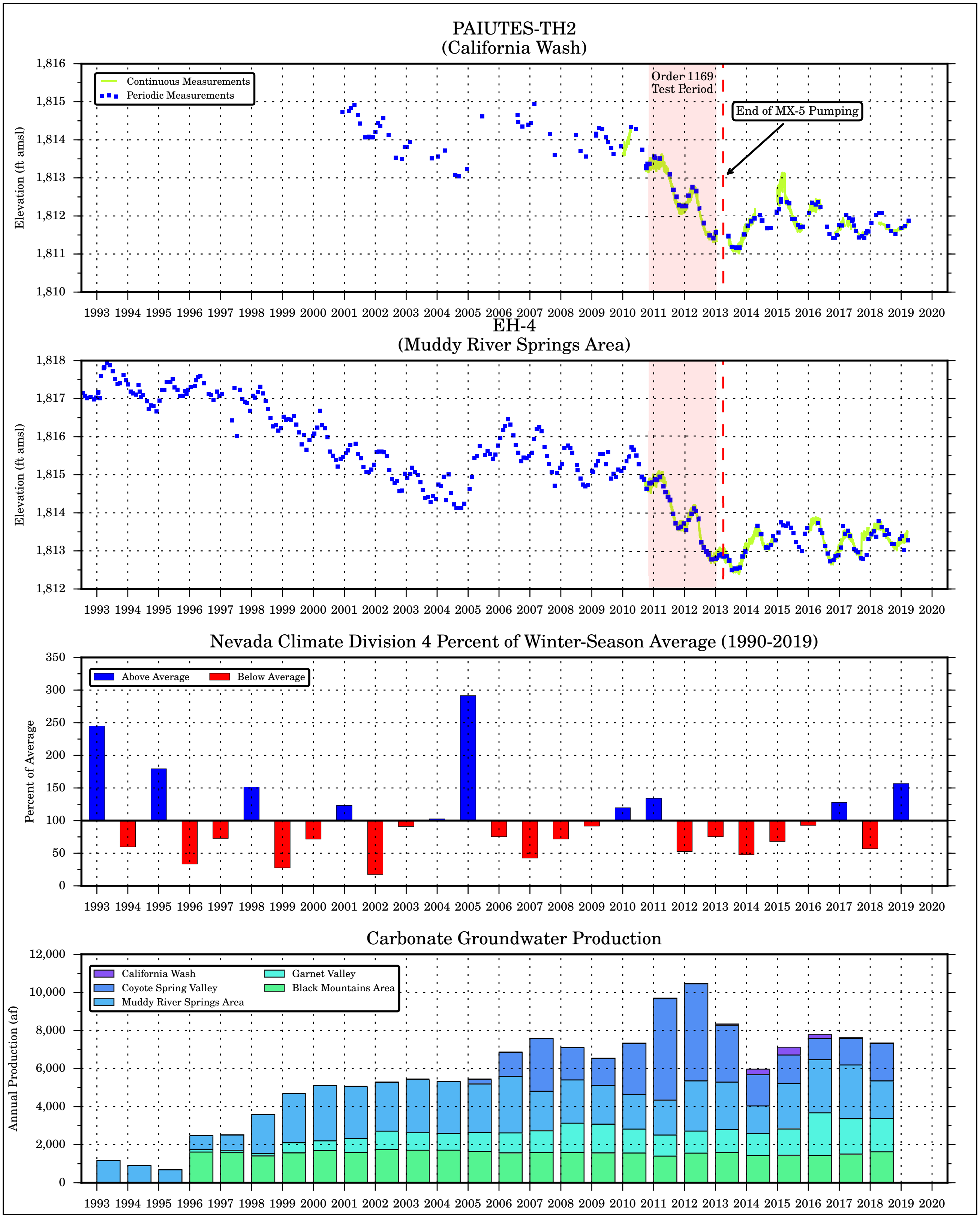


Figure 5-13
Carbonate-Aquifer Water Levels and Groundwater Production

An analysis of the correlations of water-level elevations between well MX-4 and other representative carbonate wells located throughout the LWRFS was performed to confirm the widespread pumping responses observed during the 2-year aquifer test. Well MX-4 was selected because it is in close proximity to the primary production well, MX-5, and therefore, strongly reflected the resulting drawdown response. The correlations were developed using monthly data collected from November 2010 to April 2013, inclusive, and are presented as graphs in Figure 5-14. All relationships exhibit linear trends with very high R^2 values ranging from 0.78 to 0.99. As expected, the highest correlation is with well CSVM-1, which is located only 0.5 mile from well MX-4 in Coyote Spring Valley. The highest correlations indicate that most of the decreases in the groundwater levels at the wells during the test period were caused by pumping from well MX-5 and other nearby wells. Correlation with well CSVM-4 is the smallest at 0.78, but still indicates that changes in groundwater levels at this well are also mainly due to pumping associated with the aquifer test. The slopes of the straight lines provide estimates of the drawdown at the selected wells relative to the drawdown in well MX-4 and are indicative of the degree of connection between their respective locations and that of the MX-4/MX-5 wells. A one-foot drawdown in MX-4 corresponds to 0.92 ft drawdown in well CSVM-1, to about 0.76 ft in wells BM-DL-2 and EH-4, 0.75 ft in wells Paiutes-TH2 and GV-1, and 0.37 ft in well CSVM-4. This analysis provides undeniable evidence that (1) the selected wells were all impacted by the MX-5 pumping during the 2-year test, and (2) the basins of the LWRFS in which these wells are located are highly connected.

5.2.3.2 Recovery Period

Recovery from the pumping stresses imposed during the aquifer test was less than expected, and never reached pre-test levels. There were two primary factors that influenced the initial recovery record observed during 2013: (1) continued carbonate-well pumping, including the MX-5 well in Coyote Spring Valley and (2) the seasonal responses to recharge pulses. The drawdown associated
Why did pumping from MX-5 continue
with continued pumping of the MX-5 well muted the recovery response during a period in which water levels typically increase to their seasonal high in April. After the MX-5 well was shut down in mid-April 2013, the recovery response was attenuated by the seasonal water-level decline that starts in May and reaches a low in October. Although these factors complicated the 2013 record, the subsequent years of monitoring provided a clear picture of the recovery response and the following observations are made:

- Carbonate-aquifer water levels have not recovered to pre-test levels.
- Spring flows measured at the Pederson Spring and Warm Springs West gages have not recovered to pre-test levels.
- Recovery achieved its maximum levels between the first quarters of 2015 and 2016.

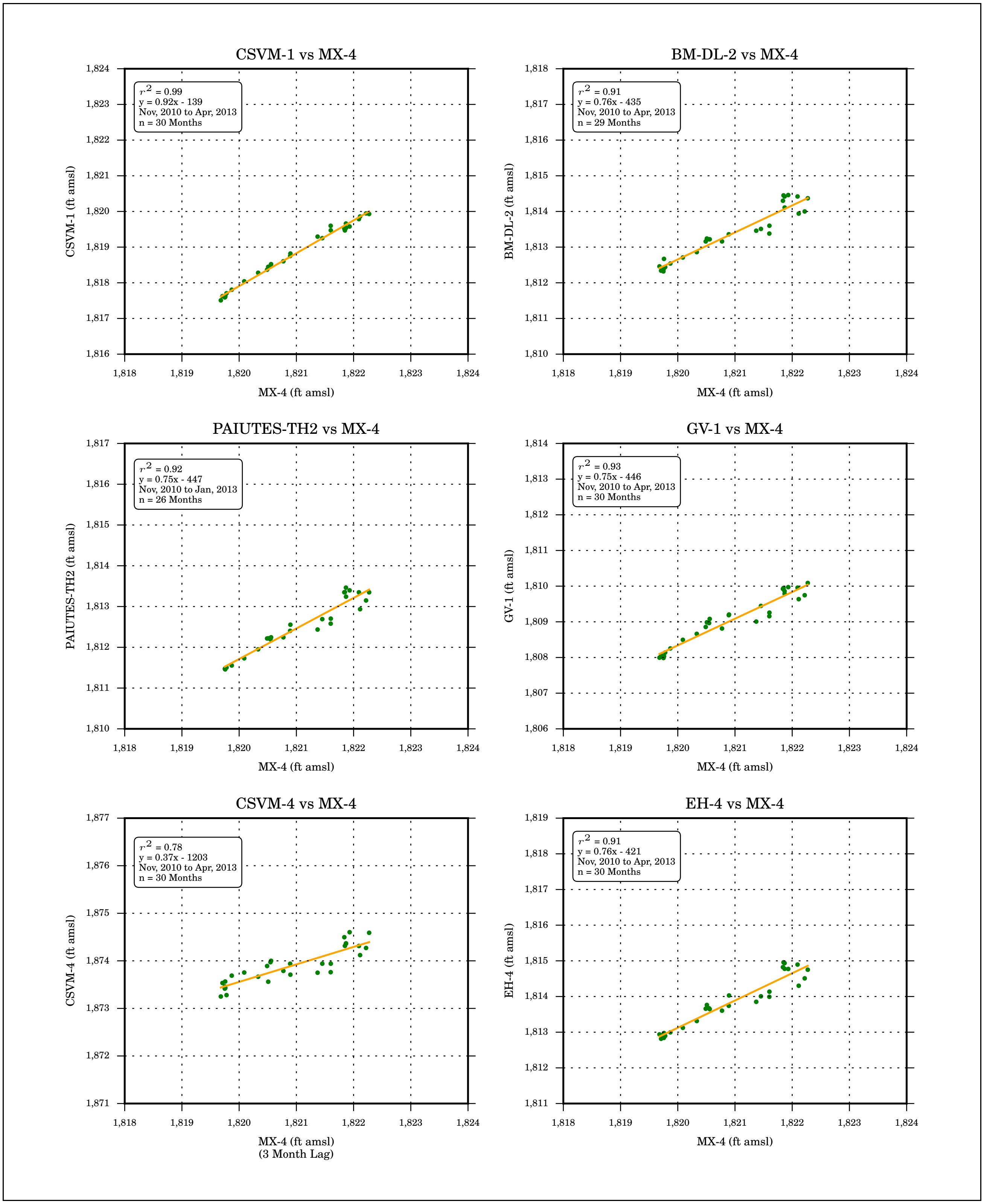


Figure 5-14
Correlation of Hydraulic Heads at Well MX-4 with Hydraulically Connected Carbonate Wells during the Order 1169 Aquifer Test

6.0 IMPLICATIONS TO CHANGES IN HYDRAULIC HEAD OF THE CARBONATE AQUIFER

As previously discussed, the carbonate aquifer is the source of all perennial springs and seeps in the MRSA that sustain the Moapa dace habitat, recharge to the local alluvial reservoir, and discharge from the MRSA as a whole. Based on the hydrologic responses to climate variability and stresses imposed by groundwater production as described in Section 5.0, there are significant implications to the development of groundwater from the carbonate aquifer.

The observed responses indicate that to eliminate conflicts with Muddy River surface-water rights, which are the most senior water rights within the LWRFS and protect spring discharge relied upon by the endangered Moapa dace, groundwater production from the carbonate aquifer must be limited. This section presents a qualitative assessment of the LWRFS carbonate aquifer based on these responses, and quantitative analysis of the amount of carbonate groundwater that may be produced over the long term while still maintaining certain flow conditions at the Warm Springs West gage.

6.1 Qualitative Assessment of Historical Responses

The time-series data presented in Section 5.2 indicate that the carbonate aquifer responds uniformly to variable winter-season precipitation, and that responses to pumping stress are small in magnitude but widespread throughout the system. These responses are observed as changes in groundwater levels and spring discharge, particularly during the 2-year aquifer test, but cannot readily be discerned in Muddy River streamflow records.. The response of the Muddy River has been dominated by the changes in surface-water diversions and groundwater production above the MR Moapa gage.Small changes in the hydraulic heads (on the order of only 2-3 ft) have resulted in significant changes in the discharges from high-elevation springs. Additionally, the lack of any significant recovery response after the completion of the Order 1169 aquifer test and the fact that the system has yet to recover to pre-test levels are critical observations. These observations indicate that the aquifer has a very high transmissivity and low storage capacity (i.e., high aquifer diffusivity). As a result, the system is very sensitive to recharge and pumping stresses and is interpreted to effectively behave like a confined aquifer system. A significant withdrawal of water from a pumping center creates similar decreases in the hydraulic head throughout the system, and within relatively short time periods. Further, recharge pulses of local origin create similar increases in hydraulic head throughout the system and within relatively short time periods. This is demonstrated by the time-series data collected from representative wells completed in the carbonate aquifer at locations within the LWRFS basins (Figures 5-5 and 5-6). This behavior is also demonstrated by the discharge records from the Pederson Spring and Warm Spring West gages in the MRSA which have exhibited responses commensurate with changes in hydraulic heads (Figure 5-7).

Several high-elevation springs compose some of the most critical habitat for the Moapa dace (Marshall and Williams, 2019). These springs also happen to be the most sensitive to changes in hydraulic heads due to the elevation of their orifices. The elevation of the spring orifice controls the hydraulic potential (hydraulic head in the carbonate aquifer minus spring-orifice elevation) driving its discharge. The hydraulic potential driving spring discharge decreases with increasing spring elevation, resulting in increasing levels of sensitivity to natural and anthropogenic stresses affecting hydraulic heads in the carbonate aquifer.

Figure 6-1 presents the MRSA spring locations with Light Detection and Ranging (LIDAR) elevation data to illustrate the distribution of spring complexes and stream reaches with respect to ground-surface elevations. Spring orifices and gaining stream reaches occurring at higher elevations are more susceptible to changes in groundwater levels than lower elevations. For instance, discharge from high-elevation springs in the MRSA have been demonstrated to respond in a manner that is consistent with changes in the hydraulic heads of the carbonate aquifer (Figures 5-8 and 5-9). Small changes in hydraulic heads during the NSE Order 1169 aquifer test resulted in reduced discharge from the Pederson Spring Complex. Springs that occur at lower elevations have a greater hydraulic potential and are less sensitive to such changes.

Since 2016, hydraulic heads in the carbonate aquifer and discharge measured at Pederson Spring and Warm Springs West gages have declined. A significant increase in carbonate groundwater production, such as that which occurred during the NSE Order 1169 aquifer test, will increase the rate of decline so that the 2006 MOA trigger ranges are encountered much sooner. In this case, groundwater production would be restricted per the annual volumes listed in Table 1-1.

The observed declines since 2016 are likely caused by the on-going carbonate groundwater production coupled with a below average winter-season precipitation in 2018, but the respective contributions of each factor are unknown. Notably, the declines have occurred even though winter-season precipitation during 2017 and 2019 were above average. Precipitation can neither be predicted nor controlled; therefore, monitoring the response of the flow system and managing groundwater production is the only way to avoid reaching the protective triggers and impacting senior water rights. Based on this assessment, the following conclusions are made:

- Flow measured at the Warm Springs West gage will reach trigger ranges sooner and at lower production rates than contemplated in the 2006 MOA if pumping in Coyote Spring Valley resumed at levels commensurate with the Order 1169 aquifer test;

- Given the current rates of carbonate groundwater production, recovery of groundwater levels and spring discharge to pre-test levels is not possible without extraordinary hydrology such as the 2004-2005 winter-season precipitation; and

- Even with such extraordinary hydrology, subsequent years of lesser precipitation with similar groundwater production volumes will result in a resumption of declining trends as has been observed in the historical record.

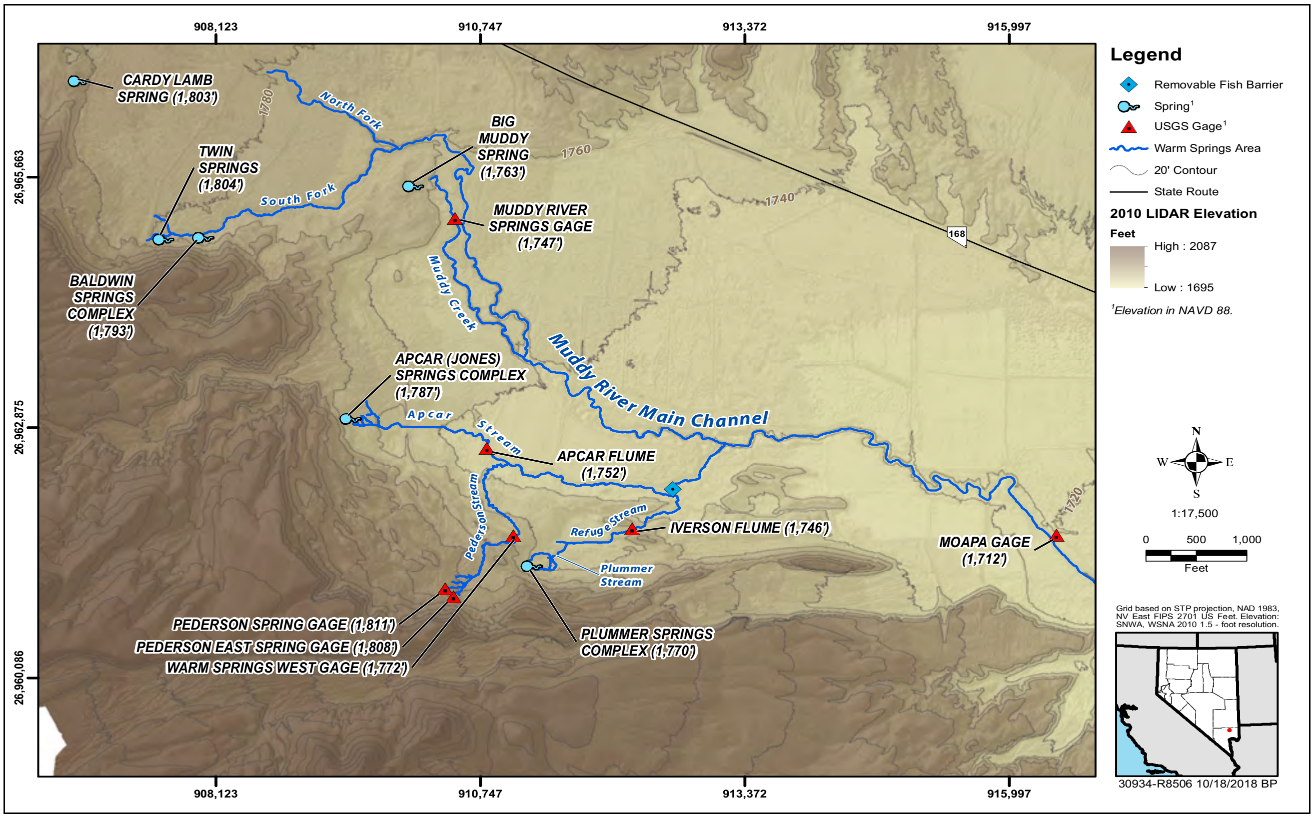


Figure 6-1
Elevation of Selected Springs and LIDAR Digital Elevation Model within the MRSA

6.1.1 Implications of Continued Pumping

Responses associated with the Order 1169 aquifer test demonstrate that the current pumping configuration within the LWRFS (i.e., pumping location, rates and duration) is not sustainable in the long-term without conflicting with senior Muddy River water rights and degrading the Moapa dace habitat in the high-elevation spring complexes.

Aren't senior Muddy River water rights already being impacted

In the long-term, it is expected that any groundwater production from the carbonate system within the LWRFS will ultimately capture discharge to the MRSA (e.g., spring discharge, subsurface inflow to the alluvial reservoir and, consequently, Muddy River streamflow) because of the high aquifer diffusivity and hydraulic connectivity throughout the flow system and because the MRSA constitutes the majority, if not all, of the discharge from the flow systemThe results of the Order 1169 aquifer test indicate that for the areas directly upgradient of the MRSA (i.e., Arrow Canyon and Coyote Spring Valley), water-level responses to pumping stresses occur very quickly. As demonstrated in Figures 5-8 and 5-9, any reduction of the hydraulic head in the carbonate aquifer results in a proportional reduction in spring discharge.

The timing of impacts from groundwater production in pumping centers located farther from the MRSA, in Garnet Valley, California Wash and the Black Mountains Area, may take longer, but the properties of the aquifer are such that these impacts will eventually reach the MRSA. This is because, as the data indicate, the MRSA is hydraulically connected to the other LWRFS basins. Based on this assessment, the following conclusions are made:

- groundwater production from the carbonate aquifer in the LWRFS has impacted discharge to the MRSA and, consequently, senior surface-water rights associated with the 1920 Muddy River Decree Well that's only been obvious for the past 30
- impacts due to groundwater production within areas directly upgradient of the MRSA occur relatively quickly, and the magnitude of the impacts depends upon the pumping rates and durations
- I.E. Pumping additional appropriations that increase groundwater production from the carbonate aquifer within the LWRFS will accelerate the timing and magnitude of impacts
- changing the spatial distribution of pumping within the LWRFS will change the distribution of drawdown and the timing of impacts, but not the long-term outcome.

6.2 Quantitative Analysis

Many studies (Eakin, 1964; Eakin and Moore, 1964; Eakin, 1966) have shown that discharge in the MRSA is sourced by groundwater from the underlying carbonate aquifer. Some studies include complex equations or numerical groundwater flow models that are not easy to use to better understand the flow system (SNWA, 2009a and b; 2010; Tetra Tech, 2012a and b). A few studies have used the existing data to develop simpler mathematical relationships (USFWS et al., 2013). However, such studies concentrate on daily or monthly data, which clouds the interpretations of the flow system with effects of short-lived stresses. This analysis uses annual data and a simplified approach to characterize the relationship between the carbonate aquifer and discharge to the MRSA area (or MRSA discharge). The annual data are more representative of the system's response to longer-term stresses such as natural recharge and groundwater production from the carbonate aquifer.

6.2.1 Objective

The objective of this analysis is to derive simple methods quantifying the relationship between the carbonate aquifer and MRSA discharge at the annual scale. Such relationships can then be used to predict spring discharge based on measurements of hydraulic heads in the carbonate aquifer and estimate the quantities of groundwater production from the carbonate aquifer based on pre-selected rates of reduced MRSA spring discharge.

6.2.2 Approach

The available groundwater-production and hydrologic-response data were used to quantify the maximum amount of production from the carbonate aquifer that can occur over the long term while still maintaining selected flows at the Warm Springs West gage. This approach included the following:

- developing a relationship between the Warm Springs West gage records and total discharge to the MRSA

- applying the relationship to quantify the maximum allowable reduction in MRSA discharge from the predevelopment condition for each selected flow rate at the Warm Springs West gage.

6.2.3 Relationship between High-Elevation Spring Discharge and MRSA Discharge

The MRSA discharge occurs in the form of springs with measurable discharge rates and seeps that cannot be measured individually. The relationship between the hydraulic head in the carbonate aquifer and the MRSA discharge is governed by Darcy's law. The changes in the MRSA discharge are directly proportional to the changes in the hydraulic head in the carbonate aquifer. The relationships between discharge at selected spring gages, Pederson Spring and Warm Springs West gages, and the hydraulic head in the carbonate aquifer (Figures 5-8 and 5-9) demonstrate that spring discharge is directly proportional to hydraulic head as predicted by Darcy's law.

At time scales of one year or more, changes in the hydraulic head of the carbonate aquifer are mainly caused by changes in natural recharge and groundwater production from the carbonate aquifer. As demonstrated by the 2-year aquifer test, an essentially equal response spreads relatively quickly to carbonate monitor wells located within the six interconnected basins of the LWRFS. This indicates that the carbonate aquifer acts as a confined aquifer with a large average transmissivity and a low average storage coefficient. Thus, the following statements must hold true:

- a change in the hydraulic head of the carbonate aquifer causes a proportional change in the MRSA discharge throughout the springs area; and
- discharge from each spring and seep contributing to the MRSA discharge changes in a proportional manner relative to the hydraulic head change in the carbonate aquifer.

The following analysis demonstrates that these statements are true by showing that the relative contribution of a given spring to the MRSA discharge, or ratio of spring discharge to MRSA discharge, remains the same, independent of stress conditions (i.e., recharge and groundwater production). A constant ratio under variable stress conditions indicates that the relationship can be applied to estimate MRSA discharge under any flow condition based on the discharge record of the subject spring.

6.2.3.1 Ratio Calculations

Data needed to estimate the contribution of a selected spring or spring complex to the MRSA discharge are the discharge measurement record of the selected spring and estimates of the MRSA discharge for the same period of time. The Warm Springs West gage was selected to represent the flow from the Pederson Spring Complex.

MRSA discharge consists of the following components: (1) subsurface flow into the alluvial reservoir, (2) spring discharge, and (3) groundwater ET. Under pre-development conditions, this discharge can be estimated by adding the MR Moapa gage record to estimates of ET. Under transient conditions, surface-water diversions and alluvial groundwater production must be added to the gage record and ET estimate to ensure a complete accounting. The period of time for which observations of all of these variables, including ET, are available is from 2001 to 2012.

All data used in this analysis for the 2001-2012 time period, along with the ratio of discharge measured at the West Springs West gage to MRSA discharge are presented in Table 6-1. Even though the discharge values for both components of the ratio vary from year to year, the ratio remains within a very narrow range. The average ratio is 0.078 with a narrow 95-percent confidence interval of 0.074 to 0.082. The variation in the ratio values are due to uncertainty in the data used to derive it (Sauer and Myer, 1992).

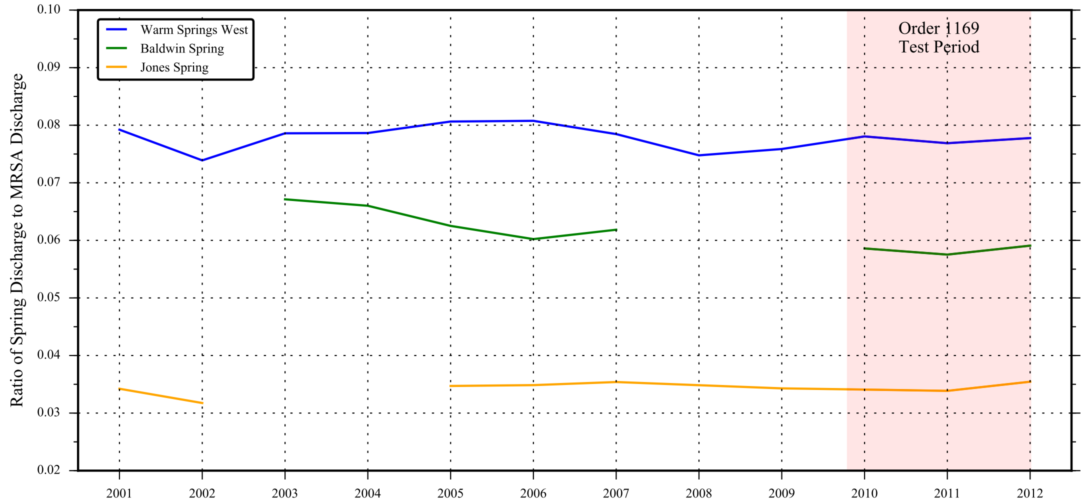
Table 6-1
Contribution of Warm Springs West Discharge to MRSA Discharge

Year	Flow at MR Moapa Gage		Losses above MR Moapa Gage			Total MRSA Discharge (af)	Flow at Warm Springs West Gage		Ratio
	Average Annual (cfs)	Annual Total (af)	Diversions (af)	MRSA Alluvial Groundwater Production (af)	ET above Gage (af)		Average Annual (cfs)	Annual Total (af)	
2001	31.37	22,726	4,363	3,560	3,359	34,008	3.72	2,694	0.079
2002	32.50	23,549	4,573	4,190	3,294	35,606	3.63	2,631	0.074
2003	30.34	21,982	4,313	3,673	2,855	32,822	3.56	2,580	0.079
2004	31.38	22,731	3,631	3,370	2,870	32,601	3.54	2,564	0.079
2005	32.34	23,432	3,425	3,837	3,426	34,121	3.80	2,752	0.081
2006	34.18	24,761	2,927	4,436	2,856	34,981	3.90	2,825	0.081
2007	32.83	23,784	4,176	3,506	2,864	34,329	3.72	2,694	0.078
2008	34.77	25,191	3,825	3,135	2,841	34,992	3.61	2,616	0.075
2009	35.61	25,799	3,985	2,539	3,134	35,456	3.71	2,690	0.076
2010	35.74	25,889	3,604	2,701	2,206	34,400	3.71	2,685	0.078
2011	36.59	26,510	1,895	3,322	2,462	34,189	3.63	2,628	0.077
2012	38.32	27,762	422	1,887	2,514	32,585	3.50	2,534	0.078

Ratios were also computed for Baldwin and Jones springs. These springs are located north and northwest of the Warm Springs West gage as depicted in Figure 6-1, and at slightly lower elevations than the Pederson Spring Complex. The ratios for each of the springs are presented with the corresponding data for the period of analysis in Figure 6-2. The average ratios are 0.061 and 0.034 for Baldwin and Jones springs, respectively. The 95-percent confidence intervals are very narrow at 0.055 to 0.068 for Baldwin spring and 0.032 to 0.036 for Jones spring. This is further proof that springs in the MRSA respond commensurately with the hydraulic head of the carbonate aquifer, regardless of the stress.

6.2.3.2 Ratio Verification

To verify that these ratios remain the same under any stress conditions, an additional estimate was made using predevelopment data reported by Eakin (1964). Data for this period reflect conditions preceding 1965, prior to the exportation of stream diversions above the MR Moapa gage. The LWRFS was practically under predevelopment conditions as Eakin (1964) reported a relatively small



Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	Avg
Total MRSA Discharge (cfs)	4.6	4.5	3.9	4.0	4.7	3.9	4.0	3.9	4.3	3.0	3.4	3.5	4.0
Baldwin Spring (cfs/[ratio])	2.8 [0.059]	--	3.0 [0.067]	3.0 [0.066]	2.9 [0.063]	2.9 [0.060]	2.9 [0.062]	--	--	2.8 [0.059]	2.7 [0.058]	2.7 [0.059]	2.9 [0.061]
Jones Spring (cfs/[ratio])	1.6 [0.034]	1.6 [0.032]	--	--	1.6 [0.035]	1.7 [0.035]	1.7 [0.035]	1.7 [0.035]	1.7 [0.034]	1.6 [0.034]	1.6 [0.034]	1.6 [0.035]	1.6 [0.034]

Figure 6-2
Ratios of Spring Discharge to Total MRSA Discharge (2001 - 2012)

volume of groundwater withdrawal from the alluvial reservoir of the MRSA, which was used for local irrigation.

Eakin (1964) collected field measurements of individual spring discharge and Muddy River flow at Moapa from late 1963 to early 1964. Eakin (1964) found that discharge rates from the individual springs remain constant during this period, while the river flow at the MR Moapa gage fluctuated from month to month. The main cause of these fluctuations is ET, which Eakin (1964) estimated to be between 2,000 and 3,000 afy.

Eakin (1964) estimated the MRSA discharge at 49.8 cfs during the 1963-1964 study period and found that the sum of the individual spring discharges measured during that period constitutes 60 percent of this discharge. The data collected by Eakin (1964) may be used to calculate the contribution of individual springs to the total MRSA discharge. Only the Warm Springs West gage is used in this verification because the Eakin (1964) discharge measurement locations and values for Baldwin and Jones springs could not be matched with the current records. The discharge at the Warm Springs West gage was measured at 3.78 cfs during the investigation period. The ratio between the discharge at the Warm Springs West gage and the MRSA discharge is 0.076 (3.78 cfs/49.8 cfs), rounded to the nearest thousandth. In other words, the discharge from the Pederson Springs Complex above the Warm Springs West gage contributes 7.6 percent to the total discharge to the area.

This analysis demonstrates that the ratio between the discharge at the Warm Spring West gage and the MRSA discharge is constant at 0.076. This ratio is within the range calculated from the 2001-2012 data and actually constitutes the best estimate because the discharge values used were measured during the same short-time period, and less variables were used to calculate it. This analysis confirms the following:

- The change in hydraulic head in the carbonate aquifer is spatially the same across the area supplying the springs and seeps of the MRSA discharge area, under variable natural and anthropogenic stress conditions.
- The carbonate aquifer behaves as a confined system. Drawdown caused by pumping from the carbonate aquifer creates a wide and shallow cone of depression extending over the area supplying the MRSA springs and seeps above the MR Moapa gage.
- As long as the hydraulic head in the carbonate aquifer is maintained at a level high enough to keep all springs and seeps flowing, each spring and seep contributes a constant proportion to the MRSA discharge.

6.2.4 Quantification of Limits on Carbonate Groundwater Production

The relationships described in the previous section can be used to calculate reductions in the MRSA discharge that correspond to potential flow conditions at the Warm Springs West gage. This gage is important because it measures discharge from the most sensitive group of springs in the MRSA; therefore, it is deemed the best location to monitor the effects of carbonate-aquifer groundwater production on both decreed Muddy River water rights and Moapa dace habitat. It is for this reason that it was used to establish Trigger Ranges in the 2006 MOA. Knowing that a reduction in the MRSA discharge could only be caused by a lowering of the hydraulic head in the carbonate aquifer, limits on production from the carbonate aquifer could be set by calculating reductions in MRSA discharge that correspond to various discharge levels at the Warm Springs West gage. including the trigger ranges set in the 2006 MOA.

Reductions were calculated from discharge values estimated for predevelopment conditions. Eakin (1964) estimated the adjusted mean MRSA discharge at 50.2 cfs using flow measurements at the MR Moapa gage for the period 1945 to 1962. No predevelopment estimate of discharge at the Warm Springs West gage is available, but such an estimate can be derived by using the ratio calculated as described in Section 6.2.3. Thus, predevelopment average discharge at Warm Springs West gage is 7.6 percent of 50.2 cfs, or a flow rate of 3.82 cfs. Potential flow reductions at the Warm Springs West gage and corresponding reductions in MRSA discharge are listed in Table 6-2. The reductions in MRSA discharge from average predevelopment conditions can be used to represent limits on groundwater production from the carbonate aquifer for different discharge levels at the Warm Springs West gage.

Table 6-2
Limits on Carbonate-Aquifer Production Based on Selected Discharge Rates at Warm Springs West Gage

WSW Flow Condition (cfs)	Decrease from Predevelopment Discharge			
	Warm Springs West		MRSA Discharge	
	(cfs)	(afy)	(cfs)	(afy)
3.82	0.00	0	0.00	0
3.60	0.22	159	2.89	2,092
3.40	0.42	304	5.53	4,000
3.20	0.62	449	8.16	5,908
3.00	0.82	594	10.79	7,816
2.90	0.92	667	12.11	8,776
2.80	1.02	739	13.42	9,724
2.70	1.12	811	14.74	10,671

[1]Predevelopment discharge at WSW gage computed at 3.82 cfs (2,767 afy); predevelopment discharge from MRSA measured at 50.2 cfs (36,367 afy) (Eakin, 1964)

6.2.5 Capture Analysis of Carbonate-Aquifer Production

Using the available data and the analysis described above, an assessment of the approximate impacts of historical groundwater production from the carbonate aquifer was made. The objective of this assessment was to estimate the components of groundwater production in terms of the capture of aquifer storage and MRSA discharge.

Records of groundwater production from the carbonate aquifer are available starting in 1992, even though some minor and unrecorded production was initiated in the mid 1980s. Also, as described in Section 3.4.1, the Warm Spring West gage record is unreliable prior to October 1997. Therefore the period of analysis starts in 1992, when significant carbonate production was initiated and recorded, and ends in 2018, the last full year for which data are available. The following assumptions are made:

- production from the carbonate aquifer prior to 1992 was relatively small; and
- during the period of 1992 to 1998, the source of the production from the carbonate aquifer is assumed to be half from groundwater storage and half from the MRSA discharge.

The analysis approach consisted of the following steps.

1. Using the discharge record for the Warm Springs West gage, the change in average annual discharge from 1998 was calculated for each subsequent year.

2. Using the Eakin (1964) ratio of Warm Springs West discharge to MRSA discharge, 0.076, and the change in Warm Springs West discharge values (Step 1), the change from the 1998 MRSA discharge was calculated for each subsequent year. These values represent the approximate annual capture of MRSA discharge by groundwater production from the carbonate aquifer.

3. The volume of groundwater captured from aquifer storage for each year was computed by calculating the difference between total groundwater production and the volume of captured MRSA discharge (Step 2).

4. The cumulative volumes of groundwater production, aquifer-storage capture, and MRSA-discharge capture were calculated for each year of the 1992 through 2018 period of analysis.

The results are provided in Table D-1 of Appendix D and presented in Figure 6-3. In 2018, after 27 years of recorded production, a total of 148,241 af of groundwater were produced, with about 69,848 af captured from the MRSA discharge and 78,393 af from aquifer storage. As of 2018, about 47 and 53 percent of groundwater production is represented by the capture of MRSA discharge and aquifer storage, respectively.

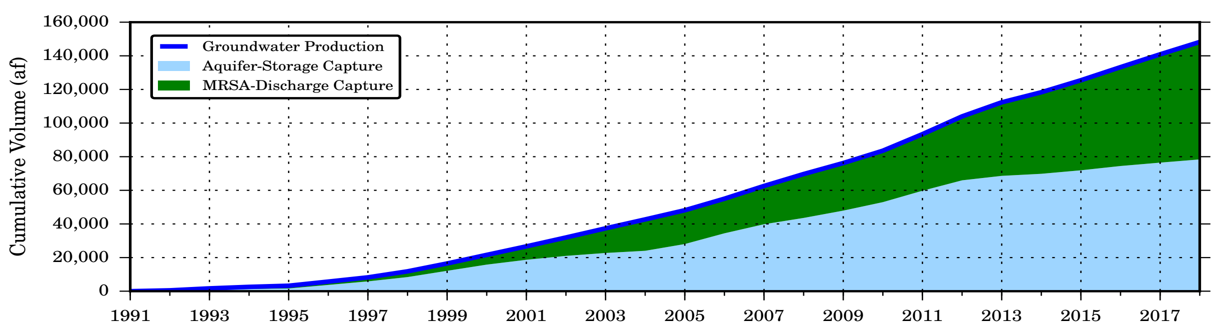


Figure 6-3
LWRFS Carbonate Groundwater Production Capture Analysis

Based on the method used to derive the MRSA capture limits in Table 6-2, the average discharge of 3.38 cfs observed at the Warm Springs West gage in 2018 corresponds to a reduction of about 4,200 afy in MRSA discharge. This value is comparable to the average capture of approximately 5,400 afy calculated for 2018 in the analysis described above.

The results of this analysis are approximate not only due to the uncertainty in the discharge and production data, but also because of the effects of recharge variability. Recharge to the LWRFS originates from local and regional sources located at different distances from the MRSA. Thus, changes in winter precipitation throughout the region create recharge pulses which arrive to the MRSA at different times, which are mostly unknown. Therefore, their effects on the spring discharge are difficult to quantify.

6.3 Findings of Qualitative Assessment and Quantitative Analysis

The analyses described in this section build on the relationships described in Section 5.0 and establish the following:

- The MRSA discharge varies with carbonate aquifer levels following a linear relationship.

- A linear relationship exists between individual spring discharge and the total MRSA discharge. Each spring contributes water to the MRSA discharge in the same proportion under any stress conditions.

- For purposes of estimating long-term limits on carbonate-aquifer production, a reduction in MRSA discharge from predevelopment conditions can be considered equivalent to a volume of groundwater withdrawn from the carbonate aquifer.

- Over the long-term, once capture of aquifer storage is reduced to levels approaching zero, production from the carbonate aquifer is expected to reduce MRSA discharge on a nearly 1:1 ratio.

7.0 Depletion of Muddy River Streamflow and Impacts to SNWA

Groundwater production from the MRSA alluvial reservoir and the LWRFS carbonate aquifer has depleted the flows of the Muddy River. Muddy River water rights were adjudicated in 1920 and the Muddy River Decree allocated the entire flow of the Muddy River. Therefore, groundwater production (whose associated rights are all junior in priority) that causes a depletion in streamflow also conflicts with the decreed rights on the river.

SNWA has significant assets associated with the Muddy River through its ownership and leases of water rights and MVIC shares, and uses these assets to create Tributary Conservation ICS credits in the Colorado River and Lake Mead. SNWA has spent over $80,000,000 on the acquisition of water rights on the Muddy River for the purpose of creating ICS credits. These credits compose a critical component of the SNWA water-resources portfolio that is needed to supply current and future water demands for a growing community with a population of over 2 million people and more than 40 million annual visitors (SNWA, 2018a).

This section describes SNWA's water-resource assets associated with the Muddy River, how they have been used to create ICS credits, and how SNWA has been impacted by Muddy River streamflow depletions caused by groundwater production within the LWRFS. The ensuing discussion describes these assets in relation to the Upper and Lower Muddy River reaches distinguished by the location of the USGS Muddy River near Glendale gaging station (MR Glendale gage) (Figure 7-1).

7.1 Upper Muddy River

Decreed water rights within the Upper Muddy River are individually owned with specific Places of Use to which water associated with the right is applied. Since 2006, SNWA has entered into lease agreements for some of these rights and has purchased others. Leased volumes may vary year to year as documented within the annual Muddy River ICS Certification reports (SNWA, 2009c; 2011a and b; 2012a and b; 2013c; 2015b and c; 2016b; 2017b; 2018c). Within the Upper Muddy River, SNWA leases or owns the following water rights;

- Up to 2,001 afy leased from the Church of Latter Day Saints (expires January 1, 2027)
- 111 afy of former Cox and Mitchell rights (SNWA-owned)
- 1,040 afy of former Hidden Valley rights (SNWA-owned)
- Up to 3,700 afy of rights held in a long-term lease by the Moapa Band of Paiutes and subleased to SNWA (expires December 31, 2026)
- 811 afy of former Knox and Holmes rights (SNWA-owned)
- Up to 3,000 afy of rights leased from MVIC (expires December 31, 2026).

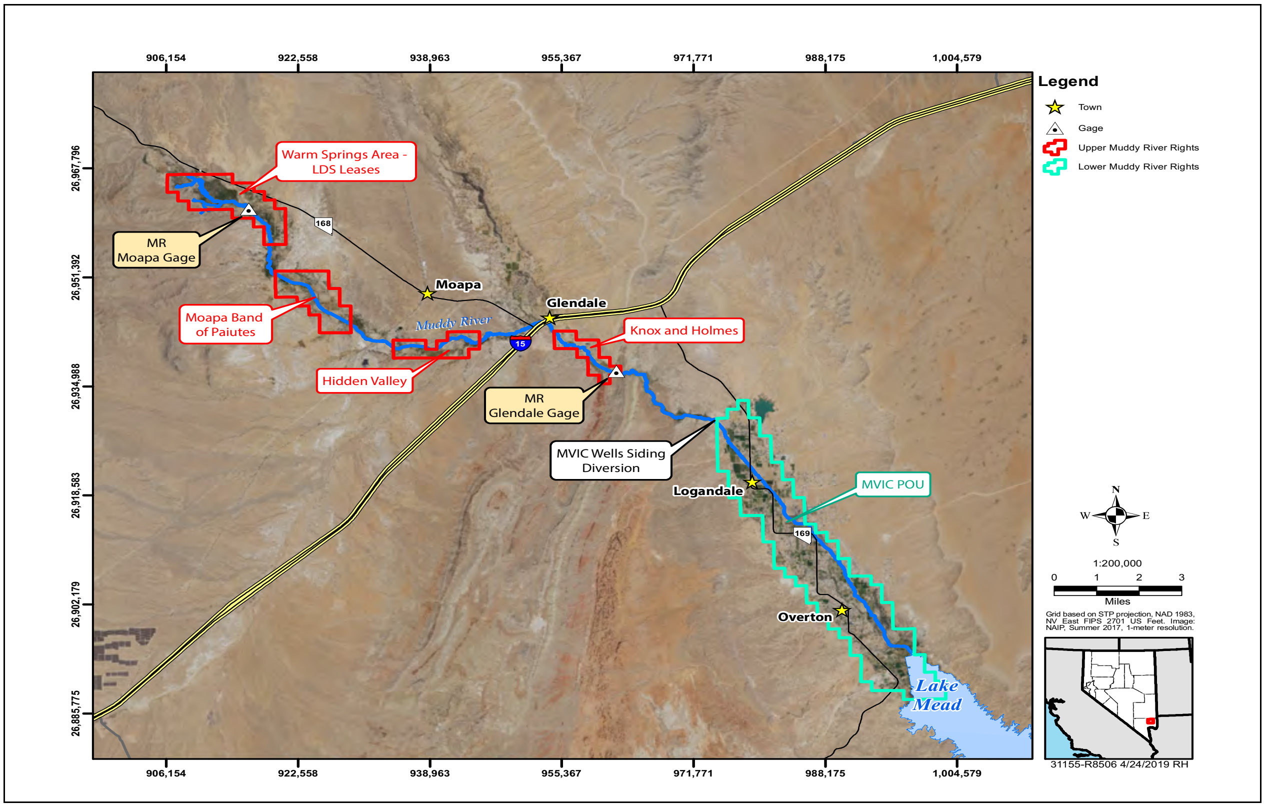


Figure 7-1
Upper and Lower Muddy River Reaches

7.2 Lower Muddy River

Decreed water rights within the Lower Muddy River are held by MVIC, which holds the largest quantity of decreed rights on the Muddy River. 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. MVIC's operations and covenants define preferred shares as 100 percent of the Muddy River summer flow and 75 percent of the winter flow. Common shares represent the remaining 25 percent of the winter flow. In addition to their decreed and certificated rights, the 1920 Muddy River Decree states that MVIC can divert any additional unused Muddy River flows that reach their diversion structure on the Muddy River. Consequently, the actual water that MVIC splits among its shareholders varies from year to year based on the actual divertible flows that reach their diversion structure. MVIC delivers water to its shareholders through a network of concrete-lined ditches and pipes.

Currently, SNWA controls, through purchases and leases, 1,166 preferred shares and 3,208 common shares. The volume of water represented by these shares changes from year to year based on the flow of the river as measured at the MR Glendale gage. In 2018, SNWA shares represented approximately 10,000 af.

7.3 SNWA Tributary Conservation ICS Credits

SNWA relies upon Muddy River water rights and MVIC shares it owns and leases to create Tributary Conservation ICS credits. SNWA is allowed to store the water associated with these credits in Lake Mead, or divert it at its intakes in Lake Mead for delivery to water purveyors in the Las Vegas Valley.

The criteria for the development and delivery of ICS was established in the Record of Decision for Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead, December 13, 2007 (USBR, 2007). Tributary Conservation ICS is one of several types of ICS and 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. ICS credits are limited to flows associated with water rights that have been used for a significant period of years and were perfected prior to the effective date of the Boulder Canyon Project Act of June 25, 1929. ICS has been declared a beneficial use under Nevada Revised Statute 533.030.

To generate ICS credits, the Guidelines require a Contractor, SNWA in this case, to submit ICS plans of creation and certification reports. Plans of creation are written to demonstrate how the ICS will be created in the ensuing year, and certification reports are used to document the creation of ICS for the previous year. NSE Order 1194 requires the submittal of an annual report to the NSE that provides a full accounting of adjudicated Muddy River water rights, owned or controlled by the Contractor, that have been conveyed through the Muddy River to the Colorado River for the creation of ICS. The certification reports must comport with this order. SNWA has created 157,824 af of Muddy River Tributary Conservation ICS credits since the Guidelines were instituted in 2008 (SNWA, 2009c; 2011a and b; 2012a and b; 2013c; 2015b and c; 2016b; 2017b; 2018c). Annual ICS credits created by SNWA are presented in Table 7-1. The 2018 ICS data are not included here as the Certification Report has not yet been finalized and approved.

7.3.1 Impacts to SNWA as a Result of Muddy River Streamflow Depletions

As described in Section 5.1.4, Muddy River streamflow has been depleted by groundwater production from both the MRSA alluvial reservoir and LWRFS carbonate aquifer. Figure 5-4 demonstrates that groundwater production within the MRSA accounts for the MR Flow Deficit observed for the period of analysis. Production wells completed in the alluvial reservoir adjacent to the Muddy River capture groundwater that would otherwise discharge to the river. In addition, MRSA production wells completed in the carbonate aquifer capture water that would otherwise replenish the alluvial reservoir though diffuse subsurface flow or discharge from discrete springs. Capturing this groundwater depletes the source of supply to the alluvial reservoir and springs, thereby, depleting the streamflow. Groundwater production from other production wells located within the LWRFS also impact the MRSA discharge, and therefore the Muddy River flow. However, the impacts are not readily discernible in the streamflow record because of their relatively small magnitude compared to the flow of the river and the masking effect caused by recharge variability.

Muddy River streamflow depletions have had, and will continue to have, a direct impact on the volume of water associated with MVIC shares and, consequently, the water resources SWNA is able to secure through the creation of ICS credits. As previously described, the volume of water represented by MVIC shares is determined by the annual flows in the Muddy River. As the flows

Table 7-1
SNWA's Muddy River Tributary Conservation ICS Credits

Year	Tributary Conservation ICS Credits (af)		
	Upper Muddy River	Lower Muddy River	Annual Total
2008	2,112	4,983	7,095
2009	5,812	7,395	13,207
2010	8,622	8,161	16,783
2011	9,420	7,142	16,562
2012	9,929	7,384	17,313
2013	10,390	7,033	17,424[a]
2014	6,471	8,627	15,098
2015	9,963	8,509	18,472
2016	9,963	8,283	18,246
2017	9,963	7,660	17,624[a]
		GRAND TOTAL	157,824

[a]Differences in annual totals are the result of rounding.

have diminished as a result of groundwater production, so too has the volume of water associated with the shares that are owned by the individual MVIC shareholders, including SNWA. The impact to MVIC was estimated for the period 2008 through 2017 by summing the annual differences between the predevelopment baseflow and the natural flow as measured at the MR Moapa gage, which totaled over 46,000 af. The predevelopment baseflow was derived using streamflow records for a period of below-normal hydrology; therefore, using it as a reference point leads to conservatively low estimates of streamflow depletion. Table 7-2 presents the impacts these streamflow depletions have had on SNWA ICS credits. To quantify the impacts, the following steps were taken:

1. The natural flow as a percentage of the predevelopment baseflow was derived for each year of ICS creation using the annual flood-adjusted flow records of MR Moapa gage. The natural flow record was derived by accounting for all surface-water diversions above the gage as described in Section 5.1.3, and represents the water available for uses downstream of the gage, including the creation of ICS from MVIC shares. The computed percentage is less than 100 when the baseflow has been depleted by groundwater production, as was the case during the period of ICS creation. By using the MR Moapa gage, it is assumed that all gains/losses (i.e., diversions, ET) between the MR Moapa and MR Glendale gages remained essentially the same for the period of analysis.

2. The potential ICS credit that would have been created had the streamflow not been depleted was computed by dividing the ICS credit certified for each year by the percentage of natural flow computed in Step 1. The potential ICS is always greater than the certified ICS when the baseflow has been depleted by groundwater production.

3. The impacts were quantified by computing the difference between the potential and certified ICS volumes. The values are listed in Table 7-2 and presented in Figure 7-2. The total

estimated impact from 2008 through 2017 is 12,040 af. The cost to purchase additional water to replace the lost flows is estimated to be $2,288,746 using the annual value of leased shares.

Table 7-2
Impacts of MR Streamflow depletions on SNWA ICS Credits

Year	Certified ICS Credits (af)	Natural Flow at MR Moapa Gage[a] (af)	Natural Flow as Percentage of Predevelopment Baseflow[b] (%)	Potential ICS Credits (af)	Impact to SNWA ICS Credits (af)	Lease Cost per Acre-Foot	Replacement Water Costs
2008	4,983	29,016	86	5,794	(811)	$283.33	$229,781
2009	7,395	29,784	88	8,403	(1,008)	$283.33	$285,597
2010	8,161	29,493	87	9,380	(1,219)	$283.33	$345,379
2011	7,142	28,405	84	8,502	(1,360)	$184.17	$250,471
2012	7,384	28,184	83	8,896	(1,512)	$184.17	$278,465
2013	7,033	28,586	84	8,373	(1,340)	$184.17	$246,788
2014	8,627	28,302	83	10,394	(1,767)	$130.00	$229,710
2015	8,509	30,150	89	9,561	(1,052)	$130.00	$136,760
2016	8,283	30,302	89	9,307	(1,024)	$145.00	$148,480
2017	7,660	30,331	89	8,607	(947)	$145.00	$137,315
			TOTAL		**(12,040)**		**$2,288,746**

[a]MR Moapa Gage values are the Flood-Adjusted Natural Flow as shown in Figure 5-3
[b]Predevelopment baseflow estimate of 33,900 afy was used in calculation.

7.4 *Potential for Increased Damages due to Additional Carbonate Groundwater Production*

The MR Flow Deficit is, at this time, primarily the result of alluvial and carbonate groundwater production within the MRSA. However, as described in Section 6.1, any groundwater production from the carbonate system within the LWRFS will ultimately capture groundwater discharge to the MRSA and, consequently, deplete Muddy River streamflow. These impacts conflict with the senior water rights adjudicated in the 1920 Muddy River Decree and affect the ability of SNWA to create ICS credits for which significant investments have been made.

I believe this is referring to the alluvium

Changing points of diversion to move groundwater production out of the MRSA to locations sourced by the carbonate aquifer will not mitigate these conflicts, only delay their inevitable occurrence. Such changes would exacerbate issues associated with the already over-appropriated carbonate aquifer by accelerating the timing of impacts to sensitive springs due to the additional groundwater production. The timing of impacts will vary based on the magnitude, duration, and location of groundwater production. The impacts may occur relatively quickly, within weeks or months, if additional groundwater production were to occur in areas directly upgradient from the MRSA. Groundwater production in areas farther away, may take longer, but the properties of the aquifer are such that these impacts will eventually result in reduced spring discharge and depletions of Muddy River streamflow.

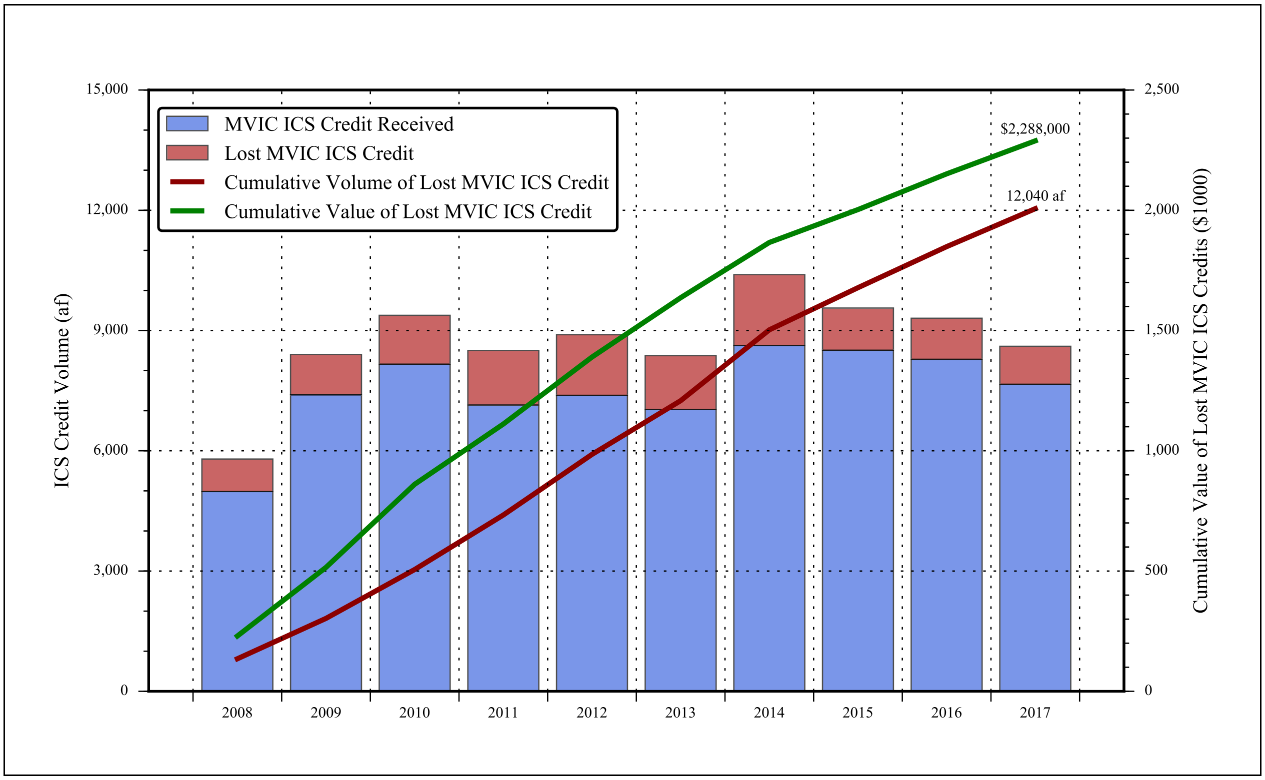


Figure 7-2
SNWA's Tributary ICS Credits and Credits Lost as a Result of Groundwater Production

8.0 RESPONSES TO NSE INTERIM ORDER 1303

An assessment of the current water-resource conditions for the LWRFS was performed and an analysis was completed to evaluate hydrologic responses to natural and anthropogenic stresses observed at various locations of interest. The analysis considered time-series data for several variables that describe the historical conditions of the hydrologic system over a period of decades. The analysis focused on the historical behavior of the Muddy River streamflow and the carbonate aquifer composing the LWRFS. The results and conclusions from this assessment are summarized in this section corresponding to the questions posed by the NSE in Order 1303.

A. Geographic Boundary of the LWRFS

The boundary of the LWRFS should be as defined by the NSE in Order 1303. The LWRFS is underlain by an interconnected distribution of carbonate rocks that constitute a laterally extensive and continuous aquifer extending beneath the basins and across the ranges. The data presented in Section 5.0 demonstrate that the aquifer responds similarly to changes in both groundwater production and recharge throughout the six basins composing the LWRFS. Observed trends are uniform across the system, with only slight variations in the magnitude of the responses. Drawdown responses to pumping stresses are small throughout the region; however, they are unequivocal and occur in very short time frames given the distances between the pumping centers and points of observation. This demonstrates the aquifer has a very high degree of hydraulic connection and should be treated as a single administrative unit.

B. Hydrologic responses to the cessation of the Order 1169 aquifer test

An analysis of the hydrologic responses to natural and anthropogenic stresses at wells and springs representative of the carbonate aquifer was performed for the LWRFS. Time-series charts of groundwater levels and gage records for the Pederson Spring and Warm Springs West gages were prepared for the period 1993 to 2018.

Small changes in the hydraulic heads (on the order of only 2-3 ft) have resulted in significant changes in the discharges from high-elevation springs. Additionally, the lack of any significant recovery response after the completion of the Order 1169 aquifer test and the fact that the system has yet to recover to pre-test levels are critical observations. These observations indicate that the aquifer has a very high transmissivity and low storage capacity (i.e., high aquifer diffusivity). As a result, the system is very sensitive to recharge and pumping stresses. The analysis observations and conclusions are listed below:

- Widespread responses to pumping stresses associated with the NSE Order 1169 aquifer test were observed in groundwater-level and spring-discharge records across all six basins of the LWRFS;

- High-elevation springs in the MRSA are highly sensitive to changes in carbonate groundwater levels and are most susceptible to impacts associated with carbonate groundwater production;

- By the end of the aquifer test, discharge from Pederson Spring decreased by about 0.15 cfs (to about 1/3 of baseflow).

- Spring discharge as measured at the Warm Springs West gage decreased about 0.3 cfs (< 10% of baseflow).

- Continuation of the aquifer test or pumping from the MX-5 well would have reduced flows at the Warm Springs West gage to the initial 2006 MOA trigger level (3.2 cfs), and lower depending on the duration.

- Groundwater levels and spring discharge rates have not recovered to pre-test levels.

- Recovery achieved its maximum levels between the first quarters of 2015 and 2016, or a period of time approximately equal to the duration of the pumping period.

- Carbonate groundwater levels and spring discharge-rates have declined since 2016.

- Flow measured at the Warm Springs West gage will reach Trigger Ranges sooner and at lower production rates than contemplated in the 2006 MOA if pumping in Coyote Spring Valley resumed at levels commensurate with the Order 1169 aquifer test.

- Given the current rates of carbonate groundwater production, recovery of groundwater levels and spring discharges to pre-test levels is not possible without extraordinary hydrology such as the 2004-2005 winter-season precipitation; and

- Even with such extraordinary hydrology, subsequent years of lesser precipitation with similar groundwater production volumes will result in a resumption of declining trends as has been observed in the historical record.

C. Groundwater production and the capture of the Muddy River (springs and river flows)

An evaluation of Muddy River streamflow was performed to identify the likely causes of a long-term trend of declining streamflow observed in the record of the MR Moapa gage since the early 1960s. Long-term climate variability and changes in land use were ruled out as major contributors to the decline. Annual records of winter-season precipitation, a reflection of climate conditions, indicate that the average annual precipitation during the period of declining streamflow (post-1965) is not substantively different than the average for the period prior to the decline (pre-1965). Land-use changes during this period may have had very short-term effects, but the incremental changes in consumptive uses above the gage have been minimal. Thus, the causes of the streamflow decline have been surface-water diversions above the MR Moapa gage and LWRFS groundwater production.

A period from 1993 to 2018, in which comprehensive records of Muddy River streamflow, surface-water diversions and groundwater production are available, were analyzed to estimate the

MR Flow Deficit. An average annual natural-flow record was constructed by adding annual surface-water diversions to the flood-adjusted flow record of the MR Moapa gage. The annual MR Flow Deficit was estimated by computing the difference between the average annual pre-development flow of the Muddy River and the natural-flow record. An analysis was performed to determine whether MRSA groundwater production could account for the MR Flow Deficit. The results of the analysis yielded the following observations and conclusions:

- Muddy River streamflow declined from a pre-development condition of 33,900 afy to a minimum of about 22,000 af in 2003.
- Since 2003, streamflow has steadily increased to its current rate of over 30,000 afy as a result of reduced surface-water diversions and MRSA groundwater production.
- The MR Flow Deficit peaked at about 7,500 af in 2003 and was about 2,300 af in 2018.
- MRSA groundwater production above the MR Moapa gage peaked in 2000 at 7,850 af, and was 1,990 af in 2018.
- Groundwater production from the MRSA alluvial reservoir depletes Muddy River streamflow on a 1:1 basis.
- Groundwater production from MRSA carbonate wells deplete Muddy River streamflow approaching a 1:1 basis. Groundwater production from other carbonate wells in the LWRFS deplete streamflow; however, their effect cannot be readily detected from the measurements.
- A significant increase in carbonate groundwater production, such as that which occurred during the NSE Order 1169 aquifer test, will cause sharp declines in carbonate-aquifer water levels and spring discharges.

An analysis was conducted to estimate the contribution of various springs to the total MRSA discharge over a period of several years and under different stress conditions. Ratios of spring discharge to total MRSA discharge were computed for the Pederson Spring Complex (as measured by the Warm Springs West gage), Baldwin Spring, and Jones Spring. Ratios were computed for the period 2001 to 2012 and were found to be relatively constant at 0.076, 0.061, and 0.034 (or 7.6, 6.1, and 3.4 percent of the total MRSA discharge), respectively. The fact that the ratios do not change under variable stress conditions indicates that the springs respond commensurately with the hydraulic head in the carbonate aquifer.

The ratio derived for the Warm Springs West gage was used to calculate reductions in the MRSA discharge that correspond to potential flow conditions at the Warm Springs West gage. Knowing that a reduction in the MRSA discharge could only be caused by a lowering of the hydraulic head in the carbonate aquifer, limits on production from the carbonate aquifer were quantified by calculating reductions in MRSA discharge (from predevelopment conditions) that correspond to selected discharge levels at the Warm Springs West gage, including trigger ranges set in the 2006 MOA. For example, a reduction of 0.62 cfs in the Warm Springs West discharge, from 3.82 to 3.20 cfs, corresponds to a decrease of approximately 8.16 cfs, or 5,908 afy in MRSA discharge. This value represents the long-term average annual production from the carbonate aquifer that can occur while still maintaining an average flow rate of 3.20 cfs at the Warm Springs West gage.

The results of the Order 1169 aquifer test demonstrate that for the areas directly upgradient of the MRSA (i.e., Arrow Canyon and Coyote Spring Valley), impacts propagate to the high-elevation springs within a matter of weeks or months. In the long-term, the location of the production wells does not matter, groundwater withdrawn anywhere within the connected carbonate aquifer or the MRSA alluvial reservoir will impact the MRSA discharge and, consequently, deplete Muddy River streamflow. These impacts have already occurred, resulting in conflicts with senior water rights. In the short term, it is preferable to keep groundwater production away from the MRSA to protect flows in the high-elevations springs that are critical habitat for the Moapa dace while groundwater production is managed to a lower threshold.

The impacts of Muddy River streamflow depletions were analyzed and quantified. Groundwater production in the MRSA and, to a lesser extent, the rest of the LWRFS has depleted Muddy River streamflows and conflicted with senior surface-water rights adjudicated in the 1920 Muddy River Decree. Streamflow depletions between 2008 and 2017 have resulted in SNWA losing an estimated 12,040 af of potential Tributary Conservation ICS credits at a replacement cost of almost $2.3 million.

These data indicate that pumping simply cannot occur without conflicting with senior rights. While it is unreasonable to assume that all pumping in the LWRFS would be eliminated, it should not be permitted to continue without strict regulatory oversight and appropriate mitigation to affected senior water-right holders and adequate protections for the Moapa dace. If the conflicts with senior water-right holders are adequately addressed, the total annual groundwater production should be managed between 4,000 – 6,000 afy over the long-term.

D. The effects of moving water rights between alluvial wells and carbonate wells

Production wells completed in the alluvial reservoir adjacent to the Muddy River capture groundwater that would otherwise discharge to the river. In addition, MRSA production wells completed in the carbonate aquifer capture water that would otherwise replenish the alluvial reservoir through diffuse subsurface flow or discharge from discrete springs. Capturing this groundwater depletes the source of supply to the alluvial reservoir and springs, thereby, depleting the streamflow. In each case, this groundwater production conflicts with senior Muddy River water rights.

Changing points of diversion to move groundwater production from the MRSA alluvial reservoir to locations sourced by the carbonate aquifer will not mitigate these conflicts, only delay their inevitable occurrence. Such changes would exacerbate issues associated with the already over-appropriated carbonate aquifer by accelerating the timing of impacts to the high-elevation springs due to the additional groundwater production. The timing of impacts will vary based on the magnitude, duration, and location of groundwater production. The impacts may occur relatively quickly, within weeks or months, if additional groundwater production were to occur in areas directly upgradient from the MRSA. Groundwater production in areas farther away, may take longer, but the properties of the aquifer are such that these impacts will eventually result in reduced spring discharge and depletions of Muddy River streamflow.

E. Any other matter believed to be relevant to the NSE's analysis

In summary, all groundwater production within the LWRFS from the MRSA alluvial reservoir or carbonate aquifer will impact discharge to the MRSA and result in Muddy River streamflow depletions. Any streamflow depletion constitutes a conflict with senior-priority Muddy River water rights and must be mitigated. In addition, groundwater production from the carbonate aquifer has been shown to impact springs that provide critical habitat for the Moapa dace. The dramatic increase in Coyote Spring Valley groundwater production during the implementation of the Order 1169 aquifer test demonstrated that these impacts can occur in very short time frames.

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Appendix A

Site Table for Wells

Table A-1
Site Table for Wells
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Site Name	UTM Northing (m)	UTM Easting (m)	Surface Elevation (ft amsl)	Drill Depth (ft bgs)	Well Depth (ft bgs)	Well Type\1	Well Completion	Water Level Obs. Date	Depth to Water (ft-bgs)	Water Level Elevation (ft amsl)
KANE SPRINGS VALLEY (HA 206)										
KMW-1	4,098,863	689,882	2,870.60	---	---	M	Carbonate	1/3/2019	992.72	1,877.88
COYOTE SPRING VALLEY (HA 210)										
BEDROC 1	4,094,151	679,399	2,492.44	---	---	P	Basin Fill	---	---	---
BEDROC 2	4,094,374	679,009	2,529.00	---	---	P	Basin Fill	---	---	---
CE-VF-1	4,083,038	683,025	2,468.34	714	714	M	Basin Fill	2/6/2019	551.36	1,916.98
CE-VF-2	4,082,892	683,007	2,468.35	1,221	860	M	Carbonate	2/6/2019	600.08	1,868.27
CSI-1	4,074,459	686,044	2,278.05	935	920	P	Carbonate	2/4/2019	462.73	1,815.32
CSI-2	4,075,780	687,084	2,208.95	1,019	1,016	P	Carbonate	3/12/2019	391.41	1,817.54
CSI-3	4,077,518	685,809	2,334.51	1,156	1,152	P	Carbonate	3/12/2019	515.92	1,818.59
CSI-4	4,080,224	682,409	2,511.88	1,397	1,384	P	Carbonate	3/12/2019	691.04	1,820.84
CSV-3	4,062,583	685,222	2,415.93	780	756	M	Basin Fill	2/6/2019	595.48	1,820.45
CSV3009M	4,094,987	681,079	2,595.08	1,580	1,578	M	Basin Fill	2/20/2019	493.64	2,101.44
CSV3011M	4,094,873	684,075	2,665.72	1,580	1,555	M	Basin Fill	2/6/2019	751.00	1,914.72
CSVM-1	4,073,793	688,602	2,160.60	1,060	1,040	M	Carbonate	2/4/2019	342.70	1,817.90
CSVM-2	4,059,370	685,625	2,572.74	1,425	1,400	M	Carbonate	2/4/2019	752.11	1,820.63
CSVM-3	4,102,600	679,319	2,650.68	1,230	1,200	M	Carbonate	2/6/2019	444.56	2,206.12
CSVM-4	4,095,971	688,086	2,842.38	1,605	1,600	M	Carbonate	3/12/2019	969.57	1,872.81
CSVM-5	4,068,774	680,295	3,130.70	1,783	1,780	M	Carbonate	2/5/2019	1,079.51	2,051.19
CSVM-6	4,078,333	686,453	2,251.66	1,200	1,160	M	Carbonate	2/5/2019	436.13	1,815.53
CSVM-7	4,101,968	678,234	2,692.08	610	607	M	Basin Fill	2/6/2019	445.31	2,246.77
CSV-RW2	4,074,082	687,862	2,200.06	720	710	P	Carbonate	3/19/2019	384.54	1,815.52
MX-4	4,074,276	688,003	2,177.02	669	669	M	Carbonate	3/26/2019	356.36	1,820.66
MX-5	4,074,219	688,084	2,176.13	628	628	P	Carbonate	3/28/2019	357.56	1,818.57
BLACK MOUNTAINS AREA (HA 215)										
BM-DL-1	4,019,493	689,926	2,467.94	1,800	1,800	M	Carbonate	11/17/2011	650.74	1,817.20
BM-DL-2	4,019,591	689,270	2,487.56	1,400	1,400	M	Carbonate	3/11/2019	675.34	1,812.22
BM-ONCO-1	4,010,748	702,650	2,055.83	1,291	1,280	M	Clastic	2/4/2019	341.96	1,713.87
BM-ONCO-2	4,010,722	702,054	2,098.17	1,575	1,570	M	Clastic	2/4/2019	385.45	1,712.72
EBM-3	4,018,550	689,601	2,388.40	1,241	900	M	Carbonate	12/3/2017	579.00	1,809.40
EBM-4	4,018,828	689,782	2,391.14	1,134	1,128	M	Carbonate	3/1/2019	601.00	1,790.14
EBM-5	4,019,030	689,858	2,440.70	1,400	1,014	P	Carbonate	---	---	---
EBM-6	4,018,803	689,765	2,421.30	1,401	1,000	P	Carbonate	---	---	---
EBP-2	4,018,604	689,629	2,442.46	1,214	1,214	P	Carbonate	---	---	---
EGV-3	4,019,000	689,857	2,434.21	960	955	M	Carbonate	3/1/2019	611.00	1,823.21
GARNET VALLEY (HA 216)										
CRYSTAL 1	4,039,716	694,389	2,072.46	497	497	M	Carbonate	3/21/2019	261.44	1,811.02
CRYSTAL 2	4,039,284	694,146	2,069.91	565	565	M	Carbonate	---	---	---

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Table A-1
Site Table for Wells
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Site Name	UTM Northing (m)	UTM Easting (m)	Surface Elevation (ft amsl)	Drill Depth (ft bgs)	Well Depth (ft bgs)	Well Type[1]	Well Completion	Water Level Obs. Date	Depth to Water (ft-bgs)	Water Level Elevation (ft amsl)
EBA-1	4,024,108	686,513	2,426.99	1,598	1,200	P	Carbonate	---	---	---
FIRST SOLAR	4,033,129	683,330	2,603.22	2,000	1,990	P	Carbonate	3/11/2019	792.90	1,810.32
GARNET	4,036,387	693,046	2,096.68	500	500	M	Basin Fill	---	---	---
GV-1	4,034,143	682,983	2,691.14	1,400	1,400	M	Carbonate	2/4/2019	883.58	1,807.56
GV-2	4,025,690	686,227	2,424.08	1,232	1,232	P	Carbonate	10/15/2018	610.63	1,813.45
GV-DUKE-WS1	4,029,104	686,286	2,243.50	685	685	P	Carbonate	3/11/2019	432.05	1,811.45
GV-DUKE-WS2	4,029,097	686,199	2,246.72	2,020	1,965	P	Carbonate	---	---	---
GV-KERR	4,029,147	683,738	2,404.60	1,145	1,145	P	Carbonate	---	---	---
GV-LENZIE-3[2]	4,029,329	686,247	2,247.00	1,960	1,920	P	Carbonate	3/11/2019	432.16	1,814.84
GV-MIRANT1	4,032,318	683,115	2,567.87	2,007	1,992	P	Carbonate	3/11/2019	756.92	1,810.95
GV-PW-MW1	4,031,730	683,460	2,502.27	1,500	1,500	M	Carbonate	2/5/2019	691.77	1,810.50
GV-PW-MW2	4,031,488	682,652	2,524.79	1,500	1,500	M	Carbonate	3/11/2019	715.02	1,809.77
GV-PW-WS1	4,031,435	683,005	2,532.29	2,020	2,000	P	Carbonate	3/13/2019	693.36	1,838.93
GV-RW1	4,036,645	692,928	2,069.20	870	833	P	Carbonate	12/13/2017	223.22	1,845.98
GV-USLIME1	4,026,564	687,748	2,286.48	860	860	P	Carbonate	---	---	---
GV-USLIME2	4,029,329	687,739	2,155.33	500	500	P	Basin Fill	---	---	---
HARVEY WELL	4,036,446	693,020	2,066.96	---	---	P	Carbonate	---	---	---
PAIUTES-M3	4,044,302	691,536	2,235	670	670	M	Carbonate	3/31/2019	423.19	1,811.81
RS-PW-1	4,028,841	690,787	2,240.00	860	860	P	Clastic	3/12/2019	511.63	1,728.37
RS-PW-2	4,027,890	690,674	2,412.00	---	---	P	Carbonate	---	---	---
RS-PW-3	4,029,719	691,026	2,162.00	720	720	P	Carbonate	---	---	---
RS-PW-5	4,029,626	691,053	2,076.94	---	---	P	Carbonate	---	---	---
RS-PW-6	4,026,318	690,552	2,471.00	---	---	P	Carbonate	---	---	---
RS-PW-7	4,027,940	691,938	2,420.00	940	940	P	Carbonate	---	---	---
Western Gypsum Well 1	4,028,739	688,924	2,197.00	725	725	P	Basin Fill	---	---	---
HIDDEN VALLEY (HA 217)										
SHV-1	4,047,256	685,751	2,650.32	920	---	M	Basin Fill	2/7/2019	834.38	1,815.94
CALIFORNIA WASH (HA 218)										
BYRON	4,051,282	710,993	1,903.06	1,095	1,095	M	Basin Fill	3/6/2019	238.32	1,664.74
PAIUTES-ECP1	4,046,590	696,729	2,230.05	1,170	1,125	P	Carbonate	3/13/2011	414.96	1,815.09
PAIUTES-ECP2	4,046,742	696,723	2,228.33	1,228	---	P	Carbonate	3/31/2019	414.86	1,813.47
PAIUTES-ECP3	4,046,984	696,714	2,243.08	1,500	---	P	Carbonate	---	---	---
PAIUTES-M1	4,057,109	704,517	1,895.69	400	400	M	Carbonate	3/31/2019	82.26	1,813.43
PAIUTES-M2	4,040,876	695,836	2,108.50	680	680	M	Carbonate	3/31/2019	298.17	1,810.33
PAIUTES-TH1	4,044,959	697,234	2,169.95	1,100	---	P	Carbonate	---	---	---
PAIUTES-TH2	4,049,916	697,684	2,338.09	1,198	---	M	Carbonate	3/31/2019	526.21	1,811.88

Table A-1
Site Table for Wells
(Page 3 of 3)

Site Name	UTM Northing (m)	UTM Easting (m)	Surface Elevation (ft amsl)	Drill Depth (ft bgs)	Well Depth (ft bgs)	Well Type\1	Well Completion	Water Level Obs. Date	Depth to Water (ft-bgs)	Water Level Elevation (ft amsl)
MUDDY RIVER SPRINGS AREA (HA 219)										
ABBOTT	4,065,656	706,443	1,712.34	100	100	M	Basin Fill	3/19/2019	10.84	1,701.50
ARROW CANYON	4,067,763	701,108	1,861.45	565	565	P	Carbonate	2/28/2019	48.87	1,812.58
ARROW CANYON 2	4,067,750	701,083	1,863.29	746	742	P	Carbonate	11/6/2018	49.40	1,813.89
BEHMER MONITORIING	4,065,080	706,031	1,716.59	115	115	P	Basin Fill	7/25/2018	11.64	1,704.95
CSV-1	4,071,630	691,378	2,160.25	765	765	M	Basin Fill	3/6/2019	350.61	1,809.64
CSV-2	4,072,967	703,217	2,188.68	---	478	M	Carbonate	3/31/2019	395.52	1,793.16
EH-4	4,064,736	703,929	1,933.93	285	285	M	Carbonate	3/19/2019	120.65	1,813.28
EH-5B	4,067,619	701,569	1,844.80	265	264	M	Carbonate	3/19/2019	31.56	1,813.24
LDS CENTRAL	4,066,544	704,114	1,762.78	52	50	P	Basin Fill	11/20/2017	3.88	1,758.90
LDS EAST	4,066,594	704,479	1,753.13	77	77	P	Basin Fill	3/19/2019	7.27	1,745.86
LDS WEST	4,067,083	702,746	1,807.80	80	80	P	Basin Fill	3/19/2019	19.95	1,787.85
LEWIS 1	4,068,043	702,164	1,823.07	90	90	P	Basin Fill	---	---	---
LEWIS 1 OLD	4,068,229	702,077	1,828.71	58	58	M	Basin Fill	3/19/2019	29.86	1,798.85
LEWIS 2	4,067,886	702,365	1,826.04	100	100	P	Basin Fill	3/19/2019	28.92	1,797.12
LEWIS 3	4,068,022	701,963	1,825.08	100	100	P	Basin Fill	---	---	---
LEWIS 4	4,067,618	702,029	1,832.87	97	97	P	Basin Fill	---	---	---
LEWIS 5	4,067,484	702,195	1,828.11	93	93	P	Basin Fill	---	---	---
LEWIS NORTH	4,067,872	701,589	1,844.71	70	70	M	Basin Fill	3/19/2019	34.79	1,809.92
LEWIS SOUTH	4,067,266	702,737	1,808.10	90	90	M	Basin Fill	3/19/2019	14.74	1,793.36
MX-6	4,071,381	697,482	2,278.11	937	937	P	Carbonate	3/29/2019	463.30	1,814.81
PERKINS OLD	4,065,223	705,637	1,728.51	60	60	M	Basin Fill	3/19/2019	20.48	1,708.03
PERKINS PRODUCTION	4,065,206	705,693	1,734.86	135	135	P	Basin Fill	3/19/2019	21.33	1,713.53
UMVM-1	4,070,248	694,305	2,061.88	1,785	1,780	M	Carbonate	3/6/2019	247.46	1,814.42

\1Well Type: M = Monitoring well, P = Production well
\3GV-LENZIE-3 is the replacement well for GV-DUKE-WS2, which was plugged and abandoned in 2016

Appendix B

Surface Water Diversions above the MR Moapa Gage

Table B-1
Surface Water Diversions above the MR Moapa Gage in the MRSA

Year	Nevada Energy Muddy River Diversion (afy)	Moapa Valley Water District Diversions	
		Baldwin Spring Box (afy)	Pipeline-Jones Spring Box (afy)
1978	2,910	---	---
1979	2,850	---	---
1980	2,630	---	---
1981	2,740	---	---
1982	2,490	---	---
1983	1,720	---	---
1984	2,280	---	---
1985	---	---	---
1986	---	---	---
1987	---	---	---
1988	2,164	---	---
1989	2,012	---	---
1990	3,526	---	---
1991	3,625	---	---
1992	2,942	492[1]	318[1]
1993	3,083	922	684
1994	2,462	948	660
1995	2,950	1,449	750
1996	3,219	1,707	659
1997	2,494	1,771	656
1998	2,296	646	700
1999	2,585	250	656
2000	3,063	53	635
2001	3,573	101	690
2002	3,727	210	635
2003	3,651	9	653
2004	2,923	44	664
2005	2,535	248	642
2006	1,659	569	699
2007	2,776	719	681
2008	2,791	332	702
2009	2,496	1,166	322
2010	2,283	1,119	202
2011	1,287	605	3
2012	393	27	3
2013	17	131	1
2014	230	990	50
2015	0	92	0
2016	0	89	0
2017	0	126	0
2018	0	802	0

[1] Value reflects a partial year of production.

Appendix C

Groundwater Production Data

Table C-1
Shallow Alluvial Wells in the Muddy River Springs Area Pumped by Nevada Energy

Well Name	Well Log	Township	Range	Section	Section Quarter	Depth Cased[a]	Top of Perforation[a]	Bottom of Perforation[a]	Well Completion Date[b]
Lewis 1	27268	14S	65E	8	NW NE	90	30	90	3/7/1986
Lewis 2	62870	14S	65E	8	SE NE	100	35	100	6/22/1972
Lewis 3	12727	14S	65E	8	SW NE	100	35	100	6/22/1972
Lewis 4	10853	14S	65E	8	NW SE	97	38	88	4/12/1969
Lewis 5	10852	14S	65E	8	NW SE	93	38	88	5/6/1969
Perkins Production	31969	14S	65E	22	NE NE	135	25	125	6/16/1988
Behmer	15623	14S	65E	23	NW NW	115	30	115	5/20/1976
LDS East	102501	14S	65E	15	NW NW	77	17	77	6/15/1988
LDS Central	102500	14S	65E	16	NE NE	50	25	50	6/15/1988
LDS West	62880	14S	65E	9	SW SW	80	10	80	11/26/1968

[a]Depth cased, Top of Perforation and Bottom of Perforation depths are in feet below land surface.
[b]Well completion dates listed are the most recent well restoration/repair dates and may not reflect installation dates.

Table C-2
MRSA Annual Groundwater Production

Year	Alluvial Well Development (afy)			Carbonate Well Development (afy)
	Lewis Wells	LDS Wells	Perkins & Behmer Wells	
1987	1,188	0	816	---
1988	1,887	1,811	942	---
1989	1,682	1,820	1,746	---
1990	1,485	1,559	997	---
1991	1,182	1,310	1,240	---
1992	1,160	1,482	776	513[1]
1993	1,648	905	1,104	1,169
1994	2,074	1,468	899	894
1995	1,299	1,583	581	678
1996	1,522	2,097	1,134	705
1997	1,195	2,175	726	808
1998	2,259	2,903	804	2,039
1999	1,876	2,390	482	2,579
2000	1,773	3,169	1,024	2,908
2001	1,303	2,257	1,320	2,743
2002	2,139	2,051	1,545	2,573
2003	1,514	2,159	1,345	2,816
2004	1,568	1,802	1,080	2,718
2005	1,699	2,138	1,390	2,557
2006	1,846	2,591	1,285	2,966
2007	1,278	2,227	1,235	2,079
2008	1,509	1,626	1,150	2,272
2009	1,007	1,532	1,553	2,034
2010	1,315	1,386	1,194	1,826
2011	1,826	1,496	1,070	1,837
2012	869	1,018	1,189	2,638
2013	1,279	1,047	1,637	2,496
2014	2,160	1,255	1,411	1,442
2015	473	176	639	2,395
2016	661	276	0	2,798
2017	136	240	159	2,819
2018	13	0	0	1,979

[1] Value reflects a partial year of production.

Table C-3
LWRFS Carbonate-Aquifer Annual Groundwater Production

Year	Coyote Spring Valley (afy)	Black Mountains Area (afy)[1]	Garnet Valley (afy)	California Wash (afy)	Muddy River Springs Area (afy)	Total (afy)
1992	---	---	---	---	513[2]	513
1993	---	---	---	---	1,169	1,169
1994	---	---	---	---	894	894
1995	---	---	---	---	678	678
1996	---	1,613	145	---	705	2,463
1997	---	1,579	126	---	808	2,514
1998	---	1,408	131	---	2,039	3,578
1999	---	1,569	536	---	2,579	4,684
2000	---	1,693	509	---	2,908	5,110
2001	---	1,588	732	---	2,743	5,063
2002	---	1,744	967	---	2,573	5,284
2003	---	1,709	917	---	2,816	5,442
2004	---	1,710	878	---	2,718	5,306
2005	259	1,640	992	---	2,557	5,448
2006	1,277	1,569	1,050	---	2,966	6,861
2007	2,781	1,585	1,141	---	2,079	7,585
2008	1,690	1,591	1,538	---	2,272	7,091
2009	1,413	1,568	1,510	15	2,034	6,541
2010	2,672	1,561	1,257	19	1,826	7,336
2011	5,331	1,398	1,250	26	1,837	9,841
2012	5,101	1,556	1,253	21	2,638	10,568
2013	2,992	1,585	1,237	59	2,496	8,369
2014	1,643	1,430	1,191	288	1,442	5,994
2015	1,494	1,448	1,395	411	2,395	7,144
2016	1,117	1,434	2,242	200	2,798	7,791
2017	1,399	1,507	1,861	43	2,819	7,630
2018	1,967	1,623	1,751	24	1,979	7,344

[1] Values represent the combined production of NV Cogeneration Association wells EBM-4, EBM-5, EBM-6, EBP-2, and EGV-2

[2] Value reflects a partial year of production.

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Table C-4
Groundwater Production
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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
210	BEDROC WELLS	Basin Fill	2012	209,512,417	642.97	Combined BEDROC wells 1-4	Western Elite, 2018
210	BEDROC WELLS	Basin Fill	2013	213,748,480	655.97	Combined BEDROC wells 1-4	Western Elite, 2018
210	BEDROC WELLS	Basin Fill	2014	189,977,650	583.02	Combined BEDROC wells 1-4	Western Elite, 2018
210	BEDROC WELLS	Basin Fill	2015	206,397,282	633.41	Combined BEDROC wells 1-6	Western Elite, 2018
210	BEDROC WELLS	Basin Fill	2016	200,632,978	615.72	Combined BEDROC wells 1-6	Western Elite, 2018
210	BEDROC WELLS	Basin Fill	2017	181,736,878	557.73	Combined BEDROC wells 1-7	Western Elite, 2018
210	CSI-1	Carbonate	2005	70,382,000	215.99		NDWR, 2018a
210	CSI-1	Carbonate	2006	235,338,000	722.23		NDWR, 2018a
210	CSI-1	Carbonate	2007	247,947,000	760.92		NDWR, 2018a
210	CSI-1	Carbonate	2008	14,273,000	43.80		NDWR, 2018a
210	CSI-1	Carbonate	2009	0	0.00		NDWR, 2018a
210	CSI-1	Carbonate	2010	0	0.00		NDWR, 2018a
210	CSI-1	Carbonate	2011	0	0.00		NDWR, 2018a
210	CSI-1	Carbonate	2012	6,885,242	21.13		NDWR, 2018a
210	CSI-1	Carbonate	2013	386,506,510	1,186.14		NDWR, 2018a
210	CSI-1	Carbonate	2014	294,814,000	904.75		NDWR, 2018a
210	CSI-1	Carbonate	2015	186,961,000	573.76		NDWR, 2018a
210	CSI-1	Carbonate	2016	233,857,000	717.68		NDWR, 2018a
210	CSI-1	Carbonate	2017	399,700,000	1,226.63		NDWR, 2018a
210	CSI-1	Carbonate	2018	131,660,000	404.05		NDWR, 2019a
210	CSI-2	Carbonate	2005	13,851,000	42.51		NDWR, 2018a
210	CSI-2	Carbonate	2006	170,586,000	523.51		NDWR, 2018a
210	CSI-2	Carbonate	2007	489,531,000	1,502.32		NDWR, 2018a
210	CSI-2	Carbonate	2008	313,515,000	962.14		NDWR, 2018a
210	CSI-2	Carbonate	2009	4,180,000	12.83		NDWR, 2018a
210	CSI-2	Carbonate	2010	0	0.00		NDWR, 2018a
210	CSI-2	Carbonate	2011	0	0.00		NDWR, 2018a

Table C-4
Groundwater Production
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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
210	CSI-2	Carbonate	2012	0	0.00		NDWR, 2018a
210	CSI-2	Carbonate	2013	0	0.00		NDWR, 2018a
210	CSI-2	Carbonate	2014	0	0.00		NDWR, 2018a
210	CSI-2	Carbonate	2015	0	0.00		NDWR, 2018a
210	CSI-2	Carbonate	2016	0	0.00		NDWR, 2018a
210	CSI-2	Carbonate	2017	0	0.00		NDWR, 2018a
210	CSI-2	Carbonate	2018	499,023,000	1531.45		NDWR, 2019a
210	CSI-3	Carbonate	2006	10,164,000	31.19		NDWR, 2018a
210	CSI-3	Carbonate	2007	160,672,000	493.08		NDWR, 2018a
210	CSI-3	Carbonate	2008	209,739,000	643.67		NDWR, 2018a
210	CSI-3	Carbonate	2009	263,978,000	810.12		NDWR, 2018a
210	CSI-3	Carbonate	2010	340,371,348	1,044.56		NDWR, 2018a
210	CSI-3	Carbonate	2011	233,891,372	717.79		NDWR, 2018a
210	CSI-3	Carbonate	2012	183,781,356	564.00		NDWR, 2018a
210	CSI-3	Carbonate	2013	11,779,752	36.15		NDWR, 2018a
210	CSI-3	Carbonate	2014	0	0.00		NDWR, 2018a
210	CSI-3	Carbonate	2015	0	0.00		NDWR, 2018a
210	CSI-3	Carbonate	2016	0	0.00		NDWR, 2018a
210	CSI-3	Carbonate	2017	0	0.00		NDWR, 2018a
210	CSI-3	Carbonate	2018	0	0.00		NDWR, 2019a
210	CSI-4	Carbonate	2007	7,898,000	24.24		NDWR, 2018a
210	CSI-4	Carbonate	2008	3,339,000	10.25		NDWR, 2018a
210	CSI-4	Carbonate	2009	187,369,000	575.01		NDWR, 2018a
210	CSI-4	Carbonate	2010	79,486,396	243.93		NDWR, 2018a
210	CSI-4	Carbonate	2011	156,854,000	481.37		NDWR, 2018a
210	CSI-4	Carbonate	2012	180,845,000	554.99		NDWR, 2018a
210	CSI-4	Carbonate	2013	0	0.00		NDWR, 2018a

Table C-4
Groundwater Production
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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
210	CSI-4	Carbonate	2014	101,517,000	311.54		NDWR, 2018a
210	CSI-4	Carbonate	2015	174,209,000	534.63		NDWR, 2018a
210	CSI-4	Carbonate	2016	130,213,000	399.61		NDWR, 2018a
210	CSI-4	Carbonate	2017	56,300,000	172.78		NDWR, 2018a
210	CSI-4	Carbonate	2018	9,116,000	27.98		NDWR, 2019a
210	CSV-RW2	Carbonate	2000	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2001	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2002	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2003	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2004	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2005	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2006	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2007	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2008	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2009	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2010	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2011	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2012	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2013	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2014	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2015	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2016	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2017	0	0.00		NDWR, 2018a
210	CSV-RW2	Carbonate	2018	0	0.00		NDWR, 2019a
210	MX-5	Carbonate	2008	9,819,500	30.13		SNWA, 2010
210	MX-5	Carbonate	2009	5,017,300	15.40		SNWA, 2010
210	MX-5	Carbonate	2010	450,905,191	1,383.78		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
210	MX-5	Carbonate	2011	1,346,243,737	4,131.47		NDWR, 2018a
210	MX-5	Carbonate	2012	1,290,557,441	3,960.58		NDWR, 2018a
210	MX-5	Carbonate	2013	576,659,399	1,769.70		NDWR, 2018a
210	MX-5	Carbonate	2014	138,903,080	426.28		NDWR, 2018a
210	MX-5	Carbonate	2015	125,583,895	385.40		NDWR, 2018a
210	MX-5	Carbonate	2016	0	0.00		NDWR, 2018a
210	MX-5	Carbonate	2017	0	0.00		NDWR, 2018a
210	MX-5	Carbonate	2018	1,265,648	3.88		NDWR, 2019a
215	EBM-4	Carbonate	1996	209,745,000	643.68		NDWR, 2018b
215	EBM-4	Carbonate	1997	252,361,100	774.47		NDWR, 2018b
215	EBM-4	Carbonate	1998	240,830,000	739.08		NDWR, 2018b
215	EBM-4	Carbonate	1999	243,225,000	746.43		NDWR, 2018b
215	EBM-4	Carbonate	2000	259,923,000	797.67		NDWR, 2018a
215	EBM-4	Carbonate	2001	277,466,000	851.51		NDWR, 2018a
215	EBM-4	Carbonate	2002	281,379,000	863.52		NDWR, 2018a
215	EBM-4	Carbonate	2003	176,807,000	542.60		NDWR, 2018a
215	EBM-4	Carbonate	2004	235,330,000	722.20		NDWR, 2018a
215	EBM-4	Carbonate	2005	250,208,000	767.86		NDWR, 2018a
215	EBM-4	Carbonate	2006	247,516,000	759.60		NDWR, 2018a
215	EBM-4	Carbonate	2007	253,668,000	778.48		NDWR, 2018a
215	EBM-4	Carbonate	2008	99,584,000	305.61		NDWR, 2018a
215	EBM-4	Carbonate	2009	208,401,000	639.56		NDWR, 2018a
215	EBM-4	Carbonate	2010	312,428,000	958.81		NDWR, 2018a
215	EBM-4	Carbonate	2011	253,605,000	778.29		NDWR, 2018a
215	EBM-4	Carbonate	2012	230,985,264	708.87		NDWR, 2018a
215	EBM-4	Carbonate	2013	218,728,708	671.25		NDWR, 2018a
215	EBM-4	Carbonate	2014	224,975,000	690.42		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
215	EBM-4	Carbonate	2015	116,017,840	356.05	Converted to monitoring well and replaced with well EBM-6 as new production well.	NDWR, 2018a
215	EBM-5	Carbonate	2015	93,435,000	286.74		NDWR, 2018a
215	EBM-5	Carbonate	2016	244,061,013	749.00		NDWR, 2018a
215	EBM-5	Carbonate	2017	271,995,048	834.72		NDWR, 2018a
215	EBM-5	Carbonate	2018	167,309,392	513.45		NDWR, 2019a
215	EBM-6	Carbonate	2015	65,970,000	202.45		NDWR, 2018a
215	EBM-6	Carbonate	2016	194,914,456	598.17		NDWR, 2018a
215	EBM-6	Carbonate	2017	208,396,543	639.55		NDWR, 2018a
215	EBM-6	Carbonate	2018	261,318,592	801.96		NDWR, 2019a
215	EBP-2	Carbonate	1996	64,080,000	196.65		NDWR, 2018b
215	EBP-2	Carbonate	1997	33,070,000	101.49		NDWR, 2018b
215	EBP-2	Carbonate	1998	9,314,000	28.58		NDWR, 2018b
215	EBP-2	Carbonate	1999	36,840,000	113.06		NDWR, 2018b
215	EBP-2	Carbonate	2000	21,987,000	67.48		NDWR, 2018a
215	EBP-2	Carbonate	2001	1,179,000	3.62		NDWR, 2018a
215	EBP-2	Carbonate	2002	23,157,000	71.07		NDWR, 2018a
215	EBP-2	Carbonate	2003	166,841,000	512.02		NDWR, 2018a
215	EBP-2	Carbonate	2004	56,501,000	173.40		NDWR, 2018a
215	EBP-2	Carbonate	2005	483,000	1.48		NDWR, 2018a
215	EBP-2	Carbonate	2006	33,961,000	104.22		NDWR, 2018a
215	EBP-2	Carbonate	2007	171,000	0.52		NDWR, 2018a
215	EBP-2	Carbonate	2008	200,241,000	614.52		NDWR, 2018a
215	EBP-2	Carbonate	2009	23,172,000	71.11		NDWR, 2018a
215	EBP-2	Carbonate	2010	59,286,000	181.94		NDWR, 2018a
215	EBP-2	Carbonate	2011	795,000	2.44		NDWR, 2018a
215	EBP-2	Carbonate	2012	10,324,000	31.68		NDWR, 2018a
215	EBP-2	Carbonate	2013	41,058,893	126.01		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
215	EBP-2	Carbonate	2014	1,954,000	6.00		NDWR, 2018a
215	EBP-2	Carbonate	2015	77,104,404	236.62		NDWR, 2018a
215	EBP-2	Carbonate	2016	28,249,904	86.70		NDWR, 2018a
215	EBP-2	Carbonate	2017	10,769,028	33.05		NDWR, 2018a
215	EBP-2	Carbonate	2018	100,124,568	307.27		NDWR, 2019a
215	EGV-3	Carbonate	1996	251,694,000	772.42		NDWR, 2018b
215	EGV-3	Carbonate	1997	228,981,000	702.72		NDWR, 2018b
215	EGV-3	Carbonate	1998	208,759,000	640.66		NDWR, 2018b
215	EGV-3	Carbonate	1999	231,181,000	709.47		NDWR, 2018b
215	EGV-3	Carbonate	2000	269,747,000	827.82		NDWR, 2018a
215	EGV-3	Carbonate	2001	238,938,000	733.27		NDWR, 2018a
215	EGV-3	Carbonate	2002	263,821,000	809.64		NDWR, 2018a
215	EGV-3	Carbonate	2003	213,277,000	654.52		NDWR, 2018a
215	EGV-3	Carbonate	2004	265,500,000	814.79		NDWR, 2018a
215	EGV-3	Carbonate	2005	283,714,000	870.69		NDWR, 2018a
215	EGV-3	Carbonate	2006	229,758,000	705.10		NDWR, 2018a
215	EGV-3	Carbonate	2007	262,651,000	806.05		NDWR, 2018a
215	EGV-3	Carbonate	2008	218,745,000	671.30		NDWR, 2018a
215	EGV-3	Carbonate	2009	279,226,000	856.91		NDWR, 2018a
215	EGV-3	Carbonate	2010	136,945,232	420.27		NDWR, 2018a
215	EGV-3	Carbonate	2011	201,293,696	617.75		NDWR, 2018a
215	EGV-3	Carbonate	2012	265,637,176	815.21		NDWR, 2018a
215	EGV-3	Carbonate	2013	256,576,104	787.40		NDWR, 2018a
215	EGV-3	Carbonate	2014	239,081,000	733.71		NDWR, 2018a
215	EGV-3	Carbonate	2015	119,275,720	366.04	Converted to a monitoring well and replaced by well EBM-5 as new production well.	NDWR, 2018a
216	EBA-1	Carbonate	1996	47,268,400	145.06		NDWR, 2019a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	EBA-1	Carbonate	1997	41,192,100	126.41		NDWR, 2019a
216	EBA-1	Carbonate	1998	42,663,100	130.93		NDWR, 2019a
216	EBA-1	Carbonate	1999	48,703,500	149.47		NDWR, 2019a
216	EBA-1	Carbonate	2000	12,835,500	39.39		NDWR, 2019a
216	EBA-1	Carbonate	2001	48,831,300	149.86		NDWR, 2019a
216	EBA-1	Carbonate	2002	45,366,300	139.22		NDWR, 2019a
216	EBA-1	Carbonate	2003	61,443,600	188.56		NDWR, 2019a
216	EBA-1	Carbonate	2004	60,837,000	186.70		NDWR, 2019a
216	EBA-1	Carbonate	2005	49,268,500	151.20		NDWR, 2019a
216	EBA-1	Carbonate	2006	45,460,300	139.51		NDWR, 2019a
216	EBA-1	Carbonate	2007	48,390,200	148.50		NDWR, 2019a
216	EBA-1	Carbonate	2008	47,455,000	145.63	Annual total of 145.63AF does not match 2008 Pumpage Report Total of 145.52AF.	NDWR, 2019a
216	EBA-1	Carbonate	2009	44,778,000	137.42	Annual total of 137.42AF does not match 2009 Pumpage Report Total of 112.45AF.	NDWR, 2019a
216	EBA-1	Carbonate	2010	40,540,300	124.41		NDWR, 2019a
216	EBA-1	Carbonate	2011	43,426,800	133.27		NDWR, 2019a
216	EBA-1	Carbonate	2012	35,922,000	110.24		NDWR, 2019a
216	EBA-1	Carbonate	2013	47,487,000	145.73		NDWR, 2019a
216	EBA-1	Carbonate	2014	22,665,000	69.56		NDWR, 2019a
216	EBA-1	Carbonate	2015	38,201,000	117.24		NDWR, 2019a
216	EBA-1	Carbonate	2016	37,062,000	113.74		NDWR, 2019a
216	EBA-1	Carbonate	2017	30,718,000	94.27		NDWR, 2019a
216	EBA-1	Carbonate	2018	31,814,000	97.63	Production data reported through Sep, 2018.	NDWR, 2019a
216	First Solar Well	Carbonate	2016	30,045,051	92.20	Well completed on Oct 8, 2016	NDWR, 2018a
216	First Solar Well	Carbonate	2017	70,833,966	217.38		NDWR, 2018a
216	First Solar Well	Carbonate	2018	58,136,000	178.41		NDWR, 2019a
216	GV-2	Carbonate	2007	10,883,423	33.40		NDWR,2007

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	GV-2	Carbonate	2008	40,620,000	124.66		NDWR, 2018a
216	GV-2	Carbonate	2009	5,560,000	17.06		NDWR, 2018a
216	GV-2	Carbonate	2010	3,232,442	9.92		NDWR, 2010
216	GV-2	Carbonate	2011	4,077,300	12.51		NDWR, 2018a
216	GV-2	Carbonate	2012	13,170,000	40.42		NDWR, 2018a
216	GV-2	Carbonate	2013	4,307,750	13.22		NDWR, 2013
216	GV-2	Carbonate	2014	5,112,602	15.69		NDWR, 2014
216	GV-2	Carbonate	2015	9,667,999	29.67		NDWR, 2015
216	GV-2	Carbonate	2016	11,300,513	34.68		NDWR, 2016
216	GV-2	Carbonate	2017	9,765,754	29.97		NDWR, 2017
216	GV-2	Carbonate	2018	---	---	Garnet Valley 2018 Pumpage Inventory report not published prior to publication of this report.	
216	GV-DUKE-WS1	Carbonate	2002	36,984,037	113.50	Well completed on Dec 7, 2001	NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2003	0	0.00		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2004	281,760	0.86		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2005	27,866,150	85.52		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2006	35,739,890	109.68		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2007	75,670,000	232.22		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2008	75,467,718	231.60		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2009	48,129,840	147.71		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2010	20,223,182	62.06		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2011	18,432,325	56.57		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2012	31,851,607	97.75		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2013	43,496,700	133.49		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2014	59,018,943	181.12		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2015	23,200,200	71.20		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2016	28,956,200	88.86		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	GV-DUKE-WS1	Carbonate	2017	7,806,300	23.96		NDWR, 2018a
216	GV-DUKE-WS1	Carbonate	2018	6,594,600	20.24		NDWR, 2019a
216	GV-DUKE-WS2	Carbonate	2002	3,312,100	10.16	Well completed on May 23, 2002	NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2003	0	0.00		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2004	0	0.00		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2005	20,176,000	61.92		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2006	52,927,802	162.43		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2007	33,780,000	103.67		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2008	54,572	0.17		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2009	95,265,432	292.36		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2010	101,809,227	312.44		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2011	103,242,291	316.84		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2012	102,565,323	314.76		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2013	31,273,855	95.98		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2014	1,767,473	5.42		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2015	66,944,359	205.44		NDWR, 2018a
216	GV-DUKE-WS2	Carbonate	2016	43,864,896	134.62	Well plugged in Dec, 2016 and replaced with GV-LENZIE-3.	NDWR, 2018a
216	GV-KERR	Carbonate	2001	681,029	2.09		NDWR, 2001
216	GV-KERR	Carbonate	2002	1,029,689	3.16		NDWR, 2002
216	GV-KERR	Carbonate	2003	1,798,698	5.52		NDWR, 2003
216	GV-KERR	Carbonate	2004	3,287,837	10.09		NDWR, 2004
216	GV-KERR	Carbonate	2005	3,173,789	9.74		NDWR, 2005
216	GV-KERR	Carbonate	2006	1,358,799	4.17		NDWR, 2006
216	GV-KERR	Carbonate	2007	984,070	3.02		NDWR, 2007
216	GV-KERR	Carbonate	2008	1,309,921	4.02		NDWR, 2008
216	GV-KERR	Carbonate	2009	1,238,234	3.80		NDWR, 2009
216	GV-KERR	Carbonate	2010	2,078,929	6.38		NDWR, 2010

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	GV-KERR	Carbonate	2011	2,078,929	6.38		NDWR, 2011
216	GV-KERR	Carbonate	2012	3,245,476	9.96		NDWR, 2012
216	GV-KERR	Carbonate	2013	3,196,598	9.81		NDWR, 2013
216	GV-KERR	Carbonate	2014	3,509,415	10.77		NDWR, 2014
216	GV-KERR	Carbonate	2015	5,774,080	17.72		NDWR, 2015
216	GV-KERR	Carbonate	2016	18,002,000	55.25		NDWR, 2018a
216	GV-KERR	Carbonate	2017	8,965,852	27.52		NDWR, 2018a
216	GV-KERR	Carbonate	2018	16,148,000	49.56		NDWR, 2019a
216	GV-LENZIE-3	Carbonate	2016	152,261,653	467.27	Replacement well for GV-DUKE-WS2. Well completed in Oct, 2016.	NDWR, 2018a
216	GV-LENZIE-3	Carbonate	2017	145,347,533	446.06		NDWR, 2018a
216	GV-LENZIE-3	Carbonate	2018	142,503,745	437.33		NDWR, 2019a
216	GV-MIRANT1	Carbonate	2002	24,939,000	76.53	Well completed on Mar 1, 2002.	NDWR, 2018a
216	GV-MIRANT1	Carbonate	2003	40,659,000	124.78		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2004	14,411,400	44.23		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2005	17,529,000	53.79		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2006	20,102,000	61.69		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2007	15,940,000	48.92		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2008	20,270,000	62.21		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2009	21,790,000	66.87		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2010	11,780,000	36.15		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2011	10,610,000	32.56		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2012	5,160,000	15.84		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2013	8,610,000	26.42		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2014	13,850,000	42.50		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2015	18,425,000	56.54		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2016	25,815,000	79.22		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	GV-MIRANT1	Carbonate	2017	30,400,000	93.29		NDWR, 2018a
216	GV-MIRANT1	Carbonate	2018	24,350,000	74.73		NDWR, 2019a
216	GV-PW-WS1	Carbonate	2002	24,628,280	75.58	Well completed on Jul 25, 2002	NDWR, 2018a
216	GV-PW-WS1	Carbonate	2003	15,721,736	48.25		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2004	46,332,890	142.19		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2005	43,064,719	132.16		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2006	51,438,313	157.86		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2007	54,400,000	166.95		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2008	45,994,581	141.15		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2009	48,684,769	149.41		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2010	52,966,620	162.55		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2011	43,557,511	133.67		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2012	45,994,240	141.15		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2013	45,222,054	138.78		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2014	37,660,958	115.58		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2015	50,122,548	153.82		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2016	56,162,212	172.36		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2017	62,814,431	192.77		NDWR, 2018a
216	GV-PW-WS1	Carbonate	2018	41,625,450	127.74		NDWR, 2019a
216	GV-RW1	Carbonate	2001	0	0.00	Well completed Jul 3, 2001. NVE production assigned to Harvey Well for accounting purposes.	NDWR, 2019a
216	GV-RW1	Carbonate	2002	0	0.00		NDWR, 2019a
216	GV-RW1	Carbonate	2003	0	0.00		NDWR, 2019a
216	GV-RW1	Carbonate	2004	0	0.00		NDWR, 2019a
216	GV-RW1	Carbonate	2005	0	0.00		NDWR, 2018a
216	GV-RW1	Carbonate	2006	0	0.00		NDWR, 2019a
216	GV-RW1	Carbonate	2007	0	0.00		NDWR, 2019a
216	GV-RW1	Carbonate	2008	0	0.00		NDWR, 2019a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	GV-RW1	Carbonate	2009	0	0.00		NDWR, 2019a
216	GV-RW1	Carbonate	2010	8,932,164	27.41	Total GV-RW1 production is 90.46 af: 27.41 af charged to SNWA (GV-RW1) and the remaining 63.06 af charged to NVE (Harvey Well).	NDWR, 2019a; and SNWA, 2011
216	GV-RW1	Carbonate	2011	12,156,162	37.31	Total GV-RW1 production is 123.97 af: 37.31 af charged to SNWA and the remaining 86.66 af charged to NVE.	NDWR, 2019a; and SNWA, 2012
216	GV-RW1	Carbonate	2012	4,240,979	13.02	Total GV-RW1 production is 87.63 af: 13.02 af is charged to SNWA (GV-RW1) and the remaining 74.60 af is charged to NVE (Harvey Well)	NDWR, 2019a; and SNWA, 2013
216	GV-RW1	Carbonate	2013	58,618,055	179.89		NDWR, 2019a
216	GV-RW1	Carbonate	2014	92,696,464	284.47		NDWR, 2019a
216	GV-RW1	Carbonate	2015	88,709,326	272.24		NDWR, 2019a
216	GV-RW1	Carbonate	2016	168,729,541	517.81		NDWR, 2019a
216	GV-RW1	Carbonate	2017	18,762,364	57.58		NDWR, 2019a
216	GV-RW1	Carbonate	2018	42,343,784	129.95		NDWR, 2019a
216	GV-USLIME1	Carbonate	2000	0	0.00	Well completed Jun 1, 1999 (75351)	NDWR, 2018a
216	GV-USLIME1	Carbonate	2001	33,388,170	102.46		NDWR, 2018a
216	GV-USLIME1	Carbonate	2002	35,554,390	109.11		NDWR, 2018a
216	GV-USLIME1	Carbonate	2003	33,117,643	101.63		NDWR, 2018a
216	GV-USLIME1	Carbonate	2004	38,606,818	118.48		NDWR, 2018a
216	GV-USLIME1	Carbonate	2005	36,171,110	111.01		NDWR, 2018a
216	GV-USLIME1	Carbonate	2006	42,614,870	130.78		NDWR, 2018a
216	GV-USLIME1	Carbonate	2007	41,089,881	126.10		NDWR, 2018a
216	GV-USLIME1	Carbonate	2008	32,559,872	99.92		NDWR, 2018a
216	GV-USLIME1	Carbonate	2009	27,974,570	85.85		NDWR, 2018a
216	GV-USLIME1	Carbonate	2010	24,452,529	75.04		NDWR, 2018a
216	GV-USLIME1	Carbonate	2011	23,470,206	72.03		NDWR, 2018a
216	GV-USLIME1	Carbonate	2012	19,097,000	58.61		NDWR, 2018a
216	GV-USLIME1	Carbonate	2013	26,117,000	80.15		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	GV-USLIME1	Carbonate	2014	19,720,000	60.52		NDWR, 2018a
216	GV-USLIME1	Carbonate	2015	23,665,000	72.63		NDWR, 2018a
216	GV-USLIME1	Carbonate	2016	17,327,967	53.18		NDWR, 2018a
216	GV-USLIME1	Carbonate	2017	18,111,927	55.58		NDWR, 2018a
216	GV-USLIME1	Carbonate	2018	23,574,739	72.35		NDWR, 2019a
216	GV-USLIME2	Basin Fill	2000	0	0.00		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2001	41,921,670	128.65		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2002	47,303,000	145.17		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2003	43,273,269	132.80		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2004	41,337,821	126.86		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2005	35,416,070	108.69		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2006	39,206,320	120.32		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2007	51,732,669	158.76		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2008	43,563,740	133.69		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2009	26,844,877	82.38		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2010	27,664,227	84.90		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2011	32,362,077	99.32		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2012	36,961,000	113.43		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2013	20,719,000	63.58		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2014	23,136,000	71.00		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2015	39,594,000	121.51		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2016	29,348,314	90.07		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2017	38,183,670	117.18		NDWR, 2018a
216	GV-USLIME2	Basin Fill	2018	30,855,521	94.69		NDWR, 2019a
216	HARVEY WELL	Carbonate	2001	15,779,600	48.43	NVE's portion of GV-RW1 production has been assigned to Harvey Well for accounting purposes.	NDWR, 2019a
216	HARVEY WELL	Carbonate	2002	27,656,500	84.87		NDWR, 2019a
216	HARVEY WELL	Carbonate	2003	379,900	1.17		NDWR, 2019a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	HARVEY WELL	Carbonate	2004	228,650	0.70		NDWR, 2019a
216	HARVEY WELL	Carbonate	2005	355,830	1.09		NDWR, 2019a
216	HARVEY WELL	Carbonate	2006	12,440,900	38.18		NDWR, 2019a
216	HARVEY WELL	Carbonate	2007	0	0.00		NDWR, 2019a
216	HARVEY WELL	Carbonate	2008	61,017,090	187.25	All GV-RW1 production charged to NVE (74399).	NDWR, 2019a
216	HARVEY WELL	Carbonate	2009	55,146,664	169.24	All GV-RW1 production charged to NVE (74399).	NDWR, 2019a
216	HARVEY WELL	Carbonate	2010	20,544,736	63.06	Total GV-RW1 production is 90.46 af: 27.41 af charged to SNWA (GV-RW1) and the remaining 63.06 af charged to NVE (Harvey Well).	NDWR, 2019a; and SNWA, 2011
216	HARVEY WELL	Carbonate	2011	40,395,489	86.66	Total GV-RW1 production is 123.97 af: 37.31 af charged to SNWA (GV-RW1) and the remaining 86.66 af charged to NVE (Harvey Well).	NDWR, 2019a; and SNWA, 2012
216	HARVEY WELL	Carbonate	2012	24,308,485	74.60	Total GV-RW1 production is 87.63 af: 13.02 af is charged to SNWA (GV-RW1) and the remaining 74.60 af is charged to NVE (Harvey Well)	NDWR, 2019a; and SNWA, 2013
216	HARVEY WELL	Carbonate	2013	24,308,485	74.60	First 74.57 af from 74399 pumped from GV-RW1 is reported as NVE production.	NDWR, 2019a
216	HARVEY WELL	Carbonate	2014	24,308,912	74.60	First 74.57 af from 74399 pumped from GV-RW1 is reported as NVE production.	NDWR, 2019a
216	HARVEY WELL	Carbonate	2015	24,298,709	74.57	First 74.57 af from 74399 pumped from GV-RW1 is reported as NVE production.	NDWR, 2019a
216	HARVEY WELL	Carbonate	2016	24,298,709	74.57	First 74.57 af from 74399 pumped from GV-RW1 is reported as NVE production.	NDWR, 2019a
216	HARVEY WELL	Carbonate	2017	24,300,000	74.57	First 74.57 af from 74399 pumped from GV-RW1 is reported as NVE production.	NDWR, 2019a
216	HARVEY WELL	Carbonate	2018	---	---	Garnet Valley 2018 Pumpage Inventory report not published prior to publication of this report.	
216	RS-PW-1	Clastic	1999	528,600	1.62		NDWR, 2018b
216	RS-PW-1	Clastic	2000	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2001	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2002	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2003	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2004	0	0.00		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	RS-PW-1	Clastic	2005	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2006	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2007	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2008	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2009	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2010	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2011	46,502,300	142.71		NDWR, 2018a
216	RS-PW-1	Clastic	2012	30,563,900	93.80		NDWR, 2018a
216	RS-PW-1	Clastic	2013	9,566,000	29.36		NDWR, 2018a
216	RS-PW-1	Clastic	2014	8,560,074	26.27		NDWR, 2018a
216	RS-PW-1	Clastic	2015	6,572,526	20.17		NDWR, 2018a
216	RS-PW-1	Clastic	2016	1,450,728	4.45		NDWR, 2018a
216	RS-PW-1	Clastic	2017	0	0.00		NDWR, 2018a
216	RS-PW-1	Clastic	2018	0	0.00		NDWR, 2019a
216	RS-PW-2	Carbonate	1999	46,625,400	143.09		NDWR, 2018b
216	RS-PW-2	Carbonate	2000	29,818,300	91.51		NDWR, 2018a
216	RS-PW-2	Carbonate	2001	22,497,650	69.04		NDWR, 2018a
216	RS-PW-2	Carbonate	2002	33,203,350	101.90		NDWR, 2018a
216	RS-PW-2	Carbonate	2003	52,891,600	162.32		NDWR, 2018a
216	RS-PW-2	Carbonate	2004	44,666,500	137.08		NDWR, 2018a
216	RS-PW-2	Carbonate	2005	8,323,200	25.54		NDWR, 2018a
216	RS-PW-2	Carbonate	2006	16,073,000	49.33		NDWR, 2018a
216	RS-PW-2	Carbonate	2007	20,714,700	63.57		NDWR, 2018a
216	RS-PW-2	Carbonate	2008	39,794,700	122.13		NDWR, 2018a
216	RS-PW-2	Carbonate	2009	39,974,400	122.68		NDWR, 2018a
216	RS-PW-2	Carbonate	2010	37,954,200	116.48		NDWR, 2018a
216	RS-PW-2	Carbonate	2011	40,543,400	124.42		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	RS-PW-2	Carbonate	2012	41,012,700	125.86		NDWR, 2018a
216	RS-PW-2	Carbonate	2013	34,236,700	105.07		NDWR, 2018a
216	RS-PW-2	Carbonate	2014	33,442,918	102.63		NDWR, 2018a
216	RS-PW-2	Carbonate	2015	11,947,708	36.67		NDWR, 2018a
216	RS-PW-2	Carbonate	2016	0	0.00		NDWR, 2018a
216	RS-PW-2	Carbonate	2017	0	0.00		NDWR, 2018a
216	RS-PW-2	Carbonate	2018	0	0.00		NDWR, 2019a
216	RS-PW-3	Carbonate	1999	0	0.00		NDWR, 2018b
216	RS-PW-3	Carbonate	2000	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2001	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2002	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2003	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2004	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2005	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2006	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2007	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2008	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2009	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2010	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2011	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2012	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2013	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2014	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2015	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2016	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2017	0	0.00		NDWR, 2018a
216	RS-PW-3	Carbonate	2018	0	0.00		NDWR, 2019a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	RS-PW-5	Carbonate	1999	17,869,200	54.84		NDWR, 2018b
216	RS-PW-5	Carbonate	2000	83,063,400	254.91		NDWR, 2018a
216	RS-PW-5	Carbonate	2001	58,488,000	179.49		NDWR, 2018a
216	RS-PW-5	Carbonate	2002	39,610,100	121.56		NDWR, 2018a
216	RS-PW-5	Carbonate	2003	55,826,300	171.32		NDWR, 2018a
216	RS-PW-5	Carbonate	2004	44,048,100	135.18		NDWR, 2018a
216	RS-PW-5	Carbonate	2005	70,927,700	217.67		NDWR, 2018a
216	RS-PW-5	Carbonate	2006	37,547,900	115.23		NDWR, 2018a
216	RS-PW-5	Carbonate	2007	29,339,400	90.04		NDWR, 2018a
216	RS-PW-5	Carbonate	2008	78,452,840	240.76		NDWR, 2018a
216	RS-PW-5	Carbonate	2009	58,241,500	178.74		NDWR, 2018a
216	RS-PW-5	Carbonate	2010	45,005,000	138.12		NDWR, 2018a
216	RS-PW-5	Carbonate	2011	6,445,500	19.78		NDWR, 2018a
216	RS-PW-5	Carbonate	2012	11,561,900	35.48		NDWR, 2018a
216	RS-PW-5	Carbonate	2013	23,462,900	72.00		NDWR, 2018a
216	RS-PW-5	Carbonate	2014	33,141,107	101.71		NDWR, 2018a
216	RS-PW-5	Carbonate	2015	39,001,222	119.69		NDWR, 2018a
216	RS-PW-5	Carbonate	2016	31,413,123	96.40		NDWR, 2018a
216	RS-PW-5	Carbonate	2017	88,328,611	271.07		NDWR, 2018a
216	RS-PW-5	Carbonate	2018	79,141,056	242.87		NDWR, 2019a
216	RS-PW-6	Carbonate	1999	60,764,900	186.48		NDWR, 2018b
216	RS-PW-6	Carbonate	2000	40,254,200	123.54		NDWR, 2018a
216	RS-PW-6	Carbonate	2001	58,762,200	180.33		NDWR, 2018a
216	RS-PW-6	Carbonate	2002	42,952,100	131.82		NDWR, 2018a
216	RS-PW-6	Carbonate	2003	37,063,000	113.74		NDWR, 2018a
216	RS-PW-6	Carbonate	2004	33,310,199	102.23		NDWR, 2018a
216	RS-PW-6	Carbonate	2005	46,520,700	142.77		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	RS-PW-6	Carbonate	2006	26,403,000	81.03		NDWR, 2018a
216	RS-PW-6	Carbonate	2007	40,707,000	124.93		NDWR, 2018a
216	RS-PW-6	Carbonate	2008	58,169,300	178.52		NDWR, 2018a
216	RS-PW-6	Carbonate	2009	45,197,400	138.71		NDWR, 2018a
216	RS-PW-6	Carbonate	2010	39,948,000	122.60		NDWR, 2018a
216	RS-PW-6	Carbonate	2011	24,497,000	75.18		NDWR, 2018a
216	RS-PW-6	Carbonate	2012	39,346,900	120.75		NDWR, 2018a
216	RS-PW-6	Carbonate	2013	42,697,000	131.03		NDWR, 2018a
216	RS-PW-6	Carbonate	2014	32,231,721	98.92		NDWR, 2018a
216	RS-PW-6	Carbonate	2015	42,679,916	130.98		NDWR, 2018a
216	RS-PW-6	Carbonate	2016	55,796,378	171.23		NDWR, 2018a
216	RS-PW-6	Carbonate	2017	68,200,752	209.30		NDWR, 2018a
216	RS-PW-6	Carbonate	2018	54,024,640	165.80		NDWR, 2019a
216	RS-PW-7	Carbonate	1999	39,430	0.12		NDWR, 2018b
216	RS-PW-7	Carbonate	2000	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2001	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2002	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2003	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2004	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2005	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2006	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2007	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2008	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2009	0	0.00		NDWR, 2018a
216	RS-PW-7	Carbonate	2010	27,310	0.08		NDWR, 2018a
216	RS-PW-7	Carbonate	2011	7,850	0.02		NDWR, 2018a
216	RS-PW-7	Carbonate	2012	152,300	0.47		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
216	RS-PW-7	Carbonate	2013	541,800	1.66		NDWR, 2018a
216	RS-PW-7	Carbonate	2014	432,500	1.33		NDWR, 2018a
216	RS-PW-7	Carbonate	2015	5,390,581	16.54		NDWR, 2018a
216	RS-PW-7	Carbonate	2016	27,925,361	85.70		NDWR, 2018a
216	RS-PW-7	Carbonate	2017	22,153,234	67.99		NDWR, 2018a
216	RS-PW-7	Carbonate	2018	50,193,066	154.04		NDWR, 2019a
216	Western Gypsum Well 1	Basin Fill	2001	1,471,600	4.52		NDWR, 2019a
216	Western Gypsum Well 1	Basin Fill	2002	2,184,700	6.70		NDWR, 2019a
216	Western Gypsum Well 1	Basin Fill	2003	2,544,400	7.81		NDWR, 2019a
216	Western Gypsum Well 1	Basin Fill	2004	755,974	2.32		NDWR, 2006
216	Western Gypsum Well 1	Basin Fill	2005	971,036	2.98		NDWR, 2006
216	Western Gypsum Well 1	Basin Fill	2006	1,000,000	3.07		NDWR, 2019a
216	Western Gypsum Well 1	Basin Fill	2007	1,127,444	3.46		NDWR, 2007
216	Western Gypsum Well 1	Basin Fill	2008	1,652,065	5.07		NDWR, 2008
216	Western Gypsum Well 1	Basin Fill	2009	1,329,472	4.08		NDWR, 2009
216	Western Gypsum Well 1	Basin Fill	2010	1,189,356	3.65		NDWR, 2010
216	Western Gypsum Well 1	Basin Fill	2011	1,202,390	3.69		NDWR, 2011
216	Western Gypsum Well 1	Basin Fill	2012	1,274,077	3.91		NDWR, 2012
216	Western Gypsum Well 1	Basin Fill	2013	1,238,234	3.80		NDWR, 2013
216	Western Gypsum Well 1	Basin Fill	2014	840,696	2.58		NDWR, 2014
216	Western Gypsum Well 1	Basin Fill	2015	1,114,410	3.42		NDWR, 2015
216	Western Gypsum Well 1	Basin Fill	2016	1,075,308	3.30		NDWR, 2016
216	Western Gypsum Well 1	Basin Fill	2017	883,056	2.71		NDWR, 2017
216	Western Gypsum Well 1	Basin Fill	2018	---	---	Garnet Valley 2018 Pumpage Inventory report not published prior to publication of this report.	
218	PAIUTES-ECP1	Carbonate	2011	1,928,600	5.92		NDWR, 2018a
218	PAIUTES-ECP1	Carbonate	2012	0	0.00		NDWR, 2018a
218	PAIUTES-ECP1	Carbonate	2013	7,610,000	23.35		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
218	PAIUTES-ECP1	Carbonate	2014	57,130,000	175.33		NDWR, 2018a
218	PAIUTES-ECP1	Carbonate	2015	95,700,000	293.69		NDWR, 2018a
218	PAIUTES-ECP1	Carbonate	2016	44,510,000	136.60		NDWR, 2018a
218	PAIUTES-ECP1	Carbonate	2017	4,190,000	12.86		NDWR, 2018a
218	PAIUTES-ECP1	Carbonate	2018	0	0.00		NDWR, 2019a
218	PAIUTES-ECP3	Carbonate	2015	28,360,000	87.03		NDWR, 2018a
218	PAIUTES-ECP3	Carbonate	2016	9,620,000	29.52		NDWR, 2018a
218	PAIUTES-ECP3	Carbonate	2017	0	0.00		NDWR, 2018a
218	PAIUTES-ECP3	Carbonate	2018	0	0.00		NDWR, 2019a
218	PAIUTES-TH1	Carbonate	2009	5,000,000	15.34		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2010	6,300,000	19.33		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2011	6,470,000	19.86		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2012	6,790,000	20.84		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2013	11,670,000	35.81		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2014	36,830,000	113.03		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2015	10,020,000	30.75		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2016	11,040,000	33.88		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2017	9,806,313	30.09		NDWR, 2018a
218	PAIUTES-TH1	Carbonate	2018	7,870,000	24.15		NDWR, 2019a
219	ARROW_CANYON	Carbonate	1992	167,289,000	513.39		MVWD, 2018
219	ARROW_CANYON	Carbonate	1993	335,084,000	1,028.34		MVWD, 2018
219	ARROW_CANYON	Carbonate	1994	164,219,000	503.97		MVWD, 2018
219	ARROW_CANYON	Carbonate	1995	99,050,000	303.97		MVWD, 2018
219	ARROW_CANYON	Carbonate	1996	89,388,000	274.32		MVWD, 2018
219	ARROW_CANYON	Carbonate	1997	163,354,000	501.32		MVWD, 2018
219	ARROW_CANYON	Carbonate	1998	641,596,000	1,968.99		MVWD, 2018
219	ARROW_CANYON	Carbonate	1999	793,268,000	2,434.45		MVWD, 2018

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	ARROW_CANYON	Carbonate	2000	904,935,000	2,777.14		MVWD, 2018
219	ARROW_CANYON	Carbonate	2001	793,065,000	2,433.83		MVWD, 2018
219	ARROW_CANYON	Carbonate	2002	737,673,750	2,263.84		MVWD, 2018
219	ARROW_CANYON	Carbonate	2003	804,304,520	2,468.32		MVWD, 2018
219	ARROW_CANYON	Carbonate	2004	816,215,000	2,504.87		MVWD, 2018
219	ARROW_CANYON	Carbonate	2005	679,303,000	2,084.70		MVWD, 2018
219	ARROW_CANYON	Carbonate	2006	641,990,508	1,970.20		MVWD, 2018
219	ARROW_CANYON	Carbonate	2007	416,343,000	1,277.71		MVWD, 2018
219	ARROW_CANYON	Carbonate	2008	583,101,000	1,789.47		MVWD, 2018
219	ARROW_CANYON	Carbonate	2009	461,027,733	1,414.84		MVWD, 2018
219	ARROW_CANYON	Carbonate	2010	375,264,540	1,151.64		MVWD, 2018
219	ARROW_CANYON	Carbonate	2011	547,436,576	1,680.02		MVWD, 2018
219	ARROW_CANYON	Carbonate	2012	641,920,168	1,969.98		MVWD, 2018
219	ARROW_CANYON	Carbonate	2013	613,093,890	1,881.52		MVWD, 2018
219	ARROW_CANYON	Carbonate	2014	379,141,924	1,163.54		MVWD, 2018
219	ARROW_CANYON	Carbonate	2015	655,291,990	2,011.02		MVWD, 2018
219	ARROW_CANYON	Carbonate	2016	736,378,979	2,259.86		MVWD, 2018
219	ARROW_CANYON	Carbonate	2017	748,223,000	2,296.21		MVWD, 2018
219	ARROW_CANYON	Carbonate	2018	367,593,000	1,128.10		MVWD, 2019
219	ARROW_CANYON_2	Carbonate	2005	66,440,000	203.90		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2006	261,000	0.80		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2007	184,622,000	566.58		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2008	32,129,000	98.60		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2009	201,394,403	618.06		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2010	216,208,406	663.52		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2011	50,554,746	155.15		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2012	159,785,076	490.36		MVWD, 2018

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	ARROW_CANYON_2	Carbonate	2013	117,203,061	359.68		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2014	90,609,576	278.07		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2015	125,232,959	384.33		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2016	175,395,278	538.27		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2017	170,436,287	523.05		MVWD, 2018
219	ARROW_CANYON_2	Carbonate	2018	277,158,869	850.57		MVWD, 2019
219	BEHMER	Basin Fill	1993	200,429,800	615.10	Combined Behmer 14" and 8" production.	Mifflin and Adenle, 1994
219	BEHMER	Basin Fill	1994	75,445,300	231.53	Combined Behmer 14" and 8" production.	Mifflin and Adenle, 1995
219	BEHMER	Basin Fill	1995	139,805,760	429.05	Combined Behmer 14" and 8" production.	Pohlmann, 1996
219	BEHMER	Basin Fill	1996	222,068,000	681.50	Combined Behmer 14" and 8" production.	Pohlmann and Russell, 1997
219	BEHMER	Basin Fill	1999	78,801,740	241.83	Combined Behmer 14" and 8" production.	Kleinfelder, 2000
219	BEHMER	Basin Fill	2000	180,081,000	552.65	Production from Behmer 14".	NDWR, 2018a
219	BEHMER	Basin Fill	2001	270,722,000	830.82	Combined Behmer 14" and 8" production.	Converse, 2002
219	BEHMER	Basin Fill	2002	267,153,000	819.86	Production from Behmer 14".	Converse, 2003
219	BEHMER	Basin Fill	2003	209,306,000	642.34	Production from Behmer 14".	Converse, 2004
219	BEHMER	Basin Fill	2004	181,153,440	555.94	Production from Behmer 14".	Converse, 2005
219	BEHMER	Basin Fill	2005	214,128,000	657.13	Production from Behmer 14".	NDWR, 2018a
219	BEHMER	Basin Fill	2006	166,359,000	510.54	Production from Behmer 14".	NDWR, 2018a
219	BEHMER	Basin Fill	2007	170,896,000	524.46	Production from Behmer 14".	NDWR, 2018a
219	BEHMER	Basin Fill	2008	156,091,000	479.03	Production from Behmer 14".	NDWR, 2018a
219	BEHMER	Basin Fill	2009	295,797,000	907.77		NDWR, 2018a
219	BEHMER	Basin Fill	2010	199,527,000	612.33		NDWR, 2018a
219	BEHMER	Basin Fill	2011	141,521,000	434.31		NDWR, 2018a
219	BEHMER	Basin Fill	2012	141,012,500	432.75		NDWR, 2018a
219	BEHMER	Basin Fill	2013	202,634,000	621.86		NDWR, 2018a
219	BEHMER	Basin Fill	2014	200,741,453	616.05		NDWR, 2018a
219	BEHMER	Basin Fill	2015	94,933,000	291.34		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	BEHMER	Basin Fill	2016	20,000	0.06		NDWR, 2018a
219	BEHMER	Basin Fill	2017	28,760,000	88.26		NDWR, 2018a
219	BEHMER	Basin Fill	2018	0	0.00		NDWR, 2019a
219	LDS CENTRAL	Basin Fill	1990	172,457,000	529.25		Mifflin, Adenle, and Johnson, 1991
219	LDS CENTRAL	Basin Fill	1993	67,869,000	208.28		Mifflin and Adenle, 1994
219	LDS CENTRAL	Basin Fill	1994	98,137,000	301.17		Mifflin and Adenle, 1995
219	LDS CENTRAL	Basin Fill	1995	159,600,000	489.79		Pohlmann, 1996
219	LDS CENTRAL	Basin Fill	1996	180,549,000	554.08		Pohlmann and Russell, 1997
219	LDS CENTRAL	Basin Fill	1999	238,859,000	733.03		Kleinfelder, 2000
219	LDS CENTRAL	Basin Fill	2000	315,045,000	966.84		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2001	310,055,000	951.52		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2002	296,357,000	909.49		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2003	317,365,000	973.96		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2004	237,541,000	728.99		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2005	252,015,000	773.41		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2006	287,471,000	882.22		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2007	230,442,000	707.20		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2008	198,628,000	609.57		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2009	267,394,000	820.60		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2010	231,525,000	710.52		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2011	161,742,000	496.37		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2012	77,824,000	238.83		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2013	128,674,000	394.89		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2014	68,333,661	209.71		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2015	5,190,000	15.93		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2016	19,670,000	60.37		NDWR, 2018a
219	LDS CENTRAL	Basin Fill	2017	0	0.00		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	LDS CENTRAL	Basin Fill	2018	0	0.00		NDWR, 2019a
219	LDS EAST	Basin Fill	1990	137,505,000	421.99		Mifflin, Adenle, and Johnson, 1991
219	LDS EAST	Basin Fill	1993	92,336,000	283.37		Mifflin and Adenle, 1994
219	LDS EAST	Basin Fill	1994	100,962,000	309.84		Mifflin and Adenle, 1995
219	LDS EAST	Basin Fill	1995	175,869,000	539.72		Pohlmann, 1996
219	LDS EAST	Basin Fill	1996	171,100,000	525.09		Pohlmann and Russell, 1997
219	LDS EAST	Basin Fill	1999	191,588,000	587.96		Kleinfelder, 2000
219	LDS EAST	Basin Fill	2000	363,754,000	1,116.32		NDWR, 2018a
219	LDS EAST	Basin Fill	2001	197,351,000	605.65		NDWR, 2018a
219	LDS EAST	Basin Fill	2002	124,970,000	383.52		NDWR, 2018a
219	LDS EAST	Basin Fill	2003	213,657,000	655.69		NDWR, 2018a
219	LDS EAST	Basin Fill	2004	183,984,500	564.63		NDWR, 2018a
219	LDS EAST	Basin Fill	2005	140,928,000	432.49		NDWR, 2018a
219	LDS EAST	Basin Fill	2006	127,973,000	392.73		NDWR, 2018a
219	LDS EAST	Basin Fill	2007	207,036,000	635.37		NDWR, 2018a
219	LDS EAST	Basin Fill	2008	165,261,000	507.17		NDWR, 2018a
219	LDS EAST	Basin Fill	2009	63,551,000	195.03		NDWR, 2018a
219	LDS EAST	Basin Fill	2010	52,720,000	161.79		NDWR, 2018a
219	LDS EAST	Basin Fill	2011	196,639,000	603.46		NDWR, 2018a
219	LDS EAST	Basin Fill	2012	188,436,000	578.29		NDWR, 2018a
219	LDS EAST	Basin Fill	2013	177,234,000	543.91		NDWR, 2018a
219	LDS EAST	Basin Fill	2014	195,257,868	599.22		NDWR, 2018a
219	LDS EAST	Basin Fill	2015	13,710,000	42.07		NDWR, 2018a
219	LDS EAST	Basin Fill	2016	0	0.00		NDWR, 2018a
219	LDS EAST	Basin Fill	2017	60,100,000	184.44		NDWR, 2018a
219	LDS EAST	Basin Fill	2018	0	0.00		NDWR, 2019a
219	LDS WEST	Basin Fill	1990	198,115,000	607.99		Mifflin, Adenle, and Johnson, 1991

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	LDS WEST	Basin Fill	1993	134,620,000	413.13		Mifflin and Adenle, 1994
219	LDS WEST	Basin Fill	1994	279,092,000	856.50		Mifflin and Adenle, 1995
219	LDS WEST	Basin Fill	1995	180,481,000	553.88		Pohlmann, 1996
219	LDS WEST	Basin Fill	1996	331,528,000	1,017.42		Pohlmann and Russell, 1997
219	LDS WEST	Basin Fill	1999	348,289,000	1,068.86		Kleinfelder, 2000
219	LDS WEST	Basin Fill	2000	353,827,000	1,085.86		NDWR, 2018a
219	LDS WEST	Basin Fill	2001	228,110,000	700.04		NDWR, 2018a
219	LDS WEST	Basin Fill	2002	246,938,000	757.82		NDWR, 2018a
219	LDS WEST	Basin Fill	2003	172,354,000	528.94		NDWR, 2018a
219	LDS WEST	Basin Fill	2004	165,522,000	507.97		NDWR, 2018a
219	LDS WEST	Basin Fill	2005	303,863,000	932.52		NDWR, 2018a
219	LDS WEST	Basin Fill	2006	428,686,000	1,315.59		NDWR, 2018a
219	LDS WEST	Basin Fill	2007	288,217,000	884.51		NDWR, 2018a
219	LDS WEST	Basin Fill	2008	166,099,000	509.74		NDWR, 2018a
219	LDS WEST	Basin Fill	2009	168,098,000	515.87		NDWR, 2018a
219	LDS WEST	Basin Fill	2010	167,529,000	514.13		NDWR, 2018a
219	LDS WEST	Basin Fill	2011	129,219,000	396.56		NDWR, 2018a
219	LDS WEST	Basin Fill	2012	65,323,000	200.47		NDWR, 2018a
219	LDS WEST	Basin Fill	2013	35,166,000	107.92		NDWR, 2018a
219	LDS WEST	Basin Fill	2014	145,313,981	445.95		NDWR, 2018a
219	LDS WEST	Basin Fill	2015	38,379,000	117.78		NDWR, 2018a
219	LDS WEST	Basin Fill	2016	70,410,000	216.08		NDWR, 2018a
219	LDS WEST	Basin Fill	2017	17,970,000	55.15		NDWR, 2018a
219	LDS WEST	Basin Fill	2018	0	0.00		NDWR, 2019a
219	LEWIS 1	Basin Fill	1993	135,885,000	417.02		Mifflin and Adenle, 1994
219	LEWIS 1	Basin Fill	1994	185,686,000	569.85		Mifflin and Adenle, 1995
219	LEWIS 1	Basin Fill	1995	59,146,000	181.51		Pohlmann, 1996

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	LEWIS 1	Basin Fill	1996	79,882,000	245.15		Pohlmann and Russell, 1997
219	LEWIS 1	Basin Fill	1999	117,567,000	360.80		Kleinfelder, 2000
219	LEWIS 1	Basin Fill	2000	101,913,332	312.76		NDWR, 2018a
219	LEWIS 1	Basin Fill	2001	35,630,000	109.34		NDWR, 2018a
219	LEWIS 1	Basin Fill	2002	123,094,000	377.76		NDWR, 2018a
219	LEWIS 1	Basin Fill	2003	93,257,000	286.20		NDWR, 2018a
219	LEWIS 1	Basin Fill	2004	100,527,000	308.51		NDWR, 2018a
219	LEWIS 1	Basin Fill	2005	92,664,000	284.38		NDWR, 2018a
219	LEWIS 1	Basin Fill	2006	86,734,000	266.18		NDWR, 2018a
219	LEWIS 1	Basin Fill	2007	77,139,000	236.73		NDWR, 2018a
219	LEWIS 1	Basin Fill	2008	103,418,000	317.38		NDWR, 2018a
219	LEWIS 1	Basin Fill	2009	17,407,000	53.42		NDWR, 2018a
219	LEWIS 1	Basin Fill	2010	44,258,000	135.82		NDWR, 2018a
219	LEWIS 1	Basin Fill	2011	133,139,200	408.59		NDWR, 2018a
219	LEWIS 1	Basin Fill	2012	71,765,700	220.24		NDWR, 2018a
219	LEWIS 1	Basin Fill	2013	64,453,800	197.80		NDWR, 2018a
219	LEWIS 1	Basin Fill	2014	89,944,300	276.03		NDWR, 2018a
219	LEWIS 1	Basin Fill	2015	0	0.00		NDWR, 2018a
219	LEWIS 1	Basin Fill	2016	0	0.00		NDWR, 2018a
219	LEWIS 1	Basin Fill	2017	0	0.00		NDWR, 2018a
219	LEWIS 1	Basin Fill	2018	0	0.00		NDWR, 2019a
219	LEWIS 2	Basin Fill	1993	76,466,000	234.67		Mifflin and Adenle, 1994
219	LEWIS 2	Basin Fill	1994	70,949,000	217.73		Mifflin and Adenle, 1995
219	LEWIS 2	Basin Fill	1995	73,164,000	224.53		Pohlmann, 1996
219	LEWIS 2	Basin Fill	1996	64,856,000	199.04		Pohlmann and Russell, 1997
219	LEWIS 2	Basin Fill	1999	72,835,000	223.52		Kleinfelder, 2000
219	LEWIS 2	Basin Fill	2000	103,158,000	316.58		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	LEWIS 2	Basin Fill	2001	6,180,000	18.97		NDWR, 2018a
219	LEWIS 2	Basin Fill	2002	78,513,000	240.95		NDWR, 2018a
219	LEWIS 2	Basin Fill	2003	68,188,000	209.26		NDWR, 2018a
219	LEWIS 2	Basin Fill	2004	102,914,000	315.83		NDWR, 2018a
219	LEWIS 2	Basin Fill	2005	100,377,000	308.05		NDWR, 2018a
219	LEWIS 2	Basin Fill	2006	74,216,000	227.76		NDWR, 2018a
219	LEWIS 2	Basin Fill	2007	116,889,000	358.72		NDWR, 2018a
219	LEWIS 2	Basin Fill	2008	108,228,000	332.14		NDWR, 2018a
219	LEWIS 2	Basin Fill	2009	97,690,000	299.80		NDWR, 2018a
219	LEWIS 2	Basin Fill	2010	113,247,000	347.54		NDWR, 2018a
219	LEWIS 2	Basin Fill	2011	127,704,000	391.91		NDWR, 2018a
219	LEWIS 2	Basin Fill	2012	35,537,000	109.06		NDWR, 2018a
219	LEWIS 2	Basin Fill	2013	26,465,000	81.22		NDWR, 2018a
219	LEWIS 2	Basin Fill	2014	44,022,000	135.10		NDWR, 2018a
219	LEWIS 2	Basin Fill	2015	0	0.00		NDWR, 2018a
219	LEWIS 2	Basin Fill	2016	0	0.00		NDWR, 2018a
219	LEWIS 2	Basin Fill	2017	0	0.00		NDWR, 2018a
219	LEWIS 2	Basin Fill	2018	0	0.00		NDWR, 2019a
219	LEWIS 3	Basin Fill	1993	129,001,000	395.89		Mifflin and Adenle, 1994
219	LEWIS 3	Basin Fill	1994	256,934,000	788.50		Mifflin and Adenle, 1995
219	LEWIS 3	Basin Fill	1995	118,406,000	363.37		Pohlmann, 1996
219	LEWIS 3	Basin Fill	1996	81,207,000	249.22		Pohlmann and Russell, 1997
219	LEWIS 3	Basin Fill	1999	205,279,000	629.98		Kleinfelder, 2000
219	LEWIS 3	Basin Fill	2000	152,499,000	468.00		NDWR, 2018a
219	LEWIS 3	Basin Fill	2001	141,026,000	432.79		NDWR, 2018a
219	LEWIS 3	Basin Fill	2002	238,372,000	731.54		NDWR, 2018a
219	LEWIS 3	Basin Fill	2003	136,780,000	419.76		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	LEWIS 3	Basin Fill	2004	121,044,000	371.47		NDWR, 2018a
219	LEWIS 3	Basin Fill	2005	101,789,000	312.38		NDWR, 2018a
219	LEWIS 3	Basin Fill	2006	145,098,000	445.29		NDWR, 2018a
219	LEWIS 3	Basin Fill	2007	105,172,300	322.76		NDWR, 2018a
219	LEWIS 3	Basin Fill	2008	52,951,600	162.50		NDWR, 2018a
219	LEWIS 3	Basin Fill	2009	53,981,600	165.66		NDWR, 2018a
219	LEWIS 3	Basin Fill	2010	60,061,000	184.32		NDWR, 2018a
219	LEWIS 3	Basin Fill	2011	114,042,000	349.98		NDWR, 2018a
219	LEWIS 3	Basin Fill	2012	75,691,000	232.29		NDWR, 2018a
219	LEWIS 3	Basin Fill	2013	111,242,000	341.39		NDWR, 2018a
219	LEWIS 3	Basin Fill	2014	173,058,834	531.10		NDWR, 2018a
219	LEWIS 3	Basin Fill	2015	3,830,000	11.75		NDWR, 2018a
219	LEWIS 3	Basin Fill	2016	63,890,000	196.07		NDWR, 2018a
219	LEWIS 3	Basin Fill	2017	0	0.00		NDWR, 2018a
219	LEWIS 3	Basin Fill	2018	0	0.00		NDWR, 2019a
219	LEWIS 4	Basin Fill	1993	144,441,000	443.27		Mifflin and Adenle, 1994
219	LEWIS 4	Basin Fill	1994	89,080,000	273.38		Mifflin and Adenle, 1995
219	LEWIS 4	Basin Fill	1995	107,707,000	330.54		Pohlmann, 1996
219	LEWIS 4	Basin Fill	1996	175,769,000	539.42		Pohlmann and Russell, 1997
219	LEWIS 4	Basin Fill	1999	78,307,000	240.32		Kleinfelder, 2000
219	LEWIS 4	Basin Fill	2000	81,103,000	248.90		NDWR, 2018a
219	LEWIS 4	Basin Fill	2001	111,354,000	341.73		NDWR, 2018a
219	LEWIS 4	Basin Fill	2002	203,322,400	623.97		NDWR, 2018a
219	LEWIS 4	Basin Fill	2003	88,076,400	270.30		NDWR, 2018a
219	LEWIS 4	Basin Fill	2004	107,038,100	328.49		NDWR, 2018a
219	LEWIS 4	Basin Fill	2005	130,254,900	399.74		NDWR, 2018a
219	LEWIS 4	Basin Fill	2006	133,886,400	410.88		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	LEWIS 4	Basin Fill	2007	103,962,300	319.05		NDWR, 2018a
219	LEWIS 4	Basin Fill	2008	108,001,400	331.44		NDWR, 2018a
219	LEWIS 4	Basin Fill	2009	67,665,100	207.66		NDWR, 2018a
219	LEWIS 4	Basin Fill	2010	89,094,000	273.42		NDWR, 2018a
219	LEWIS 4	Basin Fill	2011	87,828,000	269.53		NDWR, 2018a
219	LEWIS 4	Basin Fill	2012	45,697,000	140.24		NDWR, 2018a
219	LEWIS 4	Basin Fill	2013	61,536,000	188.85		NDWR, 2018a
219	LEWIS 4	Basin Fill	2014	154,217,229	473.28		NDWR, 2018a
219	LEWIS 4	Basin Fill	2015	15,250,000	46.80		NDWR, 2018a
219	LEWIS 4	Basin Fill	2016	17,310,000	53.12		NDWR, 2018a
219	LEWIS 4	Basin Fill	2017	680,000	2.09		NDWR, 2018a
219	LEWIS 4	Basin Fill	2018	0	0.00		NDWR, 2019a
219	LEWIS 5	Basin Fill	1993	51,249,000	157.28		Mifflin and Adenle, 1994
219	LEWIS 5	Basin Fill	1994	73,265,000	224.84		Mifflin and Adenle, 1995
219	LEWIS 5	Basin Fill	1995	64,863,000	199.06		Pohlmann, 1996
219	LEWIS 5	Basin Fill	1996	94,302,000	289.40		Pohlmann and Russell, 1997
219	LEWIS 5	Basin Fill	1999	137,169,000	420.96		Kleinfelder, 2000
219	LEWIS 5	Basin Fill	2000	139,206,000	427.21		NDWR, 2018a
219	LEWIS 5	Basin Fill	2001	130,284,000	399.83		NDWR, 2018a
219	LEWIS 5	Basin Fill	2002	53,624,000	164.57		NDWR, 2018a
219	LEWIS 5	Basin Fill	2003	107,017,000	328.42		NDWR, 2018a
219	LEWIS 5	Basin Fill	2004	79,409,000	243.70		NDWR, 2018a
219	LEWIS 5	Basin Fill	2005	128,429,000	394.13		NDWR, 2018a
219	LEWIS 5	Basin Fill	2006	161,538,500	495.74		NDWR, 2018a
219	LEWIS 5	Basin Fill	2007	13,424,600	41.20		NDWR, 2018a
219	LEWIS 5	Basin Fill	2008	119,084,000	365.46		NDWR, 2018a
219	LEWIS 5	Basin Fill	2009	91,462,000	280.69		NDWR, 2018a

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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	LEWIS 5	Basin Fill	2010	121,690,000	373.45		NDWR, 2018a
219	LEWIS 5	Basin Fill	2011	132,237,000	405.82		NDWR, 2018a
219	LEWIS 5	Basin Fill	2012	54,629,000	167.65		NDWR, 2018a
219	LEWIS 5	Basin Fill	2013	153,055,672	469.71		NDWR, 2018a
219	LEWIS 5	Basin Fill	2014	242,481,080	744.15		NDWR, 2018a
219	LEWIS 5	Basin Fill	2015	135,082,000	414.55		NDWR, 2018a
219	LEWIS 5	Basin Fill	2016	134,160,000	411.72		NDWR, 2018a
219	LEWIS 5	Basin Fill	2017	43,690,000	134.08		NDWR, 2018a
219	LEWIS 5	Basin Fill	2018	4,320,000	13.26		NDWR, 2019a
219	MX-6	Carbonate	1993	45,945,000	141.00		MVWD, 2018
219	MX-6	Carbonate	1994	127,033,000	389.85		MVWD, 2018
219	MX-6	Carbonate	1995	122,008,000	374.43		MVWD, 2018
219	MX-6	Carbonate	1996	140,352,000	430.72		MVWD, 2018
219	MX-6	Carbonate	1997	100,087,000	307.16		MVWD, 2018
219	MX-6	Carbonate	1998	22,782,800	69.92		MVWD, 2018
219	MX-6	Carbonate	1999	47,099,500	144.54		MVWD, 2018
219	MX-6	Carbonate	2000	42,504,600	130.44		MVWD, 2018
219	MX-6	Carbonate	2001	100,855,300	309.51		MVWD, 2018
219	MX-6	Carbonate	2002	100,644,540	308.87		MVWD, 2018
219	MX-6	Carbonate	2003	113,150,568	347.25		MVWD, 2018
219	MX-6	Carbonate	2004	69,423,000	213.05		MVWD, 2018
219	MX-6	Carbonate	2005	87,378,000	268.15		MVWD, 2018
219	MX-6	Carbonate	2006	324,073,000	994.54		MVWD, 2018
219	MX-6	Carbonate	2007	76,330,000	234.25		MVWD, 2018
219	MX-6	Carbonate	2008	125,056,000	383.78		MVWD, 2018
219	MX-6	Carbonate	2009	507,102	1.56		MVWD, 2018
219	MX-6	Carbonate	2010	3,645,192	11.19		MVWD, 2018

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Groundwater Production
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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	MX-6	Carbonate	2011	460,864	1.41		MVWD, 2018
219	MX-6	Carbonate	2012	57,878,530	177.62		MVWD, 2018
219	MX-6	Carbonate	2013	82,912,071	254.45		MVWD, 2018
219	MX-6	Carbonate	2014	0	0.00		MVWD, 2018
219	MX-6	Carbonate	2015	0	0.00		MVWD, 2018
219	MX-6	Carbonate	2016	0	0.00		MVWD, 2018
219	MX-6	Carbonate	2017	0	0.00		MVWD, 2018
219	MX-6	Carbonate	2018	0	0.00		MVWD, 2019
219	PERKINS PRODUCTION	Basin Fill	1993	159,155,000	488.43		Mifflin and Adenle, 1994
219	PERKINS PRODUCTION	Basin Fill	1994	217,349,000	667.02		Mifflin and Adenle, 1995
219	PERKINS PRODUCTION	Basin Fill	1995	49,595,000	152.20		Pohlmann, 1996
219	PERKINS PRODUCTION	Basin Fill	1996	147,494,000	452.64		Pohlmann and Russell, 1997
219	PERKINS PRODUCTION	Basin Fill	1999	78,396,000	240.59		Kleinfelder, 2000
219	PERKINS PRODUCTION	Basin Fill	2000	153,475,000	471.00		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2001	159,530,000	489.58		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2002	236,304,000	725.19		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2003	228,829,000	702.25		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2004	170,913,000	524.51		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2005	238,755,000	732.71		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2006	252,270,000	774.19		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2007	231,534,000	710.55		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2008	218,774,000	671.39		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2009	210,205,000	645.10		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2010	189,468,000	581.46		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2011	207,057,000	635.43		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2012	246,502,000	756.49		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2013	330,911,000	1,015.53		NDWR, 2018a

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Groundwater Production
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Hydrographic Area	Well Name	Aquifer Material	Year	Production (gallons)	Production (af)	Comments	Source
219	PERKINS PRODUCTION	Basin Fill	2014	258,918,323	794.59		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2015	113,142,000	347.22		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2016	0	0.00		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2017	23,170,000	71.11		NDWR, 2018a
219	PERKINS PRODUCTION	Basin Fill	2018	0	0.00		NDWR, 2019a

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Appendix D

Carbonate Production Capture Analysis

D.1.0 CARBONATE PRODUCTION CAPTURE ANALYSIS

This appendix contains a table detailing the calculations performed to identify the sources of groundwater production from the carbonate aquifer of the LWRFS.

Table D-1
Capture Analysis of Carbonate Groundwater Production from the LWRFS

Year	MRSA Carbonate Production (1)	Total Carbonate Production (af) (2)	Warm Springs West Average Discharge (cfs) (3)	Warm Springs West Discharge Capture (cfs) (4)	MRSA Discharge Capture (cfs) (5)	MRSA Discharge Capture (afy) (6)	Aquifer Storage Capture (afy) (7)	Cumulative Groundwater Production (af) (8)	Cumulative MRSA Capture (af) (9)	Cumulative Storage Capture (af) (10)
1991	0	0	---	0.00	0.00	0	0	0	0	0
1992	513	513	---	0.00	0.35	256	257	513	256	257
1993	1,169	1,169	---	0.00	0.81	584	585	1,682	840	842
1994	894	894	---	0.00	0.62	447	447	2,576	1,287	1,289
1995	678	678	---	0.00	0.47	339	339	3,254	1,626	1,628
1996	705	2,463	---	0.00	0.49	352	2,111	5,717	1,978	3,739
1997	808	2,514	---	0.00	0.56	404	2,110	8,231	2,382	5,849
1998	2,039	3,578	3.95	0.00	1.41	1,020	2,558	11,809	3,402	8,407
1999	2,579	4,684	3.85	0.10	1.32	956	3,728	16,493	4,358	12,135
2000	2,908	5,110	3.80	0.15	1.97	1,427	3,683	21,603	5,785	15,818
2001	2,743	5,063	3.72	0.23	3.03	2,195	2,868	26,666	7,980	18,686
2002	2,573	5,284	3.64	0.31	4.08	2,956	2,328	31,950	10,936	21,014
2003	2,816	5,442	3.56	0.39	5.13	3,716	1,726	37,392	14,652	22,740
2004	2,718	5,306	3.53	0.42	5.53	4,006	1,300	42,698	18,658	24,040
2005	2,557	5,448	3.80	0.15	1.97	1,427	4,021	48,146	20,085	28,061
2006	2,966	6,861	3.90	0.05	0.66	478	6,383	55,007	20,563	34,444
2007	2,079	7,585	3.72	0.23	3.03	2,195	5,390	62,592	22,758	39,834
2008	2,272	7,091	3.60	0.35	4.61	3,340	3,751	69,683	26,098	43,585
2009	2,034	6,541	3.72	0.23	3.03	2,195	4,346	76,224	28,293	47,931
2010	1,826	7,336	3.71	0.24	3.16	2,289	5,047	83,560	30,582	52,978
2011	1,837	9,841	3.63	0.32	4.21	3,050	6,791	93,401	33,632	59,769
2012	2,638	10,568	3.49	0.46	6.05	4,383	6,185	103,969	38,015	65,954
2013	2,496	8,369	3.35	0.60	7.89	5,716	2,653	112,339	43,731	68,607
2014	1,442	5,994	3.45	0.50	6.58	4,767	1,227	118,332	48,498	69,834
2015	2,395	7,144	3.42	0.53	6.97	5,050	2,094	125,476	53,548	71,928
2016	2,798	7,791	3.40	0.55	7.24	5,245	2,546	133,267	58,793	74,474
2017	2,819	7,630	3.36	0.59	7.76	5,622	2,008	140,897	64,415	76,482
2018	1,979	7,344	3.38	0.57	7.50	5,433	1,911	148,241	69,848	78,393

Notes:
Column number shown inside parenthesis.
(4) = 3.95 - (3)
(5) = (6) / 724.4628 [1992 - 1998]; (5) = (4) / 0.076 [1999 - 2018]
(6) = 0.50 * (1) [1992 - 1998]; (6) = (5) * 724.4628 [1999-2018]
(7) = (2) - (6)