Case No. 84739

IN THE SUPREME COURT OF THE STATE OF NEVADA

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

Appellants,

vs.

LINCOLN COUNTY WATER DISTRICT, et al.

JOINT APPENDIX

VOLUME 12 OF 49

PREDICTIONS OF THE EFFECTS OF GROUNDWATER PUMPING IN THE COLORADO REGIONAL GROUNDWATER FLOW SYSTEM SOUTHEASTERN NEVADA

Prepared For:

National Park Service

U.S. Fish & Wildlife Service

Bureau of Land Management

Prepared by:

Tetra Tech Inc.
363 Centennial Parkway, Suite 210
Louisville, CO 80027

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SE ROA 12382

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1.0 INTRODUCTION

With the projected population growth in southeastern Nevada and the increase in industrial activities and generation of electricity, there is an increasing demand for water. During the recent several decades, the Office of the Nevada State Engineer has received many applications for water-rights permits for groundwater production within the Colorado River Groundwater Flow System in southeastern Nevada.

This report provides the results of modeling simulations of the groundwater system in selected basins of the Colorado River Groundwater Flow System in southeastern Nevada and in parts of Utah and Arizona. The simulations were performed using a recently updated groundwater flow model of the area (Tetra Tech, 2012).

Seven different scenarios were evaluated. The first two were developed within the framework of existing permits. The first scenario evaluates the effects of existing pumping, assuming that the average of the reported pumping during the years 2009, 2010, and 2011 would continue at that rate in the future. The exception to this statement is that the rate for pumping of carbonate-rock aquifer wells in Coyote Spring Valley and the Muddy River Springs Area in 2011 would continue in the future. The second scenario simulates pumping the full amount of all existing groundwater rights, continued into the future.

Scenarios 3 through 7 simulate pumping the full amount of all existing groundwater rights, plus pending groundwater applications before the Nevada State Engineer's Office through 2009, in five different steps. Scenario 3 simulates all existing groundwater rights plus all large (>1,000 af/yr) pending applications with filing dates up to and through 1989. Scenario 4 simulates all existing groundwater rights plus all large pending applications with filing dates up to and through 1994. Scenarios 5 through 7 continue similar cumulative simulations by including all large pending applications through 1999, 2004, and 2009, respectively.

Predictions are provided for a period of 1,000 years, beginning in 2011. Because of the large increases in projected pumping, the simulated drawdown reached the boundaries of the model. The model was constructed without head-dependent boundary conditions at the edges of the model domain, with the exception of the boundary with Lake Mead. Thus, as originally constructed, drawdown at the edge of the model would not cause capture of water from basins outside the model domain. The model was modified to include General-Head Boundary (GHB) conditions for those external model cells where known flux boundary conditions (implemented using the Well Package) are specified in the model. These additional boundary conditions allow water to enter the model from neighboring basins in response to drawdown at these cells.

Results are presented at simulated pumping times of 10, 50, 100, 500, and 1000 years. The predicted drawdowns are presented in a series of maps for the uppermost model layer, which represents the water table. Temporal plots present the changes in simulated discharge at selected springs in the Muddy River Springs Area, at Rogers and Blue Point Springs (combined), and at selected locations along the Muddy River and the Virgin River.

2.0 APPROACH

This section describes the approach used to incorporate the rates and locations of pumping into the simulations, and the possible effects that boundary conditions will have on the predictions.

2.1 FUTURE PUMPING

Seven different pumping scenarios were simulated, each with increasing rates of pumping from the model area. Pumping in surrounding areas (outside the model area) is not considered. Information on the locations and rates of existing groundwater rights and pending groundwater-rights applications was provided to Tetra Tech by the National Park Service (William Van Liew, written communication, 2012), based on a review and compilation of records of the Nevada State Engineer's Office by National Park Service personnel.

The seven different scenarios are based on existing groundwater rights and pending applications:

1. Current locations and rates of pumping
2. All existing groundwater rights, both currently pumped and unpumped
3. All existing groundwater rights, plus all large pending applications filed through 1989.
4. All existing groundwater rights, plus all large pending applications filed through 1994.
5. All existing groundwater rights, plus all large pending applications filed through 1999.
6. All existing groundwater rights, plus all large pending applications filed through 2004.
7. All existing groundwater rights, plus all large pending applications filed through 2009.

Pending applications were compiled into groups, depending on the application date. For example, Group 1 is composed of the applications submitted through 1989, Group 2 are those applications submitted in 1990 through 1994, and so forth. Table 2.1-1 provides the total pumping per Hydrographic Area (HA) for each grouping, and the total pumping for each scenario. For the pending applications, only applications for 1,000 af/yr or greater were included. This table provides a snapshot of the increase in pumping as a function of pending application filing date, and the total projected pumping by HA of all existing groundwater rights plus large pending applications. The most pumping would occur in the Virgin River Valley (251,192 af/yr), followed by Coyote Spring Valley (210,892 af/yr) and Tule Desert (44,092 af/yr). The simulated pumping rate increases from 21,016 af/yr (Scenario 1, current pumping rates) to 656,901 af/yr (Scenario 7, all existing groundwater rights plus all large pending applications through 2009). This is more than a thirty-fold increase.

Table 2.1-1 Rates and Locations of Groundwater Pumping for Predictive Scenarios 1 through 7.

Group	1	2	3	4	5	6	7	
	Current Pumping[1]	Total, existing rights	thru 1989	1990-1994	1995-1999	2000-2004	2005-2009	Total
Hydrographic Area (HA)								
Clover Valley (HA 204)	-	-	-	-	-	14,480	-	14,480
Lower Meadow Valley Wash (HA 205)	-	-	-	-	-	-	-	-
Kane Springs Valley (HA 206)	-	1,000	-	-	-	-	17,376	18,376
Coyote Spring Valley (HA 210)	5,727	16,100	27,512	-	163,280	4,000	-	210,892
Black Mountains (HA 215)	1,510	1,665	-	1,665	4,000	4,000	-	11,330
Garnet Valley (HA 216)	1,249	3,328	1,665	-	5,614	4,000	-	14,607
Hidden Valley (North) (HA 217)	-	-	-	-	24,164	4,000	-	28,164
California Wash (HA 218)	20	2,862	7,240	2,534	4,000	11,724	-	28,360
Muddy River Springs Area (HA 219)	5,964	13,688	-	7,240	-	-	-	20,928
Lower Moapa Valley (HA 220)	-	-	-	14,480	-	-	-	14,480
Tule Desert (HA 221)	-	9,340	-	-	13,032	-	21,720	44,092
Virgin River Valley (HA 222)	6,546	12,272	65,884	119,460	53,576	-	-	251,192
TOTALS	21,016	60,255	102,301	145,379	267,666	42,204	39,096	656,901
Scenario Totals								
Scenario #1[2]	21,016							
Scenario #2[3]		60,255						
Scenario #3[4]			162,556					
Scenario #4[5]				307,935				
Scenario #5[6]					575,601			
Scenario #6[7]						617,805		
Scenario #7[8]							656,901	

[1] "Current pumping" is the average of pumping for three years (2009 through 2011), with the exception of carbonate-rock aquifer wells MX-5 and CSI-1 thru 4 in Coyote Spring Valley; and MX-6, Arrow Canyon Well, and Arrow Canyon Well #2 in Muddy River Springs Area, for which it is the annual pumping for one year: 2011.
[2] Scenario #1 is all current pumping.
[3] Scenario #2 is all existing groundwater rights.
[4] Scenario #3 is all existing groundwater rights plus all large (over 1,000 af/yr) pending applications through 1989.
[5] Scenario #4 is all existing groundwater rights plus all large (over 1,000 af/yr) pending applications through 1994.
[6] Scenario #5 is all existing groundwater rights plus all large (over 1,000 af/yr) pending applications through 1999.
[7] Scenario #6 is all existing groundwater rights plus all large (over 1,000 af/yr) pending applications through 2004.
[8] Scenario #7 is all existing groundwater rights plus all large (over 1,000 af/yr) pending applications through 2009.

While the existing groundwater rights and pending applications greater than 1,000 af/yr total 656,901 af/yr, the sum of all pending applications and existing permits has been estimated to exceed one million af/yr. Thus, the simulations likely only evaluate about 65% of the total pumping if all existing rights and pending applications were granted.

The wells simulated in Scenario 1 are those listed in Group 1, and the projected rates of pumping are, for wells not involved in the Order 1169 pumping, the averages of the reported rates of pumping in 2009, 2010, and 2011. For the wells involved in Order 1169 pumping, the projected rates are the reported rates in 2011.

For Scenarios 2 through 7, the projected rates are the cumulative rates. For Scenario 2, the projected rates are those given for Group 2 wells. For Scenario 3, the projected rates are for Group 2 and Group 3 wells combined. The addition of a new group continues for each successive scenario. For Scenario 7, the projected rates are the cumulative rates for Groups 2 through 7.

Attachment I provides the names of wells (existing and proposed) and the rates of pumping from each well for the different temporal groupings. The assigned names of pumping locations ("wells") for pending applications were developed from information on the geographic area, the applicant, and the temporal grouping. In addition, a sequence number is added at the end of the "well" name so that each well has a unique name. For example, the name "CSV_CSI_5_3" indicates a projected well in Coyote Spring Valley by the applicant Coyote Springs Investment. This groundwater-right application was submitted during the period 1994 through 1999 (Group 5). The sequence number "3" was arbitrarily assigned to distinguish it from other future "wells" by the same applicant in the same geographic area during the same time frame.

The pending water-rights applications provide the locations of wells using the cadastral (township and range) system, rather than locations based on latitude and longitude, or other coordinate system. The cadastral descriptions were used to estimate locations using the Bureau of Land Management's Geocommunicator system (www.geocommunicator.gov). This system provides coordinates for the center of the quarter-quarter section. The locations of the wells, as provided by the coordinates, were checked by plotting using the ArcGIS datasets that were used for development of the model. In instances where there was an existing well at the location specified in a pending water-right application, the pumping was allocated to the existing well, and the depths of the screened interval were used to determine the model layers to be pumped.

For those locations that did not have nearby existing wells, model layers were assigned by first evaluating the depths of HGUs in the model cell in which the new diversion would occur, using HUFPrint (Banta and Provost 2008). In most instances, there was a clear choice of the HGU to simulate pumping at a location. Unless a carbonate HGU was present within the upper 3,000 to 4,000 feet (approximately), simulated pumping was assumed to be from the upper 6 to 8 model layers, or 1,060 to 1,860 feet below the top of model layer 1. The top of this layer is at the approximate elevation of the water table, so that these wells could be 2,000 to 3,000 feet deep, depending on location. If a Paleozoic carbonate HGU was present in the model cell at a reasonable depth, the top of the screened interval in the well was assumed to be in the uppermost layer where the carbonate HGU was present, and the bottom was assumed to be approximately 1,000 feet deeper. These values were used as guidelines, with the intent being to have the simulated well pumping from several model layers to avoid excessive close-in drawdown, while still be at reasonable depths.

2.2 MODEL SETUP

For the predictions of the effects of pumping, some of the datasets for the model described in Tetra Tech (2012) were modified for the longer simulations. Others were unchanged.

Initial Conditions – The hydraulic heads calculated by the model for the end of the long-term run (representing December 31, 2011) were used as the initial hydraulic heads for the predictive simulations.

Time discretization – During the model calibration, monthly and yearly stress periods were used allowing seasonal effects and longer term changes in pumping rates to be evaluated. The model predictions cover 1,000 years with constant pumping over this period. Therefore, a single-stress period of 1,000 years was used, with time steps every 10 years. Constant time steps were used to allow storage of heads and drawdowns at convenient times.

Material Properties – No material properties were changed.

Boundary Conditions – Most boundary-condition datasets were not changed. These include recharge, stream-flow routing, and external boundary fluxes (implemented with the Well Package). Because seasonal ET was not being evaluated, the ET rate was changed from monthly to annual totals. ET was simulated using the Well Package during calibration and for the predictive simulations. The Well Package was used during calibration so that the seasonal changes could be used to drive changes in the flow system. For the predictions, changing to the ET Package was considered, but was not implemented because of concerns about model stability that use of a head-dependent flux boundary condition might cause. The primary cause of convergence issues in the calibration models was the result of use of the Stream-Routing Package. Adding a second head-dependent boundary condition near the streams was considered as likely to cause additional convergence problems, and was not attempted for these predictions.

During model calibration, the stage in Lake Mead was adjusted monthly. However, for the predictions, the stage was set to an elevation of approximately 1,133 ft, the lake stage at the end of the long-term simulation (representing the end of 2011). This stage is lower than was present during much of the long-term simulation, and water levels were declining near the lake at the end of that simulation. Because of these transient changes that were occurring near the end of the long-term simulation, the predictive models indicate some small drawdowns occurring near the lake. These are the result of the changed lake stage, not local pumping.

Preliminary simulations of the predictive runs indicated that substantial drawdown was simulated at some of the external boundaries of the model, indicating that water would be captured from neighboring basins outside the domain of the model, if the intervening rocks were not impermeable. Certainly, if drawdown occurred along boundaries where a prescribed flux into or out of the model was applied, the flux should change as the result of the drawdown. Therefore, for the predictive runs, general-head boundaries (GHB) were applied to those external model cells where non-zero prescribed flux boundaries were used in the model. A GHB dataset was developed, in which the boundary head for each GHB cell was set to the initial head used for the predictive runs, and the GHB conductance was calculated from the hydraulic conductivity calculated for the cell by HUFPrint (Banta and Provost 2008), the thickness of the cell, the length of the cell measured perpendicular to the dominant compass direction (north-south or east-west) of the flow into or out of the model, and an arbitrarily selected distance from the cell center. For these predictive runs, this distance was set to 15,000 feet. Increasing this distance would decrease the GHB conductance and cause the model to simulate less capture from neighboring basins and greater drawdown, whereas decreasing the distance would cause the GHB to act more like a constant-head boundary and produce more capture and less drawdown. As there is no information with which to estimate this parameter through model calibration, this parameter will remain a source of uncertainty in the predictions which could be evaluated through sensitivity analysis and/or by expansion of the model to include the neighboring basins.

Preliminary runs indicated that wells that were placed in lower permeability materials, such as the Muddy Creek (CAU) or volcanic rocks might not be able to sustain the prescribed pumping rate. The model, through the MNW package, calculates the drawdown in the well caused by entrance losses and uses this to calculate water levels in the well. If the water level decreases to below the bottom of the well, the production rate is decreased. It was assumed that the management action to this well response would be to drill additional wells near the location of the original point of diversion. In the model, this meant the definition of additional wells in the model cell, with the rate of simulated pumping from each well equal to the simulated production rate at that location divided by the number of wells at that location. The wells where this modification was necessary were determined by running Scenario 7 for 20 or 30 years and noting those where the well drawdown was too great. In most areas, only one well was needed. However, some areas required up to 8 wells. With continued pumping, even production from the group of wells might be reduced, and declines in the simulated pumping rates indicate that this happened in the simulations.

2.3 FEATURES OF THE MODEL THAT MAY AFFECT THE PREDICTIONS

There are several features of the model that should be considered when considering the model's predictions:

1. Because the model is an approximation of the groundwater system, the model predictions can be used to estimate the timing and relative magnitudes of effects of pumping, but consideration of the uncertainty inherent in the model predictions should be a factor in permitting and management decisions. As reliable data are collected on the response of the groundwater system to pumping and models are improved, the uncertainty in modeling predictions will decrease.
2. The model was developed using the simplification that the transmissivities of model layers would not change as water levels change. As drawdown occurs at the water table, the uppermost sediments and/or rock becomes desaturated and are unable to transmit water to wells. The resulting decrease in the aquifer transmissivity is not simulated in this model. This simplification will cause the model to calculate less drawdown (because of the constant transmissivity) than it would if the changes in thickness were simulated. In the simulations where drawdowns of hundreds of feet are calculated, the effects of this simplification may become significant, and the drawdown would be underestimated.
3. Most of the Las Vegas Valley Shear zone is treated as a no-flow boundary in the model, because the current-day movement of water is considered to be minor. Because this boundary segment was simulated as no-flow, GHB boundary conditions were not developed along this segment. However, with changes in pumping within the model domain and in Las Vegas Valley, the flow across the shear zone may change. These changes are not considered in the model. Future pumping in the model domain may impact water levels and groundwater flow in Las Vegas Valley, and vice versa.
4. As discussed in Section 2.2, the model does not consider changes in ET rate as drawdown is simulated beneath ET areas. The highest ET rates occur along streams or in groundwater discharge areas where there is a supply of water to support the plants. If pumping were to cause the water supply to dry up, the ET rate would decrease because the plant community would have to change to one that did not consume as much water. However, in the model, the ET rate is not changed. As a result, the model will tend to overpredict the amount of drawdown where ET is occurring after the spring or stream dries up, and thus tend to overpredict the drawdown near those areas later in the simulation. The effect only becomes apparent after the stream or spring dries up. The only places where this effect was observed were in a small area along Meadow Valley Wash where the simulated streamflow was small and the stream was dried up by pumping in other areas, and an area in the lower part of the Virgin River, where large amounts of pumping upstream caused the

river to dry up. In both instances, the drawdown caused by pumping became larger than the drawdown caused by the excess ET. The effect was not detected near the Muddy River Springs.

3.0 PREDICTION RESULTS

The results of the model predictions are presented through a series of maps of the model area showing the simulated drawdown at selected times, and graphs of the simulated spring discharge or streamflow vs. time at selected locations. The scales for figures at a location or locations are the same for all scenarios to allow the reader to more easily compare the differences in the simulation results.

Information is provided on both drawdown and discharge because of the relation between the two. For example, when drawdown occurs beneath a stream that is well-connected with the groundwater system, the drawdown will cause either a decrease in the groundwater discharge into a gaining stream, or an increase in the loss from a losing stream. The pumping causing the drawdown is “capturing” water from the stream. A second effect is a decrease in the drawdown beneath the stream. The change in water level is “buffered” or reduced by the change in the flux into or from the stream. Similar effects occur with springs that are fed by the groundwater system. If the stream or spring is dry, however, drawdown cannot change the flux and the drawdown is not buffered. Thus, drawdown maps can provide information on whether a stream or spring is flowing and able to buffer the drawdown. In the drawdown maps presented below, streams or spring which appear to affect the drawdown patterns are likely to be flowing. If the pattern of drawdown is not affected by the stream or spring, the stream or spring is likely to be dry, or to be poorly connected to the groundwater system.

These simulations predict changes from the conditions described by the long-term model, which simulated the groundwater system through 2011. In areas where pumping has already caused drawdown or changes in flow, the predicted changes are in addition to the changes that have already occurred.

3.1 SCENARIO 1

Scenario 1 is based on the current pumping within the project area. There likely is some pumping from wells in Lower Meadow Valley Wash; however, no information on pumping there was found in available reports or in the on-line database available on the Nevada State Engineer’s website. The total pumping in this scenario was intended to be 21,106 acre feet per year (af/yr); however, the model would not allow pumping of well MVWD30 at the specified rate, and the simulated pumping was 20,916 af/yr. This rate remained essentially constant during the 1,000-year simulation, but did vary slightly during the simulation.

Drawdown Maps

Simulated drawdown in layer 1 of the model is shown on Figures 3.1-1a through 3.1-1e, for simulated times of 10, 50, 100, 500, and 1,000 years. Layer 1 represents the water table, and drawdown in deeper layers will differ from that simulated for layer 1, depending on the depth of pumping and the geology. In addition, the streams are in layer 1, and their effect on the drawdown is greater in layer 1 than in deeper layers. Where the model simulates the streams as flowing, they reduce the drawdown beneath and adjacent to them because they effectively add recharge to the model through the capture of streamflow. The simulated water table may change little near flowing streams, but drawdown can be transmitted beneath the streams in deeper sediments or rocks.

The model-predicted drawdown is calculated based on the simulated water levels at the end of the long-term run (December 2011), which includes pumping at these wells at similar rates. Thus, Scenario 1 is an estimate of the future changes in the groundwater system assuming that pumping continues at the same locations and at similar rates as it has been occurring within the period 2009 through 2011. Groundwater pumping has been occurring in four primary areas: the Muddy River Springs area, Garnet Valley, Coyote Spring Valley, and the Virgin Valley.

The simulated drawdown at the water table after 10 years of additional pumping is slightly less than 1 foot in the vicinity of the Muddy River Springs. In the carbonate aquifer beneath Coyote Spring Valley, Hidden Valley (North), Garnet Valley, California Wash, and the rest of the Muddy River Springs Area HA, drawdown is widespread and in the range of 1 to 2 feet. The combination of high transmissivity and low storativity results in widespread but small declines in water levels. On the western side of the model, drawdown greater than 1 foot does not extend west of the Gass Peak Thrust. In the Virgin Valley, the predicted drawdown is much more limited in extent, but is in the range of 5 to 10 feet in places. There is a well (VVWD30) located in the southern part of the valley near the Nevada-Arizona boundary which has little drawdown. The hydraulic conductivity in the model at this location is too low to sustain the pumping, and the MNW turned off the pumping from this well. As a result, this well is effectively removed from the predictive simulations.

The effect of the flow in the Virgin River on the simulated drawdown in layer 1 is apparent in the pattern of drawdown near the river. The drawdown is causing capture of water from the river, either by decreasing the discharge of groundwater into the river, or by increasing the loss of water from the river. The capture of this water buffers, or decreases the drawdown beneath and adjacent to the river, and the indicated drawdown is less than in areas more distant from the river. Drawdown near the river is less than 1 foot although there is pumping occurring both north and south of the river. In comparison, the model simulates drawdown between 2 and 5 feet in the area between the northernmost area of pumping in the Virgin Valley and the area immediately north of the river.

The model is simulating small amounts of water-level change occurring near Lake Mead, although there is no pumping being simulated in this area. Part of these changes in water levels is caused by changes in lake stage that were simulated in the long-term run. The lake stage used in the predictive scenarios is lower than the lake stage during much of the long-term calibration simulation which was used to develop the initial-head dataset for the predictive simulations, and water levels close to the lake decrease as a result of the decrease in lake stage. At later times, the effects of pumping begin to dominate. The net change in flux to the lake is an increase in the discharge to the lake of 174 af/yr.

At 50 years (Figure 3.1-1b), the drawdown in the carbonate aquifer in the western part of the model has increased to the range of 2 to 5 feet with two small areas of drawdown greater than 5 feet. These occur where no pumping is being simulated. The cause of these small areas has not been investigated, but it is likely that the drawdown is being propagated upwards from a deeper zone of greater drawdown. The eastern extent of drawdown has moved eastward beyond the area of the Muddy River Springs, and the simulated drawdown near the springs is in the range of 2 to 5 feet. The drawdown has also extended to the western boundary of the model and southward to essentially all of the Las Vegas Shear Zone (LVVSZ), which was treated as a no-flow boundary in the model. GHB cells are present along the western edge of the model to simulate movement of water from the basins to the west. At 50 years, the model simulates a small increase of inflow (about 2 af/yr) around the entire model boundary. The great majority of this increase is across the western boundary. There is uncertainty in the predicted magnitude of the increase in GHB flux because of the absence of any information related to changes in flows across the model boundary. The values provided here should be evaluated in comparisons between different predictive scenarios, but not to estimate impacts on neighboring basins.

Drawdown in parts of the Virgin Valley has increased into the range of 20 to 50 feet, and has spread to the east. The buffering effect of the Virgin River on drawdown is more apparent in the 50-year simulation results than at 10 years. Within Arizona, the effect of the river on drawdown does not extend past where the river valley is aligned approximately east-west. The buffering effect is greatly diminished upstream of where the river valley alignment changes generally to the northeast near Littlefield Springs. Closer investigation of the geologic model indicates that the hydrogeologic unit QCD is absent through this more upstream reach of the river in the model. The QCD unit has a higher hydraulic conductivity than does the CAU hydrogeologic unit, and thus cells containing the QCD unit are more highly connected to the river than where it is absent, and therefore the buffering effect is greater.

Simulation results for 100 years are similar to those at 50 years, but with increased drawdown. Where the carbonate aquifer in the western part of the model is being pumped, drawdown has increased to the range of 5 to 10 feet. In the vicinity of the Muddy River Springs, the drawdown in approximately 5 feet, and the pattern of the drawdown shows the buffering effect of the springs. Thus, decreases in the discharge rates from the springs would be expected; these are discussed below. Drawdown in the Virgin Valley has increased to greater than 20 feet, and has begun to spread to the west as well as to the east. Between the areas of drawdown in the carbonate-rock aquifer in the western part of the model and the Virgin Valley, two small areas of drawdown have developed. One area runs along the east side of the Lower Meadow Valley

Wash topographic basin. The other area where greater than 1 foot of drawdown is simulated is along the east side of the Mormon Mountains. These appear to examples of the transmission of drawdown upward from deeper layers.

The primary changes at 500 and 1,000 years are the continued growth of the area where drawdown is occurring and the deepening of the drawdown in the interior of these areas. Simulated pumping in the Virgin Valley near Mesquite has impacted water levels to the south of the Virgin River, and to the east of Beaver Dam Wash; the drawdown is transmitted from layers below the water table (deeper than the buffering effects of the rivers). Drawdown in the Muddy River Springs area at 1,000 years is approximately 10 feet, and the pattern of drawdown still shows the buffering effects of capture of the discharge. The drawdown at Rogers and Blue Point Springs is predicted to be less than 1 foot, although the edge of the 1-2 foot region is only a few miles away. The model simulates a decrease in the combined discharge from the springs (discussed below), indicating that the model does simulate drawdown at these springs in Scenario 1. Along the LVVSZ south of Apex, there is an area where the drawdown at the water table is approximately 20 to 23 feet, a few feet more than in surrounding areas. The higher values of drawdown along the LVVSZ were also present in a simulation in which the pumping in a group of nearby wells (in the Black Mountains HA) was set to zero. This area of higher simulated drawdown coincides with an area where the CAU is present at the water table (in layer 1). The carbonate aquifer (PC4) is present to the north of this area of higher drawdown, and has a hydraulic conductivity three to four orders of magnitude greater than the CAU. The large contrast in hydraulic conductivity appears to have caused minor numerical problems along this boundary between the two HGUs. Cells where these problems appear to originate are visible in Figure 3.1-1b and 3.1-1c two to three miles north of the LVVSZ.

<u>Graphs of Discharge vs. Time</u>

Changes in spring discharge and stream flow are shown in Figures 3.1-2a through 3.1-2d. The simulated discharges from springs in the Muddy River Springs area are shown in Figure 3.1-2a. Percentage decreases in spring discharge range from 22% at Baldwin and Muddy Springs up to 99% at Pederson. The simulation predicts that Pederson would dry up in slightly less than 500 years.

The decrease in spring discharge causes declines in the simulated flow in the Muddy River (Fig 3.1-2b). The location called “Muddy River, upper” is in the Muddy River a short distance below where the discharge from Baldwin Spring enters the river. This location was identified as stream location 09415880 in the synoptic stream gaging report for the Muddy River (Beck and Wilson, 2006). The flow at this location is predicted to decrease approximately 38% during the 1,000 year simulation. Note that the simulated flow at the gage near Moapa at the beginning of the predictive simulation (approximately 25 cfs) is approximately two-thirds of the observed flow (37 cfs in early 2010), as discussed in the model documentation report (Tetra

Tech, 2012). The average flow measured near Glendale in 2011 was also approximately 37 cfs, but the model simulates additional groundwater and surface water discharge (from Meadow Valley Wash) into the Muddy River upstream of the Glendale gage, producing a simulated flow of approximately 63 cfs at the gage. Flow at the gage near Moapa is predicted to decrease approximately 29%, and near Glendale and near the Bowman Reservoir diversion by about 21%. Approximately two-thirds of the decrease in flow that was simulated at the Glendale gage occurs upstream of the Moapa gage, and one-third occurs along the Muddy River downstream of the Moapa gage and in Meadow Valley Wash.

The simulated combined discharge from Rogers and Blue Point Springs is shown on Figure 3.1-2c. There is a simulated 12% decrease in the discharge in 1,000 years. This discharge point is simulated through use of Drain boundary conditions in layers 1 through 18, based on a conceptual model that the Rogers Spring Fault provides a permeable pathway throughout the geologic section, and that the rocks, rather than the permeability of the fault, limit the movement of water to the surface. In the model, the flow is derived primarily from layers 1 through 10, and a small amount comes from layers 16 through 18. The highest head is in layer 9 (1595.19), which 1.19 feet higher than the elevation of the drain (1594 ft) used to represent the springs. Thus, a small amount of drawdown will cause the simulated discharge to decrease, and only 1.2 feet of drawdown will cause the flow to stop. As a result, the drawdown map is too coarse of a tool to evaluate the impacts of pumping on the combined discharge at Rogers and Blue Point Springs, and the calculated spring discharge (which was used to develop Figure 3.1-2c) should be used instead.

The simulated flow in the Virgin River and Beaver Dam Wash are shown in Figure 3.1-2d. For Scenario 1, the streamflow in Beaver Dam Wash is essentially un-affected by the pumping. However, streamflow in the Virgin River is affected by a few percent. The streamflow near Overton is impacted more than that at Littlefield.

Pumping also caused increases of flow into the model domain through the GHBs. The changes in GHB flow were 2 af/yr (50 years), 5.8 af/yr (100 years), 14 af/yr (200 years), 31 af/yr (500 yrs), and 41 af/yr (1,000 years). As noted previously, these estimates should be used primarily to compare the results from different scenarios. However, these values are small compared to the simulated pumping (approximately 21,000 af/yr), indicating that with the current pumping, impacts on surrounding basins will probably be minor.

During the 1,000 year simulation, there was a net increase in the simulated discharge of 174 af/yr to Lake Mead (from 3571 af/yr to 3745 af/yr), largely in response to the lower lake stage used in the predictive simulation. The discharge into Lake Mead increased from 3,571 af/yr to more than 3,900 af/yr 20 years after the start of the simulation. It then decreased to 3,745 af/yr after 1,000 years, for a net decrease of 174 af/yr. Most of this change is the result of changing lake stage in the long-term simulation (1949-2011) that was used to generate the starting-head dataset used for the predictive simulations. A simulation was made with no pumping, and the groundwater flow in and out of the lake was similar to that simulated in Scenario 1. With no pumping for 1,000 years, the net flow into the lake was 3,763 af/yr, compared with 3,745 af/yr with the present-day pumping. Thus the effect of the Scenario 1 pumping on flow into the lake was a reduction of approximately 18 af/yr.

Because of the variability in flow into the lake caused by the changing lake stage during the long-term run, the results for Scenarios 2 through 7 will be compared with the 18 af/yr decrease in discharge to the lake predicted to occur by the present-day pumping (Scenario 1).

3.2 SCENARIO 2

Scenario 2 evaluates the effects of pumping at rates equal to the total of all existing groundwater rights, both those currently pumped and unpumped. In addition to wells simulated in Scenario 1, there are 13 new simulated locations of pumping included. Three are in Coyote Spring Valley, two in Kane Springs Valley, two within the Moapa Indian Reservation in California Wash, three near Apex in Garnet Valley, and two in the Tule Desert. In Coyote Spring Valley, the simulated pumping increases from 5,727 af/yr to 16,100 af/yr. The total simulated pumping increases from 21,106 af/yr (Scenario 1) to 60,254 af/yr in Scenario 2, an approximate three-fold increase. Because of limitations on the productivity of wells imposed by the MNW package, the simulated pumping decreased from 60,064 af/yr in year 10 down to 60,063 af/yr in year 1,000, a minor change from the intended amount.

<u>Drawdown Maps</u>

Simulated drawdown is shown on Figures 3.2-1a through 3.2-1e. In the vicinity of the Muddy River Springs, the simulated drawdown after 10 years is approximately 5 feet, compared with less than 1 foot simulated for Scenario 1 pumping. The drawdown pattern shows the effects of capture of water from the Muddy River Springs. Throughout much of the carbonate aquifer in the western part of the model, drawdown after 10 years of simulated pumping is greater than 2 feet. In the Tule Desert, drawdown is greater than 20 feet near the two pumping wells, and is simulated as being approximately 100 feet near PW-1, the eastern of the two wells. [In the simulations, it was necessary to distribute the pumping from PW-2 using four wells located at the same cell to avoid having the MNW package reduce the rate of pumping from PW-2 significantly.] As would be expected, the drawdown in the Virgin River Valley near Mesquite has also increased from the 10-year Scenario 1 prediction.

At 50 years (Figure 3.2-1b), drawdown near the Muddy River Springs has increased to more than 10 feet. The area affected by drawdown greater than 2 feet has expanded to most of the western and southwestern boundaries of the model and much of this area experiences greater than 10 feet of drawdown. Drawdown in the Tule Desert has increased to greater than 50 feet near the two wells, and the drawdown cones caused by pumping in the Tule Desert and Kane Springs Valley have begun to coalesce.

Continued pumping causes greater and wider drawdown (Figures 3.2-1c through 3.2-1e). Near the Muddy River Springs, the drawdown at 100 years is approximately 20 feet, at 500 years it is approximately 25 to 35 feet, and at 1000 years, the simulated drawdown is approximately 50 feet. The patterns of drawdown still show the effects of buffering caused by capture of the spring discharge and stream flow after 1,000 years of pumping. Drawdown in the Tule Desert has increased to greater than 100 feet near the two pumping wells at 100 years, more than 200 feet at 500 years, and greater than 500 feet near PW-1 at 1,000 years.

Along stretches of the Muddy River, Meadow Valley Wash, the Virgin River, and Beaver Dam Wash, drawdown is less than on either side of these stretches, because of the buffering effect of capture of the surface flow. Drawdown is transmitted below the streams and rivers in deeper layers. For example, there is drawdown on the east side of Beaver Dam Wash at 100 years and later, although there is no pumping being simulated in this area.

In the 500 and 1,000 year simulations, there is an approximately east-west zone of low drawdown that is located approximately seven miles south of Mesquite. Evaluation of the details in the geologic model indicated that there is part of the carbonate aquifer (PC1 thrust sheet) present in this zone along the southeastern side of the structural basin that is connected with the carbonate aquifer present at much greater depth beneath the basin. As a result, this shallow occurrence of the carbonate aquifer can transmit water upward, and limit the drawdown where it is present at shallow depth.

In Figure 3.2-1e, there is a small area along Meadow Valley Wash where the simulated drawdown is in the 100 to 200-foot range. This is likely caused by the continued simulation of ET in this area after the stream has dried up and can no longer serve as a source of water to the model. In nature, the plant community would change to one that could survive using less water. However, in the model, the ET rate is not changed, and the model calculates more drawdown than would occur along this short stretch of the stream.

Graphs of Discharge vs. Time

Simulated discharges from the springs in the Muddy River Springs area are shown in Figure 3.2-2a. In contrast with the results from Scenario 1, where only the discharge from Pederson Spring is predict to cease, the pumping in Scenario 2 is predicted to cause all of the springs but Muddy Spring to effectively stop flowing by the end of the simulation. Pedersen Spring and Plummer are predicted to go completely dry quickly, in approximately 30 and 60 years, respectively. Pipeline-Jones Springs would go completely dry in approximately 325 years. Flow at Baldwin Spring would stop in approximately 525 years. Cardy-Lamb Spring is predicted to become dry in approximately 1,000 years. The rate of decline at Muddy Spring is high enough that it would likely cease flowing by 1,100 years; however, it would lose half its flow in approximately 200 years. The differences in the lengths of time that the springs continue to flow is caused by their different elevations. The higher springs (such as Pederson and Plummer) are more sensitive to drawdown, and stop flowing earlier. Muddy Spring is located close to the Muddy River, and continues to flow longer.

The simulated impact on the flow in the Muddy River is shown in Figure 3.2-2b. The model predicts that the flow near Moapa will cease in approximately 1,000 years. The streamflow in the river at Glendale and above the diversion near Bowman Reservoir is predicted to decrease by about 50% in 200 years. These two locations receive discharge from Meadow Valley Wash, which continues to be fed by groundwater discharge occurring in the lower part of Meadow Valley Wash.

The pumping simulated in Scenario 2 is predicted to cause the combined discharge from Rogers and Blue Point springs to decrease from 2.25 cfs to approximately 1.3 cfs in 1,000 years (Figure 3.2-2c), or about 40%. The drawdown maps show drawdown in layer 1, and indicate that there will be less than 1 foot of drawdown at 500 years at the water table. However, Figure 3.2-2c indicates that there likely will be noticeable reductions in discharge at 100 or 200 years. The greatest change in discharge occurs in layers 9 and 10. However, the simulated drawdown is only a few tenths of a foot. In these layers, drawdown of about 1.2 feet would cease the discharge from these layers. Thus the simulated discharge is sensitive to small amounts of head change. There is a large degree of uncertainty related to the magnitude of the effect of drawdown on the discharge rate, but it is likely that the impact of drawdown on the discharge from Rogers and Blue Point Springs would be less than simulated by the model. Vegetated areas that appear to be fed by groundwater are located along the Rogers Springs fault, and have higher elevations than Rogers Spring. This suggests that the excess head in the groundwater system is greater than the 1.2 feet that the model simulates.

In the Virgin River Valley (Figure 3.2-2d), the simulated discharges in Beaver Dam Wash do not change substantially, and there are small changes in the simulated flows in the Virgin River. The Virgin River near Overton shows the greatest decline, about 10% in 300 years and 15% over the 1,000-year period.

Over the 1,000 year simulation, the model simulates a net decrease in groundwater discharge to Lake Mead of 26 af/yr more than Scenario 1. There is also more water that enters the model through the GHB cells around the margin of the model. At 1,000 years, the GHB cells provide 98 af/yr, compared with 41 af/yr for Scenario 1.

3.3 SCENARIO 3

Scenario 3 evaluates the effects of the pumping included in Scenario 2 (all existing groundwater rights, currently pumped and unpumped, 60,254 af/yr) plus simulated pumping at rates equal to all pending applications filed through 1989. The total simulated pumping would increase to 162,555 af/yr. The simulated pumping was approximately 162,366 af/yr after 10 years, and decreased a small amount to 161,680 af/yr after 1,000 years. Additional withdrawals were simulated in Coyote Spring Valley, California Wash, Garnet Valley, and along the Virgin River approximately 12 to 18 miles downstream of Mesquite. The predicted drawdown is presented in Figure 3.3-1a through 3.3-1e. The simulated pumping locations from Scenario 2 are shown on these drawdown maps as white circles; new simulated pumping locations that were added in Scenario 3 are shown as blue circles.

Drawdown Maps

After 10 years of pumping (Figure 3.3-1a), the predicted drawdown in the Muddy River Springs area is approximately 10 feet, approximately twice that for Scenario 2. The drawdown pattern shows the buffering effect caused by capture of the discharge from the springs. The extent of the drawdown in the carbonate aquifer is predicted to be slightly greater than in Scenario 2 at this time; however the magnitude of the drawdown within this area is substantially greater than in Scenario 2, reaching 10-20 feet over an area of the Muddy River Springs Area and central Coyote Spring Valley. The Tule Desert drawdown is the same after 10 years in Scenario 2 and 3. The new simulated pumping along the Virgin River shows predicted drawdown greater than 100 feet.

After 50 years of pumping, the drawdown in the Muddy River Springs area has increased to more than 20 feet. The area with greater than 20 feet of drawdown also extends over most of the distribution of the PC4 thrust sheet, which will be referred to as the western carbonate aquifer (only in the context of this model) in this report. The new area of simulated pumping along the Virgin River shows predicted drawdown between 200 and 500 feet, and greater than 500 feet in the pumping center.

Scenario 3 pumping for 100 years shows predicted drawdown of approximately 50 feet at the Muddy River Springs area (Figure 3.3-1c). Drawdown along the western model boundary (between Coyote Spring Valley and Tikapoo Valley) is predicted to be approximately 20 feet. At the water table, the predicted drawdown at Rogers and Blue Point Springs is less than 1 foot. Widespread drawdown greater than 200 feet is predicted along the Virgin River, with more than 500 feet of drawdown locally.

The drawdown near the Muddy River Springs (and throughout much of the western model area) after 500 years (Figure 3.3-1d) is predicted to be greater than 100 feet. The drawdown along the Virgin River is greater than 500 feet near the pumping center of the new wells after 500 years. After 1,000 years, the predicted drawdown has increased further, and drawdown greater than 100 feet is shown in approximately 40% of the model domain. After 500 years, the line representing 1 foot of drawdown at the water table is approximately 3 miles away from Rogers and Blue Point Springs. After 1,000 years, the line is only about 1 mile away.

Graphs of Discharge vs. Time

The impacts on the Muddy River Springs (Figure 3.3-2a) occur much faster in Scenario 3 than in Scenario 2. All of the springs are predicted to dry up within about 175 years, including the Muddy Spring. The streamflow in the Muddy River also declines much more and faster than in Scenario 2. At the locations near the Bowman Reservoir diversion and at Glendale, the streamflow is predicted to decrease by approximately two-thirds within 175 years, and to be zero cfs near Moapa. These rapid declines in streamflow at Glendale will cause significant impacts to downstream water users.

Figure 3.3-2c shows the predicted impacts to the combined discharge from Rogers and Blue Point Springs. By 200 years, the discharge rate is predicted to decline by approximately 25%. The discharge is predicted to have ceased before 1,000 years, probably around 800 years. [The point at 1,000 years indicates that the discharge is zero at 1,000 years, but the spring discharge may have stopped prior to that time. The projection of the trend based on the points at 100, 200 and 500 years indicates that the spring would dry up after approximately 800 years of pumping.]

The net flux of water at Lake Mead has changed from discharge from the groundwater system into the lake at approximately 3,571 af/yr to a flow from the lake into the groundwater system at about 897 af/yr at 1,000 years. This is a net change of approximately 4,642 af/yr greater than occurred in Scenario 1, or about 2.9% of the total pumping. The inflow into the model from areas outside the model was 392 af/yr.

The flow in the Virgin River near Overton is predicted to decrease 50% in about 30 years, and to cease at about 170 years (Fig. 3.3-2d). Streamflows at the other locations are relatively un-impacted because they are upstream of the large number of wells introduced in Scenario 3.

In summary, while the impacts of simulated pumping of all existing groundwater rights (Scenario 2) are predicted to cause substantial, but relatively slow, impacts on the groundwater and surface water in the Muddy River Springs area and Muddy River, the simulation of pumping at rates equal to all existing groundwater rights plus all pending applications through 1989 (as evaluated in Scenario 3) is predicted to greatly accelerate the impacts in the Muddy River Springs and Muddy River, as well as to substantially deplete surface flows in the Virgin River below the locus of the proposed new pumping wells along the Virgin River.

3.4 SCENARIO 4

Scenario 4 (all existing rights plus all pending applications filed through 1994) involves an increase in the simulated pumping up to 307,934 af/yr, an increase of approximately 140,000 af/yr over Scenario 3. The additional simulated pumping would occur primarily in the Beaver

Dam Wash drainage basin within Nevada. There would also be additional pumping near Apex; in the Lower Moapa Valley (two locations a few miles south of the Muddy River, and a third a few miles south of the Mormon Mountains); and in the Muddy River Springs Area HA at the southern end of the Meadow Valley Mountains north of the Muddy River. The model-simulated pumping rate was 305,635 af/yr after 10 years, and decreased substantially to 233,364 af/yr after 1,000 years. More than a third of this decline occurred in the first 100 years, indicating that pumping at these rates cannot be maintained in some areas (those with high simulated drawdown discussed below).

Drawdown Maps

The drawdown at 10 years differs from the Scenario 3 drawdown primarily where new wells are simulated along the eastern Nevada boundary, and in Lower Moapa Valley (Figure 3.4-1a). In the northernmost pumping center in Beaver Dam Wash, the simulated drawdown exceeds 1,700 feet, indicating that this production will not be sustainable. The drawdown in the western carbonate aquifer is very similar to that in Scenario 3. However, drawdown from the southern pumping center in Lower Moapa Valley has already coalesced with the drawdown caused by pumping further west.

By 50 years, the simulated drawdown in the northernmost pumping center along Beaver Dam Wash has exceeded 3,400 feet, and exceeds 200 feet in other centers (Figure 3.4-1b). After 100 years, the maximum drawdown exceeds 3,700 feet, and the drawdown reaches the eastern model boundary along most of its length (Figure 3.4-1c). In the Lower Moapa Valley, the drawdown in the northern center exceeds 500 feet near the well, and exceeds 100 feet in the southern center. Drawdown near the Muddy River Springs is approximately 50 feet.

After 500 years, the drawdown along the eastern Nevada border near Beaver Dam Wash exceeds 500 feet over large areas (Figure 3.4-1d). Maximum drawdown has increased to over 3,900 feet. The drawdown in the Muddy River Springs area is greater than 100 feet. After 1,000 years, the simulated drawdown exceeds 200 feet over approximately 2/3 of the model area (Figure 3.4-1e). The greatest drawdown is nearly 4,000 feet.

Graphs of Discharge vs. Time

The effect of the pumping on spring discharge and streamflow is shown in Figures 3.4-2a through 3.4-2d. In the Muddy River Springs area, all springs are predicted to be dry by approximately 100 years, and some much sooner (Figure 3.4-2a). The Muddy River near Moapa is predicted to be totally dry in about 100 years; the Muddy River near the Bowman Reservoir diversion is predicted to be dry in less than 500 years, and the river at Glendale is predicted to be dry by about 630 years (Figure 3.4-2b).

The combined discharge at Rogers and Blue Point Springs is predicted to decrease by 10% in 100 years, and by more than 30% in 200 years (Figure 3.4-2c). Springflow is predicted to cease in less than 600 years.

In the Virgin River Valley, Beaver Dam Wash at the gage near Enterprise (which is located in Utah about one-half mile downstream of where Beaver Dam Wash flows from Nevada into Utah) is predicted to become dry by 10 years. Further downstream near Littlefield, it becomes dry after 100 years (Figure 3.4-2d). The Virgin River near Overton is predicted to be dry by 30 years of pumping. Upstream, near Littlefield, the flow in the Virgin River is predicted to decrease by approximately 20% within 60 years, but to nearly stabilize after that. The quantity of water in the Virgin River introduced into the model at the Virgin River Gorge is sufficient to prevent the river at Littlefield from drying up with this amount of pumping.

The flow into the lake reverses approximately 400 years after pumping starts, and the lake becomes a net source of water to the groundwater system. The net change in flux represents a capture of 7,028 af/yr more than the capture in Scenario 1. The neighboring basins are estimated to provide approximately 517 af/yr.

3.5 SCENARIO 5

The pumping in Scenario 5 (based on all existing rights plus all pending applications filed through 1999) has increased to 575,600 af/yr, with several new wells simulating a very large increase (163,280 af/yr) in pumping rate in Coyote Spring Valley. There are several new wells in other locations in the southern part of the western carbonate aquifer, in the Tule Desert, in the Tule Springs Hills area in the Virgin River Valley HA just east of the Tule Desert, and along the Virgin River near and west of Mesquite. The pumping in the model was about 570,419 af/yr after 10 years, and decreased to 464,462 af/yr after 1,000 years for a decline of 105,957 af/yr. Approximately 72,300 af/yr of this decreased productivity resulted from production that was simulated in Scenario 4. The simulated drawdown is shown in Figures 3.5-1a through 3.5-1e.

Drawdown Maps

After 10 years, the additional simulated pumping has created an area of drawdown exceeding 50 feet in the central part of Coyote Spring Valley, and drawdown exceeding 20 feet in most of the western carbonate aquifer. The drawdown in the vicinity of the Muddy River Springs exceeds 20 feet. In the Tule Desert, the simulated drawdown is more than 100 feet near some of the wells. Drawdown in other areas is similar to that simulated in Scenario 4.

Simulated drawdown after 50 years exceeds 100 feet in most of the western carbonate aquifer, including the area near the Muddy River Springs. In the Tule Desert and vicinity, the drawdown exceeds 200 feet near all the new simulated pumping wells. The simulated drawdown cones of all pumping centers in the western carbonate aquifer have coalesced, and the simulated drawdown cones in the Virgin Valley and Tule Desert have begun to coalesce, meaning that the drawdown simulated near one pumping center is increased by pumping in nearby pumping centers.

After 100 years (Figure 3.5-1c), the drawdown in most of the western carbonate aquifer is greater than 200 feet, including the Muddy River Springs area. Drawdown in the Tule Desert and vicinity exceeds 200 feet. In addition, the increase in pumping along the Virgin River near Mesquite has increased the drawdown simulated in the pumping center approximately 15 miles downstream from Mesquite. This impact is caused by drying up the Virgin River further upstream than was simulated in Scenario 4. At this time, the simulated drawdown from most pumping centers has coalesced throughout the model area.

After 500 years of pumping, the simulated drawdown throughout the western carbonate aquifer exceeds 500 feet, as does the drawdown along more than 1/3 of the Virgin River and approximately 2/3 of the well fields along the eastern Nevada boundary and in the Tule Desert and vicinity. After 1,000 years, drawdown exceeds 500 feet over more than 2/3 of the model domain.

Graphs of Discharge vs. Time

The discharge from all the springs in the Muddy River Springs area is predicted to cease within 20 years (Figure 3.5-2a). Streamflow in the Muddy River (Figure 3.5-2b) above the Bowman Reservoir diversion is predicted to cease within 110 years, and at Glendale about 20 years later. Discharge from Rogers and Blue Point Springs is predicted to cease within 200 years (Figure 3.5-2c). The Virgin River is predicted to stop flowing within 20 years near Overton, while the simulated decrease in flow near Littlefield is similar to that simulated in Scenario 4. Streamflow in Beaver Dam Wash at Enterprise is predicted to cease within 10 years, and within 100 years near Littlefield.

The direction of net flow at Lake Mead changes from groundwater discharge to recharge at about 210 years. The net change in flux is approximately 9,446 af/yr greater than in Scenario 1 after 1,000 years of pumping. The net change in the flux from neighboring basins at 1,000 years is approximately 2,584 af/yr.

3.6 SCENARIO 6

Scenario 6 (based on all existing rights plus all pending applications filed through 2004 increases the total simulated pumping to 617,805 af/yr. Simulated pumping added in Scenario 6 occurs in the southern half of the western carbonate aquifer, and in the Clover Mountains. The simulated pumping rate was 612,623 af/yr after 10 years, and declined to 505,931 af/yr after 1,000 years, a decline of 106,691 af/yr. This is only slightly greater than in Scenario 5, and indicates that the wells that will not be able to sustain the initial productivity were added in Scenarios 4 and 5.

Drawdown Maps

The predicted drawdown is presented in Figures 3.6-1a through 3.6-1e. After 10 years of pumping, the drawdown in the southern half of the western carbonate aquifer has increased a relatively small amount. The pumping in the Clover Mountains has caused coalesced drawdown cones to develop around each of the four additional wells. Continuing pumping causes the drawdown to increase in the areas where these new wells are simulated, but drawdown is similar to calculated in Scenario 5 in other areas. After 100 years, drawdown exceeds 500 feet around each of the new simulated pumping wells in the Clover Mountains.

Graphs of Discharge vs. Time

The figures for the discharge from springs in the Muddy River Springs area for Scenarios 5 (Figure 3.5-2a) and 6 (Figure 3.6-2a) are nearly identical. Both predict flow from the springs will cease within 20 years, but discharge rates for Scenario 6 are less at 10 years than those for Scenario 5. The simulated streamflows in the Muddy River are also very similar, with both scenarios predicting similar declines in flow rates, and similar dates for the flow to cease totally.

The combined discharge from Rogers and Blue Point Springs decreases more rapidly in Scenario 6 (Figure 3.6-2c) than in Scenario 5. Scenario 6 indicates that discharge will cease within 150 to 200 years.

The simulated streamflows in the Virgin River basin are essentially identical in Scenarios 5 and 6 (Figure 3.6-2d). The additional pumping in the Clover Mountains is too distant to noticeably affect flow rates in the Virgin River within 1,000 years, and the Scenario-6 simulated pumping dried up the flows in Beaver Dam Wash quickly.

Lake Mead recharge to the model at 1,000 years increases from 5,701 af/yr in Scenario 5 to 5,989 af/yr in Scenario 6. The net change in lake flux is a reduction of approximately 9,734 af/yr greater than Scenario 1. Surrounding basins provide an additional 2,858 af/yr in year 1,000 in response to the pumping.

3.7 SCENARIO 7

The final scenario evaluates pumping from all existing rights plus all pending applications filed through 2009. The total simulated pumping for Scenario 7 was set to 656,901 af/yr. New wells are simulated in Kane Springs Valley, in the northern Tule Desert, and in the Clover Mountains. The simulated pumping was 651,468 af/yr after 10 years, and decreased to 537,860 af/yr in year 1,000, a reduction of 113,608 af/yr.

Drawdown Maps

The simulated drawdowns are shown on Figures 3.7-1a through 3.7-1e. The most apparent changes in the drawdown at 10 years are in the northern part of the Tule Desert, around the new simulated pumping wells there. There is also more simulated drawdown in the northern part of Kane Springs Valley. After 50 years of pumping, the drawdown cone from the new wells in northern Tule Desert is beginning to coalesce with the drawdown from the wells along the Nevada-Utah border. Continued pumping results in expansion of the areas affected by the pumping. By 500 years, the effects of continuing baseflow in the streams are present only in upper Meadow Valley Wash, stretches of Clover Creek (a tributary of Meadow Valley Wash east of Caliente), stretches of Beaver Dam Wash in its northern third of its length, and two sections of the Virgin River (upstream of Littlefield Springs and a few miles on either side of the Nevada-Arizona border). These stretches continue to show the effects of buffered drawdown due to capture, but the effects are absent in other areas where they were previously present. After 1,000 years, these perennial stretches are slightly smaller. More than 500 feet of drawdown is predicted to have occurred over approximately 70% of the model domain.

Graphs of Discharge vs. Time

The simulated spring discharges and streamflows are presented in Figures 3.7-2a through 3.7-2e. These figures are very similar to those of Scenarios 5 and 6. Except for the streamflow in the Virgin River at Littlefield, all surface flow rates are quickly diminished. Rogers and Blue Point Springs flows decline more slowly than flows closer to the areas of significant production. Nonetheless, the simulations predict that the flow at Rogers and Blue Point Springs will cease between 150 and 200 years after the start of Scenario 7 simulated pumping (Figure 3.7-2c).

After 1,000 years, simulated water movement from Lake Mead into the groundwater system is at a rate of 5,980 af/yr, slightly less than in Scenario 6. The cause of the small decrease, with the increased pumping, is unknown but may be associated with changes in the other boundary fluxes. This represents capture of 9,725 af/yr more than in Scenario 1. The net flow from neighboring basins increased from 2,858 af/yr (Scenario 6) to 3,028 af/yr (Scenario 7).

4.0 SUMMARY AND CONCLUSIONS

Seven different predictive scenarios were evaluated, ranging from a continuation into the future of current pumping rates only, through pumping from all existing rights plus all pending applications filed through 2009. These simulations indicate:

1. The impacts of pumping on spring discharge and stream flow will increase as time passes, and as the rates of pumping increase.
2. With a continuation of current rates of pumping (Scenario 1), the model predicts that a new equilibrium may be established after more than 1,000 years, and the impacts on most springs will be less than a 35% reduction in discharge. Pederson Spring, however, is predicted to dry up in approximately 500 years, and the discharge from Cardy-Lamb Spring is predicted to decrease by 74% in 1,000 years.
3. If pumping were to increase to a rate equal to the total of all existing groundwater rights (Scenario 2), the Muddy River Springs will completely dry up in approximately 1,100 years. The higher elevation springs will dry up sooner. Pedersen Spring and Plummer Spring are predicted to go completely dry in approximately 30 and 60 years, respectively. Pipeline-Jones Springs would go completely dry in approximately 325 years. Flow at Baldwin Spring would stop in approximately 525 years. The rate of decline at Muddy Spring is high enough that it would likely cease flowing by 1,100 years; however, it would lose half its flow in approximately 200 years. After 50 years, the flow in the Muddy River at Glendale is predicted to decline by 16%, and is predicted to decrease to less than 40% of the existing flow within about 500 years. The model further predicts that the discharge from Rogers and Blue Point Springs will decline approximately 40% in 1,000 years. Flows in the Virgin River basin near Overton will be reduced by approximately 13% over this period. Thus, the model is predicting that the groundwater system will not be able to supply the existing groundwater rights without impacting surface-rights holders. There will also be impacts at areas where there are sensitive habitats.
4. With the addition of simulated pumping of all pending applications through 1989, as represented by Scenario 3, impacts become greater and occur more quickly. Pedersen Spring is predicted to go completely dry in **less than 20 years**. All discharge from the Muddy River Springs ceases within approximately 150 years, and the flow in the Muddy River at Moapa ceases in about 160 years. The modeling predicts that the streamflow does not stabilize at a new equilibrium, but continues to decline past the end of the 1,000-year simulation. Pumping near the Virgin River will totally deplete the baseflow in the lower reaches. The combined discharge from Rogers and Blue Point Springs is predicted to decrease by 65% in 500 years.
5. The pumping simulated in Scenarios 4 through 7 is predicted to cause greater and faster impacts to the groundwater and surface-water resources.

6. The effects of drawdown will cause impacts outside the modeled area, and capture flow from adjoining basins, including those in Utah and Arizona. The magnitude of this impact is not known, but could be estimated by linking this model with models of other areas.
7. In some areas, the aquifers may not be able to sustain the projected pumping, regardless of effects elsewhere. In Scenarios 4 through 7, the maximum predicted drawdown exceeded 3,000 feet. The model also lowered the rate of production as water levels were lowered to below the assigned screen intervals of the wells.
8. There is uncertainty in these projections that needs to be evaluated further. A detailed uncertainty analysis is recommended. However, it is unlikely that the general conclusions will be altered substantially, but changes in new equilibrium discharge rates (for lower pumping rates) or rates of depletion would be expected to become better defined through the uncertainty analysis.

5.0 REFERENCES

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Beck, D.A. and Wilson, J.W., 2006, Synoptic discharge, water-property, and pH measurements for Muddy River Springs Area and Muddy River, Nevada, February 7, 2001: U.S. Geological Survey Scientific Investigations Report 2006-5237, 12 p.

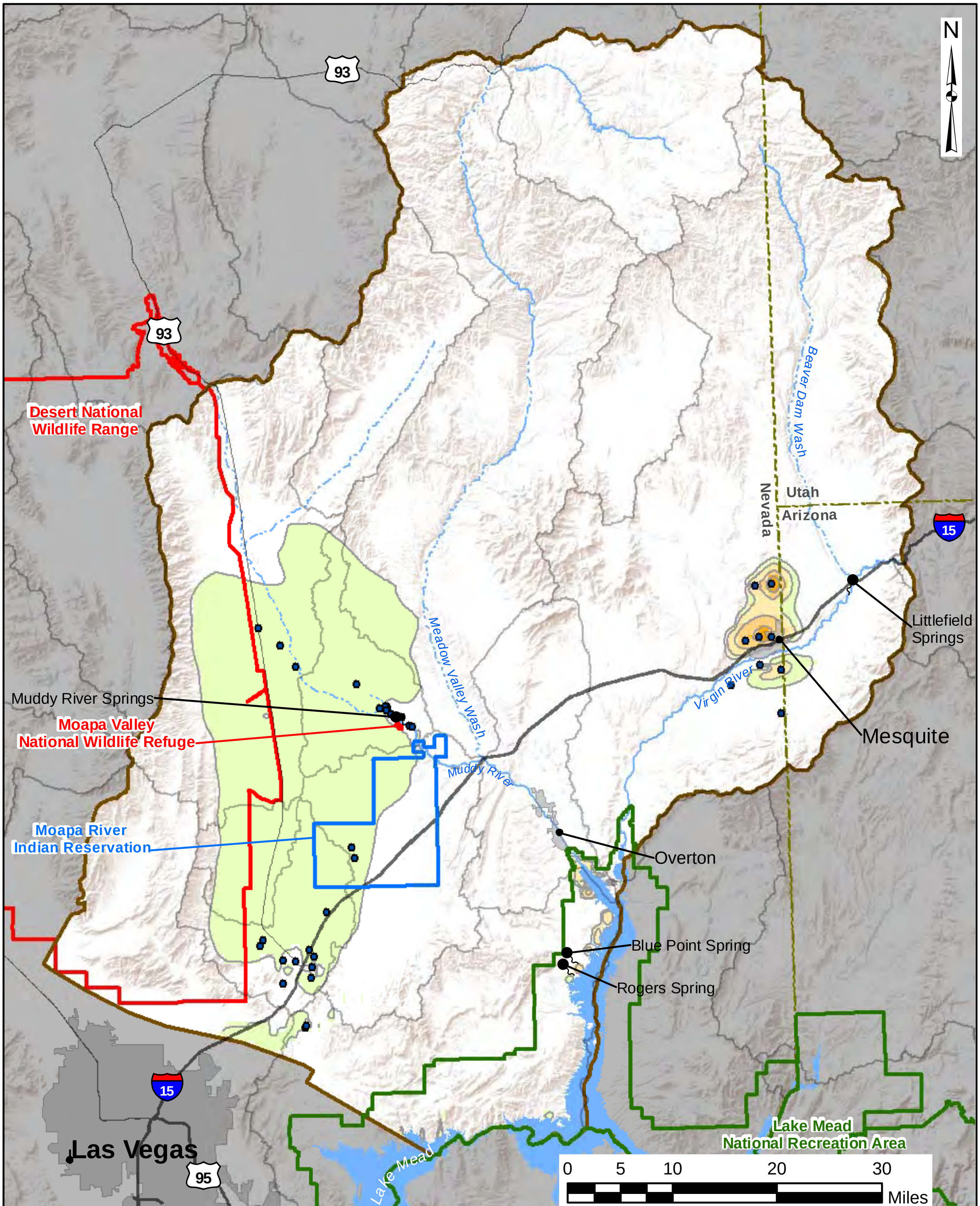
Tetra Tech GEO, 2012, Development of a Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada (Version 1.0), 70 p., plus figures and 2 appendices.

FIGURES

TETRA TECH

SE ROA 12415

SE ROA 12416



Legend

< 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 500
10 - 20	> 500

Pumping Wells

Active Model Domain

State Boundary

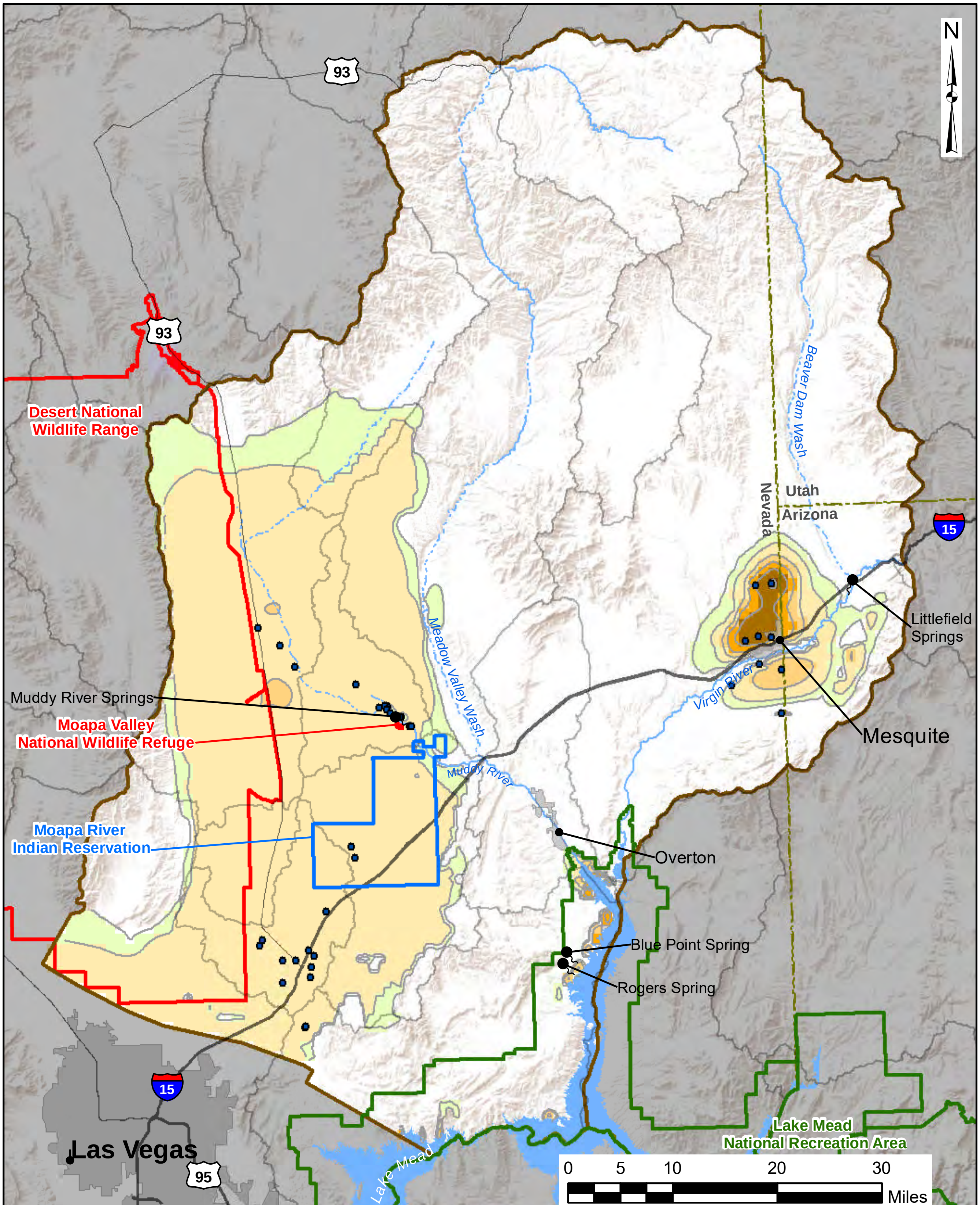
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 1 10 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.1-1a**



Legend

< 1	20 - 50	Pumping Well Location
1 - 2	50 - 100	Active Model Domain
2 - 5	100 - 200	
5 - 10	200 - 500	
10 - 20	> 500	State Boundary

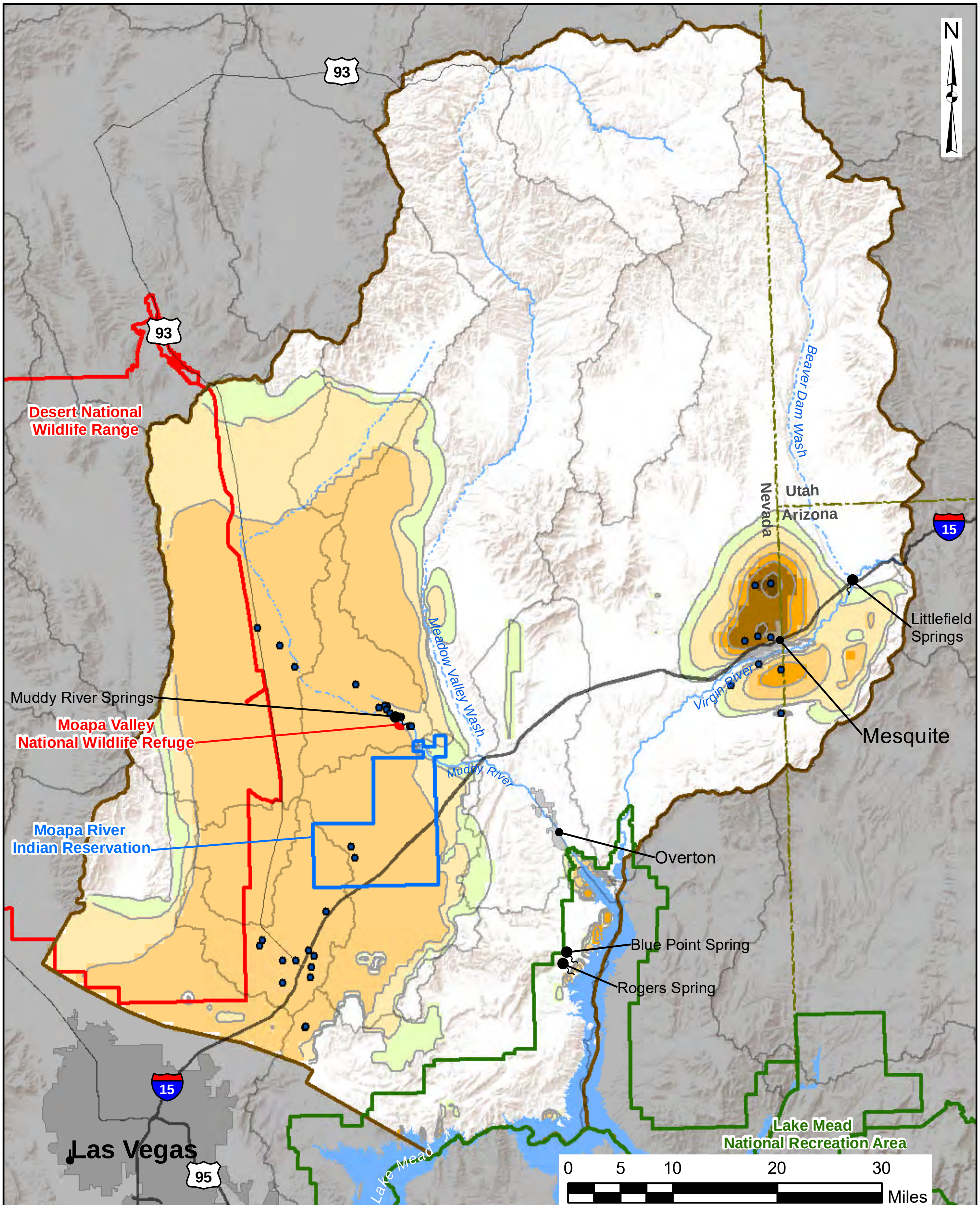
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 1 50 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.1-1b**



Legend

< 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 500
10 - 20	> 500

Pumping Well Location

Active Model Domain

State Boundary

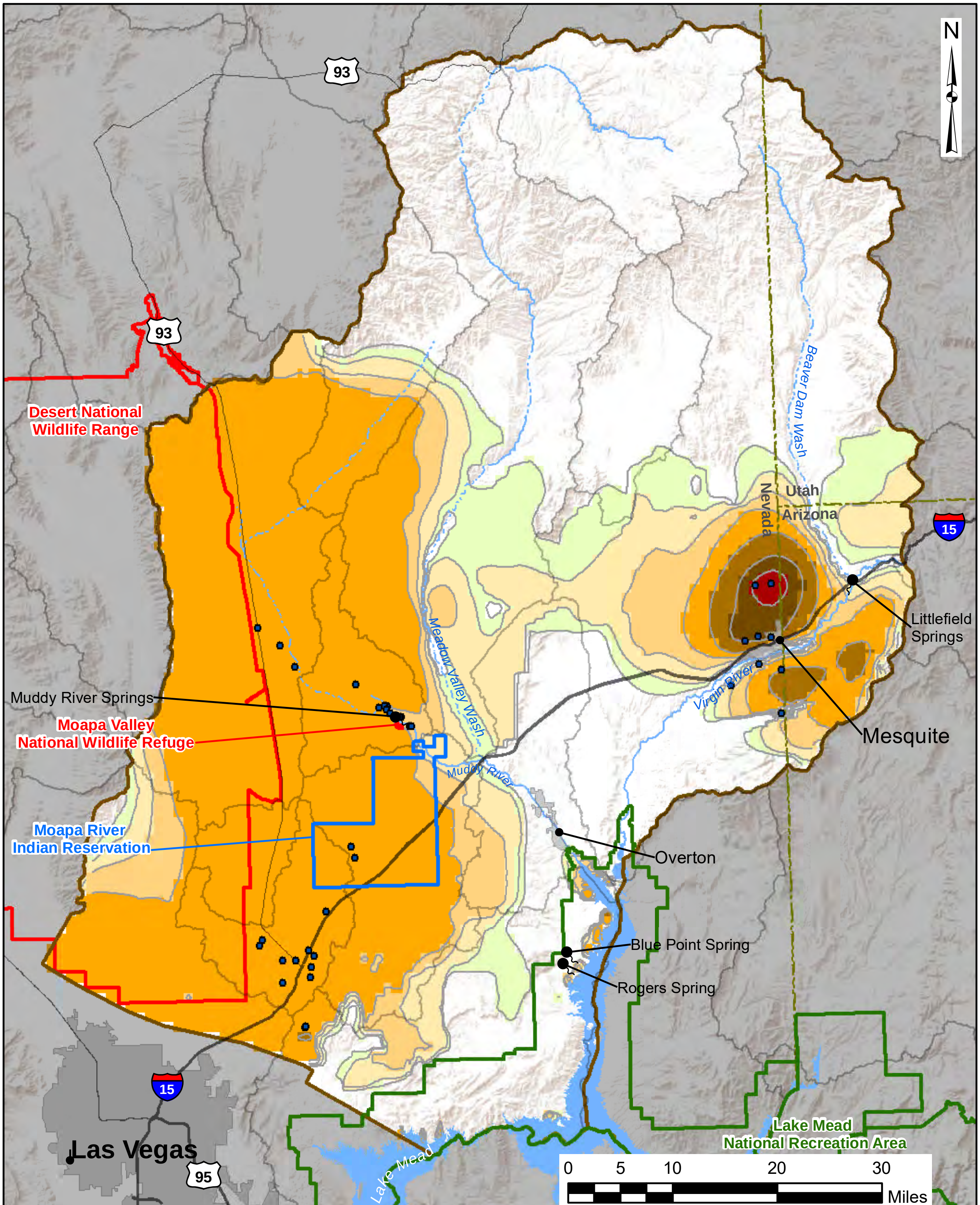
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 1
100 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE **3.1-1c**



Legend

< 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 500
10 - 20	> 500

Pumping Well Location

Active Model Domain

State Boundary

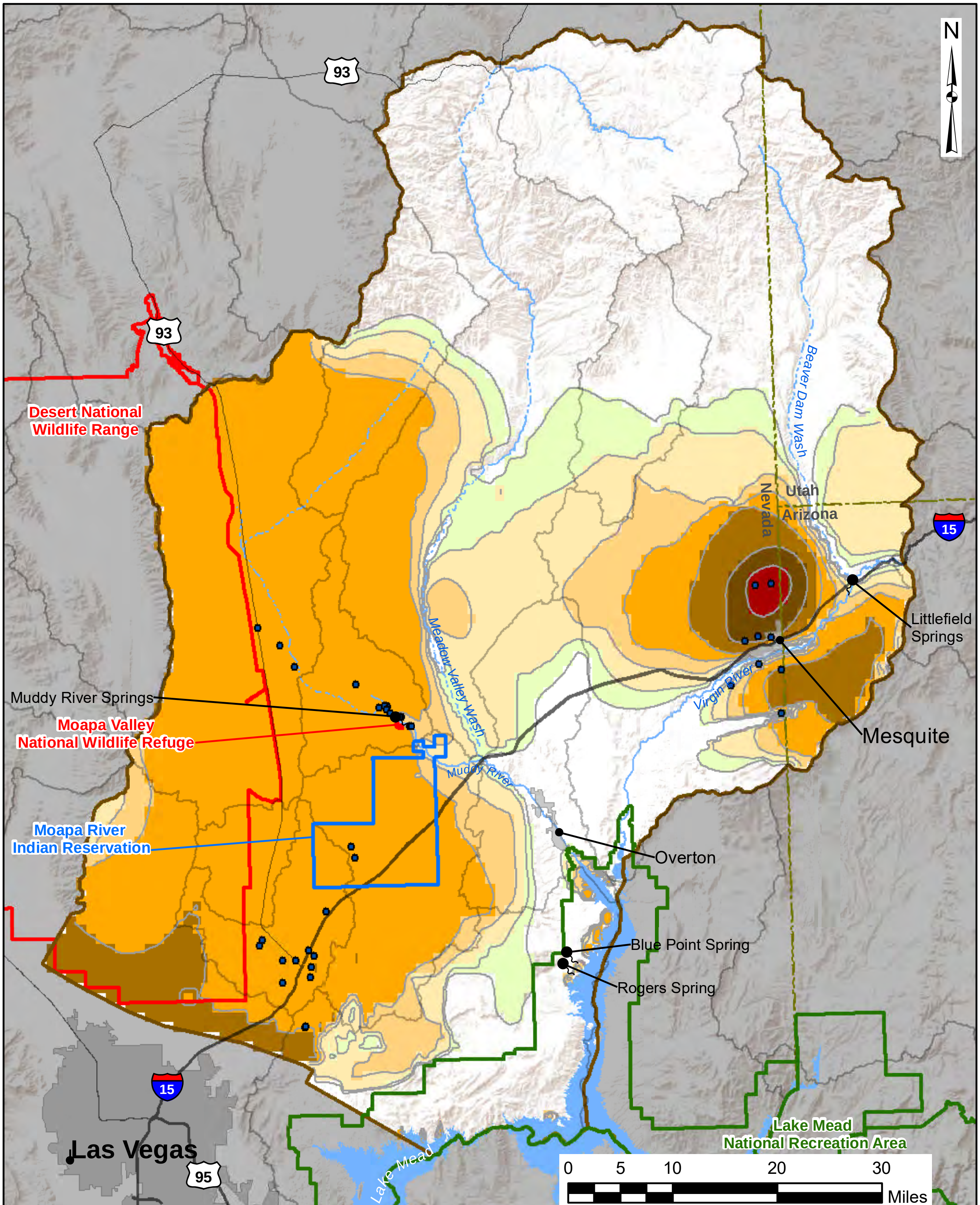
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 1 500 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.1-1d**



Legend

- < 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500
- Pumping Well Location
- Active Model Domain
- State Boundary

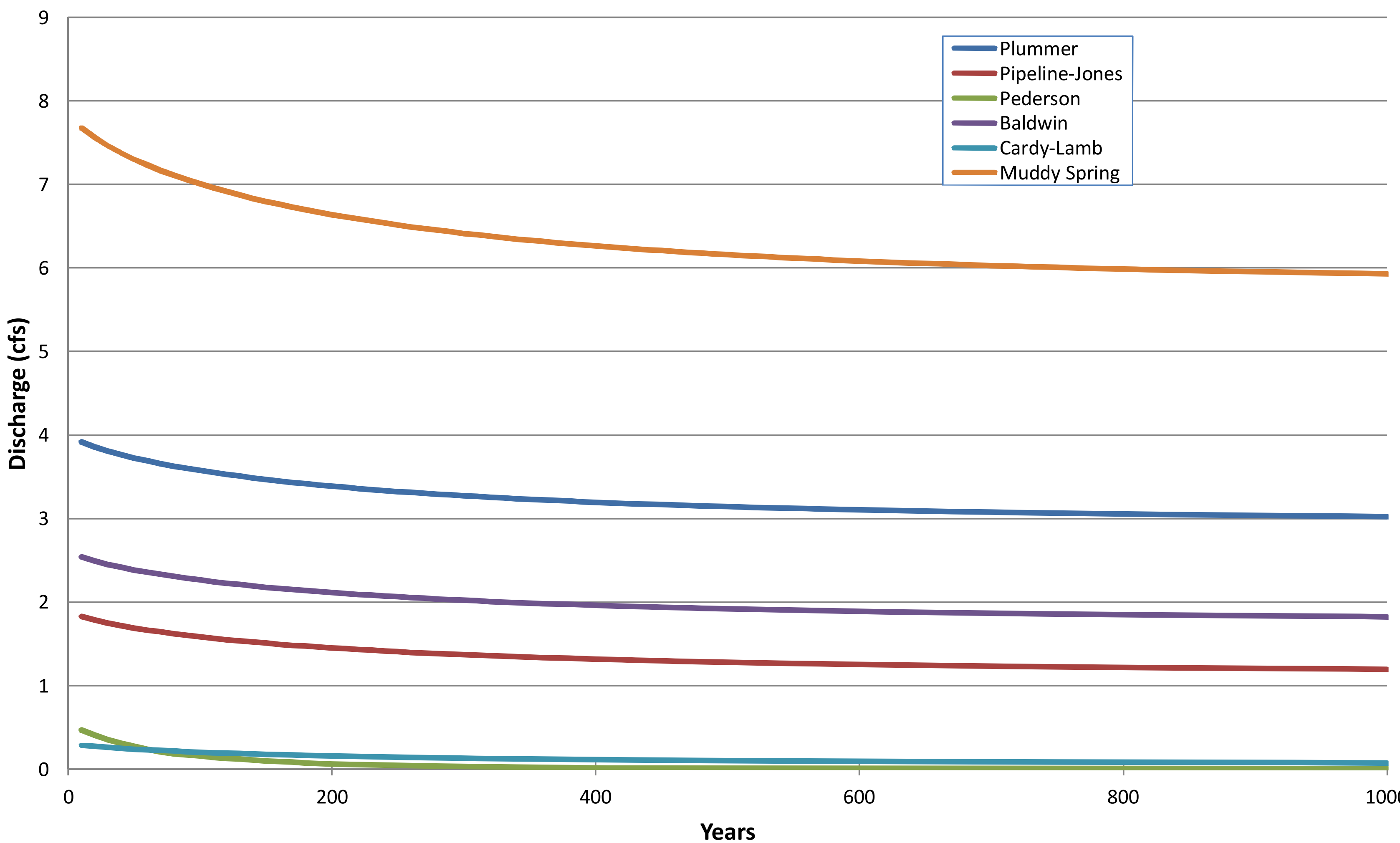
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 1
1000 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE **3.1-1e**

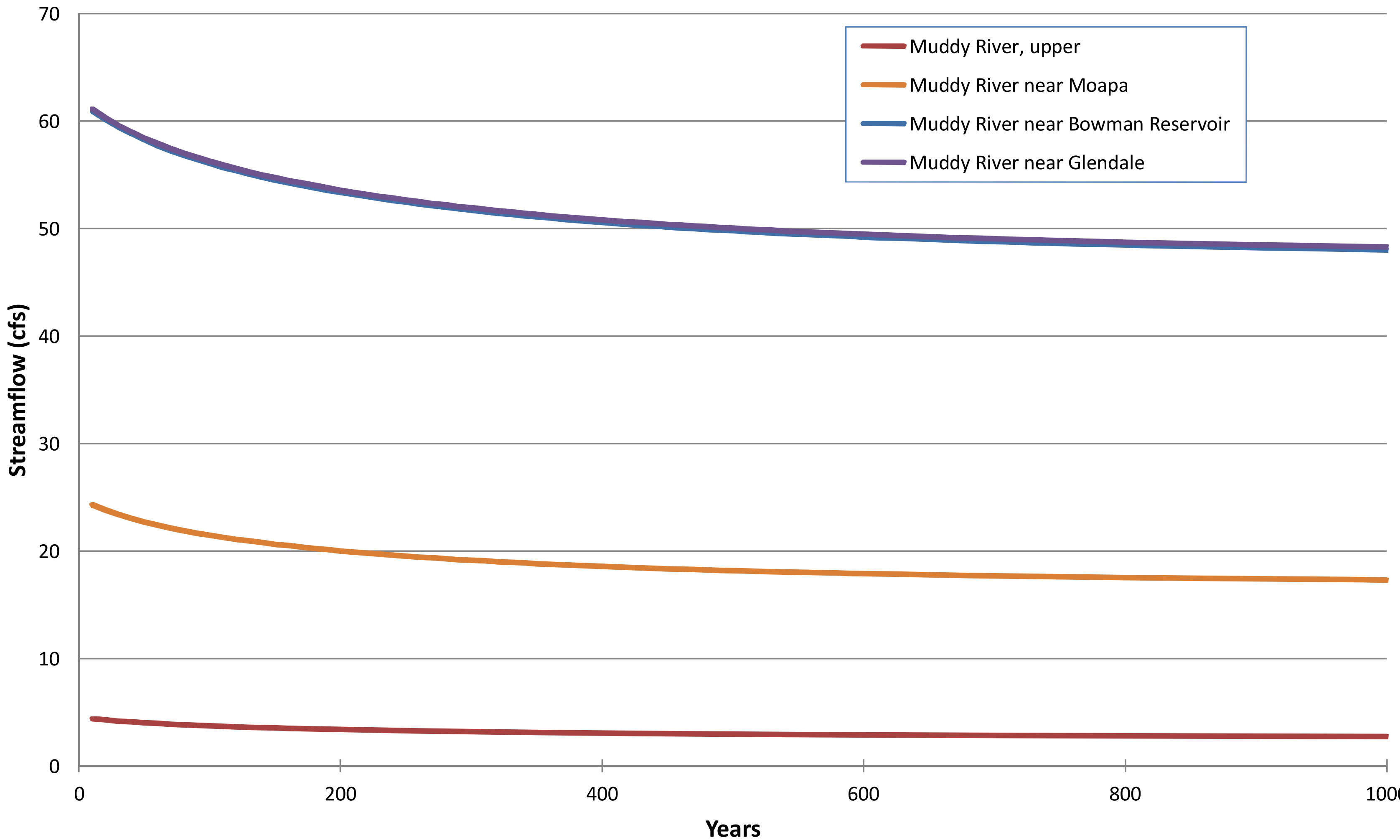


Simulated spring discharges in the Muddy River Springs area, Scenario 1

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.1-2a

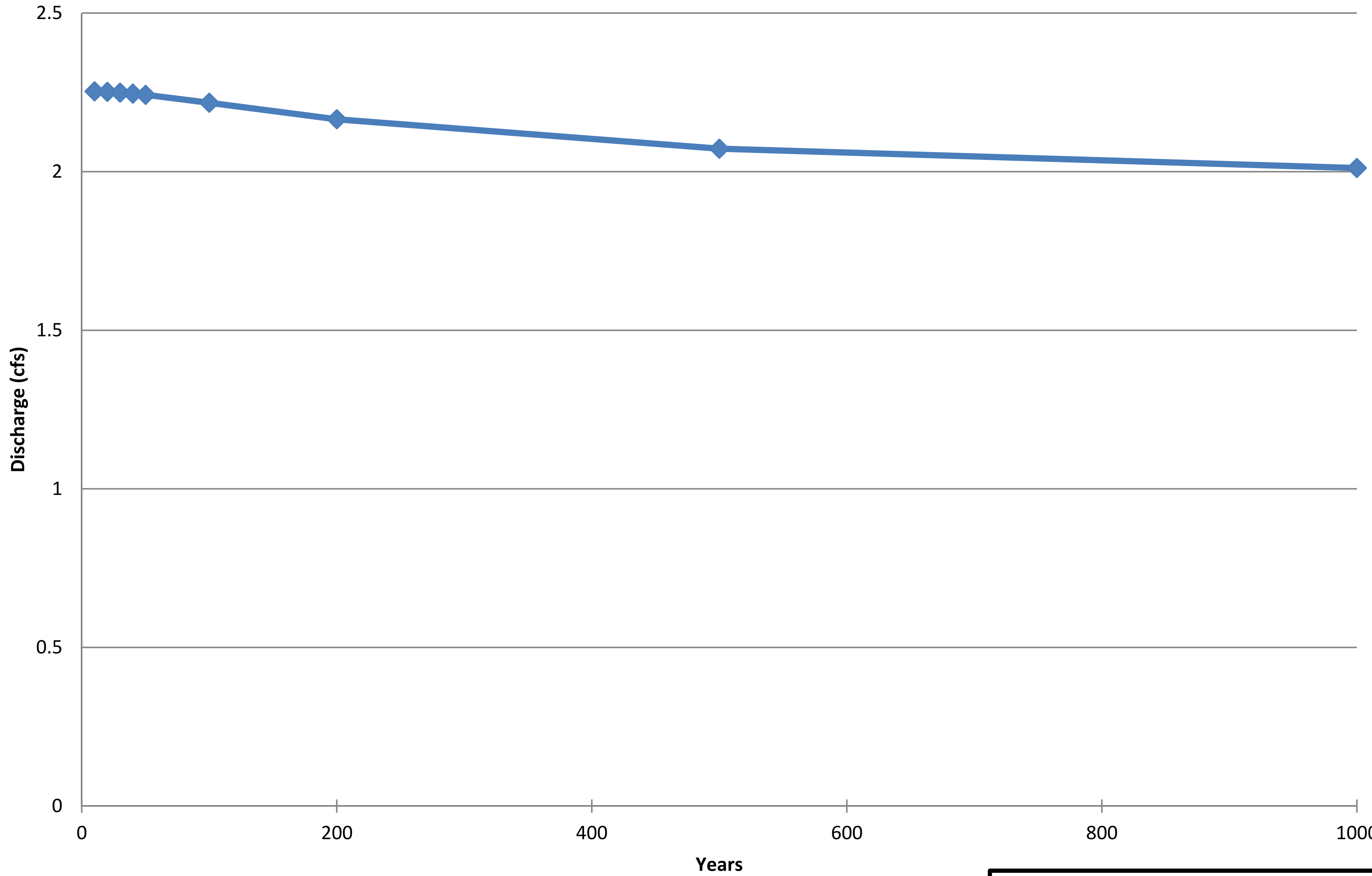


Simulated streamflow in the Muddy River, Scenario 1

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.1-2b



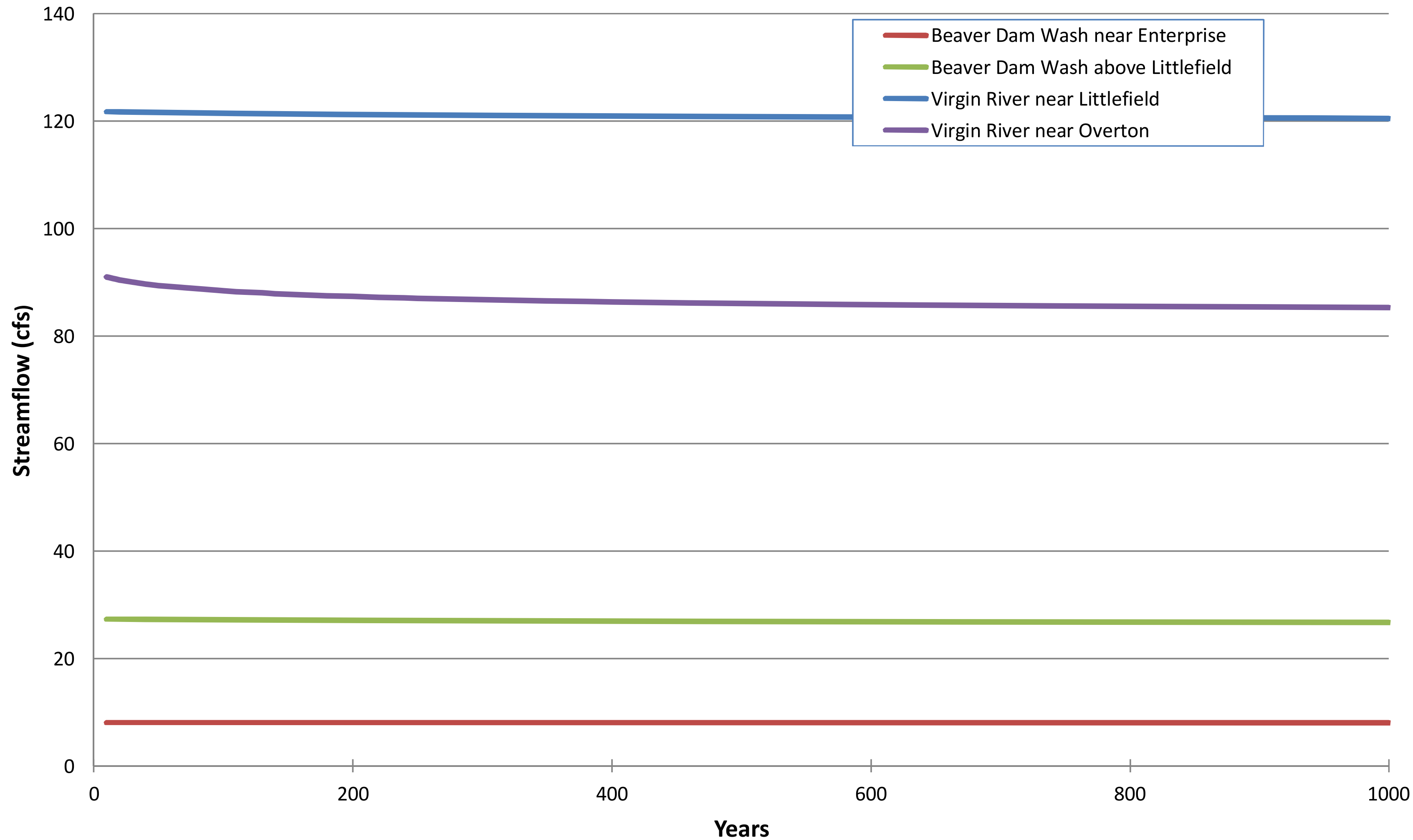
Simulated combined discharge from Rogers and Blue Point Springs, Scenario 1

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.1-2c

SE ROA 12424



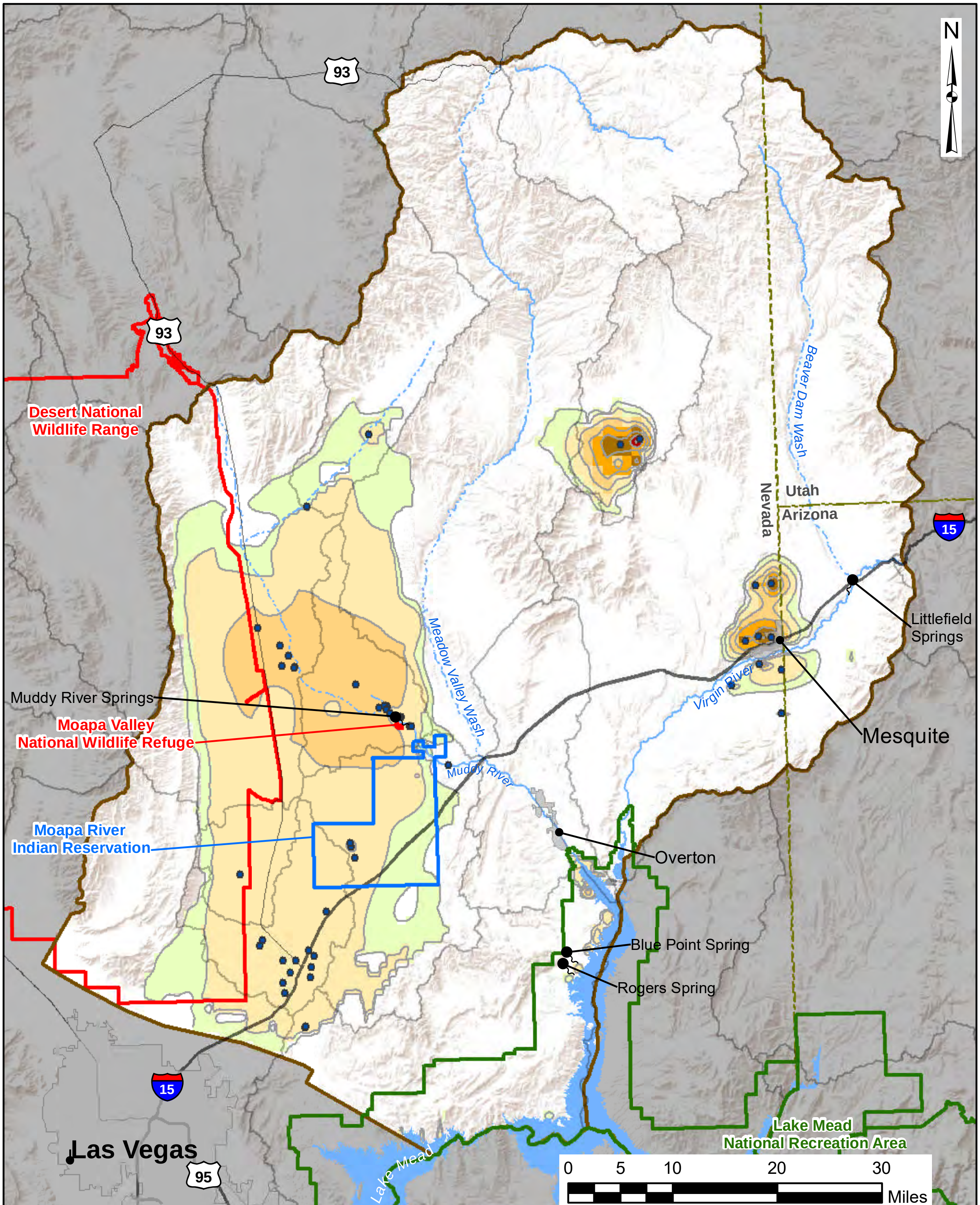
Simulated streamflow in Beaver Dam Wash and the Virgin River, Scenario 1

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.1-2d

SE ROA 12426



Legend

< 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 500
10 - 20	> 500

Pumping Well Location

Active Model Domain

State Boundary

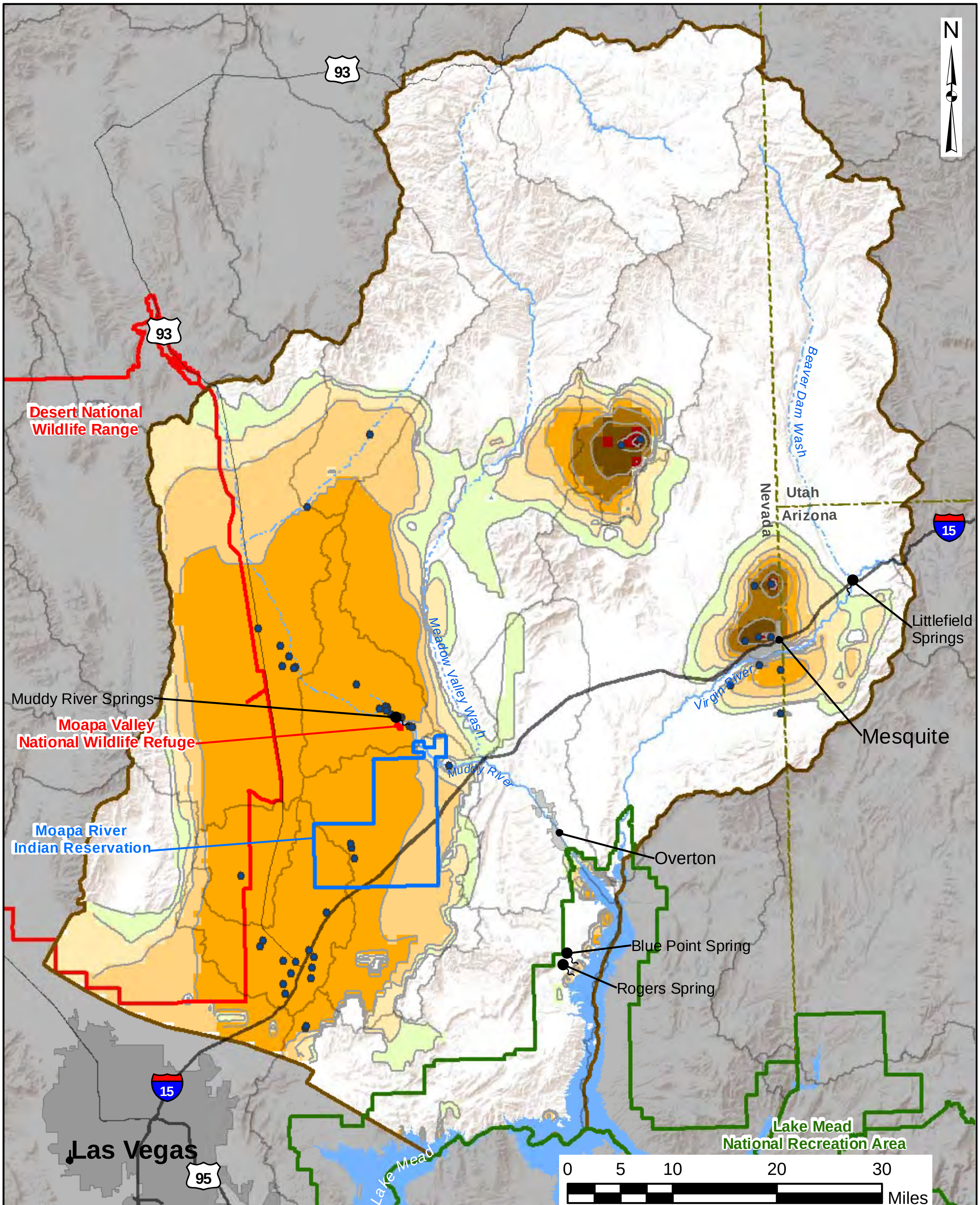
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 2
10 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE **3.2-1a**



Legend

- < 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500
- Pumping Well Location
- Active Model Domain
- State Boundary

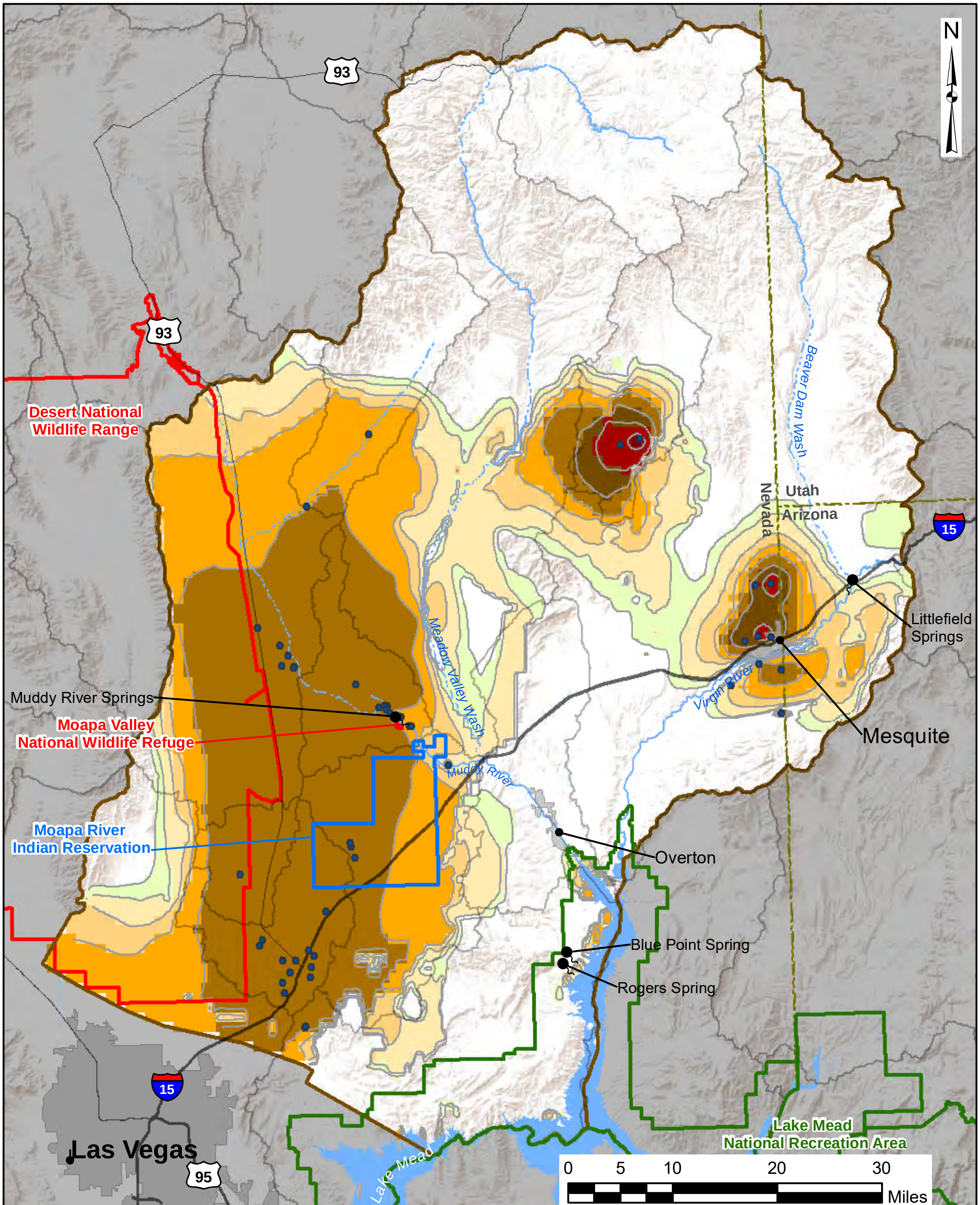
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 2 50 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.2-1b**



Legend

< 1	20 - 50	Pumping Well Location
1 - 2	50 - 100	Active Model Domain
2 - 5	100 - 200	
5 - 10	200 - 500	
10 - 20	> 500	State Boundary

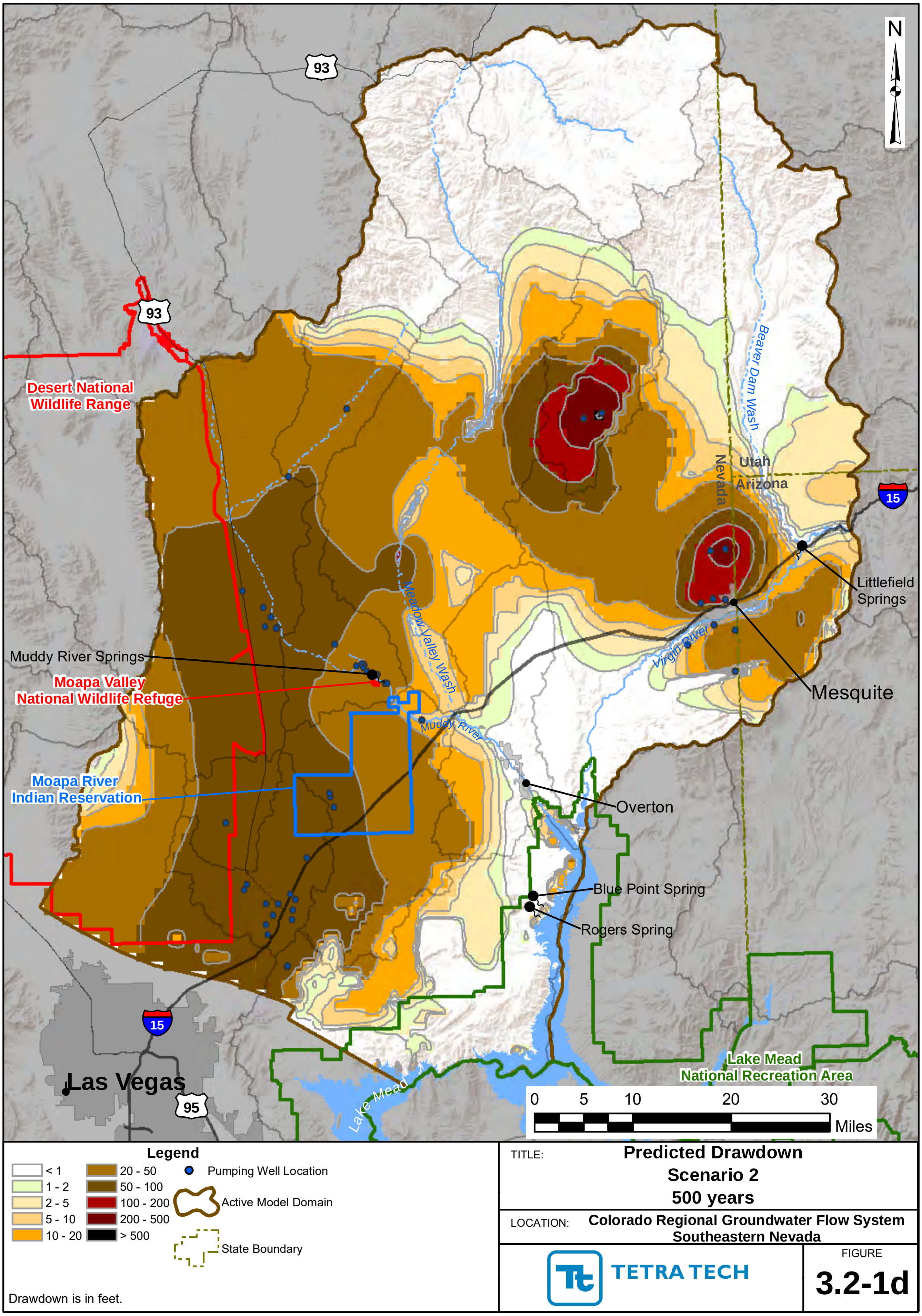
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 2
100 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.2-1c

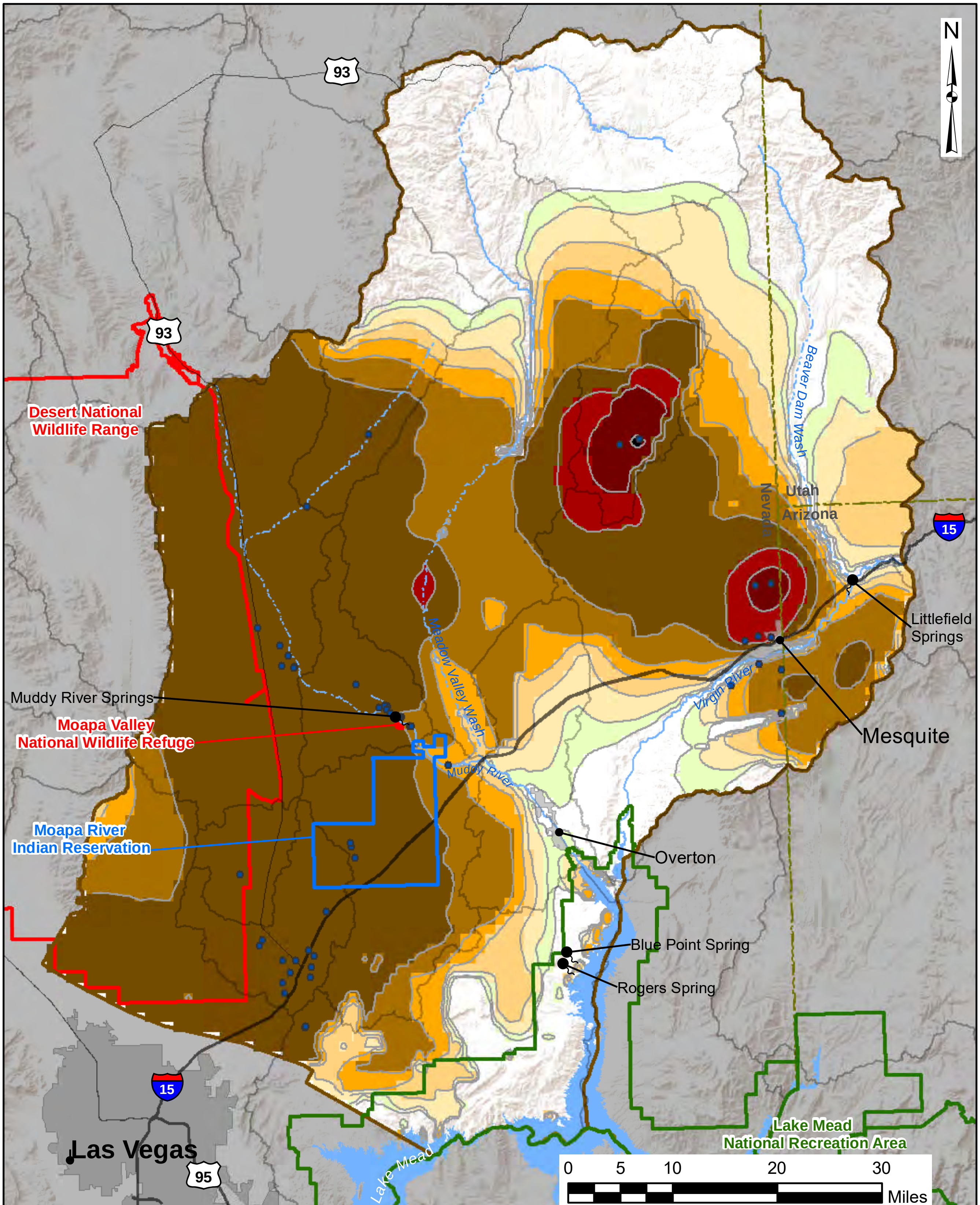


TITLE: **Predicted Drawdown Scenario 2 500 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.2-1d**



Legend

- < 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500
- Pumping Well Location
- Active Model Domain
- State Boundary

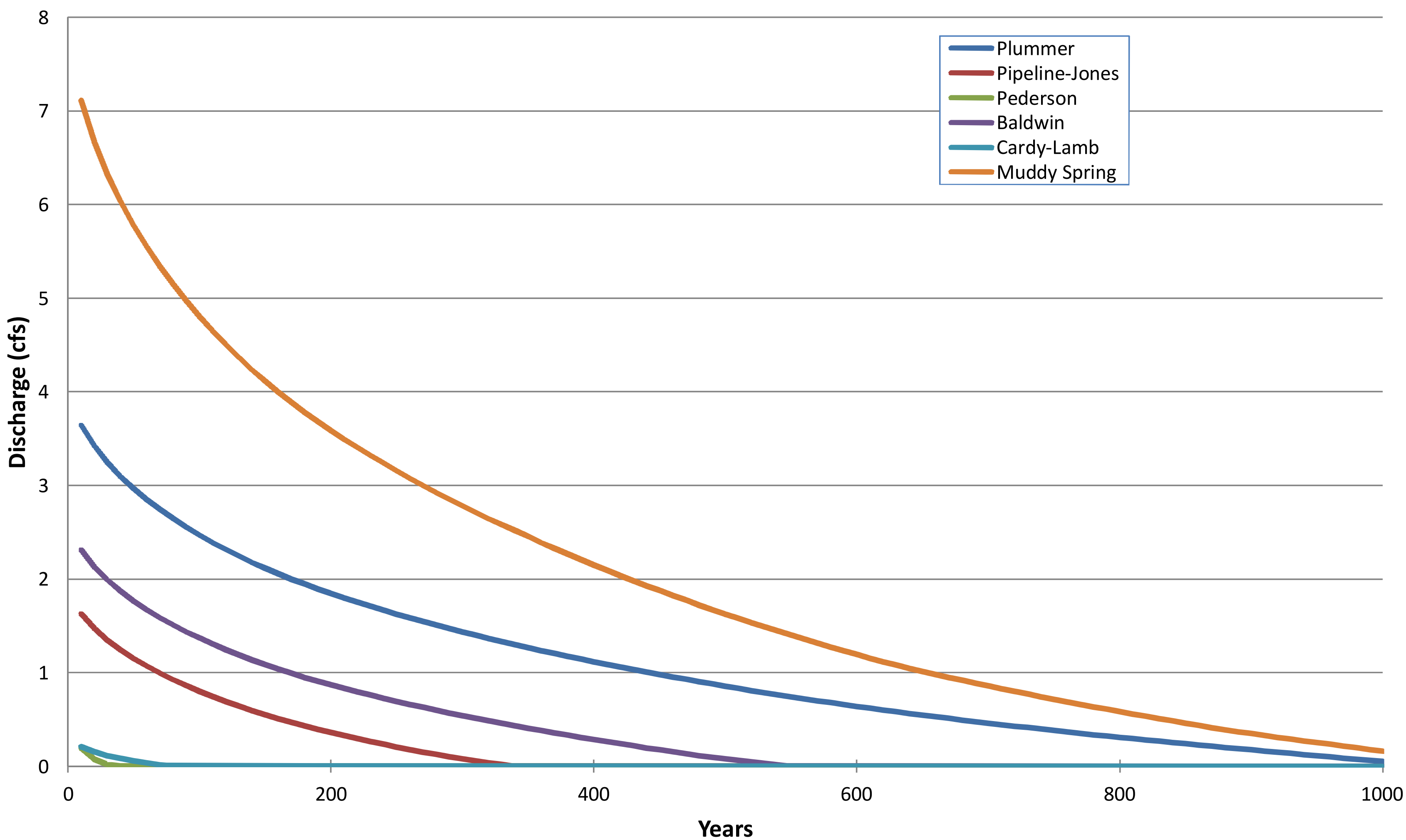
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 2 1000 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.2-1e**

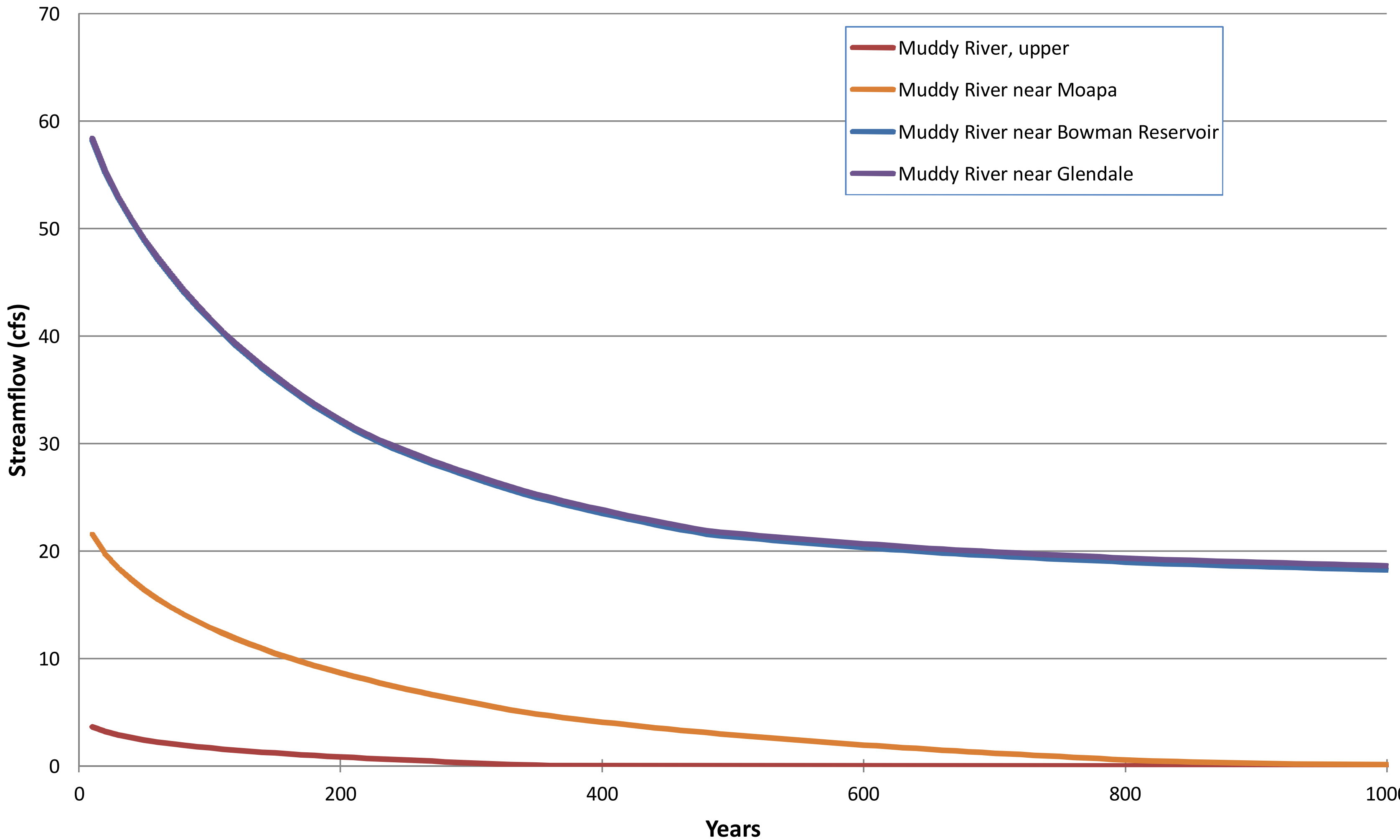


Simulated spring discharges in the Muddy River Springs area, Scenario 2

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.2-2a

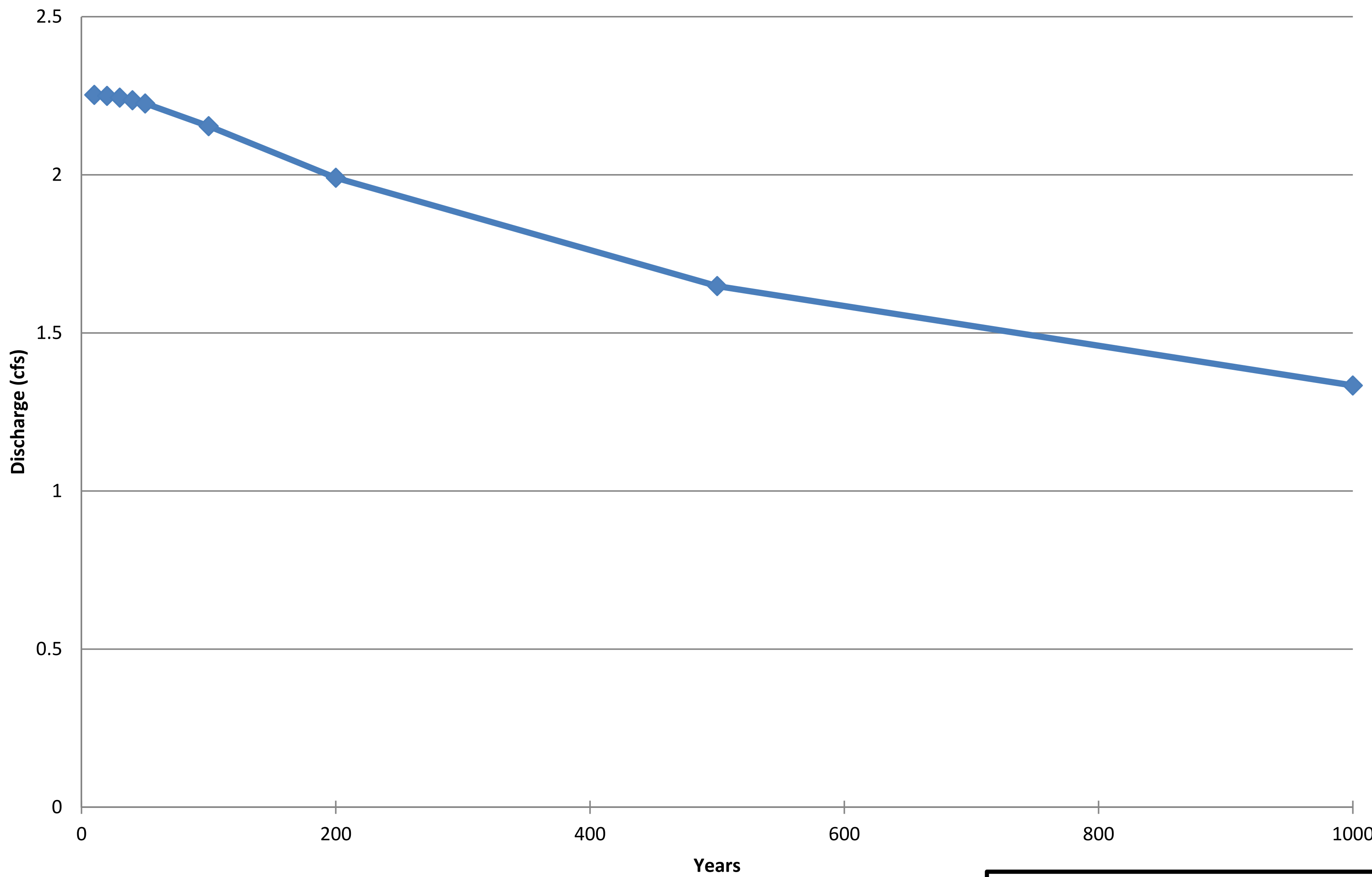


Simulated streamflow in the Muddy River, Scenario 2

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.2-2b

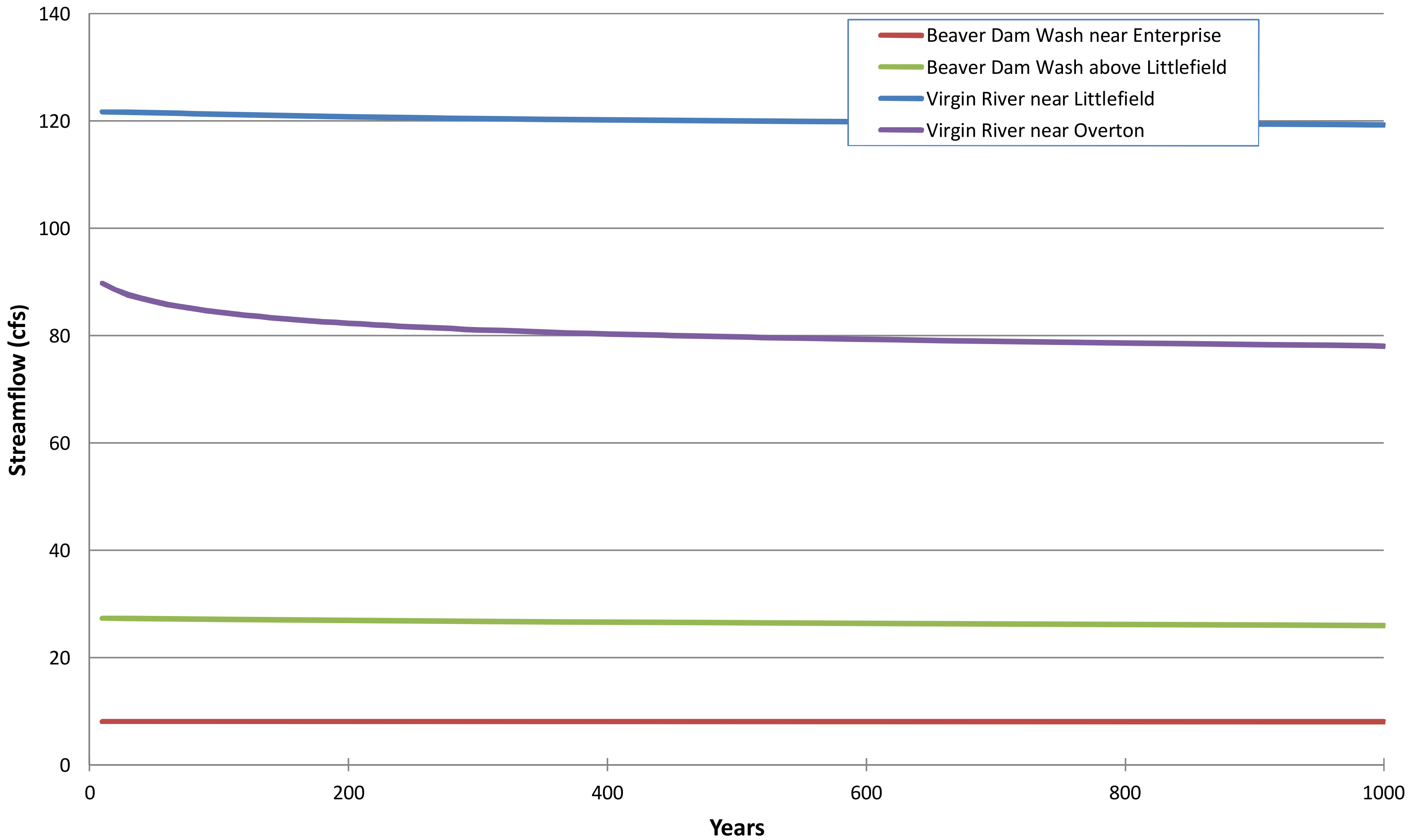


Simulated combined discharge from Rogers and Blue Point Springs, Scenario 2

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.2-2c



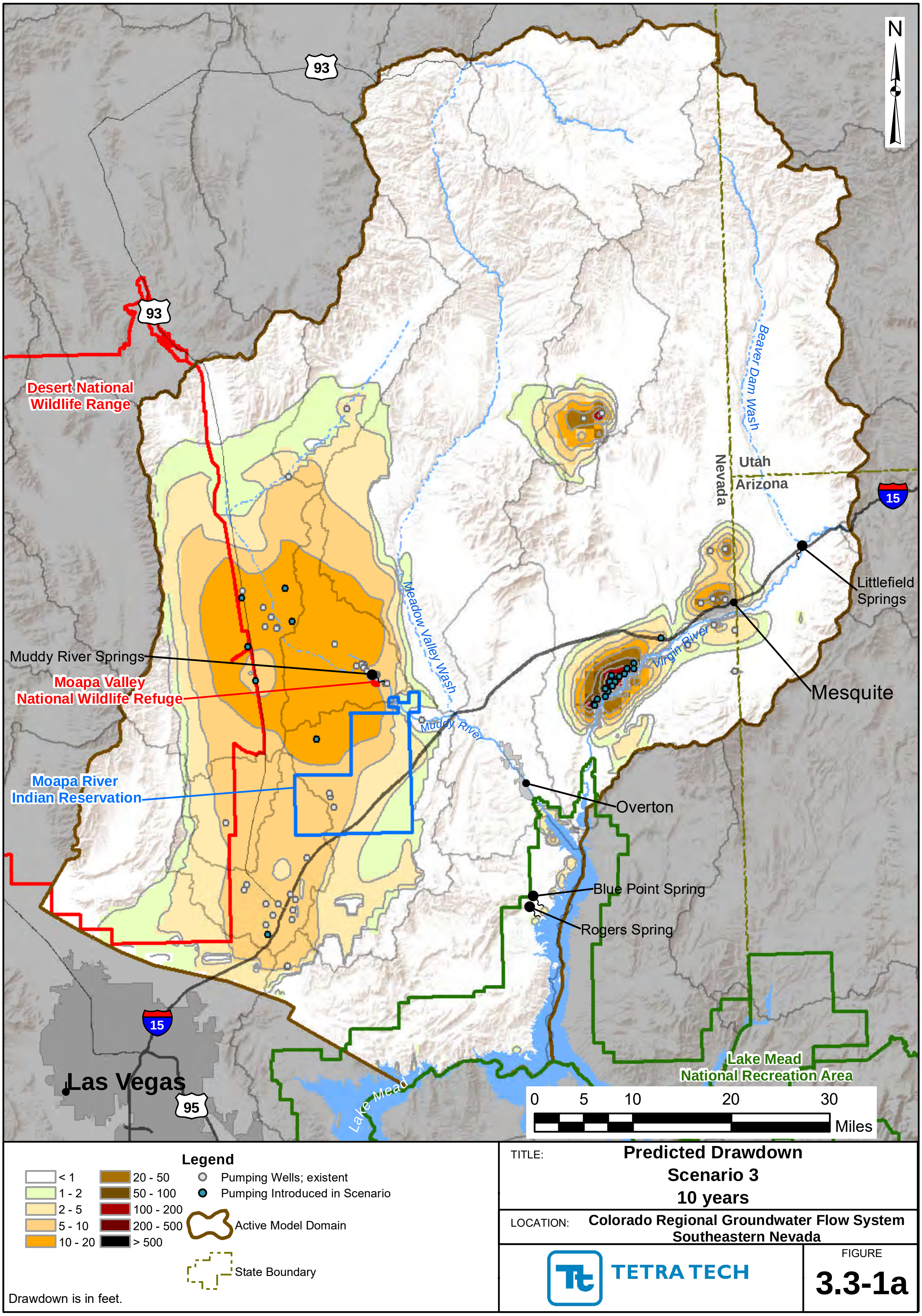
Simulated streamflow in Beaver Dam Wash and the Virgin River, Scenario 2

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.2-2d

SE ROA 12436

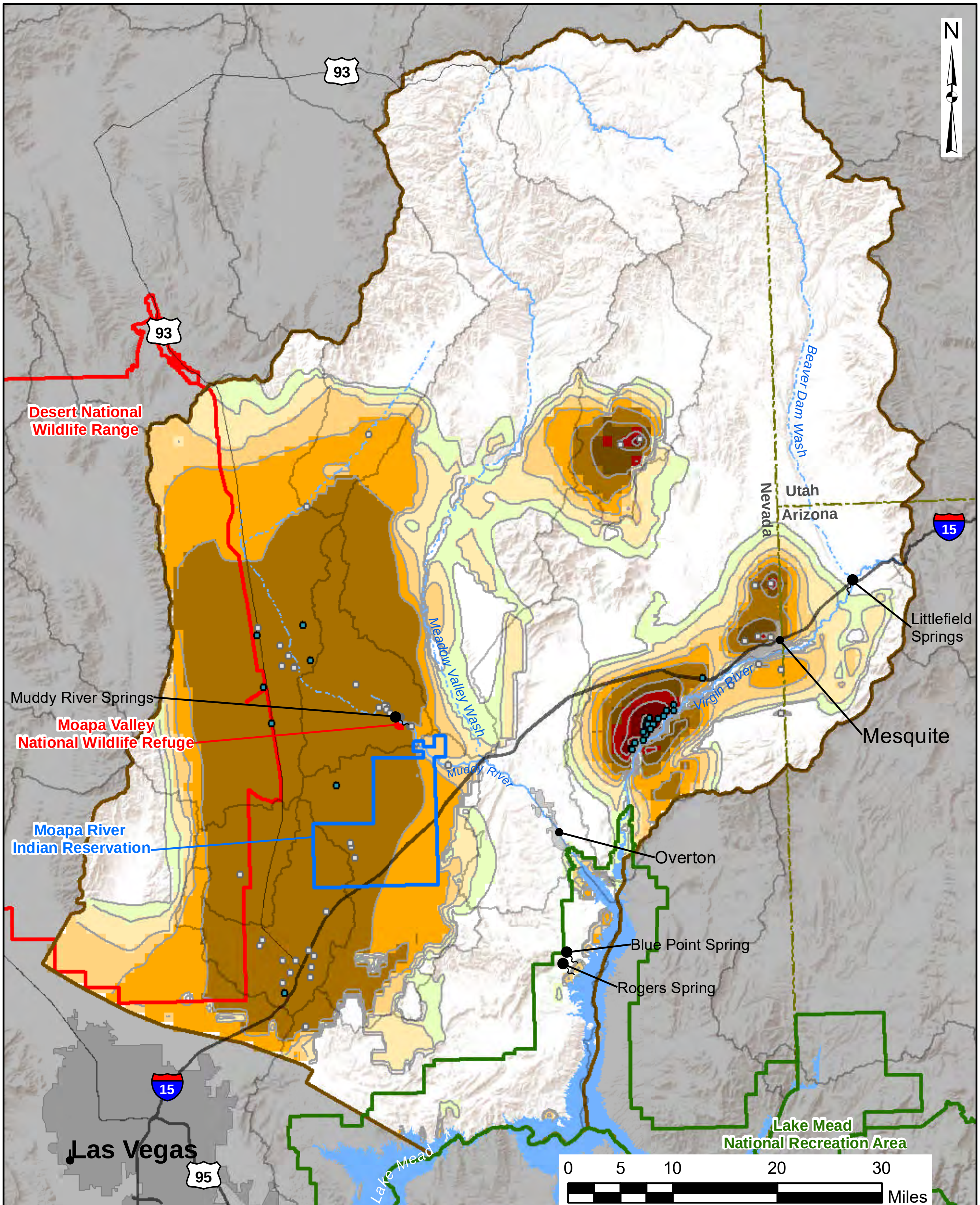


TITLE: **Predicted Drawdown**
Scenario 3
10 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE **3.3-1a**



Legend

< 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
50 - 100
100 - 200
200 - 500
> 500
Pumping Wells; existent
Pumping Introduced in Scenario
Active Model Domain
State Boundary

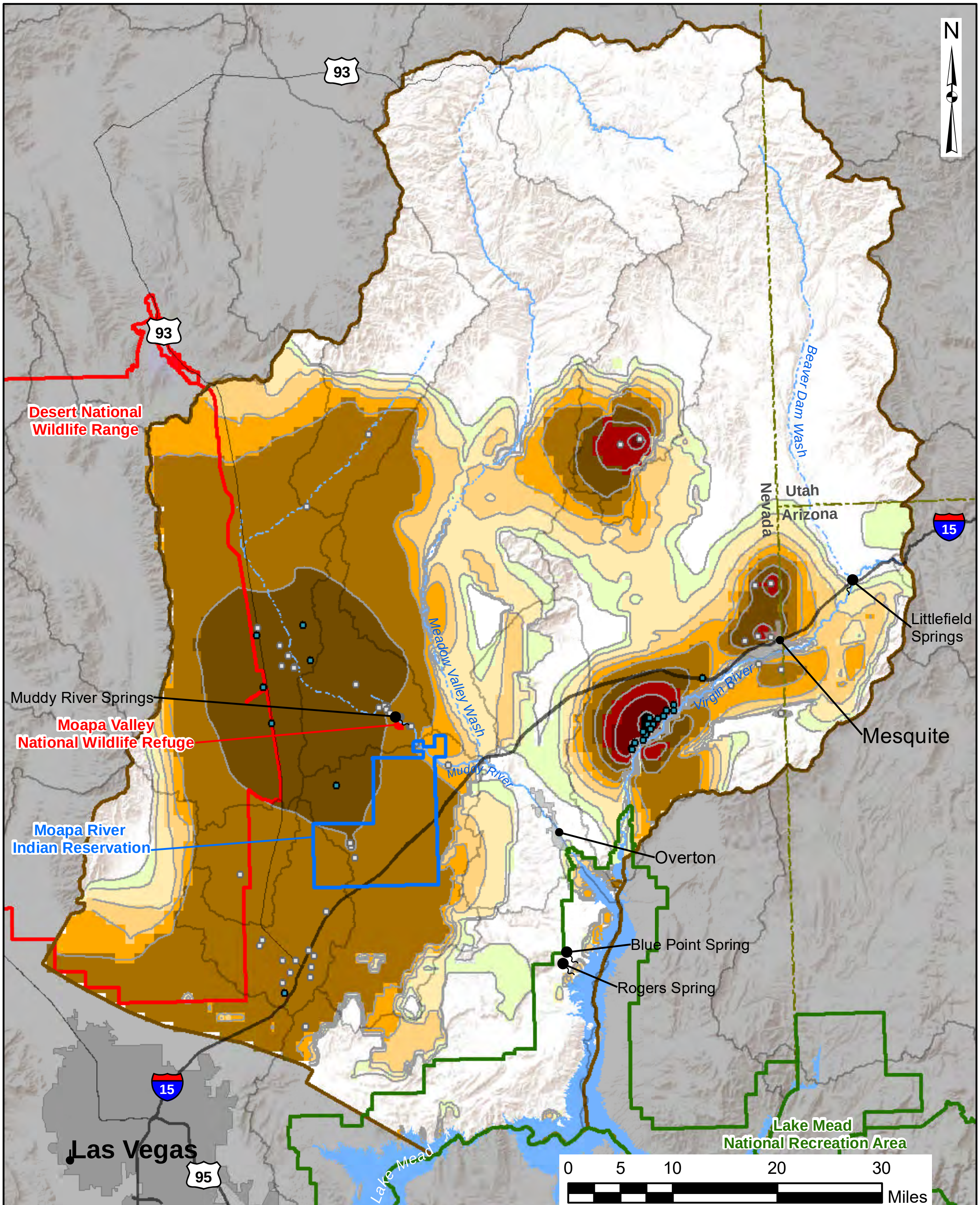
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 3 50 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.3-1b**



Legend

< 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
50 - 100
100 - 200
200 - 500
> 500
Pumping Wells; existent
Pumping Introduced in Scenario
Active Model Domain
State Boundary

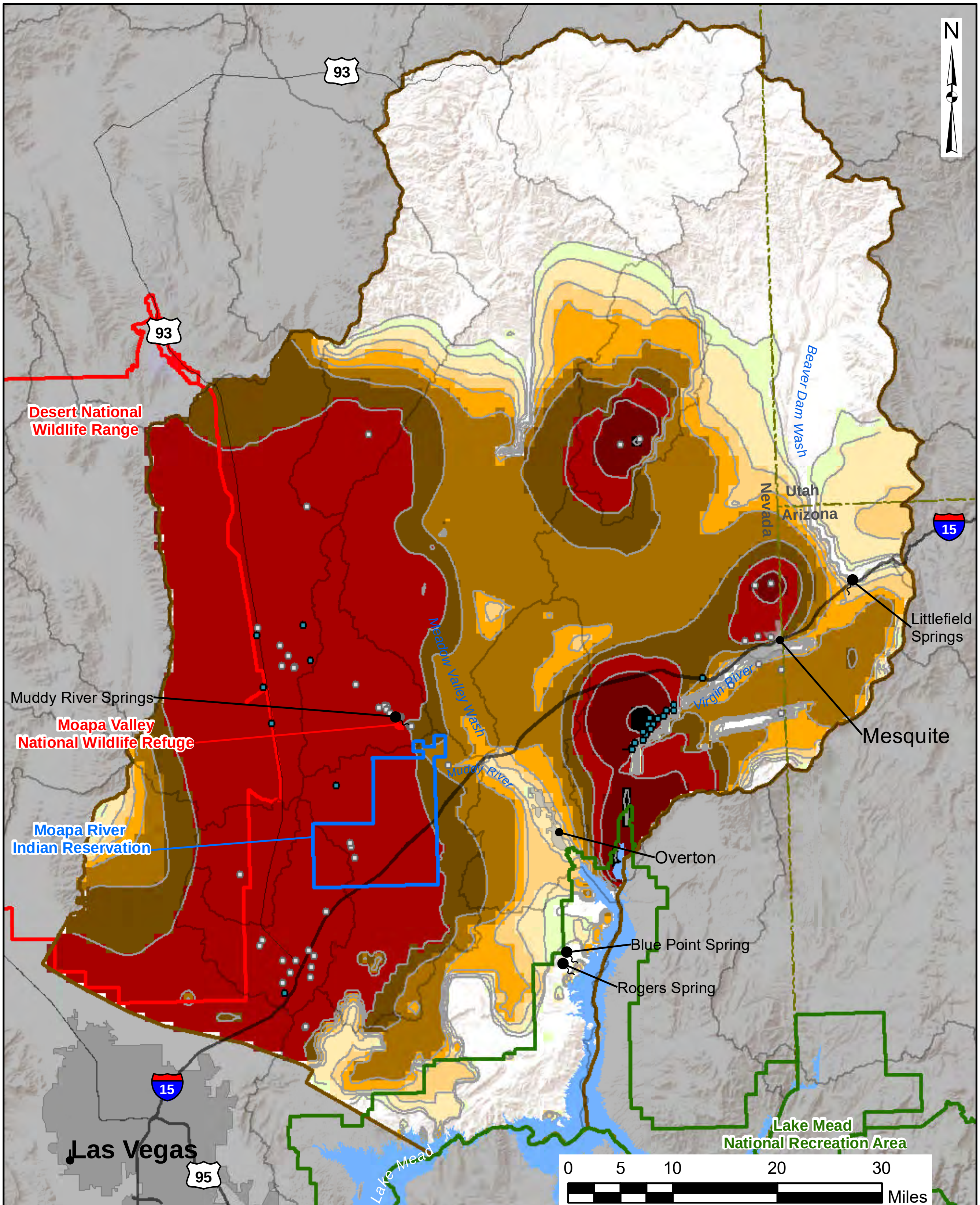
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 3
100 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.3-1c



Legend

< 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 500
10 - 20	> 500

Pumping Wells; existent

Pumping Introduced in Scenario

Active Model Domain

State Boundary

Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 3 500 years**

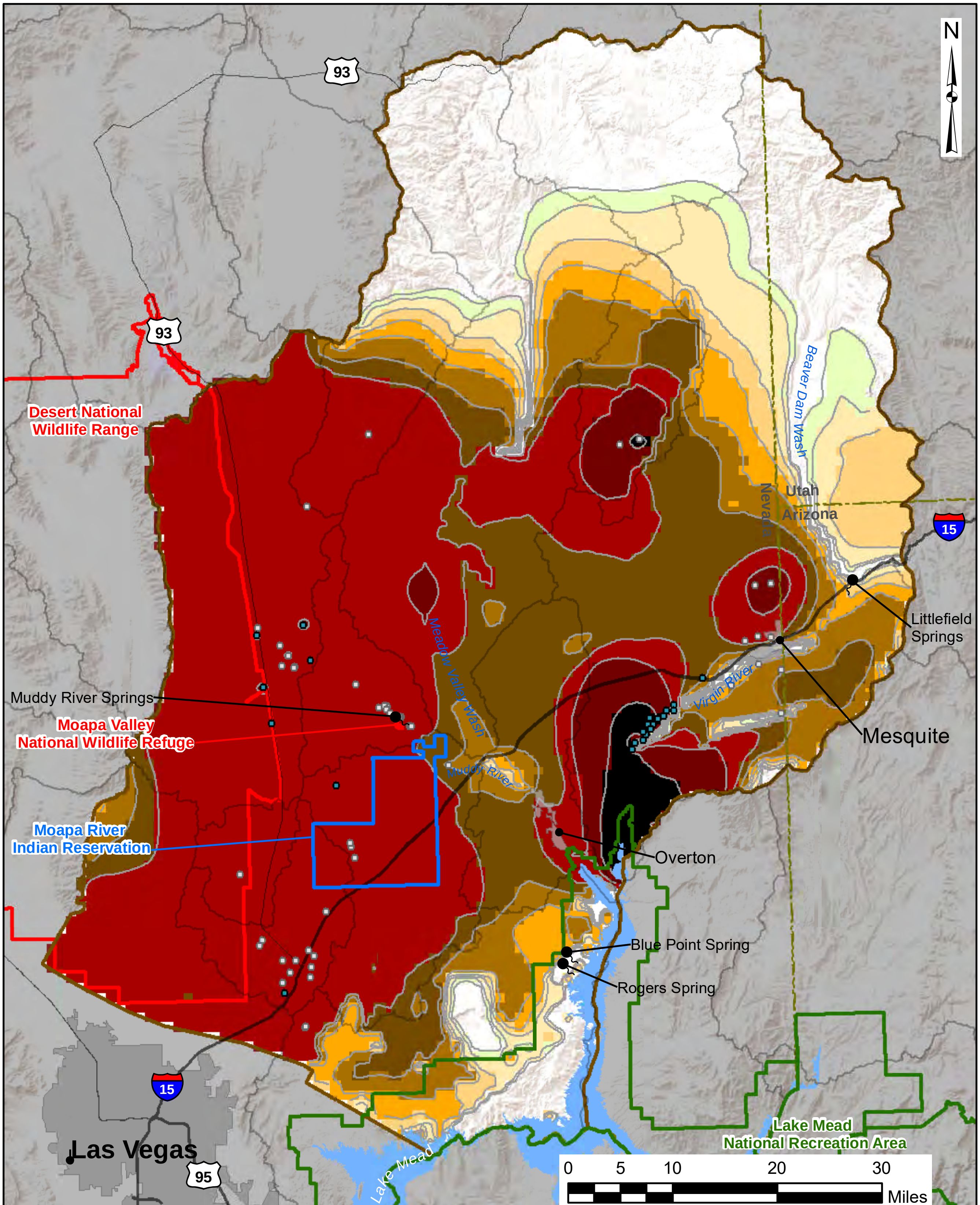
LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.3-1d**

SE ROA 12440

JA_5202



Legend

< 1	20 - 50	Pumping Wells; existent
1 - 2	50 - 100	Pumping Introduced in Scenario
2 - 5	100 - 200	
5 - 10	200 - 500	Active Model Domain
10 - 20	> 500	
		State Boundary

Drawdown is in feet.

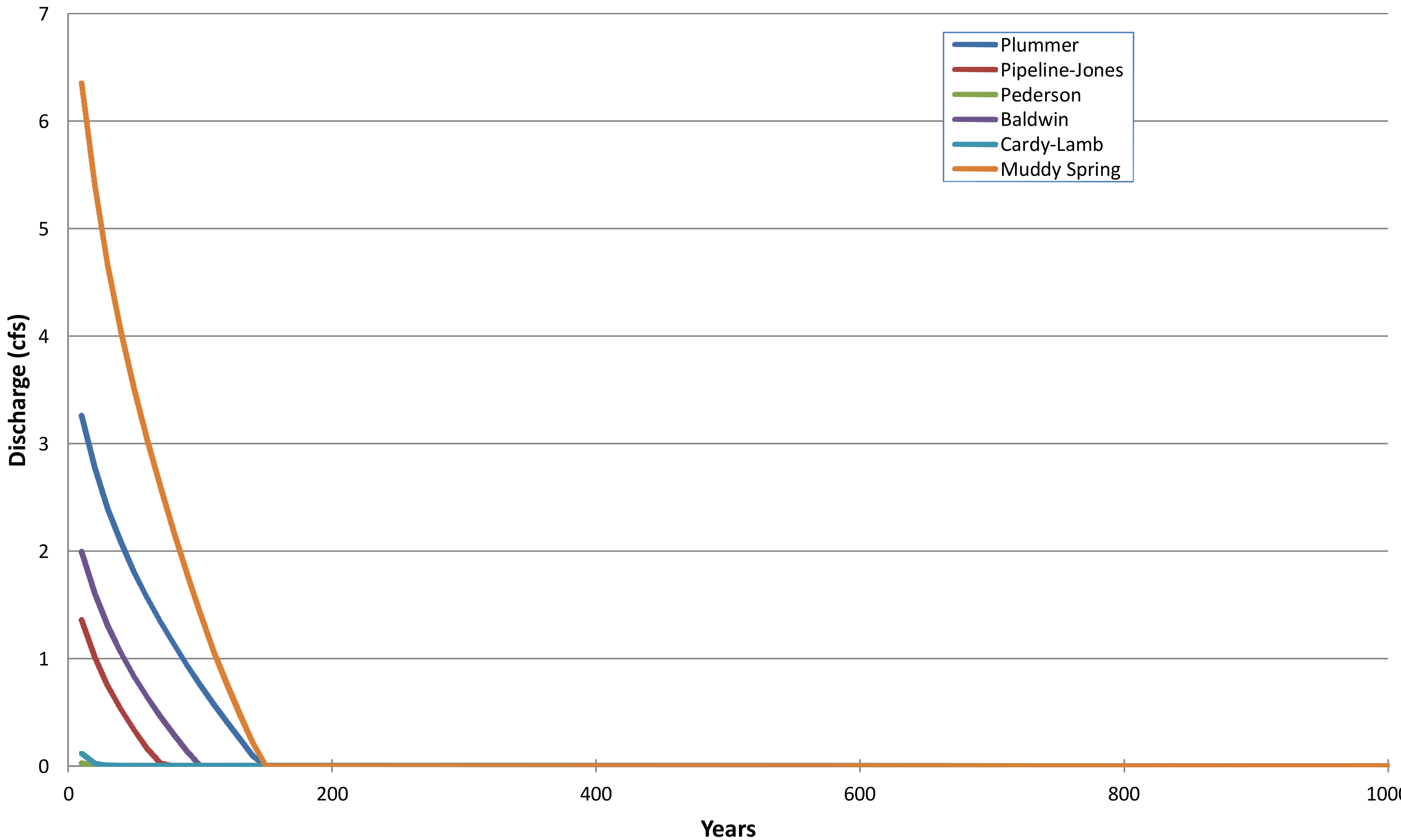
TITLE: **Predicted Drawdown Scenario 3 1000 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.3-1e**

SE ROA 12441

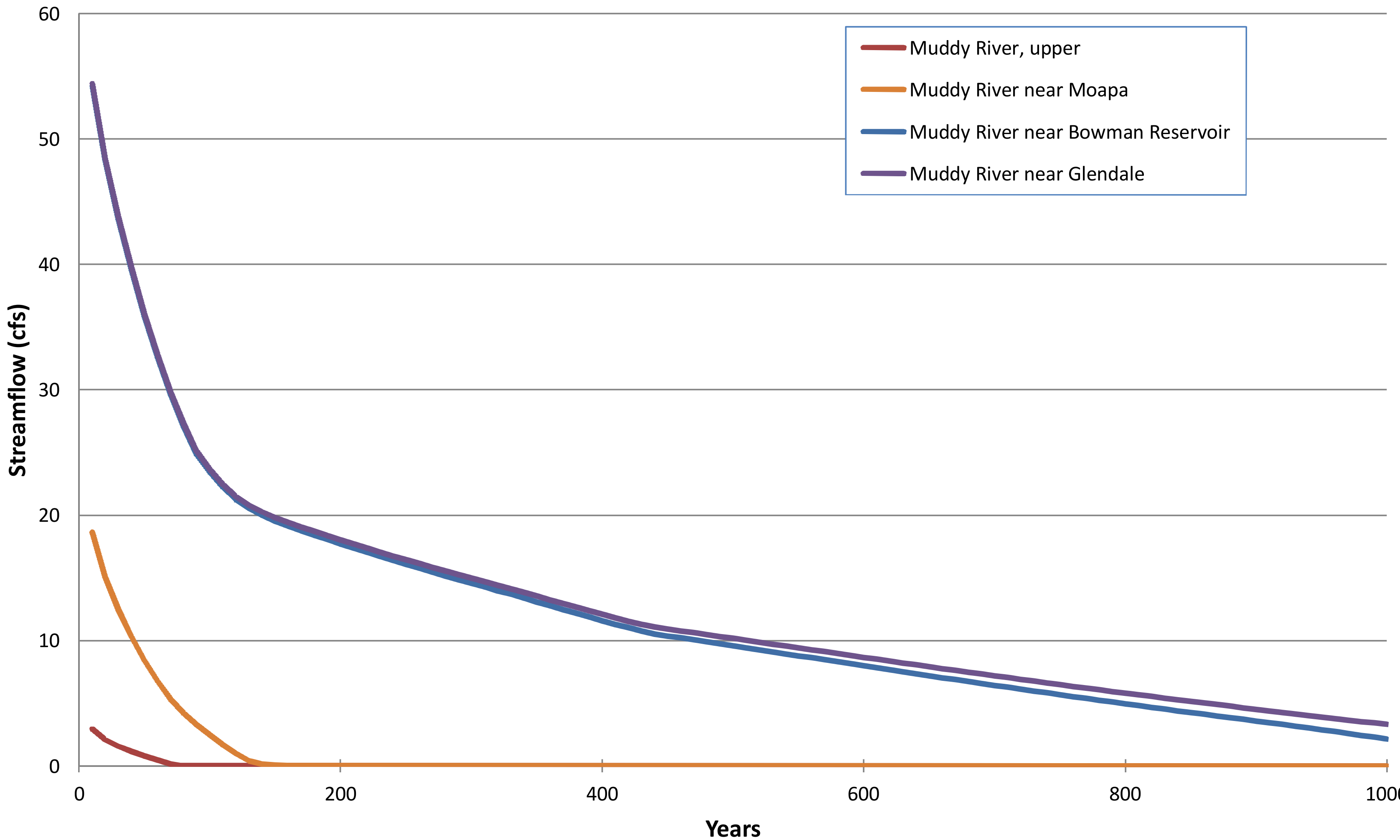


Simulated spring discharges in the Muddy River Springs area, Scenario 3

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.3-2a

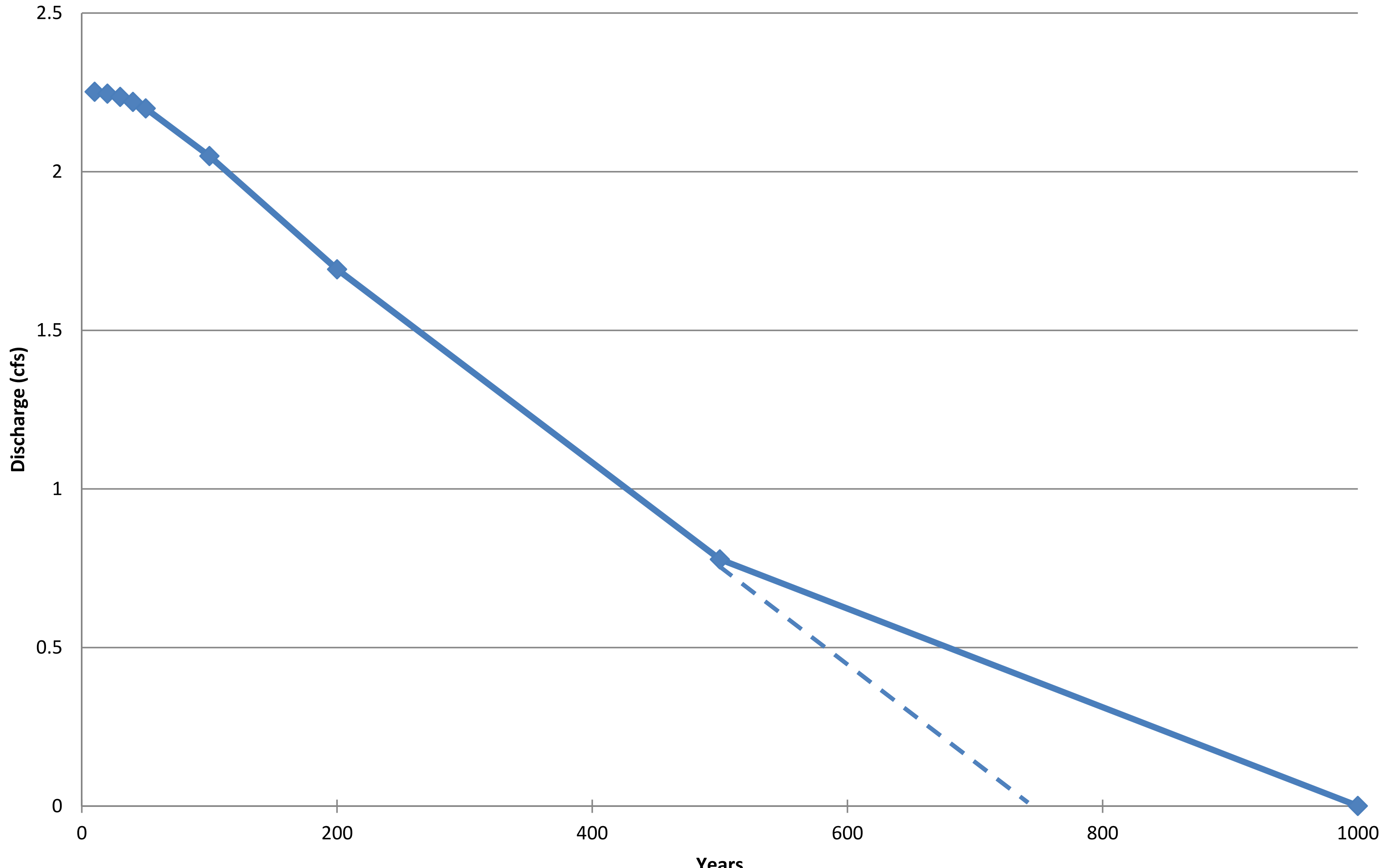


Simulated streamflow in the Muddy River, Scenario 3

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.3-2b

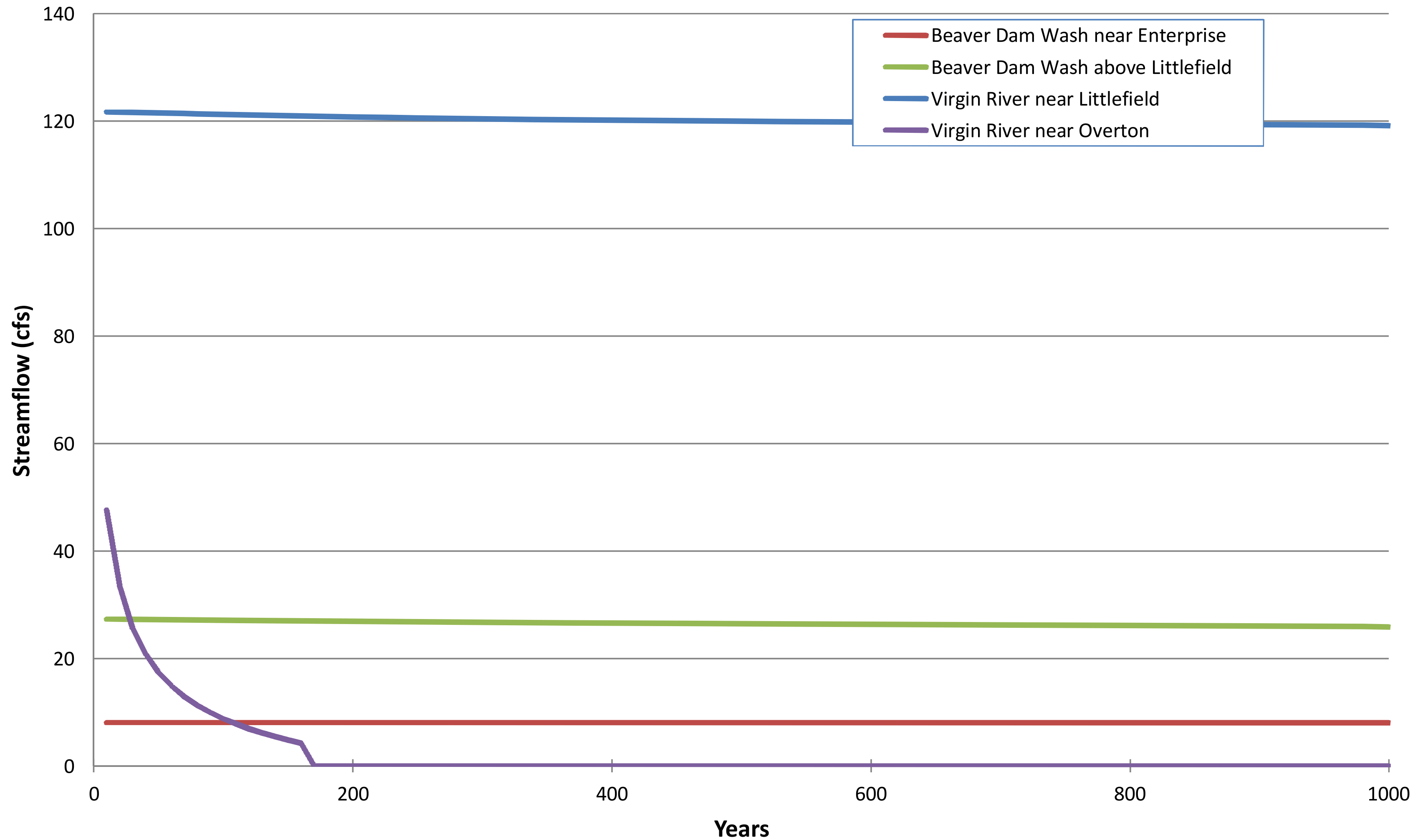


Simulated combined discharge from Rogers and Blue Point Springs, Scenario 3

Lower Colorado River Flow System

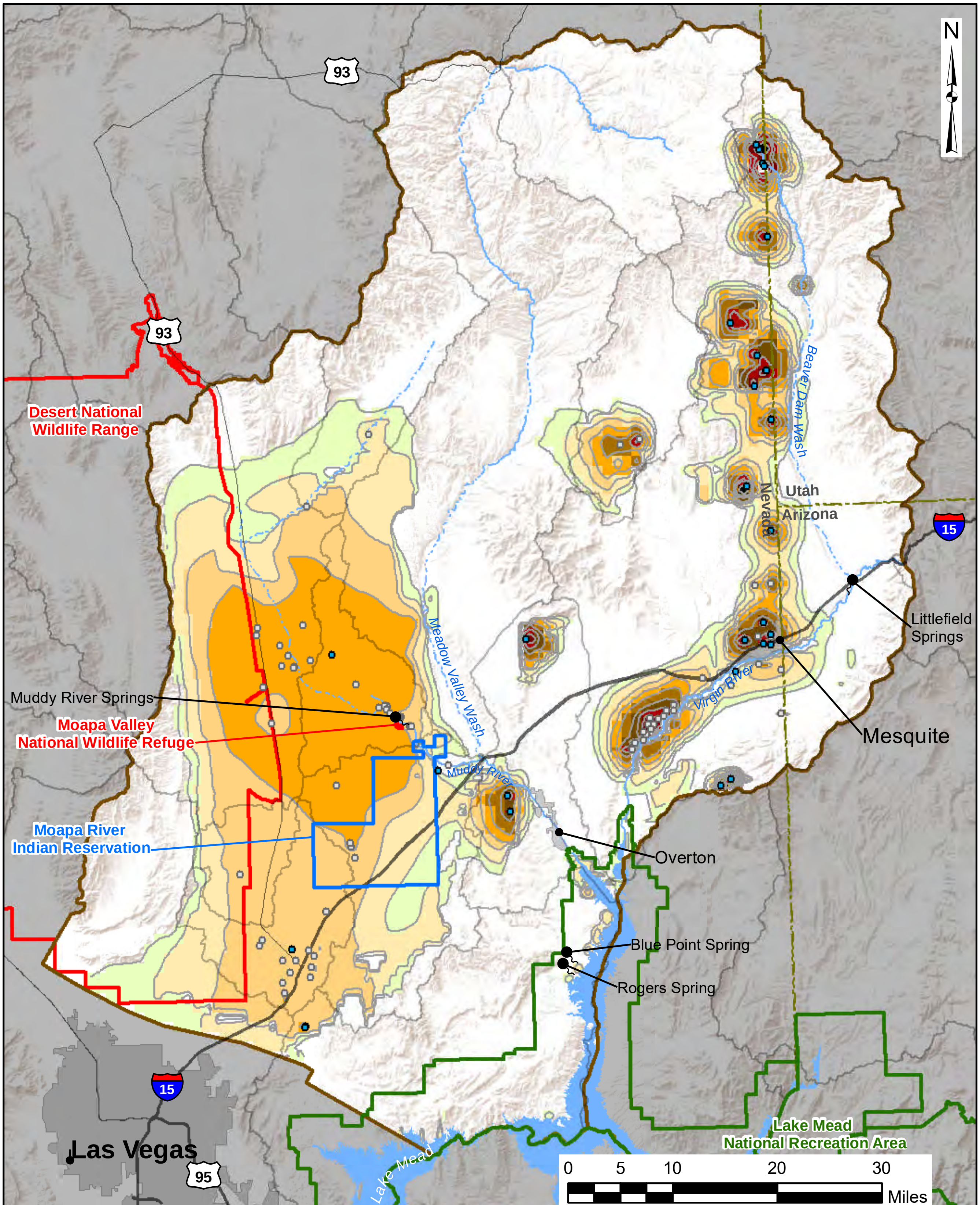
TETRA TECH GEO

Figure 3.3-2c



Simulated streamflow in Beaver Dam Wash and the Virgin River, Scenario 3	
Lower Colorado River Flow System	
TETRA TECH GEO	Figure 3.3-2d

SE ROA 12446



Legend

- < 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500
- Pumping Wells; existent
- Pumping Introduced in Scenario
- Active Model Domain
- State Boundary

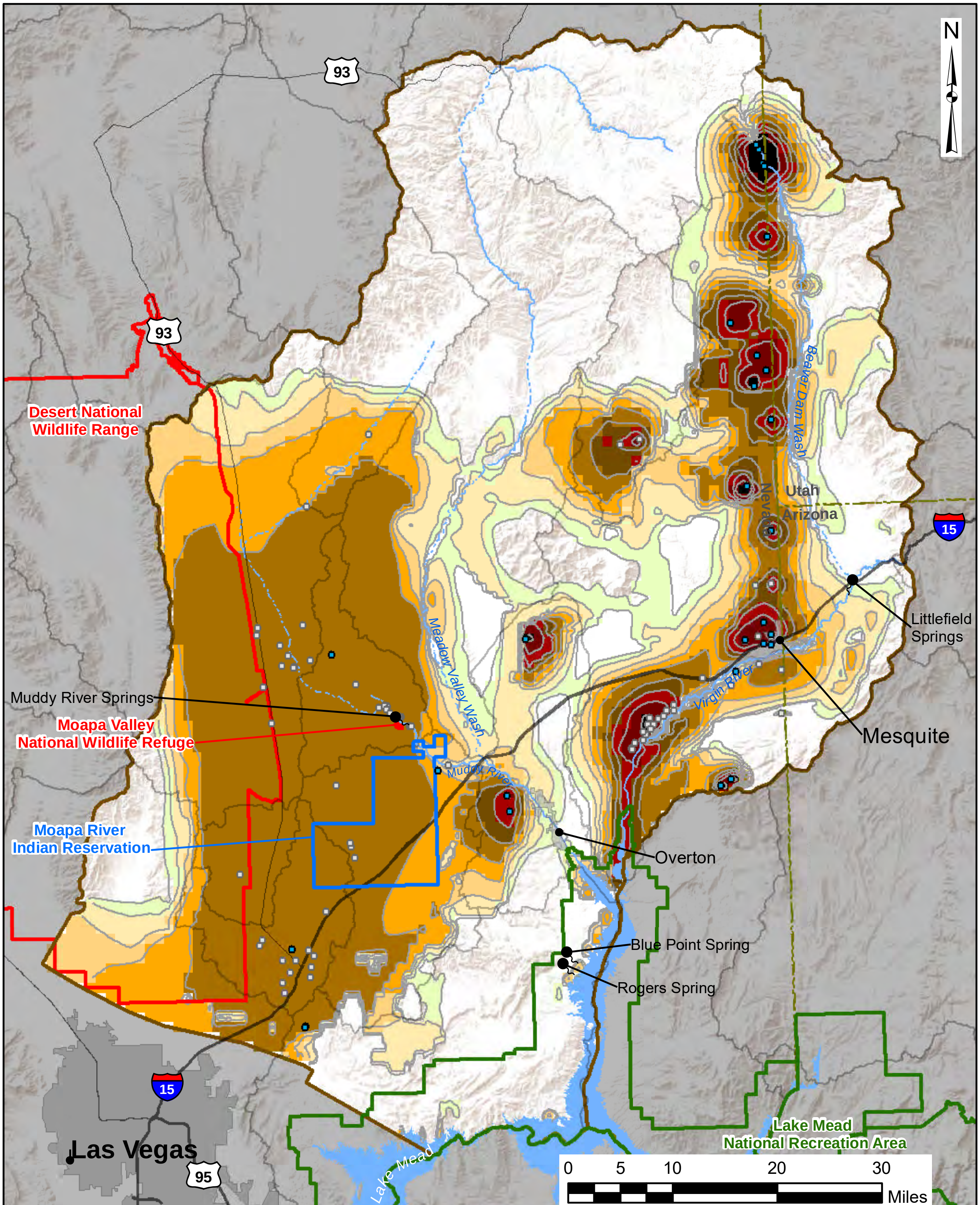
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 4
10 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.4-1a



Legend

< 1	20 - 50	Pumping Wells; existent
1 - 2	50 - 100	Pumping Introduced in Scenario
2 - 5	100 - 200	
5 - 10	200 - 500	Active Model Domain
10 - 20	> 500	
		State Boundary

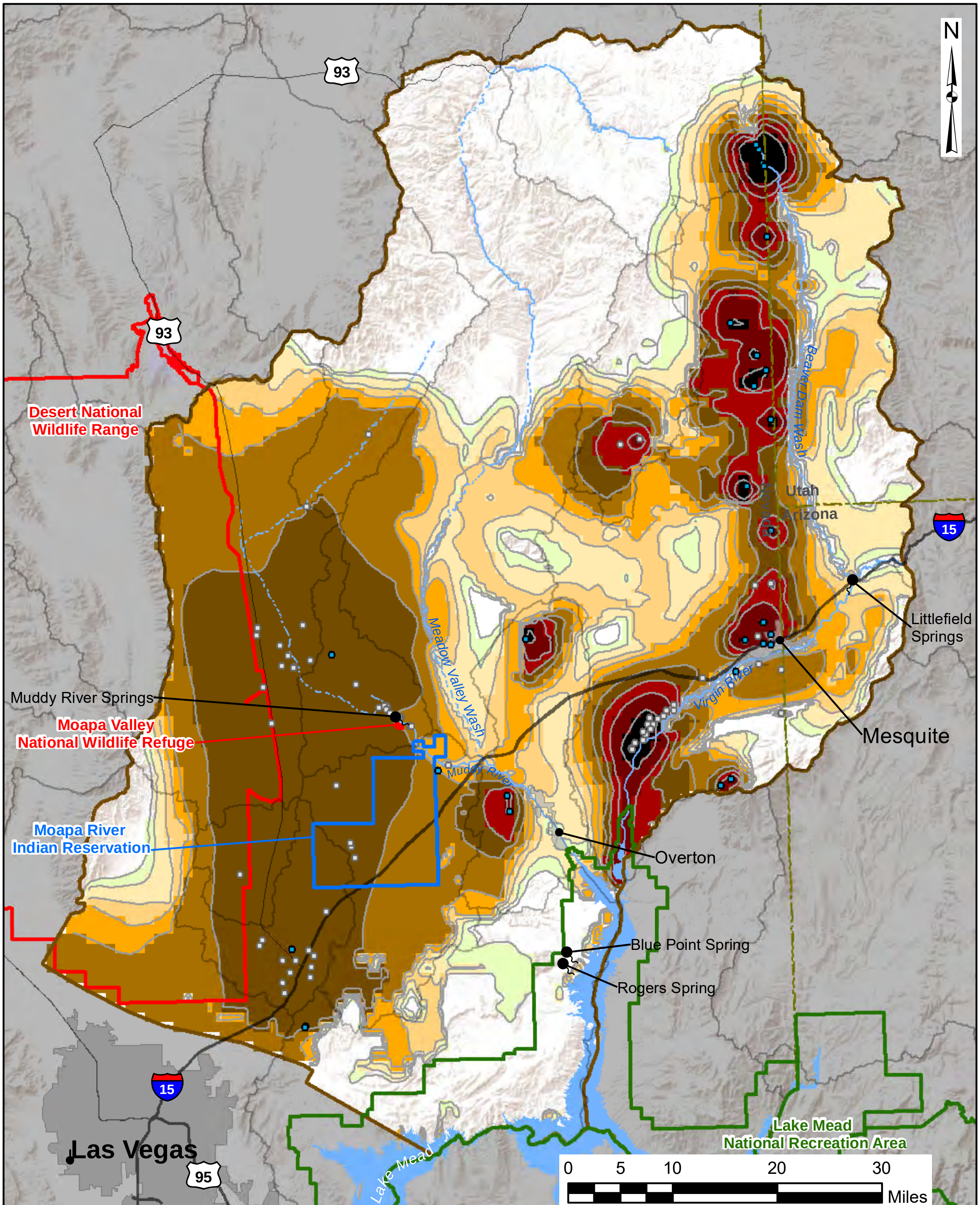
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 4
50 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.4-1b



Legend

< 1	20 - 50	Pumping Wells; existent
1 - 2	50 - 100	Pumping Introduced in Scenario
2 - 5	100 - 200	
5 - 10	200 - 500	Active Model Domain
10 - 20	> 500	
		State Boundary

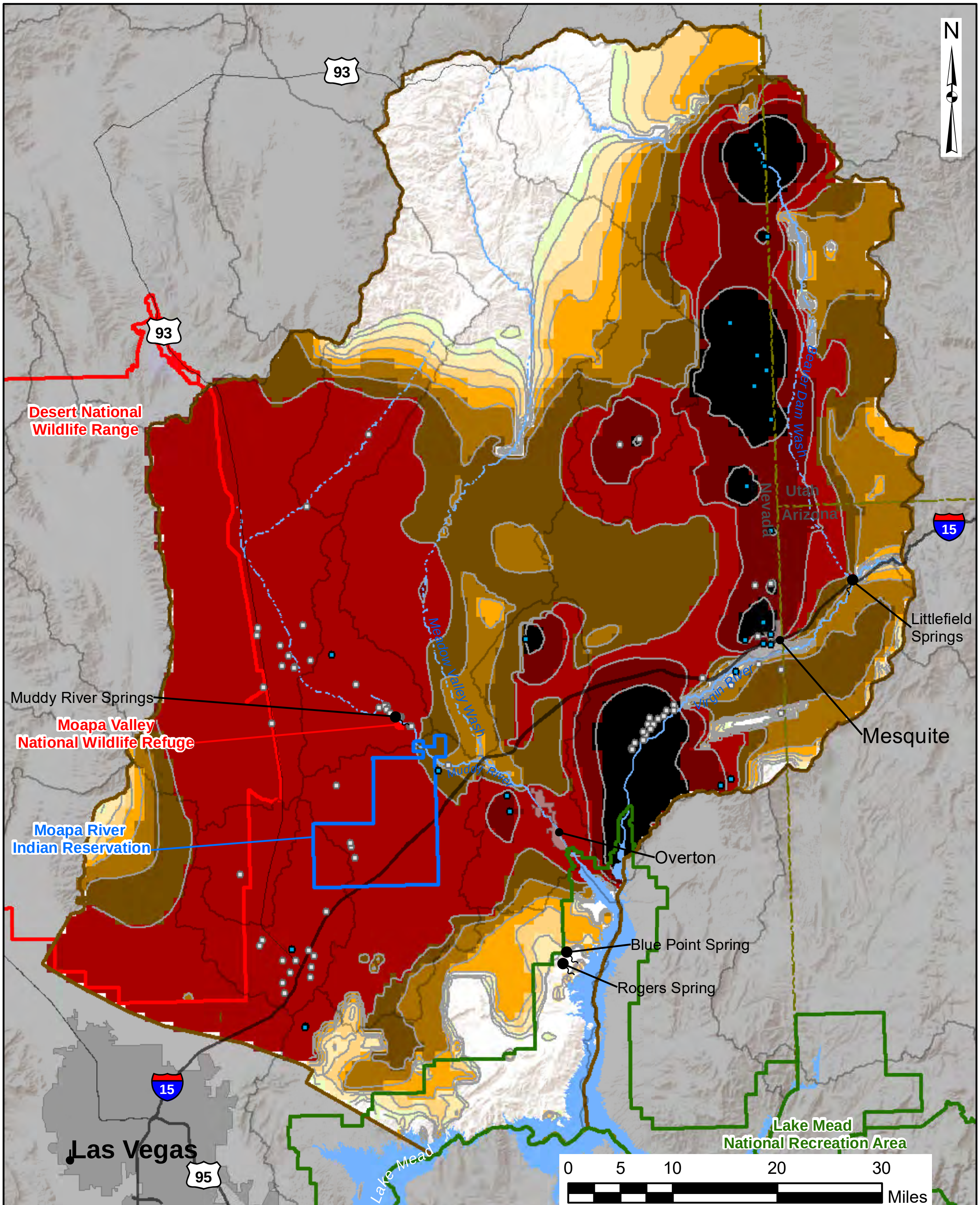
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 4
100 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE **3.4-1c**



Legend

< 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 500
10 - 20	> 500

Pumping Wells; existent

Pumping Introduced in Scenario

Active Model Domain

State Boundary

Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 4 500 years**

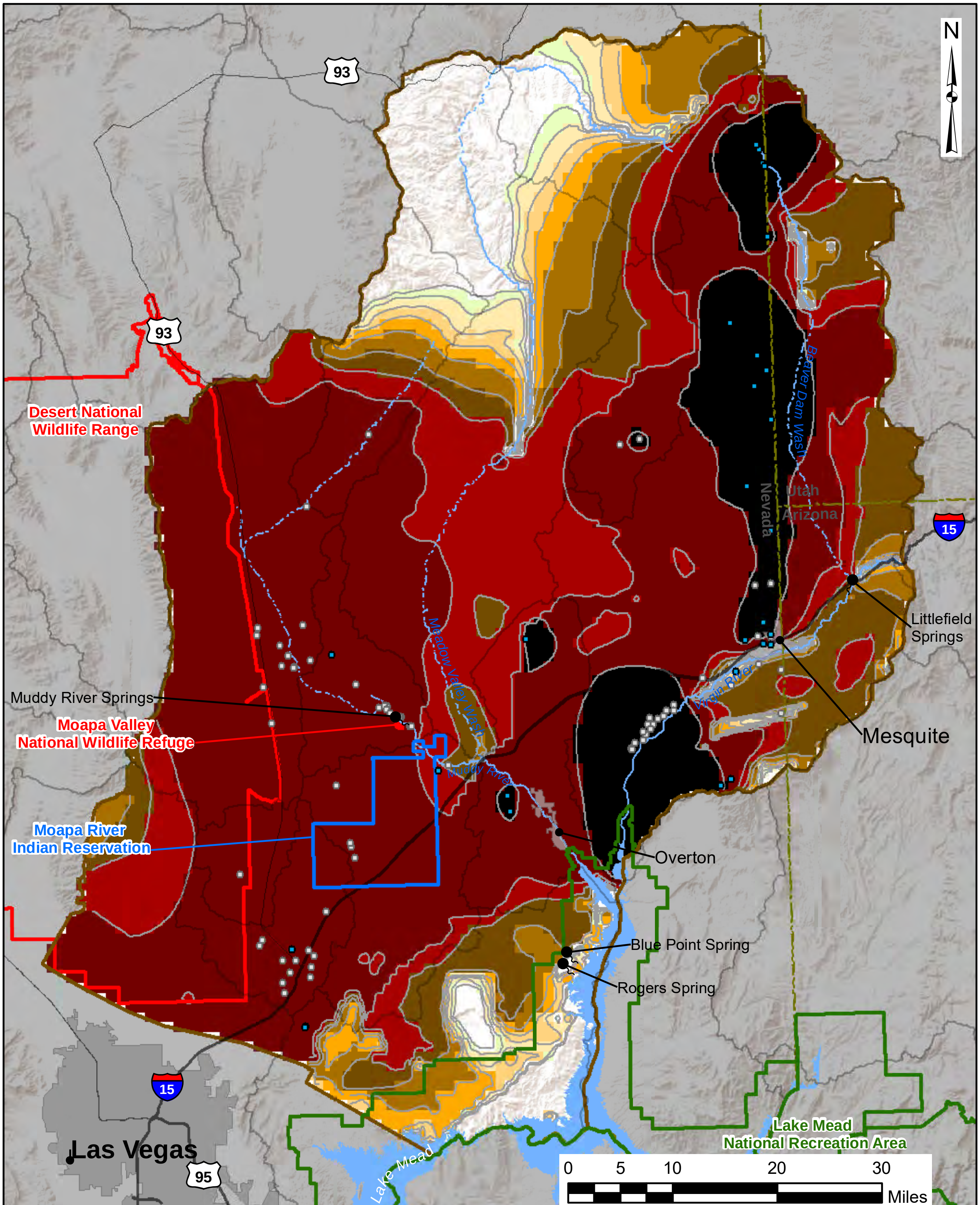
LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.4-1d**

SE ROA 12450

JA_5212



Legend

< 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 500
10 - 20	> 500

Pumping Wells; existent

Pumping Introduced in Scenario

Active Model Domain

State Boundary

Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 4 1000 years**

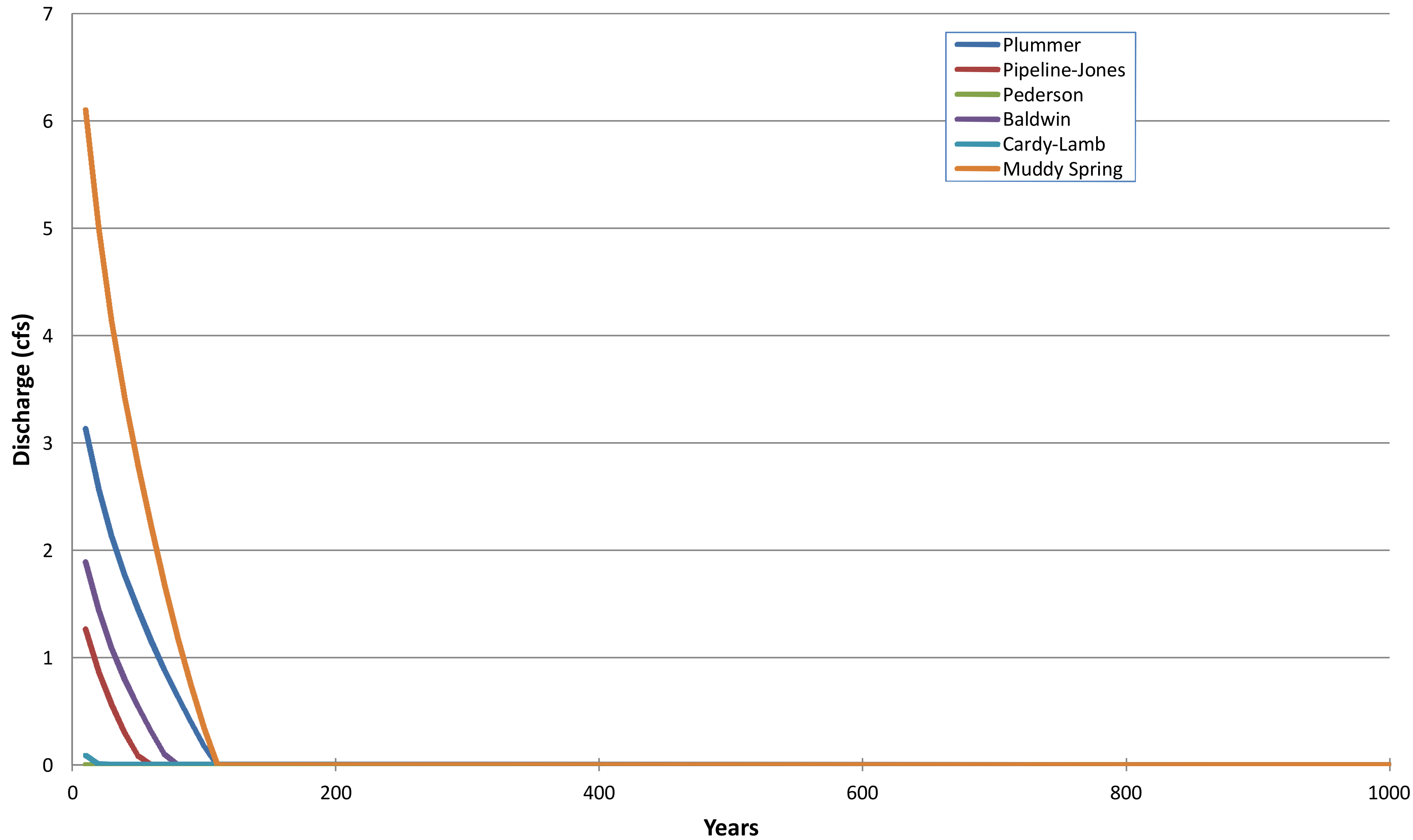
LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.4-1e**

SE ROA 12451

JA_5213

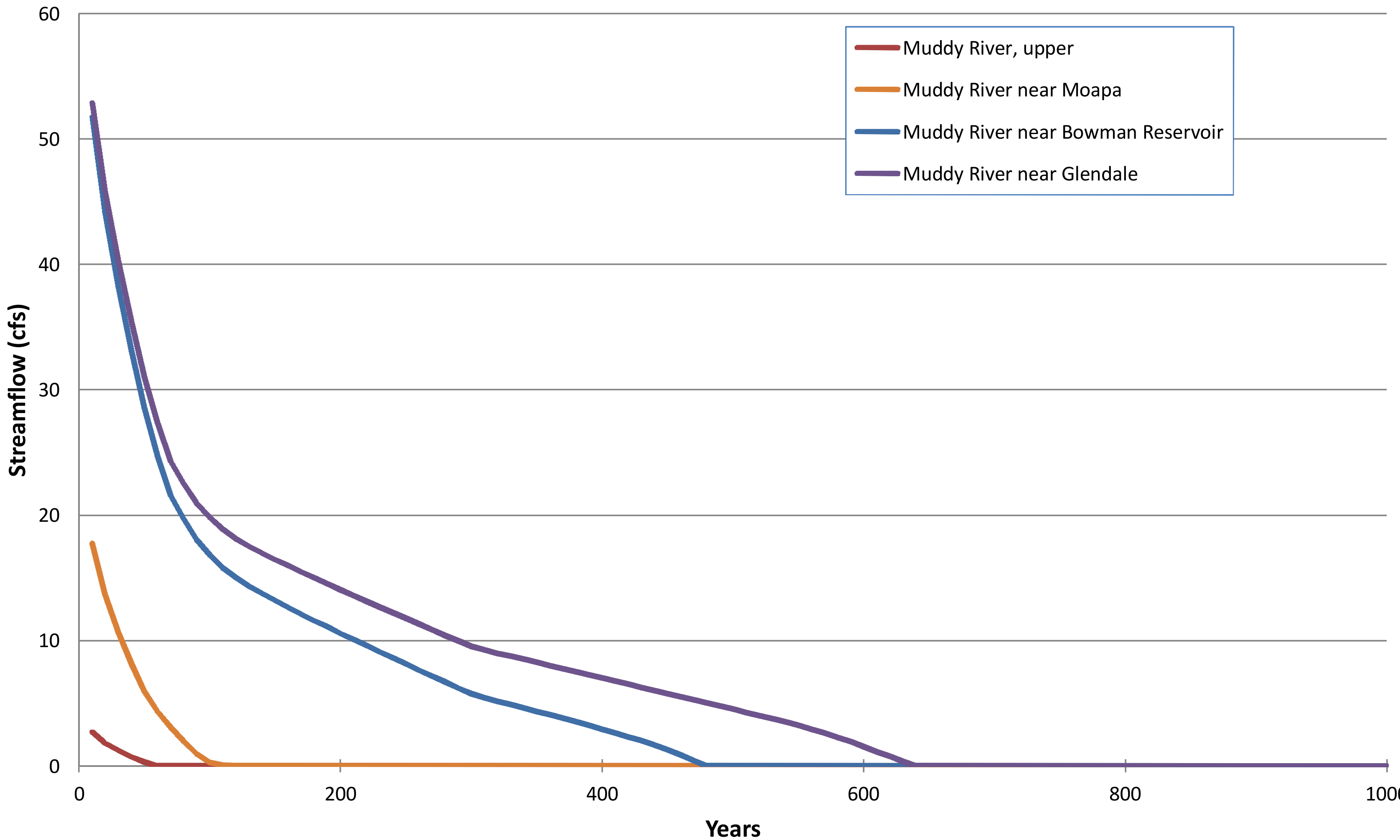


Simulated spring discharges in the Muddy River Springs area, Scenario 4

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.4-2a

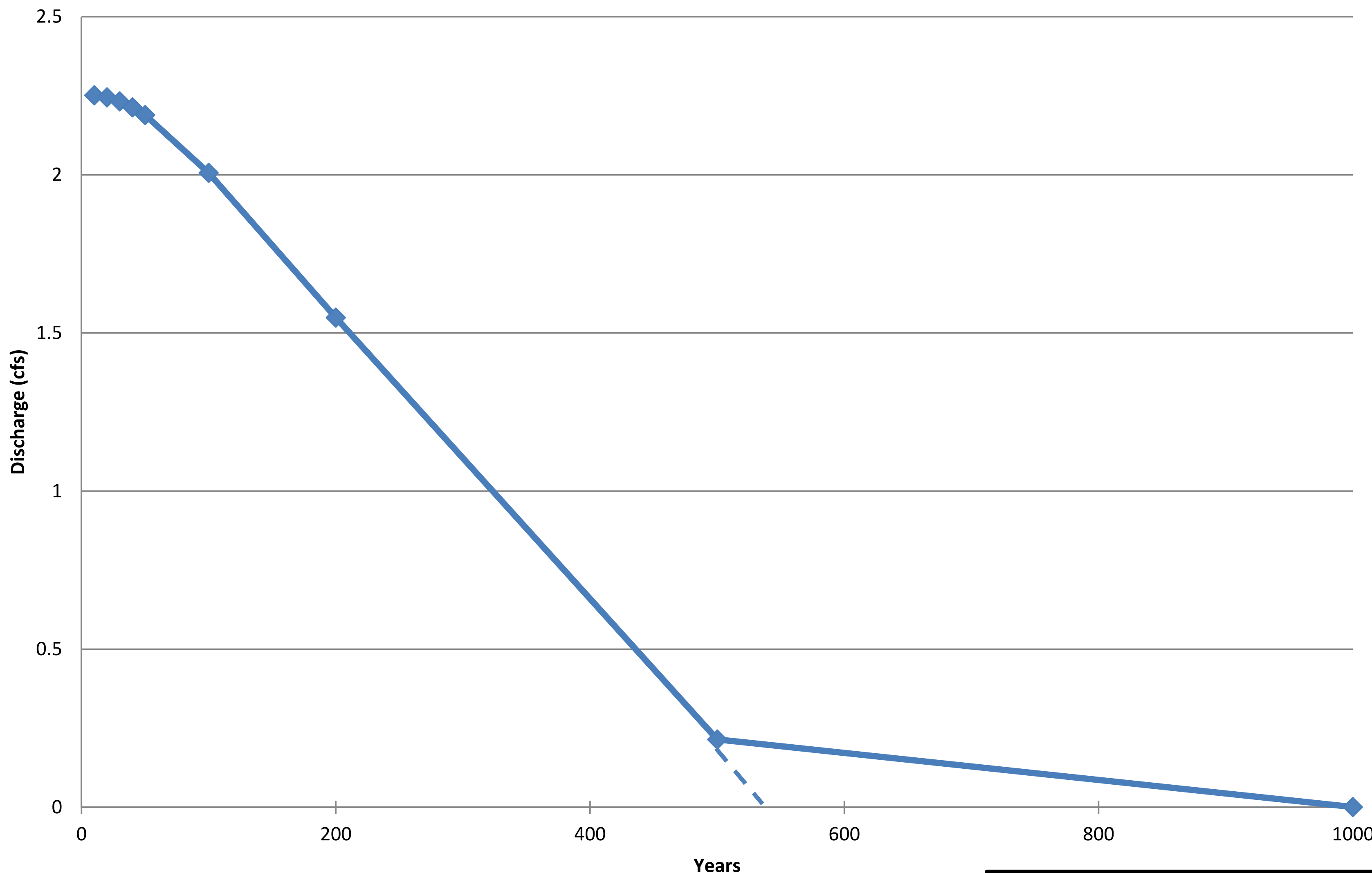


Simulated streamflow in the Muddy River, Scenario 4

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.4-2b

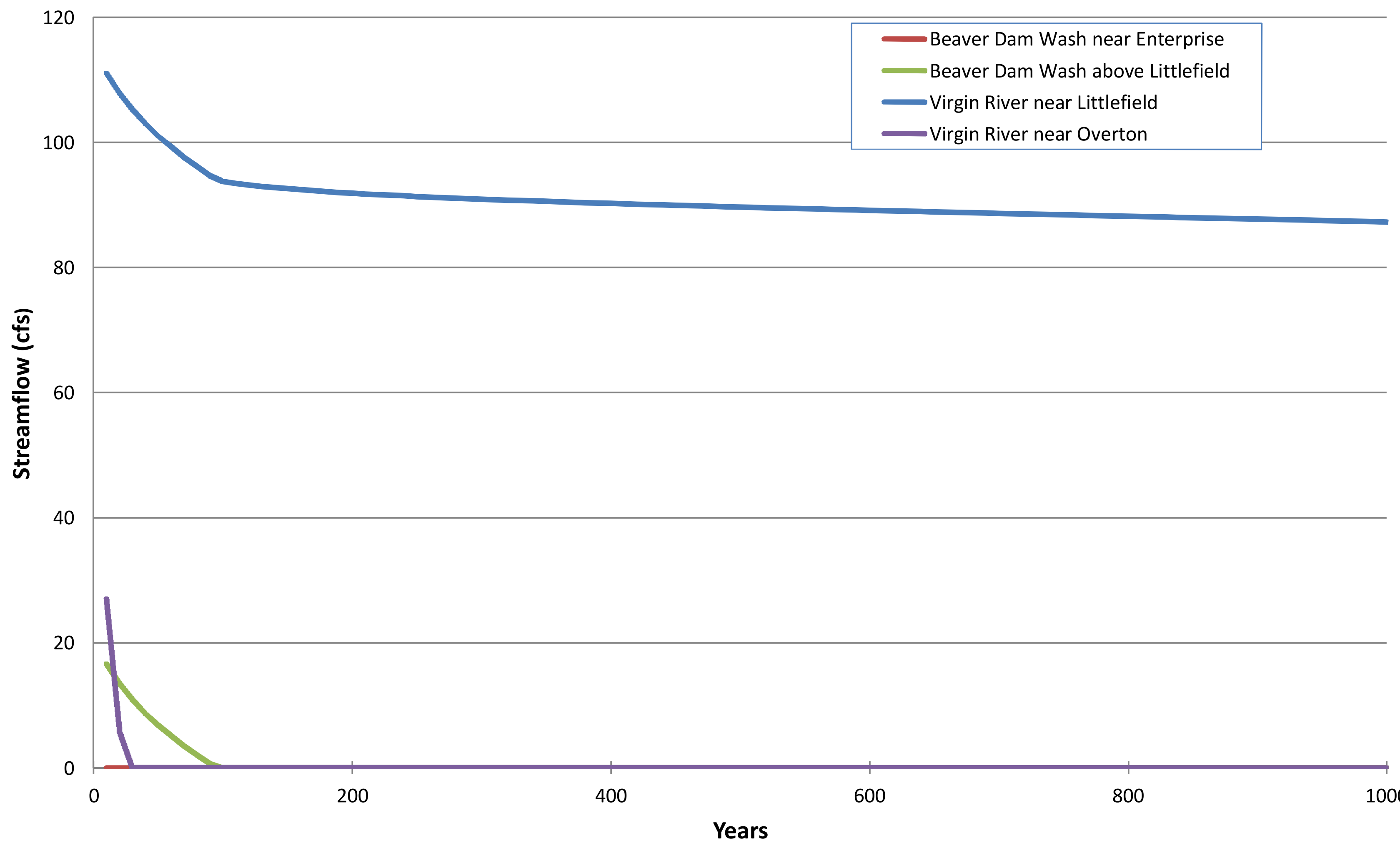


Simulated combined discharge from Rogers and Blue Point Springs, Scenario 4

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.4-2c



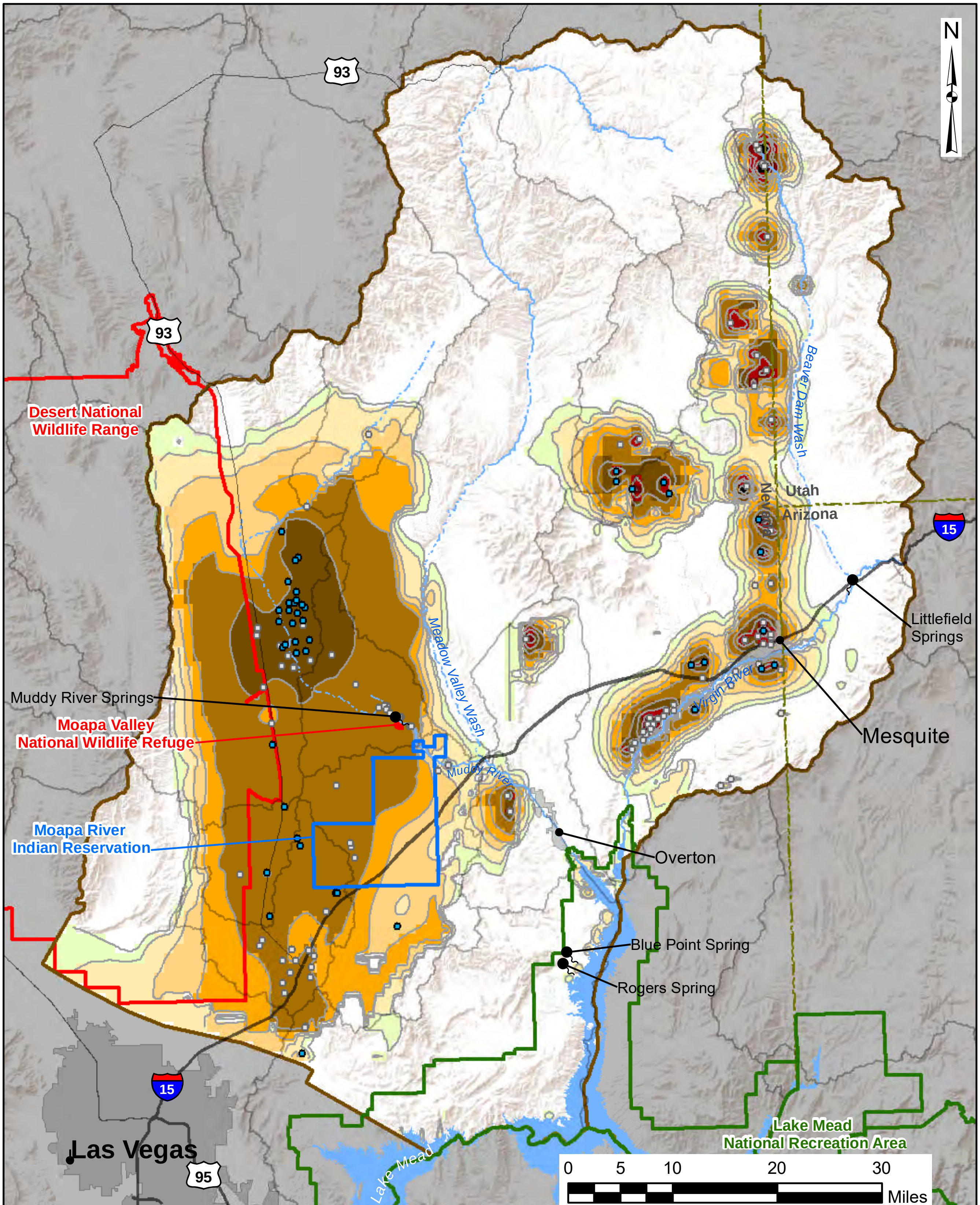
Simulated streamflow in Beaver Dam Wash and the Virgin River, Scenario 4

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.4-2d

SE ROA 12456



Legend

< 1	20 - 50	Pumping Wells; existent;
1 - 2	50 - 100	Pumping Introduced in Scenario
2 - 5	100 - 200	Active Model Domain
5 - 10	200 - 500	State Boundary
10 - 20	> 500	

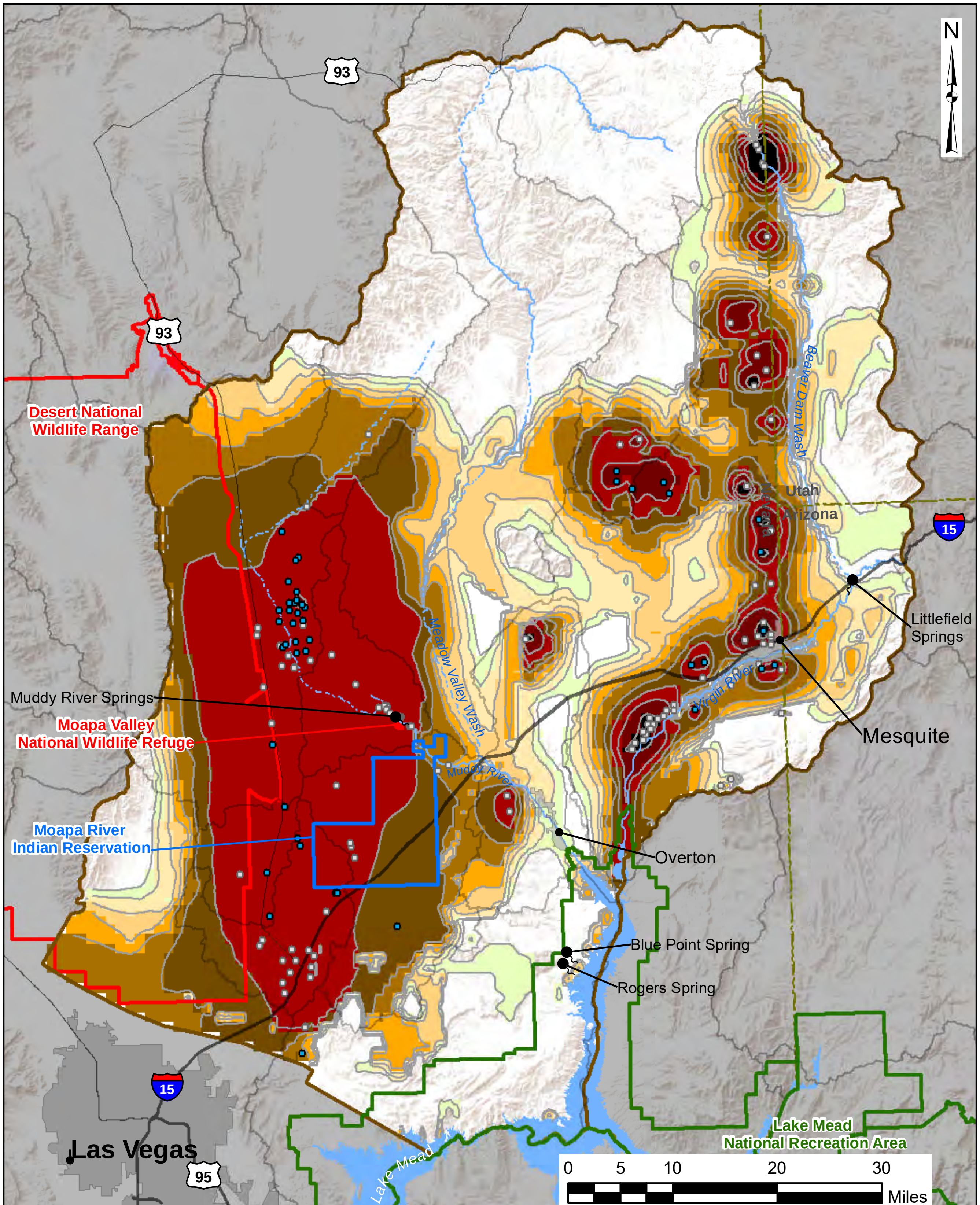
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 5 10 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.5-1a**



Legend

< 1	20 - 50	Pumping Wells; existent;
1 - 2	50 - 100	Pumping Introduced in Scenario
2 - 5	100 - 200	
5 - 10	200 - 500	Active Model Domain
10 - 20	> 500	
		State Boundary

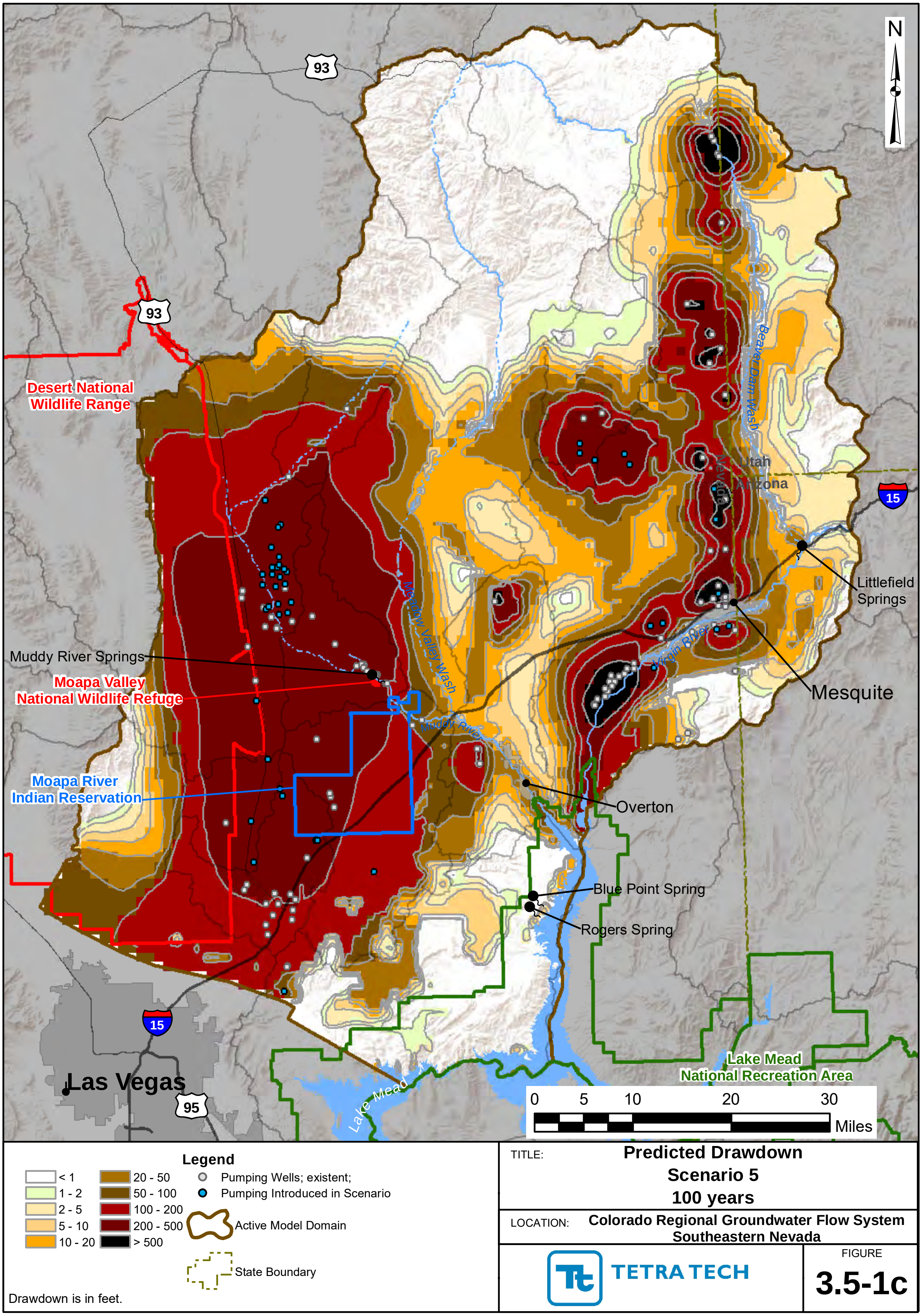
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 5
50 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.5-1b

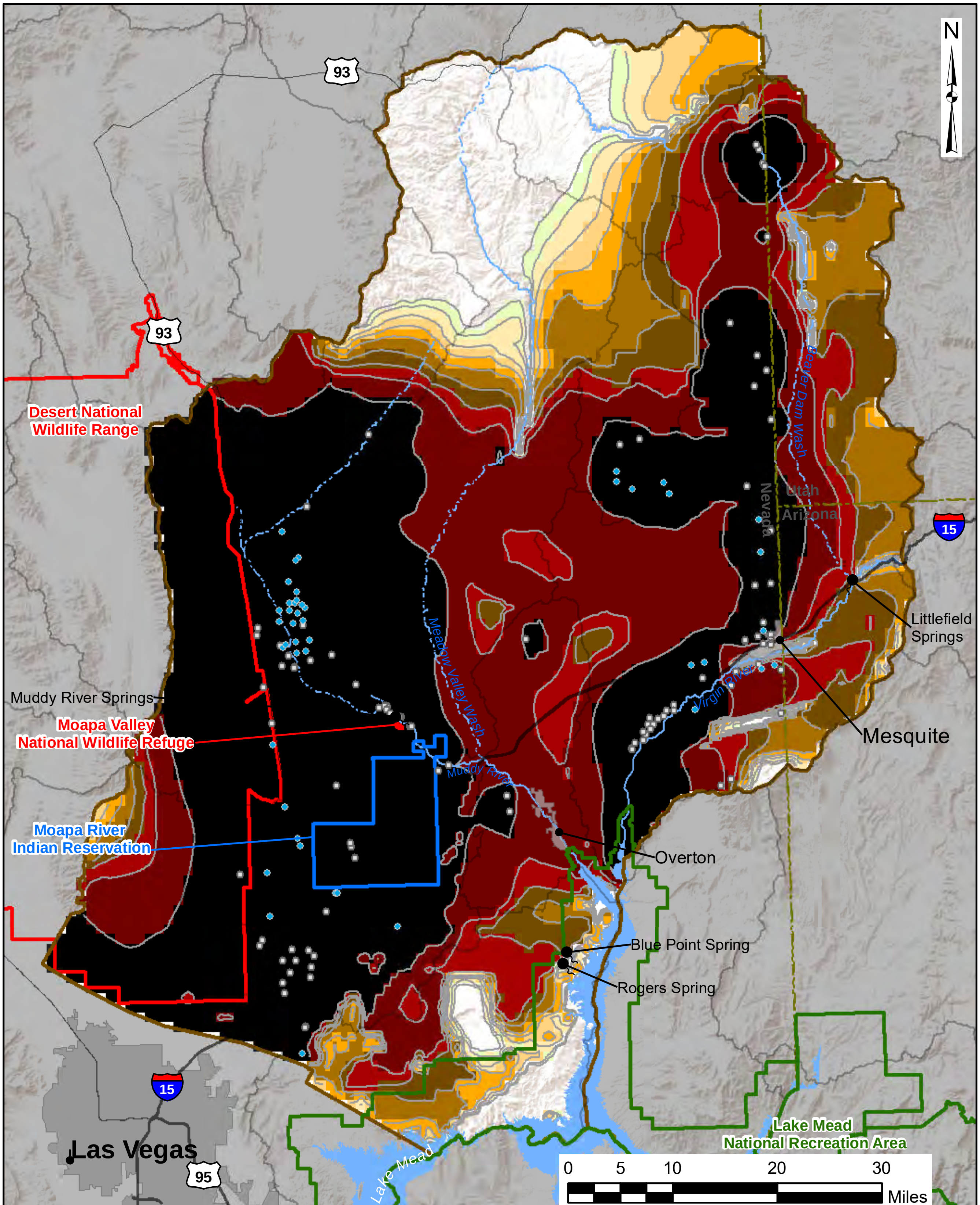


TITLE: **Predicted Drawdown**
Scenario 5
100 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE **3.5-1c**



Legend

< 1	20 - 50
1 - 2	50 - 100
2 - 5	100 - 200
5 - 10	200 - 500
10 - 20	> 500

Pumping Wells; existent;

Pumping Introduced in Scenario

Active Model Domain

State Boundary

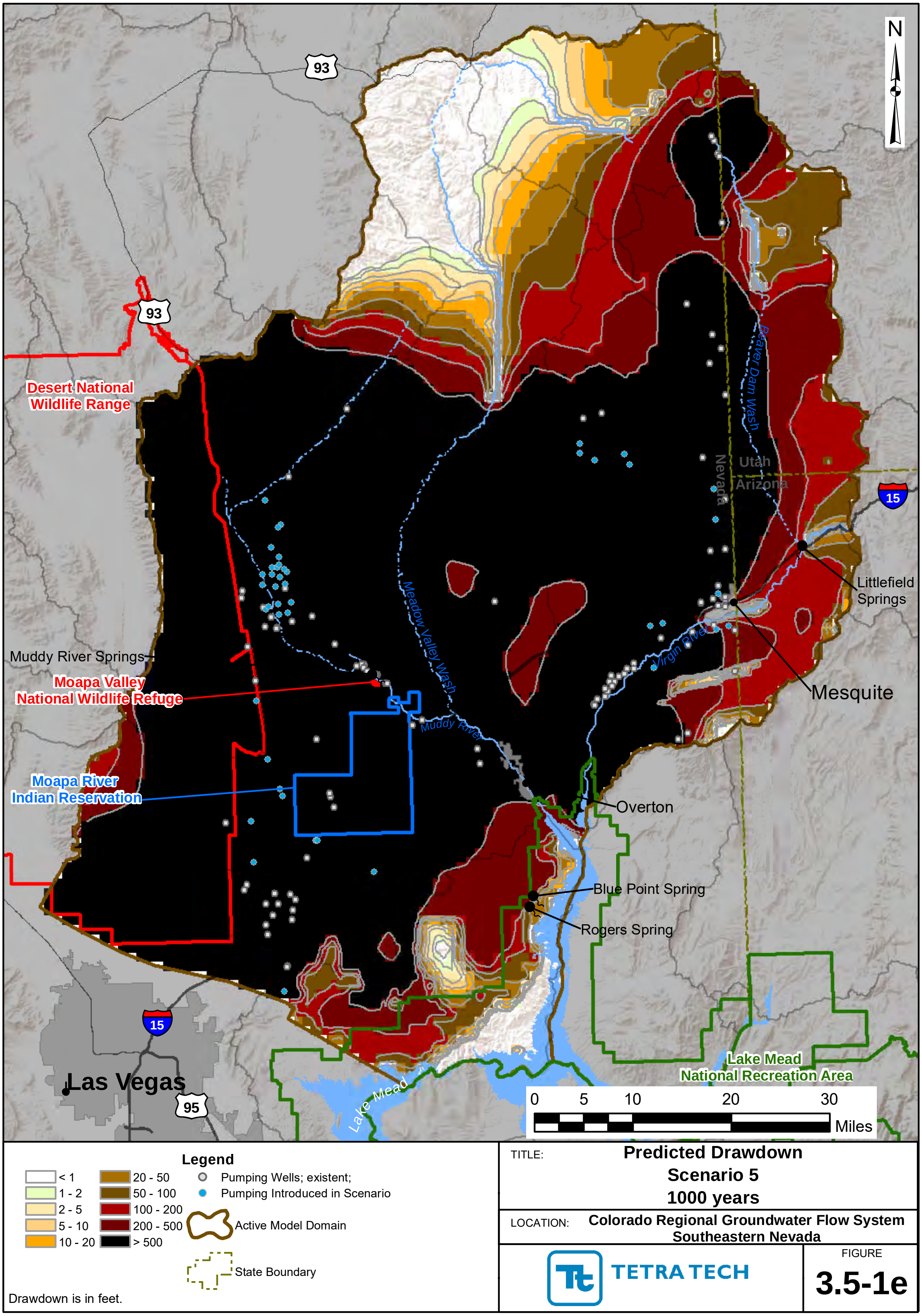
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 5 500 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.5-1d**

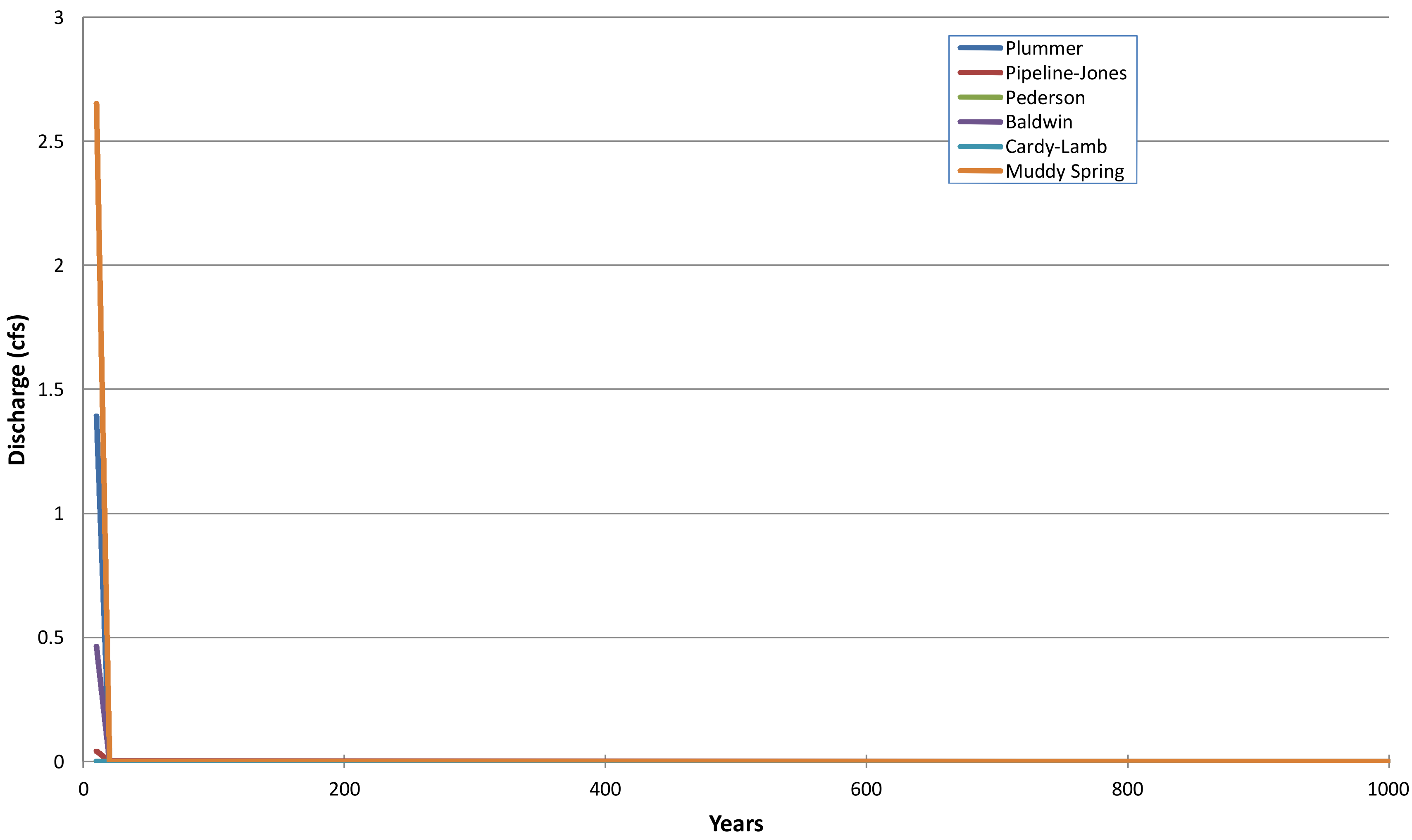


TITLE: **Predicted Drawdown**
Scenario 5
1000 years

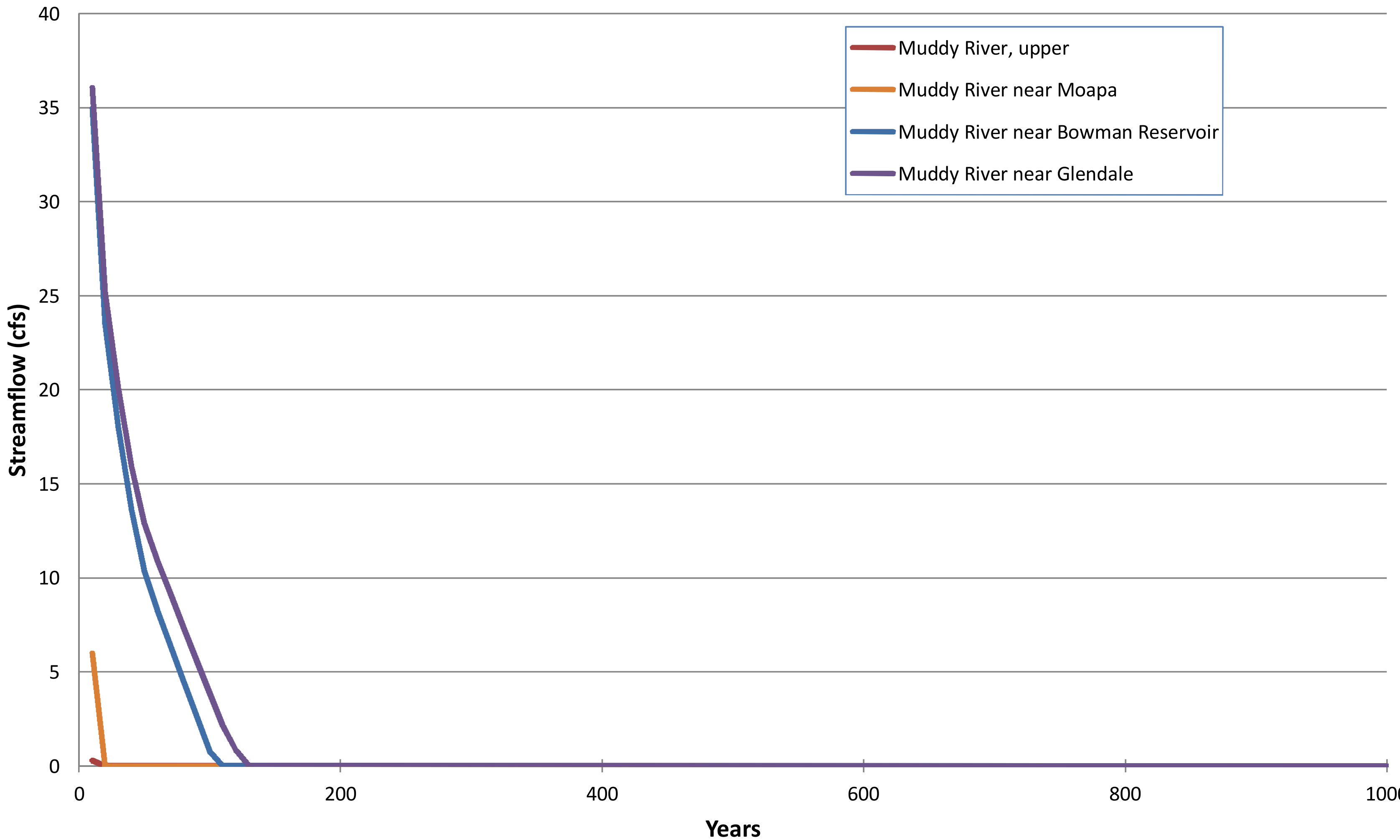
LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.5-1e



Simulated spring discharges in the Muddy River Springs area, Scenario 5	
Lower Colorado River Flow System	
TETRA TECH GEO	Figure 3.5-2a

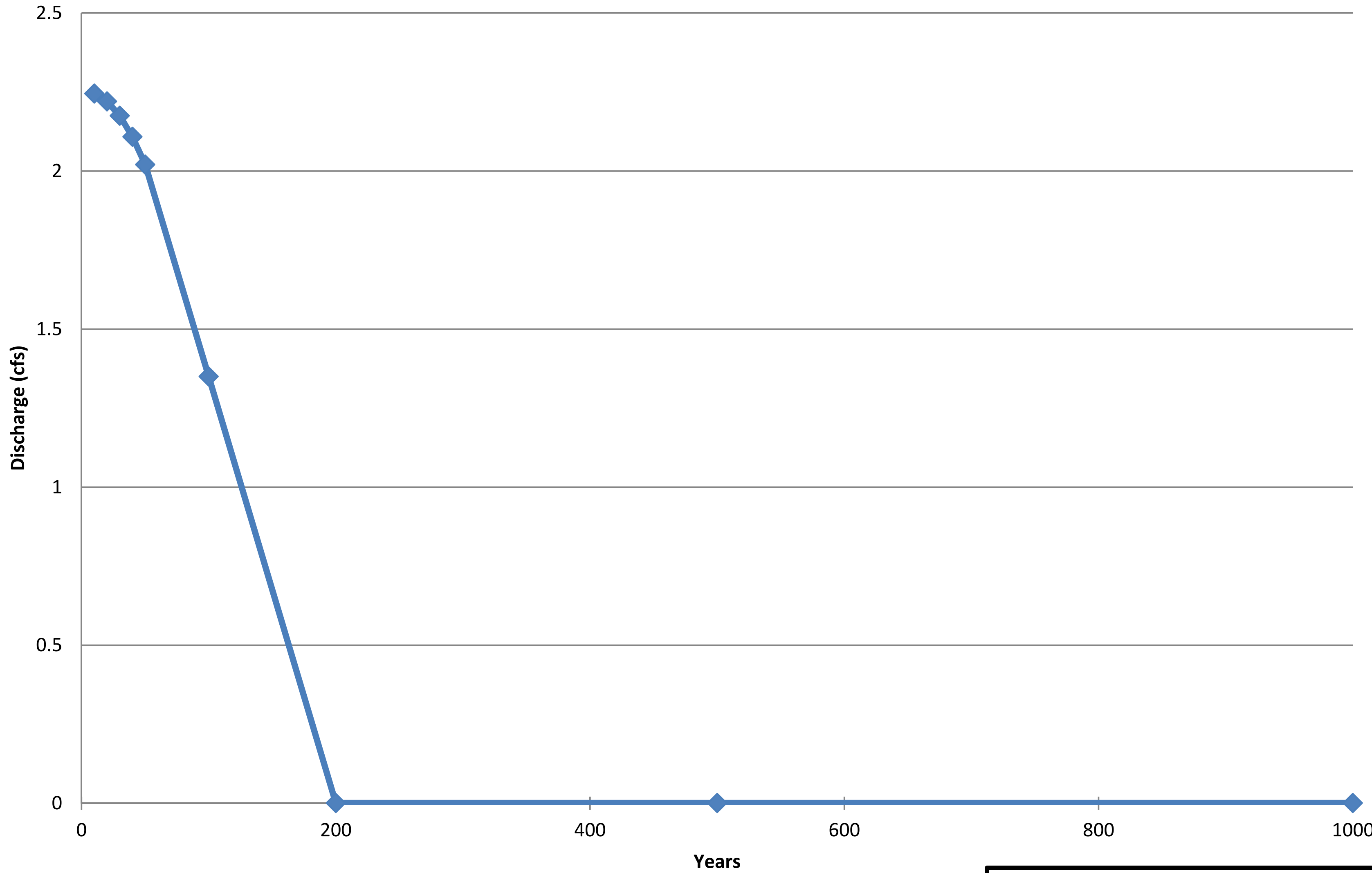


Simulated streamflow in the Muddy River, Scenario 5

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.5-2b

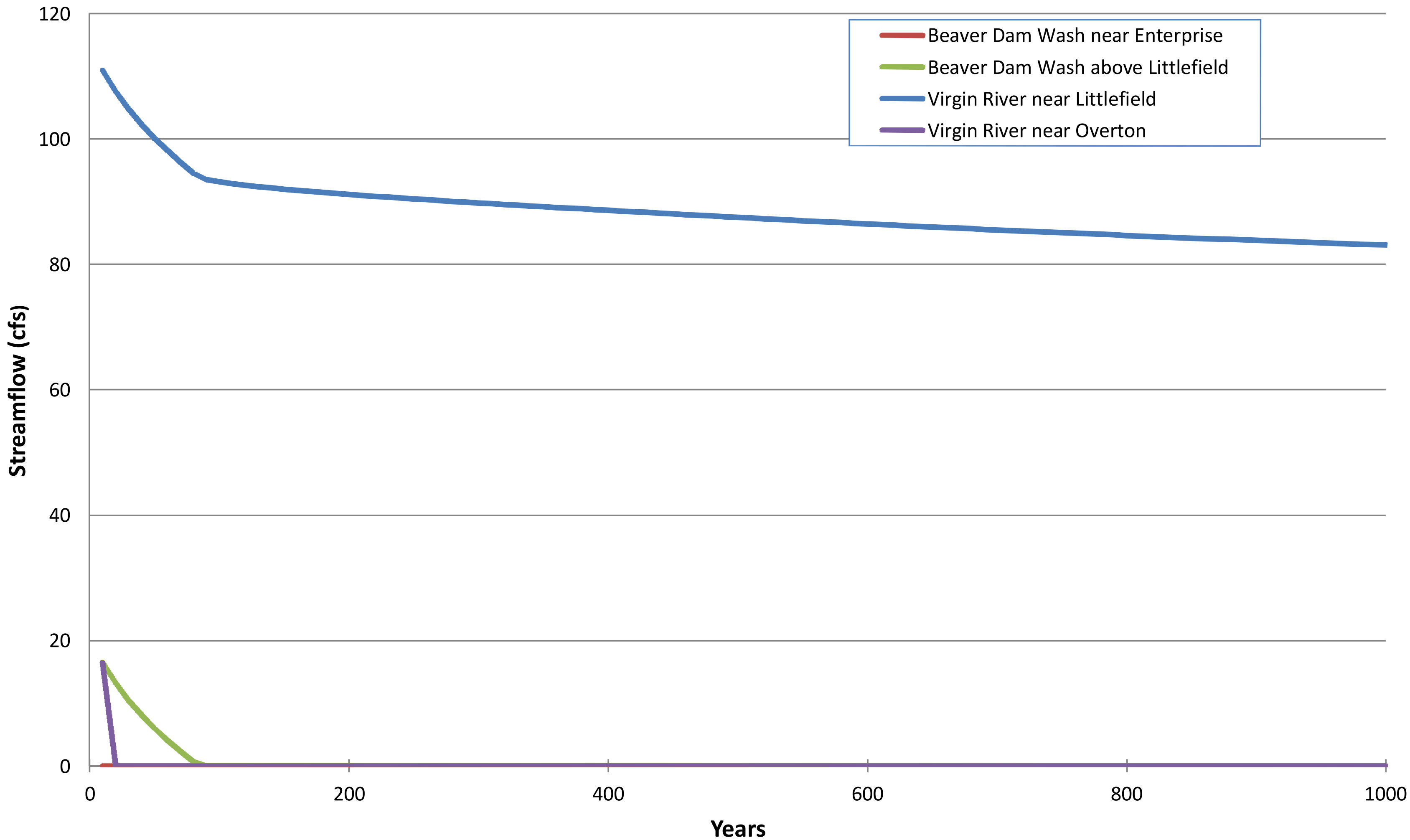


Simulated combined discharge from Rogers and Blue Point Springs, Scenario 5

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.5-2c



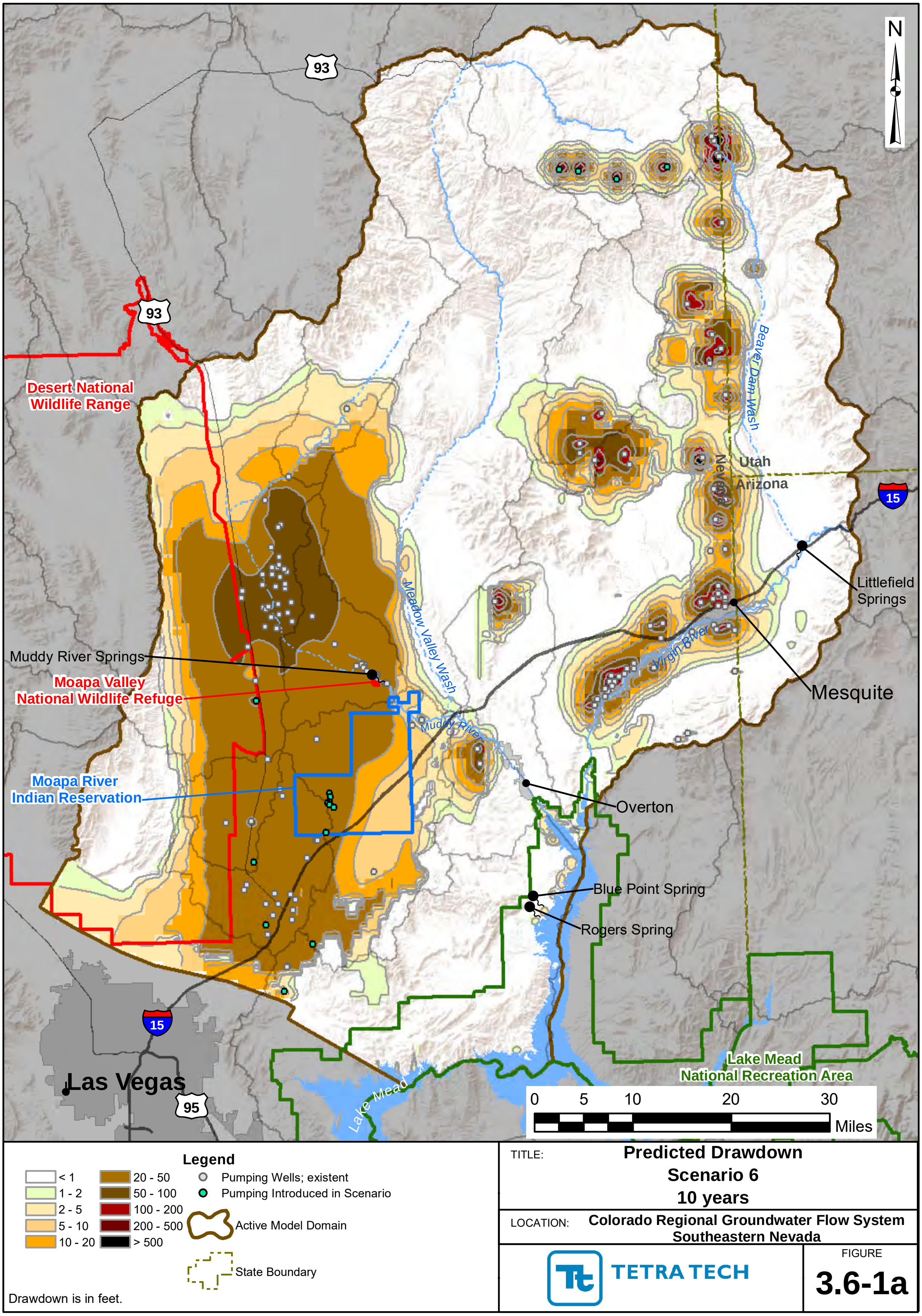
Simulated streamflow in Beaver Dam Wash and the Virgin River, Scenario 5

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.5-2d

SE ROA 12466

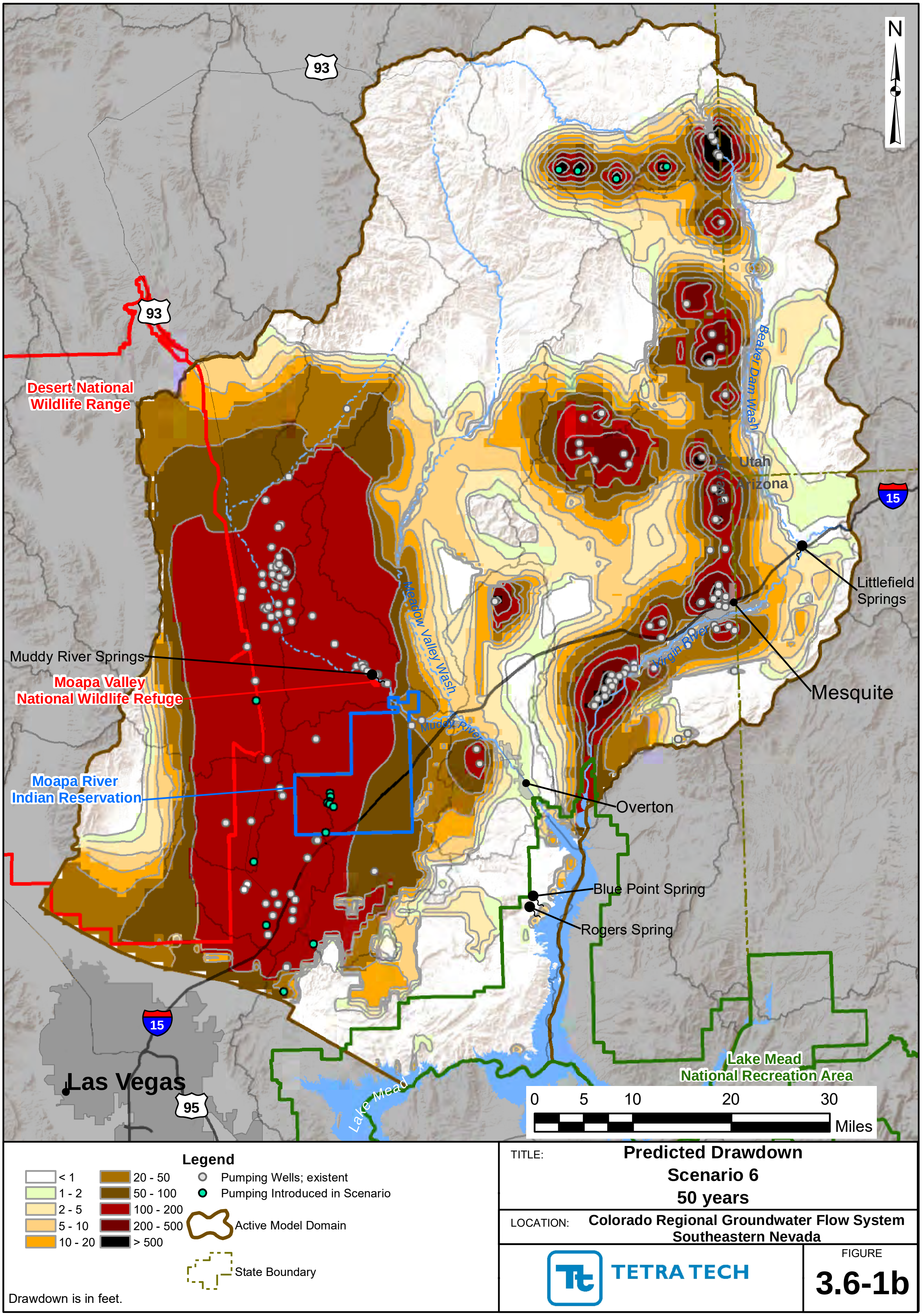


TITLE: **Predicted Drawdown Scenario 6 10 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.6-1a**

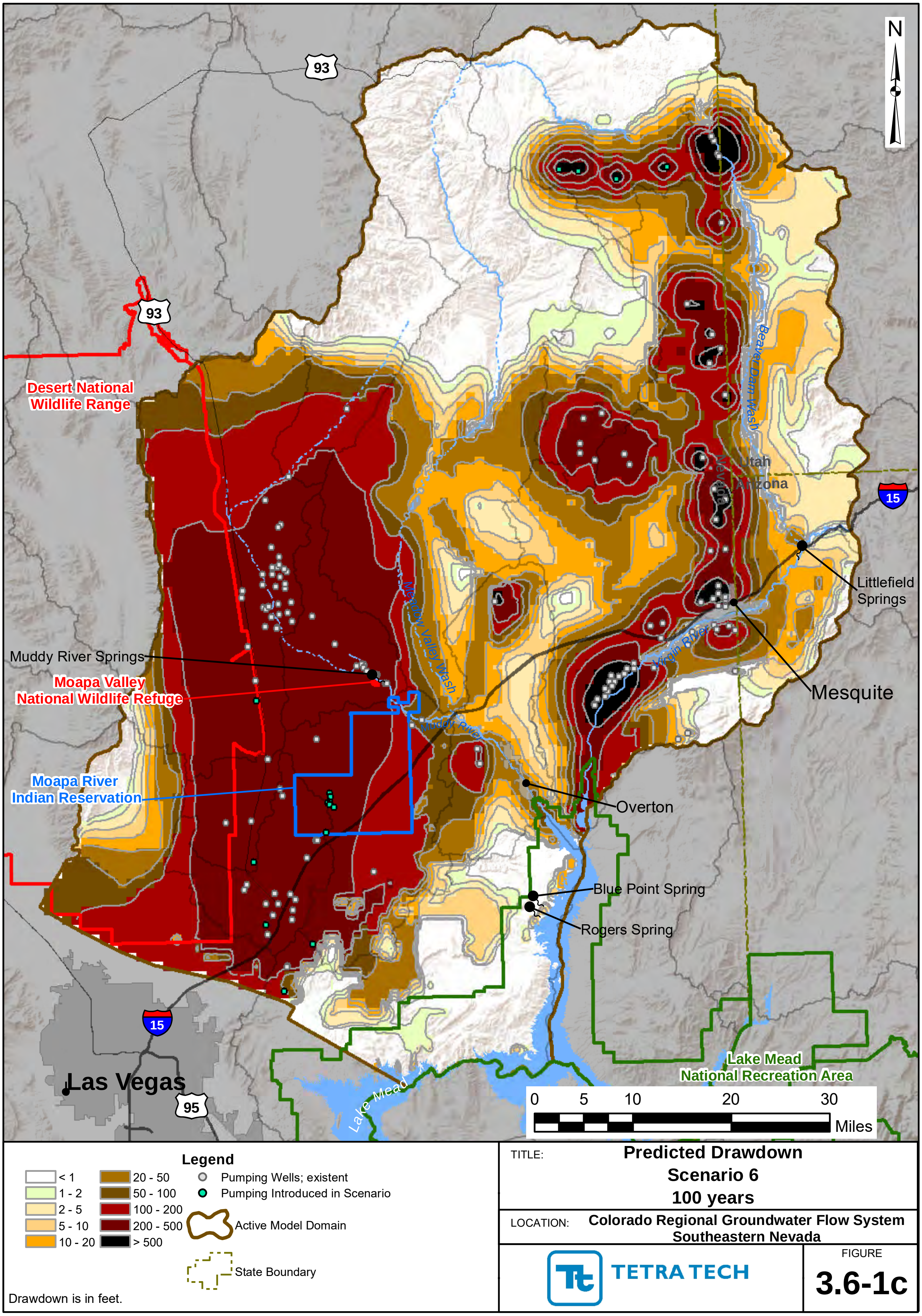


TITLE: **Predicted Drawdown Scenario 6 50 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.6-1b**

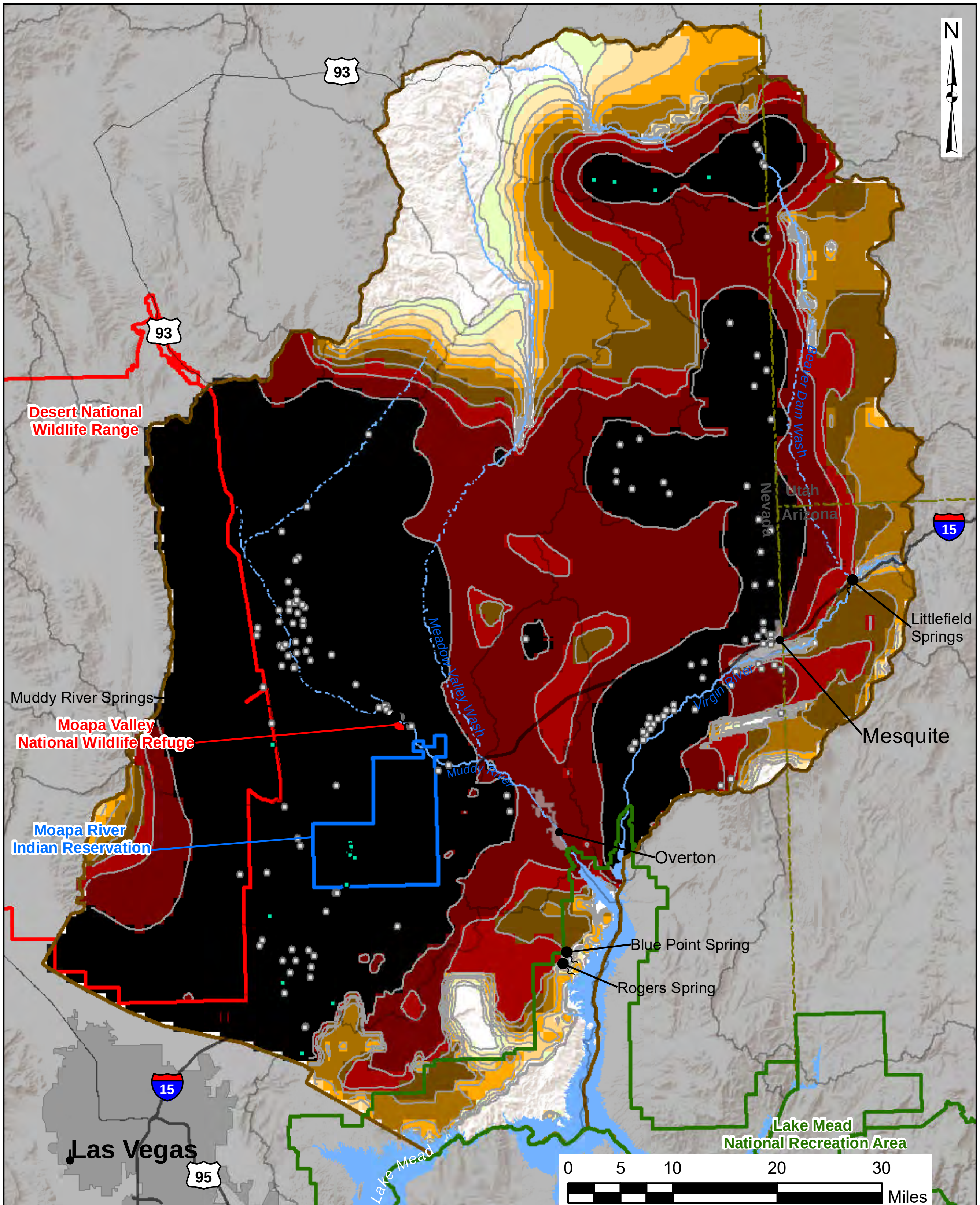


TITLE: **Predicted Drawdown**
Scenario 6
100 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE **3.6-1c**



Legend

- < 1
- 1 - 2
- 2 - 5
- 5 - 10
- 10 - 20
- 20 - 50
- 50 - 100
- 100 - 200
- 200 - 500
- > 500
- Pumping Wells; existent
- Pumping Introduced in Scenario
- Active Model Domain
- State Boundary

Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 6 500 years**

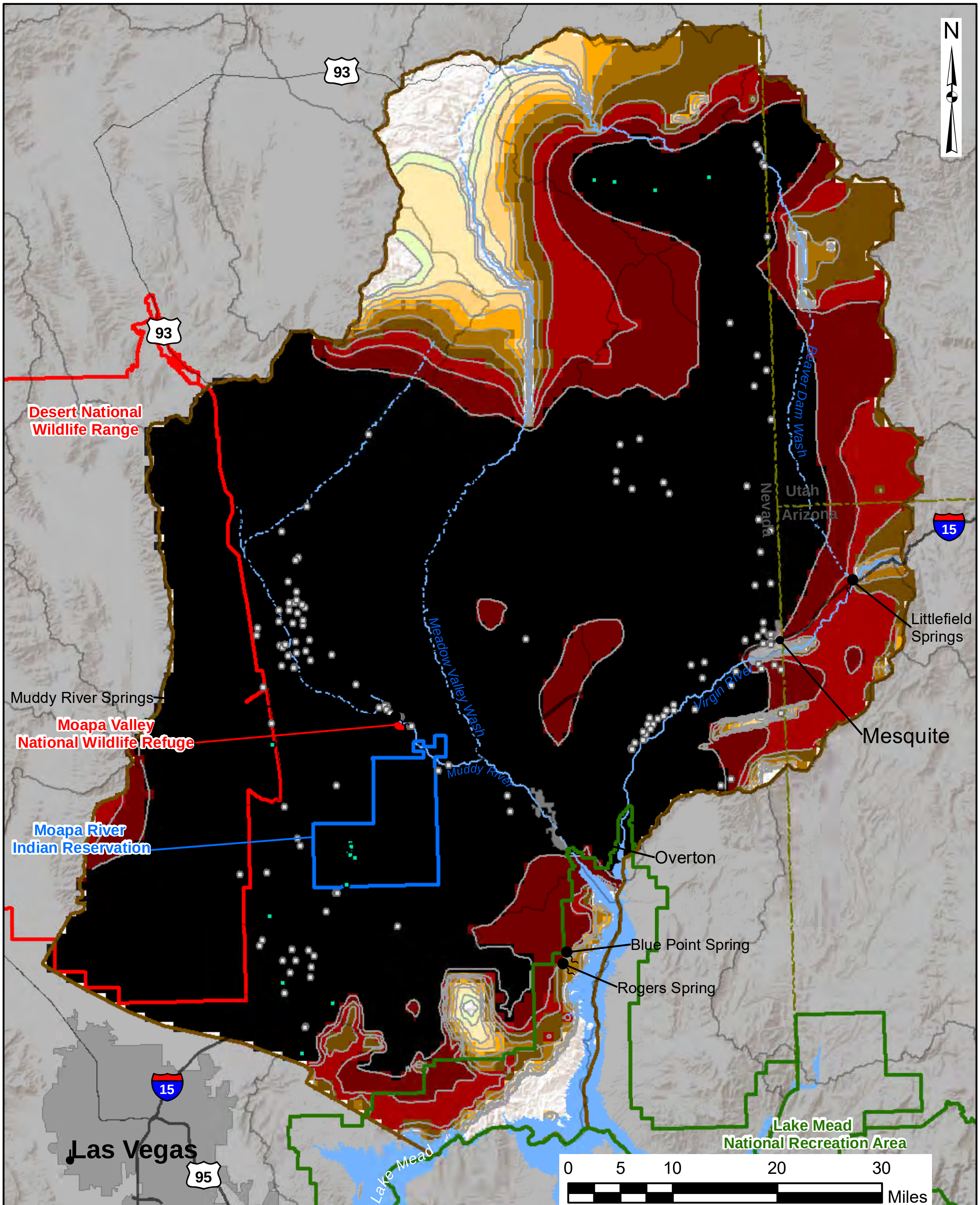
LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.6-1d**

SE ROA 12470

JA_5232



Legend

< 1	20 - 50	Pumping Wells; existent
1 - 2	50 - 100	Pumping Introduced in Scenario
2 - 5	100 - 200	
5 - 10	200 - 500	Active Model Domain
10 - 20	> 500	
		State Boundary

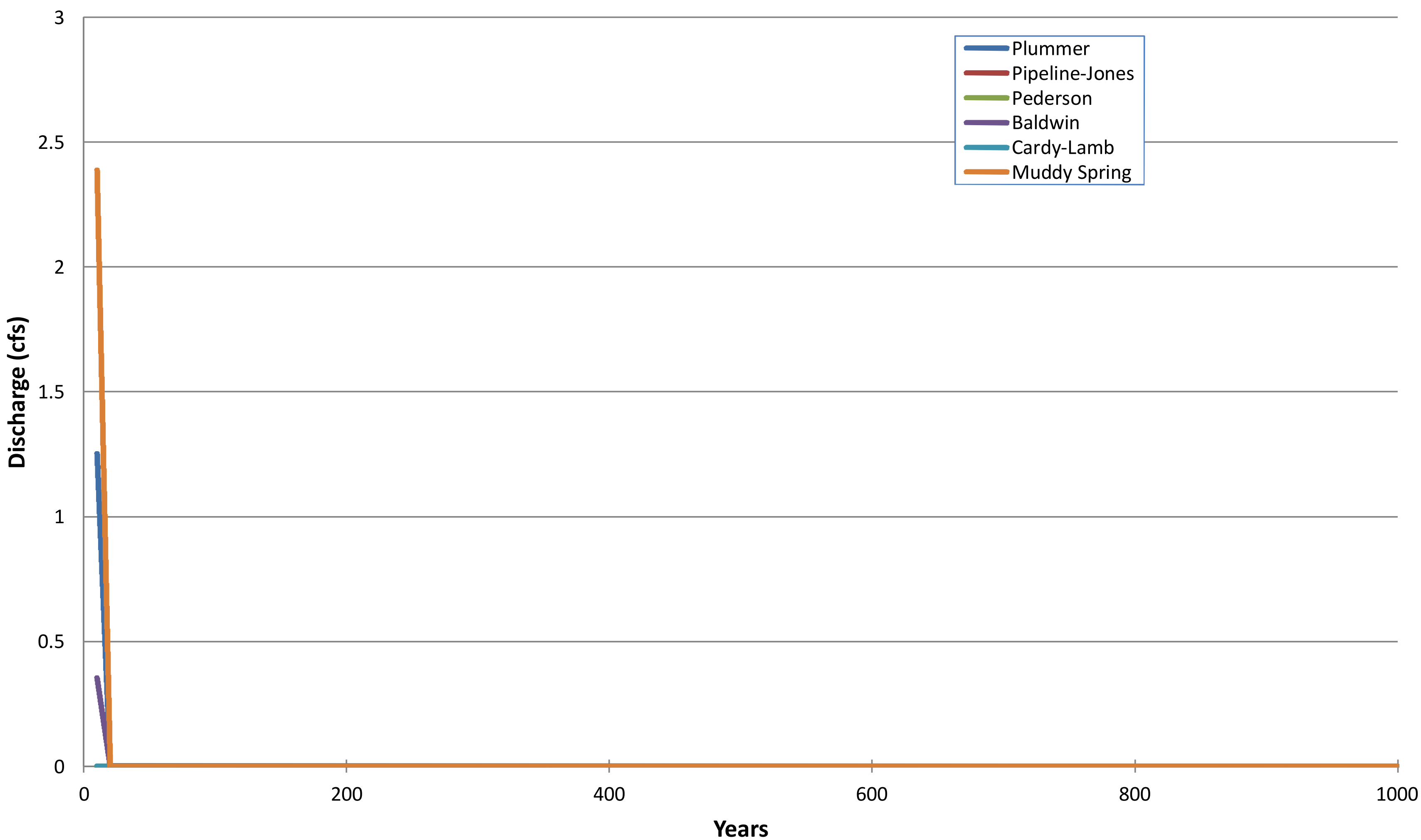
Drawdown is in feet.

TITLE: **Predicted Drawdown Scenario 6 1000 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.6-1e**

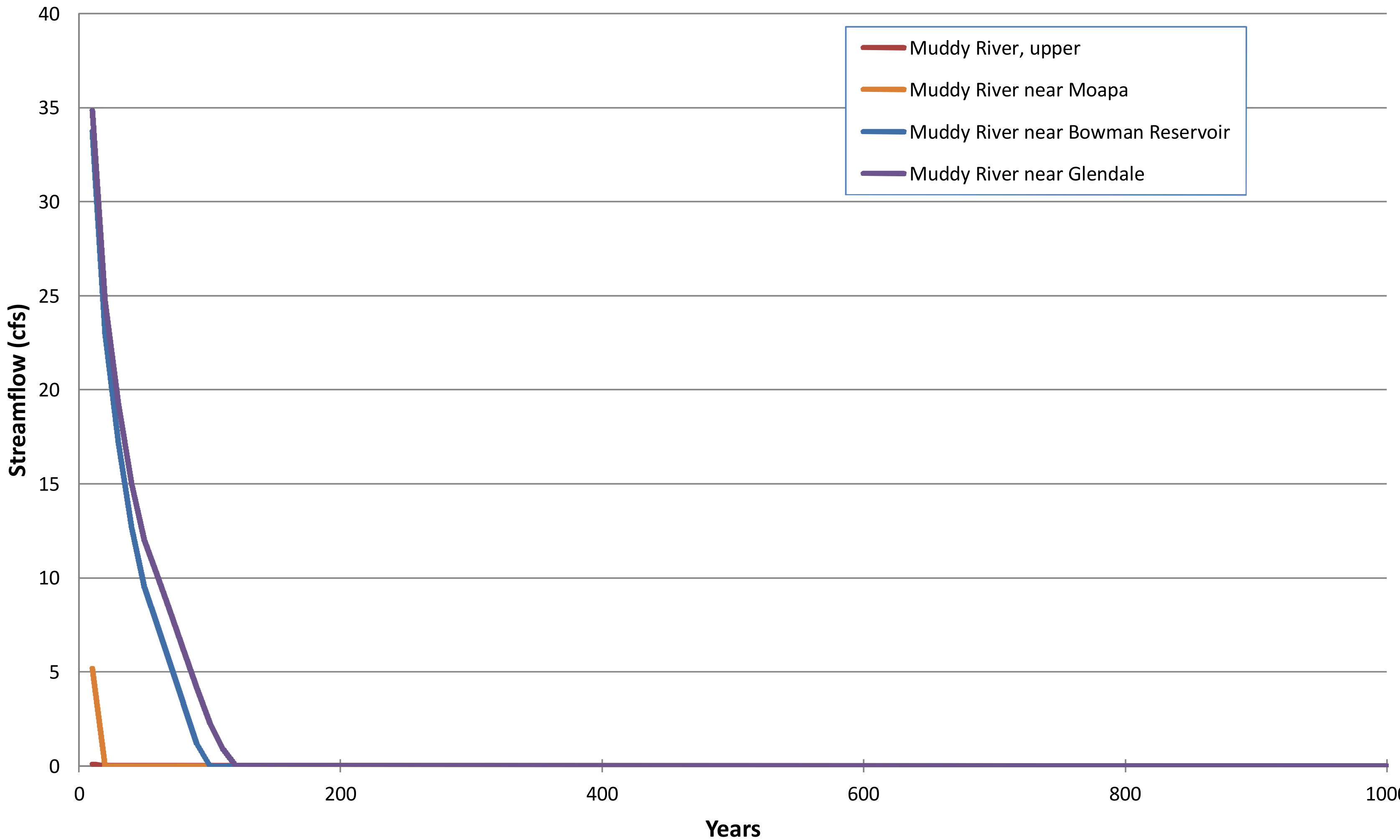


Simulated spring discharges in the Muddy River Springs area, Scenario 6

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.6-2a

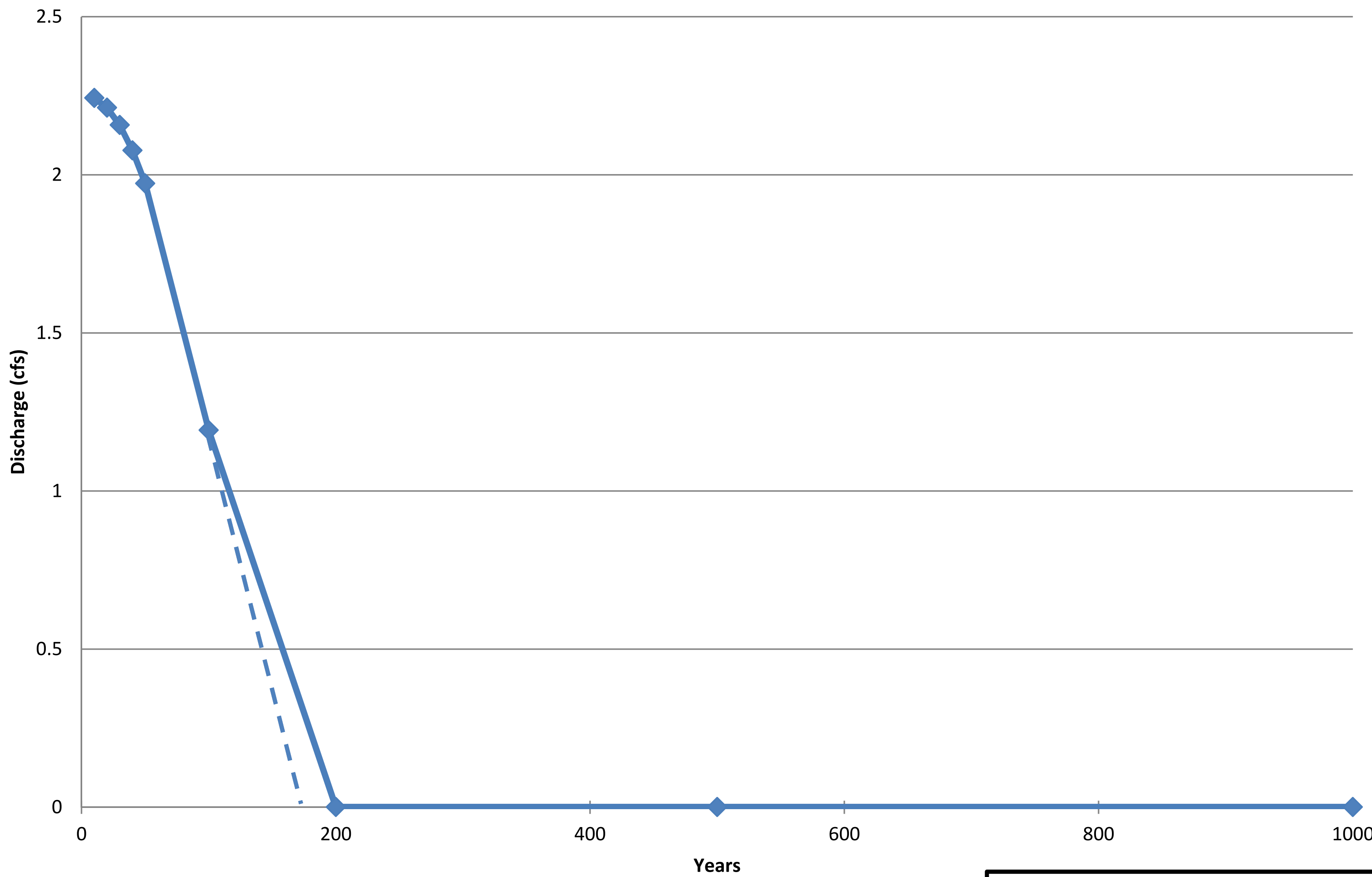


Simulated streamflow in the Muddy River, Scenario 6

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.6-2b

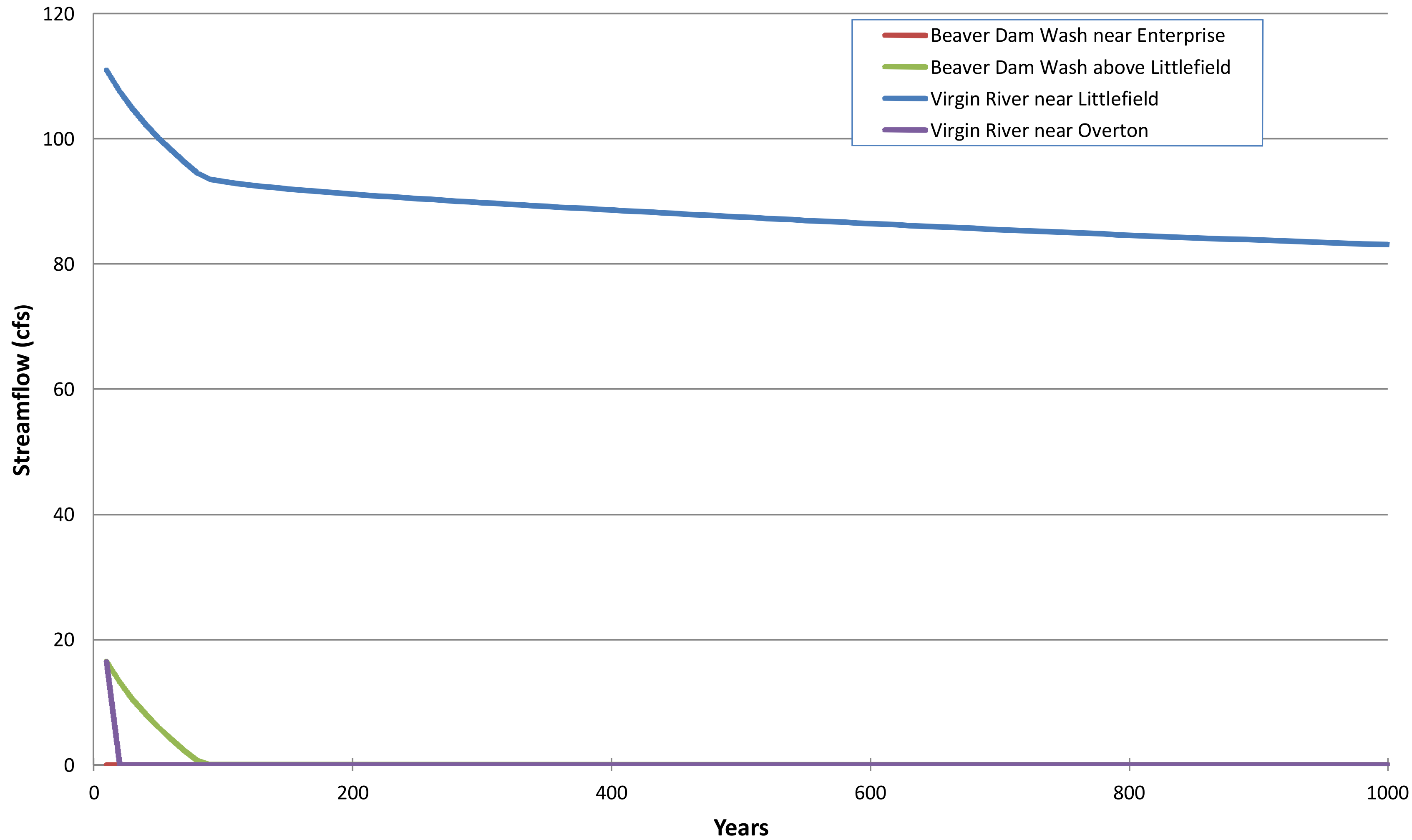


Simulated combined discharge from Rogers and Blue Point Springs, Scenario 6

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.6-2c



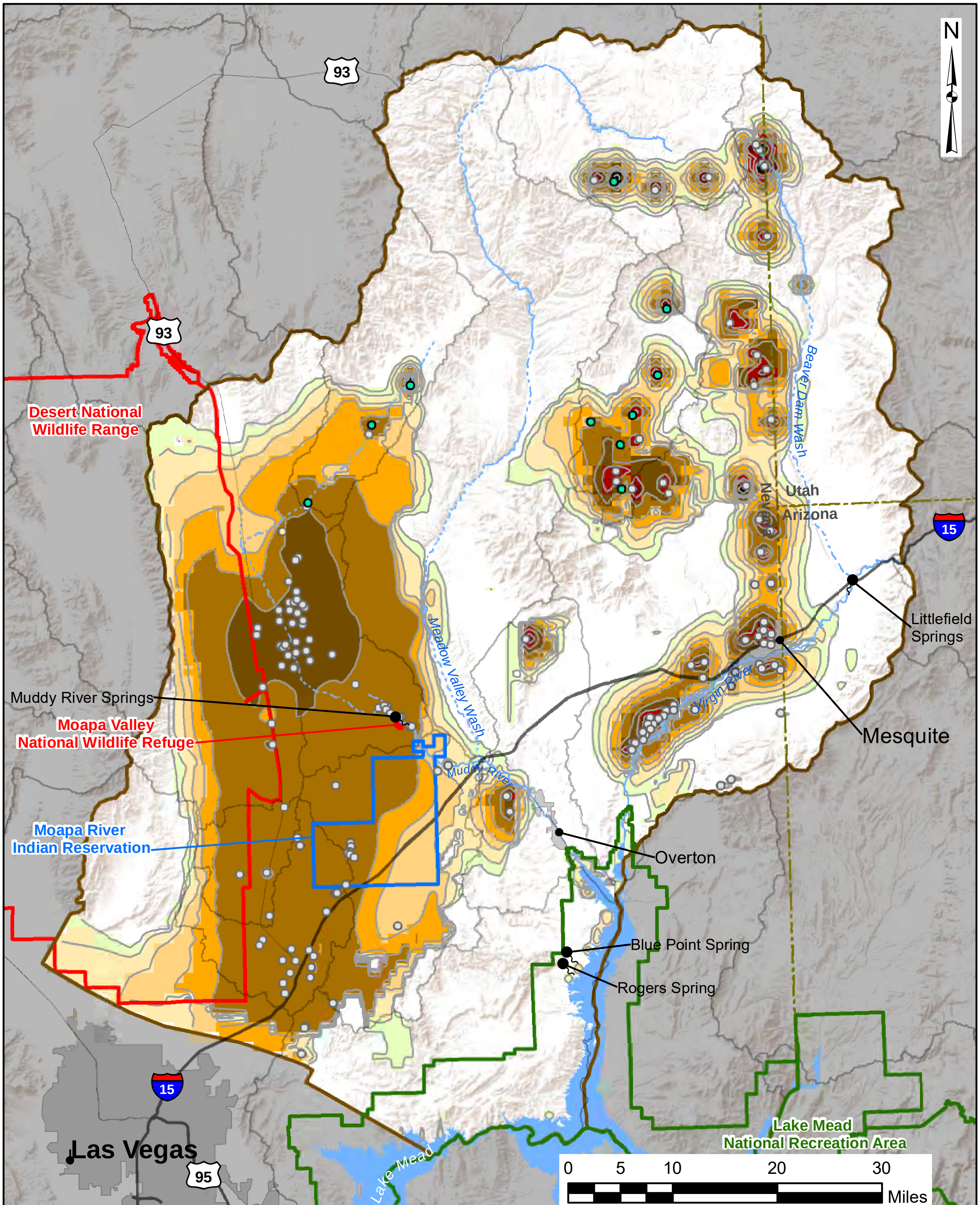
Simulated streamflow in Beaver Dam Wash and the Virgin River, Scenario 6

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.6-2d

SE ROA 12476



Legend

< 1	20 - 50	Pumping Wells; existent
1 - 2	50 - 100	Pumping Introduced in Scenario
2 - 5	100 - 200	
5 - 10	200 - 500	Active Model Domain
10 - 20	> 500	
		State Boundary

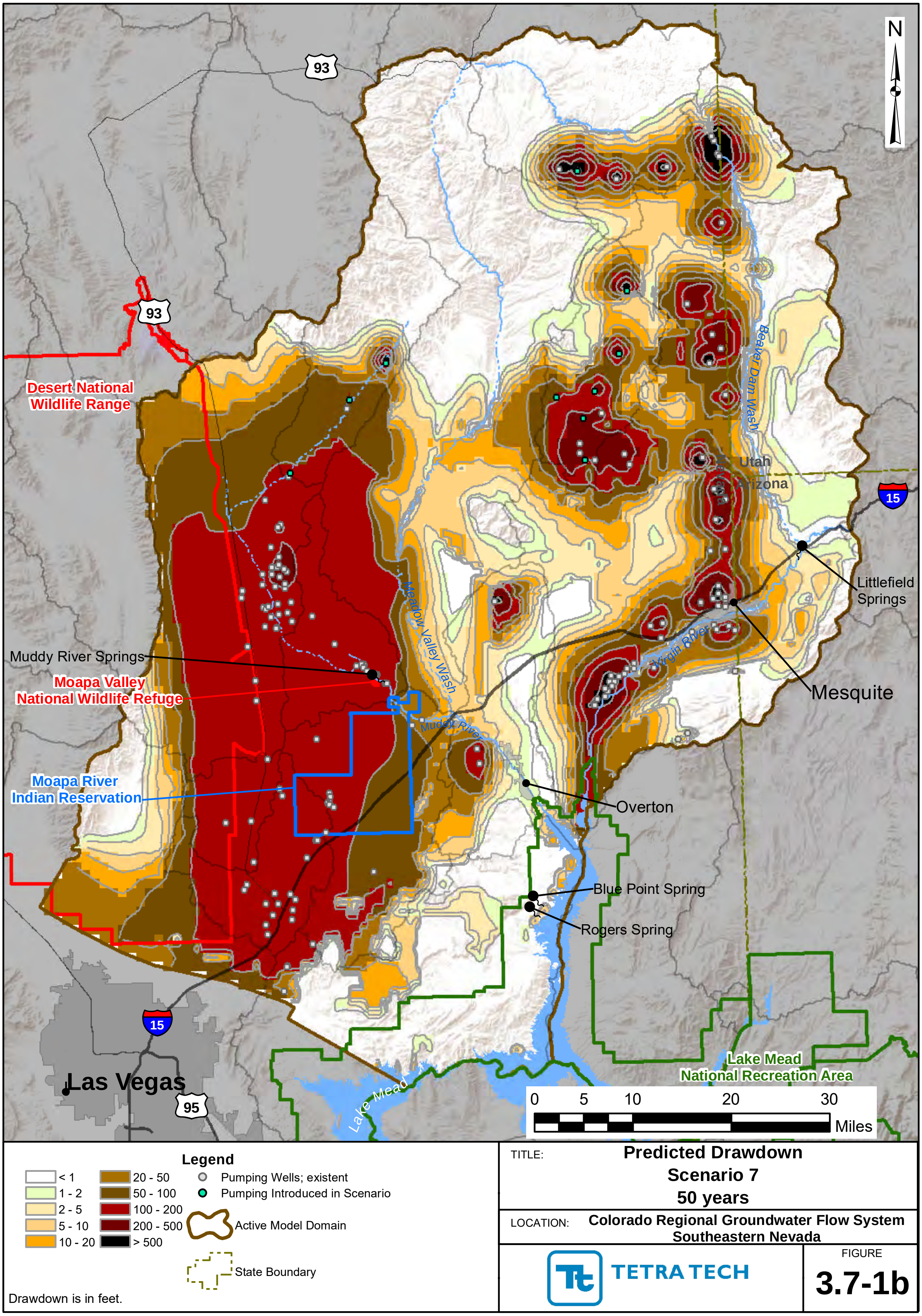
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 7
10 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.7-1a

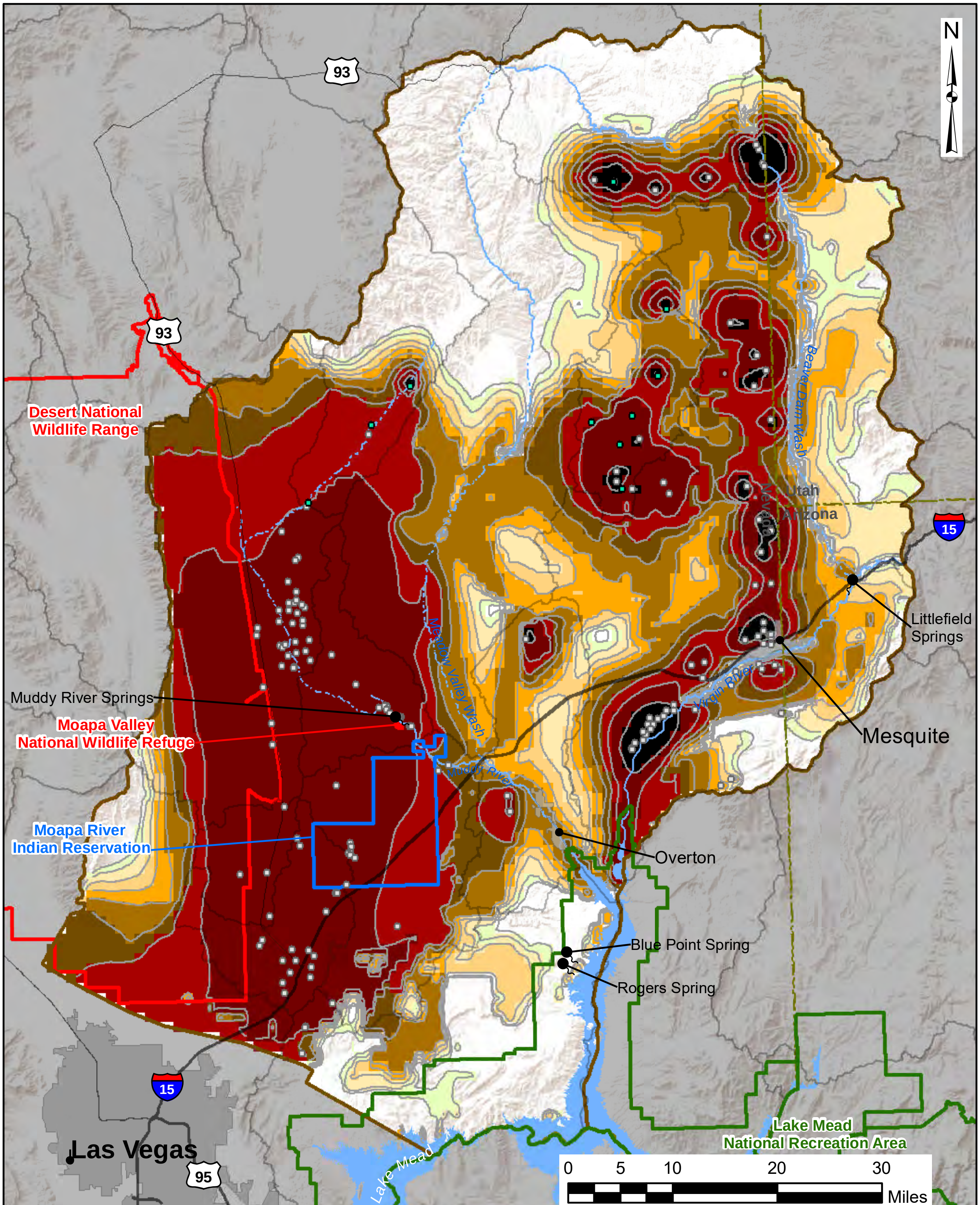


TITLE: **Predicted Drawdown Scenario 7 50 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.7-1b**



Legend

< 1	20 - 50	Pumping Wells; existent
1 - 2	50 - 100	Pumping Introduced in Scenario
2 - 5	100 - 200	
5 - 10	200 - 500	Active Model Domain
10 - 20	> 500	
		State Boundary

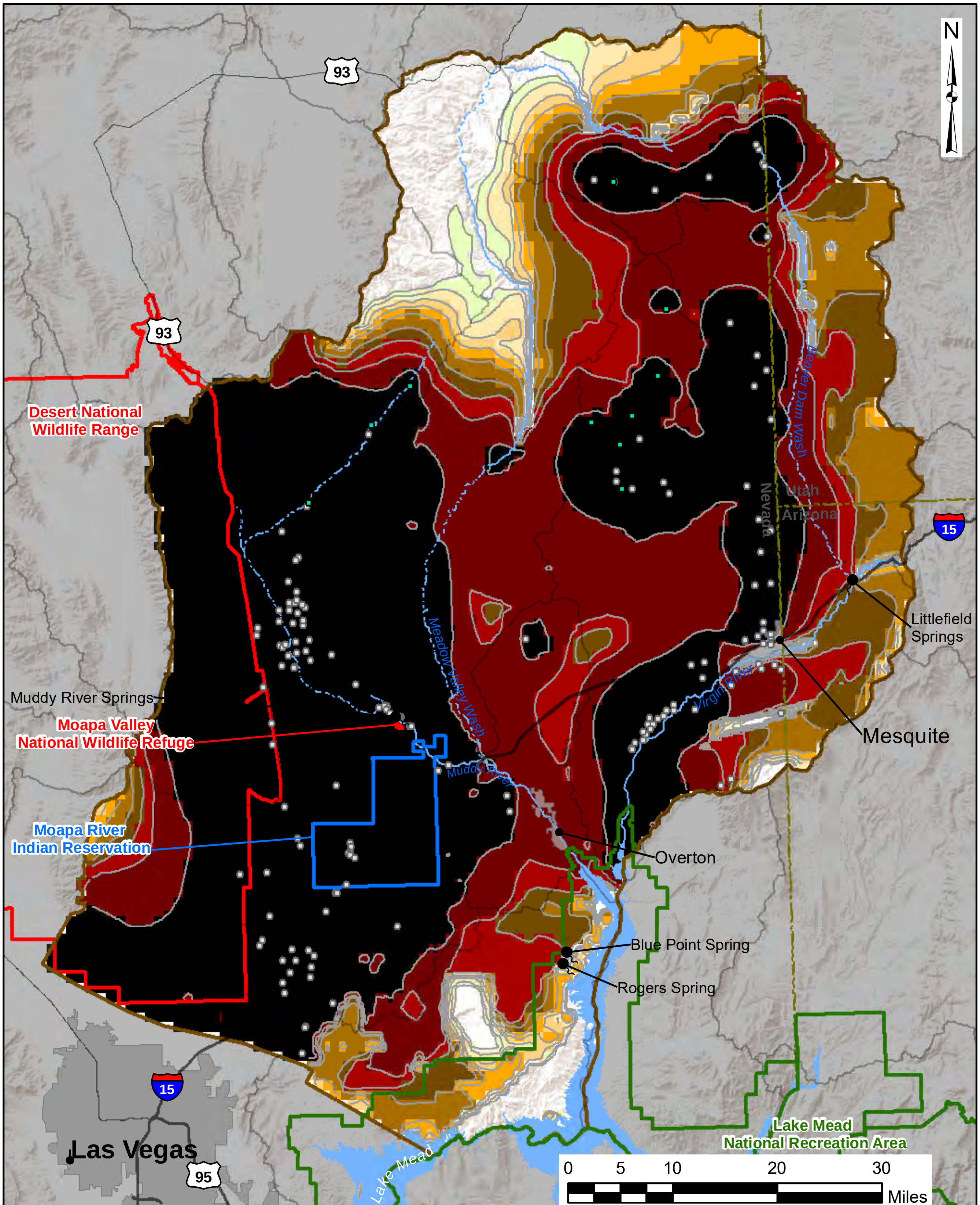
Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 7
100 years

LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.7-1c



Legend

< 1	20 - 50	Pumping Wells; existent	
1 - 2	50 - 100	Pumping Introduced in Scenario	
2 - 5	100 - 200		
5 - 10	200 - 500	Active Model Domain	
10 - 20	> 500		
		State Boundary	

Drawdown is in feet.

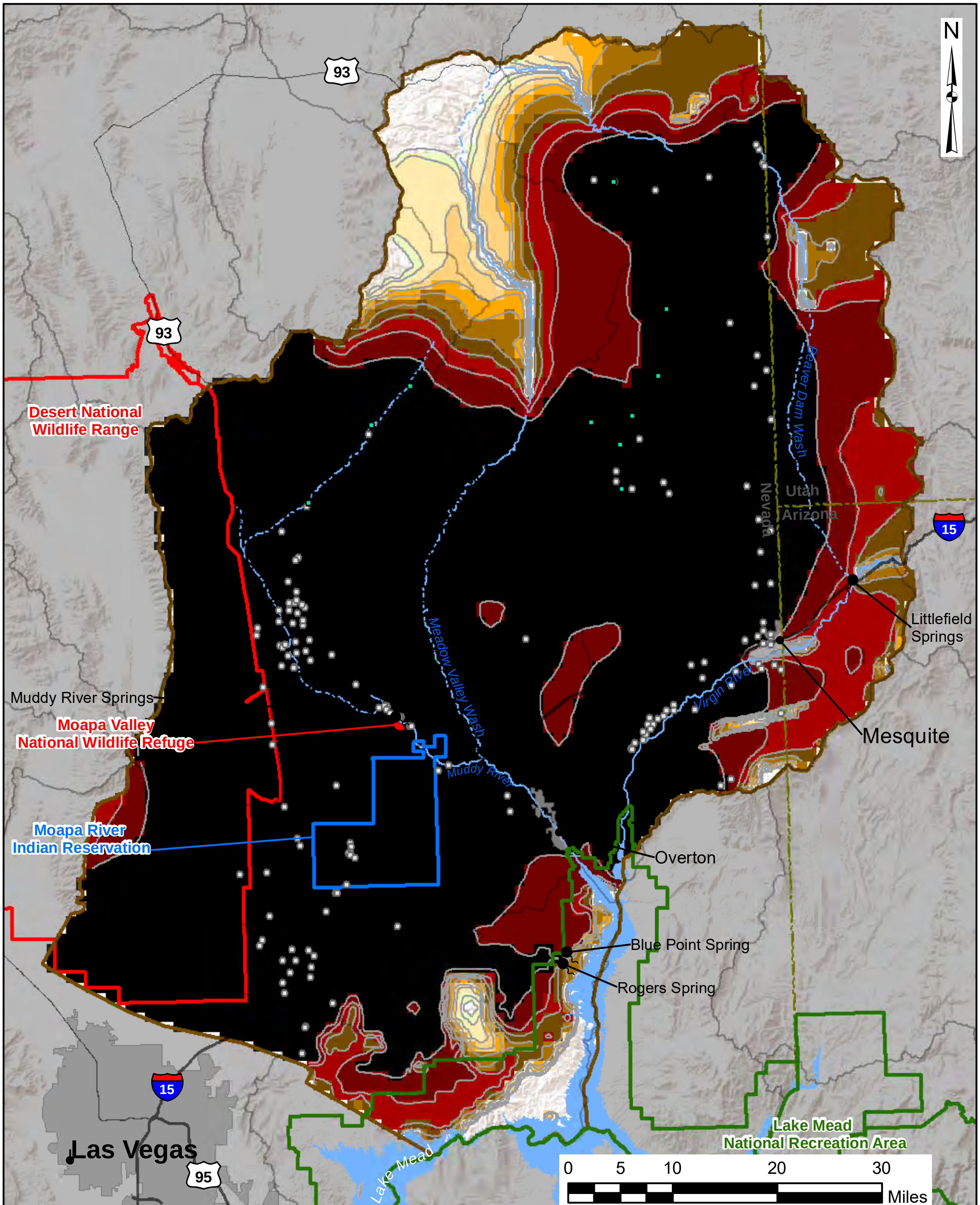
TITLE: **Predicted Drawdown Scenario 7 500 years**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **3.7-1d**

SE ROA 12480



Legend

< 1
1 - 2
2 - 5
5 - 10
10 - 20
20 - 50
50 - 100
100 - 200
200 - 500
> 500
Pumping Wells; existent
Pumping Introduced in Scenario
Active Model Domain
State Boundary

Drawdown is in feet.

TITLE: **Predicted Drawdown**
Scenario 7
1000 years

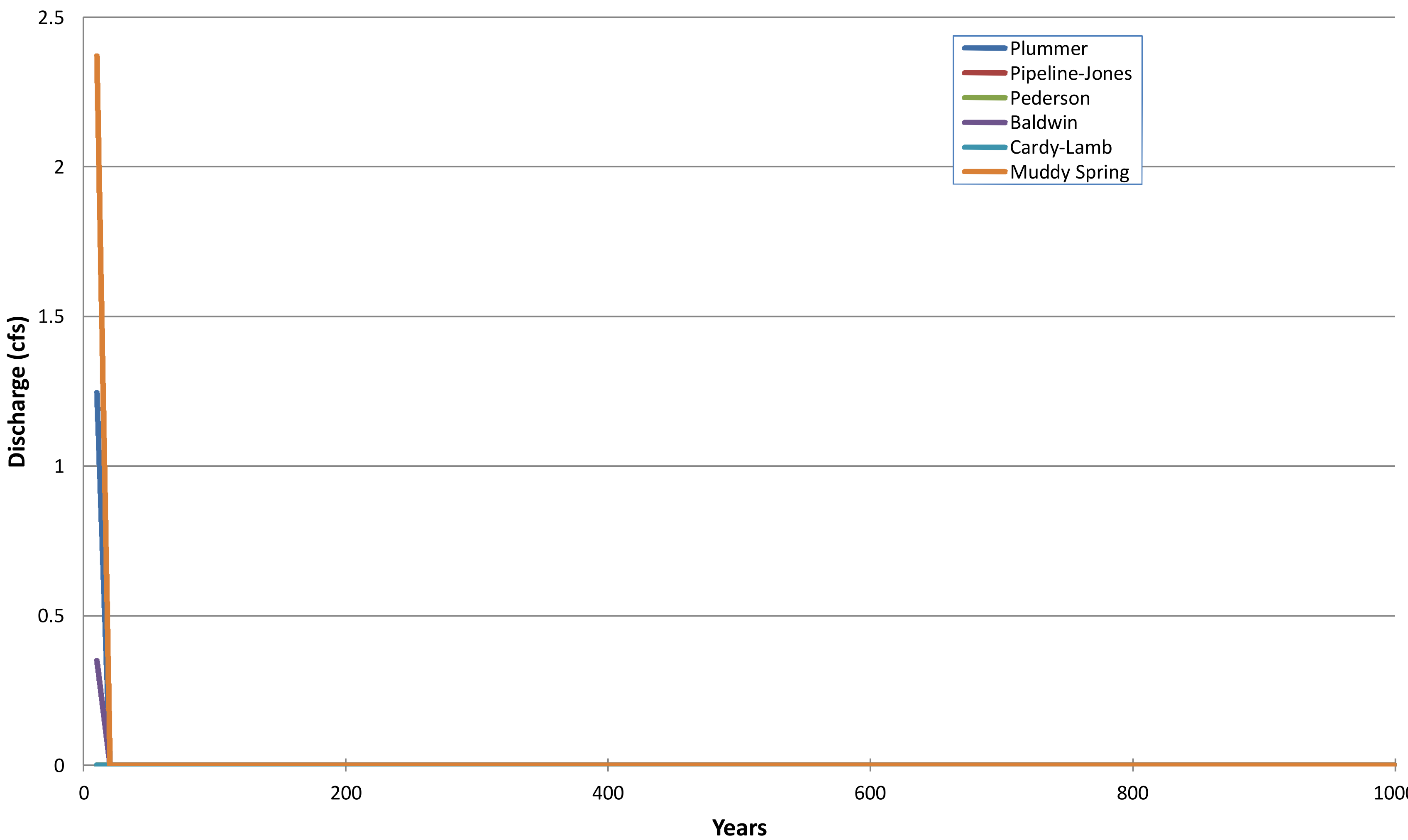
LOCATION: **Colorado Regional Groundwater Flow System**
Southeastern Nevada

TETRA TECH

FIGURE
3.7-1e

SE ROA 12481

JA_5243

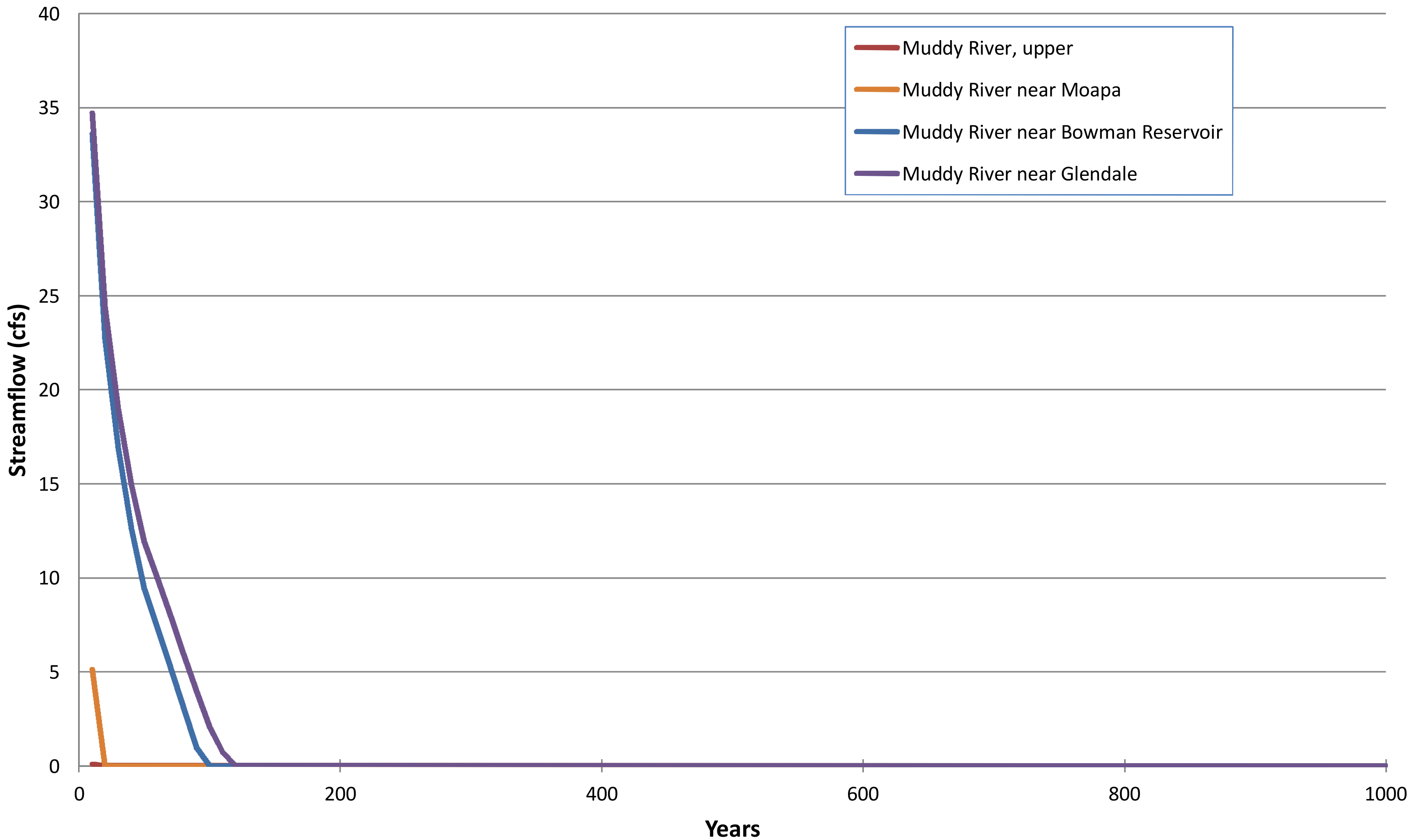


Simulated spring discharges in the Muddy River Springs area, Scenario 7

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.7-2a

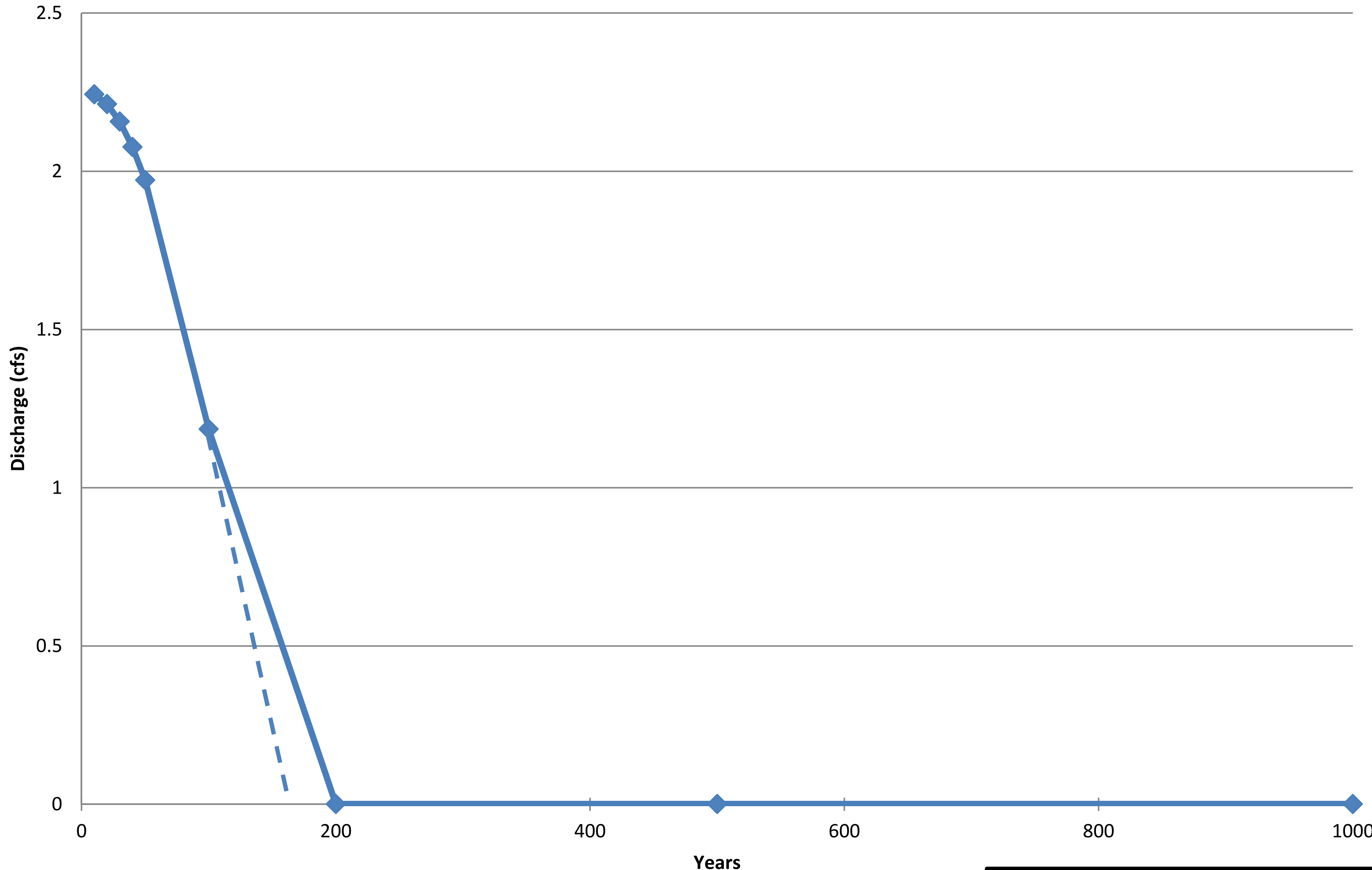


Simulated streamflow in the Muddy River, Scenario 7

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.7-2b

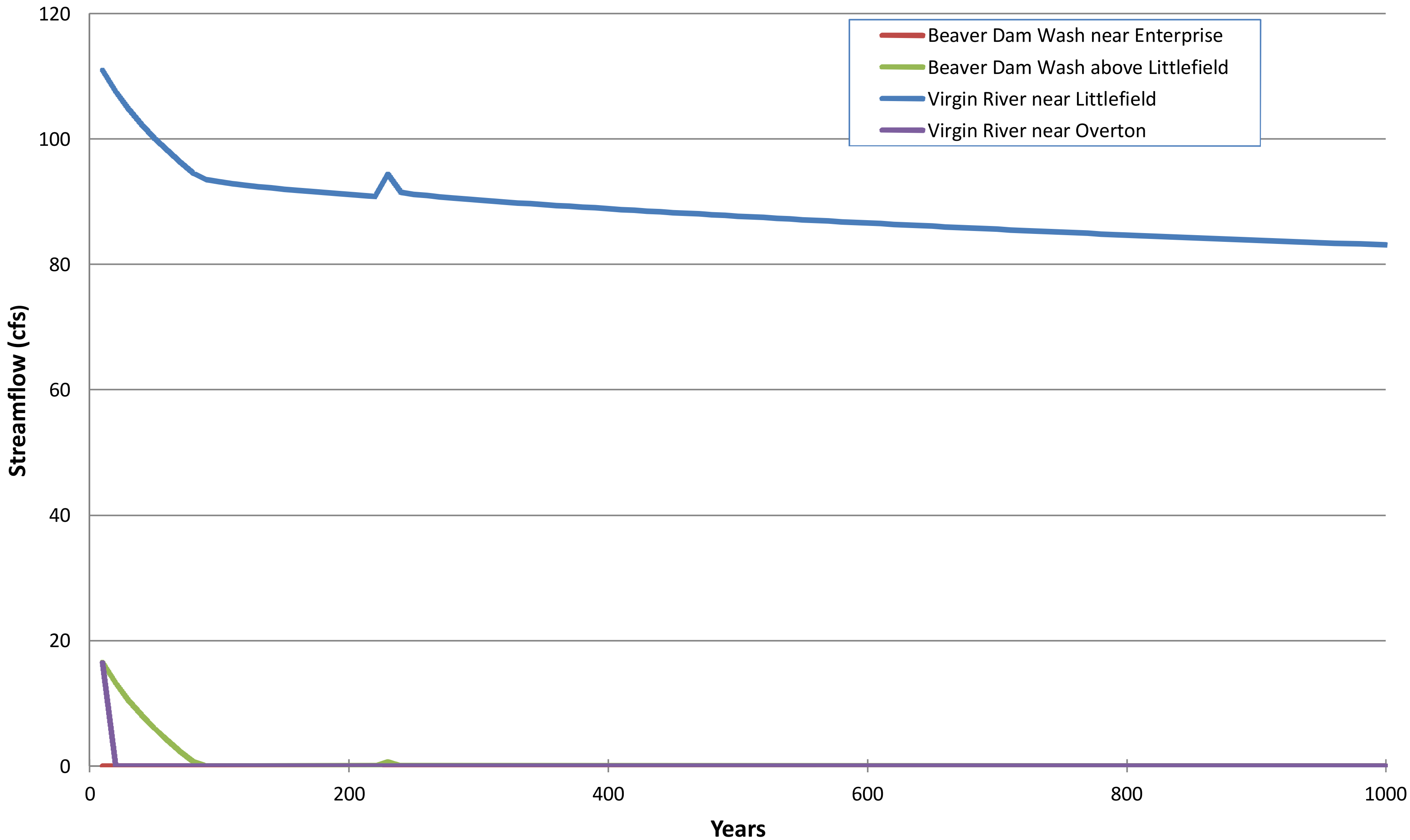


Simulated combined discharge from Rogers and Blue Point Springs, Scenario 7

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.7-2c



Simulated streamflow in Beaver Dam Wash and the Virgin River, Scenario 7

Lower Colorado River Flow System

TETRA TECH GEO

Figure 3.7-2d

SE ROA 12485

SE ROA 12486

ATTACHMENT I

Production Wells

TETRA TECH

SE ROA 12487

SE ROA 12488

PERMITS APPLICATION

TETRA TECH

SE ROA 12489

SE ROA 12490

GROUP NO	HYDROGRAPHIC AREA	GROUNDWATER DEVELOPER	Pumping Rate (af/yr))	PUMPING WELL(S)	QQ	QTR	SEC	TWN	RNG	Top Screen Elev (ft)	Bottom Screen Elev	PERMIT/APPLICATION NOS	PRIORITY/FILING DATE
1	Coyote Spring Valley (HA 210)	SNWA	4131	MX-5	SE	SE	23	13S	63E	2050.1	1548.1	77291-77306	
1	Coyote Spring Valley (HA 210)	CSI	1114	CSI-3	SW	SE	10	13S	63E	2282.4	1200.4	74094	
1	Coyote Spring Valley (HA 210)	CSI	482	CSI-4	NW	NE	5	13S	63E	2467.2	1144.2	74095	
1	Black Mountains (HA 215)	Nevada Cogeneration Associates	85	EPB-2	SE	SE	13	19S	63E	1684.7	1225.7	55269	1990
1	Black Mountains (HA 215)	Nevada Cogeneration Associates	632	EGV-3	NE	SE	13	19S	63E	1733.5	1480.5	58032	1990
1	Black Mountains (HA 215)	Nevada Cogeneration Associates	793	EBM-4	NE	SE	13	19S	63E	1825.9	1304.9	58031	1992
1	Garnet Valley (HA 216)	Las Vegas Valley Water District	89	Duke WS-1	NE	NE	15	18S	63E	1711.5	1563.5	54073, 79001-79010	1989
1	Garnet Valley (HA 216)	Las Vegas Valley Water District	307	Duke WS-2	NE	NE	15	18S	63E	1455.9	304.9	54073, 79001-79010	1989
1	Garnet Valley (HA 216)	Las Vegas Valley Water District	45	Mirant 1	NE	NE	5	18S	63E	2266.0	587.0	54073, 79001-79010	1989
1	Garnet Valley (HA 216)	Las Vegas Valley Water District	149	PW-WS1	NE	SE	5	18S	63E	2478.3	548.3	54073, 79001-79010	1989
1	Garnet Valley (HA 216)	Chemical Lime Company of AZ	78	US LIME-1						1532.2	1232.2		1997
1	Garnet Valley (HA 216)	Chemical Lime Company of AZ	62	US LIME-2	NE	NE	14	18S	63E	1814.9	1664.9	63261	1997
1	Garnet Valley (HA 216)	Dry Lake Water LLC	6	DRY LAKE GV-2	NE	NE	27	18S	63E	1573.0	1193.0	66784	2000
1	Garnet Valley (HA 216)	Republic Environmental Technologies		#1									
1	Garnet Valley (HA 216)	Republic Environmental Technologies	169	#2	NW	NE	19	18S	64E	1483.2	1403.2	67711-67720	2001
1	Garnet Valley (HA 216)	Republic Environmental Technologies	112	#5	SE	SE	7	18S	64E	1691.9	1451.9	67711-67720	2001
1	Garnet Valley (HA 216)	Republic Environmental Technologies	112	#6	SE	SW	19	18S	64E	2439.5	1349.5	67711-67720	2001
1	Garnet Valley (HA 216)	Nevada Power Company	120	RW-1	NW	SW	21	17S	64E	1572.3	1239.3	74399	2006
1	California Wash (HA 218)	Moapa Band of Paiutes	2	ECP-1	SE	NE	15	16S	64E	2171.8	1108.8	70257	1989
1	California Wash (HA 218)	Moapa Band of Paiutes	18	TH-1	SW	NW	23	16S	64E	1968.5	1106.0	76643	1989
1	Muddy River Springs Area (HA 219)	Moapa Valley WD	1681	Arrow Canyon Well	SE	NE	7	14S	65E	1748.3	1303.3	52520, 55450, 58269	1988
1	Muddy River Springs Area (HA 219)	Moapa Valley WD	155	Arrow Canyon Well #2	SE	NE	7	14S	65E	1399.5	1127.5	66043	2000
1	Muddy River Springs Area (HA 219)	Moapa Valley WD	1	MX-6	NE	NE	35	13S	64E	1831.0	1351.0	46932	1983
1	Muddy River Springs Area (HA 219)	Nevada Power Company	199	Lewis #1	NW	NE	8	14S	65E	1840.8	1740.8	24185-24186	1967
1	Muddy River Springs Area (HA 219)	Nevada Power Company	346	Lewis #2	SE	NE	8	14S	65E	1806.1	1760.1	22635	1965
1	Muddy River Springs Area (HA 219)	Nevada Power Company	233	Lewis #3	SW	NE	8	14S	65E	1867.9	1767.9	22633	1965
1	Muddy River Springs Area (HA 219)	Nevada Power Company	250	Lewis #4	NW	SE	8	14S	65E	1837.2	1737.2	22632	1965
1	Muddy River Springs Area (HA 219)	Nevada Power Company	353	Lewis #5	NW	SE	8	14S	65E	1831.0	1731.0	22636	1965
1	Muddy River Springs Area (HA 219)	Nevada Power Company	621	Perkins	NE	NE	22	14S	65E	1718.6	1618.6	50272	1986
1	Muddy River Springs Area (HA 219)	Nevada Power Company	653	Behmer	NW	NW	23	14S	65E	1678.5	1613.5	29296 & 29298	1975
1	Muddy River Springs Area (HA 219)	LDS	320	LDS East	NW	NW	15	14S	65E	1757.2	1680.2	50723-50733	1987
1	Muddy River Springs Area (HA 219)	LDS	476	LDS West	SW	SW	9	14S	65E	1803.6	1733.6	50723-50733	1987
1	Muddy River Springs Area (HA 219)	LDS	676	LDS Central	NE	NE	16	14S	65E	1763.2	1713.2	50723-50733	1987
1	Virgin River Valley (HA 222)	Virgin Valley WD	197	VVWD2						1608.7	1470.7		
1	Virgin River Valley (HA 222)	Virgin Valley WD	735	VVWD26						1347.3	847.3		
1	Virgin River Valley (HA 222)	Virgin Valley WD	1430	VVWD27						1472.3	232.3		
1	Virgin River Valley (HA 222)	Virgin Valley WD	567	VVWD28						1151.1	651.1		
1	Virgin River Valley (HA 222)	Virgin Valley WD	73	VVWD29						1478.2	458.2		
1	Virgin River Valley (HA 222)	Virgin Valley WD	111	VVWD30						520.7	-479.4		
1	Virgin River Valley (HA 222)	Virgin Valley WD	2089	VVWD31						278.2	-721.8		
1	Virgin River Valley (HA 222)	Virgin Valley WD	50	VVWD32						1737.5	877.5		
1	Virgin River Valley (HA 222)	Virgin Valley WD	1294	VVWD33						1355.3	15.3		
2	Kane Springs Valley (HA 206)	CSI	500	KPW-1	NE	SW	6	11S	64E			72220	
2	Kane Springs Valley (HA 206)	CSI	500	(none)	SE	SW	31	9S	65E			72219	
2	Coyote Spring Valley (HA 210)	SNWA	9000	MX-5	SE	SW	14	13S	63E	2050.1	1548.1	77291-77306	
2	Coyote Spring Valley (HA 210)	CSI	1500	CSI-2	SE	SW	14	13S	63E	1930.0	1204.0	70429	
2	Coyote Spring Valley (HA 210)	CSI	1600	CSI-1	SW	SE	22	13S	63E	2226.6	1396.6	70430	
2	Coyote Spring Valley (HA 210)	CSI	1000	CSI-3	SW	SE	10	13S	63E	2282.4	1200.4	74094	
2	Coyote Spring Valley (HA 210)	CSI	500	CSI-4	NW	NE	5	13S	63E	2467.2	1144.2	74095	
2	Coyote Spring Valley (HA 210)	Nevada Power Company	2500	RW-2	NE	NE	26	13S	63E	2150.1	1500.1	77164	
2	Black Mountains (HA 215)	Nevada Cogeneration Associates	95	EPB-2	SE	SE	13	19S	63E	1684.7	1225.7	55269	1990
2	Black Mountains (HA 215)	Nevada Cogeneration Associates	695	EGV-3	NE	SE	13	19S	63E	1733.5	1480.5	58032	1990
2	Black Mountains (HA 215)	Nevada Cogeneration Associates	875	EBM-4	NE	SE	13	19S	63E	1825.9	1304.9	58031	1992

GROUP NO	HYDROGRAPHIC AREA	GROUNDWATER DEVELOPER	Pumping Rate (af/yr))	PUMPING WELL(S)	QQ	QTR	SEC	TWN	RNG	Top Screen Elev (ft)	Bottom Screen Elev	PERMIT/APPLICATION NOS	PRIORITY/FILING DATE
2	Garnet Valley (HA 216)	SNWA	325	Duke WS-1	NE	NE	15	18S	63E	1711.5	1563.5	54073, 79001-79010	1989
2	Garnet Valley (HA 216)	SNWA	1120	Duke WS-2	NE	NE	15	18S	63E	1455.9	304.9	54073, 79001-79010	1989
2	Garnet Valley (HA 216)	SNWA	165	Mirant 1	NE	NE	5	18S	63E	2266.0	587.0	54073, 79001-79010	1989
2	Garnet Valley (HA 216)	SNWA	545	PW-WS1	NE	SE	5	18S	63E	2478.3	548.3	54073, 79001-79010	1989
2	Garnet Valley (HA 216)	SNWA	45	RW-1	NW	SW	21	17S	64E	1572.3	1239.3	54073, 79001-79010	1989
2	Garnet Valley (HA 216)	Georgia Pacific Corp	144	EBA-1	SE	NE	34	18S	63E	2418.0	833.2	1991	56855
2	Garnet Valley (HA 216)	Chemical Lime Company of AZ	0	US LIME-1						1532.2	1232.2		
2	Garnet Valley (HA 216)	Chemical Lime Company of AZ	158	4(none)	SW	SE	23	18S	63E			64880	1997
2	Garnet Valley (HA 216)	Chemical Lime Company of AZ	126	US LIME-2	NE	NE	14	18S	63E	1814.9	1664.9	63261	1997
2	Garnet Valley (HA 216)	Dry Lake Water LLC	157	DRY LAKE GV-2	NE	NE	27	18S	63E	1573.0	1193.0	66784	2000
2	Garnet Valley (HA 216)	Republic Environmental Technologies	0	#1									
2	Garnet Valley (HA 216)	Republic Environmental Technologies	202	#2	NW	NE	19	18S	64E	1483.2	1403.2	67711-67720	2001
2	Garnet Valley (HA 216)	Republic Environmental Technologies	133	#5	SE	SE	7	18S	64E	1691.9	1451.9	67711-67720	2001
2	Garnet Valley (HA 216)	Republic Environmental Technologies	133	#6	SE	SW	19	18S	64E	2439.5	1349.5	67711-67720	2001
2	Garnet Valley (HA 216)	Nevada Power Company	75	RW-1	NW	SW	21	17S	64E	1572.3	1239.3	74399	2006
2	Hidden Valley (North) (HA 217)	Nevada Power Company	0	(none)	SW	SW	25	16S	62E			54074	1989
2	California Wash (HA 218)	Nevada Power Company	362	(none)	SE	SW	5	15S	66E			50559	1987
2	California Wash (HA 218)	Moapa Band of Paiutes	1000	ECP-1	SE	NE	15	16S	64E	2171.8	1108.8	70257	1989
2	California Wash (HA 218)	Moapa Band of Paiutes	500	ECP-2	NE	NE	15	16S	64E	2094.7	1005.7	70258	1989
2	California Wash (HA 218)	Moapa Band of Paiutes	500	ECP-3	NE	NE	15	16S	64E	2202.4	776.4	70259	1989
2	California Wash (HA 218)	Moapa Band of Paiutes	500	TH-1	SW	NW	23	16S	64E	1968.5	1106.0	76643	1989
2	Muddy River Springs Area (HA 219)	Moapa Valley WD	6215	Arrow Canyon Well	SE	NE	7	14S	65E	1748.3	1303.3	52520, 55450, 58269	1988
2	Muddy River Springs Area (HA 219)	Moapa Valley WD	573	Arrow Canyon Well #2	SE	NE	7	14S	65E	1399.5	1127.5	66043	2000
2	Muddy River Springs Area (HA 219)	Moapa Valley WD	4	MX-6	NE	NE	35	13S	64E	1831.0	1351.0	46932	1983
2	Muddy River Springs Area (HA 219)	Nevada Power Company	680	Lewis #1	NW	NE	8	14S	65E	1840.8	1740.8	24185-24186	1967
2	Muddy River Springs Area (HA 219)	Nevada Power Company	616	Lewis #2	SE	NE	8	14S	65E	1806.1	1760.1	22635	1965
2	Muddy River Springs Area (HA 219)	Nevada Power Company	680	Lewis #3	SW	NE	8	14S	65E	1867.9	1767.9	22633	1965
2	Muddy River Springs Area (HA 219)	Nevada Power Company	680	Lewis #4	NW	SE	8	14S	65E	1837.2	1737.2	22632	1965
2	Muddy River Springs Area (HA 219)	Nevada Power Company	680	Lewis #5	NW	SE	8	14S	65E	1831.0	1731.0	22636	1965
2	Muddy River Springs Area (HA 219)	Nevada Power Company	905	Perkins	NE	NE	22	14S	65E	1718.6	1618.6	50272	1986
2	Muddy River Springs Area (HA 219)	Nevada Power Company	325	Behmer	NW	NW	23	14S	65E	1678.5	1613.5	29296 & 29298	1975
2	Muddy River Springs Area (HA 219)	LDS	675	LDS East	NW	NW	15	14S	65E	1757.2	1680.2	50723-50733	1987
2	Muddy River Springs Area (HA 219)	LDS	655	LDS West	SW	SW	9	14S	65E	1803.6	1733.6	50723-50733	1987
2	Muddy River Springs Area (HA 219)	LDS	1000	LDS Central	NE	NE	16	14S	65E	1763.2	1713.2	50723-50733	1987
2	Tule Desert (HA 221)	Lincoln County/Vidler	2100	PW-1	SW	NW	4	10S	69E			66932	
2	Tule Desert (HA 221)	Lincoln County/Vidler	7240	PW-2	SE	SW	6	10S	69E			81619	
2	Virgin River Valley (HA 222)	Virgin Valley WD	369	VVWD2						1608.7	1470.7		
2	Virgin River Valley (HA 222)	Virgin Valley WD	1378	VVWD26						1347.3	847.3		
2	Virgin River Valley (HA 222)	Virgin Valley WD	2681	VVWD27						1472.3	232.3		
2	Virgin River Valley (HA 222)	Virgin Valley WD	1062	VVWD28						1151.1	651.1		
2	Virgin River Valley (HA 222)	Virgin Valley WD	137	VVWD29						1478.2	458.2		
2	Virgin River Valley (HA 222)	Virgin Valley WD	208	VVWD30						520.7	-479.4		
2	Virgin River Valley (HA 222)	Virgin Valley WD	3917	VVWD31						278.2	-721.8		
2	Virgin River Valley (HA 222)	Virgin Valley WD	93	VVWD32						1737.5	877.5		
2	Virgin River Valley (HA 222)	Virgin Valley WD	2426	VVWD33						1355.3	15.3		
3	Coyote Spring Valley	SNWA	4344	CSV_S_3_1	SE	SW	5	13S	63E			54055	1989
3	Coyote Spring Valley	SNWA	4344	CSV_S_3_2	SE	SE	32	13S	63E			54056	1989
3	Coyote Spring Valley	SNWA	4344	CSV_S_3_3	SE	NW	16	14S	63E			54057	1989
3	Coyote Spring Valley	SNWA	7240	CSV_S_3_4	NE	NE	1	13S	63E			54058	1989
3	Coyote Spring Valley	SNWA	7240	CSV_S_3_5	NW	NW	19	13S	64E			54059	1989
3	California Wash	Moapa Band of Paiutes	7240	CW_MBP_3_1	NW	NW	16	15S	64E			54076	1989
3	Garnet Valley	Bonneville Nevada Corp.	1665	GV_BNC_3_1	SE	NE	34	18S	63E			54130	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_1	NE	SE	11	14S	69E			54078	1989

GROUP NO	HYDROGRAPHIC AREA	GROUNDWATER DEVELOPER	Pumping Rate (af/yr))	PUMPING WELL(S)	QQ	QTR	SEC	TWN	RNG	Top Screen Elev (ft)	Bottom Screen Elev	PERMIT/APPLICATION NOS	PRIORITY/FILING DATE
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_2	NE	NE	14	14S	69E			54079	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_3	NW	NW	14	14S	69E			54080	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_4	NE	SE	15	14S	69E			54081	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_5	SE	SW	15	14S	69E			54082	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_6	SW	SE	16	14S	69E			54083	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_7	SE	NE	21	14S	69E			54084	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_8	SE	NW	21	14S	69E			54085	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_9	SW	SE	21	14S	69E			54086	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_10	SW	NW	28	14S	69E			54087	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_11	NE	NE	29	14S	69E			54088	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_12	SE	SE	29	14S	69E			54089	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_13	NW	NW	32	14S	69E			54090	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_14	NW	SW	31	14S	69E			54091	1989
3	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_3_15	SE	SE	31	14S	69E			54092	1989
3	Virgin River Valley	Virgin Valley WD	724	VR_VVWD_3_16	SE	NE	32	13S	70E			54175	1989
4	Virgin River Valley	Virgin Valley WD	724	VR_VVWD_4_1	NE	SE	26	13S	70E			54681	1990
4	Virgin River Valley	Virgin Valley WD	14480	VR_VVWD_4_2	SE	SW	21	05S	71E			54682	1990
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_3	NW	NE	33	05S	71E			54683	1990
4	Virgin River Valley	Virgin Valley WD	14480	VR_VVWD_4_4	SE	NE	33	05S	71E			54684	1990
4	Virgin River Valley	Virgin Valley WD	3620	VR_VVWD_4_5	NE	NE	4	07S	71E			54689	1990
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_6	SW	NW	13	08S	70E			54690	1990
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_7	SE	SW	32	08S	71E			54691	1990
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_8	NW	NE	4	09S	71E			54692	1990
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_9	NE	SW	8	09S	71E			54693	1990
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_10	SE	SE	28	09S	71E			54694	1990
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_11	SW	SW	31	10S	71E			54695	1990
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_12	SW	NW	21	05S	71E			54696	1990
4	Virgin River Valley	Virgin Valley WD	3620	VR_VVWD_4_13	SE	SW	21	11S	71E			54697	1990
4	Virgin River Valley	Virgin Valley WD	3620	VR_VVWD_4_14	NW	NW	34	11S	71E			54698	1990
4	California Wash	Nevada Power Company	2534	CW_NPC_4_1	SE	NW	7	15S	66E			54634	1990
4	Garnet Valley	James Adams	0	GV_JA_4_1	NW	NE	11	18S	63E			57011	1991
4	Virgin River Valley	Virgin Valley WD	1448	VR_VVWD_4_15	SW	NW	22	15S	70E			55943	1991
4	Virgin River Valley	Virgin Valley WD	1448	VR_VVWD_4_16	SW	SW	14	15S	70E			55944	1991
4	Virgin River Valley	Virgin Valley WD	3620	VR_VVWD_4_17	SE	SW	8	13S	71E			56793	1991
4	Virgin River Valley	Virgin Valley WD	3620	VR_VVWD_4_18	NW	NW	16	13S	71E			56828	1991
4	Virgin River Valley	Virgin Valley WD	3620	VR_VVWD_4_19	NE	NW	9	13S	71E			56829	1991
4	Virgin River Valley	Virgin Valley WD	7240	VR_VVWD_4_20	NE	SE	12	13S	70E			56959	1991
4	Black Mountains	Nevada Cogeneration Co	555	BM_NCG_4_1	NE	SE	13	19S	63E			58592	1993
4	Black Mountains	Nevada Cogeneration Co	555	BM_NCG_4_2	NE	SE	13	19S	63E			58593	1993
4	Black Mountains	Nevada Cogeneration Co	555	BM_NCG_4_3	SE	SE	13	19S	63E			58594	1993
4	Muddy River Springs Area	Moapa Valley WD	7240	MRS_MVWD_4_1	NE	NE	33	13S	64E			59369	1993
4	Lower Moapa Valley	Moapa Valley WD	7240	LMV_MVWD_4_1	NW	NW	10	13S	67E			59368	1993
4	Lower Moapa Valley	Moapa Valley WD	3620	LMV_MVWD_4_2	SW	NW	32	15S	67E			59370	1993
4	Lower Moapa Valley	Moapa Valley WD	3620	LMV_MVWD_4_3	SE	SE	19	15S	67E			59371	1993
5	Hidden Valley (North)	Nevada Power Company	4033	HV_NPC_5_1	NW	SE	27	15S	63E			62997	1997
5	Hidden Valley (North)	Nevada Power Company	16131	HV_NPC_5_2	NW	SE	29	16S	63E			62999	1997
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_1	NE	SE	20	13S	70E			63292	1997
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_2	SW	SE	19	13S	70E			63293	1997
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_3	NE	NE	5	13S	71E			63294	1997
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_4	NE	NE	18	14S	70E			63295	1997
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_5	NW	NE	28	13S	71E			63296	1997
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_6	SE	NW	29	13S	71E			63297	1997
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_1	SE	SW	23	12S	63E			63272	1997

GROUP NO	HYDROGRAPHIC AREA	GROUNDWATER DEVELOPER	Pumping Rate (af/yr))	PUMPING WELL(S)	QQ	QTR	SEC	TWN	RNG	Top Screen Elev (ft)	Bottom Screen Elev	PERMIT/APPLICATION NOS	PRIORITY/FILING DATE
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_2	SE	NE	25	12S	63E			63273	1997
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_3	NE	NE	15	13S	63E			63274	1997
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_4	SE	SE	23	12S	63E			63275	1997
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_5	NE	SW	36	11S	63E			63276	1997
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_6	NW	SW	12	13S	63E			63867	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_7	NW	SW	13	13S	63E			63868	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_8	SW	SW	11	13S	63E			63869	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_9	NE	SW	7	13S	64E			63870	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_10	NW	SW	18	13S	64E			63871	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_11	SE	SW	11	12S	63E			63872	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_12	SW	SW	25	12S	63E			63873	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_13	SW	SW	13	12S	63E			63874	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_14	SW	SW	36	11S	63E			63875	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_15	NE	NE	22	11S	63E			63876	1998
5	5Coyote Spring Valley	5Dry Lake Water	4000	CSV_DLW_5_1	NE	SE	28	14S	63E			64039	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_16	NW	SE	36	12S	63E			64186	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_17	SW	SE	35	12S	63E			64187	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_18	NE	SW	34	12S	63E			64188	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_19	NE	SW	27	12S	63E			64189	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_20	NW	NE	25	12S	63E			64190	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_21	NW	SW	24	12S	63E			64191	1998
5	Coyote Spring Valley	CSI	7240	CSV_CSI_5_22	NE	SW	26	12S	63E			64192	1998
5	5Hidden Valley (North)	5Dry Lake Water	4000	HV_DLW_5_1	SW	SE	21	17S	63E			66162	1998
5	5Black Mountains	5Dry Lake Water	4000	BM_DLW_5_1	NE	NW	36	19S	63E			64041	1998
5	5Garnet Valley	5Dry Lake Water	2000	GV_DLW_5_1	NE	NE	14	16S	63E			62996	1998
5	5Garnet Valley	5Dry Lake Water	2000	GV_DLW_5_2	SW	NE	11	16S	63E			62998	1998
5	5California Wash	5Dry Lake Water	4000	CW_DLW_5_1	NE	NE	33	17S	65E			64037	1998
5	Garnet Valley	Nevada Power Company	807	GV_NPC_5_1	SE	SE	9	17S	64E			64222	1998
5	Garnet Valley	Nevada Power Company	807	GV_NPC_5_2	SW	SW	10	17S	64E			64223	1998
5	Virgin River Valley	Lincoln County WD	7240	VR_LCWD_5_1	SE	NE	17	11S	69E			64694	1998
5	Virgin River Valley	Lincoln County WD	7240	VR_LCWD_5_2	NE	SE	32	12S	71E			64695	1998
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_1	NE	NE	5	13S	71E			64793	1999
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_2	NE	SE	35	10S	69E			64974	1999
5	Virgin River Valley	Virgin Valley WD	4344	VR_VVWD_5_3	NE	SW	26	10S	69E			64795	1999
5	Tule Desert	Virgin Valley WD	4344	TD_VVWD_5_1	NE	NW	32	10S	69E			64796	1999
5	Tule Desert	Virgin Valley WD	4344	TD_VVWD_5_2	SE	NE	25	10S	68E			64797	1999
5	Tule Desert	Virgin Valley WD	4344	TD_VVWD_5_3	SE	NE	24	10S	68E			64798	1999
6	California Wash	Moapa Paiutes	1300	ECP-2	NE	NE	15	16S	64E	2094.7	1005.7	65948, 66473	2000
6	California Wash	Moapa Paiutes	2600	ECP-1	SE	NE	15	16S	64E	2171.8	1108.8	65946, 65947, 65949, 66475	2000
6	California Wash	Moapa Paiutes	600	CW_MBP_6_1	SE	SE	15	16S	64E			65944	2000
6	California Wash	Moapa Paiutes	600	CW_MBP_6_2	SW	SE	15	16S	64E			66474	2000
6	California Wash	Moapa Paiutes	600	CW_MBP_6_3	NE	NE	22	16S	64E			65945	2000
6	California Wash	Moapa Paiutes	1300	CW_MBP_6_4	SE	SW	34	16S	64E			65954, 65955	2000
6	California Wash	Moapa Paiutes	724	TH-1	SW	NW	23	16S	64E	1968.5	1106.0	66476	2000
6	Clover Valley	Lincoln County/Vidler	3620	CV_LCV_6_1	SW	SE	2	06S	68E			67964	2001
6	Clover Valley	Lincoln County/Vidler	3620	CV_LCV_6_2	NE	SW	6	06S	69E			67965	2001
6	Clover Valley	Lincoln County/Vidler	3620	CV_LCV_6_3	NE	SW	11	06S	69E			67966	2001
6	Clover Valley	Lincoln County/Vidler	3620	CV_LCV_6_4	NE	NE	3	06S	70E			67967	2001
6	5Coyote Spring Valley	5Dry Lake Water	4000	CSV_DLW_6_1	NE	SE	28	14S	63E			67892	2001
6	5Black Mountains	5Dry Lake Water	4000	BM_DLW_6_1	NE	NW	36	19S	63E			67893	2001
6	5Garnet Valley	5Dry Lake Water	4000	GV_DLW_6_1	NE	NE	27	18S	63E			67894	2001
6	5Hidden Valley (North)	5Dry Lake Water	4000	HV_DLW_6_1	SW	SE	21	17S	63E			67895	2001
6	5California Wash	5Dry Lake Water	4000	CW_DLW_6_1	NE	NW	4	19S	64E			67896	2001

GROUP NO	HYDROGRAPHIC AREA	GROUNDWATER DEVELOPER	Pumping Rate (af/yr))	PUMPING WELL(S)	QQ	QTR	SEC	TWN	RNG	Top Screen Elev (ft)	Bottom Screen Elev	PERMIT/APPLICATION NOS	PRIORITY/FILING DATE
7	Kane Springs Valley	Lincoln County WD	4344	KSV_LCWD_7_1	SW	SE	25	08S	65E			74147	2006
7	Kane Springs Valley	Lincoln County WD	4344	KSV_LCWD_7_2	SE	SW	31	09S	65E			74148	2006
7	Kane Springs Valley	Lincoln County WD	4344	KSV_LCWD_7_3	SE	SW	6	11S	64E			74149	2006
7	Kane Springs Valley	Lincoln County WD	4344	KSV_LCWD_7_4	SE	SW	11	09S	65E			74150	2006
7	Tule Desert	Lincoln County/Vidler	3620	TD_LCV_7_1	SE	SW	6	10S	69E			76285	2007
7	Tule Desert	Lincoln County/Vidler	3620	TD_LCV_7_2	SW	NW	2	09S	69E			76286	2007
7	Tule Desert	Lincoln County/Vidler	3620	TD_LCV_7_3	NW	SE	27	09S	68E			76287	2007
7	Tule Desert	Lincoln County/Vidler	3620	TD_LCV_7_4	SW	SW	1	08S	69E			76288	2007
7	Tule Desert	Lincoln County/Vidler	3620	TD_LCV_7_5	NE	NW	31	10S	69E			76289	2007
7	Tule Desert	Lincoln County/Vidler	3620	TD_LCV_7_6	NW	NE	29	09S	69E			76290	2007

SE ROA 12496

MODEL COORDINATES

TETRA TECH

SE ROA 12497

SE ROA 12498

Group	Well	Pumping Rate (af/yr)	UTM East (m)	UTM North (m)	LSE (ft)	Top Screen Elev (ft)	Bottom Screen Elev. (ft)	Row	Col	Top Layer	Bottom Layer	HGU
1	MX-5	4131	688163	4074022	2176	2050	1548	144	67			
1	CSI-3	1114	685892	4077334	2332	2282	1200	131	58			
1	CSI-4	482	682445	4079988	2517	2467	1144	121	44			
1	EPB-2	85	689628	4018599	2440	1685	1226	301	73			
1	EGV-3	632	689784	4018826	2436	1734	1481	301	74			
1	EBM-4	793	689784	4018826	2434	1826	1305	301	74			
1	Duke WS-1	89	686264	4028981	2249	1712	1564	294	60			
1	Duke WS-2	307	686264	4028981	2249	1456	305	294	60			
1	Mirant 1	45	683194	4032122	2566	2266	587	292	47			
1	PW-WS1	149	682733	4031264	2528	2478	548	293	45			
1	US LIME-1	78	690310	4030549	2072	1532	1232	293	76			
1	US LIME-2	62	688253	4028887	2165	1815	1665	294	68			
1	DRY LAKE GV-2	6	686306	4025493	2425	1573	1193	297	60			
1	#2	169	690674	4027890	2366	1483	1403	295	77			
1	#5	112	691053	4029626	2152	1692	1452	294	79			
1	#6	112	690552	4026318	2499	2439	1349	296	77			
1	RW-1	120	693007	4036449	2072	1572	1239	289	87			
1	ECP-1	2	696808	4046393	2234	2172	1109	255	102			
1	TH-1	18	697313	4044763	2206	1969	1106	261	104			
1	Arrow Canyon Well	1681	701103	4067768	1868	1748	1303	169	119			
1	Arrow Canyon Well #2	155	701103	4067768	1870	1400	1128	169	119			
1	MX-6	1	697482	4071381	2288	1831	1351	155	104			
1	Lewis #1	199	702182	4068043	1841	1841	1741	168	123			
1	Lewis #2	346	702339	4067921	1826	1806	1760	169	124			
1	Lewis #3	233	701956	4068021	1868	1868	1768	168	122			
1	Lewis #4	250	702196	4067485	1837	1837	1737	171	123			
1	Lewis #5	353	702196	4067485	1831	1831	1731	171	123			
1	Perkins	621	705772	4065009	1744	1719	1619	180	138			
1	Behmer	653	706110	4064883	1729	1679	1614	181	139			
1	LDS East	320	704558	4066397	1757	1757	1680	175	133			
1	LDS West	476	702825	4066886	1814	1804	1734	173	126			
1	LDS Central	676	704193	4066346	1763	1763	1713	175	131			
1	VVWD2	197	759660	4074456	1676	1609	1471	143	192			
1	VVWD26	735	761450	4078650	1647	1347	847	126	193			
1	VVWD27	1430	759511	4078740	1642	1472	232	126	192			
1	VVWD28	567	757413	4078028	1651	1151	651	128	190			
1	VVWD29	73	755318	4071219	1678	1478	458	156	189			
1	VVWD30	111	762985	4066979	2821	521	-479	173	194			
1	VVWD31	2089	762985	4073582	1878	278	-722	146	194			
1	VVWD32	50	758997	4086619	2136	1738	878	94	191			
1	VVWD33	1294	761445	4086857	2055	1355	15	93	193			
2	KPW-1	500	689961	4098665	-1	-1	-1	52	74	1	6	PC4
2	KSV_CSI_2_1	500	699543	4109817	-1	-1	-1	205	158	1	6	CAU,QCD
2	MX-5	9000	687083	4075781	2176	2050	1548	137	63			
2	CSI-2	1500	687083	4075781	2210	1930	1204	137	63			
2	CSI-1	1600	686122	4074262	2277	2227	1397	143	59			
2	CSI-3	1000	685892	4077334	2332	2282	1200	131	58			
2	CSI-4	500	682445	4079988	2517	2467	1144	121	44			
2	RW-2	2500	687941	4073885	2200	2150	1500	145	66			

SE ROA 12499

Group	Well	Pumping Rate (af/yr)	UTM East (m)	UTM North (m)	LSE (ft)	Top Screen Elev (ft)	Bottom Screen Elev. (ft)	Row	Col	Top Layer	Bottom Layer	HGU
2	EPB-2	95	689628	4018599	2440	1685	1226	301	73			
2	EGV-3	695	689784	4018826	2436	1734	1481	301	74			
2	EBM-4	875	689784	4018826	2434	1826	1305	301	74			
2	Duke WS-1	325	686264	4028981	2249	1712	1564	294	60			
2	Duke WS-2	1120	686264	4028981	2249	1456	305	294	60			
2	Mirant 1	165	683194	4032122	2566	2266	587	292	47			
2	PW-WS1	545	682733	4031264	2528	2478	548	293	45			
2	RW-1	45	693007	4036449	2072	1572	1239	289	87			
2	EBA-1	144	686592	4023911	2431	2418	833	298	61			
2	US LIME-1	0	690310	4030549	2072	1532	1232	293	76			
2	GV_CLC_2_1	158	687405	4027035	-1	-1	-1	295	64	2	6	PC4
2	US LIME-2	126	688253	4028887	2165	1815	1665	294	68			
2	DRY LAKE GV-2	157	686306	4025493	2425	1573	1193	297	60			
2	#2	202	690674	4027890	2366	1483	1403	295	77			
2	#5	133	691053	4029626	2152	1692	1452	294	79			
2	#6	133	690552	4026318	2499	2439	1349	296	77			
2	RW-1	75	693007	4036449	2072	1572	1239	289	87			
2	HV_NPC_2_1	0	679721	4042115	-1	-1	-1	272	33	1	6	PC4
2	CW_NPC_2_1	362	711724	4058934	-1	-1	-1	205	158	1	8	CAU,QCD
2	ECP-1	1000	696808	4046393	2234	2172	1109	255	102			
2	ECP-2	500	696714	4046984	2234	2095	1006	253	101			
2	ECP-3	500	696714	4046984	2276	2202	776	253	101			
2	TH-1	500	697313	4044763	2206	1969	1106	261	104			
2	Arrow Canyon Well	6215	701103	4067768	1868	1748	1303	169	119			
2	Arrow Canyon Well #2	573	701103	4067768	1870	1400	1128	169	119			
2	MX-6	4	697482	4071381	2288	1831	1351	155	104			
2	Lewis #1	680	702182	4068043	1841	1841	1741	168	123			
2	Lewis #2	616	702339	4067921	1826	1806	1760	169	124			
2	Lewis #3	680	701956	4068021	1868	1868	1768	168	122			
2	Lewis #4	680	702196	4067485	1837	1837	1737	171	123			
2	Lewis #5	680	702196	4067485	1831	1831	1731	171	123			
2	Perkins	905	705772	4065009	1744	1719	1619	180	138			
2	Behmer	325	706110	4064883	1729	1679	1614	181	139			
2	LDS East	675	704558	4066397	1757	1757	1680	175	133			
2	LDS West	655	702825	4066886	1814	1804	1734	173	126			
2	LDS Central	1000	704193	4066346	1763	1763	1713	175	131			
2	PW-1	2100	741241	4109052	-1	-1	-1	44	179	1	6	MU1
2	PW-2	7240	738290	4108210	-1	-1	-1	44	177	6	8	PC1
2	VVWD2	369	759660	4074456	1676	1609	1471	143	192			
2	VVWD26	1378	761450	4078650	1647	1347	847	126	193			
2	VVWD27	2681	759511	4078740	1642	1472	232	126	192			
2	VVWD28	1062	757413	4078028	1651	1151	651	128	190			
2	VVWD29	137	755318	4071219	1678	1478	458	156	189			
2	VVWD30	208	762985	4066979	2821	521	-479	173	194			
2	VVWD31	3917	762985	4073582	1878	278	-722	146	194			
2	VVWD32	93	758997	4086619	2136	1738	878	94	191			
2	VVWD33	2426	761445	4086857	2055	1355	15	93	193			
3	CSV_S_3_1	4344	682238	4078963	-1	-1	-1	125	43	1	6	PC4
3	CSV_S_3_2	4344	683231	4070947	-1	-1	-1	157	47	2	6	PC4

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Group	Well	Pumping Rate (af/yr)	UTM East (m)	UTM North (m)	LSE (ft)	Top Screen Elev (ft)	Bottom Screen Elev. (ft)	Row	Col	Top Layer	Bottom Layer	HGU
3	CSV_S_3_3	4344	684552	4065360	-1	-1	-1	179	53	6	8	PC4
3	CSV_S_3_4	7240	689342	4080522	-1	-1	-1	118	72	1	6	PC4
3	CSV_S_3_5	7240	690473	4075060	-1	-1	-1	140	76	1	6	PC4
3	CW_MBP_3_1	7240	694468	4055878	-1	-1	-1	217	92	1	6	PC4
3	GV_BNC_3_1	1665	686592	4023911	-1	-1	-1	298	61	1	6	PC4
3	VR_VVWD_3_1	4344	746521	4068213	-1	-1	-1	168	183	1	8	CAU
3	VR_VVWD_3_2	4344	746537	4067408	-1	-1	-1	171	183	1	8	CAU
3	VR_VVWD_3_3	4344	745326	4067373	-1	-1	-1	171	182	1	8	CAU
3	VR_VVWD_3_4	4344	744937	4066557	-1	-1	-1	174	182	1	8	CAU
3	VR_VVWD_3_5	4344	744137	4066132	-1	-1	-1	176	181	1	8	CAU
3	VR_VVWD_3_6	4344	742855	4066265	-1	-1	-1	175	180	1	8	CAU
3	VR_VVWD_3_7	4344	743346	4065303	-1	-1	-1	179	181	1	8	CAU
3	VR_VVWD_3_8	4344	742540	4065279	-1	-1	-1	179	180	1	8	CAU
3	VR_VVWD_3_9	4344	742960	4064486	-1	-1	-1	183	180	1	8	CAU
3	VR_VVWD_3_10	4344	742171	4063655	-1	-1	-1	186	180	1	8	CAU
3	VR_VVWD_3_11	4344	741760	4064048	-1	-1	-1	184	180	1	8	CAU
3	VR_VVWD_3_12	4344	741782	4062837	-1	-1	-1	189	180	2	8	CAU
3	VR_VVWD_3_13	4344	740574	4062416	-1	-1	-1	191	179	1	8	CAU
3	VR_VVWD_3_14	4344	739968	4061477	-1	-1	-1	195	178	1	8	CAU
3	VR_VVWD_3_15	4344	740090	4061372	-1	-1	-1	195	179	1	8	CAU
3	VR_VVWD_3_16	724	750976	4072362	-1	-1	-1	151	186	1	8	CAU
4	VR_VVWD_4_1	724	756012	4073315	-1	-1	-1	147	189	2	8	CAU
4	VR_VVWD_4_2	14480	759648	4153473	-1	-1	-1	14	192	1	6	TVC
4	VR_VVWD_4_3	7240	760121	4151477	-1	-1	-1	16	192	1	6	TVC
4	VR_VVWD_4_4	14480	760458	4151042	-1	-1	-1	16	192	1	6	TVC
4	VR_VVWD_4_5	3620	760867	4140223	-1	-1	-1	23	192	1	8	TVC, MU1
4	VR_VVWD_4_6	7240	755159	4126886	-1	-1	-1	32	189	1	8	KT1, PR1
4	VR_VVWD_4_7	7240	759307	4121920	-1	-1	-1	35	191	1	8	PR1, PC1
4	VR_VVWD_4_8	7240	760751	4119677	-1	-1	-1	37	192	1	6	PCI
4	VR_VVWD_4_9	7240	758898	4117242	-1	-1	-1	38	191	1	8	MUI
4	VR_VVWD_4_10	7240	761474	4112088	-1	-1	-1	42	193	1	8	CAU
4	VR_VVWD_4_11	7240	757706	4101892	-1	-1	-1	49	190	1	8	MUI
4	VR_VVWD_4_12	7240	759219	4154265	-1	-1	-1	14	191	1	8	TVC
4	VR_VVWD_4_13	3620	761400	4094972	-1	-1	-1	61	193	1	8	CAU
4	VR_VVWD_4_14	3620	760370	4080952	-1	-1	-1	117	192	1	8	CAU
4	CW_NPC_4_1	2534	710125	4058049	-1	-1	-1	208	155	9	10	PC4
4	GV_JA_4_1	0	687632	4030678	-1	-1	-1	293	65	3	8	PC4
4	VR_VVWD_4_15	1448	753786	4055843	-1	-1	-1	217	188	1	1	XLB
4	VR_VVWD_4_16	1448	755314	4056800	-1	-1	-1	213	189	1	1	XLB
4	VR_VVWD_4_17	3620	760384	4077693	-1	-1	-1	130	192	1	8	CAU
4	VR_VVWD_4_18	3620	761458	4077424	-1	-1	-1	131	193	2	8	CAU
4	VR_VVWD_4_19	3620	761509	4079118	-1	-1	-1	124	193	1	8	CAU
4	VR_VVWD_4_20	7240	757515	4078196	-1	-1	-1	128	190	1	8	CAU
4	BM_NCG_4_1	555	689784	4018826	-1	-1	-1	301	74	5	8	PC4
4	BM_NCG_4_2	555	689784	4018826	-1	-1	-1	301	74	5	8	PC4
4	BM_NCG_4_3	555	689628	4018599	-1	-1	-1	301	73	1	6	PC4
4	MRS_MVWD_4_1	7240	693846	4075953	-1	-1	-1	137	90	1	6	PC4
4	LMV_MVWD_4_1	7240	723780	4078324	-1	-1	-1	127	168	1	4	PC1
4	LMV_MVWD_4_2	3620	721322	4051839	-1	-1	-1	233	166	1	8	MU2

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Group	Well	Pumping Rate (af/yr)	UTM East (m)	UTM North (m)	LSE (ft)	Top Screen Elev (ft)	Bottom Screen Elev. (ft)	Row	Col	Top Layer	Bottom Layer	HGU
4	LMV_MVWD_4_3	3620	720810	4054265	-1	-1	-1	223	166	1	8	MU2, MU1
5	HV_NPC_5_1	4033	686550	4052558	-1	-1	-1	230	61	1	6	PC4
5	HV_NPC_5_2	16131	683834	4042430	-1	-1	-1	271	50	1	6	PC4
5	VR_VVWD_5_1	4344	751181	4074788	-1	-1	-1	141	186	1	8	CAU
5	VR_VVWD_5_2	4344	749179	4074325	-1	-1	-1	143	185	1	8	CAU
5	VR_VVWD_5_3	4344	760294	4079624	-1	-1	-1	122	192	1	8	CAU
5	VR_VVWD_5_4	4344	749762	4067503	-1	-1	-1	170	185	1	6	CAU
5	VR_VVWD_5_5	4344	762057	4074303	-1	-1	-1	143	193	1	8	CAU
5	VR_VVWD_5_6	4344	760059	4073841	-1	-1	-1	145	192	1	8	CAU
5	CSV_CSI_5_1	7240	687269	4083930	-1	-1	-1	105	64	3	8	PC4
5	CSV_CSI_5_2	7240	689711	4083150	-1	-1	-1	108	73	1	8	PC4
5	CSV_CSI_5_3	7240	686320	4077026	-1	-1	-1	132	60	1	8	PC4
5	CSV_CSI_5_4	7240	688078	4083931	-1	-1	-1	105	67	2	8	PC4
5	CSV_CSI_5_5	7240	688662	4090807	-1	-1	-1	77	69	1	6	PC4
5	CSV_CSI_5_6	7240	688299	4077869	-1	-1	-1	129	68	1	6	PC4
5	CSV_CSI_5_7	7240	688339	4076254	-1	-1	-1	135	68	1	6	PC4
5	CSV_CSI_5_8	7240	686712	4077439	-1	-1	-1	131	61	1	6	PC4
5	CSV_CSI_5_9	7240	690381	4078235	-1	-1	-1	128	76	1	6	PC4
5	CSV_CSI_5_10	7240	689877	4076495	-1	-1	-1	134	74	1	6	PC4
5	CSV_CSI_5_11	7240	687179	4087152	-1	-1	-1	92	63	1	8	CAU, PC4
5	CSV_CSI_5_12	7240	688517	4082322	-1	-1	-1	111	69	1	8	PC4
5	CSV_CSI_5_13	7240	688420	4085545	-1	-1	-1	98	68	3	8	PC4
5	CSV_CSI_5_14	7240	688278	4090398	-1	-1	-1	79	68	1	6	PC4
5	CSV_CSI_5_15	7240	686170	4094804	-1	-1	-1	61	59	5	8	PC4
5	CSV_DLW_5_1	4000	684692	4062157	-1	-1	-1	192	53	1	6	PC4
5	CSV_CSI_5_16	7240	689362	4081128	-1	-1	-1	116	72	1	6	PC4
5	CSV_CSI_5_17	7240	687766	4080704	-1	-1	-1	118	66	1	6	PC4
5	CSV_CSI_5_18	7240	685738	4081074	-1	-1	-1	116	57	3	8	PC4
5	CSV_CSI_5_19	7240	685692	4082687	-1	-1	-1	110	57	4	8	PC4
5	CSV_CSI_5_20	7240	689300	4083546	-1	-1	-1	106	72	1	6	PC4
5	CSV_CSI_5_21	7240	688465	4084337	-1	-1	-1	103	68	2	8	PC4
5	CSV_CSI_5_22	7240	687301	4082720	-1	-1	-1	110	64	2	8	PC4
5	HV_DLW_5_1	4000	684300	4035822	-1	-1	-1	289	52	1	6	PC4
5	BM_DLW_5_1	4000	689185	4014613	-1	-1	-1	304	71	8	9	PC4
5	GV_DLW_5_1	2000	688969	4046566	-1	-1	-1	254	70	1	6	PC4
5	GV_DLW_5_2	2000	688539	4047764	-1	-1	-1	249	69	1	6	PC4
5	CW_DLW_5_1	4000	703978	4034249	-1	-1	-1	291	130	8	10	PC4
5	GV_NPC_5_1	807	694347	4039258	-1	-1	-1	283	92	1	6	PC4
5	GV_NPC_5_2	807	694649	4039265	-1	-1	-1	283	93	1	6	PC4
5	VR_LCWD_5_1	7240	759657	4096709	-1	-1	-1	55	192	1	8	CAU
5	VR_LCWD_5_2	7240	759866	4091705	-1	-1	-1	74	192	1	8	CAU
5	VR_VVWD_5_1	4344	760294	4079624	-1	-1	-1	122	192	1	8	CAU
5	VR_VVWD_5_2	4344	745752	4100765	-1	-1	-1	49	182	1	6	KTI, PRI
5	VR_VVWD_5_3	4344	744901	4102353	-1	-1	-1	48	182	1	5	KTI
5	TD_VVWD_5_1	4344	740092	4101413	-1	-1	-1	49	179	1	6	PC1
5	TD_VVWD_5_2	4344	737668	4102555	-1	-1	-1	48	177	2	6	PC1
5	TD_VVWD_5_3	4344	737625	4104165	-1	-1	-1	47	177	2	6	PC1
6	ECP-2	1300	696714	4046984	2234	2095	1006	253	101			PC4
6	ECP-1	2600	696808	4046393	2234	2172	1109	255	102			PC4

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Group	Well	Pumping Rate (af/yr)	UTM East (m)	UTM North (m)	LSE (ft)	Top Screen Elev (ft)	Bottom Screen Elev. (ft)	Row	Col	Top Layer	Bottom Layer	HGU
6	CW_MBP_6_1	600	696607	4045627	-1	-1	-1	258	101	1	6	PC4
6	CW_MBP_6_2	600	696305	4045400	-1	-1	-1	259	100	1	6	PC4
6	CW_MBP_6_3	600	696644	4045194	-1	-1	-1	260	101	1	6	PC4
6	CW_MBP_6_4	1300	696020	4040580	-1	-1	-1	278	99	1	6	PC4
6	TH-1	724	697313	4044763	2206	1969	1106	261	104			
6	CV_LCV_6_1	3620	734231	4148778	-1	-1	-1	17	175	1	6	TVC
6	CV_LCV_6_2	3620	737326	4148592	-1	-1	-1	17	177	1	6	TVC
6	CV_LCV_6_3	3620	743662	4147312	-1	-1	-1	18	181	1	6	TVC
6	CV_LCV_6_4	3620	751924	4149285	-1	-1	-1	17	186	1	6	TVC
6	CSV_DLW_6_1	4000	684692	4062157	-1	-1	-1	192	53	1	6	PC4
6	BM_DLW_6_1	4000	689185	4014613	-1	-1	-1	304	71	8	9	PC4
6	GV_DLW_6_1	4000	686306	4025493	-1	-1	-1	297	60	1	6	PC4
6	HV_DLW_6_1	4000	684300	4035822	-1	-1	-1	289	52	1	6	PC4
6	CW_DLW_6_1	4000	693989	4022382	-1	-1	-1	299	90	1	6	PC4
7	KSV_LCWD_7_1	4344	737293	4148614	-1	-1	-1	17	177	1	6	TVC
7	KSV_LCWD_7_2	4344	699962	4111206	-1	-1	-1	42	114	1	6	PC4
7	KSV_LCWD_7_3	4344	690192	4099255	-1	-1	-1	51	75	1	4	PC4
7	KSV_LCWD_7_4	4344	705883	4117247	-1	-1	-1	38	138	1	6	TVC
7	TD_LCV_7_1	3620	738290	4108210	-1	-1	-1	44	177	6	8	PC1
7	TD_LCV_7_2	3620	744018	4118829	-1	-1	-1	37	181	1	6	CAU,TVC,MU1
7	TD_LCV_7_3	3620	733795	4111709	-1	-1	-1	42	174	6	8	PC1
7	TD_LCV_7_4	3620	745430	4129017	-1	-1	-1	30	182	1	6	MU1
7	TD_LCV_7_5	3620	738482	4101369	-1	-1	-1	49	177	3	6	PC1
7	TD_LCV_7_6	3620	740169	4112689	-1	-1	-1	41	179	1	6	CAU,MU1

Comparison of Simulated and Observed Effects of Pumping from MX-5 Using Data Collected to the End of the Order 1169 Test, and Prediction of the Rates of Recovery from the Test

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Prepared For:

National Park Service

U.S. Fish & Wildlife Service

Bureau of Land Management

Prepared By:

Tetra Tech, Inc.
363 Centennial Parkway, Suite 210
Louisville, Colorado 80027

June 10, 2013

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1.0 INTRODUCTION AND PURPOSE

On behalf of three Department of the Interior agencies (the US Fish and Wildlife Service, National Park Service, and Bureau of Land Management), Tetra Tech (2012a) prepared a three-dimensional model of groundwater flow of part of the Colorado River Flow System. This model is intended to provide information on the effects of current and future groundwater use on the groundwater system, which includes resources that are the responsibility of these three agencies.

Calibration of the model was based in part on the observed responses to pumping of the carbonate aquifer in Coyote Spring Valley (CSV) over the first part of the Order 1169 test, during the period September 2010 through December 2011. Data are now available on the effects of pumping in CSV through December 2012, when the Order 1169 test was declared complete. The first part of this present evaluation is designed to determine how well the modeling results agree with the observed water-level drawdown and spring discharge data collected in 2012. The model was not calibrated to the more recent information. The results can be used to estimate whether the model over-predicts or under-predicts the effects of pumping in CSV. The conclusions of this evaluation should only be applied to the effects of pumping in CSV, and not from other areas of groundwater use.

The model is also used to evaluate what is likely to happen if pumping in CSV were to be reduced. One possible management option for protecting the stream and spring environments in the Muddy River Springs area would be to reduce pumping rates if water levels declined to a mitigative threshold value. However, it is unknown whether a reduction in the pumping rate would cause an "immediate" recovery of water levels and spring flow in the Muddy River Springs area, or if drawdown and water-discharge would continue to decline for some time, and by how much. The second part of this report evaluates the likely recovery effects, using cessation of pumping in MX-5 at the end of the Order 1169 test as the imposed change in pumping stress.

2.0 POST-AUDIT SIMULATION

The post-audit simulation is a comparison of the simulated versus measured changes in water levels and discharge rates in the Muddy River Springs area, based on an additional year of simulation using reported rates of pumping. In order to perform this simulation, reported monthly pumping data were obtained from the Nevada Division of Water Resources' website used to distribute information pertaining to the Order 1169 pumping test. In addition, measured water level and spring discharge data were obtained for comparison with the simulation results. Results are presented in the form of graphs in Section 2.4.

2.1 APPROACH

The simulation was performed with the long-term model described in Tetra Tech (2012a), modified to include an additional 12 months of pumping to cover the period January 1, 2012 through December 31, 2012. [In addition, the model simulation time was extended an additional 15 years to evaluate the time required for the groundwater system to recover from the effects of Order 1169 pumping. These changes and the results are discussed in more detail in Section 3.0.] The Multinode Well package dataset was modified by adding the reported 2012 monthly pumping volumes, converted to cubic feet per day, into additional monthly stress period records. If reported values were not available for a well during 2012, the average of the monthly pumping for the previous three-year period was used for the applicable month in 2012, under the assumption that water needs in 2012 were similar to those in recent years.

Other data sets needed to be extended as well. These included data sets describing recharge, the stage in Lake Mead, evapotranspiration, and streamflow. For recharge, this was done simply by informing MODFLOW to use the information for the previous stress period, as recharge was assumed to remain constant throughout the year. The stage in Lake Mead throughout 2012 was assumed to be the same as it was in December 2011. For evapotranspiration and streamflow, the 12 stress periods representing 2011 were repeated for 2012, so that the seasonally varying stresses were applied for 2012 in the same manner as previous stress periods.

The file for the Head Observation Package was modified to include the additional data for 2012, in order that simulation results corresponding to the dates of the measurements would be printed out.

2.2 PUMPING RATES

Figures 2-1a and 2-1b display the monthly pumping (expressed in gallons per minute, gpm) from wells completed in carbonate rocks, and completed in basin-fill sediments, respectively, in Coyote Spring Valley and the Muddy River Springs Area, for the period 2005 through 2012. While the pumping is expressed in gpm, the values represent the average rate over the month, not the instantaneous rate that was pumped at any time. The pumping from the carbonate rocks began in 1992, when production from Arrow Canyon began. The rate of pumping varies seasonally, with the higher rates occurring during the summer months. During the period 2005 through mid-2009, the seasonal high rates (summer) ranged from approximately 2,000 gpm to 3,000 gpm. The winter usage ranged from zero to approximately 1,000 gpm.

During the summer of 2010 (prior to the start of significant pumping from MX-5), the rate increased more than 3,000 gpm, due to pumping of CSI-3 and CSI-4.

In September 2010, pumping of MX-5 at significant rates (greater than 1,500 gpm on average) began. Smaller volumes were pumped in July and August. The maximum average rates were approximately 3,500 gpm. There were two one to two month periods, in mid-2011 and early 2012, when MX-5 pumping essentially stopped. Pumping continued to the end of 2012, when the State Engineer's Office declared that the test was officially completed, and may have continued in 2013. During the period when MX-5 was being pumped, total pumping from the carbonate aquifer exceeded 6,000 gpm on several occasions during the summer. Thus, the Order 1169 pumping from MX-5 approximately doubled the amount of water being removed from the carbonate aquifer, primarily during the summer months.

Pumping from the basin-fill wells near the Muddy River Springs also followed a seasonal pattern, with the greatest pumping occurring during the summer months. The maximum rate varied from about 3,000 gpm to 4,500 gpm, similar to rates of pumping from the carbonate aquifer. However, there was not an appreciable difference in pumping rates for the periods before and during the Order 1169 test. Average rates during the winter months were typically down to 500 to 1000 gpm.

2.3 OBSERVED WATER LEVEL AND DISCHARGE CHANGES

Figure 2-2 provides water-level measurements for selected wells completed in the carbonate aquifer, over the period 2005 through 2012. The figure also shows the average monthly pumping rate from MX-5, inverted so that increases in pumping rate are downward on the figure, in the same direction as decreases in water level.

The water-level data in many wells show both seasonal changes, caused by seasonal pumping and evapotranspiration in the Muddy River Springs area, pumping in Coyote Spring Valley, and longer term declines caused by general groundwater usage. Significant pumping from MX-5 began in September 2010, although the official start of the Order 1169 pumping was November 2010. The following discussion is divided by geographic area.

Coyote Spring Valley – There are four wells that are located in Coyote Spring Valley that are shown on Figure 2-2.

- MX-4 is located 100 feet from MX-5, and is the closest observation well to MX-5. Water levels in this well showed seasonal effects prior to pumping of any wells in Coyote Spring Valley, indicating that changes in water consumption/pumping in the Muddy River Springs area are transmitted into this part of Coyote Spring Valley. There was also a long-term decline in water levels observed in MX-4 that is likely attributable to greater amounts of pumping from the carbonate aquifer from the Arrow Canyon and Arrow Canyon 2 wells in the Muddy River Springs area. With the onset of pumping at MX-5, the slope of this long-term downward trend increased, as would be expected. It is interesting to note that following the brief periods when MX-5 pumping stopped in mid-2011 and early 2012, there were distinct increases in water levels observed in MX-4 (and also in CSVM-1). [The three plotted measurements for MX-4 during the second half of

2011 with values of approximately 1816.5 feet amsl appear to be a data-entry error, as the transducer data indicate that the water levels were about 2 feet higher during this period.] However, when substantial pumping of MX-5 started in September 2010, a distinct increase in the decline in water levels did not occur in MX-4 or CSVM-1, only a continuation of the same downward trend. Figure 2-1 shows that the pumping rate from the Arrow Canyon well decreased at the same time that pumping increased from MX-5, so that the observed water-level responses may reflect the combined off-setting effect of these two pumping changes.

- CSVM-1 is located east of MX-5 approximately one-half mile. The water levels in this well are very similar to those in MX-4. The slope of the longer-term decline in water levels is similar to that observed in MX-4.

- CSVM-2 is located in the southern part of Coyote Spring Valley, approximately eight miles from MX-5 and MX-4. Water level trends in this well are similar to those in MX-4 and CSVM-1, but the water levels in this well are higher in elevation than those in the other two wells. Seasonal trends are present in the water level record, as are the slow long-term decline in water levels prior to the start of the Order 1169 test, and the more rapid decline in water levels during the test. Even short-term changes are apparent in CSVM-2 water levels that are quite similar to those observed in MX-4, which seem to be visually correlated with changes in MX-5 pumping rates. The water levels in this well are approximately 2.5 feet higher than those in MX-4 prior to the start of MX-5 pumping, but the difference increases to about 3.3 feet when pumping is occurring. The increase in the difference is consistent with pumping of MX-5, as drawdown should be greater near the well being pumped.

Muddy River Springs Area – Two wells, EH-5B and EH-4, were selected to show temporal changes in water levels in the carbonate aquifer.

- EH-5B is located east of the two Arrow Canyon wells, and is expected to respond to pumping from these two wells, as well as from pumping in MX-5. Pumping from shallower alluvial wells and seasonal ET will also have effects. With the beginning of pumping at MX-5, the general rate of decline in water levels increased, as in other wells. One notable difference from the response in the wells in Coyote Spring Valley occurred at the beginning of pumping in MX-5. In the Coyote Spring Valley wells, water levels declined with the start of MX-5 pumping. However, in EH-5B (and EH-4), water levels rose at this time, probably because of the reduction in pumping from the Arrow Canyon wells that occurred at that time. Thus, the responses in EH-5B reflect both MX-5 pumping effects and pumping effects in the Muddy River Springs area, as do responses in Coyote Spring Valley wells. However, the effect of pumping in the Muddy River Springs area has a proportionally greater effect on EH-5B water levels than on water levels in Coyote Spring Valley.

- EH-4 is located south of the two Pedersen springs, and to the southwest of the alluvial deposits which are both pumped and provide natural diffuse groundwater discharge into the Muddy River. The water level responses in EH-4 are very similar to those in EH-5B.

California Wash – Two wells, Paiute M-1 and Paiute M-3, were selected for evaluation of changes in California Wash water levels. Paiute M-1 is located in the northern part of California Wash, about five miles south of the Muddy River Springs area. Paiute M-2 is located 15 miles from the Muddy River Springs area, and approximately eighteen miles from MX-5, on the east side of the Arrow Canyon Range.

- Paiute M-1 water levels show both seasonal effects and an increase in the rate of longer-term downward decline when pumping of MX-5 began. The earlier measurements included in the spreadsheet that was obtained from the State Engineers Office appear to contain a shift in the datum during 2006 and has some time gaps. In contrast, the data reported from 2009 to the present visually correlate well with carbonate water levels measured in Coyote Spring Valley and the Muddy River Springs area. The rise in water levels that was observed in EH-4 and EH-5B at the beginning of the pumping of MX-5, attributed to a reduction in Arrow Canyon pumping, also occurred in Paiute M-1, but was less pronounced than in the wells in the Muddy River Springs area.

- Paiute M-3 water level data are similar to the measurements from Paiute M-1, with the elevation being approximately 1 foot lower.

In summary, the water-level data presented here indicate that seasonal changes in water levels were observed over a large area. The most likely causes are seasonal pumping and evapotranspiration in the Muddy River Springs area, and seasonal pumping in Coyote Spring Valley. The widespread transmission of these effects is evidence of the high permeability and low storage properties of the carbonate aquifer in this region. A relatively slow decline in carbonate water levels was occurring prior to pumping of MX-5. With the increase in pumping from the carbonate aquifer when pumping of MX-5 began, there was a distinct increase in the rate of water-level decline over a large area.

2.4 MODEL SIMULATION RESULTS

The simulation results are presented in the same format as in Tetra Tech (2012a), with minor changes. Figure 6.2-5 of that report provided several graphs of simulated and observed drawdown, from the start of the Order 1169 simulation. The Order 1169 simulation began two years before the start of the MX-5 pumping, and the results were shown for that two-year period. In this report, results are shown starting at the beginning of 2010, or about 9 months before the start of MX-5 pumping. The time axis, located across the plot area of the graphs, shows the calendar year, rather than simulated year, for easier evaluation. In addition, “drawdown” is referenced to the date of the closest measurement relative to September 1, 2010.

The discharge in the Muddy River Springs area is presented in the same format as Figure 6.3-1 in Tetra Tech (2012a), except that the figure starts on January 1, 2010, and the discharge is only shown for the springs.

2.4.1 DRAWDOWN THROUGH TIME

Figure 2-3 shows the simulated and observed water-level changes for several selected monitoring wells in the study area, as described above. The addition of another year of MX-5 pumping to the simulation, and the comparison of simulated and observed drawdown, makes it apparent that the model under-simulates the amount of drawdown that is being caused by pumping of the carbonate aquifer. Tetra Tech (2012a, p. 44) had noted that the model does not simulate short-term (seasonal) variability in some areas where it is observed, and suggested that adjustment of carbonate transmissivity and storage parameters may improve the model fit to observed changes in water levels. It was unclear, based on simulating pumping through 2011, whether the model under-simulated the amount of drawdown caused by pumping at MX-5. The current results clearly indicate that the model under-simulates the amount, and probably the extent, of drawdown. For example, at CSVM-6 (located about 3 miles north of MX-5), the simulated drawdown is approximately 0.6 feet, while the observed drawdown is up to 2.4 feet. At CSVM-2 and CSV-3, approximately eight to ten miles south of MX-5, the measured drawdowns were up to 2 feet, but the simulated values are less than 0.5 feet. In California Wash, the observed drawdown was also about 2 feet (Paiute M-1 and Paiute M-3) but the simulated drawdown is 0.3 feet or less.

2.4.2 SPRING FLOW

Figure 2-4 shows the observed and simulated discharge rates from the springs. In general, the model simulates very little change in the discharges, while there are small observed declines in the measured values during the Order 1169 test period. [The increases in observed discharge at Muddy Spring are believed to have been caused by anthropogenic changes near the spring.] The limited simulated impact on the discharge is, at least in part, caused by the under-simulation of drawdown.

2.4.3 SPATIAL EXTENT OF SIMULATED DRAWDOWN

Maps of the simulated drawdown caused by pumping of MX-5 were developed by first simulating the effects of all pumping (including MX-5), then simulating the effects of all pumping except MX-5, and subtracting the simulated water levels of the second run from those of the first run. The result is a dataset with the simulated drawdown caused by pumping of MX-5. This approach was used to eliminate possible effects that might be caused by non-linear boundary conditions. It isolates the effects of MX-5 pumping.

Figure 2-5 shows the simulated drawdown in model layer 5 caused by MX-5 pumping as part of the Order 1169 test, at three different times. The leftmost panel shows the simulated effects at the end of December 2011, while the central panel shows the simulated effects of an additional year of pumping. The rightmost panel is the predicted drawdown 15 years after MX-5 pumping is turned off in the model at the beginning of 2013; this panel is discussed in a following section. Layer 5 is the model layer exhibiting the greatest drawdown at the location of MX-5. Figure 2-6 is a similar set of maps, for model layer 11. This layer exhibited the greatest extent of drawdown.

In the time interval between the end of 2011 and the end of 2012, pumping continued from MX-5, and the extent of simulated drawdown increased in all directions. The amount of drawdown near MX-5 also increases, in both layer 5 and 11. The area of drawdown has begun to extend more in a north-south direction, reflecting the influence of the geology. To the north, the area of simulated drawdown greater than 0.1 feet has reached Kane Spring Valley (layers 5 and

11). To the south, it has reached the central part of Garnet Valley and nearly all of Hidden Valley (layer 11).

As noted above, the model under-simulates the drawdown caused by MX-5 pumping. Thus, the simulated amount and the extent of drawdown depicted on these maps is less than has been observed.

2.5 DISCUSSION

This post-audit evaluation of the CRFS model indicates that the model under-simulates the amount of drawdown that was caused by the Order 1169 pumping of MX-5 through the end of 2012. As a result of this, the simulated effect of this pumping on the discharge from springs in the Muddy River Springs area is too small. These results indicate that additional calibration of the model using the more recent data would be beneficial. In the interim, the predictive results presented in Tetra Tech (2012b) that pertain to pumping existing and pending water rights from the carbonate rock aquifer in Coyote Spring Valley and Muddy River Springs area should be viewed as conservative, as the impacts are likely to be under-estimated. Specifically, the carbonate water levels that drive the discharge from the springs in the Muddy River Springs area will decline more quickly than simulated, and the flows from the springs and in the Muddy River will decline more quickly.

3.0 RECOVERY SIMULATION

3.1 APPROACH

The model was run using monthly stress periods for a 15-year period, in which no pumping was assumed to occur from MX-5, but other pumping was assumed to occur at the average of the rates in 2010, 2011 and 2012. The simulated pumping rates from carbonate wells in Coyote Spring Valley and the Muddy River Springs area are shown in a plot at the bottom of Figure 3-1. Evapotranspiration was assumed to continue to occur seasonally at the same rates as simulated at earlier times. The stage of Lake Mead was assumed to remain at the level it was in December 2012.

3.2 SIMULATION RESULTS

3.2.1 DRAWDOWN THROUGH TIME

Simulated drawdown at several wells is shown on Figure 3-1. The earlier-time water levels show the effects of MX-5 superimposed on a general downward trend. The effect of stopping MX-5 pumping is very evident in wells close to MX-5 (MX-4, CSV-RW2, CSVM-1, UMVW-1, MX-6) and easily discernible in more distant wells (DF-1, CSVM-6, CSVM-5, CSV-3, CSVM-2, CSV-1, CSI-2, CSI-1), as water levels in these wells begin to rise. The effect is also present (as observable changes in slope) in the simulated responses of Arrow Canyon, Arrow Canyon 2, KMW-1, CSVM-4, CE-VF-2, CSV-2, EH-5B, EH-4, BW-01, Paiutes M-1 and Paiutes M-3.

The time required for recovery is a function of the distance from MX-5 and the criterion used to define when recovery is complete. Figure 3-2a through 3-2h show the drawdown and recovery as a result of MX-5 pumping, after removing the effects of pumping of other wells and seasonal evapotranspiration. For example, at MX-4 (Figure 3-2a), about 75% of the drawdown is recovered very quickly, but after 15 years, the recovery is about 90% complete. At MX-6 (Figure 3-2c), the simulated recovery is about 75% complete after 15 years. At EH-4 (Figure 3-2d), the maximum drawdown is simulated as occurring several months after cessation of MX-5 pumping. The recovery for this well is about 70% complete after 15 years. In areas that are much further away, recovery is simulated as not beginning until after 15 years. Although the simulated drawdown at CSVM-3 (Figure 3-2h) is only 0.03 feet after the 28 months of MX-5 pumping and 15 years of recovery, the drawdown is continuing to increase after cessation of pumping at MX-5.

3.2.2 SPRING FLOW

Because there was no easily observable decrease in the simulated spring discharge, no easily observable increase in simulated spring flow should occur after MX-5 pumping is stopped (Figure 3-3). For example, the decline simulated for Baldwin Spring is less than 2% of the flow in 2010.

3.2.3 Spatial Extent of Drawdown

The rightmost panel in Figures 2-5 and 2-6 shows the simulated drawdown after 15 years of recovery. Recovery near MX-5 is nearly complete (recovery was about 90% at MX-4). However, comparison of the results presented in the central and rightmost panels in both figures indicates the area with at least 0.01 feet of drawdown continued to expand after pumping ceased, and has reached the western and southern model boundaries in layers 5 and 11. While the simulated drawdown in these areas is small, the simulation demonstrates that although drawdown has nearly recovered near the pumping well, impacts in other areas might continue to increase a decade or more after pumping has stopped.

3.3 Discussion

There are two significant conclusions from the recovery simulation:

- Recovery from the effect of the 28-month pumping of MX-5 will take longer than the 28 months of pumping, and may take substantially longer depending on the location of interest. Near the Muddy River Springs, approximately one-third of the simulated drawdown remains after 15 years of recovery.

- The model predicts that the drawdown in Coyote Spring Valley and the Muddy River Springs area caused by MX-5 pumping is superimposed on a slower decline of water levels that is likely largely caused by pumping of carbonate aquifer water from the Arrow Canyon and Arrow Canyon 2 wells. However, existing carbonate pumping from wells in Coyote Spring Valley, Garnet Valley and the western part of the Black Mountains Hydrographic Area was also included in the recovery simulation and may be responsible for part of the observed decline in simulated water levels in the vicinity of MX-5.

If additional calibration were to be performed to better match the last year of Order 1169 pumping, it is likely that the hydraulic properties of the carbonate rocks in the western part of the model would change. The transmissivity would likely increase and the specific storage would likely decrease, in order to increase the extent of the drawdown area affected by MX-5 pumping and to increase the amount of drawdown simulated in areas distant from MX-5. These changes would be expected to shorten the period required for complete recovery to occur, but increase the impacts on the discharge from springs in the Muddy River Springs area.

4.0 CONCLUSIONS

The Tetra Tech (2012a) model was calibrated using information available through December 2011. The pumping of MX-5, and the related collection of water-level and discharge information, has provided additional information that was used in evaluating the predictions made with the model pertaining to the effects of pumping in Coyote Spring Valley. The pumping dataset for the model was updated with monthly pumping information for 2012, and the model was run with this revised dataset. Results indicate that the model under-simulates the amount (i.e., calculates less effect) of drawdown and reduction of spring discharge than has occurred as a result of MX-5 pumping during the Order 1169 pumping test period. The observed drawdown is more widespread, and is of greater magnitude, than simulated by the model during this period. The model simulates that the discharge from springs is not affected to a measureable amount, but the real effects are measureable. Thus, predictions that have been made with the model that evaluate the effects of pumping in Coyote Spring Valley should be considered conservative. More specifically, the actual impacts from pumping would be larger and more widespread than simulated by the model.

In addition, the 15-year period after the end of the Order 1169 pumping test on December 31, 2012 was simulated to determine how quickly water level (and spring discharge) recovery is likely to occur. This evaluation indicates that recovery from the 28-month pumping test will occur over years. In the Muddy River Springs area, it was estimated that recovery will be approximately 70% complete after 15 years. In areas that are “distant” from MX-5, results suggest that drawdown can still be increasing 15 years after pumping of MX-5 stopped. If pumping were to occur for longer than 28 months (the total time of the pumping at MX-5 as part of the Order 1169 test), the rate of recovery can be expected to be slower.

The data collected during 2012 could be used to improve the calibration of the model to the observed effects of pumping in Coyote Spring Valley. A revised model would be expected to simulate greater and more widespread drawdown than the current model, more impact on spring flow, and shorter recovery times.

5.0 REFERENCES

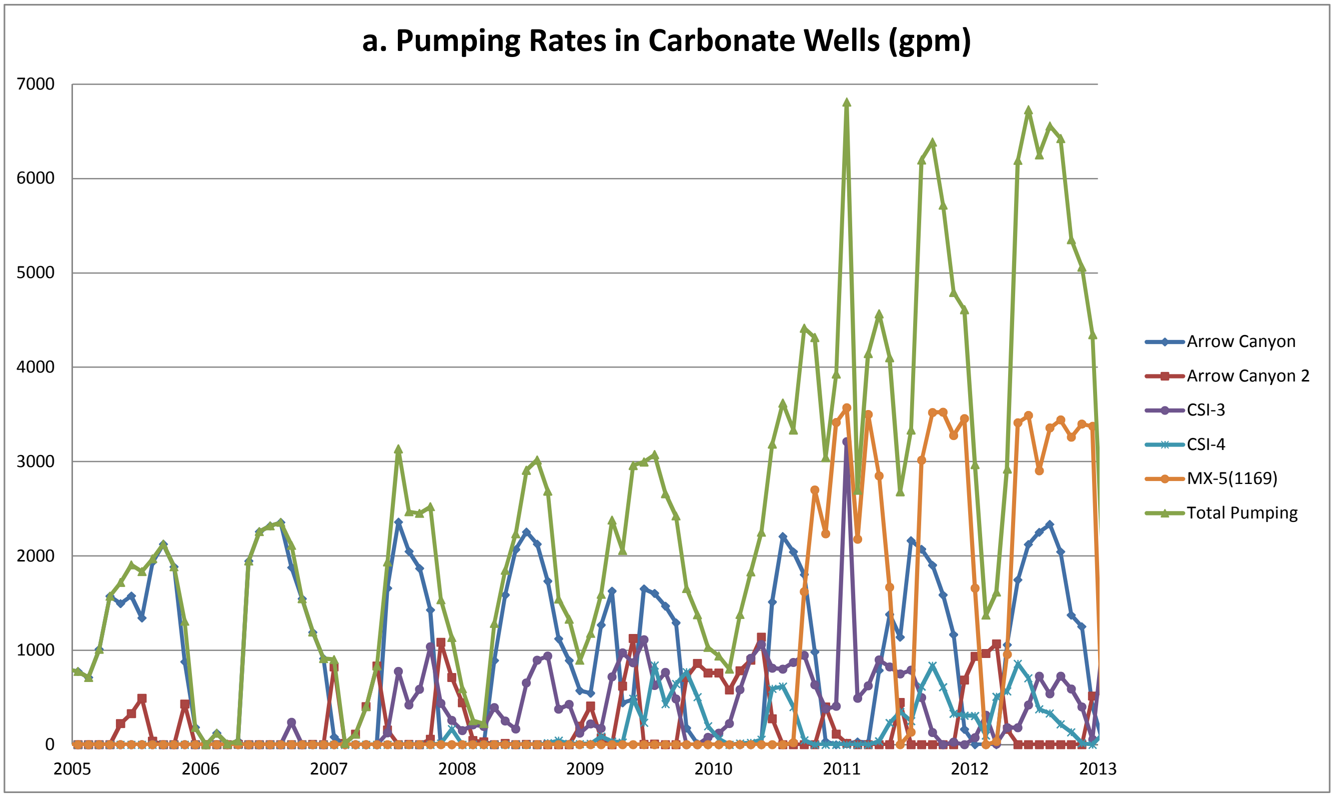
Tetra Tech, 2012a, Development of a numerical groundwater flow model of selected basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada.

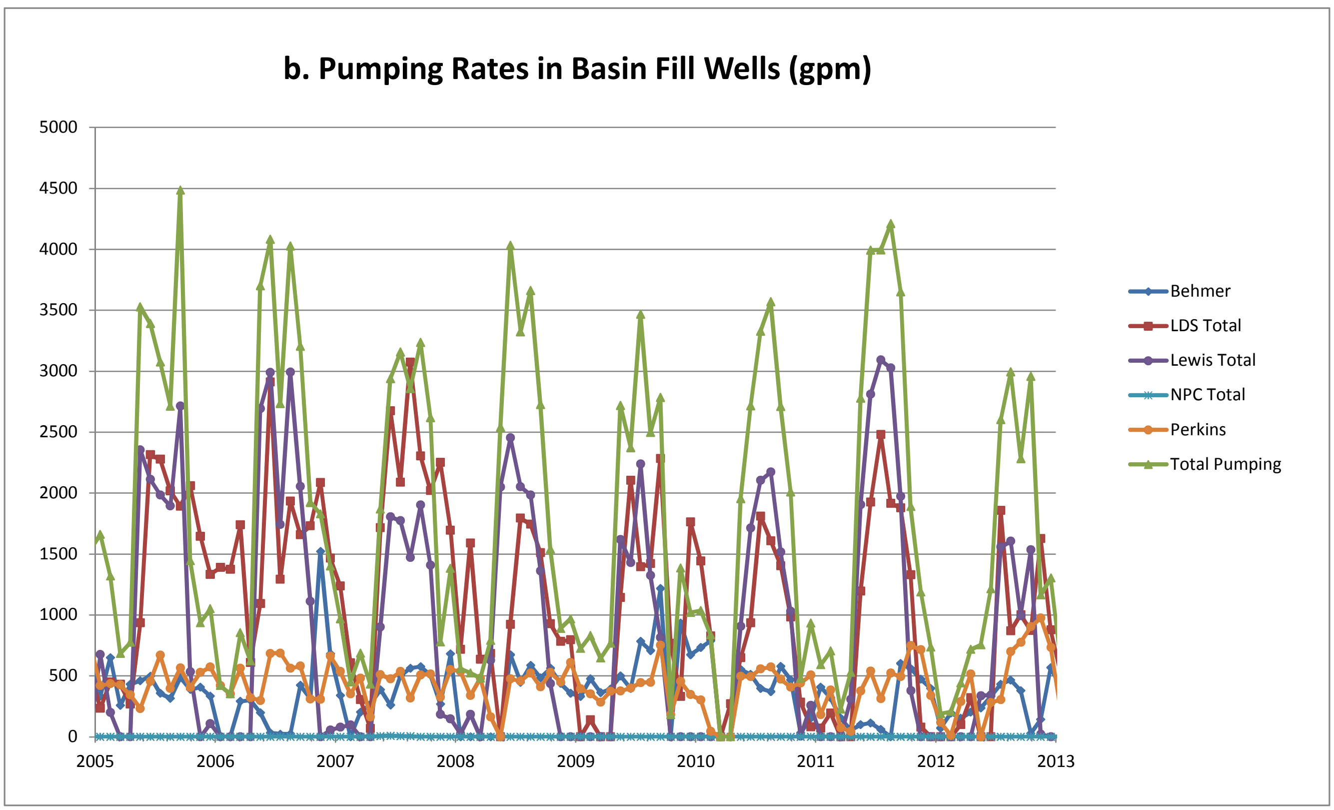
Tetra Tech, 2012b, Predictions of the effects of groundwater pumping in the Colorado Regional Groundwater Flow System, Southeastern Nevada.

FIGURES

TETRA TECH

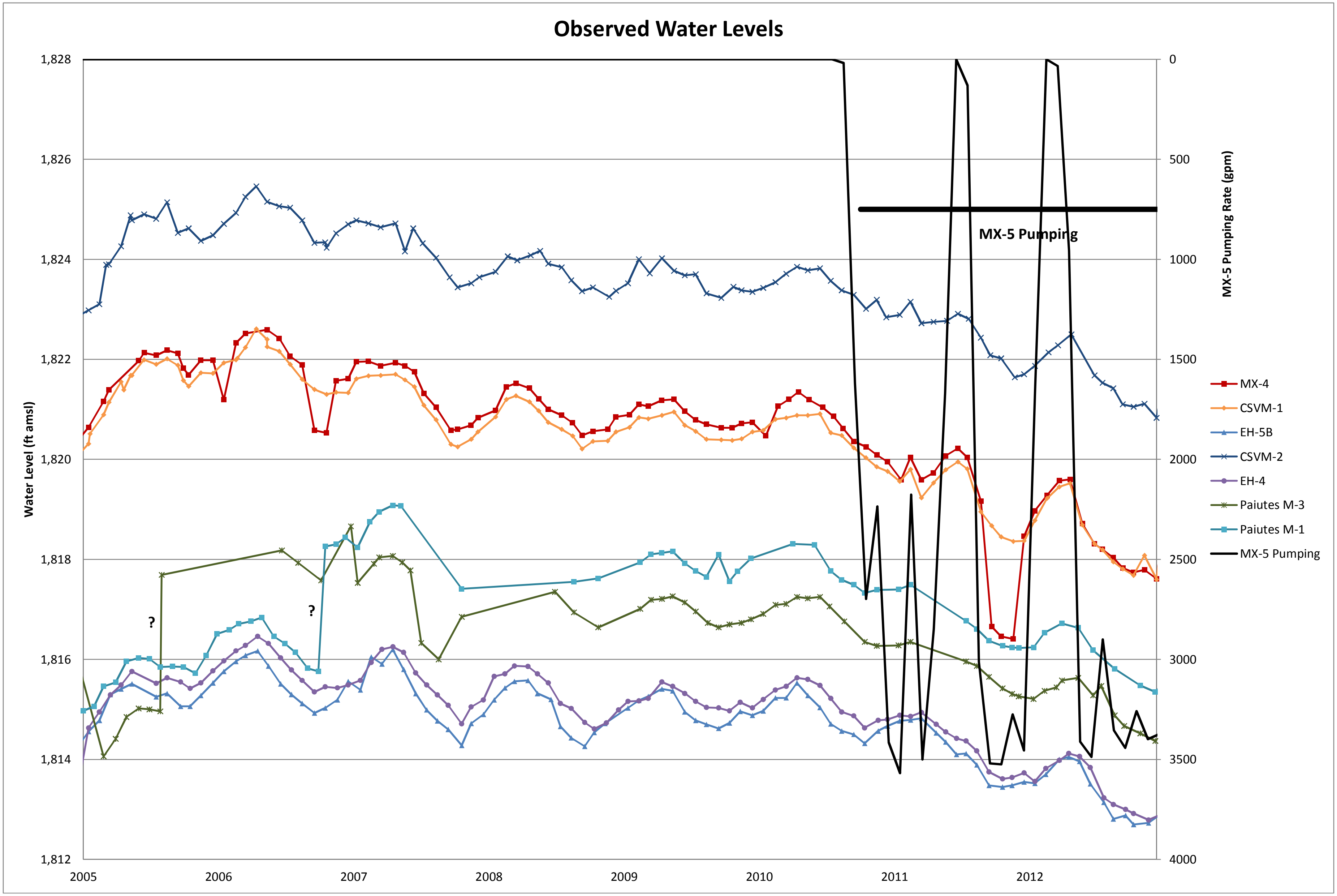
Figure 2-1. Rates of groundwater pumping in Coyote Spring Valley and the Muddy River Springs area, 2005-2012





Note: Dates on the x-axis represent January 1st of each year

Figure 2-2. Observed water levels in selected wells, and MX-5 pumping rate (inverted), 2005-2012



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JA_5281

Figure 2-3. Comparison of simulated and observed drawdown in selected wells, 2010-2012

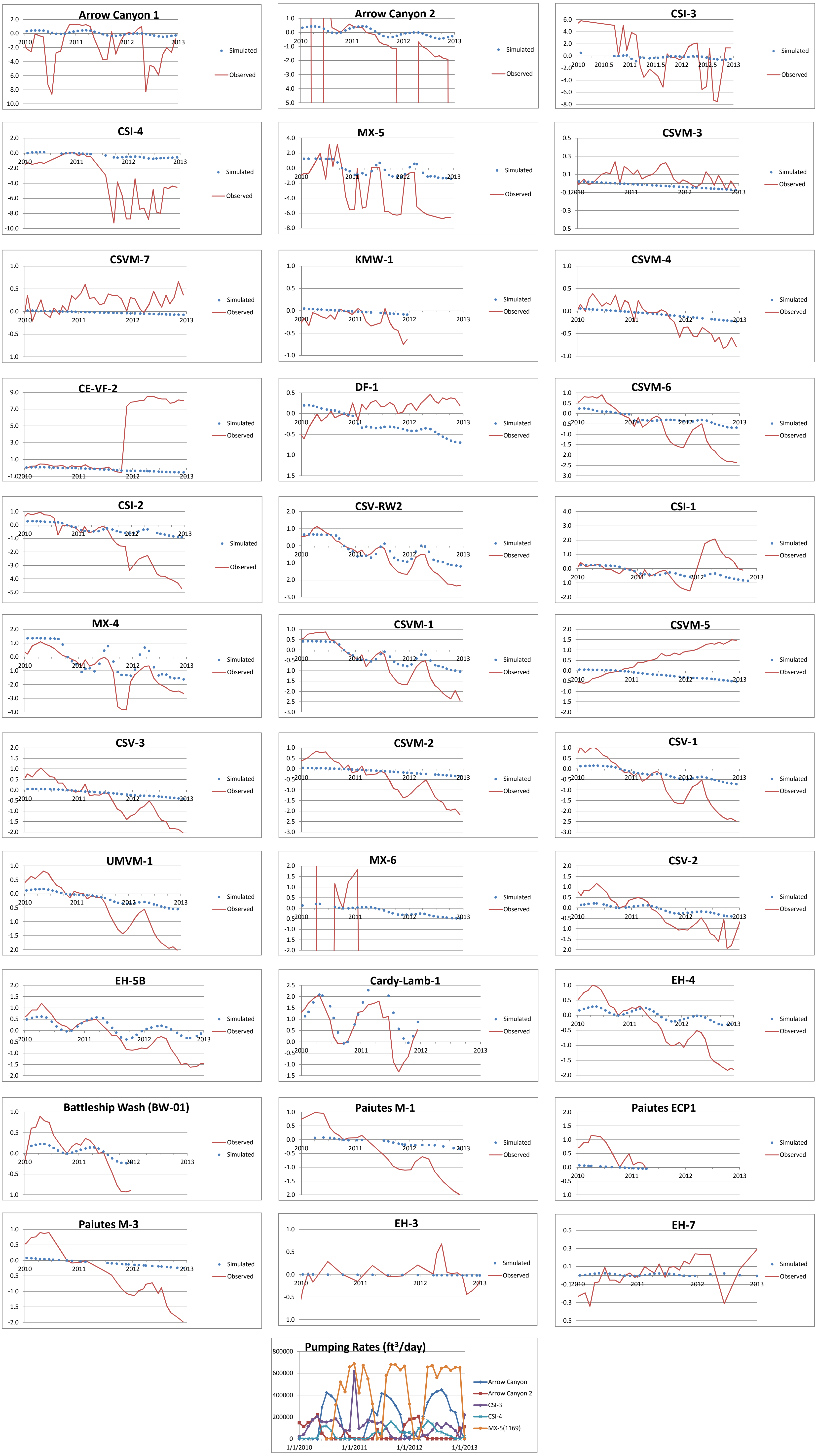
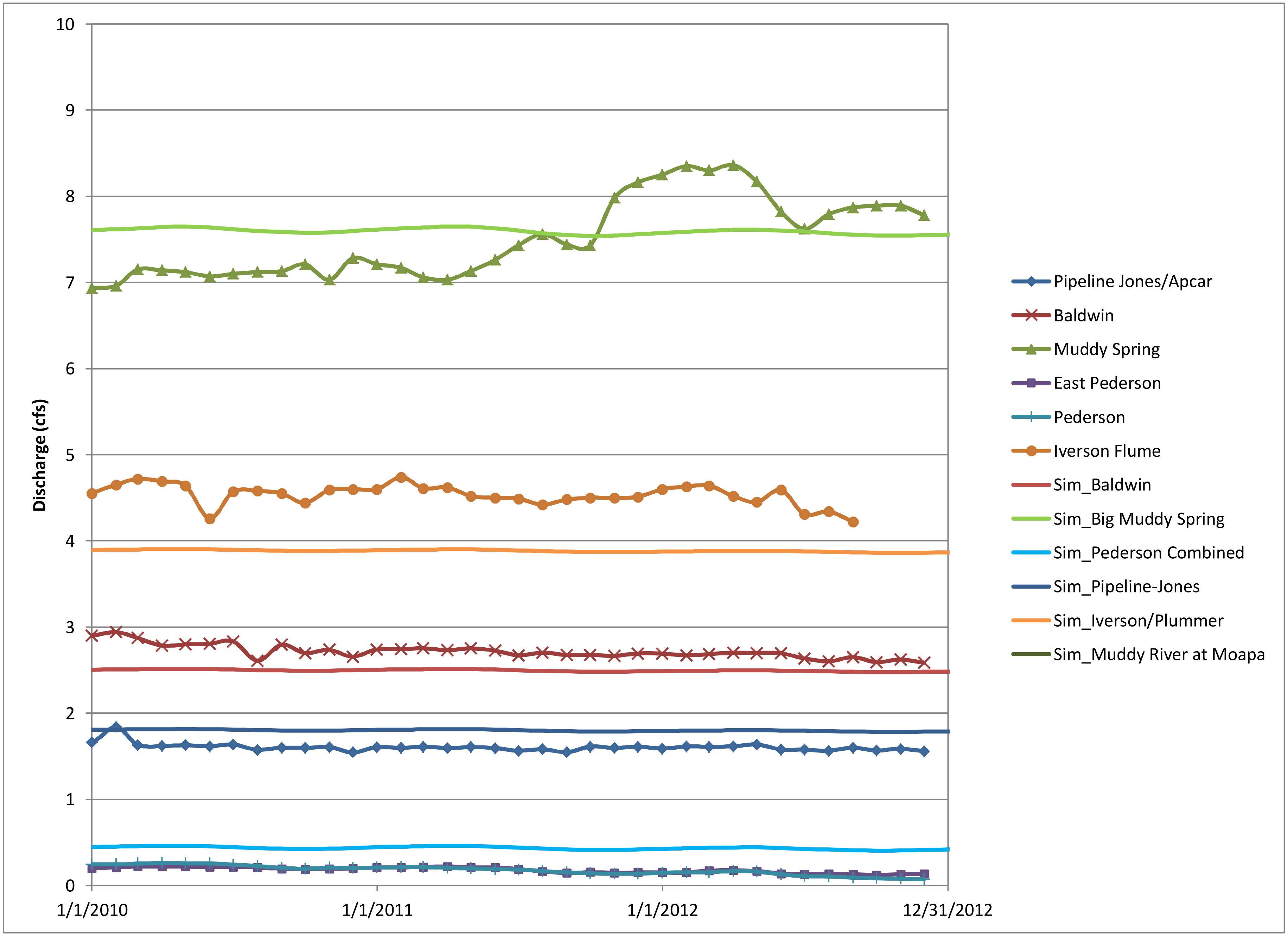
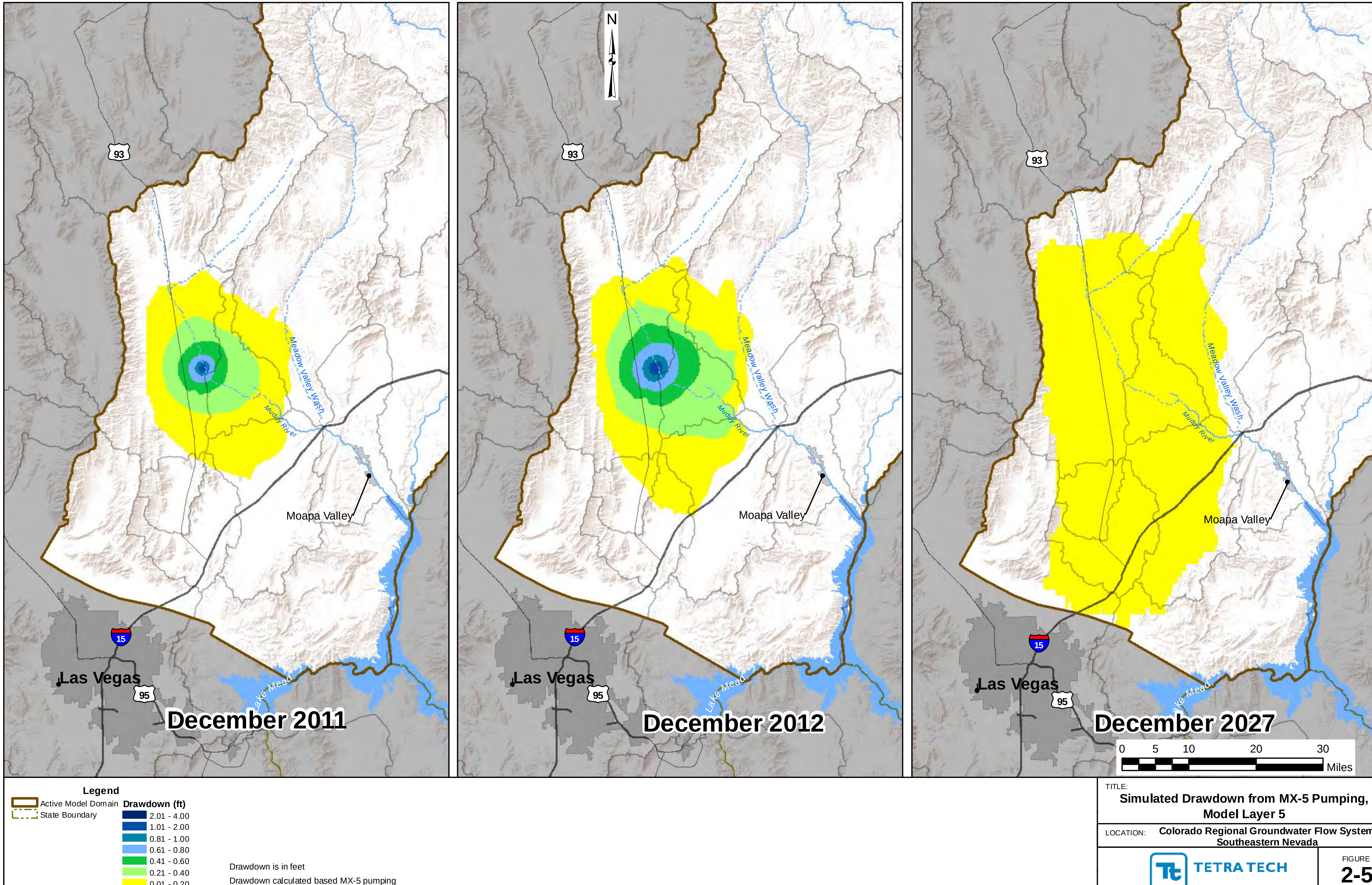


Figure 2-4. Comparison of observed and simulated spring discharge, Muddy River Springs area, 2010-2012





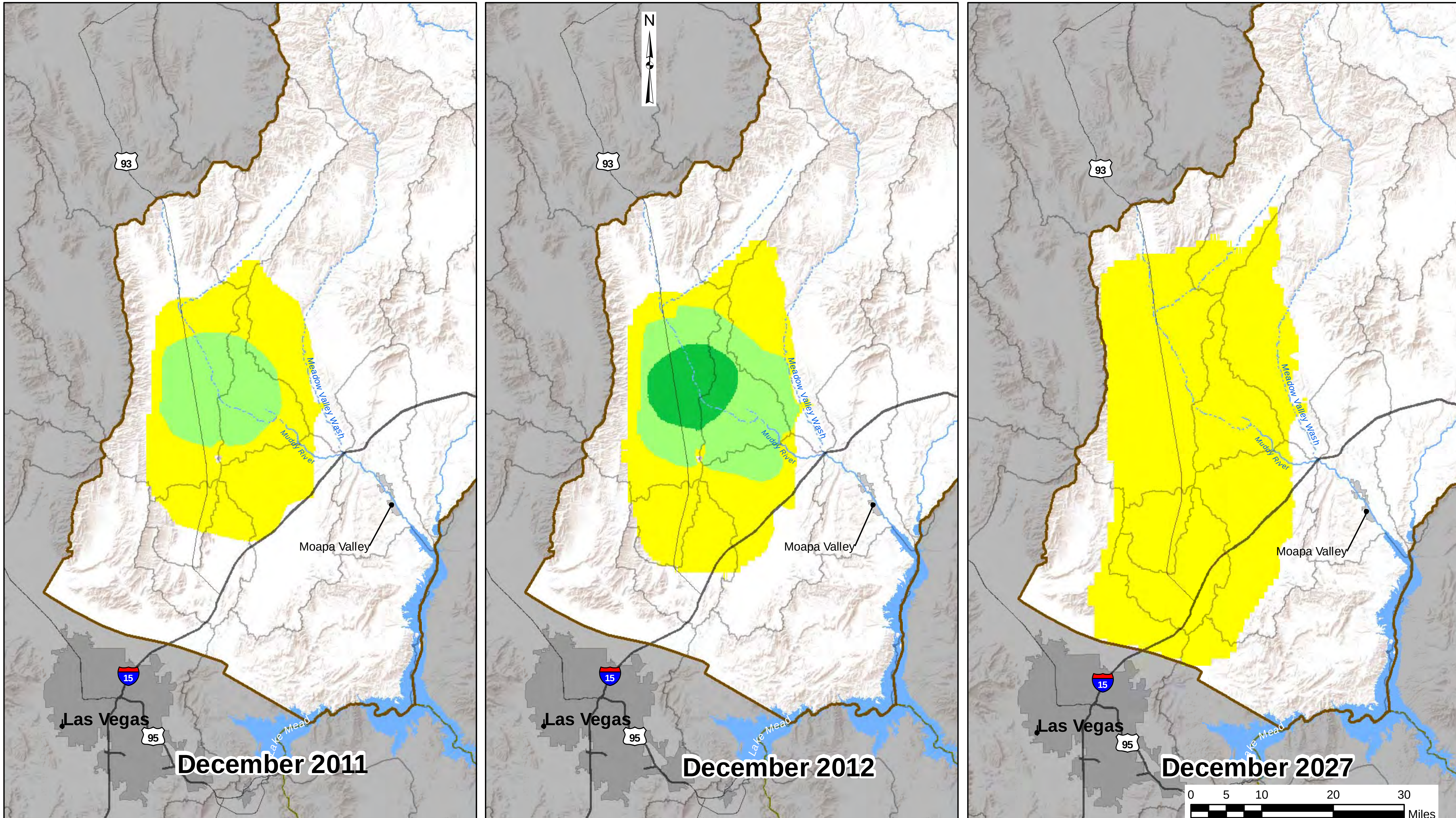
TITLE: **Simulated Drawdown from MX-5 Pumping, Model Layer 5**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **2-5**

SE ROA 12522



Legend

Active Model Domain

State Boundary

Drawdown (ft)

- 2.01 - 4.00
- 1.01 - 2.00
- 0.81 - 1.00
- 0.61 - 0.80
- 0.41 - 0.60
- 0.21 - 0.40
- 0.01 - 0.20

Drawdown is in feet

Drawdown calculated based MX-5 pumping

TITLE: **Simulated Drawdown from MX-5 Pumping, Model Layer 11**

LOCATION: **Colorado Regional Groundwater Flow System Southeastern Nevada**

TETRA TECH

FIGURE **2-6**

Figure 3-1. Simulation of water levels in selected wells, 2010-2027

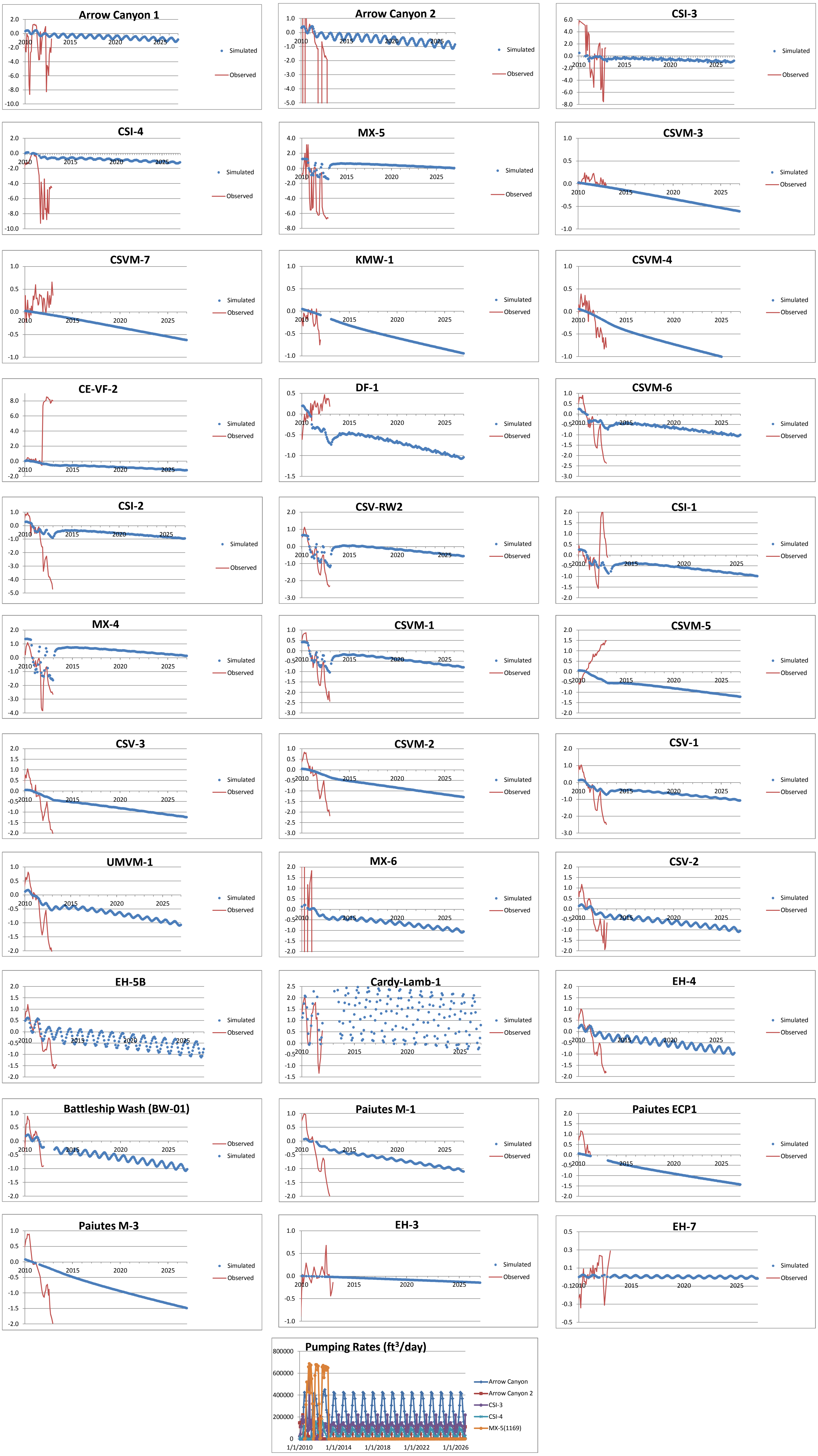
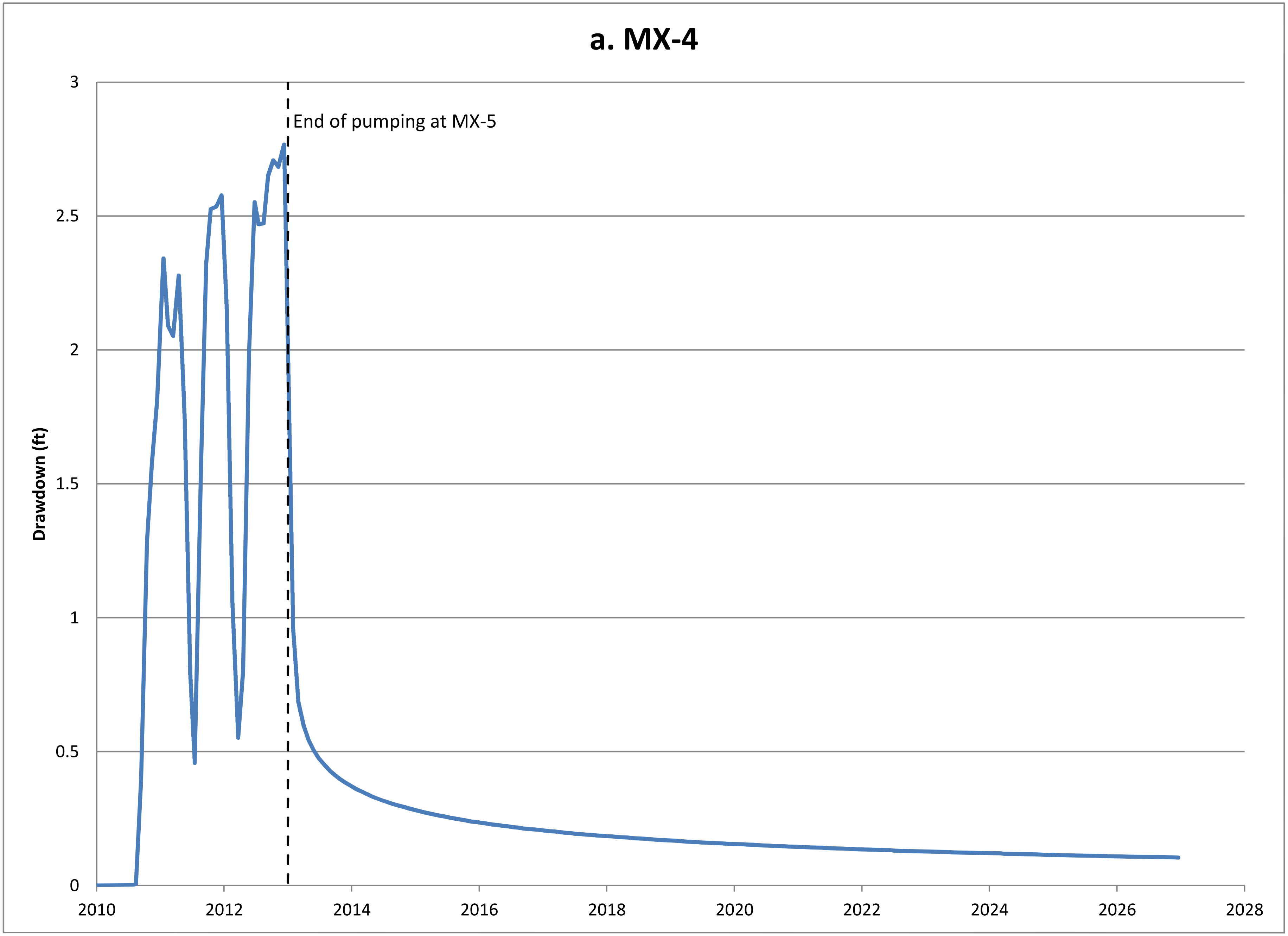


Figure 3-2. Simulated drawdown and recovery caused by pumping of MX-5, at selected wells



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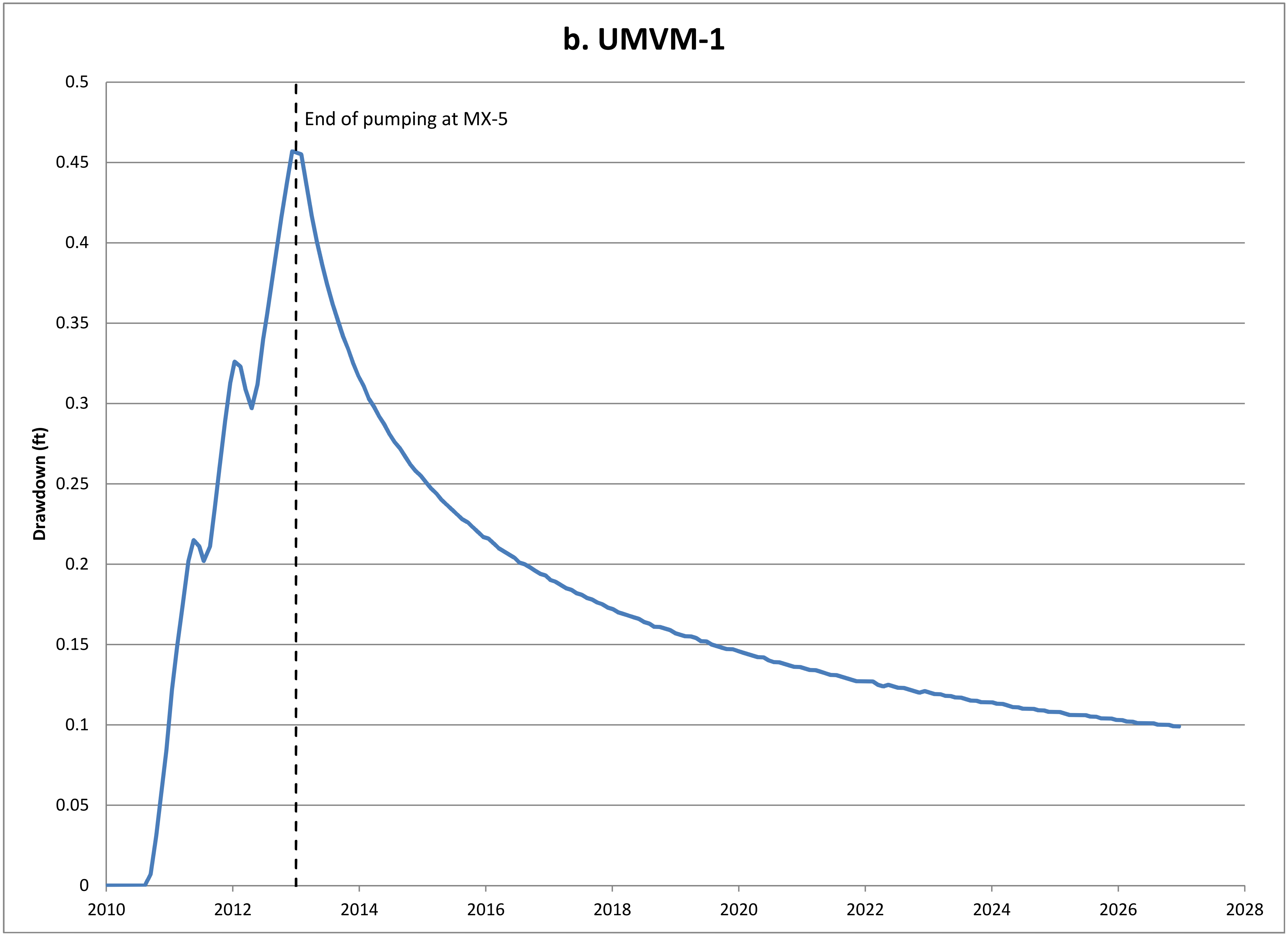
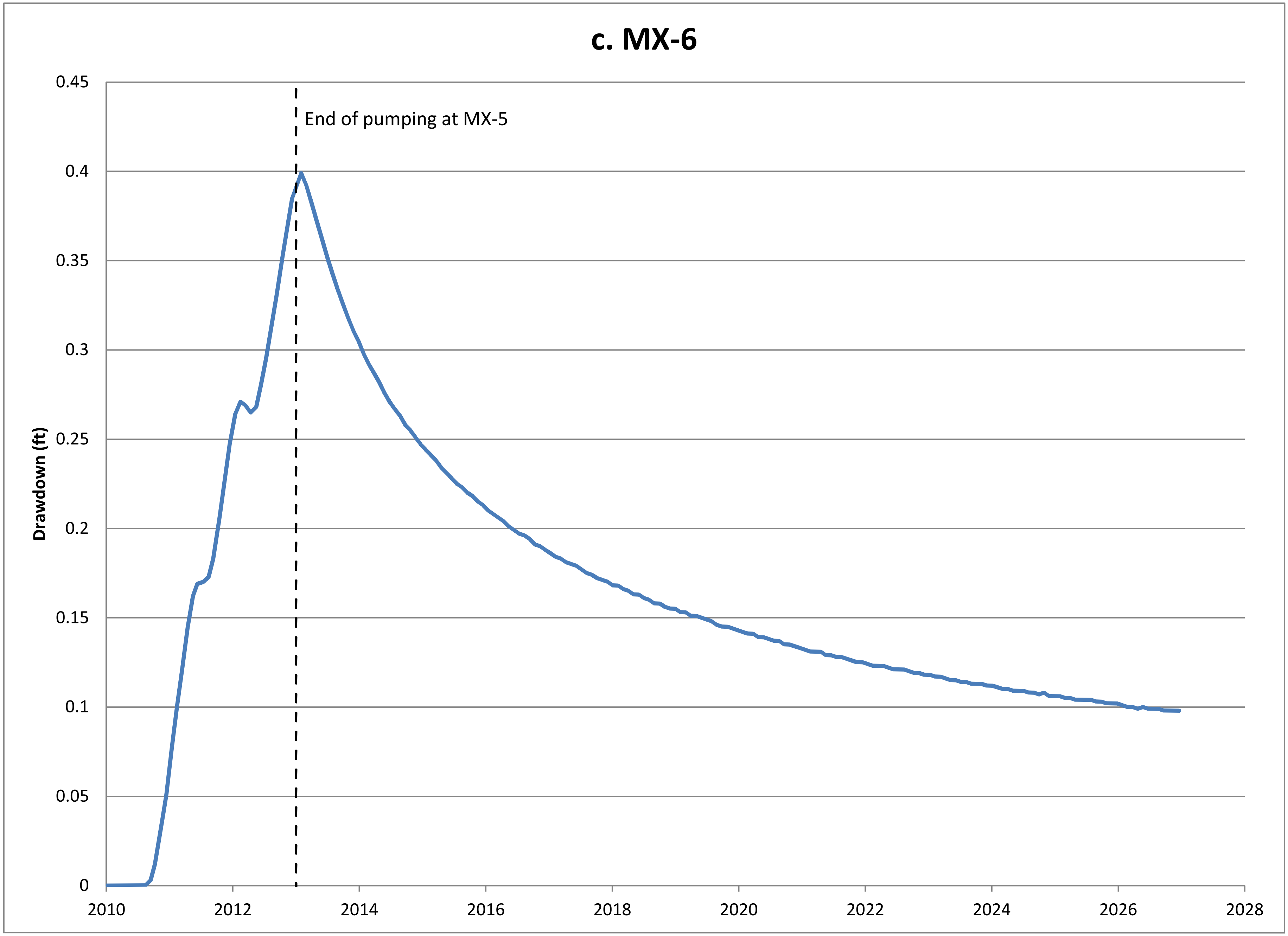
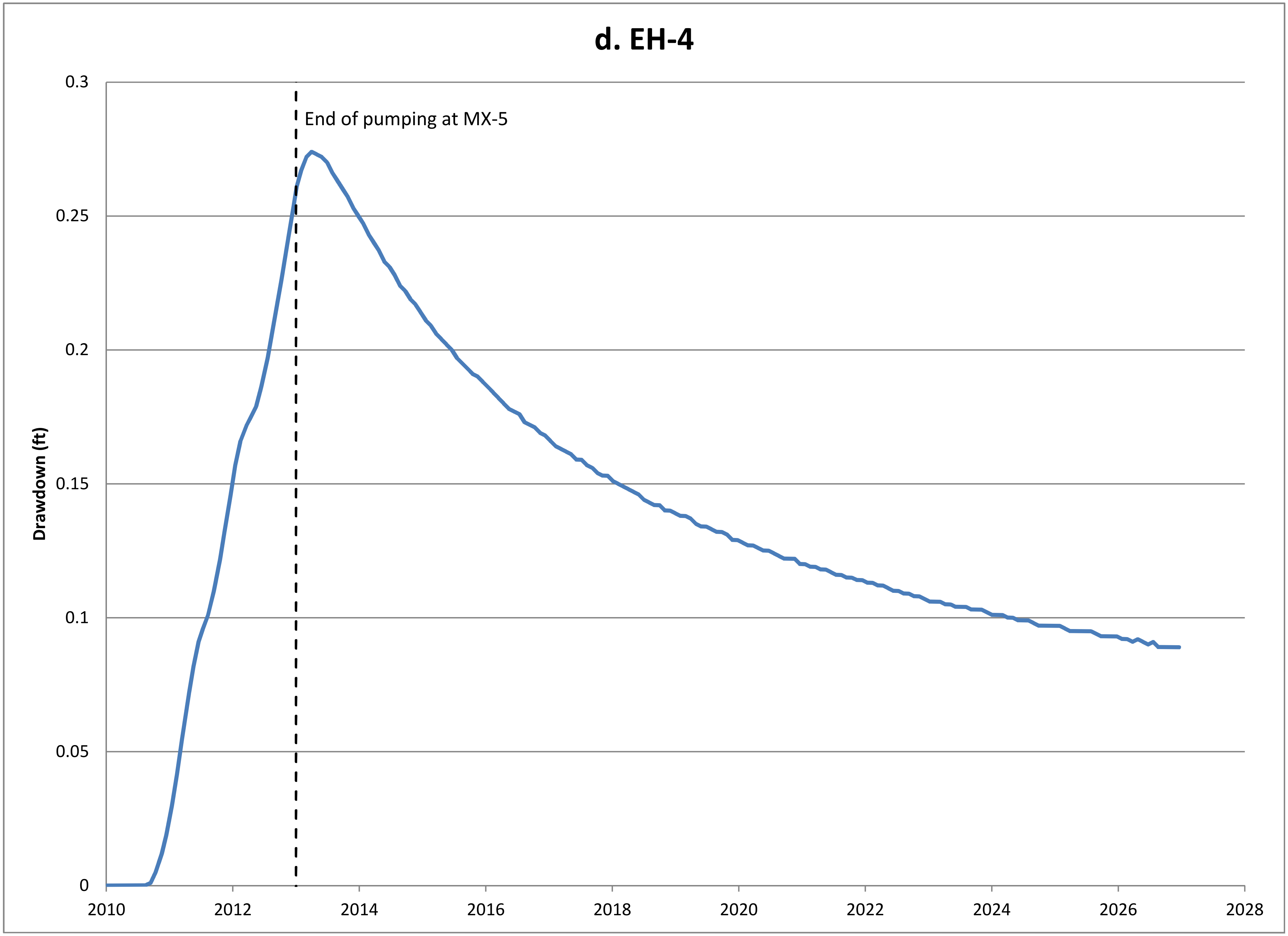

b. UMVM-1
Drawdown (ft)
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
End of pumping at MX-5

SE ROA 12526

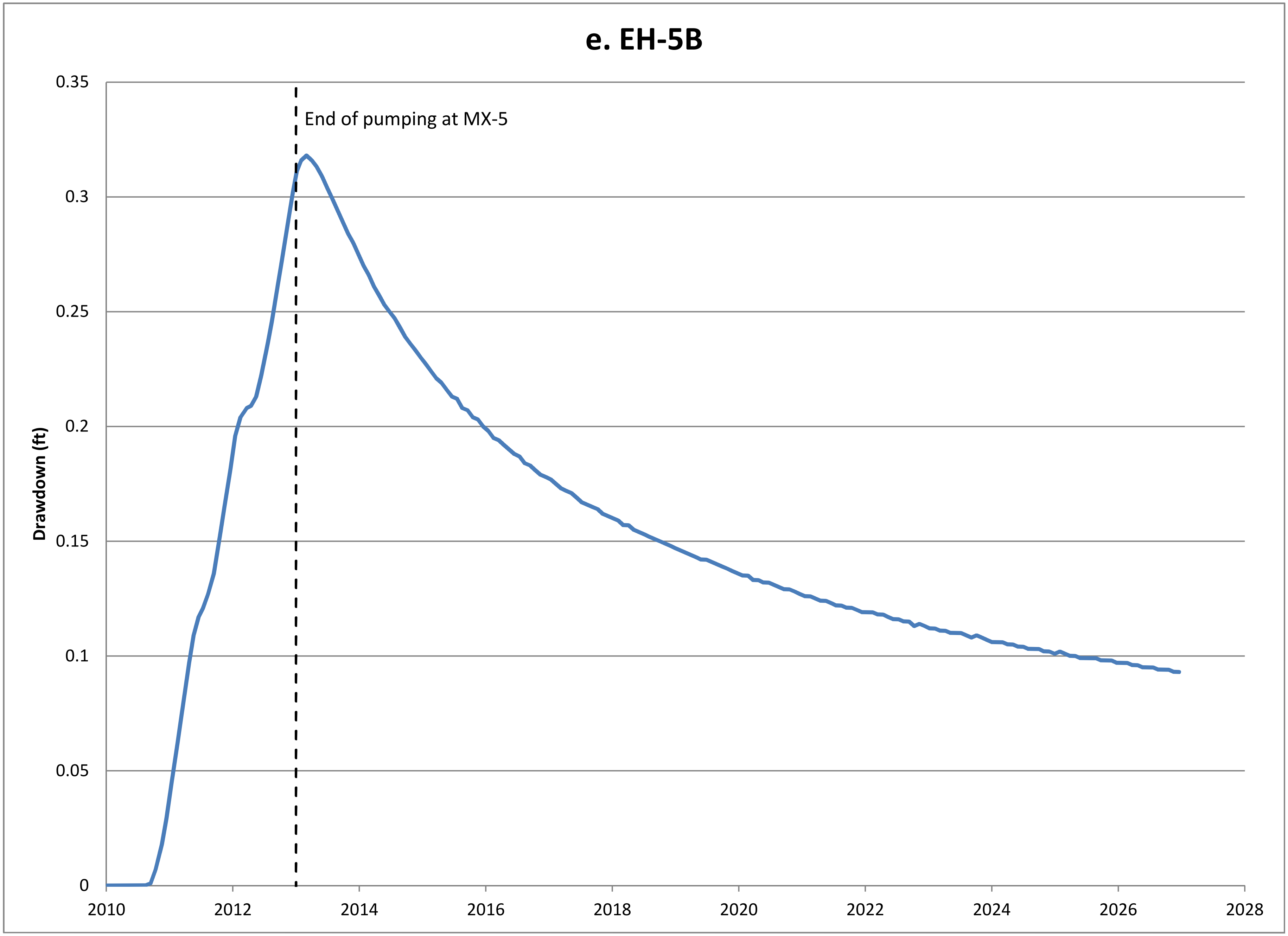


c. MX-6
End of pumping at MX-5
Drawdown (ft)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028

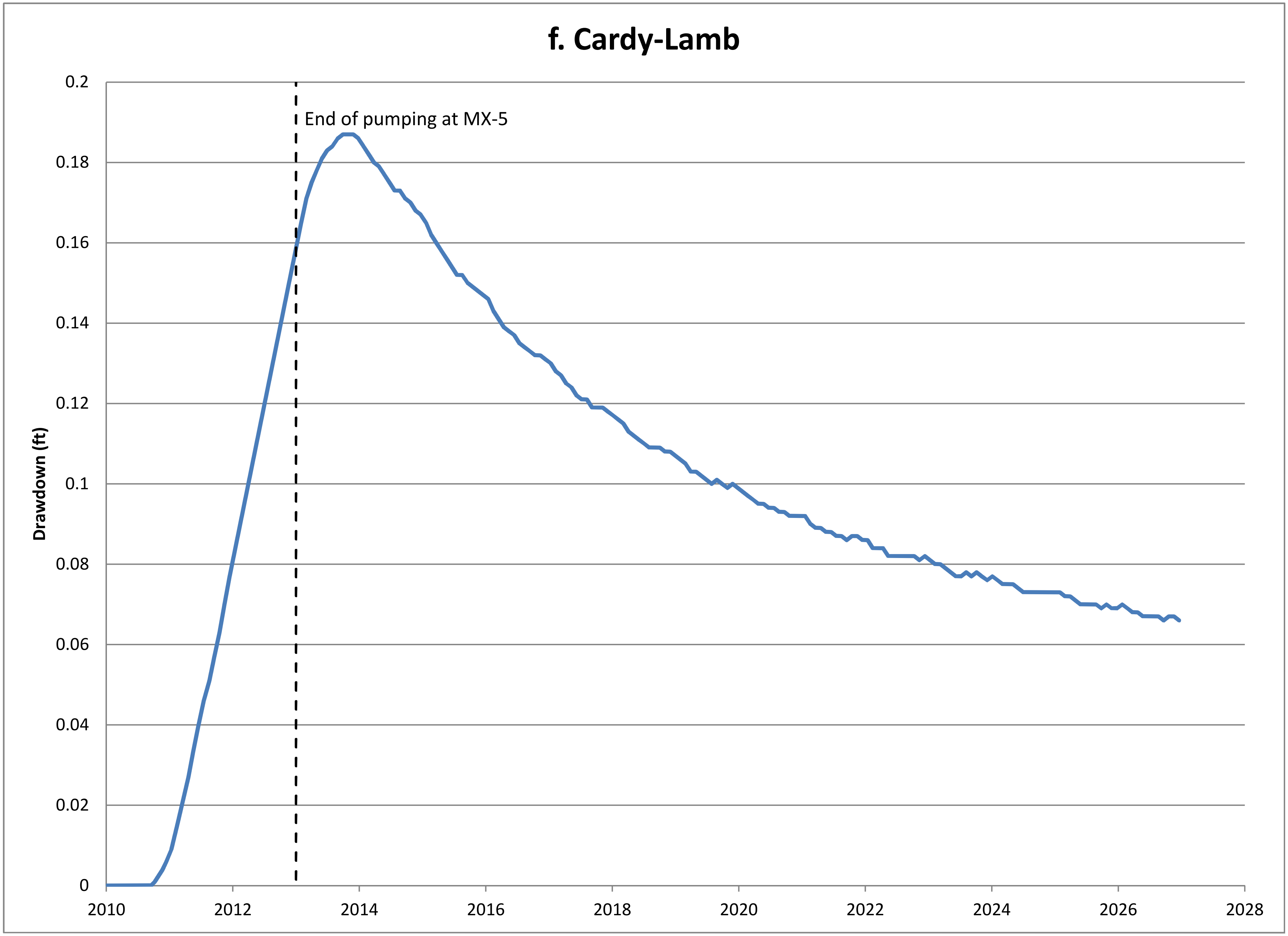
SE ROA 12527


d. EH-4
0.3
0.25
0.2
0.15
0.1
0.05
0
Drawdown (ft)
End of pumping at MX-5
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028

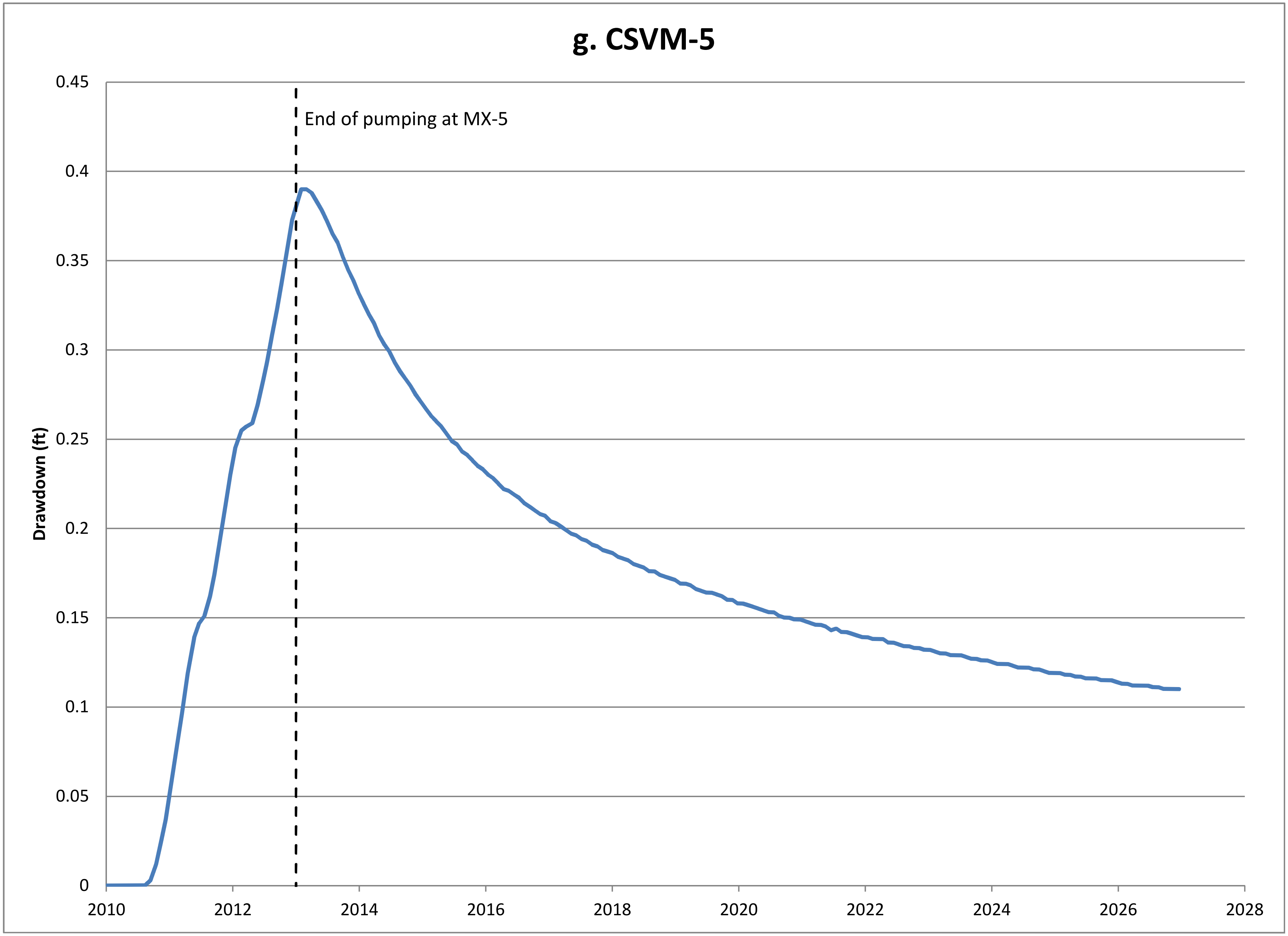
SE ROA 12528


e. EH-5B
End of pumping at MX-5
Drawdown (ft)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028

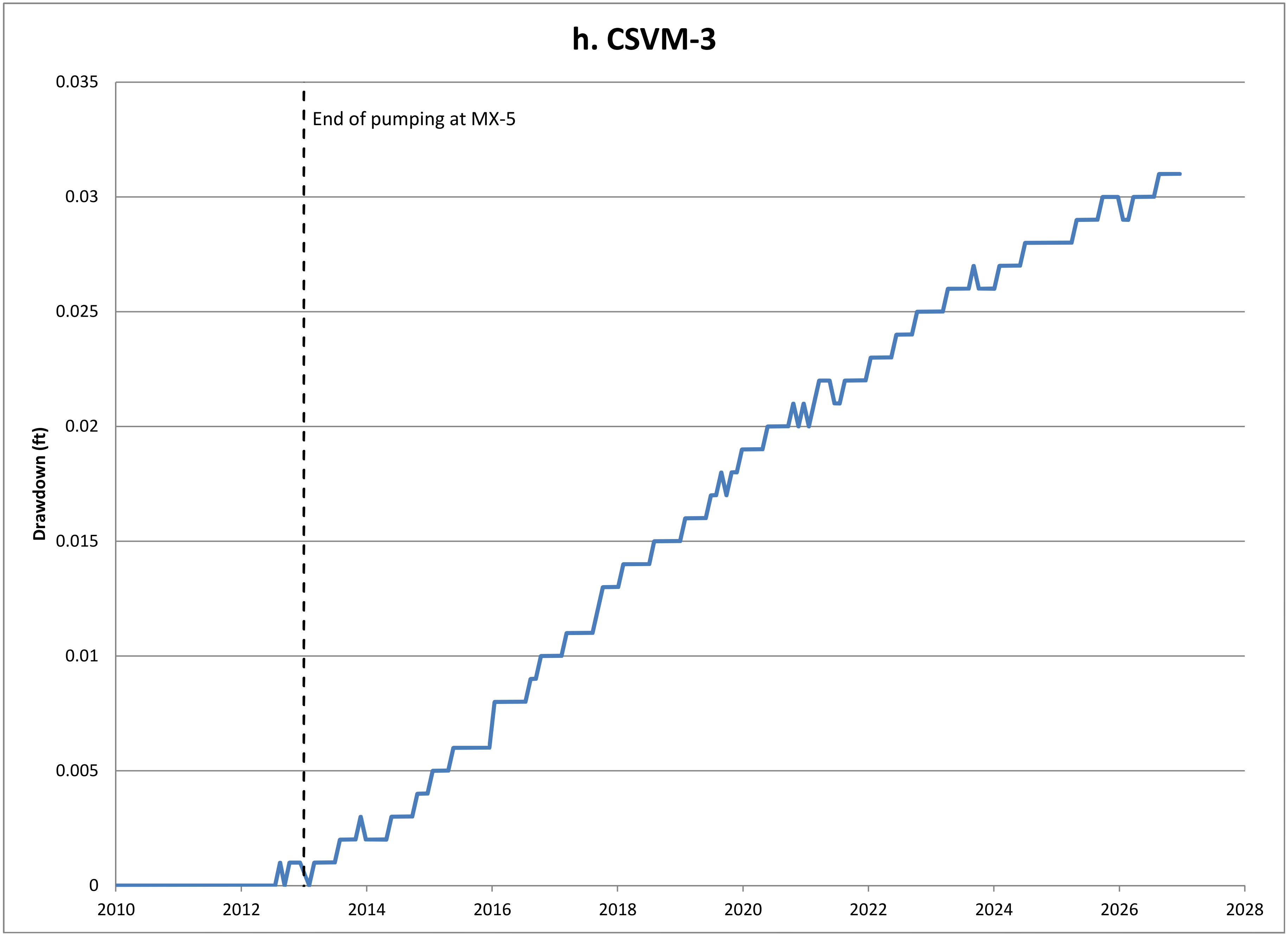
SE ROA 12529

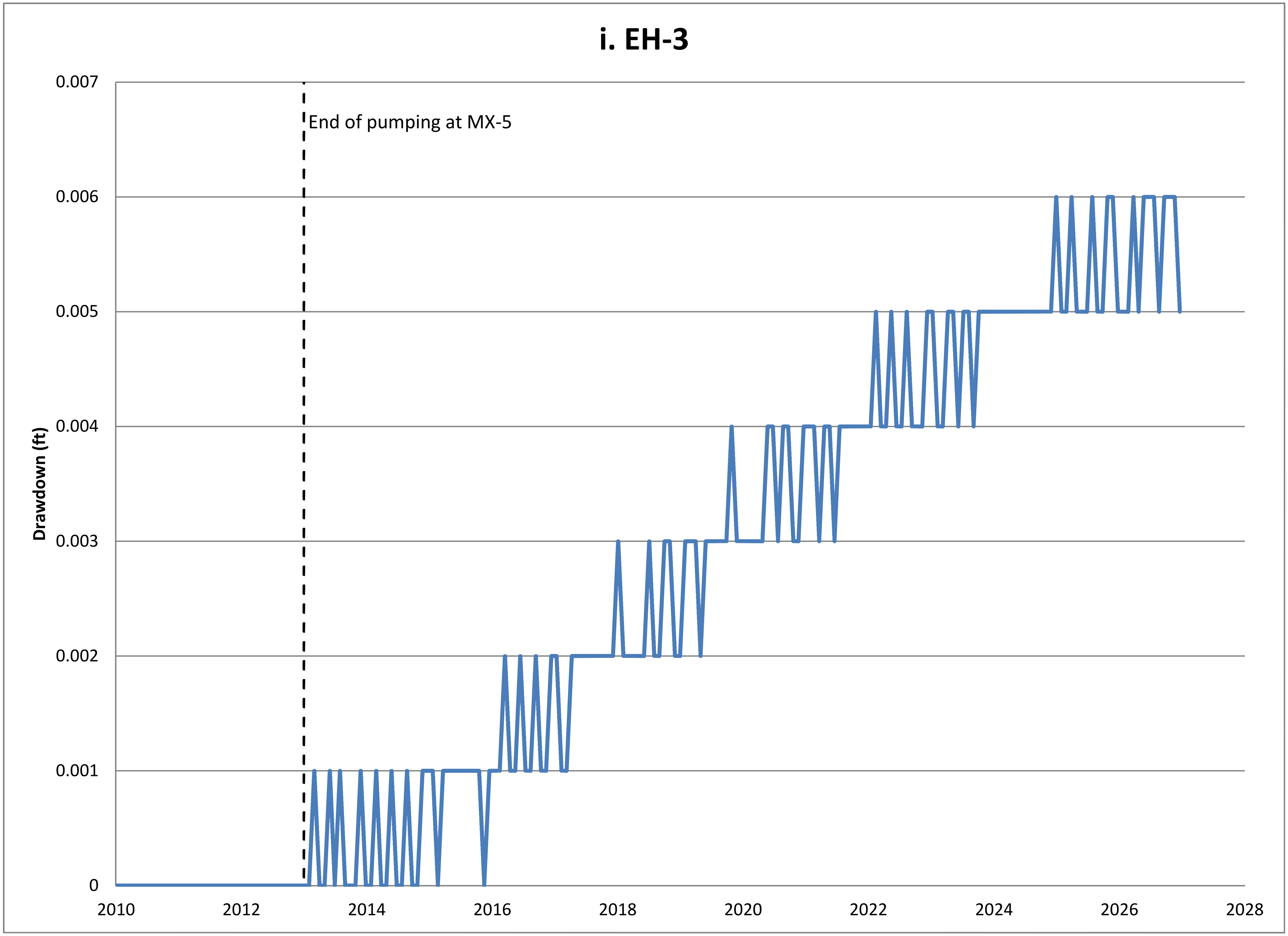

f. Cardy-Lamb
End of pumping at MX-5
Drawdown (ft)
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028

SE ROA 12530


g. CSVM-5
End of pumping at MX-5
Drawdown (ft)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028

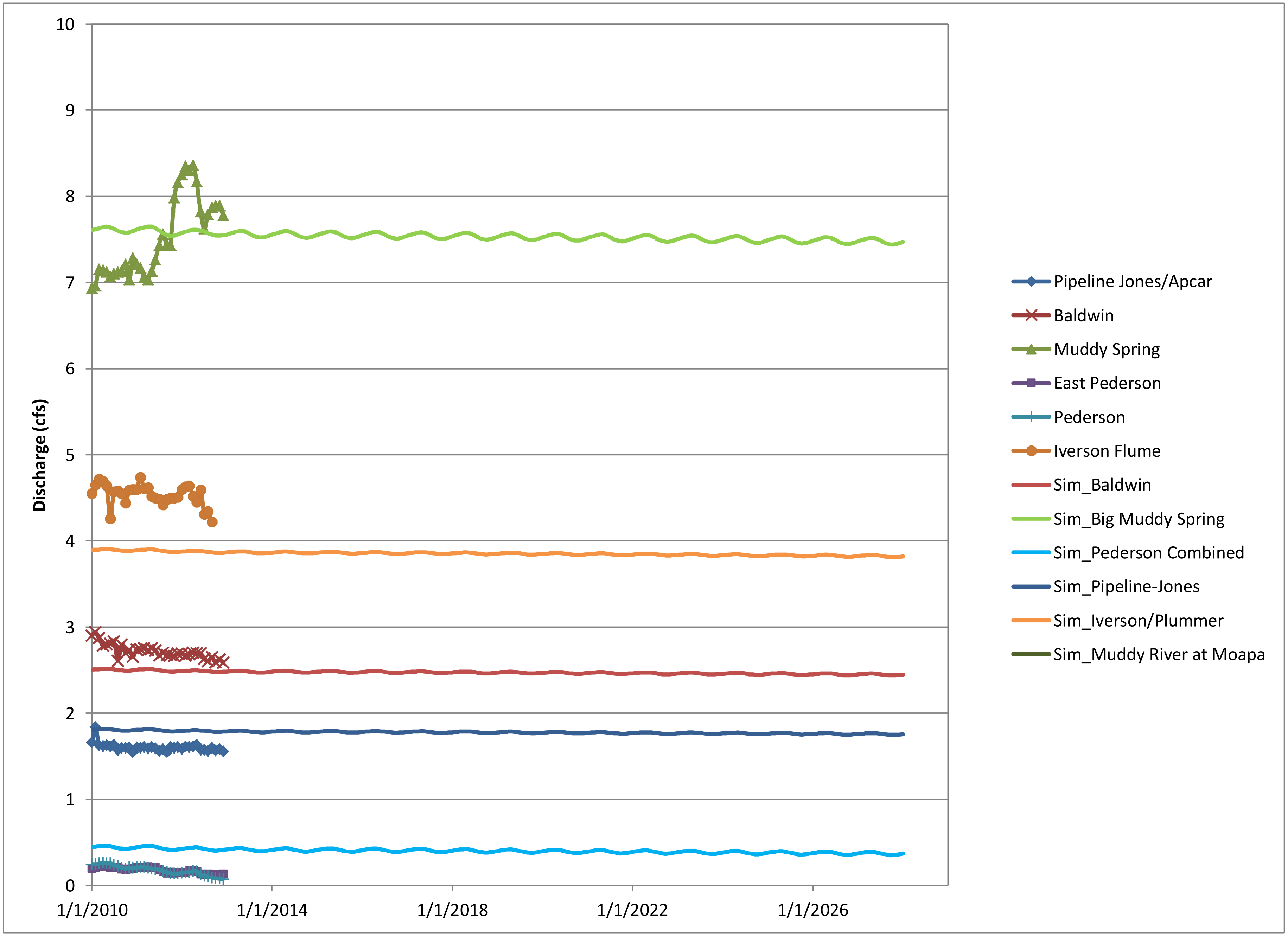
SE ROA 12531


h. CSVM-3
End of pumping at MX-5
Drawdown (ft)
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028


i. EH-3
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
Drawdown (ft)
End of pumping at MX-5
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028

SE ROA 12533

Figure 3-3. Simulated spring discharge rates, Muddy River Springs area, 2010-2027



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Geochemistry and Isotope Hydrology of Representative Aquifers in the Great Basin Region of Nevada, Utah, and Adjacent States

By JAMES M. THOMAS, ALAN H. WELCH, *and* MICHAEL D. DETTINGER

REGIONAL AQUIFER-SYSTEM ANALYSIS—GREAT BASIN, NEVADA–UTAH

U.S. GEOLOGICAL SURVEY PROFESSIONAL PAPER 1409–C

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FOREWORD

THE REGIONAL AQUIFER-SYSTEM ANALYSIS PROGRAM

The Regional Aquifer-System Analysis (RASA) Program was started in 1978 following a congressional mandate to develop quantitative appraisals of the major ground-water systems of the United States. The RASA Program represents a systematic effort to study a number of the Nation's most important aquifer systems, which in aggregate underlie much of the country and which represent an important component of the Nation's total water supply. In general, the boundaries of these studies are identified by the hydrologic extent of each system and accordingly transcend the political subdivisions to which investigations have often arbitrarily been limited in the past. The broad objective for each study is to assemble geologic, hydrologic, and geochemical information, to analyze and develop an understanding of the system, and to develop predictive capabilities that will contribute to the effective management of the system. The use of computer simulation is an important element of the RASA studies, both to develop an understanding of the natural, undisturbed hydrologic system and the changes brought about in it by human activities, and to provide a means of predicting the regional effects of future pumping or other stresses.

The final interpretive results of the RASA Program are presented in a series of U.S. Geological Survey Professional Papers that describe the geology, hydrology, and geochemistry of each regional aquifer system. Each study within the RASA Program is assigned a single Professional Paper number, and where the volume of interpretive material warrants, separate topical chapters that consider the principal elements of the investigation may be published. The series of RASA interpretive reports begins with Professional Paper 1400 and thereafter will continue in numerical sequence as the interpretive products of subsequent studies become available.

Gordon P. Eaton

Gordon P. Eaton
Director

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CONVERSION FACTORS AND VERTICAL DATUM

Inch-pound units of measure used in this report may be converted to International System of units (SI) by using the following factors

Multiply	By	To obtain
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year
foot (ft)	0.3048	meter
foot per day (ft/d)	0.3048	meter per day
foot per mile (ft/mi)	0.1894	meter per kilometer
foot per year (ft/yr)	0.3048	meter per year
gallon (gal)	3.785	liter
inch (in.)	25.40	millimeter
square mile (mi^2)	2.590	square kilometer

Temperature: Degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) by using the formula °F = [1.8(°C)]+32.

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

GEOCHEMISTRY AND ISOTOPE HYDROLOGY OF REPRESENTATIVE AQUIFERS IN THE GREAT BASIN REGION OF NEVADA, UTAH, AND ADJACENT STATES

By James M. Thomas, Alan H. Welch, and Michael D. Dettinger

ABSTRACT

The Great Basin region of Nevada, Utah, and adjacent States, contains approximately 260 basins, which form 39 ground-water flow systems. These flow systems are primarily in unconsolidated basin-fill deposits and in carbonate rock that surround the basin-fill deposits in the eastern Great Basin. This report briefly describes the general quality and chemical character of the ground water, discusses in detail the geochemical and hydrologic processes that produce the chemical and isotopic compositions of water in the two principal flow systems (basin fill and carbonate rock), delineates flow systems in carbonate-rock aquifers of southern Nevada, and discusses ground-water ages and resulting flow velocities within those carbonate-rock aquifers.

Water in aquifers of the Great Basin generally contains less than 1,000 milligrams per liter of dissolved solids, except in natural-discharge and geothermal areas. Aquifers in industrial, mining, urban, and agricultural areas and aquifers containing highly soluble evaporative salts and minerals may contain water having either dissolved-solids concentrations greater than 1,000 milligrams per liter or elevated concentrations of constituents that are considered undesirable for certain uses of the water or both. Generally, the chemical character of ground water in the Great Basin is dominated by sodium, calcium, and bicarbonate in basin-fill aquifers in the predominantly volcanic terrain of the western part of the basin; calcium, sodium, magnesium, and bicarbonate in basin-fill aquifers in the eastern part of the basin; and calcium, magnesium, and bicarbonate in carbonate-rock aquifers in the eastern part of the basin. The chemical character of ground water concentrated by evapotranspiration in discharge areas is generally dominated by sodium, chloride, and sulfate.

In Smith Creek Valley in west-central Nevada, the chemical and isotopic composition of ground water in a hydrologically closed basin-fill aquifer evolves as the water moves from recharge areas to the discharge area. Evapotranspiration concentrates the dissolved solids of precipitation in the recharge areas. This concentrated precipitation dissolves carbon dioxide gas and volcanic groundmass and phenocrysts (dominantly albite and anorthite), chalcedony precipitates from the water, and kaolinite forms by incongruent dissolution, producing a sodium calcium bicarbonate water. In addition, small amounts of gypsum, potassium feldspar, and biotite dissolve. In the terminal playa area, where the basin-fill deposits grade into finer grained sediments, the exchange of calcium and magnesium in the water for sodium on clay minerals causes the sodium calcium bicarbonate water to evolve into a sodium bicarbonate water. Calcium also may be removed from the water by the weathering of plagioclase to calcium sodium montmorillonite and the precipitation of a zeolite mineral. In this part of the aquifer, the dissolution of carbon dioxide gas, albite, anorthite, and potassium feldspar, the precipitation of chalcedony, and the formation of kaolinite continue. In addition, sulfate is reduced to hydrogen sulfide gas. Where ground water discharges by transpiration and evaporation, chloride-containing evaporative salts dissolve and calcite and zeolite minerals precipitate, causing the sodium bicarbonate water to evolve into a sodium chloride water. Evapotranspiration of the ground water also results in heavier deuterium and oxygen-18 compositions.

In the carbonate-rock aquifers of southern Nevada, water in recharge areas dissolves calcite, dolomite, and carbon dioxide gas and rapidly reaches saturation with respect to calcite and dolomite. This water contains predominantly calcium, magnesium, and bicarbonate. Heating of this calcite-saturated water during deep circulation results in the precipitation of calcite. In most of the carbonate-rock aquifers, the following reactions take place: Gypsum (or anhydrite) dissolves, causing dolomite to dissolve, which in turn causes calcite to precipitate (dedolomitization); chalcedony precipitates; calcium and magnesium in the water exchange for sodium in clays; kaolinite forms; and, in some spring areas, carbon dioxide gas exsolves. In parts of the aquifers, water with high concentrations of sulfate and sodium leak into the aquifer from an overlying low-permeability unit. In addition, halite dissolves, sodium and potassium probably are added to the water by the dissolution of volcanic glass, volcanic-rock minerals (dominantly albite and potassium feldspar), and zeolite minerals (probably clinoptilolite); all of which are present in parts of the study area. Thus, outside the recharge areas of the carbonate-rock aquifers in southern Nevada, sodium, sulfate, and chloride can be major constituents dissolved in the water. Waters within the carbonate-rock aquifers that originate in different areas and contain different chemical and isotopic compositions can mix, producing a water that is chemically and isotopically different from the source waters.

Regional ground-water flow systems in the carbonate-rock aquifers of southern Nevada were delineated using deuterium, water chemistry, and adjusted carbon-14 ages. The results are as follows: (1) Ground water discharging at the terminus of the White River flow

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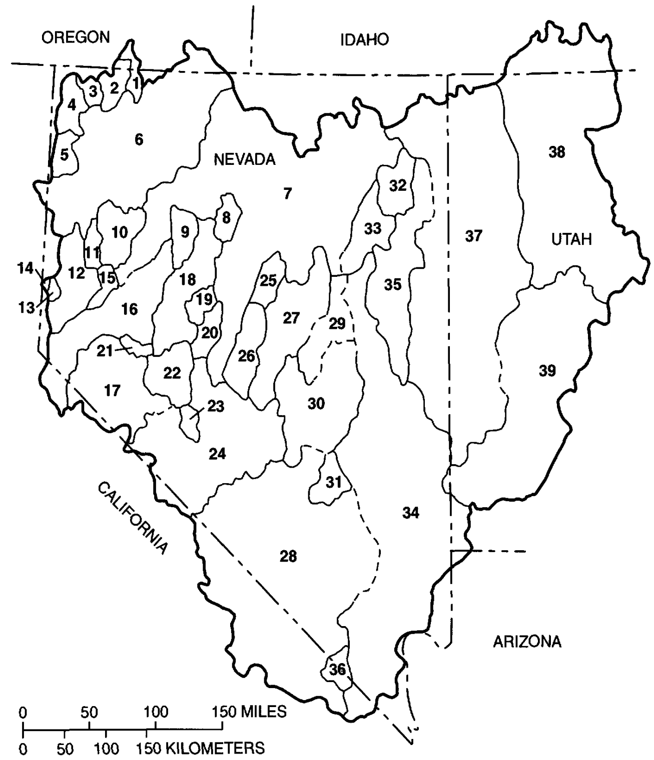
system (Muddy River springs) is a mixture of 40 percent Pahranagat Valley water, 38 percent Sheep Range water, and 22 percent southern Meadow Valley Wash water. (2) Ground water discharging at the terminus of the Ash Meadows flow system (Ash Meadows springs) is a mixture of 60 percent Spring Mountains water and 40 percent Pahranagat Valley water. (3) Las Vegas Valley receives all, or almost all, its ground water from the Spring Mountains (the Sheep Range may supply a small amount to northern Las Vegas Valley). (4) Pahrump Valley receives all its ground water from the Spring Mountains.

Ground-water flow velocities in the carbonate-rock aquifers calculated from adjusted carbon-14 ages are slower than those calculated from hydrologic data. Velocities calculated from adjusted ages range from 9.6 to 144 feet per year, whereas velocities calculated from hydrologic data range from 50 to 740 feet per year. The discrepancy in velocities indicates that ages and average hydraulic conductivities used for the calculations may be overestimated, and effective porosity and flow path length may be underestimated.

INTRODUCTION

The Great Basin, as delineated in this study, includes approximately 260 individual hydrographic areas. These areas can be grouped into 39 flow systems (Harrill and others, 1988), in which ground water flows toward a common hydrographically low discharge area (fig. 1). Some of the larger systems contain subsystems that discharge water at intermediate (higher) positions. The principal aquifers within these flow systems are basin-fill deposits and carbonate rock (Harrill and others, 1988). Volcanic rock form aquifers of local importance, but in Nevada less than 1 percent of total ground-water withdrawal is from volcanic rock (Frick and Carman, 1990, p. 354–356). Highly permeable basin-fill aquifers can be surrounded by generally low-permeability volcanic rock, or by high-permeability carbonate rock. Where basin-fill aquifers are surrounded by low-permeability rock, ground-water flow is mostly contained within the basin-fill sediments. Basin-fill aquifers are present primarily in the western Great Basin, where volcanic rock predominate, and they consist of single-valley, or multivalley, flow systems. In multivalley systems, the basin-fill aquifers are linked by ground-water flow through basin-fill deposits. Basin-fill aquifers also may be hydrologically linked by rivers because of the interaction of surface water and ground water near the rivers. The basin-fill aquifers surrounded by high-permeability rock (mostly carbonate rock) are generally in good hydrologic connection with the underlying and adjacent rock, resulting in deep (several thousand feet) and extensive (hundreds of square miles) ground-water flow within the basin-fill deposits and the surrounding rock.

Highly permeable carbonate-rock aquifers form regional systems in which ground water flows in basin-fill deposits and in carbonate rock that transmit the flow beneath topographic boundaries. These flow



EXPLANATION

Study-area boundary

Flow-system boundary—Dashed where uncertain

Flow systems

1 Continental Lake
2 Virgin Valley
3 Swan Lake Valley
4 Long Valley
5 Duck Lake Valley
6 Black Rock Desert
7 Humboldt
8 Buffalo Valley
9 Buena Vista Valley
10 Granite Springs
11 Winnemucca Lake
12 Truckee
13 Lemmon Valley*
14 Cold Spring Valley
15 Fernley Sink
16 Carson
17 Walker
18 Dixie Valley
19 Edwards Creek
20 Smith Creek Valley
21 Rawhide Flats
22 Gabbs Valley
23 Monte Cristo Valley
24 South Central Marshes
25 Grass Valley
26 Northern Big Smoky Valley
27 Diamond Valley
28 Death Valley
29 Newark Valley
30 Railroad Valley
31 Penoyer Valley
32 Independence Valley
33 Ruby Valley
34 Colorado
35 Goshute Valley
36 Mesquite Valley
37 Great Salt Lake Desert
38 Great Salt Lake
39 Sevier Lake

* Part of multibasin system. Not known whether subsurface drainage is to the northwest (out of study area) or to the Truckee system.

FIGURE 1.—The 39 major flow systems of the Great Basin, as delineated by Harrill and others (1983, fig. 3).

systems are in the eastern part of the study area (fig. 1), where sequences of carbonate rock generally are more than 20,000 ft thick (Plume and Carlton, 1988).

In 1978, the U.S. Geological Survey began a series of Regional Aquifer-System Analysis (RASA) studies to aid effective management of the Nation's ground-water resources by providing information on the hydrology and geochemistry of the Nation's major aquifers (Bennett, 1979). The Great Basin RASA study is the 10th in this series. The objectives of the geochemistry part of the RASA studies are to describe the quality of water in aquifers on a regional scale and to determine the geochemical processes that produce the observed water chemistry. As work on the Great Basin RASA study was nearing completion, the State of Nevada began a study of the carbonate-rock aquifers of eastern and southern Nevada involving the U.S. Geological Survey, Bureau of Reclamation, and the Desert Research Institute. The overall objective of this study was to explore the potential for developing the carbonate-rock aquifers as water supplies (U.S. Department of the Interior, 1985). In the carbonate-rock aquifers study, geochemical information was used extensively to delineate ground-water flow systems of southern Nevada. This report incorporates the geochemical findings of both studies.

PURPOSE AND SCOPE

The purposes of the study upon which this report is based were to (1) briefly describe the general chemical character of ground water in the Great Basin; (2) identify and illustrate by examples the processes that produce the chemical and isotopic compositions of water in representative aquifers of the Great Basin; (3) delineate ground-water flow paths and mixing of water in the carbonate-rock aquifers of southern Nevada using chemical and isotopic data; and (4) determine ground-water ages and use these ages to calculate flow velocities of ground water in the carbonate-rock aquifers in southern Nevada, and compare these velocities with velocities calculated using hydrologic data.

The Great Basin RASA study encompassed most of Nevada, the west half of Utah, and small parts of Arizona, California, Idaho, and Oregon. This 140,000-mi^2 area contains 39 ground-water flow systems (fig. 1; Harrill and others, 1988, table 1). In this report, general ground-water quality is briefly described for the entire area and geochemical processes affecting chemical and isotopic compositions of ground water are described in detail for two principal types of flow systems: a hydrologically closed basin-fill aquifer (Smith Creek Valley) and a regional system in which ground water flows through several valleys in basin-fill and carbonate-rock aquifers (southern Nevada).

SAMPLING METHODS AND GEOCHEMICAL DATA

Alkalinity, pH, temperature, specific conductance, and dissolved oxygen were measured at each sampling site. Water samples for major-ion analyses were filtered through a 0.45-μm membrane filter and stored in polyethylene bottles. Samples for cation analysis were acidified to a pH of about 1.5 with nitric acid (Wood, 1976). Samples for nutrient analyses were stored in opaque bottles, preserved with mercuric chloride, and kept at 4°C until analyzed. Dissolved organic carbon samples were filtered in a stainless steel assembly using a 0.45-μm silver membrane filter, stored in glass bottles, and kept at 4°C until analyzed. Samples for deuterium, oxygen-18, and tritium analyses were collected in glass bottles. Samples for carbon-14 analysis were collected in a 2-L linear polyethylene bottle that was attached to the bottom of a 50-gal precipitation tank. The tank was flushed with nitrogen gas prior to being filled with water. The pH of the water was raised to above 10 by adding a CO_2-free sodium hydroxide solution to convert all dissolved carbon to carbonate, and then a CO_2-free strontium chloride solution was added to the water to precipitate strontium carbonate. Samples for carbon-13 analysis were collected in a 1-L glass bottle by flushing the bottle with several volumes of sample water, filling the bottle with sample water, and then precipitating strontium carbonate with a CO_2-free ammoniacal strontium chloride solution. For both carbon isotope samples, suspended particles were filtered out of the water with an in-line filter closed to the atmosphere.

Major-ion and nutrient concentrations were determined by the National Water-Quality Laboratory of the U.S. Geological Survey, in Arvada, Colo., and the Desert Research Institute Laboratory in Reno, Nev. Dissolved organic carbon was analyzed at the U.S. Geological Survey National Water-Quality Laboratory. Deuterium and oxygen-18 were analyzed by the U.S. Geological Survey Research Laboratory in Reston, Va., and the Desert Research Institute Isotope Laboratory in Las Vegas, Nev. Carbon isotopes were analyzed by the U.S. Geological Survey National Water-Quality Laboratory, the Desert Research Institute Isotope Laboratory in Las Vegas, Nev., and the Teledyne Isotope Laboratory in Westwood, N.J. Tritium was analyzed at the U.S. Geological Survey National Water-Quality Laboratory and the Desert Research Institute Isotope Laboratory in Reno, Nev.

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GENERAL CHEMICAL CHARACTER OF GREAT BASIN GROUND WATER

Most water in the principal aquifers of the Great Basin, except in natural discharge and geothermal areas, contains less than 1,000 milligrams per liter (mg/L) of dissolved solids. Ground water in industrial, mining, urban, or agricultural areas, as well as in areas affected by dissolution of readily soluble minerals, can contain dissolved-solids concentrations in excess of 1,000 mg/L or constituent concentrations above National and State drinking water standards, or both (Lamb and Woodward, 1988; Parliman, 1988; Thomas and Hoffman, 1988; Waddell and Maxell, 1988).

Water containing natural (in contrast to human-affected) concentrations of dissolved solids exceeding 1,000 mg/L generally is in areas of evapotranspiration, evaporite deposits, or geothermal activity. Evapotranspiration in areas of shallow ground water (generally less than 20 ft below land surface) increases the dissolved-solids concentration of the residual water. Evapotranspirative concentration is most prevalent in ground-water discharge areas, such as playas, at the distal end of flow systems.

Evaporite salts and minerals, such as gypsum and halite, are highly soluble, and their dissolution results in a marked increase in dissolved solids. Evaporite salts and minerals are generally present in playa areas and in carbonate rock of Permian and younger age in the Great Basin (Hintze, 1980; Stewart, 1980).

Geothermal heating of water in aquifers generally produces higher concentrations of dissolved solids because the solubility of most minerals increases with temperature. Geothermal waters also can contain high concentrations of undesirable constituents, such as arsenic, boron, fluoride, and lithium. Geothermal activity occurs in localized areas throughout the Great Basin because of the extensional tectonic processes that have formed the characteristic basin-and-range structure (Fiero, 1986).

Human-induced degradation of water quality in industrial, mining, urban, and agricultural areas of the Great Basin is covered in several articles of the 1986 National Water Summary (Lamb and Woodward, 1988; Parliman, 1988; Thomas and Hoffman, 1988; Waddell and Maxell, 1988).

The chemical composition of water in basin-fill aquifers of the Great Basin containing less than 1,000 mg/L dissolved solids generally is dominated by calcium, sodium, magnesium, and bicarbonate. The chemical composition of water in basin-fill aquifers containing more than 1,000 mg/L dissolved solids generally is dominated by sodium, chloride, and sulfate. The chemical composition of water in carbonate-rock aquifers of the Great Basin generally is dominated by calcium, magnesium, and bicarbonate. Sodium also can be a dominant ion in these waters if volcanic rock or clay minerals are present before the ground water enters the carbonate-rock aquifers, or are found within the aquifers.

The chemical composition of water recharging aquifers in the Great Basin is derived from dissolution of soil-zone minerals and CO_2 gas. Chemical composition can change along flow paths as different processes take effect or as ground water comes in contact with different minerals. The chemical types of ground water in the principal aquifers of the Great Basin, based on the dominant ions dissolved in the water, are shown on four State maps at a scale of 1:500,000 (Thompson and Chappell, 1984a, b; Thompson and Nutter, 1984; Thompson and others, 1984) and in detail on 14 maps showing most of the Great Basin at a scale of 1:250,000 (Welch and Williams, 1986a–d, 1987a–j).

Basin-fill aquifers in the western Great Basin are derived by erosion of the predominantly volcanic rock in mountains that surround the basins (Plume and Carlton, 1988). Thus, these aquifers contain sediments that consist of volcanic glass and minerals primarily composed of sodium, potassium, calcium, silica, aluminum, and oxygen. Water chemistry in recharge areas and the upgradient part of the aquifers is dominated by sodium, calcium, and bicarbonate ions (Thompson and Chappell, 1984a, b; Thompson and Nutter, 1984; Thompson and others, 1984; Welch and Williams, 1986a–d, 1987a–j) because of the dissolution of volcanic glass and minerals by CO_2-rich water. Most of these basins and flow systems contain a discharging playa area. Near, or within, these playa areas, the chemical composition of ground water may evolve into a sodium dominated water, and with increasing dissolved-solids concentration, chloride and sulfate become dominant over bicarbonate. The water type changes because of (1) exchange of calcium and magnesium dissolved in the water for sodium on clay minerals; (2) dissolution of evaporative salts and minerals in sediments in the discharge area; (3) precipitation of minerals that removes select ions from the water; or (4) any combination of these processes.

Basin-fill aquifers in the eastern Great Basin are derived by erosion of the predominantly carbonate- and volcanic-rock mountains (Plume and Carlton, 1988). Thus, these aquifers contain sediments that consist of carbonate and volcanic minerals primarily composed of calcium, magnesium, and carbonate, in addition to sodium, potassium, silica, aluminum, and oxygen. Water chemistry in recharge areas and the upgradient part of aquifers, consisting mainly of carbonate rock, is dominated by calcium, magnesium, and bicarbonate ions, whereas aquifers consisting mainly of volcanic rock are dominated by sodium, calcium, and bicarbonate ions. Most basins in this part of the Great Basin do not have discharging playas, instead the basin-fill aquifers drain through carbonate rock to large springs. Thus, water chemistry along a flow path generally changes little in composition.

Carbonate-rock aquifers in the eastern Great Basin are composed primarily of calcite and dolomite. Water chemistry in recharge areas and the upgradient part of these aquifers is dominated by calcium, magnesium, and bicarbonate ions. As water flows through the carbonate-rock aquifers and comes in contact with volcanic rock and clay minerals, sodium ion concentration increases. Some carbonate-rock aquifers in the southeastern Great Basin contain interbedded evaporite deposits; as a result, sulfate, chloride, and sodium ions may predominate in ground water in these areas.

GEOCHEMICAL AND ISOTOPIC CHARACTERIZATION OF REPRESENTATIVE GREAT BASIN FLOW SYSTEMS

The Great Basin does not contain a single aquifer (as is common in other regional ground-water flow systems, such as, the Floridan, Madison, and Ogallala aquifers) but instead contains numerous aquifers. The two principal types of flow systems in the Great Basin are basin-fill and carbonate-rock aquifers. This report discusses geochemical processes that produce the major-ion chemistry and isotopic composition of ground water in aquifers representative of these two types. These processes are (1) evapotranspiration, (2) dissolution of minerals and CO_2 gas, (3) precipitation of minerals or formation by incongruent dissolution, (4) ion exchange, (5) mixing of chemically or isotopically different waters, and (6) geothermal heating.

Ground water is concentrated by evapotranspiration in areas of shallow water (less than about 20 ft below land surface) generally in the discharge areas of flow systems. This process is important in large areas of shallow ground water, such as playas.

Dissolution of soil-zone minerals and CO_2 gas in recharge areas of aquifers produces the chemical composition of water in the upper parts of aquifers. As residence time of water in an aquifer increases, constituent concentrations may increase until the water reaches saturation with respect to the dissolving mineral or gas. Water chemistry also changes as different minerals along the flow path dissolve.

Precipitation or formation of minerals can change the chemical composition of water because select ions are removed from the water. Mineral precipitation, in the principal aquifers of the Great Basin, is generally the result of evapotranspirative concentration of the water, temperature changes, or dedolomitization. Evapotranspirative concentration of ground water causes the water to become supersaturated with respect to some minerals, resulting in precipitation of those minerals. An increase in water temperature, generally caused by water circulating to depths of several thousand feet, causes some minerals to precipitate. For example, an increase in temperature from 10°C to 25°C of a water that is saturated with respect to calcite results in an approximately 25 percent decrease in total carbonate content because of calcite precipitation (Palmer and Cherry, 1984). Dedolomitization is the dissolution of dolomite and precipitation of calcite from a water saturated with respect to calcite and dolomite and undersaturated with respect to gypsum. This reaction is driven by the dissolution of gypsum (or anhydrite). Dedolomitization also increases sulfate and magnesium concentrations in the water.

Ion exchange removes one or more ions from the water while simultaneously adding one or more ions to the water. For example, calcium and magnesium ions may be removed from the water by exchanging with sodium and potassium ions on clay minerals.

Mixing waters of different chemical or isotopic compositions produces a water that is chemically or isotopically different from the original waters. For example, a mixture of 50 percent water with a chloride composition of 10 mg/L and 50 percent water with a chloride composition of 30 mg/L would result in a water containing 20 mg/L chloride.

Increased temperature due to deep circulation of ground water can increase or decrease the solubility of minerals (Palmer and Cherry, 1984) and cause a shift in the oxygen-18 composition of the water. For example, chalcedony becomes more soluble with increasing temperature, resulting in an increase in silica concentration with increased water temperature. Conversely, calcite solubility decreases with increasing temperature and calcite precipitates, so increased temperature removes calcium and carbon from the water. Higher water temperature also can result in a shift in oxygen-18 composition of the water because the exchange rate of oxygen in water for oxygen in minerals increases with increasing temperature (Gat and Gonfiantini, 1981).

GEOCHEMICAL EVOLUTION OF GROUND WATER IN A TYPICAL BASIN-FILL AQUIFER

Typical basin-fill aquifers consist of unconsolidated sedimentary deposits ranging from high-permeability sand and gravel to low-permeability clay and silt. These generally mixed deposits grade inward from poorly sorted alluvial-fan deposits, consisting of boulders to clay-size particles, around the margin of the basin to well-sorted sand and gravel deposits and ultimately into fine-grained playa deposits near the center of the basin. In some valleys the basin-fill deposits are surrounded and underlain by relatively low-permeability rock, such as volcanic rock, and in other valleys the basin-fill deposits are surrounded and underlain by rock that includes relatively high-permeability carbonate rock. Basin-fill aquifers surrounded by low-permeability rock are found throughout the Great Basin but are more common in the western part where low-permeability volcanic rock predominates. Smith Creek Valley in west-central Nevada is a typical basin-fill aquifer surrounded and underlain by low-permeability rock.

In most basin-fill aquifers surrounded by low-permeability rock, ground water flows within the basin-fill deposits and is discharged in an extensive area (tens to hundreds of square miles), commonly a centrally located playa surrounded by phreatophytic vegetation. Smith Creek Valley is hydrologically closed. Precipitation that falls within the topographic basin is discharged within the basin, except in the extreme southern part of the valley. Ground water flows southward from this part, because in this area the aquifer is hydrologically separated from the main basin-fill aquifer by igneous intrusions that form a barrier to northward ground-water flow (figs. 2, 3).

Smith Creek Valley encompasses 583 mi^2 and ranges in altitude from about 6,000 ft above sea level at the playa surface to more than 10,000 ft in the surrounding mountains. Climate differs from arid (about 6 in. of precipitation a year on the valley floor) to semiarid (up to about 20 in. of precipitation) in the mountains (Thomas, Carlton, and Hines, 1989, p. 5–8). The principal source of ground-water recharge probably is precipitation in the mountains above an altitude of 7,000 ft (Everett and Rush, 1964).

The hydrology of Smith Creek Valley has been studied by Everett and Rush (1964) and Thomas, Carlton, and Hines (1989). These studies describe the hydrology of the shallow part of the basin-fill aquifer and include a water budget for the basin. The ground-water chemistry of Smith Creek has been described by Thomas, Welch, and Preissler (1989).

GEOLOGIC FRAMEWORK

Consolidated rock and unconsolidated deposits in Smith Creek Valley can be divided into three hydrogeologic units: (1) low-permeability consolidated rock, (2) high-permeability basin-fill deposits, and (3) low-permeability playa deposits (fig. 2). Consolidated rock surrounds and underlies the unconsolidated basin-fill deposits. Basin-fill deposits consist of poorly sorted heterogeneous sediments at the basin margin that grade sequentially inward to well-sorted coarse-grained sediments, to mixed coarse-, medium-, and fine-grained sediments (heterogeneous sediments), to fine-grained playa sediments near the center of the basin (fig. 4).

The mineralogy of the basin-fill sediments and the water chemistry reflect to differing degrees the mineral composition of the rock composing the surrounding mountains. About 95 percent of the exposed consolidated rock are volcanic rock of Tertiary to Quaternary age (Stewart and McKee, 1977; Kleinhampl and Ziony, 1985). Rock composing the Desatoya Mountains on the west side of the basin and the southern Shoshone Mountains on the east side of the basin is almost entirely rhyolitic tuff. These mountain ranges are the principal source areas for the basin-fill deposits and also the source areas for approximately 95 percent of the recharge to the basin (Thomas, Carlton, and Hines, 1989, p. 16).

The Desatoya Mountains are composed primarily of an unnamed densely welded crystal-poor rhyolite ash-flow tuff containing less than 10 percent phenocrysts (Stewart and McKee, 1977, p. 42). Modal (mineralogic) analyses of this tuff (Barrows, 1972, p. 41 and 67) show that the phenocrysts consist mainly of plagioclase feldspar with lesser amounts of alkali feldspar and quartz (table 1). Four plagioclase samples range in calcium content from 17 to 45 percent (Barrows, 1972). A crystal-rich biotite-bearing ash-flow tuff composes 15 percent of the rock exposed in the Desatoya Mountains (Stewart and McKee, 1977); this tuff occupies the highest altitude zone of the range, the source area for about 35 percent of the recharge to the basin-fill aquifer (Thomas, Carlton, and Hines, 1989). This tuff contains

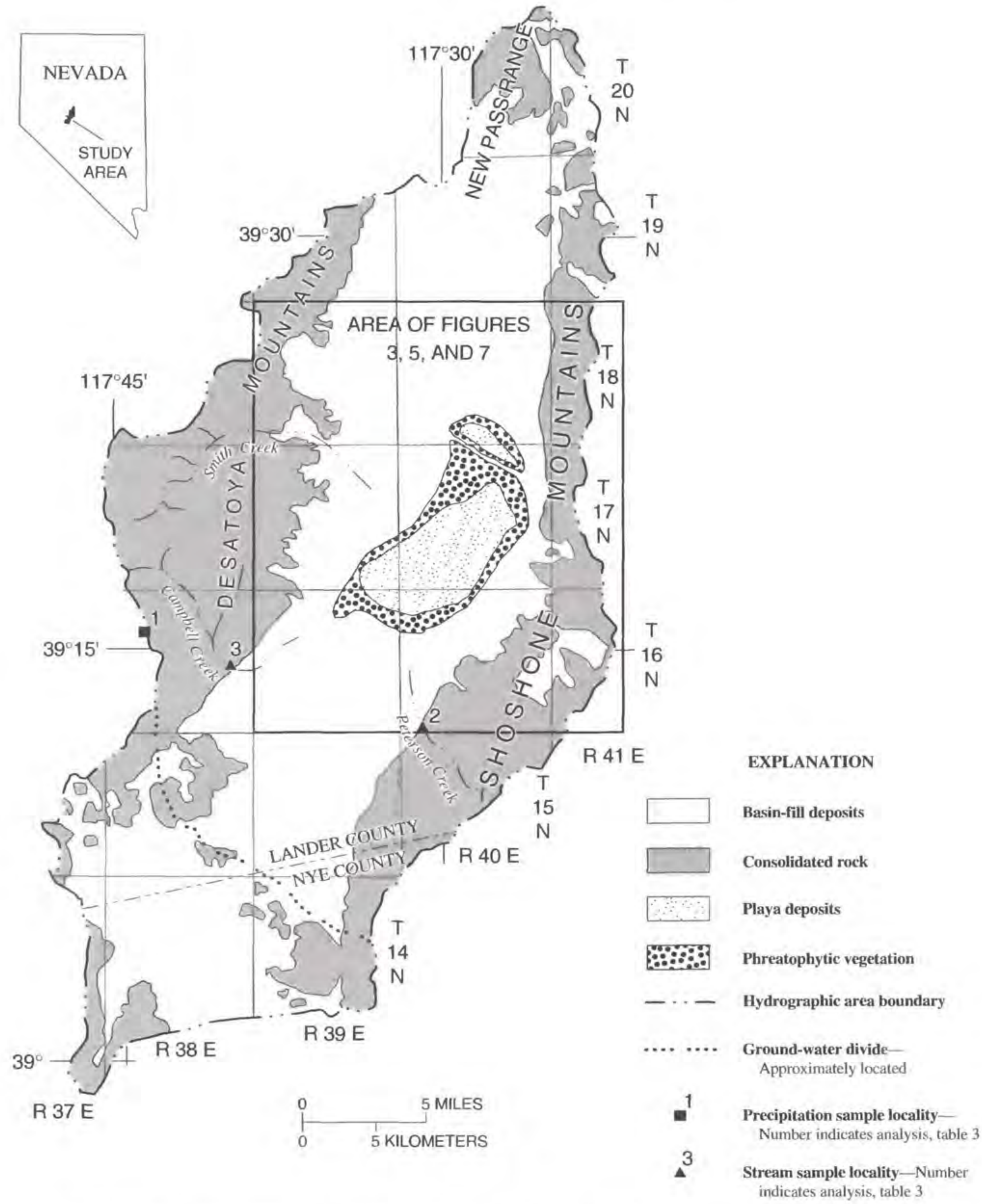

FIGURE 2.—Location and general features of Smith Creek Valley, Nev., showing precipitation and stream sample localities.

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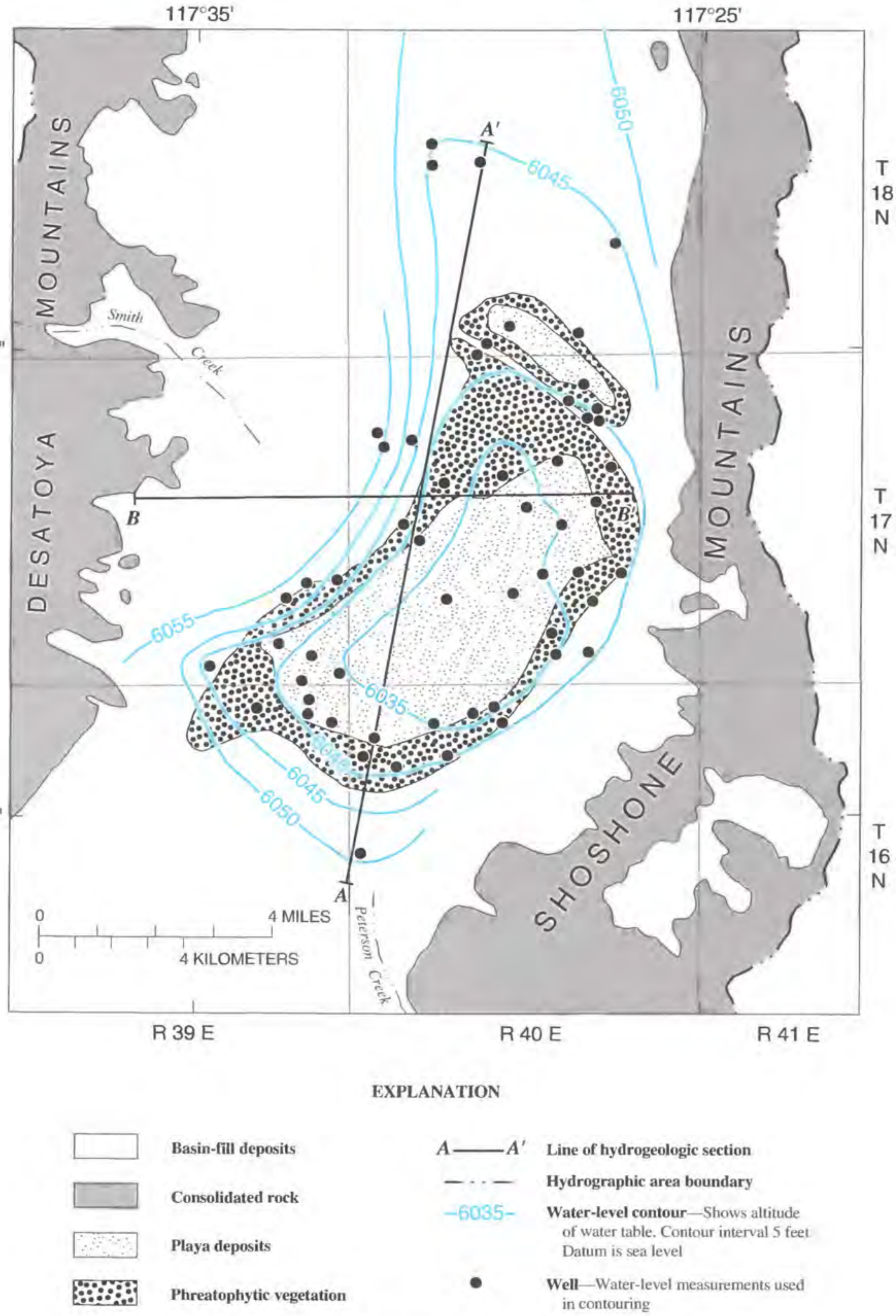


FIGURE 3.—Water-table configuration in central Smith Creek Valley, Nev., June 1982. Sections *A-A'* and *B-B'* shown in figure 4.

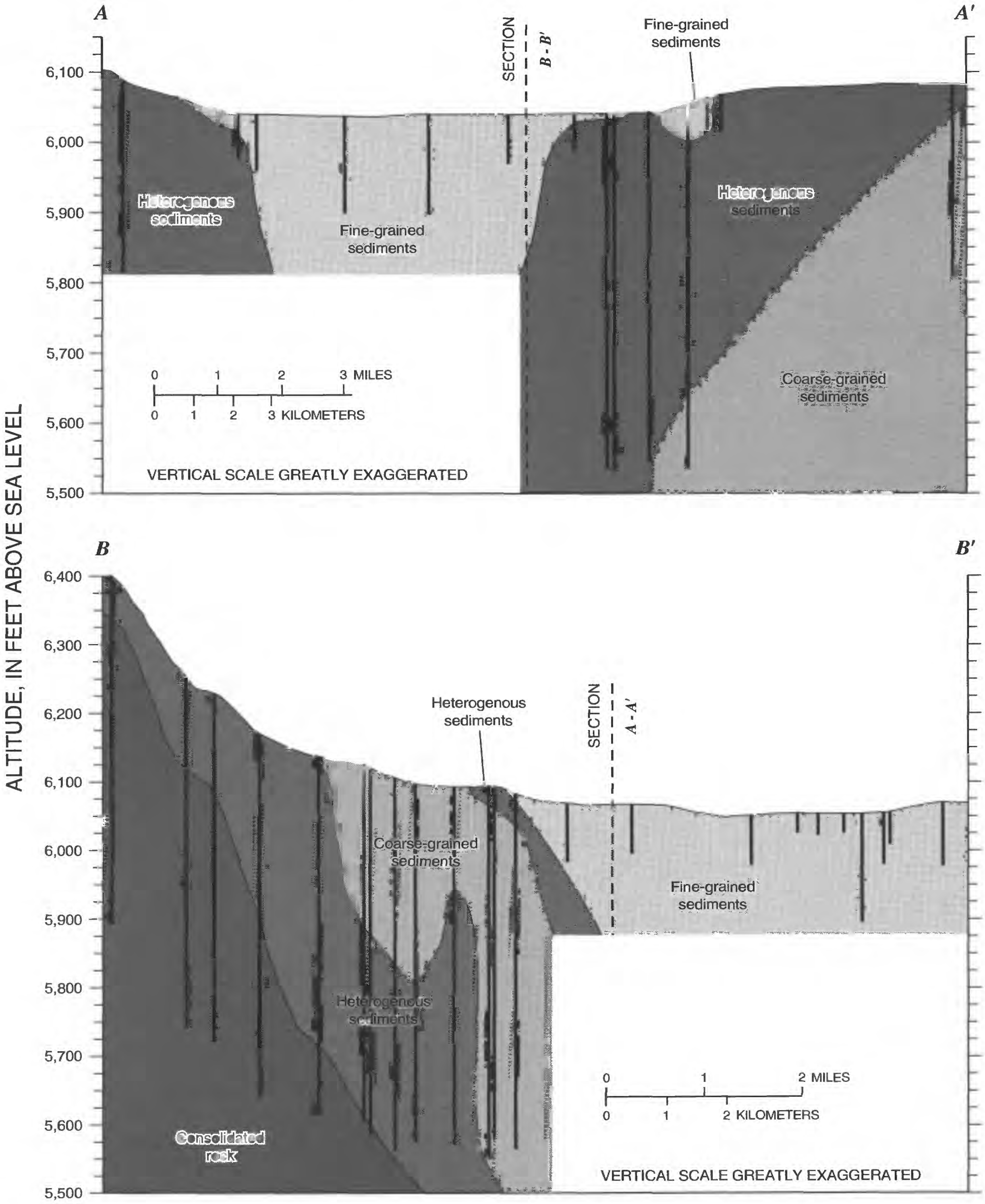


FIGURE 4.—Hydrogeologic sections across central Smith Creek Valley, Nev. Heterogeneous sediments consist of poorly sorted sediments at the margin of the basin and mixed coarse-, medium-, and fine-grained sediments near the center of the basin; coarse-grained sediments are coarse- to medium-grained well-sorted sands and gravels: and fine-grained sediments are primarily silts and clays. Hydrogeologic section locations are shown in figure 3. Wells (vertical lines) used to construct the sections, in addition to wells shown in figure 3, include geothermal temperature–gradient holes and observation wells that were destroyed prior to this study.

11 to 36 percent phenocrysts of predominantly plagioclase and alkali feldspar (table 1; Barrows, 1972, p. 87–88).

TABLE 1.—*Modal mineralogy and whole-rock chemistry of crystal-poor and crystal-rich ash-flow tuffs in the Desatoya Mountains and whole-rock chemistry of the Fish Creek Mountains Tuff (Smith Creek Valley), Nev.*

	Mineralogic analyses (volume percent)			
	Crystal-poor ash-flow tuff[1]		Crystal-rich ash-flow tuff[2]	
	Mean	Range	Mean	Range
Groundmass	93.0	90.2–96.0	74.2	64.2–89.2
Phenocrysts:				
Quartz	.7	0.0–1.4	1.9	0.0–4.7
Alkali feldspar	1.1	0.5–1.9	8.2	0.4–13.2
Plagioclase	4.9	0.9–9.0	13.2	8.7–18.9
Biotite	.1	0.0–0.2	1.5	0.0–3.6
Pyroxene	.0	0.0	.2	0.0–1.1

	Chemical analyses[3] (weight percent)		
	Crystal-poor ash-flow tuff[4]	Crystal-rich ash-flow tuff[5]	Fish Creek Mountains Tuff[6]
SiO_2	69.0	68.9	74.6
Al_2O_3	15.1	13.9	12.9
CaO	1.0	1.6	.7
MgO	.2	.3	.1
Na_2O	3.9	3.6	3.8
K_2O	5.1	4.4	5.2

[1] Based on analyses by Barrows (1972, p. 41 and 67, samples 12-9-3, 13-10-1, 13-11-1, and 14-9-1). Modal (mineralogical) analyses are based on an average of 1,021 point counts per sample.

[2] Based on analyses by Barrows (1972, p. 87-88, samples 11-11-D1, D2, D3, D4, D6, D7, D8, D9; 11-10-D10, D11, D13, D15; 12-10-4; 13-11-3, and 13-11-12). Modal (mineralogical) analyses are based on an average of 1,003 point counts per sample.

[3] By long-standing convention, whole-rock chemical analyses are expressed in weight percent of constituent oxides. Oxides listed are of silicon, aluminum, calcium, magnesium, sodium, and potassium.

[4] Analysis by Barrows (1972, p. 337, sample 13-10-1).

[5] Based on analyses by Barrows (1972, p. 338, samples 11-10-D9, 11-11-D4, and 11-11-D5).

[6] Based on two analyses by McKee (1970, p. 11).

The southern part of the Shoshone Mountains is capped almost entirely by the Toiyabe Quartz Latite—a crystal-rich ash-flow tuff containing 35 to 50 percent phenocrysts of smoky quartz and sanidine, with minor amounts of plagioclase and trace amounts of biotite. This so-called latite is mineralogically similar to the rhyolitic Fish Creek Mountains Tuff, hence the term "quartz latite" is misleading (Stewart and McKee, 1977, p. 43). Although modal and chemical analyses are not available for the Toiyabe Quartz Latite, its mineralogic similarity to the Fish Creek Mountains Tuff implies that the whole-rock chemistry also may be similar (table 1).

Playa sediments are composed of 77 to 93 percent silt and clay—on the basis of six soil-core samples (F.E. Rush and J.R. Harrill, U.S. Geological Survey, written commun., 1965). Clay-mineral analyses indicate the playa-area sediments consist primarily of illite and mixed-layer montmorillonite and illite, with lesser amounts of montmorillonite and kaolinite (table 2). Quartz, plagioclase, potassium feldspar, and calcite also are present in the playa-area deposits (Keith Papke, Nevada Bureau of Mines and Geology, written commun., 1983). X-ray diffraction analysis of bulk sediment samples from sites B, C, and D (see fig. 7) indicate that the zeolite minerals natrolite, thomsonite (or a zeolite intermediate between the two), and clinoptilolite are present also. In addition, the nonclay minerals quartz, feldspar, chlorite, gypsum, and calcite were identified in the bulk samples (Nelson Shaffer, Indiana State Geological Survey, written commun., 1987)

HYDROLOGIC FRAMEWORK

Basin-fill aquifers in Smith Creek Valley are recharged by subsurface inflow from the surrounding mountains and infiltration of surface water into alluvial-fan deposits at the margin of the basin. Streams are perennial along some stretches in the mountains but generally are ephemeral less than 1 mi from the mountain-front basin-fill contact as they traverse the permeable alluvial-fan deposits. Surface flow caused by severe storms, rapid snowmelt, or both can reach the playa in the central part of the basin, but most of this water is lost by evaporation prior to recharging the aquifer. If water flows onto a dry playa surface, an initial pulse of water may recharge the water-table aquifer by flowing through cracks in the dry playa sediments. However, after initial wetting, the fine-grained sediments swell quickly, restricting the downward flux of water (J.R. Harrill, written commun., 1967). The remaining water stands on the playa surface until it evaporates. Recharge to the aquifer is estimated to be approximately 8,000 acre-ft/yr (Thomas, Carlton, and Hines, 1989, p. 15–16).

Ground water generally flows toward the centrally located playa, which is the topographically lowest point in the valley. Shallow ground water is consumed by evapotranspiration in an area of phreatophytic vegetation surrounding the playa, where depth to water ranges from about 8 to 30 ft below land surface, or by direct evaporation from the bare soil of the playa, where depth to water is about 6 to 10 ft below land surface. Ground water moves upward in the discharging playa area, as indicated by the upward gradient measured in pairs of shallow wells (fig. 5). The vertical gradient remains relatively constant over time. Even when water is standing on the playa surface, the

TABLE 2.—*X-ray diffraction analyses of playa-area sediments, Smith Creek Valley, Nev.*

[Analyses by Keith Papke, Nevada Bureau of Mines and Geology, Reno, Nev.; --, not identified in sample]

Site[1]	Sample depth (feet)	Clay content	Relative abundance[2]							
			Clay minerals				Nonclay minerals			
			Illite	Montmorillonite	Mixed layer[3]	Kaolinite	Quartz	Plagioclase	K-feldspar	Calcite
A	2.0	moderate	1	3	--	2	1	2	3	--
	21.5	minor	1	2	--	--	1	2	--	--
B	5.5	abundant	3	1	--	2	1	3	2	--
	23.0	minor	1	--	2	--	1	--	2	--
	34.0	moderate	1	--	2	3	1	3	2	--
C	7.5	moderate	2	3	1	4	1	2	3	4
	22.5	minor	1	--	2	--	1	--	2	--
	34.0	abundant	2	--	1	3	2	3	1	--
D	5.5	moderate	1	--	2	--	1	2	--	3
	22.5	abundant	2	--	1	3	1	2	--	3
	27.0	abundant	2	--	1	3	1	2	--	3
E	16.5	moderate	2	--	1	3	1	2	3	--

[1] Site designation from figure 7.

[2] Mineral abundance is arbitrary ranking of relative amounts of mineral in sample, with 1 representing most abundant mineral and 4 least abundant mineral.

[3] Interlayered montmorillonite-illite.

upward gradient remains virtually unchanged and depths to water in wells remain at 6 to 10 ft beneath the playa surface. Ground water in the valley is mostly undeveloped; less than 1,000 acre-ft/yr is pumped for irrigation and livestock use.

WATER CHEMISTRY

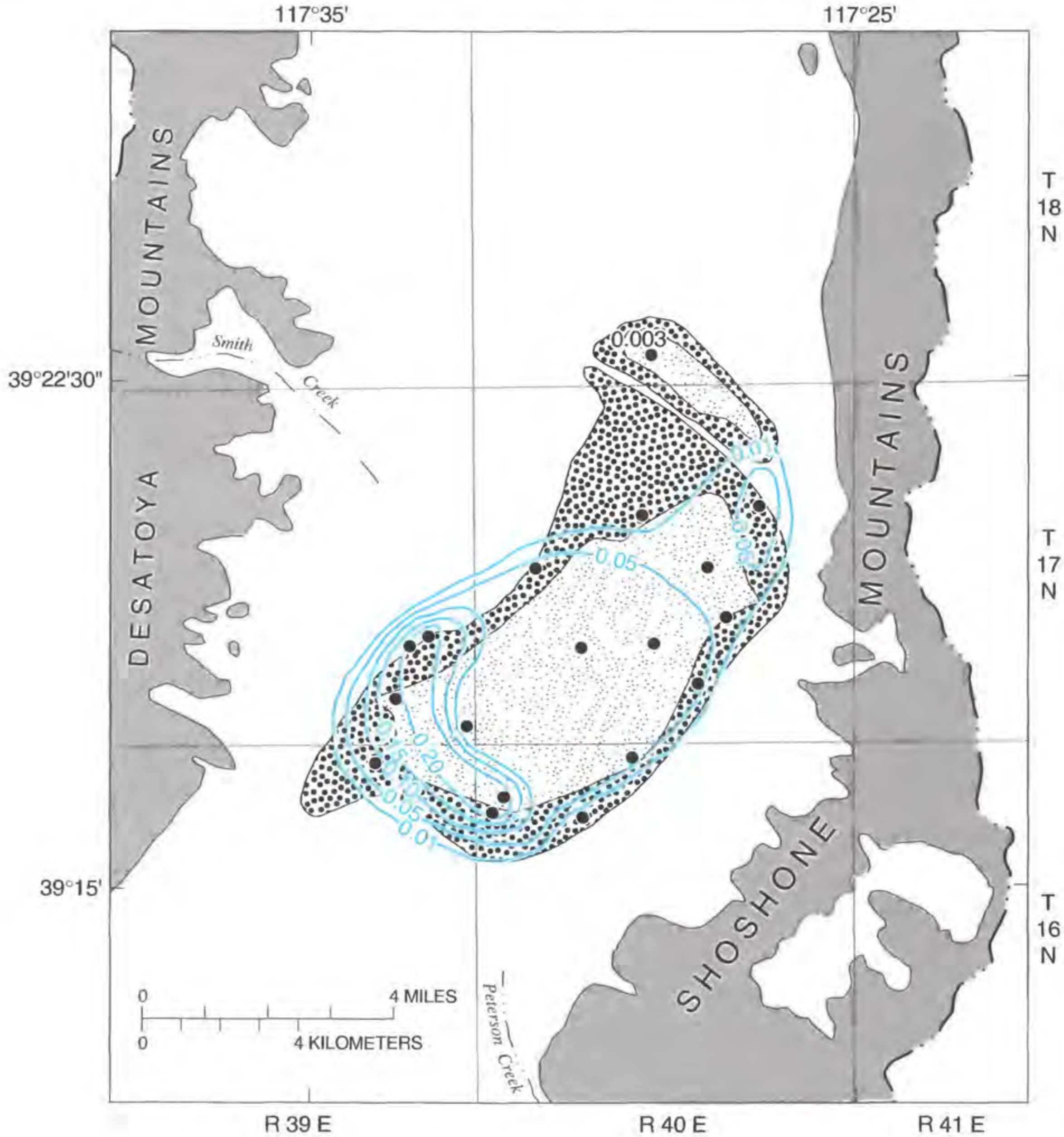
Water in the basin-fill aquifer evolves from a dilute sodium calcium bicarbonate (Na-Ca-HCO_3) type to a more concentrated sodium bicarbonate (Na-HCO_3) type to a briny sodium chloride (Na-Cl) type as it flows from recharge to discharge areas (table 3; figs. 6, 7). Measured dissolved-solids concentration increases from 90 mg/L in the recharge areas to 51,000 mg/L in the discharge area

Chemical evolution of ground water and surface water in hydrologically closed basins of the Western United States has been studied by Jones (1965), Hardie (1968), Phillips and Van Denburgh (1971), Van Denburgh (1975), and Smith and Drever (1976), and outside the Western United States by Lerman (1967), Eugster (1970), Jones and others (1977), Rettig and others (1980), Yuretich and Cerling (1983), Green and Canfield (1984), and Macumber (1984). Jones (1966), Hardie and Eugster (1970), and Eugster and Jones (1979) summarized the geochemical processes that affect the chemical evolution of water from dilute waters to brines in hydrologically closed basins. Deuterium, oxygen-18, geochemical data, and interpretive methods described in previous studies were used to determine the processes that affect the chemical evolution of ground water in Smith Creek Valley (Thomas, Welch, and Preissler, 1989).

Mass-balance descriptions of the evolution of one water chemistry to another along a flow path generally are not unique. However, a mass-balance solution that includes phases which are mineralogically possible and thermodynamically feasible can be used to determine the processes that control the evolution of observed water chemistry. Stoichiometry of reactions associated with the chemical evolution were identified using mass-balance calculations by the computer program BALANCE (Parkhurst and others, 1982). Plausible phases used in the calculations were based on the mineralogy and whole-rock chemistry of the rocks and sediments in the study area (tables 1, 2) and the water chemistry (tables 3, 4). The computer program WATEQ4F (Ball and others, 1987) was used to calculate saturation indices for phases used in the mass-balance calculations (table 5). Phases that are below saturation in the water (negative value) can dissolve, if present in the aquifer, whereas phases above saturation (positive value) generally can precipitate.

EVOLUTION OF PRECIPITATION TO RECHARGE WATER

Water recharging the basin-fill aquifer is a sodium calcium bicarbonate type (samples from sites 2 and 3; table 3, fig. 6). Dissolved constituents in the recharge water are primarily from evapotranspirative concentration of dissolved constituents before the water



EXPLANATION

	Basin-fill deposits	— · · —	Hydrographic area boundary
	Consolidated rock	—0.15—	**Line of equal vertical hydraulic gradient**—Interval, in feet per foot, is variable
	Playa deposits	0.003 ●	**Vertical hydraulic gradient at well, in feet per foot**
	Phreatophytic vegetation	●	**Well pair**—Used in determining hydraulic gradient

FIGURE 5.—Upward hydraulic gradient in the discharge area of central Smith Creek Valley, Nev.

TABLE 3.—*Chemical analyses of water from Smith Creek Valley, Nev.*

[Milligrams per liter, unless noted otherwise. Symbol: --, not determined]

Site[1]	Site name	Well depth (feet)	Water temperature (degrees Celsius)	pH (standard units)	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Carbonate	Sulfate	Chloride	Silica	Dissolved solids[2] (calculated)	Delta deuterium (permil)	Delta oxygen-18 (permil)
	Precipitation															
1	Carroll Summit[3]		--	--	1.1	0.2	0.7	0.3	--	--	1.5	2.2	--	--	--	--
	Recharge water															
2	Peterson Creek		15.3	7.6	6.6	1.0	13	1.5	41	0	10	3.8	34	90	–123	–16.2
3	Campbell Creek		12.9	8.0	13	2.1	19	2.6	76	0	12	7.3	38	130	–118	–15.2
	Sodium calcium bicarbonate water															
4	S. Brown well	282	10.6	6.8	20	3.8	24	3.8	94	0	13	8.2	56	180	–123	–15.7
5	USGS well 35	66	9.8	6.5	29	4.2	33	7.9	100	0	43	28	56	250	–118	–14.7
6	N. Brown well	200	14.7	7.5	35	5.5	48	6.8	150	0	52	25	62	310	–130	–16.2
	Sodium bicarbonate water															
7	USGS well 67	22	9.0	6.7	12	1.9	56	6.7	160	0	21	11	34	220	–124	–15.6
8	USGS well 50	22	10.0	7.2	10	1.1	110	6.0	300	0	11	20	19	320	–122	–15.9
9	USGS well 27	22	8.1	6.9	21	3.1	170	8.4	400	0	12	85	12	510	–117	–14.8
	Sodium chloride water															
10	USGS well 23	66	10.4	8.4	110	13	710	17	32	0	180	1,200	11	2,300	–132	–16.4
11	USGS well 55	66	9.8	8.1	76	14	2,200	27	170	0	380	3,600	5.2	6,400	–124	–15.2
12	USGS well 70	22	9.2	7.4	73	41	6,400	75	1,300	0	2,700	8,900	24	19,000	–122	–14.2
13	USGS well 56	22	10.8	9.2	10	1.2	11,000	81	3,500	280	3,500	12,000	5.0	29,000	–98	–9.7
14	USGS well 68	22	9.1	6.6	150	10	13,000	86	480	0	4,300	20,000	3.8	38,000	–101	–10.0
15	USGS well 32	([4])	10.9	7.5	490	100	14,000	140	140	0	6,000	21,000	2.5	42,000	–110	–12.0
16	USGS well 24	22	9.0	6.8	850	340	16,000	290	200	0	8,700	25,000	20	51,000	–118	–13.8

[1] Number corresponds to site shown in figures 2 or 7.

[2] Summation includes bicarbonate multiplied by 0.4916 to make result comparable to a "residue-on-evaporation" value.

[3] Analysis is average for 11 samples.

[4] Sample probably represents shallow water at depth of about 15 feet, rather than at 66-foot total depth.

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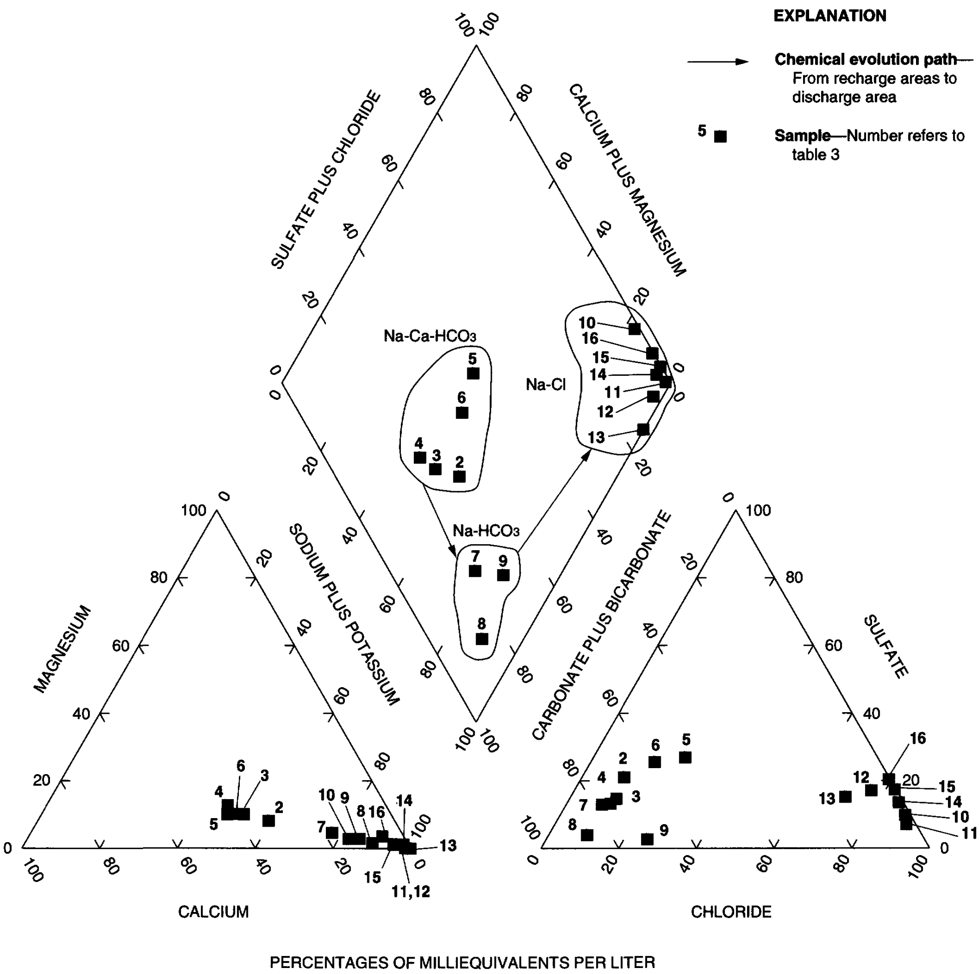

FIGURE 6.—Chemical evolution of ground water in the basin-fill aquifer of Smith Creek Valley, Nev.

percolates below the root zone and dissolution of soil-zone carbon dioxide gas and the volcanic groundmass and phenocrysts. These dissolution processes are similar to dissolution processes in the Absaroka Mountains in Wyoming (Miller and Drever, 1977) and in the Oasis Valley in Nevada (White, 1979). Constituents dissolved in precipitation are concentrated by evapotranspiration in the recharge areas. This evapoconcentration is accounted for by assuming the increase in chloride in the recharge water (table 4) is due only to evapotranspiration before the water percolates below the root zone.

Windblown gypsum is commonly deposited in uplands of desert environments (Pewe, 1981) and is the main component of dust in southern Nevada (Ronald Amundson, University of California, Berkeley, oral commun., 1987; Marith Reheis, U.S. Geological Survey, oral commun., 1987). Thus, gypsum is the most likely source of sulfate dissolved in recharge waters in Smith Creek Valley. Pyrite, if present in the volcanic rock, also may supply sulfate to the ground water in the upland areas. The increase in chloride concentration was assumed to result from evapotranspiration; however, part of the increase could be from dissolution of salts containing chloride that have blown into the recharge area. The small increase in magnesium concentration [0.04 millimoles per liter (mmol/L; table 4)] is most likely the result of magnesium biotite dissolution, because biotite is in volcanic rock in the recharge areas (table 1). Dissolution of illite, chlorite, or both, which are in the basin-fill sediments, also may be a source of magnesium. Aluminum and silica released by the weathering of volcanic groundmass and phenocrysts probably are removed from the water by formation of kaolinite, or some other clay mineral, and chalcedony (table 5). A mass-balance solution for the evolution of precipitation, concentrated by evapotranspiration, to recharge water is given by mass-balance solution 1 in table 6.

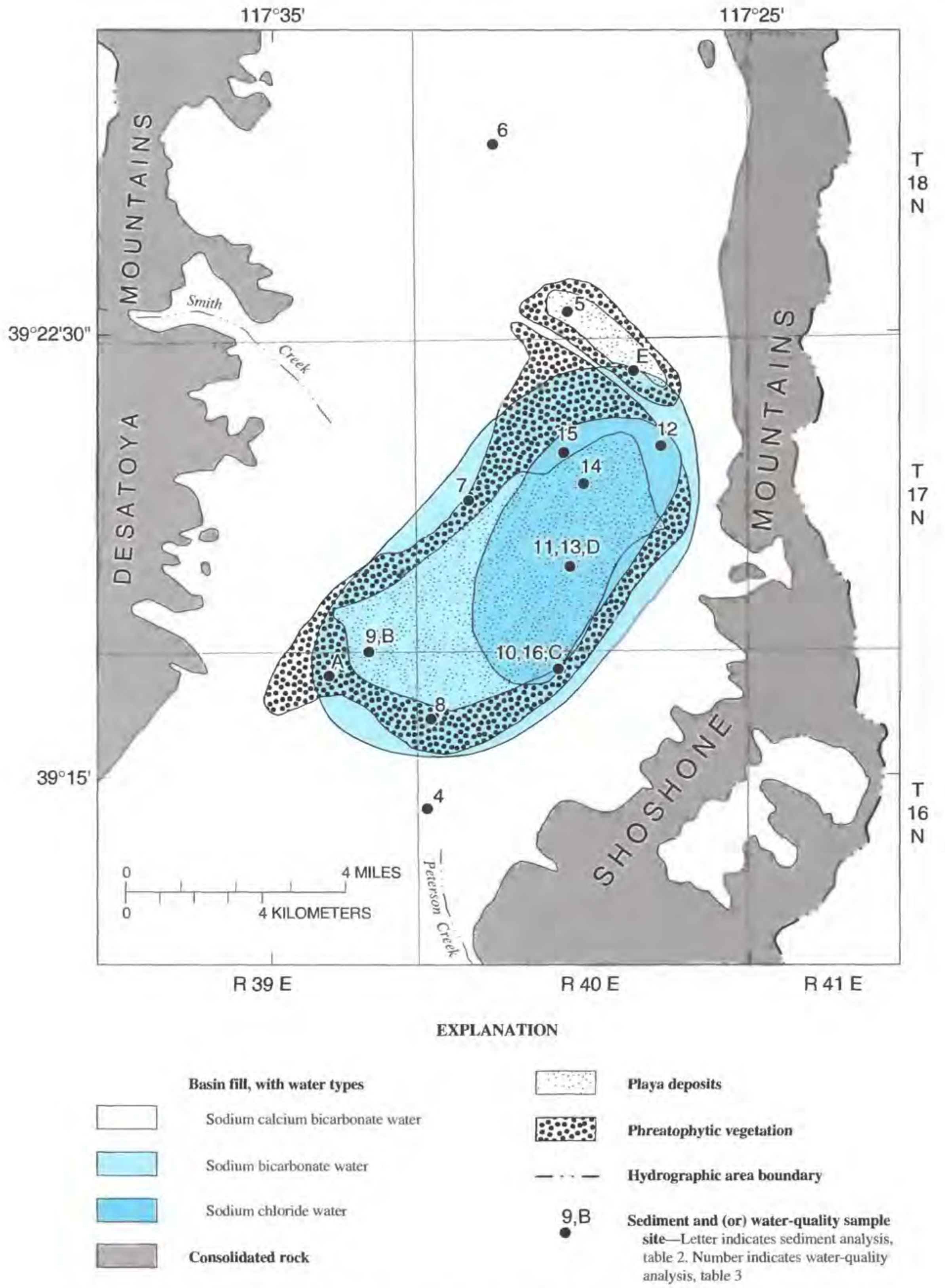

FIGURE 7.—Water types in shallow basin-fill aquifer of central Smith Creek Valley, Nev., based on dominant ions. Sites having two wells list the deeper well (66 feet) first and the shallower well (22 feet) second.

TABLE 4.—*Average constituent concentrations of water types used in mass-balance calculations, Smith Creek Valley, Nev.*

[Millimoles per liter]

Water type	Calcium	Mag-nesium	Sodium	Potassium	Total inorganic carbon	Sulfate	Chloride	Silica
Precipitation	0.03	0.01	0.03	0.01	[2]0.03	0.02	0.06	[3]0.00
Precipitation, concentrated by evapotranspiration[1]	.07	.02	.08	.02	.12	.04	.16	[3].00
Recharge water (samples 2 and 3)	.24	.06	.70	.05	.99	.11	.16	.60
Sodium calcium bicarbonate water (samples 4–6)	.70	.19	1.52	.16	2.50	.37	.58	.97
Sodium bicarbonate water (samples 7–9)	.36	.08	4.87	.18	6.21	.15	1.09	.36
Sodium chloride water (sample 10)	2.75	.54	30.95	.44	.51	1.88	33.93	.18

[1] Concentration of precipitation before percolation below root zone was assumed to be proportional to the increase in chloride from precipitation to recharge water.

[2] Total inorganic carbon calculated using the computer program PHREEQE (Parkhurst and others, 1980), assuming precipitation was in equilibrium with the atmosphere; that is, the logarithm of the partial pressure of carbon dioxide gas is −3.5 (Sundquist and others, 1979).

[3] SiO_2 was assumed to be zero in precipitation.

EVOLUTION OF RECHARGE TO SODIUM CALCIUM BICARBONATE WATER

As water recharging the basin-fill aquifer flows toward the playa from around the margin of the basin, constituent concentrations increase because of the dissolution of tuff-derived deposits and chloride and sulfate evaporative salts (samples from sites 4–6; tables 3, 4). Dissolution of albite, anorthite, and K-feldspar results in increased sodium, calcium, and potassium concentrations. Dissolution of salts formed by evapotranspiration in the unsaturated zone or in ephemeral stream channels are probable sources of chloride, sodium, and sulfate. During extremely wet periods, some water probably flushes through the unsaturated zone, dissolving the salts and carrying them to the water table. Chloride, sodium, and sulfate form the most soluble salts in desert soils and are readily dissolved by water flushing through the unsaturated zone (Drever and Smith, 1978). In addition, evaporative salts buried by sedimentation also may dissolve as ground water flows through the basin-fill sediments. In the mass-balance calculations, halite dissolution is used for the input of chloride and sodium, and gypsum dissolution is used for the input of sulfate. Bicarbonate

TABLE 5.—*Saturation indices for selected minerals in water of Smith Creek Valley, Nev.*[1]

[Calculated using computer program WATEQ4F (Ball and others, 1987).]

Site[2]	Albite	Anorthite	Ca-montmorillonite	Calcite	Chalcedony	Gypsum	Halite	Kaolinite	K-feldspar	Mg-biotite
Recharge water										
2	−2.2	−6.1	0.3	−1.4	0.4	−3.3	−8.8	0.7	−0.7	−34.0
3	−1.5	−5.1	.8	−.6	.5	−3.0	−8.4	.8	.1	−30.5
Sodium calcium bicarbonate water										
4	−2.1	−7.2	1.1	−1.5	.7	−2.8	−8.2	1.2	−.4	−37.9
5	−2.2	−7.7	1.0	−1.7	.7	−2.2	−7.6	1.2	−.3	−39.8
6	−1.0	−5.2	1.4	−.4	.7	−2.1	−7.5	1.2	.6	−31.6
Sodium bicarbonate water										
7	−2.4	−8.2	.2	−1.7	.5	−2.8	−7.7	.8	−.8	−40.2
8	−2.4	−7.7	−.6	−1.0	.2	−3.2	−7.2	.3	−1.2	−38.1
9	−3.1	−8.6	−1.3	−.9	.0	−3.0	−6.4	−.1	−1.9	−39.8
Sodium chloride water										
10	−1.2	−4.9	−.9	.0	.0	−1.4	−4.7	−.2	−.3	−27.3

[1] Saturation index = $\log\left[\frac{\text{ion-activity product}}{K_T}\right]$, where K_T = equilibrium constant at temperature T. By convention, positive value indicates mineral can precipitate from solution, whereas negative value indicates mineral can dissolve if present in the aquifer. Aluminum concentrations were calculated using computer program PHREEQE (Parkhurst and others, 1980), assuming each water was saturated with respect to gibbsite and using thermodynamic data for gibbsite from Robie and others (1978, p. 140).

[2] Number corresponds to site listed in table 3 and shown in figures 2 or 7.

TABLE 6.—*Mass transfer of constituents in Smith Creek Valley, Nev.*[1]

[Symbol: --, phase not included in mass-balance calculation]

Phase	Mass-balance solutions[2] (millimoles per liter)					
	1	2	3	4	5	6
Albite [$NaAlSi_3O_8$]	0.62	0.41	1.79	1.94	2.26	1.72
Anorthite [$CaAl_2Si_2O_8$]	.10	.19	.08	.17	.57	6.36
K-feldspar [$KAlSi_3O_8$]	.02	.06	.02	.02	.67	.26
Gypsum [$CaSO_4 \cdot 2H_2O$]	.08	.26	--	--	--	1.73
H_2S (gas)	--	--	−.22	−.22	−.22	--
CO_2 (gas)	.87	1.51	3.71	3.71	3.71	--
Calcite [$CaCO_3$]	--	--	--	--	--	−5.70
Halite [NaCl]	--	.42	.52	.52	.52	32.8
Mg-biotite [$KMg_3Si_3AlO_{10}(OH)_2$]	.01	.04	--	--	--	--
Chlorite [$Mg_5 Al_2 Si_3 O_{10}(OH)_8$]	--	--	--	--	--	.09
Chalcedony [SiO_2]	−.71	−.66	−4.23	−3.22	--	--
Kaolinite [$Al_2Si_2O_5(OH)_4$]	−.43	−.45	−.99	--	−1.23	−3.21
Ca,Mg-Na exchange[3]	--	--	1.04	1.06	1.06	--
Ca/Na-montmorillonite [$Ca_{0.083}Na_{0.167}Al_{2.33}Si_{3.67}O_{10}(OH)_2$]	--	--	--	−.99	--	--
Clinoptilolite [$(Na_{0.3}K_{0.4}Ca_{0.3})(AlSi_5O_{12}) \cdot 4H_2O$]	--	--	--	--	−1.62	--
Natrolite [$Na_2(Al_2Si_3O_{10}) \cdot 2H_2O$]	--	--	--	--	--	−4.24

[1] Mass-transfer value is change in mass of indicated phase, calculated from changes in water chemistry between different water types. Negative value indicates transfer out of solution, and positive value indicates transfer into solution.

[2] Mass-balance solutions 1–6 correspond to mass balances between the following water types given in table 4:
1. From precipitation concentrated by evapotranspiration to recharge water;
2. From recharge water to sodium calcium bicarbonate water;
3–5. Three examples of mass-balance solutions for sodium calcium bicarbonate water to sodium bicarbonate water;
6. From sodium bicarbonate water to the most dilute sodium chloride water.

[3] Positive value indicates calcium and magnesium in water are being exchanged for sodium on clay minerals. Values are millimoles of sodium per liter.

concentration increases from the reaction of carbonic acid, which is derived from soil-zone carbon dioxide, with the volcanic groundmass and phenocrysts in the tuff-derived deposits. Magnesium concentration increase is probably from biotite dissolution. Feldspar hydrolysis releases cations and results in the formation of kaolinite, or some other clay mineral, and chalcedony. A mass-balance solution for the evolution of recharge water to sodium calcium bicarbonate water is given by solution 2 in table 6.

EVOLUTION OF SODIUM CALCIUM BICARBONATE TO SODIUM BICARBONATE WATER

Ground water in the aquifer evolves from a sodium calcium bicarbonate to a sodium bicarbonate type in the vicinity of the fine-grained playa area (tables 3, 4; figs. 6, 7). Average calcium and magnesium concentrations decrease from 28 to 14 and from 4.5 to 2.0 mg/L, respectively; average sodium and bicarbonate concentrations increase from 35 to 112 and from 115 to 287 mg/L, respectively (samples from sites 4–6 and 7–9; table 3). The removal of calcium and magnesium from the water may be the result of several processes, but the presence of montmorillonite in the discharge area (table 2, fig. 7) indicates that cation exchange of calcium and magnesium in the water for sodium adsorbed on clays is the most probable process (table 6, solution 3). The decrease in calcium concentration cannot result from calcite precipitation because samples from sites 4–9 are undersaturated with respect to calcite (table 5). The ratio of calcium to magnesium exchanged for sodium is based on the average ratio of calcium to magnesium (4:1) in the sodium calcium bicarbonate and sodium bicarbonate waters (table 4).

Calcium also may be removed by the weathering of plagioclase to Ca/Na-montmorillonite [$Ca_{0.083}Na_{0.167}Al_{2.33}Si_{3.67}O_{10}(OH)_2$] (table 6, solution 4) or by the precipitation of a zeolite mineral, such as clinoptilolite [$(Na_{0.3}K_{0.4}Ca_{0.3})(AlSi_5O_{12}) \cdot 4H_2O$] (table 6, solution 5).

All three solutions would increase sodium and bicarbonate concentrations in the water by cation exchange and dissolution of plagioclase and evaporative salts, along with the addition of carbon dioxide gas. Any mix of these processes is possible given the observed chemistries.

An activity diagram for the system CaO-CO_2-Na_2O-SiO_2-Al_2O_3-H_2O (fig. 8) shows that the different water types plot along a 2:1 slope, and in particular, sodium bicarbonate waters plot close to the phase

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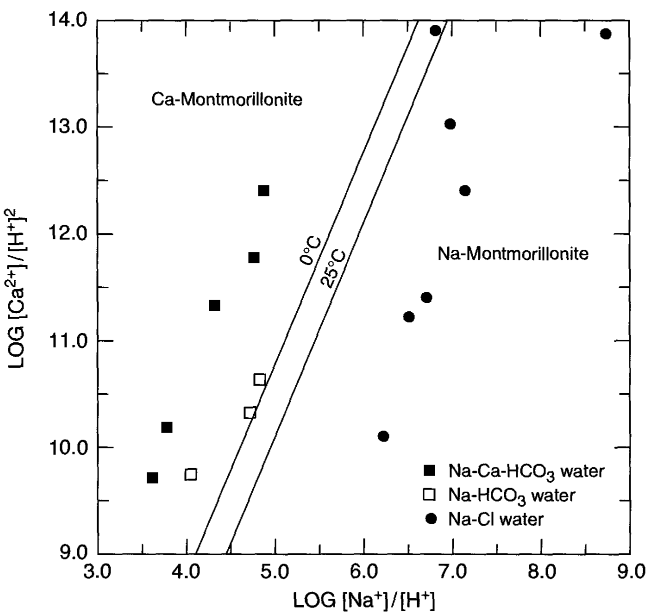

FIGURE 8.—Aqueous activities for the system CaO-CO_2-Na_2O-SiO_2-Al_2O_3-H_2O in Smith Creek Valley, Nev. The phase boundary is based on the thermodynamic data of Arnorsson and others (1982). Chemical symbols: Ca^{2+}, calcium; H^+, hydrogen; Na^+, sodium. Bracketed items are ion activities.

boundary between Ca-montmorillonite and Na-montmorillonite as would be expected for either cation exchange or formation of Ca/Na-montmorillonite.

Precipitation of zeolite minerals in the Smith Creek Valley basin-fill aquifer is evidenced by the presence of zeolite minerals in the basin-fill deposits. Furthermore, rhyolitic tuff and basin-fill aquifers derived from rhyolitic tuff in southern Nevada, similar to those in Smith Creek Valley, contain ground water in which calcium is removed by weathering of tuff or tuff-derived deposits to montmorillonite and by precipitation of zeolite minerals, predominantly clinoptilolite with a composition of $(Na_{0.3}K_{0.4}Ca_{0.3})(AlSi_5O_{12})\cdot 4H_2O$ (Hoover, 1968; White, 1979; White and others, 1980; Claassen, 1985).

Chloride and potassium concentrations increase and sulfate concentration decreases as the water evolves from a sodium calcium bicarbonate to a sodium bicarbonate type. Chloride concentration increases along the flow path by evapotranspiration of the water and dissolution of chloride salts. Potassium concentration increases, probably because of K-feldspar dissolution. Sulfate concentration decreases along the flow path probably because of the reduction of sulfate to hydrogen sulfide gas and precipitation of FeS (Jones, 1966; Phillips and Van Denburgh, 1971; Eugster and Jones, 1979) or possibly because of surface sorption (Wood, 1978; Eugster and Jones, 1979), because more fine-grained sediments with larger surface areas are present in the playa area. The sodium bicarbonate waters are undersaturated with respect to gypsum (table 5), so gypsum precipitation cannot be the cause of the decrease in sulfate.

EVOLUTION OF SODIUM BICARBONATE TO THE MOST DILUTE SODIUM CHLORIDE WATER

In the playa area, ground water evolves from a sodium bicarbonate to a sodium chloride water (tables 3, 4; figs. 6, 7). Constituent concentrations increase because of the dissolution of evaporative salts, evapotranspiration, and mixing.

Dissolution of evaporative salts probably is the major source of increasing chloride and sodium concentrations as the water evolves from sodium bicarbonate to sodium chloride type because (1) chloride and sodium concentrations increase in about equal amounts, (2) other constituents increase less than chloride, and (3) the isotopic composition of the dilute sodium chloride water is similar to that of the sodium bicarbonate water. Evaporative salt dissolution is the simplest explanation consistent with all three observations.

Dissolution of evaporative salts containing chloride and sodium should add these constituents to the water in about equal amounts (Drever and Smith, 1978). The approximately 30 mmol/L increase of chloride and sodium observed as the water evolves from sodium bicarbonate (samples from sites 7–9; fig. 7) to the most dilute sodium chloride (sample from site 10; fig. 7) water (table 4) supports this dissolution process. The increase in sulfate, calcium, magnesium, and potassium also may be from the dissolution of salts or minerals (table 6, solution 6) that are below saturation in the water [table 5; also the saturation index of chlorite (not shown) for the sample from site 10 is −1.4].

Sodium, sulfate, calcium, magnesium, and potassium increase in concentration as the water evolves from a sodium bicarbonate to sodium chloride water, but they do not increase in proportion to chloride as would be expected if evapotranspiration were occurring (table 4, figs. 9–13). This is a second indication that dissolution of evaporative salts and minerals is a major source of constituents. Constituent concentrations resulting from salt or mineral dissolution would not increase in proportion to chloride but, rather, would increase in proportions determined by the chemical composition of the soluble salt or minerals. If chloride concentration were the result of only evapotranspiration, then 60 to 80 percent of sodium, sulfate, calcium, and magnesium ions and 92 percent of potassium ions would have to be removed from the water to obtain the chemistry observed in the most dilute sodium chloride water (sample from site 10, fig. 7). The sample, however, is below saturation with respect to most minerals that could precipitate, thereby removing constituents from the water, with the exception of calcite, which will be discussed later. Thus, precipitation of most minerals is unlikely.

The third indication that dissolution is the major process producing a sodium chloride water is the isotopic composition of the sample from site 10. Dissolution of evaporative salts would not alter the isotopic composition of the water, whereas evaporation would shift the isotopic composition of the water to a heavier (more negative) value. The sample from site 10 has an isotopic composition similar to the sodium bicarbonate waters (samples from sites 7–9), indicating that the sample has not been significantly evaporated (fig. 14). In addition, the sample from site 10 was obtained from 66 ft below land surface, where evaporation would be improbable. The sample from site 10 is below saturation with respect to albite, so although another source of sodium is not needed to obtain the sodium concentration in the sample, a small amount of sodium is probably added to the water by albite dissolution.

Transpiration also may be an important process for increasing chloride and sodium concentrations as the water evolves from a sodium bicarbonate to a sodium chloride type. Transpiration can concentrate dissolved solids in water to depths greatly exceeding evaporation depths and, thus, could have increased constituent concentrations in water sampled from site 10. Phreatophyte roots will follow fresh water to depths exceeding 60 ft (P.A. Glancy, U.S. Geological Survey, oral commun., 1989) and, unlike evaporation, transpiration has been shown to concentrate dissolved solids in residual water with little or no effect on isotopic composition (Wershaw and others, 1966; Zimmerman and others, 1967, p. 576; Ziegler and others, 1976; Gat and Gonfiantini, 1981, p. 223–238; Szecsody and others, 1983; Koltermann, 1984; White and others, 1985; Turner and others, 1987). Thus, the observed higher constituent concentrations and unchanged isotopic composition are consistent with transpiration removing water and thereby increasing constituent concentrations in the residual water. However, transpiration could account for only a 20 to 40 percent increase in constituent concentrations (or 8 percent for potassium), unless constituents are being removed from the water as they become more concentrated.

Mixing deeper water that contains lower dissolved solids with shallower water that contains higher dissolved solids (whether by molecular diffusion, dispersion, or density-driven flow) is probably not an important process for increasing constituent concentrations as the water evolves from sodium bicarbonate to sodium chloride. The Peclet number calculated for the fine-grained Smith Creek playa sediments is considerably less than one, indicating that molecular diffusion predominates over mechanical dispersion (Bear, 1972). This indicates that molecular diffusion of chloride and sodium ions from shallow briny water to

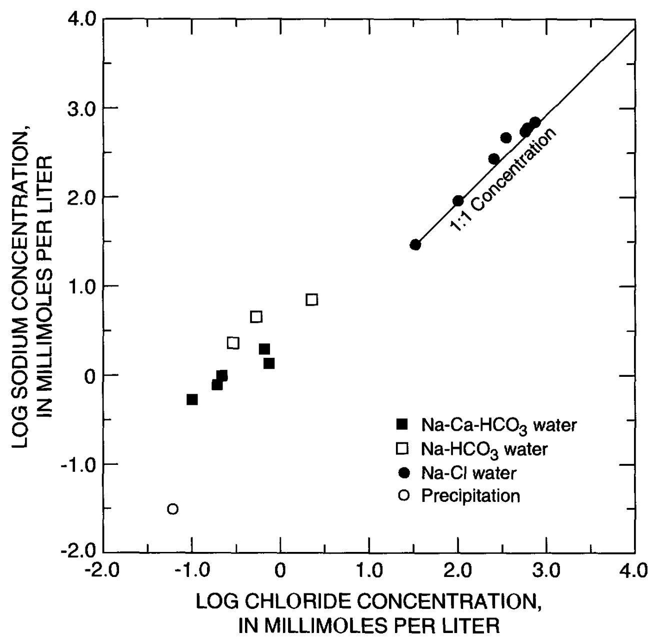

FIGURE 9.—Relation between sodium and chloride concentrations in Smith Creek Valley, Nev.

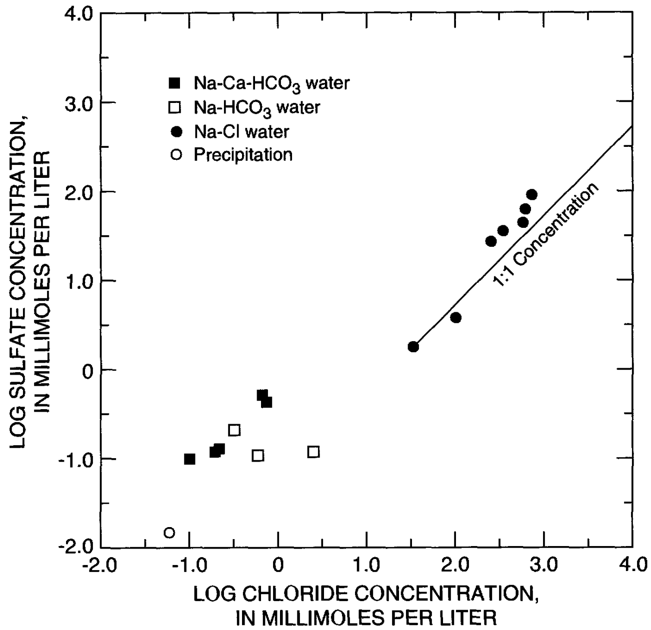

FIGURE 10.—Relation between sulfate and chloride concentrations in Smith Creek Valley, Nev.

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greater depths is a possibility, whereas mechanical dispersion is less likely. Calculation of a Rayleigh number relating diffusive flow to density-driven flow (Combarnos and Bories, 1975; Clifford Voss, U.S. Geological Survey, oral commun., 1987) indicates that density-driven flow does not occur in the Smith Creek playa sediments.

A convincing argument against mixing deep and shallow waters also comes from the stable isotope composition of the deeper sodium chloride water (samples from sites 10 and 11; fig. 7). The molecular diffusion rate of deuterium and oxygen-18 is greater than that of chloride and sodium (Wang and others, 1953, p. 468; Sherwood and others, 1975, p. 37), and mechanical mixing mechanisms do not differentiate between ions and isotopes. Therefore, if mixing is important, the deuterium and oxygen-18 isotopes would mix as fast, or faster, than the chloride and sodium ions. A mixture of water containing low dissolved solids with water containing high dissolved solids that was concentrated by evaporation would have a mixed isotopic composition, as well as intermediate ionic concentrations. However, the deep sodium chloride water has a deuterium and oxygen-18 composition similar to sodium bicarbonate water unaffected by evaporation (fig. 14) and is different from that of the shallow sodium chloride water, which has been affected by evaporation. Therefore, mixing (by whatever mechanism) of isotopically heavy (less negative) water containing high chloride and sodium concentrations is not indicated at depth (66 ft).

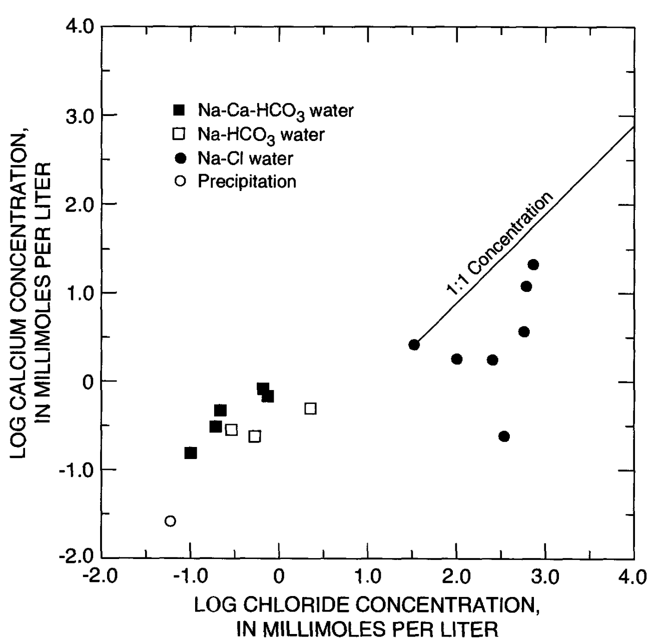

FIGURE 11.—Relation between calcium and chloride concentrations in Smith Creek Valley, Nev.

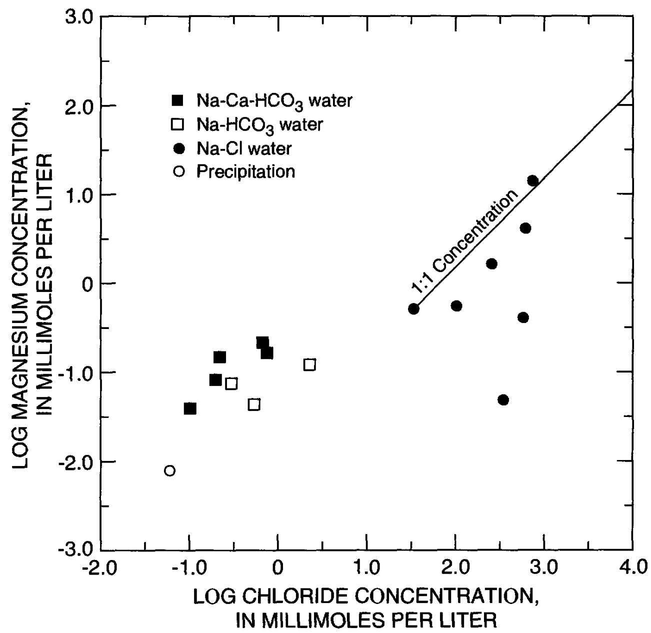

FIGURE 12.—Relation between magnesium and chloride concentrations in Smith Creek Valley, Nev.

Ground water may mix in the shallower part of the aquifer beneath the playa or phreatophytic area surrounding the playa, but not within the approximately 44-ft vertical interval between the shallow and deep wells. In the deep wells, the isotopic composition of the water shows little effect of evaporation.

Evaporation is not an important process for increasing chloride and sodium concentrations as the water evolves from a sodium bicarbonate to sodium chloride type. This is shown by samples from sites 10 and 11, which were collected from 66 ft below land surface in an area of upward flow. This water already has evolved from sodium bicarbonate to sodium chloride type in a zone well below that where evaporation occurs. Also, as noted, significant evaporation would produce an isotopic shift to heavier values, and this was not observed in samples from sites 10 and 11.

Bicarbonate concentration decreases as the water evolves from a sodium bicarbonate to a sodium chloride water (table 4) because of calcite precipitation (table 6). A sample from site 10 is saturated with respect to calcite (table 5). Calcium concentration is approximately 5 percent of the bicarbonate concentration in the sodium bicarbonate water, but precipitation of calcite does not totally deplete calcium. Calcite precipitation reduces bicarbonate concentration because calcium ions are added to the water by the dissolution of gypsum:

$$CaSO_4 \cdot 2H_2O + CO_3^{2-} = CaCO_3 + SO_4^{2-} + 2H_2O. \quad (1)$$

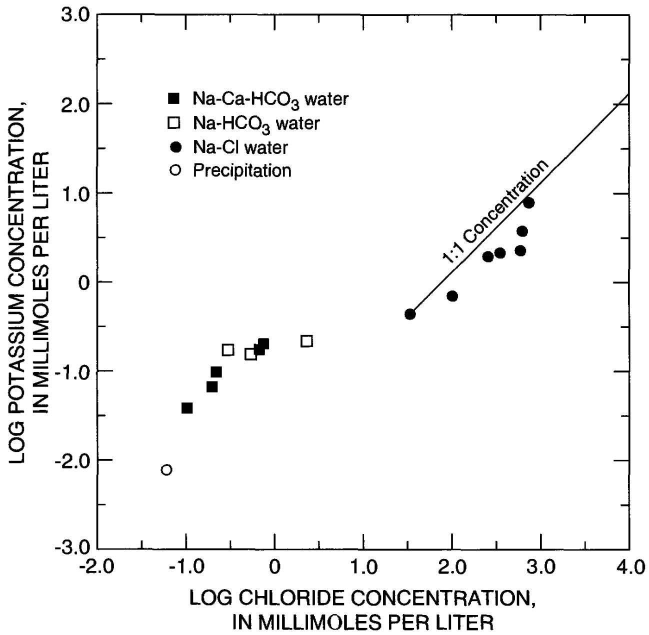

FIGURE 13.—Relation between potassium and chloride concentrations in Smith Creek Valley, Nev.

EVOLUTION OF DILUTE TO CONCENTRATED SODIUM CHLORIDE WATER

Ground water in the playa area evolves from a slightly saline (measured dissolved-solids concentration, 2,300 mg/L) to a briny (measured dissolved solids, 51,000 mg/L) sodium chloride water (samples from sites 10–16; table 3, fig. 7). The increase in sodium concentration is proportional to the increase in chloride concentration (fig. 9) as the water evolves from the most dilute to most concentrated sodium chloride water. This 1:1 increase can result from evaporation, dissolution of evaporative salts, or transpiration.

A plot of deuterium in relation to oxygen-18 (fig. 14) indicates that ground water is being removed in some parts of the playa area by evaporation. A plot of deuterium in relation to chloride (fig. 15) shows that chloride concentration increases in areas in which isotopic compositions of ground water are largely unaffected by evaporation. The overall contribution of evaporation to the chemical evolution of the water was estimated from the stable isotope composition and chloride concentration by using the Rayleigh distillation equation (Dansgaard, 1964), assuming that chloride remains conservative during evaporation. The Rayleigh distillation curve for evaporative concentration was calculated using initial deuterium and chloride compositions of the average sodium bicarbonate water (samples from sites 7–9, table 3) and a fractionation factor (1.0079) calculated for a basin-fill aquifer in northwestern Nevada (Welch and Preissler, 1990, p. 32–41). The increase in chloride concentration in samples from sites 13, 14, and 15 is accompanied by a moderate shift in deuterium to heavier (less negative) values, indicating that some of the increase in chloride is caused by evaporation. In contrast, the increase in chloride concentration in samples from sites 10, 11, 12, and 16 is not accompanied by a deuterium shift characteristic of evaporation and, thus, must be the result of other processes.

Dissolution of evaporative salt could increase chloride and sodium concentrations more than evaporation. Salt dissolution induces no isotope shift. Dissolution of evaporative salts could greatly increase chloride and sodium concentrations and would account for the evolution of other constituents. For example, sulfate concentration in the sodium chloride water generally increases at a rate greater than 1:1 with respect to chloride (fig. 10). This increase requires addition of sulfate, most likely from dissolution of gypsum, in addition to concentration of sulfate by evapotranspiration. If gypsum is dissolving, other salts probably also are dissolving.

Transpiration is an important hydrologic process in Smith Creek Valley that also may explain the increased constituent concentrations. Approximately 70 percent of ground water discharged from Smith Creek Valley is transpired from the phreatophytic area surrounding the playa (Thomas, Carlton, and Hines, 1989).

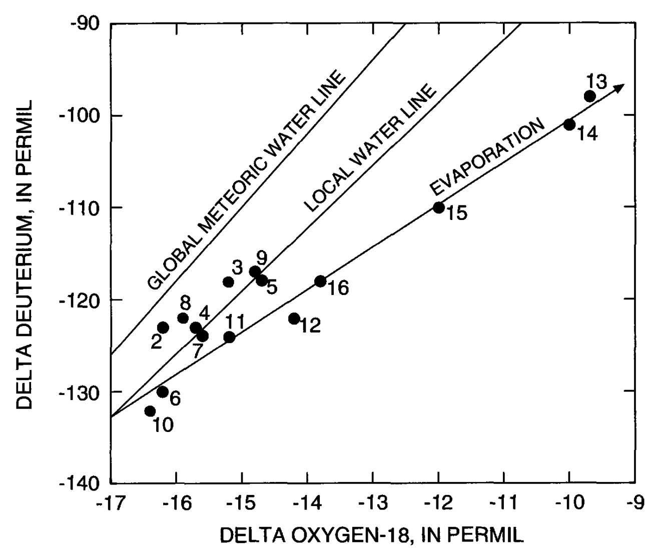

FIGURE 14.—Relation between deuterium and oxygen-18 in Smith Creek Valley, Nev. The global meteoric water line [$\delta D=8(\delta^{18}O)+10$] is based on worldwide precipitation data (Craig, 1961). The local water line [$\delta D=6.82(\delta^{18}O)-16.8$] is based on a linear regression of samples from sites 2 to 11 (see figs. 2, 7; table 3).

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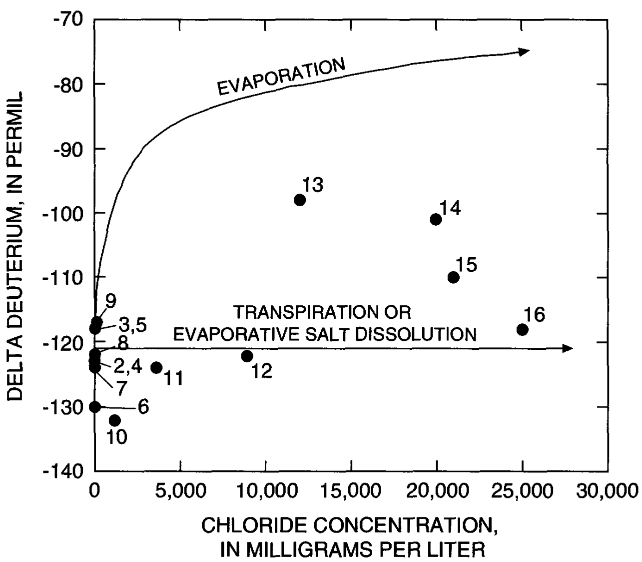


FIGURE 15.—Relation between deuterium and chloride concentrations in samples from wells in Smith Creek Valley, Nev. Numbered circles correspond to sites in figures 2 and 7 and table 3.

Transpiration results in concentration of ions but induces no isotopic shift, so it is also a simple and reasonable explanation for concentration of constituents in the sodium chloride water. Sodium chloride water from shallow wells (22 ft deep) in or along the phreatophytic area that surrounds the playa (samples from sites 12, 15, and 16) show the least effect of evaporation, whereas samples from shallow wells (samples from sites 13 and 14) directly beneath the playa surface show the greatest evaporative concentration, as indicated by the stable-isotope and chloride concentrations (figs. 7, 14, 15). A limit to transpirative concentration of dissolved solids in ground water is the unknown maximum salt tolerance of the phreatophytic plants in Smith Creek Valley.

Other reactions also probably modify the chemistry of the ground water as it evolves into a more concentrated sodium chloride water. For example, evapotranspirative concentration would result in an increase of calcium, magnesium, and potassium concentrations in proportion to chloride. However, the observed increase in the concentrations of these three constituents generally is less than 1:1 with respect to chloride (figs. 11–13). Thus, other processes also are affecting calcium, magnesium, and potassium concentrations. These constituents could be removed from the water by precipitation of calcite and zeolite minerals, exchange on clay minerals, and the formation of clay minerals. In addition, dissolution of minerals and evaporative salts is probably adding calcium, magnesium, and potassium to the water, as well as sodium, chloride, and sulfate.

GEOCHEMICAL AND ISOTOPIC DELINEATION OF GROUND-WATER FLOW IN A TYPICAL CARBONATE-ROCK AQUIFER

In carbonate-rock aquifers in the east half of the Great Basin, ground water generally flows in the basin-fill deposits and the underlying and adjacent carbonate rock, thus resulting in large regional flow systems that encompass numerous topographic basins and have circulation depths of several thousand feet. The dominant geochemical processes in these flow systems generally are (1) dissolution of minerals and soil zone CO_2 gas, (2) precipitation or formation of minerals, (3) mixing of chemically or isotopically different waters, or both, (4) ion exchange, and (5) geothermal heating due to deep circulation.

The carbonate-rock aquifers in southern Nevada are an example of these carbonate-rock flow systems (fig. 16). The aquifers include two regional flow systems that discharge in southern Nevada: the White River flow system, which discharges at Muddy River springs (fig. 16) and is a subsystem of the Colorado flow system (fig. 1), and the Ash Meadows flow system, which discharges at Ash Meadows springs (fig. 16) and is a subsystem of the Death Valley flow system (fig. 1; Eakin, 1966; Mifflin, 1968; Winograd and Friedman, 1972; Winograd and Thordarson, 1975; Hess and Mifflin, 1978; Thomas and others, 1986; Harrill and others, 1988; Dettinger, 1989; Kirk and Campana, 1990). In the north-central part of the study area, ground water also flows from the White River system to the Ash Meadows system (figs. 16, 17). These flow systems encompass thousands of square miles and include several valleys. Recharge to these regional systems is from several sources, and most of the flow discharges from a common area that contains numerous springs. Smaller carbonate-rock flow systems, such as the Las Vegas Valley flow system, also are present in the study area. In these smaller systems, recharge is primarily from one source and water may discharge from the aquifers in several places.

Geochemical processes that produce the chemical and isotopic compositions of the water in carbonate-rock aquifers were identified using stable and radioactive isotopes, major-ion chemistry, mass-balance calculations, thermodynamic calculations, and mineral identification. The isotopic and chemical compositions of water from different areas were used further to delineate regional flow systems. The primary processes that produce the isotopic and chemical content of the

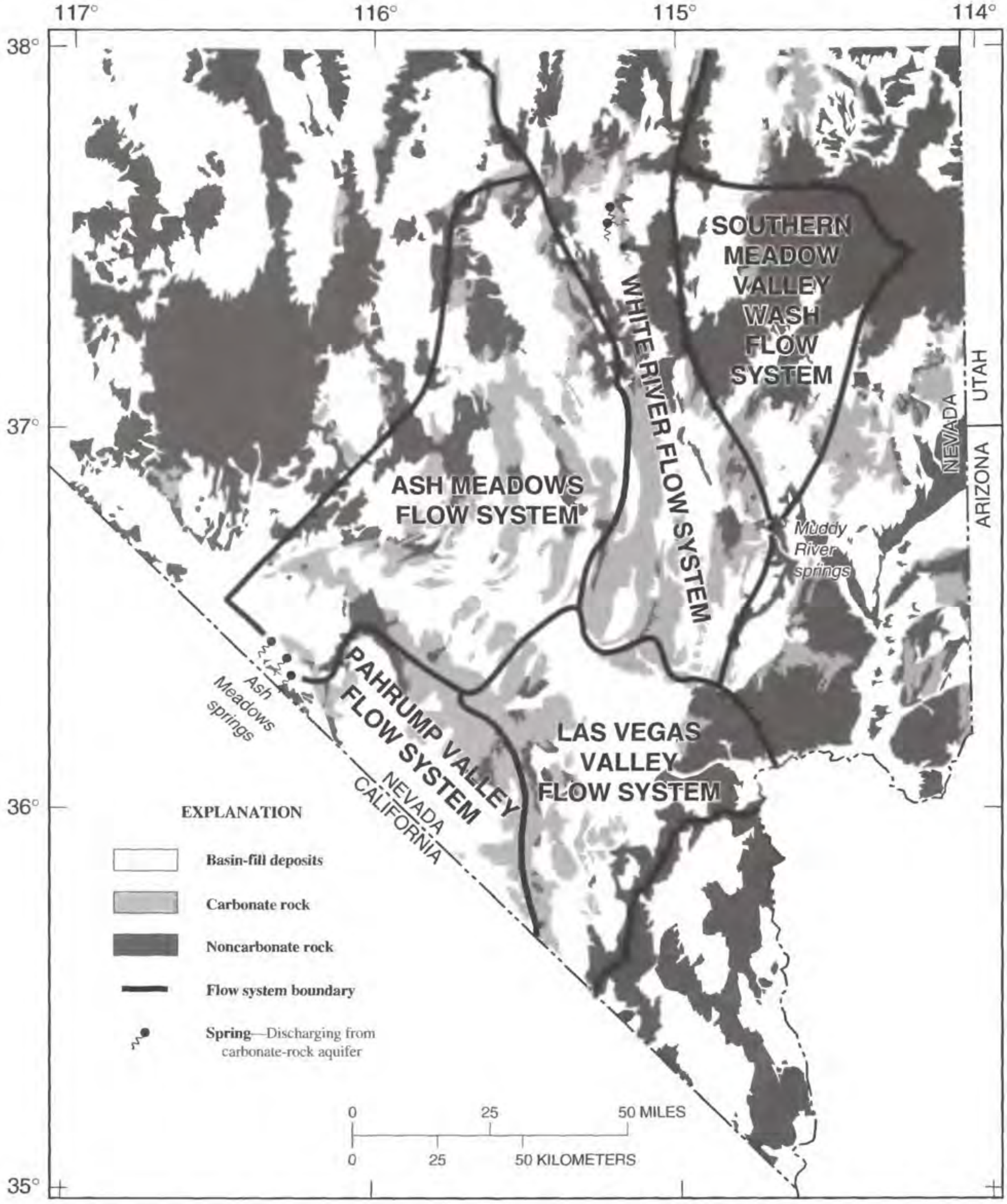


FIGURE 16.—Map showing ground-water flow systems in southern Nevada, as delineated in this study.

ground water in these regional systems of southern Nevada are (1) dissolution of CO_2 gas in the soil zone, (2) dissolution of carbonate sediments and rock (calcite and dolomite) in the recharge areas (most spring and well waters in recharge areas are at or near saturation with respect to calcite and dolomite), (3) precipitation of calcite, (4) leakage of water with high sulfate and sodium concentrations from the Tertiary confining unit, or dissolution of gypsum and halite, (5) mixing of different waters, (6) dissolution of volcanic rock, (7) exchange of calcium and magnesium in the water for sodium in clay minerals, (8) precipitation of chalcedony, and (9) formation of kaolinite

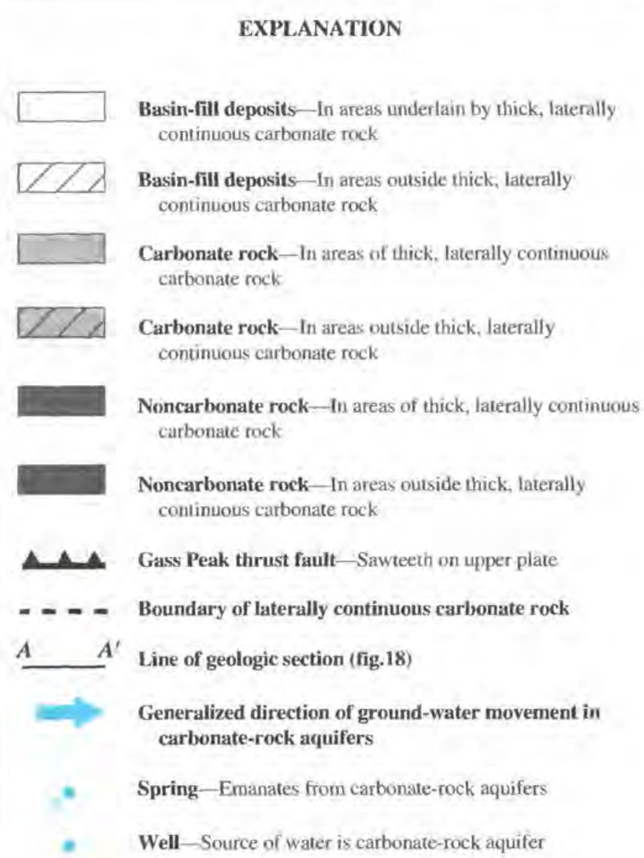
GEOLOGIC FRAMEWORK

Southern Nevada has had a complex geologic history of sedimentation, volcanic activity, and faulting. Miogeosynclinal sedimentation from Cambrian through Permian time produced thick sequences of carbonate and clastic sedimentary rock in southeastern Nevada and the Death Valley area of California. Widespread volcanism from Tertiary through present time produced extensive volumes of volcanic rock now exposed over much of the area. Major thrust faulting associated with the Sevier orogeny (late Mesozoic) and Cenozoic low-angle, near-surface thrust faulting and right-lateral strike-slip faulting have produced shear zones and high-angle basin-and-range faulting, resulting in the topography observed today (Stewart and Carlson, 1978). A detailed description of the hydrogeology of the entire Great Basin, as delineated by this RASA study, is given by Plume (1996).

Stratigraphic units in the study area were grouped into six hydrogeologic units to correspond to Winograd and Thordarson's (1975) hydrogeologic units in the Nevada Test Site area of southern Nevada (table 7). The hydrogeologic units are (1) Cambrian and older noncarbonate rock, (2) Cambrian to Devonian carbonate rock, (3) Devonian and Mississippian noncarbonate rock, (4) Mississippian to Permian carbonate rock, (5) Triassic to Quaternary noncarbonate rock, and (6) Tertiary and Quaternary basin-fill deposits (pl. 1). The hydrogeologic map is modified from that of Plume and Carlton (1988), which is based on geologic maps of Nevada and California compiled by Stewart and Carlson (1978) and Jennings (1977). Winograd and Thordarson's (1975) lower clastic confining unit was used in the Amargosa-Death Valley area of California to delineate the boundary between the Cambrian and older noncarbonate rock and the Cambrian to Devonian carbonate rock.

The Cambrian and older noncarbonate rock includes primarily siltstone, quartzite, shale, and sandstone in the northern and western parts of the study area and metamorphic and granitic rocks in the southern and eastern parts of the study area (Longwell and others, 1965; Tschanz and Pampeyan, 1970; Cornwall, 1972; Winograd and Thordarson, 1975; Jennings, 1977; Stewart and Carlson, 1978). These rocks probably underlie most of the study area at differing depths. Hydraulic conductivity of this unit is low, less than 0.1 ft/d, compared with the overlying carbonate-rock unit (median value of 2.0 ft/d: Dettinger and others, 1995). Thus, this unit retards ground-water flow and forms the base, or an adjacent boundary, to the carbonate-rock aquifers.

Cambrian to Devonian carbonate rock includes mostly limestone and dolomite. The limestone and dolomite formations contain numerous, generally basal, silty limestone and dolomite units. This hydrogeologic unit also contains numerous interbedded quartzites, sandstones, and shales, and many of the limestone and dolomite beds contain chert nodules (Langenheim and others, 1962; Longwell and others, 1965; Tschanz and Pampeyan, 1970; Cornwall, 1972; Winograd and Thordarson, 1975; Jennings, 1977; Stewart and Carlson, 1978). In some places the hydraulic conductivity of this unit is high, as much as 940 ft/d (Dettinger and others, 1995), because of sec-



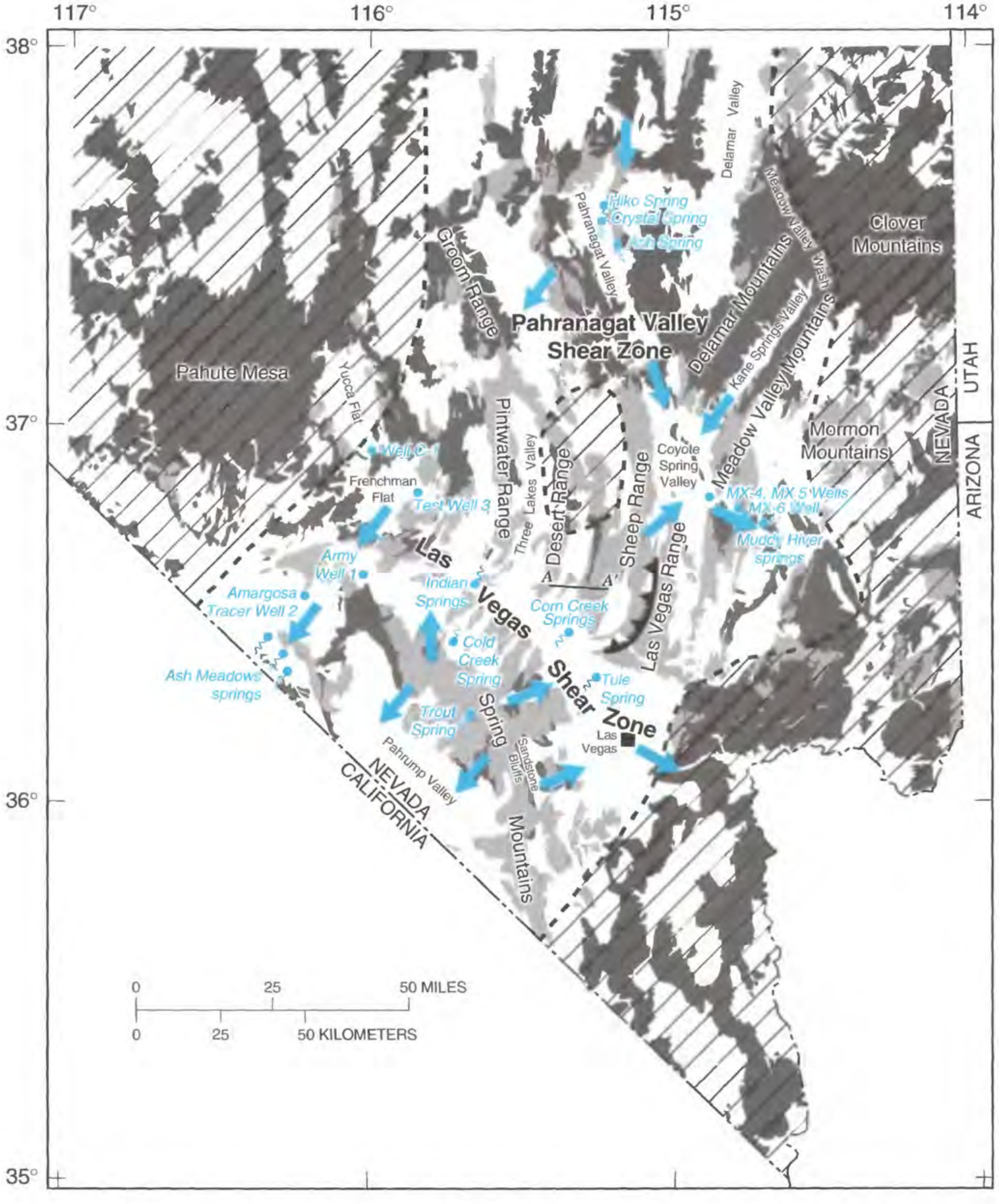


FIGURE 17.—Ground-water flow directions and hydrogeologic features associated with carbonate-rock aquifers in southern Nevada. Modified from Dettinger (1989, figs. 3, 4).

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TABLE 7.—*Hydrostratigraphy in southern Nevada and southeastern California*

Hydrogeologic unit and geologic age (see plate 1)	Hydrogeologic unit names used by Winograd and Thordarson (1975)	Calculated hydraulic conductivity (feet per day)
Basin-fill deposits, Quaternary and Tertiary	Valley-fill aquifer	Ranges from 0.6 to 17 (Winograd and Thordarson, 1975; Harrill, 1986; Morgan and Dettinger, 1996).
Noncarbonate rock, Quaternary to Triassic	Tuff aquitards and aquifers	Ranges from 0.1 to 92, but most aquifers are generally less than 1.0, except for highly permeable Piapi Canyon Group (Winograd and Thordarson, 1975).
Carbonate rock, Permian to Mississippian	Upper carbonate aquifer	Ranges from 0.1 to 900, with mean value of 102 and median value of 5.2 (Dettinger and others, 1995).
Noncarbonate rock, Mississippian and Devonian	Upper clastic aquitard	0.01 for two wells (Dettinger and others, 1995).
Carbonate rock, Devonian to Cambrian	Lower carbonate aquifer	Ranges from 0.01 to 940, with mean value of 96 and median value of 2.0 (Dettinger and others, 1995).
Noncarbonate rock, Cambrian and older	Lower clastic aquitard	Less than 0.1 for two wells (Dettinger and others, 1995).

ondary permeability produced by fracturing (Winograd and Thordarson, 1975). Consequently, this unit can transmit vast quantities of water.

Devonian to Mississippian noncarbonate rock includes mostly shale, argillite, siliceous siltstone, quartzite, and conglomerate (Cornwall, 1972; Winograd and Thordarson, 1975). Because the hydraulic conductivity of this unit is extremely low, 0.01 ft/d (Dettinger and others, 1995) this unit restricts ground-water flow (Winograd and Thordarson, 1975). However, this low-permeability unit is greater than 200 ft thick only in the north-central part of the study area. Elsewhere, the carbonate-rock units form one continuous aquifer.

Mississippian to Permian carbonate rock is mainly limestone. The limestone consists of numerous argillaceous, cherty, and fetid limestone beds and interbedded shale, siltstone, and sandstone, along with gypsum in the upper part of the unit (Langenheim and others, 1962; Longwell and others, 1965; Tschanz and Pampeyan, 1970; Cornwall, 1972; Winograd and Thordarson, 1975; Stewart and Carlson, 1978). Hydraulic conductivity of this unit is as high as 900 ft/d (Dettinger and others, 1995) because of secondary permeability produced by fracturing (Winograd and Thordarson, 1975). Thus, this unit is capable of transmitting large quantities of water.

Triassic to Quaternary noncarbonate rock is mostly volcanic rock consisting of welded to nonwelded ash-flow and ash-fall tuffs, and basalt and rhyolite flows (Longwell and others, 1965; Tschanz and Pampeyan, 1970; Cornwall, 1972; Winograd and Thordarson, 1975; Jennings, 1977; Stewart and Carlson, 1978). Although the hydraulic conductivity of this unit generally ranges from 0.1 to 2.0 ft/d, in places it is as high as 92 ft/d. In areas of high hydraulic conductivity, the unit can form transmissive aquifers. The older and more pervasive volcanic rock generally form low-permeability aquifers, with an average hydraulic conductivity of about 0.2 ft/d (Winograd and Thordarson, 1975; Dettinger and others, 1995). This unit also includes sandstone, siltstone, and conglomerate, which generally have low hydraulic conductivity and commonly form a low-permeability layer on top of more permeable carbonate-rock units. This unit also includes small areas of low transmissivity, Triassic to Quaternary intrusive rock that have invaded the carbonate rock, primarily along the south edge of the study area.

Tertiary and Quaternary basin-fill deposits are composed of alluvial-fan, fluvial, fanglomerate, lake-bed, and mudflow deposits (Winograd and Thordarson, 1975; Jennings 1977; Stewart and Carlson, 1978). Basin-fill deposits are fairly conductive (0.6 to 17 ft/d) and can transmit large quantities of water (Winograd and Thordarson, 1975; Harrill, 1986; Morgan and Dettinger, 1996). Basin-fill deposits in southern Nevada commonly are underlain by or are adjacent to carbonate rock. Together the basin-fill deposits and carbonate rock may form a single, highly transmissive aquifer.

Southern Nevada has undergone episodes of regional compression, extension, and volcanism, which have resulted in the disruption of the originally thick and continuous carbonate-rock strata deposited during the Paleozoic. Primarily because of extension over the last 25 million years, only a central corridor of thick, laterally continuous Paleozoic carbonate rock remains in southern Nevada (fig. 17; Dettinger, 1989). This central corridor contains most of the regional groundwater flow in southern Nevada, including both the White River and Ash Meadows flow systems (fig. 16). The corridor of thick, continuous carbonate rock is bounded in places on the east and west by thin or isolated carbonate rock, or noncarbonate rock. Ground-water flow in the carbonate rock outside this corridor is not significant in volume (Dettinger, 1989).

Geologic constraints on flow within the central corridor of carbonate rock are caused primarily by noncarbonate rock that has been rotated or emplaced close to the land surface. One postulated geologic constraint (Dettinger, 1989) that could significantly impede westward ground-water flow from the Sheep Range to Ash Meadows (fig. 17) is a low permeability wedge of noncarbonate clastic rock several thousand feet thick (Guth, 1980) extending a minimum of 1,000 ft above the water table along the west side of the Sheep Range (fig. 18). Another postulated geologic constraint to ground-water flow to the west from the Sheep Range is the absence of carbonate rock between Three Lakes Valley and the northern Sheep Range (fig. 17; Guth, 1989).

A probable geologic constraint on southward and southeastward ground-water flow from the Sheep Range was recognized by Winograd and Thordarson (1975). Cambrian noncarbonate rock along the Gass Peak Thrust Fault (fig. 17, pl. 1; Longwell and others, 1965) in the Las Vegas Range greatly reduces ground-water flow from the Sheep Range. Thus, most of the recharge to the southern part of the Sheep Range may flow north and then east toward Muddy River springs because of noncarbonate-rock barriers to westward, southward, and southeastward flow. Also, eastward flow is enhanced by the 5 to 50 degree eastward dip of the strata in the Sheep Range (Longwell and others, 1965; Tschanz and Pampeyan, 1970).

Major structural zones that intersect the central carbonate-rock corridor also may alter ground-water flow by impeding or enhancing flow in some areas and directions. The Las Vegas Valley shear zone and Pahranagat Valley shear zone are two major structural zones in the central corridor that may influence ground-water flow by reducing flow across the zones and enhancing (or allowing) flow along the strike of the zones (fig. 17; Winograd and Thordarson, 1968; Winograd and Friedman, 1972; Winograd and Pearson, 1976; Kirk, 1987; Lyles and Hess, 1988; Thomas, Carlton, and Hines, 1989; Thomas, Welch, and Preissler, 1989; Kirk and Campana, 1990).

Aquifers in the study area from which regional springs emanate are primarily Cambrian to Devonian dolomite and limestone and Devonian through Permian limestone. X-ray diffraction analyses of rocks of Precambrian to Permian age show that the mineralogy of the upper and lower carbonate-rock aquifers is predominantly dolomite and calcite (table 8). Whole-rock major-element analyses indicate that the dolomites and limestones generally are composed of extremely pure carbonates containing less than 1.5 weight percent of major element oxides other than calcium carbonate and magnesium carbonate (table 9). Sulfur analyses (table 10) also show the limestones and dolomites are extremely pure. Samples used for whole-rock major-element analyses were limestones and dolomites with few fracture fillings or notable impurities; the chemistry of more veined or shaley limestones and dolomites may differ. X-ray diffraction analyses (table 8) and analyses of the insoluble residue from the whole-rock chemical analyses (table 11) indicate that minerals other than calcite and dolomite in the carbonate rock are mostly quartz with lesser amounts of illite, smectite, feldspar, alunogen, chlorite, kaolinite, palygorskite, clinoptilolite, and unidentified zeolite (table 11). Fracture-filling vein minerals are primarily calcite and dolomite but also include quartz, aragonite, iron and manganese oxides, and clays (table 8; Winograd and Thordarson, 1975). These vein minerals are primarily precipitated from the ground water, except for clays which are weathering products. Although the carbonate rock may contain inclusions of connate seawater, the low sodium and sulfur concentrations (tables 9, 10) indicate they are not common. Because surface samples may have undergone leaching, subsurface rocks are more likely to contain inclusions.

Interbedded quartzite, sandstone, siltstone, and shale, and silty limestone and dolomite in the lower and upper carbonate-rock aquifers contain major amounts of quartz and alumino-silicate minerals in addition to the carbonate minerals (tables 8, 9, 11).

X-ray diffraction analyses of Miocene volcanic rock from the Kane Springs Wash and Meadow Valley Wash areas (pl. 1) show the dominant minerals in these rocks are primarily plagioclase feldspar, K-feldspar, quartz, biotite, and clinoptilolite (table 12). Hornblende, halite, clinopyroxene, olivine, and mica also are present in the rock. Calcite, mordenite, and cristobalite also may be present. The volcanic rock also contain large amounts of volcanic glass. These results are in good agreement with previous work on rock from this area by Ekren and others (1977). Tertiary volcanic rock in the Nevada Test Site area have similar mineralogies (Byers and others, 1976) and have undergone zeolitization, resulting in a downward zonation of clinoptilolite to mordenite to analcime, that cuts across volcanic-rock units (Hoover, 1968).

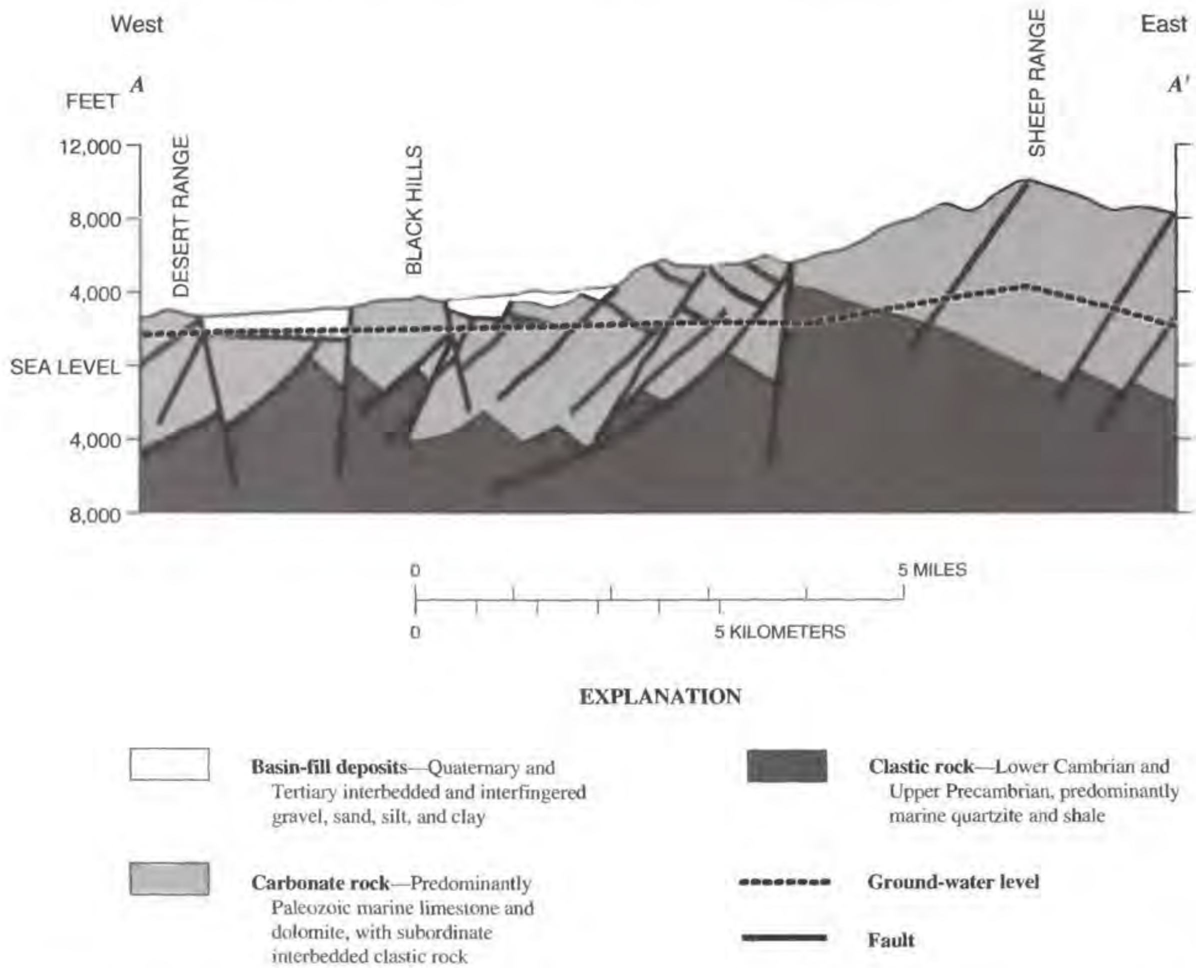

FIGURE 18.—Geologic section across southern Sheep Range north of Las Vegas, Nev. Line of section shown in figure 17. Modified from Guth (1980, pl. 2) and Dwight Schmidt (U.S. Geological Survey, written commun., 1986).

Evaporite minerals, primarily gypsum, are present in Permian and younger rock throughout the study area. Other minerals associated with these evaporite deposits are halite, magnesite, and glauberite (Longwell and others, 1965).

HYDROLOGIC FRAMEWORK

Water in carbonate-rock aquifers of southern Nevada primarily originates from high-altitude winter precipitation (Winograd and Riggs, 1984), mainly in the Spring Mountains and Sheep Range (fig. 17), and from ground water flowing into southern Nevada by way of the White River flow system to the north (fig. 16). Water recharged at high altitudes generally infiltrates carbonate rock and flows through carbonate-rock aquifers to a sink, such as the springs at Ash Meadows, where the water is discharged. Water flowing through the aquifers often mixes with water from different source areas before reaching the common discharge area of the flow system. Ground water flowing into southern Nevada from other flow systems, such as the White River flow system to the north, mixes with water that has been recharged in southern Nevada and is part of the water discharging at regional springs.

Water levels of springs emanating from the carbonate-rock aquifers in wells completed in carbonate rock and in wells completed in basin-fill deposits (where springs emanating from, or wells completed in, carbonate rock are absent) have been used to help delineate flow systems in the carbonate rock of southern Nevada (pl. 1; Eakin, 1966; Winograd and Thordarson, 1975; Thomas and others, 1986). Water levels indicate that Muddy River springs at the terminus of the White River flow system receives water from the Pahranagat Valley area to the northwest as originally delineated by Eakin (1966). In addition, Muddy River springs also

TABLE 8.—*X-ray diffraction analyses of rock samples from southern Nevada*

[Analysis by Robert Mariner, U.S. Geological Survey, Menlo Park, Calif. Symbol: --, no mineral identified]

Site[1]	Geologic unit, vein, or rock type sampled	Geologic age	Minerals identified			
			Major[2]	Minor	Trace[2]	Possible
1	Eureka Quartzite	Ordovician	quartz	--	--	--
2	Bonanza King Formation	Cambrian	dolomite	--	quartz, aragonite	--
3	Nopah Formation	Cambrian	dolomite	--	calcite	--
4	Undifferentiated	Silurian	dolomite	--	calcite	--
5	Toroweap Formation	Permian	calcite, quartz	--	feldspar	--
6	Gneiss	Precambrian	quartz, plagioclase, biotite, chlorite, dolomite	--	--	--
	Schist		biotite, plagioclase, quartz	--	amphibole	--
7	Tapeats Sandstone	Cambrian	quartz	--	calcite	--
8	Pioche Formation	Cambrian	quartz	K-feldspar	--	--
9	Lyndon Limestone	Cambrian	calcite	--	--	--
10	Limestone and dolomite	Cambrian	dolomite	calcite	quartz	--
11	Muddy Peak Formation	Devonian	dolomite	quartz	calcite	--
12	Callville Limestone	Mississippian-Permian	calcite	quartz	--	--
13	Undifferentiated vein	Devonian	dolomite	--	calcite	--
14	Pogonip Group	Ordovician	dolomite	--	--	calcite
15	Lone Mountain Dolomite	Silurian	dolomite, quartz	--	calcite, feldspar (microcline)	sphene
16	Pogonip Group (lower part)	Ordovician	calcite	--	quartz	--
	Vein in Pogonip Group		calcite, quartz, dolomite, aragonite	--	--	
17	Upper unnamed unit	Cambrian	dolomite	--	calcite	--
	Vein in upper, unnamed unit		calcite		quartz	--
18	Sevy Dolomite	Devonian	dolomite	--	--	--
19	Bird Spring Formation	Mississippian-Permian	dolomite, quartz, calcite	--	--	--
20	Pogonip Group (Antelope Valley Formation)	Ordovician	dolomite	--	--	--
21	Undifferentiated Dolomite	Cambrian	dolomite	--	--	--
22	Monte Cristo Formation	Mississippian	calcite, dolomite	--	quartz	--
	Vein in Dawn Limestone		calcite	--	quartz	--

[1] See plate 1.

[2] Listed in order of approximate abundance.

TABLE 9.—*Whole-rock chemical analyses of rock samples from southern Nevada*

[Analyses by Nelson Shaffer, Indiana Geological Survey, Bloomington, Ind., except as noted. Analyses are recalculated to total 100.0 percent. Rock analyses are expressed in weight percent of constituent oxides or, for calcium and magnesium, carbonates. Symbol: --, not determined.]

Site[1]	Geologic unit or rock type sampled	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	MnO	$CaCO_3$
E-1	Nopah Dolomite	1.05	0.12	0.061	0.009	0.010	53.9
E-2	Ely Springs Dolomite	.25	.070	.057	.008	.010	54.8
E-3	Yellowpine Limestone	1.21	.12	.057	.006	.008	97.7
E-5	Monte Cristo Limestone, Dawn Member[2]	.30	.20	.10	--	--	56.4
E-6	Sultan Limestone[2]	.60	.40	.05	--	--	98.1
E-7	Carrara Formation Shale	70.3	13.5	5.30	.82	.10	2.07
E-8	Bright Angel Shale	57.4	22.1	7.97	.92	.039	.87
E-9	Indian Springs Shale	70.1	18.8	2.94	1.25	.092	3.10

Site[1]	Geologic unit or rock type sampled	$MgCO_3$	Na_2O	K_2O	P_2O_5	SrO	Total
E-1	Nopah Dolomite	44.8	0.011	0.050	0.016	0.006	100.0
E-2	Ely Springs Dolomite	44.7	.018	.067	.011	.017	100.0
E-3	Yellowpine Limestone	.79	.007	.036	.032	.019	100.0
E-5	Monte Cristo Limestone, Dawn Member[2]	43.0	--	--	--	--	100.0
E-6	Sultan Limestone[2]	.90	--	--	--	--	100.0
E-7	Carrara Formation Shale	2.99	1.64	3.17	.13	.005	100.0
E-8	Bright Angel Shale	4.17	.59	5.75	.24	.012	100.0
E-9	Indian Springs Shale	1.46	.47	1.48	.18	.12	100.0

[1] See plate 1.

[2] Analysis from Longwell and others (1965, p. 157).

receives water from the southern part of the Meadow Valley Wash flow system and, due to structural controls (see previous section titled "Geologic Framework"), receives most of the recharge to the Sheep Range (figs. 16, 17, pl. 1).

The Ash Meadows flow system drains the Frenchman Flat-Yucca Flat area to the northeast of the Ash Meadows springs, and on the basis of water-level, isotopic, and geochemical data the Pahranagat Valley area also supplies water to Ash Meadows springs (Winograd and Friedman, 1972; Winograd and Thordarson, 1975; Winograd and Pearson, 1976). The scarcity of wells between Frenchman Flat and Pahranagat Valley and Frenchman Flat and Sheep Range limits interpretation of ground-water flow in this area. However, geologic information (see section titled "Geologic Framework") indicates that the Pahranagat Valley area is connected to Ash Meadows by a thick and continuous carbonate-rock section, whereas the Sheep Range probably does not supply much water to the Ash Meadows flow system (figs. 16, 17, 18).

Water levels in Las Vegas Valley indicate that the valley receives water from the Spring Mountains and Sheep Range (pl. 1). However, structural controls probably prevent significant amounts of recharge to the Sheep Range from flowing into Las Vegas Valley (figs. 17, 18). This conclusion is supported by ground-water flow models of the basin-fill aquifers in Las Vegas Valley by Harrill (1976) and by Morgan and Dettinger (1996). Water levels also indicate that ground water flows into southwest Las Vegas Valley from Ivanpah Valley (pl. 1).

Water levels in Pahrump Valley indicate that recharge from the Spring Mountains is the source of all the water in Pahrump Valley (pl. 1). Water levels for areas outside the thick carbonate-rock aquifers in southern Nevada and southeastern California also are shown on plate 1.

TABLE 10.—*Sulfur content of rock samples from southern Nevada*

[Analyses by Nelson Shaffer, Indiana Geological Survey, Bloomington, Ind.]

Site[1]	Geologic unit sampled	Sulfur, as S (parts per million)	Sulfur, as S (percent)
E-1	Nopah Dolomite	22	0.0022
E-2	Ely Springs Dolomite	82	.0082
E-3	Yellowpine Limestone	72	.0072
E-4	Dawn Limestone	100	.0100
E-7	Carrara Formation Shale	29	.0029
E-8	Bright Angel Shale	94	.0094
E-9	Indian Springs Shale	130	.0130

[1] See plate 1.

Hydrologic data for southern Nevada indicate that on a regional scale the White River flow system, which discharges at Muddy River springs, and the Ash Mead-

TABLE 11.—*X-ray diffraction analyses of insoluble residues from whole-rock chemical analyses of rock samples from southern Nevada*

[Analyses by Nelson Shaffer, Indiana Geological Survey, Bloomington, Ind.]

Site[1]	Geologic unit sampled	Insoluble residue (percent)	Minerals identified[2]
E-1	Nopah Dolomite	1.33	Quartz, illite, smectite, feldspar, and alunogen.
E-2	Ely Springs Dolomite	.33	Quartz, illite, chlorite, kaolinite, palygorskite, and possibly K-feldspar.
E-3	Yellowpine Limestone	1.34	Quartz.
E-4	Dawn Limestone	.28	Quartz, clinoptilolite, illite, and an unidentified zeolite.
E-7	Carrara Formation Shale	93.12	Quartz, illite, feldspar, smectite, kaolinite, and possibly zeolites.
E-8	Bright Angel Shale	91.08	Quartz, palygorskite, smectite, and chlorite.
E-9	Indian Springs Shale	94.28	Quartz, kaolinite, smectite, and illite.

[1] See plate 1.
[2] Listed in order of approximate abundance.

ows flow system, which discharges at Ash Meadows springs, encompass large areas that contain several topographic basins which drain to a common discharge area (figs. 16, 17). In addition, both Muddy River springs and Ash Meadows springs receive water from the Pahranagat Valley area. Las Vegas and Pahrump Valleys receive water primarily from recharge to the Spring Mountains.

STABLE ISOTOPES OF THE GROUND WATER

Deuterium and oxygen-18 data can be used to help delineate ground-water flow systems by identifying water from different source areas. Most water in carbonate-rock aquifers of southern Nevada is chemically similar because mineralogy of the carbonate rock is relatively homogeneous, so the stable isotopes deuterium and oxygen-18 become an important tool for delineating source areas and flow paths in this area. Deuterium rather than oxygen-18 is used to delineate flow systems in southern Nevada because it has been used in previous studies (Winograd and Friedman, 1972; Claassen, 1985, 1986; Lyles and Hess, 1988; Noack, 1988; Kirk and Campana, 1990) and generally is not affected by water-rock interactions that can change oxygen-18 compositions.

Deuterium data used for flow-system delineation are primarily from samples analyzed by the U.S. Geological Survey research laboratory in Reston, Va. Additional deuterium data are included for samples analyzed prior to 1973 by the U.S. Geological Survey research laboratory in Denver, Colo. [after correcting for interlaboratory differences, the deuterium values analyzed before 1973 were divided by 1.03 (I.J. Winograd, U.S. Geological Survey, written commun., 1985)] and by the Desert Research Institute Isotope Laboratory in Las Vegas, Nev. An interlaboratory comparison between the Desert Research Institute Laboratory and U.S. Geological Survey Reston laboratory analyses showed that the average difference between deuterium values for 9 duplicate samples analyzed at the two laboratories was less than 1.0 part per thousand (permil), with only 1 sample difference greater than 2 permil; the average difference for 18 samples (9 duplicate samples plus 9 samples from springs that have a constant

TABLE 12.—*X-ray diffraction analyses of Miocene volcanic rocks from southern Nevada*

[Analysis by Robert Mariner, U.S. Geological Survey, Menlo Park, Calif. Symbol: --, no mineral identified]

Site[1]	Geologic unit or rock type sampled	Minerals identified		
		Major[2]	Trace[2]	Possible
V-1	Ash-flow tuff	Plagioclase, quartz, biotite, hornblende, halite	--	--
V-2	Basalt	Plagioclase	--	--
V-3	Ash-flow and ash-fall tuffs	Quartz, plagioclase, K-feldspar	--	--
V-4	Basalt	Plagioclase, clinopyroxene, olivine	--	Calcite
V-5	Kane Wash Tuff	Clinoptilolite	--	Mordenite
V-6	Rhyolite lavas	Quartz, K-feldspar, plagioclase	--	Cristobalite
V-7	Hiko Tuff	Biotite, plagioclase, K-feldspar, quartz	--	--
V-8	Bedded tuff	Quartz, plagioclase, K-feldspar, clinoptilolite	Mica	--

[1] See plate 1.
[2] Listed in order of approximate abundance.

deuterium concentration over time) was less than 0.3 permil, with only 3 sample differences greater than 2 permil (data are in appendix A). For consistency, if a sample site had data from the Reston laboratory and either of the other laboratories, only the Reston laboratory data were used to determine the average deuterium composition for that site.

ISOTOPIC COMPOSITION OF GROUND WATER IN SOURCE AREAS AND FLOW SYSTEMS

The average deuterium composition of ground water in recharge areas and in flow systems contributing to the carbonate-rock aquifers of southern Nevada (pl. 2) was determined from a data base compiled for this study (appendix A). All the data were plotted to eliminate samples significantly affected by evaporation (fig. 19). All samples that plot to the right of the line [$\delta D=8(\delta^{18}O)+0$] are assumed to have undergone significant evaporation and were not used in calculating the average deuterium composition of water from a sample site (fig. 20, pl. 2). Most samples plot to the right of the meteoric water line, indicating that water in southern Nevada has undergone a small amount of evaporation prior to infiltrating into aquifers.

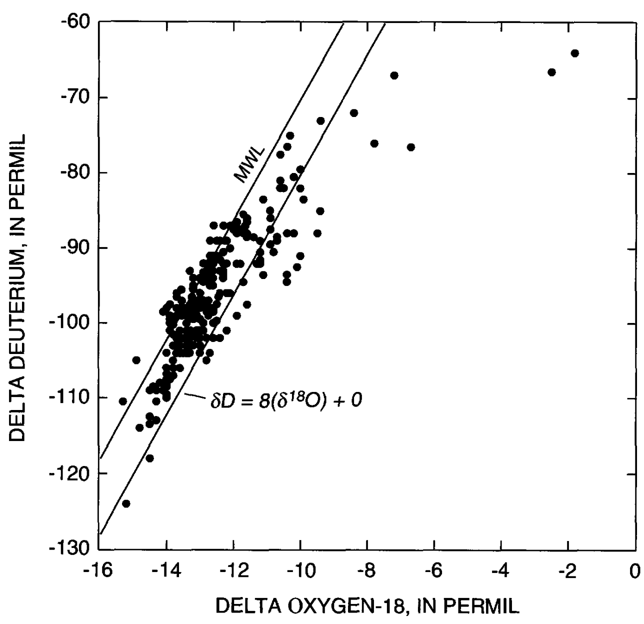

FIGURE 19.—Relation between mean deuterium and mean oxygen-18 for ground-water samples from sites in southern Nevada and southeastern California. MWL is the meteoric water line ($\delta D=8(\delta^{18}O)+10$; Craig, 1961).

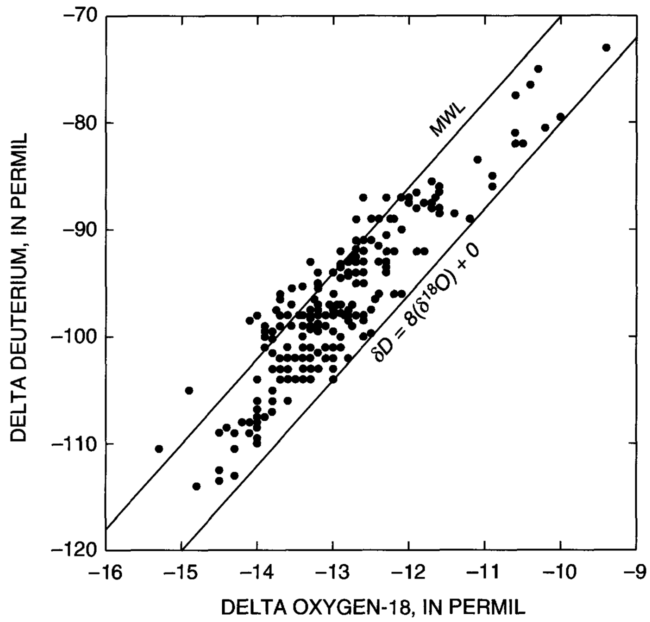

FIGURE 20.—Relation between mean deuterium and mean oxygen-18 for ground-water samples that have not undergone significant evaporation, southern Nevada and southeastern California. MWL is the meteoric water line ($\delta D=8(\delta^{18}O)+10$; Craig, 1961).

SPRING MOUNTAINS

Recharge from the Spring Mountains can be divided on the basis of isotopic composition into recharge from the central part of the mountains north of the Sandstone Bluffs area and from the Sandstone Bluffs area and everything south of that area (fig. 17; pl. 2). The central part of the Spring Mountains reaches an altitude of almost 12,000 ft, whereas the southern part of the Spring Mountains (Sandstone Bluffs and south of Sandstone Bluffs) reaches an altitude of only about 8,500 ft. The difference in altitude results in water in the higher central part having an average deuterium composition that is 9 permil lighter (more negative) than water in the lower southern part (table 13).

The average deuterium composition of Spring Mountains recharge for the central part of the Spring Mountains is −99 permil (table 13). This deuterium value is based on the average deuterium composition of the two largest discharging springs, Trout Spring and Cold Creek Spring (fig. 17), which also have the longest sampling record (1968–89). Water from Trout Spring has a mean deuterium composition of −97.7 permil, standard deviation 1.3, for 19 samples, and water from Cold Creek Spring has a mean deuterium composition of −100.1 permil, standard deviation 1.2, for 16 samples (Winograd and Riggs, 1984; I.J. Winograd, U.S. Geological Survey, written commun., 1989; Thomas and others, 1991). The average value of –99 permil for the central part of the Spring Mountains is the same as that presented by Winograd and Riggs (1984) for springs and wells in the Spring Mountains. Their data included 9 samples in addition to their combined 28 samples at Trout Spring and Cold Creek Spring. The average deuterium value agrees with other isotope data collected during a shorter period from smaller springs in the Spring Mountains (appendix A; pl. 2).

The average deuterium composition of recharge to the southern part of the Spring Mountains is –90 permil (table 13).

Deuterium values are different for the two parts of the Spring Mountains, but within each part, deuterium composition does not discernibly change with altitude (fig. 21). Thus, deuterium composition of winter precipitation that recharges the Spring Mountains (Winograd and Riggs, 1984) is not affected by altitude (deuterium composition does not become lighter with increasing altitude). Consequently, recharge from each part of the Spring Mountains should have similar deuterium composition regardless of altitude.

SHEEP RANGE

The average deuterium composition of recharge to the Sheep Range is –93 permil based on the average deuterium value of 17 samples at six springs (table 13, appendix A). This average deuterium composition is

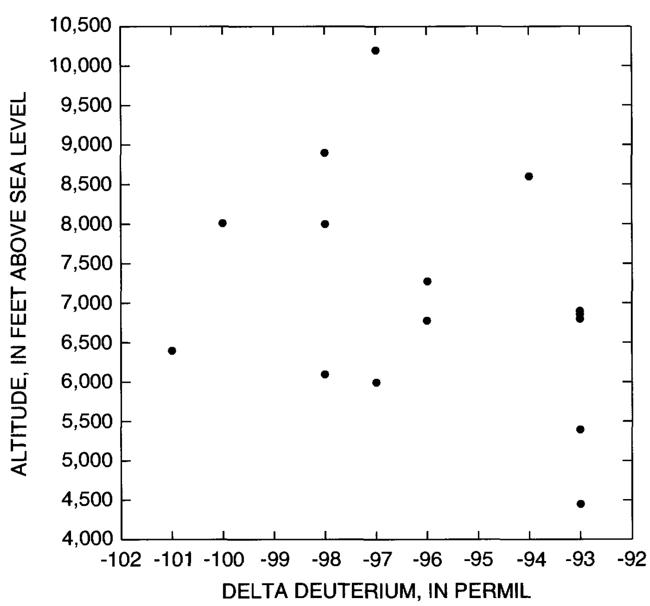

FIGURE 21.—Relation between mean deuterium composition and altitude for spring and well samples that contain tritium in the Spring Mountains, southern Nevada. Tritium indicates the water was less than about 50 years old at the time of sampling.

the same as that of water discharging from Corn Creek Springs (–93 permil; appendix A, fig. 17, pl. 2). Corn Creek Springs is on a fan on the southwest flank of the Sheep Range and, therefore, should be representative of water that flows either south to Las Vegas Valley or west to Ash Meadows from the Sheep Range.

Six springs in the Sheep Range are at altitudes from about 5,600 to 8,400 ft. Their average deuterium composition changes by only 4 permil, so on the basis of limited data, altitude probably does not affect the deuterium composition of water in the Sheep Range. Thus, –93 permil represents the deuterium composition of recharge to the Sheep Range, as is observed at Corn Creek Springs, which is probably well-mixed water from the Sheep Range.

SOUTHERN MEADOW VALLEY WASH FLOW SYSTEM

The average deuterium composition of ground water in the southern Meadow Valley Wash flow system (fig. 16) is –87 permil (table 13). This value is an average for springs and wells in the Meadow Valley Wash drainage south of Caliente, the Delamar Mountains, the Meadow Valley Mountains, and the southwest Clover Mountains (pl. 2).

WHITE RIVER FLOW SYSTEM

The average deuterium composition of springs emanating from carbonate-rock aquifers in Pahranagat Valley is –109 permil (fig. 17, pl. 2). This average value is for samples from Ash and Crystal Springs that were analyzed by the Reston laboratory (table 13). This value agrees with data for previous samples from Ash, Crystal, and Hiko Springs in Pahranagat Valley, which were analyzed at the Denver and Las Vegas laboratories (appendix A). These samples were chosen as representative of water in the carbonate-rock aquifers of the White River flow system that flows into southern Nevada because they are large springs discharging from the carbonate-rock aquifers upgradient from Muddy River and Ash Meadows springs.

PALEOCLIMATIC EFFECTS ON ISOTOPIC COMPOSITION

Ground water discharging from the carbonate-rock aquifers in southern Nevada is a mixture of waters that were recharged primarily during the last 10,000 years (see table 18; Winograd and Pearson, 1976; Benson and others, 1983; Waddell and others, 1984; Claassen, 1985, 1986; Kirk, 1987; Benson and Klieforth, 1989; Kirk and Campana, 1990). The average deuterium composition of waters recharging the carbonate-rock aquifers of southern Nevada would have had to remain relatively constant during this time for deuterium to be

TABLE 13.—*Deuterium composition of ground water in source areas of southern Nevada*

[Analyses from U.S. Geological Survey research laboratory, Reston, Va., unless otherwise noted]

Site	Number[1]	Delta deuterium (permil)	Standard deviation
Central part of Spring Mountains			
Trout Spring[2]	19	−97.7	1.3
Cold Creek Spring[2]	16	−100.1	1.2
Sites averaged	2	−98.9	1.7
Southern part of Spring Mountains			
Bird Spring[3]	1	−88.0	--
Sandstone Spring	1	−89.0	--
BLM Visitors Center well	1	−89.0	--
Red Spring	1	−89.0	--
Willow Spring	1	−90.5	--
White Rock Spring	1	−91.0	--
Castilio well[3]	1	−94.0	--
Sites averaged	7	−90.1	2.0
Sheep Range			
Wiregrass Spring	9	−94.3	1.8
Mormon Well Spring	3	−91.8	.8
Cow Camp Spring	2	−92.0	1.8
Lamb Spring	1	−92.5	--
Sawmill Spring	1	−92.0	--
Sheep Spring	1	−96.0	--
Sites averaged	6	−93.1	1.7
Southern Meadow Valley Wash flow system			
Upper Riggs Spring	1	−88.0	--
Boulder Spring	1	−87.0	--
Kane Spring	1	−86.5	--
Grapevine Spring	1	−87.5	--
Willow Spring	1	−88.0	--
Caliente City well	1	−89.0	--
Bishop Spring	1	−85.5	--
Bradshaw well	1	−88.5	--
Railroad Elgin well	1	−86.0	--
Randono well	1	−87.5	--
Jensen well	1	−88.5	--
North Ella Spring	1	−86.5	--
Grassy Spring[4]	1	−85	--
Stock well[5]	1	−88.0	--
Sites averaged	14	−87.3	1.2
White River flow system			
Ash Spring	1	−108.0	--
Crystal Spring	1	−109.0	--
Sites averaged	2	−108.5	0.7

[1] Number of samples per site, and number of sites averaged.

[2] Data from I.J. Winograd (U.S. Geological Survey, written commun., 1989).

[3] Data from Desert Research Institute laboratory, Las Vegas, Nev. (Thomas and others, 1991).

[4] Unpublished data from Desert Research Institute laboratory, Las Vegas, Nev.

[5] Data from Desert Research Institute laboratory, Las Vegas, Nev. (Kirk, 1987, p. 81).

used to calculate mixing of water from different sources. This seems unlikely because of climatic changes during this period (Mifflin and Wheat, 1979; Winograd and Doty, 1980; Spaulding and others, 1984; Spaulding, 1985; Quade, 1986; Benson and Thompson, 1987; Quade and Pratt, 1989). However, a plot of deuterium and carbon-14 (fig. 22) for water that was recharged in the Spring Mountains shows that deuterium has remained relatively constant for a carbon-14 range of 1.9 to 100 percent modern carbon (pmc). Deuterium composition varies by only a total of 6 permil, with an average concentration of −99 permil. A similar plot for water recharged in the Sheep Range contains fewer data points; it shows that deuterium composition varies by less than 2 permil for a carbon-14 range of 13.7 to 96.8 pmc (fig. 23).

In summary, the deuterium composition of water in the Spring Mountains, Sheep Range, and surrounding areas has remained constant with time for a carbon-14 range of 1.9 to 100 pmc. Thus, deuterium can be used to determine source areas, flow paths, and mixing of ground water in the carbonate-rock aquifers of southern Nevada.

FLOW-SYSTEM DELINEATION ON THE BASIS OF DEUTERIUM

Deuterium composition of water discharging from large springs in southern Nevada can be used to determine the sources of water that supply the springs and, thus, help delineate flow paths. Mixing of isotopically different waters from different source areas can be determined from observed differences in the deuterium composition of the ground water upgradient from the springs. The two largest spring areas in southern Nevada are Muddy River springs (36,000 acre-ft/yr) in Moapa Valley, at the terminus of the White River flow system, and Ash Meadows springs (17,000 acre-ft/yr) in the Amargosa Desert, at the terminus of the Ash Meadows flow system (figs. 16, 17). These spring flow rates represent minimum ground-water flow, because additional water may be flowing past the springs in the carbonate-rock aquifers and because evapotranspiration in the spring areas may include ground water that is not discharged at the springs. However, the proportion of water from different sources determined on the basis of deuterium composition would be the same; only the absolute amount from the different areas would increase if the spring flow does not include all the water in the carbonate-rock aquifers in the spring area. In addition, the isotopic composition of water from wells, or discharging from springs, in Las Vegas and Pahrump Valleys can be used to determine sources of water in the carbonate and basin-fill aquifers in these areas.

If deuterium is used as a tracer, the deuterium composition of the different source areas has to be different. Although waters from the two major recharge areas in southern Nevada, the Spring Mountains and Sheep Range, are only 6 permil different in mean deuterium composition (table 13), a Mann-Whitney test shows that the medians of the two populations are detectably different at the 0.001 significance level. Additional, and perhaps even more compelling, evidence that deuterium values from the two areas are different is that deuterium composition of water along flow paths from each area is the same as the deuterium composition in the recharge area (pls. 1, 2). The mean deuterium composition of 22 samples along flow paths from the central part of the Spring Mountains is –98.4 permil (standard deviation 1.6) and ranges from –102.0 to –95.0 permil; the mean composition of 4 samples along flow paths from the Sheep Range is –93.6 permil (standard deviation 0.5) and ranges from –94.0 to –93.0 permil. Consequently, although waters from these recharge areas are only 6 permil different, they are statistically different populations, and ground water flowing from each recharge area maintains the same average deuterium value as the recharge-area water. Thus, the mean values of –99 and –93 permil can be used as the isotopic inputs for the two recharge areas. Other significant sources of ground water in carbonate-rock aquifers of southern Nevada are the southern part of the Spring Mountains (deuterium composition is –90 permil), the White River flow system (deuterium composition is –109 permil), and the southern Meadow Valley Wash flow system (deuterium composition is –87 permil; table 13).

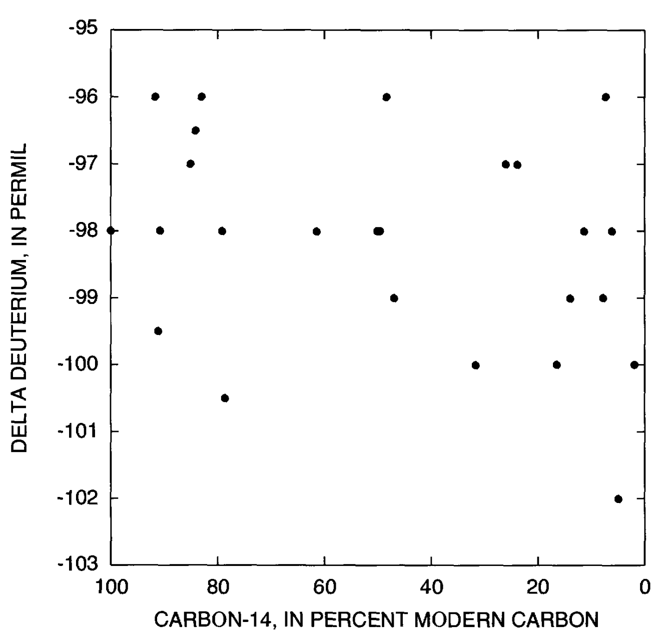

FIGURE 22.—Relation between mean deuterium and carbon-14 for water recharged in the Spring Mountains, southern Nevada.

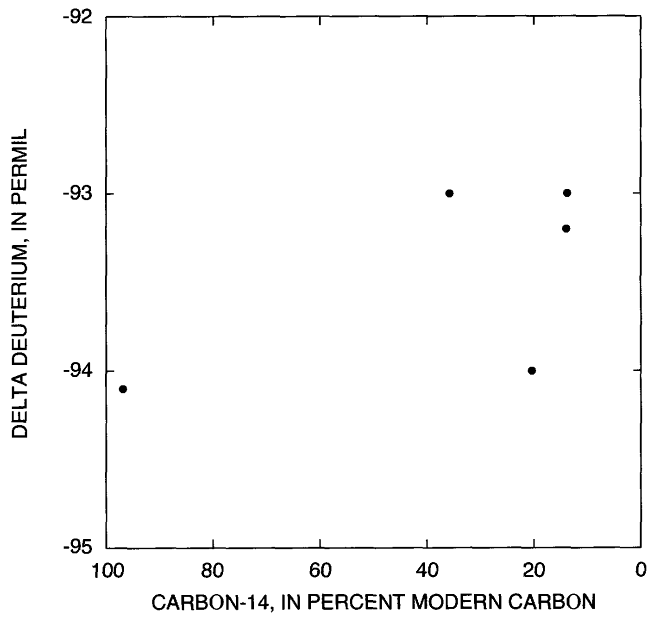

FIGURE 23.—Relation between mean deuterium and carbon-14 for water recharged in the Sheep Range, southern Nevada.

WHITE RIVER FLOW SYSTEM

Muddy River springs discharge 36,000 acre-ft/yr of water at the distal end of the White River flow system (Eakin and Moore, 1964). The average deuterium composition of water from five springs in the Muddy River springs area, including Big Muddy Spring, which is the largest discharging spring, is –98 permil (isotope analyses from the Reston laboratory; appendix A). The sources of water discharging from the springs were determined from hydraulic gradients in the carbonate-rock aquifers in this area (see section "Hydrologic Framework" and pl. 1), the geologic and structural ground-water flow constraints (see section "Geologic Framework" and figs. 17, 18), and the average deuterium composition of possible source waters.

Water emanating from Muddy River springs can be from three sources: (1) the Sheep Range, (2) the White River flow system, and (3) the southern Meadow Valley Wash flow system (including Kane Springs and Delamar Valleys). Directly upgradient from Muddy River springs is Coyote Spring Valley. In this valley, the average isotopic composition of water from three wells completed in carbonate rock is –101 permil, whereas water from a well completed in basin-fill deposits is –94 permil. The basin-fill well is adjacent to one of the wells completed in carbonate rock. A downward head gradient of 0.12 ft/ft over about a 500-ft vertical interval exists between the basin-fill and carbonate-rock wells (Berger and others, 1988). This downward head gradient and the isotope value similar to that of average Sheep Range recharge (–93 permil) indicate that recharge from the Sheep Range probably flows primarily through the basin-fill aquifer in Coyote Spring Valley.

The basin-fill aquifer in Coyote Spring Valley is bound on the east by the carbonate rock of the northern Arrow Canyon Range and southern Meadow Valley Mountains. In this area, the carbonate rock that compose these mountains are exposed at land surface, and water in the basin-fill aquifer mixes with water in the carbonate-rock aquifers. This mixed water is observed at Muddy River springs. Water from a well (MX-6; fig. 17) completed in carbonate rock, about halfway between the east edge of the Coyote Spring Valley basin-fill aquifer and Muddy River springs, has a deuterium composition of –97 permil (pl. 2). This isotopic composition is similar to Muddy River springs (–98 permil) and is more evidence supporting the conceptual flow and mixing model: water in the Muddy River springs area is probably a mixture of Sheep Range recharge water and water from the carbonate-rock aquifers beneath Coyote Spring Valley. Using the average deuterium composition of Sheep Range recharge water (–93 permil) and Coyote Spring Valley carbonate-rock aquifer water (–101 permil) to determine the sources of water at Muddy River springs (–98 permil) results in a mixture of 38 percent (14,000 acre-ft/yr) Sheep Range water and 62 percent (22,000 acre-feet/yr) Coyote Spring Valley water.

Water in the carbonate-rock aquifers of Coyote Spring Valley (deuterium composition of –101 permil) can be from two sources, the White River flow system (deuterium composition of –109 permil) and the southern Meadow Valley Wash flow system (deuterium composition of –87 permil; pls. 1 and 2, figs. 16, 17). A mixture of 64 percent (14,000 acre-ft/yr) White River flow-system water and 36 percent (8,000 acre-ft/yr) southern Meadow Valley Wash flow-system water results in water isotopically the same as water in the carbonate-rock aquifers in Coyote Spring Valley.

In summary, water discharging from Muddy River springs is a mixture of 40 percent (14,000 acre-feet/yr) White River flow-system water, 38 percent (14,000 acre-ft/yr) Sheep Range water, and 22 percent (8,000 acre-ft/yr) southern Meadow Valley Wash flow-system water. The 14,000 acre-ft/yr contribution of White River flow-system water to Muddy River springs is significantly less than the 35,000 acre-ft/yr proposed by Eakin (1966) on the basis of water-level data and Maxey-Eakin recharge estimates (Maxey and Eakin, 1949) but is similar to recent estimates by A.H. Welch (U.S. Geological Survey, written commun., 1988) and Kirk and Campana (1990). Welch estimated 18,000 acre-ft/yr of underflow from Pahranagat Valley to Coyote Spring Valley on the basis of the isotopic compositions of empirically derived Maxey-Eakin recharge estimates for the entire White River flow system. Kirk and Campana (1990) calculated a contribution of 16,500 to 19,100 acre-ft/yr for three different flow scenarios for the White River flow system on the basis of Maxey-Eakin recharge estimates and water-level data with a discrete-state compartment model using deuterium to calibrate their models. These flow-system delineations are based on water-level data only, with no consideration of geologic or structural constraints on ground-water flow.

The Sheep Range contribution of 14,000 acre-ft/yr is significantly higher than the estimated 2,000 acre-ft/yr of Eakin (1966), 3,000 acre-ft/yr of A.H. Welch (written commun., 1988), and 5,000 to 6,000 acre-ft/yr of Kirk and Campana (1990). The greater contribution of Sheep Range water compared to previous studies is balanced by not including 6,000–9,800 acre-ft/yr of ground-water from Dry Lake Valley, north of Delamar Valley, because of geologic constraints to ground-water flow (Dettinger and others, 1995) and less underflow from Pahranagat Valley to Coyote Spring Valley. Geologic constraints on Sheep Range water flowing to the west and south, as previously discussed in the section titled "Geologic Framework," indicates that most of the recharge to the Sheep Range probably flows to the northeast toward the Muddy River springs area. The calculated contribution of 14,000 acre-ft/yr of Sheep Range water is higher than the empirical Maxey-Eakin recharge estimate of 11,000 acre-ft/yr, but the amount is reasonable if most of the recharge to the Sheep Range discharges at Muddy River springs. Winograd and Friedman (1972) also postulated, on the basis of deuterium data, that the Sheep Range may be a significant source of water discharging from Muddy River springs.

The 8,000 acre-ft/yr of ground water calculated to flow from the southern Meadow Valley Wash flow system to Muddy River springs agrees with previous estimates by Welch (8,000 acre-ft/yr) and Kirk and Campana (5,500–9,000 acre-ft/yr).

Ash Meadows Flow System

Springs at Ash Meadows discharge 17,000 acre-ft/yr at the distal end of the Ash Meadows flow system (Winograd and Thordarson, 1975). The average deuterium composition of the water from seven springs (the six largest discharging springs plus Scruggs Spring) is –103 permil (Winograd and Pearson, 1976;

appendix A). The sources of water discharging from the springs were determined on the basis of hydraulic gradients in the carbonate-rock aquifers in this area (see section titled "Hydrologic Framework" and pl. 1), the geologic and structural constraints on ground-water flow (see section titled "Geologic Framework" and figs. 17, 18), and the deuterium composition of possible source waters.

The first carbonate-rock aquifer sample site that is upgradient from Ash Meadows springs and has deuterium and water chemistry data is Army Well 1 (fig. 17). Water from Army Well 1 has an average deuterium composition of –104 permil (appendix A). Thus, given the hydrologic position of the well and the isotopic similarity of its water to Ash Meadows springs, water at Army Well 1 is considered representative of water that flows to Ash Meadows. This conclusion was previously reached by Winograd and Friedman (1972), but they also noted that the chemistry at Army Well 1 was more dilute than water discharging at Ash Meadows. At a carbonate-aquifer sample site about halfway between Army Well 1 and Ash Meadows (Amargosa Tracer Well 2; fig. 17), deuterium data are lacking but oxygen-18 data are similar to data from Ash Meadows springs (appendix B). Water chemistry also is similar, although slightly more dilute, so this water also is considered representative of flow to Ash Meadows. The water chemistry from these two sites and how they relate to flow in the Ash Meadows flow system is discussed in the section titled "Water Chemistry."

No water samples from carbonate-rock aquifer sites upgradient from Army Well 1 had deuterium compositions similar to samples from Ash Meadows. Thus, isotopically different waters must be mixing to produce the deuterium composition measured at Ash Meadows and Army Well 1. Given the hydrologic, geologic, and structural constraints (see sections titled "Hydrologic Framework" and "Geologic Framework"), the two nearest carbonate-rock aquifer water sources upgradient from Army Well 1 and Ash Meadows that could mix to produce their deuterium composition are in the area of Well C-1 in south Yucca Flat and Indian Springs (fig. 17, pls. 1 and 2).

A mixture of 33 percent (6,000 acre-ft/yr) Well C-1 water (–111 permil) and 67 percent (11,000 acre-feet/yr) Indian Springs water (–99 permil) is needed to produce the deuterium composition of water at Ash Meadows and Army Well 1 (–103 permil). The source of Indian Springs water is recharge to the Spring Mountains, on the basis of the hydraulic gradient (pl. 1) and deuterium composition of Indian Springs water, which is the same as that of average Spring Mountains recharge (-99 permil). The source of Well C-1 water is less obvious: three possible sources, on the basis of hydrologic, geologic, and structural constraints, are recharge to the Eleana Range (or farther to the west in Pahute Mesa), drainage of paleowater, or White River flow-system water.

The Eleana Range contains 4,000 to 8,000 ft of Devonian to Mississippian noncarbonate rock under the west third of Yucca Flat (Winograd and Thordarson, 1975, "upper clastic aquitard"). Therefore, little precipitation that falls on the Eleana Range probably recharges the carbonate-rock aquifers in the Yucca Flat area. Winograd and Thordarson (1975) estimated the quantity of water flowing into the carbonate-rock aquifers beneath Yucca Flat from both the west (Eleana Range) and northeast (Emigrant Valley) is less than 250 acre-ft/yr. In addition, aeromagnetic interpretations by Bath and Jahren (1984) and recent interpretations of Tertiary extensional tectonics by Guth (1988) indicate that little of the carbonate-rock aquifer underlies the Eleana Formation in this area; instead, the Eleana Formation is probably underlain by noncarbonate basement. Thus, the possibility that water in the volcanic rock of Pahute Mesa, west of the Eleana Range, flows at depth into the carbonate-rock aquifers and then east to Yucca Flat is unlikely. No isotope data exist for the carbonate aquifers beneath the Eleana Range, so the isotopic composition of this water is unknown.

Drainage of water recharged during the last glacial episode is a possible source of water at Well C-1. However, Winograd and Doty (1980) show that water levels in the carbonate-rock aquifers in the Nevada Test Site area have fluctuated less than 100 ft during Wisconsin time, and Jones (1982) shows fluctuations of less than about 150 ft in the northern Frenchman Flat area through most of Quaternary time. Thus, drainage of paleowater is not probable.

White River flow-system water in Pahranagat Valley is isotopically similar (–109 permil) to Well C-1 water (–111 permil) and, on the basis of hydraulic gradients, could be flowing southwest to Yucca Flat (pl. 1). Continuous, thick sequences of carbonate rock provide a flow path for White River flow system water to Frenchman Flat (fig. 17). Thus, of the three possible sources of Well C-1 water, the White River flow system is hydrologically and geologically the most likely.

Another possibility is that little water flows from the Yucca Flat area to Ash Meadows. Winograd and Thordarson (1975, p. 94) estimated the total flow within the carbonate-rock aquifers beneath Yucca Flat to the south to be less than 350 acre-ft/yr. A likely alternative is that water from Pahranagat Valley flows through the Frenchman Flat area south of Well C-1 and mixes with Spring Mountains water, producing the water at Ash Meadows. This interpretation is reasonable because the central core of thick, continuous carbonate rock extends from Pahranagat Valley to Ash Meadows (fig. 17). Using the average isotope value of Pahranagat Valley water (–109 permil) and Indian Springs water (–99 permil) to produce Ash Meadows water (–103 permil) results in a mixture of 40 percent (7,000 acre-ft/yr) Pahranagat Valley water and 60 percent (10,000 acre-ft/yr) Spring Mountains water. The 40 percent contribution of Pahranagat Valley water to Ash Meadows spring discharge is in good agreement with the 35 percent estimated by Winograd and Friedman (1972) and Winograd and Thordarson (1975).

The Spotted, Pintwater, Desert, and Groom Ranges are assumed to contribute little water to the carbonate-rock aquifers (fig. 17). This assumption agrees with previous work by Winograd and Friedman (1972) and Winograd and Thordarson (1975). These mountains, with the exception of the Groom Range, are less than 7,100 ft in altitude and, therefore, do not receive large amounts of winter precipitation that could become available to recharge the carbonate-rock aquifers. The Groom Range is composed mostly of Precambrian basement rock and is not underlain by carbonate-rock aquifers (M.D. Dettinger, U.S. Geological Survey, oral commun., 1989); therefore, little precipitation in the Groom Range recharges the carbonate-rock aquifers. In addition, any potential recharge water in these ranges generally is isotopically heavy; median deuterium composition of 13 samples from the Pintwater and Groom Ranges is –90 permil (pl. 2; B.F. Lyles, Desert Research Institute, written commun., 1986) compared with recharge water in the Spring Mountains (–99 permil) and water in the White River flow system (–109 permil). This heavy deuterium composition severely limits the possibility that any significant recharge to these mountains contributes to Ash Meadows discharge.

As previously discussed, recharge to the Sheep Range probably contributes little to spring discharge at Ash Meadows due to geologic and structural constraints. The relatively heavy deuterium composition of Sheep Range water (–93 permil), as compared with Ash Meadows spring water (–103 permil), also limits the percentage of Sheep Range water that could mix with Spring Mountains and Pahranagat Valley water to produce the deuterium composition measured at Ash Meadows.

In summary, a mixture of 40 percent (7,000 acre-ft/yr) Pahranagat Valley water and 60 percent (10,000 acre-ft/yr) Spring Mountains water discharging at Ash Meadows springs is geologically, hydrologically, and isotopically the most likely alternative. Previous work by Winograd and Friedman (1972), Winograd and Thordarson (1975), Winograd and Pearson (1976), Welch and Thomas (1984), and Kirk and Campana (1990) postulated a 24 to 35 percent input of Pahranagat Valley water to Ash Meadows, which is similar to the 40 percent proposed by this isotopic mixing model. The 60 percent Spring Mountains contribution also is reasonable, if the previous estimate of about 65 percent Spring Mountains plus Sheep Range water (Winograd and Friedman, 1972; Winograd and Thordarson, 1975; Winograd and Pearson, 1976) is assumed to be mostly Spring Mountains water. This assumption seems reasonable because the previous studies assumed that the Spring Mountains and Sheep Range were isotopically the same and no flow barriers existed between the Sheep Range and Ash Meadows springs. Other evidence to support the concept that recharge from the Spring Mountains contributes 60 percent of Ash Meadows springs discharge is as follows:

1. A Maxey-Eakin recharge estimate, which assumes that only precipitation above 6,000 ft becomes recharge, for the part of the Spring Mountains that topographically drains to the Ash Meadows flow system is 7,000 acre-ft/yr. This estimate is lower than the 10,000 acre-ft/yr estimated by the isotope mixing model, but ground-water flow modeling studies of Las Vegas and Pahrump Valleys (Harrill, 1976, 1986) indicate that Maxey-Eakin recharge estimates for the Spring Mountains underestimate recharge by about 20 to 35 percent.
2. Winograd and Thordarson (1975) suggest on the basis of structural disposition that some recharge south of the topographic divide in the Spring Mountains flows northward into Indian Springs Valley rather than southwestward into Pahrump Valley.
3. In a recharge area such as the Spring Mountains, which contains well-mixed water, as indicated by the lack of isotopic depletion with increased altitude (fig. 21), topographic divides probably have less effect on the areas of recharge than in a recharge area that contains less well-mixed water.

Las Vegas Valley

Isotopic composition of ground water in the basin-fill aquifers of Las Vegas Valley indicates that the aquifers are supplied almost entirely by recharge to the Spring Mountains. This conclusion agrees with ground-water flow modeling studies by Harrill (1976) and Morgan and Dettinger (1996). The average deuterium composition of water from 10 wells and springs in northern Las Vegas Valley is –98 permil, ranging from –101 to –96 permil (pl. 2). This average value is similar to that of recharge to the central part of the Spring Mountains (–99 permil). Ground water in the central part of the valley has a deuterium composition that ranges from –106 to –94 permil, but deuterium for most of the water ranges from –101 to –94 permil, indicating this water is either from northern Las Vegas Valley or is upward flow from the carbonate-rock aquifers that originated as high-altitude recharge in the Spring Mountains. The lightest sample (–106 permil) may contain some isotopically light paleowater recharged during the last glacial period.

Another possible source of recharge to northern Las Vegas Valley, on the basis of topographic boundaries and hydrologic data, is the Sheep Range. Although deuterium data indicate that ground water in northern Las Vegas Valley originates primarily as precipitation in the central part of the Spring Mountains, hydrologic data indicate that some water from the Corn Creek area, which originates as precipitation in the Sheep Range, flows into northern Las Vegas Valley. However, geologic flow constraints (see section titled "Geologic Framework") and ground-water flow modeling studies (Harrill, 1976; Morgan and Dettinger, 1996) indicate that only a small amount of recharge to the Sheep Range flows into Las Vegas Valley.

Ground water from four wells in the southwestern part of Las Vegas Valley has an average deuterium composition of –89 permil, which is similar to that of recharge to the southern part of the Spring Mountains (table 13, pl. 2). Therefore, given the isotopic similarity between the recharge waters in the southern Spring Mountains and ground water in southwestern Las Vegas Valley, the hydraulic gradients in this area (pl. 1), and the lack of any other major recharge area nearby, water in southwestern Las Vegas Valley is most likely derived from precipitation in the southern part of the Spring Mountains.

Another possible source of water for southern Las Vegas Valley is the McCullough Range (pl. 1, fig. 17). However, the deuterium composition of sampled water in the range, –73 and –88 permil, is significantly heavier than that of water samples from southern Las Vegas Valley (pl. 2).

PAHRUMP VALLEY

Deuterium data combined with hydrologic and geologic information indicate water in Pahrump Valley originates entirely in the Spring Mountains. This observation is in agreement with a ground-water flow modeling study by Harrill (1986). Three sites in Pahrump Valley have an average deuterium composition of –98 permil, which is similar to the composition (–99 permil) of average recharge in the central part of the Spring Mountains. Ground water in Pahrump Valley flows out of the valley to the southwest through carbonate-rock aquifers to Chicago Valley and the Amargosa Desert area of Shoshone and Tecopa (pl. 1).

SUMMARY OF DEUTERIUM-DELINEATED FLOW SYSTEMS

Source areas and flow paths were delineated by deuterium mass-balance mixing models for the major carbonate-rock aquifers in southern Nevada (fig. 24). The volumes of flow are based on the discharge of water from Muddy River and Ash Meadows springs for the White River and Ash Meadows flow systems (so they represent minimum flow volumes) and on ground-water flow model studies of Las Vegas and Pahrump Valleys (Harrill, 1976, 1986; Morgan and Dettinger, 1996).

WATER CHEMISTRY

Changes in water chemistry along flow paths and resulting from mixing different waters, as determined by deuterium mass-balance calculations, have to be accounted for by realistic geochemical processes for the flow paths and mixing to be probable. Geochemical processes can be defined by mass-balance reaction models on the basis of the chemical composition of the initial (or mixed) and final waters along a flow path. Input to the models must be phases (minerals and gases) that have been identified in the aquifers and processes (mineral dissolution, precipitation, and formation; gas dissolution or exsolution; and ion exchange) that are thermodynamically and physically feasible, to describe the inputs and outputs (mass transfers) of constituents between the initial and final waters. For example, calcium concentration cannot decrease along a flow path unless calcium is contained in some phase in concentrations greater than saturation in the water and is able to precipitate, unless calcium is exchanged for another ion in a solid phase, or unless the water mixes with another water of lower calcium concentration. Amounts of mass transfer and mineral saturation were calculated using average chemical composition of samples along flow paths or, in the case of mixing, using samples from the different areas that also have deuterium and oxygen-18 data (appendix B).

The mass-balance approach (Plummer and Back, 1980; Parkhurst and others, 1982; Plummer and others, 1983; Plummer, 1984; Plummer and others, 1990) does not produce a unique numerical solution. Therefore, three different mass-balance models were used for each flow path and mixing scenario (table 14, col. 2). Mass transfers were calculated using the computer program NETPATH (Plummer and others, 1991). Flow-path sites with averaged chemistries, or mixtures of waters with averaged chemistries, used for flow-path

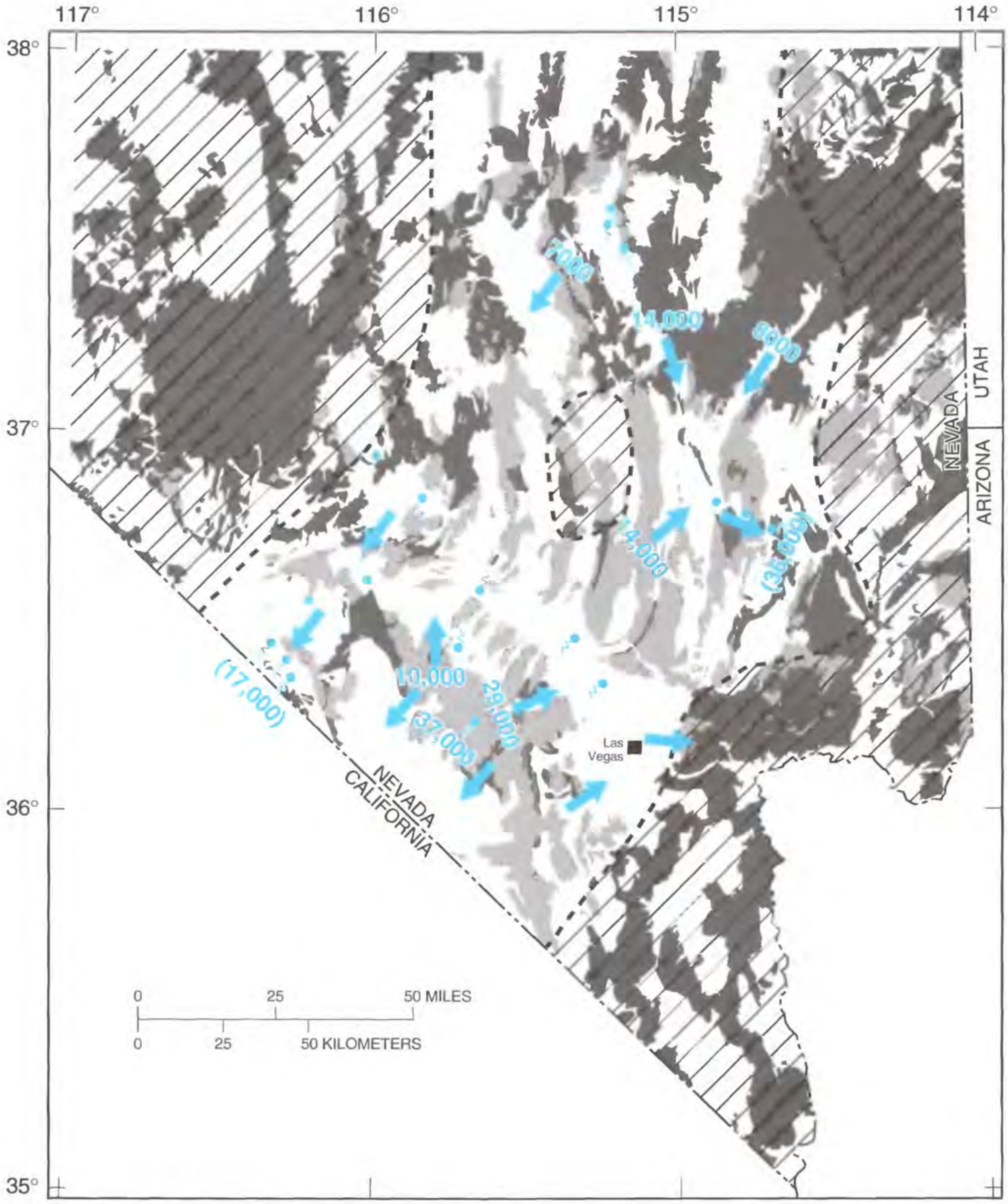

FIGURE 24.—Deuterium-derived delineation of ground-water flow in the carbonate-rock aquifers of southern Nevada. See figure 17 for feature names. Modified from Dettinger (1989, fig. 3).

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calculations are numbered for reference in table 14, col. 1 and footnote 1. Phases used in the mass-balance reaction models are the prevalent minerals in the aquifers of southern Nevada (see section titled "Geologic Framework"). These minerals include calcite, dolomite, albite, kaolinite, K-feldspar, chalcedony, and clinoptilolite. Gypsum and halite are included as phases in the models of the White River flow system because Permian and younger rock in the Coyote Spring Valley area contain evaporite minerals. The Ash Meadows flow system, except for the Spring Mountains, consists of lower and middle Paleozoic carbonate rock that do not contain evaporite minerals. Thus, leakage of water from the noncarbonate Tertiary rock ("Tertiary aquitard" of Winograd and Thordarson, 1975) overlying the carbonate-rock aquifers is assumed to be the source of increased sulfate and sodium concentrations, as proposed by Winograd and Thordarson. Carbon dioxide gas is used as a source or sink for carbon in addition to calcite and dolomite. Cation exchange of calcium and magnesium for sodium in clay minerals also is used because clays are present (see section "Geologic Framework"). Calcite, dolomite, kaolinite, CO_2 gas, chalcedony, gypsum, and halite, or in place of gypsum, leakage from the Tertiary aquitard, are used in all three mass-balance reaction models. Albite and K-feldspar are used in two reaction models, calcium and magnesium exchange for sodium is substituted for albite in one reaction model, and clinoptilolite is substituted for K-feldspar in another reaction model (table 14). The zeolite mineral analcime also could be used in place of albite as a source of sodium, because water in the carbonate-rock aquifers of southern Nevada are all below saturation with respect to analcime (table 15), and analcime is common in volcanic rock that overlie carbonate-rock aquifers in the Nevada Test Site area (Hoover, 1968).

Although many mass-balance reaction models require input of CO_2 gas, the source of the CO_2 gas is not apparent. Carbon dioxide gas is probably not added to the water. Instead, this small input may result from the large variability (2.9–7.1 mmol/L) of total dissolved inorganic carbon (TDIC) in water of springs and wells in the Spring Mountains and Sheep Range. Average TDIC concentration of the water in the recharge areas probably is less than actual TDIC of water recharging the carbonate-rock aquifers. In addition, some carbon dioxide gas in water in the recharge areas may not have been measured. Exsolution of CO_2 gas from high-altitude springs would result in lower measured than actual CO_2 concentrations in recharge waters. This exsolution is indicated by oversaturation of the spring waters with respect to calcite in the Spring Mountains and Sheep Range (table 15). The amount of carbon dioxide exsolution was calculated to range from 0.00 to 0.42 mmol/L by the computer program PHREEQE (Parkhurst and others, 1980), which assumes the waters are at saturation with respect to calcite and oversaturation is the result of carbon dioxide exsolution (Pearson and others, 1978).

Another explanation for higher CO_2 concentrations than those currently measured in recharge areas could be that older water in the aquifers was recharged during past cooler and wetter climatic conditions. This recharge would result in greater CO_2 concentrations in soil zones in recharge areas and, therefore, higher CO_2 concentrations in these older waters in the flow systems (White and Chuma, 1987).

Organic carbon is probably not a significant source of CO_2 gas in the carbonate-rock aquifers because (1) organic matter was not detected in the rock during the carbon-13 analysis of calcite and dolomite (David Meredith, Global Geochemistry, oral commun., 1987); (2) concentrations of dissolved organic carbon in the water are low—average 0.7 mg/L for 14 samples in southern Nevada (Thomas and others, 1991)—and concentrations of total organic carbon also are low—1.0 to 2.2 mg/L for 3 samples (Winograd and Pearson, 1976, p. 1133); (3) dissolved oxygen concentration is greater than 2.0 mg/L for all samples in southern Nevada (appendix B), which indicates the source of dissolved carbon is probably not oxidation of organic matter, because oxidation rapidly depletes dissolved oxygen in

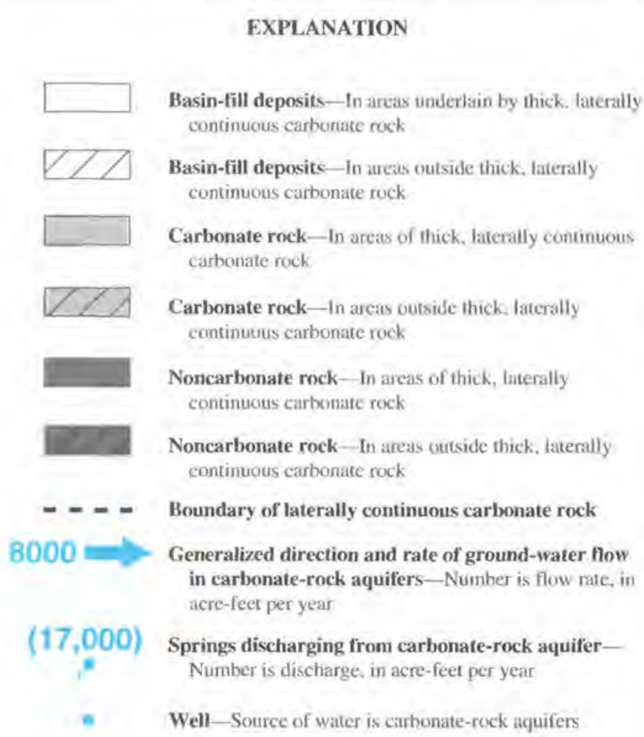

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TABLE 14.—*Mass transfer of constituents and mixing of waters along flow paths in carbonate-rock aquifers of southern Nevada*

[Coefficients of mass-transfer reactions were calculated using the computer program NETPATH (Plummer and others, 1991). Except for Ca-Mg/Na exchange, negative value indicates phase leaving solution (precipitating or degassing) and positive value indicates phase entering solution (dissolving). For exchange reaction, positive value indicates sodium entering solution and calcium and magnesium leaving solution. Symbol: --, constituent not used in mass-balance reaction]

Flow path[1]	Reaction model[2]	Millimoles per liter										
		Calcite ($CaCO_3$)	Dolomite ($CaMg(CO_3)_2$)	Gypsum ($CaSO_4 \cdot 2H_2O$)	Halite (NaCl)	Albite ($NaAlSi_3O_8$)[3]	Kaolinite ($Al_2Si_2O_5(OH)_4$)	K-feldspar ($KAlSi_3O_8$)	CO_2 gas	Chal-cedony (SiO_2)	Clinoptilolite ($Na_{0.3}K_{0.4}Ca_{0.3}$)($AlSi_5O_{12}$)	Ca,Mg/Na exchange[4]
White River flow system												
2 to 1	1	-0.97	-0.02	1.30	0.95	0.84	-0.45	0.07	0.30	-1.77	--	--
	2	-.97	-.02	1.30	.95	.76	-.45	--	.30	-2.06	0.14	--
	3	-.88	.15	1.30	.95	--	-.04	.07	-.12	-.10	--	0.42
3 to 2A	1	-0.76	0.15	0.62	0.48	1.32	-0.72	0.12	0.97	-2.90	--	--
	2	-.76	.15	.62	.48	1.20	-.72	--	.97	-3.36	0.23	--
	3	-.66	.43	.62	.48	--	-.06	.12	.31	-.27	--	0.66
3A to 1	1	-1.44	0.08	1.68	1.25	1.67	-0.91	0.14	0.87	-3.60	--	--
	2	-1.44	.08	1.68	1.25	1.53	-.91	--	.87	-4.17	0.29	--
	3	-1.26	.41	1.68	1.25	--	-.07	.14	.04	-.26	--	0.83
Ash Meadows flow system												
5 to 4	1	0.10	-0.12	--	0.19	0.86	-0.46	0.06	0.74	-1.77	--	--
	2	.05	-.12	--	.19	.81	-.49	--	0.79	-2.18	0.16	--
	3	.17	.06	--	.19	--	-.03	.06	.31	-.05	--	0.43
6 to 4	1	-0.37	0.06	--	0.51	1.15	-0.64	0.12	0.53	-2.37	--	--
	2	-.46	.06	--	.51	1.06	-.67	--	.62	-3.11	0.29	--
	3	-.27	.30	--	.51	--	-.06	.12	.65	-.08	--	0.57
6 to 5	1	-0.47	0.18	--	0.32	0.34	-0.19	0.05	0.47	-0.71	--	--
	2	-.51	.18	--	.32	.30	-.21	--	.51	-1.03	0.13	--
	3	-.46	.25	--	.32	--	-.03	.05	.30	-.03	--	0.17
8 to 7	1	-0.90	0.25	0.08	0.08	0.04	-.03	0.02	-0.54	-0.02	--	--
	2	-.90	.25	.08	.08	.02	-.03	--	-.54	-.09	0.03	--
	3	-.90	.26	.08	.08	--	-.01	.02	-.55	.05	--	0.02
10 to 9	1	0.00	0.05	--	0.40	1.35	-0.67	0.00	1.03	-2.73	--	--
	2	.00	.05	--	.40	1.35	-.67	--	1.03	-2.73	0.00	--
	3	-.13	.32	--	.40	--	.00	.00	.36	-.04	--	0.67
6 to 9	1	-0.52	0.02	--	0.49	2.57	-1.34	0.10	1.97	-5.24	--	--
	2	-.52	.02	--	.49	2.46	-1.34	--	1.97	-5.66	0.20	--
	3	-.15	.44	--	.51	--	-.04	.08	.60	-.01	--	0.83
11 to 4	1	-0.38	-0.05	--	0.35	0.66	-0.39	0.12	0.79	-1.37	--	--
	2	-.46	-.05	--	.35	.57	-.43	--	.88	-2.12	0.29	--
	3	-.32	.18	--	.35	--	-.06	.12	.46	-.06	--	0.33

TABLE 14.—*Mass transfer of constituents and mixing of waters along flow paths in carbonate-rock aquifers of southern Nevada*—Continued

Flow path[1]	Reaction model[2]	Millimoles per liter										
		Calcite ($CaCO_3$)	Dolomite [$CaMg(CO_3)_2$]	Gypsum ($CaSO_4 \cdot 2H_2O$)	Halite (NaCl)	Albite ($NaAlSi_3O_8$)[3]	Kaolinite [$Al_2Si_2O_5(OH)_4$]	K-feldspar ($KAlSi_3O_8$)	CO_2 gas	Chalcedony (SiO_2)	Clinoptilolite ($Na_{0.3}K_{0.4}Ca_{0.3}$)($AlSi_5O_{12}$)	Ca,Mg/Na exchange[4]
						Las Vegas Valley						
13 to 12	1	−0.95	0.35	0.08	0.10	0.19	−0.11	0.03	−0.07	−0.24	--	--
	2	−.95	.35	.08	.10	.16	−.11	--	−.07	−.35	0.06	--
	3	−.95	.40	.08	.10	--	−.01	.03	−.16	.14	--	0.10
15 to 14	1	−3.65	1.61	4.48	0.08	0.23	−0.13	0.04	−0.37	−0.49	--	--
	2	−3.65	1.61	4.48	.08	.19	−.13	--	−.37	−.63	0.07	--
	3	−3.63	1.66	4.48	.08	--	−.02	.04	−.40	−.03	--	0.11
17 to 12	1	−0.71	0.21	0.07	0.08	0.18	−0.10	0.02	−0.11	−0.26	--	--
	2	−.71	.21	.07	.08	.15	−.10	--	−.11	−.35	0.04	--
	3	−.71	.25	.07	.08	--	−.01	.02	−.20	−.09	--	0.09
						Pahrump Valley						
13 to 16	1	−0.77	0.30	0.15	0.03	0.09	−0.05	0.02	−0.12	−0.10	--	--
	2	−.77	.30	.15	.03	.08	−.05	--	−.12	−.16	0.03	--
	3	−.77	.32	.15	.03	--	−.01	.02	−.17	.09	--	0.05

[1] Flow-path numbers, and average chemistries for waters, are:

1 Big Muddy Spring.
2 Mixture of 62 percent Coyote Spring Valley water (MX-4, MX-5, and VF-2 wells) and 38 percent Sheep Range water (Wiregrass, Cow Camp, and Mormon Well Spring).
2A Coyote Spring Valley (MX and VF-2 wells).
3 Mixture of 64 percent White River flow system water from Pahranagat Valley (Crystal and Ash Springs) and 36 percent southern Meadow Valley Wash flow system water (Boulder, Kane, Grapevine, and Willow Springs, and Bradshaw, Railroad, Randono and Jensen wells).
3A Mixture of 40 percent White River flow system water from Pahranagat Valley (Crystal and Ash Springs), 38 percent Sheep Range water (Wiregrass, Cow Camp, and Mormon Well Spring), and 22 percent southern Meadow Valley Wash flow system water (Boulder, Kane, Grapevine, and Willow Springs, and Bradshaw, Railroad, Randono, and Jensen wells).
4 Discharge-weighted average for springs at Ash Meadows (Winograd and Pearson, 1976, p. 1130-1131).
5 Army Well 1.
6 Mixture of 60 percent central part of Spring Mountains water (Sky Mountain, Summer Homes, and Highway Maintenance wells, and Willow, Deer Creek no. 1, Deer Creek no. 2, Rainbow, Trout, and Cold Creek Springs) and 40 percent White River flow system water from Pahranagat Valley (Crystal and Ash Springs).
7 Indian Springs.
8 Cold Creek Spring in Spring Mountains.
9 Test Well 3 in Frenchman Flat.
10 White River flow system water from Pahranagat Valley (Crystal and Ash Springs).
11 Mixture of 60 percent central part of Spring Mountains water and 40 percent Test-Well-3 water.
12 Tule Spring area in north Las Vegas Valley (Holland, Racel, Mulder, Martin, and Tule Spring wells).
13 Central part of Spring Mountains.
14 Southwestern Las Vegas Valley (Stocks and Spanish Trail wells; water from Tenaya well is excluded because it contains twice as much chloride as sodium—in milliequivalents per liter).
15 Southern part of the Spring Mountains southwest of Las Vegas Valley (BLM Visitors Center well and Sandstone, Red, and White Rock Springs).
16 Pahrump Valley (Manse well and Pahrump Spring well).
17 Mixture of 85 percent central part of Spring Mountains water (no. 13) and 15 percent Sheep Range water in Corn Creek Springs area (Corn Creek Springs, and Shown, Young, and Brooks wells).

[2] Most constituents are involved in all three mass-balance reactions; clinoptilolite is used in place of K-feldspar in reaction 2 and calcium-magnesium exchange for sodium is used in place of albite in reaction 3. See p. 41 for more detailed discussion.

[3] Zeolite mineral analcime can be used in place of albite; only resulting mass-transfer difference is reduction in amount of precipitating chalcedony (or other silicate mineral); see text.

[4] Calcium and magnesium exchange for sodium is based on calcium-to-magnesium ratio in final water; see text.

TABLE 15.—*Saturation indices for selected minerals in water from carbonate-rock aquifers of southern Nevada*[1]

[Calculated using computer program WATEQ4F (Ball and others, 1987)]

Site	Calcite	Dolomite	Gypsum	Halite	Albite	Kaolinite	K-feldspar	Chalcedony	Analcime
WHITE RIVER FLOW SYSTEM									
Muddy River springs									
Big Muddy Spring	0.0	−0.1	−1.4	−6.8	−1.4	1.9	−0.1	0.1	−3.2
Coyote Spring Valley									
MX well	0.0	0.1	−1.8	−7.2	−1.4	1.7	0.0	0.2	−3.2
VF-2 well	.2	.3	−1.8	−7.2	−1.3	1.6	.1	.2	−3.2
Sheep Range									
Wiregrass Spring	0.0	−0.3	−2.7	−9.6	−4.0	0.9	−1.6	0.0	−5.9
Cow Camp Spring	.1	.1	−2.4	−7.7	−2.3	1.5	−1.3	.1	−4.2
Mormon Well Spring	.2	.2	−2.5	−8.2	−2.8	1.4	−1.6	.1	−4.8
Southern Meadow Valley Wash									
Boulder Spring	−0.3	−1.0	−3.1	−8.5	−1.0	2.3	0.7	0.4	−3.3
Kane Spring	−.4	−1.2	−2.5	−8.0	−1.0	2.6	.9	.6	−3.5
Grapevine Spring	.0	−.2	−2.0	−7.9	−2.1	2.2	−.5	.2	−4.1
Willow Spring	−.6	−1.9	−2.4	−7.4	.0	3.0	1.3	.6	−2.5
Bradshaw well	.3	−.2	−1.7	−6.8	.0	2.8	1.4	.7	−2.5
Railroad Elgin well	.1	−.2	−2.0	−6.9	.0	2.7	1.4	.6	−2.4
Randono well	.2	.0	−2.0	−6.9	.1	2.8	1.4	.6	−2.4
Jensen well	.4	.3	−1.8	−6.9	.2	2.7	1.4	.6	−2.2
Pahranagat Valley									
Crystal Spring	0.2	0.3	−2.2	−8.3	−1.6	2.0	0.2	0.2	−3.6
Ash Spring	.0	−.2	−2.2	−8.2	−2.0	1.7	−.3	.1	−3.8
ASH MEADOWS FLOW SYSTEM									
Ash Meadows springs									
Ash Meadows springs[2]	0.1	0.0	−1.8	−7.4	−1.4	2.1	0.1	0.1	−3.3
Mercury Valley									
Army Well 1	0.1	0.2	−2.0	−7.8	−2.2	1.4	−0.8	0.0	−3.9
Indian Springs Valley									
Indian Springs	0.2	0.3	−2.5	−9.4	−3.5	1.2	−1.7	−0.2	−5.0
Central part of Spring Mountains									
Sky Mountain well	0.1	−0.3	−2.1	−9.4	−3.6	1.4	−2.1	−0.1	−5.4
Summer Homes well	−.1	−.5	−2.6	-10.2	−4.9	.4	−2.6	−.3	−6.6
Willow Spring	.1	−.3	−2.5	-10.0	−4.4	.7	−2.4	−.2	−6.1
Deer Creek Spring no. 1	.1	−.5	−3.2	-10.7	−5.1	−.3	−3.0	−.3	−6.7
Deer Creek Spring no. 2	.9	1.2	−2.9	-10.4	−4.4	−.1	−2.2	−.3	−5.9
Highway maintenance well	0.2	−0.2	−2.1	−10.2	−4.7	0.5	−2.7	−0.3	−6.3
Rainbow Spring no. 2	.0	−.6	−2.8	−9.9	−5.0	.4	−2.8	−.3	−6.6
Trout Spring	.6	.6	−2.9	−10.7	−4.9	−.3	−2.7	.4	−6.4
Cold Creek Spring	.2	−.1	−2.6	−10.3	−4.6	.6	−2.6	−.2	−6.2
Frenchman Flat									
Test Well 3	0.2	0.3	−1.8	−7.3	−2.0	1.0	−0.8	0.0	−3.6

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TABLE 15.—*Saturation indices for selected minerals in water from carbonate-rock aquifers of southern Nevada*[1]—Continued

Site	Calcite	Dolomite	Gypsum	Halite	Albite	Kaolinite	K-feldspar	Chalcedony	Analcime
South Yucca Flat									
C-1 Well	0.9	1.8	−1.9	−7.0	−1.5	0.5	−0.2	0.1	−3.3
LAS VEGAS VALLEY FLOW SYSTEM									
Tule Spring area - North Las Vegas Valley									
Martin well	0.2	0.4	−2.6	−8.9	−2.6	1.4	−0.9	0.0	−4.3
Racel well	.2	.4	−2.5	−9.0	−2.5	1.5	−.9	.0	−4.3
Tule Spring State Park well	.1	.2	−2.5	−8.9	−2.4	1.8	−.7	.1	−4.3
Mulder well	.3	.6	−2.4	−8.6	−2.5	1.3	−1.1	.0	−4.3
Holland well	−.2	−.4	−2.5	−9.2	−2.9	2.1	−1.2	.0	−4.6
Southern part of Spring Mountains									
Sandstone Spring	−0.4	−1.0	−2.0	−8.8	−3.8	1.5	−1.9	−0.2	−5.5
BLM Visitors Center well	.1	.0	−1.3	−8.8	−3.1	1.6	−1.5	−.1	−4.7
Red Spring	.2	.3	−2.4	−9.1	−3.2	1.5	−1.2	−.1	−4.9
White Rock Spring	−.3	−.8	−1.3	−8.5	−3.3	2.0	−1.6	−.1	−4.9
Southwestern Las Vegas Valley									
Tenaya well	0.0	0.0	−1.1	−7.2	−2.2	2.0	−0.6	0.0	−4.0
Spanish Trail Country Club	.1	.1	−.7	−8.4	−3.0	1.7	−1.3	−.1	−4.6
Stocks Mill and Supply Co.	.0	.0	−.8	−8.4	−2.8	1.9	−1.1	−.1	−4.5
Corn Creek Springs area									
Corn Creek Spring	0.2	0.5	−2.5	−8.9	−2.6	1.8	−0.7	0.0	−4.5
Shown well	−.2	−.3	−2.6	−8.9	−2.1	2.4	−.2	.3	−4.2
Brooks well	.8	1.9	−2.6	−8.9	−1.8	1.1	−.1	.3	−3.8
Young well	−.2	.1	−2.9	−9.0	−1.2	2.6	.9	.5	−3.6
PAHRUMP VALLEY FLOW SYSTEM									
Pahrump Valley									
Manse well	0.1	0.0	−2.3	−9.5	−3.2	1.6	−1.6	−0.1	−4.9
Pahrump Spring well	.2	.4	−2.3	−9.4	−3.2	1.3	−1.4	−.1	−4.9

[1] Saturation index = $\log \frac{\text{(ion-activity product)}}{K_T}$, where K_T = equilibrium constant at temperature *T*. By convention, positive value indicates mineral can precipitate from solution, whereas negative value indicates mineral can dissolve if present. Data for aluminum concentration were not available for these sites, so a value of 10 µg/L was used for all sites in calculating saturation indices.

[2] Discharge-weighted average was used.

water; and (4) perhaps the strongest evidence of the lack of oxidation of organic carbon is that a large influx of organically derived CO_2 would cause a shift to a lighter carbon-13 composition, and this is not observed (see section titled "Ground-Water Age").

Carbon-dioxide gas from rock units overlying the aquifers was eliminated as a possible source of CO_2 gas in the aquifer, even though large amounts of CO_2 gas are present in some of the overlying rock units (D.C. Thorstenson, U.S. Geological Survey, oral commun., 1988), because (1) partial pressures of CO_2 in rock units overlying the aquifers are less than partial pressures of CO_2 in the aquifer waters, (2) the rates of diffusion and dispersion for CO_2 gas into the aquifer waters would be slow, and (3) there should be a shift to lighter carbon-13 values instead of the heavier measured values (average carbon-13 of CO_2 gas in rock units overlying the aquifers in the Nevada Test Site area of southern Nevada is −16.5 permil; D.C. Thorstenson, oral commun., 1988). However, exchange of large quantities of dissolved carbon for carbon in calcite could balance the input of some CO_2 gas with light carbon-13.

WHITE RIVER FLOW SYSTEM

COYOTE SPRING VALLEY + SHEEP RANGE → MUDDY RIVER SPRINGS (PATH 2-1)

A deuterium mass-balance calculation to determine sources of water emanating from Muddy River springs, the terminus of the White River flow system, indicates that water discharging from the springs consists of 62 percent water from the carbonate-rock aquifers of Coyote Spring Valley and 38 percent water from the Sheep Range. Mass-balance calculations based on water-chemistry differences between the initial mixture of Sheep Range and Coyote Spring Valley water and final Muddy River springs water show that gypsum, halite, albite, and K-feldspar dissolve; calcite and chalcedony precipitate; and kaolinite forms (table 14). Dolomite dissolves if cation exchange occurs, otherwise dolomite does not dissolve or precipitate. The average chemistry of water at Muddy River springs used for mass balance calculations is from Big Muddy Spring. Big Muddy Spring is the largest spring in the Muddy River springs area with complete chemical and isotopic data and is the only spring of the Muddy River springs with carbon isotope data (appendix B).

Gypsum and halite dissolution are used as sources of SO_4, Cl, and Na in this model because seven wells drilled in the area (Berger and others, 1988) indicate that the Tertiary aquitard of the Ash Meadows flow system does not exist in this part of the White River flow system. The wells generally penetrate about 20 to 850 ft of unconsolidated sands and gravels which directly overlie the carbonate-rock aquifers. In addition, samples from a well about 7 mi west of and upgradient from Muddy River springs contain gypsum (Berger and others, 1988). Sulfur isotope data indicate that dissolved sulfate in Muddy River springs and Coyote Spring Valley water samples ($\delta^{34}S$ of 13.4 and 13.0 permil, respectively) could be derived from dissolution of gypsum in marine carbonates of Permian to lower Triassic age (Claypool and others, 1980). Upper Permian carbonate rock south and east of the Muddy River springs area contain gypsum (Longwell and others, 1965), so although gypsum has not been reported in exposed Permian rock in the Muddy River springs-Coyote Spring Valley area, gypsum may be present in these rocks at depth. A more likely source of gypsum in this area are the Tertiary Muddy Creek and Horse Springs Formation units, which overlie the carbonate-rock aquifers west of Muddy River springs (Longwell and others, 1965). These formations contain evaporite deposits, which include gypsum. A sample of gypsum from the Muddy Creek Formation in southern Nevada has a $\delta^{34}S$ of 14.0 permil, which is similar to that of sulfate dissolved in Muddy River springs and Coyote Spring Valley water samples. Evaporite deposits also probably contain some NaCl in addition to the gypsum.

Cation exchange of calcium and magnesium in the water for sodium in clay minerals also may be a source of sodium in the water and can be used to replace albite in the mass-balance reaction model. Clinoptilolite also may be a source of potassium and can be used in place of K-feldspar in the mass-balance reaction model. No thermodynamic data were available for clinoptilolite, so the mineral saturation state and, therefore, the thermodynamic feasibility of this reaction could not be determined.

In the mass-balance calculation that includes exchange of calcium and magnesium in the water for sodium in clay minerals, 0.12 mmol/L of carbon dioxide gas is lost from the water. This loss is most likely from degassing of the water in the spring area. Water from most of the springs and wells tapping the carbonate-rock aquifers contain gas bubbles, and because water supplying the springs generally flows upward from the rocks through unconsolidated deposits before reaching land surface, spring waters may loose some of their CO_2 gas before being sampled.

The mass-balance reaction models are thermodynamically feasible because gypsum, halite, albite, and K-feldspar are all below saturation in Coyote Spring Valley or Sheep Range samples (table 15), so they would dissolve. Calcite and chalcedony are at or above saturation, so they would precipitate. Kaolinite is above saturation in the water and, thus, could precipitate but more likely is formed by incongruent dissolution. Although dolomite is at saturation in the water, it would dissolve because of dedolomitization. Dedolomitization is the irreversible dissolution of gypsum that results in the precipitation of calcite. Calcite precipitation causes the pH to decrease and thus dolomite to dissolve (Back and others, 1983).

Mixing of 62 percent Coyote Spring Valley water with 38 percent Sheep Range water, along with the mass transfer of constituents in the modeled geochemical reactions, can produce Big Muddy Spring water. These processes are mineralogically and thermodynamically possible using minerals identified in the aquifers and assuming that either CO_2 in recharge-area waters is higher than measured, or calcium and magnesium in the water is exchanging for sodium in clay minerals and CO_2 is exsolving in the Muddy River springs area (table 14).

White River + Southern Meadow Valley Wash → Coyote Spring Valley (Path 3-2A)

A deuterium mass-balance calculation to determine the sources of water in the carbonate-rock aquifers of Coyote Spring Valley indicates that 64 percent of the water is from the White River flow system and 36 percent of the water is from southern Meadow Valley Wash. Mass-balance calculations based on water chemistry for the initial mixture of White River flow system and southern Meadow Valley Wash water and final Coyote Spring Valley water indicate dolomite, gypsum, halite, albite, and K-feldspar dissolve; calcite and chalcedony precipitate; and kaolinite forms (table 14).

In addition, the concentration of CO_2 in the recharge area waters would have to be higher than measured. Calcium and magnesium exchange can be substituted for albite as a sodium source, and clinoptilolite can be substituted for K-feldspar as a potassium source, in the mass-balance reaction models.

Thermodynamic calculations show that the mass-balance reaction models are feasible (table 15), with the exception of the dissolution of K-feldspar, which is at saturation in the waters. Therefore, the small mass transfer of potassium (0.12 mmol/L) is more likely due to the dissolution of clinoptilolite, or perhaps, exchange with calcium and magnesium in the water.

Mixing of 64 percent White River flow system water with 36 percent southern Meadow Valley Wash water, along with the mass transfer of constituents in the modeled geochemical reactions, can produce the water in the carbonate-rock aquifers of Coyote Spring Valley. These processes are mineralogically and thermodynamically possible using minerals identified in the aquifers and assuming that CO_2 in recharge areas is higher than measured.

ASH MEADOWS FLOW SYSTEM

ARMY WELL 1 → ASH MEADOWS (PATH 5-4)

Deuterium data for the Ash Meadows flow system show that water discharging at Ash Meadows springs, the terminus of the Ash Meadows flow system, has the same deuterium composition as water from Army Well 1, the first carbonate-rock well upgradient from the springs that has deuterium, carbon isotope, and chemical data. Mass-balance calculations for water chemistry, assuming the only source of sulfate and the major source of sodium is leakage from the Tertiary aquitard, for water flowing from Army Well 1 to Ash Meadows springs, shows that calcite, albite, K-feldspar, and clinoptilolite dissolve; chalcedony precipitates; and kaolinite forms (table 14). Calcite is at saturation in the waters and should precipitate, however because of changes in temperature and pressure along deep and tortuous flow paths (Winograd and Pearson, 1976), calcite is assumed to dissolve and precipitate. This calcite dissolution and precipitation is indicated by the carbon-13 composition of the waters and results of mass-balance models and is discussed in the section titled "Ground-Water Age."

A small amount of dolomite dissolves in the mass-balance reaction model involving cation exchange, and 0.12 mmol/L of dolomite precipitates in the other two reaction models. The improbability of dolomite precipitating from these waters makes these two reaction models unlikely. However, the model with dolomite dissolution is also unlikely because both waters are saturated with respect to dolomite. Therefore, the 0.06 mmol/L of dolomite dissolution may represent (1) analytical error, (2) dedolomitization (if not all the sulfate is from leakage, but a small amount of gypsum is present to dissolve), or (3) temperature and pressure differences—although dolomite would not precipitate, these differences could result in water becoming understated with dolomite along parts of the flow path.

The source of all the sulfate and most of the sodium added to the water was assumed to be leakage from the Tertiary aquitard, as proposed by Winograd and Thordarson (1975). A sample from the upper part of the saturated Tertiary aquitard overlying the carbonate-rock aquifers in Mercury Valley (pl. 1) contained 3,600 mg/L sulfate and 1,230 mg/L sodium, assuming 5 percent of the reported sodium plus potassium is potassium (Winograd and Thordarson, 1975, table 11). The absence of gypsum or anhydrite in the Paleozoic carbonate-rock aquifers in this part of the Ash Meadows flow system and the extremely low sulfur concentration in two limestone, two dolomite, and three shale samples (table 10) also indicate the main source of sulfate is probably a water of higher sulfate concentration, rather than a result of gypsum dissolution. Most of the increase in sodium (70 percent) also is assumed to be leakage from the Tertiary aquitard. The remaining increase in sodium is assumed to be from NaCl and, thus, is equal to the increase in chloride. The NaCl may be from connate sea water trapped in the marine sediments that has been released by fracturing or from dissolution of NaCl in shales present in the carbonate-rock aquifers. A sample from the Tertiary aquitard contained only 35 mg/L chloride (Winograd and Thordarson, 1975, table 11), so unless chloride is high in other parts of the Tertiary aquitard this is not a likely source of the increase in chloride. The discharge-weighted average chemistry for the Ash Meadows springs (Winograd and Pearson, 1976, p. 1130–1131) was used for the mass-balance calculations. Thermodynamic calculations show that the mass-balance reaction models are thermodynamically feasible (table 15).

As previously noted in the section titled "Flow System Delineation on the Basis of Deuterium," water from Amargosa Tracer Well 2—about halfway between Army Well 1 and Ash Meadows springs—lacks deuterium data, but the oxygen-18 composition of this water is similar to Ash Meadows springs and probably represents water flowing to the springs. Chemically, this water is similar to, although slightly more dilute than, Ash Meadows springs water. This water could evolve into Ash Meadows springs water by the same processes as those determined for the evolution of Army Well 1 water, but with much smaller mass transfers of chemical constituents. Mass transfers of constituents in water are all calculated to be less than 0.10 mmol/L between Amargosa Tracer Well 2 and Ash Meadows springs, thus Amargosa Tracer Well 2 is not included as a separate site in geochemical calculations.

Water from Army Well 1 can evolve chemically into Ash Meadows water if calcium and magnesium are exchanged for sodium and CO_2 gas enters the water between the sample sites. The source of CO_2 gas would be a water that is isotopically and chemically similar to that of Army Well 1 water but contains a higher CO_2 concentration. Alternatively, Army Well 1 water may not be entirely representative of water in this part of the flow system that discharges at Ash Meadows; instead, a water containing higher CO_2 concentrations, that is a mixture of Spring Mountains and White River flow system water, may be evolving into Ash Meadows water.

Spring Mountains + White River → Ash Meadows (Path 6-4)

A deuterium mass-balance calculation to determine sources of water emanating from Ash Meadows springs (Army Well 1 water is isotopically similar to water emanating from springs at Ash Meadows) indicates that water discharging from the springs consists of 60 percent Spring Mountains water and 40 percent White River flow system water. Mass-balance calculations based on water chemistry of the initial mixture of Spring Mountains and White River flow system waters and final Ash Meadows springs water indicate that dolomite, halite, albite, and K-feldspar dissolve; calcite and chalcedony precipitate; kaolinite forms; and high sulfate and sodium water leak from the Tertiary aquitard into the carbonate-rock aquifers (table 14). Calcium and magnesium exchange can be substituted for albite as a sodium source, and clinoptilolite can be substituted for K-feldspar as a potassium source in the models. The mass-balance calculations also require that CO_2 concentration be higher than the average measured value in recharge-area waters. Dolomite can dissolve because most of the waters in the Spring Mountains are undersaturated with respect to dolomite (table 15) and gypsum also is present in parts of the Spring Mountains, so dedolomitization also may occur.

Mixing 60 percent Spring Mountains water with 40 percent White River flow system water, along with the mass transfer of constituents in the modeled geochemical reactions, can produce the water discharging at Ash Meadows springs. These processes are mineralogically and thermodynamically possible using minerals identified in the aquifer and assuming that CO_2 in recharge areas is higher than measured.

The mixture of Spring Mountains and White River flow system waters also can produce water of the chemical composition measured at Army Well 1, using the same mass-balance reaction models (path 6-5 in table 14). As discussed in the section titled "Stable Isotopes of Ground Water," Army Well 1 water is isotopically similar to Ash Meadows spring water and probably represents mixed Spring Mountains and White River flow system water. Thus, the mass transfers for the intermediate step between the mixed water and Ash Meadows spring water is omitted in determining ages and flow rates in later sections of this report.

Indian Springs water also can be used as the input chemistry for the Spring Mountains water. Similar models result; however, because Indian Springs water contains higher ion concentrations than the more dilute samples in the Spring Mountains, the mass transfers are less for models that use Indian Spring water chemistry to represent Spring Mountains water chemistry.

Cold Creek Spring → Indian Springs (Path 8-7)

Cold Creek Spring is about 12 mi directly upgradient from Indian Springs in the Spring Mountains (fig. 17), is isotopically similar to Indian Springs, and is one of two large springs with long-term records (20 years) of chemical and isotopic data, thus it is used as the Spring Mountains recharge water that flows to Indian Springs. Mass-balance calculations, based on water chemistry, between these waters shows that gypsum, halite, albite, K-feldspar, and dolomite would dissolve; calcite and chalcedony (except if cation exchange is involved) would precipitate; kaolinite would form; and CO_2 would exsolve (table 14). Gypsum and halite, which are used as the sources for the small increases in sulfate and chloride (0.08 mmol/L), could be in Permian rock that the water flows through or in the Muddy Creek Formation in the area of spring discharge. In the area between Cold Creek Spring and Indian Springs, the existence of a water with high sulfate and chloride concentrations is unlikely. Calcium and magnesium exchange can be substituted for albite, as a sodium source, and clinoptilolite can be substituted for K-feldspar, as a potassium source, in the reaction models. The reaction models are thermodynamically feasible (table 15) if a small amount of chalcedony can either dissolve or precipitate, because both waters are near saturation with respect to chalcedony.

The chemical evolution of Cold Creek Spring water to Indian Springs water is mineralogically and thermodynamically feasible using known minerals identified in the aquifers and assuming CO_2 is exsolving in the Indian Springs and Cold Creek Spring areas. The amount of CO_2 outgassing at Indian Springs and Cold

Creek Spring, calculated using the computer program PHREEQE (Parkhurst and others, 1980) and the method of Pearson and others (1978), was 0.16 and 0.23 mmol/L, respectively. The total CO_2 outgassed, 0.39 mmol/L, is similar to the value from mass-balance calculations, 0.54 mmol/L.

SPRING MOUNTAINS + TEST WELL 3 → ASH MEADOWS (PATH 11-4)

Hydrologic, geologic, deuterium, and chemical data indicate the most likely sources of water discharging at Ash Meadows springs are the Spring Mountains and Pahranagat Valley. Test Well 3 (a well completed in carbonate rock east of Frenchman Flat) is along the flow path between Pahranagat Valley and Ash Meadows (pl. 1, fig. 17), and water from this area may be mixing with Spring Mountains water to produce the water observed at Ash Meadows springs, or this water may already be a mixture of Pahranagat Valley and Spring Mountains waters. However, no deuterium data exist for Test Well 3. Mass-balance calculations based on water chemistry between Pahranagat Valley and Test Well 3 show that Test Well 3 water could evolve chemically from Pahranagat Valley water (path 10-9 in table 14). The mass-balance calculations assume leakage from the Tertiary aquitard, and the model that includes cation exchange has 0.13 mmol/L of calcite dissolving (without leakage calcite would precipitate). The initial and final waters are both saturated with respect to calcite (table 15), but as stated previously, calcite may dissolve and precipitate because of temperature and pressure differences along flow paths in the carbonate-rock aquifers. Therefore, Test Well 3 water could have a deuterium composition similar to that of Pahranagat Valley water. Subsequently, a mixture of 40 percent Test Well 3 water and 60 percent Spring Mountains water would be needed to produce Ash Meadows spring water. Mass-balance calculations for a mixture of 40 percent Test Well 3 water plus 60 percent Spring Mountains water show the chemistry observed at Ash Meadows could evolve chemically from this mixed water (path 11-4 in table 14, table 15).

Winograd and Thordarson (1975) noted that the chemical composition of the water at Test Well 3 is similar to that of water discharging at Ash Meadows springs and may represent already mixed water that changes little chemically between the well and Ash Meadows. This scenario, however, would require (1) water in Test Well 3 be isotopically similar to Ash Meadows water (an unknown); (2) some sodium be removed from Test Well 3 water before reaching Ash Meadows, or a more dilute water with the same isotopic composition as water from Test Well 3 be mixed with Test Well 3 water to achieve the chemistry at Ash Meadows; (3) water flowing from Test Well 3 to Ash Meadows bypass Army Well 1 (as indicated by their vast differences in chemistry), or Army Well 1 water does not represent most water flowing to Ash Meadows in this area, although it has a similar deuterium composition; and (4) the isotopic composition of Army Well 1 water be produced by some process other than mixing of Spring Mountains and Pahranagat Valley waters upgradient from the well. If Test Well 3 water has an isotopic composition similar to Ash Meadows springs water, then the most likely sources of Test Well 3 water would still be a mixture of 40 percent Pahranagat Valley water and 60 percent Spring Mountains water to obtain a deuterium composition similar to Ash Meadows springs. Mass-balance calculations based on water chemistry, using 40 percent Pahranagat Valley water and 60 percent Spring Mountains water to produce Test Well 3 water, are thermodynamically feasible (path 6-9 in table 14, table 15).

As stated in (2) of the preceding paragraph, Test Well 3 water may mix with a more dilute water of similar isotopic composition to produce the water discharging at Ash Meadows. Army Well 1 water could be such a water, but only if Army Well 1 water is entirely from the Spring Mountains and is not a mixture of Spring Mountains and Pahranagat Valley waters. Then the deuterium composition of Army Well 1 water would represent a 4 permil shift in the average deuterium composition of Spring Mountains water.

SPRING MOUNTAINS + YUCCA FLAT → ASH MEADOWS

Another less likely scenario for the origin of Ash Meadows spring water (see section titled "Geologic Framework") is the mixing of water from south Yucca Flat, represented by water from Well C-1, which is completed in carbonate rock, with Spring Mountains water. Deuterium data indicate that a mixture of 33 percent Yucca Flat water and 67 percent Spring Mountains water could produce the deuterium composition of water sampled at Ash Meadows springs. However, on the basis of chemical mass-balance calculations using the average chemistry of water from Well C-1 and Indian Springs, none of the three reaction models is thermodynamically feasible.

LAS VEGAS VALLEY

Recharge to Las Vegas Valley from the Spring Mountains is from two different areas within the mountains; each area has a unique isotopic signature. Northern Las Vegas Valley receives an isotopically light component of recharge from the central part of the Spring Mountains, and southwestern Las Vegas Valley receives an isotopically heavier component of recharge from the southern part of the Spring Mountains.

In addition, northern Las Vegas Valley may receive as much as 15 percent of its water from the Sheep Range (see section titled "Flow System Delineation on the Basis of Deuterium").

SPRING MOUNTAINS → NORTH LAS VEGAS VALLEY (PATH 13-12)

Mass transfers based on water chemistry were calculated for the central part of the Spring Mountains to the Tule Spring area of northern Las Vegas Valley (table 14). Mass-balance calculations show that gypsum, halite, albite, K-feldspar, and dolomite dissolve; calcite and chalcedony precipitate (unless cation exchange is involved); kaolinite forms; and CO_2 exsolves. Calcium and magnesium exchange can be substituted for albite as a sodium source, and clinoptilolite can be substituted for K-feldspar as a potassium source, in the reaction models. The mass-balance reaction models are thermodynamically feasible (table 15) if the ground water is degassing in the Tule Spring area and a small amount of chalcedony either dissolves, or precipitates, because both waters are near saturation with respect to chalcedony.

The chemical evolution of Spring Mountains water to Tule Spring area water in north Las Vegas Valley is mineralogically and thermodynamically feasible (table 15) using known minerals in the aquifers and assuming that CO_2 is exsolving in the Tule Spring area. The small amount of CO_2 outgassing (0.07 to 0.16 mmol/L) is within the range of calculated values for samples within the Tule Spring area.

SPRING MOUNTAINS + SHEEP RANGE → NORTH LAS VEGAS VALLEY (PATH 17-12)

Mass-balance calculations based on water chemistry for a mixture of 85 percent Spring Mountains water and 15 percent Sheep Range water (represented by samples from the Corn Creek Springs area) produce north Las Vegas Valley water (represented by samples from the Tule Spring area). Results of these calculations are similar to results of the reaction model using solely Spring Mountains water (tables 14 and 15).

SOUTHERN SPRING MOUNTAINS → SOUTHWEST LAS VEGAS VALLEY (PATH 15-14)

Mass-balance calculations based on water chemistry from the southern part of the Spring Mountains to southwestern Las Vegas Valley show that gypsum, halite, albite, K-feldspar, and dolomite dissolve; calcite and chalcedony precipitate; kaolinite forms; and CO_2 exsolves (table 14). Calcium and magnesium exchange can be substituted for albite as a sodium source, and clinoptilolite can be substituted for K-feldspar as a potassium source, in the reaction models. The chemical evolution of southern Spring Mountains water to southwestern Las Vegas Valley water is mineralogically and thermodynamically (table 15) feasible using known minerals in the aquifers.

PAHRUMP VALLEY

SPRING MOUNTAINS → PAHRUMP VALLEY (PATH 13-16)

Ground water in Pahrump Valley is isotopically similar to average recharge water in the central part of the Spring Mountains. Thus, ground water in Pahrump Valley should evolve chemically from recharge water in the Spring Mountains. Mass transfers based on water chemistry were calculated for water flowing from the central part of the Spring Mountains to Pahrump Valley (table 14). Mass-balance calculations show that gypsum, halite, albite, K-feldspar, and dolomite dissolve; calcite and chalcedony precipitate (except if cation exchange occurs, then chalcedony dissolves); kaolinite forms; and CO_2 exsolves. Calcium and magnesium exchange can be substituted for albite as a sodium source, and clinoptilolite can be substituted for K-feldspar as a potassium source, in the reaction models. The mass-balance reaction models are thermodynamically feasible (table 15) using known minerals in the aquifers, if chalcedony either dissolves or precipitates, because the waters are close to saturation with respect to chalcedony, and water degases CO_2 in the old spring areas of Pahrump Valley. The small amount of CO_2 outgassing is within the range of values calculated for the two samples in Pahrump Valley.

SUMMARY OF MASS-BALANCE REACTION MODELS

Chemical mass-balance reaction models can be constructed for flow paths and mixing of water from different areas in southern Nevada that were determined by deuterium mass-balance calculations. The models are based on water chemistry and mineralogy observed in the flow system and leakage from the Tertiary aquitard. The models are thermodynamically feasible, except for flow from Yucca Flat to Ash Meadows springs. Geologic information in this area also indicates that flow from Yucca Flat to Ash Meadows springs is small (Winograd and Thordarson, 1975). The deuterium-derived flow paths and mixing of water from different areas, as shown in figure 24, are supported by chemical mass-balance calculations.

GROUND-WATER AGE

Ground-water age provides another constraint on flow paths and mixing in southern Nevada. Ground-water age must increase along a flow path, or be an average age between the ages of two initial waters that mix for flow paths or mixtures of waters to be probable. The age of mixed water has to increase along a flow path; thus, the mixture has to be older than the youngest mixing water, and the final water may be older than both mixing waters if travel times after mixing are long. Ground-water ages from several thousand years to about 30,000 years can be determined using carbon isotopes. Waters less than about 60 years contain measurable tritium (Fritz and Fontes, 1980).

Ground-water age, adjusted for the mass transfer of carbon into and out of the water, can be calculated from carbon isotope compositions of the water if (1) the carbon isotope composition of the recharge water when the water becomes isolated from atmospheric and soil-zone CO_2 gas is known, (2) the mass and sources of carbon added to or removed from the water are known, (3) the isotope composition of the sources of carbon are known, and (4) the fractionation of the isotopes during removal of carbon from the water is known (Wigley and others, 1978). The biggest sources of error in calculating ground-water age using this approach are (1) the estimation of the starting, or original, carbon-14 composition of the recharge waters (A_0, pre-nuclear-detonation carbon-14), (2) the accuracy of the mass-transfer reaction models in describing the input and output of carbon to the water along the flow path, and (3) the isotope composition of carbon added to the water.

The carbon-14 composition of a recharge water (A_0) can be calculated assuming a system is either closed or open to soil-zone CO_2 gas. Ground-water ages determined for this study assumed that ground water in recharge areas became closed to soil-zone gas. Initial carbon-14 compositions (A_0) were calculated using a modified Tamers approach (Tamers, 1967, 1975; Tamers and Scharpenseel, 1970) with the computer program NETPATH (Plummer and others, 1991). The Tamers calculation used in this study is a mass-balance calculation including calcite, dolomite, and CO_2 gas, assuming the carbon in calcite and dolomite contains 0 pmc (percent modern carbon) and the CO_2 gas contains 100 pmc. These calculated carbon-14 values for A_0 are shown in table 18. The assumption that the system is closed to CO_2 gas in recharge areas may result in adjusted carbon-14 ages younger than actual ages, because almost all water samples in recharge areas are saturated with respect to calcite and most are saturated, or close to saturation, with respect to dolomite (table 15), yet waters in the two main recharge areas—the central Spring Mountains and Sheep Range—contain 76 to 100 pmc (table 16). These waters contain post-nuclear-detonation tritium (table 16) and, thus, also contain carbon-14 compositions greater than the pre-nuclear-detonation level of 100 pmc. Therefore, A_0 of water recharged before nuclear detonations, which includes all water outside the recharge areas containing little or no tritium, would have values smaller than those measured in recharge areas after above-ground nuclear detonations, so the modified Tamers values probably are reasonable estimates of A_0. If water was recharged under totally open system conditions, then the closed system ages could be in error by about one half-life of carbon-14 (the water would be 5,730 years older than calculated). However, the system is not totally open, as indicated by carbon-14, which is 76 to 100 pmc in water in these areas; as compared to CO_2 gas in the soil zone of Yucca Mountain, which is 110 pmc (D.C. Thorstenson, U.S. Geological Survey, oral commun., 1988); and carbon-14 in plant tissue, which reached a maximum of about 180 pmc (Tamers and Scharpenseel, 1970, p. 243). Thus, the maximum error of the adjusted ages due to an open, rather than closed, system has to be less than 5,730 years. The amount of possible error depends on whether the system is closed, partially closed, or open to CO_2 gas during recharge.

Water from a well and springs in the foothills of the southern part of the Spring Mountains, in southwest Las Vegas Valley (Sandstone Bluffs area), was determined to represent recharge to southwest Las Vegas Valley on the basis of hydrologic, geologic, deuterium, and water-chemistry data. The average carbon-13 composition in the well and spring-water samples is –10.4 permil, and average carbon-14 composition is 50.8 pmc (table 16, fig. 25). Two of the four samples contain tritium, indicating that the waters are less than 60 years old or are old waters that have been mixed with young water containing tritium. If the waters are not a mixture including young water, little decay of carbon-14 has occurred. The low, or absent, tritium concentration indicates that these waters are probably pre-nuclear-detonation waters, and thus their carbon-14 compositions should represent A_0 values. Although the well is completed in, and springs discharge from, sandstone units, the source of this water probably is recharge in carbonate rock of the southern Spring Mountains. Therefore, their A_0 values should be similar to those of water in the central part of the Spring Mountains. The similarity of carbon-14 compositions of these waters to calculated values for water in the central part of the Spring Mountains and Sheep Range (table 18; 53–55 pmc) indicates that the assumption of a closed system in the calculations of A_0 for recharge waters in southern Nevada is probably reasonable.Mass-balance calculations presented in the section titled "Water Chemistry" account for the carbon inputs and outputs of waters along flow paths (table 14). The mass-balance reaction model including the exchange of calcium and magnesium in the water for sodium in clay minerals (reaction model 3 in table 14) was used for calculating adjusted ages.

TABLE 16.—*Carbon-13, carbon-14, and tritium compositions of ground water in carbonate-rock aquifers of southern Nevada*

[Symbol: --, data not available; <, less than]

Site	Number of samples[1]	Delta carbon-13 (permil)	Carbon-14 (percent modern carbon)	Tritium (picocuries per liter)	Source[2]
Central part of Spring Mountains					
Sky Mountain well	1	−10.1	84.1	34	1
Summer Homes well	1	−10.8	91.1	89	1
Willow Spring	1	−9.6	79.2	57	1
Deer Creek Spring 1	2	−8.4	--	78	1
Deer Creek Spring 2	1	−9.6	100.0	73	1
Highway maint well	1	−10.1	83.0	87	2
Rainbow Spring 2	1	−9.8	91.7	98	2
Trout Spring	6	−7.9	90.8(1)	257 (3)	1,3,4
Cold Creek Spring	6	−9.5	76.0(4)	92 (4)	1,3,4
Southern part of Spring Mountains					
BLM Visitors Center well	1	−9.3	46.0	9.0	1
Sandstone Spring	2	−10.6	49.8	<15 (1)	1
Red Spring	2	−10.5	62.4	3.0(1)	1
White Rock Spring	2	−11.2	44.8(1)	<2.0	1
Sheep Range					
Wiregrass Spring	1	−10.2	96.8	90	1
Mormon Well Spring	1	−9.9	--	--	4
Coyote Spring Valley					
MX well	1	--	7.6	<2.0	4
VF-2 Well	1	−6.1	7.0	<1.0	4
Pahranagat Valley					
Crystal Spring	3	−7.0	7.8(2)	<2.0(1)	3,4
Ash Spring	2	−6.7	6.3(3)	0.0	3,4
Muddy River springs					
Big Muddy Spring	1	−6.0	6.7	<1.0	4
Indian Springs Valley					
Indian Springs	3	−7.6	8.3	<2.0(2)	1,3
Southern Yucca Flat					
C-1 Well	1	−3.8	0.8	<0.3	3,5
Mercury Valley					
Army Well 1	2	−5.6	2.8(1)	0.6	3
Ash Meadows					
Average of springs[3]	11	−4.9	4.7(13)	0.3(13)	3
Corn Creek Springs area					
Corn Creek Spring	3	−7.7	13.9(1)	<1.0(2)	1,3
Shown well	1	−8.8	20.4	<1.0	1
Young well	1	−6.7	13.7	<1.0	1
Brooks well	1	−6.9	35.7	<15	1
Tule Spring area - North Las Vegas Valley					
Holland well	1	−6.2	11.3	--	2
Mulder well	1	−7.2	23.8	<15	1
Tule Spring well	1	−7.0	13.9	<15	1
Martin well	1	−6.7	1.9	--	1
Racel well	1	−6.7	7	--	4
Southwest Las Vegas Valley					
Stocks Mill well	1	−7.9	11.0	<15	1
Pahrump Valley					
Manse well	1	−8.3	46.9	<2.0	1
Pahrump Spring well	1	−7.6	26.0	<1.0	1

[1] Where average is based on fewer or more samples than shown in this column, exact number is listed in parentheses after average constituent value.

[2] Sources of data:
1 Thomas and others (1991).
2 Schulke (1987, p. 78).
3 Winograd and Pearson (1976).
4 Unpublished data, U.S. Geological Survey, Carson City, Nev.
5 Boughton (1986, p. 84).

[3] Discharge-weighted average, for springs at Ash Meadows (Winograd and Pearson, 1976, table 2).

Sources of carbon in the carbonate-rock aquifers outside of the recharge areas are carbonate minerals (calcite and dolomite), organic matter, and CO_2 gas in rock units. Atmospheric and soil-zone CO_2 gas are not considered sources of carbon outside the recharge areas because depths to water in the carbonate-rock aquifers are generally several hundred to as much as 2,000 ft below land surface. Mass-balance calculations (see section titled "Water Chemistry") indicate that dolomite dissolves by dedolomitization, and in some areas because dolomite is undersaturated in the water. Calcite also dissolves and subsequently precipitates, as indicated by the lighter calculated than measured carbon-13 compositions of the water (shown as cycled carbon in table 18). Calcite dissolution and precipitation are caused by temperature and pressure changes over tortuous flow paths (Winograd and Pearson, 1976) and possibly increased surface area of calcite due to grinding as the result of faulting. Oxidation of organic matter, which would produce CO_2 gas, and CO_2 gas in rock units overlying the aquifers do not contribute significant amounts of carbon to the water (as discussed in the section titled "Water Chemistry").

Carbon isotope fractionation factors between precipitating calcite or exsolving CO_2 gas and a carbonate solution at varying temperatures and pH's can be measured (Deines and others, 1974; Mook, 1980).

EXPLANATION

Basin-fill deposits—In areas underlain by thick, laterally continuous carbonate rock

Basin-fill deposits—In areas outside thick, laterally continuous carbonate rock

Carbonate rock—In areas of thick, laterally continuous carbonate rock

Carbonate rock—In areas outside thick, laterally continuous carbonate rock

Noncarbonate rock—In areas of thick, laterally continuous carbonate rock

Noncarbonate rock—In areas outside thick, laterally continuous carbonate rock

Boundary of laterally continuous carbonate rock

Generalized direction of ground-water flow in carbonate-rock aquifer

Spring—Emanates from carbonate-rock aquifers

Well—Source of water is carbonate-rock aquifers

-4.9/4.7 **Average carbon-13, in permil, and average carbon-14, in percent modern carbon**

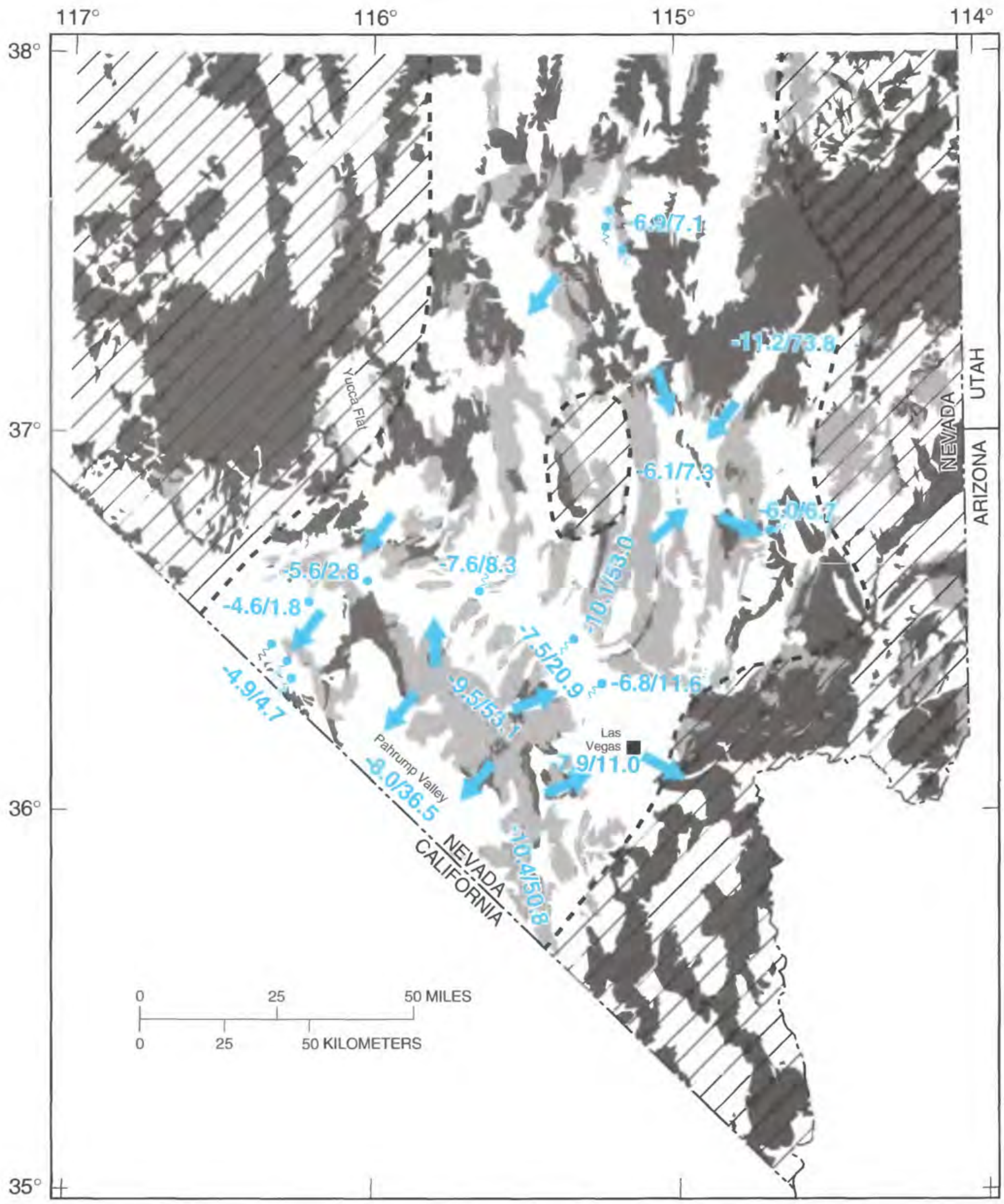

FIGURE 25.—Average carbon-13 and carbon-14 compositions of ground water in carbonate-rock aquifers of southern Nevada. See figure 18 for feature names. Modified from Dettinger (1989, fig. 3).

These fractionations have to be accounted for in calculating the carbon-13 composition resulting from the mass transfer of carbon into and out of the water.

The following assumptions were made in using carbon-13 to determine the amount of carbon moving into and out of the water along flow paths:

1. Carbon is removed from the water by calcite precipitation and in some spring areas by exsolution of CO_2 gas (table 14).

2. Carbon is added to the water by dissolution of dolomite. In all flow systems except parts of the Ash Meadows system, dolomite dissolution is primarily the result of dedolomitization (table 14), as indicated by the saturation of most waters with respect to calcite and dolomite and undersaturated with respect to gypsum (table 15). In the Ash Meadows flow system, except for flow paths and mixing involving Spring Mountains area waters, the increase in sulfate concentration was assumed to be the result of leakage of high sulfate waters from the Tertiary aquitard. Dolomite dissolution in these parts of the aquifer may be attributed to temperature and pressure changes along deep and tortuous flow paths or to the presence of small amounts of gypsum that would cause dedolomitization or may represent analytical error. The carbon-13 composition of dolomite was taken as 0.0 permil on the basis of seven samples identified as dolomite (table 17), and the carbon-14 composition was assumed to be 0 pmc.

3. Carbon input, in addition to that from dolomite dissolution, along some flow paths (shown in the mass-balance calculations as CO_2 gas in table 14) is assumed to be the result of the dissolution of CO_2 gas, calcite, or dolomite in the recharge areas. This carbon is added to the recharge water because the concentration of dissolved inorganic carbon in water circulating to depth in the aquifers is probably greater than measured at high-altitude springs and wells. For these calculations, the total dissolved inorganic carbon concentration of the recharge water was increased by the mass-balance calculated CO_2 input. This carbon is added to account for the sparse data for ground water from high altitudes, the large range in inorganic carbon concentration in samples from high-altitude sites (Thomas and others, 1991), and CO_2 degassing from spring water.

4. The carbon-13 composition of dissolving calcite is difficult to determine because calcite veins are prevalent within the carbonate-rock aquifers (I.J. Winograd, U.S. Geological Survey, oral commun., 1988). Primary calcite in southern Nevada has a carbon-13 composition ranging from –0.5 to +3.7 permil, with an average of 1.2 permil (table 17), whereas secondary (vein) calcite has a carbon-13 composition ranging from about –6 to –1.5 permil (I.J. Winograd, written and oral communs., 1991). Thus, geochemical models using carbon-13 were developed for several scenarios. First, the cycled carbon (table 18) was modeled assuming all dissolving calcite is primary calcite with a carbon-13 value of 1.2 permil. Second, the cycled carbon was modeled assuming all the dissolving calcite is secondary (vein) calcite assumed to be precipitating from a water with the average carbon-13 composition of water along the flow path. For example, the carbon-13 composition of water flowing from Ash Meadows springs is –4.9 permil and the average carbon-13 composition of a mixture of 60 percent Spring Mountains and 40 percent Pahranagat Valley waters plus leakage from the Tertiary aquitard is –8.6 permil, so an average carbon-13 composition of the water along the flow path would be –6.75 permil (the average of water discharging at Ash Meadows springs and the initial mixed water). Hence, using a fractionation factor of 3.0 (Tyler Coplen, U.S. Geological Survey, written commun., 1991), the precipitating calcite would have a composition of –3.75 permil. This fractionation factor was used because in Devils Hole in southern Nevada calcite precipitating from water with a carbon-13 composition of –4.8 permil has a carbon-13 composition of –1.8 permil (Tyler Coplen, written commun., 1991). Because of the sparse data on carbon-13 in calcite veins, a value for present-day calcite precipitation was used for vein calcite. The carbon-13 composition of calcite in vein DH-11 from Devils Hole ranges from –2.8 to –1.5 permil over a span of 50,000 to 500,000 years before present (Tyler Coplen, written commun., 1991), so the carbon-13 composition of vein calcite probably varies little over time in different parts of the study area. Third, the cycled carbon was modeled assuming the dissolving calcite is half primary calcite and half vein calcite. Fourth, the cycled carbon was modeled as in the third model, but the fractionation factors of Deines and others (1974) were used for calcite precipitation.

Given that most mass transfer models require the dissolution of dolomite (table 14), some primary calcite probably also dissolves, and because veins are prevalent throughout the carbonate rock, some vein calcite probably dissolves. Thus, adjusted carbon-14 age calculations based on mass transfers calculated using a carbon-13 value that is some proportion of primary and vein-calcite values probably gives the most realistic adjusted age (model 3 in table 18). In addition, if dissolving calcite was entirely vein calcite, then the average age of water discharging from Ash Meadows and Muddy River springs would be modern, which is unlikely given flow distances of tens of miles and the absence of tritium in the water (tables 16, 18).

TABLE 17.—*Carbon-13 composition of calcite and dolomite in southern Nevada*

Site[1]	Geologic unit or site sampled	Rock type	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Delta carbon-13 (permil)
1	Yellowpine Limestone	Calcite	36 43 57	114 46 05	+2.5
2	Ely Springs Dolomite	Dolomite	36 29 57	115 17 20	+.6
3	Nopah Dolomite	Dolomite	36 34 06	115 21 34	+.4
4	Dawn Limestone	Calcite	36 56 00	114 18 50	+2.6
5	Arcturus Limestone	Calcite	39 21 32	115 20 54	+2.7
6	Upper Cambrian	Calcite	38 59 18	114 57 25	+3.4
7	Simonson Dolomite	Dolomite	39 03 36	114 56 47	+.4
8	Sevy Dolomite	Dolomite	36 03 36	114 56 53	–1.4
9	Sevy Dolomite	Dolomite	37 27 49	115 11 34	–.1
10	Sevy Dolomite (?)	Dolomite	37 31 53	115 13 58	–.1
11	Laketown Dolomite	Dolomite	39 03 36	114 57 18	+.2
12	Lower Pogonip Group	Calcite	38 59 28	114 56 41	–.5
13	Upper Cambrian	Calcite	38 59 21	114 57 04	–.4
14	Test Well D	--	37 04 28	116 04 30	+3.7
15	Well U3CN5	--	37 03 35	116 01 30	+.4
16	Army Well 1	--	36 35 30	116 02 14	+.6
17	Test Well 4	--	36 34 54	115 50 08	+2.1
18	Test Well 2	--	37 09 58	116 05 15	+2.3
19	Test Well F	--	36 45 34	116 06 59	+.9
20	Test Well 3	--	36 48 30	115 51 26	+1.0
21	Test Well 1	--	37 09 29	116 13 23	+.3
22	Well UE15D	--	37 12 33	116 02 29	+2.3
23	Tracer Well 3	--	36 32 12	116 13 47	+2.2
24	Well C-1	--	36 55 07	116 00 34	+.6
25	Well C	--	36 55 08	116 00 35	+1.2
26	Blue Diamond road cut	--	36 02 05	115 23 45	+2.7

[1] Data for sites 14–26 from Hans Claassen (U.S. Geological Survey, oral commun., 1987).

The four models presented for each flow path in table 18 demonstrate that the adjusted carbon-14 age is extremely sensitive to the carbon-13 composition of the dissolving calcite. Adjusted ages range from modern for vein-calcite dissolution to as old as 13,900 years for primary calcite dissolution. When only calcite veins, which are isotopically light compared with the primary calcite, are dissolved, a large amount of carbon is exchanged between the water and rock, resulting in modern adjusted ages. This large amount of exchange (greater than 10 mmol/L of carbon) is probably unrealistic, even in an area like southern Nevada with deep fracture flow. The other extreme of dissolving only primary calcite can result in ages greater than 10,000 years in waters that are probably much younger, as indicated by the hydrology of the area and the distinct oxygen-18 record of precipitated calcite at Devils Hole, Nev., which suggests an age of less than 10,000 years for water in Devils Hole (I.J. Winograd, written commun., 1991). In addition, the ubiquitous presence of calcite veins in outcrops and cores from wells in southern Nevada indicates some vein calcite should be exposed to ground water. Thus, the carbon-13 composition of the dissolving calcite probably is between primary calcite (1.2 permil) and vein calcite (–6.0 to –1.5 permil).

5. The measured carbon-13 composition of the final water is heavier (less negative) than the calculated composition (table 18). This difference is assumed to be the result of dissolution and subsequent precipitation of calcite caused by temperature and pressure changes along the lengthy, deep, and tortuous flow paths (Winograd and Pearson, 1976) and possibly because of increased carbon exchange resulting from increased calcite surface area caused by faulting. The increase in calcite surface area, plus the exposure of fresh surfaces, produced by fracturing and grinding associated with faulting, would increase the exchange rate of carbon between solution and calcite (Mozeto and others, 1984). This additional input of carbon was determined by accounting for the fractionation of carbon-13 in a hypothetical sequence of dissolving and precipitating calcite using the Rayleigh distillation equations (Plummer and others, 1991).

6. All carbon-13 fractionation factors used in the computer program NETPATH were set for the fractionation of carbon-13 during calcite precipitation for models 1–3, and calculated using the equations from Deines and others (1974) for model 4. All CO_2 gas and carbonate solution fractionations were calculated using the equations from Deines and others (1974; table 18). A carbon-13 fractionation factor of 3.01 (6.02 for carbon-14) was used for the equilibrium fractionation between precipitating calcite and a carbonate solution in models 1–3.

7. Mixing waters have similar histories. The carbonate-rock aquifers contain relatively homogeneous mineralogies, and waters in the aquifers are similar in chemical composition, indicating that most of the water in the aquifers has undergone the same major geochemical processes.

WHITE RIVER FLOW SYSTEM

Water discharging from the Muddy River springs area was determined to be a mixture of 40 percent Pahranagat Valley water, 38 percent Sheep Range water, and 22 percent southern Meadow Valley Wash water. To obtain the measured carbon-13 composition of Muddy River springs water (fig. 25), carbon, in addition to the calculated mass transfer (table 14), must be cycled through the water by calcite dissolution and precipitation. The amount of carbon cycled depends on the carbon-13 composition of the dissolving calcite (table 18). As previously discussed, the average traveltime (age) for the following interpretations will be for the model that includes half primary and half secondary (vein) calcite dissolution.

The average traveltime from the three source areas to Muddy River springs was calculated to be 5,000 years (model 3 in table 18). This age was calcu-

TABLE 18.—*Ground-water ages in carbonate-rock aquifers of southern Nevada*

[Ages are corrected for mass transfer of carbon into and out of water, on basis of mass-balance calculations (table 14) and isotope data (table 16). Adjusted ages were calculated using carbon-13 composition of sources and sinks, and taking into account fractionation factors for these processes. Carbon-13 fractionation for exsolution of CO_2 gas is from Deines and others (1974). Carbon-13 fractionation for precipitating calcite for models 1–3 is from Tyler Coplen (U.S. Geological Survey, oral commun., 1991) and for model 4 is from Deines and others (1974). The mass-balance reaction model using exchange of calcium and magnesium in water for sodium in clay minerals was used for age corrections (table 14). Abbreviations and symbols: mmol/L, millimole per liter; pmc, percent modern carbon; >, greater than; -- not determined]

Flow path (flow-path terminus)[1]	Model[2]	Measured initial $\delta^{13}C$ (permil)	Measured final $\delta^{13}C$ (permil)	Calculated final $\delta^{13}C$ (permil)	Cycled carbon (mmol/L)[3]	A_0 initial carbon-14 (pmc)[4]	A_{nd} adjusted carbon-14 (pmc)	Measured carbon-14 (pmc)	Age (years before present)[5]
				White River Flow System					
3A-1	1	−9.0	−6.0	−8.4	2.4	39.2	21.2	6.7	9,500
(Muddy River	2				>10		--		modern
springs)[6]	3				5.2		12.3		5,000
	4			−8.4	4.7		13.6		5,800
2-1	1	−7.6	−6.0	−7.5	1.7	24.7	16.9	6.7	7,600
(Muddy River	2				>10		--		modern
springs)	3				3.5		12.0		4,800
	4			−7.5	3.0		13.2		5,600
3-2A	1	−8.4	−6.1	−7.5	1.5	31.1	19.8	7.3	8,200
(Coyote Valley)	2				>10		--		modern
	3				3.0		14.8		5,800
	4			−7.4	2.4		16.6		6,800
				Ash Meadows Flow System					
6-4	1	−8.4	−4.9	−7.8	3.4	34.1	16.0	4.7	10,100
(Ash Meadows	2				>10		--		modern
springs)	3				8.4		6.2		2,300
	4			−7.1	6.7		8.6		5,000
8-7	1	−9.5	−7.6	−8.2	0.45	54.9	44.6	8.3	13,900
(Indian Springs)	2				>10		--		modern
	3				.91		40.3		13,100
	4			−8.1	.63		42.9		13,600
				Las Vegas Valley					
13-12	1	−9.5	−6.8	−8.2	1.0	53.1	34.5	11.6	9,000
(Tule Spring area)	2				>10		--		modern
	3				2.2		25.9		6,600
	4			−8.1	1.7		29.2		7,600
17-12	1	−9.2	−6.8	−8.3	1.10	48.3	33.0	11.6	8,600
(Tule Spring area)	2				>10		--		modern
	3				2.3		24.8		6,300
	4			−8.2	1.8		27.9		7,300
15-14	3	−10.4	—7.9	−5.8	--	50.8	21.3	11.0	5,500
(Southwest Las	4			−5.7	--		21.3		
Vegas Valley)									5,500
				Pahrump Valley					
13-16	1	−9.5	−8.0	−8.4	0.30	53.1	42.4	36.5	1,200
(Pahrump Valley)	2				>10		--		modern
	3				0.58		39.7		680
	4			−8.3	0.40		41.4		1,000

[1] Flow-path designations are same as those in table 14.

[2] Model 1 uses carbon-13 value for dissolving calcite of average primary calcite, 1.2 permil (table 17). Model 2 uses carbon-13 value for dissolving calcite of vein calcite, taken as carbon-13 composition of calcite that would precipitate from an average water along flow path. Model 3 uses carbon-13 value for dissolving calcite assuming half the calcite is primary calcite (1.2 permil) and half the calcite is vein calcite (carbon-13 of vein calcite is that used in model 2). Model 4 uses carbon-13 values of model 3 for dissolving calcite. Models are described on p. 54.

[3] Additional input of carbon, from calcite dissolution and subsequent precipitation, needed to match measured carbon-13 composition of water.

[4] A_0 was calculated using modified Tamers approach with computer model NETPATH (Plummer and others, 1991) in recharge waters that contain measurable tritium and as was determined by mixing for waters containing no tritium and less than 50 pmc. In the case of one mixing water being from a recharge area, A_0 was first calculated for recharge water and then the mixed carbon-14 value was calculated using this value plus measured value for other water.

[5] $\text{Age} = \left(\frac{5,730}{\ln 2}\right)\left(\ln\left(\frac{\text{C-14 (adjusted)}}{\text{C-14 (measured)}}\right)\right)$, where C-14 (adjusted) is the carbon-14 composition calculated from mass-balance reaction model using carbon-14 compositions and fractionations of carbon inputs and outputs assuming no decay and C-14 (measured) is carbon-14 measured in water.

[6] Chemistry of White Rock Spring in volcanic terrain of Nevada Test Site was used to represent carbon-isotope chemistry of southern Meadow Valley Wash water. This water has a carbon-13 composition of -11.2 permil and a carbon-14 composition of 91.0 pmc.

lated by adjusting a volume-weighted average of the carbon-14 composition of the three source waters (A_0 in table 18), using the carbon mass transfers calculated for the mixed water to Muddy River springs, and then comparing the adjusted carbon-14 composition (A_{nd} in table 18) to the measured carbon-14 composition of the spring water. The mass-transfer adjusted carbon-14 composition (12.3 pmc) is larger than the measured composition (6.7 pmc), and the difference is assumed to be due to radioactive decay. The adjusted traveltime (age) was calculated by using the equation:

$$t = \frac{5{,}730}{\ln 2}\left[\ln\frac{\text{C}-14\,(\text{adjusted})}{\text{C}-14\,(\text{measured})}\right], \qquad (2)$$

where t = adjusted carbon-14 traveltime, or age, of the water, in years;
5,730 = half-life of carbon-14, in years;
C-14 (adjusted) = carbon-14 composition adjusted for the mass transfer of carbon on the basis of carbon-13, in percent modern carbon, assuming no decay (A_{nd}); and
C-14 (measured) = carbon-14 composition measured in the water, in percent modern carbon.

An average adjusted carbon-14 age for Ash and Crystal Springs, in Pahranagat Valley, was calculated to be 8,500 years before present. Thus, the total average age of water discharging from Muddy River springs is the average traveltime of the mixed water (5,000 years) plus the volume-weighted average of the starting ages of the source waters, corrected for the carbon-14 change associated with the traveltime from Pahranagat Valley to Muddy River springs (1,100 years). The average age of water discharging from Muddy River springs, therefore, is calculated to be 6,100 years (fig. 26).

The mixing percentages of the three source waters for Muddy River springs was determined by first mixing Sheep Range and Coyote Spring Valley waters to produce Muddy River springs water and then mixing Pahranagat Valley and southern Meadow Valley Wash waters to produce Coyote Spring Valley water (see sections titled "Stable Isotope" and "Water Chemistry"). The average ages of these mixed waters also are included in table 18 because they are used later in the report for calculating flow velocities based on adjusted carbon-14 ages.

ASH MEADOWS FLOW SYSTEM

Water discharging from springs at Ash Meadows was determined to be a mixture of 60 percent Spring Mountains water and 40 percent Pahranagat Valley water. Carbon, in addition to the carbon determined from mass-transfer calculations (table 14), must be cycled through the water by calcite dissolution and precipitation to obtain the measured carbon-13 composition of the spring water (table 18).

The average traveltime from the two sources to Ash Meadows springs was calculated to be 2,300 years by using equation 2 with volume-weighted carbon isotope compositions and correcting for mass transfers of carbon (table 18). Assuming that the adjusted carbon-14 age is 8,500 years for Pahranagat Valley water, the average age of water discharging from Ash Meadows, corrected for the carbon-14 change associated with the traveltime from Pahranagat Valley to Ash Meadows springs is 4,100 years (fig. 26).

LAS VEGAS VALLEY

The average age of ground water in the Tule Spring area of northern Las Vegas Valley was calculated two ways. First, the age was calculated assuming that the central part of the Spring Mountains is the sole source of water for the Tule Spring area. Second, the age was calculated assuming that water in the Tule Spring area is a mixture of 85 percent Spring Mountains water and 15 percent Sheep Range water (Corn Creek Springs area). Carbon, in addition to that determined from mass-transfer calculations (table 14), must be cycled through the water by calcite dissolution and precipitation to obtain the measured carbon-13 composition of the spring water (table 18). The average traveltime for water recharging the Spring Mountains to reach the Tule Spring area is 6,600 years (table 18, fig. 26). Because Spring Mountains water is modern, this also is the average age of Tule Spring area water.

A mass-balance reaction model was made for a mixture of 85 percent Spring Mountains water and 15 percent Sheep Range water to evolve into Tule Spring area water. The model results in an average age of 6,300 years (table 18).

The average age of ground water in southwest Las Vegas Valley was calculated using the average carbon isotope and chemical compositions of water in the Sandstone Bluffs area of the southern part of the Spring Mountains and water from two wells in southwest Las Vegas Valley (tables 14, 16). The average traveltime for water to flow from the Sandstone Bluffs area to the wells is 5,500 years (table 18, fig. 26). However, this age is probably younger than the actual age because the calculated carbon-13 composition is 2.1 permil heavier than measured carbon-13 (table 18).

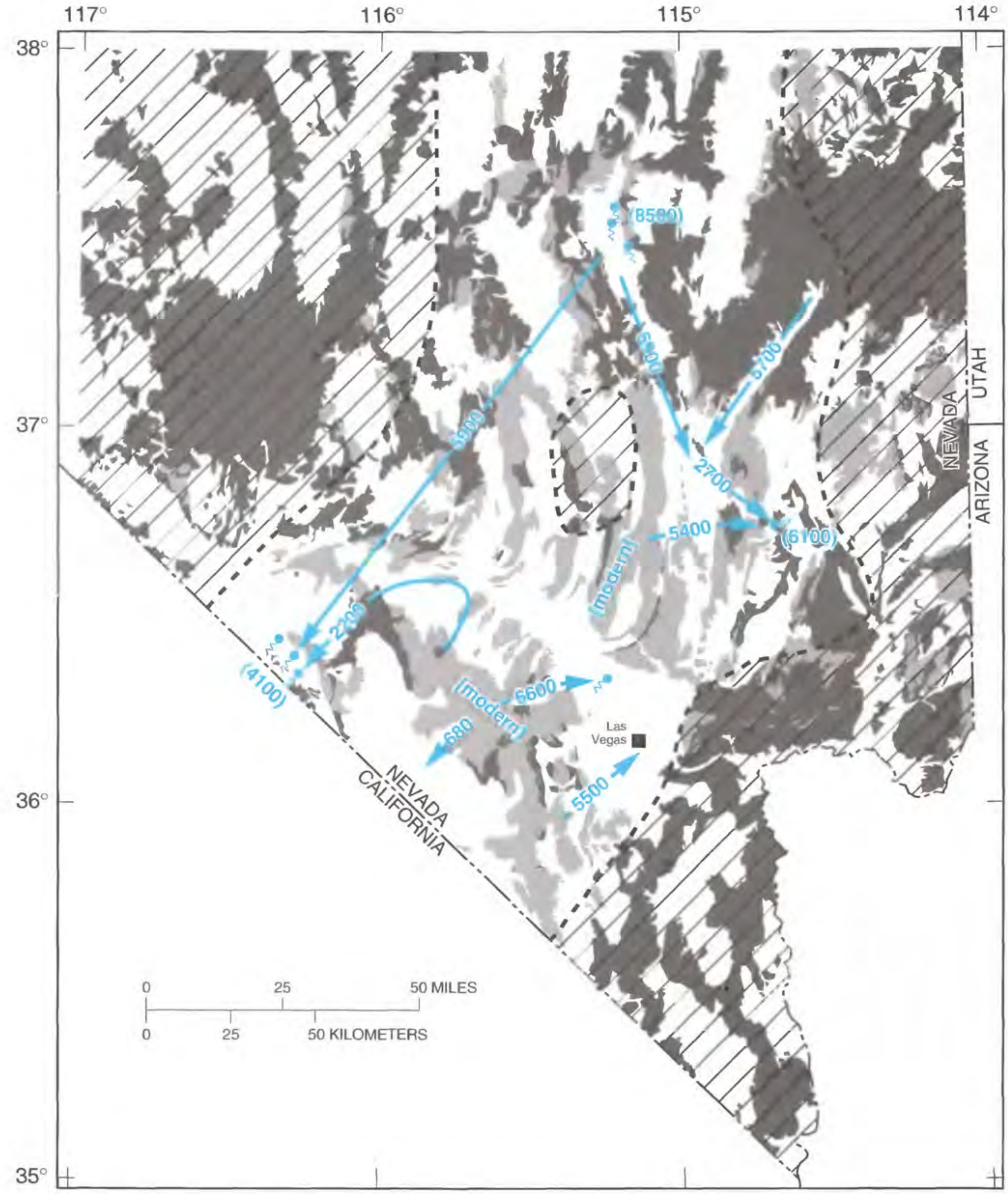

FIGURE 26.—Traveltimes and ages of ground water in carbonate-rock aquifers of southern Nevada, based on adjusted carbon-14 ages. See figure 17 for feature names. Modified from Dettinger (1989, fig. 3).

PAHRUMP VALLEY

The average age of ground water in the Pahrump and Manse Springs area of Pahrump Valley was calculated using the average chemical and carbon isotopic compositions of the central part of the Spring Mountains and Pahrump and Manse Springs wells (tables 14, 16). The average traveltime (and age) of the Pahrump and Manse Springs area water is 680 years (table 18, fig. 26).

SUMMARY OF GROUND-WATER AGES

Adjusted carbon-14 ages increase along flow paths for flow systems in southern Nevada (fig. 26). Therefore, adjusted carbon-14 ages agree with the flow paths delineated using deuterium data and mixing. Carbon-13 composition increases along flow paths for flow systems in southern Nevada (fig. 25). The only source of carbon outside of recharge areas is dissolution of carbonate minerals, which have a carbon-13 composition heavier than that of the water (discussed earlier in this section); therefore carbon-13 composition should increase along a flow path. The increase in carbon-13 composition along flow paths also agrees with the flow paths delineated using deuterium data and mixing.

EXPLANATION

Basin-fill deposits—In areas underlain by thick, laterally continuous carbonate rock

Basin-fill deposits—In areas outside thick, laterally continuous carbonate rock

Carbonate rock—In areas of thick, laterally continuous carbonate rock

Carbonate rock—In areas outside thick, laterally continuous carbonate rock

Noncarbonate rock—In areas of thick, laterally continuous carbonate rock

Noncarbonate rock—In areas outside thick, laterally continuous carbonate rock

Boundary of laterally continuous carbonate rock

5400 **Generalized direction and traveltime of ground-water flow in carbonate-rock aquifer**—Number is adjusted carbon-14 age of water, in years before present

[modern] **Age of ground water in source area**

(8400) **Spring**—Discharging from carbonate rock aquifer. Number is adjusted carbon-14 age of water, in years before present

Well—Source of water is carbonate-rock aquifers

GROUND-WATER FLOW VELOCITIES

Ground-water traveltimes (ages) can be used to determine flow velocities of ground water within the aquifers, which provide an independent estimate of hydraulic properties of the aquifers. Age-determined flow velocities for flow paths with a single source were calculated by dividing the horizontal flow-path distance (l) by the adjusted carbon-14 traveltime (t). Age-determined flow velocities for flow paths that involved mixing of two waters (labeled flow path a and flow path b) were calculated by using equations 15 and 16. These equations are derived as follows:

The adjusted carbon-14 age of the water at the end of flow path a can be written as

$$P_a = P_{ao} f_{nd} e^{\left(\frac{-t_a}{8,270}\right)}, \qquad (3)$$

where P_a = percent modern carbon at the end of the flow path adjusted for geochemical reactions and decay;

t_a = adjusted carbon-14 age at the end of the flow path;

8,270 = 5,730 (half-life of carbon-14) divided by ln2 (from eq. 2);

f_{nd} = fractional change, in percent modern carbon, associated with the chemical reactions, fractionation, and carbon sources but not decay; and

P_{ao} = initial percent modern carbon of the source water (Wigley and others, 1978, eqs. 23 and 30).

The adjusted carbon-14 age of the water at the end of flow path b can be written as

$$P_b = P_{bo} f_{nd} e^{\left(\frac{-t_b}{8,270}\right)}, \qquad (4)$$

where the variables are the same as equation 3, except subscript a's are replaced by subscript b's.

The amount of carbon-14 in a mixture of water from flow path a and flow path b that produces the water at c is conserved (carbon-14 does not decay during mixing and mixing occurs before the water at c is sampled). Thus,

$$P_c = XP_a + (1 - X) P_b, \qquad (5)$$

where P_c = adjusted (for geochemical reactions and decay) percent modern carbon at c; and

X = fraction of total flow at c that derives from source a (the percents of P_a and P_b were originally determined by deuterium mass-balance calculations); assuming the f_{nd}

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adjustment factor is the same for both flow paths (see the previous discussion of carbon-13 adjustments).

The traveltime along flow path a (t_a) is

$$t_a = \frac{l_a n}{K I_a}, \quad (6)$$

where l_a = average length of flow path a;

I_a = hydraulic gradient ($\Delta h/\Delta l$: Δh is the change in head and Δl is the flow path length) along flow path a;

K = hydraulic conductivity; and

n = effective porosity.

A similar equation holds for flow path b (replacing subscript a's with subscript b's throughout eq. 6 and assuming—for lack of more detailed information—that K and n are the same along both flow paths). A corollary relates the two traveltimes and allows elimination of the hydraulic terms. Dividing the two equations of form (6) yields

$$t_b = \frac{l_b n K I_a}{l_a n K I_b}(t_a) = \frac{l_b I_a}{l_a I_b}(t_a), \quad (7)$$

which, upon division by −8,270 years, and exponentiation gives

$$e^{\left(\frac{-t_b}{8,270}\right)} = e^{\left(\frac{-rt_a}{8,270}\right)}, \quad (8)$$

where

$$r = \frac{l_b I_a}{l_a I_b}. \quad (9)$$

This relation combined with equations 3 and 4 gives

$$P_b = P_{bo} f_{nd} e^{\left(\frac{-rt_a}{8,270}\right)}, \quad (10)$$

$$= P_{bo} f_{nd}\left(\frac{P_a}{P_{ao} f_{nd}}\right)^r, \quad (11)$$

so that equation 5 can be rewritten as

$$P_c = XP_a + (1-X) P_{bo} f_{nd}\left(\frac{P_a}{P_{ao} f_{nd}}\right)^r. \quad (12)$$

Equation 12 is an implicit expression for P_a, if P_c, X, P_{bo}, P_{ao}, f_{nd}, and r are known. P_a can be obtained by iterative solution, for example, by application of the Newton-Raphson method (Chapra and Canale, 1988). Once P_a is obtained, the traveltime along path a is

$$t_a = -8,270 \ln\left(\frac{P_a}{P_{ao} f_{nd}}\right), \quad (13)$$

and from equations 7 and 9

$$t_b = rt_a. \quad (14)$$

The age-determined velocities are then estimated as

$$V_{pa} = \frac{l_a}{t_a}, \quad (15)$$

and

$$V_{pb} = \frac{l_b}{t_b}, \quad (16)$$

where V_{pa} = flow velocity along path a; and

V_{pb} = flow velocity along path b (table 19).

These age-determined velocity calculations do not require that the hydraulic conductivity and effective porosity be known, but do assume they are constant for the entire aquifer. Ground-water flow velocities along each flow path also were calculated from estimates of the hydraulic properties of the aquifers using Darcy's equation in the form

$$V_{ha} = \frac{K}{n} I_a, \quad (17)$$

where V_{ha} = linear flow velocity;

K = hydraulic conductivity;

I_a = hydraulic gradient; and

n = effective porosity.

Hydrologic flow velocities were calculated using a hydraulic conductivity of 4.3 ft/d [the median value of 39 aquifer tests for wells completed in carbonate rock in eastern and southern Nevada (Dettinger and others, 1995)], horizontal flow-path distances perpendicular to water-level contours, hydraulic head differences measured along the flow path, and an effective porosity of 2.0 percent.

Hydraulic head differences were taken as difference in water-level altitudes between the initial and final sites along a flow path. Hydraulic head differences for flow paths involving the Spring Mountains were estimated assuming water levels in the Spring Mountains were 500 ft higher than the final site in the adjacent valley (Tule Spring area, southwest Las Vegas Valley, and Pahrump Valley), except for Ash Meadows. For Ash Meadows, the water level for the Spring Mountains was chosen as 500 ft higher than Indian Springs.

This approach was taken because water levels in springs and wells in the Spring Mountains probably do not represent a regional water level, but instead represent local levels. In addition, tritium in water samples from some wells and springs on alluvial fans of the Spring Mountains indicates that traveltime of ground water from the mountains to adjacent alluvial fans is less than about 60 years. Thus, the flow of ground water within the Spring Mountains to adjacent alluvial fans is rapid, so flow in this part of the flow system is omitted in determining flow velocities for the carbonate-rock aquifers.

Effective porosity was chosen as 2.0 percent on the basis of studies that measured or calculated porosities in the carbonate-rock aquifers of southern Nevada (Winograd and Thordarson, 1975; Berger, 1992; Kilroy, 1992). The effective porosity used in this study is secondary fracture porosity; the intercrystalline porosity is minor compared with the fracture porosity of the carbonate rock (Winograd and Thordarson, 1975). Effective porosity was estimated by harmonic analysis of water-level fluctuations in 11 wells and Devils Hole, which penetrate the carbonate-rock aquifers in southern Nevada (Kilroy, 1992). Effective porosity ranged from 1.0 to 4.4 percent, with an average of 2.2 percent and a median of 1.8 percent. For 16 core samples, total porosity ranged from 0.4 to 12.4 percent, with a mean of 5.4 percent and a median of 5.5 percent (Winograd and Thordarson, 1975). Total porosity was estimated using geophysical methods for 43 zones in five wells completed in carbonate rock in southern Nevada (Berger, 1992). Total porosity ranged from 0.0 to 18.5 percent with a mean of 4.7 percent and a median of 4.2 percent.

Flow velocities calculated from adjusted carbon-14 ages range from 29 to 38 ft/yr, whereas flow velocities determined from hydrologic data range from 50 to 540 ft/yr for the White River flow system (table 19). Flow velocities calculated from hydrologic data are about twice those calculated from adjusted carbon-14 data for two flow paths that have hydraulic gradients of 3.3 ft/mi, and about 14 times greater for two other flow paths that have hydraulic gradients of about 35 ft/mi.

The differences in flow velocity between the age and hydrologic calculations could result from (1) the calculated median hydraulic conductivity of the carbonate aquifers being too high, (2) the assumed effec-

TABLE 19.—*Flow velocities in the carbonate-rock aquifers of southern Nevada, calculated from adjusted carbon-14 ages and hydrologic data*

Flow path	Traveltime[1] (years)	Distance[2] (miles)	Change in hydraulic head[3] (feet)	Hydraulic gradient (feet per mile)	Flow velocity (feet per year)	
					From carbon-14 ages[4]	From hydrologic data[5]
White River Flow System						
Coyote Valley to Muddy River springs	2,700	15	50	3.3	29	50
Sheep Range to Muddy River springs	5,400	30	100	3.3	29	50
Pahranagat Valley to Coyote Valley	6,900	50	1,800	36	38	540
Meadow Valley Wash to Coyote Valley	5,700	40	1,400	35	37	520
Ash Meadows Flow System						
Spring Mountains to Ash Meadows springs	2,200	60	1,400	23	140	350
Pahranagat Valley to Ash Meadows springs	5,900	95	1,300	14	85	200
Las Vegas Valley						
Central part of Spring Mountains to Tule Spring area	6,600	15	500	33	12	500
Southern part of Spring Mountains to southwest Las Vegas Valley	5,500	10	500	50	9.6	740
Pahrump Valley						
Spring Mountains to Pahrump Valley	680	10	500	50	78	740

[1] Adjusted carbon-14 traveltime between two samples along a flow path, or for two mixing waters calculated by using equations 15 and 16. For mixing waters, traveltime is dependent on hydraulic gradients of two flow paths.

[2] Horizontal flow-path distance.

[3] Differences in water level between source area and end of flow path.

[4] Flow velocity was calculated by dividing distance by adjusted carbon-14 age.

[5] Flow velocity was calculated by using equation 17.

tive porosity being too low, (3) the actual flow paths being longer than the horizontal flow-path distances, (4) some combination of these factors, or (5) the adjusted ages being too old. For the flow paths with a gradient of 3.3 ft/mi, the average hydraulic conductivity used for calculating velocity may be 50 percent less because measurements are few and the range is large: hydraulic conductivity, 0.01 to 940 ft/d (Dettinger and others, 1995). Effective porosity of 2.0 percent could be higher because of the 1.0 to 4.4 percent range (Kilroy, 1992). A 50-percent greater flow-path length is probable, given that the flow-path distances are horizontal distances and flow in the study area is fracture flow that is tortuous and deep (generally thousands of feet). Uncertainties in age calculations also can be substantial, as discussed previously in the section titled "Ground-Water Age." Thus, average flow velocities for these parts of the White River flow system probably are in the range of 29 to 50 ft/yr.

The two flow paths in the White River flow system, with hydraulic gradients of 35 and 36 ft/mi, have age-calculated velocities of 37 and 38 ft/yr. These velocities are in the range of the velocities calculated from age and hydrologic data for the two flow paths with a hydraulic gradient of 3.3 ft/mi. However, velocities calculated from hydrologic data (520 and 540 ft/yr) are about 14 times greater than the velocities calculated from age determinations because of the high hydraulic gradients. These higher gradients probably indicate areas of lower hydraulic conductivity than was assumed as an average for the flow path. The hydraulic gradient is 36 ft/mi along the flow path from Pahranagat Valley to Coyote Spring Valley. However, water levels decline about 1,200 ft in less than 20 mi (pl. 1), and most of this decline could be in a shorter distance, thus, ground-water flow apparently is restricted between the south end of Pahranagat Valley and the north end of Coyote Spring Valley. A similar high gradient also is present between Meadow Valley Wash and Coyote Spring Valley. Both of these high gradients may result from volcanic rock that overlie and intrude the carbonate-rock aquifers (pl. 1), because volcanic rock generally have lower hydraulic conductivity than the carbonate rock (Winograd and Thordarson, 1975). Thus, flow velocities calculated from hydrologic data may overestimate the average velocities along these flow paths. Velocities calculated from age account for areas of low hydraulic conductivity and hence low velocities, whereas velocities calculated from average hydrologic data do not. Therefore, the age-calculated velocities may be more representative of an average velocity than those calculated from hydrologic data.

The hydraulic gradient also could be high between the Sheep Range and Muddy River springs. However, the gradient used to calculate flow velocity is based on the head differences between wells completed in basin fill and carbonate rock in Coyote Spring Valley plus the head differences between the wells completed in carbonate rock in Coyote Spring Valley and Muddy River springs. Water in the well completed in basin fill is assumed to represent water that recharges the carbonate-rock aquifer beneath Coyote Spring Valley from the Sheep Range (see the previous discussion on stable isotopes).

Flow velocities calculated using ground-water ages are 140 and 85 ft/yr, as compared with 350 and 200 ft/yr for velocities calculated from hydrologic data for the Ash Meadows flow system (table 19). Flow velocities calculated from hydrologic data are about 2.5 times greater than age-estimated velocities. This difference is probably the result of the same five factors as discussed for the White River flow system. The velocities calculated from hydrologic data are about half the minimum velocity estimated by Winograd and Thordarson (1975, p. 115) for the carbonate-rock aquifers beneath the Specter Range approximately 15 mi upgradient from Ash Meadows. Using their data for total discharge and cross-sectional area and an effective porosity of 2 percent, a velocity of 280 ft/yr was calculated. This value is about the average of the two velocities estimated from the hydrologic data for this study. Thus, average flow velocities in the Ash Meadows flow system probably are in the range of 85 to 350 ft/yr.

Flow velocities calculated using adjusted carbon-14 age are significantly less than velocities calculated from hydrologic data for flow paths from the Spring Mountains to Las Vegas and Pahrump Valleys (table 19). This large difference is a result of the steep hydraulic gradient for the flow paths, as compared with most other flow paths in the carbonate-rock aquifers, and the relatively old ages of ground water in Las Vegas Valley. The hydraulic gradients for these flow paths are assumed high because recharge to the Spring Mountains is at altitudes greater than 10,000 ft. For these flow paths, the velocities calculated from hydrologic data may be more reasonable than velocities calculated from age because the amount of recharge to the Spring Mountains is large and ground water is assumed to mound beneath the mountains and adjacent alluvial fans. The velocities calculated from ground-water age for the flow paths that end at the Tule Spring area and southwestern Las Vegas Valley (table 19) are less than half the minimum velocity calculated from age data for other flow paths in the carbonate-rock aquifers of southern Nevada. This age difference indicates that the adjusted ages may be too old or that ground water is not flowing directly from the Spring Mountains to these areas. In Pahrump Valley, the relatively young ground-water age results in a velocity of 78 ft/yr, which is in the range of other age-calculated velocities, but still about an order of magnitude less than the velocity calculated from hydrologic data. Thus, the average velocity for these flow paths ranges from 78 to 740 ft/yr and probably is closer to the high velocity because of the steep gradient. However, the lack of measurable tritium in water samples from these sites (table 16) indicates the velocity of 740 ft/yr is a maximum.

In summary, flow velocities calculated from adjusted carbon-14 ages are less than velocities calculated from hydrologic data. Thus, either the adjusted ages are too old or the sparse hydrologic data do not represent average hydraulic properties of the carbonate-rock aquifers. As discussed in the section titled "Ground-Water Age," the ages could be much younger if more vein calcite is exchanging carbon with the water than the 50 percent assumed. On the other hand, age-estimated flow velocities of 9.6 to 140 ft/yr are in the range of velocities calculated for the Madison aquifer in Montana, Wyoming, and South Dakota. The Madison aquifer is a carbonate-rock aquifer in Montana, Wyoming, and South Dakota. Flow velocities calculated using adjusted ages range from 7.2 to 86.7 ft/yr, and velocities simulated by ground-water modeling range from 11.2 to 74.2 ft/yr, for 22 flow paths in the Madison aquifer (Downey, 1984; Plummer and others, 1990, table 12). Thus, velocities calculated from ground-water age for the carbonate-rock aquifers of southern Nevada have a similar, but slightly larger, range as velocities for the Madison aquifer calculated from both age and hydrologic data. These similar velocities indicate that the adjusted ages of the ground water are probably reasonable. However, the Madison aquifer is not in an area of active extension like southern Nevada, so flow within the Madison aquifer may not be primarily along secondary fractures like in aquifers of southern Nevada. Thus, a direct comparison of velocities in the aquifers may not be valid.

The discrepancy in velocities calculated from age compared with those calculated from hydrologic data indicate that either the ages or the average hydraulic conductivity may be overestimated, and effective porosity and horizontal flow path lengths may be underestimated. The large discrepancy in velocities calculated from age and hydrologic data for flow from the Spring Mountains to adjacent valleys indicates the lack of knowledge about the recharge process for the carbonate-rock aquifers in southern Nevada.

IMPLICATIONS OF CHEMICAL AND ISOTOPIC COMPOSITION OF GROUND WATER IN AQUIFERS OF THE GREAT BASIN

Major processes affecting the chemical and isotopic composition of ground water in Smith Creek Valley are similar to those in other hydrologically closed systems of the Great Basin. The principal aquifers in these flow systems consist of unconsolidated sedimentary deposits underlain by less permeable consolidated rock. Numerous systems in which the flow is primarily in basin-fill deposits that culminate in a discharging playa area exist throughout the Great Basin (Harrill and others, 1988). Near recharge areas, ground-water chemistry results from the dissolution of primary minerals and soil-zone CO_2. As the water moves downgradient into finer grained sediments near the center of the basin, ion exchange becomes an important process. In the discharging playa area, evaporation, transpiration, and dissolution of salts left behind by evapotranspiration are dominant processes affecting water chemistry. Precipitation of secondary minerals and formation of clays remove ions from water throughout the flow system. Deuterium and oxygen-18 become heavier (more positive) in the discharge area due to evaporation.

Major processes affecting the chemical and isotopic composition of ground water in the carbonate-rock aquifers of southern Nevada should be similar to those in carbonate-rock flow systems throughout the Great Basin. The principal aquifers in these flow systems consist of carbonate rock, but unconsolidated basin-fill deposits also may be hydrologically connected with the carbonate rock. Near recharge areas, ground-water chemistry results from dissolution of primary minerals—mainly calcite and dolomite—and soil-zone CO_2 gas. Mixing of chemically and isotopically different waters produces ground water of chemical and isotopic composition different from the initial waters. As the water circulates to depth, geothermal heating causes precipitation of calcite, removing calcium and bicarbonate ions from the water. Ion exchange, precipitation of secondary minerals, and formation of clay minerals removes ions from the water throughout the flow system; exchange reactions also add ions to the water. The carbon-isotope composition of the ground water changes because of (1) the dissolution of calcite, dolomite, and soil-zone CO_2 gas, which adds carbon of different isotopic composition to the water, and (2) the precipitation of calcite and outgassing of CO_2, which remove isotopically heavier (calcite precipitation) or lighter (CO_2 outgassing) carbon from the system. The chemical and isotopic compositions resulting from these processes can be used in conjunction with hydrologic and geologic information to determine sources, flow paths, and mixing of water in carbonate-rock flow systems. This information can be used to help determine rates and volumes of flow within the aquifers.

Carbonate-rock aquifers and hydrologically closed basin-fill aquifers form the two principal types of flow systems in the Great Basin. Other types may (1) be a combination of the basin-fill and carbonate-rock systems, (2) involve ground-water flow primarily in volcanic rock, or (3) be affected by mixing with surface water. In the Railroad Valley flow system in central Nevada, for example, ground water flows in carbonate-rock aquifers and volcanic rock and discharges from the playa area of a basin-fill aquifer. The initial chemical character of water in this flow system is a result of the dissolution of primary minerals and soil-zone CO_2 gas. As the ground water flows into underlying carbonate-rock aquifers, dissolution of carbonate-rock minerals, followed by precipitation of calcite (where water is heated at greater depths), dominates. The chemical composition of water flowing through volcanic rock changes because volcanic glass and minerals dissolve. In the discharge area, a playa surrounded by phreatophytic vegetation, evaporation and transpiration are the dominant processes affecting the chemical and isotopic composition of the water. In addition, dissolution of any salts formed previously as the result of evapotranspiration could be a major source of ions in the water. Several processes, such as precipitation of secondary minerals, formation of clays, and ion exchange, may occur throughout the flow system.

In the Pahute Mesa area of southern Nevada, ground-water flow is primarily in volcanic rock (Blankennagel and Weir, 1973). Processes affecting the chemical and isotopic compositions of the water are similar to those in the carbonate-rock aquifers, but the mineralogy is different. The water chemistry results from dissolution of volcanic glass and minerals (such as feldspars) rather than carbonate-rock minerals. Precipitation of minerals, formation of clay minerals, and ion exchange also are important processes affecting the water chemistry (White, 1979; White and others, 1980; Kerrisk, 1983).

In the Humboldt River basin-fill system of north-central Nevada, the chemical and isotopic composition of ground water is affected by mixing with surface water in parts of the aquifer. Along the river, some surface water infiltrates into the basin-fill aquifers, particularly during periods of high flow (for example see Cohen and others, 1965, p. 79–80). Because the chemical and isotopic compositions of the surface water and ground water are likely to be different, mixing of the two waters would produce a blend with a composition intermediate to the two end-member waters. The proportions of mixing end-member waters, along with any subsequent hydrologic or geochemical processes that affect the water chemistry, determine the chemical and isotopic composition of the resulting blend. Unless a river is a major source of recharge in such a system, interaction between streamflow and water in the aquifer affects the chemical and isotopic composition of the ground water only adjacent to the river. However, in areas of surface-water irrigation, water applied on the land surface percolates to the shallow water table (Loeltz and others, 1949, p. 33; Harrill and Moore, 1970, p. 74), thus affecting the chemical and isotopic composition of ground water in those areas. The isotopic composition of ground water changes due to the infiltration of isotopically different surface water.

SUMMARY

This report, a product of the Great Basin Regional Aquifer-System Analysis and Southern Nevada Carbonate studies, briefly describes the distribution of dissolved solids and the chemical character of ground water in the study area; discusses the geochemical and hydrologic processes that result in the chemical evolution of ground water in a hydrologically closed basin-fill aquifer; discusses the geochemical and hydrologic processes that produce the chemical and isotopic compositions of ground water in carbonate-rock aquifers of southern Nevada; delineates ground-water flow paths, source areas, and mixing of waters in the carbonate-rock aquifers of southern Nevada; discusses ground-water ages calculated from mass-balance reaction models and carbon isotopes; and compares the resulting age-calculated flow velocities with velocities determined using hydrologic data for the carbonate-rock aquifers of southern Nevada. Smith Creek Valley, in west-central Nevada, represents hydrologically closed basin-fill flow systems, with ground water flowing primarily through basin-fill aquifers. Carbonate-rock aquifers in southern Nevada represent carbonate-rock flow systems, in which ground water flows through both basin-fill and carbonate-rock aquifers and underneath topographic divides through carbonate rock.

Water in the principal aquifers of the Great Basin generally contains less than 1,000 mg/L of dissolved solids, except in natural-discharge and geothermal areas. Aquifers in industrial, mining, urban, and agricultural areas, and aquifers containing highly soluble evaporative salts and minerals, may have dissolved-solid concentrations greater than 1,000 mg/L or elevated concentrations of undesirable constituents, or both. These areas of known higher dissolved solids, or

elevated constituent concentrations, are shown in a series of water-quality reports for States in the Great Basin.

The general chemical character of water in principal aquifers of the Great Basin is dominated by sodium, calcium, and bicarbonate in basin-fill aquifers of the western Great Basin; calcium, sodium, magnesium, and bicarbonate in basin-fill aquifers of the eastern Great Basin; and calcium, magnesium, and bicarbonate in carbonate-rock aquifers of the eastern Great Basin. The chemical character of water concentrated by evapotranspiration in discharging playa areas is generally dominated by sodium, chloride, and sulfate.

Geochemical and hydrologic processes that produce the major-ion chemistry and isotopic composition of water in aquifers throughout the Great Basin are identified for examples of the two principal types of flow systems in the Great Basin: a hydrologically closed basin-fill aquifer in Smith Creek Valley, west-central Nevada, and a regional carbonate-rock aquifer system in southern Nevada.

Chemical and isotopic compositions of water in the basin-fill aquifer in Smith Creek Valley evolve as a result of (1) evapotranspirative concentration of the water, (2) dissolution of minerals and soil-zone CO_2 gas, (3) precipitation, or formation by incongruent dissolution, of minerals, and (4) ion exchange. Water recharging the basin-fill aquifer originates mainly as precipitation in the surrounding mountains. Precipitation in the recharge areas is concentrated by evapotranspiration. The concentrated precipitation infiltrates to the soil zone where it dissolves CO_2 gas, and volcanic groundmass and phenocrysts (dominantly albite and anorthite), producing a sodium calcium bicarbonate water. In addition, small amounts of K-feldspar, gypsum, biotite, and possibly pyrite, illite, and chlorite are dissolved, adding ions to the water. Chalcedony precipitates, removing ions from the water, and kaolinite (or some other clay mineral) forms, probably as the result of incongruent dissolution of the feldspars.

Calcium and magnesium in the water exchange for sodium on clays in the playa area, where basin-fill deposits grade to finer grained sediments. This exchange results in the sodium calcium bicarbonate water evolving into a sodium bicarbonate water. Calcium also may be removed from the water by the weathering of plagioclase to Ca/Na-montmorillonite and the precipitation of a zeolite mineral. Ions are added to the water by the dissolution of albite, anorthite, K-feldspar, CO_2 gas, and salts containing chloride. Ions are removed from the water by precipitation of chalcedony and reduction of sulfate to hydrogen sulfide gas. Incongruent dissolution of feldspars probably results in the formation of kaolinite.

Evapotranspiration, dissolution of evaporative salts containing chloride, and precipitation of calcite and zeolite minerals are the main processes affecting ground-water chemistry in the discharge area. These processes result in the sodium bicarbonate water evolving into a sodium chloride water. Constituents also are added to the water by dissolution of albite, anorthite, K-feldspar, gypsum (or evaporative salts containing sulfate), and chlorite, and kaolinite is formed by incongruent dissolution of feldspars. Evaporation of shallow ground water in the discharge area also causes the water to become heavier in deuterium and oxygen-18.

Chemical and isotopic compositions of water in the carbonate-rock aquifers of southern Nevada evolve as a consequence of (1) dissolution of minerals and soil-zone CO_2 gas, (2) precipitation or formation of minerals, (3) ion exchange, (4) mixing of chemically or isotopically different waters, and (5) geothermal heating. Water in the carbonate-rock aquifers originates primarily as precipitation in the Spring Mountains and Sheep Range. This water is concentrated by evapotranspiration and obtains most of its ions from dissolution of CO_2 gas, calcite, and dolomite in the recharge areas. Recharge waters generally are saturated with respect to both calcite and dolomite and contain predominantly calcium, magnesium, and bicarbonate. These waters circulate to depth, which causes the water to heat and to precipitate calcite.

Throughout the carbonate-rock aquifers, calcite precipitates, calcium and magnesium in the water exchange for sodium in clays, chalcedony precipitates, kaolinite forms, and in some spring areas CO_2 gas exsolves. In large areas of the carbonate-rock aquifers, gypsum dissolves, causing calcite to precipitate and dolomite to dissolve (dedolomitization). In addition, sodium and potassium probably are added to the water by the dissolution of volcanic glass and minerals (dominantly albite and K-feldspar) and zeolite minerals (probably clinoptilolite), which are present in parts of the study area. Sodium chloride salts also are present in some parts of the study area and dissolve. In the Ash Meadows flow system, downward leakage of water containing high sodium and sulfate from the Tertiary aquitard into the carbonate-rock aquifers is the primary source of increased sulfate and sodium concentrations. Thus, outside of the recharge areas of the carbonate-rock aquifers in southern Nevada, sodium, sulfate, and chloride can be major dissolved constituents in the water.

Waters of differing chemical and isotopic compositions mix in the carbonate-rock aquifers. This mixing can result in a water that is isotopically and chemically different from the source waters. However, all the waters generally are undergoing the same geochemical processes, which produce waters of similar chemical composition. Thus, the primary evidence of mixing in the carbonate-rock aquifers is the modified isotopic composition of the mixed water, compared to the mixing waters. The mixing waters generally originate in different areas, and therefore, have different isotopic compositions.

The isotopic and chemical compositions of water in the carbonate-rock aquifers of southern Nevada were used to delineate flow systems. First, the deuterium content of water in the carbonate-rock aquifers was used to determine source areas, flow paths, and mixing. Second, these deuterium-delineated flow paths and mixing scenarios were checked for chemical feasibility using mass-balance and mineral-equilibrium models based on water chemistry and the geochemical processes that are assumed to have produced the chemical composition of the water. Third, adjusted carbon-14 ages were determined from carbon-isotope data on the basis of the mass-balance reaction models. These ages provide another check on the flow path and mixing scenarios because ground-water ages increase along flow paths, and apparent ages change due to mixing of different age waters.

These isotopic and geochemical models produced the following results:

1. Ground water discharging at the terminus of the White River flow system (Muddy River springs) is a mixture of 40 percent (14,000 acre-ft/yr) Pahranagat Valley water, 38 percent (14,000 acre-ft/yr) Sheep Range water, and 22 percent (8,000 acre-ft/yr) southern Meadow Valley Wash water.
2. Ground water discharging at the terminus of the Ash Meadows flow system (Ash Meadows springs) is a mixture of 60 percent (10,000 acre-ft/yr) Spring Mountains water and 40 percent (7,000 acre-ft/yr) Pahranagat Valley water.
3. Las Vegas Valley receives all, or almost all, of its ground water from the Spring Mountains (the Sheep Range may supply as much as 2,500 acre-ft/yr to northern Las Vegas Valley).
4. Pahrump Valley receives all its ground water from the Spring Mountains.

Flow velocities calculated from adjusted carbon-14 ages are less than velocities calculated from hydrologic data. This difference indicates that the ages or average hydraulic conductivities may be overestimated, and effective porosity and horizontal flow path lengths may be underestimated. Calculated ground-water ages are sensitive to the carbon-13 composition of the dissolving calcite. To determine ages for velocity estimates, 50 percent of the dissolving calcite was assumed to be vein calcite. Calculated ground-water ages could be much younger if more vein calcite, which has a lighter carbon-13 composition than the primary calcite, is dissolving. Knowledge about the recharge process for the carbonate-rock aquifers of southern Nevada is insufficient to explain the large difference in velocities calculated from age and hydrologic data for flow from the Spring Mountains to adjacent valleys.

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APPENDIXES

APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*

[Average deuterium composition for each site is plotted on plate 2. Permil values of deuterium and oxygen-18 are reported relative to V-SMOW]

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
Cresent Spring	35 28 43	115 10 47	-73.0	-9.4	06-22-85	2
Pine Spring	35 34 25	115 09 23	-88.0	-11.9	06-22-85	2
Ora Hana Spring	35 37 25	115 04 07	-72.0	-8.4	06-22-85	2
Saratoga Spring	35 40 53	116 25 18	-90.5	-10.8	04-23-82	1
McClanahan Spring	35 41 42	115 11 05	-67.0	-7.2	06-21-85	2
Test Hole A1-1 (505 feet)	35 45 28	115 15 05	-91.0	-9.3	--	2
Test Hole A1-1 (625 feet)	35 45 28	115 15 05	-94.0	-10.9	--	2
Test Hole A1-2 (408 feet)	35 46 04	115 15 46	-94.0	-12.4	--	2
Test Hole A1-2 (485 feet)	35 46 04	115 15 46	-95.0	-11.0	--	2
Test Hole A3-3 (580 feet)	35 47 16	115 20 39	-90.0	-10.7	--	2
Test Hole A3-3 (600 feet)	35 47 16	115 20 39	-87.0	-10.5	--	2
Test Hole A3-3 (740 feet)	35 47 16	115 20 39	-97.0	-13.6	--	2
Test Hole A3-3 (855 feet)	35 47 16	115 20 39	-89.0	-10.2	--	2
Test Hole A3-3 (890 feet)	35 47 16	115 20 39	-94.0	-11.2	--	2
Jean Prison Well	35 47 18	115 20 43	-94.0	-10.4	--	2
Jean Prison Well	35 47 18	115 20 43	-95.0	-12.1	06-21-85	2
Test Hole A3-2 (740 feet)	35 47 43	115 21 34	-93.0	-10.8	--	2
Test Hole A3-2 (840 feet)	35 47 43	115 21 34	-91.0	-11.5	--	2
Test Hole A3-1 (833 feet)	35 48 13	115 22 38	-89.0	-10.8	--	2
Test Hole A3-1 (903 feet)	35 48 13	115 22 38	-88.0	-10.5	--	2
Rosechrist Well	35 48 18	115 41 41	-94.0	-13.20	09-27-86	1
Castillo Well	35 50 02	115 26 09	-94.0	-12.8	06-21-85	2
Tecopa Hot Spring	35 52 19	116 13 50	-98.0	-12.85	06-30-85	1
Bird Spring	35 53 20	115 22 12	-88.0	-11.7	06-23-85	2
Arizona Seep Spring (Black Canyon #13)	35 55 42	114 42 20	-82.0	-10.0	01-00-81	9
Wilson's Tank	35 56 02	115 25 28	-87.5	-10.9	06-22-85	2
Bighorn Sheep Spring (Black Canyon #12)	35 56 22	114 44 06	-80.5	-10.2	01-00-81	9
Ringbolt Rapids Spring (Black Canyon #10)	35 57 39	114 43 26	-83.5	-11.1	03-00-82	9
Sky Harbor Airport	35 58 16	115 08 50	-95	-13.1	02-28-86	16
Shoshone Spring	35 58 48	116 16 23	-94.5	-12.9	04-25-82	1
Palm Tree Cold Spring (Black Canyon #7)	35 59 42	114 44 15	-82.0	-10.5	03-00-82	9
Tenaya Well	36 00 42	115 15 05	-92.0	-12.3	05-10-83	1
Showboat Country Club #2	36 02 51	115 04 48	-97	-13.3	02-27-86	16
Genstar Gypsum Plant	36 03 04	115 23 43	-86	-12.3	07-11-86	16
Flowing Well (DRI LG153)	36 03 22	115 03 08	-100.0	-12.9	05-11-83	1
Sandstone Spring #1	36 03 47	115 28 09	-89.0	-12.20	06-25-85	1
Sandstone Spring #1	36 03 47	115 28 09	-90.0	-12.7	06-25-85	2
Sunset Park Well	36 03 49	115 06 49	-94.0	-12.7	05-09-83	1
Gravel Pit Well	36 05 17	114 56 32	-76.0	-7.8	05-12-83	1
Spanish Trail Country Club Well	36 05 56	115 15 38	-89	-12.2	03-13-86	16
Stocks Mill & Supply Co. Well	36 06 07	115 15 46	-86	-12.4	03-13-86	16
Tropicana Country Club South #1	36 06 22	115 10 09	-95	-13.2	05-16-86	16
Sands Hotel And Casino #3	36 07 28	115 10 09	-98	-13.5	05-16-86	16
Sparklettes Drinking Water Co.	36 07 41	115 11 45	-99	-13.6	04-22-86	16
BLM Visitors Center	36 07 44	115 26 03	-89.0	-12.25	06-30-85	1
Las Vegas Country Club	36 08 20	115 08 49	-100	-13.7	07-08-86	16
Hartzski Well	36 08 36	115 15 47	-90	-12.4	03-04-86	16
Red Spring	36 08 40	115 25 10	-89.0	-12.25	06-26-85	1
Red Spring	36 08 40	115 25 10	-93.0	-12.2	06-26-85	2
Manse Well	36 09 17	115 53 42	-99.0	-13.55	06-27-85	1
Manse Spring	36 09 21	115 54 10	-97.0	--	08-00-68	3

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APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
Manse Spring	36 09 21	115 54 10	-101.0	--	03-00-70	3
DRI Well LG047	36 09 33	115 05 51	-101.0	-13.6	05-11-83	1
Shetland Mutual Water Users Association	36 09 39	115 10 33	-100	-13.5	03-06-86	16
LVVWD #1A	36 09 39	115 13 32	-94	-13.2	05-14-86	16
Willow Spring	36 09 41	115 29 51	-90.5	-12.3	06-26-85	1
LVVWD #11A	36 09 52	115 11 22	-97	-13.4	06-13-86	16
Kiup Spring	36 09 56	115 43 28	-93.0	-12.7	06-28-85	1
Cave Spring	36 09 58	115 35 52	-93.0	-12.8	06-28-85	1
Union Pacific Railroad Well #3	36 10 05	115 09 13	-100	-13.8	04-09-86	16
LVVWD #7A	36 10 06	115 11 23	-96	-13.2	06-17-86	16
Sky Mt. Resort	36 10 13	115 34 44	-96.5	-13.25	06-28-85	1
LVVWD #14	36 10 18	115 11 22	-97	-13.2	05-06-86	16
White Rock Spring	36 10 27	115 28 43	-91.0	-12.5	06-26-85	1
LVVWD #15A	36 10 31	115 11 23	-97	-13.8	05-14-86	16
LVVWD #34	36 10 31	115 11 06	-99	-13.6	05-16-86	16
LVVWD #16	36 10 31	115 11 39	-97	-13.6	06-04-86	16
LVVWD #17	36 10 31	115 11 39	-97	-13.5	06-04-86	16
LVVWD #18A	36 11 12	115 14 38	-94	-13.4	06-06-86	16
LVVWD #45	36 11 50	115 12 13	-101	-14.0	05-13-86	16
LVVWD #22A	36 12 05	115 15 43	-100	-14	03-27-79	2
NLVWD Robinson Well	36 12 17	115 11 41	-100	-14.1	06-03-86	16
Pahrump Spring Well	36 12 27	115 59 01	-97.0	-13.55	06-27-85	1
NLVWD West Cheyenne Well	36 12 38	115 11 21	-104.0	-13.5	05-10-83	1
NLVWD West Cheyenne Well	36 12 38	115 11 21	-100	-13.8	06-12-86	16
Nellis AFB #13	36 12 44	115 03 00	-98	-13.8	04-03-86	16
Trout Spring	36 13 22	115 40 59	-99	--	03-28-70	3
Trout Spring	36 13 22	115 40 59	-99.1	-14.1	06-04-73	4
Trout Spring	36 13 22	115 40 59	--	-13.8	09-07-73	4
Trout Spring	36 13 22	115 40 59	--	-13.8	11-14-73	4
Trout Spring	36 13 22	115 40 59	--	-13.7	03-25-74	4
Trout Spring	36 13 22	115 40 59	-98.4	-13.85	12-08-74	4
Trout Spring	36 13 22	115 40 59	-97.6	-13.30	05-01-75	4
Trout Spring	36 13 22	115 40 59	-96.2	-13.35	11-11-75	4
Trout Spring	36 13 22	115 40 59	-99.8	-14.02	02-16-76	4
Trout Spring	36 13 22	115 40 59	-98.6	-13.90	11-17-76	4
Trout Spring	36 13 22	115 40 59	-98.8	-14.10	03-08-77	4
Trout Spring	36 13 22	115 40 59	-99.0	-14.10	05-13-77	4
Trout Spring	36 13 22	115 40 59	-98.6	-13.45	11-19-77	4
Trout Spring	36 13 22	115 40 59	-96.0	-12.85	03-21-78	4
Trout Spring	36 13 22	115 40 59	-97.0	-12.90	05-08-78	4
Trout Spring	36 13 22	115 40 59	-96.0	-13.20	05-04-83	4
Trout Spring	36 13 22	115 40 59	-95.5	-13.05	05-16-83	4
Trout Spring	36 13 22	115 40 59	-99.5	-13.65	11-30-83	4
Trout Spring	36 13 22	115 40 59	-96.5	-13.65	03-19-84	4
Trout Spring	36 13 22	115 40 59	-97.0	-13.7	06-30-87	2
Trout Spring	36 13 22	115 40 59	-96.5	-13.70	03-24-88	4
Trout Spring	36 13 22	115 40 59	-97.0	-13.70	04-04-88	1
Trout Spring	36 13 22	115 40 59	-98.5	-13.70	12-11-88	1
Trout Spring	36 13 22	115 40 59	-97.0	-13.60	06-21-89	4
Well 5 Franklin Lake Nr Death Valley	36 14 06	116 17 32	-93.5	-11.1	11-21-83	1
Well 10 Franklin Lake Nr Death Valley	36 14 06	116 17 39	-91.0	-10.0	11-21-83	1
NLVWD Desert Aire Well	36 14 15	115 12 16	-102	-14.0	03-06-86	16
Lake Mead Base Well #3	36 14 21	115 00 16	-101.5	-13.80	09-29-86	1
Lake Mead Base Well #3	36 14 21	115 00 16	-103.0	-13.8	09-29-86	2

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APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
Craig Ranch Country Club #2	36 14 29	115 09 00	-106	-14.5	03-04-86	16
Rainbow Spring #2	36 14 36	115 37 55	-96.0	-12.4	08-19-82	2
Peak Spring Canyon Creek	36 14 40	115 43 09	-92.5	-13.10	09-27-86	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-93.5	-13.4	04-07-87	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-92.0	-13.0	06-09-87	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-92.5	-12.95	08-03-87	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-97.5	-13.5	11-10-87	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-98.0	-13.70	03-08-88	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-101.0	-13.85	04-05-88	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-98.5	-13.85	05-17-88	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-95.5	-13.60	06-23-88	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-95.5	-13.25	09-06-88	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-94.5	-13.30	10-18-88	1
Peak Spring Canyon Creek	36 14 40	115 43 09	-94.5	-13.45	11-25-88	1
GS-18 Franklin Lake Nr Death Valley	36 14 51	116 17 08	-66.5	-2.5	11-18-83	1
Nellis AFB Well #4	36 14 56	115 00 15	-95	-13.2	04-03-86	16
Well 13 Franklin Lake Nr Death Valley	36 14 57	116 18 34	-92.0	-11.3	11-17-83	1
Calnev Pipeline Well	36 14 59	115 02 39	-98.0	-13.1	00-00-86	1
GS-15 Franklin Lake Nr Death Valley	36 15 27	116 17 13	-66.0	-2.1	11-14-83	1
GS-15 Franklin Lake Nr Death Valley	36 15 27	116 17 13	-62.0	-1.5	10-20-84	1
Pat Well	36 15 45	115 19 37	-92.0	-12.9	03-31-87	2
Echo Spring	36 15 55	115 39 29	-94.5	-12.8	04-16-80	2
GS-4 Franklin Lake Nr Death Valley	36 16 00	116 16 22	-93.5	-10.4	11-16-83	1
GS-4 Franklin Lake Nr Death Valley	36 16 00	116 16 22	-93.5	-10.3	10-18-84	1
Highway Maintenance Well	36 16 17	115 35 38	-96.0	-12.2	08-19-82	2
GS-12 Franklin Lake Nr Death Valley	36 16 35	116 17 21	-76.0	-6.6	11-14-83	1
GS-12 Franklin Lake Nr Death Valley	36 16 35	116 17 21	-77.0	-6.7	10-27-84	1
Taylor's Steak House Rest.	36 17 08	115 14 41	-101	-13.7	11-03-86	16
Martin Well	36 17 25	115 14 35	-100.0	-13.4	06-30-85	2
GS-8 Franklin Lake Nr Death Valley	36 17 27	116 17 09	-100.0	-12.9	11-19-83	1
Grapevine Springs	36 18 03	115 29 25	-91.0	-11.6	06-28-85	2
Grapevine Springs	36 18 03	115 29 25	-92.0	-13.2	07-09-87	2
Deer Creek Spring #1	36 18 27	115 38 13	-97.0	-14.1	06-28-85	2
Deer Creek Spring #1	36 18 27	115 38 13	-100.0	-14.0	03-30-87	2
Deer Creek Spring #2	36 18 27	115 37 37	-98.0	-13.45	06-28-85	2
Racel Well	36 18 40	115 15 39	-99.0	-13.3	05-10-83	1
Gilbert Well	36 18 45	115 25 06	-98.0	-12.7	08-20-82	2
Well 15 Franklin Lake Nr Death Valley	36 18 51	116 16 60	-98.0	-12.7	11-21-83	1
Stewart Well	36 19 10	115 40 20	-100	-13.4	06-24-86	2
Tule Spring State Park Well	36 19 14	115 16 00	-100.0	--	01-00-69	3
Tule Spring State Park Well	36 19 14	115 16 00	-100.0	-11.5	08-20-82	2
Tule Spring State Park Well	36 19 14	115 16 00	-99.0	-13.4	06-30-85	2
Clark Spring	36 19 14	115 43 15	-93.5	-12.9	06-29-85	1
Clark Spring	36 19 14	115 43 15	-99.0	-13.7	06-24-87	1
Mulder Well	36 19 25	115 13 22	-97.0	-13.2	06-25-86	2
Mifflin Well	36 19 32	115 25 23	-100	-12.6	08-20-82	2
Lee's Oasis Well	36 19 48	115 18 55	-98.0	-13.4	06-24-86	2
Holland Well	36 20 00	115 17 00	-98.0	-12.6	08-20-82	2
Summer Homes Well	36 20 06	115 39 18	-99.5	-13.80	09-26-86	1
Summer Homes Well	36 20 06	115 39 18	-101.0	-13.5	09-26-86	2

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APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
G.P. Apex Well	36 20 28	114 55 36	-97.5	-13.35	09-29-86	1
G.P. Apex Well	36 20 28	114 55 36	-98.0	-13.45	09-30-86	1
G.P. Apex Well	36 20 28	114 55 36	-96.0	-13.8	09-30-86	2
Cortney Well	36 20 42	115 20 52	-96.0	-12.1	08-21-82	2
Adams Well	36 20 47	115 19 50	-98.0	-12.7	08-20-82	2
Paiute Indian Reservation Well	36 21 02	115 20 33	-98.0	-14.0	08-21-86	2
Big Spring	36 22 30	116 16 25	-104.0	--	01-00-69	3
Big Spring	36 22 30	116 16 25	-104.0	--	03-00-70	3
Big Spring	36 22 30	116 16 25	-102.0	-13.4	05-24-73	6
Big Spring	36 22 30	116 16 25	-102.0	--	03-09-75	6
Rogers Spring	36 22 39	114 26 38	-92.0	-12.2	07-21-81	1
Grace Petroleum Arrow Canyon Water Well	36 22 58	114 54 60	-96.0	-13.7	04-26-82	1
Blue Point Spring	36 23 21	114 25 26	-93.5	-12.50	07-01-85	1
Blue Point Spring (Duplicate Sample)	36 23 21	114 25 26	-92.5	-12.35	07-01-85	1
Blue Point Spring	36 23 21	114 25 26	-93.0	-12.4	06-24-85	2
Genstar Well	36 23 29	114 54 14	-97.0	-13.05	03-31-86	1
Point of Rocks (King) Spring	36 24 05	116 16 14	-106.5	--	08-00-68	3
Point of Rocks (King) Spring	36 24 05	116 16 14	-101.0	--	01-00-69	3
Point of Rocks (King) Spring	36 24 05	116 16 14	-104.0	--	03-00-70	3
Point of Rocks (King) Spring	36 24 05	116 16 14	-104.0	--	03-03-75	6
Point Of Rocks (King) Spring	36 24 05	116 16 14	-102.0	-13.6	03-09-81	1
Cold Creek Spring	36 24 50	115 44 20	-97	--	08-24-68	3
Cold Creek Spring	36 24 50	115 44 20	-102	--	01-27-69	3
Cold Creek Spring	36 24 50	115 44 20	-103	--	03-30-70	3
Cold Creek Spring	36 24 50	115 44 20	-99.1	-14.1	05-31-73	4
Cold Creek Spring	36 24 50	115 44 20	-98.4	-14.2	08-29-73	4
Cold Creek Spring	36 24 50	115 44 20	--	-13.8	11-13-73	4
Cold Creek Spring	36 24 50	115 44 20	--	-13.9	04-04-74	4
Cold Creek Spring	36 24 50	115 44 20	-100.4	-13.80	12-09-74	4
Cold Creek Spring	36 24 50	115 44 20	-100.0	-13.75	04-28-75	4
Cold Creek Spring	36 24 50	115 44 20	-98.0	-13.30	11-10-75	4
Cold Creek Spring	36 24 50	115 44 20	-100.4	-13.95	11-16-76	4
Cold Creek Spring	36 24 50	115 44 20	-100.7	-14.20	02-17-77	4
Cold Creek Spring	36 24 50	115 44 20	-101.8	-14.15	05-12-77	4
Cold Creek Spring	36 24 50	115 44 20	-101.5	-13.85	11-18-77	4
Cold Creek Spring	36 24 50	115 44 20	-99.5	-13.15	03-20-78	4
Cold Creek Spring	36 24 50	115 44 20	-98.5	-13.15	05-06-78	4
Cold Creek Spring	36 24 50	115 44 20	-102.5	-14.00	12-04-82	4
Cold Creek Spring	36 24 50	115 44 20	-100.5	-13.75	05-02-83	4
Cold Creek Spring	36 24 50	115 44 20	-100.5	-13.65	05-15-83	4
Cold Creek Spring	36 24 50	115 44 20	-99.5	-13.85	12-12-83	4
Cold Creek Spring	36 24 50	115 44 20	-99.0	-13.8	03-31-87	2
Cold Creek Spring	36 24 50	115 44 20	-100.0	-13.75	04-05-88	1
Willow Spring	36 25 00	115 45 47	-97.0	-13.9	06-02-73	5
Willow Spring	36 25 00	115 45 47	-98.0	-13.4	06-26-85	2
Willow Spring	36 25 00	115 45 47	-98.0	-13.60	04-05-88	1
Young Well	36 25 11	115 22 58	-93.0	-12.80	09-25-86	1
Crystal Pool Spring	36 25 14	116 19 21	-106.5	--	08-00-68	3
Crystal Pool Spring	36 25 14	116 19 21	-103.0	--	01-00-69	3
Crystal Pool Spring	36 25 14	116 19 21	-104.0	--	03-00-70	3

APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
Crystal Pool Spring	36 25 14	116 19 21	-102.0	-13.7	05-24-73	6
Crystal Pool Spring	36 25 14	116 19 21	-104.0	--	03-04-75	6
Brooks Well	36 25 20	115 22 40	-93.0	-12.7	06-24-86	2
Valley of Fire Well	36 25 21	114 32 52	-82.0	-10.6	06-24-85	2
Shown Well	36 25 31	115 22 44	-94.0	-13.00	09-25-86	1
Amargosa Well #20 (Ash Tree Spring)	36 25 35	116 24 32	-102.0	-12.4	03-06-74	8
Scruggs Spring	36 25 59	116 18 28	-103.0	--	03-10-75	6
Corn Creek Spring Well	36 26 20	115 21 26	-95.0	--	01-00-69	3
Corn Creek Spring Well	36 26 20	115 21 26	-94.0	--	03-00-70	3
Corn Creek Spring	36 26 20	115 21 26	-96.0	-13.0	06-29-85	2
Corn Creek Spring	36 26 20	115 21 26	-93.0	-12.85	09-25-86	1
Corn Creek Spring	36 26 20	115 21 26	-93.0	-12.9	06-17-87	1
Corn Creek Spring	36 26 20	115 21 26	-93.5	-12.9	01-05-88	1
Travertine Spring	36 26 27	116 49 49	-105.5	--	03-00-70	3
Travertine Spring	36 26 27	116 49 49	-102.0	-13.7	04-22-82	1
Big Timber Spring	36 26 42	115 55 37	-93.0	-13.3	06-27-85	2
Dry Lake Valley Well	36 27 18	114 50 38	-97.5	-13.30	07-01-85	1
Grapevine Springs	36 27 27	116 01 35	-92.5	-12.75	06-28-85	1
Texas Spring	36 27 28	116 50 11	-105.0	--	03-00-70	3
Texas Spring	36 27 28	116 50 11	-102.0	-13.7	04-22-82	1
Corn Creek Well	36 27 53	115 23 54	-95.5	-13.55	12-02-86	2
Longstreet Spring	36 28 03	116 19 31	-103.0	--	03-10-75	6
Silver Flag Alpha Well	36 28 34	115 26 45	-99.0	-13.7	12-18-87	2
Rogers Spring	36 28 46	116 19 31	-102.0	--	03-09-75	6
Amargosa Well #18	36 29 04	116 28 08	-102.0	-13.0	03-06-74	8
Fairbanks Spring	36 29 25	116 20 29	-103.0	--	08-00-68	3
Fairbanks Spring	36 29 25	116 20 29	-103.0	--	01-00-69	3
Fairbanks Spring	36 29 25	116 20 29	-104.0	--	03-00-70	3
Fairbanks Spring	36 29 25	116 20 29	-103.0	-13.6	05-23-73	6
Amargosa Well #17	36 29 38	116 27 00	-105.0	-12.8	03-01-74	8
Amargosa Well #16	36 29 38	116 30 01	-104.0	-12.7	03-01-74	8
Amargosa Well #15	36 30 28	116 30 25	-104.0	-13.0	03-05-74	8
Nevares Spring	36 30 44	116 49 14	-105.5	--	03-00-70	3
Nevares Spring	36 30 44	116 49 14	-104.0	-13.6	04-22-82	1
Divide Well	36 30 45	115 28 05	-98.0	-13.7	07-26-87	2
Indian Springs Prison Well #1	36 30 52	115 33 15	-102.0	-13.7	06-26-85	2
Amargosa Well #30	36 31 24	116 24 02	-104.0	-13.7	06-24-79	8
Amargosa Well #14	36 31 28	116 30 24	-98.5	-12.6	03-04-74	8
Mathew's Well	36 31 32	116 24 00	-104.0	-13.7	05-11-81	1
Old Dry Well	36 31 35	115 28 13	-95.0	-13.2	12-19-87	2
Alpha Post Well	36 32 06	115 33 55	-98.0	-13.2	06-23-86	2
South Black Hills Well	36 32 12	115 24 03	-87.0	-12.10	08-05-87	1
South Black Hills Well	36 32 12	115 24 03	-88	-11.9	08-05-87	2
Amargosa Well #13	36 32 19	116 30 24	-102.0	-13.0	03-05-74	8
Amargosa Well #21	36 32 48	116 25 07	-99.0	-13.2	06-25-79	8
Amargosa Well #11	36 32 49	116 29 19	-101.0	-13.1	03-05-74	8
Rancho Amargosa Well	36 32 52	116 32 30	-99.0	-11.9	05-12-81	1
South Hidden Valley Well	36 33 08	114 55 30	-90.5	-11.20	03-28-86	1
Amargosa Well #10	36 33 13	116 28 12	-97.5	-13.2	06-26-79	8
Amargosa Well #9	36 33 16	116 29 45	-102.0	-12.6	03-01-74	8

APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
Albitre Well (Formerly Thiede's Well)	36 33 20	116 28 09	-97.5	-11.6	05-06-81	1
Amargosa Well #50	36 33 25	116 35 50	-104.0	-13.6	06-25-79	8
Indian Springs #2	36 33 54	115 40 06	-98.0	--	08-00-68	3
Indian Springs #2	36 33 54	115 40 06	-100.0	--	01-00-69	3
Indian Springs #2	36 33 54	115 40 06	-101.0	--	03-00-70	3
Indian Springs #2	36 33 54	115 40 06	-93.0	-11.9	06-23-86	2
Indian Springs #2	36 33 54	115 40 06	-97.0	-12.9	06-18-87	1
Indian Springs #2	36 33 54	115 40 06	-101.5	-13.7	01-04-88	1
Indian Springs #1	36 33 56	115 40 06	-96.5	-12.7	06-18-87	1
Indian Springs #1	36 33 56	115 40 06	-101.0	-13.7	01-04-88	1
Indian Springs #3	36 33 56	115 40 05	-93.5	-12.6	06-18-87	1
Indian Springs #3	36 33 56	115 40 05	-100.0	-13.5	01-04-88	1
Amargosa Well #23	36 33 58	116 32 37	-103.0	-13.4	03-31-71	8
Amargosa Well #29	36 33 59	116 26 12	-105.0	-13.8	03-31-71	8
Nichols' Well	36 34 05	116 32 40	-103.0	-13.0	05-06-81	1
Amargosa Well #8	36 34 10	116 27 35	-103.0	-13.4	03-01-74	8
Amargosa Well #25	36 34 24	116 33 25	-102.0	-13.4	03-31-71	8
Cook's Well	36 34 25	116 23 50	-104.0	-13.4	05-08-81	1
Fox Well (Formerly Kirker's Well)	36 34 25	116 33 20	-101.0	-12.2	05-10-81	1
Amargosa Well #27	36 34 37	116 25 19	-105.0	-13.8	04-01-71	8
Indian Springs AFB Well #1	36 34 47	115 40 47	-96.0	-13.0	06-27-85	2
Amargosa Well #47	36 34 49	116 36 38	-102.0	-13.1	03-31-71	8
Amargosa Well #5	36 34 56	116 28 41	-99.5	-13.2	11-17-72	8
Cow Camp Spring	36 35 01	115 18 26	-90.5	-12.6	10-28-81	1
Cow Camp Spring	36 35 01	115 18 26	-93.0	-12.6	05-10-83	1
Amargosa Well #4	36 35 28	116 28 42	-103.0	-13.2	03-04-74	8
Army Well No. 1	36 35 30	116 02 14	-104.0	--	01-00-69	3
Army Well No. 1	36 35 30	116 02 14	-103.0	--	03-00-70	3
Amargosa Well #3	36 37 18	116 26 32	-102.0	-12.8	11-20-72	8
Wiregrass Spring	36 38 00	115 12 29	-94.0	-12.8	10-28-81	1
Wiregrass Spring	36 38 00	115 12 29	-96.0	-12.7	05-11-83	1
Wiregrass Spring	36 38 00	115 12 29	-94.0	-12.85	10-09-86	1
Wiregrass Spring	36 38 00	115 12 29	-94.0	-12.9	10-09-86	2
Wiregrass Spring	36 38 00	115 12 29	-91.5	-12.80	03-20-87	1
Wiregrass Spring	36 38 00	115 12 29	-92.0	-12.50	06-17-87	1
Wiregrass Spring	36 38 00	115 12 29	-94.0	-12.8	08-04-87	1
Wiregrass Spring	36 38 00	115 12 29	-97.0	-12.8	01-05-88	1
Wiregrass Spring	36 38 00	115 12 29	-95.5	-12.95	04-06-88	1
Wiregrass Spring	36 38 00	115 12 29	-94.5	-12.85	12-12-88	1
Juanita Spring	36 38 13	114 14 51	-87.0	-11.65	01-25-86	1
Wamp Spring	36 38 30	115 04 12	-81.0	-10.60	03-20-87	1
Mormon Well Spring	36 38 38	115 05 52	-92.5	-12.9	10-27-81	1
Mormon Well Spring	36 38 38	115 05 52	-91.0	-12.5	05-09-83	1
Mormon Well Spring	36 38 38	115 05 52	-92.0	-12.6	10-07-87	1
Weiser Wash EH-2 (235 feet)	36 38 50	114 38 55	-70.0	-6.7	10-05-85	13
Weiser Wash EH-2 (255 feet)	36 38 50	114 38 55	-69.0	--	10-05-85	13
Weiser Wash EH-2 (295 feet)	36 38 50	114 38 55	-71.0	--	10-05-85	13
Weiser Wash EH-2 (335 feet)	36 38 50	114 38 55	-79.0	-9.3	10-05-85	13
Weiser Wash EH-2 (375 feet)	36 38 50	114 38 55	-86.0	--	10-05-85	13
Weiser Wash EH-2 (395 feet)	36 38 50	114 38 55	-97.0	--	10-05-85	13

APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
Weiser Wash EH-2 (415 feet)	36 38 50	114 38 55	-101.0	--	10-05-85	13
Weiser Wash EH-2 (495 feet)	36 38 50	114 38 55	-97.0	--	10-05-85	13
Weiser Wash EH-2 (535 feet)	36 38 50	114 38 55	-99.0	-12.9	10-06-85	13
Weiser Wash EH-2 (555 feet)	36 38 50	114 38 55	-100.0	--	10-06-85	13
Weiser Wash EH-2 (655 feet)	36 38 50	114 38 55	-103.0	-13.0	10-06-85	13
Weiser Wash EH-2 (675 feet)	36 38 50	114 38 55	-105.0	-14.3	10-06-85	13
Weiser Wash EH-2 (715 feet)	36 38 50	114 38 55	-102.0	--	10-00-85	13
Weiser Wash EH-2 (735 feet)	36 38 50	114 38 55	-102.0	--	10-00-85	13
Weiser Wash EH-2 (755 feet)	36 38 50	114 38 55	-96.5	--	10-00-85	13
Weiser Wash EH-2 (775 feet)	36 38 50	114 38 55	-102.0	--	10-00-85	13
Weiser Wash EH-2 (795 feet)	36 38 50	114 38 55	-101.0	--	10-00-85	13
Weiser Wash EH-2 (815 feet)	36 38 50	114 38 55	-99.5	--	10-00-85	13
Weiser Wash EH-2 (835 feet)	36 38 50	114 38 55	-92.0	--	10-00-85	13
Weiser Wash EH-2 (875 feet)	36 38 50	114 38 55	-101.5	-13.4	10-08-85	13
Weiser Wash EH-2 (895 feet)	36 38 50	114 38 55	-99.0	--	10-00-85	13
Weiser Wash EH-2 (955 feet)	36 38 50	114 38 55	-102.0	--	10-00-85	13
Weiser Wash EH-2 (981 feet)	36 38 50	114 38 55	-98.0	--	10-00-85	13
Weiser Wash EH-2 (997 feet)	36 38 50	114 38 55	-104.0	--	10-00-85	13
Weiser Wash EH-2 (1,017 feet)	36 38 50	114 38 55	-90.0	--	10-00-85	13
Weiser Wash EH-2 (1,055 feet)	36 38 50	114 38 55	-96.5	--	10-00-85	13
Weiser Wash EH-2 (1,075 feet)	36 38 50	114 38 55	-92.0	--	10-00-85	13
Weiser Wash EH-2 (1,095 feet)	36 38 50	114 38 55	-99.0	-12.1	10-14-85	13
Weiser Wash EH-1 (drilling water)	36 39 37	114 37 52	-97.0	-13.0	--	13
Weiser Wash EH-1 (105 feet)	36 39 37	114 37 52	-95.0	--	10-00-85	13
Weiser Wash EH-1 (135 feet)	36 39 37	114 37 52	-98.0	-13.0	10-02-85	13
Weiser Wash EH-1 (175 feet)	36 39 37	114 37 52	-95.0	--	10-00-85	13
Weiser Wash EH-1 (215 feet)	36 39 37	114 37 52	-95.0	--	10-00-85	13
Weiser Wash EH-1 (235 feet)	36 39 37	114 37 52	-94.0	--	10-00-85	13
Weiser Wash EH-1 (255 feet)	36 39 37	114 37 52	-96.0	--	10-00-85	13
Weiser Wash EH-1 (295 feet)	36 39 37	114 37 52	-96.0	-13.4	10-03-85	13
Weiser Wash EH-7 (175 feet)	36 40 14	114 31 53	-91.5	-12.3	04-05-86	13
Weiser Wash EH-7 (305 feet)	36 40 14	114 31 53	-90.0	-13.5	04-06-86	13
Weiser Wash EH-7 (405 feet)	36 40 14	114 31 53	-92.0	-12.5	04-09-86	13
Weiser Wash EH-7 (505 feet)	36 40 14	114 31 53	-93.5	-12.2	04-09-86	13
Weiser Wash EH-7 (615 feet)	36 40 14	114 31 53	-96.0	-13.1	04-00-86	13
Weiser Wash EH-7 (USGS composite sample)	36 40 14	114 31 53	-91.0	-12.45	03-19-87	1
Keane Wonder Spring	36 40 25	116 55 11	-99.5	-13.0	04-23-82	1
Weiser Wash EH-8 (drilling water)	36 40 26	114 34 33	-94.0	-12.1	05-10-86	13
Weiser Wash EH-8 (115 feet)	36 40 26	114 34 33	-90.0	-12.5	05-10-86	13
Weiser Wash EH-8 (175 feet)	36 40 26	114 34 33	-92.0	-12.5	05-10-86	13
Weiser Wash EH-8 (195 feet)	36 40 26	114 34 33	-97.0	-13.7	05-10-86	13
Weiser Wash EH-8 (225 feet)	36 40 26	114 34 33	-97.0	-13.8	05-10-86	13
Weiser Wash EH-8 (244 feet)	36 40 26	114 34 33	-96.0	-13.6	05-10-86	13
Sawmill Spring (Sheep Range)	36 40 50	115 10 34	-92.0	-12.85	05-19-88	1
Weiser Wash EH-6 (85 feet)	36 40 54	114 34 12	-86.0	-11.3	03-24-86	13
Weiser Wash EH-6 (145 feet)	36 40 54	114 34 12	-94.5	-12.8	03-24-86	13
Weiser Wash EH-6 (295 feet)	36 40 54	114 34 12	-105.0	-14.3	03-25-86	13
Weiser Wash EH-6 (304 feet)	36 40 54	114 34 12	-99.0	-12.3	03-25-86	13
Weiser Wash EH-6 (335 feet)	36 40 54	114 34 12	-99.0	-14.6	03-26-86	13
Weiser Wash EH-6 (455 feet)	36 40 54	114 34 12	-100.0	-13.1	03-26-86	13

APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
CSV-3 Well	36 41 27	114 55 30	-75.0	-10.3	10-07-87	1
Weiser Wash EH-3 (295 feet)	36 41 32	114 31 32	-92.0	-12.1	02-02-86	13
Weiser Wash EH-3 (355 feet)	36 41 32	114 31 32	-90.0	-12.7	02-02-86	13
Weiser Wash EH-3 (455 feet)	36 41 32	114 31 32	-90.0	-12.2	02-02-86	13
Weiser Wash EH-3 (545 feet)	36 41 32	114 31 32	-93.0	-13.4	02-02-86	13
Weiser Wash EH-3 (795 feet)	36 41 32	114 31 32	-91.0	-13.2	02-05-86	13
Weiser Wash EH-4 (165 feet)	36 42 23	114 42 58	-100.0	-13.2	03-18-86	13
Weiser Wash EH-4 (285 feet)	36 42 23	114 42 58	-96.0	-12.8	03-18-86	13
White Rock Spring	36 42 30	115 14 20	-82.0	-9.9	10-29-81	1
White Rock Spring	36 42 30	115 14 20	-85.0	-9.8	05-10-83	1
Pederson's Warm Spring (M-13)	36 42 36	114 42 54	-98.0	--	01-00-69	3
Pederson's Warm Spring (M-13)	36 42 36	114 42 54	-97.0	--	03-00-70	3
Pederson's Warm Spring (M-13)	36 42 36	114 42 54	-97.0	-12.75	10-30-85	1
Iverson's Spring	36 42 37	114 42 43	-97.0	--	03-00-70	3
Spring Feeding Moapa	36 42 53	114 43 05	-97.0	--	03-00-70	3
Big Muddy Spring Area (M-8)	36 43 15	114 43 39	-99.0	-12.75	10-30-85	1
Big Muddy Spring	36 43 20	114 42 48	-98.0	--	03-00-70	3
Big Muddy Spring	36 43 20	114 42 48	-96.5	-12.9	07-22-81	1
Big Muddy Spring	36 43 20	114 42 48	-98.0	-12.75	10-30-85	1
Big Muddy Spring	36 43 20	114 42 48	-99.0	-13.0	01-07-88	1
Big Muddy Spring	36 43 20	114 42 48	-98.0	-14.0	--	2
Big Muddy Spring Area (M-9)	36 43 33	114 43 38	-96.5	-12.45	10-30-85	1
Weiser Wash EH-5A (65 feet)	36 43 58	114 44 36	-99.0	-13.1	03-05-86	13
Weiser Wash EH-5A (205 feet)	36 43 58	114 44 36	-98.0	-12.9	03-05-86	13
Weiser Wash EH-5A (265 feet)	36 43 58	114 44 36	-107.0	-13.7	03-12-86	13
Well J-12 (NTS)	36 45 54	116 23 24	-99.0	--	01-00-69	3
Well J-12 (NTS)	36 45 54	116 23 24	-97.5	-12.8	03-26-71	10
Nuclear Engr. Co. Well	36 45 58	116 41 10	-108.5	--	12-00-68	3
ERTEC MX-6 Well	36 46 04	114 47 13	-97.0	-12.95	09-28-86	1
ERTEC MX-6 Well	36 46 04	114 47 13	-99.0	-13.1	09-28-86	2
CSV-2 Well	36 46 50	114 43 20	-98.0	-12.85	01-26-86	1
USW VH-1 (Amargosa Well #55)	36 47 32	116 33 07	-108.0	-14.2	02-11-81	10
ERTEC MX-4 Well	36 47 44	114 53 32	-102.5	-13.0	12-23-80	1
ERTEC MX-5 Well	36 47 44	114 53 32	-99.5	-12.9	07-22-81	1
Well 5B	36 48 05	115 58 08	-106.5	--	01-00-69	3
Well J-13	36 48 29	116 23 40	-97.5	-13.0	03-26-71	10
Railroad Well Farrier	36 48 49	114 39 14	-97.5	-12.5	02-04-84	1
Sand Spring	36 49 30	115 34 05	-88	-11.9	01-03-88	2
UE-25P-1	36 49 38	116 25 21	-107.5	-13.7	02-11-83	11
UE-25P-1	36 49 38	116 25 21	-106.0	-13.8	05-12-83	11
USW H-3	36 49 42	116 27 60	-101.0	-13.9	03-13-84	1
UE-25C-1	36 49 47	116 25 43	-102.0	-13.5	09-30-83	1
UE-25C-2	36 49 47	116 25 43	-101.0	-13.4	03-13-84	1
UE-25C-3	36 49 47	116 25 43	-103.0	-13.5	05-09-84	1
USW H-4	36 50 32	116 26 54	-104.0	-14.0	05-17-82	10
USW H-6	36 50 49	116 28 55	-106.0	-13.8	10-16-82	10
Tim Spring	36 50 58	115 34 10	-99	-13.2	01-02-88	2
UE-25B-1 (Amargosa Well #57)	36 51 08	116 26 23	-99.5	-13.4	08-07-81	10
UE-25B-1 (Amargosa Well #57)	36 51 08	116 26 23	-101.0	-13.4	09-01-81	10
UE-25B-1 (Amargosa Well #57)	36 51 08	116 26 23	-99.5	-13.5	07-20-82	10

APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
USW G-4	36 51 14	116 27 04	-103.0	-13.8	12-09-82	10
USW H-5	36 51 22	116 27 55	-102.0	-13.6	07-03-82	10
USW H-5	36 51 22	116 27 55	-102.0	-13.6	07-26-82	10
USW H-1 (Amargosa Well #56)	36 51 58	116 27 12	-102.0	-13.4	10-01-80	8
USW H-1 (Amargosa Well #56)	36 51 58	116 27 12	-103.0	-13.4	10-20-80	10
USW H-1 (Amargosa Well #56)	36 51 58	116 27 12	-101.0	-13.5	12-08-80	10
Dejesus Spring	36 52 28	115 34 45	-100	-13.1	05-09-87	2
VF-2 Well	36 52 30	114 56 44	-101.0	-12.95	02-05-86	1
VF-2 Well	36 52 30	114 56 44	-101.0	-13.1	01-06-88	1
VF-1 Well	36 52 32	114 55 44	-94.0	-12.6	01-06-88	1
Well 12S/47E/19ADC	36 52 41	116 45 19	-104.0	-13.3	--	7
Well 12S/47E/20BBB	36 53 01	116 45 02	-106.0	-13.6	--	7
Littlefield Road-Cut Spring	36 53 42	113 54 54	-97.5	-12.8	07-01-88	1
Sheep Spring (Sheep Range)	36 53 42	115 06 53	-96.0	-13.35	05-19-88	1
Well 12S/47E/7DBA	36 54 19	116 45 26	-108.0	-13.9	--	7
Well 12S/47E/6CDD	36 54 52	116 45 42	-102.0	-13.3	--	7
Hackberry Spring	36 55 04	114 26 16	-87.0	-12.3	02-05-84	1
Well C-1	36 55 07	116 00 34	-110.5	--	01-00-69	3
Well 11S/47E/32DDA	36 55 52	116 44 03	-102.0	-13.4	--	7
Horse Spring	36 56 29	114 26 47	-89.0	-12.7	02-05-84	1
UE-29A-2	36 56 29	116 22 26	-93.5	-12.8	01-08-82	10
UE-29A-2	36 56 29	116 22 26	-93.0	-12.8	01-15-82	10
UE-29A-1	36 56 29	116 22 26	-92.0	-12.1	01-29-82	1
Lamb Spring (Sheep Range)	36 56 42	115 06 21	-92.5	-13.15	05-19-88	1
Well 11S/47E/28DAC	36 56 53	116 43 06	-109.0	-14.1	--	7
Well 11S/47E/28ACC	36 57 07	116 43 22	-108.0	-14.1	--	7
Desert Dry Lake Well	36 57 11	115 11 51	-98.0	-13.10	03-18-87	1
Peach Spring	36 57 16	114 17 23	-76.5	-10.4	02-06-84	1
Gourd Spring	36 57 31	114 17 30	-77.5	-10.6	02-06-84	1
Well 11S/47E/21DBB	36 57 55	116 43 22	-108.0	-14.0	--	7
Davies Spring	36 57 56	114 30 07	-89.0	-12.5	02-06-84	1
Well 11S/47E/16DCA	36 58 36	116 43 13	-110.0	--	--	7
Quartz Spring	36 59 10	115 36 00	-88	-11.6	01-02-88	2
Well 11S/47E/5CDA	37 00 25	116 44 35	-108.0	-14.1	--	7
Well 11S/47E/4CAD	37 00 32	116 43 29	-108.0	-14.0	--	7
Well 10S/47E/33AAB	37 01 59	116 42 29	-108.0	-14.0	--	7
Well 10S/47E/31AAB	37 01 59	116 45 06	-102.0	-13.3	--	7
UE-16F	37 02 09	116 09 25	-105.0	-14.9	09-25-77	12
Well 10S/47E/27CBA	37 02 26	116 41 39	-110.0	-14.3	--	7
Well 10S/47E/30BBC	37 02 45	116 46 05	-102.0	-13.4	--	7
Well 10S/47E/14BAB	37 04 37	116 37 40	-112.0	-14.5	--	7
Willow Spring KSV-1	37 05 34	114 49 52	-88.0	-11.6	02-03-84	1
Grapevine Spring KSV-2	37 08 08	114 42 02	-87.5	-12.0	02-03-84	1
Well #8 (NTS) (Amargosa Well #64)	37 09 56	116 17 21	-104.0	-13.0	03-24-71	8
Snow Spring	37 10 49	114 07 53	-79.5	-10.0	11-13-86	1
Jensen Well	37 11 03	114 27 52	-88.5	-11.6	04-10-85	1
Maynard Lake Spring	37 11 30	115 02 02	-94.0	-12.3	01-14-85	2
Lone Tree Spring	37 12 07	115 03 32	-89.5	-10.9	01-14-85	2
U-20A2	37 14 34	116 25 51	-114.0	-14.8	--	7,14
Kane Spring KSV-3	37 14 46	114 42 21	-86.5	-11.9	02-02-84	1
Boulder Spring KSV-4	37 16 12	114 38 44	-87.0	-12.6	02-02-84	1
Irrigation Well	37 16 46	115 07 11	-91	--	--	15
UE-19E	37 17 50	116 19 59	-109.5	-14.0	--	7,14
UE-19GS	37 18 30	116 21 53	-113.5	-14.5	--	7,14
Randono Well	37 19 26	114 30 08	-87.5	-11.7	02-03-84	1

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APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
Cane Spring	37 20 27	115 44 50	-88	-9.5	05-15-85	2
Bradshaw Well	37 20 57	114 32 38	-88.5	-11.4	02-01-84	1
Stock Well	37 20 58	114 45 30	-88	--	--	15
Railroad Well	37 21 04	114 32 02	-86.0	-11.6	01-31-84	1
Upper Riggs Spring	37 22 06	114 38 52	-88.0	-11.9	02-02-84	1
Sheep Spring	37 24 02	114 16 37	-87.0	-12.0	06-03-85	1
Cattle Spring	37 24 57	115 45 05	-85	-9.4	05-15-85	2
Bishop Spring	37 25 07	114 38 26	-85.5	-11.7	02-02-84	1
Rock Spring	37 25 53	115 41 23	-86	-10.9	05-15-85	2
Quail Spring	37 26 29	115 41 01	-92	-11.9	05-15-85	2
Hells Acre Gulch Spring	37 27 37	115 07 29	-93.0	-12.3	01-14-85	2
Ash Spring	37 27 49	115 11 34	-107.0	--	08-00-68	3
Ash Spring	37 27 49	115 11 34	-109.0	--	01-00-69	3
Ash Spring	37 27 49	115 11 34	-112.0	--	03-00-70	3
Ash Spring	37 27 49	115 11 34	-108.0	-14.1	07-20-81	1
Ash Spring	37 27 49	115 11 34	-108	-12.3	--	2
Indian Spring	37 27 50	115 44 28	-88	-10.4	05-15-85	2
Rabbitbrush Spring	37 28 56	115 41 28	-89	-11.2	05-14-85	2
Bullwhack Spring	37 29 45	115 45 47	-88	-10.2	05-17-85	2
North Ella Spring	37 29 57	114 27 09	-86.5	-11.6	06-03-85	1
Ramone Mathews Well	37 31 36	114 14 39	-92.0	-12.3	06-03-85	1
Crystal Spring	37 31 53	115 13 58	-109.0	--	08-00-68	3
Crystal Spring	37 31 53	115 13 58	-110.0	--	01-00-69	3
Crystal Spring	37 31 53	115 13 58	-109.0	--	03-00-70	3
Crystal Spring	37 31 53	115 13 58	-109.0	-14.3	07-20-81	1
Crystal Spring	37 31 53	115 13 58	-110	--	--	2
April Fool Spring	37 32 14	115 44 19	-89	-10.7	05-16-85	2
Grassy Spring	37 32 28	114 47 27	-85.0	-10.9	01-14-85	2
Acoma Well	37 32 55	114 10 23	-95.0	-12.6	06-03-85	1
Meadow V. Wash Below Caliente	37 33 27	114 33 54	-93.5	-12.3	11-13-86	1
Hiko Spring	37 36 34	115 12 51	-111.0	--	08-00-68	3
Hiko Spring	37 36 34	115 12 51	-110.0	--	01-00-69	3
Hiko Spring	37 36 34	115 12 51	-110.0	--	03-00-70	3
Hiko Spring	37 36 34	115 12 51	-110.0	-15.3	01-14-85	2
Hiko Spring (Duplicate Sample)	37 36 34	115 12 51	-105.0	-14.0	01-14-85	2
Clover Creek	37 36 47	114 28 21	-87.5	-11.8	11-13-86	1
Caliente City Well	37 36 57	114 30 48	-89.0	-12.4	01-31-84	1
Caliente Hot Spring	37 37 16	114 30 34	-109.0	-14.5	04-10-85	1
Irrigation Well	37 38 10	115 12 54	-109	--	--	15
Meadow V. Wash At Cove Canyon	37 39 15	114 29 45	-98.0	-12.6	11-13-86	1
Pahroc Spring	37 39 52	114 58 47	-89.0	-12.5	01-14-85	2
SK-18 (MX 10" Well)	37 42 15	114 45 31	-95	--	--	15
Mustang Spring	37 44 09	114 55 14	-91.0	-12.6	01-14-85	2
The Seeps	37 44 22	115 34 32	-98.0	-13.3	01-15-85	2
Weaver Well	37 44 41	114 25 28	-101.0	-13.1	06-04-85	1
Cedar Spring	37 45 05	116 16 25	-101.0	-13.6	01-15-85	2
Well B-1 Tonopah Test Range Nellis B&G RG	37 45 06	116 29 23	-110.0	-14.0	09-10-80	1
Cedar Pass Well	37 45 07	116 28 57	-110.0	-14.0	--	2
John Wadsworth Well	37 46 07	114 24 25	-101.0	-12.9	06-04-85	1
Bennett Spring	37 47 03	114 31 41	-103.0	-13.7	04-10-85	1
Sandia 6	37 47 03	116 45 05	-124.0	-15.2	--	2
Lester Mathews Well	37 47 37	114 23 59	-103.0	-13.3	06-04-85	1
Panaca Town Well	37 47 50	114 23 57	-106.0	-14.0	06-04-85	1
Panaca Spring	37 48 24	114 22 47	-106.0	-13.9	04-26-84	1
Panaca Spring	37 48 24	114 22 47	-108.0	-14.0	04-08-85	1

APPENDIX A.—*Deuterium and oxygen-18 compositions of water from wells and springs in southern Nevada and southeastern California between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Deuterium (permil)	Oxygen-18 (permil)	Date	Source[1]
Panaca Spring	37 48 24	114 22 47	-106.5	-14.2	11-11-86	1
Panaca Spring	37 48 24	114 22 47	-107	-14.4	--	2
North Lee Well	37 49 28	114 23 04	-101.0	-13.3	06-04-85	1
Well 9	37 51 15	116 43 06	-113.0	-14.3	--	2
Delmues Spring	37 51 36	114 19 20	-104.0	-13.4	04-08-85	1
Georges Spring	37 51 37	116 20 57	-98.0	-13.6	01-15-85	2
Meadow Valley Wash Above Delmues Spring	37 51 40	114 19 18	-98.0	-12.8	04-08-85	1
Well 1A	37 53 00	116 46 53	-118.0	-14.5	--	2
Oxborrow Well	37 53 10	114 18 17	-92.0	-11.8	06-05-85	1
Flatnose Spring	37 53 46	114 13 33	-101.0	-13.4	04-08-85	1
White Rock Spring	37 53 46	115 01 11	-90.0	-12.1	01-13-85	2
Upper Conners Spring	37 54 10	114 33 38	-100.0	-13.9	11-11-86	1
Runoff At Pine Spring	37 54 29	114 32 56	-99.0	-13.4	04-07-85	1
Lime Spring	37 54 52	114 32 25	-97.0	-12.9	04-07-85	1
Deadman Spring	37 55 07	114 32 29	-99.0	-13.3	04-07-85	1
Oceana Spring	37 55 07	115 09 26	-87	--	--	15
Highland Spring	37 55 16	114 32 56	-98.5	-13.3	04-07-85	1
Highland Spring	37 55 16	114 32 56	-98.0	-13.2	11-11-86	1
Pioche Municipal Well	37 57 33	114 24 51	-108.5	-14.4	11-10-86	1
Edan Creek Ranch Spring	37 58 12	116 22 53	-99.0	-13.9	01-15-85	2

[1] Sources of data:
1 U.S. Geological Survey (unpublished).
2 Desert Research Institute (unpublished).
3 Winograd and Friedman (1972). Deuterium values were multiplied by 0.97 to make comparable with deuterium data from the U.S. Geological Survey Laboratory, Reston, Va. (I.J. Winograd, U.S. Geological Survey, written commun., 1985).
4 I.J. Winograd, (U.S. Geological Survey, written commun., 1989).
5 I.J. Winograd, (U.S. Geological Survey, written commun., 1986).
6 Winograd and Pearson (1976).
7 Waddell and others (1984).
8 Claassen (1985).
9 McKay and Zimmerman (1983).
10 Benson and others (1983).
11 Craig and Robison (1984).
12 Dinwiddie and Weir (1979).
13 Schroth (1987).
14 White and Chuma (1987).
15 Kirk (1987).
16 Noack (1988).

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*

[For Las Vegas Valley, chemical data are included only for sites that also have deuterium and oxygen-18 data. Deuterium and oxygen-18 are reported relative to V-SMOW, carbon-13 is reported relative to peedee belemnite, and carbon-14 is reported as percent modern of National Bureau of Standards 1950 oxalic acid. Units of measure: milligrams per liter, except as indicated. Number in parentheses indicates number of samples if different from total number of samples. Abbreviations: °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°Celsius; pmc, percent modern carbon; pCi/L, picocuries per liter; L, measured in laboratory]

Site	Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Number of samples	Temperature (°C)	pH	Specific conductance (µS/cm)	Calcium	Magnesium	Sodium	Potassium
1	Big Bend Well 1 Area 2	35 07 21	114 38 03	4	23.0	7.7	1,400	120	36	132	4.8
2	B. Laughlin (Knight) Well	35 07 23	114 36 42	22	18.3	7.8	1,300	114	33	112	4.5
3	Cromer Well	35 07 26	114 37 55	23	19.1	7.8	1,200	98	32	115	3.6
4	Sundance Shores Well	35 09 10	114 34 40	30	22.9	7.8	1,200	76	18	151	3.8
5	Nevada Club Well	35 09 20	114 34 19	22	18.8	7.8	1,400	113	30	146	4.9
6	Big Bend Well 1 Area 1	35 09 31	114 34 16	5	16.0	7.8	1,200	97	25	106	4.0
7	Riverside Trailer Court	35 09 37	114 34 15	24	20.6	7.8	1,300	112	31	125	4.9
8	Cresent Spring	35 28 43	115 10 47	1	20.5	7.8	990	108	25	37	5.0
9	Pine Spring	35 34 25	115 09 23	1	30.0	7.6	980	99	31	81	2.2
10	Ora Hana Spring	35 37 25	115 04 07	1	20.5	7.2	760	55	31	43	4.8
11	Saratoga Spring	35 40 53	116 25 17	1	28.5	8.0	4,700	30	37	980	32
12	McClanahan Spring	35 41 42	115 11 05	1	25.0	8.0	620	58	22	48	7.6
13	Jean Prison Well	35 47 18	115 20 43	1	22.0	6.8	850	60	41	30	3.8
14	Rosechrist Well	35 48 18	115 41 41	1	20.0	7.3	490	53	38	17	1.6
15	Castillo Well	35 50 02	115 26 09	1	24.0	7.3	1,400	97	68	86	4.1
16	Tecopa Hot Spring	35 52 19	116 13 50	1	42.0	8.2	3,600	4.0	1.5	850	16
17	Bird Spring	35 53 20	115 22 12	1	29.0	7.6	640	35	39	36	3.0
18	Wilson's Tank	35 56 02	115 25 28	1	29.0	7.4	830	68	57	36	1.7
19	Bighorn Sheep Spring (Black Canyon #12)	35 56 22	114 44 06	1	36.0	8.7	--	4.2	.2	156	1.1
20	Ringbolt Rapid Spring (Black Canyon #10)	35 57 39	114 43 26	1	50.0	7.8	--	239	14	592	12
21	Sky Harbor Airport	35 58 16	115 08 50	1	25.6	7.8	1,200	64	31	130	10
22	Palm Tree Cold Springs (Black Canyon #7)	35 59 42	114 44 15	1	24.0	7.8	--	389	39	986	16
23	Tenaya Well	36 00 42	115 15 05	1	23.0	7.3	1,300	110	56	31	4.6
24	Showboat Country Club #2	36 02 51	115 04 48	1	26.7	7.9	1,100	74	38	98	14
25	Genstar Gypsum Plant Well	36 03 04	115 23 43	1	23.7	7.0	710	89	38	9.9	1.6
26	Flowing Well (DRI LG153)	36 03 22	115 03 08	1	24.0	8.3	1,100	40	22	130	14
27	Sandstone Spring #1	36 03 47	115 28 09	1	17.0	7.0	460	53	29	5.9	2.0
28	Sunset Park Well	36 03 49	115 05 51	1	26.0	7.3	1,700	160	58	50	15
29	Spanish Trail Country Club Well	36 05 56	115 15 38	1	28.0	7.2	1,300	175	66	14	3.4
30	Stocks Mill & Supply Co. Well	36 06 07	115 15 46	1	26.2	7.2	1,100	161	69	14	3.1

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Number of samples	Temperature (°C)	pH	Specific conductance (µS/cm)	Calcium	Magnesium	Sodium	Potassium
31	Tropicana Country Club South Well #1	36 06 22	115 10 09	1	23.0	7.6	760	78	38	18	3.2
32	Sands Hotel And Casino #3	36 07 28	115 10 09	1	22.5	7.7	510	57	29	7.5	2.5
33	Sparklettes Drinking Water Co.	36 07 41	115 11 45	1	22.7	7.7	460	51	27	5.9	2.5
34	BLM Visitors Center	36 07 44	115 26 03	1	25.0	7.4	600	85	30	8.3	1.6
35	Las Vegas Country Club	36 08 20	115 08 49	1	22.5	7.4	520	54	27	8.7	3.2
36	Hartzski Well	36 08 36	115 15 47	1	21.3	7.6	860	103	42	8.2	2.2
37	Red Spring	36 08 40	115 25 10	1	20.0	7.6	430	51	25	5.2	2.0
38	Manse Well	36 09 17	115 53 42	1	22.5	7.5	400	48	22	4.7	.9
39	DRI Well LG047	36 09 33	115 05 51	1	21.5	8.1	440	26	32	7.8	3.5
40	Shetland Mutual Water Users Association	36 09 39	115 10 33	1	22.3	7.7	470	49	27	7.3	2.6
41	LVVWD #1A	36 09 39	115 13 32	1	25.1	7.6	480	62	31	8.0	2.9
42	LVVWD #11A	36 09 52	115 11 22	1	26.0	6.9	460	50	27	6.9	3.4
43	Union Pacific Railroad #3	36 10 05	115 09 13	1	24.8	7.6	350	41	21	7.	2.7
44	LVVWD #7A	36 10 06	115 11 23	1	25.6	7.5	420	54	26	6.8	3.2
45	Sky Mt. Resort	36 10 13	115 34 44	1	14.0	7.3	470	80	22	4.8	.6
46	LVVWD #14	36 10 18	115 11 22	1	24.5	7.3	460	54	28	6.3	2.7
47	White Rock Spring	36 10 27	115 28 43	1	25.0	7.0	720	94	29	8.4	1.8
48	LVVWD #15A	36 10 31	115 11 23	1	24.9	7.0	410	50	25	5.6	2.3
49	LVVWD #34	36 10 31	115 11 06	1	24.0	7.5	440	46	24	7.1	3.1
50	LVVWD #16	36 10 31	115 11 39	1	24.8	7.5	400	55	25	6.	2.9
51	LVVWD #17	36 10 31	115 11 39	1	23.8	7.4	410	53	25	5.8	2.0
52	LVVWD #18A	36 11 12	115 14 38	1	23.0	7.4	500	56	2.8	6.0	2.0
53	LVVWD #45	36 11 50	115 12 13	1	25.4	7.0	410	49	25	5.8	1.6
54	LVVWD #22A	36 12 05	115 15 43	1	24.0	7.5	450	48	26	5.9	2.6
55	NLVWD Robinson Well	36 12 17	115 11 41	1	25.7	7.3	400	45	23	6.7	1.6
56	Pahrump Spring Well	36 12 27	115 59 01	1	25.0	7.6	420	47	24	4.7	1.3
57	NLVWD West Cheyenne Well	36 12 38	115 11 21	2	25.0	7.2	450	45	22	6.7	1.4
58	Pahrump Community Church	36 12 42	115 59 18	1	27.0	--	--	47	23	5.7	1.2
59	Nellis AFB #13	36 12 44	115 03 00	1	24.5	7.8	600	27	27	44	6.5
60	Trout Spring	36 13 22	115 40 59	8	7.5	8.4	--	45	10	.9	.4
61	Well 5 Franklin Lake Nr Death Valley	36 14 06	116 17 32	1	20.2	9.3	27,000	2.6	2.0	4,500	87
62	Well 10 Franklin Lake Nr Death Valley	36 14 06	116 17 39	1	19.5	9.3	22,000	4.0	4.4	6,200	230
63	NLVWD Desert Aire Well	36 14 15	115 12 16	1	26.4	7.4	370	44	22	6.8	1.3
64	Lake Mead Base Well #3	36 14 21	115 00 16	1	25.0	7.6	700	36	25	76	7.5
65	Mazie Spring	36 14 26	115 38 19	1	3.0	--	120	37	7.8	.7	.2

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Number of samples	Temperature (°C)	pH	Specific conductance (μS/cm)	Calcium	Magnesium	Sodium	Potassium
66	Craig Ranch Country Club #2	36 14 29	115 09 00	1	23.1	7.8	360	30	19	16	3.
67	Rainbow Spring #2	36 14 36	115 37 55	1	9.8	7.5	360	61	13	1.1	.5
68	Peak Spring Canyon Creek	36 14 40	115 43 09	1	7.0	8.7	400	64	13	1.4	.4
69	East Spring #2	36 14 45	115 39 07	1	4.0	--	100	40	8.0	.9	.2
70	GS-18 Franklin Lake Nr Death Valley	36 14 51	116 17 08	1	17.0	9.8	65,000	4.0	6.6	28,000	830
71	Nellis AFB #4	36 14 56	115 00 15	1	25.9	8.04	550	31	32	41	5.0
72	GS-13 Franklin Lake Nr Death Valley	36 14 57	116 18 34	1	20.9	8.4	3,300	9.3	5.2	750	21
73	West Spring	36 15 11	115 39 42	1	5.5	--	--	56	8.9	.7	.3
74	Rainbow Spring #1	36 15 14	115 39 23	1	5.0	--	160	53	7.4	.7	.3
75	Mt Charleston Lodge	36 15 24	115 38 50	5	--	--	290	50	8.8	1.0	.4
76	Rainbow Well	36 15 34	115 37 47	4	8.7	--	370	61	13	1.5	.5
77	Pat Well	36 15 45	115 19 37	1	17.5	8.1	600	50	28	6.1	2.1
78	Echo #3	36 15 55	115 39 29	4	8.6	--	350	59	11	1.4	.5
79	Echo Spring	36 15 55	115 39 29	1	8.0	--	360	60	11	1.3	.5
80	Daines	36 16 12	115 35 33	4	--	--	390	58	16	2.3	.5
81	Highway Maintenance Well	36 16 17	115 35 38	5	10.5	7.6	410	65	16	1.7	.5
82	Lower Stanley B Spring	36 16 14	115 38 18	1	10.0	--	430	81	41	1.4	.4
83	Fletcher Spring	36 16 26	115 37 33	1	11.5	--	380	84	24	2.5	.7
84	Taylor's Steak House Rest.	36 17 08	115 14 41	1	21.2	7.6	390	42	24	6.4	1.3
85	Martin Well	36 17 25	115 14 35	1	22.0	7.8	450	35	23	9.2	1.8
86	GS-8 Franklin Lake Nr Death Valley	36 17 27	116 17 09	1	18.9	8.5	3,600	3.9	5.2	760	71
87	T-Bar Spring	36 17 38	115 40 60	1	6.0	--	240	41	8.3	.8	.4
88	Cave Spring #1	36 17 40	115 39 55	2	5.3	--	240	51	10	1.0	.4
89	Grapevine Springs	36 18 03	115 29 25	2	18.5	7.5	630	62	28	20	2.2
90	Ski Lodge Well	36 18 11	115 40 44	1	8.0	--	340	47	14	.9	.4
91	Youth Camp	36 18 26	115 40 28	4	7.3	--	400	56	21	1.6	.5
92	Deer Creek Spring #1	36 18 27	115 38 13	1	4.3	7.9	270	45	10	1.3	.3
93	Deer Creek Spring #2	36 18 27	115 37 37	1	8.0	8.5	670	56	13	1.4	.5
94	Deer Cr Picnic Area Spg	36 18 33	115 37 25	2	7.5	--	290	56	16	1.1	.4
95	Racel Well	36 18 40	115 15 39	1	24.0	7.7	430	37	24	8.6	1.6
96	Gilbert Well	36 18 45	115 25 06	1	15.5	7.2	410	60	20	2.6	0.5
97	Lee's Crest	36 19 07	115 40 22	4	9.0	--	470	45	31	2.8	.8
98	Stewart Well	36 19 10	115 40 20	1	9.7	8.6	570	44	32	2.0	.9
99	Tule Spring State Park Well	36 19 14	115 16 00	1	21.0	7.6	520	40	26	8.6	1.8
100	Clark Spring	36 19 14	115 43 15	1	10.0	7.5	480	75	38	2.0	.6

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Number of samples	Temperature (°C)	pH	Specific conductance (µS/cm)	Calcium	Magnesium	Sodium	Potassium
101	Mulder Well	36 19 25	115 13 22	1	24.0	7.8	400	42	23	10	1.3
102	Mifflin Well	36 19 32	115 25 23	1	18.0	7.5	400	50	23	3.0	1.2
103	Lee's Oasis Well	36 19 48	115 18 55	1	20.0	8.2	530	63	26	4.6	.7
104	Holland Well	36 20 00	115 17 00	1	26.0	7.2	400	44	25	6.2	1.5
105	Summer Homes Well	36 20 06	115 39 18	3	9.0	7.4	390	51	26	1.5	.9
106	G.P. Apex Well	36 20 28	114 55 36	1	31.0	7.0	1,570	120	46	129	12
107	Cortney Well	36 20 42	115 20 52	1	20.5	7.2	510	67	25	4.8	.7
108	Adams Well	36 20 47	115 19 50	1	22.5	7.3	490	64	25	4.6	.7
109	Paiute Indian Reservation Well	36 21 02	115 20 33	1	18.7	7.0	460	60	22	3.5	.6
110	Big Spring	36 22 30	116 16 25	6	27.0	7.4	--	43	19	97	9.4
111	Rogers Spring	36 22 39	114 26 38	3	30.0	7.4	3,800	430	136	290	20
112	Grace Petroleum Arrow Canyon Water Well 1	36 22 58	114 55 00	1	26.5	7.3	1,600	120	46	140	16
113	Blue Point Spring	36 23 21	114 25 26	1	30.0	7.0	3,800	510	170	360	23
114	Genstar Well	36 23 29	114 54 14	1	24.0	7.4	1,500	120	47	140	1.3
115	Cold Creek Spring	36 24 50	115 44 20	9	10.0	7.6	--	69	16	1.6	.4
116	Amargosa Well #41	36 24 51	116 25 41	1	24.0	7.4	730	29	12	120	9.7
117	Willow Sring	36 25 00	115 45 47	1	10.5	7.5	720	72	15	2.1	.6
118	Young Well	36 25 11	115 22 58	1	17.0	7.7	380	20	38	7.1	2.7
119	Crystal Pool Spring	36 25 14	116 19 21	6	31.0	7.4	--	47	21	74	9.4
120	Brooks Well	36 25 20	115 22 40	1	24.6	8.2	490	40	43	7.1	1.4
121	Valley of Fire Well	36 25 21	114 32 52	1	28.0	7.4	1,100	118	53	39	8.2
122	Shown Well	36 25 31	115 22 44	1	17.0	7.3	380	38	40	7.2	2.0
123	Amargosa Well #20	36 25 35	116 24 42	1	--	7.9	370	14	4.4	46	8.0
124	Corn Creek Spring	36 26 20	115 21 26	4	21.0	7.4	540	46	33	6.2	2.0
125	Travertine Spring	36 26 27	116 49 49	1	30.5	7.8	1,000	39	20	160	11
126	Big Timber Spring	36 26 42	115 55 37	1	11.0	7.7	580	50	20	4.2	0.6
127	Dry Lake Valley Well	36 27 18	114 50 38	1	29.0	7.3	1,400	110	48	120	13
128	Grapevine Spring	36 27 27	116 01 35	1	20.0	7.7	670	57	40	27	1.5
129	Texas Spring	36 27 28	116 50 11	1	31.0	7.9	950	36	19	150	11
130	Corn Creek Well	36 27 53	115 23 54	1	18.5	8.0	380	17	27	13	2.5
131	Silver Flag Alpha Well	36 28 34	115 26 45	1	--	7.8	360	32	21	5.8	1.5
132	Amargosa Well #19	36 28 39	116 26 37	1	--	8.1	320	21	4.0	32	8.2
133	Amargosa Well #18	36 29 04	116 28 08	1	--	8.0	300	21	2.7	36	7.5
134	S17 E48 12 BC	36 29 20	116 31 10	1	--	7.7	1,300	74	24	160	16
135	Fairbanks Spring	36 29 25	116 20 29	8	27.0	7.4	--	48	20	69	8.2

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Number of samples	Temperature (°C)	pH	Specific conductance (µS/cm)	Calcium	Magnesium	Sodium	Potassium
136	Amargosa Well #36	36 29 36	116 25 15	1	--	8.1	800	40	14	97	14
137	Amargosa Well #16	36 29 38	116 30 01	1	--	8.0	360	24	1.8	48	7.3
138	Amargosa Well #17	36 29 40	116 26 58	1	--	7.9	420	25	3.6	48	9.7
139	Amargosa Well #15	36 30 28	116 30 25	1	--	8.0	310	19	1.5	40	7.1
140	Nevares Spring	36 30 44	116 49 14	1	36.5	7.7	980	43	20	140	11
141	Divide Well	36 30 45	115 28 05	1	19.0	8.1	370	22	21	18	3.4
142	Indian Springs Prison Well #1	36 30 52	115 33 15	1	23.0	7.8	410	39	21	3.6	1.
143	Amargosa Well #30	36 31 24	116 24 02	1	--	7.8	--	52	22	120	18
144	Amargosa Well #14	36 31 28	116 30 24	1	--	7.9	300	17	2.0	40	6.1
145	Mathew's Well	36 31 32	116 24 00	1	24.5	7.6	940	50	20	110	1.2
146	Old Dry Well	36 31 35	115 28 13	1	23.0	8.1	390	22	22	15	2.2
147	Alpha Post	36 32 06	115 33 55	1	25.1	8.7	330	35	22	4.9	1.
148	South Black Hills Well	36 32 12	115 24 03	1	29.0	7.5	400	39	21	7.3	4.
149	Amargosa Tracer Well 2	36 32 12	116 13 47	4	31.0	7.4	--	44	20	65	7.8
150	Amargosa Well #13	36 32 19	116 30 24	1	--	7.9	320	19	.8	43	7.3
151	Amargosa Well #21	36 32 48	116 25 07	1	--	8.2	--	16	1.7	56	6.4
152	Amargosa Well #11	36 32 49	116 29 19	1	--	7.9	320	24	1.1	36	8.2
153	South Hidden Valley Well	36 33 08	114 55 30	1	25.0	7.8	820	33	30	86	12
154	Amargosa Well #12	36 33 13	116 30 25	1	27.0	7.0	320	18	.7	54	6.9
155	Amargosa Well #10	36 33 13	116 28 12	1	--	7.9	--	30	1.9	40	4.3
156	Amargosa Well #9	36 33 23	116 29 44	1	--	8.0	340	20	2.7	42	8.8
157	Amargosa Well #50	36 33 25	116 35 50	1	--	7.7	--	53	8.5	150	11
158	Indian Springs #2	36 33 54	115 40 06	5	25.5	7.6	400	46	22	4.2	1.
159	Amargosa Well #23	36 33 58	116 32 37	1	25.5	8.1	--	9.6	3.2	58	5.9
160	Amargosa Well #29	36 33 59	116 26 12	1	23.8	7.7	--	41	7.5	80	9.8
161	Amargosa Well #8	36 34 10	116 27 35	1	--	7.6	430	23	2.6	56	9.0
162	Amargosa Well #25	36 34 24	116 33 25	1	24.5	8.3	--	9.2	3.9	61	5.5
163	Amargosa Well #27	36 34 37	116 25 19	1	30.6	7.6	--	48	17	111	13
164	Indian Springs AFB Well #1	36 34 47	115 40 47	1	23.5	7.3	1,300	126	66	43	4.5
165	Amargosa Well #47	36 34 49	116 36 38	1	24.2	7.7	--	47	16	130	9.4
166	Amargosa Well #5	36 34 56	116 28 41	1	23.0	7.0	310	30	2.6	37	5.6
167	Cow Camp Spring	36 35 01	115 18 26	2	12.3	7.6	540	49	33	23	.6
168	Amargosa Well #4	36 35 28	116 28 42	1	--	7.8	310	29	2.2	35	5.2
169	Army Well No. 1	36 35 30	116 02 14	3	31.0	7.4	--	45	22	38	5.5
170	Test Well 10	36 35 31	115 51 04	2	27.0	7.4	--	39	18	7.4	2.0

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APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Number of samples	Temperature (°C)	pH	Specific conductance (µS/cm)	Calcium	Magnesium	Sodium	Potassium
171	S15 E50 25BD 1	36 37 15	116 24 45	2	44.0	7.9	340	22	1.3	49	2.5
172	S15 E49 22DC 1 (BR supply)	36 37 40	116 26 39	1	--	7.8	340	28	2.1	39	4.9
173	Amargosa Well #3	36 37 50	116 20 00	1	--	6.7	330	27	2.0	43	4.6
174	Wiregrass Spring	36 38 00	115 12 29	8	8.6	7.3	560	70	33	3.0	1.7
175	Juanita Spring	36 38 13	114 14 51	1	26.0	7.3	940	130	43	25	5.3
176	Wamp Spring	36 38 30	115 04 12	1	7.0	8.1	320	71	13	10	2.1
177	Moorman Well	36 38 38	115 05 52	3	11.2	7.4	670	77	42	12	.6
178	Weiser Wash EH-2	36 38 50	114 38 55	3	24.0	8.2	890	38	26	101	15.6
179	Weiser Wash EH-1	36 39 37	114 37 52	2	--	8.2	3,000	262	116	278	26
180	Weiser Wash EH-7	36 40 14	114 31 53	5	23.2	7.7	3,900	481	198	163	24
181	Weiser Wash EH-8	36 40 26	114 34 33	3	--	7.6	3,800	375	104	416	22
182	Weiser Wash EH-6	36 40 54	114 34 12	3	24.8	7.7	3,000	341	131	274	31
183	CSV-3 Well	36 41 27	114 55 30	1	41.0	7.4	650	51	25	38	10
184	Weiser Wash EH-3	36 41 32	114 31 32	4	24.1	7.8	3,700	511	201	170	22
185	TH20 Nevada Power	36 41 49	114 35 33	1	24.0	7.1	3,500	195	147	497	13
186	Weiser Wash EH-4	36 42 23	114 42 58	2	22.8	8.3	920	49	30	90	12
187	White Rock Spring	36 42 30	115 14 20	2	12.5	7.5	420	37	30	14	7.2
188	B. Lewis Well	36 42 40	114 36 00	1	22.0	7.6	1,800	107	76	203	12
189	Pederson Warm Springs (M-13)	36 42 36	114 42 54	1	32.2	--	1,000	75	26	110	8.8
190	Big Muddy Spring	36 43 20	114 42 48	1	32.5	7.2	930	66	26	96	10
191	Weiser Wash EH-5A	36 43 58	114 44 36	2	28.0	8.2	890	49	26	96	12
192	Test Well F	36 45 34	116 06 59	2	64.5	7.4	650	45	16	62	9.0
193	J-12 Well	36 45 54	116 23 24	1	26.8	7.1	290	14	2.1	38	5.1
194	ERTEC MX-6 Well	36 46 04	114 47 13	1	33.5	7.2	980	58	25	87	10
195	CSV-2 Well	36 46 50	114 43 20	1	27.0	7.4	1,000	60	27	100	10
196	USW VH-1 (Amargosa Well #55)	36 47 32	116 33 07	3	35.4	7.6	--	10	1.5	79	1.9
197	ERTEC MX-4 anD MX-5 Wells	36 47 44	114 53 32	2	34.7	7.3	750	46	20	81	11
198	Well J-13	36 48 29	116 23 40	1	31.0	7.2	250	12	2.1	42	5.0
199	Test Well 3	36 48 30	115 51 26	1	38.0	7.3L	--	51	21	83	7.4
200	Railroad Well Farrier	36 48 49	114 39 14	1	22.8	8.0	1,300	84	31	150	19
201	Sand Spring	36 49 30	115 34 05	1	15.0	8.7L	450	19	44	19	4.6
202	UE-25P-1	36 49 38	116 25 21	1	57.0	6.7	1,200	94	31	150	12
203	UE-25C-2	36 49 45	116 25 43	1	40.5	7.7	300	12	.3	54	2.0
204	UE-25C-3	36 49 47	116 25 43	1	40.8	7.7	300	11	.4	55	1.9
205	USW H-4	36 50 32	116 26 54	1	34.8	7.4	--	17	.3	73	2.6

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Number of samples	Tem-pera-ture (°C)	pH	Specific conduc-tance (µS/cm)	Cal-cium	Magne-sium	Sodium	Potas-sium
206	USW H-6	36 50 49	116 28 55	1	37.8	8.1	--	4.1	0.1	86	1.3
207	Tim Spring	36 50 58	115 34 10	1	14.0	8.4	340	19	28	13	2.9
208	UE-25B-1 (Amargosa Well #57)	36 51 08	116 26 23	3	36.4	7.3	--	18	0.7	48	3.3
209	USW G-4	36 51 14	116 27 04	1	35.6	7.7	--	13	0.2	57	2.1
210	USW H-5	36 51 22	116 27 55	2	36.0	7.8	--	1.9	0.01	60	2.1
211	USW H-1 (Amargosa Well #56)	36 51 58	116 27 12	2	33.8	7.6	--	5.3	<.1	51	2.0
212	Dejesus Spring	36 52 28	115 34 45	1	15	7.5	590	41	45	18	3.7
213	VF-2 Well	36 52 30	114 56 44	1	34.0	7.4	800	47	21	81	11
214	VF-1 Well	36 52 32	116 55 44	1	28.0	7.0	460	41	7.5	34	1.2
215	C-1 Well	36 55 07	116 00 34	4	37.0	7.7	--	74	30	123	14
216	UE-29A-2	36 56 29	116 22 26	2	24.0	7.1	--	10	.2	44	1.2
217	Desert Dry Lake Well	36 57 11	115 11 51	1	19.0	8.0	400	22	27	35	5.7
218	Quartz Spring	36 59 10	115 36 00	1	18.0	8.0	800	67	39	54	2.2
219	UE-16F	37 02 09	116 09 25	1	23.3	8.4	1,600	4.7	1.3	425	2.2
220	Tippipah Spring	37 02 36	116 12 26	3	18.0	7.4	340	23	1.7	49	2.3
221	Well U3CN5	37 03 34	116 01 20	1	--	--	590	41	17	54	9.7
222	Willow Spring KSV-1	37 05 34	114 49 52	1	17.4	7.5	--	20	2.7	56	4.6
223	Grapevine Spring KSV-2	37 08 08	114 42 02	1	18.5	7.3	--	75	22	17	2.3
224	Well #8 (NTS) (Amargosa Well #64)	37 09 56	116 17 21	1	26.5	7.4	--	8.4	1.2	31	3.5
225	Jensen Well	37 11 03	114 27 52	1	18.0	7.7	840	55	14	100	7.2
226	Maynard Lake Spring	37 11 30	115 02 02	1	9.6	7.9	910	43	23	114	14
227	Lone Tree Spring	37 12 07	115 03 32	1	11.0	7.5	1,300	45	43	164	20
228	Whiterock Spring	37 12 09	116 07 52	1	--	6.2	120	6.2	.2	17	3.0
229	Kane Spring KSV-3	37 14 46	114 42 21	1	16.4	7.2	--	44	13	20	5.9
230	Boulder Spring KSV-4	37 16 12	114 38 44	1	16.8	7.9	--	21	4.9	12	2.3
231	Randono Well	37 19 26	114 30 08	1	17.2	7.6	760	46	14	100	8.4
232	Cane Spring	37 20 27	115 44 50	1	--	7.6	810	84	48	24	2.4
233	Bradshaw Well	37 20 57	114 32 38	1	14.8	7.3	1,100	85	28	120	11
234	Railroad Well	37 21 04	114 32 02	1	16.0	7.6	730	42	14	98	8.8
235	Sheep Spring	37 24 02	114 16 37	1	10.0	6.8	140	24	5.0	9.8	1.3
236	Cattle Spring	37 24 57	115 45 05	1	--	8.0	530	56	11	41	5.3
237	Rock Spring	37 25 53	115 41 23	1	--	7.8	580	87	19	13	1.7
238	Quail Spring	37 26 29	115 41 01	1	--	7.8	670	86	19	29	1.9
239	Hells Acre Gulch Spring	37 27 37	115 07 29	1	13.0	8.0	380	45	9.0	21	2.4
240	Ash Spring	37 27 49	115 11 34	3	35.3	7.2	460	46	15	29	7.7

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Site name	Latitude (degree, minute, second)	Longitude (degree, minute, second)	Number of samples	Temperature (°C)	pH	Specific conductance (µS/cm)	Calcium	Magnesium	Sodium	Potassium
241	Little Ash	37 27 50	115 11 30	1	36.0	7.6L	500	56	14	31	5.6
242	Indian Spring	37 27 50	115 44 28	1	--	8.1	360	30	7.1	39	.9
243	Rabbitbrush Spring	37 28 56	115 41 28	1	--	7.9	380	42	8.9	25	3.5
244	Savio Spring	37 29 42	115 42 04	1	--	8.3	470	55	14	24	6.2
245	Rose Bud Spring	37 30 32	115 46 25	1	--	7.3	850	89	60	18	2.0
246	Ramone Mathews Well	37 31 36	114 14 39	1	18.5	7.8	270	42	6.3	20	5.9
247	Crystal Spring	37 31 53	115 13 58	2	27.5	7.3	410	44	22	22	5.3
248	Acoma Well	37 32 55	114 10 23	1	17.0	7.7	260	38	5.3	21	7.0
249	Hiko Spring	37 36 34	115 12 51	2	26.0	7.4	--	49	23	26	7.4
250	Walis Health Well	37 37 13	114 30 44	1	63.0	7.8L	440	41	4.4	40	11
251	Caliente Hot Spring	37 37 16	114 30 34	1	45	--	480	37	7.3	49	19
252	Weaver Well	37 44 41	114 25 28	1	17.0	7.7	980	100	42	110	14
253	Well B-1 Tonopah Test Range Nellis B&G Rg	37 45 06	116 29 23	1	26.7	7.9	280	19	.6	34	9.6
254	John Wadsworth Well	37 46 07	114 24 25	1	14.5	7.5	1,100	120	47	150	9.5
255	Bennett Spring	37 47 03	114 31 41	1	24.0	7.5	580	56	26	6.5	1.5
256	Lester Mathews Well	37 47 37	114 23 59	1	20.0	8.1	1,000	73	21	140	10
257	Panaca Town Well	37 47 50	114 23 57	1	29.5	7.9	500	45	13	47	8.3
258	Panaca Spring	37 48 24	114 22 47	2	29.0	7.8	460	33	10	37	7.0
259	North Lee Well	37 49 28	114 23 04	1	22.0	8.0	580	59	12	44	9.9
260	S01 E47 15 CC	37 50 40	116 42 40	1	17.5	7.7	320	14	1.1	49	6.7
261	S01 E 51 21BA	37 50 45	116 20 55	1	15.0	7.4	290	27	3.2	26	6.9
262	Delmues Spring	37 51 36	114 19 20	1	18.0	7.7	560	47	6.7	30	6.3
263	Oxborrow Well	37 53 10	114 18 17	1	11.5	7.9	800	130	22	65	11
264	Flatnose Spring	37 53 46	114 13 33	1	25.0	8.0	400	26	3.5	34	5.6
265	N01 E53 31CD	37 54 03	116 03 51	1	17.0	7.8	270	17	1.8	39	5.0
266	Upper Conners Spring	37 54 10	114 33 38	1	8.0	7.4	490	73	26	2.2	0.5
267	N01 E53 32CAA	37 54 15	116 02 20	1	--	7.8	360	25	1.8	42	7.8
268	Lime Spring	37 54 52	114 32 25	1	21.0	8.3	330	55	31	3.8	0.9
269	N01 E47 30ABB	37 54 55	116 45 08	1	17.0	7.7	400	23	3.5	53	7.7
270	Deadman Spring	37 55 07	114 32 29	1	9.5	7.1	370	98	41	5.0	0.9
271	Highland Spring	37 55 16	114 32 56	1	10.0	7.2	380	86	36	4.7	1.0
272	S02 E47 07AA	37 57 20	116 45 00	1	25.0	8.5	450	1.4	.1	96	5.6
273	Pioche Municipal Well	37 57 33	114 24 51	1	20.5	7.7	300	31	4.4	17	5.5
274	N01 E53 07AD	37 57 50	116 02 60	1	17.0	9.9	4,100	.7	.1	980	9.6
275	N01 E47 02BAB	37 58 18	116 41 04	1	16.0	7.5	350	23	1.5	47	7.2

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Bicar-bonate	Car-bonate	Chloride	Sulfate	Fluor-ide	Silica	Sum of consti-tuents[1]	Dis-solved oxygen	Deuterium (permil)	Oxygen-18 (permil)	Carbon-13 (permil)	Carbon-14 (pmc)	Tritium (pCi/L)	Date	Source[2]
1	262	--	118	362	0.4	20	920	--	--	--	--	--	--	--	1
2	194	--	114	344	--	16	830	--	--	--	--	--	--	--	1
3	209	--	95	313	--	19	780	--	--	--	--	--	--	--	1
4	160	--	188	195	--	28	740	--	--	--	--	--	--	--	1
5	194	--	157	341	--	17	910	--	--	--	--	--	--	--	1
6	183	--	94	288	.3	16	720	--	--	--	--	--	--	--	1
7	184	--	142	320	--	15	840	--	--	--	--	--	--	--	1
8	168 L	--	66	235	.6	55	610	--	-73.0	-9.4	--	--	--	06-22-85	2
9	300 L	--	76	208	.6	18	650	--	-88.0	-11.9	-9.9	--	--	06-22-85	2
10	368 L	--	30	26	.5	80	450	--	-72.0	-8.4	--	--	--	06-22-85	2
11	410	--	730	1,000	2.6	41	3,100	--	-90.5	-10.8	--	--	--	04-23-82	1
12	169 L	--	112	53	1.3	29	410	--	-67.0	-7.2	-7	68.1	--	06-21-85	2
13	230	--	55	550	1.5	34	1,100	--	-95	-12.1	-7.6	2.4	--	06-21-85	2
14	242	--	7.6	109	.4	25	370	--	-94.0	-13.2	--	--	--	09-27-86	1
15	315 L	--	126	263	.3	18	820	--	-94	-12.5	-9.3	39.4	--	06-21-85	2
16	730	--	460	500	3.1	91	2,300	2.0	-98.0	-12.85	-4.3	--	<1.0	06-30-85	1
17	168 L	--	51	98	.2	15	360	--	-88.0	-11.7	-7.8	67.5	--	06-23-85	2
18	366 L	--	59	101	.5	29	530	--	-87.5	-10.9	-9.4	60.4	--	06-22-85	2
19	89	--	82	141	1.0	24	450	--	-80.5	-10.2	--	--	--	01-00-81	3
20	38	--	980	575	4.2	40	2,500	--	-83.5	-11.2	--	--	--	03-00-82	3
21	154	--	198	177	.9	31	720	--	-95	-13.1	-6.8	--	--	02-28-86	4
22	141	--	1,530	1,030	4.2	45	4,100	--	-82.0	-10.5	--	--	--	03-00-82	3
23	210	--	88	310	.4	17	720	3.8	-92.0	-12.3	-7.4	4	--	05-10-83	1
24	152 L	--	95	292	.6	39	730	--	-97	-13.3	--	--	--	02-27-86	4
25	249	--	7.4	171	--	9.7	450	--	-86	-12.3	-9.7	59	--	07-11-86	4
26	150	--	97	250	0.7	53	680	3.6	-100.0	-12.9	-6.4	1	--	05-11-83	1
27	260	--	10	42	.2	10	290	6.0	-89.0	-12.2	-10.6(2)	49.8(2)	<15 (1)	06-25-85	1
28	210	--	110	450	.8	26	690	3.4	-94.0	-12.7	-6.7	4	--	05-09-83	1
29	192	--	12	548	.3	14	930	--	-89	-12.2	--	--	--	05-18-79	4
30	192	--	13	518	.3	15	890	--	-86	-12.4	-7.9	11.0	<15	03-13-86	4
31	215	--	21	176	.3	15	320	--	-95	-13.2	-7.9	--	--	05-10-79	4
32	223	--	8.0	80	.2	16	310	--	-98	-13.5	-8.0	--	--	05-08-79	4
33	228 L	--	4.8	59	.2	15	280	--	-99	-13.6	-9.3	39.4	--	03-21-79	4
34	210	--	7.3	170	.2	13	430	6.0	-89.0	-12.25	-9.3	46.0	9.0	06-30-85	1
35	223	--	7.8	73	.2	16	300	--	-100	-13.7	-7.6	--	--	05-15-79	4

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Bicar-bonate	Car-bonate	Chloride	Sulfate	Fluor-ide	Silica	Sum of constituents[1]	Dis-solved oxygen	Deuterium (permil)	Oxygen-18 (permil)	Carbon-13 (permil)	Carbon-14 (pmc)	Tritium (pCi/L)	Date	Source[2]
36	206	--	7.0	244	0.2	13	520	--	-90	-12.4	-8.5	--	--	03-28-79	4
37	260	--	6.0	21	.2	12	260	6.4	-89.0	-12.25	-10.5(2)	62.4(2)	3.0	06-26-85	1
38	230	--	2.4	23	.1	13	230	8.8	-99.0	-13.55	-8.3	46.9	<2.0	06-27-85	1
39	200	--	4.5	49	.5	35	260	7.1	-101.0	-13.6	-7.9	9	--	05-11-83	1
40	230	--	5.8	54	.2	18	280	--	-100	-13.5	-7.2	--	--	03-29-79	4
41	223	--	6.5	116	.2	13	340	--	-94	-13.2	-8.3	--	--	06-26-79	4
42	226	--	4.8	65	.2	14	280	--	-97	-13.4	-7.3	14	--	06-13-86	4
43	207	--	3.5	33	.2	15	230	--	-100	-13.8	-7.7	--	--	06-28-79	4
44	227	--	7	67	.2	14	290	--	-96	-13.2	-7.7	--	--	06-26-79	4
45	330	--	3.3	25	.2	11	320	7.7	-96.5	-13.25	-10.1	84.1	34	06-28-85	1
46	229	--	5.0	72	--	14	290	--	-97	-13.2	-7.8	--	--	05-06-86	4
47	200	--	16	180	.2	13	450	5.4	-91.0	-12.5	-12.0	--	<2.0	06-26-85	1
48	235	--	3.7	48	.2	14	250	--	-97	-13.8	-7.2	--	--	05-14-86	4
49	230	--	4.5	43	.2	15	260	--	-99	-13.6	-7.3	--	--	03-27-79	4
50	236	--	4.5	50	.2	13	270	--	-97	-13.6	-8.0	--	--	06-26-79	4
51	238	--	5	52	.2	13	280	--	-97	-13.5	-8.0	--	--	06-26-79	4
52	229	--	4.8	73	.2	14	270	--	-94	-13.4	-8.3	--	--	03-27-79	4
53	239	--	4.0	36	.2	14	530	--	-101	-14.0	-7.3	--	--	05-13-86	4
54	233	--	3.5	48	.2	14	260	--	-100	-14	-8.2	--	--	03-27-79	2
55	234	--	3.1	33	.2	14	240	--	-100	-14.1	-7.0	--	--	06-03-86	4
56	240	--	3.4	28	.2	14	240	6.9	-97.0	-13.55	-7.6	26.0	<1.0	06-27-85	1
57	231	--	3.5	31	0.2	14	240	6.0	-104.0	-13.5	-6.8	13	--	--	1,4
58	240	--	4.5	35	.2	13	250	--	--	--	--	--	--	01-09-76	1
59	256	--	8.0	68	.4	80	390	--	-98	-13.8	-8.0	--	--	05-15-79	4
60	178	--	.7	6.0	.2	4	160	9.4	-97.7(19)	-13.6(22)	-8.1(5)	90.8(1)	257 (3)	--	5
61	2,350	720	3,800	2,800	15	8.7	72,000	0.8	-93.5	-11.1	--	--	--	11-21-83	1
62	2,450	590	6,700	3,400	12	20	8,000	1.5	-91.0	-10.0	--	--	--	11-21-83	1
63	231	--	2.8	29	.2	15	240	--	-102	-14.0	-7.2	--	--	03-06-86	4
64	192	--	41	150	2.1	55	490	3.4	-101.5	-13.8	-5.3	5.6	<.3	09-29-86	1
65	150	--	.7	3.7	.1	3.2	130	--	--	--	--	--	--	08-25-78	6
66	197	--	3.5	27	.3	34	230	--	-106	-14.5	-8.2	3	--	05-11-79	4
67	235	--	4.1	5.7	--	6.0	210	--	-96.0	-12.4	-9.8	91.7	98	08-19-82	2
68	242	8.3	1.9	6.7	.2	5.1	220	--	-95.5	-13.4(12)	--	--	--	04-05-88	1
69	150	--	.8	4.6	.1	3.8	130	--	--	--	--	--	--	08-24-78	6
70	15,980	10,200	23,000	19,000	30	28	9,000	6.5	-66.5	-2.5	--	--	--	11-18-83	1

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APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Bicar-bonate	Car-bonate	Chloride	Sulfate	Fluor-ide	Silica	Sum of consti-tuents[1]	Dis-solved oxygen	Deuterium (permil)	Oxygen-18 (permil)	Carbon-13 (permil)	Carbon-14 (pmc)	Tritium (pCi/L)	Date	Source[2]
71	234	--	20	78	.5	41 0	360	--	-95	-13.2	-6.3	21	--	04-03-86	4
72	600	--	480	550	3.4	67	2,200	5.8	-92.0	-11.3	--	--	--	11-17-83	1
73	210	--	3.7	5.9	.2	4.6	180	--	--	--	--	--	--	08-24-78	6
74	180	--	.7	5.1	.1	4.1	160	--	--	--	--	--	--	08-24-78	6
75	185	--	.7	3.8	.1	4.8	160	--	--	--	--	--	--	--	6,7
76	235	--	2.4	6.2	.1	5.6	210	--	--	--	--	--	--	--	6,7
77	252	--	6.3	34	.2	13	260	--	-92.0	-12.9	--	--	<15	03-31-87	2
78	225	--	.8	6.4	.1	5.6	200	--	--	--	--	--	--	--	6,7
79	232	--	1.2	6.5	.2	6.3	200	--	-94.5	-12.8	-7.4	--	.3	04-16-80	2,7
80	244	--	1.4	9.9	.1	6.5	220	--	--	--	--	--	--	--	7
81	257	--	1.3	26	.2	6.1	240	--	-96.0	-12.2	-10.1	83	87	--	2,6,7
82	--	--	2.5	14	--	7.1	--	--	--	--	--	--	--	08-18-78	6
83	340	--	2.9	19	.1	7.7	310	--	--	--	--	--	--	08-23-78	6
84	224	--	3.3	25	.2	17	230	--	-101	-13.7	-7.1	--	--	11-03-86	4
85	213 L	--	4.6	16	.2	20	210	--	-100.0	-13.4	-6.7	1.9	--	06-30-85	2
86	720	25	690	280	6.1	35	2,200	0.2	-100.0	-12.9	--	--	--	11-19-83	1
87	170	--	.3	3.4	.2	3.1	140	--	--	--	--	--	--	07-24-80	1
88	200	--	.6	3.4	.2	3.9	170	--	--	--	--	--	--	--	1,6
89	292	--	16	53	.2	22	340	--	-91.5	-12.4	-9.1	46	<15	--	2
90	207	--	1.4	9.9	.1	4.9	180	--	--	--	--	--	--	08-23-78	6
91	260	--	.9	11	.1	6.1	230	--	--	--	--	--	--	--	7
92	181 L	--	.5	2.8	.1	5.0	160	--	-98.5(2)	-14.1(2)	-8.4(2)	--	78.4(2)	06-28-85	2
93	238 L	--	.9	4.3	.1	5.1	200	8.3	-98.0	-13.45	-9.6	100	73.2	06-28-85	2
94	245	--	.9	3.1	.1	5.2	210	--	--	--	--	--	--	--	2
95	240	--	4.1	19	.3	18	230	5.6	-99.0	-13.3	-6.7	7	--	05-10-83	1
96	244	--	1.8	30	--	7.0	240	--	-98	-12.7	-8.8	61.4	--	08-21-85	2
97	277	--	1.5	21	.8	7.9	240	--	--	--	--	--	--	--	6,7
98	244	--	1.6	20	.01	8	230	2.0	-100	-13.4	-8.0	31.6	<15	06-24-86	2
99	251 L	--	4.7	18	.2	19	240	--	-99.7(3)	-12.5(2)	-7.0	13.9	<15	06-30-85	2
100	440	--	1.5	5.8	.1	7.2	360	--	-93.5	-12.9	--	--	--	06-29-85	1
101	226	--	9.2	22	.3	17	240	--	-97.0	-13.2	-7.2	23.8	<15	06-25-86	2
102	223	--	1.5	39	--	11	240	--	-100	-12.6	-7.7	16.4	--	08-20-85	2
103	257	--	3.4	59	.2	9.0	290	--	-98.0	-13.4	-8.6	49.6	<15	06-24-85	2
104	247	--	3.7	18	--	18	220	--	-98.0	-12.6	-6.2	11.3	--	08-20-82	2
105	278	--	1.3	11	.7	6.5	220	--	-99.5	-13.8	-10.8	91.1	89	--	1,6,7

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Bicar-bonate	Car-bonate	Chloride	Sulfate	Fluor-ide	Silica	Sum of consti-tuents[1]	Dis-solved oxygen	Deuterium (permil)	Oxygen-18 (permil)	Carbon-13 (permil)	Carbon-14 (pmc)	Tritium (pCi/L)	Date	Source[2]
106	226	--	200	380	1.4	23	1,000	5.5	-98.0	-13.45	-5.5	2.7	<.3	09-30-86	1
107	255 L	--	3.5	67	--	10	300	--	-96.0	-12.1	-7.9	48.4	--	08-21-82	2
108	255	--	3.3	64	--	10	300	--	-98.0	-12.7	-8.2	50.1	--	08-20-82	2
109	243	--	2.5	43	.7	9.7	260	--	-98.0	-14.0	-8.2	57	32	08-21-82	2
110	318	--	27	111	1.3	28	490	4.5	-103.0(4)	-13.4(1)	-4.6(1)	3.2(3)	.5(2)	--	5
111	163	--	333	1,633	1.4	18	2,900	2.3	-92.0	-12.2	-4.05	1.6	--	--	1
112	230	--	190	360	1.6	21	1,000	.5	-96.0	-13.7	--	--	--	04-26-82	1
113	160	--	500	2,300	1.4	18	4,000	3.4	-93.0(2)	-12.4(2)	-5.3	7.2	--	07-01-85	1
114	226	--	180	370	1.6	23	1,000	4.8	-97.0	-13.05	-4.9	1.5	<1.0	03-31-86	1
115	292	--	1.1	9.0	.2	7	250	8.2	-100.1(16)	-13.8(18)	-9.6(5)	76.0(4)	92 (4)	--	5
116	350	--	20	74	3.7	59	500	--	--	--	--	--	--	11-18-72	1
117	289 L	--	1.8	9.9	.2	7.6	250	--	-97.5(3)	-13.75(3)	-9.6	79.2	57	06-26-85	2
118	242	--	5.5	15	.5	46	260	6.1	-93.0	-12.8	-6.7	13.7	1.0	09-25-86	1
119	312	--	26	89	1.7	26	450	3.7	-104.0(5)	-13.7(1)	-5.0(1)	11.1(2)	1.6(2)	--	5
120	320	--	5.9	16	.4	35	310	--	-93.0	-12.7	-6.9	35.7	<15	06-24-86	2
121	164 L	--	21	449	.2	8.3	780	--	-82.0	-10.6	-8.5	18.7	--	06-24-85	2
122	294	--	6.5	17	.4	30	290	--	-94.0	-13.0	-8.8	20.4	1.0	09-25-86	1
123	160	--	6.5	40	2.3	82	280	--	-102.0	-12.4	--	--	--	03-06-74	8
124	284 L	--	7.1	18	.2	18	300	--	-93.2(3)	-12.9(3)	-7.7(3)	13.9(1)	1.0(2)	--	1,5
125	350	--	41	190	6.9	31	660	--	-102.0	-13.7	--	--	--	04-22-82	1
126	243 L	--	2.7	11	.1	8.7	220	8.2	-93.0	-13.3	-8.8	87.3	46	06-27-85	2
127	210	--	170	360	2.1	21	960	2.0	-97.5	-13.3	-4.2	3.0	7.0	07-01-85	1
128	270	--	12	130	.2	21	430	6.4	-92.5	-12.75	-7.2	--	10	06-28-85	1
129	340	--	37	160	7.1	31	610	--	-102.0	-13.7	--	--	--	04-22-82	1
130	195	--	4.6	12	.4	24	200	--	-95.5	-13.55	-7.7	7.0	<15	12-02-86	2
131	197	--	3.3	13	.2	15	190	8.7	-99	-13.7	-8.0	--	--	12-18-87	2
132	120	--	10	35	1.4	73	240	--	--	--	--	--	--	03-06-74	8
133	120	--	6.4	27	1.4	81	240	--	-102.0	-13.0	--	--	--	03-06-74	8
134	400	--	78	180	6.8	46	770	--	--	--	--	--	--	03-03-74	8
135	306	--	21	80	1.7	22	420	3.2	-103.2(4)	-13.6(1)	-5.1(2)	1.9(3)	.5(3)	--	5
136	210	--	28	160	2.9	53	510	--	--	--	--	--	--	03-07-74	8
137	150	--	9.5	31	1.7	80	280	--	-104.0	-12.7	--	--	--	03-01-74	8
138	130	--	10	69	1.2	70	300	--	--	--	--	--	--	03-01-74	8
139	140	--	6.3	25	1.7	79	250	--	-104.0	-13.0	--	--	--	03-05-74	8
140	350	--	38	180	6.4	25	630	--	-104.0	-13.6	--	--	--	04-22-82	1

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Bicar-bonate	Car-bonate	Chloride	Sulfate	Fluor-ide	Silica	Sum of consti-tuents[1]	Dis-solved oxygen	Deuterium (permil)	Oxygen-18 (permil)	Carbon-13 (permil)	Carbon-14 (pmc)	Tritium (pCi/L)	Date	Source[2]
141	202	--	3.4	11	.6	26	200	9.3	-98.0	-13.7	-6.9	--	--	12-19-87	2
142	219 L	--	3.1	11	.1	13	200	7.0	-102.0	-13.7	-6.6	4.9	--	06-26-85	2
143	314	--	27	168	--	38	600	--	-104.0	-13.7	--	--	--	06-24-79	8
144	130	--	6.9	25	1.6	79	240	--	-98.5	-12.6	--	--	--	03-04-74	8
145	320	--	29	170	4.4	33	570	--	-104.0	-13.7	--	--	--	05-11-81	1
146	195	--	5.3	13	0.5	26	200	9.2	-95.0	-13.2	-7.2	--	--	12-19-87	2
147	203	--	4.2	12	.1	13	200	7.2	-98.0	-13.2	-7.1	6.1	<15	06-23-86	2
148	197	--	6.7	32	.5	22	230	--	-87.0	-12.1	-6.2	9.2	--	08-05-87	1
149	291	--	20	70	1.7	22	400	--	--	-13.6(1)	-4.6(1)	1.8(1)	--	--	5
150	130	--	9.3	28	1.3	72	240	--	-102.0	-13.0	--	--	--	03-05-74	8
151	127	--	8.9	35	--	76	260	--	-99.0	-13.2	--	--	--	06-25-79	8
152	130	--	6.6	33	1.0	75	250	--	-101.0	-13.1	--	--	--	03-05-74	8
153	245	--	64	90	1.2	27	470	3.8	-90.5	-11.2	--	--	<1.0	03-28-86	1
154	150	--	7.8	30	1.5	79	270	--	--	--	--	--	--	11-17-72	8
155	132	--	8.2	51	--	77	280	--	-97.5	-13.2	--	--	--	06-26-79	8
156	150	--	7.4	28	1.2	59	240	--	--	--	--	--	--	03-01-74	8
157	236	--	63	187	--	77	670	--	-104.0	-13.6	--	--	--	06-25-79	8
158	242	--	3.8	16	.2	12	220	4.8	-99.3	-13.3	-7.6(3)	8.3(3)	<2.0(2)	--	1,5
159	153	--	7.4	29	--	68	260	--	-103.0	-13.4	--	--	--	03-31-71	8
160	195	--	23	130	--	46	430	--	-105.0	-13.8	--	--	--	03-31-71	8
161	140	--	10	67	.9	72	310	--	-103.0	-13.4	--	--	--	03-01-74	8
162	166	--	8.2	33	--	64	270	--	-102.0	-13.4	--	--	--	03-31-71	8
163	291	--	29	152	--	29	540	--	-105.0	-13.8	--	--	--	04-01-71	8
164	222	--	76	398	.3	18	840	3.2	-96.0	-13.0	-6.9	7.3	<15	06-27-85	2
165	239	--	62	180	--	64	630	--	-102.0	-13.1	--	--	--	03-31-71	8
166	150	--	7.7	30	.7	54	240	--	-99.5	-13.2	--	--	--	11-17-72	8
167	290	--	29	19	.2	16	310	5.9	-92.0	-12.6	--	--	--	--	1
168	140	--	6.0	26	1.0	62	230	--	-103.0	-13.2	--	--	--	03-04-74	8
169	275	--	16	54	.9	19	340	2.8	-103.5(2)	--	-5.6(2)	2.8(1)	.6(2)	--	5,14
170	197 L	--	6.0	14	.2	14	200	--	--	--	--	--	--	--	5
171	150	--	7.4	38	.9	20	220	--	--	--	--	--	--	--	1
172	150	--	6.7	33	1.0	49	240	--	--	--	--	--	--	03-04-74	8
173	150	--	8.5	33	0.9	49	240	--	-102.0	-12.8	--	--	--	11-20-72	8
174	370	--	3.1	7.0	.1	12	310	5.4	-94.3(9)	-12.8(9)	-10.2	96.8	89.6	--	1
175	--	--	15	370	1.0	29	--	--	-87.0	-11.65	--	--	--	01-25-85	1

APPENDIX B.—*Average chemical and isotopic compositions of water from wells and springs in southern Nevada and southeastern California, between latitudes 35 and 38 degrees north, and longitudes 114 and 117 degrees east*—Continued

Site	Bicar-bonate	Car-bonate	Chloride	Sulfate	Fluor-ide	Silica	Sum of consti-tuents[1]	Dis-solved oxygen	Deuterium (permil)	Oxygen-18 (permil)	Carbon-13 (permil)	Carbon-14 (pmc)	Tritium (pCi/L)	Date	Source[2]
211	118	--	5.7	18	1.1	44	190	--	-102.0	-13.4	-11.4	21.9	--	--	10,12
212	287	--	14	64	.5	16	340	--	-100	-13.1	-12.0	--	51.2	05-09-87	2
213	303	--	34	90	1.7	34	470	2.9	-101.0(2)	-13.0(2)	-6.1	7.0	<1.0	02-05-86	1
214	156	--	42	20	.5	14	230	--	-94.0	-12.6	--	--	--	01-06-88	1
215	584	--	32	67	1.1	29	660	--	-110.5	--	-3.8(1)	.8(1)	<.3(1)	--	5,14
216	107	--	9.9	21	.9	44	180	--	-93.2	-12.8	-12.9	61	--	--	12
217	207	--	8.9	48	.6	49	300	--	-98.0	-13.1	-5.3	1.3	<.6	03-18-87	1
218	383	--	31	80	.6	52	520	11.0	-88.0	-11.6	-11.3	--	--	01-02-88	2
219	930	33	26	120	4.4	4.7	1,100	--	-105.0	-14.9	--	--	--	09-25-77	13
220	160	--	8.9	18	.3	53	240	--	--	--	--	--	58	--	1
221	270	--	32	41	0.8	38	370	--	--	--	--	--	--	11-15-74	1
222	140 L	--	22	34	1.1	65	270	--	-88.0	-11.6	--	--	--	02-03-84	1
223	280 L	--	27	40	.9	22	340	--	-87.5	-12.0	--	--	--	02-03-84	1
224	80	--	7.4	14	--	41	150	--	-104.0	-13.0	--	--	--	03-24-71	8
225	340	--	45	80	2.1	56	520	--	-88.5	-11.6	--	--	--	04-10-85	1
226	405 L	--	30	88	--	--	510	--	-94.0	-12.3	--	--	--	01-14-85	2
227	539 L	--	50	145	--	--	730	--	-89.5	-10.9	--	--	--	01-14-85	2
228	41	--	3.7	12	.1	24	86	--	--	--	--	--	--	03-14-73	1
229	210 L	--	17	14	2.8	60	280	--	-86.5	-11.9	--	--	--	02-02-84	1
230	100 L	--	7.8	6	1.7	41	140	--	-87.0	-12.6	--	--	--	02-02-84	1
231	350	--	44	63	2.3	54	500	--	-87.5	-11.7	--	--	--	02-03-84	1
232	360	--	18	136	--	--	490	--	-88	-9.5	--	--	--	05-15-85	2
233	550	--	52	76	2.3	63	710	--	-88.5	-11.4	--	--	--	02-01-84	1
234	300	--	42	60	2.3	51	460	--	-86.0	-11.6	--	--	--	01-31-84	1
235	96	--	7.9	7.0	0.7	33	140	--	-87.0	-12.0	--	--	--	06-03-85	1
236	261 L	--	16	39	--	--	300	--	-85	-9.4	--	--	--	05-15-85	2
237	348 L	--	5.8	35	--	--	330	--	-86.0	-10.9	--	--	--	05-15-85	2
238	166 L	--	11	206	--	--	430	--	-92.0	-11.9	--	--	--	05-15-85	2
239	198 L	--	8.2	20	--	--	200	--	-93.0	-12.3	--	--	--	01-14-85	2
240	259	--	8.0	33	0.9	30	290	2.3	-108.0	-14.1	-6.7(2)	6.3(3)	0 (2)	--	1,5
241	270 L	--	21	34	8.7	29	320	--	--	--	--	--	--	02-04-74	1
242	173 L	--	9.4	31	--	--	200	--	-88	-10.4	--	--	--	05-15-85	2
243	197	--	9.0	27	--	--	210	--	-89	-11.2	--	--	--	05-14-85	2
244	268 L	--	10	26	--	--	270	--	--	--	--	--	--	05-14-85	2
245	400 L	--	11	150	--	--	530	--	--	--	--	--	--	05-17-85	2

Notices

DEPARTMENT OF THE INTERIOR

Fish and Wildlife Service

HURON ISLANDS AND SENEY UNITS

Notice of Public Hearing Regarding Wilderness Study

Notice is hereby given in accordance with provisions of the Wilderness Act of September 3, 1964 (P.L. 88-577; 78 Stat. 890, 892; 16 U.S.C. 1131, 1132), that a public hearing will be held beginning at 9 a.m. on May 10, 1967, at the Northern Michigan University Center, Marquette, Mich., on studies leading to recommendations to be made to the President of the United States by the Secretary of the Interior regarding the desirability of including the Huron Islands and Seney Wilderness Study Areas in the National Wilderness Preservation System. The Units consist of approximately 147 acres and 20,000 acres within the Huron Islands and Seney National Wildlife Refuges located in Marquette and Schoolcraft Counties, Mich., respectively.

A brochure containing a map and information about the Huron Islands and Seney Wilderness Units may be obtained from the Refuge Manager of Seney National Wildlife Refuge, Seney, Mich. 49883, or the Regional Director, Bureau of Sport Fisheries and Wildlife, 1006 West Lake Street, Minneapolis, Minn. 55408.

Individuals or organizations may express their oral or written views by appearing at this hearing, or they may submit written comments for inclusion in the official record of the hearing to the Regional Director at the above address by May 10, 1967.

JOHN S. GOTTSCHALK,
Director, Bureau of Sport Fisheries and Wildlife.

MARCH 8, 1967.

[F.R. Doc. 67-2721; Filed, Mar. 10, 1967; 8:48 a.m.]

Office of the Secretary

NATIVE FISH AND WILDLIFE

Endangered Species

In accordance with section 1(c) of the Endangered Species Preservation Act of October 15, 1966 (80 Stat. 926; 16 U.S.C. 668aa(c)) I find after consulting the States, interested organizations, and individual scientists, that the following listed native fish and wildlife are threatened with extinction.

Mammals:

Indiana Bat—*Myotis sodalis.*
DelMarva Peninsula Fox Squirrel—*Sciurus niger cinereus.*
Timber Wolf—*Canis lupus lycaon.*
Red Wolf—*Canis niger.*
San Joaquin Kit Fox—*Vulpes macrotis mutica.*
Grizzly Bear—*Ursus horribilis.*
Black-Footed Ferret—*Mustela nigripes.*
Florida Panther—*Felis concolor coryi.*
Caribbean Monk Seal—*Monachus tropicalis.*
Guadalupe Fur Seal—*Arctocephalus philippi townsendi.*
Florida Manatee or Florida Sea Cow—*Trichechus manatus latirostris.*
Key Deer—*Odocoileus virginianus clavium.*
Columbian White-Tailed Deer—*Odocoileus virginianus leucurus.*
Sonoran Pronghorn—*Antilocapra americana sonoriensis.*

Birds:

Hawaiian Dark-Rumped Petrel—*Pterodroma phaeopygia sandwichensis.*
Hawaiian Goose (Nene)—*Branta sandvicensis.*
Aleutian Canada Goose—*Branta canadensis leucopareia.*
Tule White-Fronted Goose—*Anser albifrons gambelli.*
Laysan Duck— *Anas laysanensis.*
Hawaiian Duck (or Koloa)—*Anas wyvilliana.*
Mexican Duck—*Anas diazi.*
California Condor—*Gymnogyps californianus.*
Florida Everglade Kite (Florida Snail Kite)—*Rostrhamus sociabilis plumbeus.*
Hawaiian Hawk (or Ii)—*Buteo solitarius.*
Southern Bald Eagle—*Haliaeetus l. leucocephalus.*
Attwater's Greater Prairie Chicken—*Tympanuchus cupido attwateri.*
Masked Bobwhite—*Colinus virginianus ridgwayi.*
Whooping Crane—*Grus americana.*
Yuma Clapper Rail—*Rallus longirostris yumanensis.*
Hawaiian Common Gallinule—*Gallinula Chloropus sandvicensis.*
Eskimo Curlew—*Numenius borealis.*
Puerto Rican Parrot—*Amazona vittata.*
American Ivory-Billed Woodpecker—*Campephilus p. principalis.*
Hawaiian Crow (or Alala)—*Corvus tropicus.*
Small Kauai Thrush (Puaiohi)—*Phaeornia palmeri.*
Nihoa Millerbird—*Acrocephalus kingi.*
Kauai Oo (or Oo Aa)—*Moho braccatus.*
Crested Honeycreeper (or Akohekohe)—*Palmeria dolei.*
Akiapolaau—*Hemignathus wilsoni.*
Kauai Akialoa—*Hemignathus procerus.*
Kauai Nukupuu—*Hemignathus lucidus hanapepe.*
Laysan Finchbill (Laysan Finch)—*Psittirostra c. cantans.*
Nihoa Finchbill (Nihoa Finch)—*Psittirostra cantans ultima.*
Ou—*Psittirostra psittacea.*
Palila—*Psittirostra bailleui.*
Maui Parrotbill—*Pseudonestor xanthophrys.*
Bachman's Warbler—*Vermivora bachmanii.*
Kirtland's Warbler—*Dendroica Kirtlandii.*
Dusky Seaside Sparrow—*Ammospiza nigrescens.*
Cape Sable Sparrow—*Ammospiza mirabilis.*

Reptiles and Amphibians:

American Alligator—*Alligator mississippiensis.*
Blunt-Nosed Leopard Lizard—*Crotaphytus wislizenii silus.*
San Francisco Garter Snake—*Thamnophis sirtalis tetrataenia.*
Santa Cruz Long-Toed Salamander—*Ambystoma macrodactylum croceum.*
Texas Blind Salamander—*Typhlomolge rathbuni.*
Black Toad, Inyo County Toad—*Bufo exsul.*

Fishes:

Shortnose Sturgeon—*Acipenser brevirostrum.*
Longjaw Cisco—*Coregonus alpenae.*
Piute Cutthroat Trout—*Salmo clarki seleniris.*
Greenback Cutthroat Trout—*Salmo clarki stomias.*
Montana Westslope Cutthroat Trout—*Salmo clarki.*
Gila Trout—*Salmo gilae.*
Arizona (Apache) Trout—*Salmo sp.*
Desert Dace—*Eremichthys acros.*
Humpback Chub—*Gila cypha.*
Little Colorado Spinedace—*Lepidomeda vittata.*
Moapa Dace—*Moapa coriacea.*
Colorado River Squawfish—*Ptychocheilus lucius.*
Cui-ui—*Chasmistes cujus.*
Devils Hole Pupfish—*Cyprinodon diabolis.*
Commanche Springs Pupfish—*Cyprinodon elegans.*
Owens River Pupfish—*Cyprinodon radiosus.*
Pahrump Killifish—*Empetrichythys latos.*
Big Bend Gambusia—*Gambusia gaigei.*
Clear Creek Gambusia—*Gambusia heterochir.*
Gila Topminnow—*Poeciliopsis occidentalis.*
Maryland Darter—*Etheostoma sellare.*
Blue Pike—*Stizostedion vitreum glaucum.*

STEWART L. UDALL,
Secretary of the Interior.

FEBRUARY 24, 1967.

[F.R. Doc. 67-2758; Filed, Mar. 10, 1967; 8:48 a.m.]

FEDERAL COMMUNICATIONS COMMISSION

[Docket Nos. 16944, 16945; FCC 67M-368]

PRAIRIELAND BROADCASTERS AND RICHARD P. LAMOREAUX

Order Rescheduling Prehearing Conference

In re applications of Stephen P. Bellinger, Joel W. Townsend, Ben H. Townsend, Morris E. Kemper, and James A. Mudd, doing business as Prairieland Broadcasters, Monmouth, Ill., Docket No. 16944, File No. BHP-5296; Richard P. Lamoreaux, Monmouth, Ill., Docket No. 16945, File No. BPH-5441; for construction permits.

On the Hearing Examiner's own motion, and with the consent of all parties: *It is ordered,* This 3d day of March 1967, that the prehearing conference in the above-entitled matter presently sched-

SE ROA 12643

JA_5405

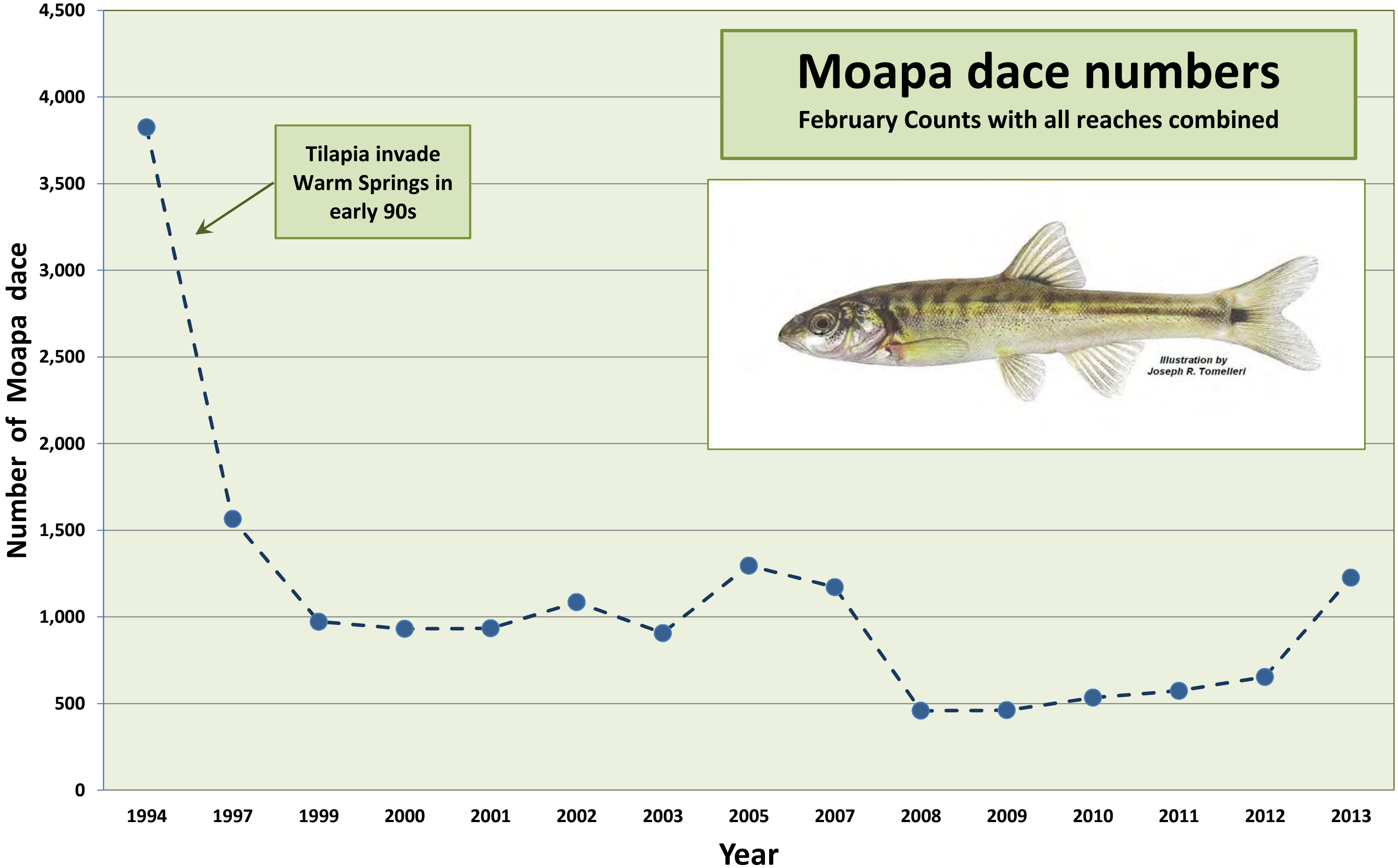
Moapa dace numbers from 1994 to 2013

Moapa Dace Counts over Time

Method: One week in **February** all inhabited reaches are surveyed by snorkelers who work upstream, strive to remain in the water, and record all fish with focus on Moapa dace.

Reach	Reach Name	1994	1997	1999	2000	2001	2002	2003	2005	2007	2008	2009	2010	2011	2012	2013
1	Refuge Apcar	x	x	5	x	87	86	40	6	0	0	0	7	28	74	69
2	Top Apcar	x	x	x	x	x	x	x	87	42	50	29	13	20	78	139
3	Middle Apcar	x	x	x	x	x	x	x	52	14	0	2	3	1	10	127
4	Lower Apcar	x	x	x	x	x	x	x	18	0	0	0	7	2	0	62
2 ,3, 4	Subtotal for reaches 2-4	407	528	x	43	85	55	30	157	56	50	31	23	23	88	328
1,2,3,4	Subtotal for all of Apcar (1-4)	407	528	5	43	172	141	70	163	56	50	31	30	51	162	397
5	Pederson	x	x	185	163	184	172	204	174	395	50	80	82	99	66	128
5.5	lower Pederson channel	x	x	x	x	x	x	x	x	x	x	29	71	96	99	244
6	Little (Goodchild) Spring	x	x	x	x	x	x	x	80	128	56	9	8	22	10	36
6.5	Sheet flow from Pederson outflow	x	x	x	x	x	x	x	x	x	19	x	x	x	x	x
7	Plummer	0	20	113	x	59	53	60	177	170	148	187	166	188	109	113
8	WSR Concrete flume to Plummer/Pedersen	x	x	x	x	x	x	x	406	282	59	61	118	78	27	141
9	Refuge Arm Concrete flume to Apcar barrier	x	x	x	x	x	x	x	166	47	40	23	43	40	180	153
5.5, 6, 8, 9	Subtotal for reaches 6 (with 5.5), 8, & 9			566	643	416	599	507	652	457	322	122	240	236	316	574
5, 5.5, 6, 7, 8, 9	Subtotal for all of "Refuge Stream"	313	595	864	806	659	824	771	1003	1022	520	389	488	523	491	815
10	Gabion to Apcar Refuge Arm barrier	x	x	x	x	x	x	x	62	54	14	32	11	0	0	14
11	Muddy River mainstem from NV Power diversion to Apcar/Refuge/Muddy confluence	x	x	x	x	x	8	0	x	0	0	0	4	0	0	0
12	Muddy river mainstem from Apcar/Refuge/Muddy confluence gabion to ranch road crossing	x	x	x	x	x	x	x	4	0	0	0	0	0	0	0
13	Muddy River from ranch road crossing to North/South fork confluence	x	x	x	x	x	x	x	45	16	5	2	0	0	0	0
	Subtotal for total Mainstem	2088	260													
12,13	Subtotal for reaches 12 & 13	x	x	x	x	34	49	19	49	16	5	2				
14	Muddy Spring outflow	236	28	14	x	5	2	0	0	0	0	0	0	0	1	
15	North Fork	426	106	77	73	46	37	33	9	15	17	7	1	0	0	0
16	South Fork	355	28	13	9	18	24	14	10	9	1	1	0	0	0	0
Total		**3825**	**1565**	**973**	**931**	**934**	**1085**	**907**	**1296**	**1172**	**459**	**462**	**534**	**574**	**654**	**1226**

Moapa dace numbers from 1994 to 2013

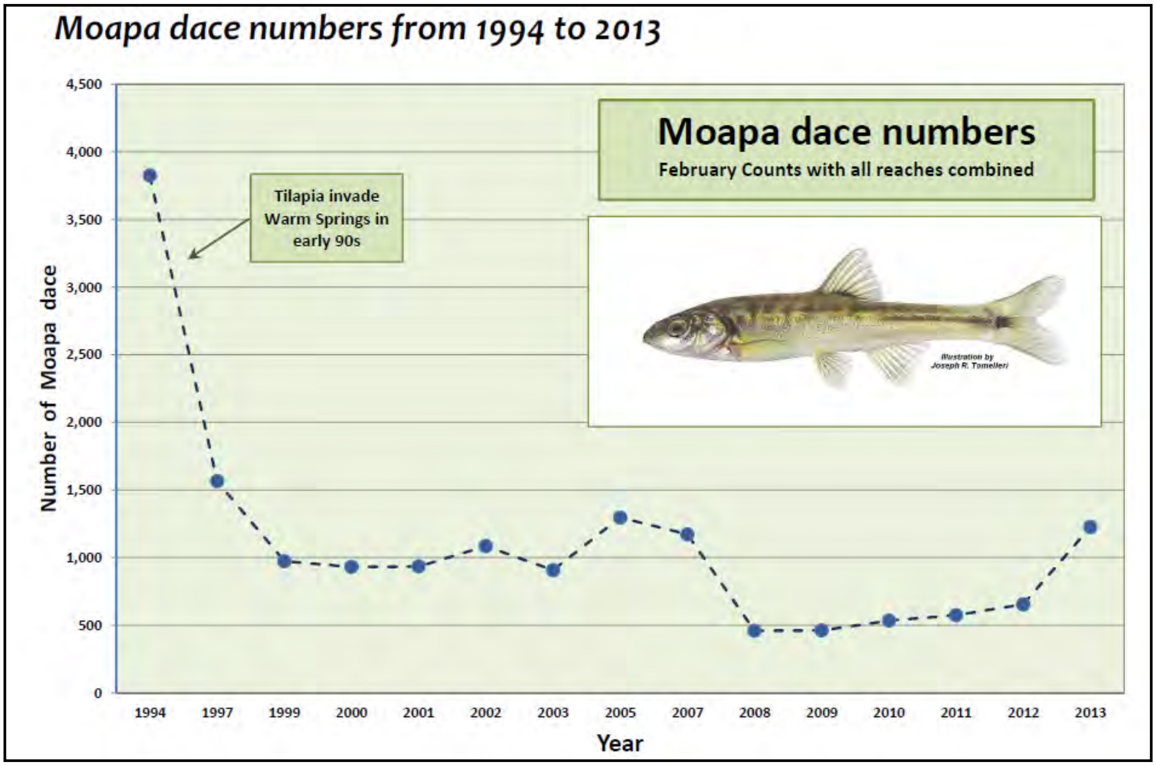


Muddy River Biological Advisory Committee

Moapa dace counts – February 2013

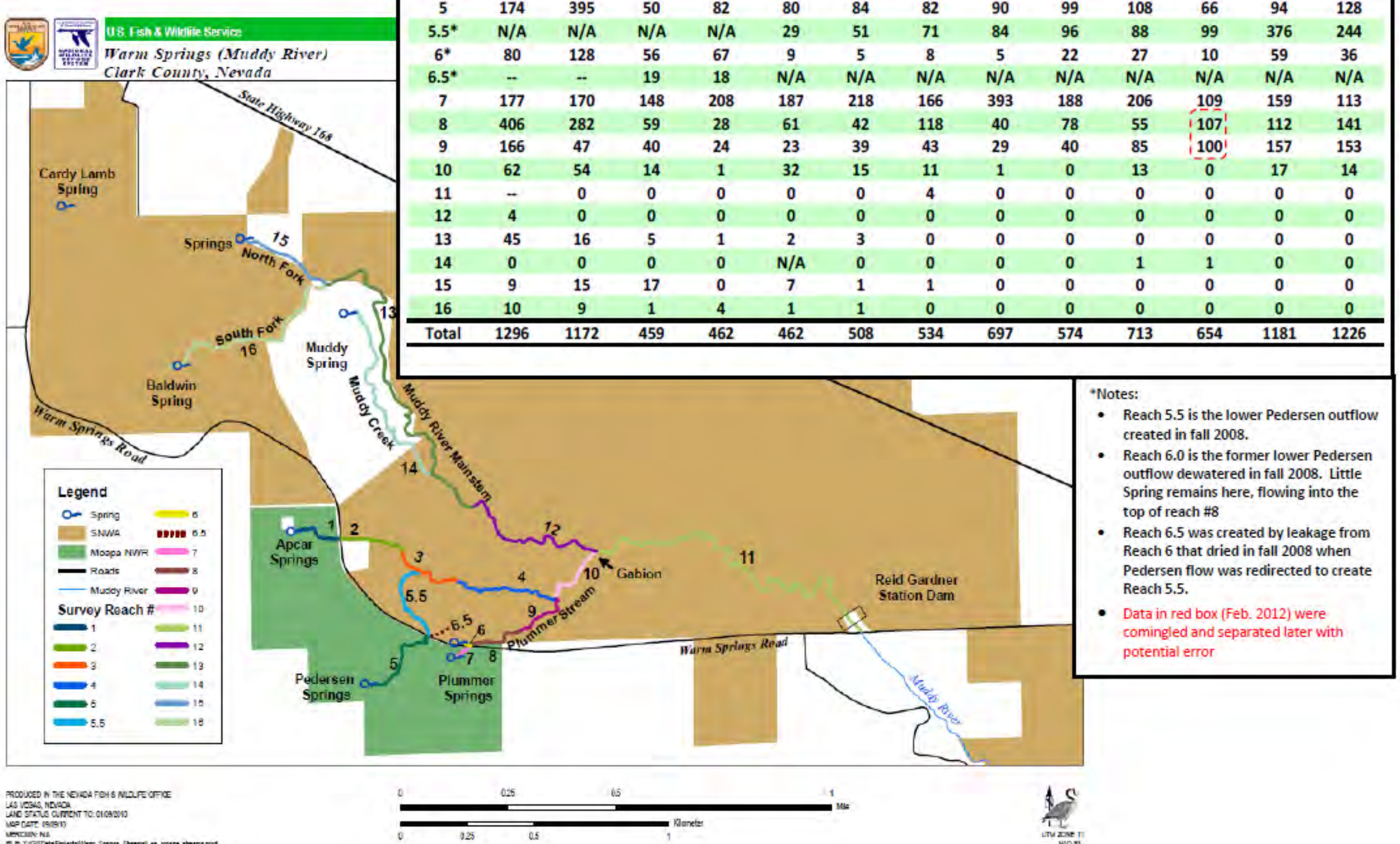
(data and map on flip side)

1. The winter 2013 Moapa dace survey was conducted on 5th and 6th February and recorded 1,226 Moapa dace, representing an increase of about 88% over the last year (+572 fish). Winter counts have occurred since the mid-1990s.
2. The Moapa dace count increased about 4% over the last 6 months (+45 fish). The dace population normally declines from August to February.
3. The surveys consist of 17 non-overlapping reaches. Compared to a year ago:
   a. 10 reaches had more Moapa dace.
   b. 2 reaches had fewer Moapa dace.
   c. 5 reaches had no change in Moapa dace (dace were absent from these areas).
4. Six reaches supported no Moapa dace in February 2013. All of these reaches are in the area where tilapia existed and chemical eradication has occurred in recent years.
5. All reaches that have been free of tilapia for many years supported dace in February 2013.
6. Two reaches that have undergone recent restoration showed large increases in Moapa dace numbers over the past 6 and 12 months (reaches 2 and 3).
7. Two reaches near other reaches that have undergone recent restoration show increases in Moapa dace numbers over the past 6 and/or 12 months (reaches 4 & 10; reach 10 had no dace a year ago, 17 dace 6 months ago, and 14 dace in February 2013).
8. Moapa Valley National Wildlife Refuge (MVNWR) supported 25% of the Moapa dace seen in February 2013. This percentage has decline from a high of 72% in August 2010, which was one month after wildfire burned the Warm Springs Natural Area. The shift in relative distribution of Moapa dace is most likely due to improved habitat conditions on the Warm Springs Natural Area (WSNA).
9. Reach 5.5 is a new spring channel created in late 2008. The reach has supported generally increasing numbers of Moapa dace since its creation and the largest number of dace of any reach in August 2012 and February 2013. This increase is likely due to both the reach's maturation as an ecosystem and the reach's proximity to other recently restored habitats nearby (reaches 2 & 3).
10. Recent declines in number of Moapa dace in reach 5 (Pedersen spring complex; MVNWR) reversed in the February 2013 survey, with increases of 36% (+34 fish) over the past 6 months and 94% (+62 fish) over the past year. These changes probably do not reflect restoration in other reaches, since an upstream fish barrier essentially isolates reach 5.
11. The area chemically treated for tilapia infestation (reaches 11-16) supported a single Moapa dace in late 2011 and early 2012. This dace was observed in the same area in both surveys (Muddy Creek; reach 14), and has not been observed subsequently. Fish in reaches 11-16 consist primarily of shortfin mollies, mosquitofish, and White River springfish. Over the past 18 months, a remnant infestation of tilapia and several large tilapia were detected and eliminated in reach 16. No evidence of reproduction by tilapia has been detected in the Warm Springs area, other than the remnant infestation, which was eradicated. Tilapia have been either completely or very nearly eradicated from the Warm Springs area, although monitoring will continue in the near future.



MOAPA DACE NUMBERS BASED ON SNORKEL SURVEYS

Reach	Feb. 2005	Feb. 2007	Feb. 2008	Aug. 2008	Feb. 2009	Aug. 2009	Feb. 2010	Aug. 2010	Feb. 2011	Aug. 2011	Feb. 2012	Aug. 2012	Feb. 2013
1	6	0	0	N/A	N/A	1	7	20	28	67	74	84	69
2	87	42	50	22	29	34	13	35	20	54	78	79	139
3	52	14	0	4	2	4	3	0	1	8	10	31	127
4	18	0	0	3	0	10	7	0	2	1	0	13	62
5	174	395	50	82	80	84	82	90	99	108	66	94	128
5.5*	N/A	N/A	N/A	N/A	29	51	71	84	96	88	99	376	244
6*	80	128	56	67	9	5	8	5	22	27	10	59	36
6.5*	--	--	19	18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7	177	170	148	208	187	218	166	393	188	206	109	159	113
8	406	282	59	28	61	42	118	40	78	55	107	112	141
9	166	47	40	24	23	39	43	29	40	85	100	157	153
10	62	54	14	1	32	15	11	1	0	13	0	17	14
11	--	0	0	0	0	0	4	0	0	0	0	0	0
12	4	0	0	0	0	0	0	0	0	0	0	0	0
13	45	16	5	1	2	3	0	0	0	0	0	0	0
14	0	0	0	0	N/A	0	0	0	0	1	1	0	0
15	9	15	17	0	7	1	1	0	0	0	0	0	0
16	10	9	1	4	1	1	0	0	0	0	0	0	0
Total	1296	1172	459	462	462	508	534	697	574	713	654	1181	1226



*Notes:

- Reach 5.5 is the lower Pedersen outflow created in fall 2008.
- Reach 6.0 is the former lower Pedersen outflow dewatered in fall 2008. Little Spring remains here, flowing into the top of reach #8
- Reach 6.5 was created by leakage from Reach 6 that dried in fall 2008 when Pedersen flow was redirected to create Reach 5.5.
- Data in red box (Feb. 2012) were comingled and separated later with potential error

Analysis and Management of Animal Populations

Modeling, Estimation, and Decision Making

Byron K. Williams
U.S. Geological Survey
Cooperative Research Units
Reston, Virginia

James D. Nichols
U.S. Geological Survey
Patuxent Wildlife Research Center
Laurel, Maryland

Michael J. Conroy
Cooperative Fish and Wildlife Research Unit
DB Warnell School of Forest Resources
University of Georgia
Athens, Georgia

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CHAPTER

1

Introduction to Population Ecology

In this chapter we introduce the concept of a population that changes over time, in response to primary biological processes that influence population dynamics. We discuss the concepts of density dependence and density independence in these processes, and their roles in regulating and limiting population growth. We incorporate these concepts into a biological context of conservation and management of animal populations. The framework of population dynamics as influenced by primary biological processes and their vital rates will be seen to be useful across ecological scales, and in particular will be seen to contribute to a unified frame of reference for investigations at the scale of individuals (evolutionary ecology), populations, and communities.

1.1. SOME DEFINITIONS

A *population* often is defined as a group of organisms of the same species occupying a particular space at a particular time (e.g., Krebs, 1972), with the potential to breed with each other. Because they tend to prefer the same habitats and utilize the same resources, individuals in a population may interact with each other directly, for example, via territorial and reproductive behaviors, or indirectly through their use of common resources or occupation of common habitat. Spatial boundaries defining populations sometimes are easily identified (e.g., organisms inhabiting small islands or isolated habitat patches) but more typically are vague and difficult to determine. Spatial and temporal boundaries often are defined by an investigator; however, this arbitrariness does not detract from the utility of the population concept.

A key quantity in population biology is population size, which refers to the number of individual organisms in a population at a particular time. In this book, the terms *abundance* and *population size* are used synonymously. We reserve the term *density* for the number of organisms relative to some critical resource. Typically the critical resource is space, so that density represents, e.g., the number of organisms per unit land area for terrestrial species, or the number of organisms per unit water volume for aquatic species. However, the concept of density is sufficiently general that it need not involve space. For example, a meaningful use of the term would be the number of organisms per unit food resource, or in the case of discrete habitat patches, the number of organisms per patch (e.g., the number of ducks per pond on prairie breeding areas).

The structure of a population often can be described in terms of the number of individual organisms characterized by specific attributes of interest. For example, the age structure of a population refers to the respective proportions of individuals in discrete age classes. A population also may be described by its stage structure, with discrete stages defined by variables such as size (the proportions of animals in discrete size classes) (e.g., see Sauer and Slade, 1987a,b), reproductive behavior (e.g., breeders or nonbreeders), or physiological development. In fact, the structure of a population can be described in terms of any attribute thought to be relevant to population dynamics. A common example utilizes the sex ratio of a population, which expresses the proportionate sex composition of a population.

1.2. POPULATION DYNAMICS

Population ecology can be viewed as the study of the distribution of the individuals in a population over time and space. Population ecologists often focus on temporal change in abundance or population dynamics, asking how and why a population changes over time. Temporal population change can be expressed via a simple balance equation that incorporates gains and losses:

$$N(t+1) = N(t) + B(t) + I(t) - D(t) - E(t), \qquad (1.1)$$

where $N(t+1)$, the population size at time $t+1$, is written as a function of population size $N(t)$ at time t, with increases to $N(t)$ during the interval t to $t+1$ as a result of reproduction $B(t)$ and immigration $I(t)$, and losses during the interval from mortality $D(t)$ and emigration $E(t)$. The four variables, $B(t)$, $I(t)$, $D(t)$, and $E(t)$, reflect the primary population processes responsible for changes in population size. If an environmental factor or a management action is to influence population size, its influence must be registered through one of these processes.

The primary population processes in Eq. (1.1) describe gains and losses in terms of numbers of individual organisms. But births and deaths during the interval $(t, t+1)$ are likely to depend on the number $N(t)$ of animals in the population at the beginning of the interval. For this reason, it often is useful to rewrite $B(t)$ as $B(t) = b(t)N(t)$, where $b(t)$ is defined as a per capita reproductive rate, or the number of new individuals in the population at time $t+1$ resulting from reproduction during $(t, t+1)$, per individual alive in the population at time t. Similarly, the number of deaths often is rewritten as $D(t) = [1 - S(t)]N(t)$, where $S(t)$ is an interval survival rate, reflecting the proportion of animals alive at time t that are still alive at time $t+1$. For populations that are geographically closed (i.e., there are no gains or losses resulting from movement), Eq. (1.1) can be rewritten as

$$N(t+1) = N(t)[b(t) + S(t)]. \qquad (1.2)$$

For populations that are not geographically closed, it is tempting to write immigration and emigration as functions of $N(t)$. This often is reasonable for emigration, and we can write $E(t)$ as $E(t) = e(t)N(t)$, where $e(t)$ is the proportion of animals in a population at time t that emigrate out of the population by time $t+1$. But it is less reasonable for immigration, given that the number of individuals immigrating into the population between t and $t+1$ is more likely a function of abundance or density in the source population of immigrants, rather than the size of the recipient population. Immigration thus is treated differently than the other primary population processes, in that it usually is not modeled as a per capita rate based on the recipient population size.

Equations (1.1) and (1.2) constitute simple mathematical models of population change, to be discussed in more detail in later chapters. For present purposes, models can be viewed generally as abstractions and simplifications of reality, and in particular, Eqs. (1.1) and (1.2) can be thought of as simple hypotheses about population change. In later chapters we expand and enhance these models, to incorporate a number of biologically relevant factors that influence population change. For example, single-species population models frequently incorporate information about the attributes of individuals in the population, with individuals grouped into classes as defined by variables such as age, size, and sex (e.g., Lefkovitch, 1965; Streifer, 1974; Caswell, 2001). The population then is characterized by a vector specifying the number of individuals in each class or stage.

Model enhancements also can include spatial structure, as in Levins' (1970) description of a metapopulation as a "population of populations." Metapopulation models often include different habitat patches that may or may not contain individuals, with reproduction occurring among individuals within a patch and movement of individuals occurring between patches (Levins, 1969, 1970; Hanski and Gilpin, 1997; Hanski, 1999). Metapopulation dynamics are thus a function of both within-patch (reproduction, survival) and between-patch (emigration, immigration) processes. Finally, both single-location and multiple-location models can be extended to include multiple species and their potential interactions.

1.3. FACTORS AFFECTING POPULATIONS

Equation (1.1) provides a framework for population change, but carries little information about why populations change. Many questions of ecological and management relevance involve factors that potentially influence the four primary processes driving population change. These can be categorized in many ways, but it often is convenient to think in terms of abiotic and biotic factors. Abiotic factors include physical and chemical characteristics of an organism's environment such as soil type, water availability, temperature, and fire frequency for terrestrial organisms, and water salinity, pH, currents, light penetration, and dissolved oxygen for aquatic organisms. Factors such as these commonly influence population dynamics via multiple rather than single population processes. For example, water and wetland availability on prairie breeding areas in North America can influence duck populations (Johnson *et al.*, 1992) by affecting reproduction (lower probabilities of breeding and increased duckling mortality when conditions are dry), survival of adults (higher mortality of hens associated with predation when nesting during wet years), and movement (increased movement away from relatively dry areas and to relatively wet areas).

On the other hand, biotic factors are understood in terms of interactions among members of the same species (intraspecific), or interactions involving species other than that of the population of interest (interspecific). Interspecific factors include vegetative components of the habitat as well as processes such as predation, interspecific competition, parasitism, and disease. Like abiotic influences, they also can affect more than one of the primary population processes. For example, predation clearly influences mortality, but may also influence movement (increased emigration from areas with large numbers of predators) and reproduction (decreased probability of reproducing in response to increased predation risk).

Intraspecific factors involve interactions among the individuals in a population, with potential influences on all of the primary population processes. They often involve direct behavioral interactions, in which some individuals in the population actively exclude other members of the population from habitat patches or deny access to food resources or even to members of the opposite sex. But they also can involve indirect interactions, through the possible depletion of common resources and the occupation of common habitat. Indirect interactions such as these almost always involve other biotic and abiotic factors.

1.3.1. Population Regulation

Because population processes are influenced simultaneously by abiotic and biotic factors, there may be only limited value in trying to ascertain which class of factors is most relevant to population change. Nevertheless, the history of population ecology has been characterized by repeated arguments about the relative importance of abiotic vs. biotic factors in controlling population dynamics, and the importance of interspecific vs. intraspecific factors (e.g., see Nicholson, 1933; Andrewartha and Birch, 1954; Lack, 1954; Slobodkin, 1961; Reddingius, 1971; Murdoch, 1994). Much of this debate has focused on explanations for the simple observation that populations do not increase indefinitely (Malthus, 1798). The terms population regulation and population limitation refer to concepts that emerge from the impossibility of indefinite population increase.

Population regulation refers to the process by which a population returns to an equilibrium size (e.g., Sinclair, 1989). A glance at Eq. (1.1) indicates that in order for a population to grow [i.e., $N(t + 1) > N(t)$], gains must exceed losses, or $B(t) + I(t) > M(t) + E(t)$. On the other hand, the equilibrium condition $N(t + 1) = N(t)$ is attained when additions to the population equal losses, that is, when $B(t) + I(t) = M(t) + E(t)$. A growing population eventually must reach a state in which the primary population processes change in the direction of equilibrium, that is, births and immigration decrease and/or deaths and emigration increase until gains equal losses. Population ecologists have expended considerable effort in attempting to identify factors that can influence the primary processes of growing populations and thereby produce equilibrium. In reality, such an equilibrium is not likely to be a single fixed population size. Instead, regulation can be viewed as producing a "long-term stationary probability distribution of population densities" (Dennis and Taper, 1994; Turchin, 1995). Murdoch (1994) identified regulation with "boundedness," noting that some cyclic and chaotic populations can also be viewed as regulated.

1.3.2. Density Dependence and Density Independence

The debate about population regulation often is framed in terms of density dependence and density independence. Sometimes these concepts are defined in terms of the rate of population change $\lambda_t = N(t + 1)/N(t)$, although such definitions can become relatively complicated (Royama, 1977, 1981, 1992). Our preference is to define density dependence and density independence in terms of the vital rates associated with the primary population processes. For example, the vital rates associated with a geographically closed population are the survival rate $S(t)$ and reproductive rate $b(t)$ in Eq. (1.2). Though the absolute numbers of births $b(t)N(t)$ and deaths $[1 - S(t)]N(t)$ occurring during the interval $(t, t + 1)$ obviously depend on the population

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size at the beginning of the interval [see Eq. (1.2)], density dependence is defined by the functional dependence of a vital rate on abundance or density {i.e., $S(t) = f[N(t)]$ and/or $b(t) = g[N(t)]$}. Density independence refers to the absence of such a functional dependence. Examples of density dependence might include survival and reproductive rates, which typically decrease as abundance or density increases. The relevance of this concept to population regulation is that regulation requires negative feedback between λ_t (and thus the vital rates that produce λ_t) and population size at t or some previous period. Finally, we note the possibility of Allee effects, in which survival and reproductive rates may decrease in populations at very low density (e.g., Allee *et al.*, 1949; Courchamp *et al.*, 1999; Stephens and Sutherland, 1999).

The concepts of density dependence and density independence provide another means of classifying factors affecting animal populations. Some factors operate as functions of density or abundance (i.e., in a density-dependent manner) and represent dynamic feedbacks. For example, in some rodent populations, intraspecific aggressive behavior among individuals appears to increase as density increases, leading to decreased rates of survival and reproduction (Christian 1950, 1961). Interspecific factors also can act in a density-dependent manner, as when rates of predation or parasitism depend on the abundance of the prey or host population (e.g., Holling, 1959, 1965).

On the other hand, some factors act in a density-independent manner, absent dynamic feedback. When flooding reduces alligator reproductive rates by destroying nests, the magnitude of the reduction in reproductive rate depends on the proportion of nests that are constructed in susceptible locations (e.g., Hines *et al.*, 1968), but not on alligator density. Similarly, severe grassland fires may cause direct mortality of insect and small mammal inhabitants, but the increase in mortality associated with fire events typically is independent of the density of the affected population. In some situations, factors acting in density-dependent and density-independent manners interact, as when density-dependent decreases in reproductive rate occur because of increases in numbers of cavity-nesting birds using a fixed supply of cavities (Haramis and Thompson, 1985).

1.3.3. Population Limitation

Every population is restricted in its growth potential, with a range of conditions beyond which the population tends to decrease because of reductions in survival rates, reproduction rates, or both. Consider a population at equilibrium, such that gains equal losses over time and population size does not deviate greatly from some average or expected value. *Limitation* refers to "the process which sets the equilibrium point" (Sinclair, 1989) or, more generally, that determines the stationary probability distribution of population densities. Limitation can involve factors that act in a density-dependent manner as well as factors that are density independent.

A limiting factor can be defined as one in which changes in the factor result in a new equilibrium level (Fretwell, 1972) or, more generally, a new stationary distribution of population densities. For example, if predation is a limiting factor for a prey population, then a sustained decrease in predation should bring about an increase in equilibrium abundance of the prey. This new equilibrium level would itself be determined by the action of other factors on the primary population processes. Consistent with this definition of a limiting factor is the recognition that populations potentially have multiple equilibria, and a given population may move among equilibria as conditions and limiting factors change (e.g., Hestbeck, 1986).

1.4. MANAGEMENT OF ANIMAL POPULATIONS

Interest in certain animal populations has led to management efforts to try to achieve population goals. These goals frequently involve a desired abundance and, for harvested species, a desired level of harvest. Some animal species exist at abundances thought to be too great, and management efforts are directed at reducing abundance. These include pest species associated with human health problems [e.g., Norway rats (*Rattus norvegicus*); see Davis, 1953] and economic problems such as crop depredation [e.g., the use of cereal crops by the red-billed quelea (*Quelea quelea*) in Africa; see Feare, 1991]. Other species are viewed as desirable, yet are declining in number or persist at low abundance. Relevant management goals for the latter typically involve increases in abundance, in an effort to reduce the probability of extinction in the near future. Such a goal is appropriate for most threatened and endangered species, and methods for its achievement dominate the field of conservation biology (e.g., Caughley, 1994; Caughley and Gunn, 1996). Still other species are judged to be at desirable abundances, and management efforts involve maintenance of population size. Finally, for harvested species, an abundance-oriented goal must be considered in the context of maintaining harvest yield that is consistent with recreational and/or commercial interests (e.g., Hilborn and Walters, 1992; Nichols *et al.*, 1995a).

If management is to influence animal abundance, then it must do so by influencing at least one of the four primary population processes in Eq. (1.1). For example, white-tailed deer are judged to be overabundant in portions of eastern North America, and management efforts to reduce abundance have been directed at both increasing mortality (via hunting and culling operations) and decreasing reproduction (via sterilization and chemical contraception) (McShea *et al.*, 1997; Warren, 1997). Management efforts directed at endangered species frequently involve attempts to decrease mortality via predator control, or attempts to influence reproduction, emigration, and mortality by setting aside or maintaining good habitat. For harvested species, the regulation of harvests focuses on both harvest yield (harvest regulations should influence yield directly) and abundance (harvest regulations influence abundance by changing rates of mortality and, sometimes, movement).

The concepts of population limitation and regulation underlie population management, especially as they factor into the roles of density dependence and independence. For example, the manager of a threatened or endangered species can utilize an understanding of limiting factors to effect management actions to improve the species status. Many endangered species are habitat specialists that are thought to be limited by the amount of suitable habitat available to them. Thus, the purchase or creation of additional habitat represents an effort to remove a limiting factor and to permit the population to increase to a new equilibrium level commensurate with the expanded habitat. Of course, a population increase occurs because of changes in the primary population processes corresponding to the increase in habitat, and it often is useful to focus on the processes as well as the limiting factors.

The concept of density dependence is especially important in management of harvested populations. As a direct mortality source, harvest acts to reduce abundance. However, reduced abundance may lead to increases in reproductive rate or to decreases in nonharvest mortality or emigration, depending on which vital rates behave in a density-dependent manner. For example, much fisheries management is based on stock-recruitment models that incorporate density-dependent reproductive rates (e.g., Beverton and Holt, 1957; Ricker, 1975; Hilborn and Walters, 1992). Management of North American mallard (*Anas platyrhynchos*) populations is based on competing models that represent different sets of assumptions about the density dependence of survival and reproductive rates (Johnson *et al.*, 1997). Because our definitions of density dependence and independence involve the population-level vital rates of survival, reproduction, and movement, density dependence again directs the manager's attention to the primary population processes.

1.5. INDIVIDUALS, FITNESS, AND LIFE HISTORY CHARACTERISTICS

The comments above, and indeed most chapters in this book, focus on the population level of biological organization. However, it is important to remember that the constituents of populations are individual organisms, and the characteristics of these organisms are shaped by natural selection. Characteristics associated with relatively high survival or reproductive rates are favored by natural selection, in that organisms possessing them tend to be represented by more descendants in future generations than do other organisms. Individuals with greater potential for genetic representation in future generations are said to have relatively high fitness.

Though they typically are thought to deal with different levels of biological organization, fitness and population growth are closely related. Thus, the growth rate of a geographically closed population is determined by survival rate and reproductive rate, whereas the fitness of an individual organism is determined by its underlying probabilities of surviving from year to year and of producing 0, 1, 2, . . . offspring each reproductive season. Indeed, fitness associated with a particular genotype can be defined operationally as the growth rate of a population of organisms of that genotype (see Fisher, 1930; Stearns, 1976, 1992; Charlesworth, 1980). An important consequence of the close relationship between population growth and individual fitness is that evolutionary ecologists, population ecologists, and population managers are often interested in the same population processes and their vital rates.

Nevertheless, a subtle difference can exist between definitions of survival and reproductive rates at the population and individual levels of organization. We defined the interval survival rate $S(t)$ as the proportion of animals in the population at time t that survives until time $t + 1$. This quantity is not so useful at the level of the individual organism, because an organism either survives or it does not; however, it can be thought of as having some underlying probability of surviving the interval between times t and $t + 1$. These two distinct quantities, the probability that an individual survives and the proportion of animals in a population that survive, are closely related. Consider a population of individuals with identical underlying survival probabilities for some interval of interest. The

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proportion of individuals that survives the interval likely is not identical with the underlying individual survival probability. On the other hand, the proportion that survives is expected to deviate little from the individual survival probability. More precisely, multiple realizations of population dynamics over comparable time intervals would produce an average proportion of survivors approaching the individual survival probability. In Chapter 8 we define the terms needed to specify the relationship between population-level survival rate and individual probability of survival. The important point for now is that these quantities are closely related. Throughout most of this book, we will use the terms *survival rate* and *survival probability* interchangeably to refer to the underlying individual survival probability. When discussing survival at the population level we will use the term *survival rate* to denote the surviving proportion of a population or group. Of course, the latter quantity is of interest regardless of whether all individuals in the population have the same survival probability.

A similar situation exists for reproductive rate. An individual can produce some integer number of offspring {0, 1, 2, . . .} during a single reproductive season, but a reproductive rate refers to the number of offspring produced per adult in the population. In essence, this offspring/adult ratio is a population-level attribute. The term *reproductive rate* could refer in concept to (1) the average number of young produced if we could observe an individual over many replicate time intervals or (2) the average number of young produced per adult in the population if we could observe the population over many replicate time intervals. Our intention here is not to dwell on subtle differences in the terms used for individuals and populations, but instead to emphasize the role of vital rates in determining both fitness and population growth.

In the discussion above we suggested that the concepts of population limitation and regulation follow naturally from the simple observation that populations do not increase indefinitely. Similarly, evolutionary ecology is based on the observation that neither species nor populations of genotypes can increase indefinitely, though temporary increases are possible. Species and populations of genotypes must eventually reach a state in which temporary increases and declines in numbers of individuals fluctuate about some equilibrium over time. The necessary balance between average survival and reproductive rates has led to various classification schemes [e.g., *r*- and *K*-selected species, "fast" versus "slow" species (Cody, 1966; MacArthur and Wilson, 1967; Boyce, 1984; Stearns, 1992)] for species based on these average values. A basic idea underlying all of these schemes is that species with high reproductive rates must also be characterized by high mortality rates, whereas species with low reproductive rates must also have low mortality rates.

The underlying survival and reproductive rates that apply at each age throughout an organism's lifetime are frequently referred to as *life history characteristics* (Cole, 1954; Stearns, 1976, 1992). Most discussions of life history characteristics also include features such as age at first reproduction, individual growth rate, body size, and age at which individuals can no longer reproduce (see Chapter 8). However, the relevance of these features to life history evolution involves their relationship to the age-specific schedule of survival and reproductive rates. The magnitudes of survival and reproductive rates throughout the organism's lifetime often are viewed as species-specific characteristics, allowing for variation in survival and reproduction rates among individuals. The expectation is that variation among individuals within a species typically is much smaller than variation among individuals of different species.

The suite of life history characteristics is important not only for understanding and predicting population dynamics, but also for managing populations. Consider, for example, the management of two harvested species, one with high mortality and reproductive rates (e.g., several commercially harvested fish species) and one with low reproductive and mortality rates (e.g., harvested whales). Imposition of a fixed harvest rate (proportion of animals in the population harvested) typically has a larger influence on the population dynamics of the species with the otherwise low mortality and the low reproductive rate. In addition to low per capita reproductive rates, such species tend to exhibit delayed sexual maturity, with the consequence that they take longer to recover from decreases in abundance.

In summary, there is a close relationship between fitness and population change, despite the fact that these quantities apply to different levels of biological organization. One consequence of this relationship is that even though population ecologists, population managers, and evolutionary ecologists address different kinds of questions and have different objectives, they are all concerned with population vital rates. Thus, the methods presented in this book for estimating vital rates should be relevant to scientists in these different disciplines. Another consequence is that life history characteristics molded by natural selection are relevant to population dynamics and population management. Knowledge of a species' life history characteristics is of key importance in predicting population responses to management, and thus should play an important role in management decisions.

1.6. COMMUNITY DYNAMICS

In this book, our focus occasionally shifts to the community level of biological organization, where the term *community* refers to a group of populations of different species occupying a particular space at a particular time. A community may include all the different plant and animal species represented in the space, or, more commonly, may refer to a subset of species defined by taxonomy (e.g., the bird community of an area), functional relationships (e.g., vegetative or herbivore community), or other criteria that are relevant to a question of interest.

One way to model community-level dynamics is to model the population for each species, perhaps linking the models via the sharing of resources to induce interactions. For example, consider a simple model of a single predator species and a single prey species. The survival and reproductive rates of the predator species might be modeled as functions of prey species abundance, such that larger numbers of prey lead to higher survival and reproductive rates of the predator species. In the same model, the survival rate for the prey species could be written as a function of predator abundance, with more predators leading to reduced survival for the prey species. A similar approach frequently is taken for the modeling of interspecific competition. The importance of population-level vital rates is again emphasized in this modeling approach, as the interactions between populations are specified as functional relationships involving the vital rates (or composite quantities that combine vital rates).

A less mechanistic and more descriptive approach for community-level modeling does not focus on interspecific interactions. This modeling approach has been used by community ecologists (e.g., MacArthur and Wilson, 1967; Simberloff, 1969, 1972) and by paleobiologists (Raup *et al.*, 1973; Raup, 1977) and simply involves models such as those of Eqs. (1.1) and (1.2) shifted to the community level. Thus, instead of projecting changes in numbers of individual organisms within a population, the models specify change in the numbers of different species in the community. The primary population processes and their corresponding vital rates are replaced by analogous processes and vital rates at the community level.

To see how, let $N(t)$ denote the number of species in the community at time t, with $S(t)$ the species-level survival rate (the complement of local extinction rate) for the interval t to $t + 1$, and $I(t)$ the number of colonists during the interval (species absent from the community at t, but present at $t + 1$). Using notation similar to that of Eqs. (1.1) and (1.2), the natural expression for change in the number of species in the community is

$$N(t + 1) = N(t)S(t) + I(t).$$

Consideration of the processes determining $S(t)$ and $I(t)$ again leads back to the primary population processes and associated vital rates. Local extinction rate for a species-population is a function of population-level rates of survival, reproduction, immigration, and emigration, and the number of colonizing species is a function of immigration at the population level.

The approach of representing a "population" of species via a model for which local extinction plays the role of mortality, and immigration/colonization plays the role of reproduction, is a natural extension of the biological framework portrayed in Eq. (1.1). This analogy has been used in biogeography for many years (MacArthur and Wilson, 1967) and is used frequently in other fields such as conservation biology (e.g., Rosenzweig and Clark, 1994; Russell *et al.*, 1995; Boulinier *et al.*, 1998, 2001; Cam *et al.*, 2000).

1.7. DISCUSSION

In this chapter we have introduced the biology of animal populations in terms of the fundamental processes of survival, reproduction, and migration, along with their associated vital rates. These quantities define the balance equation [Eq. (1.1)] by which population dynamics can be investigated, and they also provide a basis for understanding the factors that influence population dynamics. In the chapters to follow we make liberal use of this framework, as we focus on the modeling of populations and the estimation of population attributes. We will see that quantities such as population size, harvest numbers and rates, recruitment levels, and migration patterns are key to an understanding of population dynamics. We focus much of what follows on the use of field data to estimate these and other population parameters. A careful accounting of the statistical properties of these estimates will be seen to be an essential component in the informed conservation of animal populations.

Prospects for Recovering Endemic Fishes Pursuant to the U.S. Endangered Species Act

ABSTRACT

If the success of the Endangered Species Act (ESA) is measured by the number of endangered species that have been recovered and delisted, then the act is not very successful. Only 15 species have been delisted because of recovery in the history of the ESA. The Borax Lake chub (*Gila boraxobius*), an endangered species restricted to an Oregon spring system, is considered to be on the brink of recovery and may warrant future delisting. A panel of scientists was convened to determine consensus regarding the species' listing status by reviewing: (1) current habitat conditions, (2) implementation of the recovery plan, and (3) applicability of ESA listing factors. Despite substantial progress towards recovery, threats to the species remain, including habitat degradation and the potential introduction of nonnative species. These are problems common to many fishes of highly restricted distribution. Because the Borax Lake chub occurs in a single spring system, the species remains vulnerable to catastrophic loss and requires continuing protection afforded by the ESA. Like many spring-dwelling fishes with a restricted range, recovery of the Borax Lake chub to the point where ESA protection is no longer required is an admirable but largely unobtainable goal. Prevention of extinction rather than delisting is a more appropriate measure of ESA success for such species.

Jack E. Williams
Catherine A. Macdonald
Cindy Deacon Williams
Hal Weeks
Georgina Lampman
Don W. Sada

Jack Williams is chief scientist for Trout Unlimited in Ashland, Oregon. He can be reached at jwilliams@tu.org. Macdonald is the vice president for stewardship at The Nature Conservancy in Portland, Oregon. Williams is a fishery consultant in Medford, Oregon. Weeks is a project leader with the Oregon Department of Fish and Wildlife in Newport, Oregon. Lampman is the Intermountain Region aquatic ecology lead for the U.S. Forest Service in Ogden, Utah. Sada is an aquatic ecologist with the Desert Research Institute in Reno, Nevada.

According to Section 2 of the Endangered Species Act of 1973 (ESA), the primary purpose of the act is to stem the tide of human-caused extinctions and to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved. The ESA is widely regarded as the most important conservation law in the United States and is viewed as the pinnacle of legislation for protecting wildlife (Bean 1983; Plater 2004). Because of its importance and influence, the ESA has been the keystone for a growing number of conservation battles across the country. Conflicts between application of the ESA and land and water development projects have increased because of several factors, but chief among these is the cumulative effects of a growing human population and increasing resource demand coupled with an increasing number of species listed as endangered or threatened.

The 30-year history of the ESA has been characterized by a growing list of protected species, subspecies, and distinct population segments (hereinafter "species"). When the ESA was signed into law by President Nixon in 1973, 119 species received "grandfathered" protection from the earlier Endangered Species Conservation Act of 1969. From 1973 through 2002, an average of nearly 43 species were added each year to the list of endangered and threatened species until a total of 1,262 species (517 animals, 745 plants) were listed in the United States as of 2003 (U.S. Fish and Wildlife Service [USFWS] 2004a).

Over this same timeframe, 37 species have been delisted and subsequently removed from ESA protection. Of these, 15 were delisted because of recovery, 7 because of extinction, and 15 because of new information or taxonomic revision showing their listing was in error (USFWS 2004b). The low number of recovered species is due largely to inadequate protection from a growing array of threats to species and habitats, and because delisting removes the primary regulatory protection available—that is, from the ESA itself (Doremus and Pagel 2001). Indeed, some scientists and legal scholars have questioned whether we are likely to see the recovery of many listed species, and instead have proposed that recovery should be viewed as an aspirational goal rather than a realistic expectation for many listed species (Doremus 2000; Doremus and Pagel 2001). On the other hand, others have encouraged delistings because of recovery for a variety of practical, political, and philosophical reasons (Bender et al. 1998).

The growing list of protected species and increasing human-caused fragmentation and degradation of natural habitats presents a looming conflagration for conservation efforts. As conflicts escalate between the ESA and human development, there are growing efforts to reduce the impact and effectiveness of the ESA. One way to reduce the impact of the ESA is to reduce the number of protected species, either by slowing the number of new species listings and/or increasing the number of delistings. For the first 20 years following passage of the ESA, there were only 18 delistings, but since 1993 the rate of delistings has increased. Elements on both sides of the conservation debate have sought to increase the number of delisted species. During the Clinton Administration, Interior Secretary Babbitt believed that the USFWS's ability to delist species because of recovery was a clear indication that the ESA was a success. During this period, USFWS expedited delisting efforts, including development of lists of species that might warrant delisting because of recovery (Bender et al. 1998). As Rohlf (2004) pointed out in a recent review of Section 4 of the ESA, federal agencies have both political incentive and institutional desire to find success in the ESA by pointing to recovered species that may be delisted. Of course, those that oppose the ESA are equally glad to see fewer species protected under the act's provisions, but for different reasons.

Among the species that might warrant contemporary delisting is the Borax Lake chub (*Gila boraxobius*), an endangered species inhabiting a small hot-spring ecosystem in southeastern Oregon. The restricted habitat occupied by the species recently has been acquired by a conservation group and surrounding public land has received additional protections. In 2003, we conducted a review of the conservation status of the Borax Lake chub to develop a scientific consensus regarding the listing status and future conservation needs of that species. The purposes of this article are to report on the results of our evaluation of the Borax Lake chub, discuss implications of our finding for the vulnerability of other species of restricted range, and to provide recommendations for status reviews for endemic species listed pursuant to the ESA. We also offer our opinion regarding appropriate criteria for measuring the success of the ESA itself. Management of endangered and threatened fishes, including their recovery and delisting, are critical topics to fisheries biologists. We hope this article stimulates further debate on measures of success for the ESA and understanding of the appropriate role of delisting.

Case Study: The Borax Lake Chub

The Borax Lake chub is endemic to the geothermally-heated waters of Borax Lake and adjacent wetlands in Oregon's Alvord Basin (Williams and Bond 1980). The chub was listed as endangered in 1980 by emergency rule and again as endangered by final rule in 1982 (USFWS 1982). At the time of listings, the primary threats to the species consisted of potential impacts from geothermal energy development and diversion of the lake's outflows by alteration of the shoreline crusts. Although no recovery team ever was formed for this species, a recovery plan was completed in 1987 that called for protection of the Borax Lake ecosystem through acquisition of key private lands, protection of subsurface and surface waters, controls on access, removal of livestock grazing, monitoring, and other recovery actions (USFWS 1987).

The Borax Lake chub exists as a single population that most likely has been maintained within its historic range of natural variability, and an increase in abundance is not a factor in successful recovery. Recovery, in this instance, is based entirely on habitat integrity, including protection of spring aquifers, and the avoidance of nonnative species introductions.

JACK WILLIAMS

Borax Lake is a spring-fed ecosystem in Oregon's Alvord Desert and, along with surrounding pools and marshes, the sole habitat for the endangered Borax Lake chub.

Numerous recovery measures have been implemented during the past two decades to secure habitat for the species. In 1983, the Bureau of Land Management (BLM) designated the public lands surrounding Borax Lake as an Area of Critical Environmental Concern. The Nature Conservancy (TNC) leased two 160-acre private land parcels, one surrounding Borax Lake and the other immediately to the north, in 1983 and purchased them outright in 1993, thereby bringing all lands designated as critical habitat into public or conservation ownership. With the acquisition by TNC, livestock grazing ceased. Passage of the Steens Mountain Cooperative Management and Protection Act of 2000 withdrew public lands from mineral and geothermal development within a majority of the Alvord Basin, including the Alvord Known Geothermal Resource Area and Borax Lake.

With removal of many of the significant threats facing the Borax Lake chub, the U.S. Fish and Wildlife Service began to examine its feasibility for reclassification (R. White, USFWS, pers. comm.). The Borax Lake chub frequently is cited by USFWS as being "on the brink of recovery" (Motivans and Balis-Larsen 2003) and is rated by that agency as having achieved a relatively high percentage of recovery implementation (51–75%; USFWS 2003). In 2003, two of the authors conducted a status review of the Borax Lake chub to determine whether a change in listing status was warranted and to review future management and monitoring needs for the species (Williams and Macdonald 2003). The status review consisted of four components: (1) review of recovery plan implementation, (2) field investigations at Borax Lake to determine current status of the species and habitat, (3) review of the five listing factors from Section 4 of the Endangered Species Act, and (4) convening of a 16-member scientific panel to review findings from the recovery plan, habitat, and listing factor reviews. The panelists were scientists that had worked previously on the species and its habitat, agency biologists with management responsibility for the species, and other scientists with extensive knowledge of desert spring systems in western North America. Panelists were asked, using their best scientific judgment on issues rather than agency positions, to develop a consensus on listing status, management, and monitoring.

The expert panel concluded that substantial progress has been made towards recovery of the Borax Lake chub, but that despite this progress, threats to the species and ecosystem remain. Results of the status review are summarized in Table 1. Threats that had been eliminated included the alteration of lake shoreline and outflows, livestock grazing, and geothermal energy development on public lands. The primary remaining threats were increasing habitat degradation associated with recreational use and the increasing potential of nonnative species introduction. Exotic goldfish (*Carassius auratus*) recently have been introduced into Mann Lake just to the north of Borax Lake (Tim Walters, Oregon Department of Fish and Wildlife, pers. comm.). Both recreation and introduced species received minor attention in the 1987 recovery plan. Borax Lake is located in a remote and sparsely-populated area, but one that is increasingly used by a public seeking opportunities for solitude, wildlife observation, and open space. The panel believed that because the range of the Borax Lake chub is restricted to single geologically fragile site, the species is vulnerable to catastrophic loss despite existing protection. The panel also noted the importance of frequent monitoring to detect and move to extirpate

Table 1. Summary of status review findings for the Borax Lake chub. For recovery plan implementation review, recovery subtasks were scored on a scale of 0–4.

0 = no implementation
1 = minor implementation
2 = approximately half implemented
3 = mostly implemented
4 = fully implemented

Recovery Plan Implementation	Task 1: Secure land and water rights. Average subtask score = 3.7. Task 2: Restore Lower Borax Lake, small ponds, and intervening marshes. Average subtask score = 4.0. Task 3: Protect Borax Lake ecosystem. Average subtask score = 2.7. Task 4: Monitor status of ecosystem. Average subtask score = 2.3. Task 5: Encourage support of recovery through public awareness. Average subtask score = 3.5.
Field Investigations	Habitat and chub population appeared in good condition and within expected range of variation observed historically. Significant recreational use (off-road vehicle use, camping, disturbance of lake substrates from wading) was noted.
Review of 5 Listing Factors	1. Present or threatened destruction, modification, or curtailment of its habitat or range. 1982: threats consisted of chipping of crusts around shoreline, diversion of outflows, development of geothermal resource, and potential development of recreation facility. 2003: threats consist of recreational use and potential water development on private lands. 2. Overutilization for commercial, sporting, scientific or educational purposes. 1982, 2003: no threats for this factor. 3. Disease or predation. 1982: no threats for this factor. 2003: potential introduction of nonnative species. 4. Inadequacy of existing regulations. 1982: no threats for this factor. 2003: no threats for this factor. 5. Other natural or manmade factors affecting its continued existence. 1982: no threats for this factor. 2003: because of restricted range, species vulnerable to disturbance event.

introduced species and to be able to act quickly in the face of other new threats. No change in listing status was recommended although the expert panel concluded reclassification from endangered to threatened could be appropriate in the near future depending primarily upon implementation of a regular monitoring program. The panel further concluded that "maintaining the Borax Lake chub on the list of Endangered and Threatened Wildlife and Plants affords the greatest likelihood that sufficient scientific and agency attention will be focused on Borax Lake such that if habitat integrity is compromised, corrective action will be timely enough to save the species."

Delisting and Vulnerability of Endemic Fishes

Given the plethora of possible causes of population endangerment, determining vulnerability of species to extinction events is difficult. Many factors are relevant, including a species' habitat requirements, population size, and dispersal abilities (Tilman et al. 1994; Driscoll 2004). Furthermore, a search for explanations of status changes in many lesser-known species listed as endangered or threatened often is hindered by our lack of knowledge of their basic life history and habitat requirements. Nonetheless, certain factors common to many endangered species are known to increase the likelihood of their extinction. These factors include small population size (Soulé 1983; Gilpin and Soulé 1986), restriction to a small geographic area (Lovejoy et al. 1986), dependence upon a specific rare habitat type (Terborgh 1974), and inability to move away from increasing sources of stress or habitat degradation (Diamond 1975).

Endemic fishes with a highly restricted range are particularly vulnerable to extinction because they occur as a single or low number of populations, depend upon a specific habitat type, and have low tolerance for habitat modification. Endemic fishes may be common in the limited areas where they occur but often have rigid habitat requirements. These endemic species therefore, become highly vulnerable to habitat change or invasion of nonnative species (Minckley and Deacon 1968; Terborgh 1974). The vast majority of recent U.S. extinctions have been in species with restricted ranges, including freshwater mussels of southeastern rivers, and plants and terrestrial invertebrates of Hawaiian forests (Suckling et al. 2004). In their review of western fish conservation, Deacon and Minckley (1991) concluded that the restricted distributions and small population sizes of many spring-dwelling fishes dictated their virtual permanent status as endangered or threatened.

Of the 15 species that have been delisted because of recovery, most are wide-ranging, such as the American alligator and peregrine falcon. Five fishes have been removed from the list of threatened and endangered species, four because of their extinction (Tecopa pupfish [*Cyprinodon nevadensis calidae*], longjaw cisco [*Coregonus alpenae*], blue pike [*Stizostedion vitreum glaucum*], and Amistad gambusia [*Gambusia amistadensis*]) and one because of taxonomic revision (Umpqua River form of coastal cutthroat trout, *Oncorhynchus clarki clarki*). No fishes have been delisted because of recovery. Although it is difficult to generalize about the characteristics of listed species that make good candidates for recovery, it seems clear that species with the following suite of characters may more readily respond to recovery efforts: (1) habitat requirements are more general than specific, (2) quality habitat remains within historic range, and (3) existing threat factors, such as overharvest, may be easily regulated. Simply stated, recovered species often faced threats that were easier to address through available regulatory channels (Abbitt and Scott 2001). On the other hand, species from specialized habitats and/or smaller ranges may be more vulnerable to loss (Terborgh 1974; Deacon and Minckley 1991). In a review of the conservation status

DON SADA

Jackrabbit Spring in Ash Meadows, Nevada, provides habitat for the endangered Ash Meadows pupfish and Ash Meadows speckled dace (*Rhinichthys osculus nevadensis*). Other nearby springs provide habitat for the endangered Devils Hole pupfish (*Cyprinodon diabolis*) and warm springs pupfish (*C. nevadensis pectoralis*). Despite designation of the springs as protected areas (Ash Meadows National Wildlife Refuge and disjunct portion of Death Valley National Park), habitats and fishes remain vulnerable.

of aquatic species in the Great Basin, Sada and Vinyard (2002) found that declines were greatest in the most narrowly distributed and vulnerable populations. According to their analysis, all extinct taxa and most taxa suffering major declines (68%) had fewer than five small populations.

A report by Bender et al. (1998) listed 22 species considered likely candidates by USFWS for delisting or reclassification because of increased protection, included three fishes: tidewater goby (*Eucyclogobius newberryi*), Ash Meadows pupfish (*Cyprinodon nevadensis mionectes*), and Pahrump poolfish (*Empetrichthys latos*). The tidewater goby is more broadly ranging, but the Ash Meadows pupfish and Pahrump poolfish are both spring-dwelling fishes with restricted ranges that are similar to the Borax Lake

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chub in terms of vulnerability. The Ash Meadows pupfish and three other listed fishes are endemic to springs in the Ash Meadows area but remain vulnerable to catastrophic loss because of introductions of nonnative species and/or modification to subsurface aquifers. These threats persist despite protective management of land around surface spring areas. The recovery plan for Ash Meadows species lists protection of aquifers, eradication of nonnative species, and restoration of natural spring habitats as essential criteria that must be met before fishes should be considered for delisting or reclassification from endangered to threatened (USFWS 1990). Recovery of the Pahrump poolfish is doubtful. This species has been eliminated from its single spring historic habitat but exists as an introduced population on the Desert Wildlife Range. Like the Borax Lake chub, these spring-dwelling desert fishes are likely to need the protection afforded by the ESA in perpetuity.

Current procedures for delisting species pursuant to Section 4 of the ESA are similar to listing. That is, the status of the species is compared to the five listing factors contained in Section 4, and if delisting is believed warranted by USFWS, a proposal is published in the *Federal Register* notifying the public of the proposed change and seeking public comments. We suggest the panel review conducted for the Borax Lake chub may provide a suitable model to evaluate the ESA status of endemic species, particularly those lacking recovery teams. For species with recovery teams, the team likely could substitute for the expert panel. Regardless, a variety of factors should be reviewed in any delisting process, including the implementation status of any applicable recovery plans and current status of subject populations and habitats, in addition to an analysis of the five listing factors.

Conclusions

The desire to delist species is driven, at least in part, by the belief that recovery of listed species is an indicator of the success of the ESA. But with only 15 taxa delisted because of recovery in the history of the ESA, success as measured by this indicator is poor. More appropriate indicators would include changes in population trends of listed species and the ability of ESA protections to prevent extinction. In its latest biennial report to Congress on recovery of listed species, USFWS (2003) reported that population trends for 39% of listed taxa were either stable or increasing, while 34% were declining, and 24% were uncertain. Pursuant to this indicator, the ESA fares better. If preventing extinction is the criterion, an assessment of the success of the ESA is even more positive, with only 7 taxa delisted because of extinction. One study estimated that based on risk of extinction alone, 192 listed taxa would have been expected to go extinct between 1973 and 1998 (Schwartz 1999). Recent data from the Center for Biological Diversity (Suckling et al. 2004) supports the value of ESA protections in preventing extinction. An analysis of 114 extinctions of U.S. species since the ESA was passed in 1973 found that 81% of extinction events involved taxa that were not protected by the ESA (19% were listed). Suckling and others (2004) believe that removal of procedural delays in listing species pursuant to the ESA and elimination of the listing backlog would have resulted in increased protection that likely would have prevented many extinctions. Additionally, many rare but non-listed species occur with listed species and may receive protection that could be indirectly credited to the ESA. Regardless, the small number of extinctions of listed species suggests strongly that the ESA has been successful in ensuring the continued existence of the taxa it protects.

Delisting of spring-dwelling fishes with restricted ranges should be approached with considerable caution because of their inherent ecological and biological vulnerability and their ability to serve as umbrella species protecting many lesser-known and unlisted organisms. Although the Borax Lake chub has a higher rate of recovery success than many listed species, it appears to an expert panel to be a poor candidate for delisting largely because of its inherent vulnerability as an endemic species dependent on a specialized habitat. Ironically, because the ESA is a strong regulatory law for species and habitat protection, removal of this protection through the delisting process also removes the preeminent tool for maintaining the species in the long run. The naturally restricted range of many endemic fishes makes their recovery to the point of delisting an admirable but largely unobtainable goal.

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Desert National Wildlife Refuge Complex

Ash Meadows, Desert, Moapa Valley, and Pahranagat National Wildlife Refuges

Final Comprehensive Conservation Plan and Environmental Impact Statement
Summary – August 2009

National Wildlife Refuge System Mission

To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.

U. S. Fish and Wildlife Service
Pacific Southwest Region
2800 Cottage Way, Room W-1832
Sacramento, CA 95825

August 2009

SE ROA 12664

Summary

Current Status of the Comprehensive Conservation Plan

The U.S. Fish and Wildlife Service (Service) began the process of developing a Comprehensive Conservation Plan (CCP) for the Desert National Wildlife Refuge Complex (Desert Complex) in fall 2001. Public, agency, and tribal involvement was an important part of the CCP process, with five scoping meetings held during the first year of the planning process, and multiple interagency and tribal meetings and workshops to address topics related to visitor services, cultural resources, and wildlife and habitat management. The Draft CCP/Environmental Impact Statement (EIS) was made available for public review and comment from July 11, 2008, through September 9, 2008. The Draft CCP/EIS has been revised to respond to public comments to produce the Final CCP and Final EIS. A Record of Decision will be signed within 30 days after the availability of the Final CCP and EIS is announced in the Federal Register.

Introduction

The Desert Complex, consisting of the Ash Meadows National Wildlife Refuge (NWR), Desert NWR[1], Moapa Valley NWR, and Pahranagat NWR, is located in Nye, Clark, and Lincoln counties in southern Nevada (Figure 1). Ash Meadows NWR is located northwest of Pahrump, Nevada, less than 5 miles from the California-Nevada border and encompasses approximately 24,000 acres (Figure 2). Desert NWR is located less than 10 miles north of Las Vegas and encompasses more than 1.6 million acres, making it the largest refuge in the continental U.S. (Figure 3). Moapa Valley NWR is located northwest of Moapa and encompasses approximately 116 acres of land (Figure 4). Pahranagat NWR is located at the northeastern corner of the Desert NWR, just south of Alamo; this Refuge encompasses more than 5,000 acres (Figure 5). Ash Meadows and Moapa Valley NWRs were established to protect endangered and threatened species, Desert NWR was established to protect desert bighorn sheep and other wildlife, and Pahranagat NWR was established to provide a habitat for migratory birds.

Ash Meadows NWR provides habitat consisting of spring-fed wetlands and alkaline desert uplands for at least 25 plants and animals found nowhere else in the world. The Refuge has a greater concentration of endemic life than any other local area in the U.S. and the second greatest concentration in all of North America. Desert NWR provides a wide range of upland habitats, from saltbush scrub to coniferous forests, as well as natural springs and wetlands. The Refuge provides one of the largest contiguous blocks of habitat for desert bighorn sheep in the U.S. Moapa Valley NWR provides habitat for the endemic Moapa dace, including streams and springs. Pahranagat NWR provides open water, marsh, riparian, and upland habitats for migratory birds and a diversity of fish and wildlife. The Refuge is an important stopover for numerous migratory birds during their fall and spring migrations.

Comprehensive Conservation Plan Process

A CCP is prepared pursuant to the National Wildlife Refuge System Administration Act of 1966 (NWRS Administration Act), as amended by the National Wildlife Refuge System Improvement Act of 1997 (Improvement Act) (Public Law [PL] 105-57), and an EIS is prepared in accordance with the requirements of the National Environmental Policy Act of 1969 (NEPA). The Improvement Act and Part 602 (National Wildlife Refuge System Planning) of the Fish and Wildlife Service Manual provide the directives and guidance for preparing CCPs and recommends that the CCP and EIS be incorporated into one document. This approach, which provides for the direct integration of the provisions of NEPA into the CCP process, complies with the requirement that Federal agencies integrate the NEPA process with other planning at the earliest possible time.

[1] The official name is Desert National Wildlife Range; however, throughout this document, it is referred to by its common name, Desert National Wildlife Refuge.

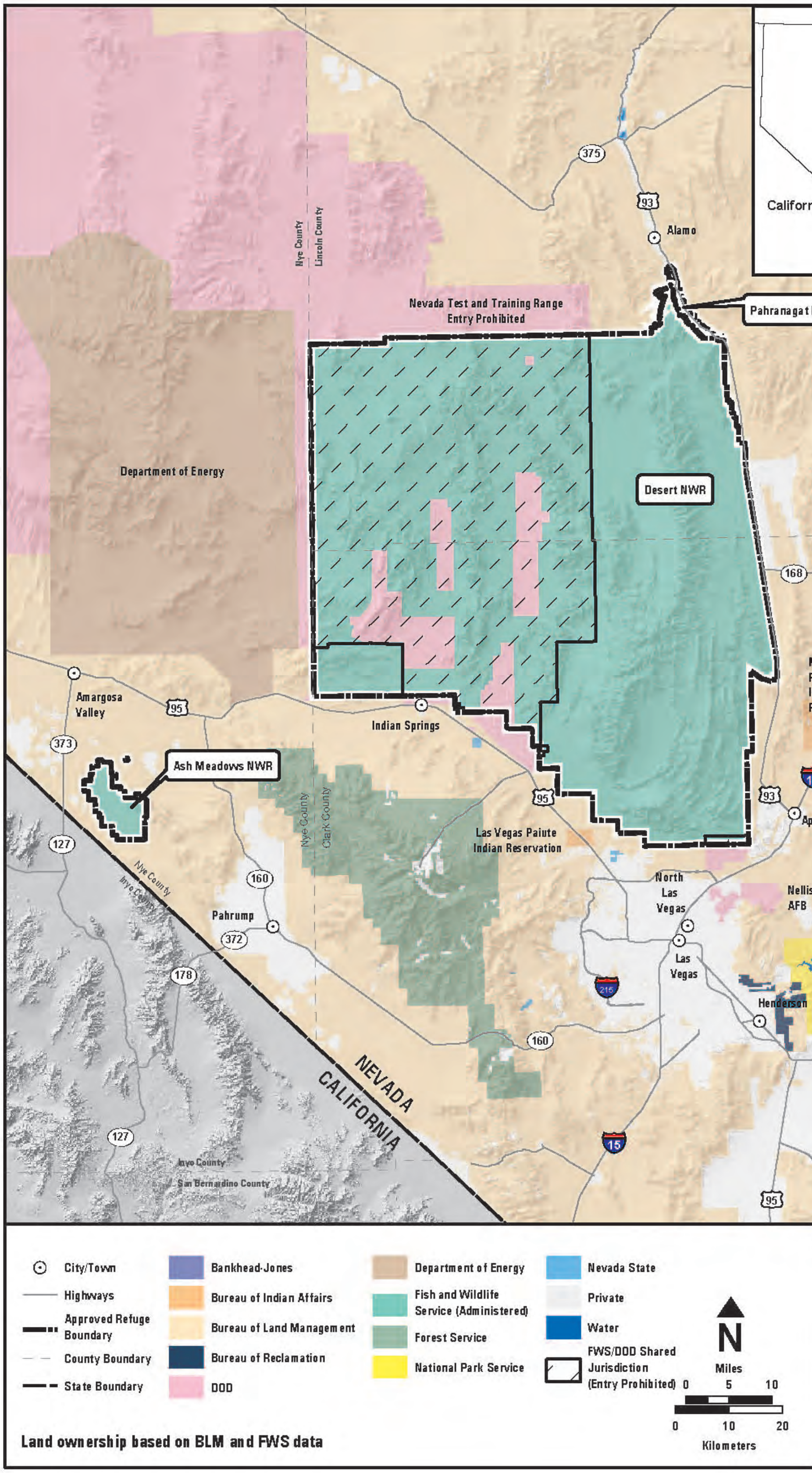

Figure 1

Desert National Wildlife Refuge Complex

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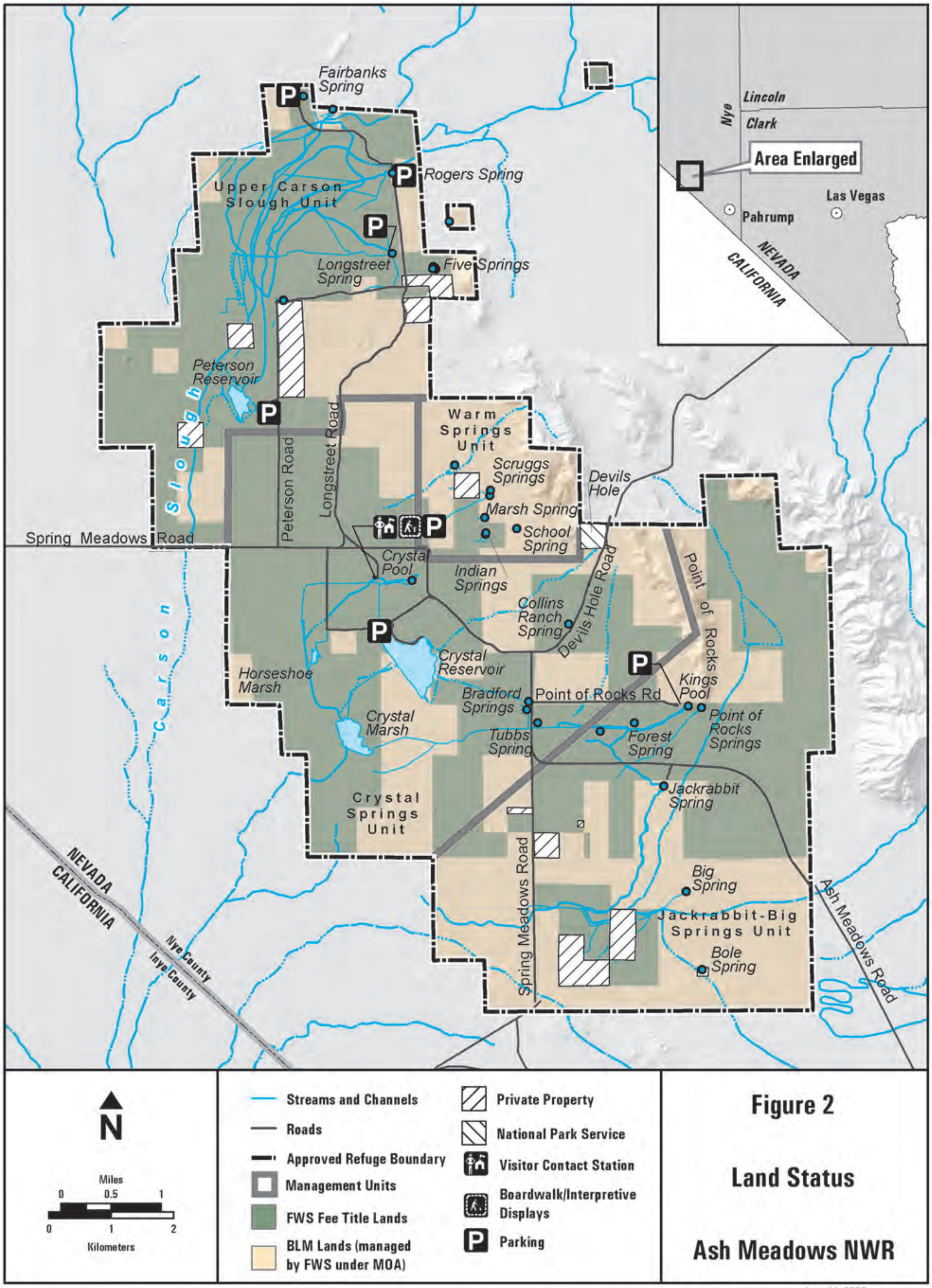

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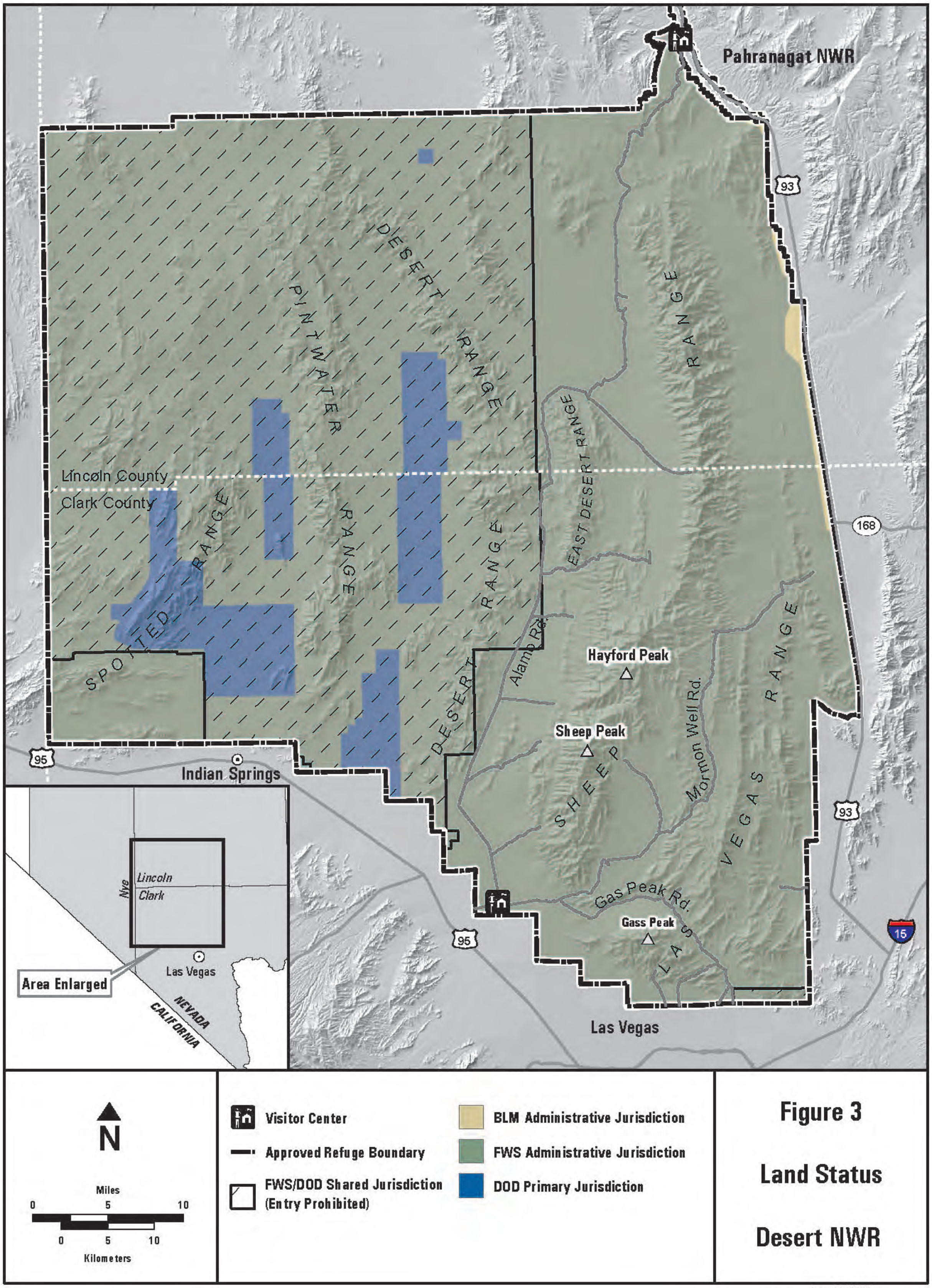

Figure 3

Land Status

Desert NWR

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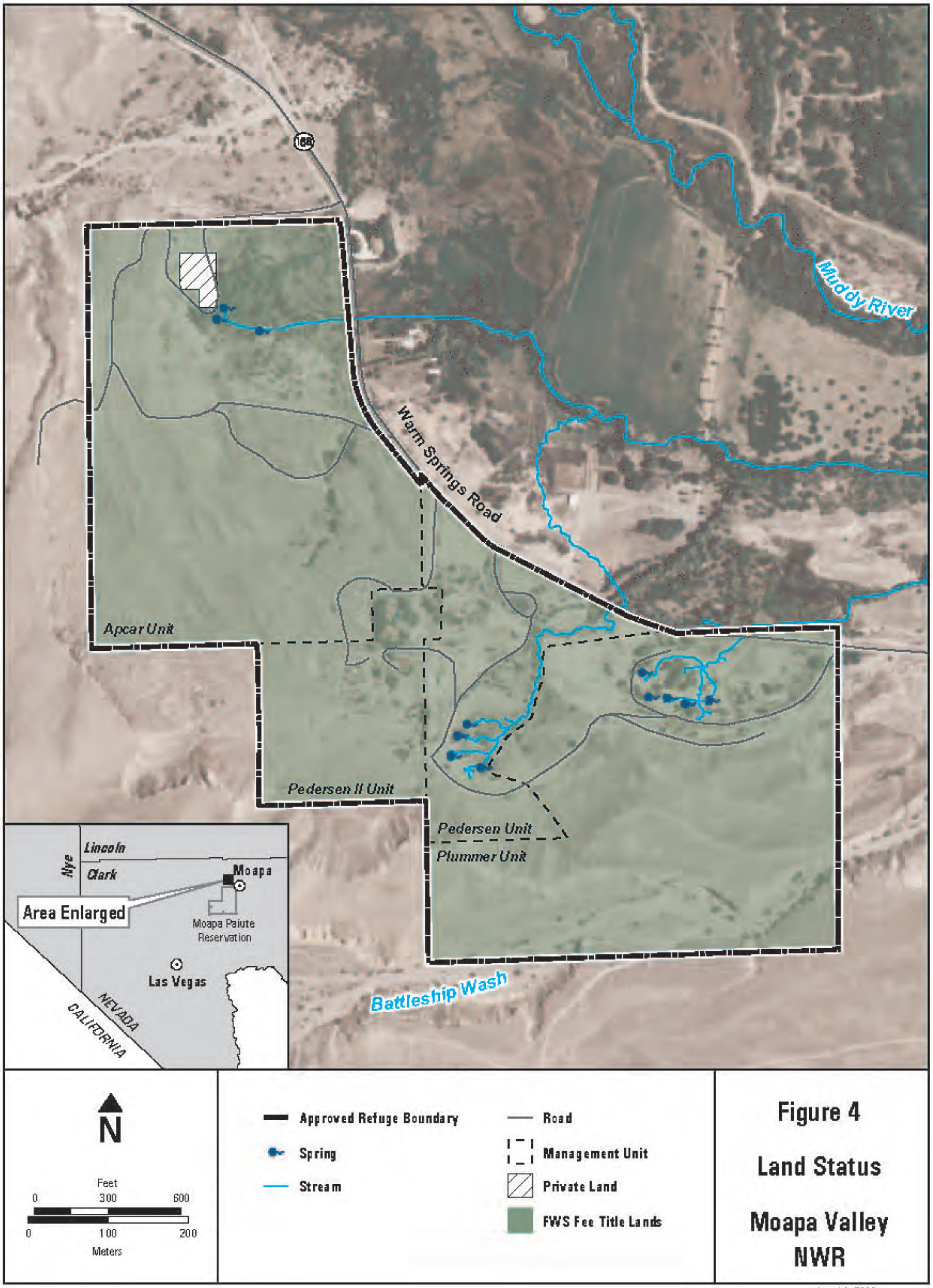
Figure 3-desert_landstatus.mxd



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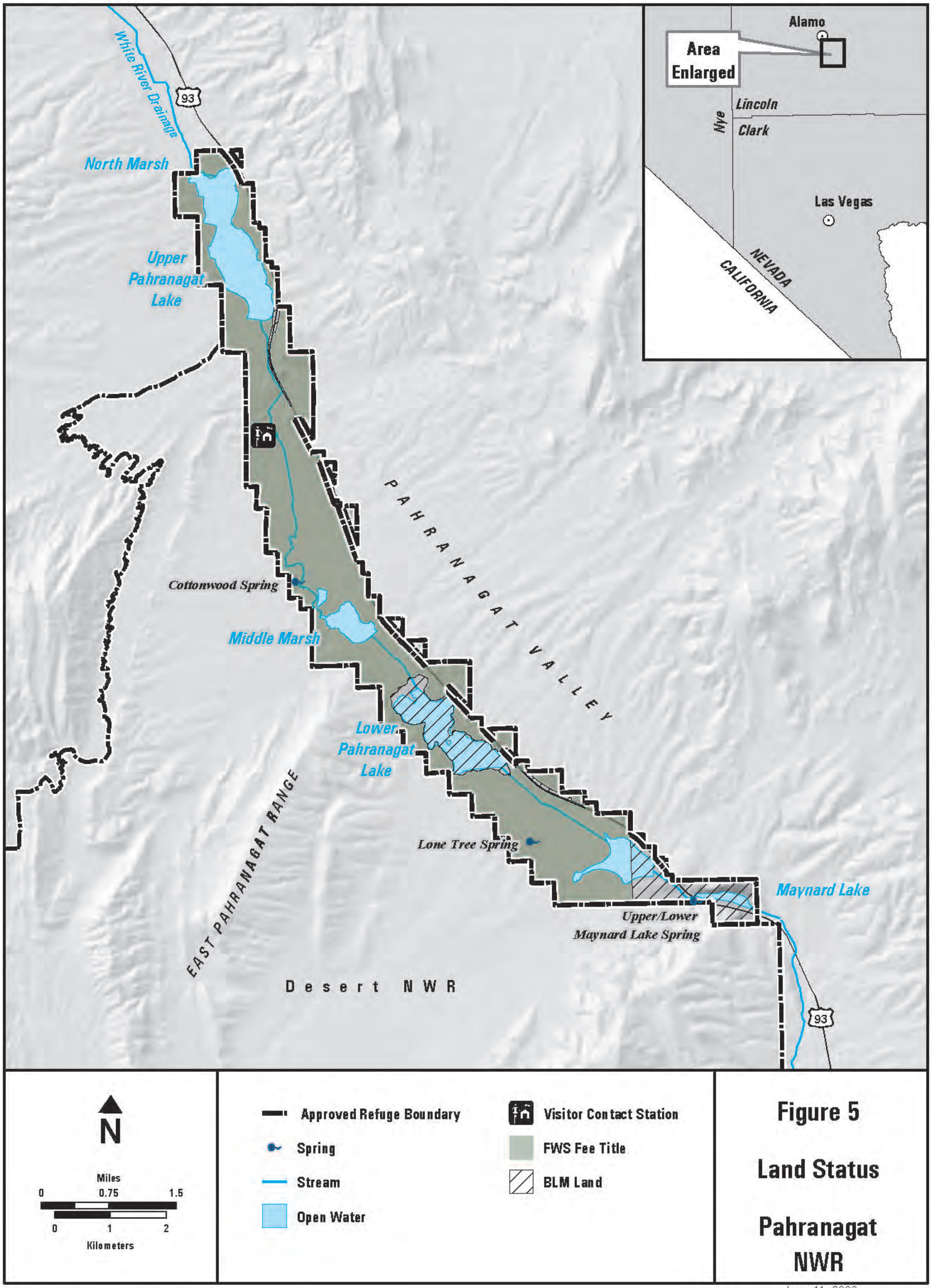

Figure 5

Land Status

Pahranagat NWR

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Figure 5-pahranagat_landstatus.mxd

The CCP/EIS is a programmatic document intended to analyze proposed actions on a conceptual level, except in those cases where sufficient information is available to provide project-specific analysis. Therefore, the extent of analysis provided for each restoration and/or visitor services proposal reflects the level of detail currently available for the specific proposal. The habitat restoration proposals analyzed in the CCP/EIS should be viewed as conceptual. It is during subsequent project level planning, referred to as "step-down" planning, that additional studies would be conducted, additional baseline data would be gathered, the appropriate project-level NEPA documentation would be prepared, all necessary permits would be acquired, and final engineering and restoration planning would be conducted. Step-down planning would also include a public involvement component similar to that provided during the CCP process.

The CCP is intended to provide a clear and comprehensive statement of the desired future conditions for the Refuge and to ensure public involvement in refuge management decisions. The public involvement component of CCP planning encourages public input throughout the process from initial scoping and public review of the Draft CCP to participating in refuge management decision and step-down planning following formal adoption of the plan.

Availability of the Final CCP/EIS

The Final CCP/EIS is available online at http://desertcomplex.fws.gov. A compact disc (CD) or hard copy of the document can be obtained by writing to: Mark Pelz, Chief, Refuge Planning, 2800 Cottage Way, W-1832, Sacramento, California 95825. Other contact methods include: 916-414-6500 (telephone), 916-414-6497 (facsimile), or fw8plancomments@fws.gov (email).

The Final CCP/EIS is also available at the following locations: Refuge Headquarters at Ash Meadows NWR, Desert NWR, and Pahranagat NWR; Desert Complex office at 4701 N. Torrey Pines Drive; Clark County Library, 1401 E. Flamingo Road, Las Vegas, NV; Las Vegas Library, 833 Las Vegas Boulevard North, Las Vegas, NV; and North Las Vegas Library, 2300 Civic Center Drive, North Las Vegas, NV.

Purpose and Need

The purpose of developing the CCP for the refuges is to provide managers with a 15-year strategy for achieving refuge purposes and contributing to the mission of the NWRS, consistent with the sound principles of fish and wildlife conservation and legal mandates. The CCP is flexible and will be revised periodically to ensure that its goals, objectives, strategies, and timetables are valid and appropriate.

The Improvement Act requires that the Service develop a CCP for each refuge by 2012, and that refuges be managed to ensure the long-term conservation of fish, wildlife, plants, and their habitats and provides for compatible wildlife-dependent recreation. The purposes for developing a CCP are:

- To provide a clear statement of direction for the future management of the refuge;
- To provide long-term continuity in Desert Complex management;
- To communicate the Service's management priorities for the refuges to its conservation partners, neighbors, visitors, and the general public;
- To provide an opportunity for the public to help shape the future management of the refuges;
- To ensure that management programs on the refuges are consistent with the mandates of the NWR System (NWRS) and the purposes for which each refuge was established;
- To ensure that the management of the refuges fully considers resource priorities and management strategies identified in other federal, state, and local plans;
- To provide a basis for budget requests to support the refuge's needs, staffing, operations, maintenance, and capital improvements; and

- To evaluate existing and proposed uses of each refuge to ensure that they are compatible with the refuge purpose(s) as well as the maintenance of biological integrity, diversity, and environmental health.

The National Wildlife Refuge System

The NWRS is the largest collection of lands and waters specifically managed for fish and wildlife conservation in the nation. Unlike other federal lands that are managed under a multiple use mandate (e.g., lands administered by the U.S. Bureau of Land Management and the U.S. Forest Service), the NWRS is managed for the benefit of fish, wildlife, plant resources, and their habitats.

Operated and managed by the Service, the NWRS comprises more than 545 national wildlife refuges with a combined area of more than 95 million acres. Most refuge lands (approximately 77 million acres) are in Alaska. The remaining acres are spread across the other 49 states and several island territories.

The mission of the NWRS is "*to administer a national network of lands and waters for the conservation, management and, where appropriate, restoration of fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans*" (16 USC 668dd et seq.).

Refuge Overview

The Desert Complex encompasses more than 1.6 million acres of land in southern Nevada in the southern part of the Great Basin and northern extent of the Mojave Desert in the Basin and Range Province. Each refuge within the Desert Complex provides important and unique habitat for wildlife, including several endemic species (species native to the refuges and often not found anywhere else). The prehistory and history of the Desert Complex region spans the last 12,000 years or more and encompasses a number of major culture areas. Visitor services vary at each refuge and are primarily focused on wildlife-dependent recreation. Each refuge also provides resources that are important to local culturally affiliated tribes.

This section provides an overview of each refuge's establishment, purpose(s), vision statement, goals, and settings.

Ash Meadows NWR

Ash Meadows NWR was established on June 18, 1984, through the purchase of 11,177 acres of former agricultural lands from The Nature Conservancy (TNC). According to the Service's 1984 Environmental Assessment: Proposed Acquisition to Establish Ash Meadows National Wildlife Refuge, the purpose of the acquisition was ". . . to protect the endemic, endangered, and rare organisms (plants and animals) found in Ash Meadows . . ." Since the original acquisition from TNC in 1984, an additional 2,309 acres have been acquired from several different landowners. Many of the Refuge's seeps, springs, pools, and streams supporting sensitive species have been destroyed or altered by human activities over the last 100 years. Habitat alterations during agricultural, municipal, and mining development caused the extinction of one fish species, at least one snail species, and possibly an endemic mammal species (Ash Meadows montane vole, *Microtus montanus nevadensis*). The Refuge provides habitat consisting of spring-fed wetlands and alkaline desert uplands for at least 25 plants and animals found nowhere else in the world. The Ash Meadows NWR has a greater concentration of endemic life than any other local area in the United States and the second greatest concentration in all of North America.

Ash Meadows NWR derives its purpose from the ESA, which authorized its creation:

> *"...to conserve (A) fish or wildlife which are listed as endangered species or threatened species...or (B) plants..."* (16 USC Sec. 1534).

The Service established the following vision statement for the Refuge during the CCP development process:

> *The springs, wetlands, and other native habitats of Ash Meadows National Wildlife Refuge support and protect the highest concentration of endemic plant and animal species anywhere in the United States. The Refuge's natural communities are restored to their historic extent and condition, and threatened and endangered species populations are recovered and maintained at sustainable levels through innovative coordination and partnerships. Refuge management continually responds to changes in the environment through adaptive management. Water supplies are ample, reliable, and of appropriate quality and temperature to sustain endemic and other fish and wildlife populations.*
>
> *Researchers are drawn to the Refuge where science-based management and monitoring is used to guide habitat restoration and endangered species recovery efforts and, in the process, further scientific knowledge of fields such as species genetics, regional water flow, geology and even the cultural and historical significance of this long inhabited area. Visitors find sanctuary among the crystal pools and springs nestled among the expansive Mojave Desert landscape.*
>
> *Local residents and visitors enjoy learning about and gaining an appreciation for the Refuge and its unique wildlife and plant species. Local educators recognize the Refuge as an exceptional regional resource for environmental education and for unique wildlife and habitat community tours. Volunteers find a meaningful and personally enriching application for their interests and talents in a responsive and appreciative setting that contributes to the conservation of rare, unique and beautiful species of wildlife and plants for the enjoyment of present and future generations of Americans.*

The following goals provide guiding principles for the Ash Meadows NWR:

Species Management (Goal 1). Restore and maintain viable populations of all endemic, endangered and threatened species within the Refuge's Mojave Desert oasis ecosystem.

Habitat (Goal 2). Restore and maintain the ecological integrity of natural communities within the Ash Meadows NWR.

Research (Goal 3). Encourage and provide opportunities for research which supports Refuge and Service objectives.

Visitor Services (Goal 4). Provide visitors with wildlife-dependent recreation, interpretation, and environmental education opportunities that are compatible with, and foster an appreciation and understanding of, Ash Meadows NWR's wildlife and plant communities.

Cultural Resources (Goal 5). Manage cultural resources for their educational, scientific, and traditional cultural values for the benefit of present and future generations of refuge users, communities, and culturally affiliated tribes.

Ash Meadows NWR is situated within the unincorporated township of Amargosa Valley near Death Valley National Park. The Refuge provides a diversity of habitats, from springs and streams to desert uplands, and supports a variety of endemic and sensitive plant, fish, and wildlife species. Examples of species unique to the Refuge's habitats include Ash Meadows milkvetch, spring-loving centaury, Devils Hole pupfish (found only in Devils Hole, which is managed by the National Park Service), and Ash Meadows speckled dace. The Refuge also contains remnants of the past, including nearly 300 known prehistoric and/or historic sites. Several sites are eligible for listing on the National Register of

Historic Places because they contain representative characteristics of the people that used the area in the past. The Refuge is a day use area, open sunrise to sunset, with numerous recreational opportunities. Wildlife-dependent activities include wildlife observation, photography, environmental education, interpretation, and hunting. Non–wildlife-dependent activities include picnicking, and virtual geocaching (use of geographic positioning systems for treasure hunting).

Desert NWR

On May 20, 1936, President Franklin D. Roosevelt established the Desert Game Range for "the conservation and development of natural wildlife resources" (Executive Order 7373). The 2.25 million acre Game Range, under the joint administration of the Service and Bureau of Land Management (BLM), included most of the lands within the current Refuge boundary, but stretched south to include portions of the Spring Mountains, including the area currently occupied by Red Rock Canyon National Conservation Area.

In 1939, a 320-acre ranch at Corn Creek was acquired from a private landowner under the authority of the Migratory Bird Conservation Act. This site became the administrative headquarters for the Game Range. Between 1970 and 1985, 440 acres in the vicinity of Corn Creek were purchased from a variety of private land owners under the authority of the Endangered Species Act (16 USC Sec. 1534) and Refuge Recreation Act (16 USC Sec. 460k-460).

In October of 1940, approximately 846,000 acres of the Desert Game Range were reserved for the use of the War Department (Department of Defense [DOD]) as an aerial bombing and gunnery range (now known as the Nevada Test and Training Range [NTTR]). Public Land Order 4079, dated August 31, 1966, as amended by Public Law (PL) 106-65 (Sec. 3011[b][3]), established the Desert National Wildlife Range under the sole administration of the Bureau of Sport Fisheries and Wildlife (now the Service). It also reduced the size of the refuge to 1,588,000 acres. The Military Lands Withdrawal Act of 1999 (PL 106-65) transferred primary jurisdiction of 112,000 acres of bombing impact areas on Desert NWR from the Service to the DOD. However, the Service retained secondary jurisdiction over these lands.

On November 6, 2002, President George W. Bush signed the Clark County Conservation of Public Land and Natural Resources Act of 2002 (PL 107-282), which administratively transferred 26,433 acres of BLM land adjacent to Desert NWR's east boundary to the Service. Desert NWR's land base changed again with the passage of the Lincoln County Conservation, Recreation, and Development Act of 2004 (PL 108-424). As part of the Act, administrative jurisdiction over approximately 8,382 acres of land along the eastern boundary of Desert NWR and west of U.S. Highway 93 was transferred from the Service to the BLM for use as a utility corridor. In addition, 8,503 acres of BLM-administered land were transferred to the Service to be managed as part of the Desert NWR. This land is located at the northeastern boundary of the Desert NWR and the western boundary of Pahranagat NWR.

Desert NWR is the largest Refuge in the continental United States and the largest protected area in Nevada. It encompasses six distinct mountain ranges with intervening valleys that provide a range of upland habitats for large mammals, birds, reptiles, and several sensitive species, such as the desert tortoise. Corn Creek Field Station, the Refuge headquarters, provides spring and pond habitat with wetland and riparian vegetation. The Desert NWR is one of the largest intact blocks of habitat for the bighorn sheep in the southwestern United States. The Refuge also contains two National Register Districts (Corn Creek Campsite and Sheep Mountain), which contain prehistoric and historic resources representative of past uses of the Refuge. Although only a small portion of the Refuge has been surveyed for archaeological resources, approximately 450 prehistoric sites and several historic sites have been recorded. The Refuge is also known to contain paleontological resources (fossils) dating back to the Pleistocene era (1.8 million to 10,000 years ago). The Refuge offers the opportunity for a unique and solitary desert experience. Primitive camping, picnicking, backpacking, and hiking are some of the non–wildlife-dependent recreational opportunities available on the Desert NWR. Wildlife-dependent recreational opportunities include wildlife observation, photography, and hunting.

Desert NWR has four purposes derived from laws under which it was established:

> *"...for the protection, enhancement, and maintenance of wildlife resources, including bighorn sheep..."* (Public Land Order 4079, dated August 31, 1966, *as amended by PL 106-65*).
>
> *"...to conserve (A) fish or wildlife which are listed as endangered species or threatened species...or (B) plants..."* (ESA, 16 USC Sec. 1534).
>
> *"...suitable for (1) incidental fish and wildlife-oriented recreational development, (2) the protection of natural resources, (3) the conservation of endangered species or threatened species..."* (16 USC Sec. 460k-1).
>
> *"...the Secretary...may accept and use...real...property. Such acceptance may be accomplished under the terms and conditions of restrictive covenants imposed by donors...*" (Refuge Recreation Act, as amended, 16 USC Sec. 460k-2).

The Service developed the following vision statement for the Refuge:

> *As the largest refuge in the contiguous United States, Desert National Wildlife Range provides the highest quality, intact habitat for desert bighorn sheep and other fish, wildlife, plants and their habitats native to the Great Basin and Mojave Desert ecosystems.*
>
> *This rugged, arid landscape supports a full range of desert habitats from playas on the valley floors through desert scrub and coniferous woodlands to ancient bristlecone pine groves on the mountain peaks. The vast, rugged wild spaces provide wildlife and people a refuge and a place for harmonious recreational opportunities.*

The following goals provide guiding principles for the Desert NWR:

Bighorn Sheep (Goal 1). Maintain and, where necessary, restore healthy population levels of bighorn sheep on Desert NWR within each of the six major mountain ranges.

Wildlife Diversity (Goal 2). Maintain the existing natural diversity of native wildlife and plants, including special-status species, at Desert NWR.

Specially-designated Areas (Goal 3). Manage specially designated areas such that they augment the purposes of the Desert NWR.

Visitor Services (Goal 4). Provide visitors with opportunities to understand, appreciate, and enjoy the fragile Mojave/Great Basin Desert ecosystem.

Cultural Resources (Goal 5). Manage cultural resources for their educational, scientific, and traditional cultural values for the benefit of present and future generations of refuge users, communities, and culturally affiliated tribes.

Moapa Valley NWR

Moapa Valley NWR was established on September 10, 1979, to secure and protect habitat for the endangered Moapa dace. The Refuge comprises multiple adjacent but visually distinct units. The original Pedersen Unit was acquired in 1979 and is 30 acres in size. An additional 11 acres were purchased in 2006 from Richard and Lorena Pedersen and are referred to as the Pedersen II unit. The 28-acre Plummer Unit was acquired in 1997, and the 48-acre Apcar Unit was acquired in 2000. Each unit has a separate stream system supported by the steady and uninterrupted flow of several springs that surface at various places throughout the Refuge. Due to the Refuge's small size, fragile habitats, ongoing restoration work, and removal of unsafe structures, the Refuge has been closed to the public since its establishment.

Moapa Valley NWR is situated in the Moapa Valley, east of the Desert NWR. The Refuge is part of a unique system of thermal springs that are part of the headwaters of the Muddy River, which eventually flow into Lake Mead east of Las Vegas. These springs provide riparian and aquatic habitats that support sensitive birds, bats, and fish, including the endemic Moapa dace. Most of the Refuge was previously privately held and used as a resort with swimming pools and other developed features. As a result, considerable alteration to the character of the landscape has occurred, and potential archaeological sites that may have been present are likely buried or destroyed as part of resort development. At present, due to its small size, fragile habitats, ongoing restoration work, and construction activities related to the removal of unsafe structures, the Refuge is closed to the general public. It is anticipated that the Refuge will be open to the public in the future to provide recreational opportunities once the restoration work is complete. Staff-conducted tours are currently being offered for interpretation and nature observation.

The purpose of Moapa Valley NWR derives from the ESA:

> *"...to conserve (A) fish or wildlife which are listed as endangered species or threatened species...or (B) plants..."* (16 USC Sec. 1534).

The Service established the following vision statement for the Refuge:

> *Moapa Valley National Wildlife Refuge supports and protects a healthy, thriving population of Moapa dace at the headwaters of the Muddy River. Stable flows from the Refuge's numerous warm springs fill meandering channels downstream that provide ideal habitat for dace, Virgin River chub and other species of endemic fish and invertebrates.*
>
> *The spring bank and riparian plant communities provide habitat for southwestern willow flycatcher as well as a rich diversity of migratory and resident songbirds, colonial nesting species, and other native wildlife.*
>
> *Local residents and visitors learn about and enjoy this restored desert oasis. Volunteers take personal satisfaction from contributing to the conservation and protection of Refuge wildlife and the unique spring system nourished habitats on which they depend.*

The following goals provide guiding principles for the Moapa Valley NWR:

Endemic and Special-Status Species (Goal 1). Protect and restore, when possible, healthy populations of endemic and special-status species, such as the endangered Moapa dace, within the Muddy River headwaters.

Visitor Services (Goal 2). Provide local communities and others with opportunities to enjoy and learn about the resources of Moapa Valley NWR and participate in its restoration.

Pahranagat NWR

Pahranagat NWR was established on August 16, 1963, to provide habitat for migratory birds, especially waterfowl. The Refuge is an important stopping point for numerous migratory birds during their fall and spring migrations. It is also an important tourist attraction for visitors traveling on U.S. Highway 93 to or from Las Vegas. An additional 1,466 acres were incorporated into the Refuge boundary later, bringing the acreage of Pahranagat NWR to a total of 5,382 acres.

Pahranagat NWR is situated at the southern end of Pahranagat Valley, northeast of the Desert NWR. The Refuge contains marshes, open water, native grass meadows, cultivated croplands, and riparian habitat and is an important migratory bird stopover within the Pacific flyway. The Refuge is known to support a population of federally endangered southwestern willow flycatchers and provides habitat for other sensitive birds, bats, reptiles, and mammals. The Pahranagat NWR area is an extremely important cultural landscape to many tribal people, and the Refuge contains a diversity of prehistoric and historic resources, including the Black Canyon National Register District. The public is encouraged to visit the "valley of many waters" to enjoy a variety of recreational opportunities and experience the desert oasis. Wildlife-dependent activities include wildlife observation, photography, fishing, hunting, environmental education, and interpretation. Currently, camping, boating, and picnicking are common non–wildlife-dependent activities on the Refuge.

The purpose of Pahranagat NWR derives from the Migratory Bird Conservation Act:

> *"…for use as an inviolate sanctuary, or for any other management purpose, for migratory birds…"* (16 USC 715d).

The Service established the following vision statement for the Refuge:

> *The Pahranagat National Wildlife Refuge is managed as a sanctuary where present and future generations of people can discover a connection to the rhythms of life. In spring, indigo bush and beavertail cactus bloom at the edges of verdant meadows and wetlands, fed by brimming lakes. The vital, spring-fed waters of this Mojave Desert oasis attract thousands of migratory birds each year. Pahranagat NWR's seasonal marsh, wet meadows, and alkali flats provide high quality resting and foraging habitat for wintering and migrating waterfowl, shorebirds and other waterbirds along the Pacific Flyway. Riparian gallery forests of willow, cottonwood, and associated plant communities support a flourishing population of southwestern willow flycatcher as well as a rich diversity of migratory and resident songbirds, colonial nesting species and birds of prey. Coveys of Gambel's quail emerge at dusk along with abundant cottontails and jackrabbits as nighthawks, coyotes, and owls begin to hunt. Each fall brings returning waterfowl and waterfowl hunters, while mountain lions follow mule deer down into the valley.*
>
> *Wetlands, wet meadows, upland plant communities, natural springs, and cultural history entice scientists and scholars to study Refuge resources and further human understanding of the processes and environments that are the foundation for the rich diversity of life on Pahranagat NWR and how humans have interacted with that environment over millennia.*
>
> *Other researchers focus on understanding the role of southwestern wetlands and diversity in the regional and national refuge system, the preeminent example of a habitat conservation system in the United States and perhaps the world. This ever expanding understanding contributes to conservation and management of Mojave Desert environments important to southern Nevada, the southwest, and the United States.*
>
> *Visitors from near and far find sanctuary among the crystal pools and springs as they learn about the Refuge's unique plant and animal communities. Local people take pride in the Refuge, and visitors tell their families and friends about this brilliant desert gem. Educators recognize the Refuge as an exceptional regional resource for environmental education and observation of wildlife and the habitats upon which they depend. Volunteers take great personal satisfaction from applying their interests and abilities to the conservation and interpretation of a unique,*

natural Mojave Desert community for the enjoyment of present and future generations of Americans.

The following goals provide guiding principles for the Pahranagat NWR:

Wetland Habitat (Goal 1). Restore and maintain wetland habitat for waterfowl and other migratory birds with an emphasis on spring and fall migration feeding and resting habitat requirements.

Wildlife Diversity (Goal 2). Restore and maintain the ecological integrity of natural communities within Pahranagat NWR and contribute to the recovery of listed and other special-status species.

Visitor Services (Goal 3). Provide visitors with compatible wildlife-dependent recreation, interpretation, and environmental education opportunities that foster an appreciation and understanding of Pahranagat NWR's wildlife and plant communities.

Cultural Resources (Goal 4). Manage cultural resources for their educational, scientific, and traditional cultural values for the benefit of present and future generations of refuge users, communities, and culturally affiliated tribes.

Issues

Based on input from the public, agencies, and affiliated tribes, the following list of planning issues is a summary of the key issues that have guided the development of alternatives and preparation of the Draft CCP/EIS:

- Endemic and Federally Listed Species: How will the Service protect and restore habitat? How will the Service gather data on special-status and endemic species? What measures will the Service take to protect and restore populations of special-status species? How will the Service monitor its actions and the status of special-status species? What measures will be implemented for invasive and pest species management?
- Fires and Fuel Management: How will the Service respond to fire events or use fire to manage the refuges?
- Research: What research opportunities are available?
- Visitor Services: How will visitor service opportunities be improved or expanded? What types of opportunities will be available at each refuge? How will the Service monitor visitor use?
- Cultural Resources: How will cultural resources be managed and protected at each refuge?
- Refuge Management: What staff are needed for each refuge?
- Special Management Areas: How will special management areas (proposed wilderness, research natural areas, etc.) be managed?
- How can refuge springs be protected from impacts of proposed groundwater development in the region?
- Climate Change: How will climate change affect refuge resources?

Areas of Controversy and Issues to Be Resolved

The following areas of controversy have been identified and will need to be resolved prior to implementation of the management actions at each refuge:

- Public comments revealed that there is concern and controversy about the potential conversion of the Pahranagat overnight camping facilities to day use only.
- Potential impacts resulting from both existing and proposed groundwater development is an area of controversy reflected in the comments received regarding the Draft CCP/EIS.

The following issues will need to be resolved prior to implementation of management actions at each refuge:

- The Service's current refuge budgets and staffing would not be adequate to implement the number of new management actions that are part of the preferred alternatives. Identification of a funding source and allocation of adequate funding and staffing would be required to implement the actions.
- The Service currently lacks adequate data or information on the biological resources that occur at each refuge, specifically the extent and requirements of special-status plant and wildlife populations. Site-specific surveys of proposed restoration or affected areas would need to be conducted prior to developing restoration plans or implementing management actions to ensure the activities would benefit the species and result in minimal adverse impacts.
- The Service currently lacks adequate data or information on the cultural resources that occur at each refuge, specifically the extent of buried or underground resources. Site-specific inventories of affected areas would need to be conducted prior to site-specific planning and implementing management actions to ensure minimal impacts on the resources.
- The Service currently lacks adequate data on the impacts to wells and springs on the refuges as a result of groundwater developments. Further research and studies would need to be conducted to ensure the groundwater development activities do not.

The Service will review public comments on the Draft CCP/EIS and consider the comments during preparation of the Final CCP and Final EIS and will resolve issues raised during the comment period as appropriate.

Management Alternatives

An important step in the CCP process is the development and analysis of alternatives. Alternatives are developed to explore and analyze different ways to achieve Refuge purposes, contribute to the mission of the NWRS, meet Refuge goals, and resolve issues identified during scoping and throughout the CCP process. The alternatives developed for each Refuge are summarized below; graphics depicting the Preferred Alternatives for each refuge are included at the end of this section. Chapter 3 of the Draft CCP/EIS provides more detailed descriptions of the alternatives and graphics for each alternative.

Ash Meadows NWR

A number of current management actions would be implemented for the Ash Meadows NWR under each of the alternatives. Common to all actions include species monitoring and baseline inventories; establishment of new pupfish refugia; managing, monitoring, and restoring Refuge habitats; monitoring water resources; protecting sensitive areas of the Refuge; implementing the Integrated Pest Management Plan; completing the pending land and mineral withdrawal; acquiring private inholdings from willing sellers; continuing research activities through special use permits, and expanding visitor services and public use opportunities, specifically through construction of boardwalks and interpretive displays and development of environmental education materials.

Alternative A – No Action: Species management on the Refuge is currently guided by the 2006 *Geomorphic and Biological Assessment* by Otis Bay and Stevens Ecological Consulting. This document provides an overview of the resources on the Refuge and identifies recommendations for species management. Management actions identified in the document are evaluated and implemented as appropriate and as staffing and funding become available. The Service would restore 70 acres of alkali/wet meadow habitat, 30 acres of mesquite bosques/lowland riparian habitat, and 30 acres of native upland habitat in the Warm Springs and Jackrabbit/Big Springs Management Units. In addition, approximately 10 to 25 percent of the old agricultural fields would be rehabilitated by controlling invasive plants and planting native species.

The Service would continue to allow research on a case-by-case basis. The Service would also continue to provide limited environmental education activities and off-Refuge outreach about the value of wildlife and the public's involvement on the Refuge. Boat access for waterfowl hunting would continue to be allowed. The Service would continue to inventory, manage, and protect cultural and historic resources on the Refuge on a project-by-project basis to comply with applicable laws and regulations. Appropriate educational information on cultural resources would continue to be provided to visitors at the visitor contact station through informal outreach.

Alternative B – Improve Habitat for Endemic Species on Portions of the Refuge and Increase Visitor Services: Under this alternative, the Service would improve species management on portions of the Refuge through habitat restoration and enhancement, hydrology modification, invasive plant control, additional plant and wildlife species monitoring and research, and expanded law enforcement and protection efforts. The population of Ash Meadows speckled dace would be restored to a portion of its historic range, and the range of the Ash Meadows naucorid population would be doubled. Endemic plants would be transplanted to suitable habitat to expand their populations. Natural hydrology would be restored on portions of the Refuge, and alkali wet meadow (520 acres), mesquite bosque/lowland riparian (220 acres), emergent marsh (150 acres), and old agricultural fields (30 to 45 percent) would be restored or rehabilitated. Salt cedar and Russian knapweed would be removed and controlled to improve habitat conditions. The Service will continue coordination with the Private Lands Program to assist private landowners with the removal of salt cedar and planting native species within the Refuge boundary. Pest species management (e.g., crayfish) would include the 10 most infested and important Refuge aquatic systems.

Research topics would be expanded under this alternative. Visitor services would be improved through development and implementation of Interpretive, Visitor Services, Outreach, and Environmental Education plans. Educational and interpretive materials would be developed for the public. A new Refuge headquarters and visitor contact station building, as well as other visitor facilities, would be constructed, and Refuge roads would be improved to good condition. Cultural resources management would be expanded through additional inventory, monitoring, and protection efforts.

Alternative C (Preferred Alternative) – Improve Habitat for Endemic Species throughout Refuge and Increase Visitor Services: Under this alternative, the Service would expand the management actions identified in Alternative B to improve habitat throughout the Refuge. Species inventories and monitoring would be increased, and habitat protection efforts would be expanded. The Service would expand fish populations on the Refuge to restore endemic fish populations to a portion of their historic range on the Refuge. In addition, the Service would reestablish Ash Meadows speckled dace to historic habitats after restoration of springs and streams. Natural hydrology would be restored on larger portions of the Refuge, and alkali wet meadow (650 acres), mesquite bosque/lowland riparian (550 acres), emergent marsh (150 acres), and old agricultural fields (40 to 65 percent) would be restored or rehabilitated. Pest species management would be expanded to encompass more of the Refuge and use more aggressive techniques.

Visitor services would be similar to Alternative B, except under this alternative, three off-site programs would be provided to local public and home schools. Additional off-Refuge cooperative agreements would be developed with public, non-government entities and private partners to provide off-Refuge educational outreach to the local public.

Desert NWR

A number of current management actions would be implemented for the Desert NWR under each of the alternatives. Common to all actions include maintaining current water sources for bighorn sheep and other wildlife; continuing habitat protection measures; maintaining hunt permit limits for bighorn sheep; conducting fall surveys for bighorn sheep; prohibiting livestock grazing; managing wildfires;

monitoring water resources, habitats, and wildlife; managing the Refuge to protect wilderness values; and constructing and maintaining certain visitor facilities, including a visitor center.

Alternative A – No Action: The Service would continue current bighorn sheep, wildlife, and habitat management actions that are common to all alternatives. The Air Force Overlay Area is currently managed through a Memorandum of Understanding (MOU) between the U.S. Air Force (USAF) and the Service. The current MOU would be renewed without changes. The Service would continue to provide public outreach through participation in two major community events annually. The Service would continue to manage and protect cultural resources on the Refuge on a project-by-project basis prior to land-disturbing projects to comply with applicable laws and regulations. Appropriate interpretive information on cultural resources would continue to be provided to visitors at the field station through informal outreach.

Alternative B – Minor Improvement in Wildlife and Habitat Management and Moderate Increase in Visitor Services: Under this alternative, the Service would improve bighorn sheep management and expand wildlife diversity. The Service would conduct yearly spring helicopter surveys to identify lambing and recruitment sites. Sheep would be translocated between subpopulations on the Refuge and to populations outside of the Refuge, as needed. The Service would conduct regular bird surveys at Corn Creek. Resource protection efforts would be expanded by constructing a boundary fence along the southern boundary and increase law enforcement patrols.

The MOU with the USAF would be modified to include elements for cooperative management of natural and cultural resources. Management of Research Natural Areas (RNAs) on the Refuge would be improved through boundary surveys and photographic documentation.

Visitor services would be improved through expanded environmental education and interpretive programs and an increase in visitor facilities. The Service would create a Refuge environmental education program and expand the volunteer program. Interpretation and educational efforts would be expanded through the development of new materials for the public. New visitor facilities would include wildlife viewing trails, an auto tour route, photography blinds, and parking turnouts. The Service would compile available data on cultural resources on the Refuge and expand cultural resources education and interpretive efforts.

Alternative C (Preferred Alternative) – Moderate Improvement in Wildlife and Habitat Management and Minor Increase in Visitor Services: Under this alternative, the Service would reduce some management actions compared with Alternative B, but would increase monitoring and habitat protection efforts. Bighorn sheep management would be improved through development of a Sheep Management Plan. An Inventory and Monitoring Plan would be implemented for special-status species. The Service would consider reestablishing Pahrump poolfish in the streams, ponds, or springs at Corn Creek. The Service would use prescribed burns and naturally ignited fires in appropriate plant communities to restore vegetation characteristics representative of a natural fire regime. Additional resource protection measures would include fencing the eastern boundary (post and cable) where necessary, posting boundary signs along the entire southern, eastern, and northern boundaries, and expanding law enforcement presence and patrols throughout the Refuge.

The Service would submit a request to the Service Director to de-designate the Papoose Lake RNA.

Visitor services would be improved similar to Alternative B; however, an auto tour route and wildlife viewing trails would not be constructed under this alternative. The Service would distribute educational materials to the public to inform them about the use of fire for habitat management. Additional cultural resources inventories and studies would be implemented.

Alternative D – Moderate Improvement in Wildlife and Habitat Management and Limited Increase in Visitor Services: Under this alternative, the Service would implement similar wildlife management actions as Alternatives B and C with a slight increase in habitat protection. Instead of transplanting sheep between populations, as identified under Alternative B, the Service would translocate sheep from outside sources onto the Refuge as needed to maintain and increase Refuge subpopulations and improve genetic diversity. Additional habitat monitoring would occur on the Refuge. The Service would construct a post-and-cable fence along the northwest boundary of the East Pahranagat Range Unit.

Under this alternative, the Service would implement fewer management actions than Alternatives B and C with regard to visitor services. Additional visitor services related to wildlife observation and photography would be expanded as under Alternatives B; however, the Service would not improve Mormon Well and Alamo Roads, construct an auto tour route or wildlife viewing trails in Gass Peak and Sheep Range Units, or map trails at Gass Peak and Sheep Range. The volunteer program would be expanded to a lesser extent than under the other action alternatives, and public outreach and cultural resources education would be minimal.

Moapa Valley NWR

A number of current management actions would be implemented for the Moapa Valley NWR under each of the alternatives. Common to all actions include restoring habitat on the Refuge, removing non-native aquatic species from Refuge waters, surveying and monitoring Moapa dace and Moapa White River springfish populations, monitoring water resources, protecting Refuge resources, using volunteers for restoration projects, and managing cultural resources on a project-by-project basis.

Alternative A – No Action: The Service would continue current management programs with no additional habitat management. The Refuge would remain closed to the general public, and the Service would continue limited participation in local community events. Information about Refuge resources would be provided to visitors and the public upon request.

Alternative B – Improve Habitat and Wildlife Management on Portions of the Refuge and Increase Visitor Services: Under this alternative, the Service would improve habitat and wildlife management on portions of the Refuge. The alternative includes actions to restore habitat, gather baseline and population data, manage water resources, and remove invasive species. The Service would restore Moapa dace habitat on the Pedersen Unit. Inventories and monitoring would be expanded to include other endemic fish, invertebrates, and wildlife species, focusing on federally listed or other special-status species. The Service would develop a long-term Water Resources Management Plan for the Refuge and implement additional actions to improve monitoring of the springs and streams. Habitat protection efforts would also be expanded.

Visitor services would be expanded through opening of the Refuge to the public on a limited basis. New facilities would be constructed to accommodate the increase in visitors, and the environmental education and interpretation programs would be improved. The Service would develop an environmental education program and create interpretive and environmental educational materials for distribution to the public.

Alternative C (Preferred Alternative) – Improve Habitat and Wildlife Management throughout the Refuge and Expand Visitor Services: Under this alternative, the Service would implement Refuge-wide habitat restoration efforts and expand the Refuge boundary by approximately 1,765 acres. Step-down habitat management plans would be prepared for habitats within the expanded boundary. In addition to restoring the springs and streams on the Plummer and Pedersen Units, the Service would complete restoration of the spring heads and channels on the Apcar Unit. Inventory and monitoring efforts would be expanded to include additional wildlife species.

Visitor services would be improved beyond Alternative B by opening the Refuge daily to the public and providing more programs for public use. The Service would develop an environmental education program at the Refuge and develop interpretive and environmental education materials for distribution to the public. A self-guided trail system would be constructed along the spring head, pools, and riparian corridor on the Plummer Unit to accommodate visitors. The Service would expand outreach through construction of a permanent environmental education display at the Moapa Valley Community Center or other local public venue. In addition, the Service would conduct a cultural resources inventory of the entire Refuge to assist in future planning efforts and improve management and protection of significant sites from inadvertent public visitation impacts.

Pahranagat NWR

A number of current management actions would be implemented for the Pahranagat NWR under each of the alternatives. Common to all actions include maintaining the current amounts of open water (640 acres), wet meadow (700 acres), and alkali flat (350 acres) habitats; implementing a wetland restoration plan for open water habitat; continuing water resources management to maintain the habitats; controlling carp populations; removing and controlling invasive plants; protecting Refuge habitats; implementing spring habitat Restoration Plans; monitoring Refuge habitats and plant and wildlife species; and providing a variety of recreational opportunities.

Alternative A – No Action: The Service would continue current management programs for habitat management and public use opportunities. The Service would continue to implement limited interpretation, environmental education, and outreach activities. The Service would continue to provide appropriate interpretive information on cultural resources to visitors at the visitor contact station through informal outreach and protect cultural resources on a case-by-case basis.

Alternative B – Limited Improvements in Water Resource and Habitat Management and Minor Increase in Visitor Services: Under this alternative, the Service would expand water monitoring, invasive plant removal efforts, and habitat protection efforts. The Service would obtain waterfowl data collected by other agencies on a seasonal basis. A new refugium for Pahranagat roundtail chub is also considered under this alternative pending a feasibility assessment.

Visitor services would be improved to accommodate an increase in visitors and monitor visitor use. The visitor contact station would be expanded to accommodate the growing number of visitors; new interpretive panels would replace old panels at the kiosk; environmental education and interpretive materials would be developed, including "least-wanted" posters for invasive plant species; and a wildlife observation trail system would be constructed throughout the Refuge. The campground would be maintained, and the Service would begin collecting fees and limit the length of stays to seven days. Generators would be prohibited between the hours of 10 p.m. and 8 a. m. Cultural resources management would also be expanded to compile data on the resources at the Refuge, manage and protect the resources, and educate the public on the resources.

Alternative C – Minor Improvements in Water Resource and Habitat Management and Minor Increase in Visitor Services: Under this alternative, the Service would provide increased invasive species control, additional species inventories, improved water resources management, and additional restoration of springs and riparian habitat. The Service would implement a species Inventory and Monitoring Plan for marsh birds, waterfowl, and shorebirds. To improve habitat for the southwestern willow flycatcher, the Service would monitor the impacts of fishing on bird use and the response of birds to the current habitat restoration and management plan.

Visitor services would also be improved similar to Alternative B, except the campground would be converted to a day use area. Visitor facilities would be improved and maintained for visitor safety, including constructing an interpretive walking trail that connects Upper Pahranagat Lake with the Headquarters Unit, constructing a new visitor contact station and office space at the Headquarters Unit, constructing additional parking at the Headquarters Unit, and constructing photography and observation blinds along the trail route. Turn lanes would be created along U.S. Highway 93 in coordination with Nevada Department of Transportation to allow visitors to safely turn onto the Refuge. Cultural resources would be inventoried, and the Service would expand cultural resources management and protection efforts.

Alternative D (Preferred Alternative) – Moderate Improvements in Water Resource and Habitat Management and Moderate Increase in Visitor Services: Under this alternative, the Service would expand upon management actions presented in Alternatives B and C, including acquiring additional water rights, expanding monitoring efforts for wildlife, and modeling climate change impact scenarios and adaptation strategies would be developed. Native upland habitat adjacent to Lower Pahranagat Lake would be restored. To protect the Refuge's habitats and resources and prevent encroachment, a fence would be installed along the eastern boundary.

Visitor services would be similar to Alternative C, including conversion of the campground to day use only. In addition, the boat ramps would be closed, and a car-top boat launch would be designated. A new wildlife observation structure would be developed. To expand cultural resources management, the Service would identify cultural resources that could educate visitors; coordinate with local affiliated tribes on their educational, scientific, and traditional cultural needs; and conduct an ethnobotany and traditional plant use study.

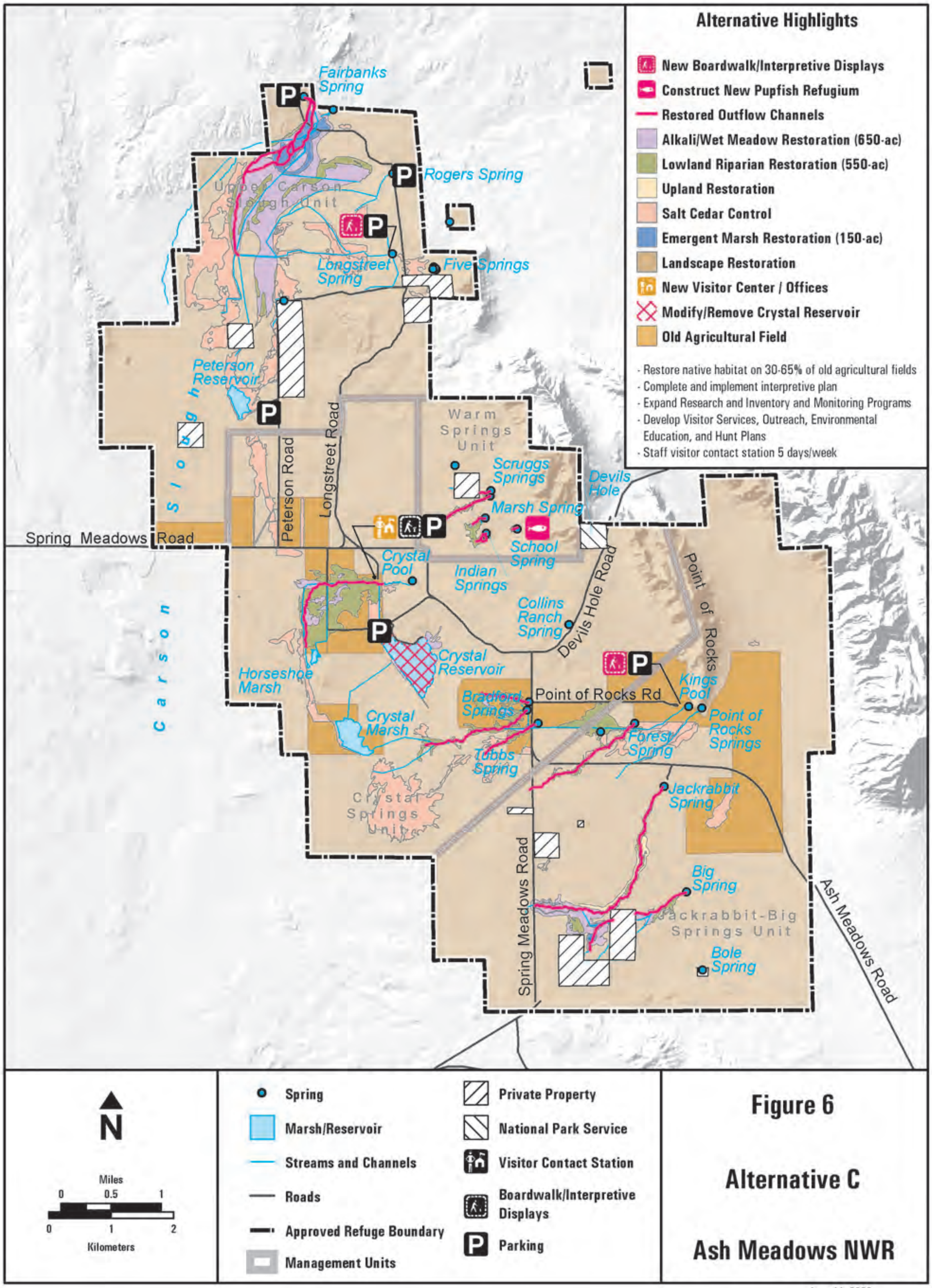

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Figure 6-ashmeadows_alt_C.mxd

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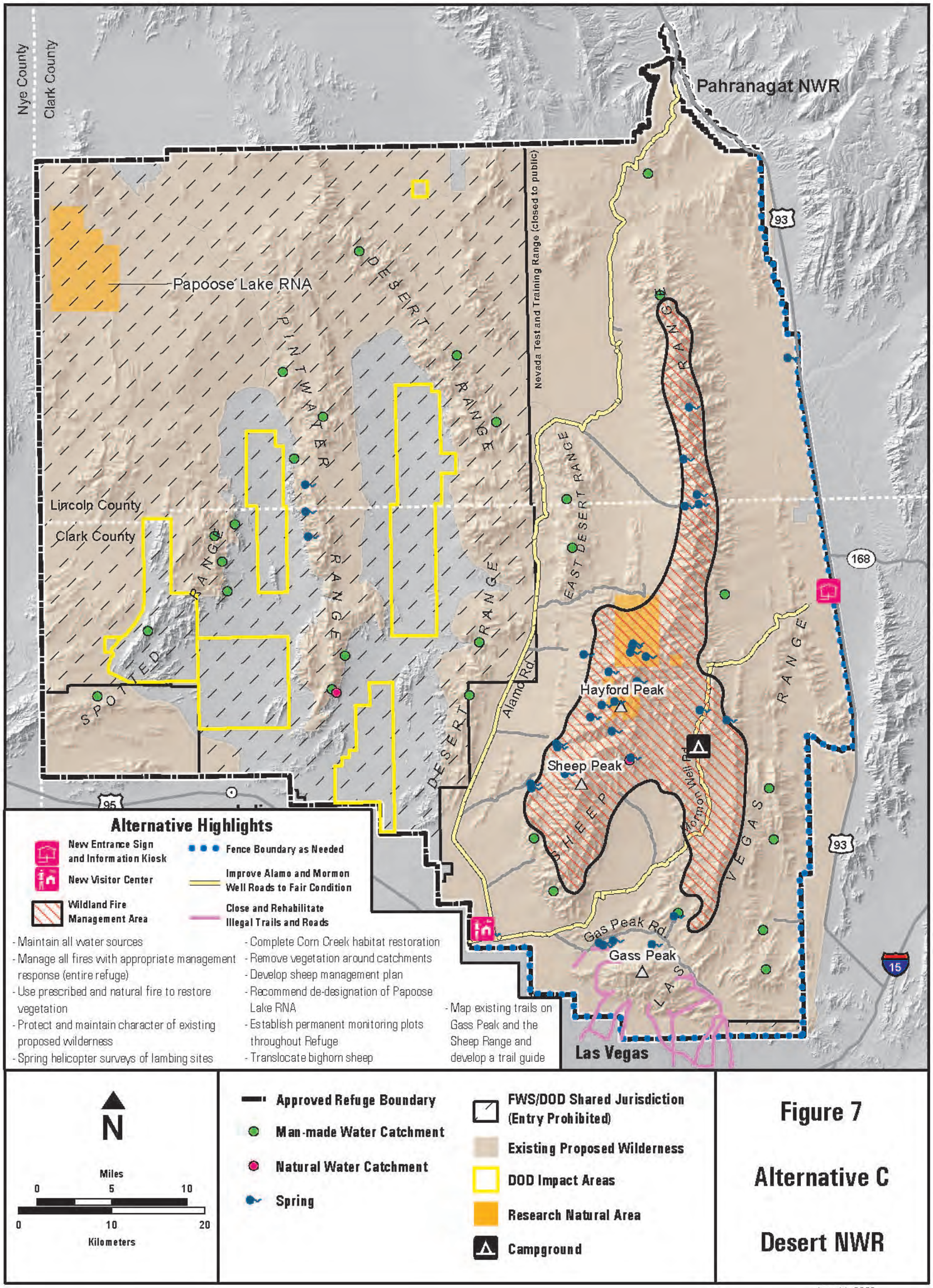

Figure 7

Alternative C

Desert NWR

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Figure 7-desert_alt_C.mxd

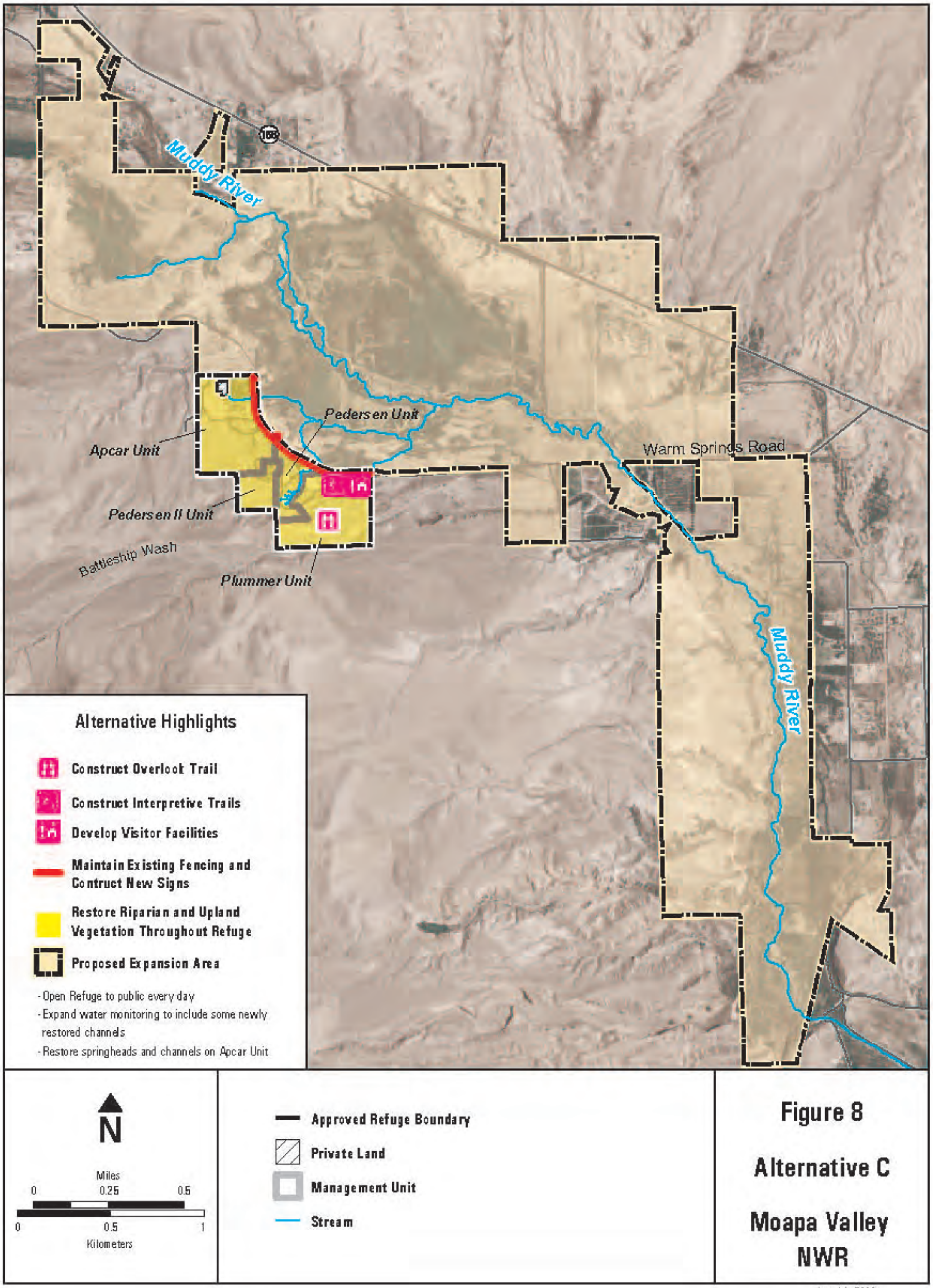

Figure 8

Alternative C

Moapa Valley NWR

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Figure 8_moapa_alt_C.mxd

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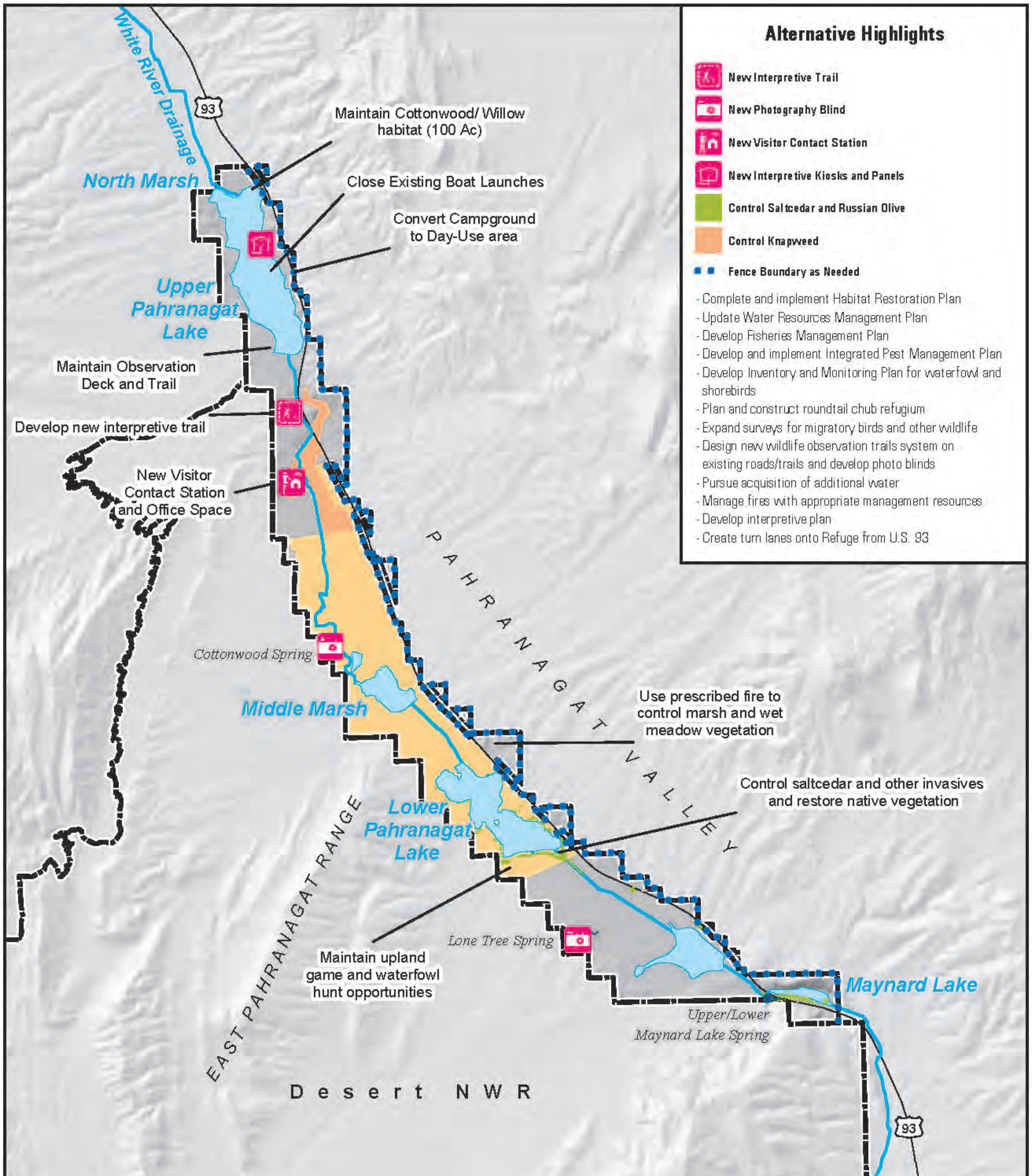

Figure 9

Alternative D

Pahranagat NWR

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Figure 9-pahranagat_alt_D.mxd

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Environmental Consequences

The Service has conducted an analysis and evaluation of the environmental consequences of implementing the various alternatives described for each refuge. This impact evaluation has considered all aspects of the affected environment, including physical, biological, cultural, and socio-economic resources. A summary of potential effects from implementing the alternatives proposed for the Ash Meadows, Desert, Moapa Valley, and Pahranagat NWRs is presented in Tables 1 through 4.

Implementation of the Proposed Action (implementing the preferred alternative for each refuge) would result in direct emission of greenhouse gases (GHG) during ground-disturbing activities (temporary emissions) due to construction and restoration projects and fire management activities (particularly fuels reduction). Fire management would help prevent catastrophic wildfire over the long term and reduce long-term GHG emissions. Indirect, long-term emissions of GHG would occur due to increased visitation by the public and increased employee vehicle trips (as staff grows).

Implementation of the preferred alternative for each refuge in combination with other reasonably foreseeable future actions in the southern Nevada region could result in cumulative impacts on physical resources (primarily water resources), biological resources (habitats and special-status species), cultural resources, and socioeconomic resources (including recreation). These impacts could be cumulatively considerable, depending on the specific nature of each action and the resources that would be affected. Larger development projects or activities that would result in a substantial amount of ground disturbance would result in cumulatively significant impacts on water quality, sensitive habitats and species, and cultural resources. Improved recreational opportunities in southern Nevada would provide a cumulative benefit to the public, and a cumulative increase in visitor use and development could improve the local economy.

Table 1. Ash Meadows National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Physical Environment			
Soils	Minimal long-term beneficial effect due to restoration activities. Temporary adverse effects related to soil erosion during restoration activities. Potential loss of topsoil from facility construction.	Same as Alternative A, only slightly more beneficial long-term effects due to increased restoration. Slightly higher temporary adverse effects. Best Management Practices (BMPs) would reduce impacts on soil.	Same as Alternative B, only more beneficial long-term effects and temporary adverse effects due to additional restoration activities.
Surface Water Hydrology	Minimal long-term beneficial effect from minor hydrology restoration. Temporary surface water diversions during refugia construction.	Same as Alternative A, only slightly greater intensity of effects due to increased restoration.	Moderately improved beneficial effects due to hydrology restoration throughout the Refuge. Temporary adverse effects due to diversions during refugia construction and hydrologic restoration projects. Improved long-term surface flows from changes in hydrology.
Surface Water Quality	Long-term improvement in water quality with restoration of native vegetation on portions of the Refuge. Potential temporary adverse effects on water quality during construction, restoration, and other ground-disturbance activities near springs, streams, and open water sources.	Same as Alternative A, only slightly more intensity of long-term beneficial and temporary adverse effects from increased restoration. BMPs would reduce impacts on water quality.	Same as Alternative B, only moderately greater intensity of long-term beneficial and temporary adverse effects from increased restoration. BMPs would reduce impacts on water quality.
Air Quality	Temporary adverse construction emissions during restoration activities and facility construction. Similar traffic-related emissions and wildfire impacts as current conditions.	Slightly more temporary adverse construction emissions during restoration activities and facility construction. Minor long-term increase in traffic-related emissions. Minor temporary adverse impacts from prescribed burns and wildfires. BMPs would reduce impacts on air quality.	Same as Alternative B.
Biological Resources			
Alkali Wet Meadow	Temporary disturbance with long-term benefit from restoration of 70 acres of alkali wet meadow.	Temporary disturbance with considerably higher long-term benefit from restoration of 520 acres of alkali wet meadow.	Temporary disturbance with considerably higher long-term benefit from restoration of 650 acres of alkali wet meadow.

Table 1. Ash Meadows National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Mesquite Bosque/Lowland Riparian	Temporary disturbance with long-term benefit from restoration of 30 acres of mesquite bosque/lowland riparian.	Temporary disturbance with moderately higher long-term benefit from restoration of 220 acres of mesquite bosque/lowland riparian.	Temporary disturbance with considerably higher long-term benefit from restoration of 550 acres of mesquite bosque/lowland riparian.
Biological Resources, continued			
Emergent Marsh	Same as existing conditions.	Temporary disturbance with slightly higher long-term benefit from restoration of 150 acres of emergent marsh.	Same as Alternative B.
Upland Habitat	Temporary disturbance with long-term benefit from restoration of 30 acres of upland habitat and rehabilitation of 10% – 25% of old agricultural fields.	Same as Alternative A, only slightly higher long-term benefit from 30% - 45% old agricultural fields.	Same as Alternative A, only slightly higher long-term benefit from 40% - 65% old agricultural fields.
Sensitive Plants	Potential adverse impacts on sensitive plants from construction activities. Long-term benefit from habitat restoration and protection.	Greater potential for adverse impacts on sensitive plants from increased construction activities. Moderately higher long-term benefit from increased habitat restoration, protection, and transplanting. Pre-construction surveys and facility design could reduce substantial impacts to sensitive plant populations.	Same as Alternative B with a considerably higher benefit from restoration, transplanting, and modification of Crystal Reservoir.
Invasive Plants	Minimal long-term benefit from removal of invasive plants at restoration areas.	Slightly greater long-term benefit from removal of invasive plants at restoration areas and controlling salt cedar and Russian knapweed populations.	Same as Alternative B with a considerably greater benefit from salt cedar and Russian knapweed control.
Common Wildlife Species	Minimal long-term benefit from habitat restoration and protection. Potential minor temporary adverse impacts from construction and restoration activities.	Same as Alternative A, only slightly more adverse impacts and long-term benefits from habitat restoration and protection. Standard construction measures would reduce impacts during construction.	Same as Alternative B with moderately greater beneficial and adverse effects from restoration activities.

Table 1. Ash Meadows National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Southwestern Willow Flycatcher	Minor long-term benefit from riparian habitat restoration. Potential temporary adverse impacts from construction and restoration activities.	<u>Slightly</u> greater long-term benefit from riparian habitat restoration. Greater potential for temporary adverse impacts from increased construction and restoration activities. Pre-construction surveys and standard construction measures could reduce impacts during construction and restoration.	Same as Alternative B with a <u>moderately</u> greater long-term benefit.
<u>Management Priority Birds</u>	Minor long-term benefit from habitat restoration. Potential temporary adverse impacts from construction and restoration activities.	<u>Moderately</u> greater long-term benefit from increased habitat restoration. Greater potential for temporary adverse impacts from increased construction and restoration activities. Pre-construction surveys and standard construction measures could reduce impacts during construction and restoration.	Same as Alternative B with a <u>considerably</u> greater long-term benefit.
Sensitive Fish	<u>Minimal</u> temporary adverse impacts from construction and restoration activities. <u>Minimal effects from improved</u> habitat conditions with establishment of refugia and minimal control of predatory species.	Greater potential for temporary adverse impacts from increased construction and restoration activities. <u>Moderately</u> greater long-term benefit from habitat restoration on portions of the Refuge, increased control of predatory and pest aquatic species, and establishment of refugia. Seasonal construction and standard construction measures, including BMPs, could reduce impacts during construction and restoration.	Same as Alternative B with a <u>considerably</u> greater long-term benefit from additional restoration throughout the Refuge, including at Crystal Reservoir.
Invasive Fish	<u>Minimal</u> long-term <u>beneficial</u> impacts on sensitive fish with minimal invasive fish control efforts.	<u>Slightly higher</u> long-term <u>beneficial</u> impacts on sensitive fish with increased invasive fish control efforts.	<u>Considerably</u> greater <u>beneficial</u> long-term impacts on sensitive fish with increased invasive fish control efforts and modification of Crystal Reservoir.
Cultural Resources			
Buried Cultural Resources	Potential adverse impacts on buried cultural resources during ground-disturbance activities.	Slightly increased potential adverse impacts on buried cultural resources during ground-disturbance activities. Mitigation measures could reduce impacts to resources during ground-disturbance.	Same as Alternative B only greater potential with more activities.

Table 1. Ash Meadows National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Aboveground Cultural Resources	Same as existing conditions (vandalism and degradation with minimal enforcement or protection efforts).	Reduced potential for vandalism or degradation of cultural resources from visitor use from increased law enforcement and protection efforts.	Same as Alternative B only less potential with increased law enforcement and protection.
Public Access and Recreation			
Roads	Same as existing conditions with minor road improvements over the long-term.	Improved long-term access with road improvements and control with law enforcement and other control measures. Mitigation measures would reduce access restrictions during construction and restoration.	Same as Alternative B.
Public Access, continued			
Traffic	Same as existing conditions.	Slightly lower beneficial effects with increased visitor traffic on and to the Refuge.	Moderately lower beneficial effects with great increase in visitor traffic.
Recreation			
Visitor Use Facilities	Same as existing conditions.	Slightly more beneficial effects as more facilities are constructed over the long term.	Same as Alternative B.
Recreation Opportunities	Same as existing conditions.	Slightly higher beneficial effects as opportunities and services improve over the long term. Minimal temporary impacts during some management activities.	Same as Alternative B.
Environmental Education/Interpretation	Same as existing conditions.	Slightly higher beneficial impacts as more materials are available over time.	Same as Alternative B but on an accelerated schedule.
Outreach	Same as existing conditions.	Slightly higher beneficial impacts as more outreach occurs over time.	Same as Alternative B.
Refuge Management and Local Economies			
Refuge Budget and Staffing	Same as existing conditions.	Minor increase in Refuge management budget and staff to implement the alternative.	Considerable increase in Refuge management budget and staff to implement the alternative.
Local Economy	Same as existing conditions.	Slight improvement to local economics with increase in visitors and projects.	Slight improvement to local economics with increase in visitors and projects.
Land Use			

Table 1. Ash Meadows National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Service-managed Lands within Boundary	Same as existing conditions.	Slightly beneficial effects as land use conflicts are reduced with acquisition of private parcels over the long term.	Same as Alternative B.
Aesthetics			
Restoration Activities	Temporary adverse impacts during construction and restoration activities. Minimal long-term visual benefits from restoration activities.	Same as Alternative A, only more temporary adverse impacts and slightly greater long-term benefits from habitat restoration and improved facilities. Mitigation measures would reduce impacts during construction.	Same as Alternative B with a greater long-term benefit.
Visitor Use Facilities	Minimal long-term visual benefits from facility improvements.	Slightly more improved visual character over the long term with temporary adverse effects during construction disturbances.	Same as Alternative B.

Table 2. Desert National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, C, or D

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Physical Environment				
Soils	Same as existing conditions.	Moderately higher potential for soil erosion from construction activities. Best Management Practices (BMPs) would reduce impacts on soil.	Moderately higher potential for soil erosion from prescribed fire, but reduced potential from construction. BMPs would reduce impacts on soil.	Same as Alternative C with less erosion potential from less construction.
Surface Water Quality	Same as existing conditions.	Moderately higher temporary adverse impacts to surface water quality from construction activities. BMPs would reduce impacts on water quality.	Less adverse impacts from construction activities and minor adverse impacts from vegetation removal. BMPs would reduce impacts on water quality.	Same as Alternative C.
Air Quality	Same as existing conditions.	Temporary adverse construction emissions during construction activities. Minor long-term increase in traffic-related emissions. BMPs would reduce impacts on air quality.	Reduced air quality impacts from construction. Moderate temporary adverse impacts from prescribed burns. Minor long-term increase in traffic-related emissions. BMPs would reduce impacts on air quality.	Same as Alternative C with reduced air quality impact from less construction.
Biological Resources				
Upland Habitat	Same as existing conditions.	Minor loss of vegetation from construction. Long-term benefit from habitat protection.	Same as Alternative B but with reduced loss of vegetation and greater long-term benefit from increased protection. Temporary disturbance from prescribed burns.	Same as Alternative C, only greater long-term benefit from increased protection.
Sensitive Plants	Same as existing conditions.	Potential for adverse impacts on sensitive plants from construction activities. Long-term benefit from increased habitat protection. Pre-construction surveys and facility design could reduce substantial impacts to sensitive plant populations.	Same as Alternative B with less potential for construction impacts and greater benefit from increased protection.	Same as Alternative C.

Table 2. Desert National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, C, or D

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Common Wildlife Species and Managemetn Priority Birds	Same as existing conditions.	Potential minor temporary adverse impacts from construction activities. Standard construction measures would reduce impacts during construction.	Same as Alternative B, only less potential for construction impacts.	Same as Alternative C.
Biological Resources, continued				
Desert Tortoise/Gila Monster	Same as existing conditions.	Potential temporary adverse impacts from construction activities. Minor long-term benefit from habitat protection. Pre-construction surveys and standard construction measures could reduce impacts during construction.	Same as Alternative B, only less adverse construction impacts and greater long-term benefit from increased protection.	Same as Alternative C.
Birds	Same as existing conditions.	Potential temporary adverse impacts from construction activities. Minor long-term benefit from habitat protection.	Same as Alternative B, only less adverse construction impacts and greater long-term benefit from increased protection. Increased impacts from prescribed burns.	Same as Alternative C.
Gilbert's skink	Same as existing conditions.	Potential temporary adverse impacts from construction activities. Minor long-term benefit from habitat protection.	Same as Alternative B, only less adverse construction impacts and greater long-term benefit from increased protection. Increased impacts from prescribed burns.	Same as Alternative C.
Bighorn Sheep	Same as existing conditions.	Temporary disturbance during construction. Long-term improvement to habitat and populations.	Same as Alternative B, only greater benefit to sheep habitat and management.	Same as Alternative C, only greater benefit to sheep management, habitat, and populations.
Sensitive Fish	Same as existing conditions.	Same as Alternative A.	Potential expanded population of Pahrump poolfish through reintroduction to Corn Creek.	Same as Alternative C.
Cultural Resources				

Table 2. Desert National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, C, or D

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Buried Cultural Resources	Same as existing conditions.	Potential adverse impacts on buried cultural resources during ground-disturbance activities. Mitigation measures could reduce impacts to resources during ground disturbance.	Same as Alternative B with slightly less potential due to less ground disturbance.	Same as Alternative C.
Aboveground Cultural Resources	Same as existing conditions (vandalism and degradation with minimal enforcement or protection efforts).	Reduced potential for vandalism or degradation of cultural resources from visitor use from increased law enforcement and protection efforts.	Same as Alternative B, only less potential with increased law enforcement and protection.	Same as Alternative C, only less potential with increased protection.
Public Access				
Access	Same as existing conditions.	Temporary access restrictions during construction activities. Improved long-term access with road improvements and control with law enforcement and other control measures. Mitigation measures would reduce access restrictions during construction.	Same as Alternative B with greater temporary access restrictions and increased control of access.	Same as Alternative C with increased control of access.
Traffic	Same as existing conditions.	Slightly higher long-term adverse effects as increased visitor numbers would increase traffic on and to the Refuge.	Same as Alternative B	Same as Alternative B.
Recreation				
Visitor Use Facilities	Same as existing conditions.	Moderately higher beneficial impacts as more facilities are constructed.	Slightly higher beneficial impacts as fewer facilities are constructed or improved than in Alternative B.	Same as Alternative C.

Table 2. Desert National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, C, or D

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Recreation Opportunities	Same as existing conditions.	Temporary restrictions on activities during construction activities. Improved and expanded long-term recreation opportunities. Mitigation measures would reduce restrictions during construction.	Same as Alternative B with greater temporary activity restrictions and fewer long-term opportunities.	Same as Alternative C with fewer long-term opportunities.
Outreach	Same as existing conditions.	Slightly higher beneficial impacts due to some increased outreach efforts.	Same as Alternative B.	Same as Alternative C with slightly increased outreach efforts.
Refuge Management and Local Economies				
Refuge Budget and Staffing	Same as existing conditions.	Minor increase in Refuge management budget and staff to implement the alternative.	Moderate increase in Refuge management budget and staff to implement the alternative.	Same as Alternative C.
Local Economy	Same as existing conditions.	Minor improvement to local economics with increase in visitors and projects.	Minor improvement to local economics with increase in visitors and projects.	Same as Alternative C.
Land Use				
RNAs	Same as existing conditions.	Moderate beneficial impacts with improved RNA use.	Minor land use change with de-designation of a Research Natural Area.	Same as Alternative C.
Aesthetics				
Visitor Use Facilities	Same as existing conditions.	Minor adverse impacts om visual quality.	Same as Alternative B.	Same as Alternative B.
Habitat Protection	Same as existing conditions.	Minor improvement to aesthetics with habitat protection.	Same as Alternative B.	Same as Alternative B.

Table 3. Moapa Valley National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Physical Environment			
Soils	Temporary adverse effects related to soil erosion during restoration activities.	Same as Alternative A, only slightly more adverse and potential loss of topsoil from facility construction. Slightly higher beneficial impacts over time as restoration efforts are established. Best Management Practices (BMPs) would reduce impacts on soil.	Same as Alternative B, only more adverse.
Surface Water Quality	Potential temporary adverse effects on water quality during restoration near springs, streams, and open water sources. Long-term improvement in water quality with restoration of native vegetation.	Same as Alternative A, only slightly more adverse with additional restoration and facility construction. Greater long-term benefit from increased restoration. BMPs would reduce impacts on water quality.	Same as Alternative B, only more adverse. Greater long-term benefit from increased restoration.
Air Quality	Temporary adverse construction emissions during restoration activities. Similar traffic-related emissions as current conditions.	Temporary adverse construction emissions during restoration activities and facility construction (more adverse than Alternative A). Minor long-term increase in traffic-related emissions. Minor temporary adverse impacts from prescribed burns. BMPs would reduce impacts on air quality.	Same as Alternative B, only more adverse.
Biological Resources			
Riparian/Wetland Habitat	Temporary disturbance with long-term benefit from restoration activities.	Temporary disturbance with long-term benefit from restoration activities and fire management actions. Potential minor loss of vegetation from facility construction. Standard construction measures would reduce impacts during construction.	Same as Alternative B with slightly more disturbance and greater long-term benefit.

Table 3. Moapa Valley National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Upland Habitat	Same as existing conditions.	Minor loss of vegetation from facility construction. Long-term benefit from invasive plant control and habitat protection efforts. Standard construction measures would reduce impacts during construction.	Same as Alternative B.
Biological Resources, continued			
Invasive Plants	Long-term benefit from removal of invasive plants at restoration areas.	Same as Alternative A, only greater benefit.	Same as Alternative B.
Common Wildlife Species	Potential minor temporary adverse impacts from restoration activities. Long-term benefit from habitat restoration.	Same as Alternative A, only more adverse impacts and greater long-term benefits from habitat restoration and protection. Standard construction measures would reduce impacts during construction.	Same as Alternative B with a greater benefit from restoration and Refuge expansion.
Riparian Species	Potential temporary adverse impacts from restoration activities. Minor long-term benefit from riparian habitat restoration.	Greater potential for temporary adverse impacts from increased construction and restoration activities. Greater long-term benefit from riparian habitat restoration. Pre-construction surveys and standard construction measures could reduce impacts during construction and restoration.	Same as Alternative B with a greater long-term benefit from restoration and Refuge expansion.
Desert Tortoise/Gila Monster	Same as existing conditions.	Potential for temporary adverse impacts from construction activities. Long-term benefit from habitat protection. Pre-construction surveys and standard construction measures could reduce impacts during construction.	Same as Alternative B with a greater long-term benefit from Refuge expansion.
Southwest Willow Flycatcher and Yellow-billed Cuckoo	Same as existing conditions.	Slightly higher beneficial impacts from increased habitat availability on Refuge.	Same as Alternative B with greater beneficial impact from more habitat availability.
Management Priority Birds	Same as existing conditions.	Moderately higher beneficial impacts with increased native habitat.	Considerably higher beneficial impacts with increased native habitat.
Western Yellow Bat	Same as existing conditions.	Slightly adverse impact due to loss of palm tree habitat on Refuge.	Same as Alternative B but with greater loss of habitat.

Table 3. Moapa Valley National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Sensitive Fish	Potential temporary adverse impacts from restoration activities. Improved habitat conditions with restoration.	Greater potential for temporary adverse impacts from increased construction and restoration activities. Greater long-term benefit from habitat restoration. Seasonal construction and standard construction measures, including BMPs, could reduce impacts during construction and restoration.	Same as Alternative B with a greater long-term benefit from restoration and Refuge expansion.
Cultural Resources			
Buried Cultural Resources	Potential adverse impacts on buried cultural resources during ground-disturbance activities.	Slightly increased potential adverse impacts on buried cultural resources during ground-disturbance activities. Mitigation measures could reduce impacts to resources during ground-disturbance.	Same as Alternative B, only greater potential with more activities.
Public Access			
Access	Same as existing conditions.	Improved long-term access with new visitor facilities and opening the Refuge on a limited basis.	Same as Alternative B with greater access by opening the Refuge on a daily basis.
Traffic	Same as existing conditions.	Slightly higher long-term adverse effects as increased visitor numbers would increase traffic on and to the Refuge.	Same as Alternative B
Recreation			
Visitor Use Facilities	Same as existing conditions.	Slightly higher beneficial impact as more facilities are constructed.	Same as Alternative B.
Recreation Opportunities	Same as existing conditions.	Expanded long-term recreation opportunities.	Same as Alternative B with more long-term opportunities.
Outreach	Same as existing conditions.	Slightly higher beneficial impact as more outreach occurs.	Same as Alternative B.
Refuge Management and Local Economies			
Refuge Budget and Staffing	Same as existing conditions.	Minor increase in Refuge management budget and staff to implement the alternative.	Same as Alternative B.
Local Economy	Same as existing conditions.	Minor improvement to local economics with increase in visitors and projects.	Same as Alternative B.

Table 3. Moapa Valley National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, or C

Resource	*Alternative A*	*Alternative B*	*Alternative C (Preferred Alternative)*
Aesthetics			
Restoration Activities	Same as existing conditions.	Moderately improved visual quality as restoration is established.	Considerable improvement to visual quality from restoration actions.
Visitor Use Facilities	Same as existing conditions.	Minimal adverse impacts from construction of facilities.	Same as Alternative B.

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Table 4. Pahranagat National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, C, or D

Resource	*Alternative A*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Physical Environment				
Soils	Potential for soil erosion from restoration activities.	Potential for soil erosion from construction and restoration activities. Best Management Practices (BMPs) would reduce impacts on soil.	Same as Alternative B, only greater potential for soil erosion from increased activities.	Same as Alternative C.
Surface Water Hydrology	Improved hydrology from restoration activities.	Same as Alternative A.	Same as Alternative A.	Same as Alternative A, only greater improvement with additional restoration
Surface Water Quality	Temporary impacts to surface water quality from restoration activities and chemical methods to control invasive plants.	Temporary impacts to surface water quality from chemical methods to control invasive plants and construction and restoration activities. BMPs would reduce impacts on water quality.	Same as Alternative B.	Same as Alternative B.
Water Use	Same as existing conditions.	Modified and expanded water use from increased visitor use and restoration. Mitigation measures could reduce impacts on the groundwater table.	Same as Alternative B.	Same as Alternative B with additional water rights.
Air Quality	Temporary adverse emissions during restoration activities and prescribed burns. Similar traffic-related emissions as existing conditions.	Temporary adverse construction emissions during construction and restoration activities and prescribed burns. Minor long-term increase in traffic-related emissions. BMPs would reduce impacts on air quality.	Same as Alternative B, only slightly more adverse.	Same as Alternative C, only more adverse.
Biological Resources				
Open Water/Marsh Habitat	Temporary disturbance with long-term benefit from restoration.	Same as Alternative A.	Same as Alternative A.	Same as Alternative A with greater long-term benefit with additional restoration.
Spring Habitat	Temporary disturbance with long-term benefit from restoration.	Same as Alternative A.	Same as Alternative B, only greater benefit over long-term with additional restoration.	Same as Alternative C with greater long-term benefit.

Table 4. Pahranagat National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, C, or D

Resource	*Alternative A*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Biological Resources, continued				
Cottonwood-Willow Habitat	Same as existing conditions (100 acres).	Slightly higher beneficial impacts as the habitat quality is improved over time.	Same as Alternative B.	Same as Alternative B.
Upland Habitat	Same as existing conditions.	Minor loss of vegetation from construction. Long-term benefit from habitat protection. Standard construction measures would reduce impacts during construction.	Same as Alternative B with additional disturbance from construction, but greater benefit from increased protection.	Same as Alternative C with additional protection.
Invasive Plants	Same as existing conditions.	Minor increase in invasive plant removal efforts.	Moderate increase in invasive plant removal efforts.	Same as Alternative C.
Common Wildlife Species	Potential minor temporary adverse impacts from restoration activities. Long-term benefit from restoration.	Potential temporary adverse impacts from restoration and construction activities. Long-term benefits from habitat restoration. Standard construction measures would reduce impacts during construction.	Same as Alternative B, only slightly greater potential for temporary impacts and greater long-term benefit.	Same as Alternative C.
Desert Tortoise	Same as existing conditions.	Potential temporary adverse impacts from construction activities. Minor long-term benefit from habitat protection. Pre-construction surveys and standard construction measures could reduce impacts during construction.	Same as Alternative B.	Same as Alternative C.
Management Priority Birds	Potential temporary adverse impacts from restoration activities. Long-term benefit from restoration.	Same as Alternative A with slightly greater long-term beneficial impacts. Pre-construction surveys and standard construction measures could reduce impacts during construction.	Same as Alternative B, only greater benefit over the long term with additional restoration.	Same as Alternative C.

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Table 4. Pahranagat National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, C, or D

Resource	*Alternative A*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Pahranagat Roundtail Chub	Same as existing conditions – not present.	Long-term benefit from refugium construction.	Same as Alternative B.	Same as Alternative B.
Waterfowl	Same as existing conditions.	Slightly increased beneficial impacts to foraging habitat over long-term.	Same as Alternative B with greater beneficial impact over time.	Same as Alternative C with greater beneficial impact over time.
Southwest Willow Flycatcher	Same as existing conditions.	Potential temporary adverse impacts from construction activities. Minor long-term benefit from habitat protection. Pre-construction surveys and standard construction measures could reduce impacts during construction.	Same as Alternative B with greater beneficial impact over time.	Same as Alternative C.
Cultural Resources				
Buried Cultural Resources	Same as existing conditions.	Potential adverse impacts on buried cultural resources during ground-disturbance activities. Mitigation measures could reduce impacts to resources during ground disturbance.	Same as Alternative B with slightly greater potential due to increased ground disturbance.	Same as Alternative C with greater potential due to increased ground disturbance.
Aboveground Cultural Resources	Same as existing conditions (vandalism and degradation with minimal protection efforts).	Reduced potential for vandalism or degradation of cultural resources from visitor use from increased protection efforts.	Same as Alternative B, only less potential with increased protection.	Same as Alternative C, only less potential with increased protection.
Public Access				
Access	Same as existing conditions.	Temporary access restrictions during construction activities. Improved long-term access with facility improvements. Mitigation measures would reduce access restrictions during construction.	Same as Alternative B with greater temporary access restrictions.	Same as Alternative C.
Traffic	Same as existing conditions.	Slightly higher long-term adverse effects as increased visitor numbers would increase traffic on and to the Refuge.	Same as Alternative B	Same as Alternative C.
Recreation				

Table 4. Pahranagat National Wildlife Refuge: Summary of Potential Effects of Implementing Alternatives A, B, C, or D

Resource	*Alternative A*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Visitor Use Facilities	Same as existing conditions.	Slightly higher beneficial impacts as more facilities are established.	Same as Alternative B.	Same as Alternative B.
Recreation Opportunities	Same as existing conditions.	Temporary restrictions on activities during construction activities. Improved and expanded long-term recreation opportunities.	Same as Alternative B with greater temporary activity restrictions and more long-term opportunities.	Same as Alternative C.
Outreach	Same as existing conditions.	Slightly higher beneficial impacts as more outreach occurs.	Same as Alternative B.	Same as Alternative B.
Refuge Management and Local Economies				
Refuge Budget and Staffing	Same as existing conditions.	Minor increase in Refuge management budget and staff to implement the alternative.	Moderate increase in Refuge management budget and staff to implement the alternative.	Same as Alternative C.
Local Economy	Same as existing conditions.	Minor improvement to local economics with increase in visitors and projects.	Same as Alternative B.	Same as Alternative B.
Aesthetics				
Restoration Activities	Same as existing conditions.	Long-term benefit to visual quality from restoration activities.	Same as Alternative B with greater benefit from increased restoration.	Same as Alternative C.
Visitor Use Facilities	Same as existing conditions.	Temporary adverse impacts on aesthetics during construction activities. Minor long-term adverse impacts associated with new and improved facilities construction. Mitigation measures could reduce construction impacts.	Same as Alternative B.	Same as Alternative B.

SE ROA 12706

JA_5468

Desert National Wildlife Refuge Complex

Ash Meadows, Desert, Moapa Valley, and Pahranagat National Wildlife Refuges

Final Comprehensive Conservation Plan and Environmental Impact Statement
Volume I – August 2009

National Wildlife Refuge System Mission

To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans.

U. S. Fish and Wildlife Service
Pacific Southwest Region
2800 Cottage Way, Room W-1832
Sacramento, CA 95825

August 2009

SE ROA 12708

Desert National Wildlife Refuge Complex
Ash Meadows, Desert, Moapa Valley, and Pahranagat National Wildlife Refuges
Final Comprehensive Conservation Plan and Environmental Impact Statement
Clark, Lincoln, and Nye Counties, Nevada

Type of Action:	Administrative
Lead Agency:	U.S. Department of the Interior, Fish and Wildlife Service
Responsible Official:	Ren Loeheffner, Regional Director, Region 8
For Further Information:	Cynthia Martinez, Project Leader Desert National Wildlife Refuge Complex 4701 North Torrey Pines Drive Las Vegas, Nevada 89130 (702) 515-5450

Abstract: The Final Comprehensive Conservation Plan and Environmental Impact Statement (Final CCP/EIS) provides a description of the preferred alternative and other alternatives developed for each refuge, the refuges' affected environments, and environmental consequences of implementing the alternatives. The alternatives for each refuge address wildlife, habitat, and cultural resources management and opportunities for compatible recreation to help achieve refuge purposes, visions, and goals. The Final CCP/EIS includes revisions to the Draft CCP/EIS, which was circulated for public review and comment between July 11 and September 9, 2008. Substantive changes to the Draft CCP/EIS text, which were made in response to or as a result of comments received during the public review, are indicated in the Final CCP/EIS using an underlined text format. Appendix M of the Final CCP/EIS includes all comments received on the Draft CCP/EIS and the Service's response to these comments.

The Desert National Wildlife Refuge Complex (Desert Complex) consists of four National Wildlife Refuges (NWRs): Ash Meadows, Desert[1], Moapa Valley, and Pahranagat. Three alternatives, including a Preferred Alternative and a No Action Alternative, are described, compared, and assessed for Ash Meadows and Moapa Valley NWRs, and four alternatives, including a Preferred Alternative and a No Action Alternative, are described, compared, and assessed for Desert and Pahranagat NWRs. In each case, Alternative A is the No Action Alternative, as required by the National Environmental Policy Act regulations. The alternatives for each refuge are summarized below.

Ash Meadows NWR

Alternative A – No Action: This alternative assumes no change from past and current management programs and serves as the baseline with which all other action alternatives are compared. There would be no major changes in habitat management or the current visitor services program under this alternative.

Alternative B – Improve Habitat for Endemic Species on Portions of the Refuge and Increase Visitor Services: This alternative provides management actions to improve species management on portions of the Refuge through expanded data collection and monitoring, habitat restoration and enhancement, hydrology modifications, and invasive plant control. Additional protection and enforcement in support

[1] The official name is Desert National Wildlife Range; however, throughout this document, it is referred to by its common name, Desert National Wildlife Refuge.

of species management would be implemented. Research requests would be reviewed using a broader and more inclusive range of criteria. Visitor services would be improved through development and/or implementation of Interpretive, Visitor Services, Outreach, Environmental Education, and Hunting plans. Expanded cultural resources inventories and evaluations would be conducted including artifacts, sites and plants.

Alternative C (Preferred Alternative) – Improve Habitat for Endemic Species throughout Refuge and Increase Visitor Services: This alternative would expand the management actions identified in Alternative B to improve habitat throughout the Refuge. Research topics would be substantially expanded and include climate change modeling and assessing the need for and feasibility of a research facility. Visitor services would be similar to Alternative B, except for an increase in off-site programs.

Desert NWR

Alternative A – No Action: This alternative assumes no change from past and current management programs and serves as the baseline with which all other action alternatives are compared. There would be no major changes in habitat management or the current visitor services program under this alternative.

Alternative B – Minor Improvement in Wildlife and Habitat Management and Moderate Increase in Visitor Services: This alternative provides management actions to improve bighorn sheep management and expand wildlife diversity. Research and management programs for Research Natural Areas would be developed. Visitor services would be improved through expanded environmental education and interpretive programs and an increase in visitor facilities and outreach efforts. Cultural resource management would be expanded and additional education and outreach focused on cultural resources would be implemented.

Alternative C (Preferred Alternative) – Moderate Improvement in Wildlife and Habitat Management and Minor Increase in Visitor Services: This alternative would reduce some management actions compared with Alternative B, but would increase monitoring and habitat protection efforts. Bighorn sheep management would be improved, and a Sheep Management Plan would be prepared to guide future management. Efforts to improve wildlife diversity and Research Natural Areas management would be expanded. Visitor services would be improved similar to Alternative B; however, an auto tour route and wildlife viewing trails would not be constructed under this alternative. Cultural resource management would be similar to Alternative B; however, improvements to cultural resource management would include additional management strategies.

Alternative D – Moderate Improvement in Wildlife and Habitat Management and Limited Increase in Visitor Services: This alternative would implement fewer management actions than Alternatives B and C with regard to visitor services, and wildlife management would be similar to Alternative C with a slight increase in habitat protection.

Moapa Valley NWR

Alternative A – No Action: This alternative assumes no change from past and current management programs and serves as the baseline with which all other action alternatives are compared. There would be no major changes in habitat management or the current visitor services program under this alternative.

Alternative B – Improve Habitat and Wildlife Management on Portions of the Refuge and Increase Visitor Services: This alternative improves habitat and wildlife management on portions of the Refuge compared with Alternative A. The alternative includes actions to restore habitat, gather baseline and population data, manage water resources, and remove invasive species. Visitor services would be expanded through opening of the Refuge to the public on a limited basis. New facilities would be constructed to accommodate the increase in visitors, and the environmental education and interpretation programs would be improved.

Alternative C (Preferred Alternative) – Improve Habitat and Wildlife Management throughout the Refuge and Expand Visitor Services: This alternative includes Refuge-wide habitat restoration efforts and would include expansion of the Refuge boundary. Visitor services would be improved beyond Alternative B by opening the Refuge daily to the public and providing more visitor service programs. Cultural resource management strategies would be similar to Alternative B; however, an inventory of the entire Refuge would be conducted to inform management decisions.

Pahranagat NWR

Alternative A – No Action: This alternative assumes no change from past and current management programs and serves as the baseline with which all other action alternatives are compared. There would be no major changes in habitat management or the current visitor services program under this alternative.

Alternative B – Limited Improvements in Water Resource and Habitat Management and Minor Increase in Visitor Services: This alternative would include management actions to obtain additional habitat use data, expand water flow monitoring, development and implementation of an IMP plan, and habitat protection efforts. A new refugium for Pahranagat roundtail chub is also considered under this alternative pending a feasibility assessment. Visitor services would be improved to accommodate an increase in visitors and to monitor visitor use. The campground would be maintained and the Service would begin collecting fees and limit the length of stays. Cultural resources data would be collected and recorded to create baseline resources and a library for the Refuge. Improvements to educational and interpretive materials and resources would be made to incorporate the additional cultural resources information as well as other newly compiled data.

Alternative C – Minor Improvements in Water Resource and Habitat Management and Minor Increase in Visitor Services: This alternative would expand upon the management actions in Alternative B and provide expanded invasive species control, additional species inventories, improved water resources management, and additional restoration of spring head and channel habitat. Visitor services would also be improved similar to Alternative B, except the campground would be converted to a day use area. New directional signs and turn lanes would be installed to allow visitors to safely turn onto the Refuge. Cultural resources management would be expanded to include significance evaluation of historic and prehistoric resources and outreach to promote cultural resources conservation.

Alternative D (Preferred Alternative) – Moderate Improvements in Water Resource and Habitat Management and Moderate Increase in Visitor Services: This alternative would expand upon management actions presented in Alternatives B and C, including acquiring additional water rights, expanding monitoring efforts for vegetation and wildlife, and climate change modeling. Native upland habitat adjacent to Lower Pahranagat Lake would be restored and a fence would be installed to protect against encroachment along the eastern boundary. Visitor services would be similar to Alternative C, except the boat ramps would be closed, and a car-top boat launch would be designated; at least one new wildlife observation structure would be constructed and an outreach plan would be developed and implemented. Cultural resource management would expand education services, coordinate with local affiliated tribes, and conduct an ethnobotany and traditional plant use study.

SE ROA 12712

Reader's Guide

The U.S. Fish and Wildlife Service (Service) will manage the Desert National Wildlife Refuge Complex (Desert Complex) in accordance with an approved Comprehensive Conservation Plan (CCP). This CCP provides long-range guidance on refuge management through its vision, goals, objectives, and strategies. The CCP also provides a basis for a long-term adaptive management process that will include monitoring the progress of management actions, evaluating and adjusting management actions based on new information or techniques, and revising management and monitoring plans accordingly. Additional step-down planning will be required prior to implementation of the various data gathering, restoration, wildlife management, and major visitor service proposals included in the CCP.

In accordance with the Service's CCP Policy, the CCP and Environmental Impact Statement (EIS) have been combined into one document, referred to as the CCP/EIS. The Final CCP/EIS provides information on each alternative and the anticipated impacts of each management action that could occur from implementation of the CCP. The Final CCP/EIS includes revisions to the Draft CCP/EIS, which was circulated for public review and comment between July 11 and September 9, 2008. Substantive changes to the Draft CCP/EIS text, which were made in response to or as a result of comments received during the public review, are indicated in the Final CCP/EIS using an underlined text format. Addendix M of the Final CCP/EIS includes all comments received on the Draft CCP/EIS and the Service's response to these comments. The Service will issue a Record of Decision (ROD) that identifies the selected alternative for each Refuge no sooner than 30 days following the publication of the Notice of Availability of the Final CCP/EIS in the Federal Register. Once the ROD is signed, the Final CCP made up of Chapter 1, the selected alternative for each Refuge from Chapter 3, all of Chapters 4 and 6, and Appendices A, G, H, and K will be prepared. The following chapter and appendix descriptions are provided to assist readers in locating and understanding the various components of this combined document.

Volume 1:

Chapter 1, Introduction and Background, includes the purpose of and need for a CCP; an overview of policies, regulations, and relevant planning documents; the regional context, establishment, and purposes of the Ash Meadows, Desert, Moapa Valley, and Pahranagat National Wildlife Refuges (NWRs); and vision and goals for future management of the refuges.

Chapter 2, Comprehensive Conservation Planning Process, includes an overview of the CCP process and key issues identified through public, agency, and tribal scoping.

Chapter 3, Alternatives, describes the various management alternatives proposed for the four refuges. Three alternatives are presented for Ash Meadows and Moapa Valley NWRs, and four alternatives are described for Desert and Pahranagat NWRs. Each alternative represents a different approach to achieving the vision, goals, and objectives for the refuges. Alternative A (No Action) for each refuge describes current management practices. Alternative C is the Preferred Alternative for Ash Meadows, Desert, and Moapa Valley NWRs, and Alternative D is the Preferred Alternative for Pahranagat NWR. This chapter also highlights the common features of each refuge's set of alternatives and the management actions eliminated from further consideration.

Chapter 4, Affected Environment, describes the existing physical and biological environment, cultural resources, visitor services, and socioeconomic conditions. This setting represents baseline conditions for the analysis provided in Chapter 5. This chapter provides descriptions of the regional and refuge-specific environments.

Chapter 5, Environmental Consequences, describes the potential impacts of each of the alternatives on the resources, uses, and conditions outlined in Chapter 4. This chapter also provides a description of cumulative impacts.

Chapter 6, Compliance, Consultation, and Coordination with Others, discusses compliance with the National Environmental Policy Act; summarizes public involvement, interagency coordination, and tribal consultation; and acknowledges those agencies, organizations, and individuals who provided significant contributions to the CCP process.

Volume 2:

Appendix A, Index, indicates where the concepts or subject areas that may be of interest to the reader are discussed in the document.

Appendix B, References, provides bibliographic references for the citations in this document as well as references for documents that provide background information for the refuges, but that are not specifically cited.

Appendix C, List of Preparers and Contributors, contains the names and project roles of those individuals directly involved in writing and preparing the Draft CCP/EIS. The names and positions of those who contributed in other ways to the preparation of the document are also included.

Appendix D, Distribution List, contains the list of federal, tribal, state, and local agencies; nongovernmental organizations; libraries; and individuals who received planning updates, summaries, and other mailings associated with this planning effort, including the release of the Draft CCP/EIS.

Appendix E, Applicable Laws, Policies, and Regulations, outlines the various federal laws, Executive Orders, regulations, and other guidance pertinent to implementation of the CCP.

Appendix F, Goals, Objectives, and Strategies for Preferred Alternative, discusses the goals, objectives, and strategies for each refuge's Preferred Alternative, including rationale for the proposed management actions.

Appendix G, Compatibility Determinations for Existing and Proposed Refuge Uses, describe uses, anticipated impacts, stipulations, and a determination of compatibility or non-compatibility for all existing and proposed visitor services on the four refuges.

Appendix H, Biological Resources, provides descriptions of special-status species that occur on the refuges, identifies potential for special-status species to occur, provides a list of management priority bird species, and provides lists of wildlife observed on each refuge.

Appendix I, Wilderness Review, provides the wilderness inventory for Ash Meadows, Moapa Valley, and Pahranagat NWRs and the existing wilderness proposal for Desert NWR.

Appendix J, Desert NWR Bighorn Sheep Discussion, describes bighorn sheep presence on Desert NWR, including historic sheep counts and population estimates.

Appendix K, CCP Implementation, addresses step-down planning, funding, phasing, monitoring, and adaptive management practices as they relate to the various habitat and wildlife management actions included in the preferred alternatives. It also provides cost estimates for proposed visitor services programs and addresses current and future staffing for the refuges.

Appendix L, Land Protection Plan and Conceptual Management Plan for Moapa Valley NWR, includes copies of the plans for expansion of the Moapa Valley NWR acquisition boundary.

Appendix M, Response to Comments on the Draft CCP/EIS, includes all comments received on the draft CCP/EIS and the Service's responses.

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Figures

Tables

Appendices (Volume 2)

Acronyms and Abbreviations

ACEC	Area of Critical Environmental Concern
afy	acre-feet per year
AMR	appropriate management response
BIDEH	biological integrity, diversity, and environmental health
BLM	U.S. Bureau of Land Management
BMP	best management practice
CCDAQM	Clark County Department of Air Quality Management
CCP	Comprehensive Conservation Plan
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
cfs	cubic feet per second
CGTO	Consolidated Group of Tribes and Organizations
CO	carbon monoxide
Desert Complex	Desert National Wildlife Refuge Complex
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOI	U.S. Department of the Interior
EA	Environmental Assessment
EIS	Environmental Impact Statement
EO	Executive Order
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FMU	Fire Management Unit
FY	fiscal year
GIS	geographic information system
GPS	global positioning system
HMA	Herd Management Area
IBA	Important Bird Area
I-15	Interstate 15
IDT	Interdisciplinary Team
INRMP	Integrated Natural Resources Management Plan
IPM	Integrated Pest Management
IWJV	Intermountain West Joint Venture
LVVWD	Las Vegas Valley Water District
mg/L	milligrams per liter
MOU	Memorandum of Understanding
MSHCP	Multiple Species Habitat Conservation Plan
msl	mean sea level
MVWD	Moapa Valley Water District
mya	million years ago
NAAQS	National Ambient Air Quality Standards
NAFB	Nellis Air Force Base
NAWMP	North American Waterfowl Management Plan
NDEP	Nevada Department of Environmental Protection
NDOT	Nevada Department of Transportation
NDOW	Nevada Department of Wildlife

Acronyms and Abbreviations, cont.

NDWR	Nevada Division of Water Resources
NEPA	National Environmental Policy Act
NNHP	Nevada Natural Heritage Program
NO_2	nitrogen dioxide
NOA	Notice of Availability
NOI	Notice of Intent
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NRHP	National Register of Historic Places
NTTR	Nevada Test and Training Range
NWR	National Wildlife Refuge
NWRS	National Wildlife Refuge System
O_3	ozone
PEC	Preferred Equities Corporation
PEIS	Programmatic Environmental Impact Statement
PL	Public Law
PM_{10}	particulate matter less than 10 microns
RNA	Research Natural Area
ROD	Record of Decision
Service	U.S. Fish and Wildlife Service
SNWA	Southern Nevada Water Authority
SO_2	sulfur dioxide
SR	State Route
SSURGO	Soil Survey Geographic Database
STATSGO	State Soil Geographic Database
SWCA	SWCA Environmental Consultants
TNC	The Nature Conservancy
USAF	U.S. Air Force
USC	United States Code
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WRCC	Western Regional Climate Center

SE ROA 12722

Chapter 1. Introduction and Background

Canyon Springs cliff face overlook at Desert National Wildlife Refuge

SE ROA 12724

Chapter 1. Introduction and Background

1.1 Introduction

The Desert National Wildlife Refuge Complex (Desert Complex) is located in southern Nevada and consists of four separate refuges: Ash Meadows National Wildlife Refuge (NWR), Desert NWR, Moapa Valley NWR, and Pahranagat NWR (Figure 1.1-1). The Desert Complex encompasses more than 1.6 million acres in Clark, Lincoln, and Nye Counties, Nevada. The four refuges represent some of the best-quality Mojave Desert wetland, riparian, and montane ecosystems and are home to species of plants and animals found nowhere else on earth.

The U.S. Fish and Wildlife Service (Service) officially began the process of developing a Comprehensive Conservation Plan (CCP) and an Environmental Impact Statement (EIS) for the Desert Complex during fall 2001. The National Wildlife Refuge System Improvement Act of 1997 (Refuge Improvement Act) directs the Service to develop a CCP for all of the refuges by 2012. Development of the CCP and EIS is a multi-year process that will produce a single plan for the four refuges in the Desert Complex. The CCP will guide overall refuge management for its lifetime (approximately 15 years), at which time it will be reviewed and updated as necessary.

This Final CCP/EIS describes the preferred alternative and other alternatives developed for each refuge, the refuges' affected environments, and the environmental consequences of implementing the alternatives. The alternatives for each refuge address wildlife, habitat, and cultural resources management and opportunities for compatible recreation to help achieve refuge purposes, visions, and goals. The Record of Decision (ROD) will identify and describe the selected alternative for each refuge.

1.2 Proposed Action

The Service's Proposed Action is to implement the preferred alternative for each refuge. Details of the specific goals, objectives, and management actions comprising the preferred alternatives are provided in Chapter 3. The Service will issue a Record of Decision which identifies the selected alternative for each refuge. The selected alternative can be the preferred alternative, one of the other alternatives, or a new alternative derived from a combination of the existing alternatives. Future projects implemented after adoption of the alternative and as part of implementation of the CCP will be evaluated in subsequent NEPA documents. These projects are discussed at a programmatic-level in this EIS, except where sufficient details are known to evaluate the actions at a project-specific level.

1.3 Purpose of and Need for the Comprehensive Conservation Plan

The purpose of developing the CCP for the Refuge is to provide managers with a 15-year strategy for achieving refuge purposes and contributing toward the mission of the National Wildlife Refuge System (NWRS), consistent with the sound principals of fish and wildlife conservation and legal mandates. The CCP is flexible; it will be revised periodically to ensure that its goals, objectives, strategies, and timetables are still valid and appropriate.

The Refuge Improvement Act of 1997 requires that the Service develop a CCP for each refuge by 2012 and that refuges be managed in a way that ensures the long-term conservation of fish, wildlife, plants, and their habitats and provides for compatible wildlife-dependent recreation. The purposes for developing a CCP are to:

- Provide a clear statement of direction for the future management of the refuges;
- Provide long-term continuity in management;
- Communicate the Service's management priorities for the refuges to its conservation partners, neighbors, visitors, and the general public;
- Provide an opportunity for the public to help shape the future management of the refuges;
- Ensure that management programs on the refuges are consistent with the mandates of the NWRS and the purposes for which each refuge was established;
- Ensure that the management of the refuges fully considers resource priorities and management strategies identified in other federal, state, and local plans;
- Provide a basis for budget requests to support the refuge's needs, staffing, operations, maintenance, and capital improvements; and
- Evaluate existing and proposed uses of each refuge to ensure that they are compatible with the refuge purpose(s) as well as the maintenance of biological integrity, diversity, and environmental health.

1.4 Legal and Policy Guidance

Legal mandates and Service policies govern the Service's planning and management of the NWRS. A list and brief description of the policies can be found at the "Division of Congressional and Legislative Affairs" Web site (http://laws.fws.gov). In addition, the Service has developed draft or final policies to guide NWRS planning and management. These policies can be found at the "NWRS Policies" Web site (http://www.fws.gov/refuges/policymakers/nwrpolicies.html).

The main sources of legal and policy guidance for the CCP and EIS are described below. Additional laws and policies guiding the CCP and EIS are listed in Appendix E.

National Wildlife Refuge System Overview

The NWRS is the largest system of lands in the world dedicated to the conservation of fish and wildlife. Operated and managed by the Service, it currently includes 545 refuges with a combined area of more than 94 million acres. The majority of refuge lands (more than 77 million acres) are located in Alaska. The remaining acreage is scattered across the other 49 states and several island territories. About 20.6 million acres are managed as wilderness under the Wilderness Act of 1964.

The NWRS was established in 1903, when President Theodore Roosevelt protected an island with nesting pelicans, herons, ibis, and roseate spoonbills in Florida's Indian River from feather collectors decimating their colonies. He established Pelican Island as the nation's first bird sanctuary and went on to establish many other sanctuaries for wildlife during his tenure. This small network of sanctuaries continued to expand, later becoming the NWRS. In contrast to other public lands, which are managed for multiple uses, refuges are specifically managed for fish and wildlife conservation.

National Wildlife Refuge System Mission and Goals

The mission of the NWRS, established by the Refuge Improvement Act, is:

> *"To administer a national network of lands and waters for the conservation, management, and where appropriate, restoration of the fish, wildlife, and plant resources and their habitats within the United States for the benefit of present and future generations of Americans."*

The goals of the NWRS, as established by the National Wildlife Refuge System Mission, Goals, and Purposes Policy (601 FW 1), are to:

- Conserve a diversity of fish, wildlife, and plants and their habitats, including species that are endangered or threatened with becoming endangered.
- Develop and maintain a network of habitats for migratory birds, anadromous and interjurisdictional fish, and marine mammal populations that is strategically distributed and carefully managed to meet important life history needs of these species across their ranges.
- Conserve those ecosystems, plant communities, wetlands of national or international significance, and landscapes and seascapes that are unique, rare, declining, or underrepresented in existing protection efforts.

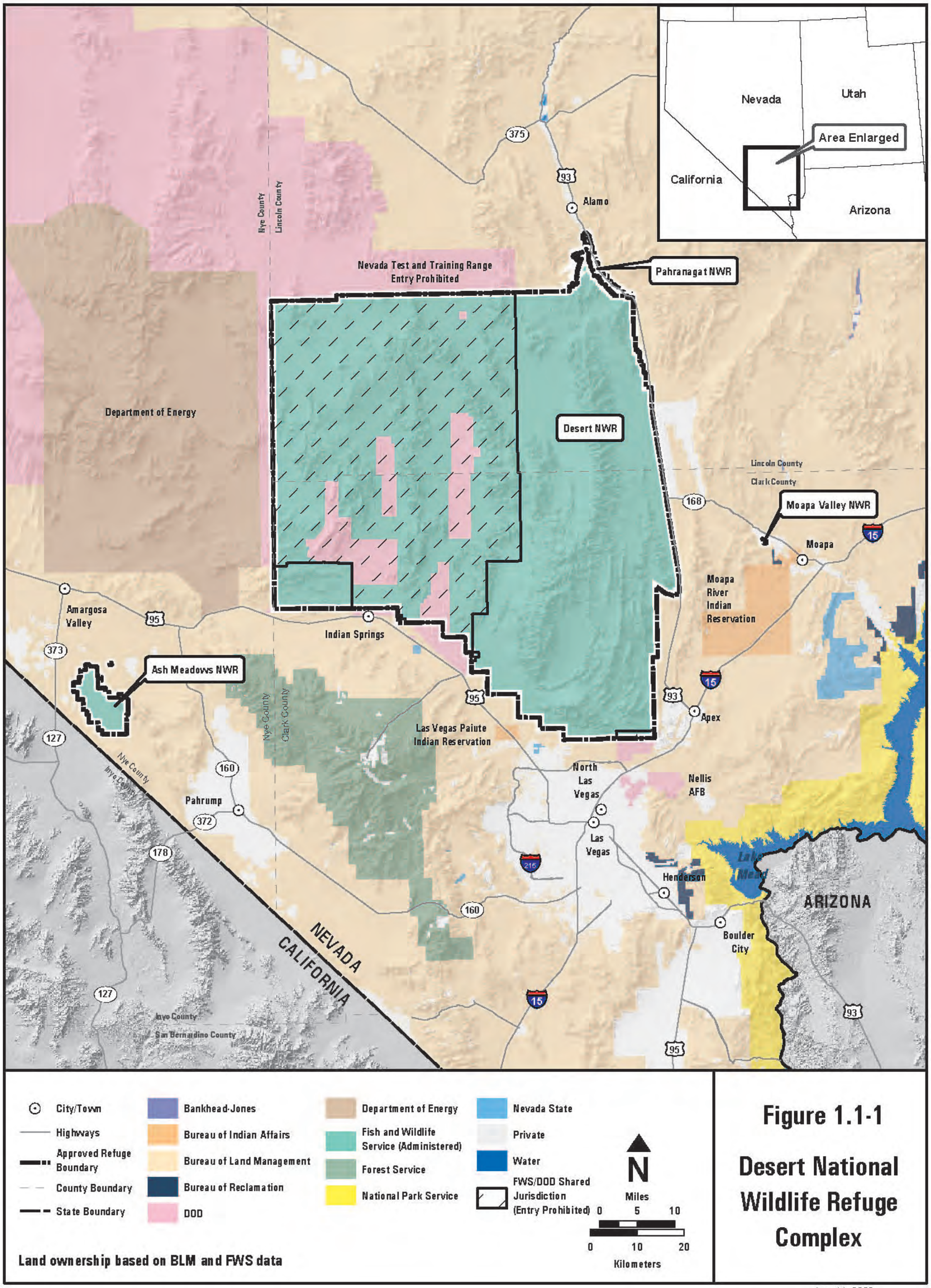

Figure 1.1-1

Desert National Wildlife Refuge Complex

June 11, 2009
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- Provide and enhance opportunities to participate in compatible wildlife-dependent recreation (hunting, fishing, wildlife observation and photography, and environmental education and interpretation).
- Foster understanding and instill appreciation of the diversity and interconnectedness of fish, wildlife, and plants and their habitats.

National Wildlife Refuge System Improvement Act of 1997

Statutory authority for Service management and associated habitat management planning on units of the NWRS is derived from the National Wildlife Refuge System Administration Act of 1966 (Refuge Administration Act), which was significantly amended by the Refuge Improvement Act (16 United States Code [USC] 668dd–668ee). Section 4(a)(3) of the Refuge Improvement Act states, "With respect to the [NWRS], it is the policy of the United States that – (A) each refuge shall be managed to fulfill the mission of the [NWRS], as well as the specific purposes for which that refuge was established…"

The Refuge Improvement Act also states that the "…purposes of the refuge and purposes for each refuge mean the purposes specified in or derived from law, proclamation, executive order, agreement, public land order, donation document, or administrative memorandum establishing, authorizing, or expanding a refuge, refuge unit, or refuge subunit."

The Refuge Administration Act, as amended, clearly establishes wildlife conservation as the core NWRS mission. House Report 105–106, accompanying the Refuge Improvement Act, states "…the fundamental mission of our System is wildlife conservation: …wildlife and wildlife conservation must come first." In contrast to other systems of federal lands, which are managed on a sustained-yield basis for multiple uses, the NWRS is a primary-use network of lands and waters. First and foremost, refuges are managed for fish, wildlife, plants, and their habitats. In addition, units of the NWRS are legally closed to all public access and use, including economic uses, unless and until they are officially opened through an analytical, public process called the refuge compatibility process. With the exception of refuge management activities, which are not economic in nature, all other uses are subservient to the NWRS' primary wildlife management responsibility, and they must be determined compatible before being authorized.

The Refuge Improvement Act provides clear standards for management, use, planning, and growth of the NWRS. Its passage followed the promulgation of Executive Order (EO) 12996 (April 1996), Management of Public Uses on National Wildlife Refuges, reflecting the importance of conserving natural resources for the benefit of present and future generations of people. The Refuge Improvement Act recognizes that wildlife-dependent recreational uses, including hunting, fishing, wildlife observation and photography, and environmental education and interpretation, when determined to be compatible with the mission of the NWRS and purposes of the Refuge, are legitimate and appropriate public uses. Section 5(C) and (D) of the

Refuge Improvement Act states "compatible wildlife-dependent recreational uses are the priority general public uses of the Refuge System and shall receive priority consideration in planning and management; and when the Secretary determines that a proposed wildlife-dependent recreational use is a compatible use within a refuge, that activity should be facilitated, subject to such restrictions or regulations as may be necessary, reasonable, and appropriate."

The Refuge Improvement Act also directs the Service to maintain adequate water quantity and quality to fulfill the NWRS mission and refuge purposes and to acquire, under state law, water rights that are needed for refuge purposes.

Compatibility Policy

Lands within the NWRS are different from other multiple-use public lands in that they are closed to all public uses unless specifically and legally opened. The Refuge Improvement Act states ". . . the Secretary shall not initiate or permit a new use of a Refuge or expand, renew, or extend an existing use of a [refuge], unless the Secretary has determined that the use is a compatible use and that the use is not inconsistent with public safety." The Refuge Improvement Act also states that "... compatible wildlife-dependent recreational uses [hunting, fishing, wildlife observation and photography, or environmental education and interpretation] are the priority general public uses of the [NWRS] and shall receive priority consideration in [refuge] planning and management."

In accordance with the Refuge Improvement Act, the Service has adopted a Compatibility Policy (603 FW 2) that includes guidelines for determining if a use proposed on an NWR is compatible with the purposes for which the refuge was established. A compatible use is defined in the policy as a proposed or existing wildlife-dependent recreational use or any other use of an NWR that, based on sound professional judgment, will not materially interfere with or detract from the fulfillment of the NWRS mission or the purposes for which the refuge was established and contributes to the maintenance of biological integrity, diversity, and environmental health. The Policy also includes procedures for documentation and periodic review of existing refuge uses.

The Compatibility Policy does not apply to overflights above a refuge or to activities authorized, funded, or conducted by a federal agency (other than the Service), which has primary jurisdiction over a refuge or portion of a refuge, if the management of those activities is in accordance with a Memorandum of Understanding between the Secretary or the Director and the head of the federal agency with primary jurisdiction over the refuge governing the use of the refuge.

The first step in determining if a use is compatible is to determine if the use is appropriate (called an appropriateness finding). <u>Wildlife-dependent recreational uses are automatically considered appropriate.</u> The Service evaluates each <u>non-wildlife–dependent</u> use to determine if it is appropriate based on <u>several factors, including compliance with</u>

applicable laws and regulations, consistency with Executive Orders and policies, consistency with public safety, consistency with goals and objectives in an approved management plan, and availability of resources (see 603 FW 1 Section 1.1 (A) for a complete list of factors). If a use is not appropriate, the use is not further considered, and a compatibility determination is not required. If a use is determined to be appropriate, the Service must prepare a compatibility determination. When a determination is made as to whether a proposed use is compatible or not, this determination is provided in writing and is referred to as a compatibility determination.

An opportunity for public review and comment is required for all compatibility determinations. For compatibility determinations prepared concurrently with a CCP or step-down management plan, the opportunity for public review and comment is provided during the public review period for the draft plan and associated National Environmental Policy Act (NEPA) document. A summary of the appropriateness findings and the compatibility determinations prepared in association with this CCP/EIS are provided in Appendix G.

Biological Integrity, Diversity, and Environmental Health Policy

Section 4(a)(4)(B) of the Refuge Improvement Act states, "in administering the [NWRS], the Secretary shall…ensure that the biological integrity, diversity, and environmental health of the [NWRS] are maintained for the benefit of present and future generations of Americans…." This legislative mandate represents an additional directive to be followed while achieving refuge purposes and the NWRS mission. The Act requires the consideration and protection of a broad spectrum of fish, wildlife, plant, and habitat resources found on a refuge. Service policy guiding implementation of this statutory requirement provides a refuge manager with an evaluation process to analyze his/her refuge and recommend the best management direction to prevent further degradation of environmental conditions and, where appropriate, and in concert with refuge purposes and NWRS mission, to restore lost or severely degraded resource components. Within the Biological Integrity, Diversity, and Environmental Health Policy (601 FW 3[3.7B]), the relationships among biological integrity, diversity, and environmental health; NWRS mission; and refuge purposes are explained as follows: "…each refuge will be managed to fulfill refuge purpose(s) as well as to help fulfill the [NWRS] mission, and we will accomplish the purpose(s) and our mission by ensuring that the biological integrity, diversity, and environmental health of each refuge are maintained and where appropriate, restored."

When evaluating the appropriate management direction for refuges, refuge managers will use sound professional judgment to determine their refuge's contribution to biological integrity, diversity, and environmental health at multiple landscape scales. Sound professional judgment incorporates field experience, an understanding of the refuge's role within an ecosystem, and the knowledge of refuge resources, applicable laws, and best available science, including consultation with resource experts both inside and outside the Service.

The priority public uses of the NWRS are not in conflict with this policy when they have been determined to be compatible. The directives of this policy do not envision or necessitate the exclusion of visitors or the elimination of visitor use structures from refuges; however, maintenance and/or restoration of biological integrity, diversity, and environmental health may require spatial or temporal zoning of visitor use programs and associated infrastructures. General success in maintaining or restoring biological integrity, diversity, and environmental health will produce higher-quality opportunities for providing wildlife-dependent recreational uses.

Wilderness Stewardship Policy

This policy provides guidance on administrative and public activities on wilderness areas within the NWRS. The purpose of the policy is to provide "... an overview and foundation for implementing the Wilderness Act and the National Wildlife Refuge System Administration Act of 1966, as amended (Administration Act)." (610FW1 1.1A). The policy states that we will manage proposed wilderness areas as if they were designated wilderness (610FW1 1.5T).

The policy emphasizes recreational uses that are compatible and wilderness-dependent. The policy clarifies conditions upon which generally prohibited uses (motor vehicles, motorized equipment, mechanical transport, structures, and installations) may be necessary for wilderness protection.

National Environmental Policy Act of 1969

The National Environmental Policy Act of 1969 (42 USC Secs. 4321 et seq.) requires that federal agencies prepare an EIS for major federal actions that significantly affect the quality of the human environment. This EIS has been prepared consistent with the requirements of NEPA, the Council on Environmental Quality (CEQ) NEPA regulations (40 Code of Federal Regulations [CFR] Secs. 1500 et seq.), and the U.S. Department of Interior's (DOI's) NEPA procedures (Department Manual, Part 516).

The Service is the NEPA lead agency responsible for EIS preparation. The Draft EIS and CCP were prepared with the assistance of a third-party contractor, SWCA Environmental Consultants (SWCA). The Service served as lead agency and independently reviewed, modified, and approved the contractor's work. Several cooperating agencies provided reviews of the document prior to the Draft EIS and CCP and contributed to various portions of the process, including U.S. Air Force (USAF), Nevada Department of Wildlife (NDOW), U.S. Bureau of Land Management (BLM), National Park Service (NPS), and the Consolidated Group of Tribes and Organizations (CGTO) Document Review Committee.

1.5 Relationship to Regional Conservation Goals

In addition to the mission and goals of the NWRS, the Service assists others in meeting conservation goals established by government and non-government agencies, when and where possible. These goals can be found in management or conservation plans that have been prepared for the region, state, county, or local area and relate to the species and habitats found on the refuges. A brief description of related plans and their goals or objectives is provided below.

1.5.1 Nevada Wildlife Action Plan

As a requirement of the State Wildlife Grant program, passed by Congress in 2001, each state was required to develop a Comprehensive Wildlife Conservation Strategy by October 2005. NDOW completed the Nevada Wildlife Action Plan in September 2005 with the assistance of other organizations, including The Nature Conservancy (TNC), the Lahontan Audubon Society, and the Nevada Natural Heritage Program (NDOW 2005a). The Wildlife Action Plan "is intended to serve as a plan of action for state wildlife conservation and funding by targeting the species of greatest conservation need and the key habitats on which they depend, and lays out strategies for conserving wildlife in each of the key habitats."

The Nevada Wildlife Action Plan is designed to provide scientific support for CCP development, input on impact analyses, and support for implementation of management actions. Partnerships and close coordination between NDOW and the Service are key to incorporating the Nevada Wildlife Action Plan into the CCP process.

1.5.2 Continental and Regional Bird Conservation Plans

Continental Plans

The Partners in Flight North American Landbird Conservation Plan provides a continental synthesis of priorities and objectives to guide landbird conservation actions at national and international scales (Rich et al. 2004). This plan covers 448 species of native landbirds that regularly breed in the United States and Canada, including species that are threatened by habitat loss, have declining populations, or have limited distribution. This plan also highlights the need for stewardship of the species and landscapes characteristic of each portion of the continent, identifying 158 species that are particularly representative of large avifaunal biomes, and whose needs should be considered in conservation planning. Recommended actions vary from region to region, and each region should prepare a step-down management plan.

The U.S. Shorebird Conservation Plan is a coordinated national initiative for shorebird conservation (Brown et al. 2001). The plan is intended to provide an overview of the current status of shorebirds, the conservation challenges facing them, current opportunities for integrated conservation, broad goals for the conservation of shorebird species and subspecies, and specific programs necessary to meet the overall vision of restoring stable and self-sustaining populations of all shorebirds.

The North American Waterbird Conservation Plan provides an overarching continental framework and guide for conserving waterbirds (Kushlan et al. 2002). It sets forth goals and priorities for waterbirds in all habitats from the Canadian Arctic to Panama, from

Bermuda through the U.S. Pacific Islands, at nesting sites, during annual migrations, and during nonbreeding periods. It advocates continent-wide monitoring; provides an impetus for regional conservation planning; proposes national, state, provincial and other local conservation planning and action; and gives a larger context for local habitat protection. The goal of these activities is to assure healthy populations and habitats for the waterbirds of the Americas.

Regional or Statewide Plans

Several bird conservation or management plans have been prepared for the Intermountain West or Nevada to provide more specific management direction for bird species identified in the continental plans. The 2005 Coordinated Implementation Plan for Birds in Nevada (Nevada Bird Plan) provides a framework for implementing the North American Waterfowl Management Plan (NAWMP) in the Intermountain West (Service 1986) and develops a more specific plan for the state of Nevada (Nevada Steering Committee 2005). The Nevada Bird Plan incorporates shorebird, waterbird, and landbird conservation priorities for the Intermountain West as well as objectives of the 1986 NAWMP. The Nevada Bird Plan also provides guidance for the Intermountain West Joint Venture (IWJV) Management Board in considering and ranking various habitat protection, restoration, and enhancement projects for funding by the North American Wetlands Conservation Act and other programs.

The Nevada Bird Plan incorporates priority species and habitat objectives identified in the Partners in Flight Bird Conservation Plan for Nevada (Nevada Partners in Flight 1999), the Intermountain West Regional Shorebird Plan (Oring and Oring 2000), the Intermountain West Waterbird Conservation Plan (Ivey and Herziger 2005), and NAWMP, as well as from other conservation organizations, particularly TNC's Ecoregional Conservation Blueprint for the Great Basin (Nachlinger et al. 2001). The Nevada Bird Plan distills these planning documents into lists of priority bird species and develops statewide goals and measurable objectives for 12 major habitat types over a six-year period (2004 to 2010). Statewide goals and objectives from the Nevada Bird Plan that are most likely to apply to the four refuges in the Desert Complex include:

- <u>Wetlands Goal</u>: Protect and maintain existing wetland habitats in good condition, and restore and improve degraded wetland habitats whenever opportunities arise.
- <u>Wetlands Objective</u>: Permanently protect and/or restore 25,000 acres of high-quality wetlands and associated habitats in Nevada.
- <u>Lowland Riparian Goal</u>: Protect, restore, and enhance lowland riparian systems wherever possible.
- <u>Lowland Riparian Objective</u>: Permanently protect and/or restore 300 linear miles of lowland riparian habitat in Nevada.
- <u>Mesquite/Catclaw Goal</u>: Minimize the loss of mesquite and catclaw habitats wherever possible.

- Mesquite/Catclaw Objective: Permanently protect and/or restore 8,000 acres of mesquite and catclaw habitat in Clark County and other areas of southern Nevada affected by growth and development.
- Pinyon-Juniper Goal: Manage pinyon-juniper stands for habitat quality and diversity of succession to maintain a diverse population of pinyon-juniper–obligate bird species.
- Pinyon-Juniper Objective: Implement alternative management on 75,000 acres of pinyon-juniper forest in Nevada to support diversity of successional stages.

The Service will incorporate these statewide goals and objectives into the management planning for each refuge. Each of the above goals and objectives was considered in the development of alternatives for the four refuges in the Desert Complex. Step-down management plans will provide more specific details and management actions that describe how the Service will help achieve the statewide goals and objectives. Refuge staff will coordinate with the Service's Ecological Services branch to implement the Nevada Bird Plan and NAWMP goals and objectives.

1.5.3 Clark County Multiple Species Habitat Conservation Plan

The Service acted as lead agency during preparation of an EIS for the Clark County Multiple Species Habitat Conservation Plan (MSHCP). County-wide conservation actions identified in the MSHCP may be implemented on the Desert NWR and Moapa Valley NWR. In addition, funding has been provided for research on the refuges through the MSHCP. The MSHCP was established to provide a means to address the conservation needs of sensitive biological resources (plants and wildlife) on non-federal lands in Clark County, Nevada (Clark County and Service 2000). The MSHCP and EIS were prepared in accordance with the Federal Endangered Species Act (ESA) (Section 10a) and NEPA. The purpose of the MSHCP was to obtain a permit or permits from the Service to allow the take of currently listed threatened and endangered species and of species proposed for listing as threatened or endangered for projects implemented on non-federal properties. The purpose of the MSHCP in terms of conservation of species is to:

> *"achieve a balance between long-term conservation and recovery of the diversity of natural habitats and native species of plants and animals that make up an important part of the natural heritage of Clark County and the orderly and beneficial use of land in order to promote the economy, health, well being, and custom and culture of the growing population of Clark County."*

Conservation measures were identified in the MSHCP with the intent that they would be implemented as a cooperative effort of the applicable federal, state and local agencies. These measures may be implemented on the refuges in Clark County and include actions to inform and educate the public, implement adaptive management, restore and enhance habitat, protect habitat, and modify underlying management actions. Due to the lack of available data for several of the species identified in the MSHCP, the 2000 version was designed to be Phase I, and Phase II would follow once additional data become available. Adaptive management would allow for modifications in the proposed conservation measures as new data become available.

1.5.4 Recovery Plan for the Endangered and Threatened Species of Ash Meadows

The Service prepared the Recovery Plan for the Endangered and Threatened Species of Ash Meadows in cooperation with members from the Eastern Mohave Desert Fishes Recovery Team (Service 1990). The purpose of the plan is to provide background information on the threatened and endangered species that occur in Ash Meadows, identify criteria for their delisting or downlisting, and identify actions needed to recover the species. The plan's objective was to delist all listed species in Ash Meadows except for the Devils Hole pupfish, which could only be downlisted to threatened due to its specific habitat requirements. The Ash Meadows NWR was established specifically for protecting threatened and endangered species; therefore, the plan's goals and strategies are central to the Refuge's purpose. These goals and strategies were considered during the CCP planning process and were incorporated into the alternatives for the Refuge.

The criteria identified in the plan for recovering species include restoring them to their historic ranges, establishing self-sustaining populations, removing threats from their habitats, restoring historic water flows in historic channels and discharge rates from springs, establishing two Devils Hole pupfish refugia, and restoring plant and aquatic communities to historic structure and composition. Several actions were identified to help meet those criteria:

1. Secure habitat and water sources for the Ash Meadows ecosystem.
2. Conduct research on the biology of the species.
3. Conduct management activities within essential habitat.
4. Reestablish populations and monitor new and existing populations.
5. Determine or verify recovery objectives.

1.5.5 Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem

The Service prepared the Recovery Plan for the Rare Aquatic Species of the Muddy River Ecosystem to recover and protect aquatic species in the Muddy River area, particularly the Moapa dace (Service 1996). The purpose of the plan is to provide background information on the rare aquatic species, identify criteria for their delisting or downlisting, and identify actions needed to recover the species. Criteria and actions are provided for the Moapa dace, with the expectation that those actions would also aid in the recovery of other rare species. The plan's objective is to delist the Moapa dace and other listed species in the Muddy River area. Moapa Valley NWR was established specifically for protecting threatened and endangered species; therefore, the plan's goals and strategies are central to the Refuge's purpose. These goals and strategies were considered during the CCP planning process and were incorporated into the alternatives for the Refuge.

The criteria identified in the plan for fully recovering and delisting the Moapa dace include restoring the adult dace population to 6,000 individuals in the five spring systems and the upper Muddy River for five consecutive years; restoring 75 percent of the historical habitat in the five spring systems and the upper Muddy River to provide spawning, nursery, cover, and/or foraging habitat; and control or eradicate non-native fish and parasites so that they no longer adversely affect the long-term survival of the Moapa dace. These criteria may be modified as new data become available for the species.

Several actions were identified to help meet those criteria:

1. Protect instream flows and historic habitat within the upper Muddy River and tributary spring systems.
2. Conduct restoration/management activities.
3. Monitor Moapa dace population.
4. Research population health.
5. Provide public information and education.

1.5.6 Muddy River Recovery Implementation Program

The goal of the Muddy River Recovery Implementation Program (MRRIP) is to implement a series of recovery actions necessary to promote recovery and/or conservation of species identified in the Muddy River ecosystem, while at the same time providing for mitigation and minimization of potential adverse effects associated with the development and use of water supplies and other activities that may affect the aquatic ecosystem. To accomplish this goal, recovery actions are based on habitat requirements and recovery goals for the target species in the Muddy River ecosystem. The successful implementation of the appropriate recovery actions is the mechanism for the MRRIP to achieve its goals, and to monitor progress toward species' recovery relative to baseline, existing, and desired conditions. Moapa Valley NWR is within the area of this program, and actions identified in the program may be implemented on the Refuge.

1.5.7 Final Recovery Plan for the Southwestern Willow Flycatcher

The endangered southwestern willow flycatcher is known to nest on two refuges within the Desert Complex: Ash Meadows and Pahranagat. The Service approved a Recovery Plan for the Southwestern Willow Flycatcher in August 2002 (Service 2002b). The plan was prepared by the Southwestern Willow Flycatcher Recovery Team, Technical Subgroup, with the assistance of several individuals. The purpose of the plan is to identify recovery criteria for the flycatcher's downlisting and ultimately for its delisting and to identify management actions that may contribute to the flycatcher's recovery, including costs and timeframes. The recovery objectives for the southwestern willow flycatcher are to downlist the species to threatened status and delist it once certain criteria have been met. The delisting criteria include increasing the total known population to a minimum of 1,950 territories or approximately 3,900 individuals with a geographic distribution that allows properly functioning metapopulations, protecting the species from threats into the distant future, and securing sufficient habitat to maintain the metapopulations over time. Suitable habitat for the southwestern willow flycatcher occurs at Ash Meadows, Moapa Valley, and Pahranagat NWR.

Nine types of recovery actions were identified in the plan:

1. Increase and improve occupied, suitable, and potential breeding habitat.
2. Increase metapopulation stability.
3. Improve demographic parameters.
4. Minimize threats to wintering and migration habitat.
5. Survey and monitor.
6. Conduct research.
7. Provide public education and outreach.
8. Assure implementation of laws, policies, and agreements that benefit the flycatcher.
9. Track recovery progress.

Implementation of these actions is anticipated to allow the species to be downlisted to threatened by 2020, and the species could be delisted within 10 years after downlisting. The Service considered these actions in the CCP planning process and incorporated applicable measures into alternatives for each of the appropriate refuges. Specific actions to aid in recovery of the southwestern willow flycatcher will be identified in step-down management plans.

1.5.8 Recovery Plan for the Aquatic and Riparian Species of Pahranagat Valley

The Service approved the Recovery Plan for the Aquatic and Riparian Species of Pahranagat Valley in May 1998 (Service 1998b). The recovery plan covers three native, endangered species: Pahranagat roundtail chub, Hiko White River springfish, and White River springfish. The primary threats to the species include habitat alteration, introduction of non-native species, and disease. The objective of the recovery plan is to delist the three species. Recovery criteria vary for each species, but generally include establishing self-sustaining populations and reducing impacts to the species and their habitat so the species are no longer threatened with extinction or an irreversible population decline.

Management actions to achieve those criteria include:

1. Maintaining and enhancing aquatic and riparian habitats in Pahranagat Valley.
2. Developing and implementing monitoring plans.
3. Providing public information and education.
4. Establishing and maintaining populations at Dexter National Fish Hatchery, Key Pittman Wildlife Management Area, and Pahranagat National Wildlife Refuge.
5. According to the recovery plan, the species would be able to be delisted by 2015 if the recovery criteria are met.

The goals and strategies of the plan were considered in the CCP planning process and in development of alternatives for the Pahranagat NWR. The Service will incorporate applicable strategies into the management of the Refuge.

1.5.9 Nevada Bighorn Sheep Management Plan

The Bighorn Sheep Management Plan (NDOW 2001) is a planning document to guide bighorn sheep management and conservation. The plan focuses on habitat management and conservation efforts to increase populations across the state of Nevada. Bighorn sheep populations in Nevada have experienced a severe decline since the late 19th century. The sheep previously were found in almost every mountain range across the state, but their populations are now scattered between a few mountain ranges, with a large population on the Desert NWR.

The Bighorn Sheep Management Plan identifies policies to protect existing habitat, improve forage and water availability, increase population numbers, allow bighorn sheep hunting, and increase public awareness and appreciation for the bighorn sheep. For each of these policies, the plan describes specific management actions and strategies to implement. NDOW is tasked with implementing this plan, and the Service has incorporated many of the strategies into management of the Desert NWR.

1.5.10 Nevada Bat Conservation Plan

The Nevada Bat Conservation Plan is an effort of the Nevada Bat Working Group to develop a comprehensive plan for 23 species of bat found in Nevada (Altenbach et al. 2002). The plan provides information on the current status of bat conservation efforts and identifies strategies for improving and standardizing those efforts. Guidelines for bat conservation are provided in the plan and are intended to educate public and private land managers about bat conservation. Because bats occur on each of the four refuges in the Desert Complex, strategies identified in the Nevada Bat Conservation Plan may be incorporated into refuge management.

1.5.11 Integrated Natural Resources Management Plan

The Integrated Natural Resource Management Plan (INRMP) for the Nellis Air Force Base (NAFB) and Nevada Test and Training Range (NTTR) provides guidance for the conservation of natural resources on NTTR and NAFB properties (NAFB 2007b). The USAF developed these guidelines within the context of the military mission of NTTR and NAFB because the military mission takes precedence over all guidance provided by the INRMP. However, the INRMP is executed within the constraints of existing laws and in a manner that sustains the ranges for future missions.

The USAF established a primary goal to "maintain ecosystem integrity and dynamics on NAFB and NTTR without compromising the military mission" (NAFB 2007b). This goal ensures that implementation of mission actions maintains ecosystem integrity to promote good stewardship by supporting existing biodiversity, ensuring sustainable use of the installation, and minimizing management costs and efforts. USAF natural resource managers and mission planners are provided with guidance from the INRMP to enable them to establish mission actions that minimize impacts to natural resources at NAFB and the NTTR. Because a portion of the NTTR overlays the Desert NWR, the USAF has a joint responsibility with the Service, through a Memorandum of Understanding, to ensure minimal impacts to natural resources that occur within the boundaries of the Refuge. The Service and USAF work together to protect and conserve the resources on the Refuge.

1.6 Prioritizing Wildlife and Habitat Management on Refuges

Refuge management priorities derive from the NWRS mission, individual refuge purpose(s), laws that specify Service trust resources, and the mandate to maintain the biological integrity, diversity, and environmental health of the public's refuges. These mandates are consistent with the Refuge Administration Act, as amended by the Refuge Improvement Act. Management on a refuge should first and foremost address the individual refuge purpose, using that purpose to direct its efforts toward the appropriate trust resources. In addition, management should address maintenance and, where appropriate, restoration of biological integrity, diversity, and environmental health. In this approach, the refuge contributes to the goals of the NWRS (601 FW 1) and achievement of the NWRS mission.

Purposes are the essential objective of our refuge stewardship. They are the legislative, legal, and administrative foundations for administration and management of a unit of the NWRS. This includes establishment of goals and objectives and authorization of public uses, which must be shown to be compatible with the refuge purpose(s) before they are allowed.

Service trust species are designated by various statutes governing the Service, as well as treaties that the Service is charged with implementing. These trust species include migratory birds, interjurisdictional fish, marine mammals, and federally listed threatened and endangered species (Table 1.6-1). Although the refuge purpose is the first and highest obligation, management for trust species, when appropriate, is an added responsibility of refuges and is a priority for management on a refuge (601 FW 1.9B). Furthermore, management for trust species directly supports the NWRS mission.

An additional directive to be followed while achieving refuge purposes and the NWRS mission is that related to biological integrity, diversity, and environmental health (BIDEH). This requires that we consider and protect the broad spectrum of native fish, wildlife, plant, and habitat resources found on a refuge: "In administering the [NWRS], the Secretary shall…ensure that the biological integrity, diversity, and environmental health of the [NWRS] are maintained for the benefit of present and future generations of Americans…" (Refuge Improvement Act, Section 4[a][4][B]).

The Policy on BIDEH (601 FW 3.3) is the Service's statement of how it will implement this mandate. The policy provides information and guidance to refuge managers to prevent degradation of BIDEH. It also offers ways to restore lost or severely degraded ecological components, where appropriate.

Table 1.6-1. U.S. Fish and Wildlife Service Trust Species

Trust Species	*Legislative Authority*	*Examples*
Threatened and Endangered Species	Endangered Species Act (16 USC Secs. 1531–1544)	Desert tortoise, Devils Hole pupfish, Moapa dace
Migratory Birds	Migratory Bird Treaty Act (16 USC 703–711) Bald and Golden Eagle Protection Act (16 USC 668a-668d)	Ducks, songbirds, raptors, and shorebirds
Marine Mammals	Marine Mammal Protection Act (16 USC 13611407)	West Indian manatee, polar bear, Pacific walrus, and sea otter
Interjurisdictional Fish	Anadromous Fish Conservation Act (16 USC 757a-757g)	Anadromous species of salmon, paddlefish, and sturgeon

1.7 Refuge Establishment and Management

Each refuge in the Desert Complex was established separately and has different management purposes. This section presents a brief discussion of each refuge's location, history, purpose, vision, and goals. Refuge purposes are a key aspect of refuge planning because management activities must be compatible with the refuge's purpose(s). The purpose of a refuge is "…specified in or derived from

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the law, proclamation, executive order, agreement, public land order, donation document, or administrative memorandum establishing, authorizing, or expanding a refuge, refuge unit or refuge subunit" (Refuge Planning Policy, 602 FW 1.6). Each refuge's purpose or purposes are identified in the following overview of the refuges.

1.7.1 Ash Meadows National Wildlife Refuge

Location

Ash Meadows NWR encompasses approximately 24,000 acres of land in southern Nye County, Nevada (Figure 1.7-1). The entire Refuge is located in Amargosa Valley and is only a few miles northeast of Death Valley National Park's eastern entrance from Death Valley Junction. U.S. Highway 95 runs just north of the Refuge. The Refuge is located approximately 90 miles northwest of Las Vegas and 30 miles west of Pahrump in the unincorporated township of Amargosa Valley.

Land Status

The Service owns approximately 13,828 acres of land within the approved Refuge boundary, including a 382-acre access easement. The Refuge's approved boundary also includes: approximately 9,700 acres of lands administered by the BLM, some of which is managed by the Service under a cooperative agreement; approximately 676 acres of private land; and 40 acres of land managed by the NPS. The entire boundary of the Refuge abuts BLM-managed lands that are designated as the Ash Meadows Area of Critical Environmental Concern (ACEC) and are set aside for protection of the endemic species found at Ash Meadows.

History of Establishment and Acquisition

The Ash Meadows area has been modified and influenced by human use for at least 4,000 years (Otis Bay and Stevens Ecological Consulting 2006). A key recent alteration occurred in the early 1960s when the extensive marshland in Carson Slough was destroyed by a peat-mining operation. This mining eliminated approximately 2,000 acres of habitat supporting one of the largest concentrations of waterfowl in southern Nevada. This marsh was also occupied by the Ash Meadows Amargosa pupfish, Ash Meadows speckled dace, and the now-extinct Ash Meadows killifish (Fisher 1983; R. Miller 1948).

Large-scale habitat alteration occurred again in Ash Meadows in the late 1960s when Spring Meadows Ranch, Inc. began a ranching operation (Sanchez 1981). For the next several years land was leveled for crop production, and aquatic habitats were altered for water diversion. Groundwater was pumped so excessively that the feeding and reproducing habitat of the nearby Devils Hole pupfish was dangerously decreased; simultaneously, the population of this fish declined to fewer than 150 individuals. The U.S. Supreme Court ruled that removal of groundwater would have to be limited to avoid eliminating or diminishing the value of Devils Hole, a component of the Death Valley National Monument (Service 1980). During the late 1970s, Spring Meadows Ranch, Inc. ceased operations and sold its

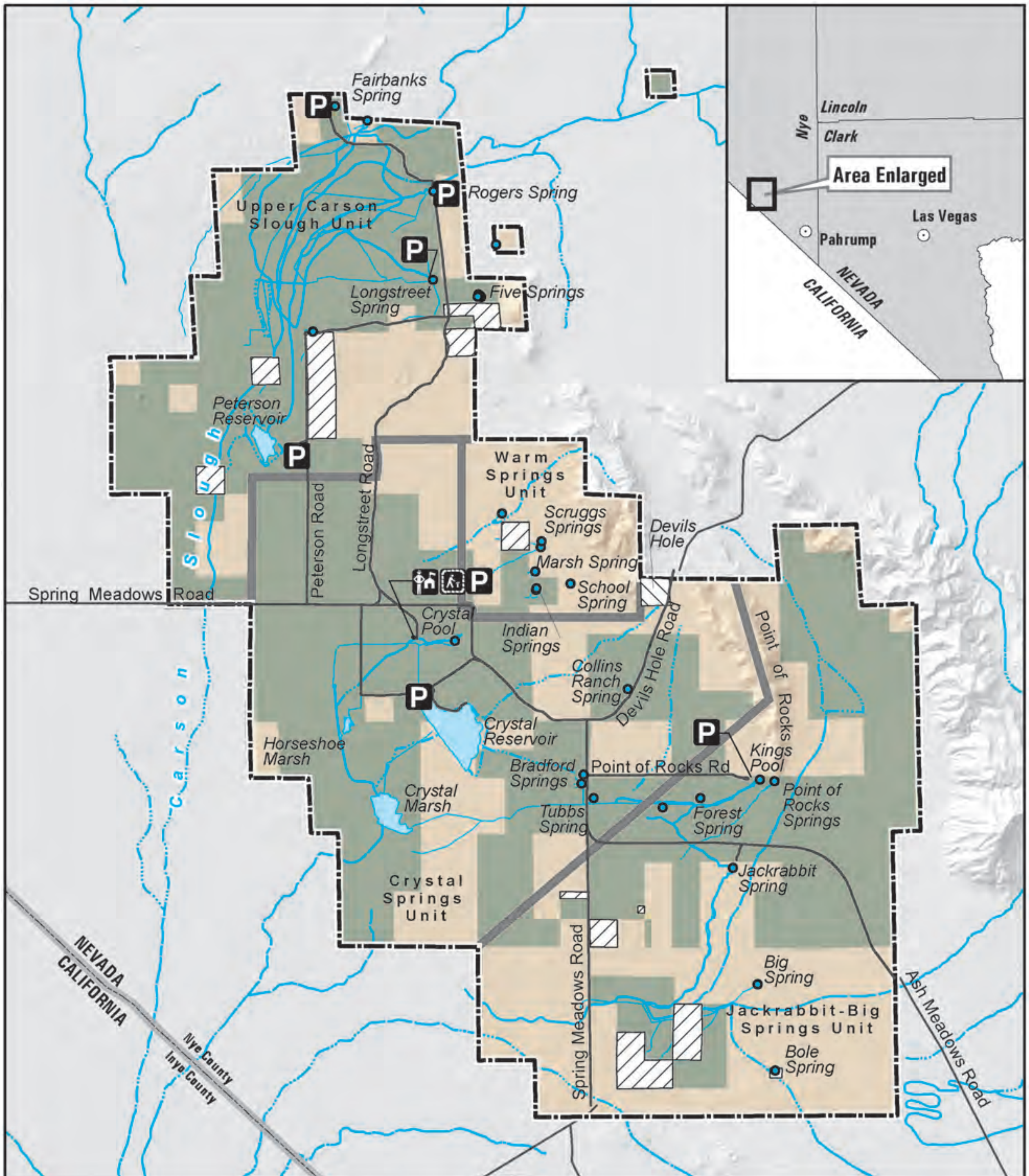

Figure 1.7-1

Land Status

Ash Meadows NWR

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holdings to Preferred Equities Corporation (PEC), which proposed developing the area into a municipal, agricultural, and recreational community for 50,000 people. Nye County and the State of Nevada approved plans for completion of part of this development, which was named Calvada Lakes. In 1984 TNC purchased all of PEC's land (12,614 acres) in Ash Meadows.

The Ash Meadows NWR was established on June 18, 1984, through the purchase of 11,177 acres of former agricultural lands from TNC. According to the Service's 1984 Environmental Assessment: Proposed Acquisition to Establish Ash Meadows National Wildlife Refuge, the purpose of the acquisition was ". . . to protect the endemic, endangered, and rare organisms (plants and animals) found in Ash Meadows . . ." Since the original acquisition from TNC in 1984, an additional 2,309 acres have been acquired from several different landowners.

The Refuge provides habitat consisting of spring-fed wetlands and alkaline desert uplands for at least 25 plants and animals found nowhere else in the world. The Ash Meadows NWR has a greater concentration of endemic life than any other local area in the United States and the second greatest concentration in all of North America.

Many of the Refuge's seeps, springs, pools, and streams supporting sensitive species have been destroyed or altered by human activities in the last 100 years. Habitat alterations during agricultural, municipal, and mining development caused the extinction of one fish species, at least one snail species, and possibly an endemic mammal species (Ash Meadows montane vole, *Microtus montanus nevadensis*). NDOW is currently aiding the Refuge in evaluating the status of the montane vole on the Refuge.

The natural Devils Hole population of pupfish is on NPS-managed land within the Refuge boundary. Devils Hole was added as a unit to Death Valley National Park in 1952. The Refuge once supported two refugia populations of Devils Hole pupfish. Plans are under way to develop a new refugium on the Refuge for the species.

Ash Meadows NWR currently provides habitat used by seven listed species: southwestern willow flycatcher (endangered), Yuma clapper rail (endangered), Devils Hole pupfish (endangered), Ash Meadows Amargosa pupfish (endangered), Warm Springs pupfish (endangered), Ash Meadows speckled dace (endangered), and Ash Meadows naucorid (threatened). Five of these listed species are endemic to the Refuge area (Appendix H).

Historic Conditions

The Ash Meadows area has been intensively used and modified by humans for at least 4,000 years, including periodic burns and diverting and excavating water sources, and it has been influenced by herbivory by ungulates introduced by Europeans (Otis Bay and Stevens Ecological Consulting 2006). Fire and herbivory on the Refuge likely affected wetlands in the Ash Meadows area. The effects of water diversions for irrigation and agricultural uses have been present for long periods of time and, as a result, have partially obscured pre-settlement conditions at the Refuge, making it difficult to describe historic conditions.

Based on aerial imagery and an understanding of human disturbances in the past century, historic conditions on the Refuge consisted of a dominance of upland vegetation, with several wet areas traversing the lowland areas with adjacent transitional vegetation (wetland/riparian) (Otis Bay and Stevens Ecological Consulting 2006). Upland vegetation likely consisted of creosote bush scrub and cottontop cactus hillsides with sparse vegetation cover. Wetland and transitional areas likely contained alkali meadows, alkali shrub/scrub, mesquite bosques, and emergent vegetation, depending on the groundwater table and surface water depth. Invasive vegetation has since become dominant in disturbed areas, and wetlands have decreased in size due to water diversions and agricultural uses.

Refuge Partnerships

The Ash Meadows NWR has partnerships with a variety of organizations and other agencies to manage the Refuge and its resources. The Service works with the following organizations and agencies:

- Death Valley Natural History Association: Plans and stocks bookstore at Refuge visitor contact station, funds educational projects, publishes needed material, works on development of future publications, and assists in outreach to local communities.
- NPS (Death Valley National Park): Education staff assists with programs for third- and fourth-graders, fish biologists assist with exotic aquatic removal programs, and a hydrotech assists with water monitoring program.
- Southern Nye County Conservation District: Funds transportation costs for local schools to participate in education programs, assists in outreach to local communities.
- Nuclear Waste and Environmental Advisory Board for the Town of Pahrump: Hosts the Pahrump Earth Day Fair.
- U.S. Geological Survey (USGS) – Reno and Las Vegas Offices: Participate in recovery team and recovery actions.
- Desert Fishes Council: Assists in outreach to scientific community and provide letters of support.
- Local Land Owners: Involved in conservation partnerships.
- Desert Springs Action Committee: Assists in aquatic removal program.
- NDOW: Participates in recovery team and recovery actions, assists in restoration projects, and assists in aquatic removal program.
- Service – Ecological Services: Assists in restoration projects, assists in aquatic removal program, and participates in recovery team and recovery actions.

- Great Basin Bird Observatory: Conducts periodic bird surveys, provides data summary of Ash Meadow study sites, and assists in outreach to birding communities.
- Desert Research Institute: Maintains an on-line weather station and conducts spring snail surveys.
- Southern Oregon University: Participates in recovery team, recovery actions, and naucorid restoration.
- CGTO: Provides recommendations/feedback on proposed Refuge projects and provides tribal monitors for construction projects.

Special Designations

Wetland of International Importance. In 1986, the Ash Meadows NWR was among the first sites in the United States to be designated as a Wetland of International Importance under the Ramsar Convention. Under this international treaty, 118 contracting parties agreed to work together to develop national policies for wetland conservation, to cooperate in managing shared wetlands and their migratory species, and to devote special attention to the conservation of designated sites.

Important Bird Area (IBA). IBAs are sites that provide essential habitat for one or more species of bird. To qualify as an IBA, sites must satisfy at least one of the following criteria:

- Support species of conservation concern (e.g., threatened and endangered species);
- Support species with restricted ranges (species vulnerable because they are not widely distributed);
- Support species that are vulnerable because their populations are concentrated in one general habitat type or biome; or
- Support species, or groups of similar species (such as waterfowl or shorebirds), that are vulnerable because they occur at high densities due to their gregarious behavior.

Ash Meadows NWR is one of two routes offering perennial surface water and cover for birds migrating through the western Great Basin (Pahranagat Valley is the other). More than 239 different species of birds have been recorded on the Refuge. Fall and especially spring migration periods produce the greatest diversity and numbers. Spring migration usually occurs in April and May, and fall migration occurs from mid-August through September. In the winter, marshes and reservoirs support the largest variety of water birds. Mesquite and ash tree groves throughout the Refuge harbor resident and migratory birds year-round, including typical southwestern species such as Crissal thrasher, verdin, phainopepla, and Lucy's warbler. Two endangered species success stories, the peregrine falcon and bald eagle, also use Ash Meadows seasonally as a migration stop-over. In addition to migrants, a few pairs of endangered southwestern willow flycatchers use Ash Meadows as breeding habitat from June through August each year.

Wilderness Status. In accordance with the Service's Refuge Planning Policy, a wilderness review of the Ash Meadows NWR was conducted during the CCP process (see Appendix I). Ash Meadows NWR was found not suitable for wilderness designation.

Refuge Purpose

The Ash Meadows NWR derives its purpose from the ESA, which authorized its creation:

> *"...to conserve (A) fish or wildlife which are listed as endangered species or threatened species...or (B) plants..." (*16 USC Sec. 1534*).*

Vision

A vision statement is a concise statement of what a refuge should be, based primarily on the NWRS mission, specific refuge purposes, and other mandates. A vision statement helps articulate the direction the refuge should be heading. The following is Ash Meadows NWR's vision statement:

> *The springs, wetlands, and other native habitats of Ash Meadows National Wildlife Refuge support and protect the highest concentration of endemic plant and animal species anywhere in the United States. The Refuge's natural communities are restored to their historic extent and condition, and threatened and endangered species populations are recovered and maintained at sustainable levels through innovative coordination and partnerships. Refuge management continually responds to changes in the environment through adaptive management. Water supplies are ample, reliable, and of appropriate quality and temperature to sustain endemic and other fish and wildlife populations.*
>
> *Researchers are drawn to the Refuge where science-based management and monitoring is used to guide habitat restoration and endangered species recovery efforts and, in the process, further scientific knowledge of fields such as species genetics, regional water flow, geology and even the cultural and historical significance of this long inhabited area. Visitors find sanctuary among the crystal pools and springs nestled among the expansive Mojave Desert landscape.*
>
> *Local residents and visitors enjoy learning about and gaining an appreciation for the Refuge and its unique wildlife and plant species. Local educators recognize the Refuge as an exceptional regional resource for environmental education and for unique wildlife and habitat community tours. Volunteers find a meaningful and personally enriching application for*

> *their interests and talents in a responsive and appreciative setting that contributes to the conservation of rare, unique and beautiful species of wildlife and plants for the enjoyment of present and future generations of Americans.*

Goals

The Service developed five goals for the management of Ash Meadows NWR. These goals were used to identify appropriate objectives and strategies and develop alternatives with specific management actions.

Species Management (Goal 1). Restore and maintain viable populations of all endemic, endangered, and threatened species within the Refuge's Mojave Desert oasis ecosystem.

Habitat (Goal 2). Restore and maintain the ecological integrity of natural communities within the Ash Meadows NWR.

Research (Goal 3). Encourage and provide opportunities for research that supports Refuge and Service objectives.

Visitor Services (Goal 4). Provide visitors with wildlife-dependent recreation, interpretation, and environmental education opportunities that are compatible with and foster an appreciation and understanding of Ash Meadows NWR's wildlife and plant communities.

Cultural Resources (Goal 5). Manage cultural resources for their educational, scientific, and traditional cultural values for the benefit of present and future generations of refuge users, communities, and culturally affiliated tribes.

1.7.2 Desert National Wildlife Refuge[1]

Location

Desert NWR is located immediately north of the city boundaries of North Las Vegas and Las Vegas and encompasses 1.6 million acres of rugged mountain ranges and panoramic valleys in Clark and Lincoln Counties (Figure 1.7-2). It is the largest Refuge in the continental United States and the largest protected area in Nevada. Desert NWR contains six distinct mountain ranges, with elevations ranging from 2,200 feet on valley floors to nearly 10,000 feet in the Sheep Range. The Refuge's wide ranges of elevation and rainfall have created diverse habitats suited to a wide variety of flora and fauna. The southern border of the Refuge abuts the northern border of the rapidly expanding cities of North Las Vegas and Las Vegas. The Refuge is bordered by U.S. Highway 93 on the east and U.S. Highway 95 along

[1] The official name is Desert National Wildlife Range; however, throughout this document, it is referred to by its common name, Desert National Wildlife Refuge.

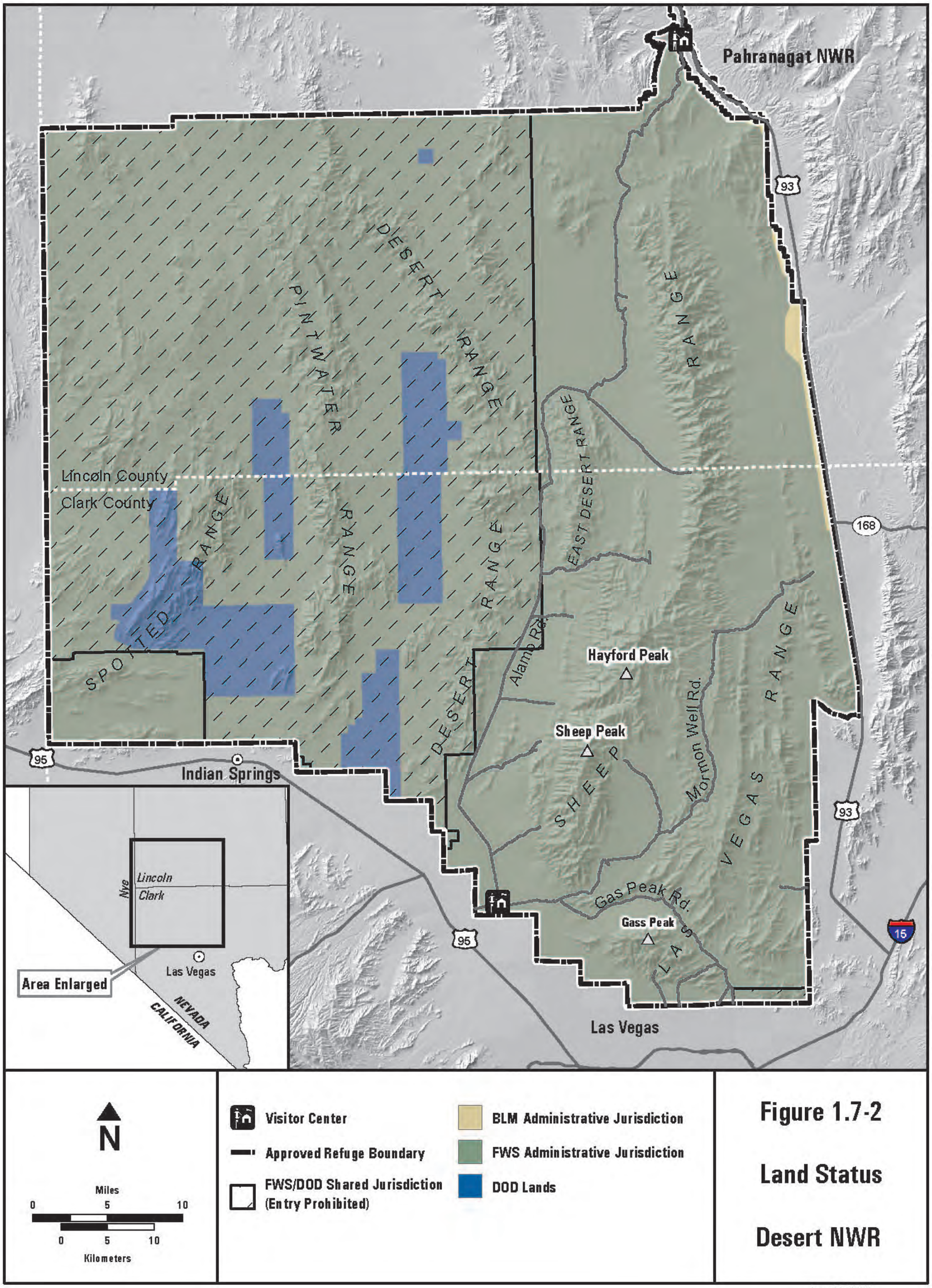

Figure 1.7-2

Land Status

Desert NWR

June 11, 2009
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Figure 1.7-2-desert_landstatus.mxd

the southwest corner. Interstate 15 (I-15) through Las Vegas is located just southeast of the Refuge. The western portion of the Refuge contains military withdrawn lands, as discussed below, which are closed to public access.

History of Establishment and Acquisition

On May 20, 1936, President Franklin D. Roosevelt established the Desert Game Range for "the conservation and development of natural wildlife resources" (EO 7373). The 2.25 million–acre Game Range, under the joint administration of the Service and BLM, included most of the lands within the current Refuge boundary, but stretched south to include portions of the Spring Mountains, including the area currently occupied by Red Rock Canyon National Conservation Area.

In 1939, a 320-acre ranch at Corn Creek was acquired from a private landowner under the authority of the Migratory Bird Conservation Act. This site became the administrative headquarters for the Game Range.

In October of 1940, approximately 846,000 acres of the Desert Game Range were reserved for the use of the War Department (U.S. Department of Defense [DOD]) as an aerial bombing and gunnery range (now known as the NTTR). The USAF's use of a portion of the Desert Game Range was governed by a Memorandum of Understanding (MOU) signed in 1949. The MOU was most recently updated in 1997 on December 22.

The approximately 10,623-acre Nellis Small Arms Range is located 3 miles northwest of NAFB on Range Road (USAF 2007a). It is managed by NAFB. The range overlays a small portion of the Desert NWR in the southeast corner. The range is used for small arms training, and most of the land is undeveloped.

Public Land Order 4079, dated August 31, 1966, as amended by Public Law (PL) 106–65 (Sec. 3011[b][3]), established the Desert National Wildlife Range under the sole administration of the Bureau of Sport Fisheries and Wildlife (now the Service). It also reduced the size of the refuge to 1,588,000 acres.

Between 1970 and 1985, 440 acres in the vicinity of Corn Creek were purchased from a variety of private land owners under the authority of the ESA (16 USC Sec. 1534) and Refuge Recreation Act (16 USC Sec. 460k-460).

The Military Lands Withdrawal Act of 1999 (PL 106–65) extended the Air Force's withdrawal on the 2,919,890-acre Nevada Test and Training Range for 20 years. These lands were reserved for use by the Air Force: " . . . (A) as an armament and high hazard testing area; (B) for training for aerial gunnery, rocketry, electronic warfare, and tactical maneuvering and air support; (C) for equipment and tactics development and testing; and (D) for other defense-related purposes . .

." This withdrawal overlays approximately 845,787 acres of the Desert. NWR. According to PL 106–65 as amended:

> *"During the period of withdrawal and reservation of lands by this subtitle, the Secretary of the Interior shall exercise administrative jurisdiction over the Desert National Wildlife Refuge . . . through the United States Fish and Wildlife Service in accordance with the National Wildlife Refuge System Administration Act of 1966 (16 U.S.C. 668dd et seq.), this subtitle, and other laws applicable to the National Wildlife Refuge System. The Secretary of the Interior, in coordination with the Secretary of the Air Force, shall manage the portion of the Desert National Wildlife Refuge withdrawn by this subtitle . . . for the purposes for which the refuge was established, and to support current and future military aviation training needs consistent with the current memorandum of understanding between the Department of the Air Force and the Department of the Interior . . ."*

PL 106-65 also transferred primary jurisdiction of 112,000 acres of bombing impact areas on Desert NWR from the Service to DOD. However, the Service retained secondary jurisdiction over these lands. All military withdrawn lands are closed to general public access.

On November 6, 2002, President George W. Bush signed the Clark County Conservation of Public Land and Natural Resources Act of 2002 (PL 107–282), which administratively transferred 26,433 acres of BLM land adjacent to Desert NWR's east boundary to the Service. Desert NWR's land base changed again with the passage of the Lincoln County Conservation, Recreation, and Development Act of 2004 (PL 108–424). As part of the Act, administrative jurisdiction over approximately 8,382 acres of land along the eastern boundary of Desert NWR and west of U.S. Highway 93 was transferred from the Service to the BLM for use as a utility corridor. In addition, 8,503 acres of BLM-administered land were transferred to the Service to be managed as part of the Desert NWR. This land is located at the northeastern boundary of the Desert NWR and the western boundary of Pahranagat NWR.

Historic Conditions

The Desert NWR has been relatively undisturbed by EuroAmericans, except for small areas affected by agricultural uses (e.g., Corn Creek) and other uses (e.g., military operations). As a result, current conditions are likely similar to pre-settlement conditions, with vast acreages of upland vegetation supporting a diversity of flora and fauna and occasional springs and wetlands. Human disturbances, such as grazing, reduction in natural herbivores, and wood harvesting, may have affected the historic conditions on the Refuge (NAFB 2007b).

Lower elevation upland habitats include creosote bush and saltbush scrubs in the southern portion, and blackbrush and Great Basin desert scrub in the northern portion (NAFB 2007b). Blackbrush may have been more dominant in historic times. Higher-elevation upland habitats include pinyon-pine and pinyon-juniper. Natural artesian springs were more common throughout the Las Vegas Valley, resulting in distinct riparian habitats supporting cottonwoods, willows, and cattails. These spring habitats, as well as the nearby Las Vegas Big Spring and Creek, supported oases in the arid desert landscape.

Refuge Partnerships

Desert NWR has partnerships with a variety of organizations and other agencies to manage the Refuge and its resources. The Service works with the following organizations and agencies:

- NDOW: Coordinates desert bighorn sheep hunt program on the refuge, including setting bag limits for each hunt unit, assists (or takes lead) with annual fall sheep surveys, works with Service and Fraternity of the Desert Bighorn to maintain water developments, conducts wildlife surveys on the Refuge, conducts removal of non-native aquatic species from Corn Creek ponds, and assists with monitoring Pahrump poolfish refugium populations.
- USAF: Provides a minimum of 20 hours of aircraft support annually, and if available, other support equipment with operating personnel as negotiated on a case-by-case basis for the purposes of aerial patrol, search and rescue, maintenance, wildlife inventory, water hole inspection, and other wildlife management practices on the Refuge; facilitates access to portions of the Refuge within the NTTR for guzzler maintenance; facilitates access to the Refuge during the bighorn sheep hunt; provides a mandatory Range Safety Briefing and Natural/Cultural Resources Briefing for all hunters; and cooperates on cultural resources management and tribal coordination.
- Fraternity of the Desert Bighorn: Assists with maintenance of sheep water developments (including manpower and funding for equipment and helicopter time).
- Southern Nevada Interpretive Association: Staffs and manages visitor contact station on Refuge, provides environmental education programs for school groups at Corn Creek, and leads hikes into back country areas and informational walks around Corn Creek.
- CGTO: Provides recommendations/feedback on proposed refuge projects and tribal monitors for construction projects.
- Service – Ecological Services: Monitors Pahrump poolfish populations, assists with Section 7 consultation, and assists with Refuge surveys for special-status species.
- USGS: Monitors water levels from Corn Creek springs.

Special Designations

Proposed Wilderness. In 1974, approximately 1.4 million acres of land within the Refuge were proposed for wilderness designation under the Wilderness Act of 1964 (Appendix I). In the President's message to Congress accompanying the proposal, he recommended that Congress defer action on the proposal until a mineral survey was completed. The

Final EIS for the proposal was released in August of 1975. A mineral assessment of the Refuge was completed in 1993 as part of the mineral withdrawal, which was later completed in 1999. However, Congress has yet to act on the wilderness proposal, and the area continues to be managed to protect its wilderness values.

Figure 3.3–1 in Chapter 3 (Alternatives) shows the area proposed for wilderness in 1974; Table 1.7-1 shows the wilderness review timeline for the Refuge from the most recent proposal to the original wilderness study report.

The wilderness proposal described 12 wilderness units within the Refuge and on BLM land adjacent to the Refuge's eastern boundary. Each unit was delineated based on man-made or natural features, such as roads, elevation contours, or the Refuge boundary. Table 1.7-2 provides information on each wilderness unit and its boundaries.

Table 1.7-1. Wilderness Review Timeline for Desert NWR

Proposal/Study	*Area (acres)*
Final Environmental Impact Statement (Service 1975)	1,398,900 acres* proposed
Revision to Wilderness Proposal (Service 1971a) due to public hearing	1,460,340 acres* determined suitable
Wilderness Proposal (Service 1971a; October)	1,443,100 acres** determined suitable
Wilderness Study Report (Service 1971b; April)	1,442,000 acres** determined suitable
Draft Wilderness Study Report, pre 1971	1,646,000 acres** determined suitable

**Acreage includes 76,000 acres of BLM land previously outside the Refuge boundaries.*

***Acreage includes 58,000 acres of BLM land previously outside the Refuge boundaries.*

Table 1.7-2. Proposed Desert NWR Wilderness Units

Wilderness Unit	*Size (acres)*	*Unit Boundaries*
Unit I Gass Peak	40,900	Northwest: Mormon Well Road South/Southwest: Refuge boundary West: 3,000 ft contour line, 1mi east of Corn Creek North/East: Gass Peak Road
Unit II Las Vegas Range	163,640	North/West: Mormon Well Road Southwest: Gass Peak Road

Table 1.7-2. Proposed Desert NWR Wilderness Units

Wilderness Unit	*Size (acres)*	*Unit Boundaries*
		West: Right-of-way of power line South/East: Refuge boundary
Unit III Sheep Range	499,900	North/East: Refuge boundary West/Northwest: Alamo Road South: Mormon Well Road Southeast: US 93 Southwest: 3,000 ft contour line, east of Alamo Road
Unit IV Hole-in-the Rock	115,700	North: Refuge boundary South: Cabin Springs/Alamo Road West: Unnamed road East: Alamo Road
Unit V Desert-Pintwater Range	278,100	North: Refuge boundary South: 4,000 foot contour West: Groom Lake Road and the 4,600-foot contour line near Emigrant Valley East: Alamo Road and unnamed road
Unit VI Spotted Range	300,700	North/South/West: Refuge boundary East: 4,600 and 3,600 ft contour lines and Spotted Range Road
Total Acreage	1,398,900	

Source: Service 1971a (see Appendix I). Acreages are prior to changes made as a result of the public hearing.

Research Natural Areas. Research natural areas (RNAs) are part of a national network of reserved areas under various ownerships. RNAs are intended to represent the full array of North American ecosystems with their biological communities, habitats, natural phenomena, and geological and hydrological formations.

In RNAs, as in designated wilderness, natural processes are allowed to predominate without human intervention. Under certain circumstances, deliberate manipulation may be used to maintain the unique features for which the RNA was established. Table 1.7-3 lists the RNAs on Desert NWR. Figure 3.3-1 shows their locations on the Refuge.

Table 1.7-3. Research Natural Areas on Desert NWR

Name	*Plant Community Represented*	*Area (acres)*
Basin	Interior Ponderosa Pine	650
Deadhorse	Grama-Galleta Steppe	3,000
Hayford Peak	Bristlecone Pine	2,000
Papoose Lake	Saltbush	23,680
Pinyon-Juniper	Pinyon-Juniper	500

Important Bird Area. In 2004, the Audubon Society designated 24,000 acres of the southern Sheep Range as an IBA, one of 35 in Nevada (National Audubon Society 2008). With a wide range of elevation and aspect, the Sheep Range IBA supports a variety of plant communities, including Mojave scrub, pinyon-juniper woodland, ponderosa pine and aspen forest, as well as scattered springs and seeps. The Sheep Range IBA provides important breeding habitat for flammulated owl, gray flycatcher, black-throated gray warbler, and Grace's warbler. It also represents the northern limit of the Mexican whip-poor-will (Nevada Audubon Society 2008).

Refuge Purposes

Desert NWR has four purposes derived from laws under which it was established:

> *"...for the protection, enhancement, and maintenance of wildlife resources, including bighorn sheep..."* (Public Land Order 4079, dated August 31, 1966, as amended by PL 106–65).
>
> *"...to conserve (A) fish or wildlife which are listed as endangered species or threatened species...or (B) plants..."* (ESA, 16 USC Sec. 1534).
>
> *"...suitable for (1) incidental fish and wildlife-oriented recreational development, (2) the protection of natural resources, (3) the conservation of endangered species or threatened species..."* (16 USC Sec. 460k-1).
>
> *"...the Secretary...may accept and use...real...property. Such acceptance may be accomplished under the terms and conditions of restrictive covenants imposed by donors..."* (Refuge Recreation Act, as amended, 16 USC Sec. 460k-2).

Vision

Desert NWR's vision statement is:

> *As the largest refuge in the contiguous United States, Desert National Wildlife Refuge provides the highest quality, intact habitat for desert bighorn sheep and other fish, wildlife, plants and their habitats native to the Great Basin and Mojave Desert ecosystems.*
>
> *This rugged, arid landscape supports a full range of desert habitats from playas on the valley floors through desert scrub and coniferous woodlands to ancient bristlecone pine groves on the mountain peaks. The vast, rugged wild spaces provide wildlife and people a refuge and a place for harmonious recreational opportunities.*

Refuge Goals

The Service developed five goals for management of Desert NWR. These goals were used to identify appropriate objectives and strategies and develop alternatives with specific management actions.

Bighorn Sheep (Goal 1). Maintain and, where necessary, restore healthy population levels of bighorn sheep on Desert NWR within each of the six major mountain ranges.

Wildlife Diversity (Goal 2). Maintain the existing natural diversity of native wildlife and plants, including special-status species, at Desert NWR.

Specially designated Areas (Goal 3). Manage specially designated areas such that they augment the purposes of the Desert NWR.

Visitor Services (Goal 4). Provide visitors with opportunities to understand, appreciate, and enjoy the fragile Mojave/Great Basin Desert ecosystem.

Cultural Resources (Goal 5). Manage cultural resources for their educational, scientific, and traditional cultural values for the benefit of present and future generations of refuge users, communities, and culturally affiliated tribes.

1.7.3 Moapa Valley National Wildlife Refuge

Location

Moapa Valley NWR encompasses 116 acres and is located about 60 miles northeast of Las Vegas in Clark County (Figure 1.7-3). The Refuge is part of a unique system of thermal springs that are part of the headwaters of the Muddy River, which eventually flow into Lake Mead east of Las Vegas. The Refuge is located south of State Highway 168 and the upper Muddy River, between I-15 and U.S. Highway 93. The entire Refuge lies within the upper Moapa Valley. It is bounded on the north by Warm Springs Road, on the south by Battleship Wash, and on the east and west by private property. The Moapa Indian Reservation is located 5 miles south of the Refuge.

History of Establishment and Acquisition

Moapa Valley NWR was established on September 10, 1979, to secure and protect habitat for the endangered Moapa dace.

As stated in a 1979 Environmental Assessment of Proposed Land Acquisition for Moapa Dace (Service 1979):

> *"The U.S. Fish and Wildlife Service proposes: 1. To acquire, in fee or by exchange in the upper Moapa Valley of Clark County, Nevada, approximately 90 acres of land deemed essential habitat of the endangered Moapa dace, Moapa coriacea, for the purpose of protecting this fish and enhancing its survival prospects."*

The endemic Moapa dace lives out its lifecycle in the Warm Springs thermal spring complex that includes more than 20 springs located within the Refuge. Historic uses of the spring pools and the surrounding landscape for agricultural and recreational purposes have altered the habitat of the Moapa dace.

The Refuge comprises multiple adjacent but visually distinct units. The original Pedersen Unit was acquired in 1979 and is 30 acres in size. An additional 11 acres were purchased in 2006 from Richard and Lorena Pedersen and are referred to as the Pedersen II Unit. The Plummer Unit was acquired in 1997 and is 28 acres in size, and the Apcar Unit was acquired in 2000 and is 48 acres in size. Each unit has a separate stream system supported by the steady and uninterrupted flow of several springs that surface at various places throughout the Refuge.

Due to the Refuge's small size, fragile habitats, ongoing restoration work, and removal of unsafe structures, the Refuge has been closed to the public since its establishment. Plans to open the Refuge to the public are currently under way as part of this planning process. Agency scientists with the USGS Biological Resources Division and NDOW, as well as local conservation and community organizations, are working with Service staff to restore the historical landscape and habitat on the Refuge, which is critical to the survival of the Moapa dace. Public education and outreach are also important to the recovery of the Moapa dace.

Historic Conditions

The Muddy River area has been affected by human activities associated with development, recreation, agricultural uses, and other land disturbing activities. The Muddy River historically flowed into the Virgin River prior to the construction of Hoover Dam (TNC 2000). It is a remnant of the White River system, which also flowed through Pahranagat NWR. Historically, the streams in the area were bordered by willow and mesquite, but activities in the past century have introduced palm trees and tamarisk into the riparian habitats along streams (Service 1996). Ash and cottonwood are also considered native, although cottonwoods were believed to have been brought into the area by Mormon settlers (TNC 2000).

Refuge Partnerships

Moapa Valley NWR has partnerships with a variety of organizations and other agencies to manage the Refuge and its resources. The Service works with the following organizations and agencies:

- USGS: Assists with monitoring Moapa dace and other native and non-native fish on the Refuge, provides recommendations on restoring habitat for dace, conducts research on Moapa dace and other species that provides critical info for restoration and management, and monitors water levels.
- NDOW: Assists with monitoring Moapa dace populations and provides input regarding non-game wildlife regarding habitat restoration efforts.
- Partners in Conservation: Assists in Refuge volunteer events and efforts.
- Muddy River Regional Environmental Implementation Action Committee: Assists in Refuge volunteer events and efforts and assists with removal of non-native vegetation on the Refuge.
- Service – Ecological Services: Conducts Moapa dace and other non-native fish population counts and monitoring and assists with trapping and removal of non-native fish and reptiles from Refuge streams and spring pools.
- The Nature Conservancy: Partner with the Service in the Muddy River Recovery Implementation Program and coordination of land management planning activities.
- Southern Nevada Water Authority: Partner with the Service in the Muddy River Recovery Implementation Program and coordination of land management planning activities.
- Other Muddy River Recovery Implementation Program Partners (Moapa Band of Paiutes, Moapa Valley Water District, and Coyote Springs Investment, LLC): Developing recovery program for protection of the moapa dace.
- CGTO: Provides recommendations/feedback on proposed refuge projects and provides tribal monitors for construction projects.

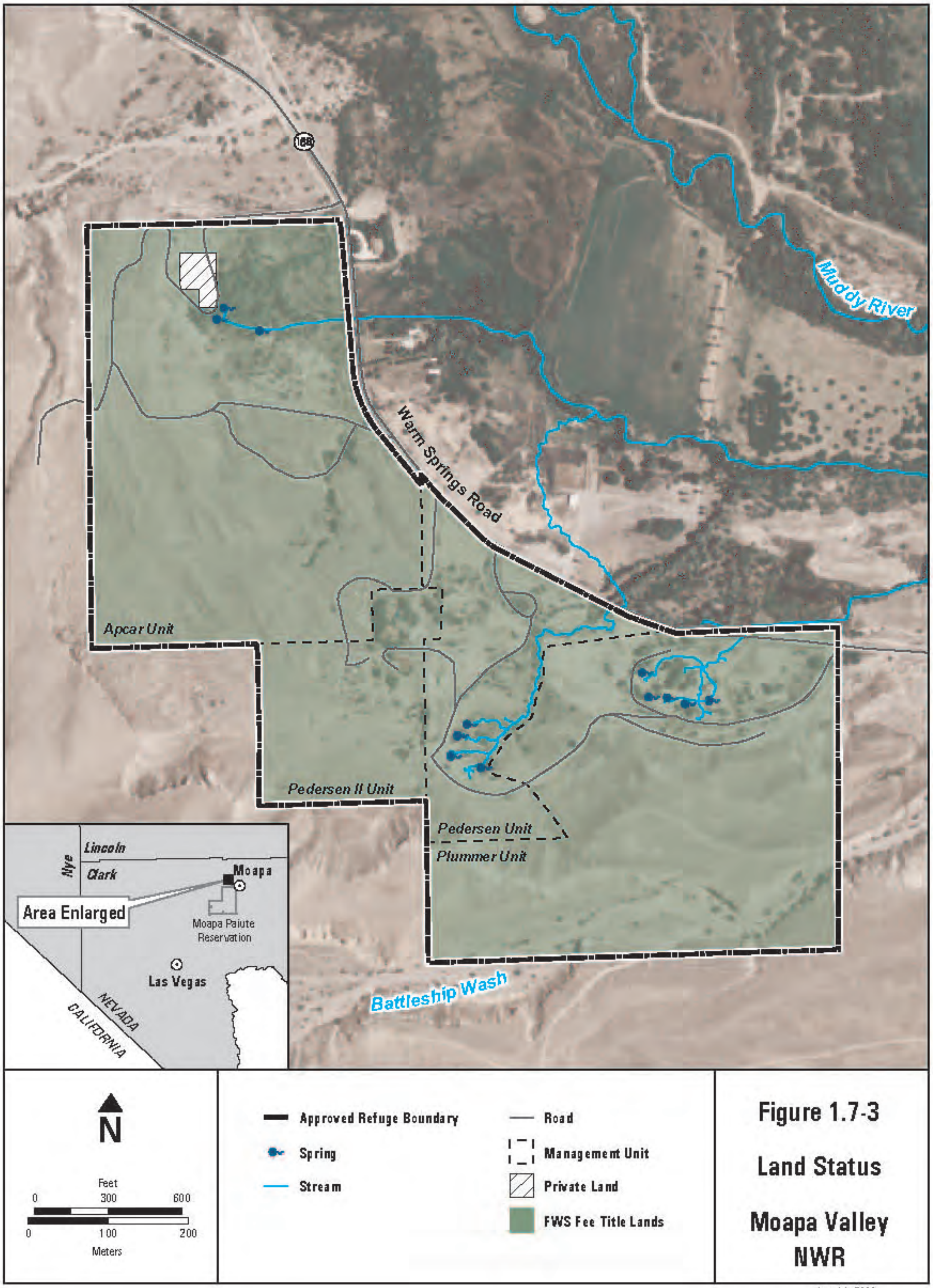

Figure 1.7-3

Land Status

Moapa Valley NWR

June 11, 2009
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Figure 1.7-3moapa_landstatus.mxd

Special Designations

Important Bird Area. Moapa Valley IBA encompasses riparian, mesquite, and Mojave Desert scrub habitat in the Moapa Valley and along the upper reaches of the Muddy River. This area supports a diversity of birds, including breeding populations of the endangered southwestern willow flycatcher. The presence of a rare habitat type in Nevada distinguishes this area from others and warrants its recognition as an IBA.

Wilderness. In accordance with the Service's Refuge Planning Policy, a wilderness review of Moapa Valley NWR was conducted during the CCP process (see Appendix I). Moapa Valley NWR was found not suitable for wilderness designation.

Refuge Purpose

The purpose of Moapa Valley NWR derives from the ESA:

> *"...to conserve (A) fish or wildlife which are listed as endangered species or threatened species...or (B) plants..."* (16 USC Sec. 1534).

Vision

Moapa Valley NWR's vision is:

> *Moapa Valley National Wildlife Refuge supports and protects a healthy, thriving population of Moapa dace at the headwaters of the Muddy River. Stable flows from the Refuge's numerous warm springs fill meandering channels downstream that provide ideal habitat for dace, Virgin River chub and other species of endemic fish and invertebrates.*
>
> *The spring bank and riparian plant communities provide habitat for southwestern willow flycatcher as well as a rich diversity of migratory and resident songbirds, colonial nesting species, and other native wildlife.*
>
> *Local residents and visitors learn about and enjoy this restored desert oasis. Volunteers take personal satisfaction from contributing to the conservation and protection of Refuge wildlife and the unique spring system nourished habitats on which they depend.*

Goals

The Service developed two goals for management of the Moapa Valley NWR. These goals were used to identify appropriate objectives and strategies and develop alternatives with specific management actions.

Endemic and Special-Status Species (Goal 1). Protect and restore, when possible, healthy populations of endemic and special-status species, such as the endangered Moapa dace, within the Muddy River headwaters.

Visitor Services (Goal 2). Provide local communities and others with opportunities to enjoy and learn about the resources of Moapa Valley NWR and participate in its restoration.

1.7.4 Pahranagat National Wildlife Refuge

Location

Pahranagat NWR is located approximately 90 miles north of Las Vegas along U.S. Highway 93 at the southern end of Pahranagat Valley (Figure 1.7-4). It encompasses 5,380 acres of marshes, open water, native grass meadows, cultivated croplands, and riparian habitat in Lincoln County. The town of Alamo is a few miles north of the Refuge.

History of Establishment and Acquisition

Pahranagat NWR was established on August 16, 1963, to provide habitat for migratory birds, especially waterfowl. The Refuge is an important stopping point for numerous migratory birds during their fall and spring migrations. It is also an important tourist attraction for visitors traveling on U.S. Highway 93 to or from Las Vegas.

Public Land Order 3348 in 1964 withdrew an additional 1,466 acres from public domain for incorporation into the Refuge boundary, bringing the acreage of Pahranagat NWR to a total of 5,382 acres. In 1966, the Service also acquired a 347-acre lake bottom on the Refuge.

Historic Conditions

The Pahranagat River has been modified and disturbed as a result of human activities related to agricultural uses and development. The river is primarily fed by spring discharge from Ash and Crystal Springs (Tuttle et al. 1990). Historically, these springs and the river likely contained a thick riparian corridor of ash, cottonwood, and willow. Native upland vegetation includes pinyons and junipers in the mountains and greasewood and sage at lower elevations.

Human activities have channelized, diverted, and dried up portions of the Pahranagat River drainage. Concrete channels have been installed to control and divert flows for irrigation of agricultural fields north of and within the Refuge. The Pahranagat River historically flowed into Maynard Lake and was a relic of the White River drainage, which discharged into the Virgin River (Tuttle et al. 1990). The White River drainage has dried up and is represented now by springs located throughout its historic channel. The Pahranagat River is now an intermittent drainage affected by agricultural uses, and it discharges into three man-made lakes on the Refuge.

Refuge Partnerships

Pahranagat NWR has partnerships with a variety of organizations and other agencies to manage the Refuge and its resources. The Service works with the following organizations and agencies:

- NDOW: Administers portions of waterfowl and upland game hunt program, conducts periodic wildlife surveys, conducts mid-winter waterfowl surveys, has a cooperative agreement to manage warm-water sport fishery, conducts yellow-billed cuckoo surveys and produces an annual report, conducts southwestern willow flycatcher surveys and produces an annual report, and conducts montane vole genetic research.
- U.S. Bureau of Reclamation: Conducts southwest willow flycatcher surveys.
- Great Basin Bird Observatory: Conducts breeding bird surveys and administers biologist contract for oversight of preplanning wetland restoration project.
- CGTO: Provides recommendations/feedback on proposed refuge management plans and provides tribal monitors for inventory of Black Canyon.
- Service – Ecological Services: Conducts spring inventories, killdeer nest monitoring, and spring restoration.
- BLM: Researches Russian knapweed treatments.
- University of New Mexico: Conducts montane vole genetics research.
- Northern Arizona University: Conducts research on cottonwood trees.
- NPS Exotic Plant Management Team and USGS: Conduct research on exotic/invasive plant management techniques.

Special Designations

Important Bird Area. Pahranagat Valley is one of two routes that offers surface water and cover for birds migrating through the western Great Basin (Ash Meadows NWR is the other). More than 230 different species of birds use Refuge habitats.

- Bird abundance and diversity is highest during spring and fall migrations, when large numbers of songbirds, waterfowl, shorebirds, and raptors are present. Common ducks are pintail, teal, mallards, and redhead. Great blue herons are found near lakes, while black-necked stilts and American avocets are found feeding in shallow water. Greater sandhill cranes can be seen from February to March and again in October and November as they migrate between nesting and wintering areas. Red-tailed hawks, northern harriers, Cooper's hawks, and American kestrels are most abundant during winter months, and bald eagles and golden eagles are also winter visitors. Cottonwood-willow habitat provides nesting habitat for warblers, orioles, flycatchers, and finches. The open fields attract shrikes, meadowlarks, blackbirds, and mourning doves. The uplands are home to Gambel's quail, roadrunners, and various sparrow species.

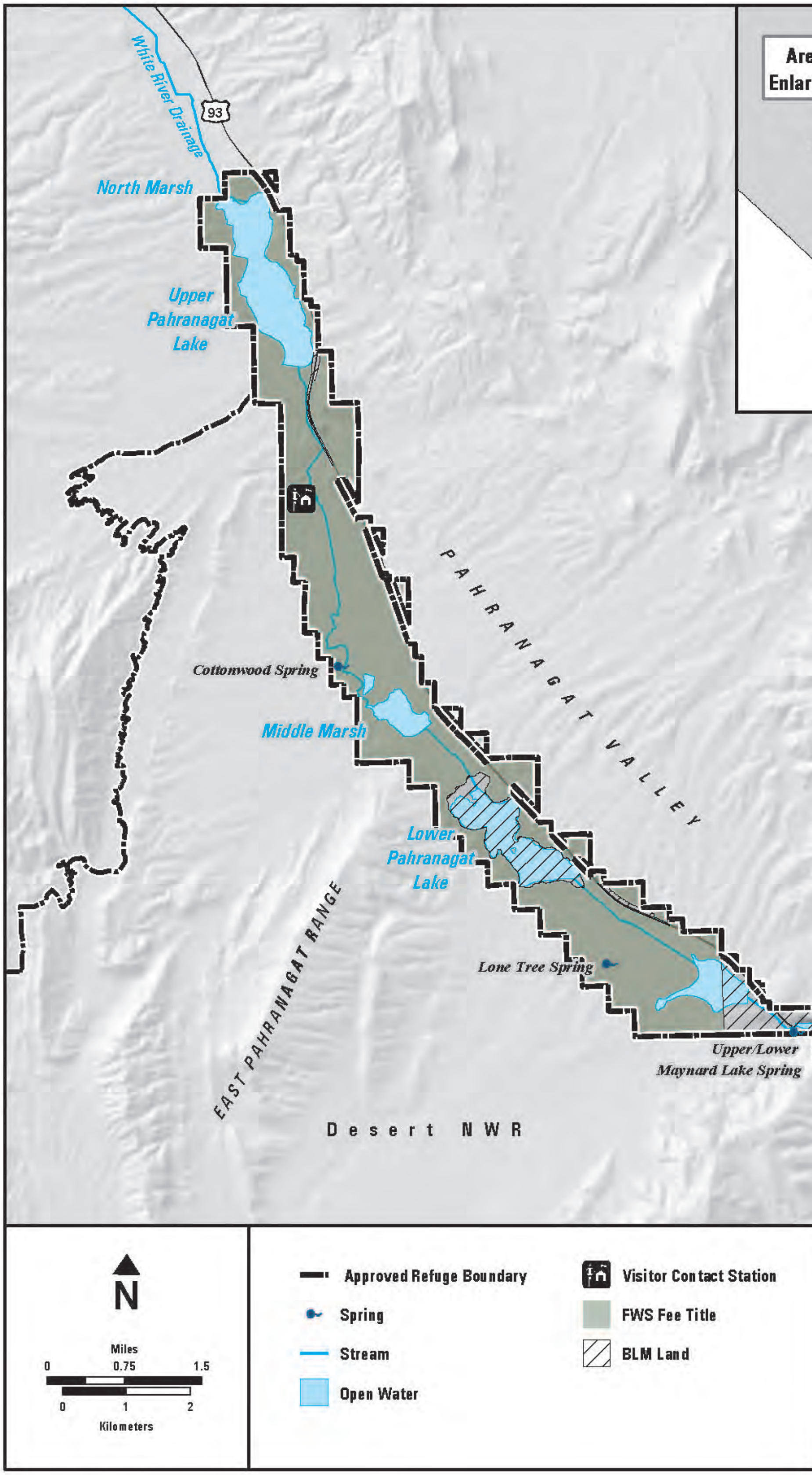

Figure 1.7-4

Land Status

Pahranagat NWR

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Wilderness. In accordance with the Service's Refuge Planning Policy, a wilderness review of Pahranagat NWR was conducted during the CCP process (see Appendix I). Three small units of Pahranagat NWR along the western side of the Refuge and adjacent to the proposed desert wilderness on Desert NWR were determined to meet the criteria for wilderness designation.

Refuge Purpose

The purpose of Pahranagat NWR derives from the Migratory Bird Conservation Act:

> "*…for use as an inviolate sanctuary, or for any other management purpose, for migratory birds…*" (16 USC 715d).

Vision

Pahranagat NWR's vision statement is:

> *The Pahranagat National Wildlife Refuge is managed as a sanctuary where present and future generations of people can discover a connection to the rhythms of life. In spring, indigo bush and beavertail cactus bloom at the edges of verdant meadows and wetlands, fed by brimming lakes. The vital, spring-fed waters of this Mojave Desert oasis attract thousands of migratory birds each year. Pahranagat NWR's seasonal marsh, wet meadows, and alkali flats provide high quality resting and foraging habitat for wintering and migrating waterfowl, shorebirds and other waterbirds along the Pacific Flyway. Riparian gallery forests of willow, cottonwood, and associated plant communities support a flourishing population of southwestern willow flycatcher as well as a rich diversity of migratory and resident songbirds, colonial nesting species and birds of prey. Coveys of Gambel's quail emerge at dusk along with abundant cottontails and jackrabbits as nighthawks, coyotes, and owls begin to hunt. Each fall brings returning waterfowl and waterfowl hunters, while mountain lions follow mule deer down into the valley.*
>
> *Wetlands, wet meadows, upland plant communities, natural springs, and cultural history entice scientists and scholars to study Refuge resources and further human understanding of the processes and environments that are the foundation for the rich diversity of life on Pahranagat NWR and how humans have interacted with that environment over millennia.*
>
> *Other researchers focus on understanding the role of southwestern wetlands and diversity in the regional*

and national refuge system, the preeminent example of a habitat conservation system in the United States and perhaps the world. This ever expanding understanding contributes to conservation and management of Mojave Desert environments important to southern Nevada, the southwest, and the United States.

Visitors from near and far find sanctuary among the crystal pools and springs as they learn about the Refuge's unique plant and animal communities. Local people take pride in the Refuge, and visitors tell their families and friends about this brilliant desert gem. Educators recognize the Refuge as an exceptional regional resource for environmental education and observation of wildlife and the habitats upon which they depend. Volunteers take great personal satisfaction from applying their interests and abilities to the conservation and interpretation of a unique, natural Mojave Desert community for the enjoyment of present and future generations of Americans.

Goals

The Service developed four goals for the management of Pahranagat NWR. These goals were used to identify appropriate objectives and strategies and develop alternatives with specific management actions.

Wetland Habitat (Goal 1). Restore and maintain wetland habitat for waterfowl and other migratory birds with an emphasis on spring and fall migration feeding and resting habitat requirements.

Wildlife Diversity (Goal 2). Restore and maintain the ecological integrity of natural communities within Pahranagat NWR and contribute to the recovery of listed and other special-status species.

Visitor Services (Goal 3). Provide visitors with compatible wildlife-dependent recreation, interpretation, and environmental education opportunities that foster an appreciation and understanding of Pahranagat NWR's wildlife and plant communities.

Cultural Resources (Goal 4). Manage cultural resources for their educational, scientific, and traditional cultural values for the benefit of present and future generations of refuge users, communities, and culturally affiliated tribes.

1.8 Intent of This CCP/EIS

The CCP/EIS is a programmatic document intended to analyze proposed management actions on a conceptual level, except in those cases where sufficient information is available to provide project-specific analysis. Therefore, the extent of analysis provided for each wildlife/habitat management and/or public use proposal reflects the level of detail currently available for the specific proposal. It is during subsequent project-level planning, referred to as "step-down" planning, that additional studies would be conducted, additional baseline data would be gathered, the appropriate project-level NEPA documentation would be prepared, all necessary permits would be acquired, and final engineering and planning would be conducted. Step-down planning would also include a public involvement component similar to that provided during the CCP process.

Chapter 2. Comprehensive Conservation Planning Process

Mountain view across North Marsh at Pahranagat National Wildlife Refuge

SE ROA 12768

Chapter 2. Comprehensive Conservation Planning Process

2.1 Planning Process Overview

The Final Environmental Impact Statement (EIS) and Comprehensive Conservation Plan (CCP) for the Desert National Wildlife Refuge Complex (Desert Complex) were prepared in accordance with U.S. Fish and Wildlife Service (Service) planning policies and the National Environmental Policy Act (NEPA). This chapter describes the planning process for CCP development. Figure 2.1-1 diagrams the CCP planning process. Key steps in the planning process include:

- Forming the planning team and conducting preplanning;
- Initiating public involvement and scoping;
- Identifying issues and developing vision and goal statements for each refuge;
- Developing alternative management actions and assessing their environmental effects;
- Identifying the preferred alternative;
- Publishing the Draft CCP/EIS; and
- Revising the Draft CCP/EIS and publishing the Final CCP/EIS.

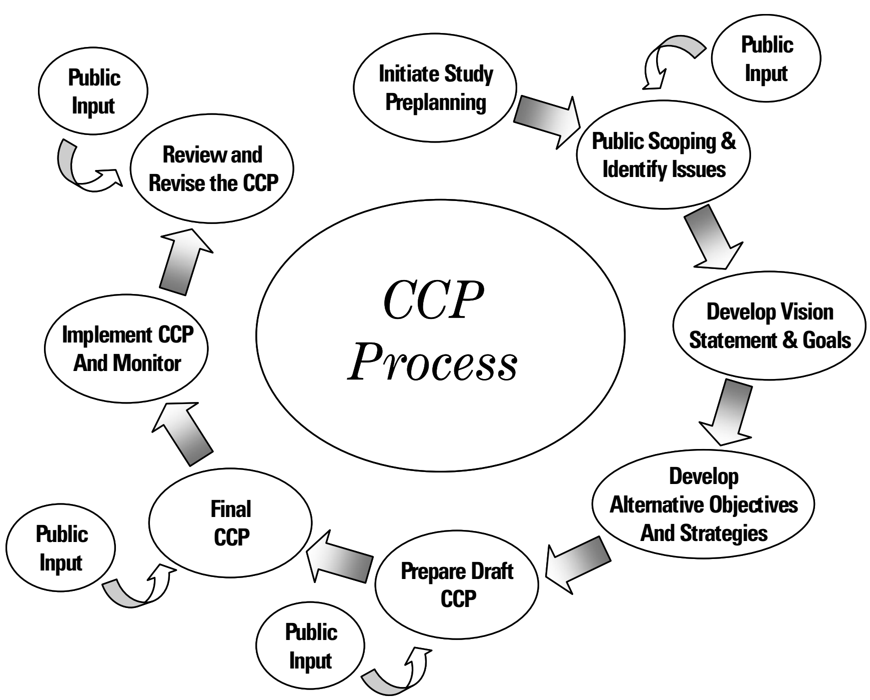

Figure 2.1-1. The Comprehensive Conservation Planning Process

Preliminary CCP planning began in the spring of 2002, and the official process began in the fall of the same year. A core planning team was established to prepare the CCP and EIS. Planners, biologists, and archaeologists from the Service's consultant (SWCA) also helped with the planning effort. Meetings were held throughout the process to discuss various planning issues and develop vision statements, goals, objectives, strategies, and alternative management actions.

An Interdisciplinary Team (IDT) comprising staff from the Service and other federal, state, and local agencies, which consists of cooperating agencies and extended planning team members, was formed to provide information and support during development of the CCP and EIS. Input from the IDT involved various forms of communication (emails, meetings, and phone conversations), and team members were invited to review and provide comments on the administrative draft document. Meetings were held throughout the process, as discussed below under Section 2.2 (Public, Agency, and Tribal Involvement). The team included staff members from the following agencies and organizations in addition to the Service:

Federal

- U.S. Air Force – Nellis Air Force Base (USAF–NAFB; Cooperating Agency)
- U.S. Bureau of Land Management (BLM; Cooperating Agency)
- U.S. National Park Service (NPS), including Death Valley National Park (Cooperating Agency) and Lake Mead National Recreation Area
- U.S. Department of Energy (DOE)
- U.S. Forest Service
- U.S. Department of Transportation, Federal Highway Administration Central Federal Lands

State

- Nevada Department of Wildlife (NDOW; Cooperating Agency)
- Nevada Division of Forestry
- Nevada State Historic Preservation Office

Local

- Clark County
- Lincoln County
- Nye County
- City of North Las Vegas
- City of Las Vegas
- Southern Nevada Water Authority

Consolidated Group of Tribes and Organizations (CGTO)

- Benton Paiute Indian Tribe
- Bishop Paiute Indian Tribe
- Chemehuevi Indian Tribe
- Colorado River Indian Tribes
- Duckwater Shoshone Tribe

- Ely Shoshone Tribe
- Fort Independence Indian Tribe
- Kaibab Band of Southern Paiutes
- Las Vegas Indian Center
- Las Vegas Paiute Tribe
- Lone Pine Paiute-Shoshone Tribe
- Moapa Band of Paiutes
- Pahrump Paiute Tribe
- Paiute Indian Tribes of Utah
- Paiute Tribe of the Owens Valley
- Timbisha Shoshone Tribe
- Yomba Shoshone Tribe

2.2 Public, Agency, and Tribal Involvement

Consultation and coordination with interested parties was an important part of the planning and EIS process. Chapter 6, Compliance, Consultation, and Coordination with Others, provides details on consultation and coordination with others throughout the process. Public involvement activities and planning issues raised through these activities are described briefly below.

On August 21, 2002, the Service published a Notice of Intent (NOI) in the Federal Register for the preparation of an EIS for the Desert Complex CCP. The NOI gave notice of public meetings and encouraged interested parties to become involved in the process. Five meetings were held in southern Nevada in September 2002 (see Chapter 6, Compliance, Consultation, and Coordination with Others). Planning updates were also distributed throughout the planning process; details on these updates as well as other public, agency, and tribal correspondence are provided in Chapter 6.

An interagency scoping meeting was held on August 28, 2002. Cooperating agencies and agencies with interests in and/or responsibilities for resources within the Desert Complex were invited to provide comments on issues that should be analyzed during development of the CCP and EIS. Interagency planning team meetings were held on March 11, 2003, July 10, 2003, and February 22, 2006, to solicit input and feedback on various aspects of the planning process, including alternatives development and reviewing early versions of the document.

The Service has a unique relationship with affiliated tribes that involves a trust responsibility unlike that of the general public. The Service has engaged in meetings with affiliated tribes and solicited input from the CGTO during the planning process. Tribal coordination meetings were held on April 7–8, 2004, June 18–19, 2005, and June 22–23, 2006. At these meetings, Service staff acquainted tribal representatives with the refuges and the planning process and obtained input on planning issues. The CGTO's Document Review

Committee has reviewed and provided comments on the administrative draft document as well as on the cultural resources overview prepared in support of the environmental document.

2.3 Planning Issues

Based on input from the public, agencies, and affiliated tribes, the following planning issues have guided the development of alternatives and preparation of the Draft CCP/EIS. These issues are discussed in the public scoping report, available on the Service's Web site at http://www.fws.gov/desertcomplex/ccp.htm.

2.3.1 Ash Meadows National Wildlife Refuge

- Endemic and Federally Listed Species
  - Upland Habitat Management: How many acres of upland habitat for endemic species should be restored? How can upland habitat for endemic species best be managed?
  - Baseline Data: How much restoration baseline data should be collected? How can the Service collect baseline data on wildlife (sensitive and non-sensitive)?
  - Vegetation: How can the Service gather information on historic vegetation on the Refuge?
  - Riparian Restoration: How much riparian vegetation should be restored?
  - Carson Slough Restoration: How many acres of the historic Carson Slough system should be restored?
  - Springs and Outflow Systems: What level of restoration is required for the spring systems that are essential habitat for Ash Meadows Amargosa pupfish, Warm Springs pupfish, and Ash Meadows speckled dace?
  - Pest Management: How should invasive plant and wildlife species be managed?
  - Water Resources Management: How can water resources for the Refuge best be managed? How can refuge springs be protected from impacts of off-Refuge groundwater development?
  - Federally Listed Species Monitoring: How intensively should the Service monitor the status of federally listed species?
  - Refuge Expansion: Should the Service pursue acquisition of remaining private lands within the approved Refuge boundary from wiling sellers?
  - Natural Resources Protection: Should existing roadways and parking areas be improved?
- Fire and Fuels Management
  - Wildland/Urban Interface: What steps need to be taken to provide protection to constructed values at risk in and near the Refuge?
  - Fire Management: How, when, and where should fire be used as a tool to improve or maintain native plant/animal habitat or to reduce hazardous fuels?

- Management: Which appropriate management responses are suitable for use on the Refuge and under what conditions?

- Research
    - Research: What opportunities should be provided for research that supports Refuge and Service objectives?
- Visitor Services
    - Environmental Education: How should environmental education opportunities be expanded?
    - Interpretation: How should interpretive opportunities be expanded on the Refuge?
    - Outreach: What is the best way to expand outreach opportunities?
    - Visitor Services: Can opportunities for wildlife observation, wildlife photography, and recreation be expanded? Should Crystal Reservoir be open for swimming and fishing?
    - Hunting: Should opportunities for waterfowl and upland game hunting be reduced? Can hunting opportunities be improved in terms of quality? Can opportunities for waterfowl and upland game hunting be expanded? Can hunt boundaries be clarified and identified for visitors?
    - Public Access: Should main roads through the Refuge be paved? Should all-terrain vehicles be allowed by permit or during special events?
- Cultural Resources
    - Management: How can cultural resources on the Refuge best be managed?
    - Interpretation: How should cultural resources interpretation opportunities be expanded?
    - Protection: How can vandalism at known cultural resources sites be reduced?
- Refuge Management
    - Staffing: What additional staff is needed to manage Refuge?
    - Cooperative Agreements: Should cooperative agreements be established with other agencies or land owners?
- Climate Change
    - Management: How will the Refuge be affected by climate change? What should the Service do to address impacts of climate change on Refuge resources? Would the Service's actions contribute to climate change?

2.3.2 Desert National Wildlife Refuge

- Bighorn Sheep Management
    - Population: What subpopulation objectives for bighorn sheep should be established?
    - Habitat Management: What measures should be taken to prevent unauthorized uses?

- Population Management: What steps should be taken to maintain subpopulations?
- Monitoring: How many helicopter surveys should be conducted?

■ Wildlife Diversity

- Baseline Inventories and Monitoring: What types of wildlife monitoring and surveys should be implemented?
- Resource Protection: What measures should be taken to prevent unauthorized uses? How can refuge springs be protected from impacts of proposed groundwater development?
- Corn Creek Restoration: What actions should be taken to restore Corn Creek springs?
- Predator Control: Can a predator control program be developed?
- Guzzlers: Should more guzzlers be created on the Refuge? Can existing guzzlers be better maintained?

■ Fire and Fuels Management

- Wildland/Urban Interface: What steps need to be taken to provide protection to constructed values at risk in and near the Refuge?
- Fire History: What was the Refuge's fire history and what role did fire play in creating and maintaining native plant/animal communities?
- Fire Use: How, when, and where should fire be used as a tool to improve or maintain native plant/animal habitat or to reduce hazardous fuels?
- Management: Which appropriate management responses are suitable for use on the Refuge and under what conditions?
- Natural Fire: Where, for what purpose, and under what conditions should naturally ignited fires be allowed to burn in order to achieve resource benefits?

■ Special Management Areas

- U.S. Air Force Overlay: Should any changes be made to the U.S. Air Force Memorandum of Understanding (MOU) when it is updated?
- Research Natural Areas (RNAs): What types of research and monitoring activities in RNAs should occur?
- Wilderness: How many acres should be recommended for wilderness designation?
- Pinyon-Juniper Habitat Management: How can prescribed burns in pinyon-juniper habitat be designed to best consider wildlife habitat needs?
- Energy Corridor: How would the proposed West-Wide Energy Corridor affect the Refuge?

■ Visitor Services

- Environmental Education and Interpretation: What quantitative visitor objectives should be established? How

should environmental education and interpretation activities be expanded? Can a museum be provided at Corn Creek?
    - Outreach: How should outreach opportunities be expanded?
    - Wildlife observation and photography: How should wildlife observation and photography opportunities be expanded? How can access for wildlife observation be increased?
    - Hunting: How should the existing hunt program be maintained? How can a representative of culturally affiliated tribes participate in the annual hunting of one bighorn sheep per year? Can hunting opportunities be more flexible during extreme weather situations? Can hunt boundaries be clarified and identified for visitors?
    - Public Access: Should all-terrain vehicles be allowed? Can roads be regularly maintained and identified as closed or open?
- Cultural Resources
    - Management: How can cultural resources on the Refuge best be managed?
    - Interpretation: How should cultural resources interpretation opportunities be expanded?
    - Protection: How can vandalism at known cultural resources sites be reduced?
- Refuge Management
    - Staffing: What additional staff is needed to manage Refuge?
    - Research: What research opportunities are available on the Refuge?
    - Cooperative Agreements: Should cooperative agreements be established with other agencies or land owners?
- Climate Change
    - Management: How will the Refuge be affected by climate change? What should the Service do to address impacts of climate change on Refuge resources? Would the Service's actions contribute to climate change?

2.3.3 Moapa Valley National Wildlife Refuge

- Endemic and Special-Status Species
    - Habitat Restoration: How can habitat for endemic and special-status species best be restored?
    - Wildlife Inventory: How intensively should the Service inventory wildlife?
    - Water Resources: How should Refuge water resources be monitored and managed? <u>How can refuge springs be protected from impacts of off-Refuge groundwater development?</u> Moapa Dace Habitat Protection: What activities should be undertaken to protect Moapa dace habitat?
    - Vegetation: Are palm trees native? Should palm trees be removed from streams to reduce impacts to fish and minimize fire potential?

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- Refugium: Should a refugium be created on the Refuge?

- Fire and Fuels Management
  - Wildland/Urban Interface: What steps need to be taken to provide protection to constructed values at risk in and near the Refuge?
  - Fire Use: How, when, and where should fire be used as a tool to improve or maintain native plant/animal habitat or to reduce hazardous fuels?
  - Management: Which appropriate management responses are suitable for use on the Refuge and under what conditions? Should fire hydrants be placed on the Refuge?
- Visitor Services
  - Visitor Services: How many visitors should be targeted? How should environmental education and interpretation activities be expanded?
  - Swimming: Should the pools be open and accessible for swimming?
  - Outreach: Can programs be developed for Moapa Valley residents to visit the Refuge?
- Refuge Management
  - Staffing: What additional staff is needed to manage Refuge?
  - Research: What research opportunities are available on the Refuge?
  - Cooperative Agreements: Should cooperative agreements be established with other agencies or land owners?
- Climate Change
  - Management: How will the Refuge be affected by climate change? What should the Service do to address impacts of climate change on Refuge resources? Would the Service's actions contribute to climate change?

2.3.4 Pahranagat National Wildlife Refuge

- Wetland Habitat
  - Open Water Habitat: How should Upper Lake water levels be managed and carp populations reduced?
  - Restoration of Springs and Outflow Systems: What level of restoration is required for the spring systems that are essential habitat for Pahranagat speckled dace?
  - Marsh Habitat: How should seasonal marshes be flooded to maintain marsh habitat?
  - Wet Meadow Habitat: How should wet meadow habitat be managed?
  - Alkali Flats Habitat: How many months should alkali flats habitat be maintained?
  - Water Resources Management: How can water resources for the Refuge best be managed? How can pending water rights be addressed? How can refuge springs be protected from impacts of off-Refuge groundwater development?

  - Invasive Vegetation: How can invasive vegetation be managed—grazing or fire?
- Wildlife Diversity
  - Southwestern Willow Flycatcher/Riparian Habitat: How many acres of new habitat should be established or restored?
  - Sandhill Cranes/Grassland Habitat/Agriculture: How many acres of new habitat should be established or restored?
  - Pahranagat Roundtail Chub/Aquatic Refugium: Should a roundtail chub refugium be constructed?
  - Speckled Dace: How can springs and seep/outflow systems be restored and managed?
  - Waterfowl: Should a percentage of the Refuge be identified for waterfowl use? How can waterfowl be managed to achieve Refuge purpose and address trust resource responsibilities under the Migratory Bird Treaty Act?
- Fire and Fuels Management
  - Wildland/Urban Interface: What steps need to be taken to provide protection to constructed values at risk in and near the Refuge?
  - Fire History: What is the Refuge's fire history and what role did fire play in creating and maintaining native plant/animal communities?
  - Fire Use: How, when, and where should fire be used as a tool to improve or maintain native plant/animal habitat or to reduce hazardous fuels?
  - Management: Which appropriate management responses are suitable for use on the Refuge and under what conditions?
- Visitor Services
  - Hunting: Should current harvest levels be maintained?
  - Fishing: Should sport-fishing opportunities be increased? How should fishing be managed?
  - Camping: Can more areas be developed for camping? Should a fee system be used?
  - Wildlife Observation and Photography: How many visitors should be targeted? How should wildlife observation and photography opportunities be increased?
  - Interpretation, Environmental Education, and Outreach: How can interpretation, environmental education, and outreach opportunities be increased?
  - Hunting: Can hunt boundaries be clarified and identified for visitors?
- Cultural Resources
  - Management: How can cultural resources on the Refuge best be managed?
  - Interpretation: How should cultural resources interpretation opportunities be expanded?

  - Protection: How can vandalism at known cultural resources sites be reduced?
- Refuge Management
  - Staffing: What additional staff is needed to manage the Refuge?
  - Research: What research opportunities are available on the Refuge?
  - Cooperative Agreements: Should cooperative agreements be established with other agencies or land owners?
- Climate Change
  - Management: How will the Refuge be affected by climate change? What should the Service do to address impacts of climate change on Refuge resources? Would the Service's actions contribute to climate change?

2.4 Development of Refuge Vision Statements and Goals

As part of the CCP process, the refuge managers, with assistance from the core planning team, developed vision statements and goals for each refuge to guide them in developing alternative management actions for analysis in the EIS. Refuge vision statements and goals are provided in Chapter 1. This section provides an overview of the process for developing the vision statements and goals.

2.4.1 Vision Statements

Prior to the start of the CCP process, each refuge had a purpose that was established by law, but none of the refuges had specific vision statements or management goals. The planning process started with the core planning team developing a vision statement for each refuge consistent with the refuge's purpose. The vision statement is a concise statement of what the refuge should be, based primarily on the National Wildlife Refuge System (NWRS) mission and specific refuge purposes.

2.4.2 Goals, Objectives, Strategies, and Alternatives

Following development of the vision statement, the core planning team developed a statement of goals for each refuge. A wide range of management objectives and strategies to achieve those goals was then developed by the extended planning team and clustered into logical groupings to form the action alternatives for each refuge. In addition, a no-action alternative was developed for each refuge, as required by NEPA, and to serve as a baseline for the action alternatives. For each refuge, one of the action alternatives was selected as the preferred alternative.

Goals and alternatives for each refuge are summarized in Chapter 3, Alternatives, and detailed descriptions of the goals, objectives, and strategies for the Preferred Alternative for each refuge are provided in Appendix F.

Key planning terms used in the CCP are defined as follows:

- Goal: a broad statement of desired future conditions that conveys a purpose.
- Objective: a concise statement of specific desired results, preferably quantified.
- Management Action/Strategy: a specific action used to achieve an objective.
- Alternative: different sets of management actions to achieve refuge goals.

2.4.3 Screening Criteria for Alternatives

Throughout the planning process, several objectives and management actions suggested through public input or by Service staff were eliminated from detailed evaluation in the CCP and EIS. Factors used to screen alternatives included:

- Inconsistency with the NWRS mission;
- Inconsistency with refuge purpose, vision, or goals;
- Excessive costs; and
- Infeasibility due to technical, legal, or other factors.

The management actions eliminated from further consideration for each refuge are listed in Chapter 3, Alternatives, with the rationale for their elimination.

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Chapter 3. Alternatives

Crystal Springs overlook at Ash Meadows National Wildlife Refuge

SE ROA 12782

Chapter 3. Alternatives

3.1 Introduction

This chapter describes the management actions identified for the alternatives for each refuge in the Desert National Wildlife Refuge Complex (Desert Complex). The alternatives described in this chapter comprise the U.S. Fish and Wildlife Service's (Service) actions for which potential impacts are analyzed in Chapter 5, Environmental Consequences. The chapter includes a description of the No Action Alternative, which consists of a continuation of the current management actions and is used as a baseline to compare the action alternatives.

Appendix F provides detailed descriptions of the goals, objectives, and management actions or strategies to achieve the preferred alternative for each refuge. It also provides rationales for each objective to explain the need for the management actions and identify how the objective meets the goals of the refuge.

In this chapter, the following topics are presented for each refuge:

- Features common to all alternatives;
- Description of alternatives considered;
- Comparison of alternatives; and
- Management actions considered but eliminated from detailed analysis as part of the alternatives

The Service proposes to develop and implement a CCP for the refuges in the Desert Complex that best achieves the purposes for which each refuge was established, helps fulfill the mission of the National Wildlife Refuge System (NWRS), is consistent with sound fish and wildlife management, and ensures that the biological integrity, diversity, and environmental health of the NWRS are maintained. The Final CCP will include proposals for wildlife and habitat management, habitat enhancement and—where appropriate—habitat restoration, and visitor services. The Service examined a wide range of management alternatives for each refuge. Of these, Alternative C represents the Service's preferred alternative for the Ash Meadows, Desert, and Moapa Valley National Wildlife Refuges (NWRs), and Alternative D represents the Service's preferred alternative for Pahranagat NWR. Of the alternatives evaluated, these alternatives appear to best achieve the purpose, vision, and goals for the Refuges while also appropriately addressing the major issues and relevant mandates identified for each Refuge during the CCP process.

3.2 Ash Meadows National Wildlife Refuge Alternatives

Ash Meadows NWR's alternatives consist of the No Action Alternative and two action alternatives. The No Action Alternative contains a variety of management actions that have recently been implemented on the Refuge or will be implemented before the CCP is approved. The two action alternatives contain management actions to improve Refuge conditions at varying levels. Alternative B would improve habitat for endemic species on portions of the Refuge and increase visitor services and facilities. Alternative C would improve habitat throughout the Refuge and provide additional increased visitor services.

3.2.1 Features Common to All Alternatives

A number of current management actions would be implemented for the Ash Meadows NWR under each of the alternatives. The two action alternatives propose additional management actions to improve Refuge conditions. Actions that are common to all alternatives are described below and are not repeated in each alternative description.

Species Management

To manage special-status plants and wildlife, the Service would continue to monitor species and conduct baseline inventories. Specifically, the Service would continue to inventory vegetation communities, small mammals, herpetofauna, and pollinators. The four-year baseline inventory and monitoring for endemic fish species, two-year refuge-wide survey of reptiles, and three-year baseline inventory and monitoring for the southwestern willow flycatcher would be completed. The Service would also monitor changes in the environment, such as changes in vegetation communities, wildlife trends, and surface and groundwater levels, to assess the effects of climate change on the Refuge. These actions would allow the Service to gain valuable knowledge about Refuge resources and make informed decisions for species management.

The Refuge provides one refugium for the Devils Hole pupfish at Point of Rocks. Under each of the alternatives, the Service would close the refugium and establish a new refugium, possibly at the Amargosa Pupfish Station site, that would be regularly monitored, including conducting quarterly fish counts and periodic water quality measurements. The refugium would be designed with a fully automated monitoring and control system (independent power, battery backup, temperature control, pump backup, remote transmittal of data, and alarms). In addition, the Service would construct a separate refugium for Warm Springs pupfish and manage it similarly. Once these refugia are operating successfully, the Service would close the refugium at Point of Rocks and restore the spring outflow and channel.

The natural communities of the Refuge would continue to be managed and monitored with an emphasis on invasive species control and removal (vegetation and aquatic species), and monitoring, restoration, and other activities would occur as staffing and funding are available. These communities include spring outflow habitat, streams and associated habitats, wetlands, mesquite and ash groves, and desert uplands. The Service would also improve the Refuge-wide vegetation map using ground surveys and updating the geographic information system data in order to initiate long-term annual vegetation monitoring and assess impacts to vegetation communities.

The Service would continue a variety of management actions relating to maintaining springs and protecting resources, including:

- Continue monitoring springs to maintain existing water flows (17,000 acre feet per year [afy]; Mayer 2006) and natural temperature range for the 30 known Refuge springs;
- Maintain existing spring outflow structures and stream channels at monitoring sites;
- Remove invasive plants and exotic aquatic species;
- Seed and plant native vegetation to restore habitats;
- Manipulate and enhance substrates;
- Remove hydrologic barriers;
- Continue current levels of enforcement measures to protect plants and wildlife;
- Continue current fuel breaks and fuel reduction projects to reduce risk of wildfire;
- Maintain the existing boundary fence to exclude wild horses; and
- Continue closing nonessential roads to control access.

As a part of water resources management, the Service would continue to monitor water parameters (flow, levels, and temperature) at springs and wells identified in the Water Monitoring Plan (Mayer 2005), compare water quality and quantity with past measurements on a biannual basis, and implement measures in coordination with the State Engineer to defend water rights and mitigate substantial changes in water flow or temperature and maintain constant water parameters.

The Service would continue to protect and manage habitat by repairing post and cable barriers, installing additional barriers where needed to protect resources, and replacing or adding gates and signs on service or fire roads to prevent unauthorized access. Wildland fires on the Refuge would be managed using the appropriate management response (AMR). Fires may be managed for one or more objectives, and these objectives may change as the fire spreads across the landscape. While one flank of a fire may be suppressed to protect life, property, or critical resources, another flank may be allowed to burn to enhance habitat. The response would consider resource values at risk and potential negative impacts of various fire suppression measures. Firefighter and public safety would be the highest priority for every incident.

Restoration

In order to enhance habitat on the Refuge for endemic species, the Service would complete and begin implementing Restoration Plans for five areas: Upper Point of Rocks, Jackrabbit Spring, the Warm Springs Management Units (North and South Indian Springs and School Springs), Crystal Springs Unit, and Carson Slough. These plans involve restoring and enhancing native habitat for endemic species. Non-native or invasive plants would be replaced with native plants that were historically present on the Refuge. In addition, approximately 30 acres of native upland habitat would be restored in the Warm Springs Complex and Jackrabbit/Big Springs Units.

Invasive plant and wildlife management would continue to occur on a project-by-project basis, with the greatest threats being prioritized. The Service would continue to remove invasive plant species at restoration sites and in burned areas using physical (cutting and extraction) and chemical (herbicides) means, as appropriate based on the Integrated Pest Management (IPM) Plan (Service 2006b). Mechanical methods would continue to be used around man-made reservoirs and other open water sources to control vegetation and improve open water habitat for fish and wildlife.

The Service would complete the pending land and mineral withdrawal with the U.S. Bureau of Land Management (BLM) in order to transfer the BLM-managed lands within the approved Refuge boundary to the Service. This would optimize the Service's ability to manage the Refuge for its intended purposes. Because Refuge staff already manages BLM lands and Refuge resources are being spent to create capital improvements on BLM lands, completing the land and mineral withdrawal would not require allocation of additional Refuge resources.

Private lands within the Refuge boundaries would also continue to be acquired from willing sellers. For private lands that are not acquired, the Service would continue to coordinate with the landowners to protect the resources.

Research

Research opportunities on the Refuge would vary by alternative. Research activities would continue to be allowed on a case-by-case basis using special use permits.

Visitor Services

To expand visitor knowledge of the Refuge and its resources, the Service would continue to develop environmental education and interpretive materials. The Interpretation Plan for the Refuge would be implemented to provide direction on preparing interpretive materials and constructing interpretive facilities (signs, trails, boardwalks, etc.). Specifically, sensitive plant and pupfish life history information would be included in Refuge brochures, fact sheets, and maps. Information on other endemic and special-status species would also be incorporated into environmental education and interpretive information, as appropriate. Current visitor services for wildlife-dependent recreation activities, such as pupfish viewing, bird watching, and hunting, would continue to be offered in accordance with the existing Public Use Management Plan (Service 1998a), and virtual geocaching (use of geographic positioning system units for treasure hunts) would continue to be allowed in accordance with Refuge policy.

Boardwalks are being designed to follow Kings Pool Stream from the parking lot to Kings Pool with a pool overlook. Specific interpretive materials are also being developed to educate visitors, including displays along the new boardwalks and panels for the new boardwalk and overlook at Longstreet Spring Pool. In addition, parking areas at Point of Rocks and Longstreet Cabin are being improved for visitor safety and access, and Refuge boundary signs would continue to be replaced as needed to control access. Spring Meadows Road would be maintained as a through road for non-commercial traffic. Other designated roads and visitor use areas would also be maintained.

Visitor education needs and opportunities would continue to be assessed through informal contact with visitors. A study would be conducted to determine the number of visitors using the Refuge and the purpose of their visits.

Hunting opportunities for upland game and waterfowl would continue to be offered on the entire Refuge, consistent with Service and Refuge policies and goals. The hunt program would continue based on the interim Hunt Plan until a revised Hunt Plan is completed.

Cultural Resources

Cultural resources management and protection would vary by alternative.

3.2.2 Alternative A – No Action (Current Management)

Alternative A is the current management situation, or No Action Alternative, for the Refuge. It serves as a baseline with which the objectives and management actions of the two action alternatives, Alternatives B and C, can be compared and contrasted. Because this alternative reflects current management, it would not result in substantial changes to the way the Refuge would be managed in the future. Figure 3.2-1 graphically summarizes the actions that would continue under this alternative.

Species Management

The Service would continue to implement those management actions identified under "Features Common to All Alternatives." Species management on the Refuge is currently guided by the 2006 Geomorphic and Biological Assessment (Otis Bay and Stevens Ecological Consulting 2006). This document provides an overview of the resources on the Refuge and identifies recommendations for species management. Management actions identified in the document are evaluated and implemented as appropriate and as staffing and funding become available.

Restoration

The Service would continue to implement those management actions identified under "Features Common to All Alternatives." In addition to restoration of 30 acres of native upland habitat, the Service would restore 70 acres of alkali/wet meadow habitat and 30 acres of mesquite bosques/lowland riparian habitat. In addition, approximately 10 to 25 percent of the old agricultural fields would be rehabilitated by controlling invasive plants and planting native species.

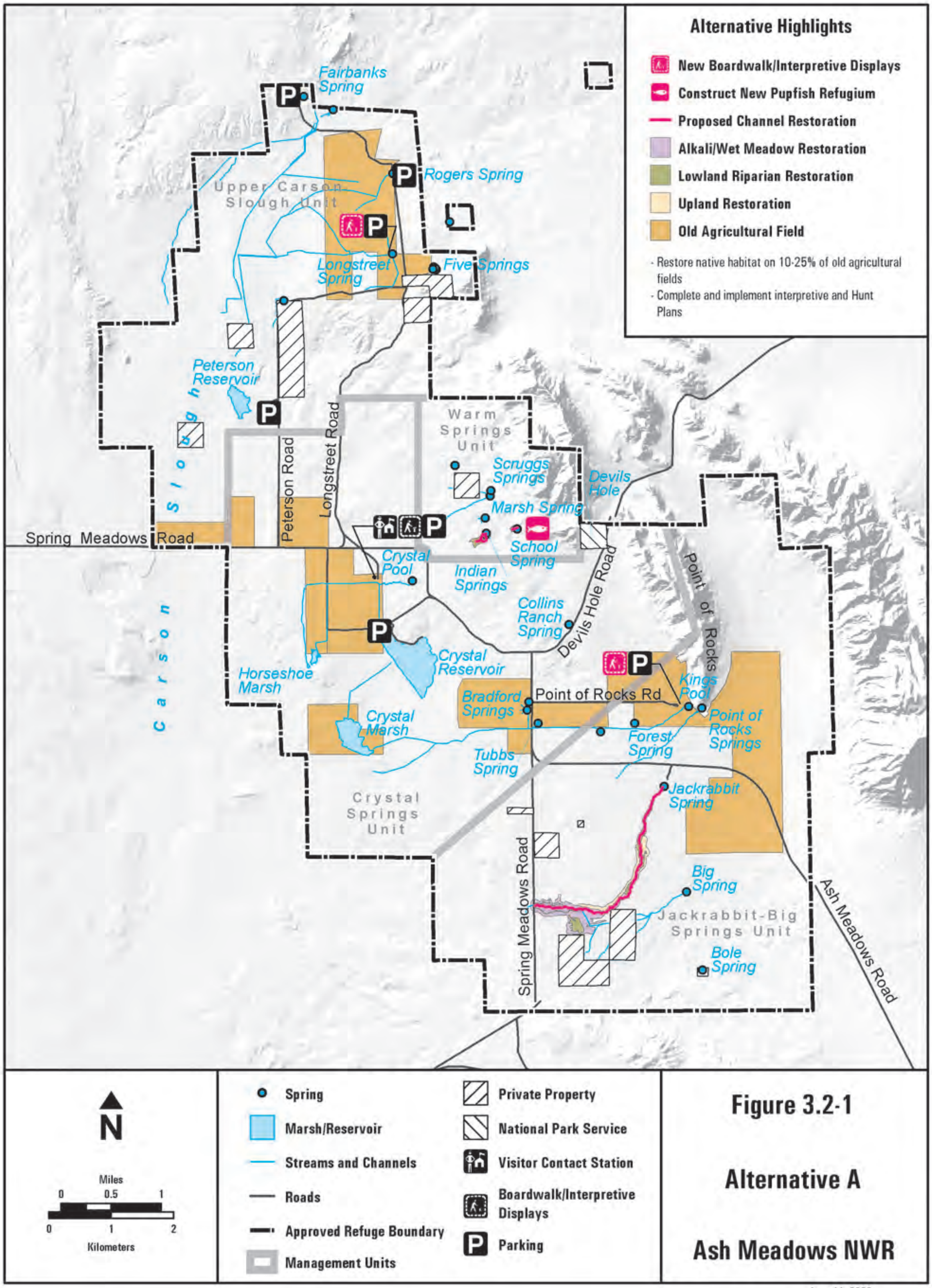

Figure 3.2-1

Alternative A

Ash Meadows NWR

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Restoration activities would involve modifying or altering hydrology of streams and channels to more closely resemble historic conditions and planting native species in appropriate areas, such as where non-native and invasive plants are removed, roads are closed, or hydrology is modified.

Research

The Service would continue to implement those management actions identified under "Features Common to All Alternatives."

Visitor Services

In addition to the management actions described under "Features Common to All Alternatives," the Service would continue to provide limited environmental education activities and off-Refuge outreach about the value of wildlife and the public's involvement on the Refuge. In addition, the Service would continue to allow boats to be used to access waterfowl hunting areas.

Cultural Resources

The Service would continue to inventory, manage, and protect cultural and historic resources on the Refuge on a project-by-project basis to comply with applicable laws and regulations. Appropriate educational information on cultural resources would continue to be provided to visitors at the visitor contact station through informal outreach.

3.2.3 Alternative B – Improve Habitat for Endemic Species on Portions of the Refuge and Increase Visitor Services

Alternative B provides for moderately increased management actions for all resource areas when compared to Alternative A (No Action). This alternative involves the objectives and management actions identified in the "Features Common to All Alternatives" section and additional management actions for more active management. Alternative B actions are portrayed in summary form in Figure 3.2-2.

Species Management

In order to obtain baseline population data on additional species, the Service would inventory listed endemic invertebrates, non-native fish, and non-listed endemic invertebrates. Baseline data on 17 springs identified in the Geomorphic and Biological Assessment (Otis Bay and Stevens Ecological Consulting 2006) would also be collected within two years of approval of the CCP. Endemic species, non-native species that adversely affect endemic species, and game species would be monitored to assess their population levels and effects on other species. The Service would establish long-term monitoring plots and transects to monitor vegetation annually.

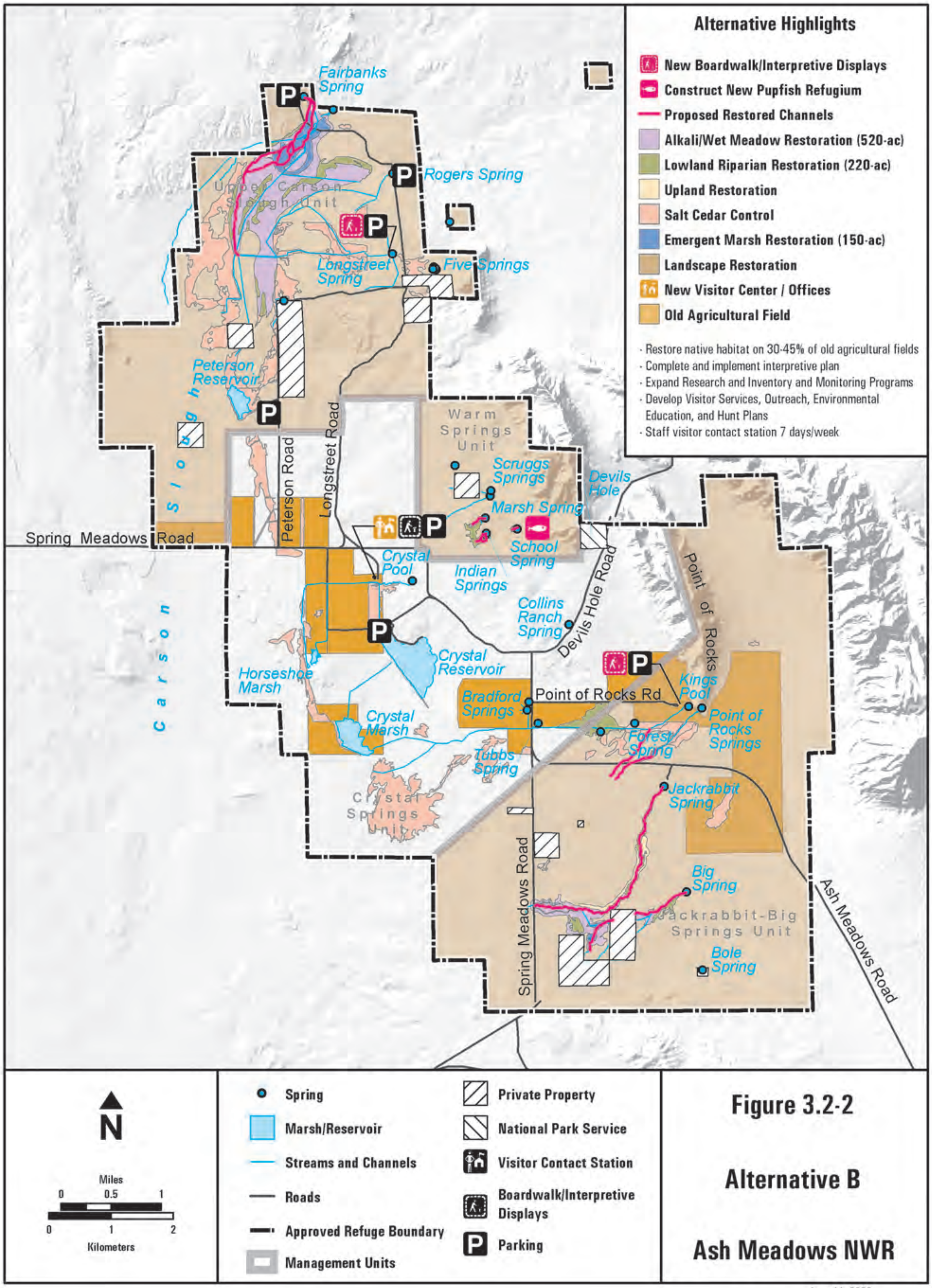

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Figure 3.2-2-ashmeadows_alt_B.mxd

Specific management actions to benefit endemic and native species include the following:

- Restore population of Ash Meadows speckled dace to 5 to 25 percent of its historic range on the Refuge by restoring suitable habitat (flowing streams with riffles) and transplanting individuals between populations for genetic diversity;
- Double the current range of the Ash Meadows naucorid population to encompass a minimum area of 20 to 40 square meters by restoring the Point of Rocks spring outflow channel habitat to be suitable for the naucorid (flowing streams with substrate);
- Investigate the use of private aquaria as refugia for sensitive fish species;
- Identify suitable areas to expand endemic plant populations within 10 years;
- Begin transplanting endemic plants to suitable habitats on the Refuge within 15 years to expand their populations; and
- Prepare a feasibility study to evaluate the construction of an on-site greenhouse to supply native plants for restoration projects.

The Service would increase law enforcement patrols on the Refuge to control and prevent off-highway vehicles, fires, species collection, and other inappropriate activities. Additional road gates would be installed in appropriate locations to prevent unauthorized use of roads and damage to resources (i.e., habitat, species, cultural sites, and springs). Prescribed fire may be used where appropriate to create, improve, or maintain desired plant and animal communities, as well as to treat hazardous fuels.

Restoration

The Service would restore natural hydrology in the Warm Springs, Jackrabbit/Big Springs, and Upper Carson Slough Management Units to improve habitat conditions and biological integrity, diversity, and environmental health of the Refuge. Berms, ditches, dams, impoundments, and unnecessary roads would be removed, as appropriate, to allow flows to return to historic conditions. Fish barriers would be installed, as needed, along water courses to allow the Service to control invasive fish.

As part of the Refuge-wide landscape restoration efforts, the Service would implement Restoration Plans for Lower Point of Rocks, Lower Kings Pool, Big, Fairbanks, and the remaining springs in the Warm Springs Complex. These plans would include restoring historic hydrology, removing non-native and invasive plants, and restoring native habitat. Once restoration activities are complete, the Service would regularly maintain and monitor the habitats to ensure restoration success.

Specific objectives for restoring habitat in the Warm Springs Complex, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs Management Units include restoration of approximately:

- 520 acres of alkali wet meadow;
- 220 acres of mesquite bosque/lowland riparian; and
- 30 acres of native upland; and
- 150 acres of emergent marsh.

In addition, 30 to 45 percent of old agricultural fields would be rehabilitated by removing hydrologic barriers, controlling invasive plants, and planting native species.

The Service would also maintain the following communities in the Warm Springs Complex, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs units by restoring natural hydrology and actively revegetating appropriate areas:

- 3,935 acres of alkaline meadow/wet meadow;
- 5,500–5,750 acres of native upland desert; and
- 1,000 acres of mesquite bosque.

Modifications to the hydrology of these areas would allow the habitats to naturally return to historic conditions, and native vegetation would be planted in appropriate areas, such as where non-native species are removed or areas become exposed due to changes in hydrology.

A large part of habitat restoration is the management of pest, or invasive, species. The Refuge has completed an IPM Plan that describes specific management actions to implement for management of non-native fish, invasive and non-native plants, and other pest species. Long-term management of the Refuge is dependent on the control and removal of pest species.

The Service would implement appropriate techniques from the IPM Plan to control non-native fish and non-native and invasive plants in the various habitats on the Refuge (alkaline meadow/wet meadow, mesquite bosques, marshes, and desert uplands). Open water habitat would be expanded for birds and fish through the control of cattails, a species that forms uniform stands in open water habitat.

Salt cedar and Russian knapweed are noxious weeds that have become well established on the Refuge and throughout Nevada. Management efforts to control and reduce these plant populations are important to restoring habitats on the Refuge. The Service would remove salt cedar and Russian knapweed over the next 10 years to reduce their extent by between 50 and 75 percent of their 2006 distribution on 4,000 acres of Refuge land, and work with BLM to control these species on the adjacent BLM Area of Critical Environmental Concern. The Service will continue coordination with the Private Lands Program to assist private landowners with the removal of salt cedar and planting native species within the Refuge boundary. Habitats containing listed plant species would be prioritized for pest management, and these species' responses to the removal of invasive plants would be monitored. Adverse effects to listed plants would require the Service to adjust their methods for pest species management to minimize the effects on listed plants.

Crayfish are a predator of native, endemic fish and invertebrates. Crayfish populations would be managed to maintain or reduce current distributions through regular trap and removal activities in spring habitats. Target areas for pest management would include the 10 most infested and important Refuge aquatic systems, as determined by the Service's Ecological Services program and Refuge staff; these areas would be expanded as appropriate.

In order to conserve the Refuge lands, the Service would establish conservation agreements with landowners or acquire inholdings from willing sellers.

Research

Research opportunities on the Refuge would be expanded to include projects such as:

- Ecology and management of invasive species;
- Taxonomy, ecology, and management of rare and endemic species;
- Ecosystem energetics and dynamics;
- Historic and current plant community diversity, composition, and structure and the role of natural processes (fire, flood, drought); and
- Wildlife-habitat relationships.

Visitor Services

To improve visitor services management, the Service would develop a comprehensive Visitor Services Plan and an Environmental Education Plan. The comprehensive Visitor Services Plan would evaluate and prescribe management actions to develop and manage compatible wildlife-dependent recreational opportunities, related infrastructure, and associated staffing and funding needs on the Refuge. The Environmental Education Plan would assess visitor education needs and opportunities and incorporate the environmental education goals of the Ash Meadows species recovery plan, the Southern Nevada Valley–wide Environmental Education Strategy, the Clark County Multiple Species Habitat Conservation Plan, and the Ramsar Convention. The Service would coordinate with local affiliated tribes to develop education and interpretation information for Refuge visitors.

The Service would contact local schools and provide at least three to five on-site programs per year for school children. The Service would participate in two or three off-Refuge annual events, such as, Pahrump Fall Festival and Earth Day. The Service would develop an educational video on the endemic fish and other wildlife of Ash Meadows.

The Service would develop multilingual interpretative materials and construct new interpretive facilities at Point of Rocks, Longstreet, Crystal Springs, and entrances to the Refuge. A volunteer program would be created to staff the visitor contact station seven days a week and provide other services for visitors and support for Refuge staff.

The Service would also improve visitor facilities on the Refuge. A new Refuge headquarters and visitor contact station building would be constructed within five years of obtaining funding. Other interpretive facilities identified in the Interpretive Plan (in progress) would be constructed as well, such as trails, boardwalks, signs, and similar facilities. The Service would improve existing roadways and parking areas to good condition based on the Refuge Transportation Plan.

Refuge staff would obtain baseline information on hunting activities on the Refuge and within three years create a hunting step-down plan to address opportunities and restrictions on waterfowl and upland game hunting on the Refuge. The Service would also monitor hunting use on the Refuge to ensure regulatory compliance and minimal effects on resources. The Service would restrict or eliminate boat use for waterfowl hunting to prevent the introduction of quagga mussels (*Dreissena polymorpha*), an invasive molusk that attaches itself to boats. Quagga mussels have been a growing concern in Lake Mead and other surface waters in southern Nevada (Benson et al. 2008); the mussels could outcompete with native and endemic special-status fish on the Refuge and affect their populations.

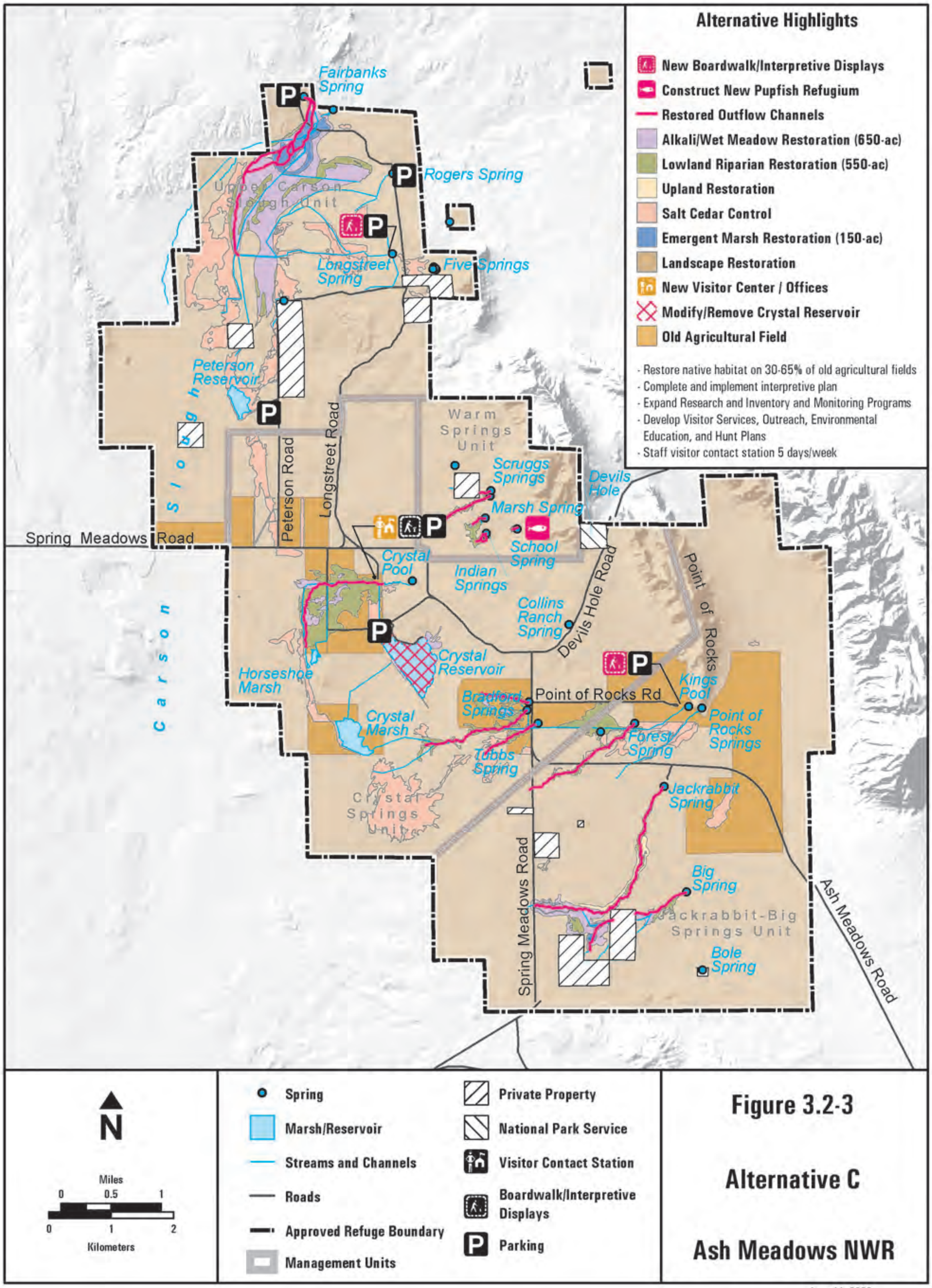
Cultural Resources

The Service would expand knowledge of cultural resources on the Refuge and develop informational materials for visitors about the Refuge's cultural resources. The Service would conduct a cultural resources inventory at all visitor facilities and areas that would be affected by Refuge projects. Eligible Traditional Cultural Properties and sacred sites would be nominated for listing on the National Register of Historic Places. A site stewardship volunteer program would be established to assist with site monitoring, education and interpretation, and promoting cultural resources conservation in neighboring communities.

Cultural resources would be protected from looting, vandalism, erosion, and deterioration through installation of barriers and signs to preserve the resources. Samples would also be preserved to provide research opportunities and mitigate adverse effects. Habitats would be protected and restored to provide harvesting opportunities for Native Americans. Traditional plant uses would be studied to determine appropriate locations on the Refuge for harvesting and other traditional uses.

3.2.4 Alternative C – Improve Habitat for Endemic Species throughout the Refuge and Increase Visitor Services

Alternative C is the preferred alternative. It is characterized by an increased emphasis on management actions for most of the resource areas, expanding upon those presented in Alternative B. This alternative includes the management actions identified in the "Features Common to All Alternatives" section and some management actions from Alternative B in addition to the activities discussed in this section. Activities that would not be implemented under this alternative are also noted; those actions would achieve different goals



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than those this alternative is targeting. Alternative C actions are summarized in Figure 3.2-3.

Species Management

In addition to the inventories and monitoring activities identified under Alternative B, the Service would complete inventories of non-native and native species diversity and distribution and monitor all non-listed endemic and game species.

The Service would expand fish populations on the Refuge by expanding the management actions identified under Alternative B to restore endemic fish populations on 25 to 50 percent of their historic range on the Refuge. In addition, the Service would reestablish Ash Meadows speckled dace to historic habitats after restoration of springs and streams. Refugia may be useful for other endemic species; therefore, the Service would conduct a feasibility assessment to determine which additional species may benefit from refugia populations.

To protect habitat, the Service would implement management actions identified under Alternative B and "Features Common to All Alternatives."

Restoration

In addition to Alternative B management actions, the Service would implement the following management actions to restore habitats and natural hydrology on the Refuge:

- Remove berms, ditches, dams, impoundments, and unnecessary roads within the Crystal Springs Management Unit, as necessary;
- Mitigate landscape disturbances from graded lands, mines, fences, and other activities by restoring native habitat;
- Implement the plan to modify or remove Crystal Reservoir to minimize adverse environmental effects on special-status species and alleviate potential concerns for visitor safety and Refuge management;
- Implement Restoration Plans for Tubbs, Bradford, Crystal, and Forest springs to restore and enhance native habitat; and
- Implement Restoration Plans to restore native habitat at Longstreet and Rogers Springs based on the Carson Slough Restoration Plan.

Specific objectives for restoring habitat in the Warm Springs Complex, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs Management Units include restoration of larger amounts of habitat than under Alternative B. These objectives include restoring approximately:

- 650 acres of alkali wet meadow;
- 550 acres of mesquite bosque/lowland riparian; and
- 30 acres of native upland; and
- 150 acres of emergent marsh.

The alkali wet meadow habitat would be restored so that alkali sacaton and salt grass become the dominant species along with other native vegetation, such as Hall's meadow hawksbeard, alkali cordgrass, Baltic rush, foxtail barley, saltbush, and associated native plant species. Several endemic species are predominately found in alkali wet meadow habitat, including the threatened spring loving century and Ash Meadows Ivesia (Otis Bay and Stevens Ecological Consulting 2006).

The mesquite bosque/lowland riparian habitat would be restored to contain native plant species, such as leather-leaf ash, narrow-leaved willow, Gooddings willow, mesquite, quailbrush, arrow weed, Emory's baccharis, and other associated native plant species. Lowland riparian habitat is important for many federally listed species; other special-status species, including the endangered southwestern willow flycatcher, peregrine falcon, vermillion flycatcher, Phainopepla, yellow-breasted chat, and long-eared myotis; and many other riparian-dependent landbird and migratory birds and resident animals (Clark County and Service 2000).

Native upland habitat would be managed to establish a range of native upland desert plant communities, including gradations between creosote bush–white bursage; dry ridgetop plant communities of predominately cotton top, beavertail cactus, and cholla; and shrub/scrub habitat with other native desert species. Two special-status species, chuckwalla and burrowing owls, use creosote-dominated upland habitat for burrowing sites and protection from predators (NDOW 2005b).

The emergent marsh habitat would be managed to establish plant communities dominated by bulrushes, saw-grass, and rushes with only minimal, sporadic patches of southern cattail. Refuge marshes provide rich habitat for native endemic fish, migratory birds, resident amphibians, and resident aquatic invertebrates (NDOW 2005a).

In addition, 40 to 65 percent of old agricultural fields would be rehabilitated by removing hydrologic barriers, controlling invasive plants, and planting native species.

The Service would also maintain the following communities in the Warm Springs Complex, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs units by restoring natural hydrology and actively revegetating appropriate areas:

- 7,850 acres of alkaline meadow/wet meadow;
- 11,000–11,500 acres of native upland desert; and
- 2,000 acres of mesquite bosque.

The Service would expand pest management in addition to the management actions under Alternative B by evaluating alternative pest control actions (sterilization and biological control) and expanding activities to cover all Refuge aquatic systems. The target for reducing salt cedar and Russian knapweed distribution would be higher than Alternative B at between 75 and 95 percent of the 2006 distribution on

4,000 acres of Refuge land. In addition, pest species in aquatic habitats would be managed and controlled, including implementation of an aggressive trap and removal program for crayfish in spring and channel habitats (targeting Marsh, North and South Indian, North and South Scrugg, Jackrabbit, Kings, Point of Rocks, Big and Crystal springs), installation of temporary fish barriers until non-native fish eradication is complete at Big and Jackrabbit springs, and removal of cattails from outflow channels at Kings, Point of Rocks, and Crystal springs.

Research

The Service would substantially expand the research topics listed under Alternative B. The Service would prepare a feasibility study to evaluate the need for an on-site research facility. If appropriate, the facility would be constructed and operated to accommodate an increase in research opportunities. The Service would model climate change impact scenarios in order to develop adaptation strategies for the Refuge.

Visitor Services

To improve visitor services on and off the Refuge, the Service would expand environmental education, interpretation, and outreach opportunities. The Environmental Education Plan would be fully implemented by 2010. The Service would provide three off-site programs to local public and home schools. Additional off-Refuge cooperative agreements would be developed with public, non-government entities and private partners to provide off-Refuge educational outreach to the local public about the value of the Refuge for wildlife and the public. The visitor contact station would be staffed five days a week.

Cultural Resources

The Service would implement the management actions identified under Alternative B.

3.2.5 Comparison of Alternatives

A comparative summary of the alternatives for the Ash Meadows NWR is found in Table 3.6-1 at the end of this chapter.

3.2.6 Management Actions Considered but Eliminated from Detailed Analysis as Part of Alternatives

During the alternatives development process, the Service evaluated additional management actions as part of the current alternatives. These actions are identified below with their reasons for elimination:

- Continue allowing public use of Crystal Reservoir for swimming and fishing. (Not compatible with human safety, Refuge purposes, and biological integrity, diversity, and environmental health of the Refuge.)
- Pave all main roads through the Refuge. (Would increase high-speed, commercial and non-commercial through traffic to the

detriment of terrestrial animals and human safety; would impact hydrology by increasing impermeable surfaces on Refuge, increasing disturbance of sensitive Refuge habitat.)

- Allow all-terrain vehicles by permit or during special events as a visitor service. (Not compatible with Refuge purposes and biological integrity, diversity, and environmental health of the Refuge.)

3.3 Desert National Wildlife Refuge Alternatives

Desert NWR's alternatives consist of the No Action Alternative and three action alternatives. The No Action Alternative contains a variety of management actions that have recently been implemented on the Refuge or are planned for implementation and are covered under another NEPA document. The three action alternatives contain management actions to improve Refuge conditions at varying levels. Alternative B would provide minimal increases in wildlife and habitat management with improved visitor services. Alternative C would provide moderate increases in wildlife and habitat management with only minor increases in visitor services. Alternative D would provide moderate increases in wildlife and habitat management with very limited increases in visitor services.

3.3.1 Features Common to All Alternatives

A number of current management actions would continue to be implemented for the Desert NWR under each of the alternatives. The three action alternatives propose additional management actions to improve Refuge conditions. Actions that are common to all alternatives are described below and are not repeated in each alternative description.

Bighorn Sheep Management

The Service would continue to manage the desert bighorn sheep population on Desert NWR through the following actions:

- Maintain existing water sources (springs and catchments);
- Install signs, fences, and barricades and use law enforcement patrols to prevent unauthorized uses and protect habitat;
- Prevent domestic livestock grazing to minimize the potential for disease transmission;
- Set the number of hunt permits based on population levels and herd health; and
- Conduct one fall helicopter survey per mountain range to estimate population size, adult sex ratio, ram age structure, and lamb survival/recruitment.

The Service would also continue to allow research on the Refuge by issuing special use permits for activities that involve the bighorn sheep.

Wildlife Diversity

Resources would be protected through maintenance of designated roads and visitor use areas and replacement of regulatory signs along boundaries and designated roadways. The Service would continue to promote awareness of and solicit support for efforts to combat trespassing along the southern boundary to protect resources. In addition, wildfires would be managed using an appropriate management response that considers resource values and Service and U.S. Air Force (USAF) assets at risk as well as potential negative impacts of various fire suppression measures. A wildland fire may be managed for one or more objectives, and these objectives can change as the fire spreads across the landscape. Response may range from monitoring high-elevation fires (above 5,000 feet) to full suppression where resource values at risk indicate that is the appropriate response. Firefighter and public safety would be the highest priority for every incident, regardless of other resources at risk. In addition, invasive weed surveys and treatments would continue.

The Pahrump poolfish population in the refugium at Corn Creek would continue to be monitored to ensure its survival. Baseline and monitoring surveys for wildlife species would continue to be conducted on a project-by-project basis and in coordination with others. During bighorn sheep helicopter surveys, the Service would continue to record observations of raptors. Wild horses or burros that occur on the Refuge would be removed as soon as possible to protect Refuge resources and minimize competition with wildlife. Well water use and discharge at Corn Creek would continue to be monitored, and the Service would work with the State Engineer to defend water rights and mitigate substantial changes in temperature or flow.

Volunteers would continue to be used for habitat restoration and maintenance efforts. The Service would also monitor changes in the environment, such as changes in vegetation communities, wildlife trends, and surface and groundwater levels, to assess the effects of climate change on the Refuge.

The Service would participate in programmatic National Environmental Policy Act (NEPA) processes, as appropriate, to evaluate impacts to Refuge resources from future energy projects relating to the proposed energy corridor through the Refuge.

Specially Designated Areas

Under each of the alternatives, the Service would continue to protect and maintain the proposed wilderness areas until Congress acts on the proposal. Protection efforts would involve prohibiting motorized activities within the proposed wilderness, except where motorized activities are authorized by stipulations in the 1974 proposal or unless an approved minimum requirement analysis documents that motorized activities would be acceptable. The Service would also prepare a revised wilderness proposal which includes technical corrections such as: correcting overlaps with the bombing range; allowing repair or relocation of hazardous sections of road; and allowing the use of helicopters to repair and maintain water developments and access remote areas for wildlife surveys.

Visitor Services

Although visitor services would be improved under the three action alternatives, most of the current visitor service actions would continue to be implemented to support public use of the open portions of the Refuge and maintain closure of the NTTR/DOD-withdrawn lands to public use, except bighorn sheep hunting. The Service is also constructing a visitor center and new office space at Corn Creek Field Station to improve visitor contact and services at the Refuge. The visitor center project is an ongoing, independent action that has been evaluated under a separate Environmental Assessment (Service 2007).

Public facilities and roads would continue to be maintained, including parking, camping, and picnic areas; Mormon Well Road; and Alamo Road. Regulatory, directional, and interpretive signs along roads, trails, and at the refugium would be replaced and updated, as needed, to provide guidance to visitors. Information about the closure of the Nevada Test and Training Range (NTTR) to the public due to safety and security reasons would be provided at the visitor center and on appropriate signs throughout the Refuge. Volunteers, including Get Outdoors Nevada (Southern Nevada Interagency Volunteer Program) volunteers, would continue to be used on the Refuge to provide interpretation, environmental education, and guidance for visitors.

The Service would continue to work with NDOW, which manages the hunting program for desert bighorn sheep. Tags would continue to be issued based on annual population estimates. Information on Refuge-specific and NDOW hunting guidelines and regulations would continue to be available to the public at Refuge headquarters.

Cultural Resources

Cultural resources management and protection would vary by alternative.

3.3.2 Alternative A – No Action (Current Management)

Alternative A is the current management situation, or No Action Alternative, for the Refuge. It serves as a baseline with which the objectives and management actions of the three action alternatives, Alternatives B, C, and D, can be compared and contrasted. Because this alternative reflects the current management, it would not result in substantial changes in the way the Refuge would be managed in the future. Figure 3.3-1 graphically summarizes the actions that would continue under this alternative.

Bighorn Sheep Management

The bighorn sheep management actions identified in the "Features Common to All Alternatives" section are current and ongoing management actions. No additional actions would occur under this alternative.

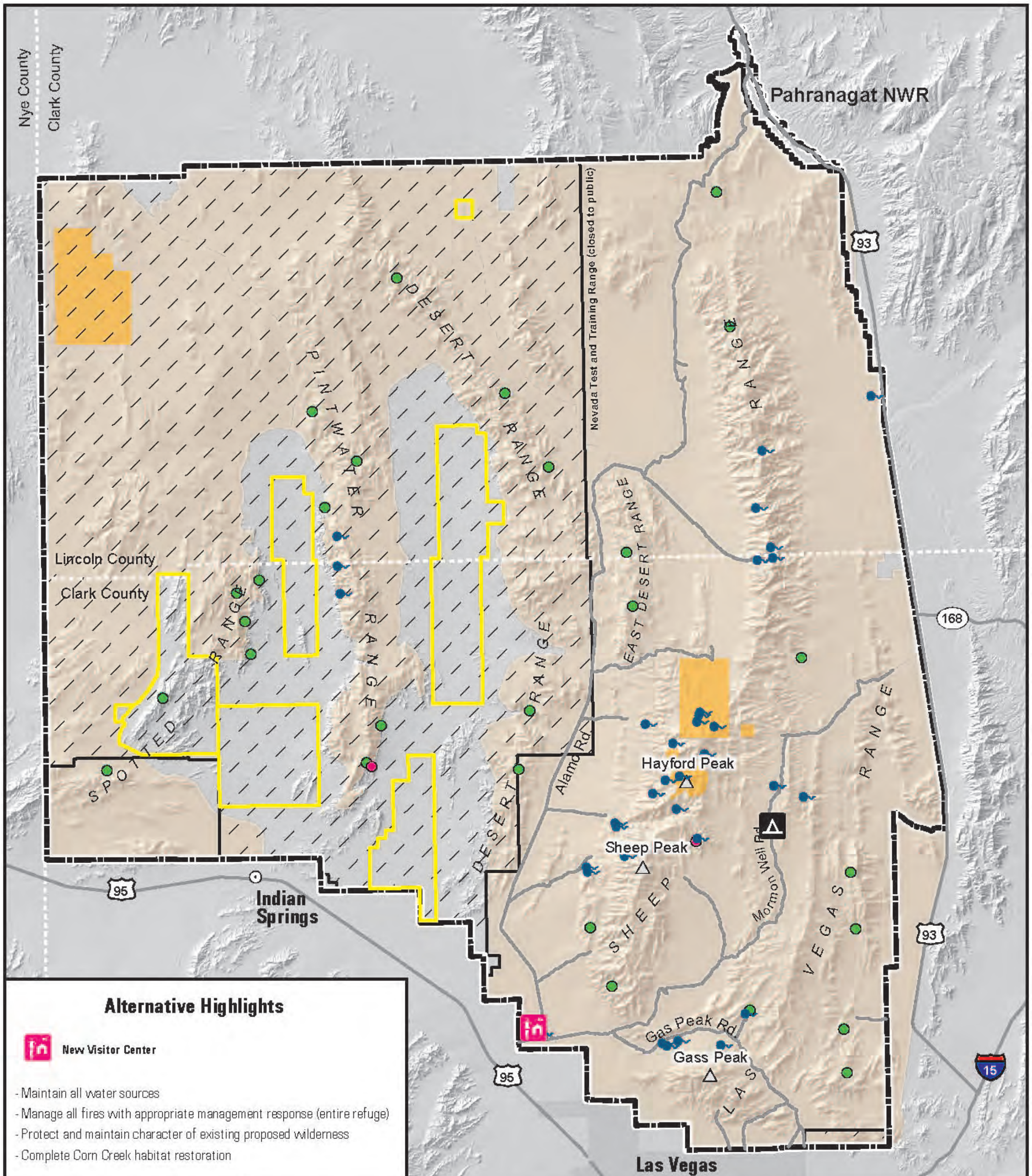

Figure 3.3-1

Alternative A

Desert NWR

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Figure 3.3-1-desert_alt_A.mxd

Wildlife Diversity

The wildlife diversity management actions identified in the "Features Common to All Alternatives" section are current and ongoing management actions. No additional actions would occur under this alternative.

Specially Designated Areas

The Air Force Overlay Area is currently managed through a Memorandum of Understanding (MOU) between the USAF and the Service. The current MOU would be renewed without changes.

The Service has not implemented an active research and monitoring program for the existing Research Natural Areas (RNAs) due to limited staffing and funding. RNAs are designed to provide baseline information for comparison with management actions. The RNAs on the Desert NWR include Basin, Hayford Peak, Deadhorse, Pinyon-Juniper, and Papoose Lake. No new research and monitoring activities would be implemented for the RNAs.

Visitor Services

In addition to the current and ongoing management actions identified in the "Features Common to All" section, the Service would continue to provide public outreach through participation in two major community events annually.

Cultural Resources

The Service would continue to manage and protect cultural resources on the Refuge on a project-by-project basis prior to land-disturbing projects to comply with applicable laws and regulations. Appropriate interpretive information on cultural resources would continue to be provided to visitors at the field station through informal outreach.

3.3.3 Alternative B – Minor Improvement in Wildlife and Habitat Management and Moderate Increase in Visitor Services

Alternative B provides for increased management actions for natural and cultural resources and for visitor services when compared to Alternative A (No Action). This alternative involves the objectives and management actions identified in the "Features Common to All Alternatives" section and additional actions. Alternative B actions are portrayed in summary form in **Error! Not a valid bookmark self-reference.**.

Bighorn Sheep Management

In addition to a fall helicopter survey, the Service would conduct yearly spring helicopter surveys to identify lambing and recruitment sites. They would also use historical records, sightings, and radio tracking data to determine the connectivity between subpopulations on the Refuge.

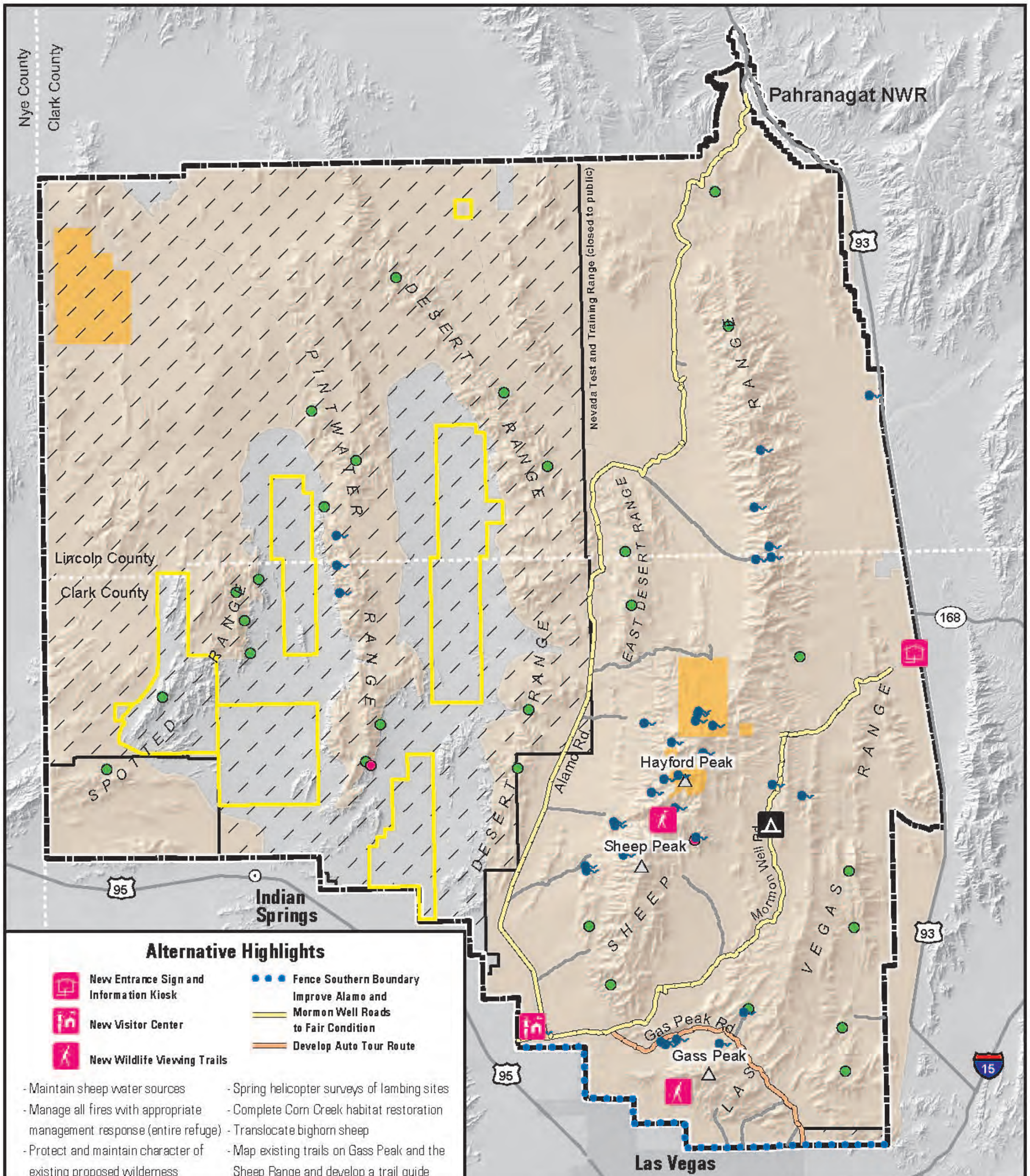

Figure 3.3-2

Alternative B

Desert NWR

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Figure 3.3-2-desert_alt_B.mxd

Sheep would be translocated between subpopulations on the Refuge and to populations outside of the Refuge with help from NDOW to maintain subpopulations on the Refuge and provide genetic diversity for the Nevada population of bighorn sheep.

Wildlife Diversity

The Service would conduct regular bird surveys at Corn Creek to monitor the effects of habitat restoration and management activities and gain a better understanding of the value of Corn Creek as a stop-over and breeding habitat for birds. Regular surveys would provide valuable information on the bird species that visit or use habitat on the Refuge throughout the year.

To protect resources on the Refuge from unauthorized uses, the Service would construct and maintain a southern boundary fence and increase law enforcement presence and patrols, with an emphasis on the southern boundary. The post-and-cable fence would be constructed to allow desert tortoise movement between the Refuge and adjacent habitats. The Service would monitor the Refuge using aerial photography, satellite imagery, or geographic positioning systems (GPSs) to identify damage caused by off-road vehicle trespassing, particularly along the southern boundary.

Monitoring efforts would allow the Service to determine if their actions are working to protect resources, and they would modify their actions, such as through increased law enforcement patrols or more signs, if additional measures are needed.

Staff and volunteers would be used to expand litter removal efforts throughout the Refuge and improve habitat conditions for wildlife.

Specially Designated Areas

The Service would update its current MOU with the USAF, which covers management and use of the western portion of the Refuge which is overlain by the NTTR.

The Service would improve its use of RNAs by surveying and marking RNA boundaries, conducting photographic reconnaissance and documentation of all RNAs, and using the RNAs as control for monitoring the effects of habitat management on other areas of the Refuge.

Visitor Services

The Service would create a Refuge environmental education program using funding from the Southern Nevada Public Lands Management Act. The volunteer program would also be expanded to allow the visitor contact station (or new visitor center) to be staffed full-time during peak use seasons and for four hours per day during other seasons. The Service would also establish a seasonal volunteer resident host/docent at the Desert Pass campground to monitor visitor activities.

As part of the environmental education and interpretation program, interpretive panels and signs would be installed at the designated entry points, including an entrance sign and information kiosk at the east end of Mormon Well Road. Interpretation and educational efforts would be expanded through the development of cultural resources materials in coordination with local affiliated Native American tribes. The Service would also develop a live "sheep cam" at water sources to educate the public on the bighorn sheep. The video would be streamed through the Web site and at the new visitor center for viewing by the public.

The Service would improve Mormon Well Road and Alamo Road to "fair" condition for public access based on the Road Inventory for the Refuge (Federal Highway Administration [FHWA] 2004). They would also create new wildlife viewing trails in the Gass Peak and Sheep Range Units, construct photography blinds at key wildlife viewing spots, and designate parking turnouts along Alamo, Mormon Well, and Gass Peak roads using post-and-cable fencing. New trails developed on the Refuge would be designed and located to minimize impacts to desert bighorn sheep and minimize maintenance costs. An auto tour route would also be designed to allow Refuge visitors to drive along Gass Peak Road from Corn Creek to State Route (SR) 215 and view the Refuge.

To improve visitor services, the Service would develop a trail guide using geographic information system (GIS) software to map existing trails and show new trails in Gass Peak and the Sheep Range. The existing and new trails would be managed to minimize visitor impacts on desert bighorn sheep, which could result in controlled public access during portions of the year along some trails. Also, the Service would evaluate the management benefits of establishing a recreation-fee program.

The Service would expand the Refuge outreach program by participating in three major community events annually and conducting an annual open house for the public. They would install a permanent environmental education/interpretive display at a public venue in the Las Vegas area.

To inform the public about the Refuge, the Service would create and distribute a video to the community that highlights the Refuge, develop a quarterly Refuge newsletter, and prepare and distribute an annual Congressional briefing. To monitor the program's effectiveness, the Service would conduct annual surveys of the public's knowledge of the Refuge and its opportunities.

The Service would begin monitoring the hunting program in coordination with NDOW. Populations of game species would be surveyed annually, and the results would be discussed in an annual report. The number of hunters and species harvested would also be inventoried to record information on the program each year. Signs would also be posted and maintained to inform visitors of the designated hunt areas.

Cultural Resources

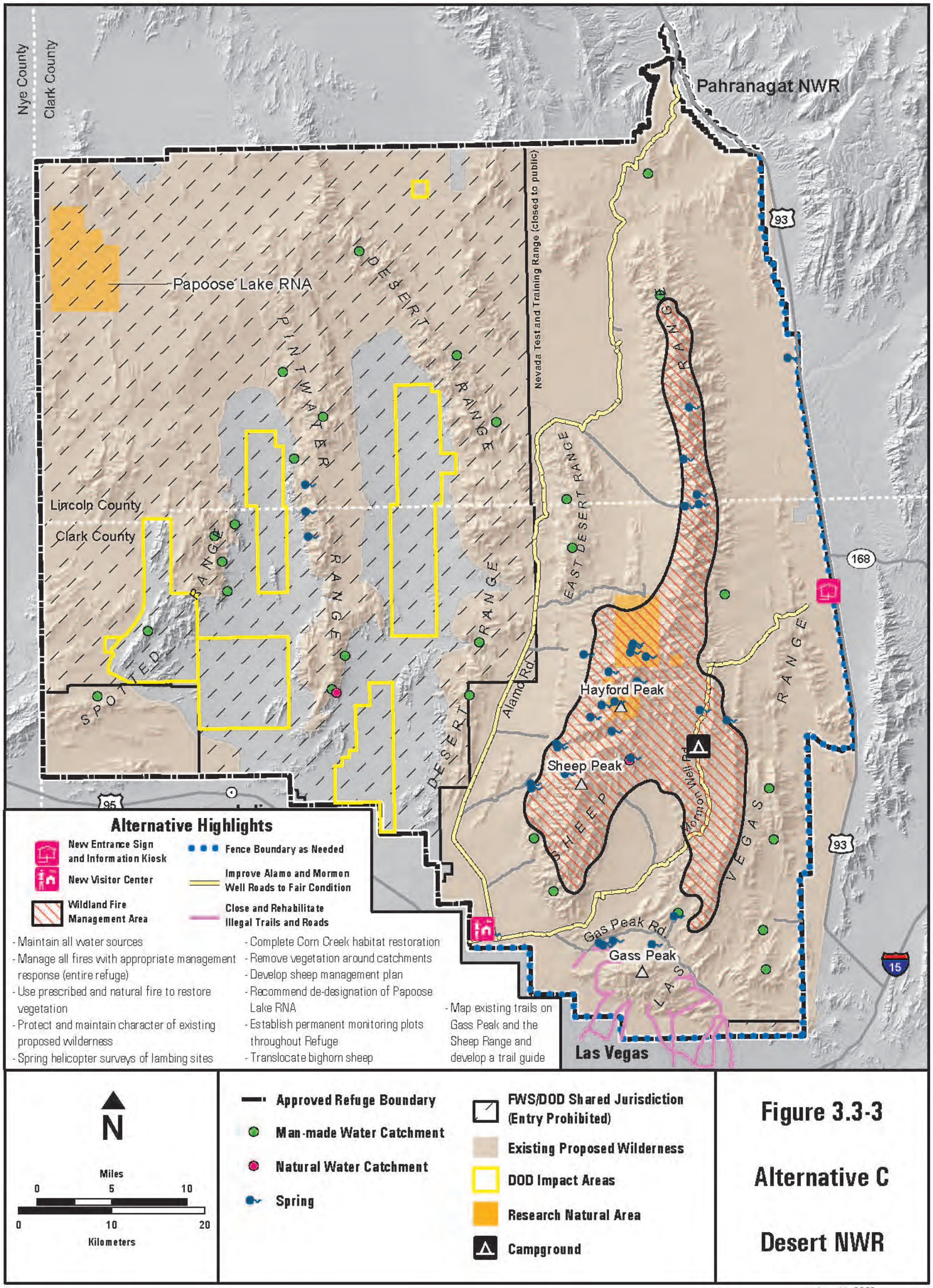
Background information on the cultural resources on the Refuge would be compiled to create databases and digital, GIS, and hard copy maps for retention in administratively confidential Refuge files. As part of the data collection effort, the Service would identify potential critical/priority critical cultural sites on the non-military overlay of the Refuge and develop a cooperative program and solicit funding to survey and record the sites. The gathered data on site locations, information, and survey areas would be used for planning, monitoring, and interpretation efforts related to cultural resources. Additional data collection efforts would be implemented to identify and evaluate resources that may be subject to looting, vandalism, erosion, or deterioration and allow the Service to implement measures, such as restricting or controlling access, to reduce threats, provide stabilization, or conduct data recovery on significant sites.

Other management actions implemented on the Refuge, such as wildlife management, habitat restoration, fire management, and trail construction, would incorporate cultural resource values, issues, and requirements into their designs and implementation procedures. The educational, interpretive, and outreach programs would also incorporate cultural resources information in their materials. The Service would use a site stewardship volunteer program to assist in site monitoring, creating and delivering educational and interpretive literature and programs, and promoting cultural resources conservation through various public outreach methods.

In addition, the Service would identify and evaluate cultural resources that could educate visitors on how humans have interacted with wildlife and habitats in the past, and they would consult with affiliated tribes and other stakeholders on ways to use these resources to achieve educational, scientific, and traditional cultural needs. The Service would also work with affiliated Native American tribes on projects to restore native habitat and harvest native plants (for traditional non-commercial purposes). To educate the public, the Service would work with affiliated tribes and other stakeholders to design and implement educational materials, programs, and activities that would address traditional or sacred resources and increase awareness on- and off-Refuge about the sensitivity of cultural resources to visitor impacts and the penalties for vandalism.

3.3.4 Alternative C – Moderate Improvement in Wildlife and Habitat Management and Minor Increase in Visitor Services

Alternative C is the preferred alternative. It involves the actions identified in the "Features Common to All Alternatives" section, some of the activities discussed in Alternative B, and some additional activities to improve Refuge management as well as reductions in activities. Activities that would not be implemented under this alternative are also noted; these actions would achieve different goals than those this alternative is targeting. The actions for this alternative are summarized in Figure 3.3-3.



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Bighorn Sheep Management

To protect bighorn sheep habitat from wildfires, the Service would remove highly flammable vegetation around catchments as needed.

As with Alternative B, the Service would translocate sheep between subpopulations on the Refuge and to outside the Refuge to maintain subpopulations as needed. The Service would also develop and implement a Sheep Management Plan as well as a formal agreement with NDOW regarding sheep management on the Refuge. As part of bighorn sheep management, predator populations (mountain lions) on the Refuge would be monitored. As necessary, the Service would construct additional rainwater catchments if existing sources are determined to be inadequate based on the Sheep Management Plan. Data collection efforts would involve conducting at least one annual fall helicopter survey to estimate adult bighorn sheep population parameters; conducting radio telemetry studies to assess bighorn sheep mortality factors, home ranges, and habitat usage; and collecting blood and fecal samples to determine the general health status of the herd, diet composition, nutrient uptake, and genetic diversity.

Wildlife Diversity

In order to track long-term trends in vegetation and wildlife communities on the Refuge, the Service would establish and inventory permanent plots throughout the Refuge. Sample design would ultimately be decided by a pilot study and subsequent analysis, but may include 20 900-square-meter plots (after Webb et al. 2000) per distinct ecosystem type (up to 100 plots total) and would use field techniques for measuring vegetation as described in Elzinga et al. (2005). Inventories would be conducted every five years to monitor natural changes in plant and wildlife composition and abundance.

In order to obtain information on special-status species on the Refuge, the Service would implement an Inventory and Monitoring Plan for these species. Implementation of the plan would involve conducting surveys for special-status species in combination with vegetation surveys and establishing monitoring protocols for each species to obtain additional information on their populations, health, diversity, range, and habitat requirements. Depending on suitable habitat characteristics at Corn Creek and management objectives, the Service would consider reestablishing Pahrump poolfish in the streams, ponds, or springs at Corn Creek.

The Service would use prescribed burns and naturally ignited fires in pinyon/juniper and ponderosa pine communities to restore vegetation characteristics representative of a natural fire regime. Some naturally ignited fires would be allowed to burn under prescribed fire conditions, and such events would be managed as fire use events with appropriate staffing to reflect the complexity of the incident. Wildland fires may be concurrently managed for one ore more objectives, which can change as the fire spreads across the landscape. Critical natural and cultural resources may be protected on one flank of the fire while the fire is allowed to enhance habitats on other flanks. As part of fuels management, the Service would consider the habitat needs of special-status species, such as Gilbert's skink (NDOW Species of Conservation Priority) and Partners in Flight priority bird species (pinyon jay and gray vireo), and modify management actions appropriately to maintain or improve habitat for these species. Once restoration activities are complete, the Service would regularly maintain and monitor the habitats to ensure restoration success.

The Service would implement additional resource protection measures, including fencing the eastern boundary (post and cable) where necessary; posting boundary signs along the entire southern, eastern, and northern boundaries; and expanding law enforcement presence and patrols throughout the Refuge with additional emphasis along the eastern boundary. Trespassing and Endangered Species Act violations would be enforced through increased awareness and support from other agencies. A second entrance point would be designated at the southeast end of the Refuge in addition to the existing entrance at Corn Creek Field Station.

The Service would coordinate with local jurisdictions along the southern boundary to ensure compatible development occurs adjacent to the Refuge. Possible measures to ensure compatibility include establishment of a greenbelt or construction of walls along the north side of developments. To rehabilitate and protect habitat along the southern boundary, the Service would develop and implement a plan to close illegal trails and rehabilitate damaged resources (i.e., habitat). Native upland vegetation would be planted to restore damaged habitat.

Specially Designated Areas

In addition to the management actions described for Alternative B, the Service would submit a request to the Service Director to de-designate the Papoose Lake RNA due to its inaccessibility because of the military overlay. In addition to monitoring activities in RNAs, academic and agency scientists would be encouraged to conduct non-manipulative research and obtain information on the RNAs.

Visitor Services

In addition to the management actions described for Alternative B, the Service would distribute educational materials to the public to inform them about the use of fire for habitat management. Two management actions would not be implemented under Alternative C: the auto tour route and wildlife viewing trails at Gass Peak and Sheep Range.

Cultural Resources

To improve cultural resources management on the Refuge, the Service would implement the following actions:

- Prepare evaluation criteria and conduct a cultural resources inventory at all public use areas, roads, affected areas, and other "destinations" on the Desert NWR;
- Inventory, evaluate, and nominate eligible Traditional Cultural Properties and sacred sites to the NRHP, in consultation with affiliated tribes;

- Inventory, evaluate, and mitigate adverse effects and stabilize samples of cultural resources on Desert NWR using a research design prepared in consultation with affiliated tribes and the scientific community; and
- Conduct studies of ethnobotany and traditional plant use on the Refuge.

3.3.5 Alternative D – Moderate Improvement in Wildlife and Habitat Management and Limited Increase in Visitor Services

Alternative D involves the actions identified in the "Features Common to All Alternatives" section, some of the activities discussed in Alternatives B and C, and minimal additional activities to improve wildlife management on the Refuge with several reductions in visitor services. Activities that would not be implemented under this alternative are also noted; these actions would achieve different goals than those this alternative is targeting. The actions for this alternative are summarized in Figure 3.3-4.

Bighorn Sheep Management

Instead of transplanting sheep between subpopulations within the Refuge, as identified under Alternatives B and C, the Service would translocate sheep from outside sources onto the Refuge to maintain and increase Refuge subpopulations and improve genetic diversity. The Service would also implement a Sheep Management Plan and improve sheep management similar to Alternative C.

Wildlife Diversity

As in Alternative C, the Service would establish permanent plots for monitoring plant and wildlife communities throughout the Refuge.

To improve resource protection efforts, the Service would construct a post-and-cable fence along the northwest boundary of the East Pahranagat Range Unit as well as the boundary fences along the southern and eastern boundaries.

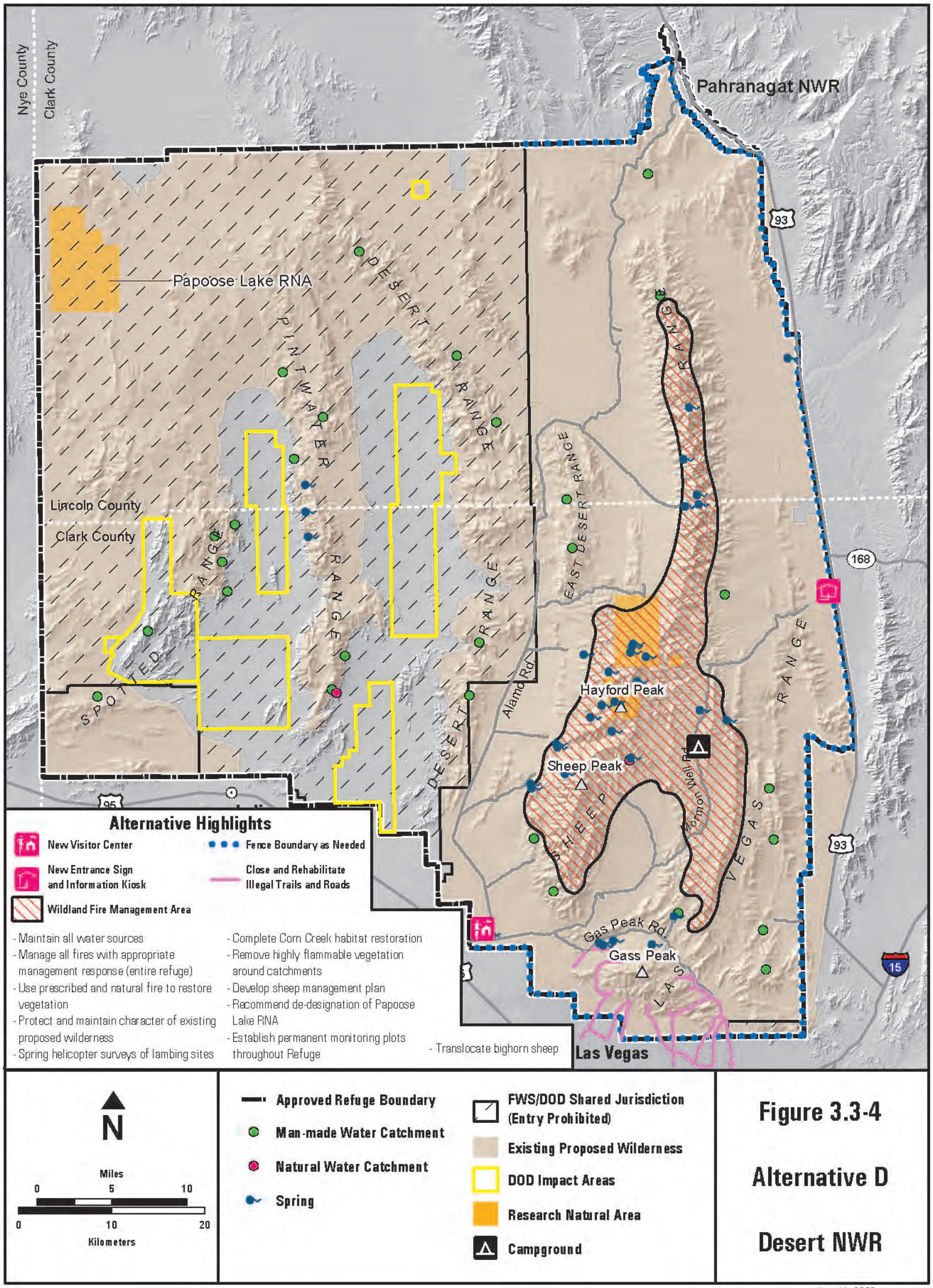
Specially Designated Areas

The Service would submit a request to the Service Director to de-designate Papoose Lake RNA, but non-manipulative research in the RNAs would be discouraged to minimize the staffing needed to oversee research projects.

Visitor Services

Environmental education and interpretation would be improved for the most part as described under Alternative B, except for the following:

- A seasonal volunteer/docent would not be used at Desert Pass campground; and



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- The volunteer program would be expanded to staff the visitor contact station full-time during peak use, but only for four hours per day on weekends during the rest of the year.

Public outreach would be minimal and would include participation in two major community events annually, conducting an annual public open house, and preparing and distributing an annual Congressional briefing. Other actions described under Alternative B would not be implemented due to the need for increased staffing and funding to support an increase in outreach activities.

Additional visitor services related to wildlife observation and photography would be expanded as under Alternatives B; however, the Service would not improve Mormon Well and Alamo Roads, construct an auto tour route or wildlife viewing trails in Gass Peak and Sheep Range Units, or map trails at Gass Peak and Sheep Range. The Service would not evaluate implementation of a recreation-fee program. These activities would not be implemented due to the need for increased staffing and funding to support such projects.

Cultural Resources

The Service would implement the management actions described under Alternatives B and C, except education and outreach would be the same as Alternative A (current management). No additional actions are proposed under Alternative D.

3.3.6 Comparison of Alternatives

A comparative summary of the alternatives for the Desert NWR is provided in Table 3.6-2.

3.3.7 Management Actions Considered but Eliminated from Detailed Analysis as Part of Alternatives

During the alternatives development process, Desert NWR staff evaluated additional management actions as part of the current alternatives. These actions are identified below with their reasons for elimination:

- Allow off-highway or all-terrain vehicle use. (Not appropriate use of Refuge.)
- Develop a museum at Corn Creek. (Not feasible.)

Develop a visitor center along the southern boundary near Gass Peak. (Not feasible.)

3.4 Moapa Valley National Wildlife Refuge Alternatives

Moapa Valley NWR's alternatives consist of the No Action Alternative and two action alternatives. The No Action Alternative contains a variety of management actions that have recently been implemented on the Refuge or will be implemented before the CCP is approved. The two action alternatives contain management actions to improve Refuge conditions at varying levels. Alternative B would improve habitat and wildlife management for two spring systems on the Refuge with an increase in visitor services. Alternative C would improve habitat and wildlife management for three spring systems on the Refuge and expand visitor services more than in Alternative B.

3.4.1 Features Common to All Alternatives

A number of current management actions would continue to be implemented for the Moapa Valley NWR under each of the alternatives. The two action alternatives propose additional management actions to improve Refuge conditions. Actions that are common to all alternatives are described below and are not repeated in each alternative description.

Endemic and Special-Status Species

The Service would continue ongoing restoration and revegetation efforts on the Plummer Unit. As part of restoration project design and implementation, the Service would consider habitat needs of special-status fish and invertebrates in addition to the Moapa dace, including Moapa White River springfish, Moapa pebblesnail, grated tryonia, Moapa Warm Spring riffle beetle, Amargosa naucorid, and Moapa naucorid. Restoration activities involve restoring native overstory, mid-level, and understory vegetation (using local seed and seedlings) along riparian corridors, in transitional upland sites, and in any disturbed or newly exposed areas on the Plummer Unit. Volunteers would also continue to be used for restoration efforts.

In addition, to improve habitat conditions for endemic species, the Service would develop management actions to remove non-native fish species, including mollies and mosquitofish, from Refuge waters. Other non-native aquatic species would also continue to be periodically removed.

As part of the restoration activities on the Plummer Unit, the Service would remove palm trees associated with riparian areas to restore habitat for the endangered Moapa dace. In addition, periodic palm tree maintenance would be required to reduce the wildfire risk. Unwanted fires would be extinguished as fast as safely possible to minimize potential adverse impacts on Moapa dace. These efforts would allow the Service to protect and maintain natural habitat, including water quality and quantity in the Refuge springs and channels, at suitable levels for Moapa dace survival, reproduction, and recruitment.

The Service would continue collecting data on Moapa dace and Moapa White River springfish through annual surveys and monitoring. This information would be used for management of the species during and following restoration activities. The Service would monitor the Moapa dace population before and after restoration activities to identify beneficial or adverse effects on its population.

The Service would continue to track monitoring of water flow and temperature of Pedersen and Pedersen East Springs and the Warm Springs West flume by the SGS. The Service would also continue to participate in local and regional water resources management efforts to assess impacts to water resources and protect water resources on the Refuge. Participation in the Muddy River Regional water monitoring planning process is a key aspect of water resources management for the Muddy River area. The Service would also monitor changes in the environment, such as changes in vegetation communities, wildlife trends, and surface and groundwater levels, to assess the effects of climate change on the Refuge.

Additional protection measures for the Refuge would include maintaining the existing boundary fence and gates and maintaining regulatory signs in good condition. Signs, fencing, and gates would be replaced as staffing and funding allow.

Visitor Services

The Service would continue to use volunteers for habitat restoration projects on the Refuge. Outreach staff would continue to attend the Moapa Day community event or other local community events, and information on Refuge resources would be provided upon request to the local community. At a minimum, the current entrance signs for the Refuge would be maintained. The Service would continue to work on establishing an accessible trail for visitors.

The Service would explore opportunities for partnerships to develop environmental education programs and for community-based outreach during on-Refuge activities. An annual open house would be held for volunteers that help on the Refuge. The Service would continue informal education of Refuge visitors on cultural resources of the area.

To comply with applicable laws and regulations, the Service would continue to inventory, manage, and protect any cultural resources on the Refuge on a project-by-project basis.

3.4.2 Alternative A – No Action (Current Management)

Alternative A is the current management situation, or No Action Alternative, for the Refuge. It serves as a baseline with which the objectives and management actions of the two action alternatives, Alternatives B and C, can be compared and contrasted. Because this alternative reflects the current management, it would not result in substantial changes in the way the Refuge would be managed in the future. Figure 3.4-1 graphically summarizes the actions that would continue under this alternative.

Endemic and Special-Status Species

The Service would continue to implement the management actions identified in the “Features Common to All Alternatives” section.

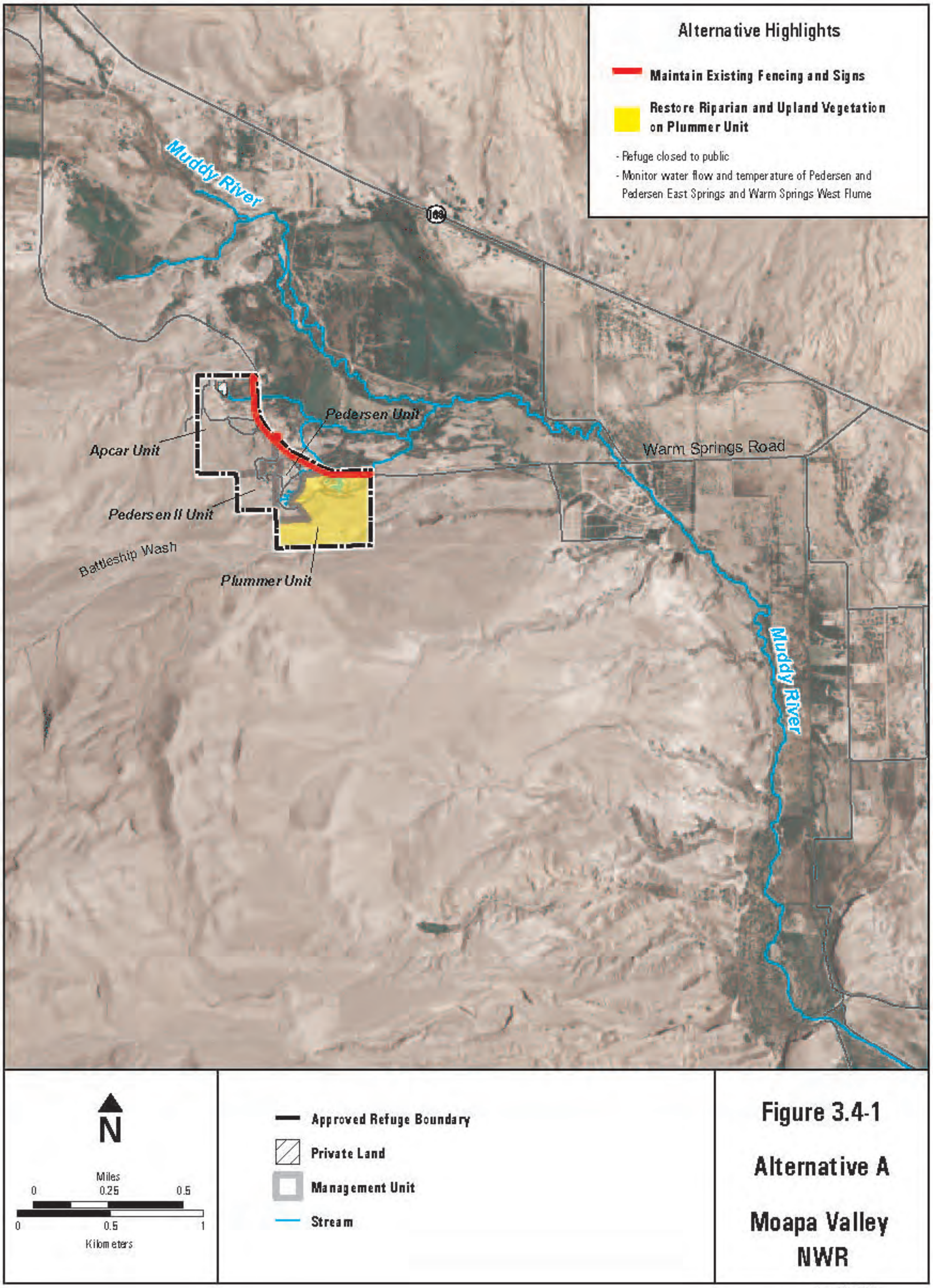

Figure 3.4-1
Alternative A
Moapa Valley NWR

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Visitor Services

The Refuge would remain closed to the general public, and the Service would continue limited participation in local community events. Existing parking facilities would be maintained for visitor safety, and the current Refuge entrance signs would be maintained. The current interpretive and environmental education materials would be periodically updated to maintain accuracy. Information about Refuge resources would be provided to visitors and the public upon request.

3.4.3 Alternative B – Improve Habitat and Wildlife Management on Portions of the Refuge and Increase Visitor Services

Alternative B provides for moderately increased management actions for all resource areas when compared to Alternative A (No Action). This alternative involves the objectives and management actions identified in the "Features Common to All Alternatives" section, some modifications of actions identified in Alternative A, and additional actions for more active management. Alternative B actions are portrayed in summary form in Figure 3.4-2.

Endemic and Special-Status Species

In addition to restoration of the Plummer Unit, the Service would continue channel restoration on the Pedersen Unit to benefit Moapa dace by planting native species, such as coyotebrush, Sporabolis, spikerushes, saltgrass, and bushy bluestem, in and surrounding spring sources. Restoration would involve maintaining water temperatures between 30 and 32 degrees Celsius (86 to 89.6 degrees Fahrenheit), establishing and maintaining flows between 0.3 and 1.0 meters per second, and planting native plant species, such as waternymph, watercress, spikerush, sedges, and grasses, in and surrounding spring sources. Riparian habitat near larger channels would be restored to contain herbaceous and woody species, such as velvet ash, cottonwood, willow, screwbean mesquite, and understory sedges. Once restoration activities are complete, the Service would regularly maintain and monitor the habitats to ensure restoration success.

The Service would also monitor streams for endemic fish and invertebrate populations before and after restoration activities to identify potential impacts and changes in their populations.

The Service would collect baseline data for fish and wildlife species to improve management of the Refuge. For federally listed and other special-status fish species, the Service would develop and implement an Inventory and Monitoring Plan within five years of CCP approval to establish strategies and protocol for monitoring and inventories, consistent with the Clark County Multiple Species Habitat Conservation Plan (Clark County and Service 2000). Surveys would be conducted for special-status species (federally listed, proposed, candidate, and other status) throughout the Refuge and for invertebrates and amphibians in aquatic habitat to determine species composition and abundance.

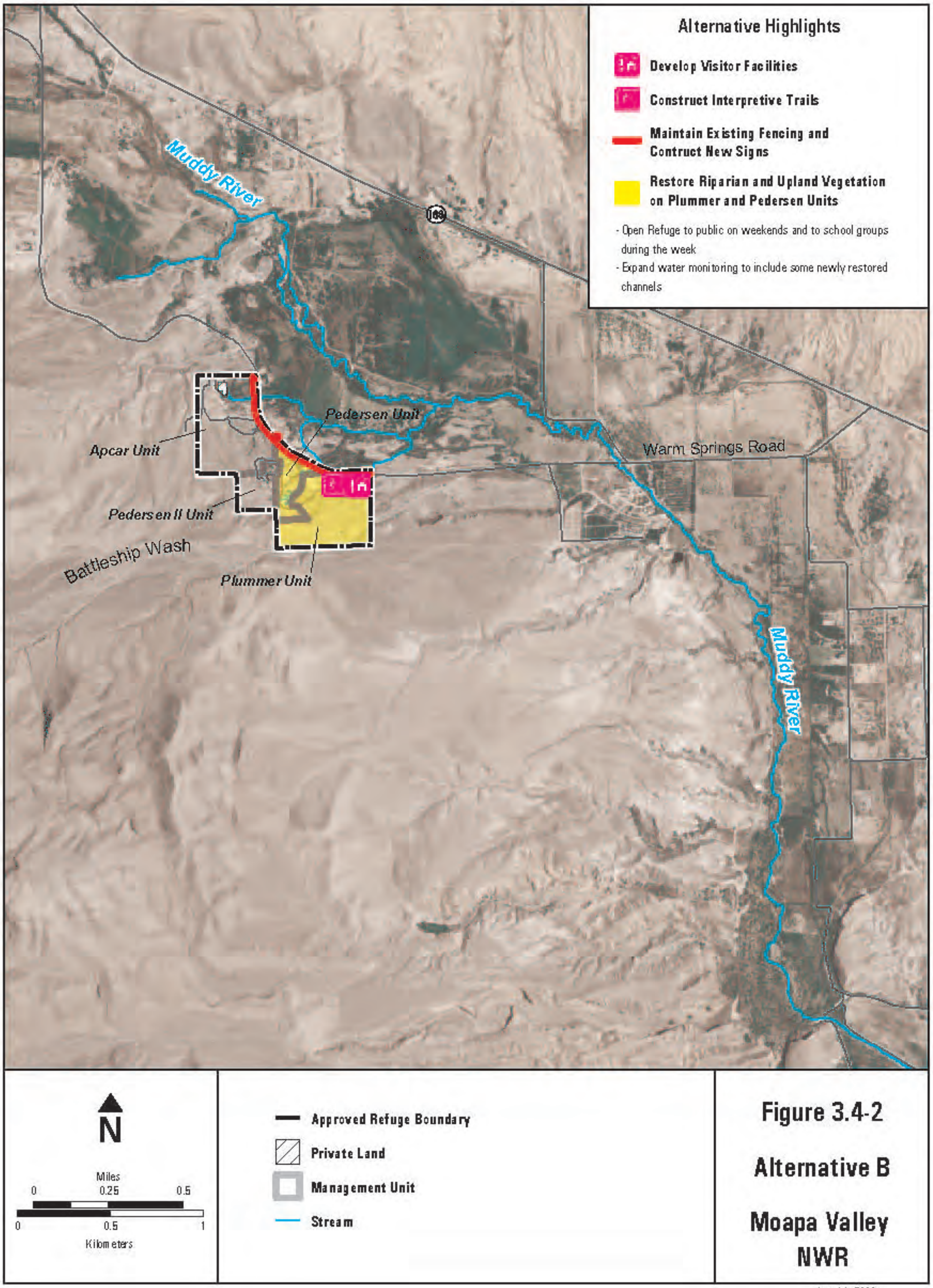

Figure 3.4-2

Alternative B

Moapa Valley NWR

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Once implemented, the Service would repeat inventories every five years to track long-term trends in populations. By 2009, the Service would complete an inventory of existing upland habitat to record information on migratory birds, mammals, and reptiles that use the Refuge. Restored stream habitat would be monitored consistent with the Muddy River Aquatic Species Recovery Plan (Service 1996).

The Service would develop a long-term Water Resources Management Plan for the Refuge and implement additional actions to improve monitoring of the springs and streams. These actions could include identifying appropriate protocols for monitoring (locations, timing, parameters, and equipment), installing equipment, and monitoring specific parameters (flow, temperature, and quality) at some springs and streams on the Plummer and Pedersen Units. The Service would collect monthly monitoring data for water flow and temperature of Pedersen East and Pedersen East Springs and Warm Springs West flume and for water quality parameters (temperature, flow, dissolved oxygen, pH, and total dissolved solids) at other Refuge springs as needed.

To protect native habitats, wildlife, and fish on the Refuge, the Service would implement an IPM Plan that would involve controlling and eradicating invasive species encroachment using an early detection/early response approach. The Service would participate in community-based fire safe planning on and off the Refuge and use prescribed fire where appropriate to reduce hazardous fuels and treat unwanted vegetation. These planning efforts would allow the Service to explore other options for protecting the Refuge and its habitats from fire.

To protect habitats and control public access, the Service would install additional entrance signs, as appropriate, and install directional, regulatory, and interpretive signs on and off the Refuge. Additional interpretive, regulatory, and directional materials would be developed to guide and enhance the visitor experience.

Visitor Services

The Service would open the Refuge to the public on a limited basis. The Refuge would be open to the general public on weekends and to school groups during the week through prior arrangement. Signs would be installed along Interstate 15 (I-15) and U.S. Highway 93 and at the entrance to the Refuge at Warm Springs Road to promote and direct the public to the Refuge. The Service would work with the Nevada Department of Transportation (NDOT) on sign installation.

Additional facilities would be constructed on the Refuge to accommodate the visitors. The Service would expand and improve parking and access roads, as necessary, to accommodate the increase in visitors. Specifically, interpretive panels would be installed along a trail system of the Plummer and Pedersen Units, and a basic trail would be constructed along the riparian corridor on the Plummer Unit.

The Service would develop an environmental education program by 2012 and create interpretive and environmental educational materials for distribution to the public, as staff or funding becomes available. Refuge education materials would be offered to local school contacts upon request. Interpretive materials, such as brochures and fact sheets, would be developed to guide and enhance visitor experience and provide information on the benefits of stream habitat restoration for the enhancement of Moapa dace habitat and human safety. To inform visitors of cultural resources in the area, the Service would develop regionally focused environmental education and interpretation materials for self-guided tours. Information would be developed in coordination with culturally affiliated tribes to incorporate their history and knowledge of native plant and animal species.

To improve outreach for the Refuge, the Service would conduct a public open house every two to three years to encourage interactions and foster relationships between Refuge staff and local constituents, as well as seek opportunities for community-based outreach, such as participation in off-Refuge activities. The Service would provide outreach at the Moapa Valley Community Center by invitation and as the staff is available. Docents would be recruited to staff the Refuge on weekends and facilitate tours, and the Service would collect data on the number of visitors using sign-in sheets to modify their visitor services accordingly.

3.4.4 Alternative C – Improve Habitat and Wildlife Management Throughout the Refuge and Expand Visitor Services

Alternative C is the preferred alternative. It involves the actions identified in the “Features Common to All Alternatives” section, the activities discussed in Alternative B, and some additional activities. Some activities from Alternative B are expanded under this alternative to improve Refuge management. The actions are summarized for this alternative in Figure 3.4-3.

Endemic and Special-Status Species

In addition to restoring the springs and streams on the Plummer and Pedersen Units, the Service would complete restoration of the spring heads and channels on the Apcar Unit by 2015. Native plants would be planted where non-native and invasive species are removed and in other disturbed areas within the Apcar Unit.

The Service would collect additional data on migratory birds, mammals, and reptiles in the upland habitat by 2009 and prepare a Monitoring Plan for those species. The long-term Inventory and Monitoring Plan identified under Alternative B would be expanded to include all federally listed, proposed, candidate, and other special-status species. The Service would also coordinate with NDOW to conduct surveys of palm tree habitat for use by bats.

Springs on the Apcar Unit would also be monitored for water quality parameters based on current and past monitoring protocols. In addition, the Service would monitor habitat changes, maintain and continue improvements for restoration efforts and other landscape

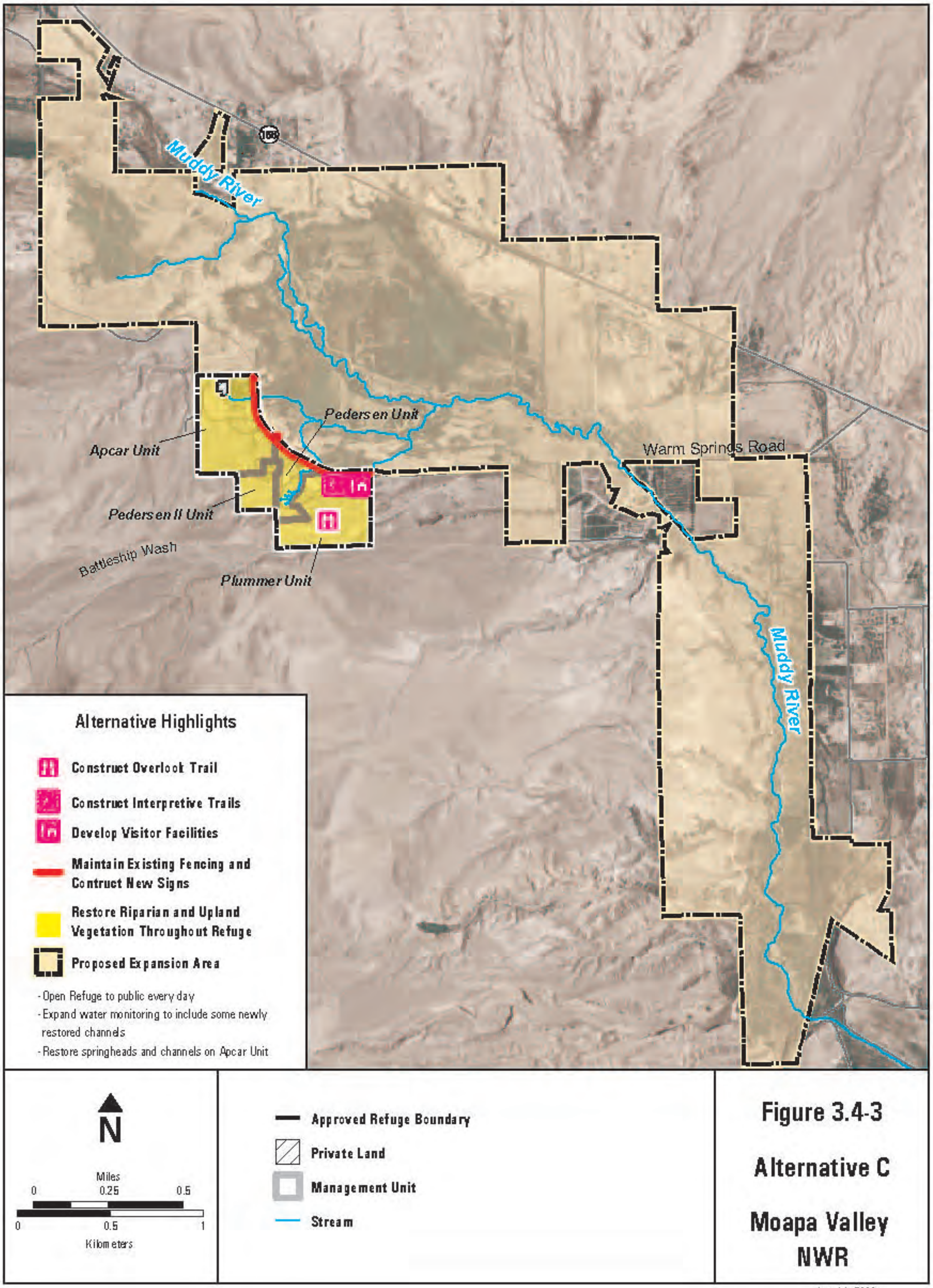

Figure 3.4-3

Alternative C

Moapa Valley NWR

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improvements, and provide adequate levels of monitoring and maintenance for invasive species control and fire management.

The Service would also expand the Refuge acquisition boundary by 1,503 acres and work with partners to protect habitat within the expanded boundary through purchase, transfer, and/or agreement (see Land Protection Plan in Appendix L). Step-down habitat management plans would also be prepared for habitats within the expanded boundary.

Visitor Services

The Refuge would be open daily to the public for self-guided or staff-guided tours. Additional parking areas, a school bus turnout, and an overlook trail with interpretive panels and shade structure would be constructed or improved to accommodate the increase in visitors. The overlook trail with interpretive panels and shade structure would be located on top of the hill on the Plummer Unit for viewing the Refuge and the Moapa Valley. A self-guided trail system would be constructed along the spring head, pools, and riparian corridor on the Plummer Unit to accommodate visitors.

The Service would develop an environmental education program at the Refuge and develop interpretive and environmental education materials for distribution to the public. A public open house would be conducted annually to encourage interactions and foster relationships between Refuge staff and local constituents.

The Service would expand outreach through construction of a permanent environmental education display at the Moapa Valley Community Center or other local public venue. To encourage schools to visit the Refuge, the Service would organize local school contacts and generate enthusiasm for visiting the Refuge and experiencing its endemic species. In addition, the Service would seek opportunities for community-based outreach, such as participation in off-Refuge activities.

Moreover, the Service would conduct a cultural resources inventory of the entire Refuge to assist in future planning efforts and improve management and protection of significant sites from inadvertent public visitation impacts.

3.4.5 Comparison of Alternatives

A comparative summary of the alternatives for the Moapa Valley NWR is provided in Table 3.6-3.

3.4.6 Management Actions Considered but Eliminated from Detailed Analysis as Part of Alternatives

During the alternatives development process, Refuge staff evaluated additional management actions as part of the current alternatives. These actions are identified below with their reasons for elimination:

- Open pools to public for swimming. (Not compatible with Refuge vision, purpose, or goals.)

- Remove all palm trees from the Refuge. (Not appropriate since they provide habitat for some bats, other mammals, and birds.)

3.5 Pahranagat National Wildlife Refuge Alternatives

Pahranagat NWR's alternatives consist of the No Action Alternative and three action alternatives. The No Action Alternative contains a variety of management actions that have recently been implemented on the Refuge or will be implemented before the CCP is approved. The three action alternatives contain management actions to improve Refuge conditions at varying levels. Alternative B would provide limited improvements in water resource and habitat management with some improvements to visitor services. Alternative C would provide minor improvements in water resource and habitat management with a minor increase in visitor services. Alternative D would provide moderate improvements in water resource and habitat management with moderate increases in visitor services.

3.5.1 Features Common to All Alternatives

A number of current management actions would continue to be implemented for the Pahranagat NWR under each of the alternatives. The three action alternatives propose additional management actions to improve Refuge conditions. Actions that are common to all alternatives are described below and are not repeated in each alternative description.

Wetland Habitat

The Service would complete and implement a habitat restoration plan to improve the quality of the existing habitat for waterfowl, waterbirds, shorebirds, and other migratory birds. As part of this planning effort, the amount of different wetland habitats would be evaluated and may be modified appropriately to provide suitable habitat for migratory birds. Current management of open water (640 acres), marsh (400 acres), wet meadow (700 acres), and alkali flat (350 acres) habitats would be continued until the plan is complete, including the following:

- Discharging water into Middle Marsh and Lower Pahranagat Lake to provide migratory waterfowl habitat;
- Clearing vegetation in irrigation ditches annually as staffing allows; and
- Maintaining current maintenance, repair, and improvement efforts on North Marsh and Upper Pahranagat Lake.

Marsh habitat would be maintained with 60 percent open water and 40 percent emergent vegetation. Supplemental flows from pumped well water into Middle Marsh would be used as needed to maintain water levels. The alkali flats habitat in the Lower Pahranagat Lake area would continue to be flooded for breeding and migrating waterfowl, waterbirds, and shorebirds. Once restoration activities are complete, the Service would regularly maintain and monitor the habitats to ensure restoration success.

Water resources management would continue under existing conditions to maintain these habitats between October and April of each year, with a primary goal of providing waterfowl and migratory bird habitat throughout the Refuge. Additional water resource management would include:

- Pursuing the 1996 application for year-round water discharges;
- Surveying existing groundwater wells and repairing or capping as appropriate;
- Installing a flume or weir at the outflow of Lower Pahranagat Lake;
- Installing and monitoring flow meters and data loggers on each of the three groundwater wells;
- Completing the update of the Water Management Plan;
- Completing a Refuge-wide water budget; and
- Using a variety of tools to defend water rights and mitigate substantial changes in parameters.

To improve wetland habitat for waterfowl, carp populations in the open water habitat would be studied and may be controlled through electro-shocking and netting. Non-native carp uproot aquatic vegetation when spawning and feeding and suspend benthic sediments, resulting in limited light for plant growth. A reduction in carp populations would allow emergent and submergent vegetation to establish along the edges of Upper Pahranagat Lake and North Marsh.

The Service would continue to use prescribed burns as needed in wet meadow and marsh habitats to maintain productivity. Noxious weed surveys would be coordinated with county, state, and federal agencies to map the extent of weeds on the Refuge. Weed removal efforts would occur as staffing and funding become available. The Service would also continue to implement limited IPM efforts to control invasive species.

To monitor waterfowl response to habitat management, the Service would continue conducting spring waterfowl surveys using volunteers and Refuge staff, as available, and would coordinate with NDOW to conduct fall and winter waterfowl surveys. A habitat restoration plan for migrating sandhill crane foraging habitat would be developed and implemented. Information on the Pahranagat Valley montane vole would continue to be collected to determine its population status, distribution, and demography.

Wildlife Diversity

The existing 100 acres of cottonwood-willow riparian habitat would be maintained around North Marsh to provide habitat for the southwestern willow flycatcher and other migratory birds. The endangered flycatcher has been documented nesting in this habitat during annual surveys over the past several years (Koronkiewicz et al. 2006). The Service would also implement additional surveys of the Refuge to collect information on riparian habitat (percentage of cover, density, age, and structure), southwestern willow flycatcher (presence or absence), and vegetation (as directed by project objectives and efforts). A habitat restoration and management plan for the willow flycatcher would be completed and implemented.

To protect upland habitat, the Service would continue to enforce prohibitions of off-road vehicles and maintain Refuge fences to reduce encroachment of cattle from adjacent lands. The Service would also prepare a wilderness study report and NEPA document to evaluate options for preserving wilderness values of the three small wilderness study areas along the western boundary of the Refuge adjacent to the proposed wilderness on Desert NWR. Wildland fires on the Refuge would be managed using the AMR, which considers resource values at risk and potential negative impacts of various fire suppression measures. Firefighter and public safety would be the highest priority on every incident.

Habitat around springs and channels on the Refuge would be improved based on recommendations of the Habitat Restoration Plan. This could include restoring native habitats, restoring springs to conditions similar to those before development, and improving hydrology and water quality to benefit native fish species. Six of the springs are currently degraded or have been modified, including three spring outflows (Cottonwood Spring, Cottonwood Spring North, and Lone Tree Spring) that have been dredged or trenched to varying degrees. To obtain information on the vegetation and wildlife that use the spring and channel habitats, the Service would conduct inventories and monitoring of the habitats.

The Service would also monitor changes in the environment, such as changes in vegetation communities, wildlife trends, and surface and groundwater levels, to assess the effects of climate change on the Refuge.

Visitor Services

The Refuge provides visitor services and facilities for a variety of recreational opportunities, including hunting for quail, migratory birds, and rabbits; sport fishing; wildlife observation; walking trails; and photography. Visitor facilities would be maintained with help from volunteers and as staff is available to ensure visitor safety, and visitor numbers would continue to be monitored to ensure the facilities are adequate to accommodate the number of visitors. Existing trails throughout the Refuge would be maintained.

As part of the hunting program, the Service would continue to provide Refuge-specific and NDOW hunting guidelines, regulations, and other information at Refuge headquarters and post and maintain designated hunting area signs on the Refuge. Wildlife lists would also be available at Refuge headquarters to support wildlife observation and similar activities.

The Refuge policy to prohibit swimming at all open water locations would be enforced, and regulatory signs at the open water areas would be maintained. Swimming poses a public health and safety concern and can adversely affect fish, wildlife, and their habitats.

Cultural Resources

Cultural resources management and protection would vary by alternative.

3.5.2 Alternative A – No Action (Current Management)

Alternative A is the current management situation, or No Action Alternative, for the Refuge. It serves as a baseline with which the objectives and management actions of the three action alternatives, Alternatives B, C, and D, can be compared and contrasted. Because this alternative reflects the current management, it would not result in substantial changes in the way the Refuge would be managed in the future. Figure 3.5-1 graphically summarizes the actions that would continue under this alternative.

Wetland Habitat

The Service would continue to implement the management actions identified in the "Features Common to All Alternatives" section.

Wildlife Diversity

The Service would continue to implement the management actions identified in the "Features Common to All Alternatives" section.

Visitor Services

The Service would maintain the campground in its current state.

The Service would continue to implement limited interpretation, environmental education, and outreach activities as needed and as staff is available. The Service would continue to participate in up to three outreach events per year, such as International Migratory Bird Day, National Wildlife Refuge Week, and Earth Day, as staff is available.

Cultural Resources

The Service currently implements minimal cultural resources management activities. The Service would continue to provide Refuge visitors with interpretive information on cultural resources through informal outreach and protect cultural resources on a case-by-case basis. Cultural resources would be managed on a project-by-project basis.

3.5.3 Alternative B – Limited Improvements in Water Resource and Habitat Management and Minor Increase in Visitor Services

Alternative B provides for limited increased management actions for all resource areas when compared to Alternative A (No Action). This alternative involves the objectives and management actions identified in the "Features Common to All Alternatives" section and additional actions for more active management. Alternative B actions are graphically summarized in Figure 3.5-2.

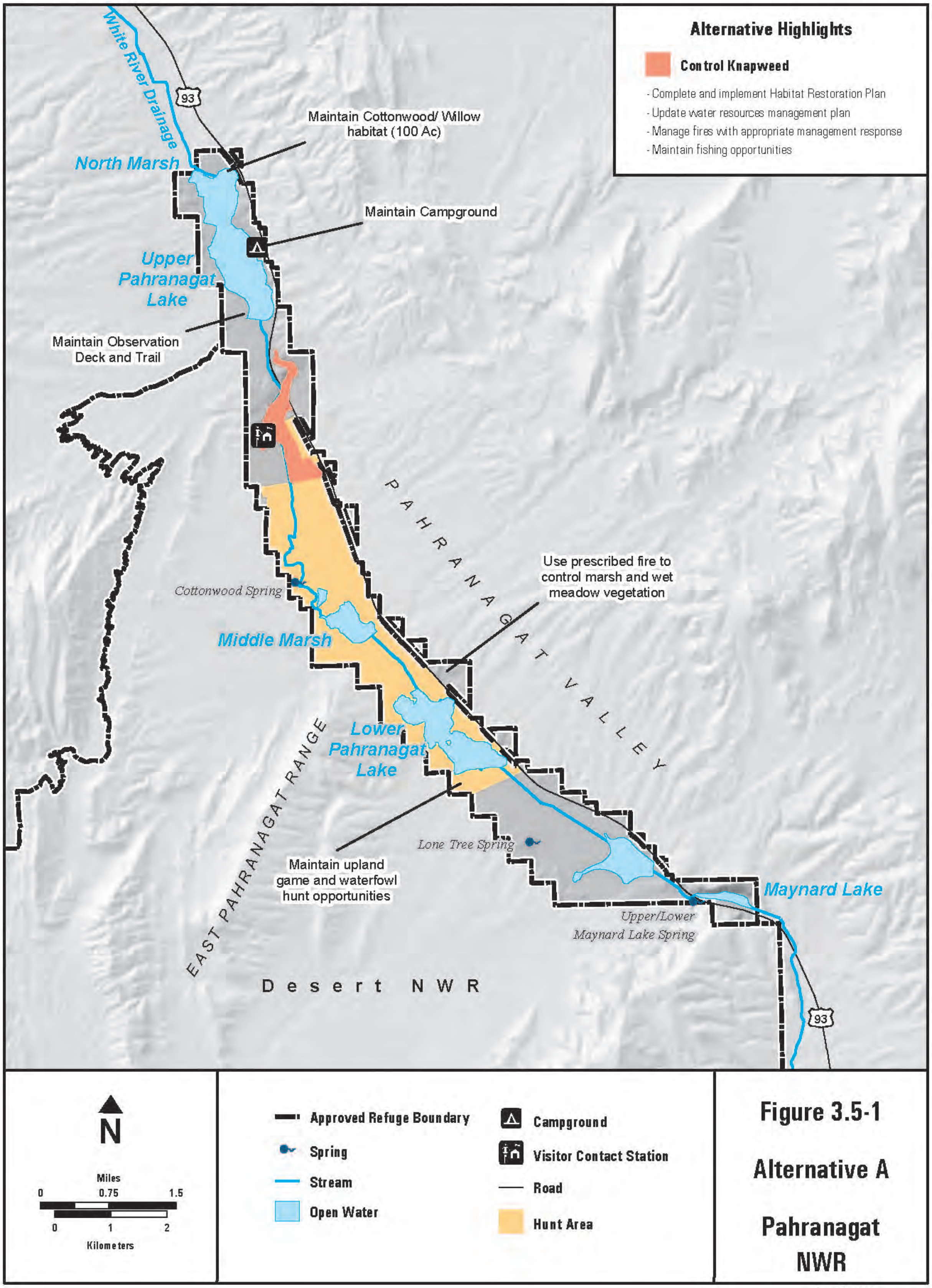

Figure 3.5-1

Alternative A

Pahranagat NWR

June 11, 2009
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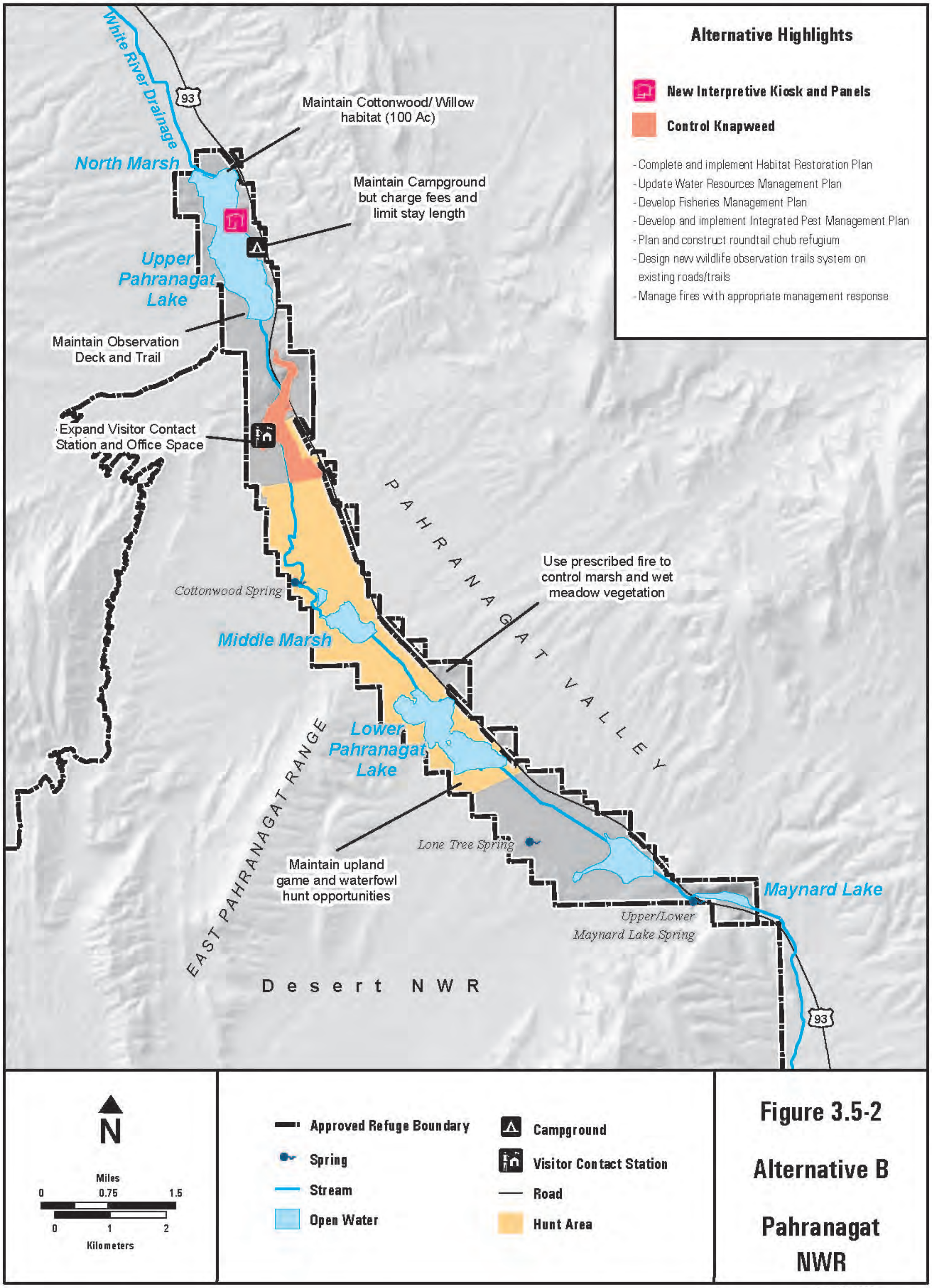

Figure 3.5-2

Alternative B

Pahranagat NWR

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Figure 3.5-2-pahranagat_alt_B.mxd

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Wetland Habitat

The Service would install a new pump for Well 3 and monitor outflow.

The Service would also expand current invasive plant removal efforts by developing and implementing an IPM Plan within five years of CCP completion.

Wildlife Diversity

To protect upland habitat, the Service would close unused roads as necessary and in coordination with the BLM.

Although the Pahranagat roundtail chub is not currently present on the Refuge, it has been documented there historically. Habitat conditions on the Refuge are also not currently suitable for reintroducing the chub. The Service would plan and develop, if feasible, a refugium on the Refuge for the chub.

The Service would continue to obtain information on the species that use the Refuge. To monitor waterfowl and bird responses to Refuge management actions, the Service would obtain data collected by other agencies on a seasonal basis.

Visitor Services

The Service would monitor the number of visitors using the Refuge each day. A Fisheries Management Plan would be prepared after CCP implementation. The campground would be maintained, and the Service would begin collecting fees and limit the length of stays to seven days. Generators would be prohibited between the hours of 10 p.m. and 8 a.m.

Visitor services on the Refuge would be improved and expanded to accommodate visitors and ensure visitor safety. The visitor contact station would be expanded to accommodate the growing number of visitors; new interpretive panels would replace old panels at the kiosk; environmental education and interpretive materials would be developed, including "least-wanted" posters for invasive plant species; and a wildlife observation trail system would be constructed throughout the Refuge.

Cultural Resources

Background information on the cultural resources on and near the Refuge would be collected and compiled to create digital, GIS, and hard copy maps, databases, and a library for the Refuge. Additional data collection efforts would be implemented to identify and evaluate resources subject to looting, vandalism, erosion, or deterioration and allow the Service to implement measures to reduce threats and preserve the resources.

Other management actions implemented on the Refuge, such as wildlife management, habitat restoration, fire management, and trail construction, would incorporate cultural resource values, issues, and requirements into their designs and implementation procedures.

The educational, interpretive, and outreach programs would incorporate cultural resources information in their materials. To educate the public, the Service would work with affiliated tribes and other stakeholders to design and implement educational materials, programs, and activities that would describe traditional or sacred resources and increase awareness on- and off-Refuge about the sensitivity of cultural resources to visitor impacts and the penalties for vandalism. The Service would implement site clearance protocols for all visitation by the general public, volunteers, and researchers.

3.5.4 Alternative C – Minor Improvements in Water Resource and Habitat Management and Minor Increase in Visitor Services

Alternative C would include the management actions identified in the "Features Common to All Alternatives" section, actions identified under Alternatives A and/or B, and some additional actions for Refuge management. Activities that would not be implemented under this alternative are also noted; these actions would achieve different goals than those this alternative is targeting. The actions are summarized for this alternative in Figure 3.5-3.

Wetland Habitat

In addition to the management actions identified previously for open water habitat, the Service would identify actions to encourage carp management on private and state-managed lands upstream of the Refuge.

In addition to the vegetation control methods identified under Alternative B, the Service would expand invasive species management efforts to control salt cedar and other species in the Lower Pahranagat Lake area. Implementation of invasive species management would continue to be a priority for the Refuge. IPM efforts would be coordinated with upstream property owners to reduce the extent of invasive plants and noxious weeds and minimize their potential to return to the Refuge.

The Service would implement a species Inventory and Monitoring Plan for marsh birds, waterfowl, and shorebirds to gather more information on the species that use the Refuge. In addition, the Service would conduct surveys every three years of birds and bats and add spring and fall surveys and breeding pair and brood counts to current fall and winter surveys coordinated with NDOW. Sandhill crane use would also be monitored.

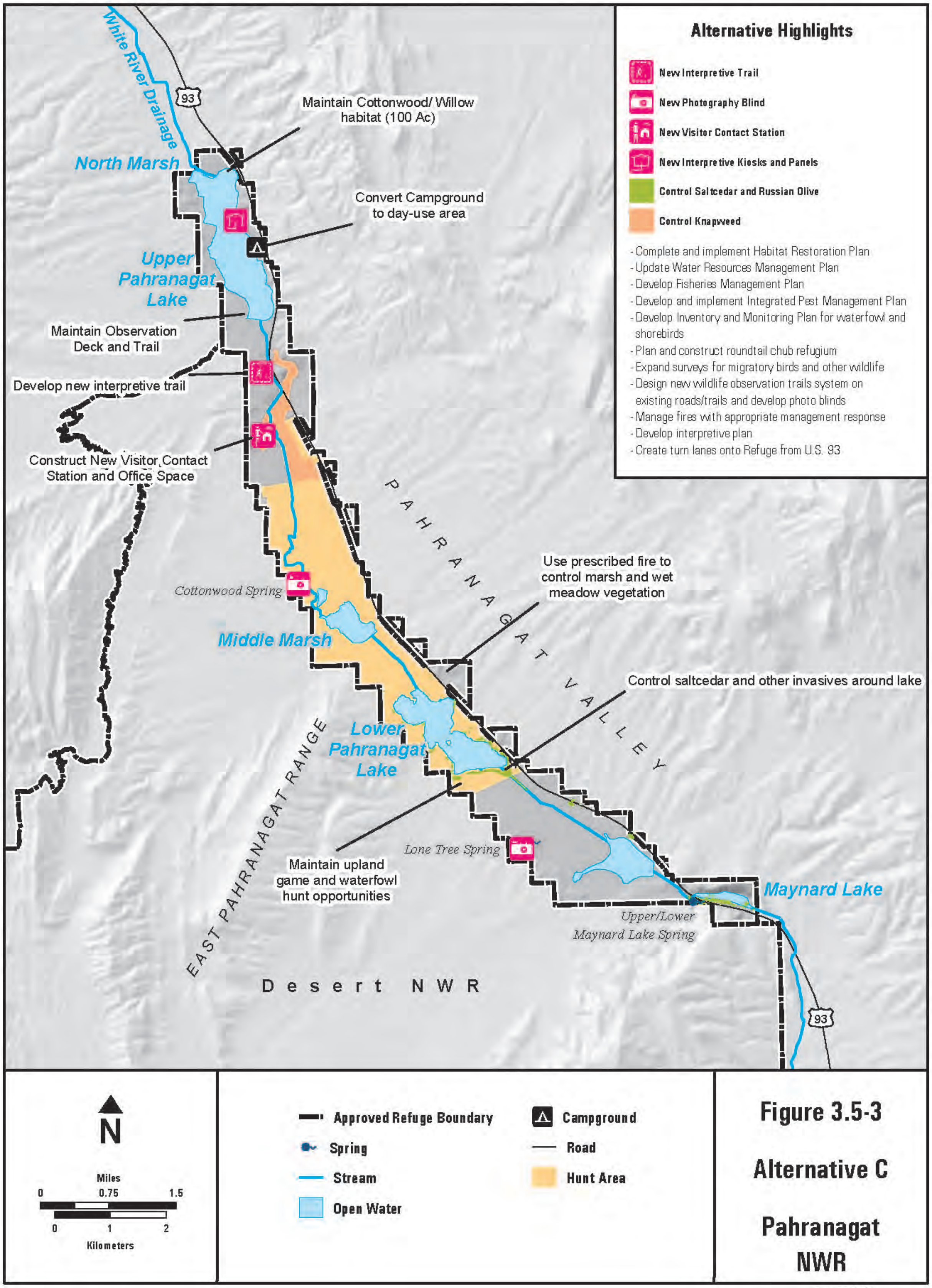

Figure 3.5-3

Alternative C

Pahranagat NWR

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Figure 3.5-3-pahranagat_alt_C.mxd

To improve water resources management, the Service would determine the status of groundwater wells on record and repair or abandon them as appropriate. As necessary, the Service would apply for changes in point of use with the Nevada Division of Water Resources. Water infrastructure on the Refuge would also be repaired as staffing and funding allow. Gauges and data-logging equipment would also be installed at springs adjacent to Middle Marsh.

Wildlife Diversity

To improve habitat for the southwestern willow flycatcher, the Service would monitor the response of birds to habitat restoration activities by surveying the habitats after restoration.

The Restoration and Management Plan recommendations for spring pools and channels would be implemented to restore habitat in those areas and increase species diversity.

Bird responses to fishing activities would also be monitored, and sensitive areas would be closed as necessary during appropriate seasons. Upland habitat would also be inventoried and monitored on a regular basis, and physical barriers would be installed to prevent vehicle traffic in closed areas and protect sensitive resources, such as wildlife, plants, and cultural resources.

Visitor Services

The Service would improve visitor services on the Refuge and implement an Interpretive Plan. The campground would be converted to a day use area. Visitor facilities would be improved and maintained for visitor safety, including constructing an interpretive walking trail that connects Upper Pahranagat Lake with the Headquarters Unit, constructing a new visitor contact station and office space at the Headquarters Unit, constructing additional parking at the Headquarters Unit, and constructing photography and observation blinds along the trail route.

To improve public access and awareness of the Refuge, the Service would install directional signs along U.S. Highway 93 and I-15 with assistance from the NDOT. Also, turn lanes would be created along the highway in coordination with NDOT to allow visitors to safely turn onto the Refuge.

The Service would increase public outreach through participation in up to six activities throughout the year.

Cultural Resources

To improve cultural resources management on the Refuge, the Service would inventory cultural resources and evaluate their historic or prehistoric significance.

The Service would implement the following actions:

- Conduct cultural resource inventories at all public use areas, roads, affected areas, and other destinations on the Refuge and evaluate any discovered sites' eligibility for listing on the NRHP;
- Develop historic contexts for classes of cultural resources;
- Inventory, evaluate, and nominate Traditional Cultural Properties and sacred sites to the National Register, in consultation with affiliated tribes;
- Identify, evaluate, and mitigate adverse effects and stabilize selected cultural resource sites on the Refuge using a Cultural Resources Management Plan prepared in consultation with affiliated tribes; and
- Use data collected on site locations and information for planning, monitoring, and interpretation efforts related to cultural resources.

The Service would continue to work with affiliated Native American tribes on projects to restore native habitat and allow harvesting of native plants (for traditional non-commercial purposes).

The Service would create and implement a site stewardship volunteer program to assist in monitoring and protection. This program would use volunteers to assist in delivery of educational and interpretive literature and programs, and to promote cultural resources conservation in neighboring communities.

3.5.5 Alternative D – Moderate Improvements in Water Resource and Habitat Management and Moderate Increase in Visitor Services

Alternative D is the preferred alternative. It involves the actions identified in the "Features Common to All Alternatives" section, some management actions from the other two action alternatives, and additional actions not discussed previously. Some activities from Alternatives B and C are expanded under this alternative to improve Refuge management, while others are reduced. Activities that would not be implemented under this alternative are also noted; these actions would achieve different goals than those this alternative is targeting. The actions are summarized for this alternative in Figure 3.5-4.

Wetland Habitat

The Service would model climate change impact scenarios and develop adaptation strategies.

The Service would acquire additional water rights from willing sellers and explore opportunities for additional water supplies.

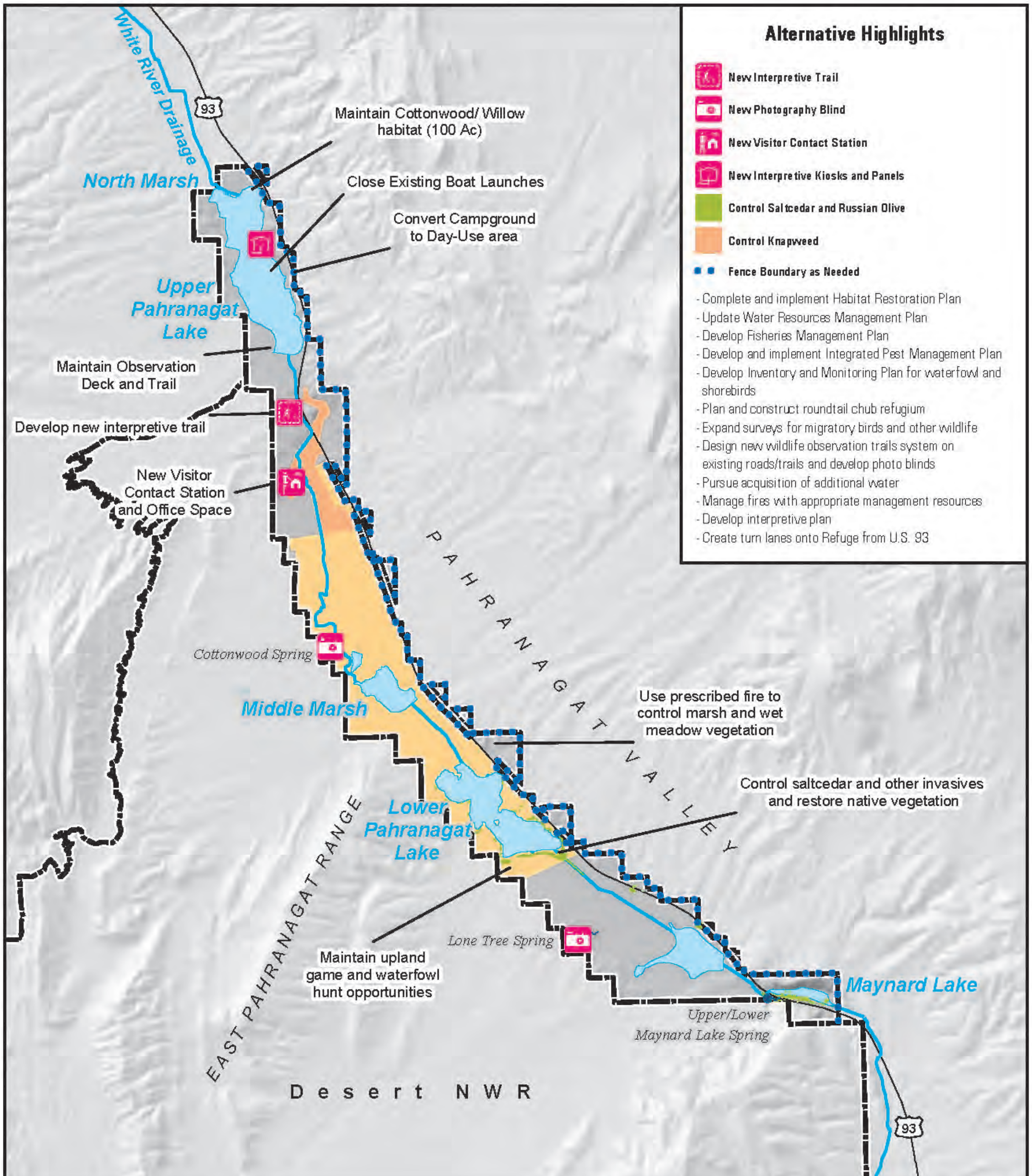

Figure 3.5-4

Alternative D

Pahranagat NWR

June 11, 2009
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The Service would monitor vegetation and wildlife responses to habitat management actions and modify their actions appropriately to minimize adverse effects. In addition to monitoring responses to habitat management, the Service would seek funding to monitor avian species abundance in wet meadow habitat and elsewhere to determine their responses to habitat manipulation during the fall and spring migration periods. Surveys of nesting colonial waterbirds would also be conducted every three years.

Wildlife Diversity

In addition to the management actions identified under the "Features Common to All Alternatives" section and Alternative B, the Service would restore native upland habitat adjacent to Lower Pahranagat Lake. To protect the Refuge's habitats and resources and prevent encroachment, a fence would be installed along the eastern boundary.

Visitor Services

The Service would not improve visitor services beyond those management actions identified under the other alternatives; however, the campground area would be converted to a day use area, as identified under Alternative C. The boat ramps in the campground area would be closed, and a new car-top boat launch would be designated. Use of boat ramps poses a concern with the introduction of quagga mussels, an invasive mollusk known to be present at Lake Mead and other major water bodies in southern Nevada (Benson et al. 2008). Use of car-top boat launches would reduce the risk of introducing quagga mussels by eliminating the types of boats that typically carry the mussels.

The Service would develop new wildlife observation structure(s). Public outreach would be implemented within three years.

Cultural Resources

In addition to management actions identified under the other alternatives, the Service would identify and evaluate cultural resources that could educate visitors on how humans have interacted with wildlife and habitats in the past, and they would consult with affiliated tribes and other stakeholders on ways to use these resources to achieve educational, scientific, and traditional cultural needs. The Service would also conduct a study of ethnobotany and traditional plant use on Pahranagat NWR through assistance and consultation with the affiliated Native American tribes.

3.5.6 Comparison of Alternatives

A comparative summary of the alternatives for the Pahranagat NWR is found in Table 3.6-4.

3.5.7 Management Actions Considered but Eliminated from Detailed Analysis as Part of Alternatives

During the alternatives development process, Refuge staff evaluated additional management actions as part of the current alternatives. These actions are identified below with their reasons for elimination:

- Develop additional areas for camping to expand the allowable limit. (Not feasible.)
- Plant and maintain riparian vegetation around Lower Pahranagat Lake. (Soils not suitable.)

3.6 Comparison of Alternatives

The following tables provide a comparison of each of the alternatives for each refuge in the Desert Complex. Additional details on the preferred alternatives, including rationale explaining management actions and additional information on cooperation with other agencies, are provided in Appendix F.

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	*Management Actions* Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
Species Management			
Gather Baseline Population Data	■ Conduct baseline inventories on vegetation communities, small mammals, herpetofauna, and pollinators ■ Complete a four-year baseline inventory and monitoring for endemic fish species, a three-year baseline inventory and monitoring for the southwestern willow flycatcher, and a two-year refuge-wide reptile survey	Same as Alternative A and: ■ Complete baseline inventory on listed invertebrates, non-native fish, and non-listed endemic invertebrates ■ Implement monitoring for all listed endemic species, non-native species that adversely affect endemic species, and game species	Same as Alternative B and: ■ Complete inventory of non-native and native species diversity and distribution ■ Implement monitoring for all non-listed endemic and game species
Special-Status Species Management	■ Continue current monitoring strategies for special-status plants and wildlife ■ Monitor changes in the environment that may be a result of climate change	Same as Alternative A and: ■ Restore Ash Meadows speckled dace to 5%–25% of historic Refuge range through habitat restoration and translocation ■ Double the current range of the Ash Meadows naucorid population to minimum of 20–40 square meters ■ Restore Point of Rocks spring outflow channel habitat to known suitability for Ash Meadows naucorid and monitor parameters ■ Identify suitable areas for range expansion of endemic plant populations within 10 years ■ Within 15 years begin out planting endemic plants to suitable habitats ■ Complete a feasibility study for construction of an on-site greenhouse	Same as Alternative B, except: ■ Restore endemic fish populations to 25%–50% of historic Refuge range

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	*Management Actions* — *Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
Endemic Fish Refugia	▪ Construct refugia for both Devils Hole pupfish and Warm Springs pupfish ▪ Maintain and monitor the newly established pupfish refugia ▪ Conduct quarterly fish counts and periodic water quality measurements	Same as Alternative A and: ▪ Investigate the use of private aquaria as refugia ▪ Update MOU with NDOW, Ecological Services, and NPS on management responsibilities under the Ash Meadows Recovery Plan	Same as Alternative B and: ▪ Reestablish Ash Meadows speckled dace to historic habitats after restoration of springs and streams is complete ▪ Complete a feasibility assessment of refugia for all other Ash Meadows NWR endemic species
Habitat Protection	▪ For the 30 known Refuge springs, protect and maintain existing water flows (17,000 acre feet per year) and natural temperature range ▪ Continue to monitor and assess water flows, levels, and temperatures at springs and wells identified in the current Water Monitoring Plan ▪ Analyze water quality and quantity biannually ▪ Use a variety of tools to defend water rights and mitigate substantial changes in temperature or flow, including the State Engineer's water rights process ▪ Maintain the existing spring outflow structures and stream channels at monitoring sites ▪ Maintain current level of enforcement measures to protect plants and wildlife ▪ Maintain existing boundary fence as a wild horse exclosure ▪ Repair post-and-cable barriers and install other barriers where needed to	Same as Alternative A and: ▪ Establish permanent, long-term vegetation monitoring plots/transects ▪ Within 10 years of CCP approval, obtain baseline data for 17 springs identified in the Refuge Geomorphic and Biological Assessment ▪ Increase law enforcement to prevent off-highway vehicles, fires, collecting of species, and other inappropriate activities ▪ Add road gates as needed to prevent unauthorized use of roads and resource damage ▪ Use prescribed fire where appropriate to create, improve, or maintain desired plant and animal communities, as well as to treat hazardous fuels	Same as Alternative B

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	Management Actions Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
	protect resources ■ Replace or add gates on service or fire roads and post signs on them ■ Maintain closure of nonessential roads ■ Continue fuel reduction projects and maintain current fuel breaks ■ Manage wildland fires on the Refuge using the AMR, which considers resource values at risk and potential negative impacts of various fire suppression measures; firefighter and public safety will be the highest priority on every incident ■ Improve Refuge-wide vegetation map through ground surveys and updating of GIS layers and initiate long-term, annual vegetation monitoring		
Restoration			
Landscape/Hydrologic Restoration	None	■ Assess and initiate removal of berms, ditches, dams, impoundments, and unnecessary roads within the Warm Springs, Jackrabbit/Big Springs, and Upper Carson Slough Management Units to restore natural hydrology on a landscape scale ■ Design and construct fish barriers to control movement of invasive fish	Same as Alternative B and: ■ Assess and initiate removal of berms, ditches, dams, impoundments, and unnecessary roads within the Crystal Springs Unit to restore natural hydrology on a landscape scale ■ Inventory, assess, and mitigate landscape disturbances including graded lands, mines, fences, and other disturbances ■ Implement the plan for the modification or removal of Crystal Reservoir that minimizes adverse environmental impacts

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	Management Actions Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
Spring/Channel Restoration	▪ Complete and implement Restoration Plans for Upper Point of Rocks, Jackrabbit Spring, and the Warm Springs Unit (North and South Indian Springs and School Springs) ▪ Develop a restoration plan for Crystal Spring Unit by 2011 ▪ Remove invasive plants and exotic aquatic species ▪ Seed and plant native vegetation ▪ Manipulate and enhance substrate ▪ Remove hydrologic barriers	Same as Alternative A and: ▪ Manage and monitor previously restored springs ▪ Complete and implement the Restoration Plans for Lower Point of Rocks, Lower Kings Pool, Big, Fairbanks, and remaining springs in the Warm Springs Complex	Same as Alternative B and: ▪ Develop and implement restoration plans for Tubbs, Bradford, Crystal, and Forest springs ▪ Based on outcome of Carson Slough Restoration Plan, develop and implement Restoration Plans for Longstreet and Rogers Springs
Native Plant Community Restoration		Same as Alternative A, except: ▪ Restore approximately 520 acres of alkali/wet meadow, 220 acres of mesquite bosque/lowland riparian, 30 acres of native upland, and 150 acres of emergent marsh in the Warm Springs Complex, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs Units by restoring natural hydrology and actively revegetate appropriate areas based on outcome of Transportation Plan, cultural investigations, and linear disturbance assessment ▪ Rehabilitate 30%–45% of old agricultural fields by removing hydrologic barriers, controlling invasive species, and planting native plants ▪ Maintain 3,935 acres of alkaline meadow/wet meadow habitat, 5,500–	Same as Alternative B, except: ▪ Restore approximately 650 acres of alkali/wet meadow, 550 acres of mesquite bosque/lowland riparian, 30 acres of native upland, and 150 acres of emergent marsh in the Warm Springs Complex, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs Units by restoring natural hydrology and actively revegetate appropriate areas based on outcome of Transportation Plan, cultural investigations, and linear disturbance assessment ▪ Rehabilitate 40%–65% of old agricultural fields by removing hydrologic barriers, controlling invasives species, and planting native plants ▪ Maintain 7,850 acres of alkaline meadow/wet meadow habitat, 11,000-

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	Management Actions: Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
	■ Develop restoration plan for Carson Slough	5,750 acres of native upland desert plant communities, and 1,000 acres of mesquite bosque habitat in the Warm Springs Complex, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs Units by restoring natural hydrology and actively revegetate appropriate areas ■ Maintain and monitor habitats on a regular basis after restoration activities are complete	11,500 acres of native upland desert plant communities, and 2,000 acres of mesquite bosque habitat in the Warm Springs Complex, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs Units by restoring natural hydrology and actively revegetate appropriate areas
Pest Management	■ Maintain current management for invasive plant and wildlife, responding to greatest threats on a project-by-project basis	Same as Alternative A and: ■ Use IPM techniques for long-term non-native fish management ■ Control non-native invasive plants, prioritizing areas with listed plant species, and monitor the response of listed plant species ■ Minimize and control impacts on aquatic habitat due to cattail growth ■ Within 10 years, reduce salt cedar and Russian knapweed distribution by between 50% and 75% of the 2006 distribution on 4,000 acres of Refuge land and work with BLM to control salt cedar and Russian knapweed on adjacent BLM land ■ Coordinate with the Service's Private Lands Program to assist private landowners with the removal of salt cedar and planting native species within the Refuge boundary	Same as Alternative B, except: ■ Evaluate alternative pest control strategies (sterilization, biological control) in cooperation with other agencies ■ Within 10 years, reduce salt cedar and Russian knapweed distribution by between 75% and 95% of the 2006 distribution on 4,000 acres of Refuge land and work with BLM to control salt cedar and Russian knapweed on adjacent BLM land ■ Aggressively trap and remove crayfish from spring and channel habitat from 10 spring systems (Marsh, N & S Indian, N & S Scruggs, Jackrabbit, Kings, Point of Rocks, Big, Crystal, and Bradford springs) ■ Install temporary fish barriers until bass eradication is complete at Big and Jackrabbit springs

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	Management Actions Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
		▪ Implement non-native plant species control as outlined in the IPM Plan for all habitat types ▪ Reduce or contain crayfish populations Refuge-wide such that current distributions are not exceeded ▪ Regularly trap and remove crayfish from spring habitat ▪ Focus on 10 most infested and important Refuge aquatic systems and expand program as necessary ▪ Implement other crayfish control strategies identified during development of the IPM Plan ▪ Evaluate current land uses such as utility corridors and ensure regulatory compliance	▪ Remove cattails from outflow channels at Kings, Point of Rocks and Crystal springs
Land Conservation	▪ Complete the pending land and mineral withdrawal with the BLM ▪ Continue ongoing efforts to acquire remaining lands within the authorized Refuge boundary from willing sellers ▪ Continue coordination with private landowners to protect Refuge resources	Same as Alternative A and: ▪ Establish conservation agreements or acquire in-holdings from willing sellers	Same as Alternative B
Research			
Research	▪ Continue to allow research activities by others on a case-by-case basis using special use permits	Same as Alternative A and: ▪ Expand research on Refuge to include: ecology and management of invasive species; taxonomy, ecology, and management of rare and endemic species; ecosystems; historic and	Same as Alternative B and: ▪ Substantially expand research on the topics listed under Alternative B ▪ Within 15 years of CCP approval, complete a feasibility study of the need for an on-site research facility; if

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Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	Management Actions: Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
		current plant community diversity, composition, and structure and role of natural processes (fire, flood, drought); wildlife-habitat relationships	appropriate, construct the facility ▪ Model climate change impact scenarios and develop adaptation strategies
Visitor Services			
Environmental Education and Outreach	▪ Continue existing, limited environmental education activities ▪ Develop environmental education materials with assistance of Desert Complex staff on a project-by-project basis ▪ Assess visitor education needs and opportunities through informal contact with visitors ▪ Provide off-Refuge educational outreach to the local public on the value of Ash Meadows NWR for wildlife and the public, as requested and depending on staff availability	Same as Alternative A, except: ▪ Develop and begin implementing an Environmental Education Plan by 2010 ▪ Incorporate environmental education goals of relevant plans ▪ Contact local schools and provide at least 3–5 on-site programs a year ▪ Work with partners to develop off-site refugium for pupfish to promote awareness of the endangered pupfish and other endemic species at the Refuge ▪ Provide off-Refuge educational outreach in 2–3 local community events annually ▪ Develop an educational video on the endemic fish and other wildlife of Ash Meadows ▪ Develop education and interpretation materials with affiliated tribes	Same as Alternative B, except: ▪ Develop and implement an Environmental Education Plan by 2010 ▪ Develop cooperative agreements with public, non-government entities and private partners to provide off-Refuge educational outreach to the local public on the value of the Refuge for wildlife and the public ▪ Provide 3 off-site programs
Wildlife Observation and Interpretation	▪ Develop interpretive materials with the assistance of the Regional Office and Desert Complex on a project-by-project basis ▪ Design and construct boardwalks to follow Kings Pool Stream from parking lot to Kings Pool, with a pool	Same as Alternative A and: ▪ Develop multilingual interpretative materials and construct new interpretive facilities at Point of Rocks, Longstreet, and Crystal Springs and entrances to the Refuge.	Same as Alternative B, except: ▪ Staff visitor contact station five days per week

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	Management Actions Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
	overlook ▪ Design and construct interpretative displays for new boardwalks to be installed at Point of Rocks ▪ Design and construct interpretative panels for the new boardwalk and overlook at Longstreet Spring pool ▪ Maintain designated roads and visitor use areas ▪ Maintain Spring Meadows Road and allow non-commercial through traffic ▪ Improve Point of Rocks and Longstreet Cabin parking areas ▪ Begin implementing the Ash Meadows NWR Interpretation Plan ▪ Maintain current visitor services for wildlife-dependent recreational activities in accordance with existing Public Use Management Plan ▪ Conduct a study of Refuge visitation to determine the number and purpose of visits ▪ Improve signs on Refuge boundary ▪ Include sensitive plant and pupfish life history information in Refuge brochures, fact sheets, and maps	▪ Within five years of funding, complete design and construction of a new Refuge headquarters/visitor contact station building ▪ Design and construct interpretive facilities identified in the Interpretive Plan ▪ Staff visitor contact station seven days per week ▪ Develop and begin implementing a comprehensive Visitor Services Plan by 2010 ▪ Improve existing roadways and parking areas to good condition as described in the Ash Meadows Refuge Roads Inventory (2004), based on Geomorphic and Biological Assessment	
Hunting	▪ Continue hunt program under the interim Hunt Plan until a revised Hunt Plan is completed ▪ Allow access by boat for waterfowl hunting ▪ Provide opportunities for waterfowl	Same as Alternative A, and: ▪ Obtain baseline information on Refuge hunting and within three years create a hunting step-down plan ▪ Monitor hunting use on the Refuge ▪ Restrict or eliminate boat use on the	Same as Alternative B

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

Issue Area	Management Actions: Alternative A (No Action)	Management Actions: Alternative B	Management Actions: Alternative C (Preferred Alternative)
	and upland game hunting on the entire Refuge	Refuge	
Cultural Resources			
Management and Protection	▪ Continue informal outreach on cultural resources to visitors that stop at the visitors contact station ▪ Collect cultural resources background information on a project-by-project basis ▪ Continue to inventory, manage, and protect cultural resources on a case-by-case basis	▪ Prepare evaluation criteria and conduct a cultural resource inventory at all visitor facilities and areas that would be affected by Refuge projects ▪ Inventory, evaluate, and mitigate adverse effects, and stabilize samples of cultural resources on the Refuge using a research design prepared in consultation with culturally affiliated tribes and the scientific community ▪ Identify and evaluate cultural resources subject to looting/vandalism, erosion, or deterioration, and implement steps, including barriers and signs, to reduce these threats and preserve the resources ▪ Implement projects to restore habitats associated with important native plants and to harvest native plant foods (for traditional, non-commercial purposes) in coordination with culturally affiliated tribes ▪ Inventory, evaluate, and nominate Traditional Cultural Properties and sacred sites to the NRHP in consultation with tribes ▪ Conduct a study of ethnobotany and traditional plant use on Ash Meadows NWR in consultation with tribes ▪ Create and implement a site stewardship volunteer program to	Same as Alternative B

Table 3.6-1. Ash Meadows NWR: CCP Alternatives

	Management Actions		
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
		assist in site monitoring, educational and interpretive programs, and to promote cultural resources conservation in neighboring communities	

Table 3.6-2. Desert NWR: CCP Alternatives

Issue Area	*Management Actions* *Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Bighorn Sheep				
Habitat Management	▪ Maintain all existing water sources (springs and catchments)	Same as Alternative A	Same as Alternative A, except: ▪ Remove vegetation around catchments as needed to protect from wildfires and limit cover for bighorn sheep predators ▪ Construct additional rainwater catchments if existing sources are inadequate	Same as Alternative C
Habitat Protection	▪ Install signs, barricading, and fencing ▪ Conduct law enforcement patrols to prevent unauthorized uses (e.g., off-road vehicles)	Same as Alternative A	Same as Alternative A	Same as Alternative A
Population Management	▪ Prevent domestic livestock grazing on the Refuge to minimize potential for disease transmission ▪ Set hunt permit limits based on population levels and herd health	Same as Alternative A and: ▪ Translocate sheep to the Refuge from outside sources to maintain and restore sub-populations	Same as Alternative B and: ▪ Develop and implement a Sheep Management Plan ▪ Develop a formal agreement with NDOW covering sheep management on the Refuge	Same as Alternative C and: ▪ Translocate sheep to and from the Refuge as needed to maintain desert bighorn sheep subpopulations and genetic diversity
Surveys	Conduct one fall helicopter survey per mountain range to estimate adult sex ratio, ram age structure, lamb survival/recruitment, and population size	Same as Alternative A and: ▪ Conduct yearly spring helicopter survey to identify bighorn sheep lambing and recruitment sites	Same as Alternative B	Same as Alternative B

Table 3.6-2. Desert NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Research and Monitoring	■ Continue to allow research on the Refuge through special use permits	Same as Alternative A and: ■ Determine connectivity between sheep subpopulations using historical records, sightings, and radio tracking data	Same as Alternative B and: ■ Conduct radio telemetry study to assess bighorn sheep mortality factors, home ranges, and habitat utilization ■ Collect blood and fecal samples to determine general health status of herd, diet composition, nutrient uptake, and genetic diversity ■ Monitor vegetation response to burns on the Refuge	Same as Alternative C
Wildlife Diversity				
Baseline Inventories, Monitoring, and Research	■ Conduct surveys for special-status species on a project-by-project basis ■ Continue monitoring the health of the Pahrump poolfish population in the refugium ■ Maintain a record of raptors observed during helicopter surveys for bighorn sheep ■ Continue invasive weed surveys and treatments ■ Monitor changes in the environment that may be a result of climate change	Same as Alternative A and: ■ Conduct regular bird surveys at Corn Creek Field Station	Same as Alternative B and: ■ Establish permanent plots in plant communities throughout the Refuge and inventory plant and animal species composition and abundance every five years in those plots ■ Conduct surveys for special-status species on the Refuge ■ Develop and implement an Inventory and Monitoring Plan for special-status species ■ Model climate change impact scenarios and develop adaptation strategies ■ Regularly monitor flow rates for springs throughout the Refuge	■ Same as Alternative C
Resource Protection	■ Maintain designated roads	Same as Alternative A and:	Same as Alternative B and:	Same as Alternative C and:

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Table 3.6-2. Desert NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
	and visitor use areas ▪ Maintain and replace regulatory signs along boundaries and designated roadways ▪ Promote awareness of and solicit support for efforts to combat trespassing and resulting impacts along the southern boundary ▪ Manage wildland fires on the refuge using an AMR that considers resource values and Service and Air Force assets at risk and potential negative impacts of various fire suppression measures. Response may range from monitoring high elevation fires to full suppression. Firefighter and public safety will be the highest priority for every incident, regardless of other resources at risk ▪ Continue utilization of volunteers for habitat restoration and maintenance efforts ▪ Continue monitoring well water use and spring discharge at Corn Creek ▪ Use a variety of tools to defend water rights and	▪ Use aerial photography, satellite imagery, and/or GPS to monitor damage caused by off-road vehicle trespass ▪ Construct and maintain post-and-cable fencing along the southern boundary, with consideration for desert tortoise movement ▪ Expand litter removal efforts using staff and volunteers ▪ Increase law enforcement presence and patrols with an emphasis on the southern boundary	▪ Fence and maintain the eastern boundary where necessary ▪ Increase law enforcement patrols throughout the Refuge with an emphasis on the eastern boundary ▪ Develop and implement a plan to close illegal roads and rehabilitate damaged habitat along the southern boundary ▪ Designate one point of entry on the southeast boundary of the Refuge in addition to the entrance at Corn Creek Field Station ▪ Coordinate with local jurisdictions to ensure development adjacent to boundary is compatible (greenbelt, walled residential) ▪ Promote awareness of and solicit support to combat Endangered Species Act violations along the boundaries ▪ Install boundary signs at regular intervals along the entire southern, eastern, and northern boundaries	▪ Construct and maintain fence along northwest boundary of East Pahranagat Range Unit

Table 3.6-2. Desert NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
	mitigate substantial changes in temperature or flow, including the State Engineer's water rights process ▪ Pursue renewal of mineral withdrawal ▪ Participate in programmatic EIS development process relating to proposed energy corridor to evaluate impacts to Refuge resources			
Wildlife and Habitat Management	▪ No current pinyon-juniper habitat management ▪ Remove any wild horses or burros that occur on the Refuge as soon as possible ▪ Restore wetland and spring habitats at Corn Creek	Same as Alternative A	▪ Use prescribed fire and naturally ignited fires in appropriate plant communities to restore vegetation characteristics representative of a natural fire regime. Wildland fires may be concurrently managed for one or more objectives ▪ Consider habitat needs of special-status species, such as Gilbert's skink and pinyon jay and gray vireo, when doing prescribed burns in pinyon-juniper habitat ▪ Consider reestablishing Pahrump poolfish at Corn Creek if suitable habitat is available and is compatible with management objectives	Same as Alternative C

Table 3.6-2. Desert NWR: CCP Alternatives

Issue Area	Management Actions: Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)	Alternative D
			■ Maintain and monitor habitats on a regular basis after restoration activities are complete ■ Prepare Integrated Pest Management Plan and associated NEPA compliance	
Specially Designated Areas				
DOD-withdrawn Lands	■ Work with USAF to update the existing MOU ■ Maintain access restrictions on DOD-withdrawn lands.	Same as Alternative A	Same as Alternative A	Same as Alternative A
RNAs	No research or monitoring in RNAs	Develop research and management program for RNAs: ■ Survey and mark all RNA boundaries ■ Conduct photographic reconnaissance and documentation of all RNAs ■ Use RNAs as control for monitoring effects of habitat management in other areas of Refuge	Same as Alternative B and: ■ Submit request to Service Director to de-designate Papoose Lake RNA ■ Encourage academic and agency scientists to conduct non-manipulative research in the RNAs	Same as Alternative B and: ■ Submit request to Service Director to de-designate Papoose Lake RNA
Wilderness	Protect and maintain the wilderness character of the proposed 1.37 million–acre Desert Wilderness Area until Congress acts on proposal: ■ Prohibit all motorized activities within the proposed wilderness unless	Same as Alternative A	Same as Alternative A	Same as Alternative A

Table 3.6-2. Desert NWR: CCP Alternatives

Issue Area	*Management Actions* *Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
	authorized by stipulations in 1974 proposal or an approved minimum tool analysis ▪ Submit recommendation to technically correct the wilderness proposal to correct overlap with bombing range, allow repair/relocation of hazardous sections of roads, and allow use of helicopters to repair/maintain water developments and access remote areas for wildlife surveys			
Visitor Services				
Environmental Education and Interpretation	Provide opportunities to support up to 100,000 visits per year: ▪ Maintain and replace interpretive signs (visitor contact station, trails, and refugium) and update sign content as needed ▪ Continue using Southern Nevada Interpretive Association volunteers to provide interpretation and environmental education programs for visitors ▪ Use volunteers as available to provide interpretation and guidance to visitors at	Same as Alternative A and: ▪ Expand volunteer program on Refuge with a target of staffing visitor center full-time during peak use and 4 hours/day during other seasons ▪ Create environmental education program using funding from Southern Nevada Public Lands Management Act ▪ Establish seasonal volunteer resident host/docent at Desert Pass campground ▪ Develop and install interpretive panels and signs at designated	Same as Alternative B and: ▪ Provide educational materials to the public about the use of fire in habitat management	Same as Alternative B, except: ▪ Expand volunteer program to staff visitor contact station/visitor center full-time during peak use periods and four hours/day on weekends during other seasons ▪ No docent at campground

Table 3.6-2. Desert NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
	Corn Creek Field Station ■ Complete planning, design, and construction of a visitor center and office space at Corn Creek Field Station	entry points ■ Develop live "sheep cam" at water development and stream video through Web site and to visitor contact station/visitor center ■ Develop cultural resources interpretive and environmental education materials in coordination with affiliated Native American tribes		
Outreach	■ Participate in two major community events annually ■ Provide information at the visitor center and appropriate signs regarding the closure of the portion of Refuge within the NTTR due to safety and security reasons	Same as Alternative A and: ■ Participate in three major community events annually ■ Develop and install a permanent environmental education/interpretive display at a prominent public venue ■ Conduct an annual public open house ■ Develop and distribute a Refuge video ■ Prepare and distribute an annual Congressional briefing ■ Develop a quarterly Refuge newsletter ■ Conduct annual surveys to measure program effectiveness	Same as Alternative B	Same as Alternative A and: ■ Conduct an annual public open house ■ Prepare and distribute an annual Congressional briefing

Table 3.6-2. Desert NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Wildlife Observation and Photography	■ Maintain visitor facilities (Mormon Well and Alamo Roads, parking areas, camping/picnic area) ■ Maintain and replace regulatory, directional, and interpretive signs as needed	Same as Alternative A and: ■ Improve and maintain Mormon Well and Alamo Road to “fair” condition ■ Use post-and-cable fencing to designate parking turnouts along Alamo, Mormon Well, and Gass Peak Roads ■ Construct an entrance sign and information kiosk at the east end of Mormon Well Road ■ Plan, design, and develop site-specific NEPA documentation for an auto tour route on Gass Peak Road from Corn Creek to SR 215 ■ Map existing trails in Gass Peak and Sheep Range Units using GPS, develop guide for visitors, and manage trails to minimize impacts to sheep ■ Evaluate and develop new wildlife viewing trails in the Gass Peak and Sheep Range Units; design and site trails to minimize maintenance costs and impacts to sheep ■ Plan and construct photography blinds ■ Evaluate the management benefits resulting from a recreation-fee program	Same as Alternative B, except: ■ No auto tour route or wildlife viewing trails in Gass Peak or Sheep Range Units	Same as Alternative C, except: ■ No road improvements ■ No mapping of trails and no recreation-fee program

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Table 3.6-2. Desert NWR: CCP Alternatives

Issue Area	Management Actions Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)	Alternative D
Hunting	Provide safe opportunities for hunting bighorn sheep on the Refuge: ■ Continue current NDOW-managed hunt program based on annual population surveys ■ Provide Refuge-specific and NDOW hunting guidelines and regulation materials to the public at the Refuge headquarters	Same as Alternative A and: ■ Conduct annual surveys and reporting of game species population numbers and the number of hunters and species harvested in coordination with NDOW ■ Post and maintain designated hunting area signs on Refuge	Same as Alternative B	Same as Alternative B
Cultural Resources				
Cultural Resources Management	■ Continue to manage and protect cultural resources on the Refuge on a project-by-project basis prior to land-disturbing projects to comply with applicable laws and regulations ■ Continue to provide appropriate interpretive information on cultural resources to visitors at the field station through informal outreach	Manage cultural resources in compliance with federal regulations: ■ Compile all existing baseline data on cultural resources sites, surveys, and reports within and near the Refuge, and create secure digital, GIS, and hard copy databases, maps, and a library ■ Incorporate cultural resource values, issues, and requirements into design and implementation of the other habitat, wildlife, and visitor service activities and strategies conducted by the Desert Complex ■ Create a cultural resource layer in the Desert Complex GIS database that aids in the	Same as Alternative B and: ■ Prepare evaluation criteria and conduct a cultural resource inventory at all visitor facilities and areas that would be affected by Refuge projects ■ Inventory, evaluate, and mitigate adverse effects, and stabilize samples of cultural resources on the Refuge using a research design prepared in consultation with culturally affiliated tribes and the scientific community ■ Inventory, evaluate, and nominate Traditional Cultural Properties and sacred sites to the NRHP in consultation with tribes	Same as Alternative C

Table 3.6-2. Desert NWR: CCP Alternatives

Issue Area	*Management Actions* Alternative A (No Action)	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
		identification, planning, monitoring, and interpretation of cultural sites	■ Conduct a study of ethnobotany and traditional plant use on Ash Meadows NWR in consultation with tribes	
Education and Outreach	Provide minimal public outreach: ■ Continue informal outreach on cultural resources to visitors that stop at the visitor center	Manage cultural resources and cultural resource information for research, education, and interpretation: ■ Incorporate cultural resources information into education and interpretive programs and media ■ Identify and evaluate cultural resources that can educate Refuge users on how humans have interacted with wildlife and habitats in the past ■ Use appropriate cultural resources to achieve educational, scientific, and traditional cultural needs ■ Identify potential priority cultural sites on the non-military overlay of the Refuge and survey and record the sites ■ Implement projects to restore habitats of important native plants and to harvest (for traditional, non-commercial purposes) native plant foods in coordination with the tribes	Same as Alternative B	Same as Alternative A

Table 3.6-2. Desert NWR: CCP Alternatives

Issue Area	Management Actions: Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)	Alternative D
		▪ Design and implement educational materials, programs, and activities that would address traditional or sacred resources to increase awareness on- and off-Refuge about the sensitivity of cultural resources to visitor impacts and the penalties for vandalism		
Protection	▪ Continue to protect any cultural and historic resources on the Refuge on a project-by-project basis to comply with applicable laws and regulations	Implement measures to protect cultural resources: ▪ Identify and evaluate cultural resources subject to looting/vandalism, erosion, or deterioration, and implement steps, including barriers and signs, to reduce these threats and preserve the resources ▪ Implement cultural resources monitoring and enforcement activities to decrease impacts on cultural resources ▪ Create and implement a site stewardship volunteer program to assist in site monitoring, educational and interpretive programs, and to promote cultural resources conservation in neighboring communities	Same as Alternative B	Same as Alternative B

Table 3.6-3. Moapa Valley NWR: CCP Alternatives

Issue Area	Management Actions Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
Endemic and Special-Status Species			
Habitat Restoration	Implement measures to restore habitat on the Refuge: ▪ Restore native overstory, mid-level, and understory vegetation (using local seed and/or seedlings) in riparian corridors, transitional upland sites, and any disturbed or newly exposed areas on the Pedersen Unit ▪ Consider habitat needs of other special-status fish and invertebrates when designing and implementing restoration projects (Moapa White River springfish, Moapa pebblesnail, grated tryonia, Moapa warm spring riffle beetle, Amargosa naucorid, and Moapa naucorid) ▪ Develop and implement strategies to remove non-native fish species, including mollies and mosquitofish, from Refuge ▪ Monitor streams before and after rehabilitation to determine benefits or detriments to Moapa dace ▪ Continue to use volunteers for restoration efforts	Same as Alternative A and: ▪ Continue channel restoration on the Plummer Unit by planting native species ▪ Monitor streams before and after rehabilitation to determine impacts on endemic fish and invertebrate populations ▪ Maintain and monitor habitats on a regular basis after restoration activities are complete	Same as Alternative B and: ▪ By 2015, complete restoration of the spring heads and channels on Apcar Unit

Table 3.6-3. Moapa Valley NWR: CCP Alternatives

Issue Area	*Management Actions* Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
Inventory and Monitor Wildlife	▪ Continue to conduct annual surveys and monitoring of Moapa dace and surveys of Moapa White River springfish	Same as Alternative A and: ▪ Within five years of the CCP's approval, conduct baseline inventories of federally listed, proposed, candidate, and species of concern on the Refuge and of aquatic habitat for invertebrates and amphibians to determine species composition and abundance ▪ Inventory existing upland habitat for migratory birds, mammals, and reptiles ▪ Repeat inventories every five years to monitor trends in community composition ▪ Monitor restored stream habitat consistent with the Muddy River Aquatic Species Recovery Plan ▪ Develop and implement an Inventory and Monitoring Plan for federally listed and special-status fish species	Same as Alternative B and: ▪ Inventory existing upland habitat for migratory birds, mammals, and reptiles and prepare and implement a Monitoring Plan for these groups ▪ Coordinate with NDOW to conduct surveys for the presence and use of fan palm habitat by bats ▪ Develop a long-term Inventory and Monitoring Plan for all federally listed, proposed, candidate, and special-status species on the Refuge ▪ Model climate change impact scenarios and develop adaptation strategies
Water Resources Monitoring	▪ Work with partners to continue monitoring water flow and temperature of Pedersen and Pedersen East Springs and Warm Springs West flume ▪ Participate in local and regional water resources management efforts to assess impacts and protect water resources on the Refuge ▪ Participate in the Muddy River regional water monitoring planning process ▪ Use a variety of tools to defend water rights and mitigate substantial changes in temperature or flow, including the State	Same as Alternative A and: ▪ Collect monthly monitoring data for water flow and temperature of Pedersen and Pedersen East springs and Warm Springs West flume and collect monthly monitoring data for water quality parameters, including temperature, flow, dissolved oxygen, pH, and total dissolved solids at other Refuge springs as needed ▪ Develop a long-term Water Resources Management Plan for the Refuge ▪ Determine appropriate monitoring site locations, frequency, parameters, and equipment	Same as Alternative B and: ▪ Include monitoring at Apcar by 2009

Table 3.6-3. Moapa Valley NWR: CCP Alternatives

Issue Area	*Management Actions* *Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
	Engineer's water rights process	▪ Purchase and install equipment	
Habitat Protection	Protect and maintain natural habitat, including water quality and quantity in the Refuge springs and channels suitable for Moapa dace survival, reproduction, and recruitment: ▪ Maintain existing boundary fencing and gates and replace as staffing and funding allow ▪ Maintain regulatory signs on the Refuge in good condition and replace as staffing and funding allow ▪ Remove dead fan palm fronds and thin the underbrush and overgrowth as needed to reduce risk of fire ▪ Extinguish unwanted fires as fast as safely possible to minimize potential negative impacts to Moapa dace. ▪ Continue periodic removal of non-native aquatic species ▪ Monitor changes in the environment that may be a result of climate change ▪ Continue to participate in the Muddy River Recovery Implementation Program and the Biological Advisory Committee	Same as Alternative A and: ▪ Develop and implement an IPM Plan to control and eradicate invasive species encroachment using an early detection/early response approach ▪ Install directional, regulatory, and interpretive signs both on- and off-Refuge ▪ Erect entrance signs as appropriate ▪ Participate in community-based fire safe planning both on- and off-Refuge and explore other options for protecting the Refuge from fire ▪ Use prescribed fire where appropriate to reduce hazardous fuels and treat unwanted vegetation ▪ Develop regulatory, directional, and interpretative signs and materials, such as brochures and fact sheets, to guide and enhance visitor experience	Same as Alternative B and: ▪ Monitor habitat changes, maintain and continue improvements for restoration efforts and other landscape improvements, and provide adequate level of monitoring and maintenance for invasive species control and fire management ▪ Expand Refuge Acquisition Boundary by 1,765 acres and work with partners to protect habitat within the expanded boundary through purchase, transfer, and/or agreement (see Land Protection Plan in Appendix L) ▪ Prepare step-down habitat management plan for lands acquired within the expansion area

Table 3.6-3. Moapa Valley NWR: CCP Alternatives

Issue Area	*Management Actions* *Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
Visitor Services			
Visitor Services	Provide public outreach and visitor service opportunities: ▪ Maintain Refuge as closed to the general public ▪ Continue participation in local community events (e.g., Clark County Fair, Moapa Day Celebration, Earth Day) as staffing and funding allow ▪ Maintain current parking facilities for visitor safety ▪ Provide information about Refuge resources upon request ▪ Explore opportunities for development of environmental education programs with potential partners ▪ Revise current interpretive and environmental education materials periodically to maintain accuracy ▪ Maintain current Refuge entrance signs ▪ Continue providing opportunities for volunteers to assist in habitat restoration projects ▪ Continue work on an accessible trail ▪ Conduct an annual open house for volunteers that assist in restoration ▪ Explore opportunities for community-based outreach during on-Refuge activities	Same as Alternative A, except: ▪ Open Refuge to the general public on weekends and to school groups during the week through prior arrangement ▪ Recruit docents to staff the Refuge on weekends and facilitate tours ▪ Construct adequate parking and public access to accommodate 500 Refuge visits annually ▪ Provide outreach, by invitation and as staff is available, at the Moapa Valley Community Center ▪ Create a basic trail along the riparian corridor on the Plummer Unit ▪ Design and install interpretive panels along trail system of Plummer and Pedersen Units ▪ Develop an environmental education program at the Refuge by 2012 ▪ Develop interpretive and environmental education materials ▪ Offer refuge educational materials to school contacts upon request ▪ Work with NDOT to erect signs on I-15 and U.S. Highway 93 promoting and directing the public to the Refuge ▪ Erect a Refuge entrance sign near Warm Springs Road ▪ Conduct a public open house every two to three years to encourage interactions and foster relationships between Refuge staff and local constituents	Same as Alternative B, except: ▪ Open Refuge every day to the general public for self-guided or Refuge staff-guided tours ▪ Recruit docents to staff the Refuge and facilitate tours ▪ Construct adequate parking, including school bus turnouts, and public access to accommodate 1,000 Refuge visits annually ▪ Coordinate the installation of a permanent environmental education display at the Moapa Valley Community Center or other public venue ▪ Construct an overlook trail with interpretive panels and shade structure on top of the hill on the Plummer Unit for viewing the Refuge and the Moapa Valley ▪ Plan and construct a self-guided trail system along the spring head, pools and riparian corridor on the Plummer Unit ▪ Organize local school contacts to generate enthusiasm for the Refuge and its endemic species ▪ Develop one environmental education program at the Refuge by 2009 ▪ Develop interpretive and environmental education materials ▪ Conduct an annual public open house to encourage interactions and foster relationships between Refuge staff and local constituents

Table 3.6-3. Moapa Valley NWR: CCP Alternatives

Issue Area	Management Actions Alternative A (No Action)	Alternative B	Alternative C (Preferred Alternative)
		▪ Seek opportunities for community-based outreach, such as participation in off-Refuge activities ▪ Monitor number of Refuge visitors through sign-in sheets at the visitor contact station	
Cultural Resources	▪ Continue to inventory, manage, and protect any cultural resources on the Refuge on a project-by-project basis to comply with applicable laws and regulations ▪ Continue with informal cultural resources education of Refuge visitors	Same as Alternative A, and: ▪ Develop regionally focused cultural resources environmental education and interpretation materials for self-guided tours ▪ Confer with culturally affiliated tribes to incorporate their history and native plant and animal species knowledge as part of the interpretive program at the Refuge	Same as Alternative B, and: ▪ Conduct cultural resource inventory of the entire Moapa Valley NWR to assist in any future planning efforts and to improve management and protection of any significant site from inadvertent public visitation impacts

Table 3.6-4. Pahranagat NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Wetland Habitat				
Open Water Habitat (640 acres)	▪ Complete and implement habitat restoration plan to improve quality of existing open water habitat for waterfowl, waterbirds, shorebirds, and other migratory birds Continue current management until wetland restoration plan completed: ▪ Discharge water into Middle Marsh and Lower Pahranagat Lake to provide migratory waterfowl habitat ▪ Manage carp populations ▪ Clear vegetation in irrigation ditches annually ▪ Continue current maintenance, repair, and improvement efforts on North Marsh and Upper Pahranagat Lake	Same as Alternative A	Same as Alternative A and: ▪ Encourage reduction of carp populations on private and state-managed lands in coordination with upstream water resources management entities and users	Same as Alternative C and: ▪ Every three years, conduct surveys of nesting colonial waterbirds ▪ Model climate change impact scenarios and develop adaptation strategies
Marsh Habitat (400 acres)	▪ Maintain marsh with 60% open water and 40% emergent vegetation ▪ Use prescribed fire as needed to control vegetation ▪ Supplement flows into Middle Marsh with pumped well water to help maintain water levels	Same as Alternative A	Same as Alternative A and: ▪ Every three years, conduct surveys of birds and bats	Same as Alternative C and: ▪ Monitor vegetation and wildlife response to habitat management

Table 3.6-4. Pahranagat NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Wet Meadow Habitat (700 acres)	▪ Manage 700 acres of wet meadow habitat ▪ Use prescribed fire as needed to maintain productivity ▪ Continue conducting spring waterfowl surveys using volunteers and Refuge staff as resources allow ▪ Continue to coordinate fall and winter waterfowl surveys with NDOW ▪ Continue project to determine population status, distribution, and demography of Pahranagat Valley montane vole	Same as Alternative A and: ▪ Obtain waterfowl data collected by other agencies on a seasonal basis	Same as Alternative B and: ▪ Add spring and fall surveys and breeding pair and brood counts to current fall and winter surveys coordinated with NDOW	Same as Alternative C and: ▪ Monitor avian species abundance during fall and spring migration for response to habitat manipulation
Alkali Flat Habitat (350 acres)	▪ Maintain 350 acres of flooded alkali flat habitat in the Lower Pahranagat Lake area	Same as Alternative A	Same as Alternative A and: ▪ Control salt cedar and other invasive species in the Lower Pahranagat Lake area ▪ Develop and implement a Species Inventory and Monitoring Plan for waterfowl and shorebirds	Same as Alternative C
Habitat for Sandhill Cranes	▪ No current habitat management for cranes ▪ Complete habitat restoration plan and implement recommendations for	Same as Alternative A	Same as Alternative A and: ▪ Monitor sandhill crane use	Same as Alternative C

Table 3.6-4. Pahranagat NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
	foraging habitat for migrating sandhill cranes			
Water Resources Management	▪ Maintain current water resources management ▪ Monitor inflow to Upper Pahranagat Lake ▪ Pursue 1996 application to Nevada Division of Water Resources for year-round water discharges ▪ Survey existing groundwater wells and repair or cap as appropriate ▪ Install a flume or weir at the outflow of Lower Pahranagat Lake ▪ Install and monitor flow meters and data loggers on each of the three groundwater wells on the Refuge ▪ Complete update of Water Management Plan ▪ Complete Refuge-wide water budget ▪ Monitor changes in the environment that may be a result of climate change ▪ Use a variety of tools to defend water rights and mitigate substantial changes in temperature or flow, including the State	Same as Alternative A and: ▪ Install new pump for Well 3 and monitor flow	Same as Alternative B and: ▪ Determine the status of groundwater wells of record, and repair and/or abandon as appropriate, and apply for change(s) in point of use with Nevada Division of Water Resources ▪ Install gauges and data-logging equipment at springs adjacent to Middle Marsh ▪ Repair existing water infrastructure as staffing and funding allow	Same as Alternative C and: ▪ Acquire additional water rights from willing sellers

Table 3.6-4. Pahranagat NWR: CCP Alternatives

Issue Area	Management Actions: Alternative A (No Action)	Alternative B	Alternative C	Alternative D (Preferred Alternative)
	Engineer's water rights process			
Integrated Pest Management	▪ Continue integrated pest management efforts including burning, mowing, spraying, and planting native species to control invasive plants ▪ Continue to coordinate noxious weed surveys and mapping efforts with county, state, and federal agencies	Same as Alternative A and: ▪ Complete and implement IPM Plan within five years of CCP completion	Same as Alternative B and: ▪ Coordinate IPM Plan implementation with upstream property owners	Same as Alternative C
Wildlife Diversity				
Southwestern Willow Flycatcher/Wetland Habitat	▪ Maintain existing 100 acres of cottonwood-willow riparian habitat around the North Marsh for southwestern willow flycatcher and other migratory birds ▪ Complete habitat restoration and management plan and implement recommendations for willow flycatcher habitat ▪ Continue to cooperate with U.S. Bureau of Reclamation on surveys for the southwestern willow flycatcher ▪ Conduct riparian habitat vegetation surveys that include percent cover,	▪ Same as Alternative A	Same as Alternative A and: ▪ Monitor impacts of fishing on bird use of habitats and adopt seasonal closure of sensitive areas as necessary ▪ Monitor response of birds to habitat restoration	Same as Alternative C

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Table 3.6-4. Pahranagat NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
	density, age, and structure			
Spring Habitat	■ Complete inventory and monitoring of vegetation and wildlife in spring habitat ■ Complete Restoration and Managemnent Plan designs to restore degraded/modified spring pools and channels on the Refuge	Same as Alternative A	Same as Alternative A and: ■ Implement spring head and channel restoration	Same as Alternative C
Upland Habitat (1,000 acres)	■ Continue to enforce prohibitions for off-road vehicles ■ Maintain Refuge fences to reduce encroachment from cattle on adjacent lands ■ Manage wildland fires on the refuge using the fitting AMR that considers resource values at risk and potential negative impacts of various fire suppression measures; firefighter and public safety will be the highest priority for every incident ■ Prepare wilderness study report and NEPA document to evaluate options for preserving wilderness values of three wilderness study areas along the western boundary	Same as Alternative A and: ■ Close unused roads as necessary ■ Coordinate road closures with BLM	Same as Alternative B and: ■ Inventory and monitor upland habitat on a regular basis ■ Install physical barriers to prevent vehicle traffic in closed areas	Same as Alternative C and: ■ Restore native upland habitat adjacent to Lower Pahranagat Lake ■ Fence eastern boundary to prevent encroachment

Table 3.6-4. Pahranagat NWR: CCP Alternatives

			Management Actions	
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Pahranagat Roundtail Chub/Aquatic Refugium	▪ No roundtail chub management	▪ Plan and, if feasible, design and construct a refugium for roundtail chub		Same as Alternative B
Visitor Services				
Hunting	▪ Maintain current hunting opportunities for quail, migratory birds, and rabbits ▪ Provide Refuge-specific and NDOW hunting guidelines and regulations to the public at Refuge headquarters ▪ Post and maintain designated hunting area signs on Refuge	▪ Same as Alternative A	Same as Alternative A	Same as Alternative A
Fishing	▪ Continue to provide sport fishing opportunities ▪ Continue to maintain visitor facilities ▪ Maintain swimming prohibitions at all open water locations and maintain regulatory signs at those locations	Same as Alternative A and: ▪ Prepare a fisheries management plan within three years	Same as Alternative B	Same as Alternative B, and: ▪ Close existing boat ramps and provide alternative car-top boat launch
Camping	▪ Maintain campground in its current state (14-day stay limit; quiet hours between 10pm and 7 am)	Same as Alternative A, except: ▪ Begin collecting fees ▪ Limit length of stays to seven days ▪ Prohibit use of generators between 10 p.m. and 8 a.m.	▪ Convert campground to day use area (vehicles still allowed)	Same as Alternative C

Table 3.6-4. Pahranagat NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Wildlife Observation/ Photography	▪ Maintain existing visitor facilities with help from volunteers ▪ Continue to offer wildlife lists at the Refuge headquarters ▪ Maintain existing trails throughout the Refuge	Same as Alternative A and: ▪ Monitor the number of visitors using the Refuge each day ▪ Design and construct a wildlife observation trail system	Same as Alternative B and: ▪ Construct photography/observation blinds along trail route	Same as Alternative C and: ▪ Develop new wildlife observation structure(s)
Interpretation/ Environmental Education	▪ Maintain existing level of interpretation, environmental education, and outreach ▪ Monitor Refuge visitation	Same as Alternative A, except: ▪ Expand the existing visitor contact station to accommodate growing numbers of visitors ▪ Develop new interpretive panels and replace panels ▪ Develop environmental education materials and "least-wanted" posters for invasive plant species	Same as Alternative B and: ▪ Construct interpretive walking trail that connects Upper Pahranagat Lake with the Headquarters Unit ▪ Construct a new visitor contact station and office space at headquarters unit ▪ Construct additional parking to accommodate visitors at the Headquarters Unit ▪ Coordinate with NDOT to create turn lanes so visitors can safely exit highway to visit the Refuge ▪ Develop and implement an Interpretative Plan for the Refuge	Same as Alternative C

Table 3.6-4. Pahranagat NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Outreach	■ Continue participating in up to three outreach events per year	Same as Alternative A	■ Participate in up to six outreach activities each year within three years ■ Coordinate with NDOT to install directional signage for I-15 and US Highway 93 to promote Refuge visitation	Same as Alternative C, and: ■ Develop and implement an outreach plan within three years
Cultural Resources				
Cultural Resources Management	■ Continue to manage cultural resources on a project-by-project basis ■ Continue to provide Refuge visitors with interpretive information on cultural resources through informal outreach	■ Incorporate cultural resource values, issues, and requirements into design and implementation of the other habitat, wildlife, and visitor service activities and strategies conducted by the Desert Complex ■ Compile all existing baseline data on cultural resources sites, surveys, and reports within and near the Refuge, and create digital, GIS, and hard copy databases, maps, and a library ■ Develop educational, scientific, and traditional cultural needs for cultural resources management in coordination with the Consolidated Group of Tribes and Organizations ■ Create a GIS-enabled element in the Cultural Resources Management	Same as Alternative B and: ■ Conduct cultural resource inventories at all public use areas, roads, affected areas, and other "destinations" on the Refuge and evaluate the discovered sites' eligibility to the NRHP. ■ Develop historic contexts for classes of cultural resources ■ Inventory, evaluate, and nominate Traditional Cultural Properties and sacred sites to the NRHP in consultation with tribes ■ Identify, evaluate, and mitigate adverse effects and stabilize selected cultural resource sites on Pahranagat NWR using a Cultural Resources Management Plan prepared in consultation with affiliated tribes and the scientific community, and use the above data on site locations	Same as Alternative C and: ■ Identify and evaluate cultural resources that could educate visitors on how humans have interacted with wildlife and habitats in the past. ■ Consult with affiliated tribes and other stakeholders on ways to use these resources to achieve educational, scientific, and traditional cultural needs. ■ Conduct a study of ethnobotany and traditional plant use on Pahranagat NWR through assistance and consultation with affiliated tribal representatives.

Table 3.6-4. Pahranagat NWR: CCP Alternatives

		Management Actions		
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
		Plan that aids in the identification, planning, monitoring, and interpretation of cultural sites	and information for planning, monitoring, and interpretation efforts related to cultural resources ▪ Secure Refuge System and non-Refuge System funding to develop and implement a mitigation, stabilization, or research project ▪ Implement projects to restore habitats of important native plants and to harvest (for traditional, non-commercial purposes) native plant foods in coordination with affiliated Native American tribes	
Cultural Resources Protection	▪ Continue efforts to protect cultural resources on a case-by-case basis	▪ Identify and evaluate cultural resources subject to looting/vandalism or deterioration; implement steps to reduce these threats and preserve the resources ▪ Implement cultural resources monitoring and enforcement activities to decrease impacts to cultural resources	Same as Alternative B, and: ▪ Create and implement a site stewardship volunteer program to assist in monitoring and protection	Same as Alternative C

Table 3.6-4. Pahranagat NWR: CCP Alternatives

	Management Actions			
Issue Area	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Cultural Resources **Education and Outreach**	■ Continue informal outreach on cultural resources	■ Design and implement educational materials, programs, and activities that would be used to address traditional or sacred resources to increase awareness on- and off-Refuge about the sensitivity of cultural resources to visitor impacts and the penalties for vandalism ■ Incorporate cultural resources information into education and interpretive programs and media	Same as Alternative B and: ■ Utilize volunteers to assist in delivery of educational and interpretive literature and programs, and to promote cultural resources conservation in neighboring communities	Same as Alternative C

Chapter 4.
Affected Environment

Kings Pool at Ash Meadows National Wildlife Refuge

SE ROA 12874

Chapter 4. Affected Environment

This chapter provides a description of the affected environment for the four refuges in the Desert National Wildlife Refuge Complex (Desert Complex) in terms of the physical, biological, cultural, and socioeconomic environments. Section 4.1 provides a regional overview of the environment focusing on southern Nevada. Sections 4.2 through 4.6 provide descriptions of each refuge in the Desert Complex: Ash Meadows National Wildlife Refuge (NWR), Desert NWR, Moapa Valley NWR, and Pahranagat NWR.

4.1 Regional Overview

4.1.1 Physical Environment

Physiography and Climate

The Desert Complex is located in southern Nevada in the southern part of the Great Basin and northern extent of the Mojave Desert in the Basin and Range Province (Figure 4.1-1). The Desert Complex region is bordered by the southern Sierra Nevada Mountains on the west, the Great Basin Desert to the north, the Colorado River to the east, and the San Bernardino Mountains and the Sonoran Desert to the south. The Sierra Nevada Mountains form a massive mountain barrier that markedly influences the climate of the state.

The region is characterized by generally north-trending, linear mountain ranges separated by intervening valleys. The Ash Meadows, Pahranagat, and Moapa Valley NWRs are located within valleys, whereas the Desert NWR consists of both mountain ranges and valleys (Figure 4.1-2).

In the United States, one of the greatest contrasts in precipitation found within a short distance occurs between the western slopes of the Sierra Nevada in California and the valleys just to the east in Nevada. As the warm, moist air from the Pacific Ocean ascends the western slopes of the Sierra Nevada Range, the air cools, condenses, and then falls as precipitation. In contrast, as the air descends the eastern slope of the range, it is warmed by compression and as a result, very little precipitation occurs in the region. The effect of the Sierra Nevada Mountains as a barrier to cooler temperatures and moisture is felt throughout the state, resulting in the desert environment found throughout the lower elevations in Nevada.

Precipitation in Nevada is lightest over the southern portion of the state where the Desert Complex is located. In valleys, the average annual precipitation is less than 5 inches. Average precipitation on the refuges in the Desert Complex ranges from 4.4 to 6.4 inches in valleys (Western Regional Climate Center [WRCC] 2003). Precipitation in the form of snow also occurs during the cooler months on some of the mountain ranges surrounding the refuges and on the Desert NWR, most commonly at higher elevations of the Sheep Range.

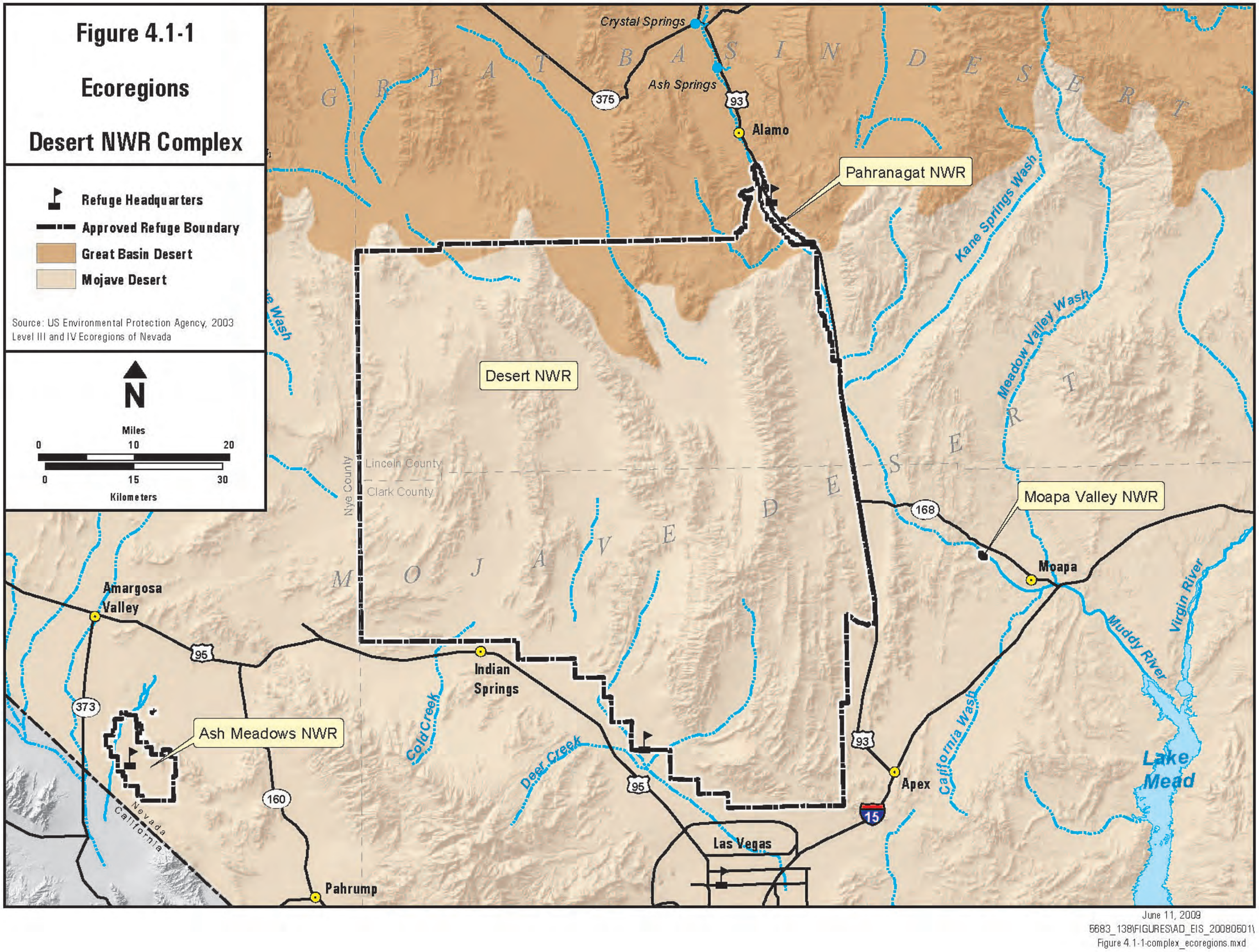

Figure 4.1-1
Ecoregions
Desert NWR Complex
Refuge Headquarters
Approved Refuge Boundary
Great Basin Desert
Mojave Desert
Source: US Environmental Protection Agency, 2003
Level III and IV Ecoregions of Nevada
N
Miles
0
10
20
0
15
30
Kilometers
G R E A T B A S I N D E S E R T
M O J A V E D E S E R T
Crystal Springs
Ash Springs
375
93
Alamo
Pahranagat NWR
Kane Springs Wash
Meadow Valley Wash
Desert NWR
Lincoln County
Clark County
Nye County
168
Moapa Valley NWR
Moapa
Virgin River
Muddy River
Amargosa Valley
95
373
Ash Meadows NWR
Indian Springs
Cold Creek
Deer Creek
California Wash
Apex
Lake Mead
160
Nevada
California
Las Vegas
15
Pahrump
June 11, 2009
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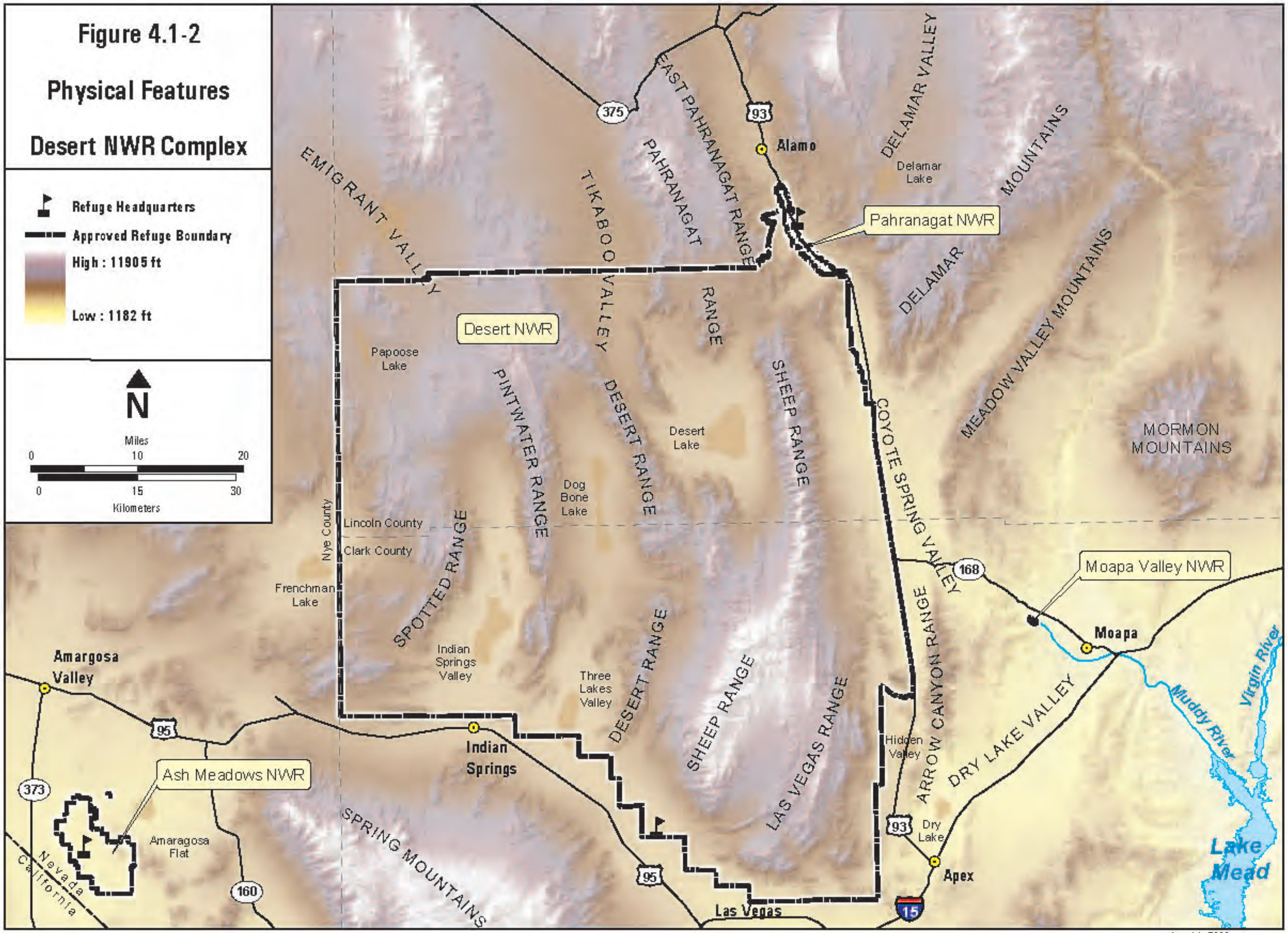
Figure 4.1-1-complex_ecoregions.mxd



June 11, 2009
5683_138FIGURESIAD_EIS_20080501I
Figure 4.1-2complex_physical.mxd

SE ROA 12877

The region is subject to high-intensity storms that can generate high peak surface flows during the late winter and summer months. Runoff from precipitation is practically non-existent during the rest of the year.

In southern Nevada, the summers are long and hot and the winters are short and mild. Long periods of extremely cold weather are rare. The Desert Complex is characterized by strong surface heating during the day and rapid nighttime cooling, which results in wide ranges of daily temperature. The average range between the highest and the lowest daily temperatures is about 30 to 35 degrees Fahrenheit (°F), with more extreme daily temperature ranges occurring in the summer (WRCC 2003). Summer temperatures above 100°F occur frequently in the south and occasionally over the rest of the state. A climatic summary for the Desert Complex is shown in Table 4.1-1.

Table 4.1-1. Climatic Summary for the Desert Complex

Refuge	*Average Temperature (°F)*		*Average Precipitation (inches)*	*Precipitation Peak Months*
	Maximum (July)	*Minimum (December–January)*		
Ash Meadows	103	30	4.5	February–March, August
Desert (Corn Creek Field Station)	102	29	4.4	February–March, July–September
Moapa Valley	105	31	5.1	March, August
Pahranagat	98	26	6.4	March, August

Source: WRCC 2003

The climate of Nevada has been affected by global changes in climate as a result of increased atmospheric concentrations of greenhouse gases over the past century (U.S. Environmental Protection Agency [EPA] 1998). Temperature and precipitation have increased in many areas of the state. In particular, Elko, Nevada, has experienced an average increase in temperature by 0.6°F. Data collected near the Ash Meadows area shows an increase in average precipitation by more than 10 percent. Future trends cannot be accurately predicted, but Nevada's climate is expected to continue to be affected by global climate change.

Increases in precipitation, particularly more rapid snowmelt, could lead to increased flooding and higher potential for flash floods. Water quality of Nevada's waters could be affected by increased flooding as a result of increased erosion and sedimentation and transportation of pollutants into the surface waters, such as Lake Mead.

Increased temperatures, as a result of global warming, could lead to various climatic impacts within each Refuge. Specifically, increased temperatures could lead to earlier snowmelt and reduced summer riparian flows. Warmer winters and earlier springs will cause drier

conditions to come earlier in the season, making for longer fire seasons. Nevada's fire suppression techniques have contributed to overgrown, fuel-heavy forests. This factor when combined with drier conditions and an earlier fire season will increase the opportunity for forest fires to develop.
Climate changes could also affect Nevada's forests by altering species composition, geographic range, and health and productivity. Hotter, drier weather could lead to a reduction in forest cover as grasslands and arid lands (deserts) become more dominant. The intensity of the changes is dependent on a variety of factors that require human intervention to control. Specific effects of climate change on each of the refuges have not been evaluated, but changes in climate could affect the special-status species found on the refuges as well as the habitats that support these species.

Geology and Minerals

The geologic structure of the Basin and Range Province, including the area of the Desert Complex, is the cumulative product of multiple episodes of compression and extension of the Earth's crust. During the last 30 million years, extension of the Earth's crust accompanied by other actions resulted in the pattern of elongated mountain ranges and intervening basins or valleys. The estimated total displacement along the major north-trending faults during the last 12 million years ranges from less than 330 feet to more than 1,600 feet (Tschanz and Pampeyan 1970).

The presence of or potential for minerals at each refuge is discussed in their respective sections of this chapter.

Paleontological Resources

Each of the refuges in the Desert Complex has potential to contain paleontological resources based on the geologic units that have been mapped. Within the Ash Meadows NWR, spring, playa and lake deposits have high paleontological potential for mollusk shells and isolated deposits of horse, camel, bison, sheep, and deer (Longwell et al. 1965). Paleozoic, Tertiary, and Quaternary deposits within Desert NWR have the potential to contain common types of fossils, such as mollusks, corals, barnacles, algae, and other invertebrates (Tschanz and Pampeyan 1970; Longwell et al. 1965). The Quaternary and Tertiary alluvium and Bird Spring Formation within Moapa Valley NWR have high fossil-containing potential for algae, echinoderm, and fusilinid (Longwell et al. 1965). The Panaca Formation surrounding Pahranagat NWR contains gastropods, ostracods, trace fossils, diatoms, plant fossils, and extinct horse remains (Tschanz and Pampeyan 1970).

Soils

Nevada, with its wide mix of geologic parent material, has a vast array of different soil types. Differences in climate, parent material, topography, and erosional conditions result in soils with diverse physical and chemical properties. The distribution and occurrence of soils is highly variable and is dependent on a number of factors, including degree of slope, geology, vegetation, climate, and age. Soils in the Desert Complex area are derived mainly from sedimentary and volcanic rocks and alluvium.

The U.S. Department of Agriculture, Natural Resources Conservation Service (NRCS) has published a Soil Survey Geographic Database (SSURGO) that provides soil association maps for most of Nevada in digital format. SSURGO includes information on soils at Ash Meadows, Moapa Valley, and Pahranagat NWRs (NRCS 2003b). No SSURGO data exist for the Desert NWR; however, soil data are available from the State Soil Geographic (STATSGO) database (NRCS 2003a). These sources were used to describe soil conditions at each refuge; the information is presented in Sections 4.2 to 4.6.

Water Resources

The Great Basin and Mojave Desert are relatively arid and have few large rivers. Each of the four refuges can be characterized by an interaction between springs discharging from the regional carbonate aquifer, groundwater stored in local alluvial aquifers, and surface flow as a result of spring discharge and precipitation. Groundwater originates as high-altitude winter precipitation in the higher mountain ranges (such as the Spring and Sheep Ranges) and can flow great distances through the carbonate rocks that make up the mountain ranges and underlie the valleys (Thomas et al. 1986). The major springs associated with the Desert Complex are part of several large regional groundwater flow systems, including the Death Valley regional groundwater flow system and the White River regional groundwater flow system (Eakin 1966; Harrill and Prudic 1998). These flow systems consist of numerous local basin fill aquifers underlain by a large regional carbonate rock aquifer that transmits groundwater from basin to basin, beneath topographic divides. Regional flow patterns are influenced by topographic relief and relative altitudes of each basin. Groundwater flow patterns are shown in Figure 4.1-3, which are based on various studies of the Death Valley regional flow system.

Various public agencies and private organizations are concerned that groundwater development of the carbonate rock aquifers may negatively impact the quantity and/or quality of regional spring systems within these flow systems, and the biological resources associated with those springs. The Service is also concerned that groundwater development and withdrawals adjacent to the four National Wildlife Refuges comprising the Desert Complex may adversely affect the populations and habitats of fish, wildlife, and plants within the Refuge. The Service has various options for protecting our water resources through the Nevada State Engineer's Office, including applying for water rights for refuge springs, protesting other water rights applications if refuge resources may be affected, and seeking redress through the State Engineer's Office of an injury to any of our water rights due to groundwater development.

As a matter of policy, the Service regularly reviews applications for groundwater withdrawal submitted to the Nevada State Engineer's Office and submits protests for those that may injure Service water rights and/or impact the Service's trust resources. In several

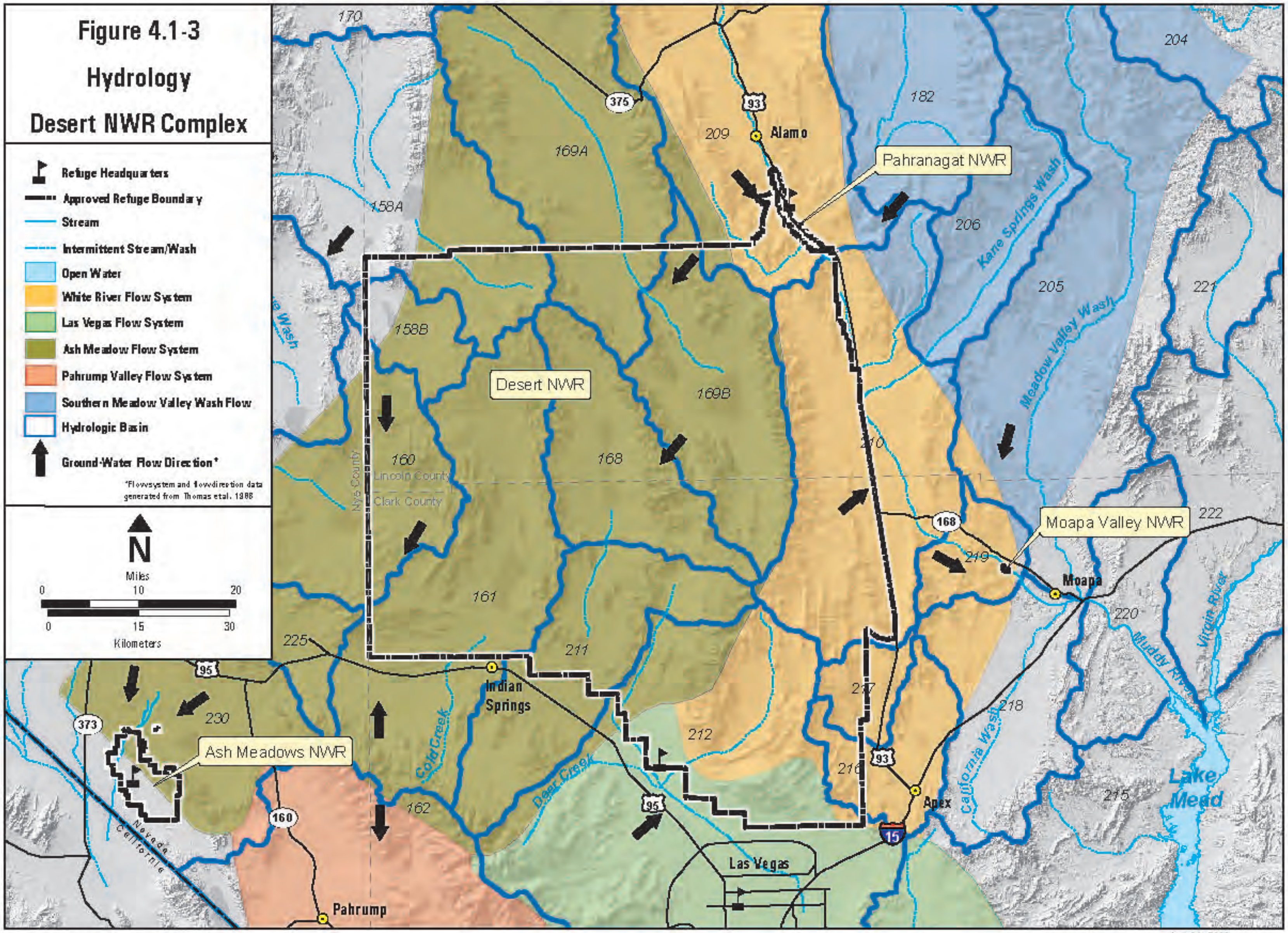


Figure 4.1-3
Hydrology
Desert NWR Complex
Refuge Headquarters
Approved Refuge Boundary
Stream
Intermittent Stream/Wash
Open Water
White River Flow System
Las Vegas Flow System
Ash Meadow Flow System
Pahrump Valley Flow System
Southern Meadow Valley Wash Flow
Hydrologic Basin
Ground-Water Flow Direction*
*Flowsystem and flowdirection data generated from Thomas et al. 1988
N
Miles
0
10
20
0
15
30
Kilometers
Pahranagat NWR
Desert NWR
Moapa Valley NWR
Ash Meadows NWR
Alamo
Moapa
Indian Springs
Apex
Las Vegas
Pahrump
Lake Mead
Kane Springs Wash
Meadow Valley Wash
California Wash
Muddy River
Virgin River
Cold Creek
Deer Creek
Nye County
Lincoln County
Clark County
Nevada
California
170
204
182
209
169A
158A
206
205
221
158B
169B
160
168
210
222
219
220
161
211
225
217
218
230
212
216
215
162
375
93
168
95
373
160
15

situations, the Service has entered into stipulations concerning protested water right applications to protect trust resources and the habitats that those resources depend on. In other situations, the Service has participated in administrative hearings before the State Engineer concerning protested water right applications; the most recent case was the Amargosa Desert Hydrographic Basin Protest Hearing on June 12–16, 2006.

Three stipulations and a Memorandum of Agreement (MOA) affect refuges within the Desert Complex: the Dry Lake, Delamar, and Cave Valleys (DDC) Stipulation; Kane Springs Valley Stipulation; Three Lakes/Tikaboo Stipulation; and the Muddy River MOA. A brief discussion of each agreement is provided below. Interested readers can refer to the agreements for more specific information on the monitoring and management requirements.

Dry Lake, Delamar, and Cave Valley (DDC) Stipulation: In January 2008, the Service entered into a stipulated agreement with the Southern Nevada Water Authority (SNWA) that resulted in the Service withdrawing its protests to SNWA's applications to withdraw groundwater from these three basins. The goals of the stipulation are to manage the development of groundwater by SNWA in the DDC basins without causing injury to federal water rights and/or any unreasonable adverse effect to federal resources, including those on Pahranagat National Wildlife Refuge. The stipulation outlines monitoring, management, and mitigation requirements, which will be cooperatively developed and implemented by hydrologic and biological resources teams. The monitoring plan will consist of groundwater monitoring wells, spring discharge monitoring, water chemistry sampling, groundwater flow modeling, and biological monitoring, as well as the creation and implementation of a Hydrologic Management and Mitigation Operation Plan. The Operation Plan will identify early warning indicators and define a range of mitigation actions to be implemented if early warning indicators are reached, including special provisions and processes to protect the resources and enhance habitat on Pahranagat National Wildlife Refuge.

The Stipulation also recognizes the need for a cumulative effects analysis of SNWA's groundwater development projects, as well as the need to integrate activities outlined in the various stipulations and agreements, both existing and future. Therefore, the parties to the stipulation will be negotiating a MOU by April 2009 that will outline the process for evaluating cumulative effects. This approach will factor in cumulative effects to resources on Pahranagat and Moapa Valley National Wildlife Refuges.

Muddy River MOA: In April 2006, the Service entered into a MOA with SNWA and several other parties (Coyote Springs Investment, Moapa Valley Water District, and Moapa Band of Paiutes) to manage the potential effects of groundwater production from the regional carbonate aquifer in Coyote Spring Valley and California Wash basins on in-stream flows in the Warm Springs Area of the Moapa Valley National Wildlife Refuge. The MOA requires the reduction or cessation of pumping if specified spring flow trigger levels are reached at the Warm Springs West flume on the refuge, as well as numerous activities to restore habitat and further recovery of the endangered Moapa dace.

Kane Springs Valley Stipulation: In August 2006, the Service entered into a stipulated agreement with Lincoln County Water District (LCWD) and Vidler Water Company (VWC) that resulted in the Service withdrawing its protests to LCWD&VWC applications to withdraw groundwater from the Kane Springs Valley hydrographic basin. The stipulation recognizes the importance of managing the development of groundwater while maintaining minimum in-stream flows in the Warm Springs Area of the Moapa Valley National Wildlife Refuge and protecting senior federal water rights on the refuge. The stipulation outlines monitoring, management, and mitigation requirements, including requiring LCWD&VWC to reduce or cease pumping if specified spring flow trigger levels as identified in the MOA are reached at the Warm Springs West flume on the Moapa National Wildlife Refuge. In addition, LCWD&VWC committed to provide funding for the recovery of Moapa dace and restoration of dace habitat.

Three Lakes/Tikaboo Stipulation: In November 2005, the Service entered into a stipulated agreement with the Bureau of Land Management, National Park Service, Department of Defense, Department of Energy, and SNWA that resulted in the Service withdrawing its protests to SNWA's change applications to withdraw groundwater from the Three Lakes Valley South hydrographic basin. The goals of the stipulation are to manage the development of groundwater by SNWA in the Three Lakes/Tikaboo basins without causing injury to senior federal water rights and/or any unreasonable adverse effect to federal resources. The stipulation outlines monitoring, management, and mitigation requirements, which would be cooperatively developed and implemented by a technical review panel. All the parties to the Stipulation agreed to implement the Monitoring, Management, and Mitigation Plan "…if and only if the Nevada State Engineer grants SNWA's Applications for changes in points of diversion for permits 53950, 53951, 54060, 54068, and 54069, in total or in part. In the event the Nevada State Engineer only grants SNWA's Applications for changes in points of diversion for permits 54062 and 54066, in total or in part, SNWA agrees that it shall negotiate in good faith with the Federal Agencies to develop 'sufficient monitoring and plans for mitigation of impacts, including cessation of pumping, if necessary'." In the ruling on these change applications, the State Engineer did not grant any of the change applications for permits 53950, 53951, 54060, 54068, and 54069, in total or in part. According to the stipulation, this means the 3-M plan originally negotiated by the parties terminated by its own terms.

Hazardous Materials

Hazardous materials are defined as any substance that, due to quantity, concentration, physical, chemical, or infectious characteristics, may present substantial danger to public health, welfare, or the environment when released. Hazardous materials are not known to be present on Ash Meadows, Moapa Valley, or

Pahranagat NWRs. Solid and hazardous wastes are generated from activities on the Nevada Test and Training Range (NTTR), which overlays a portion of the Desert NWR.

Fire History and Management

In the past few decades, drought-killed trees in the west have made forests more vulnerable to fires; sustained drought exacerbates the scenario by making them less likely to recover, favoring replacement by grass-dominated semi-arid systems (Bachelet et al. 2007). Recently observed large-scale drought-related dieback of pinyon pine in the Southwest, for example, could set the stage for large fires that trigger vegetation shifts (Bachelet et al. 2007). Simulation results of past and future vegetation across the western United States illustrate a shift in community types within the Desert Complex region (Bachelet et al. 2007). Simulations from 1990 through 2090 indicate a gradual shifting from desert vegetation to an expansion of savannas and woodlands to eventual grasslands and shrublands.

There is uncertainty in future precipitation regimes (Lenihan et al. 2003). While large-scale climate models, on average, project a drying of the western United States (IPCC 2007), regional-scale models indicate a general increase in precipitation within the Desert Complex region (Bachelet et al. 2007). Because of the uncertainty in the future precipitation regime, two types of vegetation changes are possible (Lenihan et al. 2003):

- Reduced precipitation would allow drought-tolerant grasses (with increased flammability) to invade native shrublands, or
- Increased precipitation would enhance woody plant expansion creating cooler, moister, shadier tree and shrub patches.

Given the uncertainty among future scenarios of rainfall, land and resource manangers should develop contingency plans for alternative futures with specific regional emphases, including monitoring ecosystem indicators to provide early warning of changing conditions (Bachelet et al. 2007).

Each refuge in the Desert Complex has a Fire Management Plan that identifies and integrates all wildland fire management guidance, direction, and activities required to implement national fire policy. Because each refuge contains different sensitive resources and has different management purposes, refuge-specific fuels management is discussed separately for each refuge.

Air Quality

Air quality of the four refuges in the Desert Complex can be described in terms of climate, regulatory requirements, and ambient air quality conditions. Climate and meteorology describe the atmospheric conditions, which affect the general air quality. Air quality regulations define the limits and controls on emissions necessary to maintain good air quality within the region. Ambient air quality provides a measure of the ambient concentration of various pollutants that affect air quality. This section defines the regulatory requirements for southern Nevada.

The U.S. Congress has promulgated National Ambient Air Quality Standards (NAAQS) to regulate the ambient air quality through the nation. The pollutants include nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), particulate matter less than 10 microns (PM_{10}), and ozone (O_3). Areas where measured concentrations of these pollutants are above the NAAQS are defined as nonattainment areas. All others are defined as attainment. Local air quality regulations for Nye and Lincoln Counties have been delegated to the Nevada Department of Environmental Protection (NDEP). Clark County air quality is regulated by the Clark County Department of Air Quality Management (CCDAQM).

The four refuges are in a region that has been classified as attainment areas for all pollutants, except for the southern portion of the Desert NWR, which is within the Las Vegas Valley Airshed. The Las Vegas Valley Airshed is considered nonattainment for CO, PM_{10}, and 8-hour ozone (Clark County 2000 and 2001; CCDAQM 2003a). As required by the EPA, CCDAQM has developed state implementation plans for CO and PM_{10} to reduce emissions countywide.

The CO State Implementation Plan for Las Vegas Valley Nonattainment Area adopted measures associated with on-road mobile sources to reduce CO emissions (Clark County 2000). The PM_{10} State Implementation Plan developed several new rules to reduce the amount of fugitive dust that enters the atmosphere, with a focus on reducing fugitive dust from construction sites (Clark County 2001).

4.1.2 Biological Resources

Vegetation

The Mojave Desert is the smallest of the four North American deserts, lying primarily in California, but also including the southern quarter of Nevada and small portions of Utah and Arizona (Royo 2002). Unlike the Sonoran Desert, the lower elevations of the Mojave Desert have only one tree, the Joshua tree (*Yucca brevifolia*). This tree-like yucca is endemic to the Mojave Desert and usually grows at elevations of 3,500 feet above mean sea level (msl) and greater. The Mojave Desert also hosts approximately 200 other plants that are not found in the Sonoran or Great Basin Deserts. Although a published flora of the Mojave Desert is incomplete, approximately 2,600 vascular plant taxa are known to occur in the Mojave Desert floristic province (excluding the higher elevations, greater than 8,000 feet above msl, of the Spring, Sheep, and Panamint Mountain Ranges), representing one of the most diverse floristic regions in the United States (Andre and Knight 1999). Although home to about 200 endemic plant species, the proportion of the Mojave Desert flora comprising special-status taxa is relatively low (10 percent of flora).

Many noxious weeds can be found dominating the areas along Nevada's borders (U.S. Bureau of Land Management [BLM] 1999), and a variety of invasive species and noxious weeds occur on each of the refuges within the Desert Complex (Appendix H). Noxious weeds mostly occur in riparian and wetland areas. They out-compete native vegetation and can spread quickly in a short time span.

Wildlife

Wildlife species are more abundant in the Mojave Desert than they are in the Great Basin Desert (MacMahon 1992), which may be due to the occurrence of fewer plant species in the Great Basin Desert. Plant communities are home to specific wildlife. For example, the creosote bush community is known to have at least 30 species of reptiles, 33 species of birds (eight of which are permanent residents), and 44 species of mammals (see list of common species in Appendix H). The blackbrush community has fewer species—19 reptiles, 26 birds, and 33 mammals—but it still contains diverse fauna. More than 200 bird species use the wetland habitats in the Mojave Desert, and approximately 20 species of fish and seven amphibians can be found in the desert springs and marshes. Each refuge within the Desert Complex provides important and unique habitat for wildlife, including some endemic species.

Special-status, or sensitive, species occur on each of the refuges. Special-status species are those species that have been listed as endangered or threatened by the U.S. Fish and Wildlife Service (Service), are candidates for listing under the Endangered Species Act (ESA), or are considered sensitive by another federal or state agency or wildlife management plan (Appendix H and Sections 4.2-4.6). Federally listed wildlife species are also protected in the State of Nevada under Nevada Revised Statutes 501 and Nevada Administrative Code Chapter 503.

4.1.3 Cultural Resources

Because the four refuges that make up the Desert Complex are so widely separated within southern Nevada, it is difficult to characterize the prehistoric and historic setting of the region as a whole. The prehistoric people who used the lands that are now part of these four different areas were well adapted to the climate and resources within their homelands. The prehistory and history of southern Nevada is summarized in a variety of major sources. Although there is general agreement on the broad patterns of regional prehistory, many areas of controversy remain, and the data needed to answer some basic research questions are lacking.

Although typically grouped within the Great Basin culture area (D'Azevedo 1986), a number of major culture areas overlap in southern Nevada. The prehistory and history of these areas spans the last 12,000 years or more. Particularly in the period after 500 A.D., Far Western Puebloan, Fremont, Patayan, and Numic traditions overlap in the region.

Cultural resources encompass a wide range of resources that are and have been important to tribes and other indigenous people. These resources include cultural artifacts as well as plants, wildlife, water resources, or other aspects of the environment that are associated with cultural practices or beliefs of a living community that may be rooted in that community's history or are important in maintaining the continuing cultural identity of the community.

Prehistoric Archaeology

Archaeologists believe that native people occupied the southern Great Basin by approximately 12,000 years ago. The limited data from the region suggest these people relied heavily on hunting for subsistence, with a focus upon large game animals that were plentiful in the riparian, marsh, and grassland environments typical at the end of the last Ice Age. Sites dating to the Paleoarchaic are rare in most parts of the southern Great Basin. The best-documented Paleoarchaic sites occur in the Mojave Desert along the shores of Pleistocene Lake Mojave, California (Campbell et al. 1937; Warren and Phagan 1988), and at Fort Irwin, California (Basgall and Hall 1991, 1994). While relatively few of these sites are associated with reliable radiocarbon dates, the consensus is that they date between 11,200 and 7,500 years ago.

In the period following the Paleoarchaic, lakes that contained plenty of water during the ice ages began to dry up as the region became increasingly arid. People broadened their resource base and began to exploit more plants and other kinds of game than during the previous period. Warren (1980) postulates that about 9,000 years ago, people began to cluster around permanent water sources. Several early archaic sites have been investigated in the southern Great Basin, including Pintwater Cave on the Desert NWR.

About 3,000 B.C., a period of increased moisture began in the region. A variety of cultural assemblages have been noted at this time with an increased number of sites. One of the best-known regional sites dating to the later portions of the Archaic is Gypsum Cave (Harrington 1933).

Cultural diversification with strong regional emphases developed after about 500 A.D. While some Indian People took up farming, others continued the Archaic lifestyle of seasonal transhumance typical of earlier times, and some probably used aspects of both. During this time, strong Southwestern influences were evident in southeastern Nevada within the drainages of the Moapa and Muddy Rivers and in the Las Vegas Valley. Far western ancestral puebloan people practiced increasingly intensive agriculture adjacent to reliable water sources, which may have occurred at Corn Creek.

Western Shoshone and Southern Paiute/Chemehuevi still occupied the southern Great Basin and northeastern Mojave Desert when the first Euro-Americans and other ethnic groups entered the area in the 1800s and earlier. These groups practiced collecting and foraging strategies similar to those of earlier periods in addition to agriculture. D'Azevedo (1986) note that the Pahranagat Paiute practiced some forms of agriculture during the Protohistoric Period, including burning areas and scattering an unidentified grass seed, and floodplain agriculture along the edges of the lakes. There is also evidence that the Las Vegas and Moapa Paiute practiced horticulture at springs and rivers.

Historic Archaeology

Southern Nevada has long been a crossroads in the American West: a crossroads of cultures (both prehistoric and historic), a crossroads of economies, and a literal crossroads. The area began as part of the Spanish Empire, became part of independent Mexico, and then joined the United States at the cessation of the Mexican-American War. As part of the historical American West, southern Nevada first was home to Mormon settlers bent on expanding their religious territory and bringing their doctrine to the local native populations. It later became a key link in the western transportation network for Mormons and non-Mormons alike.

The earliest transportation route to traverse southern Nevada was the Old Spanish Trail/Mormon Road. With the coming of the Los Angeles, San Pedro, and Salt Lake railroad in 1905, southern Nevada—and Las Vegas in particular—thrived as a connection in the transportation grid that linked California with Utah and other areas farther east (Myrick 1991).

Mormon influence waned after 1857 when most of the residents of the Las Vegas community returned to Utah. From then on the small Las Vegas Valley community focused on ranching and farming to supply regional mining interests. In the Las Vegas, Moapa, and Virgin Valleys, farming communities continued to develop from the 1850s until the early 1900s. Mining ventures in southern Nevada were typically short-lived, and most of the areas survived as transportation hubs or ranching centers.

4.1.4 Public Access and Recreation

Because of the differences in location, size, habitat, and wildlife of each of the refuges, public access and recreational opportunities are quite different and are therefore discussed in the sections addressing conditions at each refuge.

4.1.5 Social and Economic Conditions

Social and Economic Regional Overview

Southern Nevada is one of the fastest-growing regions in the United States. According to U.S. Census data, the population of the state increased by more than 20 percent between 2000 and 2005 to more than 2.4 million residents (U.S. Census Bureau 2006). The Nevada Development Authority (2008) notes that the Las Vegas metropolitan area accounts for most of the growth. The rapid growth in the Las Vegas Valley is a driving force in the social and economic settings. Increasing growth in the Las Vegas Valley exerts environmental pressures on the Desert Complex as development moves closer to the largest refuge—the Desert NWR. Development also creates an increased demand for open spaces, which will likely translate into more visitors to the Desert Complex, and increased environmental pressures, including increased groundwater demand.

This rapid growth also means that other more rural and remote communities may experience different pressures, such as more growth as people relocate from the Las Vegas Valley to nearby communities, or possibly declining growth as people move away for the increased economic opportunities elsewhere. The BLM is undergoing a process of land disposal in Clark and Lincoln Counties, which will result in some of these lands being transferred to private ownership and may provide land for development opportunities.

Clark County

The population of Clark County was estimated at about 1.7 million people in 2005, which represents an increase of almost 25 percent since the 2000 Census (U.S. Census Bureau 2006). More than 70 percent of Nevada's population resided in Clark County in 2005. The population is projected to increase to 2,751,082 by the year 2024, an increase of about 60 percent over the 20-year period. Communities in Clark County include larger, rapidly developing cities in the urbanized areas of Las Vegas Valley and Mesquite, as well as those in more rural areas such as Indian Springs, Moapa, Overton, and Logandale.

Lincoln County

Lincoln County's population was estimated at 4,391 people in 2005, an increase of 5.4 percent from the 2000 Census population of 4,165 (U.S. Census Bureau 2006). Most of the population is found in the towns of Alamo, Caliente, Panaca, Pioche (the county seat), and Rachel. Lincoln County's population is expected to increase to 5,292 people by 2024. According to the 2001 Lincoln County Master Plan, future population growth is expected to change and shift to the area near the southern county line shared with Clark County, particularly in the area near Mesquite (Lincoln County 2007).

Nye County

Nye County's population was estimated at 40,477 in 2005, an increase of 24.5 percent since the 2000 Census (U.S. Census Bureau 2006). The communities in Nye County range from rural to urban. While the small town of Amargosa Valley practices traditional farming and mining, the larger, more urban town of Pahrump serves as a major service center, with 73 percent of the county's population in 2000.

Refuge Management Economics

The Desert Complex is managed by a staff located in Las Vegas, and each of the refuges has separate budgets and staff located at the refuges. The current Desert Complex staff consists of six permanent full-time employees. The refuge operations budget for the Desert Complex in 2005 was $432,533. The maintenance budget for the Complex in 2005 was $14,900. There were also funds in the amount of $72,531 for volunteers at the Complex and four refuges. Fire-related budgets for the Desert Complex and four refuges included $83,481 for fire protection and management services, $50,000 for wildland urban interface services, and $449,735 for burned area emergency restoration. Additional funds for specific projects at each refuge are provided through the Southern Nevada Public Lands Management Act; these funds are allocated separately and are not identified as part of the refuge management budgets.

Environmental Justice

In 1994, the President of the United States issued Executive Order (EO) 12898, "Federal Actions to Address Environmental Justice in Minority and Low-Income Populations." The objectives of the EO include developing federal agency implementation strategies, identifying minority and low-income populations where proposed federal actions could have disproportionately high and adverse human health and environmental effects, and encouraging the participation of minority and low-income populations in the National Environmental Policy Act (NEPA) process.

Each of the four refuges in the Desert Complex holds special traditional and cultural significance to the affiliated Native American tribes who inhabited southern Nevada. The same present-day affiliated Native American tribes in southern Nevada and neighboring California and Arizona maintain rich cultural heritage ties to these areas. The affiliated tribes may be considered low-income, minority populations in the vicinity of the refuges.

Regional Land Use

Lands in southern Nevada are primarily managed by federal agencies, with a small portion in private, state, or municipal ownership. The disposal of lands by the BLM throughout Clark and Lincoln Counties is increasing the amount of land that is in private or municipal ownership, which is also increasing the availability of land for development. The following sections provide information on the land owners and managers in the counties where the Desert Complex is located. Figure 1.1-1 (Chapter 1, Introduction) shows an overview of the land ownerships and managers in southern Nevada.

<u>Clark County</u>

Of the 5.12 million acres of land in Clark County, about 4.5 million acres (approximately 90 percent) are administered by seven federal agencies or departments (BLM unknown date). These are:

- Department of Defense (379,961 acres),
- Bureau of Land Management (2,727,406 acres),
- National Park Service (466,746 acres),
- U.S. Fish and Wildlife Service (517,249 acres),
- Forest Service (274,574 acres),
- Bureau of Reclamation (39,998 acres), and
- Bureau of Indian Affairs (78,832 acres).

The remaining 10 percent of lands in Clark County (approximately 500,000 acres) are under private ownership or state and local government ownership.

<u>Lincoln County</u>

Lincoln County is the third-largest county in terms of land area in Nevada, consisting of 6.8 million acres. It is primarily a rural county in which most of the land is under public ownership (Lincoln County 2007). The federal government currently manages more than 98 percent of the land in the county:

- Bureau of Land Management (5.6 million acres),
- Department of Defense (DOD) (771,087 acres),

- U.S. Fish and Wildlife Service (268,698 acres), and
- U.S. Forest Service (29,371 acres).

Only 129,000 acres are privately owned, and a scant 5,700 acres are under state jurisdiction.

Nye County

Of the 11.6 million acres of land in Nye County (including lands within the Department of Energy [DOE]-controlled Nevada Test Site and the DOD-controlled Nevada Test and Training Range [NTTR]), approximately 11.3 million acres (about 97 percent) are administered by the following federal agencies:

- Bureau of Land Management (6.5 million acres; 8,400 acres are jointly managed with the Service),
- U.S. Fish and Wildlife Service (13,700 acres),
- U.S. Forest Service (1.9 million acres),
- Department of Defense (1.8 million acres),
- Department of Energy (863,000 acres),
- National Park Service (107,000 acres), and
- Bureau of Indian Affairs (8,000 acres).

An additional 19,000 acres are under state jurisdiction, and a total of 249,000 acres in Nye County are privately owned.

Aesthetics

Aesthetics, or visual resources, include both natural and man-made physical features and infrastructure that provide a particular landscape its character and importance as an environmental and visual factor. There are different approaches to identify aesthetics of a landscape that have been used by different agencies. Typical features that provide an overall impression of a landscape include the presence or absence of land features, vegetation, water, color, surrounding scenery, and man-made and cultural features. Criteria used for this discussion include scenic quality, distance from selected public viewpoints, and distance from areas of interest.

The overall Desert Complex is made up of four different areas that have unique features within them, but are within an area generally defined as transition between the Mojave Desert and the Great Basin. The topography consists of a series of mountain ranges, generally in a north-south orientation separated by broad valleys. Elevation ranges from 2,200 feet at the desert floor to about 10,000 feet above msl. The mountains consist of side slopes, ridgelines, rock outcrops, and canyons. In the valleys, there are playas, alluvial fans and plains, small hills, intermittent drainages, and occasional volcanic rock formations. There are dry desert lakes as well as isolated perennial springs.

Creosote bush (*Larrea tridentata*) is the dominant plant in the desert shrub habitats, with sagebrush (*Artemisia* spp.), saltbush (*Atriplex* spp.), and blackbrush (*Coleogyne ramosissima*) consistently found throughout the area. Agriculture is limited in the region. Riparian areas and associated vegetation are primarily located within the refuges and are subject to protection and preservation.

The areas surrounding and in the vicinity of the Desert Complex consist of very low density desert and rural lands, scattered with small, rural towns and unincorporated areas. The exception is the Las Vegas metropolitan area, which is south of the Desert NWR and is beginning to encroach on the views to and from the refuge. As both Las Vegas and North Las Vegas develop to the north toward the Desert NWR, the area will become subject to aesthetic impacts, particularly along major roads, such as Interstate 15 (I-15), U.S. Highway 95, U.S. Highway 93, and Clark County 215, due to pollution, traffic, light, and glare.

4.2 Ash Meadows National Wildlife Refuge

4.2.1 Physical Environment

Physiography

The approved boundary of Ash Meadows NWR encompasses approximately 24,000 acres (Figure 1.7-1, Chapter 1, Introduction). The Refuge is located at the southern end of the Amargosa Valley and is bordered to the north, south, and west by the Amargosa Desert and to the east by the Devils Hole Hills.

The valley floor of the Refuge slopes gently to the southwest and has an average elevation of 2,060 feet above msl. The Devils Hole Hills have an elevation of approximately 3,100 feet above msl at the Refuge boundary. A large playa is located at the northwest corner of the Refuge and collects runoff from Rock Valley and adjacent uplands to the north. The playa drains to the south into Death Valley via Carson Slough, which empties into the Amargosa River. A smaller playa is located along the southern boundary and collects runoff from Devils Hole Hills located to the east, from the Resting Spring Range located to the south, and from several springs located along the southeast corner of the Refuge.

Geology and Minerals

The valley floor of the Ash Meadows NWR is underlain primarily by alluvial fan and playa deposits of Quaternary age (1.8 million years ago [mya] to present). Tertiary age (65 to 1.8 mya) sedimentary rocks are exposed near the southwestern boundary and central portion of the western boundary. The alluvial fan deposits consist of gravel and rubble near the highlands and grade downward into sand and silt playa deposits in the valley bottoms (Denny and Drewes 1965; Hess and Johnson 2000). The total thickness of the Quaternary sediments in the Ash Meadows Valley is unknown. Data collected from several water well drilling logs installed at a ranch located a few miles northwest of the Refuge indicate that gravel and clay are encountered to depths in excess of 700 feet (Denny and Drewes 1965).

The eastern boundary of the Refuge is formed of limestone and dolomite ridges from the Cambrian period (545 to 490 mya) (Otis Bay and Stevens Ecological Consulting 2006). This boundary contains carbonate hills and ridges as a result of bedrock being dropped down along the Ash Meadows fault system.

The Ash Meadows NWR is located in the Ash Meadows mining district, which was established in 1917 (Tingley 1998). The Ash Meadows district was once the largest producer of calcium and bentonite in Nevada and is in an area of historic mining interest, primarily for specialty clays and zeolite. In the early 1960s approximately 2,000 acres of marshland in the Carson Slough were disturbed by peat mining (Service 2006a). Although some major oil companies still retain mineral rights in portions of the district, production of bentonite has been at a standstill since the 1930s (Cornwall 1972). A review of Singer (1996) and Lovering (1954) indicates that neither metal nor radioactive ores are present at the Refuge. Twenty-six mining and two mill claims have been reported within the Refuge boundary (Service 1999a); however, more recent records from the BLM indicate there are three active placer claims and five lode claims (BLM 2007). The Service has a mineral withdrawal application pending with BLM covering 9,460 acres of BLM land and 5,360 acres of Service land within the Refuge's approved boundary. No private lands or valid existing mineral rights were affected by the proposed withdrawal (Service 1999a).

Paleontological Resources

Within Ash Meadows NWR, spring, playa and lake deposits have the highest paleontological potential. The deposits in the region are composed of thin horizontal layers of sand, silt, and clay with abundant mollusk shells and isolated deposits of Quaternary vertebrate remains, including horse, camel, bison, sheep, and deer (Longwell et al. 1965). In the Ash Meadows Quadrangle, Denny and Drewes (1965) found no fossils in the spring and playa deposits, but similar deposits in Amargosa Valley where these sediments occur contain Pleistocene mammal remains.

No fossils have been found in the other geological units mapped in Ash Meadows NWR (Denny and Drewes 1965), but those units may overlie other geologic units that contain fossils (Service 2000b).

Soils

A total of 16 soil-mapping units are present on the Refuge, and the soils generally consist of gravelly sandy loam derived from either mixed rock sources or lake deposits (NRCS 2003b). Finer loam soil types (silty clay loam, sand to clayey loam) are derived from or occur near lake deposits, on the distal edges of alluvial fans, or on floodplains.

Water Resources

<u>Surface Water</u>

Ash Meadows NWR lies within the Upper Amargosa hydrologic subbasin, which is characterized by surface water drainage southwest towards Death Valley (Figure 4.2-1). The primary drainage within Ash Meadows is the Carson Slough, a tributary to the Amargosa River. Crystal Spring and Jackrabbit/Big Spring drainages are tributary to the slough and drain large portions of the Refuge. Little to no water exits the Refuge, except during major storm events that produce a large amount of surface runoff (Otis Bay and Stevens Ecological Consulting 2006).

Surface water originates from precipitation and from more than 30 flowing springs that discharge groundwater from the Ash Meadows Flow System (Denny and Drewes 1965). The major springs on the Refuge consist of circular pools 20 to 40 feet in diameter and 5 to 20 feet deep (Denny and Drewes 1965). The total annual discharge of Refuge springs has been estimated at about 17,000 acre-feet per year (afy) (Laczniak et al. 1999). Runoff from the springs feeds the two man-made reservoirs.

Devils Hole, an opening to the carbonate aquifer, is one of the most widely recognized and significant water features within the Refuge boundaries (actually part of Death Valley National Park). Devils Hole is a rectangular opening in a carbonate rock formation that is approximately 10 feet wide by 65 feet long (Hunt and Robinson 1960). The depth of Devils Hole has not been mapped, but the deepest any diver has been is about 436 feet (Riggs and Deacon 2002). Devils Hole is a unique habitat for a species of desert pupfish, which is listed as endangered. The pupfish breed on ledges just a few inches below the water surface.

The stability of water levels within Devils Hole is crucial to maintaining pupfish habitat, and thus the impacts of local groundwater pumping are of major concern. In the late 1960s and early 1970s, groundwater use for local irrigation resulted in declines in the pool level. A U.S. Supreme Court decision in 1976 mandated a minimum water level in the pool and resulted in cessation of local irrigation. Following the Supreme Court decision, water levels improved, although they continue to slowly decline.

The Service is currently engaged in restoration of many of the historic stream channels on the Ash Meadows NWR. The Ash Meadows area was previously farmed, and many of the surface water channels were redirected into man-made ditches. Work has recently been conducted at Point of Rocks and Crystal Pool to redirect spring flow into historic flow channels, although this work is not yet complete.

Historic redirection of springs and flow channels for irrigation also had a major impact on Carson Slough, which used to be one of the largest wetland areas in southern Nevada. Carson Slough was drained, mined for peat, and recontoured for farming. Surface flows were redirected into man-made reservoirs: Peterson and Crystal.

Groundwater

Ash Meadows NWR lies within the Amargosa Valley hydrographic basin. The Refuge is underlain by a regional carbonate aquifer and a local valley-fill aquifer (Dudley and Larson 1976 and Winograd 1971). The valley-fill aquifer is fed by regional groundwater through direct flows and surface water percolation from springs created by

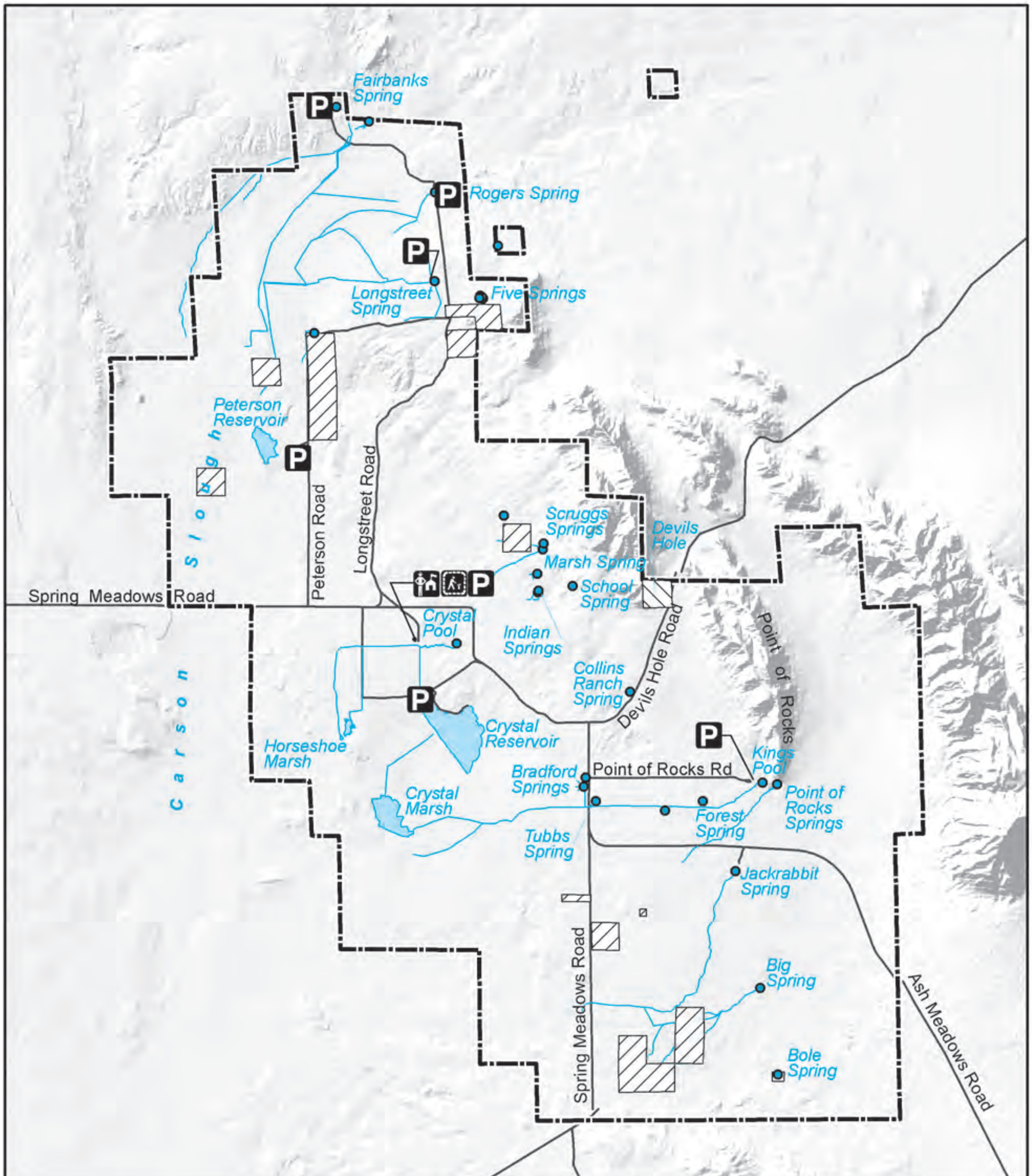


Figure 4.2-1

Hydrology

Ash Meadows NWR

June 11, 2009
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Figure 4.2-1-ashmeadows_hydro.mxd

groundwater. Groundwater surfaces along the Ash Meadows fault system, which trends southeast to northwest through the eastern portion of the Refuge; springs are created by groundwater discharge along the fault, such as at Point of Rocks and Crystal Spring. All of the springs discharge carbonate water. At Point of Rocks, springs appear to discharge directly from the carbonate aquifer because of the carbonate rock outcrop. Other springs on the Refuge discharge from the valley-fill aquifer, which is derived from and connected to the carbonate aquifer but is covered by valley-fill sediments.

Warmer springs (greater than 90°F) tend to be found on the eastern side of the Refuge, where the groundwater travels a shorter distance to the surface from the carbonate aquifer (Walker and Eakin 1966). Springs in the central to western portion of the Refuge tend to be cooler (less than 90°F) because groundwater travels through the valley-fill aquifer, which contains lower temperature waters, to reach the surface.

The estimated perennial yield of the Amargosa Valley hydrographic basin is estimated at 24,000 afy (Walker and Eakin 1966). This includes the 17,000 afy of spring discharge in the Ash Meadows area. The Service has state appropriative water rights for all of the spring flow at the Refuge. The difference (7,000 afy) between perennial yield and regional spring discharge is the estimated groundwater available for other water rights in the basin.

Water Quality

Water quality from springs generally varies depending on the source area of the spring. Springs connected to regional flow systems have discharge waters containing relatively large concentrations of sodium, potassium, chloride, and sulfate ions. Some springs discharge thermal water warmer than 80°F. These waters have been in transit for thousands of years and thus have small concentrations of tritium, which is a result of radioactive fallout from nuclear testing in the 20th century. Water derived locally, instead of from regional flow systems, would have smaller concentrations of ions, larger concentrations of tritium, and lower temperatures (Laczniak et al. 1999). Water quality from major springs within Ash Meadows NWR is consistent with water from the regional flow system, rather than local precipitation and runoff. Water quality is fair overall. Levels of dissolved solids are approximately 450 milligrams per liter (mg/L), which is below the recommended level for potable water of 500 mg/L.

Water Use

Within the Refuge, groundwater is a complex interaction between springs discharging from the regional flow system and groundwater in the aquifers. Dewatering of the aquifers likely occurred as a result of historic pumping in the area (Dudley and Larson 1976). Since cessation of local pumping, water levels appear to have stabilized or recovered in some areas of the Refuge, although the lack of historic water level information makes it difficult to fully analyze the conditions.

Since the Nevada Division of Water Resources (NDWR) began maintaining records in 1982, annual groundwater pumping from the Amargosa Valley has varied between 4,000 afy and nearly 16,000 afy (NDWR 2003). In general, groundwater use between 1982 and 1992 was between about 4,000 and 10,000 afy; beginning in 1993, water use increased and now fluctuates between 12,000 and 15,500 afy. Agriculture still accounts for the bulk of water use. Industrial use has ranged from generally less than 1,000 afy in the 1980s to about 2,500 afy in the 1990s. Commercial use began a sharp increase from 10 to 20 afy prior to 1995 to over 1,000 afy in 2000. Domestic uses were in decline in the 1980s, reaching an average of about 100 afy from 1986 to 1996, but more recently rising to about 370 afy. Development of surface and groundwater resources on private inholdings is limited and regulated by the Nevada State Engineer.

Groundwater levels within the Refuge may also be affected by groundwater development elsewhere in the Amargosa Valley hydrographic basin. The largest source of concern is pumping from agricultural areas north of the Refuge and groundwater users located within 5 miles of the Refuge, including the Amargosa Dairy and the American Borate mining facilities (recently closed). Water levels in the agricultural area have been in decline. The hydrologic connection between the agricultural pumping and water levels within Ash Meadows NWR is unclear, but at this time, water levels within the Refuge do not exhibit a similar decline. Recent water use of the dairy and mining facilities averages approximately 1,500 afy and 700 afy, respectively; however, the potential for these groundwater users to affect groundwater resources at Ash Meadows NWR is also unknown. The area is being studied by various agencies and private groups as a key indicator of long-term hydrologic, geologic, and climatologic change in southern Nevada due to its proximity to the proposed Yucca Mountain nuclear waste repository, which is located approximately 20 miles north of the Refuge.

Because the springs at Ash Meadows NWR are derived from the regional flow system, groundwater development of the regional aquifer in other, more distant basins is also a concern. Currently, upgradient uses include DOE wells in Frenchman and Yucca Flat (DOE 2002). In Frenchman and Yucca Flat, DOE peak historic water demand is 530 and 912 afy, respectively. In Yucca Flat, this amount of pumping has likely exceeded the perennial yield of the basin and may have decreased downgradient subsurface flow by decreasing underground storage. There are pending water rights in other upgradient basins that have not been developed yet.

Water Rights

There are few current uses of groundwater within Ash Meadows NWR. According to records from the NDWR (2003), the Service has filed for 57 water rights on the Ash Meadows NWR (55 rights for spring flow, two rights for wells). All rights have been certified by the Nevada State Engineer. The total quantity of water rights held by the Service is approximately 17,674 afy for the Ash Meadows NWR (Mayer 2006).

Development of water rights within the Amargosa Valley hydrographic basin has the potential to affect groundwater levels and spring flow on the Refuge. Within the basin, more than 56,000 afy of water rights have been certified, including both groundwater and surface water rights. Groundwater rights within the basin amount to approximately 28,000 afy. However, only about 12,000 to 15,500 afy of this amount are currently pumped (NDWR 2003).

To safeguard water rights and resources and address the concerns of potential impacts from present and future groundwater pumping, the Service has implemented an extensive water monitoring plan for the refuge. Groundwater levels and spring discharge are measured regularly at a number of different sites on the refuge. For a description of this plan, see Mayer (2005).

Hazardous Materials

Ash Meadows NWR is largely undeveloped land with no history of development other than agriculture and homesteads. The only past mining activity on the Refuge was bentonite mining, which took place in the early 1900s. A review of Lovering (1954), Garside (1973), and Singer (1996) indicates that neither metal nor radioactive deposits are present on the Refuge.

Fire History and Management

Ash Meadows NWR currently lacks the site-specific histories of fire and forest structure that are necessary for scientifically based land-management planning in the region (Service 2004b). Site-specific fire histories provide the physical evidence of historical conditions that are critical to assessing the need for active management of specific watersheds, e.g., mechanical fuel treatment, prescribed fire or wildland fire use, and justifying such management actions within agencies and to the public. In general, fire regimes varied across space in response to variation in factors such as topography and climate. Although archival records reveal the modern factors such as fuel structure through fire exclusion, the influence of factors on past fire regimes is not fully understood. Extrapolating historical fire regimes across Nevada is further hampered by the nearly complete lack of information on historical fire regimes in any watershed in this region.

Fire occurrence in the desert areas of Ash Meadows has been historically infrequent (Service 2004b). However, fire frequencies may increase, due both to increased human-caused fires and to increased continuity of fine fuels caused by the growing dominance of introduced annual grasses.

Ash Meadows NWR is managed as part of the Ash Meadows Fire Management Unit (FMU); this unit consists of both the Refuge and the surrounding Ash Meadows Area of Critical Environmental Concern (ACEC), which is managed by the BLM. Records from the BLM for the Ash Meadows FMU, which covers about 52,600 acres, indicate an average of 0.3 ignitions per year between 1980 and 2002, with an average of 63 acres burned per year (Service 2004b). Fires ranged in size from 0.3 to 1,100 acres, and 71 percent were less than 100 acres in size. The median wildfire size was 206 acres, with an average of approximately 628 acres burned per decade. Fires generally occurred from April through October. Human-caused ignitions accounted for 86 percent of all fires, with the remaining 14 percent attributed to lightning. Most wildfires in this FMU occurred in tamarisk-infested areas. Typically, these fires are wind driven and are of moderate to high intensity. Small, low-intensity wildfires in tamarisk are less common but do occur.

Approximately two-thirds of the Ash Meadows FMU is riparian and marsh vegetation (Service 2004b). In undisturbed areas of this habitat, saltgrass is the carrier fuel and will burn at moderate intensity and spread. The remainder of the FMU (the surrounding ACEC) is predominantly creosote bursage and saltbush, with scattered stands of mesquite/acacia. Wildfires in this portion of the FMU are rare and generally depend upon ephemeral buildups of red brome and other introduced fine fuels.

The riparian/marsh portion of this FMU is infested with tamarisk, mainly along a series of irrigation channels (Service 2004b). These introduced non-native fuels allow transport of fire into the interior of the marsh system. Tamarisk and other undesirable plant species also promote wildfires of larger size and intensity, versus the historical norm for this ecosystem.

Most wildfires in this FMU occur on the Refuge and generally involve tamarisk as the carrier fuel (Service 2004b). Although not typical, tamarisk fires in this FMU tend to be fuel driven, rather than wind dependent. Aside from tamarisk, the other vegetative type that is prone to fire within this FMU consists of scattered stands of mesquite/acacia woodland. Tamarisk fires here have exhibited high intensity and spread, whereas fires in the mesquite/acacia are usually single tree. The large fires in this FMU have been human-caused ignitions.

A recent example of a wildfire on the Refuge is the Longstreet Fire, which was caused by lightning and started on August 1, 2004 (Service 2004b). The fire was controlled on August 4 at 1,670 acres (1590 USFWS, 80 BLM). The origin was 0.5 mile southeast of private land near Cold Spring. Fuels consisted of annual grasses, perennial grasses, tamarisk, and mesquite. The fire was considered extreme, and a single-engine airtanker was initially used to combat it; however, this method was not effective due to heavy accumulation of annual and perennial grasses. A variety of methods were considered, and indirect attacks using existing roads were found to be the most effective. Fuel breaks at the ownership boundary of private land were effective in having an established anchor point to proceed with burn-out operations.

Only one known prescribed fire has occurred on the Refuge. In 1990 an old cotton field was burned (Service 2004b). Recent fire history at Ash Meadows suggests that a component of prescribed fire would be desirable to maintain the diversity necessary to protect existing threatened and endangered species. Prescribed burns could also be used as part of a program to control noxious and exotic plants.

Air Quality

Ambient air quality is not currently measured at Ash Meadows NWR. It is expected that low ambient concentrations of criteria pollutants would occur in this area based on nearby uses. Fugitive dust may occasionally produce high amounts of pollutants from nearby activities related to the American Borate facility closure, as well as traffic on nearby dirt roads. The nearest development sources of emissions are in Pahrump (approximately 22 miles to the southeast) and the Las Vegas area (approximately 80 to 90 miles to the southeast). Due to synoptic wind patterns and the overall distance from these cities, these sources are not expected to have an impact on this region. The NDEP has operated a PM_{10} ambient monitor in Pahrump since 2001. Although the data indicate that there have been exceedances of the 24-hour PM_{10} standard, these conditions were eliminated from the attainment determination due to naturally occurring emissions, which are a reoccurring problem in Amargosa Valley (NDEP 2003).

4.2.2 Biological Resources

Vegetation

Habitat Types

In 2006, the Service completed a coarse-scale vegetation mapping effort that involved identifying and describing the different habitat types on the Ash Meadows NWR and creating geographic information system (GIS) data and maps of the habitat types (Figure 4.2-2). This effort was part of the Geographic and Biological Assessment that also included management recommendations for the Refuge (Otis Bay and Stevens Ecological Consulting 2006). The habitat types described and mapped for the Ash Meadows NWR include wetlands (emergent vegetation), riparian woodlands and shrublands (mesquite bosque and tamarisk), meadows (alkali wet meadow), alkali or saltbush shrub, creosote bush shrub, and non-native oldfields. More than 350 plant species are known to occur on the Refuge, 15 of which are special-status species. More than 60 invasive species and 10 species of noxious weeds have been observed on the Refuge (Service 2006b). Because Ash Meadows NWR was historically developed as agricultural lands, the distribution of the native vegetation has been altered. Thousands of acres were affected by Spring Meadows Ranch, Inc., during the early 1970s for alfalfa farming and cattle grazing (Service 1990).

For purposes of managing the various habitats, the Service has established multiple management units on the Refuge. These units were established based on the hydrologic features of the Refuge and encompass the surrounding habitats. The major units on the Refuge include Warm Springs, Jackrabbit/Big Springs, Upper Carson Slough, and Crystal Springs. Other smaller units encompass the various springs and their habitats. Descriptions of the habitats found throughout the Refuge are provided below.

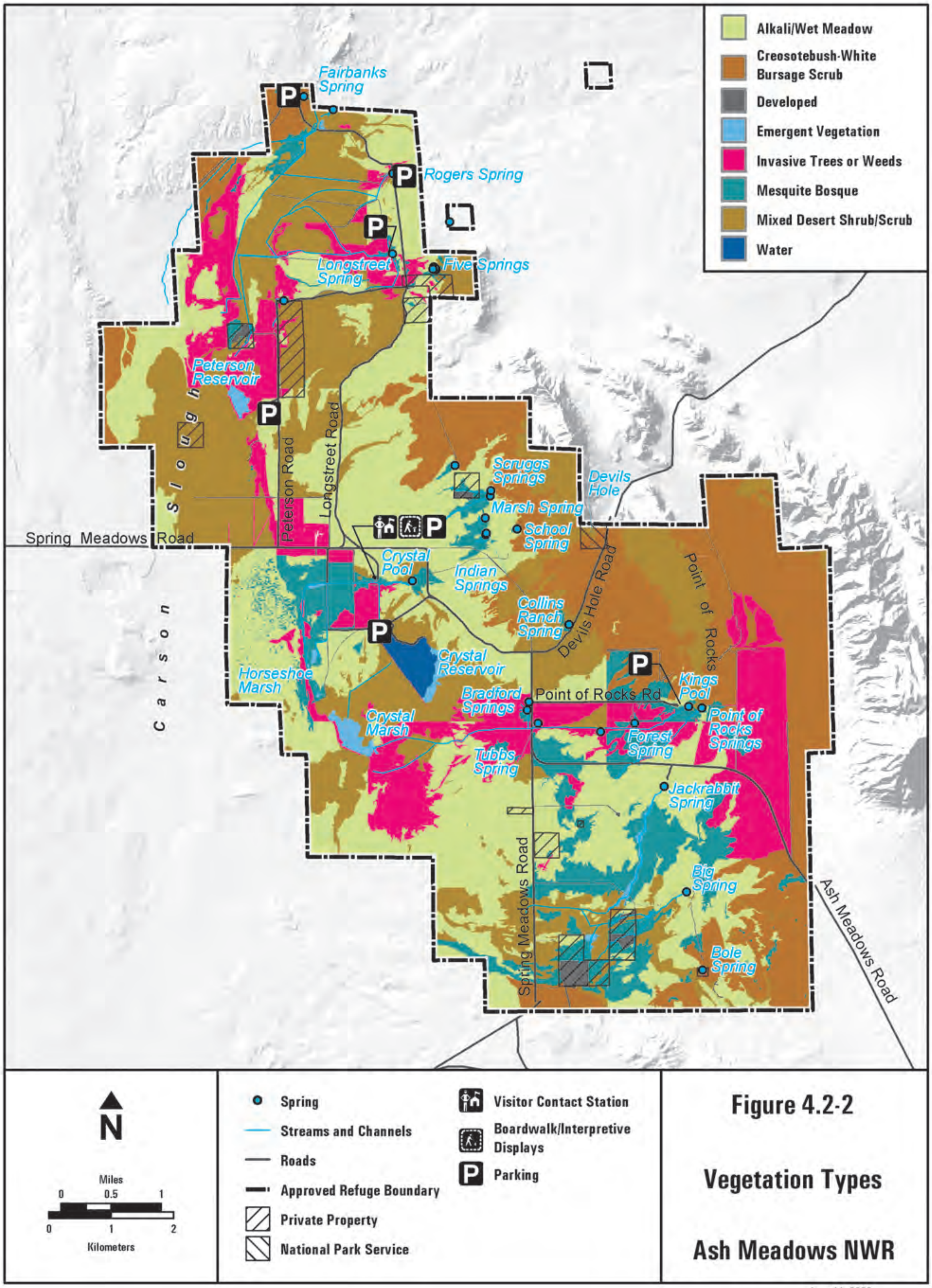

Figure 4.2-2

Vegetation Types

Ash Meadows NWR

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Wetland habitat at Ash Meadows NWR has been isolated for thousands of years, which has prevented several plant species from expanding their range outside the Refuge boundaries (Service 1990). Many of these plants have become distinct from others in the region and are now endemic to Ash Meadows NWR. Due to their limited range, these species are considered sensitive and are protected by the Service and the State of Nevada. A further discussion of the sensitive species found at Ash Meadows NWR is provided in the Sensitive Species section.

Approximately 30 seeps and springs provide high-quality habitat for many wildlife species. Emergent vegetation occurs around these water sources and around some of the reservoirs. Emergent vegetation is frequently or continually inundated and consists of herbaceous plants that are adapted to saturated conditions, such as cattails (*Typha* spp.) and rushes (*Juncus* spp.). Common species at the Refuge include southern cattail (*Typha domingensis*), rush, spikerush (*Eleocharis* spp.), bulrush (*Scirpus* spp.), and wetland grasses (*Sporobolus* spp. and *Distichlis* spp.) (Otis Bay and Stevens Ecological Consulting 2006). Emergent vegetation covers approximately 132 acres of the Refuge, which is about 0.5 percent of the total area.

Riparian woodland and shrubland habitat types occur along drainages or outflow channels throughout the Refuge and around springs. Riparian habitat includes mesquite bosques, which cover approximately 2,000 acres or 8 percent of the Refuge, and tamarisk, which covers approximately 1,200 acres or 5 percent of the Refuge (Otis Bay and Stevens Ecological Consulting 2006). Common overstory species associated with riparian habitat on Ash Meadows NWR include mesquite (*Prosopis pubescens* and *P. glandulosa*), Fremont cottonwood (*Populus fremontii*), willow (*Salix* spp.), and the invasive tamarisk (*Tamarix* spp.). Common understory species include saltbush (*Atriplex* spp.), saltgrass (*Distichlis spicata*), arrowweed (*Pluchea sericea*), and coyote willow (*Salix exigua*). Seasonal flooding is common in mesquite bosques, and annual flooding or high water tables are common in areas with tamarisk. Restoration efforts are currently under way to remove tamarisk and restore native mesquite bosques and other habitat on the Refuge.

Alkali meadows are the dominant habitat type on the Refuge; they currently occupy approximately 7,900 acres or 33 percent of the Refuge (Otis Bay and Stevens Ecological Consulting 2006). Alkali meadows occur throughout the Refuge, with the largest contiguous meadows in the southern and central portions at lower elevations. Common vegetation in the alkali meadow habitat includes Baltic rush (*Juncus balticus*), mesquite, desert isocoma (*Isocoma acradenia*), alkali sacaton (*Sporobolus airoides*), saltgrass, and velvet ash (*Fraxinus velutina*).

Alkali meadows tend to provide habitat for rare species, and at Ash Meadows, they provide the largest habitat for Ash Meadows ivesia (*Ivesia eremica*) and the spring loving centaury (*Centauriam namophilum*). Alkali meadows are reliant on shallow groundwater, which is critical to the characteristics species found in the habitat.

Areas where groundwater has lowered tend to become dominated by alkali shrub or saltbush species.

Alkali shrub is the second most common habitat type on the Refuge; it occupies approximately 5,000 acres or 21 percent (Otis Bay and Stevens Ecological Consulting 2006). Saltbush species, such as big saltbush (*Atriplex lentiformis*), fourwing saltbush (*A. canescens*), and shadscale (*A. confertifolia*) dominate the habitat. Other common species include rabbitbrush (*Chrysothamnus* spp.), greasewood (*Sarcobatus vermiculatus*), and inkweed (*Suaeda moquinii*). Alkali shrub is frequently intermixed with alkali meadows.

Groundwater pumping in the area and vegetation manipulation may have resulted in the conversion of alkali meadows to alkali shrub due to the lowering of the groundwater table; however, the extent of this conversion is unknown. In some areas, alkali shrub occurs on mounds within alkali meadow habitat.

Alkali shrub is most common in the northern portion of the Refuge, in the Carson Slough area. The Carson Slough was historically the largest wetland in southern Nevada (Service 1990). Approximately 2,000 acres of marshland in Carson Slough were destroyed when it was drained and mined for peat during the 1960s (Service 1990). Today, the Carson Slough is an ephemeral channel in the northwestern portion of the Refuge that contains alkali shrub habitat, some riparian woodlands dominated by the non-native tamarisk, and some alkali meadows.

The creosote bush shrub or creosote–white bursage (*Larrea tridentata-Ambrosia dumosa*) scrub alliance is one of the most common habitat types in the Mojave Desert. This habitat type occurs on approximately 4,500 acres or 19 percent of the Refuge (Otis Bay and Stevens Ecological Consulting 2006). Creosote bush and white bursage are the codominants in this habitat. Other common species include fourwing saltbush, desert holly (*Atriplex hymenelytra*), brittlebrush (*Encelia farinosa*), wolfberry (*Lycium* spp.), and beavertail (*Opuntia basilaris*). The herbaceous layer is sparse, but seasonally abundant after rain events. Creosote bush shrub habitat occurs primarily along the eastern, southern, and extreme northwestern boundaries of the Refuge. The habitat is relatively undisturbed, except for an area east of Point of Rocks Spring that has been leveled, irrigated, and furrowed.

Non-native oldfields occur throughout the Refuge adjacent to native habitats. They occupy approximately 2,000 acres or 8 percent of the Refuge. The Refuge's history of land and water manipulation for various purposes has resulted in the establishment of non-native plants, and in some areas (i.e., the oldfields), non-native plants have become the dominant species. Typical species in the oldfields include Russian knapweed (*Acroptilon repens*), star thistles (*Centaurea* spp.), other thistles (*Cirsium* spp.), Bermuda grass (*Cynodon dactylon*), tansy mustards (*Descurania* spp.), and tamarisk. In some areas, native species, such as creosote bush and mesquite, are recolonizing where non-native species or agricultural fields previously occurred. Native species may continue to recolonize previously disturbed areas, but the presence of noxious weeds (e.g., Russian knapweed and tamarisk) currently prevents native species from reestablishing.

On steep upland hillslopes and dry ridgetops, creosote bush and bursage disappear, and succulents dominate the shrub layer. This habitat type is sparse on the Refuge, occurring on approximately 900 acres or 4 percent of the Refuge. Common succulent include beavertail cactus, cottontop (*Echinocactus polycephalus*), and cholla (*Opuntia* spp.). Common herbaceous species include fluff grass (*Erioneruon pulchellum*), buckwheat (*Eriogonum* spp.), and phacelia (*Phacelia* spp.).

Sensitive Plant Species

There are 15 sensitive plant species found at Ash Meadows NWR (Appendix H). Nine of these species are endemic to Ash Meadows. One is federally endangered, Amargosa niterwort (*Nitrophila mohavensis*), and six are federally threatened: Ash Meadows milkvetch (*Astragalus phoenix*), spring-loving centaury (*Centaurium namophilum*), Ash Meadows sunray (*Enceliopsis nudicaulis* var. *corrugata*), Ash Meadows gumplant (*Grindelia fraxino-pratensis*), Ash Meadows ivesia (*Ivesia eremica*), and Ash Meadows blazing star (*Mentzelia leucophylla*).

The other plant species are considered sensitive by other organizations, such as the State of Nevada or the Nevada Natural Heritage Program (NNHP). Six plants are on Nevada's "At Risk" list (NNHP 2004): white bearpoppy (*Arctomecon merriamii*), alkali mariposa lily (*Calochortus striatus*), Ash Meadows lady's tresses (*Spiranthes infernalis*), Tecopa birdsbeak (*Cordylanthes tecopensis*), Death Valley blue-eyed grass (*Sisyrinchium funereum*), and St. George blue-eyed grass (*Sisyrinchium radicatum*). Three others are considered sensitive by the NNHP: Darin buckwheat (*Eriogonum concinnum*), Parish's phacelia (*Phacelia parishii*), and Death Valley sage (*Salvia funerea*).

A recovery plan for 12 endangered and threatened species at Ash Meadows NWR has been approved and is being implemented by the Service (1990). The recovery plan describes each species and its habitat in detail, along with recovery goals and objectives.

Noxious Weeds

Sixty-three non-native species have been identified on Ash Meadows NWR, of which 10 are considered noxious.

The Service prepared an Integrated Pest Management (IPM) Plan in 2006 and is beginning to implement strategies to manage invasive species (Service 2006b). The IPM Plan describes a variety of methods that include a combination of biological, mechanical, chemical, and cultural controls. The use of chemical and mechanical controls on Ash Meadows NWR is limited by the presence of sensitive species. Removal of weeds must be combined with revegetation and restoration techniques to avoid adverse effects to these sensitive species. The IPM Plan outlines herbicide methods, specific time frames, adaptive management, and cost estimates for control of invasive, non-native plants, especially the noxious weeds.

Wildlife

Ash Meadows NWR is a haven for wildlife, especially rare fish, plants, snails, and insects, many of which are found nowhere else on earth (See Appendix H for a species list). Water bubbles up from underground sources into clear spring pools as silvery blue and grayish green pupfish dart between swaying strands of algae. Pebbled streams gurgle from small hillside springs, sheltering tiny beetles and snails. The water is warm and the air moist, in contrast to the surrounding Mojave Desert.

Ash Meadows NWR has a greater concentration of endemic species than any other local area in the United States, and it has the second greatest concentration in North America. Five of these species are fish, one is a mammal, at least 12 are aquatic snails, and two are aquatic insects. Several of these species are considered sensitive. One fish, at least one snail, and possibly one mammal have become extirpated from the Refuge in the past century due to habitat loss related to human activities, particularly agricultural, municipal, and mining development.

<u>Amphibians and Reptiles</u>

Five amphibians and 20 reptiles are known to occur on the Ash Meadows NWR. Reptiles and amphibians are most visible during the spring and fall. Toads are most visible right after spring and summer rains, when they become very active feeders and breeders. Snakes are also observed more often during the spring and early fall because they become more nocturnal during the heat of mid-summer (Service 2006a). Horned lizards (*Phrynosoma platyrhinos*) are also present at the Refuge. Bullfrogs (*Rana catesbeiana*) were introduced into the wetlands and natural springs sources on the Refuge (Service 1994b). Bullfrogs prey on native fish, including their eggs and young, and thus adversely affect recovery efforts. Following completion of an Environmental Assessment for frogging activities (Service 1994b), the Service has allowed bullfrog harvesting by Refuge staff, Nevada Department of Wildlife (NDOW) staff, and permitted members of the public to protect native fish species.

<u>Birds</u>

More than 239 different species of birds have been recorded within Ash Meadows NWR. The greatest diversity and numbers of birds occur during migration periods from the Pacific Flyway migration route. Spring migration usually occurs during April and May, and fall migration occurs from mid-August through September, when Ash Meadows supports thousands of pass-through migrants fattening up for the coming breeding season or for wintering in the tropics. It appears to be a very important stop-over site for migrant landbirds. During the winter, marshes and reservoirs support a large variety of water birds.

Mesquite and ash tree groves throughout the Refuge harbor resident and migratory birds year-round. Several species of migrants and residents that occur at Ash Meadows are listed on the Service list of Birds of Conservation Concern and as conservation priorities in the Partners in Flight bird conservation plan for Nevada. Some of these priority bird species include eared grebe (*Podiceps nigricollis*), western grebe (*Aechmophorus occidentalis*), Franklin's gull (*Larus pipixcan*), black tern (*Chlidonias niger*), snowy egret (*Egretta thula*), marbled godwit (*Limosa fedoa*), snowy plover (*Charadrius alexandrinus*), long-billed curlew (*Numenius americanus*), white-throated swift (*Aeronautes saxatalis*), Arizona Bell's vireo (*Vireo bellii arizonae*), southwestern willow flycatcher, western yellow-billed cuckoo (*Coccyzus americanus occidentalis*), and canvasback (*Aythya valisineria*) (see Appendix H for more species and the habitats the species occur in on the Refuge).

A few pairs of endangered southwestern willow flycatchers have been documented using Ash Meadows as breeding habitat from June through August each year (Service 2006a). Two endangered species success stories, the peregrine falcon and bald eagle, also use Ash Meadows seasonally as a migration stop-over.

<u>Mammals</u>

More than 30 species of mammals have been observed on the Refuge. Desert bighorn sheep are occasionally observed at Point of Rocks Spring and Devils Hole (Service 2006a). Small game species also occur on the Refuge, such as cottontail rabbit (*Sylvilagus* spp.) and jackrabbits (*Lepus* spp.).

<u>Aquatic Species</u>

Four of the 10 species of fish present in Refuge waters are endangered; the other six are introduced exotic species (Service 2006a). Non-native species such as largemouth bass (*Micropterus salmoides*), mosquitofish (*Gambusia affinis*), and sailfin molly (*Poecilia latipinna*) are being removed by the Service, as they are harmful to the native fish by competing for the same limited resources, preying on native fish, and introducing non-native parasites (Service 1990). Crystal Reservoir provides favorable spawning habitat for non-native species and is a source for these predatory non-native species that threaten native fish populations in the springs and channels upstream.

Ash Meadows Amargosa pupfish (*Cyprinodon nevadensis mionectes*) can be observed year-round at all the major springs and streams on the Refuge, but they are most visible at Point of Rocks Spring. Male pupfish take on a bluish cast during the spring and summer breeding season, whereas females remain olive green year-round. Warm Springs pupfish (*Cyprinodon nevadensis pectoralis*) can be found in a wide variety of habitats, including shallow and deep streams flowing from springs. The Ash Meadows speckled dace (*Rhinichthys osculus nevadensis)* were historically located in numerous springs and streams on the Refuge, but these populations were extirpated except at Bradford and Jackrabbit Springs. The Devils Hole pupfish occurs in a small, water-filled cavern called Devils Hole (Figure 4.2-3). Devils

Hole is the most restricted habitat in the world containing the entire population of a vertebrate species (Service 1980). The National Park Service (NPS) manages the habitat and species of pupfish at this location. The Refuge also supported two refugia populations of the pupfish, one at Point of Rocks (currently online) and a second refugium at School Springs (currently offline).

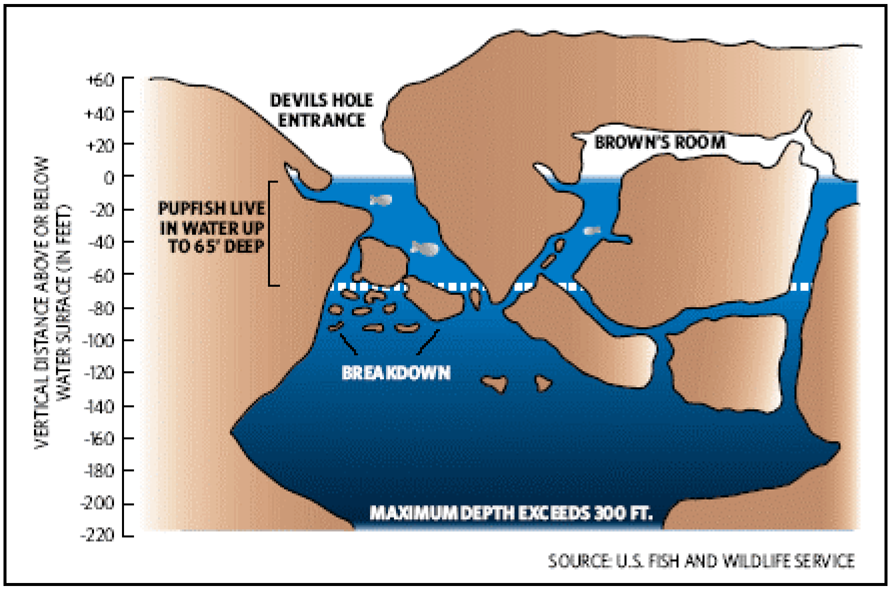


Figure 4.2-3. Devils Hole Pupfish Habitat

Like many of the endemic species on the Refuge, aquatic invertebrates have become isolated from other similar populations due to their specialized habitat requirements. Their ancestors tend to resemble species found in South America and southern latitudes in North America (Service 1990). The Ash Meadows naucorid (*Ambrysus amargosus*) is endemic to Ash Meadows. Other aquatic invertebrates endemic to Nevada with habitat or known occurrences on the Refuge include the Devils Hole warm spring riffle beetle (*Stenelmis calida calida*), sportinggoods tryonia (*Tryonia angulata*), Point of Rocks tryonia (*T. elata*), minute tryonia (*T. ericae*), median-gland Nevada spring snail (*Pyrgulopsis pisteri*), Fairbanks spring snail (*P. fairbanksensis*), and other spring snails (*Pyrgulopsis* spp.) (Otis Bay and Stevens Ecological Consulting 2006).

Mollusks and crustaceans, such as spring snails and crayfish, occupy the spring pools and immediate outflows of most of the local springs and seeps on the Refuge. The non-native Malayan trumpet snail (*Melanoides tuberculata*) is found in Refuge springs. The non-native Louisiana crayfish (*Procambarus clarkii*) preys on native fish in the springs and streams of Ash Meadows NWR. Crayfish were likely introduced through the release of live bait, and they have spread into streams and spring habitats throughout Nevada. Active crayfish trapping programs are implemented on the Refuge to control this species; however, crayfish continue to threaten native aquatic species.

Sensitive Wildlife Species

Fifty-three sensitive wildlife species have the potential to occur at Ash Meadows NWR. These species are federally listed as threatened or endangered or are considered sensitive by the NNHP or state of Nevada (Appendix H). Of these species, two are reptiles, 16 are birds, 13 are mammals, four are fish, and 18 are invertebrates. Species accounts for the federally listed species are provided in Appendix H. Some details on the fish and birds are described above.

All of the sensitive fish species are endemic to Nevada, as are several of the invertebrates and one of the mammals. The endangered and threatened species include: southwestern willow flycatcher, Yuma clapper rail, bald eagle (*Haliaeetus leucocephalus*, delisted August 8, 2007, being monitored), Devils Hole pupfish, Ash Meadows Amargosa pupfish, Warm Springs pupfish (*Cyprinodon nevadensis pectoralis*), Ash Meadows Speckled Dace, and the threatened Ash Meadows naucorid.

A Recovery Plan for the Endangered and Threatened Species of Ash Meadows has been approved and is being implemented by the Service (1990). The recovery plan describes each species, its habitat needs, and its recovery goals in detail.

4.2.3 Cultural Resources

Introduction

Water was a key resource for prehistoric and historic-period people attempting to survive in a harsh desert environment. The plant and animal habitat at the springs provided sustenance for these groups and allowed them to thrive despite the harsh surroundings. Most of the Ash Meadows NWR has been recently investigated through archaeological reconnaissance surveys.

Prehistoric Archaeology

Nearly 300 prehistoric and/or historic sites are known to exist on the Refuge that reflect short-term, limited types of activities, and some are extensive campsites representing a variety of activities over several thousand years. At the sites determined to be eligible for listing on the National Register of Historic Places (NRHP), diagnostic artifacts, hearths, and fire-affected rock are often found, and a variety of grinding tools are common. Ceramics associated with the Southern Paiute and Shoshone as well as Far Western Puebloan groups have also been recorded.

Historic Archaeology

Historic sites are those sites that resulted from use of the region by Euro-Americans or other groups after contact with native peoples. They document interactions between Euro-Americans and Native Americans. For many portions of southern Nevada, this happened during the mid-1800s. On the Ash Meadows NWR, a smaller percentage of historic sites relate to mining and ranching activities in the area. These generally consist of modest structural remains and associated historic debris scatters or trash dumps. Buildings on the

Refuge include a cabin made of railroad ties and others made of rock and wood. Some of the buildings are evident only through observation of piles of fallen bricks. One important historic site is the Charles King homestead. It was the first Anglo homestead at Ash Meadows established as a modest ranch to supply the miners near Death Valley with beef. The site includes King's house and associated historic-period debris. The Jack Longstreet cabin is associated with an extensive lithic and pottery scatter that documents his close association with many of the Paiutes living in Ash Meadows. He was married to a Southern Paiute woman and befriended other Paiutes on occasion in dealing with other Anglo-Americans in the area. Both of these sites have characteristics that make them eligible for listing on the NRHP. There is also an Indian Cemetery within the Refuge that tribal descendants still visit that reflects the long, continued use of the Ash Meadows area.

4.2.4 Public Access and Recreation

Public Access

Ash Meadows NWR is open daily to the public year-round from sunrise to sunset; access is free of charge. The public is encouraged to visit the Refuge and experience this valuable and unprecedented example of desert oases that are now extremely uncommon in the southwestern United States.

The southern entrance to Ash Meadows NWR can be accessed from Pahrump, Nevada, by traveling west on Bell Vista Road and turning north onto Spring Meadows Road (Figure 1.7-1). Access to the western portion is via Nevada State Route (SR) 373/Highway 127 from Death Valley Junction. None of the roads on the Refuge are paved, and many are inaccessible during and following inclement weather. Refuge roads are subject to closure in the wet winter months due to high clay content on native roads. Because of the sensitivity of many of the listed species and their habitats, vehicles are restricted to major roads. The entire Refuge, including roads, is closed to off-highway vehicle use by the public. Vehicle parking is restricted to existing parking areas (Service 2000a).

The Refuge receives visitors from the local areas of Amargosa Valley, Pahrump, and Las Vegas, as well as from numerous other states and foreign countries. A visitor sign-in sheet is located at the Refuge office, and visitors are asked for comments and the number of people in their group. Traffic counters are located on the access roads to track the number of cars entering the Refuge. Based on recent estimates, Ash Meadows NWR receives approximately 65,000 visitors annually.

Recreation

The Refuge is a day use area, open sunrise to sunset, with numerous recreational opportunities. Wildlife-dependent activities include wildlife observation, photography, environmental education, interpretation, and hunting. Non–wildlife-dependent activities include picnicking and virtual geocaching. Wildlife observation, picnicking, and hunting are the more popular activities enjoyed by Refuge visitors (Service 2006a).

The Refuge administrative office serves as a visitor contact station. The office is currently open Monday through Friday from 8:00 a.m. to 4:00 p.m. —as staffing permits. The visitor contact station is currently closed on weekends. Brochures, maps, and fact sheets are available at the visitor contact station. The Crystal Springs Interpretive Boardwalk Trail and an interpretive kiosk are located near the visitor contact station. The boardwalk offers a unique opportunity for visitors to view the restored spring system and associated wildlife. Picnic tables and restrooms are located at the visitor contact station, and one picnic table and portable toilet are located at the Point of Rocks parking area. The planning and design for a loop boardwalk in the Point of Rocks/Kings Pool area with interpretive panels, improved parking, and restrooms are currently under development. Power, phone service, and running water are available at the administrative offices and at select locations on the Refuge for maintenance purposes.

Nature trails, kiosks, and the administrative office/visitor contact station are the primary facilities used by visitors (Service 2006a). During fiscal year (FY) 2002, almost 8,000 people stopped at the contact station, about 4,000 people visited the kiosks, and 14,000 visitors hiked the nature trails and paths.

Wildlife-Dependent Recreation

Wildlife photography and observation opportunities are available throughout the Refuge, with the best places being near bodies of water and at Carson Slough. The presence of riparian vegetation and open water attracts numerous birds to the area and makes bird-watching a popular activity. The National Audubon Society performs surveys for birds at Ash Meadows NWR, and bird lists generated from the Refuge have been included in the Nevada Breeding Bird Atlas. A bird list is available at the Refuge headquarters and online at the Ash Meadows NWR Web site. The Refuge is also internationally known as a top birding spot because of its classification as a Wetland of International Importance (Ramsar Convention 2004) and is designated as a Nevada Important Bird Area (IBA).

Opportunities for observing the endangered Ash Meadows pupfish exist at all major springs, but are best at Kings Pool, located at Point of Rocks. Devils Hole, home of the endangered Devils Hole pupfish, is managed by the NPS and is part of Death Valley National Park.

Educational opportunities are available on and off the Refuge. Ash Meadows NWR has a partnership with Death Valley National Park to educate the local students about pupfish. During FY 2002, 1,125 visitors participated in environmental education opportunities (Service 2006a). Less than half of these visits were staff-conducted tours, with students and teachers as the primary participants. Off-site educational outreach opportunities include group presentations and exhibits. Ash Meadows NWR had an estimate of 30 visits to environmental education exhibits and 201 visits to interpretation exhibits during FY 2005. Other special events to promote the Refuge include news releases and radio or television spots. Many of these activities have decreased in the past three years due to limited funding and staff; however, Refuge visitors have increased more than three-fold since 2000.

An active volunteer program provides additional opportunities for the public to enjoy the Refuge and interact with the staff. The Service works with the other public land agencies in southern Nevada to coordinate volunteer work through the Southern Nevada Interagency Volunteer Program–Get Outdoors Nevada. Internships are also available for students to earn college credits. Some of the volunteer projects include tree-planting and habitat restoration. The Ash Meadows NWR is extensively used by students and professionals for environmental ecosystem research, including endangered and threatened species studies, groundwater modeling, groundwater chemistry studies, and habitat conservation. College classes occasionally take field trips to the Refuge.

The Desert Complex hosts events for National Wildlife Refuge Week and Migratory Bird Day, and the Refuge had a ribbon-cutting ceremony for the restored Jack Longstreet cabin in 2005. The Desert Complex staff also attends local events to promote environmental education about Ash Meadows NWR. Such events include the Clark County Fair, Clark County ECOJAM (Earth Day event), Gran Fiesta (September 2002), and Boy Scout Day Camp (May 2003). Desert Complex staff or Refuge staff also attended the Governor's Conference on Tourism, Dia de los Niños, and Las Vegas Chamber of Commerce Preview, depending on staff availability and funding.

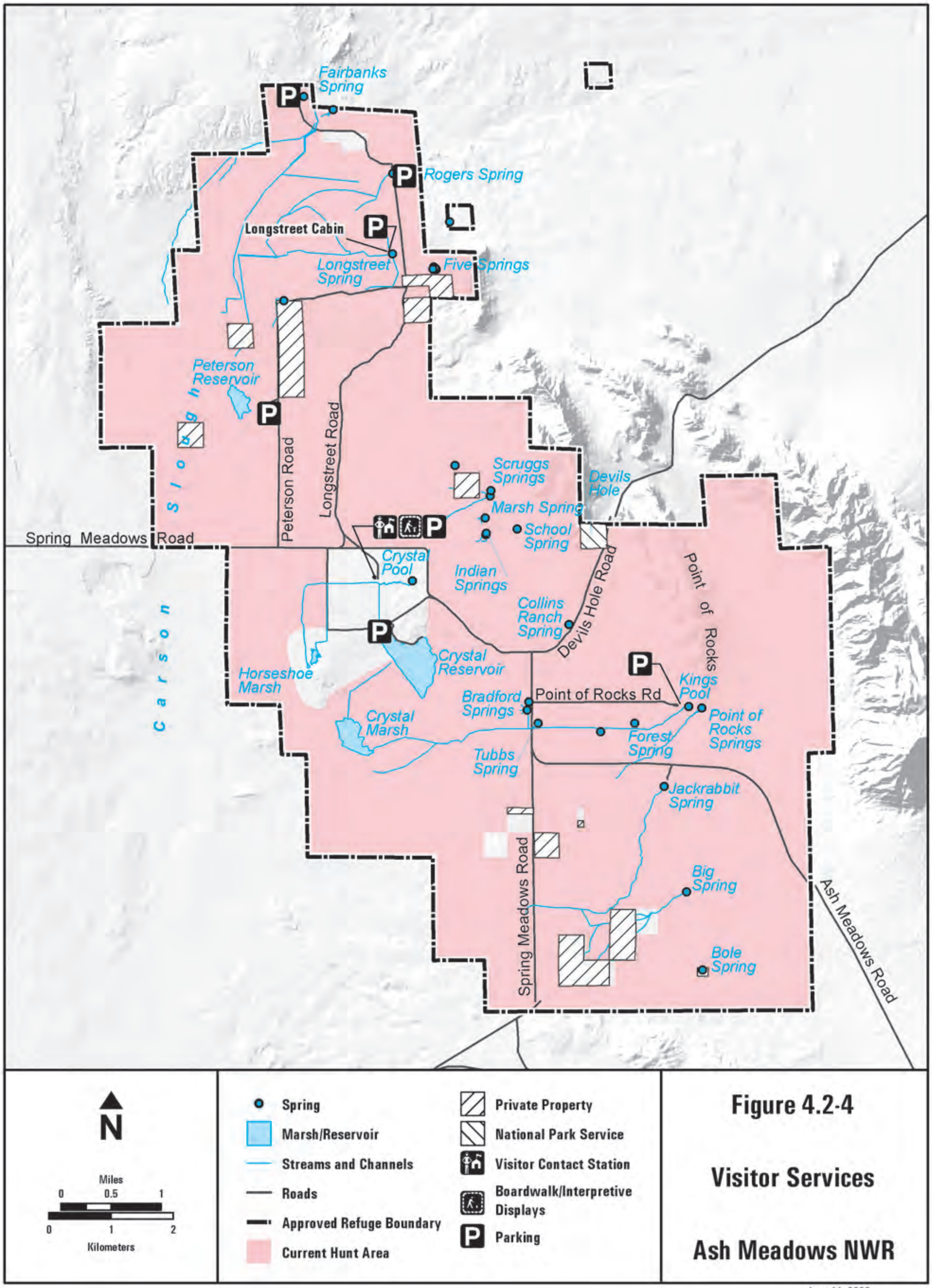
Hunting for waterfowl, dove, and quail is allowed on the Refuge where posted and in accordance with state regulations (Service 2000a) (Figure 4.2-4). Waterfowl hunting generally occurs at Peterson Reservoir, the southern portion of Crystal Reservoir, and Lower Crystal Marsh. Currently, during the migratory waterfowl hunting season, only nonmotorized boats or boats with electric motors can be used. Target practicing is not allowed at any time. In FY 2002, 2,900 visitors participated in hunting activities (Service 2006a).

Fishing is not allowed on the Refuge. The largemouth bass was introduced into most Refuge waters in the 1960s. This non-native fish is considered a threat to the native endangered fish and is being removed from Refuge waters (Service 2000a).

Non–Wildlife-Dependent Recreation

Hiking is available along designated roads and trails. No camping or overnight parking is permitted (Service 2000a). Due to the presence of waterfowl and sensitive species, swimming is prohibited in all spring pools. Off-road vehicle use is also prohibited on the Refuge. Virtual geocaching is allowed with permission from the Refuge Manager.

Picnicking opportunities are currently available at the visitor contact station and at the Point of Rocks Spring area. The visitor contact station also has picnic tables and restrooms. Point of Rocks Spring has picnic tables and a portable toilet.



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4.2.5 Social and Economic Conditions

Refuge Management Economics

The current Refuge staff consists of four full-time employees, one non-funded biologist, and one non-funded outdoor planner and laborer. The refuge operations budget for 2005 was $235,000. The maintenance budget for the Refuge was $58,175.50.

NWRs contribute funds to local counties through revenue-sharing programs that are intended to cover costs for either lands purchased in fee title or lands reserved from the public domain. For FY 2003, Nye County received payment in the amount of $21,895 from the federal government under this revenue-sharing program.

Environmental Justice

The Ash Meadows NWR is located within an area once occupied by Western Shoshone, particularly the Timbisha Shoshone, the Pahrump Paiute Tribe, and the Las Vegas (*Tuh'du Ningwoo*) Paiute band (Kelly 1934; D'Azevedo 1986; Martineau 1992; Steward 1997; Timbisha Shoshone Tribe 1999). The Timbisha Shoshone reservation currently includes approximately 10,600 acres throughout southwestern Nevada and eastern California. The Timbisha Shoshone also co-manage 300,000 other acres within Death Valley National Park. In 2000, the Timbisha Shoshone Homeland Act (Public Law [PL] 106-423) identified the potential for a cooperative agreement between the affiliated tribe and the Service.

The communities of Pahrump and Amargosa Valley are located within 10 miles of the Refuge. Both communities indicate that the Hispanic or Latino population is the largest minority group, approximating 10 percent of the total population (U.S. Census Bureau 2000). The communities may also be considered low-income communities based on the median family income, which is approximately $10,000 less than the state median family income, although it is comparable to the county's median family income at around $40,000.

Land Use

Land surrounding Ash Meadows NWR is a rural setting with a low population density and a relatively small number of ranches, farms, and mining enterprises (Service 1987). From 1980 to 1983 municipal development activities disturbed 12,654 acres of private land, which are now within the Refuge boundary (Service 1984).

The land was subsequently purchased by The Nature Conservancy (TNC) and resold to the Service to establish the Ash Meadows NWR (Service 1990). Since establishment of the Refuge on June 18, 1984, the Service has undertaken restoration activities throughout the Refuge.

Of the 24,000 acres within the approved Refuge boundary, the Service manages approximately 22,729 acres (including BLM lands), the NPS manages 40 acres around Devils Hole, and the rest are privately owned (approximately 676 acres) (Figure 1.7-1). Private lands are mostly unoccupied and consist of residences, a clay processing plant, and a private landing strip. The Service has a Cooperative Management Agreement with the BLM to manage BLM-administered lands within the Refuge. The NPS manages and monitors Devils Hole to protect and research the Devils Hole pupfish.

The entire boundary is surrounded by BLM lands that were designated as the Ash Meadows ACEC. This area has been set aside for the protection of the endemic species of Ash Meadows.

Aesthetics

Ash Meadows NWR consists of more than 24,000 acres of spring-fed wetlands and alkaline desert uplands and provides excellent views of the night sky for stargazers due to the lack of light sources in the vicinity. The Refuge provides habitat for at least 25 plants and animals found nowhere else in the world and provides a unique visual quality opportunity.

The Refuge is a major discharge point for a large underground aquifer system stretching 100 miles to the northeast. Water-bearing strata come to the surface in more than 30 seeps and springs, providing a rich and complex variety of habitats. Wetlands, springs, and springbrook channels are scattered throughout the Refuge. Sandy dunes, rising up to 50 feet above the landscape, appear in the central portions of the Refuge.

Mesquite and ash groves flourish near wetlands and stream channels, and saltbush dominates large portions of the Refuge in dry areas adjacent to wetlands. Creosote bush habitat occurs in the drier elevated areas along the east and southeastern portions of the Refuge. Cacti occur along the outer eastern edge of the Refuge, with a variety at Point of Rocks.

The land within Ash Meadows NWR was intensively farmed in the 1960s and 1970s, prior to its establishment as a Refuge. As a result, many of the visual qualities associated with that use are still evident. The Refuge is currently in the habitat restoration stage and will likely remain so for years to come. The overall goal of the Refuge is to restore the area to its natural historic condition by re-directing spring outflows back into former natural channels, restoring wetlands, removing non-native species, restoring native riparian and upland vegetation, and removing unnecessary structures such as roads, fences, dams, levees, and power lines. Once this is accomplished, visual quality will be improved.

4.3 Desert National Wildlife Refuge

4.3.1 Physical Environment

Physiography

The boundary of the Desert NWR encompasses approximately 1.6 million acres. The Desert NWR consists of typical basin and range topography—a series of narrow north/south-trending mountain ranges separated by wide valleys. Desert NWR is bordered to the north by Emigrant Valley, Desert Mountain Range, Tikaboo Valley, Pahranagat

Range, East Pahranagat Range, and the Pahranagat NWR; to the east by the Delamar Mountains, Coyote Spring Valley, and Hidden Valley; to the south by Las Vegas Valley; and to the west by Frenchman Flat and the Halfpint Range (Figure 4.1-2).

Six primary mountain ranges are located within the Desert NWR and consist of, from west to east, the Spotted Range, the Pintwater Range, the Desert Mountain Range, the East Desert Range, the Sheep Range, and the Las Vegas Range. The Papoose Range, a relatively small mountain range, occurs in the northwest corner of Desert NWR. Most of Desert NWR consists of closed hydrographic basins (basins that have interior drainage). Exceptions are the east side of the Sheep Range, where drainage flows east toward Coyote Spring Valley, and the east side of the Las Vegas Range, where drainage flows east toward Hidden Valley. In addition, drainage from the western side of the Spotted Range flows west towards Frenchman Lake, which is a large playa that covers most of Frenchman Flat.

Elevations of Desert NWR extend from approximately 3,500 feet above msl in the valleys to 9,950 feet above msl in the Sheep Range. The elevations of both mountains and valleys are lower in the western half of Desert NWR.

Geology and Minerals

Desert NWR is characterized by a series of north/south-trending mountain ranges separated by wide valleys. Mountains consist mostly of carbonate rocks dating from the Paleozoic period from 543 mya to 248 mya (Tschanz and Pampeyan 1970). Some mountains also contain Precambrian (more than 543 mya) and Tertiary (65 to 1.8 mya) rocks. Valleys contain deposits of Tertiary and Quaternary (1.8 mya to present) alluvium derived from erosion of adjacent mountain ranges.

Several faults cross through the mountain ranges on the Refuge. The larger faults run north to south parallel to the ranges (Tingley et al. 1993). Some of these faults include Wildhorse Pass Fault, Mormon Pass Fault, Sheep Basin Fault, and Gass Peak Thrust. Other faults that run southwest to northeast along the mountain ranges in the northeast portion of the Refuge include Maynard Lake Fault, Buckhorn Fault, and Arrowhead Mine Fault.

Both nonmetallic (mostly construction materials) and metallic minerals such as zinc, silver, lead, gold, and uranium are found in the Desert NWR (Tingley et al. 1993). Although the Desert NWR probably contains large amounts of material that would be suitable for construction aggregate, under current market conditions, aggregate production from the Desert NWR is not economically competitive due to high transportation costs (Tingley 1998). Review of Tingley (1998) and Tschanz and Pampeyan (1970) indicates that there were six mining districts within the Desert NWR: Papoose, Southeastern, Slate, Joe May Canyon, White Caps, and Gass Peak. These mines were active during the early 20th century but are no longer in operation.

In 1994, the BLM withdrew 769,543 acres of public mineral estate from location and entry under the mining laws to protect the Desert NWR

(BLM 1994). The land has been and will remain open to mineral leasing.

Paleontological Resources

A number of geologic units in Desert NWR have the potential to contain fossils. In general, Paleozoic, Tertiary, and Quaternary deposits have the potential to contain fossils in the region, while Precambrian rocks and igneous or molten rocks are of low potential. Common types of fossils found in those units include primarily sea creatures, such as mollusks, corals, barnacles, algae, and other invertebrates (Tschanz and Pampeyan 1970; Longwell et al. 1965). Horse and other vertebrate fossils may also be present.

Mammoth and bison fossils have been found on the Refuge and have been dated to approximately the Pleistocene era (Hallman 1998). Fusulinid fossils have also been found in the Arrow Canyon and Las Vegas Ranges on the Refuge (Langenheim et al. 1977). These fossils are indicator fossils because of their abundance. They have formed entire limestone formations in some areas and date to the Mississippian Period. Brachiopod fossils have also been found in the Wamp Spring area of the Las Vegas Range (Mills and Langenheim 1987).

Soils

Soil mapping and classification has not been completed for the Desert NWR. However, STATSGO data are available from the NRCS (2003a). General soil characteristics are described below for each major vegetative community (Service 1994a).

Soils are generally silty loam within the saltbush community. Soils within the creosote bush community are commonly sandy loams developed from alluvial deposits. In many places there is an overlapping of desert pavement or cobblestone. Soils common to the blackbrush community have developed from the older alluvium deposited on the upper slopes and the rocky soils of the lower mountains. This desert soil is slightly darker and contains more organic material than the soil in the creosote bush community.

Soils associated with the pinyon-juniper community tend to be deep sandy loams with some development of distinct soil horizons. Soils in the fir-pine community are higher in organic content than those in the pinyon-juniper community. There is a well-developed soil horizon, and the surface is commonly covered by conifer needles and other ground litter. Soils are shallow and fragile in the bristlecone pine community, which is restricted to steep slopes and ridges at the highest elevations of the Sheep Range.

Water Resources

<u>Surface Water</u>

Surface water on Desert NWR is comprised primarily of direct runoff from precipitation, with the exception of Corn Creek Springs and seeps and springs at higher elevations. Precipitation flows into playa lakes that have no external drainage, including Frenchman Flat, Papoose

Lake, Desert Lake, and Dog Bone Lake. Like the springs at Ash Meadows NWR, Corn Creek Springs is a perennial water source that contains discharge from a regional carbonate flow system. The high elevation seeps and springs collect water from precipitation and runoff and provide a small, but important, source of surface water for wildlife. Other surface waters that the Service has rights to include Sand, Tim, Indian Spring Canyon, and Quartz springs within the NTTR overlay.

A variety of artificial rainwater catchments have also been built on Desert NWR to expand the quantity and distribution of water for wildlife. There are currently at least 27 functional catchments in scattered locations (Service 1994a). Artificial catchments of two types are used on Desert NWR. Guzzlers use an impermeable surface of sheet metal, fiberglass, or polyethylene to collect rainwater. Slickrock developments use a small concrete dam to collect rainwater/runoff from a smooth, up-canyon rock surface. Water collected by both types is piped to one or more enclosed tanks with storage capacities from 1,000 to 6,600 gallons. Water from the tanks is piped to float-regulated troughs for wildlife use. There are also two natural water catchments, known as tinajas, which are of value to desert bighorn sheep and other wildlife.

Groundwater

Corn Creek Springs spring flow is typical of regional groundwater because the springs are relatively high yielding, have warmer temperatures, and do not display seasonal variability. Spring flow is suspected to derive largely from precipitation falling in the Sheep Range on the eastern edge of the Refuge that is forced to the surface through faults (Thomas et al. 1996). Compared to the Ash Meadows NWR, Corn Creek Springs are relatively small. They currently have an annual average discharge of about 0.3 cfs or 200 afy. The springs have flowed continuously for at least 130 years.

In addition to Corn Creek Springs, there are 35 other known springs on the Refuge, many of which are shown in Figure 4.3-1 (Service 1994a). Instead of being fed by the deep carbonate aquifer system (such as Corn Creek Springs), these springs are local springs that receive water from precipitation. Twenty-nine of the springs are typical small mountain springs with flows derived from nearby areas of higher altitude.

Local springs typically have small, variable flow rates ranging from several gallons per minute to only a few gallons per hour. Discharges are seasonably variable, with highest flows occurring during or immediately after spring runoff and storm events and then diminishing or ceasing in late summer or early fall. Discharge from the springs usually travels only a short distance because much of the flow is lost to evapotranspiration.

Water catchments with float-regulated troughs, or drinkers, have been strategically located and constructed across the Refuge. Several thousand gallons of water can be stored in large reservoirs at these mountainous sites where precipitation is seasonally or severely

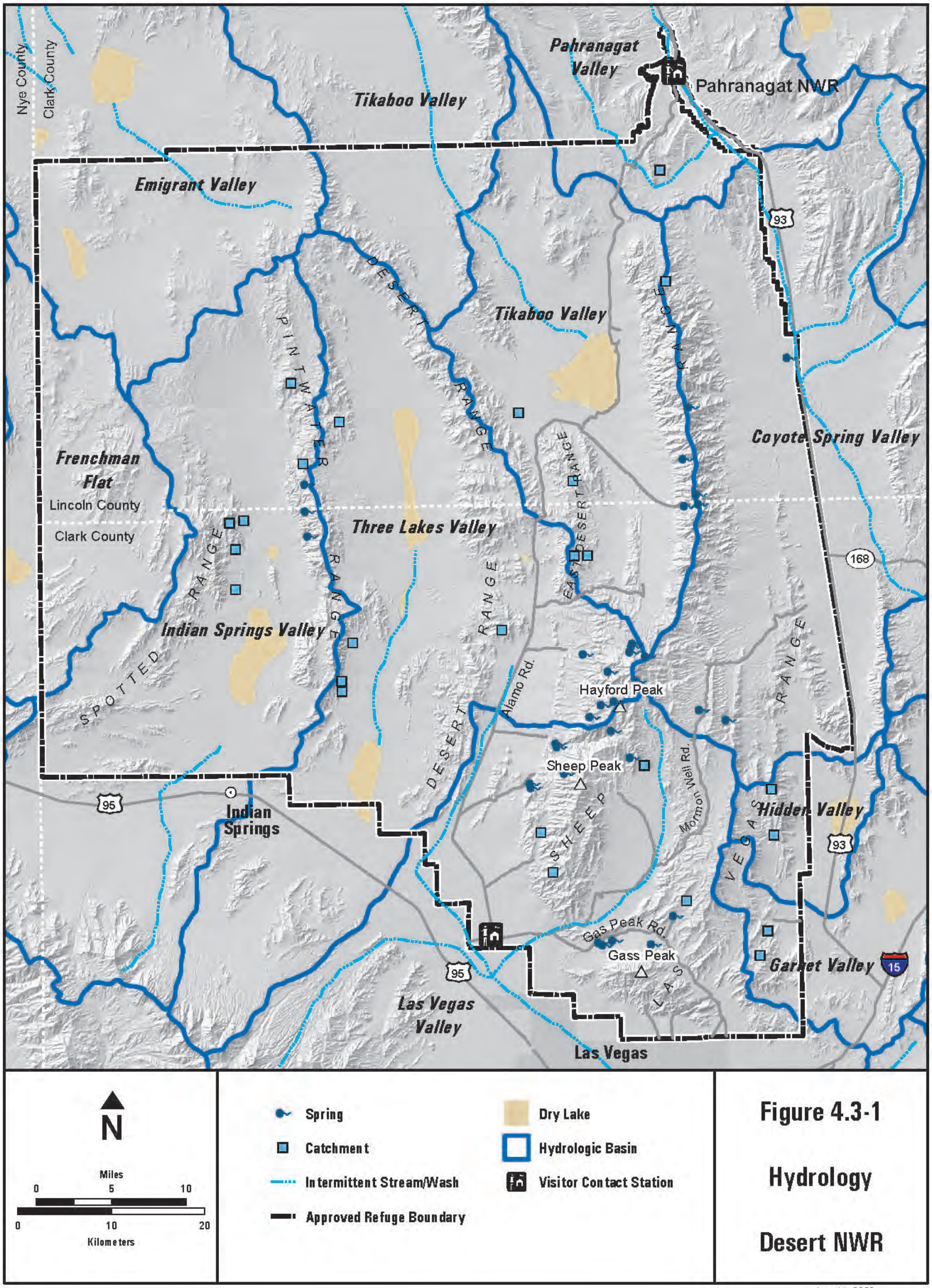

Figure 4.3-1

Hydrology

Desert NWR

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Figure 4.3-1-desert_hydro.mxd

reduced during dry conditions. Thirty springs have been improved, and 26 water troughs have been constructed and maintained.

Though derived from local precipitation, Coyote Spring, on the east side of the Sheep Mountains, is also reported to be relatively high yielding. Recharge from the Sheep Mountains flows eastward, discharging from an alluvial, water-bearing zone in the bluffs on the west side of the White River channel.

Six groundwater monitoring wells exist on or near the Refuge in the Corn Creek Springs area. All of them are part of a long-term monitoring program conducted by the USGS through a joint funding agreement with SNWA, NDWR, and USGS. Five of these wells are monitored quarterly: USBLM Corn Creek, USGS Cow Camp, USFWS DR-1, USFWS SBH-1, and USAF 2372-1. The Creech Field monitoring well is monitored continuously. In addition, there is a single carbonate monitoring well located on the Refuge on the east side of the Sheep Mountains, CSVM-5, that is monitored continuously by SNWA.

Water Quality

With the exception of Corn Creek Springs, little is known about the groundwater quality in the majority of springs on Desert NWR. Water from Corn Creek Springs is quite similar to that from springs at Ash Meadows NWR with respect to dissolved solids (418 mg/L). In contrast, water sampled from other springs is of poorer quality, with concentrations of dissolved solids as high as 3,700 mg/L (Thomas et al. 1996).

Water Use

Primary water use on Desert NWR is by wildlife from springs and catchments, with some domestic water use at Corn Creek Field Station. Groundwater pumping occurs in the Las Vegas Valley for domestic uses, and about 58,000 acre-feet of water were pumped in 2001 (NDWR 2001).

Water Rights

Water rights within the main undeveloped hydrographic basins that comprise Desert NWR total approximately 22,000 afy. About 1,300 afy of groundwater rights are held within 6 miles of Corn Creek Springs, primarily by the U.S. Air Force (USAF) and the Las Vegas Paiute Tribe. The SNWA filed for and was granted water rights on and near the Refuge, but these rights have not been developed to date. Their water rights on the Refuge include 1,700 afy in Tikaboo Valley (southern part) and 2000 afy in Three Lakes Valley North. They also have 2,618 afy in Three Lakes Valley South, adjacent to the Refuge. In 2005, SNWA applied to the State Engineer to change the point of diversion for water rights in Three Lakes Valley North and Tikaboo Valley basins to Three Lakes South. However, the State Engineer denied the requests.

The Service has 12 adjudicated federal reserved water rights for springs and two adjudicated vested rights, one for groundwater and one for springflow, at the Desert NWR. The two vested water rights include an 1885 right for 0.5 cfs from Corn Creek Springs and a 1922 water right from an artesian well at Corn Creek. The federal reserved rights all have a priority date of May 20, 1936, and are for spring flow at Corn Creek Springs and numerous other springs within the Las Vegas Artesian Basin.

Hazardous Materials

The Desert NWR is located in the South Range of the NTTR. Solid and hazardous wastes are generated on the South Range. Trash disposal areas, exploded ordnance disposal sites, practice and live ordnance ranges, and electronic countermeasures sites are typical examples. In addition, depleted uranium from munitions testing; residues from bomb testing, spills, and aircraft crashes; and radiation testing have also presented environmental concerns on the Desert NWR. Site and facility assessments conducted by the USAF on the NTTR overlay of the Refuge concluded that buried solid waste does not have the potential to cause adverse environmental effects, and the use of depleted uranium rounds on one target complex of the NTTR does not appear to pose a hazard to public health or create an environmental hazard (BLM 2001).

The USAF implements measures to contain hazardous materials and prevent environmental impacts. Hazardous wastes are stored on designated sites for up to 90 days prior to being picked up by a contractor and transported to appropriate off-site disposal facilities. The waste materials are typically stored in drums or other containers that are sealed, labeled, and placed on spill containment pallets or wooden pallets and covered with a tarp or hard Apoly shell. At hazardous waste accumulation points, containers are housed within locked and ventilated hazardous waste containment buildings or within other appropriate facilities. The wastes are isolated from the ground with asphalt, concrete, or bermed concrete surfaces. The accumulation site locations are fenced. Underground storage tanks on the NTTR are removed or replaced when they are found to be leaking (BLM 2001).

Fire History and Management

Desert NWR's fire history generally revolves around naturally ignited fires occurring at higher elevations of the Refuge. Generally, most natural ignitions occur on the Refuge from June to October (Service 2004c). In lower-elevation portions of the Refuge, the fuels are not continuous and fire size is limited. In higher elevations, lightning-caused fire likely played a key role in maintaining an open stand structure. The fire frequency of pinyon-juniper woodlands varies with the abundance of fine fuels, but they generally burn every 50 to 100 years when fuels are sparse. It is unkown what role Native Americans had in fire ignitions.

Fire exclusion probably began with the establishment of the Corn Creek Ranch in the early 1900s (Service 2004c). At present, the burning season (including human-caused ignitions) is primarily April through September. Current fire history shows an average of three fires per year for a total of 10 acres. These data are not accurate due to remoteness and lack of observed fire activity. Most fires are caused by lightning and occur during the monsoonal season, usually from July through September.

Fire occurrence on the Refuge has a higher incidence than what is recorded because of the remoteness of the area and difficulties with detection. Numbers of detected fires per year vary from zero to usually fewer than 10. Most fires occur on the Sheep Range as a result of lightning. The largest fire in the pinyon-juniper habitat from records dating back to 1946 was 100 acres. However, fires in the low desert shrub fuel type have burned in excess of 40,000 acres between 1994 and 2006. In most instances, fires are extinguished by rain or lack of adjacent fuels rather than suppression efforts. However, due to the expansion of invasive non-native grasses in low desert plant communities, large fires are expected to be more common and require greater suppression efforts.

There is no recorded recent prescribed fire history on the Refuge.

Air Quality

Currently, ambient air quality is not measured at Desert NWR, and the nearest major sources of emissions are in the Las Vegas area. It is expected that low ambient concentrations of criteria pollutants would occur in most of this area. The nearest air quality sampling station is located less than 5 miles south of the Desert NWR boundary at Bemis Road and Craig Road. This station is located in an area where new construction is occurring and measurements of concentrations are likely higher than in non-construction areas. Although these concentrations may be representative of the southern boundary of the Desert NWR, the concentrations are expected to be significantly lower as one moves further north of the developed areas (CCDAQM 2003b).

The regional air quality section (Section 4.1.1) provides additional information on air quality protection and regulatory measures in Clark County.

4.3.2 Biological Resources

Vegetation

Habitat Types

Desert NWR is located in a transition zone between the Mojave and Great Basin Deserts and contains diverse flora and fauna found over a wide elevation range that are representative of both deserts (Figure 4.3-2). The Refuge contains more than one-third of the 75 different ecological systems mapped in Nevada (USGS 2004). The predominant communities are desert shrubland and montane (Ackerman 2003). Corn Creek consists of a small amount of riparian, wetland, and aquatic habitats. Ackerman (2003) identified 702 plant species in 80 families within the Desert NWR. Of the species identified, 52 are introduced or non-native species. Most of the introduced species (31 species) occur in the Corn Creek Field Station and vicinity. Ackerman also discovered three plants endemic to the Desert NWR: Ackerman milkvetch (*Astragalus ackermanii*), remote rabbitbrush (*Chrysothamnus*

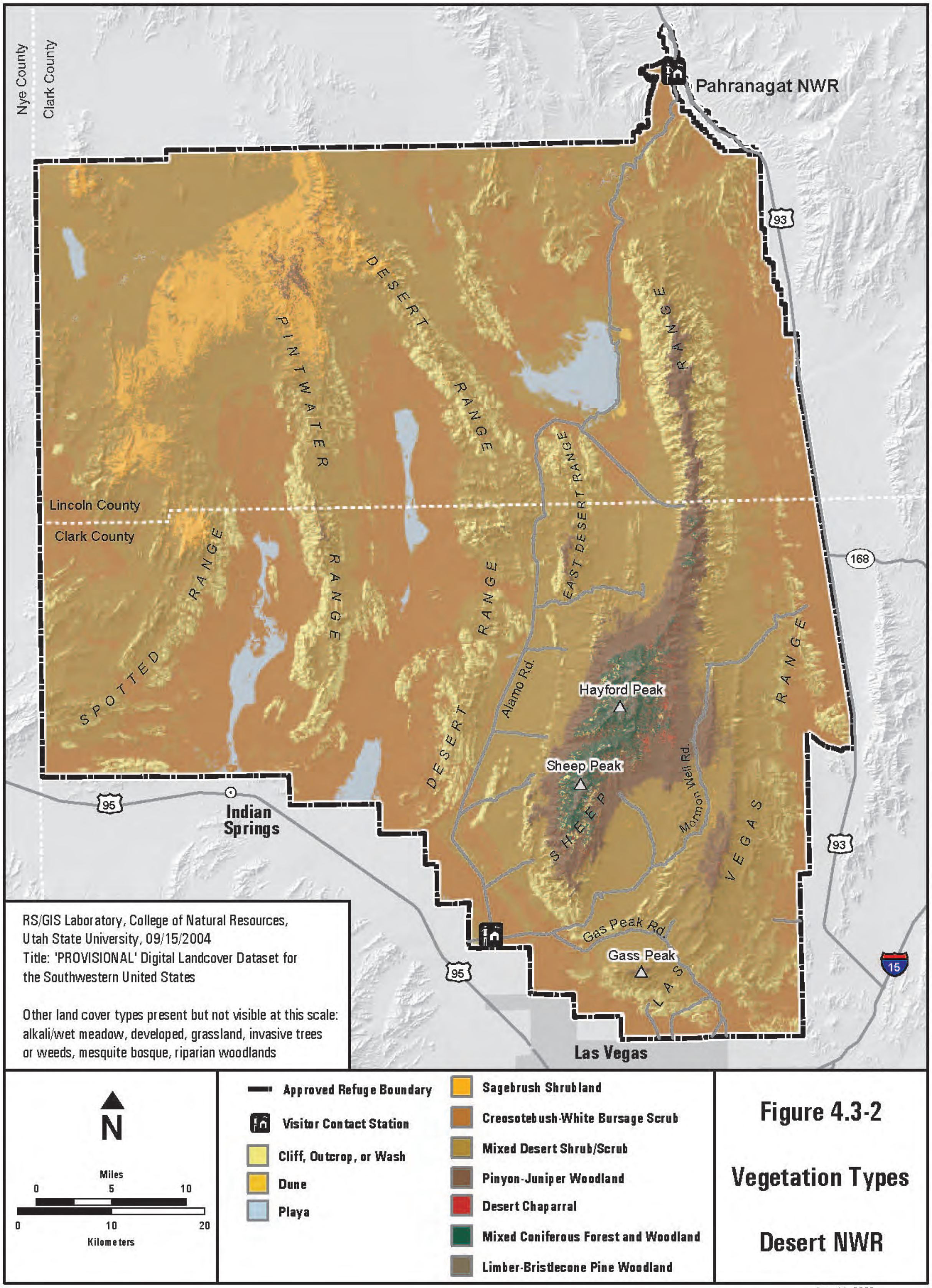

Figure 4.3-2

Vegetation Types

Desert NWR

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Figure 4.3-2-desert_veg.mxd

eremobius), and pygmy poreleaf (*Porophyllum pygmaeum*). A description of each habitat type is provided in the following paragraphs.

Corn Creek Field Station contains the main aquatic habitat on the Desert NWR. Corn Creek Springs are part of the field station and consist of three main springs. Water from the springs flows down a common channel toward the Desert NWR's main reservoir, which is about 400 feet west of the springs. Water is pumped from the reservoir to irrigate the pasture. Dense vegetation can be found along the length of the channel and surrounding the springs and pond. This vegetation consists of riparian woodlands and shrublands and mesquite bosques. The riparian woodlands consist of non-native deciduous trees, such as black locust (*Robinia pseudoacacia*) and Russian olive (*Elaeagnus angustifolia*). Native species include honey mesquite (*Prosopis glandulosa*) and willow (*Salix* spp.) and ash species. Common reed (*Phragmites australis*) and southern cattail occur in and around the springs and ponds. Numerous migratory birds and other wildlife use habitat at the Corn Creek Field Station.

At low elevations on the Refuge, grassland, steppe, and shrubland habitats dominate. The grassland habitat contains primarily perennial bunch grasses and drought-tolerant plants and occurs on dry plains and mesas. This habitat is dominated by invasive species, such as brome (*Bromus* spp.) and Mediterranean grass (*Schismus barbatus*). The steppe habitat occurs on alluvial fans and flats and consists mostly of graminoids, or grass-like plants, with an open shrub layer.

The salt desert scrub habitat consists of various saltbush species found in saline basins on valley floors and around playas. Areas with low nocturnal temperatures and very high soil salinity are common in these basins and support most of this habitat. This habitat, including playas, encompasses about 200,000 acres on the Desert NWR (Service 1977). The typical elevation range for the salt desert scrub habitat in the Mojave Desert is 3,000 to 5,600 feet, but on the Desert NWR, it is found mostly at lower elevations (DOE 2002). At the higher elevations, salt desert scrub often mixes with the creosote–white bursage alliance.

The creosote–white bursage scrub alliance occurs in broad valleys, lower bajadas, plains and low hills. This alliance is characterized by widely spaced shrubs and succulents averaging 2 to 8 feet tall, with 2 to 50 percent cover (Holland 1986; Rowlands et al. 1982; Vasek and Barbour 1977). Creosote bush and white bursage are the codominants in this habitat. Mojave yucca and Joshua tree comprise the overstory. The herbaceous layer is sparse, but seasonally abundant after rain events. The creosote–white bursage scrub alliance occupies about 600,000 acres of the Desert NWR (Service 1977).

Creosote–white bursage scrub transitions to mixed desert scrub at elevations near 4,000 feet above msl. The replacement of white bursage by blackbrush (*Coleogyne ramossissima*) typically demarcates this boundary (Holland 1986; Rowlands et al. 1982; Vasek and Barbour 1977). This habitat covers about 530,000 acres of the Desert NWR (Service 1977). Plant species found in this habitat are very similar to those in the creosote–white bursage alliance, but they typically consist of intricately branched shrubs that range from 1.5 to 3 feet tall (Holland 1986). This community often integrates with mixed sagebrush shrublands, Joshua tree woodlands, and pinyon-juniper woodlands. Mojave yucca and Joshua tree are very common throughout the mixed desert scrub habitat (BLM 1990).

Mixed sagebrush and big sagebrush shrublands occur above the mixed desert scrub habitat. Big sagebrush shrublands occur on broad basins between mountain ranges, on plains, and on foothills. The dominant species is big sagebrush (*Artemisia tridentata*). Juniper species (*Juniperus* spp.), other sagebrush (*Artemisia* spp.), small shrubs and herbaceous vegetation are also found with big sagebrush. The mixed sagebrush shrublands occur on dry flats, plains, alluvial fans, rolling hills, rocky slopes, saddles, and ridges. They are typically exposed to wind and consist primarily of shrubs with a sparse herbaceous layer of bunch grasses. The dominant species include black sagebrush (*Artemisia nova*) and little sagebrush (*A. arbuscula*).

Chaparral habitats occur on sideslopes as a transition zone from low elevations to woodlands. They consist primarily of evergreen shrubs, such as bearberry (*Arctostaphylos* spp.) and scrub oak (*Quercus* spp.).

At higher elevations, the Desert NWR consists of woodlands, coniferous forests, and alpine habitats. The pinyon-juniper woodland occurs on warm, dry sites on slopes mesas, plateaus, and ridges, typically at elevations between 6,000 and 7,500 feet (Ackerman 2003). The dominant species on the Desert NWR are Utah juniper (*Juniperus osteosperma*) and single-leaf pinyon pine (*Pinus monophylla*).

The understory consists mainly of shrubs, such as sagebrush species. Ponderosa pine (*Pinus ponderosa*) and white fir (*Abies concolor*) are common at the upper extremes of the habitat. The pinyon-juniper woodland covers about 183,000 acres of the Desert NWR (Service 1977).

Mixed coniferous forest and woodlands occur above the pinyon-juniper habitat and exist on all aspects of the mountain ranges. Temperature, moisture, and successional stages define the composition and structure of this habitat. A Ponderosa pine–white fir alliance covers about 70,000 acres of the Desert NWR (Service 1977) and occurs between elevations of 7,500 and 9,000 feet above msl (Ackerman 2003). Ponderosa pine exists mostly in canyon bottoms and on protected slopes. White fir is more abundant at higher elevations.

The limber–bristlecone pine (*Pinus flexilis–P. longaeva*) alliance occurs at high elevations on ridges and rocky slopes above the coniferous forests and woodlands. Harsh conditions due to the short growing season limit plant growth, and the understory contains a sparse shrub and herbaceous layer. The alliance covers about 3,000 acres of the Desert NWR (Service 1977) and is generally restricted to the Sheep Range at elevations between 7,600 ft and 9,000 feet (Ackerman 2003).

Alpine wet meadows can be found at high elevations, primarily on the Sheep Range. The wet meadow is associated with snowmelt and occurs in flat areas, on gentle slopes, or in valleys around open water. Dominant species are graminoids, but varieties of black sagebrush may also occur at high elevations on the Refuge. It covers approximately 200 acres of the Desert NWR (Service 1977) on the south and west facing slopes of Hayford and Sheep Peaks above 9,500 feet (Ackerman 2003).

Other cover types on the Refuge include playas, cliffs and outcrops, desert pavement, dunes, and volcanic rockland. These covers are mostly unvegetated (less than 10 percent). Playas, or dry lakes, are subject to intermittent flooding and occur adjacent to the salt desert scrub habitat. Salt-tolerant species often form vegetation rings around the playas. Dry lakes include Papoose Lake, Desert Lake, Three Lake, and two other unnamed lakes. Desert pavement is found in flat basins and is coated with a "desert varnish." Desert pavement is typically less than 2 percent vegetated with forbs.

Cliffs and rock outcrops occur on steep slopes, ridges, and cliffs in the mountain ranges at elevations between 5,000 feet and 9,000 feet. Vegetation found on cliffs and outcrops includes succulents, holly-leaved goldenbush (*Hazardia brickellioides*), desert snowberry (*Symphoricarpos longiflorus*), and mountain-mahogany (*Cercocarpus* spp.).

Dunes and sandy areas are typically a result of spring mounds and support woody species, such as woolly bursage (*Ambrosia eriocentra*), sticky-leaved rabbitbrush (*Chrysothamnus viscidiflorus* ssp. *viscidiflorus*), Kearny buckwheat (*Eriogonum nummulare*), and Thurber penstemon (*Penstemon thurberi*), and annual species, which are often more productive in years with adequate moisture (Ackerman 2003).

Desert washes also occur on the Desert NWR. These are intermittently flooded washes or arroyos associated with rapid sheet and gully flow. They often consist of linear or braided strips within desert scrub or shrublands and grassland habitats.

Sensitive Plant Species

There are no federally listed plant species found on the Desert NWR. However, 21 sensitive species may occur on the Desert NWR (Appendix H). Halfring milkvetch (*Astragalus mohavensis* var. *hemigyrus*) and Las Vegas bearpoppy (*Arctomecon californica*) are listed as critically endangered by the State of Nevada. Appendix H provides a list of sensitive plant species that may occur.

Noxious Weeds

Desert NWR does not currently have an IPM Plan to manage the control of invasive species within its boundaries. Lincoln County and Clark County have treated some areas for the spread of tall whitetop (*Lepidium latifolium*) (Noxious Weed Action Committee 2001). On the Refuge, the Weed Sentry program surveys and treats noxious weeds near public roads and in areas of regular public use, and

Southern Nevada Public Land Management Act funding provides a means to treat noxious and invasive weeds and restore sites with native vegetation.

Species common in Clark and Lincoln Counties are likely to occur on the Refuge. Appendix H provides a list of the noxious weeds that may occur or are known to occur at Desert NWR. Common invasive species known to occur on the NTTR are tumbleweed or Russian thistle (*Salsola tragus*), red brome (*Bromus rubens*), and cheat-grass (*Bromus tectorum*). Red brome has adapted to desert climates, but cheat-grass is more prominent in cooler steppe environments (NAFB 2007b).

Wildlife

The Desert NWR is home to many species of wildlife that are supported by its wide variety of habitats over a large elevation range. The various habitats provide food and/or shelter for indigenous mammals, birds, reptiles, amphibians, and invertebrates. Habitat quality varies widely between locations, as do species diversity and richness. Some species are restricted to a particular habitat type, while others may occur in different habitats.

Approximately 320 bird species, 53 mammal species, 35 reptile species, and four amphibian species have been identified in the different communities on the Desert NWR (See Appendix H for a list of species). The majority of wildlife species found on the Desert NWR are non-game species.

Amphibians and Reptiles

Amphibians are not very common on the Desert NWR because they have a high water requirement for survival, and only the Corn Creek Springs and isolated mountain springs provide suitable habitat. In the Mojave Desert–Great Basin Region, only 24 amphibian species are known to occur (Mac et al. 1998). The more common species, such as bullfrogs and toads, are more likely to occur on the Refuge.

Reptiles found on the Desert NWR include various species of lizards and snakes, the threatened desert tortoise, and the sensitive Gilbert’s skink. Populations of some reptiles potentially occurring on the Desert NWR are threatened by pet collectors, who illegally remove these species from their environment to sell as pets to the public (Mac et al. 1998). Chuckwallas (*Sauromalus obesus*) are among the most popular reptiles collected. Desert tortoise, western banded gecko (*Coleonyx variegatus*), banded Gila monster (*Heloderma suspectum cinctum*), and other reptiles known to occur in southern Nevada are also threatened with collection (NDOW 2005a).

Birds

More than 300 different species of birds have been recorded on the Refuge. Many of these are migratory songbirds and waterfowl that are attracted to the wetland and riparian habitats at Corn Creek Field Station. Numerous raptors are also found on the Desert NWR and are most commonly viewed on the Refuge during the summer. Corn Creek is a desert oasis used by thousands of landbird migrants each year. The bald eagle (delisted on August 8, 2007) and peregrine falcon (delisted in 1999) occur on the Refuge, as well as several birds of special concern, including northern goshawk, ferruginous hawk, burrowing owl, and phainopepla.

The Sheep Range IBA provides important breeding habitat for flammulated owl, gray flycatcher, black-throated gray warbler, Grace's warbler, and other songbirds (National Audubon Society 2008). It also represents the northern limit of the Mexican whip-poor-will (Nevada Audubon Society 2008). Small seeps and springs provide much needed surface water for birds.

Because of the large variety of habitats present on the Refuge, a wide variety of bird species use the Refuge for breeding, foraging, resting, and during migration periods, including various high-priority management bird species (see Appendix H). Some of these species include eared grebe, western grebe, Franklin's gull, black tern, snowy egret, Bendire's thrasher (*Toxostoma bendirei*), white-throated swift, pinyon jay, Arizona Bell's vireo, southwestern willow flycatcher, black-chinned sparrow (*Spizella atrogularis*), flammulated owl (*Otus flammeolus*), and western yellow-billed cuckoo (see Appendix H for additional species and the habitats they occur in on the Refuge).

Management of these birds and their habitats is considered a priority by the Nevada Working Group of Partners in Flight (1999) and the Great Basin Bird Observatory (2005). For example, bighorn sheep management would also consider pinyon jays and gray vireos because they use similar habitats. Pinyon jays require large, cone-bearing pinyon trees (75 years or older) in patches of at least 18 square kilometers (Balda and Bateman 1971) in mature pinyon-juniper woodlands or monotypic pinyon stands. Gray vireos require open, mature pinyon-juniper woodlands with shrubby understory on moderate, rocky slopes.

<u>Mammals</u>

Bats are common on the Desert NWR, and six of the potentially occurring bat species are sensitive (BLM 2001). Bats are important to the Refuge because they help regulate insect and invertebrate populations, and some help pollinate plants. Most bats are commonly observed during evening hours. A study of bats at a desert spring (White Spot Spring) in southern Nevada revealed the presence of several species of bats throughout the year (O'Farrell and Bradley 1970). Western pipistrelle (*Pipistrellus hesperus*), California myotis (*Myotis californicus*), and pallid bat (*Antrozus pallidus*) were encountered year-round; the first two are the most active, even in winter months. Activity tends to peak during warmer periods of the day and year.

Many mammal species are found in the creosote bush scrub habitat. Rodents are very common and often make their homes at the bases of shrubs. The six mountain ranges of Desert NWR provide habitat for predatory mammals, desert bighorn sheep, and mule deer (*Odocoileus hemionus*).

Desert bighorn sheep *(Ovis canadensis nelsoni)* are a subspecies of the bighorn sheep (*Ovis canadensis*). *O. canadensis* is a large, herbivorous ungulate that lives in open grasslands or shrub-steppe communities in mountains, foothills, or river canyons (Shackleton 1985). Figure 4.3-3 shows suitable habitat on the Refuge for the sheep. Escape terrain, such as cliffs and talus slopes, are a necessary habitat requirement for the bighorn sheep.

During winter months, as much as 86 percent of their time is spent near escape terrain. In southern Nevada, *O. canadensis nelsoni* lives at higher elevations and moves to lower elevations during the cold winter months (Monson 1964, Berner et al. 1992). This vertical migration coincides with the increasing abundance of new growth and presence of snow at higher elevations. During spring and summer, new growth begins to appear and provides food for the bighorn sheep as they return to the higher elevations.

Desert bighorn sheep are adapted to survival in the desert by being able to withstand 10 days without water (Warrick and Krausman 1989). They will eat barrel cactus to satisfy their water requirements. The mating season for desert bighorns is in the fall and may encompass several months (Shackleton 1985). Lambs are born in early spring, usually March, and are weaned in four to six months. Females live with their young, and males live apart from both during most of the year.

Desert bighorn sheep use habitat within the Refuge along all of the major mountain ranges: Las Vegas, Sheep, East Desert, Desert, Pintwater, and Spotted (BLM 2001). They forage, breed, and raise young on barren cliffs along these mountain ranges. The Desert NWR is one of the largest intact blocks of habitat for the bighorn sheep in the southwestern United States. Water is a limiting resource, so 30 springs and 26 "guzzlers," or water troughs, have been improved to maintain a permanent water source.

Table 4.3-1 provides an estimate of the 2007 bighorn sheep populations in each of the mountain ranges on the Refuge and is based on the 2006 estimates obtained during NDOW surveys of mountain ranges throughout Nevada (NDOW 2007a). Figure 4.3-4 shows the bighorn sheep count trends, based on data collected by NDOW, for each of the subpopulations (mountain ranges) on the Refuge.

Table 4.3-1. Desert Bighorn Sheep Population Estimates [2007]

Mountain Range	*Sheep Count*
Las Vegas Range	140
Sheep Range	190
Desert Range	80
Pintwater Range	140
Spotted Range	90

Source: NDOW 2007a

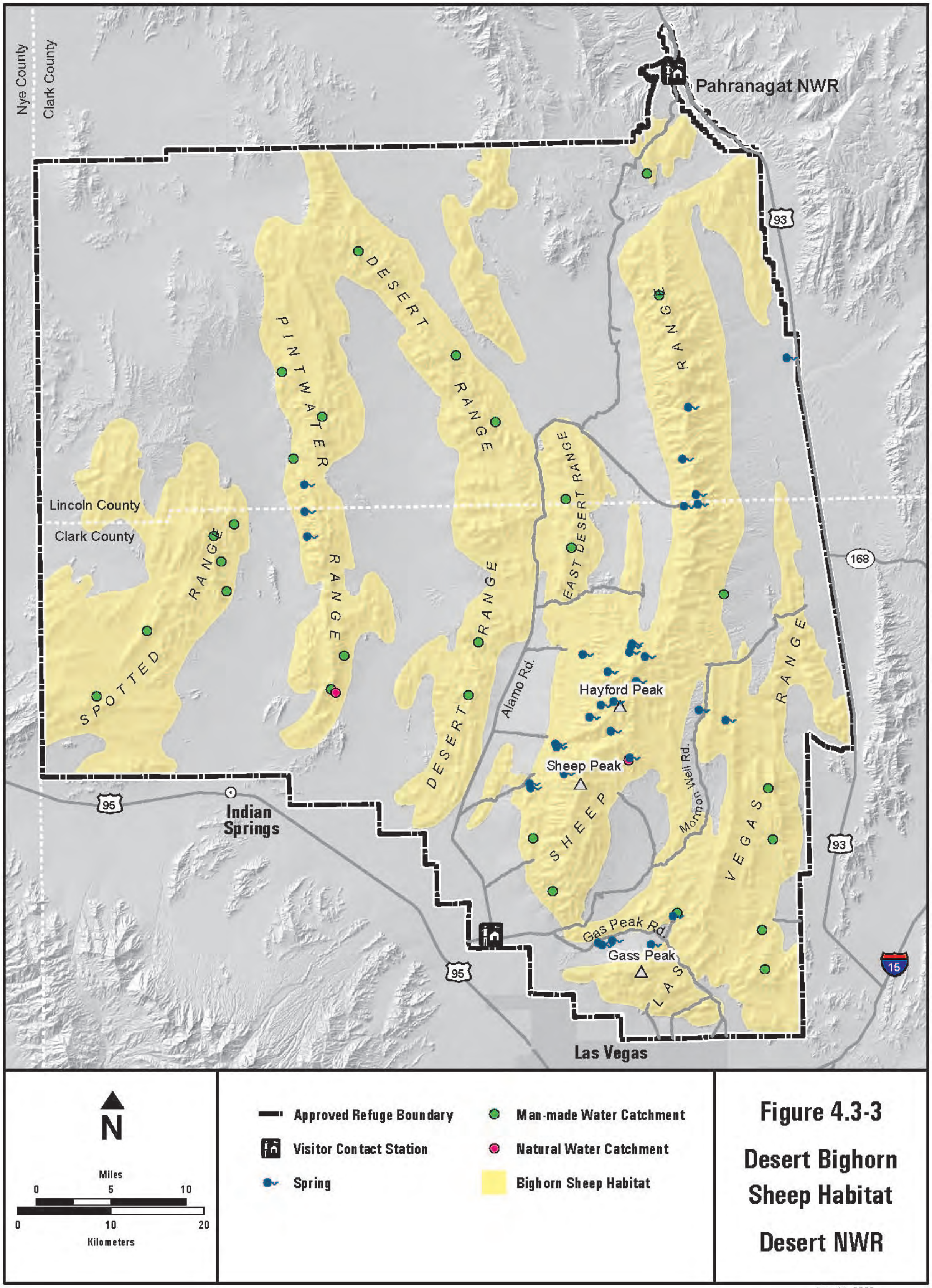

Figure 4.3-3

Desert Bighorn Sheep Habitat

Desert NWR

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Figure 4.3-3-desert_bighorn_hunt.mxd

Bighorn sheep populations have declined since the 1980s, and the primary threats to their populations include disease, low lamb survival rates, and predation (NDOW 2005b, 2006; Appendix J). Population trends for bighorn sheep in the mountain ranges of the Desert NWR are provided in Figure 4.3-4 for the years 1974 to 2005. Data were not available for each year in all of the ranges; however, the general trend of population estimates shows the decline of sheep numbers since the 1970s and 1980s, particularly in the Sheep Mountain Range.

Wild burros occasionally wander onto the Desert NWR, but they have not yet established a territory there. Wild horse and burro Herd Management Areas (HMAs) are located east and south of Desert NWR, but none have been designated on the Refuge. The closest one is located in the Spring Mountains along Wheeler Pass (BLM 2002). HMAs were created by the Wild Free-Roaming Horse and Burro Act, and in Clark County they are managed by the Las Vegas BLM Field Office.

Aquatic Species

Springs are the primary water source on the Desert NWR. Desert NWR spring resources likely support an important and unique aquatic invertebrate (mollusk) diversity, especially spring snails. Non-native fish species and a few species of amphibians are present primarily at Corn Creek. Introduced species include goldfish (*Carassius auratus*) and crayfish, which are the most common.

In the 1970s, Pahrump poolfish (*Empetrichthys latos*) were transplanted to three locations in Nevada, including Corn Creek Springs. At this time, the poolfish was near desiccation in its only known natural habitat at Manse Spring due to groundwater pumping. The species persisted in the ponds at Corn Creek until the late 1990s, when the population of poolfish was lost to illegally introduced non-native crayfish. In June 2003, a refugium for the Pahrump poolfish was completed at Corn Creek, and the fish was reintroduced. This refugium is designed to provide a safer habitat for the fish, so that it can recover and become stable enough to be reintroduced into the wild. The poolfish refugium is an important recovery tool that will provide fish for introduction into the existing population in the ponds and outflow channels at Corn Creek. The poolfish population at Corn Creek is one of only three populations extant globally (Sjoberg 2006). The 2005 population estimate for the Pahrump poolfish was 180 individuals, with approximately 90 per tank at the refugium (Sprunger-Allworth 2006).

In addition to the fish at Corn Creek, the Corn Creek pyrg (Pyrgulopsis fausta) is an endemic snail present in the main outflow system at Corn Creek (Otis Bay 2003). Habitat modification and competition with crayfish are potential threats to the survival of the species.

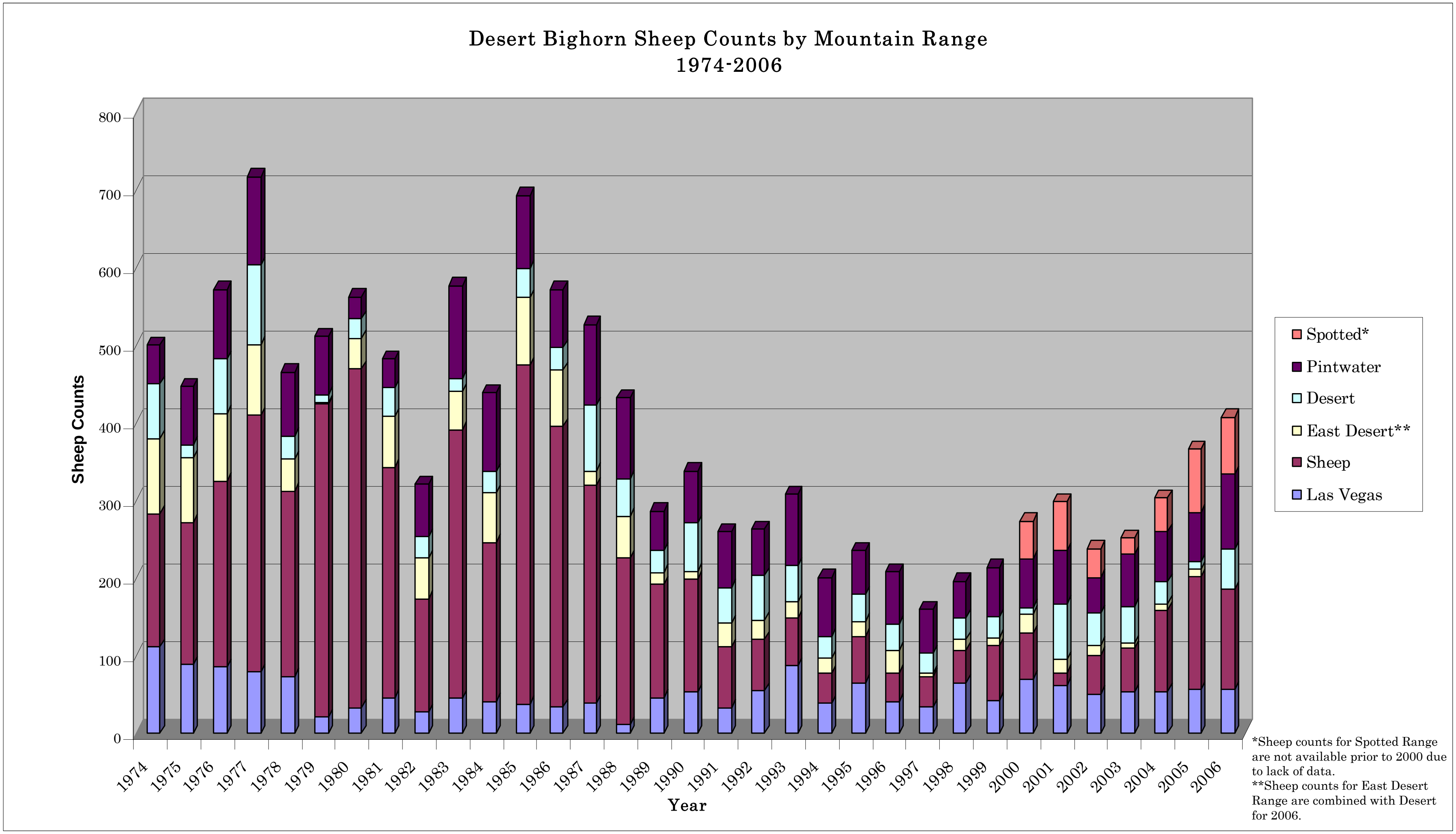

Figure 4.3-4. Desert Bighorn Sheep Counts by Mountain Range 1974-2006

SE ROA 12931

Sensitive Wildlife Species

Three federally listed wildlife species, one federal candidate species, and 34 sensitive species have the potential to occur on the Desert NWR (Appendix H). The desert tortoise is the only threatened species that is known to occur on the Refuge, and the Pahrump poolfish, an endangered species, occurs only in a refugium at Corn Creek. The desert tortoise and its habitat are threatened by trespass vehicle use along the southern boundary.

4.3.3 Cultural Resources

Introduction

Approximately 47,885 acres (3.2 percent) of the Desert NWR has been investigated through archaeological reconnaissance surveys. Given the acreage of the Desert NWR, the total amount of archaeological reconnaissance conducted is small. Most archaeological work on the Desert NWR has been driven by demands of DOD undertakings.

Prehistoric Archaeology

There are approximately 450 recorded prehistoric sites on the Refuge; many of these are on lands administered by the USAF. These include sites from virtually all categories and time periods, including campsites, lithic scatters, rock shelters, rock art, quarries, special activity sites, and multi-component sites (Fergusson and DuBarton 2005). Many of these sites have not been evaluated for NRHP eligibility. Six prehistoric sites are eligible for NRHP listing, and more than 40 are located within the Sheep Mountain Archaeological District, listed on the NRHP in 1974. The large archaeological district encompasses approximately 617,788 acres. It was never intensively surveyed, so the nomination was based on the presence of certain kinds of cultural resources known to occur within the area; however, many have not been field verified or recorded. Other kinds of sites found in the district include all sizes of lithic scatters resulting from seasonal campsites or specific task activities, rock shelters, rock art, and trails. Many other features that are tied to traditional Paiute stories and use areas are yet to be documented.

The Corn Creek Campsite National Register Archaeological District located at the field station was accepted to the NRHP in 1975 and includes roughly 800 acres of significant prehistoric and historic deposits and features. Investigations have revealed that this location has been inhabited and manipulated by humans for more than 5,000 years either on a permanent or continued reuse basis. It is an extremely important location for the Southern Paiute. Its archaeological importance is enhanced due to the discovery of evidence of a pit house village dating to the Far Western Puebloan Basketmaker Period of A.D. 530–710 (Roberts et al. 2007) in the greater Las Vegas Valley.

Historic Archaeology

Historical sites on the Refuge include sites primarily associated with historic trails, bootlegging, livestock grazing, ranching, mining, logging, the Civilian Conservation Corps, and early Refuge management of the Corn Creek Field Station. The Conservation Corps men stationed at Corn Creek from 1939 to 1941 made grazing improvements, such as water troughs, impoundments, and corrals as well as improving or constructing most of the roads on the Desert NWR. The Mormon Well Road route roughly follows an earlier American Indian trail that passed between Moapa and Las Vegas and extended further west. It was followed by early explorers and Mormon settlers. The Southern Paiute currently call this route the "Indian Honeymoon Trail," as it was commonly used for men obtaining wives from adjacent groups (Stoffle et al. 2002). They considered this route an area important for religious and spiritual activities as well as for hunting and gathering.

The historic aspects of the Corn Creek Campsite National Register Archaeological District are primarily associated with human activities from the turn of the 19th century. These include trails and roads stopping at the springs and connecting the major valleys and springs, bootlegging, ranching, and the Civilian Conservation Corps. It also includes the historic aspects of the early Service management of the Desert NWR that was established in 1936.

4.3.4 Public Access and Recreation

Public Access

The eastern half of the Desert NWR is open to the public year-round, but the western half is closed to the public because access to the area is restricted by the USAF. The NTTR lands were closed to public access under PL 106–65, Military Lands Withdrawal Act of 1999. The basis of access restriction is three-fold: to protect the public from injury due to ordnance hazards, to ensure national security is not compromised, and to ensure that military programs can be conducted without disruption.

Four access roads lead to the eastern portion of the Desert NWR (Figure 1.7-2). Principal public access is from U.S. Highway 95 at a point approximately 23 miles northwest of Las Vegas. A sign on the east side of the highway marks the 4-mile gravel road to Corn Creek Field Station. From the Field Station, access to the eastern portion of the Desert NWR is via either Mormon Well Road or Alamo Road. Alamo Road travels from Corn Creek Field Station to Pahranagat NWR, while Mormon Well Road leads to U.S. Highway 93, just south of its intersection with SR 168. A portion of Alamo Road (at the dry Desert Lake) is currently off-limits to the public due to unsafe driving conditions. Access to the south end of the Refuge is via Gass Peak Road. These roads, as well as several smaller roads into the Sheep Range, are in primitive condition, and four-wheel drive vehicles are recommended. All vehicles must remain on the designated roads, and access to remote areas is only by foot or on horseback.

The Desert NWR receives visitors from the Las Vegas area as well as numerous other states and foreign countries. Visitation information is gathered in two ways at Desert NWR: a traffic counter at the entrance and a sign-in sheet at Corn Creek Field Station. Between 1998 and 2000, visitation to the Desert NWR increased from 43,086 to 47,412 (CH2M Hill 2002). From October 2000 to September 2003, records maintained by the Service show that visitation ranged from approximately 60,000 to 68,000 per year (Le'au Courtright 2006).

Recreation

Corn Creek Field Station serves as the Desert NWR's visitor contact station and headquarters (Figure 4.3-5). The visitor contact station is open for a few hours Friday through Sunday and holidays, from Labor Day through Memorial Day. Several facilities are available to the public at the Field Station, including an interpretive kiosk, restrooms, shade structures, potable water, and a horse barn. An interpretive trail with signs provides access to visitors for wildlife viewing at Corn Creek Springs. Public use near springs and other sources of water is closely regulated to avoid conflicts with wildlife.

The Desert NWR offers the opportunity for a unique and solitary desert experience. Primitive camping, picnicking, backpacking, and hiking are some of the non-wildlife–dependent recreational opportunities available on the Desert NWR (Service 2006a). Wildlife-dependent recreational opportunities include wildlife observation, photography, and hunting. Fishing is not allowed on the Desert NWR, and limited environmental education and interpretation opportunities are available.

Kiosks, nature trails, and the visitor contact station are the most important facilities available to visitors on the Desert NWR. In FY 2002, 1,800 visitors stopped at the visitor contact station, more than 50,000 visitors viewed the kiosk, and more than 45,000 hiked along nature trails (Service 2006a).

Wildlife-Dependent Recreation

Wildlife observation and photography opportunities are available throughout the Desert NWR. Corn Creek Field Station provides the best opportunity to view the widest variety of birds. A bird list is available at the Desert NWR headquarters and online.

Environmental education opportunities are available on and off the Desert NWR. No staff-guided tours are conducted on the Desert NWR. During FY 2002, however, 2,160 non–staff-conducted tours occurred. Off-site educational outreach opportunities include group presentations and exhibits. Desert NWR had an estimated 700 visits to environmental education exhibits and 210 visits to interpretation exhibits during FY 2005. Other special events to promote the Desert NWR included news releases, radio or television spots, and other special events. Educational outreach and environmental education for the Desert NWR have increased in the past three years as a result of increased interest from the public (Service 2006a).

An active volunteer program provides additional opportunities for the public to enjoy the Desert NWR, and students may be able to earn college credits through internships. The Service works with the other public land agencies in southern Nevada to coordinate volunteer work through the Southern Nevada Interagency Volunteer Program–Get Outdoors Nevada. Volunteers help staff the visitor contact station.

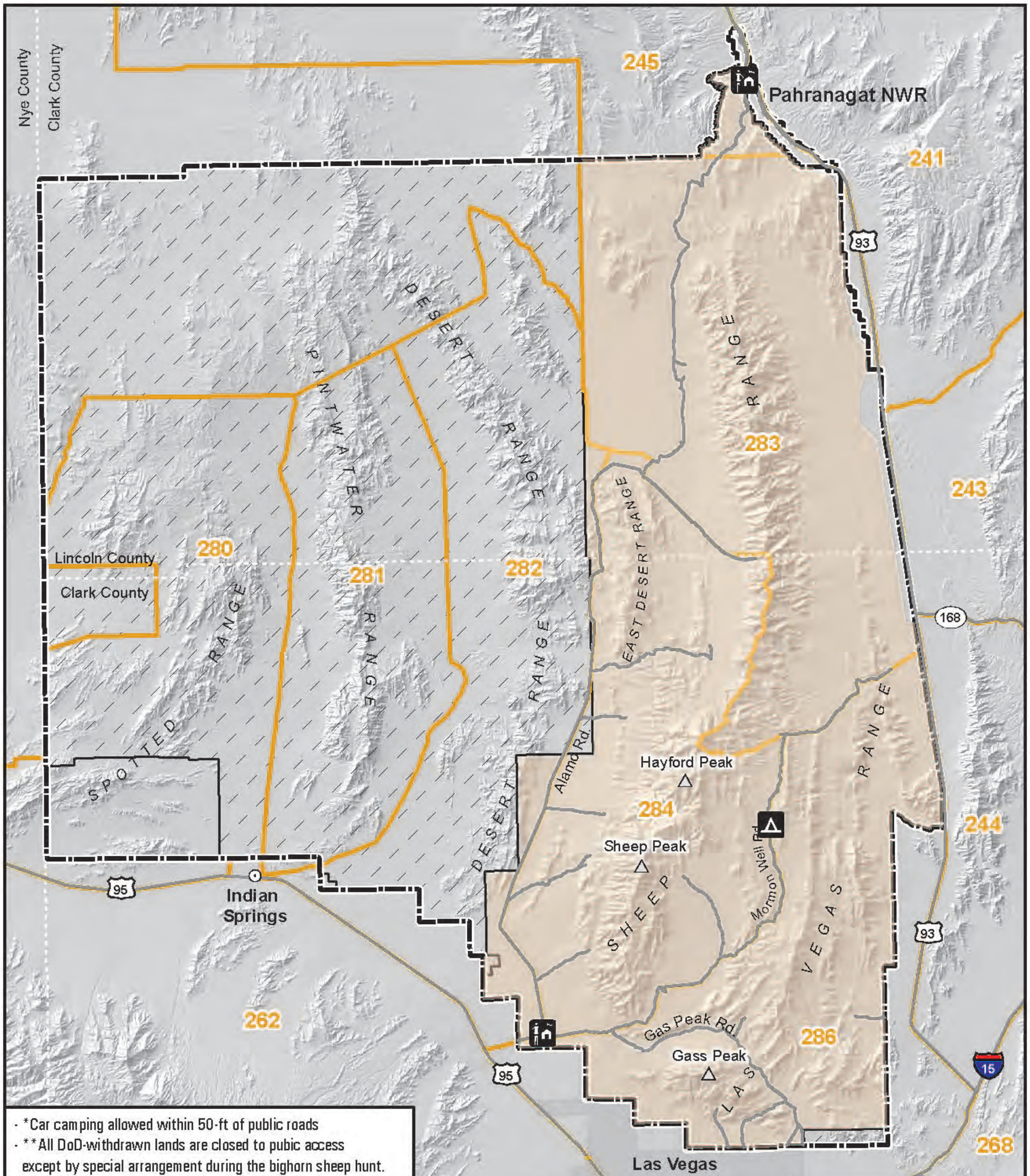

Figure 4.3-5

Visitor Services

Desert NWR

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Figure 4.3-5-desert_visitor_services.mxd

The Desert Complex hosts events for National Wildlife Refuge Week and Migratory Bird Day. In FY 2004, the staff hosted events for National Wildlife Refuge Week. Other attended events include the Clark County Fair, Clark County ECOJAM (Earth Day event), Gran Fiesta (September 2002), and Boy Scout Day Camp (May 2003). Refuge staff or Desert Complex staff also attended the Governor's Conference on Tourism, Dia de los Niños, Las Vegas Chamber of Commerce Preview, depending on staff availability and funding.

The hunt program on Desert NWR is administered by NDOW. The majority of the Refuge is contained within six hunt units (280, 281, 282, 283, 284, and 286). Permits for hunting bighorn sheep are issued on an annual basis depending on the size of the herd; when sheep counts are low, no permits are issued. NDOW is responsible for determining how many permits can be issued. Hunting is permitted for a 15-day period on the co-managed lands in hunt units 280, 281, and 282. During the 14-year period between 1992 and 2005, a total of 182 tags were issued for these units with an average of 13 per year. The average success over the same period was 61 percent. The tags issued on the Desert NWR hunt units represent about 10 percent of the 128 issued on average statewide each year.

Non–Wildlife-Dependent Recreation

Camping, backpacking, hiking, and horseback riding are permitted with certain restrictions year-round (Service 2006a). Picnicking is permitted along designated roads and in picnic areas. The primitive Desert Pass Campground also contains picnic tables, fire pits, and pit toilets for public use. Car camping is allowed within 50 feet of existing roads, and back country camping is allowed throughout the backcountry (outside of the NTTR). Horseback riding is allowed east of Alamo Road (outside the NTTR) in support of other uses.

Illegal off-highway recreational vehicle use along the southern, northern, and eastern boundaries has become a concern because it destroys habitat and disturbs wildlife. The proximity of the cities of Las Vegas and North Las Vegas increases this threat along the southern boundary.

An increasing nonpermitted activity is geocaching. This activity is similar to treasure hunting and involves use of geographic positioning systems (GPS) to locate specific points on the Desert NWR. At these points, people leave either coordinates for a new point or a small treasure, and the treasure hunter replaces the treasure with something new at the end of the search. Fossil hunting and pine nut gathering for Native American use also occur on the Desert NWR.

4.3.5 Social and Economic Conditions

Refuge Management Economics

The current Refuge staff consists of six permanent full-time employees, and one vacant part-time seasonal employee position. The refuge operations budget for FY 2005 was $210,000. The maintenance budget for the Refuge was $58,175.50.

NWRs contribute funds to local counties through revenue-sharing programs that are intended to cover costs for either lands purchased in fee title or lands reserved from the public domain. For FY 2003, Clark County received payment in the amount of $19,095 from the federal government under this revenue-sharing program.

Environmental Justice

The Desert NWR is located in closest proximity to Las Vegas, Indian Springs, and North Las Vegas. These cities are predominantly white (70–88 percent). Las Vegas and North Las Vegas have median family incomes that are comparable to the state and county estimates at around $50,000 (U.S. Census Bureau 2000); however, Indian Springs is below the state and county average at close to $40,000. The Las Vegas Paiute Tribe also has approximately 3,850 acres of tribal land south of the Refuge on U.S. Highway 95 in Clark County. The population of the tribe reported on tribal lands in 2000 was 108 people, which represents a minority (Native American) population. The median family income for the Las Vegas Paiute Tribe was generally above $57,000 in 2000 (U.S. Census Bureau 2000).

Land Use

Desert NWR is bounded on the north and west by the NTTR, a complex assemblage of lands managed or regulated by several federal, state, and local agencies, including the DOD and the DOE (Figure 1.7-2). It also shares portions of its northern, eastern, southern, and western borders with BLM-managed lands that are interspersed with county- and city-managed lands as well as private property. Adjacent land uses include military activities on the NTTR overlay, encroaching (within the 15-year life of the CCP) commercial and residential development along the southern and eastern boundaries, industrial development (mineral extraction/processing and power development/transmission) along the southeast border at Apex, and resort/tourism facilities development at the Las Vegas Paiute Indian Reservation along the southwestern boundary.

The NTTR overlay consists of 846,000 acres on the western portion of the Refuge and has been used since 1940 for testing armament and for training pilots in aerial warfare. PL 106–65 authorizes the USAF to use the NTTR (A) as an armament and high hazard testing area; (B) for training for aerial gunnery, rocketry, electronic warfare, and tactical maneuvering and air support; (C) for equipment and tactics development and testing; and (D) for other defense-related purposes consistent with the purposes specified above. Use of this area is subject to the terms of a Memorandum of Understanding (MOU) between the Secretary of the Interior and the Secretary of the Air Force. The first MOU was signed in 1949. Under the MOU, the Service is the federal agency with primary responsibility for the welfare and management of the land. The USAF controls access to the areas affected by the MOU, including the airspace. In 1986 and 1999, certain military lands were withdrawn to be co-managed by the Service and USAF.

In 1974, approximately 1,323,000 acres of land within Desert NWR were proposed for wilderness designation under the Wilderness Act of 1964. Since that time, those portions of the Refuge have been managed as de facto wilderness (Service 2006a; see Appendix I). Also, five Research Natural Areas (RNAs) have been designated within the Desert NWR, but these are not currently managed as RNAs due to lack of staff and funding. The purpose of an RNA is to provide baseline information to compare with actively managed areas, such as areas burned for habitat enhancement. Management actions are not typically implemented in RNAs, but surveys of resources are conducted and compared with surveys of managed areas to document long-term trends and effects on the resources. The RNAs on the Desert NWR include Basin, Hayford Peak, Deadhorse, Pinyon-Juniper, and Papoose Lake.

As part of the Clark County Conservation of Public Land and Natural Resources Act of 2002 (PL 107–282), approximately 26,433 acres of BLM-managed land have been transferred to the Service for inclusion in the Desert NWR. The Lincoln County Conservation, Recreation, and Development Act of 2004 (House of Representatives 4593) also modified the lands managed by the Service. As part of the act, approximately 8,382 acres of land managed by the Service were transferred to the BLM. This land is located along the west side of U.S. Highway 93 and forms the eastern boundary of the Desert NWR. In addition, 8,503 acres of land managed by the BLM were transferred to the Service to be managed as part of the Desert NWR. This land is located at the northern boundary of the Desert NWR and encompasses a large block of land that also abuts the western boundary of Pahranagat NWR.

Aesthetics

The Desert NWR contains six major mountain ranges, the highest rising to nearly 10,000 feet above msl, and multiple intervening valleys, with the lowest elevation on the Refuge at 2,500 feet above msl. The Refuge is populated with a diversity of wildlife and plants; bighorn sheep and numerous other wildlife species are found throughout. Plant communities and wildlife vary with altitude and climate. Most of the plant species can be seen while driving the Mormon Well Road. The desert shrub community occurs in the hottest, lowest elevations of Desert NWR. Above the valley floor, Mojave yucca and cactus become abundant. At the upper edge of the desert shrub communities, blackbrush and Joshua tree become dominant. Beyond the blackbrush community, forests become predominant.

From many areas within the Refuge, the background views are of the many mountain ranges that dominate the area, along with the valleys. The diversity of the ranges in terms of elevation and vegetation provides a character that is diverse and largely unobstructed. On the southern portion of the Refuge, lights from the Las Vegas area may obstruct viewing of the night sky.

4.4 Moapa Valley National Wildlife Refuge

4.4.1 Physical Environment

Physiography

Moapa Valley NWR occupies approximately 116 acres in the upper Moapa Valley, upstream from the town of Moapa (Figure 1.7-3). The Refuge is bordered to the north and east by the Muddy River, to the south by the Dry Lake Valley, and to the west by the foothills of the Arrow Canyon Range. Several springs are located along the eastern half of the Refuge, and several east-flowing ephemeral washes bisect the Refuge. The ephemeral washes convey runoff from the Arrow Canyon Range to the Muddy River.

Moapa Valley NWR is located on the Muddy River floodplain at elevations ranging from approximately 1,700 feet above msl near the eastern boundary to approximately 1,800 feet above msl to the western boundary (USGS 1983). The Muddy River drains from the northwest to southeast and receives its flows from the Muddy River springs, which discharge perennially (NRCS 1980).

Geology and Minerals

Moapa Valley NWR is underlain by thick deposits of Pleistocene (1.8 mya to present) alluvium that consists of silt, sand, and gravel. A small section of the Pennsylvanian to Permian (350 to 248 mya) Bird Spring Formation outcrops along the extreme southeastern end of the Refuge (Hess and Johnson 2000; Tschanz and Pampeyan 1970).

A review of Tingley (1998) and Tschanz and Pampeyan (1970) indicates that there is no recorded history of mining at the Refuge. Although the Refuge probably contains large amounts of material that would be suitable for construction aggregate, under current market conditions, aggregate production is not economically competitive due to high transportation costs.

Paleontological Resources

The county geologic map shows two geologic units within the Refuge: Quaternary (1.8 mya to present)/Tertiary (65 to 1.8 mya) alluvium and the Bird Spring Formation (Hess and Johnson 2000). The marine Bird Spring Formation typically contains abundant fossils and is considered to have high fossil-containing potential. Typical fossils are marine and consist of algae, echinoderm, and fusilinid (Longwell et al. 1965 and Service 2002a).

Soils

The Moapa Valley NWR is located on the floodplain of the Muddy River and is flanked by a series of low alluvial fans, terraces, and benches that grade into higher alluvial fans (NRCS 2003b). A total of six soil-mapping units are present on the Refuge, and the soils generally range from gravelly fine sand to silty clay. The gravelly fine sand soil types are derived from or occur near the proximal edges of alluvial fans. The silty clay soil types are derived from or occur near lake deposits or floodplains.

Water Resources

Surface Water

The Moapa Valley NWR is composed of a portion of the Muddy River Springs, a series of springs that arise alongside and feed the Muddy River. More than 20 spring orifices occur within the Refuge, including the Plummer and Apcar stream/spring systems (Figure 4.4-1). Flow from the combined springs forms a network of pools and small streams that flows northward beyond the property boundaries.

Just downstream from the Refuge, but within the hydrographic basin, USGS operates the Moapa stream gauge on the main stem of the Muddy River. Flow in the Muddy River has been declining since the early 1960s (Mayer and Van Liew 2003; LVVWD 2001). The decline is attributed to surface water diversions and, primarily, nearby groundwater pumping in the alluvial aquifer, which began about the same time as the declines.

The USGS, in cooperation with the SNWA, currently collects data from a number of gages at springpools and on streams fed by spring complexes. The USGS maintains three spring monitoring sites on the Refuge: Pedersen, Pedersen East, and Warm Springs West. All three sites are located on the Pedersen Unit of the Refuge. The quality of the flow measurement records from these sites is questionable prior to about 1998. Problems include upstream diversions, stream and spring alterations, changes in measurement methods and locations, and leaks at flow measurement structures. Since 1998, the quality of measurements has improved considerably.

The Warm Springs West gage measures the collective spring discharge from all springs on the Pederson unit of the Refuge. Flows at this site have declined significantly since 1998, except for an increase in flows from 2005 to mid-2006. Flows at the other two sites on the Pederson unit, Pedersen Spring and Pedersen East Spring, show trends similar to the Warm Springs West gage, but the records for these two sites are shorter, and in the case of Pedersen Spring, interrupted. Potential causes of this decline in flows are discussed in the groundwater section below.

Groundwater

Underground flow through the carbonate-rock aquifer in southern Nevada provides the primary source of water for the Muddy River Springs. The source of the underground flow is unknown, but is postulated to come from the Sheep Range, the White River Flow System, the Meadow Valley Flow System, or a combination of these sources (Thomas et al. 1996). Predevelopment spring discharge from the Muddy River Springs was relatively constant at 36,000 afy (Eakin and Moore 1964).

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Figure 4.4-1_moapa_hydro.mxd

Monitoring of water levels in the carbonate-rock aquifer in the Muddy River Area first began in 1987. Water levels were relatively stable for the first 11 years of the record, but then started declining significantly beginning in 1998. They have continued to decline each year, except for an increase during the period from 2005 and mid-2006, which was probably in response to the extremely wet year in 2005.

The decline in carbonate-rock aquifer water levels correlates with a period of significantly increased pumping from the carbonate-rock aquifer that began in 1998 as well. Some researchers believe that this pumping has caused the declines in water levels (Mayer and Congdon 2008), although others dispute this (see individual chapters in the Hydrologic Review Team [HRT] Baseline Report, 2007). What has been acknowledged by all is that the water level declines in the carbonate aquifer are unique to the Muddy River/Coyote Spring/California Wash area and that the entire water level record, including the period of stable water levels and the more recent period of declines, can not be explained solely by climate fluctuations.

This decline in carbonate-rock aquifer water levels coincides with and is likely responsible for the decline in spring discharge measured at the Warm Springs West gage. This decline and the potential future declines in groundwater levels and spring discharge from additional pumping from the carbonate-rock aquifer led to the negotiation of a Memorandum of Agreement (MOA) in 2005. The MOA is between the Service and several parties either currently pumping or intending to pump groundwater in the area and is part of the Service's Biological Opinion for the Coyote Spring Pipeline right-of-way. Under conditions in the MOA, the carbonate-rock aquifer pumping will be limited and ultimately stopped as the flow at the Warm Springs West gage declines to "trigger" levels specified in the agreement. The MOA also includes several conservation and habitat restoration measures to be implemented cooperatively by all the parties. Finally, the MOA also requires the parties to form an HRT for the purposes of assessing monitoring and information needs in the area and developing technical analyses.

Water Quality

Little water quality information exists within the Refuge. Based on available information, water discharged from the Muddy River Springs is similar in nature to that derived from the regional carbonate aquifers, with dissolved solids concentrations of about 550 mg/L (Scoppettone 1987).

Water Use

Water from the local alluvial aquifer has been developed in the Muddy River Springs area for some time, for both irrigation and domestic uses and later by Nevada Power Company by the late 1940s for power generation. Water from the regional carbonate aquifer was developed by the MVWD for municipal supplies beginning in 1986. The SNWA has developed and plans to develop several groundwater monitoring and extraction wells within the next five years to the northwest of the Refuge in Coyote Springs Valley.

Primary use of water in the Muddy River Springs area today is for power production and municipal supplies to areas downstream. Local irrigation and domestic uses account for a small portion of water consumption. Groundwater production has increased over time, with a significant increase in the 1980s and 1990s and the largest increase in recent years (beginning in 1999).

Records for surface water diversions are not as complete as those for groundwater pumping. In general, since 1990, Nevada Power Company has diverted 2,300 to 3,600 afy from the Muddy River downstream of the Refuge (NDWR 2003). Within the Refuge, MVWD has diverted water from Jones Springs since 1959, with annual diversions ranging from 687 to 1,509 acre-feet (Buqo 2002).

Within the Refuge, historic uses of the spring pools and the surrounding landscape included recreation and agriculture. Prior to acquisition by the Service, the area was developed and operated as a resort with thermal spring-fed swimming pools, waterslides, bathhouses, a snack bar, and recreational vehicle hook-ups. A number of palm trees were planted by Moapa Valley settlers and resort owners over the last century (Cornett 1988).

Water Rights

In the Muddy Springs area, most of the water rights are developed and in use in varying amounts. However, most of the water rights in Coyote Spring Valley, hydraulically upgradient in the flow system, are permitted but as yet are undeveloped (NDWR 2003). Additional groundwater applications from the regional carbonate aquifer in six hydrographic basins within the southern portions of the White River Flow System are being held in abeyance while aquifer studies are conducted (NDWR 2002). A five-year study and pump test is expected to start in 2010.

The Service has two water rights for the Refuge that have been certificated by the Nevada State Engineer. One of these is a nonconsumptive right for 3.5 cfs of spring flow. The other is for approximately 1.4 afy of well water. Surface water from the springs on the Refuge is also adjudicated for uses downstream from the Refuge. Use of these surface water rights does not generally affect the Refuge in any way. In November 2008, the Service also applied for nonconsumptive in-stream flow rights on the Apcar and Plummer units. These water right applications are being held in abeyance until the completion of the five-year study and pump test.

Hazardous Materials

Moapa Valley NWR was formerly developed as a recreational resort. No mining activity is known to have been conducted at the Refuge. A review of Lovering (1954), Garside (1973), and Singer (1996) indicates that neither metal nor radioactive deposits are present on the Refuge.

Fire History and Management

The historic role of fire at Moapa Valley is generally unknown. Fire likely had a minor to limited role in the Refuge's ecosystems (Service

2004a). Before the area was developed into a resort setting, the area most likely saw long fire return intervals typical of desert vegetation. Due to the lack of continuity of fuels in a desert setting, fire probably did not reach significant size.

Fire season is generally from April through October in the desert fuel types (Service 2004a). The Warm Springs riparian area has a palm tree component fuel type that can burn in any month. These fuels have a history of burning about every 10 years. It is unknown when fire suppression and exclusion began in the area.

Records from the BLM for the Moapa-Overton Fire Management Unit, which covers about 89,000 acres, indicate an average of one ignition per year between 1980 and 2002, with an average of 8 acres burned per year (Service 2004a). Fires ranged in size from 0.1 to 140 acres, and 96 percent were less than 100 acres in size. An average of approximately 80 acres burned per decade. Fires generally occur in late spring through September, but can occur year-round. Human causes accounted for 73 percent of all fires, with the remaining 27 percent attributed to lightning. Most wildfires in this FMU occur in the tamarisk-infested portions of the Muddy River riparian corridor. Typically, these fires are wind driven and are of moderate to high intensity. Small, low-intensity wildfires in tamarisk are less common but do occur.

The Refuge has experienced two larger fires. In 1994 a lightning-caused fire of 40 acres began on the Refuge and minimally spread to private lands. In 2003, a human-caused fire of 47 acres burned adjacent to the Refuge and threatened residences in the area.

No prescribed fires or pile burns have occurred on the Refuge.

Air Quality

Ambient air quality is not currently measured at Moapa Valley NWR. It is expected that low ambient concentrations of criteria pollutants would occur for this area. The nearest sources of emissions are in the Las Vegas area, approximately 20 to 30 miles to the southwest and the Apex industrial complex, located approximately 10 miles to the southwest. Due to the variation in airshed basins for the three regions, it is anticipated that emissions from the Las Vegas and Apex regions would not affect the Moapa Valley NWR (CCDAQM 2003b).

4.4.2 Biological Resources

Vegetation

Habitat Types

Moapa Valley, located in northeastern Clark County, Nevada, is one of the few areas of the Mojave Desert with a perennial river. The Muddy River, which is also known as the Moapa River, originates at the Muddy River Springs. These springs are a part of the Warm Springs thermal springs complex in which the Moapa Valley NWR occurs (Service 1983). Moapa Valley NWR encompasses more than 20 springs from this complex. These springs provide high-quality habitat for numerous wildlife species. They also support a variety of vegetation within a narrow elevation range of 1,700 to 1,800 feet above msl (Figure 4.4-2).

Riparian and aquatic habitats on the Refuge consist of three adjacent, but visually distinct units: Plummer, Pedersen, and Apcar (Figure 4.4-2). Each unit has a separate stream system supported by the steady and uninterrupted flow of several springs that come to the surface at various points throughout the Refuge.

Historically, willow (*Salix* spp.) and screwbean mesquite were the dominant riparian species along the streams in the area. Due to habitat alteration and modification, the riparian habitat is now dominated by invasive palm trees (*Washingtonia filifera*). These palm trees can be detrimental to aquatic wildlife and habitats. The palm trees out-compete native species, and although it is used by some species, it does not generally provide high-quality habitat for wildlife (Lund 2001). In comparison to native plants, palm trees use much more water, use more nutrients that would otherwise be available for fish, and accumulate salt at its base.

Following a fire on the Pedersen Unit in 1994, several hundred palm trees were removed from riparian habitats, allowing many native species to become reestablished in the riparian and aquatic habitats within this unit (Service 2006a). Aquatic plants, such as muskgrass (*Chara* spp.), spike rush (*Eleocharis* spp.), water nymph (*Najas* spp.), and watercress (*Rorippa* spp.), are abundant in the spring pools and other slack water areas.

The presence of salt grass as ground cover has provided suitable conditions for the reestablishment of native trees, such as ash, cottonwood, willow, and mesquite.

Riparian habitat on the Plummer and Apcar Units continues to bear the scars of the 1994 fire and is still dominated by palm trees. Non-native tape grass (*Vallisneria americana*) is also present on the Plummer Unit (Service 2006a).

The salt desert scrub and creosote–white bursage scrub habitats dominate the surrounding Mojave Desert and occur primarily on the western and southern portions of the Refuge. The salt desert scrub habitat consists of various saltbush species, such as fourwing saltbush (*Atriplex canescens*) and big saltbush (*A. lentiformis*), found in saline basins on valley floors and around playas. Areas with low nocturnal temperatures and very high soil salinity are common in these basins and support most of this habitat.

The creosote–white bursage scrub alliance occurs in lower bajadas, plains, and low hills. This alliance is characterized by widely spaced shrubs and succulents averaging 2 to 8 feet tall, with 2 to 50 percent cover (Holland 1986; Rowlands et al. 1982; Vasek and Barbour 1977). Creosote bush and white bursage are the codominants in this habitat. Mojave yucca and Joshua tree comprise the overstory. The herbaceous layer is sparse, but seasonally abundant after rain events.

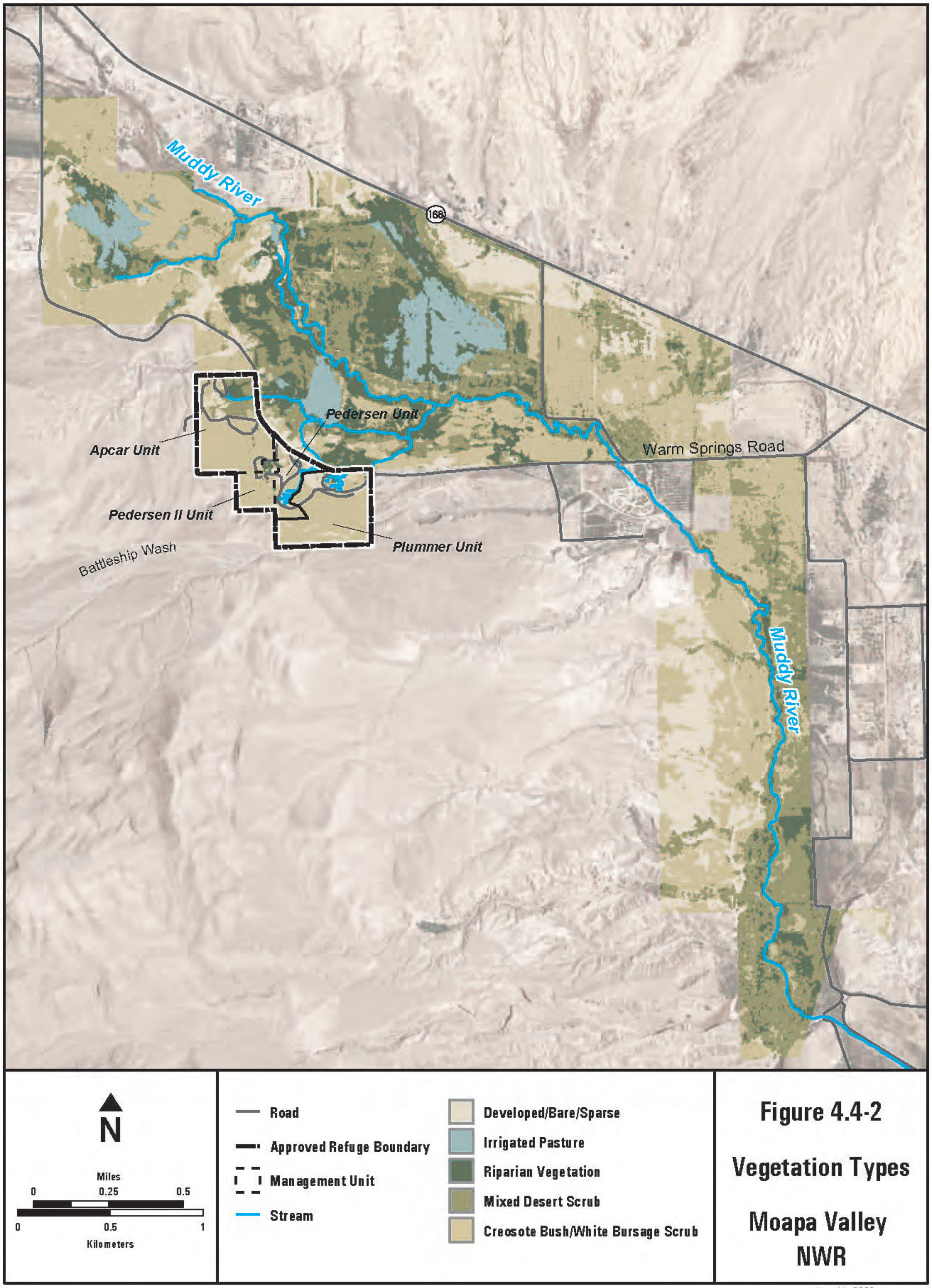

Figure 4.4-2

Vegetation Types

Moapa Valley NWR

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Sensitive Plant Species

Parts of the Moapa Valley have been ranked by the NNHP as the highest-priority conservation sites in Nevada (NNHP 2000). Highest-priority conservation sites may need new actions to prevent the loss of one or more extremely sensitive species, which could happen within the immediate future if no species-specific management actions are implemented. Moapa Valley NWR is a part of the Moapa Valley macrosite, which includes Logandale, Overton, Moapa, and the Moapa Valley springs.

Although the Moapa Valley is a sensitive area, there are no federally listed plant species that potentially occur at Moapa Valley NWR. There is, however, one sensitive plant that may occur at the Refuge: the Virgin River thistle (*Cirsium virginense*).

Invasive Species and Noxious Weeds

Invasive species are common at Moapa Valley NWR due to the Refuge's extremely moist habitat and disturbed conditions. The construction of recreational facilities in the past removed much of the native vegetation and destroyed suitable habitat for their reestablishment. The lack of competition with native species set the stage for several invasive species to dominate the area. Some of these species include palm trees, Russian thistle, eel grass, salt cedar, oleander and pampas grass. Many of these species were introduced to the area as ornamentals and have become well-established on the Refuge, especially in areas where the old resort/recreational facilities have been removed. Tape grass, an invasive aquatic weed, is significantly affecting aquatic habitats on or adjacent to the Refuge.

Although several invasive species are present, only three noxious weeds, as defined by the State of Nevada, are known to occur at Moapa Valley NWR (L. Miller 2003). These are Russian knapweed, salt cedar, and Malta starthistle. Tall whitetop also potentially occurs at Moapa Valley NWR. Appendix H provides a list of the noxious weeds that may occur or are known to occur at Moapa Valley NWR.

Wildlife

Although the Moapa Valley NWR encompasses only 116 acres, there is an abundance of wildlife that uses the area on a seasonal basis or year-round (see Appendix H for a list of species). These species are adapted to the desert riparian and upland communities, and many are drawn to the area by the abundant water supply.

Amphibians and Reptiles

Native amphibians inhabiting riparian and aquatic areas of the Warm Springs area include the California tree frog (*Hyla regilla*) and the red-spotted toad (*Bufo punctatus*). Non-native species include the bullfrog (*Rana catesbeiana*) and the spiny soft-shelled turtle (*Trionyx spiniferus*).

Common native reptiles of the Warm Springs area include yellow-backed spiny lizard (*Sceloporus uniformis*), side-blotched lizard (*Uta stansburiana*), coachwhip (*Masticophis flagellum*), and Great Basin whiptail (*Aspidoscelis tigris*). The banded Gila monster and chuckwalla, sensitive species, occur in rocky upland habitat and may occur on the Refuge. The chuckwalla was observed on the Refuge in 1999 (Goodchild 2004). Desert tortoise may also use upland habitat on the Refuge. The refuge is also within the historic distribution of the relict leopard frog (*Rana onca*), and Refuge lands may play an important role in conservation for the frog (Sjoberg 2006).

Birds

Approximately 230 bird species have been identified along or adjacent to the Muddy River (Lund 2002). Of these, 162 may be categorized as year-round residents. The others are mostly migratory birds passing through along the Pacific Flyway migration route. The Refuge is an important stop-over site for migrant landbirds. Approximately 68 of the 230 bird species have been observed infrequently or were recorded in habitats adjacent to the Muddy River. An estimated 86 birds use woodland habitat, of which nine have been documented as using palm tree fruit as a food source. Riparian shrubland habitat is used by about 79 species, and 13 species are associated with marsh habitat.

Several residents and migrants are on the Service's list of Birds of Conservation Concern and are priorities for conservation in the Partners in Flight bird conservation plan for Nevada. Some of these species include eared grebe, western grebe, Franklin's gull, black tern, snowy egret, Bendire's thrasher, Arizona Bell's vireo, southwestern willow flycatcher, western yellow-billed cuckoo, and canvasback (see Appendix H for additional species and the habitats they occur in on the Refuge).

Mammals

Twenty-three species of bats are known to occur in Nevada, 15 of which have been documented in the Muddy River drainage (Williams 2002). Six of these bats are designated as Nevada sensitive species. Extensive studies of bat species have not been conducted along the Muddy River; however, the western yellow bat (*Lasiurus xanthinus*) has been documented as a year-round resident on the Refuge. This area is the only known Nevada location for this bat, which is a palm obligate species.

Aquatic Species

The Moapa Valley supports four species of native fish: Moapa dace, Virgin River chub (*Gila seminuda*), Moapa White River springfish, and the Moapa speckled dace (*Rhinichthys osculus moapa*). In addition, thirteen non-native species of fish have been documented in the Muddy River system.

The Moapa dace is endemic to approximately 9.5 km (6 miles) of stream habitats in five thermal headwater spring systems and on the main stem of the upper Muddy River. Moapa dace are dependent upon the link between the upper river and its tributaries (Scoppettone et al. 1992). Cooler water temperatures in the middle and lower Muddy River are likely a natural barrier to downstream movement of Moapa dace (La Rivers 1962).

The Virgin River chub is found in the middle Muddy River, and high water temperatures of the upper Muddy River system are believed to preclude adult chubs (Service 2004a). The Moapa speckled dace co-occurs with the Virgin River chub. The Moapa White River springfish is found in the upper Muddy River and spring tributaries. It is adapted to slower water than the Moapa dace and is fairly common throughout suitable habitat.

Non-native fish present in the upper Muddy River and tributaries include blue tilapia (*Oreochromis aurea*), shortfin molly (*Poecilia mexicana*), mosquitofish (*Gambusia affinis*) and rarely, common carp (*Cyprinus carpio*). The Service, NDOW, and other collaborators have been conducting a program to eradicate blue tilapia from the Muddy River system and control other non-native populations in order to facilitate recovery of Moapa dace and restore Moapa White River springfish to historic population levels.

More than 100 species of aquatic invertebrates are known from thermal springs at the source of the Muddy River (Sada 2002). The abundance of populations along the river is believed to be seasonal, with peak populations occurring during spring and lowest populations occurring during the winter months. This diversity of species includes several endemic invertebrates, including two mollusks and four aquatic invertebrates (Service 2004a).

The Moapa pebblesnail (*Fluminicola avernalis*) occurs on pebbles, cobble, concrete, and submerged vegetation at or downstream of springs. The pebblesnail has been considered locally abundant in the Warm Springs area. The grated tryonia (*Tryonia clathrata*) occurs within algae and detritus throughout the Warm Springs system. The Moapa Warm Springs riffle beetle (*Stenelmis moapae*) occurs in the Warm Springs area in outflow streams immediately downstream of the spring source. They have also been found in the upper Muddy River and in marsh habitat connected to spring sources. The Amargosa naucorid (*Pelocoris shoshone shoshone*) occurs in the Warm Springs area on vegetation in pools or reaches of stream with lower velocities, often associated with overhanging banks near marshy habitats.

Two endemic aquatic invertebrates are also present on the Refuge: the Moapa naucorid (*Usingerina moapensis*) and a water strider (*Rhagovelia becki*) (Service 1996). Current population size, distribution, and potential threats to these two species are largely unknown. The naucorid occurs in warm stream pebble beds, and the water strider occurs in swift riffles (Usinger 1956).

Sensitive Wildlife Species

Three federally listed wildlife species, one federal candidate species, and 36 sensitive species have the potential to occur at the Moapa Valley NWR (Appendix H). The southwestern willow flycatcher, Yuma clapper rail, and Moapa dace are the only endangered species that potentially occur on the Refuge. Both the flycatcher and the yellow-billed cuckoo (*Coccyzus americanus*) breed in the adjacent Muddy River drainage. In addition, the Yuma clapper rail is known to have occurred in the Muddy River area near Moapa in the past.

The Moapa Valley NWR was established to protect and secure habitat for the Moapa dace. This species' habitat is restricted to the headwaters of the Muddy River due to its narrow temperature requirements. Habitat modifications and the presence of introduced fish species make the habitat further downstream unsuitable for the dace. A species account for the dace is provided in Appendix H.

Recovery plans for the endangered and rare aquatic species of the Muddy River ecosystem have been approved and are being implemented by the Service (Service 1983, 1996). A recovery plan for the southwestern willow flycatcher has also been approved and implemented (Service 2002b). The recovery plans describe each species, its habitat needs, and specific recovery goals for the de-listing or downlisting of the species.

4.4.3 Cultural Resources

Because most of the area making up the Moapa Valley NWR was privately held until recently, considerable alteration to the character of the landscape has occurred and any sites that may have been present are likely buried or destroyed as part of resort development. Approximately 17 acres or about 16 percent of the Moapa Valley NWR has been investigated through archaeological reconnaissance surveys.

Prehistoric Archaeology

While numerous sites have been recorded in the surrounding region, only one site has thus far been recorded within the boundaries of the Moapa Valley NWR (Fergusson and DuBarton 2005). It was a small lithic scatter that was recorded in 1979 by a non-professional archaeologist. No surface evidence remains due to land disturbances in the area of the spring. Sites in the immediate vicinity of the Refuge include pit houses and surface structures of Far Western Puebloan design, rock shelters, and large open sites with lithics and both Far Western Puebloan and Numic ceramics. Local tradition suggests other sites exist in the region, but many have never been formally recorded.

Historic Archaeology

No historic sites have yet been recorded within the Moapa Valley NWR.

4.4.4 Public Access and Recreation

Public Access

Moapa Valley NWR is located on 116 acres in northeastern Clark County and is approximately 60 miles north of Las Vegas, Nevada. Currently, due to its small size, fragile habitats, ongoing restoration work, and construction activities related to the removal of unsafe structures, the Refuge is closed to the general public. It is anticipated that the Refuge will be open to the public in the future to provide recreational opportunities once the restoration work is complete. Staff-conducted tours are currently being offered for interpretation and nature observation. In FY 2002, 65 visitors participated in staff-conducted tours (Service 2006a).

Access to the Refuge is via SR 168, which can be reached from I-15 or from U.S. Highway 93. From SR 168, access is via Warm Springs Road, which runs along the northeast boundary of the Refuge. Average daily traffic counts on SR 168 were 1,200 per day in 2004 (Nevada Department of Transportation [NDOT] 2004). Several unpaved roads on the Refuge are currently used for restoration efforts and administrative access.

Recreation

Recreational opportunities at Moapa Valley NWR include wildlife observation, photography, environmental education, and outreach. These activities are very limited because the Refuge is currently closed to the public, except through special arrangement (Figure 4.4-3).

The Service does not currently have an environmental education program for the Refuge; however, environmental education opportunities have been provided by TNC in the past. Schools may also visit the Refuge if they schedule a tour in advance with the Refuge Manager. During FYs 2000 and 2001, 78 and 45 people, respectively, visited the Refuge for educational activities (Service 2006a). All of these were staff-conducted tours for teachers and/or students.

The Service works with the other public land agencies in southern Nevada to coordinate volunteer work through the Southern Nevada Interagency Volunteer Program–Get Outdoors Nevada. Volunteers and student interns receive environmental education and provide much-needed assistance with Refuge projects. They are often able to complete work that Refuge staff would otherwise be unable to do. The hours and work assignments are tailored to meet the needs of both the Refuge staff and the volunteer or intern. Volunteer projects may include conducting biological surveys, providing clerical assistance in the office, general maintenance of facilities and equipment, photography and artwork, habitat restoration activities, and visitor interaction. College students may be able to earn college credits while gaining valuable work experience as an intern at the Refuge. Internships are available year-round.

Educational outreach currently consists of exhibits only, but in 2000 and 2001, exhibits and group presentations were offered to the public. News releases about the Refuge were also used to inform the public about the Refuge in 2002.

The Desert Complex hosts events for National Wildlife Refuge Week and Migratory Bird Day. In FY 2004, they hosted a few events for National Wildlife Refuge Week. Other events that Desert Complex staff have attended include the Clark County Fair, Clark County ECOJAM (Earth Day event), Gran Fiesta (September 2002), Boy Scout Day Camp (May 2003), and Moapa Day (2003). Refuge staff or Desert Complex staff also attended the Governor's Conference on Tourism, Dia de los Niños, Las Vegas Chamber of Commerce Preview, and National Public Lands Day, depending on staff availability and funding.

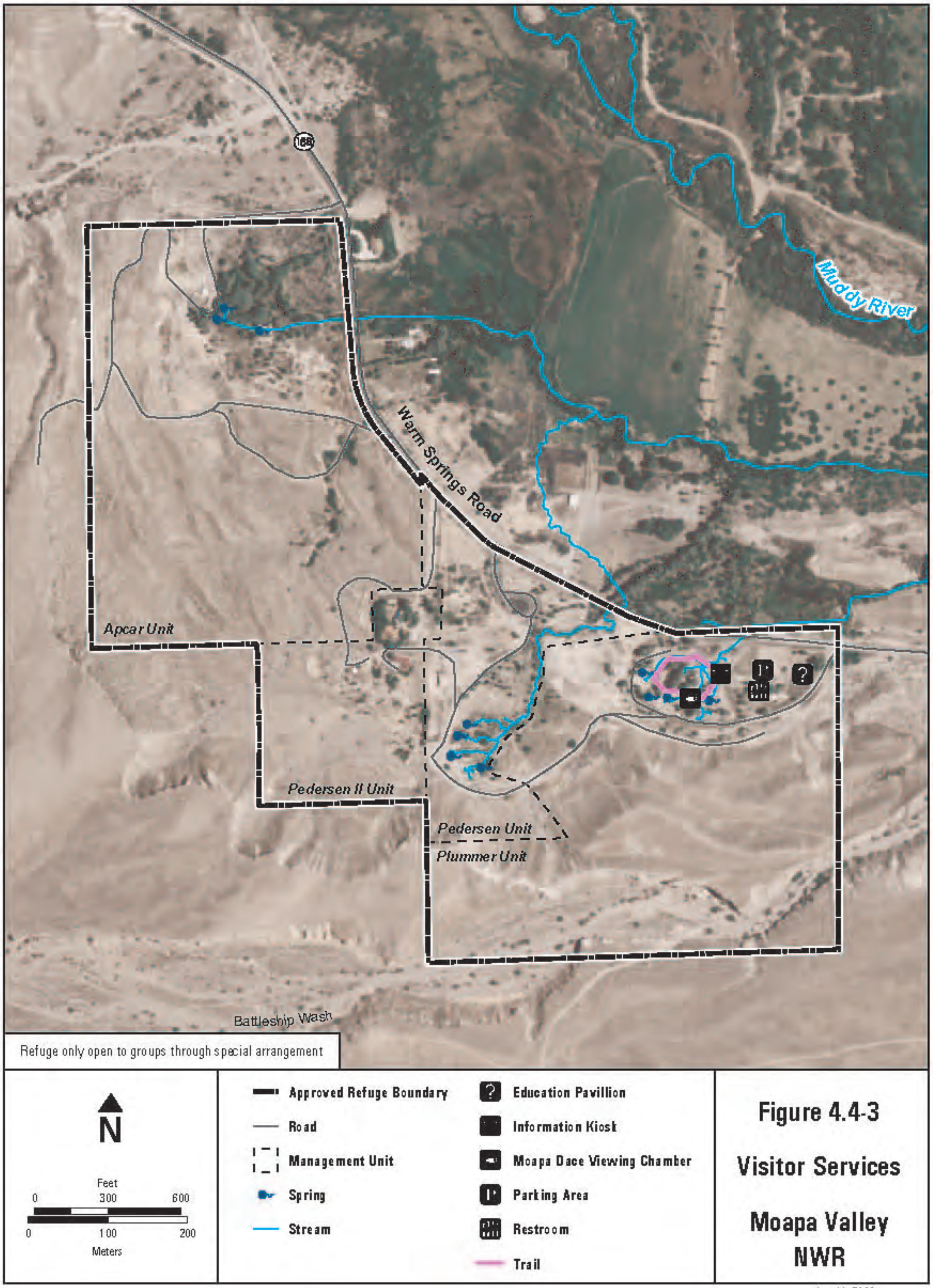

Figure 4.4-3

Visitor Services

Moapa Valley NWR

June 11, 2009
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Figure 4.4-3_moapa_visitor_services.mxd

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4.4.5 Social and Economic Conditions

Refuge Management Economics

The Refuge is not currently staffed on a regular basis. The manager for the Desert NWR is also the manager for the Moapa Valley NWR. The refuge did not have a maintenance or operations budget in FY 2006.

NWRs contribute funds to local counties through revenue-sharing programs that are intended to cover costs for either lands purchased in fee title or lands reserved from the public domain. For FY 2003, Clark County received payment in the amount of $10,310 from the federal government under this revenue-sharing program.

Environmental Justice

Communities closest to the Refuge include the rural areas of Moapa Valley, the town of Moapa, and the city of North Las Vegas. These communities are predominantly white (74 percent) and have median family incomes comparable to the state and county estimates of about $50,000 (U.S. Census 2000). These communities as a whole would not constitute low-income, minority populations.

The Moapa Valley NWR lies within the aboriginal territory of the Moapa (Mou'paw) Paiute Band (Kelly 1934; D'Azevedo 1986; Martineau 1992). Although comprised of a small area, the Moapa Valley NWR is culturally significant to the Moapa Paiute people. The reservation of the Moapa Paiute Band is found within the Moapa Valley, south of the Refuge. According to the 2000 Census, the population of the reservation was 206 people. The band's median family income was estimated at $22,000 in 1999, which is substantially lower than the Clark County and Nevada estimates of about $50,000. The Moapa Paiute Band is considered a low-income, minority population.

Land Use

Moapa Valley NWR is bounded on the north and west by private land holdings, including the pending Southern Nevada Public Land Management Act lands, and to the south and east by BLM-managed lands (Figure 1.7-3). The Mormon Mesa ACEC, established for the protection of the desert tortoise, is located to the north of the Refuge. At least one currently occupied private residence is directly adjacent to the Refuge. The Moapa River Indian Reservation lies to the southeast.

The Refuge was established September 10, 1979, to secure habitat for the endangered Moapa dace. Prior to acquisition, the Pedersen and Plummer Units had been developed and operated as resorts. The primary management objectives of the Refuge are to restore these units to as near a natural condition as possible and to optimize available stream habitat for recovery and downlisting of Moapa dace.

Aesthetics

The Moapa Valley NWR consists of stream channels supported by six thermal springs emerging near the center of the Refuge. Generally, the area surrounding the Refuge consists of riparian habitat and agriculture to the north and creosote vegetation to the south. There is little change in elevation and very little light pollution that would affect viewing of the night sky.

The Refuge is comprised of three adjacent, but visually distinct units. Prior to acquisition, both the Pedersen and Plummer Units had been developed and operated as resorts. Restoration efforts are under way at the Pedersen Unit and Plummer Unit, where only native fish remain in the Pedersen stream channels and pools. However, restoration work is still required on the Apcar Unit. Until the restoration is completed, the man-made structures located on the site remain part of the visual experience.

4.5 Pahranagat National Wildlife Refuge

4.5.1 Physical Environment

Physiography

Pahranagat NWR occupies approximately 5,380 acres in the southern reach of Pahranagat Valley, along a narrow, approximately 11-mile long corridor of the former White River (Figure 1.7-4). The Refuge is bordered to the north by Pahranagat Valley, to the east by Delamar Valley and the Delamar Mountains, to the south by the foothills of the Sheep Range, and to the west by the East Pahranagat Range.

Upper Pahranagat Lake and North Marsh are located at the northern tip of the Refuge and cover approximately 450 acres, while Lower Pahranagat Lake is located near the southern end and covers approximately 365 acres (Lincoln County Conservation District 1980). Pahranagat NWR is a closed basin; no surface water flows from it. Surface water comes from Ash and Crystal Springs, which are located approximately 9 and 15 miles, respectively, north of the Refuge.

Elevations of Pahranagat NWR range from approximately 3,020 feet above msl at Lower Pahranagat Lake to approximately 3,600 feet above msl along the valley walls formed by the Sheep Range at the extreme southeast corner of the Refuge.

Geology and Minerals

Thick sections of Pleistocene (1.8 mya to present) alluvium, deposited by the ancestral White River, underlay the Pahranagat NWR. The ancestral river channel eroded older Tertiary (65 to 1.8 mya) gravels, lakebed deposits, and volcanic sediments. Remnants of the river channel are exposed in the valley outside the ancestral floodplain. A small section of the Cambrian Highland Formation (part of the Paleozoic carbonate rocks, 543 to 490 mya) outcrops along the extreme southern end of the Pahranagat NWR (Hess and Johnson 2000; Tschanz and Pampeyan 1970). The Pahranagat Shear Zone, which is a subparallel, northeast-striking fault, occurs at the southern edge of the Refuge (Sweetkind et al. 2004). The shear zone may provide throughflow for the groundwater flow system in the Pahranagat Range that recharges the Tikaboo Valley (Faunt et al. 2004).

Mining production has not been recorded from locations within the Refuge (Tingley et al. 1993; Tingley 1998; Tschanz and Pampeyan 1970). The East Pahranagat Range District occurs northwest of the Refuge and contains small, isolated gold and uranium prospects. Mining production has not been recorded from this district. Although the Refuge may contain material that would be suitable for construction aggregate, under current market conditions, aggregate production is not economically competitive due to high haulage costs.

Paleontological Resources

Within the Pahranagat NWR, the Lincoln County geologic map shows five geologic units: two volcanic units, an older gravel unit, older lake beds, and younger alluvium (Tschanz and Pampeyan 1970). Volcanic rocks are not fossiliferous and have a low paleontological potential. In Lincoln County, no fossils have been found in older gravels. Reworked older alluvium and lacustrine sediments have a low potential for fossils because of the additional erosion and transportation. However, younger alluvium may overlay potentially fossiliferous geologic material.

In southern Nevada, the Panaca and Muddy Creek Formations have a high potential to contain fossils. The Muddy Creek Formation has the potential to produce significant fossils (BLM 1990). Blair and Armstrong (1979) document the occurrence of gastropods, ostracods, trace fossils, diatoms, and plant fossils in the upper member of the Muddy Creek in the Lake Mead area. In addition, in Lincoln County, the Panaca Formation has yielded extinct horse remains (*Pliohippus* sp.) (Tschanz and Pampeyan 1970). The occurrence of fossils in this formation within Pahranagat NWR is unknown, but based on observations of similar rocks in nearby areas, the potential for significant fossils is high.

Soils

The ancestral White River has left an ancient, well-preserved river channel that is generally 0.25 to 0.5 mile wide in Pahranagat Valley (NRCS 1968). The channel and its associated floodplain and adjacent terraces are cut into the alluvial fans shed from the surrounding mountain ranges of the Pahranagat hydrographic basin. The Pahranagat NWR occupies a part of the ancient floodplain that has been strongly modified by runoff. A total of 11 soil-mapping units are present on the Refuge, and the soils generally range from coarse sandy loam to silty loam (NRCS 2003b). Coarse sandy loam soil types have been washed from higher elevations and occur near the proximal edges of alluvial fans. The silty loam soil types are derived from or occur near lake deposits, on the distal edges of alluvial fans, or on floodplains.

Water Resources

<u>Surface Water</u>

Pahranagat NWR receives surface water solely through the White River channel north of the Refuge boundary, which is fed by springs north of Alamo (Ash and Crystal Springs) that discharge a measured 26,000 afy (Burbey and Prudic 1991). After consumptive use of spring discharge from agriculture <u>upstream of the Refuge</u>, approximately

6,500 afy of water enters the Refuge annually into Upper Pahranagat Lake (Service 1999b). The majority of water is received during the winter months (less than 20–30 cubic feet per second [cfs]), with only minimal flows during the summer (<0.5 cfs).

Water is seasonally released from Upper Pahranagat Lake to irrigate the downgradient meadows and to flood a series of small impoundments and Lower Pahranagat Lake. During most years, Lower Pahranagat Lake serves as the terminal lake in the Crystal and Ash Springs subbasin. However, when adequate water is available, water may be released to Maynard Lake, the southernmost wetland in Pahranagat Valley (Service 1999b). Maynard Lake is alternately wet and dry, depending on the availability of water.

The three principal springs that feed the White River channel are Hiko, Crystal, and Ash, which are located north of the Refuge (Figure 4.5-1). These are thermal springs that flow at a fairly constant rate and are derived from regional carbonate aquifers (Eakin 1966). Crystal Springs, the northernmost spring in the Crystal and Ash Springs subbasin, is located just south of Frenchy Lake, approximately 15 miles north of Pahranagat NWR. Crystal Springs consists of at least two springs that discharge a combined volume between 4,000 and 7,000 afy.

The outflow from Crystal Springs is used mostly for pasture and crop irrigation during the irrigation season. Pastures are irrigated using flood irrigation, and a few wells have been set up with center pivot irrigation (Wurster 2007). In the off-season, surface flows from Crystal Springs merge with outflow from Ash Springs, located approximately 4 miles to the south, and forms White River. Ash Springs consists of at least seven springs that discharge a combined volume of 10,000 afy. Outflow from Ash Springs enters a remnant of the historic White River and eventually provides irrigation water to much of the agricultural land between Ash Springs and Pahranagat NWR. Outside of the irrigation season, water also enters the historic river channel and extends to the Refuge. Pahranagat NWR is the lowest elevation in the valley, so runoff from irrigation or storm events that is not lost to evaporation eventually reaches the Refuge.

Upper Pahranagat Lake is actually a storage reservoir, formed in the mid-1930s by construction of a large containment levee that reaches across the valley. During irrigation season, very little water flows into the reservoir because it is diverted upstream for agricultural uses (Ducks Unlimited 2002).

There are also several smaller springs located within the boundaries of the Refuge. These include Cottonwood Spring, Cottonwood Spring North, Lone Tree Spring, L Spring, and Maynard Lake Upper and Lower Springs. Three of the spring outflows (Cottonwood Spring, Cottonwood Spring North, and Lone Tree Spring) have been dredged or trenched to varying degrees.

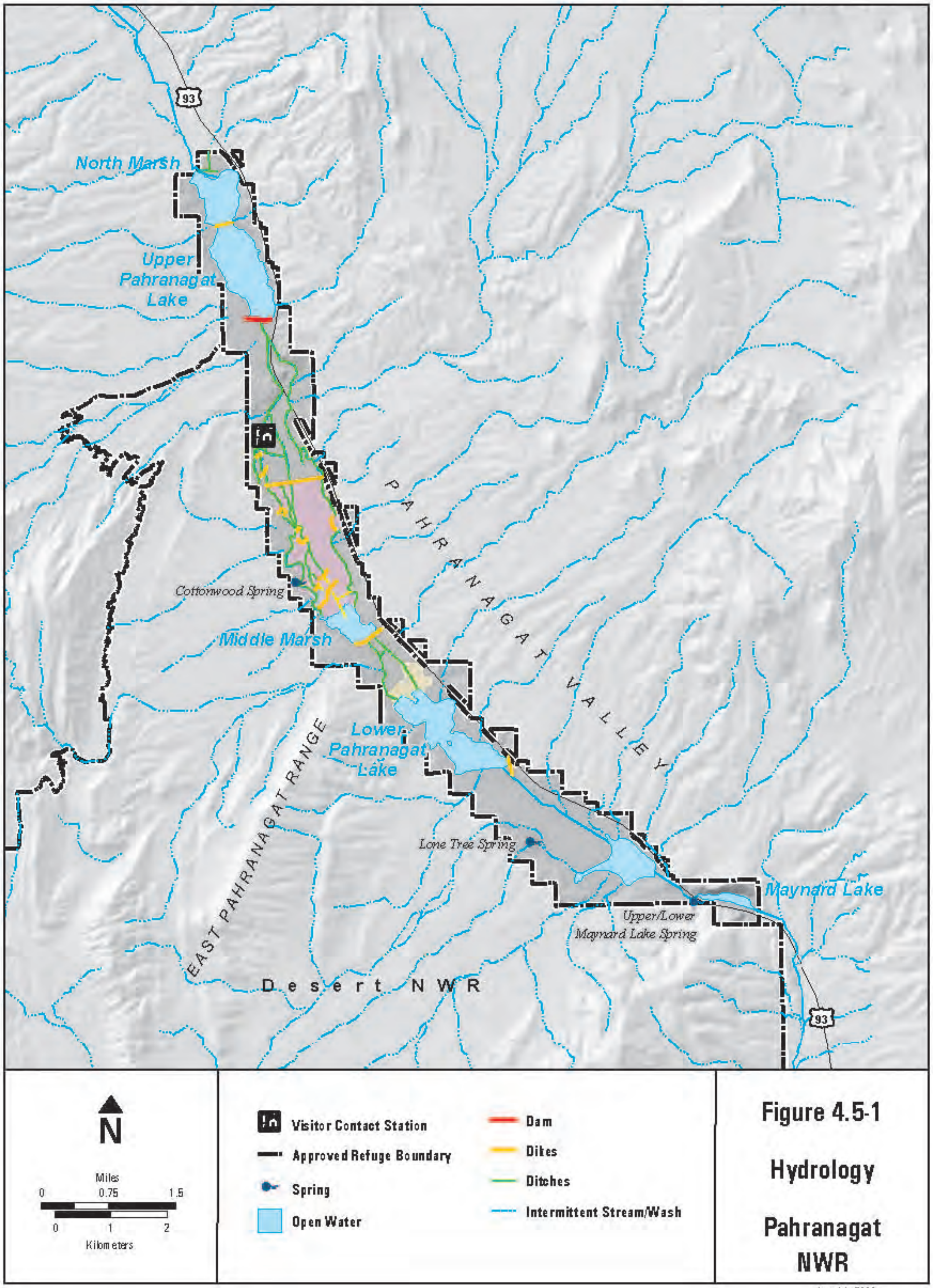

Figure 4.5-1

Hydrology

Pahranagat NWR

June 11, 2009
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Figure 4.5-1 pahranagat_hydro.mxd

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Groundwater

Groundwater flow through Pahranagat Valley is generally from north to south, parallel to the drainage. Pahranagat Valley is underlain by two groundwater aquifers, a large regional carbonate aquifer and a local basin-fill aquifer. Depth to groundwater in Pahranagat Valley is at or near surface from the regional springs south to the end of the valley. Outflow from Pahranagat Valley may enter the regional carbonate aquifer of the Ash Meadows Flow System or may partially recharge the White River Flow System in northern Coyote Spring Valley (Thomas et al. 1996 and Dettinger et al. 1995).

Groundwater level monitoring data on the Refuge is scarce. One well has historical measurements back to 1952 (USGS 2003a and 2003b). The total depth of the well is 92 feet, so it is likely that the well monitors alluvial aquifer water levels. The water level shows much fluctuation, and until 1991, measurements were only recorded in late winter–early spring (February and March). Alluvial aquifer water levels are likely highly dependent on nearby pumping, upgradient surface water diversions, recharge from surface water and/or local precipitation, and recharge from the regional carbonate aquifer system.

Recently, SNWA filed for and was granted water right applications to develop the carbonate aquifer in three hydrographic basins near or adjacent to the Refuge: Delamar, Dry Lake, and Cave Valleys. Concern about potential impacts to the Refuge led to the development of the DDC stipulated agreement and monitoring plan between SNWA, NPS, BLM, BIA and the Service. Under the plan, water levels, spring discharge, and pumping will be monitored within and beyond the boundaries of the Refuge. The plan establishes a several multi-party teams to monitor the biologic and hydrologic effects that may occur as a result of the carbonate pumping.

Water Quality

Discharge from Crystal and Ash Springs make up the bulk of surface water and therefore contribute significantly to the overall water quality of the valley. The practice of flushing salts and alkali from agricultural fields, along with evaporative concentration, contributes to an increase in dissolved solids as water flows from its source through agricultural lands to Upper Pahranagat Lake (Service 1999b). Because of increased evaporation rates and the lack of inflow to downgradient wetlands, dissolved solids concentrations are greatest during late summer. Dissolved solids have been estimated to exceed 6,000 mg/L in terminal wetlands within the Refuge, which is 12 times the recommended potable water limit of 500 mg/L. By contrast, Crystal and Ash Springs have averaged approximately 350 mg/L dissolved solids.

Water Use

Water use within the Pahranagat Hydrographic Basin is primarily for irrigation. During the irrigation season (March 15 through October 15), spring discharge is used to irrigate agricultural fields (Service 1999b). To a very minor extent, wells are used to supplement irrigation. Only one farming operation in the vicinity relies solely on well water for irrigation. That operation is a farm that irrigates 120 acres near Crystal Springs.

The flow of thermal springs during the five winter months is not used by agriculture in the valley, but is adjudicated to the Refuge. From 1991 to 1994, the USGS measured the amount of water reaching the Refuge from the regional springs. The average annual flow for the four water years was 6,500 afy. The Refuge currently uses water to maintain reservoir levels for recreation and to maintain wildlife habitat.

The Service has had difficulties with water conveyance and distribution at the Refuge. The previous distribution system did not allow Refuge personnel to selectively convey water to various areas for habitat benefit. The Service is currently partnering with Ducks Unlimited to develop a surface water delivery system that would move water from the upper riparian areas to drier parts of the system, thus enhancing habitat and hunting opportunities. A new system was installed in 2001 to allow conveyance of water to specific areas of the Refuge. The new system was expected to have capacity to convey and/or dissipate relatively high flows without significant damage. At present, portions of the conveyance system (concrete ditch) are not functional due to faulty construction.

Water Rights

Water in the Pahranagat Valley is used primarily for irrigation of pasture-land, quasi-municipal purposes, and domestic water supply. Three large springs discharging from the regional carbonate aquifer are the principal sources of surface water used for irrigation in the valley. Use of these springs' water was adjudicated in the 1926 Pahranagat Lake Decree and amended later in 1965. Water rights identified in the Decree pre-date Nevada Water Law and carry priority dates ranging from the 1880s to 1900. The Service holds some of these water rights, which allow irrigation of lands on Pahranagat NWR using Ash and Crystal Springs water stored in Upper Pahranagat Lake. Users upstream of the Refuge have right to use winter flows to flush salts from the agricultural fields.

In addition, the Service holds several water rights that are junior to the Pahranagat Lake Decree for waters stored in both Upper and Lower Pahranagat Lakes. Many of these water rights were obtained by the original owners of the Pahranagat NWR property. The Service filed applications with the NDWR to change the Refuge's water rights to reflect the Service's ownership and adjust the purpose of water use from irrigation to wildlife purposes. In addition, the Refuge filed new applications for water from three small springs on the Refuge (Cottonwood, North Maynard, and South Maynard). The applications were submitted to the NDWR in 1996 and are currently classified as "ready-for-action but protested."

Hazardous Materials

In 1995, the Service conducted a study to identify and quantify potential human-induced environmental contaminate impacts to the Pahranagat Valley (Service 1999b). Specific objectives included:

- Identification and characterization of contaminant source areas;
- Identification and characterization of environmental contaminants on Service lands;
- Assessment of contaminant concentrations in abiotic and biotic habitat components, fish, and migratory bird eggs;
- Characterization of the toxicity of water; and
- Identification and quantification of contaminant threats to endangered species and migratory birds.

Total dissolved solids, pH, and concentrations of some soluble trace elements in water increased substantially between the spring sources and lakes on Key Pittman Wildlife Management Area and the Pahranagat NWR. Agricultural practices appeared to contribute to the mobilization of the contaminants from agricultural soils and the transport to downgradient lakes. Reduced water inflow and high rates of evapotranspiration contributed to the concentration of dissolved solids and trace elements in one or more of these lakes, which exceeded Nevada water quality standards for applicable beneficial uses and/or concentration associated with adverse effects to aquatic invertebrates, fish, and birds. The highest concentrations were found in both the Upper and Lower Pahranagat Lakes. Pesticides did not appear to represent a threat to fish and wildlife on the Refuge. Arsenic, mercury, and selenium were found at concentrations of concern in water, sediment, or biological tissues collected from areas occupied by endangered fish. Detection of mercury and selenium in samples collected from spring source pools suggest that these elements are, at least in part, originating from the carbonate-rock aquifer (Service 1999b).

Review of Lovering (1954) and Garside (1973) indicates that radioactive minerals have not been mapped on the Refuge.

Fire History and Management

Fire, either wild or prescribed, is a fairly infrequent event on the Pahranagat NWR. The plant communities characteristically have adapted to a very arid climate (7 inches of annual precipitation) (Service 2001). When the communities are in good condition, shrubs are the dominant vegetative feature, and prior to Euro-American settlement, fine fuels were limited. Areas with less than about 8 inches of rainfall rarely support enough vegetation to carry a fire. Fire occurrence in areas receiving more than about 8 inches has been influenced by introduced grasses. Shrub cover is generally widely spaced with large amounts of bare ground between individuals. Most species in this plant community are either somewhat fire-resistant or are vigorous re-sprouters after disturbance. Pre-settlement fire in such a community was likely a rare event, dependent upon extreme conditions of weather and prolonged periods of drought.

Due to expanses of standing water and lack of naturally occurring ignitions, historic natural fire in the Pahranagat NWR wetlands likely was also a rare event (Service 2001). It is quite feasible, however, that Native Americans regularly burned portions of the wetlands prior to Euro-American settlement to enhance resource availability and quality.

Historical overutilization of the shrub community through cattle and sheep grazing has led to declines in range condition and serious reduction of normally sparse native grass species, while allowing the introduction of exotic annuals (Service 2001). In recent years, exotic native annuals have invaded increasingly large areas of the salt desert community, including portions of the Pahranagat NWR. In particular, cheat-grass has become co-dominant in some areas. This invasion can dramatically alter fire return intervals in this ecosystem from a rare event to one in often less than 10 years. When fire is applied to the desert-shrub community with few or no perennial plants and an exotic annual component present in the understory, the post-fire community will very likely be dominated by annuals.

Prescribed burns have been used on the Refuge since 1985, based on available data (Service 2001).

Air Quality

Ambient air quality is not currently measured at Pahranagat NWR. It is expected that low ambient concentrations of criteria pollutants would occur for this area. The nearest major sources of emissions are in the Las Vegas area, approximately 80 miles to the south. Minor sources from automobile traffic and campfires on the Refuge may result in very localized increases in ambient concentrations.

4.5.2 Biological Resources

Vegetation

<u>Habitat Types</u>

Pahranagat NWR contains 5,380 acres of marshes, lakes, meadows, springs, and riparian habitat (Service 2006a). Most of the Refuge landscape was used for agricultural practices in the past, so several areas still contain remnant signs of these agricultural uses. Many of the historically cultivated agricultural fields have naturally become re-vegetated and now consist of wetland or riparian vegetation (Figure 4.5-2). Management efforts are ongoing to establish native wetland and upland habitats.

Thermal springs along the flood plain provide water to the various ponds, lakes, and marshes found throughout Pahranagat Valley (Service 2006a). The floodplain was formed by an ancient perennial stream, White River, which flowed from the north and was a tributary of the Colorado River. The flood plain it created is well-defined but very narrow. This floodplain is ancestral and has been dry for thousands of years, except for a small creek running down the center that is fed by thermal springs.

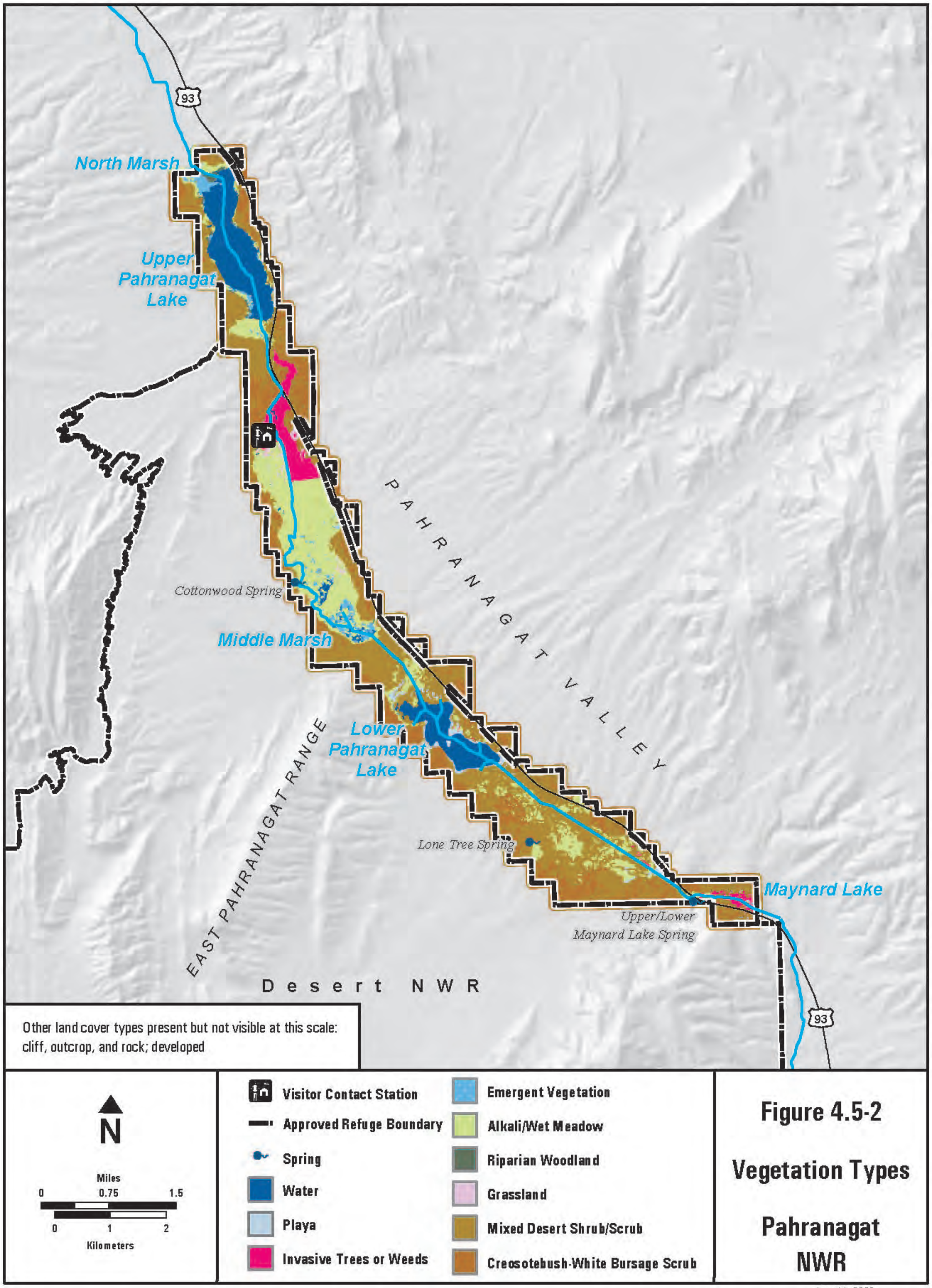

Figure 4.5-2

Vegetation Types

Pahranagat NWR

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Figure 4.5-2-pahranagat_veg.mxd

Four main water impoundments are found on the Refuge, including North Marsh, the Upper and Lower Pahranagat Lakes, and Middle Pond/Marsh (Figure 4.5-2). Water draining from Ash and Crystal Springs (about 15 miles north of the Refuge) flows along Pahranagat Creek and spills into Upper Pahranagat Lake and North Marsh (Service 1998b). Open water habitat covers approximately 640 acres of the Refuge.

Upper Pahranagat Lake and North Marsh only receive water during winter months when the upgradient agriculture fields and ranches are not using water from Pahranagat Creek for irrigation. North Marsh and Upper Pahranagat Lake also receive and store quantities of water from the thermal springs just north of the Refuge (Service 2006a). Water in the lake is released by Gardner Dam, on the south side of Upper Pahranagat Lake, throughout the year to create and enhance the marsh, wetland, and grassland habitats farther south. Middle Marsh captures the released water and creates habitat for many wildlife species.

Lower Pahranagat Lake is used to store water from Middle Marsh, and water flowing through Middle Marsh is released toward Lower Pahranagat Lake. Lower Pahranagat Lake is the last storage unit for the Refuge and captures all excess water from the other three impoundments. The lake, wetland, and marsh areas provide lush habitat for various species of birds, mammals, fish, and other wildlife. The southernmost lake on the Refuge and the southernmost wetland in Pahranagat Valley is Maynard Lake. This lake receives water from the main storage impoundments only when adequate water is available. The releases of water can create habitat for many resident and migratory wildlife species.

The vegetation types at Pahranagat Refuge range from lakes, riparian woodland, wetlands, wet meadows, and springs to uplands, alkaline playas, and rocky outcroppings. Although the riparian woodland is very limited in size, it is the rarest and most irreplaceable of the vegetation communities found at the Refuge.

The riparian woodlands consist of Gooddings willows (*Salix gooddingii*), Fremont cottonwoods (*Populus fremontii*), and coyote willows (*Salix exigua*). At the northern edge of Upper Pahranagat Lake, the mature gallery forest of towering Gooddings willows provides critical habitat for the endangered southwestern flycatcher and other songbirds. This forest covers approximately 100 acres of the Refuge. Small stands of cottonwoods can be found around the perimeter of Upper Pahranagat Lake. Isolated stands of cottonwoods or individual cottonwoods are also found at each spring and in patches of better soils.

Emergent wetlands grow at the margins of all permanent ponds and lakes in the Refuge. Emergent vegetation consists of tules and cattails (*Schoenoplectus maritimus* and *Typha domingensis*). Mats of floating aquatic plants (*Polygonum amphibium*) are found only at the northern end of Upper Pahranagat Lake. The spring habitats are characterized by lush stands of American bulrush (*Schoenoplectus americanus*) and are generally dominated by massive cottonwoods. A wet meadow supporting a dense mixture of Baltic rush (*Juncus balticus*) and yerba mansa *(Anemopsis californica*) extends downstream of Lone Tree spring but Cottonwood spring currently supports only cottonwoods and a small patch of emergent American bulrush.

Middle Marsh is composed of wet meadows, grassy meadows, and scattered wetlands. In the most alkaline soils, saltgrass and alkali sacatone dominate. In the drier portions of Middle Marsh, non-natives such as quackgrass (*Elytrigia repens*) and tall wheatgrass (*Elytrigia pontica*) are abundant and can even form monocultures, excluding all other vegetation. The wet meadows support dense stands of yerba mansa (*Anemopsis californica*) and Baltic rush (*Juncus balticus*).

Small patches of Indian hemp (*Apocynum cannabinum*), bulrushes (*Schoenoplectus maritimus* and *Schoenoplectus americanus*), cattails (*Typha domingensis*), spikerushes *(Eleocharis* spp.), and sedges (*Carex* spp.) are also scattered within the wet meadow complexes. Wet meadow habitat covers approximately 700 acres, and alkaline wet meadow habitat covers approximately 350 acres of the Refuge. Emergent wetland habitat at Middle Marsh covers approximately 400 acres.

Upland vegetation communities change according to subtle variations in topography and salinity. The salt desert scrub habitat consists of various saltbush species found in saline basins on valley floors and around playas. Areas with low nocturnal temperatures and very high soil salinity are common in these basins and support most of this habitat. Salt desert scrub habitat at the Refuge is dominated at the lowest elevations by green rabbitbrush (*Ericameria nauseosus*), often mixed with saltbushes (*Atriplex* spp.). At slightly higher elevations, greasewood (*Sarcobatus vermiculatus*) is more abundant and is often found with four-winged or big saltbush (*Atriplex canescens*, *Atriplex lentiformis*). Traveling up the sides of Pahranagat Valley, widely spaced creosote bushes (*Larrea tridentata*) come to dominate the upland vegetation. Joshua trees (*Yucca brevifolia*) appear among the creosote bushes as the topography continues to rise. This habitat forms the creosote–white bursage alliance.

The creosote–white bursage scrub alliance occurs in broad valleys, lower bajadas, plains, and low hills. This alliance is characterized by widely spaced shrubs and succulents averaging 2 to 8 feet tall, with 2 to 50 percent cover (Holland 1986; Rowlands et al. 1982; Vasek and Barbour 1977). The herbaceous layer is sparse, but seasonally abundant after rain events. Creosote–white bursage scrub transitions to mixed desert scrub at the highest elevations on the Refuge. The mixed desert scrub habitat is dominated by the blackbrush shrub. Plant species found in this habitat are very similar to those in the creosote–white bursage alliance, but they typically consist of intricately branched shrubs that range from 1.5 to 3 feet tall (Holland 1986). Mojave yucca and Joshua tree are very common throughout the mixed desert scrub habitat (BLM 1990).

Rocky outcroppings are also present in the upland portion of the Refuge. These areas are dominated by the invasive red brome grass (*Bromus madritensis* var. *rubens*), but various species of cactus (*Opuntia* spp.) can be found as well as woody shrubs such as Mormon tea (*Ephedra nevadensis*) and indigo bush (*Psorothamnus fremontii*).

Other cover types on the Refuge include playas and desert washes. Playas are mostly unvegetated (less than 10 percent) and are subject to intermittent flooding. Salt-tolerant species often form vegetation rings around the playas. Desert washes are intermittently flooded washes or arroyos associated with rapid sheet and gully flow. They often consist of linear or braided strips within desert scrub or shrublands and grassland habitats. The desert washes of Pahranagat are characterized by dense growths of rabbitbrush, interspersed with alkali sacatone and patches of saltgrass.

Sensitive Plant Species

No federally listed plant species are known to occur on Pahranagat NWR. One sensitive plant, Nye milkvetch (*Astragalus nyensis*), has potential to occur on the Refuge (Appendix H).

Noxious Weeds

The Refuge is located in Lincoln County, Nevada, which is a part of the Tri-County Weed Control Program. Lincoln County treated some areas for tall whitetop (*Lepidium latifolium*) invasions during 2001 (Noxious Weed Action Committee 2001). Many other invasive weeds have become established at the Refuge. Salt cedar forms dense thickets around the southern half of Lower Pahranagat Lake, and Russian olive spreads rapidly in wet meadows. Russian knapweed (*Acroptilon repens*) and various pigweeds (*Amaranthus* spp.) form monocultures in disturbed areas such as the previously cultivated fields of Black Canyon or the Maynard Lake area. The red brome invasive grass is widespread in the drier uplands, while quack grass and tall wheatgrass are locally abundant in the grassy meadows. The constructed ponds near Headquarters are home to a wide variety of weeds that colonized moist disturbed areas, such as bindweed (*Convolvus* spp.), Johnson grass (*Sorghum halepense*), sunflowers (*Helianthus* spp.) and foxtail barley (*Hordeum jubatum*). Appendix H provides a complete list of the noxious weeds that may occur on the Refuge.

Wildlife

More than 230 species of migratory birds and other wildlife use the wetland habitats found on the Refuge (see Appendix H for a list of species). Numerous non-game migratory birds use habitat on the Refuge during the fall and spring migrations. They visit during the fall on their flight south and again in the early spring on their way back north. Some species nest in the dense riparian areas. The riparian areas, marshes, open water, croplands, and native grass meadows attract and support hundreds of species and thousands of individual birds and other wildlife annually. The majority of the wildlife species found on the Refuge are non-game species, and some of them are considered sensitive.

Amphibians and Reptiles

The Refuge's lakes and marsh habitat provide suitable habitat for a variety of amphibians. Amphibians that likely occur on the Refuge include bullfrog, Pacific chorus frog, western toad, and northern leopard frog (*Rana pipiens*).

Reptiles are more common in Nevada than amphibians. They occur in the drier, upland communities on the Refuge. Common reptiles include Gila monster, collared lizard (*Crotaphytus collaris*), coachwhip, common kingsnake (*Lampropeltis getulus*), western shovel nose (*Chionactis occipitalis*), gopher snake (*Pituophis catenifer*), western rattlesnake (*Crotalus viridis*), and Mojave rattlesnake (*Crotalus scutulatus*). At the northern extreme of its range, the threatened desert tortoise occurs in desert upland habitats of the Refuge at unknown densities.

Birds

Pahranagat NWR was established to provide habitat for migratory birds, especially waterfowl. The Refuge is located within the Pacific Flyway, as are the other refuges in the Desert Complex. Many migratory birds are found on the Refuge, including shorebirds, grebes, herons, egrets, and many other non-game birds that use wetland habitat. Many of the waterfowl species found on the Refuge are residents because of the permanent water supply in the valley. Some use the habitat for a short period of time and continue on their migration path.

Pahranagat NWR is considered to be highly important to migratory birds, waterfowl, and songbirds because of its historic geological and hydrological setting on the edge of the Mojave Desert and Great Basin physiographic regions in southern Nevada. In 1999, the American Bird Conservancy designated Pahranagat NWR as a "Continentally Important Bird Area." Approximately one-half of Refuge acreage contains lakes, marshes, springs, and associated riparian habitat. These wetlands are important to the survival of migratory waterfowl and songbirds as well as resident wildlife.

Some of the management priority bird species include eared grebe, western grebe, American white pelican (*Pelecanus erythrorhynchos*), Franklin's gull, black tern, snowy egret, marbled godwit, snowy plover, long-billed curlew, white-throated swift, pinyon jay, Arizona Bell's vireo, southwestern willow flycatcher, black-chinned sparrow, western yellow-billed cuckoo, and canvasback (see Appendix H for more species and the habitats they occur in on the Refuge).

Surveys conducted in the past eight years have confirmed the presence of the federally endangered southwestern willow flycatcher on the Refuge. They use a stand of large cottonwoods and willows at the north end of the Refuge for nesting. Yellow-billed cuckoos have been observed in similar Refuge habitat.

American peregrine falcons are known to use the Refuge for foraging and probably nest on adjacent cliffs. Small numbers of bald eagles use the Refuge for foraging and roosting during winter migration.

Approximately 2,000 of the Lower Colorado River population of greater sandhill cranes (almost 25 percent of this declining population) have used the Refuge as a migrational staging area.

Fall duck migration to the Refuge usually begins in late August with the arrival of several hundred mallards, pintails, and green-winged teal. Peak waterfowl use on the Refuge for the year usually occurs near the end of October. The average duck population on the Refuge in late October for the last five years is approximately 10,000 birds. Pintails and green-winged teal each make up about 40 percent of the population, and mallards and American wigeon share most of the remaining 20 percent. Refuge populations decrease in December as ducks migrate farther south, leaving usually fewer than 1,000 for the remaining winter months.

The Refuge holds a wintering population of tundra swans each year averaging approximately 250 birds. They generally arrive in November and depart north in January.

The paucity of riparian and wetland habitat in Southern Nevada underscores the importance of the Refuge in providing migratory and nesting habitat for passerines. Well over 100 species of perching birds can be found on the Refuge that use both desert uplands and riparian/wetland habitats.

Mammals

The following sensitive mammals can be found on the Refuge: Pahranagat Valley montane mole, Townsend big-eared bat, Allen's big-eared bat, small-footed myotis, long-legged myotis, and Yuma myotis.

The Pahranagat Valley montane vole is endemic to the Pahranagat Valley; according to refuge records, it has been captured as recently as 2007 (NDOW 2007b) and is known to be reproducing on the Refuge (Service 2001). Very little is known about this small, herbivorous mammal that inhabits moist meadow habitats. Trapping efforts have captured voles in several areas of the Refuge, all with good grass cover, and the montane vole is part of a continuing genetic study on the Refuge. These areas include east and north of the North Marsh, the northern portion of the Middle Marsh unit, and just north and west of the Middle Marsh Pond.

Bats are very common on the Refuge, and nine of the potentially occurring bat species are sensitive. Bats are important to the Refuge because they help regulate insect and invertebrate populations, and some help pollinate plants. Most bats are commonly observed during evening hours.

According to the 1992 Annual Narrative Report, cottontail rabbits, a game species, are found in low densities (Service 1992). Black-tailed jackrabbits and white-tailed antelope squirrels are also common.

Mule deer are found in low numbers on the Refuge, but they are not hunted on the Refuge. The 1992 Annual Narrative Report estimated that about 20 deer used the Refuge throughout the year; however, six of them were killed in 1992 from vehicle collisions. The current population is estimated at about 120 deer using the Refuge (Maxwell 2007). Deer crossing signs were erected in late 1992 at each end of the Refuge along U.S. Highway 93 to promote safer driving conditions and reduce the number of roadkills.

Aquatic Species

Several fish species can be found at the Refuge. Pahranagat speckled dace (*Rhinichthys osculus velifer*) is endemic to springs in Pahranagat Valley. Three other Pahranagat Valley endemic fish species are listed as endangered: Pahranagat roundtail chub (*Gila robusta jordani*), White River springfish (*Crenichthys baileyi baileyi*), and Hiko White River springfish (*Crenichthys baileyi grandis*). However, these three fish species are not presently known to occur on the Refuge. Two other endemic fish have become extinct: desert sucker (*Catastomus clarki* ssp.) and Pahranagat spinedace (*Lepidomeda altivelis*). Water quality of the Pahranagat Valley has been considered a factor limiting the range of these fish (Service 1999b).

Several game fish occur in Upper Lake, North Marsh, and Middle Pond. The main sport fish are largemouth bass and bullhead catfish (*Ameiurus nebulosus*). Approximately 15,000 largemouth bass were stocked in May of 1992 from a hatchery in New Mexico (NDOW 2008). Common carp (*Cyprinus carpio*) also occur on the Refuge and are detrimental to other fish populations because of the competition for limited resources. In 1996, an attempt to eradicate carp from Upper Pahranagat Lake appeared successful, but carp were later found in North Marsh and Upper Pahranagat Lake. The percentage of fish in Upper Pahranagat Lake in 1999 was 39 percent bass, 28 percent bullhead, 18 percent green sunfish (*Lepomis cyanellus*), and 15 percent carp. Carp populations are expected to be continually increasing.

Sensitive Wildlife Species

The southwestern willow flycatcher, an endangered species, is known to occur in the cottonwood-willow riparian habitat on the Refuge. In 2005, 29 southwestern willow flycatchers were recorded at the Refuge, nesting in a total of 21 territories (Koronkiewicz et al. 2006). In 2006, 29 resident, breeding flycatchers were recorded at the Refuge, nesting in a total of 15 territories (McLeod et al. 2007). All of the observed nests were found in coyote or Gooddings willows and cottonwood; no nesting was observed in salt cedar habitat. The Refuge's nesting population is considered one of the largest nesting populations in the Colorado River Basin.

The Pahranagat roundtail chub, also an endangered species, is not known to occur on the Refuge, although it was present historically. Bald eagle (delisted), desert tortoise, and yellow-billed cuckoo have the potential to occur on the Refuge. An additional 44 sensitive species have the potential to occur on the Refuge. Appendix H provides a list of the endangered and threatened species and sensitive species that may occur at the Pahranagat NWR.

4.5.3 Cultural Resources

Introduction

The Pahranagat NWR area is an extremely important cultural landscape to many tribal people, especially the Southern Paiute, Western Shoshone, Owens Valley Paiute, and Mohave, as it is a shared use place of sacred power and origins. The natural and cultural resources in the area are all physically and spiritually interrelated. There was extensive historic use of the area for habitation, resource gathering, hunting, fishing, agriculture, and ceremonies prior to Euro-Americans entering the area. In the late 1800s, when non-Indians began to move into the greater Pahranagat Valley vicinity, confrontations occurred, followed by multiple accounts of Paiute and Shoshone Indians being massacred by solders, miners, and settlers. No specific locales for these atrocities have been yet been identified or recorded on the Refuge. In fact, very little systematic archaeological reconnaissance has been conducted in the Pahranagat Valley. Approximately 185 acres or 3.44 percent of the Pahranagat NWR has been investigated through archaeological reconnaissance surveys (Fergusson and DuBarton 2005).

Prehistoric Archaeology

Although more exist, there are currently only 21 recorded prehistoric sites on the Refuge, and these early official site records typically contain very limited information. Cultural resources in the Pahranagat Valley include campsites, lithic scatters, rock shelters, rock art, quarries, special activity sites, multi-component sites, and historic sites. For many of the sites, it is impossible to define temporal characteristics without further investigation. Some of the most well-known sites are rock art, which have attracted public interest.

Sites that may date to the Archaic period around 3,000 B.C. include rock art, stone rings, and lithic scatters found within the Black Canyon National Register District within the Pahranagat NWR. Because the District has not yet been thoroughly investigated, it is impossible to determine if the sites can be assigned to this period or to earlier ones. This petroglyph complex includes several sites featuring unique anthropomorphic figures that are unique to the Pahranagat area (Stoffle et al. 2002). A professional recordation of the complex and coordination with the Moapa Band of Paiutes and other affiliated tribes that associate with this important area would benefit the Refuge's management of the complex.

Other prehistoric resources identified within the Refuge include the Red Tail Hawk origin spot (Maynard Lake) and Coyote's Jar (Origin spot for Paiutes in the area) (Stoffle et al. 2002). Two Southern Paiute villages were also reported to occur in the area, consisting of approximately 300 people who practiced complex horticulture using an extensive network of irrigation. Rock art sites in the area also identify the area as a Water Baby site (supernatural beings who protect the water).

Historic Archaeology

Historic sites are those sites that resulted from use of the region by Euro-Americans or other groups after contact with native peoples. For many portions of southern Nevada, this happened during the mid-1800s. Only four historic sites have thus far been recorded on the Pahranagat NWR. One historic "Walden House" was nominated to the NRHP, but the process has not yet been completed. The Service has improved the house so the building could be used as part of the headquarters complex. Other historic sites on the Refuge include a historic road around Maynard Lake and features associated with historic habitations and ranching.

4.5.4 Public Access and Recreation

Public Access

Pahranagat NWR is open to the public year-round. The public is encouraged to visit the "valley of many waters" to enjoy a variety of recreational opportunities and experience the desert oasis.

Principal public access to Pahranagat NWR is from U.S. Highway 93, about 71 miles north of its junction with I-15. Two unpaved roads lead to Lower Lake and Middle Marsh from the highway. A sign along the highway marks the gravel road to the Refuge headquarters. This road connects to Alamo Road and continues through the Refuge and onto the Desert NWR. About 4 miles north of the headquarters road, an unpaved road leads to the North Marsh and Upper Pahranagat Lake and provides access to the campsites. Vehicles must remain on the designated roads. All-terrain vehicles are prohibited on the Refuge.

Pahranagat NWR receives visitors from the nearby communities as well as from other states and foreign countries. Visitation numbers are gathered in two ways on the Refuge: traffic counters at the entrances and a sign-in sheet at the Refuge headquarters. Between 1999 and 2001, approximately 21,500 vehicles visited Pahranagat NWR (CH2MHill 2002). Specific data on visitation are not available; however, visitation at the Refuge is expected to increase as the nearby communities grow. Based on current estimates, the Refuge accommodates approximately 35,000 visitors per year (Le'au Courtright 2006).

Recreation

The Refuge administrative office also serves as a visitor contact station with brochures, maps, and fact sheets. The office is open Monday through Friday from 8:00 a.m. to 4:00 p.m., or as the staff is available. An outside contact station with interpretive kiosk is located at the north end of the Refuge in the camping area. A dike at Upper Pahranagat Lake serves as a fishing and observation pier (Service 2006a). A hunting and observation platform is available at Middle Marsh. Campsites are available along the eastern shore of the Upper Pahranagat Lake. Picnic tables and grills are available at the campsites. Non-flush toilets and dumpsters are provided in the campground area. Parking is available in several places along designated roads.

The nature trails and fishing pier are the most common facilities used by the public. In FY 2002, more than 10,000 people visited the Refuge to fish, and more than 3,000 people hiked along the nature trails. The platform was used by more than 600 visitors, and 1,500 visitors stopped at the kiosk. The administrative office/visitor contact station was visited by 500 people in 2002. More than 20,000 people visited the Refuge for other recreational opportunities, such as camping and picnicking.

Numerous recreational opportunities are available at Pahranagat NWR (Figure 4.5-3). Wildlife-dependent activities include wildlife observation, photography, fishing, hunting, environmental education, and interpretation. Camping, boating, and picnicking are common non–wildlife-dependent activities.

Wildlife-Dependent Recreation

Wildlife observation, fishing, and hunting are the more popular activities enjoyed by Refuge visitors (Service 2006a). Wildlife observation is available throughout the Refuge, and a bird list is available at the Refuge or online. The large bodies of water and riparian habitat provide excellent opportunities for birders to view a variety of waterfowl and other migratory birds.

Educational opportunities about Pahranagat NWR are available on and off the Refuge. During FY 2002, 261 visitors participated in environmental education activities (Service 2006a). Half of these (132) were staff-conducted tours for students, while the remaining half (129) were non–staff-conducted tours. Exhibits are the only off-site educational outreach opportunities offered to the public, and the Refuge had 520 visits to environmental education exhibits and 165 visits to interpretation exhibits in 2005. Other special events to promote the Refuge in 2002 included news releases and other special events.

An active volunteer program provides additional opportunities for the public to enjoy the Refuge, and student interns may be able to earn college credits through an internship at the Refuge. The Service works with the other public land agencies in southern Nevada to coordinate volunteer work through the Southern Nevada Interagency Volunteer Program–Get Outdoors Nevada. Recent research at Pahranagat NWR has primarily centered on activities that directly support reconstruction/restoration efforts of select habitat areas, including enumeration of wildlife populations, surveying of vegetative habitats, GIS-related data gathering and analysis, and routine baseline monitoring of air and water quality.

The Desert Complex hosts events for National Wildlife Refuge Week and Migratory Bird Day. In FY 2004, they hosted a few events for National Wildlife Refuge Week. Other events that Desert Complex staff have attended include the Clark County Fair, Clark County ECOJAM (Earth Day event), Gran Fiesta (September 2002), and Boy Scout Day Camp (May 2003). Refuge staff or Desert Complex staff also attended the Governor's Conference on Tourism, Dia de los Niños, and Las Vegas Chamber of Commerce Preview, depending on staff availability and funding.

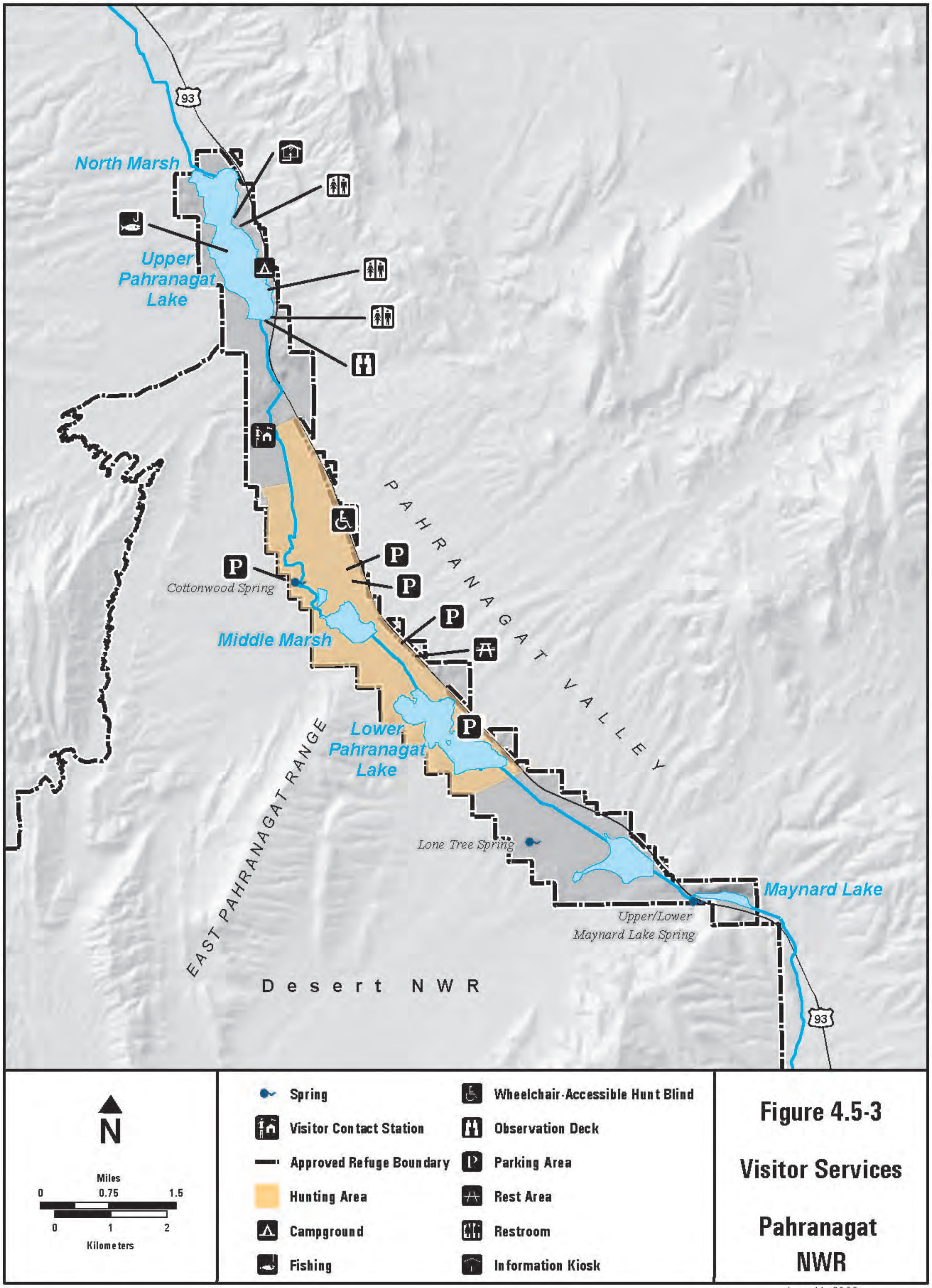

Figure 4.5-3

Visitor Services

Pahranagat NWR

June 11, 2009
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Figure 4.5-3-pahranagat_visitor.mxd

Fishing opportunities are available at Upper Pahranagat Lake. Species in the lake include largemouth bass, catfish, and carp. The NDOW and the Service signed a cooperative agreement to establish and maintain the warmwater sport fishery on the Refuge. The Service was tasked with maintaining the level of the Upper Pahranagat Lake at 4.0 on the staff gauge at the outlet structure, and NDOW was tasked with stocking the lake, North Marsh, and Middle Pond with game fish.

Hunting is available on the Refuge south of the Refuge headquarters (Figure 4.5-3). A wheelchair -accessible hunting blind is available near the Refuge headquarters. During FY 2002, 1,081 hunters visited the Refuge (Service 2006a). Geese, ducks, coots, moorhens, snipe, and doves are the only migratory birds allowed to be hunted on the Refuge. Species hunted on the Refuge in 2002 included waterfowl (423 hunters), other migratory birds (516 hunters), and upland game (284 hunters). More than 10,000 people visited the Refuge to fish in 2002. Hunting and fishing are subject to all applicable state, federal, and Refuge regulations. Hunting opportunities are also available north of the Refuge at a state-managed hunting area. Hunting opportunities are offered alternately between each location to reduce stress on waterfowl.

Non–Wildlife-Dependent Recreation

Camping and picnicking are permitted along the eastern shoreline of Upper Pahranagat Lake in the designated campground. Hiking is permitted on designated trails and roads. Off-highway vehicles are not permitted on the Refuge. Swimming is not allowed at any of the water bodies. Boat launching facilities are unimproved and accommodate only small craft, and only non-motorized boats, float boats, or boats with electric motors are permitted on Upper Pahranagat Lake and Lower Pahranagat Lake. No boats, rafts, or any other types of flotation devices are allowed at North Marsh.

4.5.5 Social and Economic Conditions

Refuge Management Economics

The current Refuge staff consists of two permanent full-time employees, and one vacant part-time seasonal employee position. The Refuge Manager lives on the Refuge, with an office at the Refuge headquarters. The refuge operations budget for FY 2005 was $160,000. The maintenance budget for the Refuge was $44,246.

NWRs contribute funds to local counties through revenue-sharing programs that are intended to cover costs for either lands purchased in fee title or lands reserved from the public domain. For FY 2003, Lincoln County received payment in the amount of $6,640 from the federal government under this revenue-sharing program.

Environmental Justice

The closest town to Pahranagat NWR is the small, unincorporated town of Alamo. The population of Lincoln County is predominantly white (92 percent); Hispanics/Latinos are the largest minority group, representing about 6 percent of the population (U.S. Census Bureau 2006). Lincoln County has a median family income of about $45,000, which is slightly below the average estimate for Nevada ($50,000). The Alamo community is not considered a low-income, minority population.

Land Use

The Pahranagat NWR is bounded on the north by privately held and BLM-managed lands, to the east and west by BLM-managed lands, and to the south by the Desert NWR (Figure 1.7-4). The NTTR is approximately 12 miles to the west.

Present-day commercial/industrial activities include open ditch irrigation development and management, operation of a landing strip/airfield by Lincoln County, basic tourist facilities, and a wastewater treatment plant. Radio and cell towers can be seen on the slopes of the east Pahranagat Range (BLM-managed) to the west of the Refuge. Future proposed uses in the vicinity include industrial park development, residential development at Alamo and Coyote Springs, and groundwater development in neighboring valleys (Delamar and Dry Lake), which could affect management of the Refuge.

Aesthetics

The Refuge encompasses a 10-mile stretch of Pahranagat Valley and associated desert uplands at an elevation of slightly less than 4,000 feet above msl. The White River is dry for many miles upstream and downstream from Pahranagat Valley, but there is water in the valley that originates from large springs to the north of the Refuge. Various types of wetland habitats exist, which support many plants that provide habitat for more than 230 species of migratory birds and other resident wildlife.

The Refuge is located along U.S. Highway 93 in a rural area. The road is a major man-made feature and is a major travel route. The surrounding area consists primarily of creosote bush scrub and some blackbrush in the distance. There is little elevation variation in the vicinity of the site, but mountain ranges to the west and east provide a natural background for visitors. Light pollution is scarce in the vicinity of the Refuge due to a lack of large cities.

Chapter 5. Environmental Consequences

Moapa dace viewing chamber at Moapa Valley National Wildlife Refuge

SE ROA 12976

Chapter 5. Environmental Consequences

5.1 Introduction

This chapter provides an analysis of the effects of each of the alternatives on physical, natural, cultural, and socioeconomic resources at the refuges in the Desert National Wildlife Refuge Complex (Desert Complex). The analysis focuses on a programmatic-level approach to evaluate the effects of plans, projects, and management actions within each alternative. Where a higher level of detail is known for some actions, the analysis provides a more thorough analysis of the anticipated impacts. Most components included in the alternatives' management actions have not been developed at a project-specific level of detail; for those components, this Environmental Impact Statement (EIS) will serve as the first-tier National Environmental Policy Act (NEPA) document for future project-specific NEPA documents. The need for project-specific NEPA documents is identified in the evaluation of each impact; for potentially significant, adverse impacts, a more detailed analysis will be required at the project-specific level. In addition, mitigation measures will need to be refined during the preparation of project-specific NEPA documents.

Each refuge has a No Action Alternative, Alternative A, that would continue current management practices with implementation of a Comprehensive Conservation Plan (CCP); a brief discussion of this alternative is included for comparison purposes. Ash Meadows National Wildlife Refuge (NWR) and Moapa Valley NWR each have two action alternatives; Desert NWR and Pahranagat NWR have three action alternatives. Mitigation measures are included for resources with potentially significant adverse impacts to reduce the intensity of the impact.

This chapter is organized by refuge and then by resource, following the same order as Chapter 4 (Affected Environment). Impacts of the alternatives on each resource topic are compared to show the similarities and differences between alternatives and the range of impacts. Summary tables of the impacts for each refuge are provided at the end of each refuge discussion.

The following resources would not be affected by the Proposed Action:

- Physiography
- Geology and Minerals
- Hazardous Materials

These resources are not further discussed in this chapter.

Criteria were established to determine if a particular impact would represent a significant or potentially significant adverse effect. These criteria are listed below for each resource.

5.1.1 Physical Environment

Paleontological Resources

While no paleontological resources are known to be present, there is potential for as-yet undiscovered paleontological resources to be affected during ground-disturbing activities. An adverse impact would be considered significant if the action would cause physical destruction of or damage to all or part of a paleontological finding.

Soils

An adverse impact is considered significant if an action would trigger or accelerate erosion, subsidence, or slope instability and affect other resources or on-site or adjacent facilities, or if an action would result in substantial loss of topsoil.

Water Resources

Surface Water

An adverse impact is considered significant if an action would:

- Alter the existing drainage pattern of the area in a manner that causes substantial erosion or siltation;
- Create runoff water that exceeds the capacity of downstream drainage systems;
- Impede or redirect 100-year flood flows; or
- Expose people or structures to a significant impact involving flooding.

Groundwater

An adverse impact is considered significant if an action would substantially deplete groundwater supplies or interfere substantially with groundwater recharge such that there would be a net deficit in aquifer volume, decline in the local groundwater table, or reduction in spring flow.

Water Quality

An adverse impact is considered significant if an action would violate water quality standards or substantially alter water quality.

Air Quality

An adverse impact is considered significant if an action would:

- Conflict with or obstruct implementation of the applicable air quality plan;
- Violate any air quality standard or contribute substantially to an existing or projected air quality violation; or
- Expose sensitive receptors to substantial pollutant concentrations.

5.1.2 Biological Resources

Vegetation

An adverse impact is considered significant if an action would:

- Substantially reduce or degrade habitats, especially riparian or wetland habitats;
- Result in an increase of non-native species such that they become the dominant species in the habitat;
- Fragment or isolate habitats, particularly specialized habitat for sensitive species;
- Cause severe degradation of a habitat such that it is no longer suitable for native or endemic species;
- Result in direct mortality of sensitive species; or
- Alter suitable habitat conditions of sensitive species.

Wildlife

An adverse impact is considered significant if an action would:

- Significantly affect habitats as described above;
- Result in mortality or forced emigration of a substantial portion of a species' population (non-sensitive);
- Allow invasive species access to areas previously restricted (e.g., aquatic habitats); or
- Reduce, through direct or indirect means, the likelihood of both the survival and recovery of a sensitive species in the wild by reducing reproductive success, numbers, or distribution of that species.

5.1.3 Cultural Resources

An adverse impact is considered significant if an action would:

- Cause physical destruction of or damage to all or part of a historic or prehistoric site;
- Alter a property, including restoration, rehabilitation, repair, maintenance, stabilization, hazardous material remediation, and provision of handicapped access, that is not consistent with the Secretary's Standards for the Treatment of Historic Properties (36 Code of Federal Regulations [CFR] part 68) and applicable guidelines;
- Remove the property from its historic location;
- Change the character of the property's use or any physical features within the property's setting that contribute to its historic significance;
- Introduce visual, atmospheric, or audible elements that diminish the integrity of the property's significant historic features; or
- Neglect a property, which causes its deterioration, except where such neglect and deterioration are recognized qualities of a property of religious and cultural significance to an affiliated Native American tribe or Native Hawaiian organization.

5.1.4 Public Access and Recreation Opportunities

Public Access

An adverse impact is considered significant if an action would:

- Substantially reduce existing public or emergency access;
- Cause traffic on the refuges to exceed accepted increases in roadway volume to capacity ratios as established by affected jurisdictions;
- Cause road capacities to be exceeded;
- Create inadequate sight distance at ingress/egress points; or
- Substantially increase the demand for on- and/or off-road parking spaces.

Recreation

An adverse impact is considered significant if an action would:

- Substantially displace public recreation opportunities; or
- Increase the use of existing recreational facilities such that substantial physical deterioration of the facility would occur or be accelerated.

5.1.5 Social and Economic Conditions

Refuge Management and Local Economics

An adverse impact is considered significant if an action would result in substantial adverse impacts to local or regional economic conditions.

Environmental Justice

An adverse impact is considered significant if an action would result in disproportionate adverse human health impacts or environmental effects to low-income or minority populations.

Land Use

An adverse impact is considered significant if an action would:

- Result in substantial incompatibility between proposed uses or activities and adjacent existing uses;
- Create a conflict with any applicable land use plan, policy, or regulation of an agency with jurisdiction over the resources;
- Cause substantial changes in use or the intensity of use, where the resulting activity or use pattern would create significant noise, traffic, public safety, or similar environment impacts that would adversely affect the existing or future use of adjacent areas; or
- Result in direct or indirect damage to utilities or other public facilities, cause utilities or other public facilities to be relocated, either permanently or temporarily, or disrupt access to a public utility or other facility or temporarily obstruct an easement.

Aesthetics

An adverse impact is considered significant if an action would:

- Substantially alter the natural landform or construct facilities that would obstruct views to a public resource from public use areas (e.g., trails, observation blinds);
- Cause a substantial adverse effect on a scenic vista;
- Cause substantial damage to scenic resources, including, but not limited to, mountains, trees, rock outcroppings, and historic buildings;
- Substantially degrade the existing visual character or quality of the site and its surroundings; or
- Create a new source of substantial light or glare that would adversely affect day or nighttime views in the area.

5.2 Ash Meadows National Wildlife Refuge

This section describes the potential impacts associated with the No Action Alternative and two action alternatives for Ash Meadows NWR. Impacts are judged for significance using the thresholds described in the introduction of this chapter. Mitigation measures are included for resources with significant impacts.

The two action alternatives involve monitoring, inventory, and research actions that would not result in adverse environmental impacts. These actions would provide the Refuge staff with an improved knowledge of the Refuge, which would later allow them to better assess the effects of their actions. These actions are not further evaluated in this section.

5.2.1 Physical Environment

Soils

Impacts

Restoration activities under each of the alternatives would disturb soils and expose them to wind and water erosion until native vegetation is restored. Areas that would be affected under each alternative include Upper Point of Rocks, Jackrabbit Springs, the Warm Springs (North and South Indian Springs and School Springs) Management Units, Crystal Springs Unit, and Carson Slough. Additional soil disturbance under Alternative B would occur in the Warm Springs, Jackrabbit/Big Springs, Crystal Springs, and Upper Carson Slough Management Units, where additional restoration is planned, and at Lower Point of Rocks, Lower Kings Pool, and Marsh, Big, and Fairbanks Springs, where restoration plans would be implemented. Under Alternative C, restoration activities would also occur at a larger scale in each of the management units and at Tubbs, Bradford, Crystal, Forest, and North and South Scruggs Springs as well as at Longstreet and Rogers Springs. Soil disturbance would increase under the two action alternatives and would result in a temporary increase in erosion, which would be significant where large areas of soil are exposed. Impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities. Establishment of native vegetation and restoration of the areas would provide long-term protection against erosion.

Removal of invasive plants under each alternative (more extensive under Alternatives B and C, specifically including salt cedar) and planting native vegetation would improve soil conditions by stabilizing soils and reducing salt and mineral concentrations that accumulate at the base of salt cedar.

In addition to the restoration activities, road maintenance and construction of visitor use facilities would result in temporary soil disturbance under each of the alternatives. Additional impacts would occur under Alternative C due to construction of a research facility and implementation of a Resurfacing Plan for Refuge roads. These impacts would not be significant where minor amounts of soil are disturbed and topsoil loss is minimal. Impacts will be analyzed further in project-specific NEPA documents to be prepared for the facility improvements and construction.

Mitigation

Mitigation measures that could reduce soil impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Native vegetation would be planted in areas where non-native vegetation is removed and soils are exposed to improve soil conditions and stabilize soils. Appropriate best management practices (BMPs) would be implemented during restoration and construction activities to minimize indirect effects of soil disturbance, including dust, erosion, and sedimentation. These measures would include pre-watering and maintaining surface soils in stabilized conditions where support equipment and vehicles will operate; applying water or dust palliative during clearing and grubbing or earth-moving activity to keep soils moist throughout the process; watering disturbed soils immediately following clearing and grubbing activities; and stabilizing sloping surfaces until vegetation can effectively stabilize the slope.

Water Resources

Impacts

Each of the alternatives involves restoration activities at major springs on the Refuge, invasive plant removal near open water sources, restoration of natural hydrology in various locations on the Refuge, and construction of a boardwalk and overlook near Kings Pool Stream. Additional facility improvements and construction would occur under Alternatives B and C. Ground disturbance activities associated with these activities and facility construction or maintenance near open water sources could cause erosion around the springs, along banks of streams, and at Kings Pool Stream and increase sedimentation and siltation, resulting in increased turbidity of the surface waters. These activities would result in significant, temporary impacts where large areas are restored or modified. Impacts will be analyzed further in project-specific NEPA documents to be prepared for the activities.

Establishment of native vegetation and restoration of historic hydrology would improve surface water conditions on the Refuge over the long term. Removal of cattails at Kings, Point of Rocks, and Crystal springs under Alternative C could improve flow from the springs into downstream drainages.

Habitat restoration increases under each alternative; therefore, impacts to hydrology and water quality would also increase. Under Alternative A, impacts would occur in the Upper Point of Rocks, Jackrabbit Spring, Warm Springs and Crystal Springs Management Units as well as at Carson Slough. Under the two action alternatives, impacts would also occur around several springs. Temporary impacts caused by removing berms, ditches, dams, and impoundments, and closing, maintaining, or modifying roads in each of these units would increase the potential for soil erosion and increased sedimentation in surface waters. Short-term impacts to water quality could be significant; therefore, impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities.

Improved wetland and riparian conditions in the management units would benefit the Refuge's surface water quality over the longer term. For example, removal of salt cedar near surface waters would improve water quality because salt cedar accumulates salt at its base, uses a larger amount of water than most native plants, and degrades aquatic habitat.

Construction of new refugia for the Devils Hole pupfish and Warm Springs pupfish under each alternative may involve ground disturbance in or near existing springs and streams or diversion of water to create the necessary habitat conditions for the pupfish. Temporary impacts may include alteration of flows downstream of the refugia, increased turbidity or other changes to water quality, and modifications of hydrology. These impacts could be significant but temporary, depending on the project-specific details of the refugia; therefore, impacts will be analyzed further in a project-specific NEPA document to be prepared for the refugia.

Construction of new buildings and visitor use facilities under Alternatives B and C may result in short-term impacts to surface water hydrology and water quality caused by ground disturbance near surface waters. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the buildings and facilities.

Alternative C includes implementing the plan to modify or remove Crystal Reservoir. Modifications to this reservoir would reduce open water habitat and allow for native habitat restoration, which would involve restoring historic hydrology (streams) and native habitats. The removal or modification of Crystal Reservoir would also reduce the potential for flooding downstream of the reservoir and benefit the social and natural environments. Construction activities associated with reservoir modifications may result in short-term impacts to surface water hydrology and water quality as a result of ground disturbance near surface waters. Over the long term, water resources on the Refuge would likely be improved through removal or modification of Crystal Reservoir because historic hydrology and native habitats would be restored, improving water conditions as described above for other restoration activities. These impacts will be analyzed further in a project-specific NEPA document to be prepared for the Crystal Reservoir modification plan.

Use of herbicides to control invasive plants under each alternative could potentially affect surface water quality in the reservoirs, springs, and streams on the Refuge. Herbicides reaching surface water could result in indirect impacts on vegetation, fish, and wildlife that rely on the water. Impacts to water quality are expected to be minimal and less than significant because mechanical methods would be used near surface water, and herbicides would be used only when necessary and in accordance with the Integrated Pest Management (IPM) Plan.

<u>Mitigation</u>

Mitigation measures that could reduce water quality impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Implementation of BMPs during ground-disturbing activities would reduce the effects of erosion, siltation, and sedimentation on water quality of the Refuge waters. These measures would include constructing small sediment collection pools downstream of work areas to trap sediment and reduce sediment movement through the aquatic system; using turbidity barriers in areas where sediment collection pools cannot be used; directing flows where feasible around the work area and temporarily detaining flows to reduce potential entrainment of sediment; and limiting the size of the area of disturbance where flows cannot be directed around the work area or detained, so that minimal sediment is added to stream flows.

Air Quality

<u>Impacts</u>

Habitat restoration activities under each of the alternatives would require the use of construction equipment to remove vegetation; plant new vegetation; remove dams, berms, and other facilities; and modify stream channels. Construction of buildings and visitor use facilities under Alternatives B and C would also require construction equipment that would disturb the ground and clear vegetation. The equipment and ground-disturbing activities would cause short-term, minor emissions (engine exhaust and fugitive dust) that may be noticeable on the Refuge. Depending on the extent of activities, an increase in emissions could violate ambient air quality standards and could be significant. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities and facility construction and improvement.

Increased traffic on and through the Refuge would result in a minor increase in traffic-related emissions and an increase in dust. Traffic would not result in violations of the ambient air quality standards for particulates because the amount of Refuge traffic at one time is expected to be small, and traffic would be limited to the main roads and parking areas. Through traffic would not remain on the Refuge for an extended period of time; thus, emissions would be minimal. Impacts associated with dust would also be minimal because under each alternative, the Refuge roads would be improved and maintained or closed to public access (more improvements would occur under the action alternatives). Increased traffic-related emissions on the Refuge would not violate ambient air quality standards and would not be significant with respect to ambient air quality because of the minimal amount of traffic at one time and improved road conditions.

Wildfires can affect air quality through the release of smoke and gases. Fuel breaks and fuel reduction projects to reduce the risk of wildfire would be implemented under each alternative. These measures would reduce the potential for and intensity of air pollutant emissions from wildfires. However, prescribed burns under Alternatives B and C would result in a temporary increase in smoke over the Refuge, which would adversely affect air quality. This would be a less-than-significant impact because small areas would be burned at one time, and the smoke would be temporary, resulting in minimal adverse effects on ambient air quality.

Ground-disturbance, construction, and fire management (particularly fuels reduction) activities under any of the alternatives would result in direct emission of greenhouse gases (GHG) (temporary emissions) from construction equipment. Fire management would help prevent catastrophic wildfire over the long term and reduce long-term GHG emissions. Indirect, long-term emissions of GHG would occur due to increased visitation by the public and increased employee vehicle trips (as staff grows). An increase in GHG emissions would contribute to regional impacts on climate change and could result in significant impacts. Climate change impacts will be further analyzed in project-specific NEPA documents, as appropriate.

<u>Mitigation</u>

Mitigation measures that could reduce air quality impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Application of dust retardants on main roads, watering roads, and regularly maintaining main roads would minimize dust generation. BMPs would be implemented during construction activities that disturb the soil to reduce particulate emissions. These measures would include the BMPs identified for mitigating soil and water resources impacts as well as the following: maintaining effective cover over stockpiled fill or debris materials; limiting vehicle speeds to 15 mph in staging areas and on all unpaved access routes; and cleaning mud, silt, and soil tracked out onto paved surfaces immediately. In addition, use of low or zero-emission construction vehicles and limiting idling time for construction vehicles could reduce GHG emissions during construction.

5.2.2 Biological Resources

Vegetation

Impacts

Ground disturbance associated with construction of the boardwalk near Kings Pool Stream and road modifications under each alternative would result in a loss of vegetation in affected areas, increased potential for invasive plants, and potential impacts to sensitive plants. Construction of additional visitor use facilities under Alternatives B and C would also result in similar types of impacts. Habitat impacts associated with boardwalk construction, road modifications, and visitor facility construction would be less than significant because of the small amount of habitat affected by each facility. Invasive plants could establish in the disturbed areas following construction activities, but this impact would not be significant because the Service would implement measures to control invasive plants as part of the IPM Plan and would restore native vegetation to disturbed areas. Due to the sensitivity of many endemic plants on the Refuge, impacts to sensitive plants could be significant, depending on the project-specific details of the facilities; therefore, impacts will be analyzed further in project-specific NEPA documents to be prepared for these facilities.

Habitat restoration increases under each alternative; therefore, short-term impacts and long-term benefits to vegetation and habitats would also increase. Under Alternative A, approximately 70 acres of alkali wet meadow, 30 acres of mesquite bosques/lowland riparian habitat, and 30 acres of native upland habitat would be restored in the Warm Springs and Jackrabbit Springs Units. Additional restoration would also occur in the Upper Point of Rocks, Carson Slough, and Crystal Springs Units, and old agricultural fields would be rehabilitated. Alternative B would involve restoring 520 acres of alkali wet meadow, 220 acres of mesquite bosque/lowland riparian habitat, and 150 acres of emergent marsh as well as rehabilitating a larger percent of agricultural fields and implementing additional restoration to maintain alkaline meadow/wet meadow, native upland desert, and mesquite bosque. Alternative C would involve restoring 650 acres of alkali wet meadow, 550 acres of mesquite bosque/lowland riparian habitat, and 150 acres of emergent marsh as well as the additional restoration/rehabilitation under Alternative B including an even greater percentage of agricultural field rehabilitation.

Temporary disturbance during habitat restoration activities could result in impacts to sensitive species populations and sensitive habitats (i.e., wetlands), which could be significant. Sensitive plants may experience short-term, adverse impacts during construction activities (direct take or loss or modification of suitable habitat conditions) in areas where habitat restoration is proposed under each alternative. Threatened and endangered species that are more likely to be affected due to their presence in wetland/riparian habitats include spring-loving centaury, Ash Meadows gumplant, and Amargosa niterwort. Threatened and endangered species that occur in upland areas include Ash Meadows milkvetch, Ash Meadows sunray, Ash Meadows ivesia, and Ash Meadows blazing star. These impacts could be significant, depending on the project-specific details of the restoration activities;

therefore, impacts will be analyzed further in project-specific NEPA documents to be prepared for restoration of the habitats in each management unit.

Over the long term, restoration would provide improved habitat conditions throughout the Refuge for sensitive plants. Additional transplanting efforts for sensitive plants under Alternatives B and C would expand and benefit sensitive plant populations on the Refuge. Removal or modification of Crystal Reservoir under Alternative C would also improve habitat conditions on the Refuge, specifically for Amargosa niterwort.

Each of the alternatives involves restoration actions at major spring locations to improve native habitat. As part of these restoration actions, non-native and invasive plants would be removed or controlled around the springs, and native plants would be planted in their place. These actions would benefit the habitats around the springs by encouraging native plant growth and reducing undesirable species. Native habitat is more desirable and suitable for most wildlife species and improves conditions of the springs by helping control water quality and temperature.

Each alternative involves removing invasive plants at restoration sites and in burned areas using physical and chemical means, in compliance with the IPM Plan, to benefit native habitats and improve conditions for native plants to reestablish. A more active invasive species removal program would be implemented under Alternatives B and C to control non-native and invasive plants throughout the Refuge. Specifically, the Service would remove 50 to 75 percent of salt cedar and Russian knapweed populations (based on 2006 estimates) under Alternative B and 75 to 95 percent of their populations under Alternative C. Additional efforts under Alternative C would include evaluating alternative pest control strategies and expanding efforts to include all aquatic systems on the Refuge.

Invasive plant removal efforts could adversely affect sensitive plants through incidental take or habitat modification, which could affect their populations and result in significant impacts. Under Alternatives B and C, the Service would adjust its efforts based on the responses of sensitive plants to ensure minimal impacts to their populations. Ongoing monitoring of the species would allow the Service to determine where management activities should be modified.

Control and removal of invasive plants would allow native plants to establish, and establishment of native plants in moist areas would provide additional protection against invasive species over the long term. Removal of salt cedar under Alternatives B and C would also improve soil conditions and reduce the risk for high-intensity fires associated with salt cedar stands.

A variety of measures under each alternative, including law enforcement, fuel reduction projects, road closures, fixing and installing barriers, and expanding Service-managed lands within the Refuge boundary, would protect habitats and sensitive plants from unnecessary disturbance. Increased law enforcement and road gates under Alternatives B and C would further protect habitat and sensitive plants.

Mitigation

Mitigation measures that could reduce vegetation (primarily sensitive species) impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 7 consultation process, as appropriate.

Standard construction practices would be implemented to prevent invasive plant species from establishing in the disturbed areas around the facilities, such as cleaning vehicles and equipment used on the Refuge with high-pressure sprayers to dislodge seeds prior to accessing the area. Facilities would be designed to avoid sensitive habitats and sensitive species populations and impact the least amount of vegetation (based on pre-construction surveys and mapping). For activities that would result in take of sensitive plants, the Service would implement transplanting or restoration plans for affected plants to transplant or plant sensitive plants in suitable habitats on the Refuge.

Wildlife

Impacts

Temporary construction activities associated with visitor use facilities, roads, and fencing would disturb fish and wildlife species in the vicinity of the activity. Amphibians, reptiles, birds, mammals, fish, and invertebrates that use the affected habitats have the potential to be directly affected by construction equipment and vegetation removal activities. These species would be forced to temporarily relocate to other areas of the Refuge or off-site until the disturbance is removed. Because only minimal road improvements would occur under Alternative A, short-term adverse impacts to fish and wildlife species would be limited to small areas of the Refuge and would not be significant. More facilities would be constructed or improved under Alternatives B and C; thus, short-term adverse impacts would be greater and could be significant if sensitive fish or wildlife species are harmed or if breeding, nesting, and spawning activities are disturbed. These impacts will be analyzed further in project-specific NEPA documents to be prepared for facility construction and road improvements.

Habitat improvements under each alternative would benefit most wildlife species by restoring native conditions, although temporary construction activities would result in short-term disturbance to fish and wildlife. Temporary impacts would be similar to those described above for facility construction, and potentially significant impacts will be analyzed further in project-specific NEPA documents to be prepared for the habitat restoration activities.

Riparian and wetland species, such as waterfowl, song birds, southwestern willow flycatcher, and amphibians, would benefit from restoration of alkali wet meadow and mesquite bosque/lowland riparian habitat under each alternative, with greater benefits occurring under Alternatives B and C because larger amounts of habitat would be restored. Management priority species that would benefit from wet meadow and riparian restoration include eared grebe, western grebe, Franklin's gull, black tern, snowy egret, marbled godwit, snowy plover, long-billed curlew, Arizona Bell's vireo, and western yellow-billed cuckoo.

Restoration of emergent marsh under Alternatives B and C would benefit migratory birds, fish, amphibians, and invertebrates. Specifically, eared grebe, western grebe, Franklin's gull, black tern, snowy egret, and canvasback would benefit from emergent marsh restoration. Control of cattails around open water sources under Alternatives B and C would expand open water habitat for migratory birds, waterfowl, and fish and may attract more birds to the Refuge. Improvements to springs and streams on the Refuge under each alternative would benefit the sensitive species occupying those habitats and could aid in their recovery.

Restoration of native upland habitat under each alternative would benefit migratory birds, burrowing owls, chuckwalla, and other reptiles, mammals, and birds that use the habitat. Specifically, white-throated swift would benefit from upland restoration. Restoration activities throughout the Refuge would benefit native, endemic, and migratory wildlife over the long term.

Habitat restoration, particularly in and around springs, continued restoration of spring outflow systems, and control of non-native species in those systems would also benefit the Warm Springs pupfish and other fish species on the Refuge. Specific restoration activities in streams to provide flowing streams with riffles would benefit the Ash Meadows speckled dace under Alternatives B and C. Additional restoration activities under Alternative C, such as removal of cattails from Kings, Point of Rocks, and Crystal Springs, would benefit the native, endemic fish species present on the Refuge. In addition, eared grebe and snowy egret would benefit from spring and channel restoration.

Temporary disturbance during stream modifications and installation of temporary fish barriers would disturb fish directly, restrict movement, or affect water quality. These impacts could be significant, depending on the project-specific details of the restoration activities; therefore, impacts will be analyzed further in project-specific NEPA documents to be prepared for restoration of the spring habitats. Improved habitat conditions, specifically through removal of pest species as discussed below, would improve reproductive success and increase populations of sensitive fish on the Refuge to aid in their recovery.

The threatened Ash Meadows naucorid population would benefit from habitat improvements under Alternatives B and C. The Point of Rocks spring outflow channel would be restored to provide flowing streams with substrate. This would encourage the naucorid population to expand its range into the suitable habitat and aid in recovering the species' population.

Crystal Reservoir provides habitat primarily for non-native or introduced fish species. These species adversely affect native species through predation and competition for resources, although efforts are ongoing to control their populations. The removal or modification plan for the reservoir would be implemented under Alternative C. Changes to the reservoir, in particular its removal, would substantially reduce or possibly eliminate non-native predatory fish in the reservoir system, which would benefit native fish populations. Native fish occurring on the Refuge can survive in the stream and spring habitats; thus, reservoir removal would not be detrimental to native species. Temporary impacts during reservoir removal or modification would be reduced through relocating any native fish that are found in waters anticipated to be affected by reservoir removal or modification activities to suitable habitat outside the disturbance area during restoration activities. These impacts will be further analyzed in a project-specific NEPA document to be prepared for the reservoir modification plan.

Restoration of the native habitat and hydrology in the Crystal Reservoir area would benefit aquatic and avian species over the long term and could improve populations of sensitive and endemic fish by removing the non-native fish.

Crayfish and bullfrogs compete with and prey on native, endemic fish and invertebrates. Under Alternatives B and C, the Service would actively remove crayfish from the spring habitats. These efforts would benefit fish and invertebrates by reducing predators and competition.

Under each alternative, the Point of Rocks refugium would be discontinued once a new refugium is established for the Devils Hole pupfish, or sooner. Construction and operation of new refugia for the endangered Devils Hole pupfish and Warm Springs pupfish under each alternative and refugia for other endemic species under Alternative C would benefit native fish species by providing a population base for reintroduction to the springs and streams on the Refuge, following restoration activities. The refugia would also ensure the continued survival of the species by providing a safe haven for the species. Temporary impacts on habitats and fish species during construction of the refugia will be analyzed in a project-specific NEPA document to be prepared for the refugia.

Mitigation

Mitigation measures that could reduce wildlife impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 7 consultation process, as appropriate.

Standard construction measures would be implemented to minimize impacts on native wildlife, such as avoiding unnecessary disturbance to habitats by driving on existing roads and working only in the required area, minimizing direct disturbance to streams and open water sources, and throwing away all trash and other construction debris in approved disposal areas. Construction activities and restoration would be implemented during the non-breeding/nesting season and outside of the spawning period for fish, to the extent feasible. Disturbance during the breeding/nesting season would require pre-construction surveys to locate active nests and establish barriers around the nest site until a qualified biologist determines the nest site is abandoned. Activities in or near waterways would be avoided during the spawning period to minimize impacts on sensitive fish.

5.2.3 Cultural Resources

Impacts

In addition to restoration activities, improvements and modifications to roads would result in ground disturbance under each of the alternatives. Additional ground disturbance would occur under Alternatives B and C because of the larger areas of restoration and construction of visitor use facilities. Cultural resources may be adversely affected by ground disturbance activities associated with construction and restoration activities. Impacts associated with each alternative have the potential to be significant, depending on the project-specific details of restoration, road construction, and visitor facilities, if important known or unknown cultural resources on the Refuge are destroyed or damaged. These impacts will be analyzed further in project-specific NEPA documents to be prepared for these activities.

Cultural resources are currently being adversely affected by vandalism, degradation, and, on occasion, fire. Alternative A involves minimal actions to reduce these impacts, and National Register–eligible cultural resource sites could be damaged, destroyed, or otherwise significantly affected. Several historic cabins on the Refuge have been destroyed by wildfires, which are carried by the salt cedars in the old farm canals. Alternatives B and C involve removing salt cedar and constructing fences, signs, and other barriers, which would provide some protection for cultural resources. Indirect adverse effects related to increased visitor use may include disturbance and destruction of sites and removal of artifacts. Impacts to cultural resources would be significant under the action alternatives if eligible sites lose their integrity through destruction, damage, or removal. Indirect impacts on cultural resources will be further analyzed in project-specific NEPA documents to be prepared for Refuge activities.

Because other aspects of the environment are important to tribes and can be considered cultural resources, adverse impacts to other resources could also be considered impacts to cultural resources. These impacts are not specifically discussed as cultural resource impacts; however, they may be of concern to culturally affiliated tribes if the resources are important to them. Examples include native plants that may be collected and used for various purposes, water resources, or geologic features.

Mitigation

Mitigation measures that could reduce cultural resource impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 106 consultation process, as appropriate.

In order to prevent adverse impacts on cultural resources during restoration and construction activities, professional archaeologists would survey the project areas for cultural resources and record the information and locations prior to project implementation. Staff members would use their knowledge of site locations to design and construct facilities to avoid eligible resources. All ground disturbance activities would be monitored by an archaeologist and a tribal monitor in areas where known cultural resources are located and in areas with high potential for buried cultural deposits. If cultural resources are inadvertently exposed during activities, activities would immediately cease and a qualified archaeologist would be consulted to implement appropriate measures for mitigation or preservation. If eligible sites or portions thereof cannot be protected and would be adversely affected, other mitigation or data recovery methods would be conducted in consultation with the Nevada State Historic Preservation Office.

5.2.4 Public Access and Recreation

Public Access

Impacts

Public access would be temporarily affected during construction and restoration activities under each alternative. More activities are proposed under Alternatives B and C; therefore, access to larger areas of the Refuge would be temporarily affected for longer periods. These activities would result in incidental traffic from construction vehicles over a short-term period that would result in a relatively small increase in traffic in the immediate vicinity of the Refuge. Some congestion on roadways and longer stop times at intersections would be expected during the construction period. Areas under construction or being restored would be temporarily off-limits to the public for their safety.

Impacts to public access during restoration and construction could be significant depending on the locations and extent of activities implemented at one time. With the small number of visitors on the Refuge at one time, most activities would have minimal effects on traffic. Visitors would continue to have access to other areas of the Refuge during construction activities. Project-specific NEPA documents will include further analysis of public access impacts of Refuge actions.

Long-term public access on the Refuge would continue to be generally unrestricted under Alternative A, with some nonessential roads being closed and minimal law enforcement patrols. Visitors would be allowed to access the Refuge at any time and use multiple routes or points along the Refuge boundary. Primary access is from the south on Spring Meadows Road and is often a result of through traffic. There are also a number of other points of access to the Refuge that, along with limited law enforcement patrols under current management, impair the ability of the Service to properly manage and protect resources on the Refuge.

Additional measures under Alternatives B and C would limit and control access on the Refuge by increasing law enforcement patrols and adding road gates to block access to non-public roads. These measures would restrict public access to certain areas, but visitors would continue to have access to open areas of the Refuge for recreational purposes, and private landowners would continue to have access to their lands. Access control measures would improve Refuge management by protecting resources on the Refuge and preventing or minimizing significant impacts to sensitive resources, which would improve the quality of the visitor's experience.

Under all alternatives, improvements to existing roadways and parking areas would have a beneficial effect on public access throughout the Refuge. Additional improvements to roads as part of the Resurfacing Plan under Alternative C would also benefit public access and improve Refuge road conditions. Improved road conditions would also encourage visitors to stay on designated roads and provide direction to public access points.

The various visitor use projects under Alternatives B and C would improve recreational opportunities for visitors and could attract more visitors to the Refuge. This increase would result in increased traffic on Highway 373/127 and increased traffic on the Refuge. The traffic impacts would be more noticeable on peak days, primarily weekends, when vehicle trips to the Refuge are highest. The increase in visitors and some additional road construction-related traffic would have a minor impact due to the relatively low number of visitors at one time and the low amount of traffic currently occurring on Highway 373/127 and the Refuge.

Mitigation

Mitigation measures that could reduce public access impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Areas under construction or being restored would be temporarily off-limits to the public for their safety. These areas would be adequately marked, and detours or alternative routes would be identified. Refuge staff would schedule construction for slower times of visitation during the week and slower seasons to minimize the impacts of construction traffic on public access.

Recreation

Impacts

Temporary construction activities associated with road improvements and restoration under each alternative would restrict access to affected areas of the Refuge for recreational purposes. Construction of visitor facilities under Alternatives B and C would also restrict public use of small areas of the Refuge where construction occurs. Recreational opportunities would continue to be available in other areas of the Refuge. Depending on the locations and extent of activities implemented at one time, impacts to recreational opportunities could be significant. With the small number of visitors on the Refuge at one time, most activities would have minimal effects on recreation. Project-specific NEPA documents will include further analysis of recreational impacts of Refuge actions.

A variety of recreational opportunities would be available to the public under each alternative, such as wildlife observation, hiking, and picnicking. These activities are supported by trails, kiosks, picnic areas, and restrooms at several locations on the Refuge. Under each alternative, recreational opportunities would be improved to provide more services for visitors. The most improvements would occur under Alternatives B and C with development of a Visitor Services Plan, an Outreach Plan, an Environmental Education Plan, and a Hunt Plan. The Visitor Services Plan and Hunt Plan would address potential public use conflicts associated with change in Refuge users and dynamics from a predominantly hunter use to school and international visitation.

Restoration activities and construction of visitor use facilities (i.e., the boardwalk at Kings Pool Stream) under each alternative would enhance visitor experiences and benefit recreational opportunities. Interpretive and education materials would also improve visitor experience and expand recreational opportunities on the Refuge. Implementation of the plan to remove or modify Crystal Reservoir under Alternative C would eliminate unauthorized fishing by removing the source of game fish. Habitat conditions for sensitive fish would be improved, but game fishing would be eliminated. The availability of other recreational opportunities on the Refuge would reduce adverse effects of eliminating unauthorized fishing.

The Refuge would continue its limited participation in community events and other forms of environmental education under Alternative A, including its partnership with Death Valley National Park to educate the public on Death Valley and the Devils Hole pupfish. Expanded outreach efforts would occur under Alternatives B and C to encourage the public to visit the Refuge and experience the opportunities available to them.

Alternatives B and C include the construction of a new visitor contact station and interpretive facilities and an expanded emphasis on educational activities and outreach to local groups. These actions would benefit environmental education and outreach opportunities for the Refuge.

Mitigation

Mitigation measures that could reduce recreation impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Areas under construction or being restored would be temporarily off-limits to the public for their safety. These areas would be adequately marked, and information on other recreational areas would be provided to the public. Refuge staff would schedule construction for slower times of visitation during the week and slower seasons when feasible, to minimize the impacts of construction traffic on public access.

5.2.5 Social and Economic Conditions

Refuge Management and Local Economics

Impacts

Under Alternative A, the annual Refuge budget, which includes operations, capital projects, and four full-time staff members, would remain comparable to current funding and staffing levels, resulting in continued limitations on management of the Refuge and opportunities for public interaction.

Under each alternative, the Service would continue to pursue acquisition of the remaining lands within the approved boundary from willing sellers. Lands acquired would be removed from the tax rolls, so state and local government income would be slightly reduced. However, this loss in property taxes would be at least partially offset by Refuge revenue-sharing payments, so this impact would not be significant.

Under each alternative, restoration projects, road improvements, and boardwalk construction would provide employment to qualified local citizens, including tribal individuals, for a short term. Under Alternatives B and C, new interpretive facilities, a visitor contact station, and Refuge headquarters would be constructed, along with other physical improvements. These actions would also require use of private contractors, which would have a minor beneficial effect in terms of providing short-term jobs to qualified local citizens, including tribal individuals. Additional activities related to environmental education would require increased expenditures to meet those needs. These actions would require increases in the Refuge management and operations budget and staffing.

An increase in the number of visitors to the Refuge would increase retail trade, lodging, and food service for the nearby local economy. Additional indirect employment as a result of the increased activity would also be expected.

Mitigation

Impacts to refuge management economics and local economies would not be significant, so specific mitigation measures are not necessary.

Environmental Justice

Impacts

Minority or low-income populations would not be affected by the continuation of existing operations of the Refuge under Alternative A.

Increased educational and outreach activities, both on-site and off-site, under Alternatives B and C would provide benefits to school children and tribal communities, including minority and low-income populations. Adverse effects on low-income or minority populations are not expected under the action alternatives.

Development of cultural resources interpretive and environmental education materials in coordination with affiliated Native American tribes under Alternatives B and C would address topics that would be of interest to the Native American population.

Mitigation

Impacts related to environmental justice would not be significant, so specific mitigation measures are not necessary.

Land Use

Impacts

With the Refuge continuing to operate at the current level of activities under Alternative A, new land use conflicts to existing or planned uses in the proximity of the Refuge are not anticipated.

Acquisition of existing private parcels within the Refuge would occur under each alternative. Any additional acquisitions of private land would allow greater public access to areas on the Refuge and would allow the Refuge to be managed as a whole with less fragmentation. Private land would only be purchased from landowners who wish to sell. Private landowners who do not want to sell would continue to have access to their property for private use.

Mitigation

Impacts to land use would not be significant, so specific mitigation measures are not necessary.

Aesthetics

Impacts

Restoration and protection efforts for native habitats under each alternative would improve visual character of the Refuge by restoring the habitats to native and historic conditions. Greater improvements to visual character would occur under Alternatives B and C because of the larger areas being affected. Temporary impacts would occur during restoration activities when vegetation is removed, and soils are exposed, adversely affecting views of the area for visitors; these impacts are not considered significant due to their short duration. These views would immediately improve upon establishment of native vegetation and restoration of historic hydrology.

Construction of a boardwalk under each alternative would affect views of the Refuge during and following construction. Additional visitor use facilities would be constructed under Alternatives B and C, including a visitor contact station and Refuge headquarters, which would result in greater temporary effects on aesthetics. Temporary dust, exposed soils, and construction activities would adversely affect views of the disturbed areas during construction; however, these impacts are not considered significant due to their short duration.

New visitor facilities could have a long-term impact on the natural features and vegetation currently on the Refuge, depending upon the siting of the facilities and integration into the Refuge's natural setting.

The new Refuge headquarters, visitor contact station, and boardwalks would be constructed to improve the visual quality of the Refuge, specifically at the current administrative site, which consists of a variety of trailers and old metal structures. Impacts to aesthetics could be significant, depending on the project-specific details of the facilities; therefore, impacts will be analyzed further in project-specific NEPA documents to be prepared for the facilities.

Mitigation

Mitigation measures that could reduce aesthetics impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Visual impacts during construction of interpretive facilities and other physical improvements would be temporary and addressed through screening, ongoing construction site maintenance and cleanup during construction. Refuge staff would schedule construction for slower times during the week and slower seasons, when feasible, to minimize these impacts. Impacts of new facilities on the long-term visual quality of the Refuge would be addressed through site-sensitive design standards that ensure compatibility with the Refuge environment.

5.2.6 Summary of Effects

Table 5.2-1 summarizes the potential effects for each of the three alternatives. Alternative A continues current management practices with little changes or improvements. Alternative A would involve restoration of 70 acres of alkali wet meadow, 30 acres of mesquite bosques/lowland riparian, and 30 acres of native upland habitat.

Compared with Alternative A, Alternative B would improve Refuge habitats to benefit native and sensitive plant and wildlife species, accommodate an increase in visitors, and enhance visitor experience. Alternative B would involve restoration of 520 acres of alkali wet meadow, 220 acres of mesquite bosque/lowland riparian, 30 acres of native upland habitat, and 150 acres of emergent marsh. Alternative B would, however, result in short-term, mitigable adverse impacts from restoration projects and facility and road construction.

Compared with Alternative B, Alternative C would provide greater biological and visitor benefits, but result in greater short-term mitigable adverse construction impacts. Alternative C would involve restoration of 650 acres of alkali wet meadow, 550 acres of mesquite bosques/lowland riparian, 30 acres of native upland habitat, and 150 acres of emergent marsh.

Impacts and mitigation measures of restoration actions, visitor facility construction and improvement, and other actions noted throughout this section will be further analyzed and refined in project-specific NEPA documents to be prepared for each action. The Service will use the analysis presented in this EIS to focus on key issues that need to be further evaluated in second-tier NEPA documents.

Table 5.2-1. Ash Meadows NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
Physical Environment			
Soil Conditions	EC[3]: Minimal long-term improvements; some temporary disturbance	SH: Improved long-term conditions through restoration; some temporary disturbance during construction and restoration	MH: Improved long-term conditions through restoration; some temporary disturbance during construction and restoration
Surface Water	EC: Some hydrology restored (long-term)	SH: Hydrology restored on portions of Refuge (long-term)	MH: Hydrology restored throughout Refuge (long-term)
Water Quality	EC: Improved with restoration over the long term in some areas; some temporary impacts	SH: Improved with restoration over the long term on portions of the Refuge; temporary impacts	MH: Improved with restoration over the long term throughout Refuge; temporary impacts
Air Quality	EC: Some emissions and dust (temporary and long-term)	SL: Minor emissions and dust from temporary construction activities and increased temporary and long-term traffic; temporary smoke from prescribed burns	SL: Minor emissions and dust from temporary construction activities and increased temporary and long-term traffic; temporary smoke from prescribed burns
Biological Resources			
Alkali Wet Meadow	EC: Restore 70 acres of habitat over the long term	CH: Restore 520 acres of habitat over the long term	CH: Restore 650 acres of habitat over the long term
Mesquite Bosque/Lowland Riparian	EC: Restore 30 acres of habitat over the long term	MH: Restore 220 acres of habitat over the long term	CH: Restore 550 acres of habitat over the long term
Emergent Marsh	EC: Maintain 132 acres of habitat over the long term	SH: Restore 150 acres of habitat over the long term	SH: Restore 150 acres of habitat over the long term
Upland Habitat	EC: Restore 30 acres of desert upland habitat over the long term	SH: Rehabilitate agricultural fields; maintain desert upland habitat over the long term	SH: Rehabilitate agricultural fields; maintain desert upland habitat over the long term
Sensitive Plants	EC: Improved habitat in some areas over the long term; minor temporary disturbance	MH: Population expansion over the long term; improved habitat on portions of the Refuge over the long term; potential for temporary impacts during restoration and facility construction activities	CH: Population expansion over the long term; improved habitat throughout the Refuge over the long term; potential for temporary impacts during restoration and facility construction activities in a larger area
Invasive Plants	EC: Minimal removal efforts over the long term	SH: Removal of invasive plants in restored areas over the long term	MH: Removal of invasive plants in restored areas over the long term

[3] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

Table 5.2-1. Ash Meadows NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
Biological Resources, continued			
Common Wildlife Species	EC[4]: Some improved habitat over the long term; minimal temporary disturbance	SH: Improved habitat on portions of the Refuge over the long term but potential for impacts during construction	MH: Improved habitat throughout Refuge over the long term but potential for impacts during construction
Southwestern Willow Flycatcher	EC: Some improved habitat over the long term	SH: Improved habitat on portions of the Refuge over the long term	MH: Improved habitat throughout Refuge over the long term
Management Priority Birds	EC: Some improved habitat over the long term	MH: Improved and increased habitat on portions of the Refuge over the long term	CH: Improved and increased habitat throughout the Refuge over the long term
Sensitive Fish	EC: Some improved habitat over the long term; minimal temporary disturbance	MH: Improved habitat on portions of the Refuge over the long term; potential for impacts during construction	CH: Improved habitat throughout the Refuge over the long term; potential for impacts during construction
Invasive Fish	EC: Minimal removal efforts over the long term	SH: Removal of some invasive fish over the long term	MH: Removal of most invasive fish over the long term
Cultural Resources			
Cultural Resources	EC: Some impacts possible during construction and restoration activities	SL: Potential for impacts during construction and restoration activities	SL: Potential for impacts during construction and restoration activities
Public Access			
Roads	EC: Minor improvements to roads over the long term	SH: Improved roads and recreation facilities improve access over the long term; closures and barriers control access over the long term	SH: Improved roads and recreation facilities improve access over the long term; closures and barriers control access over the long term
Traffic	EC: Current traffic	SL: Increase in visitors would increase traffic on and to the Refuge over the long term	ML: Increase in visitors would increase traffic on and to the Refuge over the long term
Recreation			
Visitor Use Facilities	EC: Some facilities available	SH: More facilities constructed over the long term	SH: More facilities constructed over the long term
Recreational Opportunities	EC: Variety of opportunities available	SH: Improved opportunities and services over the long term; some temporary impacts	SH: Improved opportunities and services over the long term; some temporary impacts
Environmental Education/Interpretation	EC: Limited materials available	SH: More materials available over the long term	SH: More materials available over the long term
Outreach	EC: Limited outreach	SH: Increased outreach over the long term	SH: Increased outreach over the long term
Refuge Management and Local Economics			
Refuge Budget and Staffing	EC: Current budget and staffing	MH: Increased budget and staff to implement actions over the long term	CH: Increased budget and staff to implement actions over the long term

[4] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

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Table 5.2-1. Ash Meadows NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
Refuge Management and Local Economics, continued			
Local Economy	EC[5]: Current economy	SH: Increase in local economy from increased visitors over the long term	SH: Increase in local economy from increased visitors over the long term
Land Use			
Service-managed Lands within Boundary	EC: Current conditions	SH: Expand Service-managed lands within Refuge boundary over the long term; maintain access for private landowners	SH: Expand Service-managed lands within Refuge boundary over the long term; maintain access for private landowners
Aesthetics			
Restoration Activities	EC: Some improvements over the long term	SH: Improved visual character from restoration activities over the long term	MH: Improved visual character from restoration activities over the long term
Visitor Use Facilities	EC: Minimal changes over the long term	SH: Improved visual character over the long term; temporary disturbance	SH: Improved visual character over the long term; temporary disturbance

[5] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

5.3 Desert National Wildlife Refuge

This section describes the potential impacts associated with each of the action alternatives for Desert NWR. Impacts are judged for significance using the thresholds described in the introduction of this chapter. Mitigation measures are included for resources with significant impacts. This section also summarizes the results of an Environmental Assessment (EA) for the visitor facilities at Corn Creek Field Station (Service 2007).

Each of the action alternatives involves monitoring, inventory, and research actions that would not result in adverse environmental impacts. These management actions would provide the Refuge staff with an improved knowledge of the Refuge, which would later allow them to better assess the effects of their actions. In addition, the proposed Desert Wilderness is treated the same under all the alternatives. These actions are not further evaluated in this section.

5.3.1 Physical Environment

Soils

Impacts

Construction of visitor use facilities and road improvements under Alternatives B and C would result in disturbance to soil, potentially causing erosion in the small affected areas. These activities would result in less-than-significant impacts on soils due to the small areas being affected.

Construction of an auto tour route under Alternative B and boundary fences under Alternatives B, C, and D would result in substantial soil disturbance due to the lengths of the route and fencing. These impacts could be significant and will be analyzed further in project-specific NEPA documents to be prepared for the auto tour route and boundary fences.

Prescribed burns and naturally ignited fires would be used to restore vegetation characteristics representative of a natural fire regime under Alternatives C and D; however, the use of fire would also increase the potential for erosion immediately following the burn and before new plants become established. Because of the potentially large amount of soil exposed under these alternatives, temporary impacts could be significant. These impacts will be analyzed further in a project-specific NEPA document to be prepared for the revised Fire Management Plan. Under Alternatives C and D, highly flammable vegetation would be removed from around water catchments to protect bighorn sheep. This would also result in a temporary increase in erosion potential until new vegetation is established.

As discussed in the visitor facilities EA (Service 2007), construction and rehabilitation activities at Corn Creek Field Station would disturb soil and expose it to wind and water erosion. Establishment of native vegetation around springs and along streams would stabilize the soils and reduce further erosion potential.

Mitigation

Mitigation measures that could reduce soil impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Appropriate dust control measures and BMPs would be implemented during restoration and construction to reduce dust, erosion, and sedimentation. Mitigation measures would be implemented during prescribed burns to reduce the potential for erosion. These measures would include pre-watering and maintaining surface soils in stabilized conditions where support equipment and vehicles will operate, applying water or dust palliative during clearing and grubbing or earth-moving activity to keep soils moist throughout the process, watering disturbed soils immediately following clearing and grubbing activities, and stabilizing sloping surfaces using soil binders until vegetation or desert pavement (ground cover) can effectively stabilize the slope.

Water Resources

Impacts

None of the alternatives involves management actions that would adversely affect hydrology.

Vegetation removal around water catchments under Alternatives C and D would expose soils to wind and water erosion and could result in increased sedimentation and other pollutants in the water. Water quality impacts would be minimal, however, due to the small size of the affected area and minor amount of affected soil around the catchments.

Road improvements, fence construction, and construction of visitor use facilities under Alternatives B, C, and D (more construction under Alternative B) would have minimal direct impacts on surface water quality on the Refuge because of the lack of surface waters in the vicinity. Under Alternative B, construction of the auto tour route would result in substantial soil disturbance and could adversely affect downstream water quality. These impacts will be further analyzed in project-specific NEPA documents to be prepared for the auto tour route.

As discussed in the visitor facilities EA (Service 2007), construction and rehabilitation activities at Corn Creek Field Station would result in soil disturbance and could discharge sediment and pollutants into the surface waters at Corn Creek. Operation of the visitor facilities would result in a negligible amount of runoff due to permeable surfaces and recycling of rain water in the visitor center gutters. Removal of the two lower ponds would alter downstream hydrology at Corn Creek, but would not affect spring discharge.

Mitigation

Mitigation measures that could reduce water quality impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

The Service would implement BMPs during all construction activities near surface waters, including ephemeral washes, to ensure minimal discharge of pollutants and to control erosion and runoff.

Air Quality

Impacts

Construction activities under Alternatives B, C, and D, such as for visitor facilities, trails (B), an auto tour route (B), and fencing (C and D), would require construction equipment that would disturb the ground and clear vegetation. This equipment would cause short-term, minor emissions (engine exhaust and fugitive dust) that may be noticeable on the Refuge. Depending on the extent of activities, an increase in emissions could violate ambient air quality standards and could be significant. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the facilities.

Increased traffic on the Refuge would result in a minor increase in traffic-related emissions. These emissions would not result in violations of the ambient air quality standards because the amount of Refuge traffic at any one time is expected to be small, and traffic would be limited to the main roads and parking areas. Therefore, traffic-related impacts to ambient air quality would not be significant.

Prescribed burns and naturally ignited fires allowed to burn under Alternatives C and D would affect air quality on the Refuge. Although the burns would generate smoke, which may be noticeable off the Refuge, impacts would not be significant because the burns would be temporary and would not be expected to violate ambient air quality standards. All burns would be completed in compliance with requirements from the Nevada Division of Environmental Protection, Bureau of Air Pollution Control. Specifics of air quality management will be further analyzed in a revised Fire Management Plan that will be subject to further public and regulatory review and NEPA compliance.

As discussed in the visitor facilities EA (Service 2007), construction activities, including building demolition, would generate dust and air pollutants and affect air quality. Increased vehicle emissions from increased visitor use would have a minor effect on air quality.

Ground-disturbance, construction, and fire management (particularly fuels reduction) activities under any of the alternatives would result in direct emission of greenhouse gases (GHG) (temporary emissions) from construction equipment. Fire management would help prevent catastrophic wildfire over the long term and reduce long-term GHG emissions. Indirect, long-term emissions of GHG would occur due to increased visitation by the public and increased employee vehicle trips (as staff grows). An increase in GHG emissions would contribute to regional impacts on climate change and could result in significant impacts. Climate change impacts will be further analyzed in project-specific NEPA documents, as appropriate.

Mitigation

Mitigation measures that could reduce air quality impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

BMPs would be implemented during construction activities that disturb the soil to reduce particulate emissions. These measures would include the BMPs identified for mitigating soil and water resources impacts as well as the following: maintaining effective cover over stockpiled fill or debris materials; limiting vehicle speeds to 15 mph in staging areas and on all unpaved access routes; and cleaning mud, silt, and soil tracked out onto paved surfaces immediately. In addition, use of low or zero-emission construction vehicles and limiting idling time for construction vehicles could reduce GHG emissions during construction.

Prescribed burns would be implemented only during favorable meteorological conditions to minimize substantial impacts to air quality.

5.3.2 Biological Resources

Vegetation

Impacts

Under each alternative, public facility and road improvements would result in minimal impacts to habitat. Construction of additional visitor use facilities and road improvements under Alternatives B and C and construction of boundary fences under each action alternative would result in additional habitat impacts, resulting in minor losses of vegetation in the small affected areas. These activities would result in less-than-significant impacts on habitats due to the small areas being affected.

Establishment of an auto tour route and construction of wildlife viewing trails under Alternative B could result in substantial impacts to vegetation, including sensitive species, depending on the specific alignment of the route and trails. These impacts could be significant, depending on the project-specific details of the tour route and trails; therefore, impacts will be analyzed further in project-specific NEPA documents to be prepared for these activities.

In addition, construction of boundary fences under Alternatives C and D could result in adverse impacts to sensitive plants, if present, along the eastern and northern boundaries. Impacts to sensitive plants under Alternative B are not anticipated because sensitive plants are not expected to occur along the southern boundary. If sensitive plant populations are affected by fence construction, impacts would be significant and would be analyzed further in a project-specific NEPA document to be prepared for the boundary fence(s).

Prescribed burns and naturally ignited fires allowed to burn under Alternatives C and D would improve habitat conditions for wildlife and help return the vegetation communities to their natural fire regime. Temporary vegetation disturbance would occur during the fires, but herbaceous vegetation would return soon after the fire, and the habitat would restore over the long term; therefore, vegetation impacts from prescribed burns would be less than significant.

A variety of measures under each alternative, including maintaining or installing fences, signs, and barriers; maintaining or improving roads; designating wilderness; increasing law enforcement; and suppressing wildfires, would protect habitats from unnecessary disturbance. In addition, rehabilitation of habitat along the southern boundary under Alternatives C and D would remove man-made disturbances and improve desert scrub habitat.

As discussed in the visitor facilities EA (Service 2007), construction and rehabilitation activities would result in temporary disturbance to habitats at Corn Creek Field Station. Construction of the visitor facilities would result in a minor loss of habitat. Habitat rehabilitation would improve habitat for native species by replacing native plants with non-native and invasive plants.

Mitigation

Mitigation measures that could reduce vegetation (specifically sensitive plants) impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 7 consultation process, as appropriate.

Standard construction practices would be implemented to prevent invasive species from establishing in the disturbed areas around the facilities, such as cleaning vehicles and equipment used on the Refuge with high-pressure sprayers to dislodge seeds prior to accessing the area. Facilities would be designed to avoid sensitive habitats and impact the least amount of vegetation, based on prior surveys and mapping. The Service would coordinate with the Nevada Fish and Wildlife Office and NDOW on pre-construction surveys and mitigation measures for ground-disturbing activities, such as boundary fences construction, road improvements, or trail construction, that would adversely affect rare or endemic plants.

Additional mitigation measures related to natural and prescribed fires include post-fire habitat monitoring, re-seeding with native species where appropriate, actions to prevent the spread of invasive exotic vegetation, and close coordination between prescribed burns and natural fires above 5,000 feet.

Wildlife

Impacts

Individuals of some wildlife species may be adversely affected by construction of visitor use facilities, roads, and fencing under Alternatives B, C, and D. Amphibians, reptiles, birds, mammals, and invertebrates that use the affected habitats have the potential to be directly affected during vegetation removal activities. These species would be forced to relocate to less disturbed areas of the Refuge where suitable habitat is available. Adverse impacts to wildlife species would be localized and dependent on the specific activity. For more common wildlife, impacts would be less than significant because of the localized nature of the disturbance and minimal effects to their population. For resident and migratory birds, impacts could be significant if disturbance occurs during the breeding or nesting periods and would affect nesting species. These impacts will be analyzed further in project-specific NEPA documents to be prepared for these activities.

Desert tortoise, a threatened species, and Gila monster may potentially be disturbed or injured during construction of visitor facilities or fencing in desert scrub habitats under Alternatives B, C, and D. Additional impacts could occur under Alternative B during construction of the auto tour route. Construction activities could adversely affect the tortoise and Gila monster populations and their habitat. Impacts to these species could be significant, depending on the project-specific details of the fence and auto tour route alignments and visitor facility locations. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the activities.

The desert tortoise is currently being adversely affected by illegal off-road activities along the southern boundary. Implementation of habitat protection efforts (e.g., fencing the boundaries and restricting access) would reduce the potential for this impact under Alternatives B, C, and D, and rehabilitation of habitat along the southern boundary under Alternatives C and D would improve habitat for the tortoise. These activities would also improve habitat for Bendire's thrasher and white-throated swift.

Habitat above 5,000 feet used by resident birds and migratory wildlife, specifically the pinyon jay, gray vireo, black-chinned sparrow, flammulated owl, and Gilbert's skink, a Nevada Department of Wildlife (NDOW) sensitive species, would be modified by prescribed burns and naturally ignited fires allowed to burn under Alternatives C and D. Prescribed and natural fires and the subsequent loss of downed woody debris may also affect the Hidden Forest Uinta chipmunk, although the status of this species has not been confirmed on the Refuge. The prescribed burns and natural fire would result in a temporary loss of habitat and could harm individuals of these species, but the burns would improve habitat diversity over the long term for these species as well as others, including the bighorn sheep. Although minor impacts would occur over the short term, long-term effects of the burns would be beneficial.

Management actions under the action alternatives to improve bighorn sheep populations include translocating sheep to increase populations, developing a sheep management plan (Alternatives C and D), construction additional water catchments (Alternatives C and D), and removing highly flammable vegetation around water catchments to reduce potential for fire (Alternatives C and D). Desert bighorn sheep would benefit from these actions because their subpopulations would increase to more stable levels. Temporary disturbance would occur during activities in bighorn sheep habitat, but the sheep would be able to return to the affected areas following the disturbance. Temporary impacts will be analyzed further in a project-specific NEPA document to be prepared for sheep management.

Reestablishment of the Pahrump poolfish into streams, ponds, or springs at Corn Creek could benefit the regional poolfish population and contribute to its recovery. However, adverse effects from public use of the Corn Creek area could adversely affect the Refuge poolfish population by introducing pest species (i.e., bullfrog, crayfish) and disturbing the habitat. Law enforcement patrols and close monitoring of the poolfish after reintroduction would be necessary to ensure minimal impacts to the reestablished population. If the habitat is determined to be unsuitable for poolfish, such as due to human disturbance, the Service would not reestablish a population at Corn Creek. These impacts will be analyzed further in a project-specific NEPA document to be prepared for the activities.

As discussed in the visitor facilities EA (Service 2007), construction and rehabilitation activities would result in temporary disturbance to fish and wildlife at Corn Creek Field Station. Construction of the visitor facilities would result in a minor loss of habitat and could affect desert tortoise. Habitat rehabilitation would improve habitat for native species, including native fish and avian species, such as the eared grebe, western grebe, snowy egret, Arizona Bell's vireo, southwestern willow flycatcher, and western yellow-billed cuckoo.

Mitigation

Mitigation measures that could reduce wildlife impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 7 consultation process, as appropriate.

Standard construction measures would be implemented to minimize impacts on native wildlife, such as avoiding unnecessary disturbance to habitats by driving on existing roads and working only in the required area, minimizing direct disturbance to streams and open water sources, and throwing away all trash and other construction debris in approved disposal areas. Construction activities, restoration, and prescribed burns would be implemented during the non-breeding/nesting season for resident and migratory birds to the extent feasible. Disturbance during the breeding/nesting season would require pre-construction surveys in suitable habitats to locate active nests and establish barriers around the nest site until a qualified biologist determines the nest site is abandoned.

Prior to construction activities in desert scrub habitat, desert tortoise and Gila monster surveys would be conducted to determine the presence/absence of these species. If present, appropriate measures would be implemented to minimize adverse impacts, such as relocating tortoises or Gila monsters away from the construction area, using tortoise fencing, and monitoring by a qualified biologist to remove tortoises and Gila monsters during construction.

Prescribed burns would be implemented during portions of the year when the bighorn sheep are not present in or near the affected area. If burns must be conducted in an area where bighorn sheep are present, appropriate measures would be implemented to keep sheep out of the burned area. The Service should coordinate with NDOW on appropriate mitigation measures for adverse effects of prescribed and natural burns to sensitive birds and small mammals above 5,000 feet in elevation.

5.3.3 Cultural Resources

Impacts

Under Alternatives B, C, and D, known and unknown cultural deposits may be adversely affected by ground disturbance activities associated with construction or modification of visitor use facilities, roads, water catchments, and boundary fences. Additional impacts may occur under Alternative B during establishment of the auto tour route. Prescribed burns around water developments under Alternatives C and D also have the potential to expose and affect cultural resources. Due to the presence of important cultural resources on the Refuge, including a variety of resources located in the Sheep Range Archaeological District, impacts associated with the action alternatives have the potential to be significant if known or unknown resources are destroyed or damaged. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the activities.

Cultural resources are currently being affected by vandalism and degradation. Actions under Alternative A have minimal effects on reducing these impacts, and eligible cultural resource sites could be damaged, destroyed, or otherwise significantly affected. Alternatives B, C, and D involve constructing fences, signs, and other barriers and expanding law enforcement patrols on the Refuge, which would provide increased protection for cultural resources. Impacts to cultural resources would still have the potential to be significant under the action alternatives if eligible sites lose their integrity through destruction, damage, or removal. These impacts will be analyzed further in project-specific NEPA documents to be prepared for Refuge activities.

Because other aspects of the environment are important to tribes and can be considered cultural resources, adverse impacts to other resources could also be considered impacts to cultural resources. These impacts are not specifically discussed as cultural resource impacts; however, they may be of concern to culturally affiliated tribes if the resources are important to them. Examples include native plants that may be collected and used for various purposes, water resources, or geologic features.

As discussed in the visitor facilities EA (Service 2007), construction and rehabilitation activities would affect portions of the Corn Creek National Register District. The carpenter's shop, a contributing element of the district, would be removed, and other resources could be adversely affected by trail construction and operation. In addition, buried cultural resources are likely present at Corn Creek Field Station and could be affected by construction of the visitor center, restoration activities, and removal of the two lower ponds.

Mitigation

Mitigation measures that could reduce cultural resource impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 106 consultation process, as appropriate.

In order to prevent significant adverse impacts to cultural resources during construction or ground-disturbing activities, professional archaeologists would survey the project areas for cultural resources information and locations prior to project implementation. Staff members would use their knowledge of site locations to construct facilities to avoid eligible resources. All ground disturbance activities would be monitored by an archaeologist and a tribal monitor in areas where known cultural resources are located and in areas with high potential for buried cultural deposits. If cultural resources are inadvertently exposed during activities, activities would immediately cease and a qualified archaeologist would be consulted to implement appropriate measures for mitigation or preservation. If eligible sites or portions thereof cannot be protected and would be adversely affected, other mitigation or data recovery methods would be conducted in consultation with the Nevada State Historic Preservation Office.

5.3.4 Public Access and Recreation

Public Access

Impacts

Construction activities under the action alternatives would result in incidental traffic over a short-term period that would result in a relatively small increase in traffic in the immediate vicinity of the Refuge. Some congestion on roadways and longer stop times at intersections would be expected during the construction period. Impacts to public access during construction could be significant depending on the locations and extent of activities implemented at one time. With the small number of visitors on the Refuge at one time, most activities would have minimal effects on traffic. Visitors would continue to have access to other areas of the Refuge during construction activities. Project-specific NEPA documents will include further analysis of public access impacts of Refuge actions.

The public would continue to have minimally restricted access to the Refuge under Alternative A, with the exception of the western half of the Refuge, which is part of the Nevada Test and Training Range (NTTR) and is closed to the public. Visitors would be allowed to access the eastern portion of the Refuge at any time and using any routes. The southern and eastern boundaries are being monitored by law enforcement patrols, but the generally unrestricted access impairs the ability of the Service to properly manage and protect resources on the Refuge.

Additional measures under Alternatives B, C, and D would control access on and to the Refuge. Boundary fences under each action alternative would guide public access to designated roads and prevent unauthorized off-road vehicle access. Road improvements to Mormon Well and Alamo Roads (not under Alternative D) and parking turnouts along Alamo, Mormon Well, and Gass Peak Roads would improve the public's ability to access remote areas of the Refuge while following designated routes. An auto tour route under Alternative B would also improve public access on the Refuge and would allow visitors from the Las Vegas area to easily access remote areas for recreational purposes. Access control measures would improve Refuge management by protecting resources on the Refuge and preventing or minimizing significant impacts to sensitive resources, which would improve the quality of the visitor's experience.

Access to recreational opportunities would also be improved through increased information on trails, roads, and the Refuge. Additional signs and a kiosk at the Mormon Well Road entrance under Alternatives B, C, and D would enhance public access by directing visitors to the Refuge and providing them with information on trails and accessible roads on the Refuge. Trail guides would also be available for visitors to direct them to specific areas for recreation (Alternatives B and C).

The various visitor use projects under Alternatives B, C, and D would improve visitor services and could attract more visitors to the Refuge. An increase in visitors and construction-related activity would result in increased traffic on the Refuge and on the access roads. Traffic impacts would be more noticeable on peak days, primarily weekends, when vehicle trips to the Refuge are highest. The increase in visitors and some additional construction-related traffic would have a minor impact due to the relatively low number of visitors at one time and low amount of traffic currently on the Refuge.

As discussed in the visitor facilities EA (Service 2007), construction and rehabilitation activities would temporarily restrict public access to portions of the Corn Creek Field Station. The new visitor facilities would improve visitor services and could attract more visitors to the Refuge.

Mitigation

Mitigation measures that could reduce public access impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Areas under construction or being restored would be temporarily off-limits to the public for their safety. These areas would be adequately marked, and detours or alternative routes would be identified. Refuge staff would schedule construction for slower times of visitation during the week and slower seasons, when feasible, to minimize the impacts of construction traffic on public access.

Recreation

Impacts

Under Alternative A, current activities would continue. The Corn Creek Field Station is open on a limited basis. Camping, picnicking, and hiking, along with wildlife observation and hunting in designated areas, are the most popular recreational activities on the Refuge.

Wildlife viewing trails would be evaluated and developed in the Gass Peak and Sheep Range in Alternative B. Wildlife observation and photography would be enhanced in Alternatives B, C, and D with construction of photography blinds. An auto tour route on Gass Peak Road is proposed in Alternative B. These facilities would enhance visitor experiences and benefit recreational opportunities, with the most improvements occurring under Alternative B and fewer improvements under Alternatives C and D. Areas under construction would be temporarily off-limits to visitors for public safety; however, other areas of the Refuge would continue to be open to the public during that time. Depending on the locations and extent of activities implemented at one time, impacts to recreational opportunities could be significant. With the small number of visitors on the Refuge at one time, most activities would have minimal effects on recreation. Project-specific NEPA documents will include further analysis of recreational impacts of Refuge actions.

Under Alternative A, the Refuge would continue its limited participation in community events and other forms of environmental education. Volunteers are currently used to provide interpretation and guidance to visitors at the field station, and signs are replaced and updated, as needed. Participation in community events is limited to two per year.

An expanded environmental education program would be implemented in Alternatives B, C, and D, including installation of interpretive panels and signs at entrances, increased participation in community events, an annual open house, and a display at a public venue in Las Vegas. An expanded emphasis on educational activities and outreach to local groups and other constituencies and displays on and off the Refuge would benefit environmental education under Alternatives B, C, and D.

As discussed in the visitor facilities EA (Service 2007), the new visitor facilities would improve recreational opportunities on the Refuge, specifically at Corn Creek Field Station, and would provide visitors with a central location to learn more about the Refuge and its resources.

Mitigation

Mitigation measures that could reduce recreation impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Areas under construction or being restored would be temporarily off-limits to the public for their safety. These areas would be adequately marked, and information on other recreational areas would be provided to the public. Refuge staff would schedule construction for slower times of visitation during the week and slower seasons, when feasible, to minimize the impacts of construction traffic on public access.

5.3.5 Social and Economic Conditions

Refuge Management and Local Economics

Impacts

Under Alternative A, the annual Refuge budget, which includes operations, capital projects, six full-time staff members, and one vacant part-time seasonal employee position, would expect to remain comparable to current limited funding and staffing levels. The continued level of restoration and management activities, recreation, and visitor services would be available.

New visitor facilities, road improvements, and other physical improvements under the action alternatives would require the use of private contractors, which would have a minor beneficial effect in terms of providing short-term jobs. Additional activities related to outreach and environmental education would require increased Refuge expenditures to meet those needs. These actions would require increases in the Refuge management and operations budget. Implementation of a recreation-fee program under Alternatives B, C, and D could help offset the costs of facility maintenance and improvements and improve the Refuge operations budget.

Alternatives B, C, and D would expand bighorn sheep habitat management, population management, and public use of the Refuge. These actions would result in increased staffing at the Refuge in order to accommodate visitor needs. Additional staff and salaries would have a beneficial effect by adding employment and income to the local economy.

An increase in the number of visitors to the Refuge would increase retail trade, lodging, and food service for the nearby local economy. Additional indirect employment as a result of the increased activity would also be expected.

As discussed in the visitor facilities EA (Service 2007), construction of the new visitor facilities and habitat rehabilitation would not require funding from the Refuge budget (they would be funded through the Southern Nevada Public Lands Management Act). The activities would generate short-term employment opportunities for construction.

Mitigation

Impacts to refuge management economics would not be significant, so specific mitigation measures are not necessary.

Environmental Justice

Impacts

There would be no adverse impacts to minority or low-income populations as a result of the continuing operations of the Refuge under Alternative A.

Development of cultural resources interpretive and environmental education materials in coordination with affiliated Native American tribes under Alternatives B, C, and D would address topics that would be of interest to the Native American population.

Mitigation

Impacts related to environmental justice would not be significant, so specific mitigation measures are not necessary.

Land Use

Impacts

With the Refuge continuing to operate at the current level under Alternative A, potential land use conflicts to existing or planned uses in the proximity of the Refuge are not anticipated. Growth continues to move toward the Refuge boundaries from the south, which is increasing unauthorized off-road vehicle use on the Refuge and creates concerns regarding further unrestricted access to the Refuge from the southern boundary, as discussed under the Public Access section.

Alternatives C and D would result in the de-designation of Papoose Lake Research Natural Area (RNA). The impact of this action would be minimal because this RNA is inaccessible and has never been used for research, Under each alternative, the Service would continue to manage the 1.3 million acres of proposed wilderness to protect its wilderness values. The proposed wilderness status would remain unchanged until Congress acts on the proposal.

Under Alternatives B, C, and D, the Refuge would coordinate with local jurisdictions to ensure that development adjacent to the Refuge is compatible with refuge land uses. Given the potential growth that may occur adjacent to the Refuge in the future, this coordination may have a beneficial effect on land uses both on and adjacent to the Refuge by protecting resources on the Refuge and controlling access. Construction of boundary fences would provide some protection against residential or urban uses along the southern boundary.

Mitigation

Impacts related to land use would not be significant, so specific mitigation measures are not necessary.

Aesthetics

Impacts

New visitor facilities to accommodate increased visitor use under each of the alternatives would have a temporary impact during construction and a long-term impact on the natural features and vegetation around the affected area, depending upon the siting of the facilities and integration into the Refuge's natural setting. Because these facilities would be small (e.g., information kiosk, signs, trails), impacts to visual character would be minimal and would not adversely affect views of the Refuge.

Habitat protection activities under each alternative, such as litter removal and general control of public access, would benefit the visual character of the Refuge for visitors by creating a more natural, native setting on the Refuge.

As discussed in the visitor facilities EA (Service 2007), temporary construction activities would have a short-term adverse effect on the visual setting of Corn Creek Field Station. Long-term visual resources would be improved through habitat rehabilitation; however, the new visitor center would create a permanent change in the visual setting of Corn Creek. The building would blend into the surrounding environment through use of earthen materials for construction, and vegetation would be used to mask views from sensitive locations, such as cultural resource sites.

Mitigation

Impacts related to aesthetics would not be significant, so specific mitigation measures are not necessary.

5.3.6 Summary of Effects

Table 5.3-1 summarizes the potential effects for each of the four alternatives. Alternative A continues current management practices with little changes or improvements.

Compared with Alternative A, Alternative B would accommodate an increase in visitors and enhance visitor experience with some beneficial effects on wildlife habitat. Alternative B would, however, result in short-term, mitigable adverse impacts from restoration projects and facility and road construction.

Compared with Alternative B, Alternative C would provide greater biological benefits and fewer visitor benefits, but result in greater short-term mitigable adverse construction impacts.

Compared with Alternative C, Alternative D would provide greater biological benefits with fewer benefits to visitors, but result in greater short-term mitigable adverse construction impacts.

Impacts and mitigation measures of bighorn sheep management, visitor facility construction and improvement, and other actions noted throughout this section will be further analyzed and refined in project-specific NEPA documents to be prepared for each action. The Service will use the analysis presented in this EIS to focus on key issues that need to be further evaluated in second-tier NEPA documents.

Table 5.3-1. Desert NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Physical Environment				
Soil Conditions	EC[6]: Minimal temporary disturbance	ML: Some temporary disturbance during facility construction	ML: Temporary disturbance during facility construction and burns	ML: Temporary disturbance during facility construction and burns
Water Quality	EC: No effects	ML: Temporary downstream water quality impacts during construction	ML: Temporary downstream water quality impacts during construction and burns	ML: Temporary downstream water quality impacts during construction and burns
Air Quality	EC: Minor emissions and dust; smoke from wildfires	SL: Some emissions and dust from temporary construction activities and increased traffic; smoke from wildfires	ML: Some emissions and dust from temporary construction activities and increased traffic; increased smoke from burns	ML: Some emissions and dust from temporary construction activities and increased traffic; increased smoke from burns
Biological Resources				
Upland Habitat	EC: Minimal disturbance	SL: Some temporary disturbance from construction	SL: Some temporary disturbance from construction	SL: Some temporary disturbance from construction
Common Wildlife Species and Management Priority Birds	EC: Minimal disturbance	SL: Some temporary disturbance from construction	SL: Some temporary disturbance from construction	SL: Some temporary disturbance from construction
Desert Tortoise and Gila Monster	EC: Some protection and reduction of potential for take	SH: Improved protection over the long term but potential for temporary disturbance during actions in upland habitat	MH: Improved protection over the long term but potential for temporary disturbance during actions in upland habitat	MH: Improved protection over the long term but potential for temporary disturbance during actions in upland habitat
Pinyon Jay and Gray Vireo	EC: Minimal disturbance	SL: Some disturbance	SH: Temporary disturbance; some benefits from burns	SH: Temporary disturbance; some benefits from burns
Gilbert's Skink	EC: Minimal disturbance	SL: Some disturbance	SH: Temporary disturbance; some benefits from burns	SH: Temporary disturbance; some benefits from burns
Desert Bighorn Sheep	EC: Existing conditions	SH: Improved foraging habitat; increased subpopulations	MH: Improved foraging habitat; improved management; increased subpopulations	CH: Improved foraging habitat; improved management; increased subpopulations

[6] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

Table 5.3-1. Desert NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*	*Alternative D*
Cultural Resources				
Cultural Resources	EC: Some protection of resources; some impacts	SL: Increased protection of resources but potential for impacts during construction	SL: Increased protection of resources but potential for impacts during construction	SL: Increased protection of resources but potential for impacts during construction
Public Access				
Access	EC[7]: Generally unrestricted	SL: Some restrictions but roads and recreation facilities would improve access	ML: More restrictions but roads and recreation facilities would improve access	ML: More restrictions but roads and recreation facilities would improve access
Traffic	EC: Some traffic	SL: Increase in visitors would increase traffic on and to the Refuge	SL: Increase in visitors would increase traffic on and to the Refuge	SL: Increase in visitors would increase traffic on and to the Refuge
Recreation				
Visitor Use Facilities	EC: Some facilities available	MH: More facilities constructed	SH: More facilities constructed	SH: More facilities constructed
Recreational Opportunities	EC: Variety of opportunities available	MH: Improved opportunities and services over the long term; some temporary impacts	SH: Improved opportunities and services over the long term; some temporary impacts	SH: Improved opportunities and services over the long term; some temporary impacts
Outreach	EC: Limited outreach	SH: Increased outreach	SH: Increased outreach	SH: Increased outreach
Refuge Management and Local Economics				
Refuge Budget and Staffing	EC: Current budget and staffing	SH: Increased budget and staff to implement actions	MH: Increased budget and staff to implement actions	MH: Increased budget and staff to implement actions
Local Economy	EC: Current economy	SH: Increase in local economy from increased visitors	SH: Increase in local economy from increased visitors	SH: Increase in local economy from increased visitors
Land Use				
RNAs	EC: No management	MH: Improve RNA use	SH: Improve RNA use but de-designate one RNA	SH: Improve RNA use but de-designate one RNA
Aesthetics				
Visitor Use Facilities	EC: Current views	SL: Minor impacts on visual quality	SL: Minor impacts on visual quality	SL: Minor impacts on visual quality
Habitat Protection	EC: Minimal protection	SH: Increased protection	SH: Increased protection	SH: Increased protection

[7] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

5.4 Moapa Valley National Wildlife Refuge

This section describes the potential impacts associated with each of the action alternatives for the Moapa Valley NWR. Impacts are judged for significance using the thresholds described in the introduction of this chapter. Mitigation measures are included for resources with significant impacts.

Each of the action alternatives involves monitoring and inventory actions that would not result in adverse environmental impacts. These management actions would provide the Refuge staff with an improved knowledge of the Refuge, which would later allow them to better assess the effects of their actions. These actions are not further evaluated in this section.

5.4.1 Physical Environment

Soils

Impacts

Construction of visitor facilities (e.g., trails, parking areas, shade structures, restrooms) under Alternatives B and C would expose soils to erosion during construction and result in a minor loss of topsoil. These activities would disturb small amounts of soil, and impacts would be limited to the facility site. Erosion would be minimal in upland areas, but would be more noticeable along streams or in riparian areas. Most of the facilities would be constructed in upland areas, and the amount of disturbance would be small. For activities near streams and riparian areas, erosion impacts will be analyzed further in project-specific NEPA documents to be prepared for the facilities.

Habitat restoration activities would result in minor disturbance to topsoil on the Refuge. Most of the springheads, channels, and associated riparian habitat on the Refuge would be restored under Alternative C (approximately 10 acres in the Plummer, Pedersen, and Apcar Units), and about half that area would be restored under Alternative B (Plummer and Pedersen Units). Alternative A would continue restoration activities on the Plummer Unit (less than 3.5 acres). Removal of palm trees and other invasive plants could also require removal of the topsoil to remove the seedbank. Topsoil impacts would be most intense under Alternative C and less intense under Alternative B due to the size of the affected area. In addition, removal of vegetation along the streams during restoration activities under each alternative and prescribed burns under Alternatives B and C would temporarily expose the soils to wind and water erosion until native plants establish. Although small areas of the Refuge would be affected by restoration, soils would be exposed to erosion, and impacts could be significant. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities. The establishment of native vegetation would stabilize soils along the banks of surface waters, improving vegetative diversity and wildlife habitat.

Mitigation

Mitigation measures that could reduce soil impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Native vegetation would be planted in areas where non-native vegetation is removed and soils are exposed to improve soil conditions and stabilize soils. Appropriate BMPs would be implemented during restoration and construction activities to minimize indirect effects of soil disturbance, including dust, erosion, and sedimentation. These measures would include pre-watering and maintaining surface soils in stabilized conditions where support equipment and vehicles will operate; applying water or dust palliative during clearing and grubbing or earth-moving activity to keep soils moist throughout the process; watering disturbed soils immediately following clearing and grubbing activities; and stabilizing sloping surfaces using soil binders until vegetation or desert pavement (ground cover) can effectively stabilize the slope.

Water Resources

Impacts

Habitat restoration activities under each of the alternatives could increase turbidity in some or all of the streams on the Refuge and have a temporary adverse effect on surface water quality. Alternative A activities would be limited to surface water on the Plummer Unit and downstream, and Alternative B activities would be expanded to surface waters on the Plummer and Pedersen Units and downstream. Alternative C activities would encompass all streams on the Refuge and downstream of the Refuge. Turbidity of affected surface waters could increase as vegetation is removed along the streams, and soils are discharged into the water. Soils along the banks may also erode and reach surface waters prior to establishment of new vegetation. In addition, ash and other sediment could be discharged into surface waters during prescribed burns under Alternatives B and C. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities.

Establishment of native plants along the banks would benefit streams on the Refuge by stabilizing stream banks and reducing the quantity of water needed for plant growth. Native species that are adapted to the desert environment require less water than invasive plants, such as palm trees.

Mitigation

Mitigation measures that could reduce water quality impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Implementation of BMPs during ground-disturbing activities would reduce the effects of erosion, siltation, and sedimentation on water quality of the Refuge waters. These measures would include constructing small sediment collection pools downstream of work areas to trap sediment and reduce sediment movement through the aquatic system; using turbidity barriers in areas where sediment collection pools cannot be used; directing flows where feasible around the work area and temporarily detaining flows to reduce potential entrainment of sediment; and limiting the size of the area of disturbance where flows cannot be directed around the work area or detained, so that minimal sediment is added to stream flows.

Air Quality

Impacts

Habitat restoration activities under each of the alternatives would require the use of construction equipment to remove trees and plant new trees. Construction activities for visitor facilities under Alternatives B and C would also require construction equipment that would disturb the ground and clear vegetation. This equipment would cause short-term, minor emissions (engine exhaust and fugitive dust) that may be noticeable on the Refuge. In addition, smoke would be visible from prescribed burns under Alternatives B and C and could adversely affect air quality. Depending on the extent of activities, an increase in emissions and smoke could violate ambient air quality standards and could be significant. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities and facilities.

Increased traffic on the Refuge under Alternatives B and C would result in a minor increase in traffic-related emissions. These emissions would not result in violations of the ambient air quality standards because the amount of Refuge traffic at one time is expected to be small, and traffic would be limited to the main roads and parking areas. Therefore, traffic-related impacts to ambient air quality would not be significant.

Ground-disturbance, construction, and fire management (particularly fuels reduction) activities under any of the alternatives would result in direct emission of greenhouse gases (GHG) (temporary emissions) from construction equipment. Fire management would help prevent catastrophic wildfire over the long term and reduce long-term GHG emissions. Indirect, long-term emissions of GHG would occur due to increased visitation by the public and increased employee vehicle trips (as staff grows). An increase in GHG emissions would contribute to regional impacts on climate change and could result in significant impacts. Climate change impacts will be further analyzed in project-specific NEPA documents, as appropriate.

Mitigation

Mitigation measures that could reduce air quality impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

BMPs would be implemented during construction activities that disturb the soil to reduce particulate emissions. These measures would include the BMPs identified for mitigating soil and water resources impacts as well as the following: maintaining effective cover over stockpiled fill or debris materials; limiting vehicle speeds to 15 mph in staging areas and on all unpaved access routes; and cleaning mud, silt, and soil tracked out onto paved surfaces immediately. In addition, use of low or zero-emission construction vehicles and limiting idling time for construction vehicles could reduce GHG emissions during construction.

5.4.2 Biological Resources

Vegetation

Impacts

Construction of visitor use facilities under Alternatives B and C would result in a loss of some vegetation within the proposed footprint of the facilities and an increase in the potential for invasive plants. Most of the facilities would likely be constructed in previously disturbed areas along existing roads. These actions would require ground disturbance, which would create suitable conditions for the reestablishment of invasive plants; however, measures would be implemented to minimize invasive plant establishment. Impacts to vegetation would be less than significant because of the small amount of vegetation that would be affected. Sensitive plant species are not expected to be affected by these activities because none are known to occur on the Refuge.

As part of restoration under each alternative, invasive plants would be removed along streams, and native plants or seeds would be planted in their place. Temporary disturbance during restoration would create desirable conditions for invasive and non-native plants because these plants prefer disturbed, moist areas and often invade these areas immediately following ground disturbance activities. These species reduce the quality of native habitats and adversely affect native species by creating uniform stands that prevent other species from establishing. Under Alternative A, habitat in the Plummer Unit would be exposed to disturbance; under Alternative B, habitats in the Plummer and Pedersen Units would be exposed; and under Alternative C, habitats in all three Refuge units would be exposed. Implementation of an IPM Plan under the action alternatives would also reduce the potential for invasive plants to spread and become established in disturbed areas of the Refuge. Once the native species become established in the disturbed areas, the potential for invasive species would be lower. Temporary impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities.

Immediately following restoration activities, the riparian community would experience a temporary loss of overstory vegetation as palm trees and other invasive plants are removed. Restoration would occur in phases and would be limited to small portions of the Refuge at one time to maintain some habitat. Native plants would be planted in the disturbed areas to provide interim habitat for wildlife species until the entire community is restored. These plantings would also encourage native plant establishment by improving the soil conditions and ensuring the availability of water and nutrients for new plant growth.

Palm trees require more water and nutrients than native species, and they accumulate salt at their bases, which creates undesirable habitat conditions for native plants. Their removal would benefit native plants, as well as native fish and wildlife, by reducing unsuitable conditions and creating more desirable habitat conditions for the native species, which would increase native, desirable habitat over the long term. Temporary impacts associated with interim habitat loss will be analyzed further in project-specific NEPA documents to be prepared for restoration activities.

Habitat restoration and protection actions under each of the alternatives would benefit riparian habitat throughout the Refuge by restoring native vegetation and protecting sensitive areas. Habitat restoration actions would affect the smallest area (less than 3.5 acres) under Alternative A. Alternatives B and C would affect about 5 and 10 acres, respectively.

Fire management actions under each of the alternatives would benefit the habitats and infrastructure on the Refuge by reducing the risk of catastrophic fire, which could destroy habitats and adversely affect streams and wildlife. This risk would be lowest under Alternatives B and C, which involve the most fire management actions. These actions involve removal of palm trees and their fronds and thinning out of undergrowth.

<u>Mitigation</u>

Mitigation measures that could reduce vegetation (specifically sensitive plants) impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 7 consultation process, as appropriate.

Invasive plant removal efforts would be implemented on a regular basis to prevent invasive species from establishing in the future. These measures would be identified in an IPM Plan and may include spraying herbicides; laying topsoil with native seedbed; mechanical removal of young invasive plants; or controlled, prescribed burns in areas where invasive plants begin to grow. Because of the presence of invasive plant seeds in the topsoil, topsoil with a native seedbed could be used to replace the existing topsoil in the restored areas. This topsoil could be obtained from off-site areas where construction activities are proposed that would require removal of topsoil (e.g., detention basins, residential development). This effort would be coordinated with local agencies and/or the U.S. Bureau of Land Management (BLM).

Standard construction practices would be implemented to prevent invasive species from establishing in the disturbed areas around the facilities, such as cleaning vehicles and equipment used on the Refuge with high-pressure sprayers to dislodge seeds prior to accessing the area. Facilities would be designed to avoid sensitive habitats and impact the least amount of vegetation (based on pre-construction surveys and mapping).

Wildlife

Impacts

Individuals of some wildlife species may be adversely affected by restoration activities under each of the alternatives and by construction of visitor use facilities and prescribed burns under Alternatives B and C. Amphibians, reptiles, birds, mammals, and invertebrates that use the riparian community and the streams have the potential to be directly affected during vegetation removal activities. These species would be forced to temporarily relocate, likely to nearby suitable habitat, until new habitat establishes along the streams. Some species may return once suitable habitat becomes established in the restored areas, but palm tree–dependent species, such as the western yellow bat, may not return to restored areas of the Refuge under Alternative C due to removal of a large number of palm trees. These impacts will be analyzed further in project-specific NEPA documents to be prepared for restoration activities, facilities, and fire management.

Activities in upland habitats, such as visitor facility construction under Alternatives B and C, could temporarily disturb or harm individual desert tortoises or Gila monsters, if present. These activities would be adverse; however, the Service would implement measures to avoid direct impacts to these species. Protective measures such as habitat restoration, invasive plant management, and controlling public access under the action alternatives would benefit these species. These impacts and measures will be analyzed further in project-specific NEPA documents to be prepared for facilities.

For common wildlife species, the impact would not be significant because a minor portion of the population would be affected in comparison to the regional population. For sensitive species with low population densities in southern Nevada, such as Moapa dace, these impacts could be significant because the proportion of species affected on the Refuge compared to their regional populations would be higher.

Habitat restoration actions under each alternative would benefit most fish and wildlife species. Alternative A would provide minor benefits on a small portion of the Refuge, and Alternative B would provide moderate benefits. Alternative C would provide the most benefits because the largest amount of native habitat would be restored, and restoration would target a larger number of sensitive species (including fish and invertebrates). Establishment of riparian vegetation along the streams would provide suitable habitat for a variety of bird and mammal species, including resident and migratory birds, and could attract new species to the Refuge, such as the yellow-billed cuckoo and southwestern willow flycatcher. Several riparian-dependent bird species that are also conservation priorities within the Service, Nevada Department of Wildlife, and Partners in Flight, such as eared grebe, western grebe, snowy egret, and Arizona Bell's vireo, would likely experience an increase in suitable nesting sites and increase in abundance on and near the Refuge.

Native fish species would benefit from improved stream habitat, which could increase invertebrates and provide more suitable spawning habitat. Improved stream and riparian habitats may also benefit amphibians by increasing the amount of available habitat and providing suitable conditions for reproduction. Spring and channel restoration would also benefit eared grebe.

Although the southwestern willow flycatcher and yellow-billed cuckoo are not currently known to occur on the Refuge, improved habitat conditions may benefit these species by providing suitable habitat for breeding, foraging, or nesting because they have been detected in areas near the Refuge. Because the flycatcher is endangered, and the cuckoo is a candidate species for listing, the availability of suitable habitat on the Refuge could potentially aid in their recovery.

The western yellow bat, which is a palm-obligate species, would be adversely affected by the removal of palm trees on the Refuge. Individuals may be harmed during palm tree removal, and habitat on the Refuge would be decreased. Additional suitable habitat is available on lands adjacent to the Refuge and along the Muddy River corridor, so the species would likely be able to relocate. The population of the yellow bat on the Refuge would experience a decline as individuals are harmed or relocate to suitable habitat off the Refuge. These actions are not expected to significantly affect the yellow bat's regional population, although they would affect the local population on the Refuge. More of the local population would be affected under Alternatives B and C than Alternative A due to the amounts of riparian habitat restored. These impacts will be analyzed further in project-specific NEPA documents to be prepared for restoration activities.

The Moapa dace population on the Refuge would substantially benefit from improved riparian and stream habitat conditions and removal of non-native fish from the streams on the Refuge. These actions would improve the aquatic habitat and could potentially increase the reproductive success of the dace, as well as other native fish, on the Refuge. Alternative C actions would benefit this species the most.

In addition, expansion of the Refuge boundary under Alternative C would increase Service-managed habitat for wildlife species. Similar types of habitat present on the Refuge would be managed by the Service under step-down habitat management plans. Future management actions would likely benefit native plants and wildlife over the long term, with temporary adverse impacts from disturbance. Specifically, management priority bird species, such as eared grebe, western grebe, Franklin's gull, black tern, snowy egret, Bendire's thrasher, Arizona Bell's vireo, southwestern willow flycatcher, western yellow-billed cuckoo, and canvasback, would benefit from the Refuge expansion. Subsequent plans and actions would be evaluated in separate NEPA documents.

Mitigation

Mitigation measures that could reduce wildlife impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 7 consultation process, as appropriate.

Standard construction measures would be implemented to minimize impacts on native wildlife, such as avoiding unnecessary disturbance to habitats by driving on existing roads and working only in the required area, minimizing direct disturbance to streams and open water sources, and throwing away all trash and other construction debris in approved disposal areas. Construction activities and restoration would be implemented during the non-breeding/nesting season and outside of the spawning period for fish to the extent feasible. Disturbance during the breeding/nesting season would require pre-construction surveys to locate active nests and establish barriers around the nest site until a qualified biologist determines the nest site is abandoned. Activities in or near waterways should be avoided during the spawning period to minimize impacts on sensitive fish. The Service would also avoid discharging sediment during the spring spawning period for Moapa dace. Pre-construction surveys for sensitive reptiles and other species would be conducted prior to activities in uplands to avoid direct impacts to the species.

The following measures should be implemented to reduce adverse impacts on yellow bats: flush bats from palm trees prior to removal to minimize harm of individuals; replace removed palms with native vegetation known to be used by yellow bats (e.g., cottonwoods); minimize palm removal in areas where palms directly affect aquatic habitat quality and retain some higher-density palm habitat in less sensitive areas; and conduct thinning and removals during winter months (although yellow bats have been documented year-round in Nevada and do not hibernate, a major portion of the breeding population may migrate south during the winter). These measures, and additional measures identified in coordination with NDOW, should also be incorporated into restoration plans.

5.4.3 Cultural Resources

Impacts

Although no significant cultural resources have yet been identified on the Refuge, ground disturbance activities associated with habitat restoration have the potential to disturb unknown cultural artifacts and sites that may be buried. Impacts to cultural resources would be significant under the action alternatives if eligible sites or resources lose their integrity through destruction, damage, or removal. These impacts will be analyzed further in project-specific NEPA documents to be prepared for Refuge actions.

Because other aspects of the environment are important to tribes and can be considered cultural resources, adverse impacts to other resources could also be considered impacts to cultural resources. These impacts are not specifically discussed as cultural resource impacts; however, they may be of concern to culturally affiliated tribes if the resources are important to them. Examples include native plants that may be collected and used for various purposes, water resources, or geologic features.

Mitigation

Mitigation measures that could reduce cultural resource impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 106 consultation process, as appropriate.

Pre-construction archaeological surveys of the restoration areas would allow Refuge archaeologists to identify significant cultural resources and mitigate potential impacts. If cultural resources are inadvertently exposed during activities, activities would immediately cease and a qualified archaeologist would be consulted to implement appropriate measures for mitigation or preservation. As appropriate, monitoring would occur by a qualified archaeologist and tribal monitor.

5.4.4 Public Access and Recreation

Public Access

Impacts

Construction of visitor use facilities under Alternatives B and C would not likely affect public access on or to the Refuge. Those facilities would be constructed prior to opening the Refuge to the public in order to provide future visitors with information on the Refuge.

Public access on the Refuge would continue to be restricted under Alternative A, with the Refuge closed to the general public.

Opening the Refuge to the public on weekends and school groups during the week in Alternative B and on a daily basis in Alternative C would benefit public access to the Refuge. Proposed directional signs on Interstate 15 (I-15), U.S. Highway 93, and on Warm Springs Road under Alternatives B and C would also benefit public access by increasing awareness of the Refuge to travelers and providing improved directions for those visiting the Refuge.

Visitor service opportunities on the Refuge would improve under Alternatives B and C and would increase visitation to the Refuge, resulting in a minor increase in traffic on U.S. Highway 93 and State Route (SR) 168 and on the Refuge. Average daily traffic counts on SR 168, the primary major road to the Refuge, were 1,200 per day in 2004 (Nevada Department of Transportation [NDOT] 2004). An increase in traffic would be most noticeable on weekends during peak visitor use. The increase in visits would have a minor impact, due to the relatively low number of visits at one time and small amount of traffic currently using the access roads.

Mitigation

Impacts to public access would not be significant, so specific mitigation measures are not necessary.

Recreation

<u>Impacts</u>

Recreational activities would continue to be restricted under Alternative A, with the Refuge closed to the general public.

Construction of facilities and other actions to support recreational activities under Alternatives B and C would benefit recreational opportunities by providing interpretive and educational signs, brochures, a self-guided trail system, a basic trail, shade structures (Alternative C), restrooms (Alternative C), water lines (Alternative C), and parking areas. An increase in days and hours of operation would also benefit visitor services and recreational opportunities associated with the Refuge.

Public outreach and environmental education would continue to be very limited under Alternative A, with limited participation in community events and exhibits.

An increase in days and hours of operation under Alternatives B and C would allow the public to experience the Refuge and participate in environmental activities. Development of interpretive and educational materials, expanded emphasis on educational activities and outreach to local groups, and displays on and off the Refuge would occur under Alternatives B and C, resulting in expanded environmental education opportunities.

<u>Mitigation</u>

Impacts to recreation would not be significant, so specific mitigation measures are not necessary.

5.4.5 Social and Economic Conditions

Refuge Management and Local Economics

<u>Impacts</u>

Under Alternative A, the annual Refuge budget, which includes operations and capital projects, would be expected to remain comparable to past funding and staffing levels. There is currently no staff located at the Refuge, so the continued limited level of restoration and management activities would be available primarily through volunteer efforts.

Under Alternatives B and C, new facilities would be constructed, including trails and parking areas, possibly requiring use of private contractors, which would have a beneficial impact in terms of providing short-term jobs. Additional activities related to outreach and environmental education would require increased expenditures by the Refuge to meet those needs. These actions would require increases in the Refuge management and operations budget.

Alternatives B and C would also see expansion of public use, resulting in increased staffing at the Refuge to accommodate visitor needs due to the opening of the Refuge to the public. Additional staff and salaries

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would have a beneficial impact by adding employment and income to the local economy.

An increase in the number of visits to the Refuge would increase retail trade, lodging, and food service for the nearby local economy. Additional indirect employment as a result of the increased activity would also be expected.

Mitigation

Impacts to refuge management economics would not be significant, so specific mitigation measures are not necessary.

Environmental Justice

Impacts

There would be no adverse impacts to minority or low-income populations as a result of the continuing operations of the Refuge under Alternative A, as the Refuge would remain closed to the general public.

Increased educational and outreach activities under Alternatives B and C would provide benefits to school children and affiliated tribes, including minority and low-income populations in the surrounding Clark County area, such as Moapa and the Moapa River Reservation. Conferring with the Moapa Band of Paiutes to incorporate their history and native plant and animal species as part of the interpretive program in Alternative C would address several topics that would be of interest to the Native American population.

Development of a water resources management plan and expanded monitoring of water quality parameters in Alternatives B and C would provide a benefit to nearby communities and residents of Clark County, including the community of Moapa and the Moapa River Reservation that may be affected by water resources in the area.

Mitigation

Impacts related to environmental justice would not be significant, so specific mitigation measures are not necessary.

Land Use

Impacts

Alternatives A and B would not result in changes to land use on the Refuge. Alternative C would result in the expansion of the Refuge acquisition boundary to include an adjacent 1,765 acres. Specific management actions for this expansion area would be developed as part of a step-down habitat management plan, which would require subsequent NEPA compliance. This expansion would improve management of the habitats and land adjacent to the Refuge and would not have an adverse effect on land use.

Mitigation

Impacts related to land use would not be significant, so specific mitigation measures are not necessary.

Aesthetics

Impacts

Alternatives B and C include construction of visitor facilities that would have a minor impact on aesthetics for visitors to the Refuge. New parking lots, trails, and structures to accommodate increased visitor use would have a temporary impact on visual quality during construction and a potential long-term impact on the natural features and vegetation viewed from locations on the Refuge, depending upon the siting of the facilities and integration into the Refuge's natural setting. Temporary impacts would be minimal because the Refuge would not be open to the public during construction activities.

Habitat protection and restoration actions under Alternative A, such as removal of invasive plants, cutting of dead palm fronds, removal of palm trees from riparian areas, and general control of public access would continue to occur. Most of these activities would occur in the Plummer Unit and would benefit views from on and off the Refuge by enhancing the existing riparian community and restoring it to native conditions.

Alternatives B and C would continue the actions in Alternative A on the Pedersen and Apcar Units of the Refuge. Restoration of all of the riparian areas under Alternative C would create a more aesthetically pleasing and natural environment for Refuge visitors when walking along trails, and for the general public as they drive along the highway.

The proposed restoration activities, along with additional trails and visitor facilities, would enhance visitor views of the natural habitat and setting of the area, providing a beneficial effect.

Mitigation

Impacts related to aesthetics would not be significant, so specific mitigation measures are not necessary.

5.4.6 Summary of Effects

Table 5.4-1 summarizes the potential effects for each of the three alternatives. Alternative A continues current management practices with little changes or improvements. Alternative A restoration would disturb and restore less than 3.5 acres of habitats.

Compared with Alternative A, Alternative B would improve Refuge habitats to benefit native and sensitive fish and wildlife species, accommodate an increase in visitors, and enhance visitor experience. Alternative B restoration would disturb and restore approximately 5 acres of habitats. Alternative B would, however, result in short-term, mitigable adverse impacts from restoration projects and facility and road construction.

Compared with Alternative B, Alternative C would provide greater biological and visitor benefits, but result in greater short-term mitigable adverse construction impacts. Alternative C would disturb and restore approximately 10 acres of habitats and expand the Refuge boundary by approximately 1,500 acres to management and protect additional riparian, stream, spring, and associated habitats.

Impacts and mitigation measures of restoration actions, visitor facility construction, and other actions noted throughout this section will be further analyzed and refined in project-specific NEPA documents to be prepared for each action. The Service will use the analysis presented in this EIS to focus on key issues that need to be further evaluated in second-tier NEPA documents.

Table 5.4-1. Moapa Valley NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
Physical Environment			
Soil Conditions	EC[8]: Some temporary disturbance; improved conditions in some areas over the long term	SH: Minor temporary disturbance; improved conditions in portions of Refuge over the long term	MH: Minor temporary disturbance; improved conditions on Refuge over the long term
Water Quality	EC: Some temporary impacts; improved water quality in some areas over the long term	SH: Minor temporary impacts; improved water quality in portions of Refuge over the long term	MH: Minor temporary impacts; improved water quality on Refuge over the long term
Air Quality	EC: Minimal emissions	SL: Minor emissions from construction activities (temporary) and increased traffic; temporary smoke from burns	SL: Minor emissions from construction activities (temporary) and increased traffic; temporary smoke from burns
Biological Resources			
Riparian/Wetland Habitat	EC: Some improved habitat on Plummer Unit and decreased potential for fire, but increased potential for invasive plants to reestablish and temporary loss of riparian habitat; less than 3.5 acres restored	MH: Improved habitat on Plummer and Pedersen Units and decreased potential for fire, but increased potential for invasive plants to reestablish and temporary loss of riparian habitat; approximately 5 acres restored	CH: Improved habitat on Plummer, Apcar, and Pedersen Units and decreased potential for fire and decreased potential for invasive plants to reestablish, but temporary loss of riparian habitat; approximately 10 acres restored
Upland Habitat	EC: Minimal disturbance	SL: Some disturbance during construction activities	SL: Some disturbance during construction activities
Desert Tortoise and Gila Monster	EC: Minimal protect or disturbance	SH: Improved protection; temporary disturbance	SH: Improved protection; temporary disturbance
Riparian Community Wildlife	EC: Some improved habitat conditions but temporary loss of riparian habitat and potential for adverse impacts during restoration activities	MH: Improved habitat conditions but temporary loss of riparian habitat and potential for adverse impacts during restoration activities	CH: Improved habitat conditions but temporary loss of riparian habitat and potential for adverse impacts during restoration activities
Southwestern Willow Flycatcher and Yellow-billed Cuckoo	EC: Some available habitat on Refuge	SH: Increased availability of habitat on Refuge	MH: Increased availability of habitat on Refuge
Management Priority Birds	EC: Some native habitat on Refuge	MH: Increased native habitat on Refuge	CH: Increased native habitat on Refuge
Western Yellow Bat	EC: Minor loss of palm tree habitat on Refuge	SL: Loss of palm tree habitat on refuge	ML: Loss of palm tree habitat on refuge
Native Aquatic Species	EC: Some improved habitat on refuge	MH: Improved habitat on Refuge	CH: Improved habitat on Refuge
Moapa Dace	EC: Some improved habitat and potentially improved reproductive success; minor temporary disturbance	MH: Improved habitat and potentially improved reproductive success; some temporary disturbance	CH: Improved habitat and potentially improved reproductive success; some temporary disturbance

[8] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

Table 5.4-1. Moapa Valley NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C (Preferred Alternative)*
Cultural Resources			
Cultural Resources	EC[9]: Minimal impacts	SL: Potential for impacts during construction and restoration activities	SL: Potential for impacts during construction and restoration activities
Public Access			
Access	EC: Minimal access for volunteers	SH: Increased access	MH: Increased access
Traffic	EC: Minimal traffic	SL: Increase in visitors would increase traffic on and to the Refuge	SL: Increase in visitors would increase traffic on and to the Refuge
Recreation			
Visitor Use Facilities	EC: Minimal facilities available	SH: More facilities constructed	SH: More facilities constructed
Recreational Opportunities	EC: Minimal opportunities	SH: Improved recreation	SH: Improved recreation
Outreach	EC: Limited efforts	SH: Increased outreach	SH: Increased outreach
Refuge Management and Local Economics			
Refuge Budget and Staffing	EC: Current budget and staffing	SH: Increased budget and staff to implement actions	SH: Increased budget and staff to implement actions
Local Economy	EC: Current economy	SH: Increase in local economy from increased visitors	SH: Increase in local economy from increased visitors
Aesthetics			
Restoration Activities	EC: Some improvements to visual quality from restoration activities	MH: Improved visual quality from restoration activities	CH: Improved visual quality from restoration activities
Visitor Use Facilities	EC: Minimal facilities	SL: Minor decreased visual quality from visitor use facilities	SL: Minor decreased visual quality from visitor use facilities

[9] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

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5.5 Pahranagat National Wildlife Refuge

This section describes the potential impacts associated with each of the action alternatives for the Pahranagat NWR. Impacts are judged for significance using the thresholds described in the introduction of this chapter. Mitigation measures are included for resources with significant impacts.

Each of the action alternatives involves monitoring and inventory actions that would not result in adverse environmental impacts. These management actions would provide the Refuge staff with an improved knowledge of the Refuge, which would later allow them to better assess the effects of their actions. These actions are not further evaluated in this section.

None of the action alternatives would involve changes to land use; this topic is not further discussed in this section.

5.5.1 Physical Environment

Soils

Impacts

Alternative A would involve some soil disturbance. No new facilities would be constructed, but restoration activities could disturb soils around open water areas. These efforts would involve primarily removing and controlling invasive and non-native plants, but may also include modifications to hydrology. Invasive plant control would involve prescribed burns in wet meadow and seasonal marsh habitats that would temporarily expose soils to erosion until vegetation is reestablished. Prescribed fire in wet meadow and chemical and mechanical clearing of plants would also be implemented under each of the action alternatives. These impacts would be minimal because of the small areas affected, and the Service would implement measures to minimize soil erosion.

Construction of visitor use facilities under each of the action alternatives would result in temporary soil disturbance, increased potential for erosion, and minor loss of topsoil. Installation of gauges and data-logging equipment in or near springs under Alternatives C and D would also increase the potential for erosion near affected open water sources. These impacts would not be significant where minor amounts of soil are disturbed and topsoil loss is minimal. Impacts will be analyzed further in project-specific NEPA documents to be prepared for the facilities.

Restoration activities around springs under each of the action alternatives would disturb soils and expose them to wind and water erosion until native vegetation is restored. Temporary soil disturbance could be significant, depending on the project-specific details of the restoration; therefore, impacts will be analyzed further in a project-specific NEPA document to be prepared for the restoration activities. Establishment of native vegetation and restoration of the areas would provide long-term protection against erosion. Removal of salt cedar and planting native vegetation would improve soil conditions by stabilizing soils and reducing salt and mineral concentrations.

Mitigation

Mitigation measures that could reduce soil impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Visitor facilities would be sited in previously disturbed areas to the extent feasible. Appropriate BMPs would be implemented during restoration and construction activities to minimize indirect effects of soil disturbance, including dust, erosion, and sedimentation. These measures would include pre-watering and maintaining surface soils in stabilized conditions where support equipment and vehicles will operate; applying water or dust palliative during clearing and grubbing or earth-moving activity to keep soils moist throughout the process; watering disturbed soils immediately following clearing and grubbing activities; and stabilizing sloping surfaces using soil binders until vegetation or desert pavement (ground cover) can effectively stabilize the slope.

Water Resources

Impacts

Vegetation clearing in ditches on the Refuge under each alternative would improve surface flow through the Refuge, but temporary disturbance could affect water quality. Construction of visitor facilities under Alternatives B, C, and D and installation of water monitoring equipment under Alternatives C and D could increase sedimentation in the open water areas and streams on the Refuge and adversely affect water quality. This impact would not be significant because a small amount of soil would be disturbed, and most construction activities would occur in previously disturbed areas away from the reservoirs and streams. Water quality would not substantially change as a result of the minor increase in sedimentation.

Restoration activities around springs and along channels under each alternative could adversely affect surface water quality. Erosion along the banks would increase sedimentation in the surface water. These impacts could be significant, depending on the project-specific details of the restoration; therefore, impacts will be analyzed further in a project-specific NEPA document to be prepared for the restoration activities.

Chemical methods to control invasive plants could affect surface water quality in the reservoirs and streams on the Refuge. Herbicides reaching surface water would increase pollutant concentrations in the water. This impact would not be significant because water levels would be reduced during treatment to reduce the possibility of herbicide concentrations reaching water systems; in addition, other management methods would be used near open water areas, such as burning or mechanical removal.

Hydrology on the Refuge would be modified under each alternative to improve habitat conditions throughout the Refuge. More open water habitat may be created, and hydrology of some springs would be returned to historic conditions. To supplement existing flows from Upper Pahranagat Lake, groundwater wells on the Refuge would be pumped to increase flows to Middle Marsh. Under Alternative D, more water may be provided to the Refuge (pending acquisition of additional water rights). This would expand the amount of open water and help recreate historic hydrologic conditions. These actions would increase surface water quantities on the Refuge.

The quantity of pumped groundwater would be dependent on the needs for the habitats and the seasons. More water would likely be pumped in the summer to account for the smaller quantity of available surface water. Groundwater recharge during summer months is likely to be minimal due to consumptive use by vegetation and high evaporation rates. During this time, pumping could cause the groundwater table to lower. Impacts to the groundwater table will be analyzed further in a project-specific NEPA document to be prepared for the water management actions.

Alternative D would also include pursuit of additional water rights to allow for increased water use on the Refuge, as well as pursuit of the 1996 application for year-round discharges, which would occur under each alternative. Changes to allocated water rights are controversial, so Service staff would need to coordinate with the upstream communities to acquire additional water rights. Acquisition of additional surface water rights could reduce the need to pump groundwater and minimize effects on the groundwater aquifer. Impacts of obtaining additional water rights are unknown because a specific water rights action has not been proposed. These impacts will be analyzed further in a project-specific NEPA document to be prepared for the water rights action.

New visitor use facilities under Alternatives B, C, and D would increase the water demand from the domestic well on the Refuge. However, additional groundwater pumping is not expected to adversely affect nearby private wells. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the facilities.

Mitigation

Mitigation measures that could reduce water quality impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Implementation of BMPs during ground-disturbing activities would reduce the effects of erosion, siltation, and sedimentation on water quality of the Refuge waters. These measures would include constructing small sediment collection pools downstream of work areas to trap sediment and reduce sediment movement through the aquatic system; using turbidity barriers in areas where sediment collection pools cannot be used; directing flows where feasible around the work area and temporarily detaining flows to reduce potential entrainment of sediment; and limiting the size of the area of disturbance where flows cannot be directed around the work area or detained so that minimal sediment is added to stream flows.

Service staff would monitor and analyze spring discharge and groundwater levels on the Refuge and evaluate impacts, if any, of groundwater pumping within and outside the Refuge. If impacts are discovered, mitigation may include pumping groundwater during non-summer months and increasing surface storage or setting a maximum limit for groundwater pumped per day.

Air Quality

Impacts

Habitat restoration activities under each alternative would require the use of construction equipment to remove vegetation and plant new vegetation. Construction of visitor facilities under the action alternatives would also require construction equipment that would disturb the ground and clear vegetation. This equipment would cause short-term, minor emissions (engine exhaust and fugitive dust) that may be noticeable on the Refuge. Depending on the extent of activities, an increase in emissions could violate ambient air quality standards and could be significant. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities and facility construction and improvement.

Prescribed burns under each alternative would adversely affect air quality on the Refuge. Although the burns would generate smoke, which may be noticeable off the Refuge, impacts would not be significant because the burns would be temporary and would not violate ambient air quality standards.

Increased traffic on the Refuge would result in a minor increase in traffic-related emissions. These emissions would not result in violations of the ambient air quality standards because the amount of Refuge traffic at one time is expected to be small, and traffic would be limited to the main roads and parking areas. Therefore, traffic-related impacts to ambient air quality would not be significant.

Ground-disturbance, construction, and fire management (particularly fuels reduction) activities under any of the alternatives would result in direct emission of greenhouse gases (GHG) (temporary emissions) from construction equipment. Fire management would help prevent catastrophic wildfire over the long term and reduce long-term GHG emissions. Indirect, long-term emissions of GHG would occur due to increased visitation by the public and increased employee vehicle trips (as staff grows). An increase in GHG emissions would contribute to regional impacts on climate change and could result in significant impacts. Climate change impacts will be further analyzed in project-specific NEPA documents, as appropriate.

Mitigation

Mitigation measures that could reduce air quality impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

BMPs would be implemented during construction activities that disturb the soil to reduce particulate emissions. These measures would include the BMPs identified for mitigating soil and water resources impacts as well as the following: maintaining effective cover over stockpiled fill or debris materials; limiting vehicle speeds to 15 mph in staging areas and on all unpaved access routes; and cleaning mud, silt, and soil tracked out onto paved surfaces immediately. In addition, use of low or zero-emission construction vehicles and limiting idling time for construction vehicles could reduce GHG emissions during construction.

5.5.2 Biological Resources

Vegetation

Impacts

Construction of visitor use facilities under Alternatives B, C, and D would result in minor losses of vegetation within the footprints of the facilities and an increased potential for invasive species. This impact would not be significant due to the small amount of vegetation that would be affected because facilities would be constructed, for the most part, in previously disturbed areas. Sensitive plants are not expected to be affected by construction activities because none are known to occur on the Refuge.

Each alternative would involve enhancing, restoring, or increasing wetland and riparian habitats on the Refuge. Under all alternatives, the Service would continue using prescribed burns in wet meadow and seasonal marsh habitats to reduce decedent vegetation and improve habitat conditions for wildlife. A habitat restoration and management plan would be completed and implemented that considers a variety of different tools to improve conditions for all habitats on the Refuge. Non-native vegetation (i.e., salt cedar and Russian olive) would be replaced with native species (i.e., cottonwood and willow), and disturbed areas would be restored with native vegetation. These activities would result in a temporary disturbance during restoration as vegetation is removed and new vegetation is planted. Temporary impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities. Long-term changes to the habitats would benefit native vegetation on the Refuge by providing a means for native plants to establish.

Invasive plants occur in riparian, wet meadow, and grassland habitats on the Refuge. These species outcompete native plants and create uniform stands that prevent establishment of native species. They also provide less desirable habitat for native wildlife. Under all the alternatives, the Service would continue implementing measures (mechanical, chemical, or biological) to control invasive plant species. Under Alternatives B, C, and D, an Integrated Pest Management Plan and associated NEPA document would be prepared and implemented. This document would evaluate a variety of approaches for improving invasive species management practices on the Refuge.

Desert upland habitat is currently being adversely affected by illegal off-road uses. Despite prohibitions on off-road vehicles, these impacts would likely continue under Alternative A. The potential for impacts to desert upland habitat would be reduced under Alternatives B, C, and D through installation of barriers around closed areas and roads and additionally under Alternative D with construction of a fence along the eastern boundary.

Mitigation

Mitigation measures that could reduce vegetation (specifically sensitive plants) impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 7 consultation process, as appropriate.

Standard construction practices would be implemented to prevent invasive species from establishing in the disturbed areas around the facilities, such as cleaning vehicles and equipment used on the Refuge with high-pressure sprayers to dislodge seeds prior to accessing the area. Facilities would be designed to avoid sensitive habitats and affect the least amount of vegetation (based on prior surveys and mapping).

Wildlife

Impacts

Individuals of some wildlife species may be adversely affected by construction of visitor use facilities and other structures under Alternatives B, C, and D. Amphibians, reptiles, birds (migrant and resident), mammals, fish, and invertebrates that use the affected habitats have the potential to be directly affected during vegetation removal activities and installation of equipment in surface waters. These species would be forced to relocate to less disturbed areas of the Refuge or in nearby suitable habitats. Adverse impacts to wildlife species would be localized and dependent on the specific activity. For more common wildlife, impacts would be less than significant because of the localized nature of the disturbance and minimal effects to their populations. Impacts to sensitive wildlife will be analyzed further in project-specific NEPA documents to be prepared for the facilities and restoration activities.

Desert tortoise, a threatened species, may be disturbed or injured during facility construction or modification in desert scrub habitats under Alternatives B, C, and D. These actions could adversely affect the regional tortoise population depending on the amount of habitat affected and extent of impacts. The Service would implement specific conservation measures as part of each action to minimize impacts on desert tortoise. Because of potential impacts to the tortoise, the facilities will be analyzed further in a project-specific NEPA document and Section 7 consultation.

The desert tortoise is currently being adversely affected by illegal off-road activities throughout the area. Implementation of habitat protection efforts (e.g., fencing closed areas and restricting access) would reduce the potential for this impact under Alternatives B, C, and D.

Construction of a refugium for the endangered Pahranagat roundtail chub under Alternative B, C, and D would benefit the species by providing a safe haven for reproduction and could aid in its recovery. Construction activities would result in minor disturbance to other wildlife on the Refuge due to the localized nature of the impact and minimal amount of habitat likely affected. These impacts will be analyzed further in a project-specific NEPA document to be prepared for the refugium. A refugium may also benefit waterfowl and migratory birds by creating diverse wetland habitat.

Improvements to wetland habitats (marsh, open water, wet meadow, and alkali flat) under each alternative would benefit a variety of bird and mammal species and the few amphibians that occur on the Refuge. Specifically, eared grebe, western grebe, Franklin's gull, black tern, snowy egret, marbled godwit, snowy plover, long-billed curlew, white-throated swift, southwestern willow flycatcher, and canvasback would benefit from wetland restoration and enhancement. These species would also be temporarily affected by disturbance during the restoration activities. These impacts would force the species to temporarily relocate away from the disturbance. Impacts will be analyzed further in project-specific NEPA documents to be prepared for the restoration activities.

Wetland species would experience improved nesting, foraging, and breeding habitat, which could potentially increase their populations on the Refuge. Expansion of open water habitat may attract more waterfowl and migratory birds to the Refuge, such as the bald eagle, during the migrating periods. Species that would benefit from these actions include Canada geese, mallards, gadwalls, pintails, greater sandhill cranes, shorebirds, green-wing teal, redheads, and particularly black-necked stilts.

Enhancement and expansion of riparian habitat under the alternatives would benefit the endangered southwestern willow flycatcher and could aid in its recovery. Many other migrant and resident birds that are conservation priorities within the Service, NDOW, and Partners in Flight would also benefit from increased acreage of native riparian habitat. These species include eared grebe, western grebe, snowy egret, pinyon jay, Arizona Bell's vireo, and western yellow-billed cuckoo.

Mitigation

Mitigation measures that could reduce wildlife impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section 7 consultation process, as appropriate.

The Service would survey upland habitats for desert tortoise prior to construction activities and implement measures to avoid impacts on the species. Tortoise fencing and relocation of individuals would reduce impacts. Habitat restoration activities and facility improvements or construction would occur outside of the breeding and nesting period for resident and migratory birds to the extent feasible.

5.5.3 Cultural Resources

Impacts

Under each alternative, cultural resources may be adversely affected by ground disturbance activities associated with construction and modification of visitor use facilities and habitat restoration activities. Due to the presence of important cultural resources on the Refuge, such as at Black Canyon, impacts have the potential to be significant if known or unknown resources are destroyed or damaged. These impacts will be analyzed further in project-specific NEPA documents to be prepared for the activities.

Cultural resources are currently being adversely affected by vandalism and degradation. Alternative A would not involve actions that would reduce these impacts, and eligible cultural resource sites could be damaged, destroyed, or otherwise significantly affected. Alternatives B, C, and D involve constructing fencing, signs, and other barriers and educating the public, which would provide some protection for cultural resources and minimize vandalism. Indirect adverse impacts related to increased visitor use may include disturbance and destruction of sites and removal of artifacts. Impacts to cultural resources would still have the potential to be significant under the action alternatives if eligible sites lose their integrity through destruction, damage, or removal. These impacts will be analyzed further in project-specific NEPA documents to be prepared for Refuge actions.

Because other aspects of the environment are important to tribes and can be considered cultural resources, adverse impacts to other resources could also be considered impacts to cultural resources. These impacts are not specifically discussed as cultural resource impacts; however, they may be of concern to culturally affiliated tribes if the resources are important to them. Examples include native plants that may be collected and used for various purposes, water resources, or geologic features.

Mitigation

Mitigation measures that could reduce cultural resource impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities and through the Section106 consultation process, as appropriate.

In order to prevent adverse impacts on cultural resources during restoration and construction activities, professional archaeologists would archaeologically survey the Refuge for cultural resources and record the information and locations prior to project implementation. Staff would use their knowledge of site locations to design facilities to avoid eligible resources. All ground disturbance activities would be monitored by an archaeologist and a tribal monitor in areas where known cultural resources are located and in areas with high potential for buried cultural deposits. If cultural resources are inadvertently exposed during activities, activities would immediately cease and a qualified archaeologist would be consulted to implement appropriate measures for mitigation or preservation. If eligible sites or portions thereof cannot be protected and would be adversely affected, other mitigation or data recovery methods would be conducted in consultation with the Nevada State Historic Preservation Office.

5.5.4 Public Access and Recreation

Public Access

Impacts

Construction activities and habitat restoration would result in incidental traffic over a short-term period in the immediate vicinity of the Refuge and temporary restrictions on access to the affected areas. Some congestion on roadways and longer stop times at intersections would be expected during the construction period. Impacts to public access during restoration and construction could be significant depending on the locations and extent of activities implemented at one time. With the small number of visitors on the Refuge at one time, most activities would have minimal effects on traffic. Project-specific NEPA documents will include further analysis of public access impacts of Refuge actions.

No adverse impacts to public access would occur under Alternative A, as no changes would occur from current operations on the Refuge. The Refuge is currently open to the public year-round with three main unpaved access roads from U.S. Highway 93. The main road to the Refuge headquarters connects to Alamo Road, which continues onto the Desert NWR. Public access is available to Lower Lake and Middle Marsh, as well as North Marsh and Upper Pahranagat Lake.

Proposed directional signs on I-15 and U.S. Highway 93 under Alternatives C and D would benefit public access by increasing awareness of the Refuge to travelers and providing improved directions for those visiting the Refuge.

Visitor services would be improved under Alternatives B, C, and D and could result in an increase in visitation, resulting in increased traffic on U.S. Highway 93. Average daily traffic counts on U.S. Highway 93 near the Refuge were 1,600 per day in 2004 (NDOT 2004). An increase in traffic would be most noticeable on weekends during peak visitor use. Improvements to visitor facilities under each action alternative would alleviate impacts by providing the necessary facilities to accommodate an increase in use; however, traffic along the adjacent highway would be expected to increase as a result of increased visitors.

Visitors attempting to access the Refuge from northbound U.S. Highway 93 would have to yield to oncoming traffic to turn left across the highway. The highway is currently a two-lane road without a left-turn lane. The increased traffic under each action alternative could create traffic safety issues and longer stop times when yielding to traffic. Turning lanes may be needed during peak visitor periods. Under Alternatives C and D, the Service would coordinate with the NDOT to construct turn lanes along the highway to allow visitors to safely turn onto the Refuge. These turning lanes could reduce traffic impacts from increased visitation. Traffic impacts will be analyzed further in project-specific NEPA documents to be prepared for Refuge actions.

Some maintenance roads would be closed to the public, as necessary, in Alternatives B, C, and D, and some historic ranch roads may be converted to trails. Barriers would be installed to prevent vehicle traffic in closed areas. These actions would reduce public access to some areas of the Refuge, but they would have a beneficial effect by protecting resources and preserving natural conditions on the Refuge.

Mitigation

Mitigation measures that could reduce public access impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Refuge staff would schedule construction and restoration for slower times of visitation during the week and slower seasons, when feasible, to minimize the impacts of construction traffic on public access. Signs and information would be provided to inform visitors of construction activities and areas that are temporarily off-limits to the public.

Recreation

Impacts

Under Alternative A, current recreational activities would continue. Recreation opportunities on the Refuge currently include fishing, hunting, and wildlife observation at Upper Pahranagat Lake and Middle Marsh, camping at Upper Pahranagat Lake, and hiking on nature trails throughout the Refuge.

Alternatives B, C, and D would generally increase and improve recreational opportunities on the Refuge. Wildlife observation and photography activities would be enhanced with construction of an expanded trail system and observation blinds under each of the action alternatives. Hunting opportunities would continue under all alternatives. Campground use would be modified under Alternatives C and D to be a day use area only, and boat use would be restricted to car top boats (no trailer accessible boat launches) under Alternative D to reduce concerns with introduced quagga mussels.

Outreach and environmental education would continue under Alternative A. The administrative building currently serves as the Refuge administrative office and visitor contact station, with brochures, maps, and fact sheets. An outside contact station with information kiosks is located at the north end of the Refuge in the camping area. The Refuge has an active volunteer program, staff-conducted and non–staff-conducted tours, and off-site exhibits.

The visitor contact station would be expanded in Alternatives B, and a new visitor contact station would be constructed in Alternatives C and D. Each of the action alternatives would also expand educational and interpretive activities on the Refuge and outreach efforts off the Refuge. The improvements and expansions would benefit environmental education opportunities on the Refuge.

Mitigation

Impacts to recreation would not be significant, so specific mitigation measures are not necessary.

5.5.5 Social and Economic Conditions

Refuge Management and Local Economics

Impacts

Under Alternative A, the annual Refuge budget and staffing, which includes operations, capital projects, two full-time staff, and one part-time seasonal employee, would remain comparable to current limited funding and staffing levels. Restoration activities, management efforts, recreation opportunities, and visitor services would continue to be implemented as staffing and funding are available.

Alternatives B, C, and D would improve and expand habitats and water resources management activities, as well as visitor services and environmental education. New trails, wildlife observation blinds, a visitor contact station, and a refugium would be constructed, as well as other physical improvements, possibly requiring use of private contractors, which would have some beneficial impact in terms of providing short-term jobs. Additional activities related to outreach and environmental education would require increased expenditures to meet those needs. These actions would require increases in the Refuge management and operations budget.

Increased staffing at the Refuge under Alternatives B, C, and D would be needed in order to accommodate expanded visitor needs and management actions. Additional staff and salaries would have a beneficial impact on the area in by adding employment and income to the local economy.

An increase in the number of visitors to the Refuge would increase retail trade, lodging, and food service for the nearby local economy. Additional indirect employment as a result of the increased activity would also be expected.

Mitigation

Impacts to refuge management economics would not be significant, so specific mitigation measures are not necessary.

Environmental Justice

Impacts

There would be no adverse impacts to minority or low-income populations as a result of the continuing operations of the Refuge under Alternative A.

Increased educational, interpretive, and outreach activities under Alternatives B, C, and D would provide benefits to minority and low-income populations in southern Lincoln County and the nearby communities, such as Alamo, that are served by off-site Refuge educational exhibits.

Development of cultural resources interpretive and environmental education materials in coordination with affiliated Native American tribes under Alternatives B, C, and D would address topics that would be of interest to the Native American population.

Mitigation

Impacts to environmental justice would not be significant, so specific mitigation measures are not necessary.

Aesthetics

Impacts

Habitat protection and restoration actions under Alternative A, such as limited control of invasive plants and general control of public access, would continue to occur. These activities would benefit views for visitors using the trails and wildlife observation/photo blinds by creating a more natural, native setting on the Refuge.

Alternatives B, C, and D would expand the actions in Alternative A. Construction of new parking areas and trails under the action alternatives would have a short-term adverse impact on visitor views during construction. Views from areas designated for wildlife observation locations along the highway could be affected, but these impacts are not considered significant due to their short duration. New facilities may also have a potential long-term visual impact on the natural features and vegetation currently on the Refuge, depending upon the siting of the facilities and integration into the Refuge's natural setting. These impacts could be significant, depending on the project-specific details of the facilities, and will be analyzed further in project-specific NEPA documents to be prepared for the facilities.

Restoration activities in each alternative would provide improved habitat that would enhance views from on and off the Refuge. These restoration activities, along with additional observation blinds and trails under the action alternatives, would enhance the visitor views of the natural habitat and setting of the area.

Mitigation

Mitigation measures that could reduce aesthetics impacts include the measures discussed below. These measures will be refined in project-specific NEPA documents to apply specifically to the proposed activities.

Visual impacts during construction of facilities and other physical improvements would be temporary and addressed through screening and ongoing construction site maintenance and cleanup during construction. Refuge staff would schedule construction for slower times during the week and slower seasons, when feasible, to minimize these impacts. Impacts of the facilities on the long-term visual quality for the Refuge would be addressed through site-sensitive design standards and ensuring compatibility with the Refuge environment.

5.5.6 Summary of Effects

Table 5.5-1 summarizes the potential effects for each of the four alternatives. Alternative A continues current management practices with little changes or improvements. Alternative A includes maintaining 100 acres of cottonwood-willow habitat.

Compared with Alternative A, Alternative B would improve Refuge habitats to benefit native and sensitive plant and wildlife species, particularly waterfowl, accommodate an increase in visitors, and enhance visitor experience. Alternative B includes maintaining and enhancing 100 acres of cottonwood-willow habitat. Alternative B would, however, result in short-term, mitigable adverse impacts from restoration projects and facility and road construction.

Compared with Alternative B, Alternative C would provide greater biological and visitor benefits, but result in greater short-term mitigable adverse construction impacts.

Compared with Alternative C, Alternative D would provide greater biological and visitor benefits, but result in greater short-term mitigable adverse construction impacts.

Impacts and mitigation measures of restoration actions, visitor facility construction and improvement, and other actions noted throughout this section will be further analyzed and refined in project-specific NEPA documents to be prepared for each action. The Service will use the analysis presented in this EIS to focus on key issues that need to be further evaluated in second-tier NEPA documents.

Table 5.5-1. Pahranagat NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Physical Environment				
Soil Conditions	EC[10]: Some temporary disturbance	SL: Increased temporary disturbance	ML: Increased temporary disturbance	ML: Increased temporary disturbance
Surface Water	EC: Some open water	SH: Increased open water over the long term	SH: Increased open water over the long term	MH: Increased open water over the long term; restored historic channel
Groundwater	EC: Current conditions	SL: Increased pumping for habitats and visitor use over the long term	SL: Increased pumping for habitats and visitor use over the long term	SL: Increased pumping for habitats and visitor use over the long term
Water Quality	EC: Some temporary impacts	SL: Increased temporary impacts	ML: Increased temporary impacts	ML: Increased temporary impacts
Water Rights	EC: Current conditions	EC: Current conditions	EC: Current conditions	SH: Increased water rights
Air Quality	EC: Minor emissions and dust from restoration; temporary smoke from burns	SL: Minor emissions from construction activities (temporary) and increased traffic; emissions and dust from restoration; temporary smoke from burns	SL: Minor emissions from construction activities (temporary) and increased traffic; emissions and dust from restoration; temporary smoke from burns	SL: Minor emissions from construction activities (temporary) and increased traffic; emissions and dust from restoration; temporary smoke from burns
Biological Resources				
Open Water/Marsh Habitat	EC: Some open water	SH: Improved habitat over the long term; more open water	SH: Improved habitat over the long term; more open water	MH: Improved habitat over the long term; more open water; restored historic channel
Spring Habitat	EC: Some improved habitat	SH: Improved habitat over the long term	SH: Improved habitat over the long term	SH: Improved habitat over the long term
Cottonwood-Willow Habitat	EC: 100 acres	SH: 100 acres; improved conditions over the long term		
Upland Habitat	EC: Current conditions	SH: Increased protection; temporary disturbance	SH: Increased protection; temporary disturbance	SH: Increased protection; temporary disturbance
Invasive Plants	EC: Some invasive plant removal efforts	SH: Increased invasive plant removal efforts	MH: Increased invasive plant removal efforts	MH: Increased invasive plant removal efforts

[10] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

Table 5.5-1. Pahranagat NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Biological Resources, continued				
Common Wildlife Species	EC[11]: Temporary disturbance from restoration; some improved habitat over the long term	SH: Temporary disturbance; improved habitat over the long term	MH: Temporary disturbance; improved habitat over the long term	MH: Temporary disturbance; improved habitat over the long term
Management Priority Birds	EC: Temporary disturbance from restoration; some improved habitat over the long term	SH: Temporary disturbance; improved habitat over the long term	MH: Temporary disturbance; improved habitat over the long term	MH: Temporary disturbance; improved habitat over the long term
Waterfowl	EC: No management	SH: Increased foraging habitat over the long term	MH: Improved and increased foraging habitat over the long term	CH: Improved and increased foraging habitat over the long term
Southwestern Willow Flycatcher	EC: Current conditions	SH: Temporary disturbance; improved and increased habitat over the long term	MH: Temporary disturbance; improved and increased habitat over the long term	MH: Temporary disturbance; improved and increased habitat over the long term
Desert Tortoise	EC: Current conditions	SH: Temporary disturbance; improved protection over the long term	SH: Temporary disturbance; improved protection over the long term	SH: Temporary disturbance; improved protection over the long term
Pahranagat Roundtail Chub	EC: Not present	SH: Refugium would establish population	SH: Refugium would establish population	SH: Refugium would establish population
Cultural Resources				
Cultural Resources	EC: Some protection of resources; potential for impacts during restoration	SL: Potential for impacts during ground disturbance; increased protection	SL: Potential for impacts during ground disturbance; increased protection	SL: Potential for impacts during ground disturbance; increased protection
Public Access				
Access	EC: Current conditions	SH: Improved access	MH: Improved access	MH: Improved access
Traffic	EC: Current conditions	ML: Increased traffic on and to the Refuge	SL: Increased traffic on and to the Refuge; improved safety on highway	SL: Increased traffic on and to the Refuge; improved safety on highway

[11] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

Table 5.5-1. Pahranagat NWR: Summary of Environmental Consequences

Resource Issue or Concern	*Alternative A (No Action)*	*Alternative B*	*Alternative C*	*Alternative D (Preferred Alternative)*
Recreation				
Visitor Use Facilities	EC: Current conditions	SH: More facilities constructed	SH: More facilities constructed	SH: More facilities constructed
Recreation	EC[12]: Current opportunities	SH: Improved opportunities	SH: Improved opportunities	SH: Improved opportunities
Outreach	EC: Limited outreach	SH: Increased outreach	SH: Increased outreach	SH: Increased outreach
Refuge Management and Local Economics				
Refuge Budget and Staffing	EC: Current budget and staffing	SH: Increased budget and staff to implement actions	MH: Increased budget and staff to implement actions	MH: Increased budget and staff to implement actions
Local Economy	EC: Current economy	SH: Increase in local economy from increased visitors	SH: Increase in local economy from increased visitors	SH: Increase in local economy from increased visitors
Aesthetics				
Restoration Activities	EC: Current conditions	SH: Improved visual quality from restoration activities	MH: Improved visual quality from restoration activities	MH: Improved visual quality from restoration activities
Visitor Use Facilities	EC: Current views	SL: Minor impacts on visual quality	SL: Minor impacts on visual quality	SL: Minor impacts on visual quality

[12] EC = existing conditions; SH = slightly higher or improved than existing conditions; MH=moderately higher or improved than existing conditions; CH=considerably higher or improved than existing conditions; SL=slightly lower or decreased than existing conditions; ML=moderately lower or decreased than existing conditions; CL=considerably lower than existing conditions.

5.6 Unavoidable Adverse Impacts

The Proposed Action would not result in direct or indirect, unavoidable adverse effects on the physical, biological, cultural, or social and economic environments. During implementation of the Proposed Action, the Service would implement measures to avoid or reduce incremental adverse impacts on the various resources at the refuges.

5.7 Irreversible and Irretrievable Commitments of Resources

Neither the Proposed Action nor other alternatives would result in an irreversible or irretrievable commitment of resources. Management actions involving construction of facilities or modification of habitats will implement appropriate measures to preserve or relocate sensitive species and avoid cultural resources.

5.8 Short-Term Uses versus Long-Term Productivity

Implementation of the Proposed Action would result in short-term resource uses that enhance long-term productivity of the refuges. Habitat restoration and management actions that are part of each of the alternatives would benefit fish and wildlife, particularly sensitive and endemic species, over the long term. Public use of the refuges would improve over the long term as new opportunities become available and new facilities are constructed.

5.9 Cumulative Impacts

A cumulative impact is the incremental impact of a Proposed Action when added to other past, present, and reasonably foreseeable future federal and non-federal actions. Cumulative impacts can result from individually minor but collectively significant actions occurring over a period of time (40 CFR 1508.7). Impacts of past and present related actions are included in the affected environment descriptions of this EIS. Therefore, this section focuses on the impacts of the Proposed Action when added to other reasonably foreseeable future actions.

5.9.1 Approach to Cumulative Impacts

Implementation of the preferred alternative for each refuge in the Desert Complex would result in cumulative effects on physical, biological, cultural, and social resources in the Desert Complex and in southern Nevada. This section discusses both the cumulative effects of increased management of the four refuges in the Desert Complex and the cumulative effects of other reasonably foreseeable future projects in southern Nevada.

The following reasonably foreseeable future projects are evaluated in the cumulative impact analysis.

Sheep Mountain Parkway

The Nevada Department of Transportation (NDOT) and FHWA, in cooperation with the City of Las Vegas and the Regional Transportation Commission of Southern Nevada (RTC), are initiating an EIS for a proposed multimodal transportation project in Clark County, Nevada. The proposed action is to identify an alignment, develop a facility type, and preserve a right-of-way corridor for the Sheep Mountain Parkway in and near northern portions of the cities of Las Vegas and North Las Vegas.

The purpose of the proposed project is to provide multimodal transportation facilities to accommodate travel demand resulting from existing and planned development in the northern Las Vegas Valley. The proposed project would provide a link between the Clark County 215 beltway, U.S. 95, and I-15 (approximately 22 miles). The project would also connect to planned regional fixed guideway transit corridors on Rancho Road and North 5th Street.

Coyote Springs 42,800-acre Development (first phases)

The Coyote Springs project, in its entirety, contains approximately 42,800 acres located about 50 miles north of Las Vegas. It is bordered by the Delamar Mountains to the north, the Meadow Valley Mountains to the east, SR 168 to the south, and U.S. Highway 93 to the west.

The Coyote Springs development includes lands in Clark County (approximately 13,100 acres) and Lincoln County. The development would include a series of villages featuring a mix of uses with a range of unit types, lot sizes, and densities, and amenities including golf courses, clubhouse facilities, parks, and open space network linking different areas of the community. The master plan for the development encourages the effective use of natural topography, open space, and other natural and existing features and has a set of design guidelines intended to act as a guide for construction and development of the planning areas as a whole.

The development of the community is projected to be over a 40-year cycle. The developer envisions maintaining the rural character of the site by developing a series of villages with varying densities surrounded by open space and recreational opportunities. The latter phases focus on creating a self-reliant planned community with a full array of facilities and amenities.

Clark, Lincoln, and White Pine Counties Groundwater Development Project

The SNWA plans to convey approximately 170,000 acre-feet per year of groundwater from five hydrographic basins in eastern Nevada. In August 2004, SNWA applied to the BLM for right-of-way (ROW) to construct and operate groundwater production, conveyance, and treatment facilities, and power conveyance facilities. The BLM is currently conducting environmental analysis for the requested ROW.

The water right permitting process is separate from the ROW process. SNWA has groundwater rights and applications in hydrographic basins in Clark, Lincoln, and White Pine Counties. In April 2007, the Nevada State Engineer approved a major portion of the groundwater rights applications, enabling development of 60,000 acre-feet of groundwater from the basin annually. In addition, In July 2008, The

Nevada State Engineer granted SNWA 18,755 acre-feet of groundwater annually from Delmar, Dry Lake, and Cave Valleys.

The water conveyance for this project will be used to serve SNWA purveyor members in the Las Vegas Valley and customers of the Lincoln County Water District in Coyote Sprine Valley. It is currently anticipated that the project would not begin construction before 2010, and would not be completed until approximately 2019.

City of North Las Vegas Comprehensive Master Plan

The City of North Las Vegas completed a Draft Comprehensive Master Plan in September 2006 to update the 1999 master plan. The City encompasses an area of 82 square miles just south of the Desert NWR. The plan will provide the City with guidance for implementation of the plan over the next 20 years.

BLM Land Disposal in Clark County

The Las Vegas Valley disposal boundary was created by the 1998 Southern Nevada Public Land Management Act and modified by the 2002 Clark County Conservation of Public Land and Natural Resources Act. The BLM has identified available lands in the Las Vegas Valley that are appropriate for auction and prepared an EIS to assess the potential environmental impacts resulting from the sale of these lands. The land disposal area consists of all lands currently identified for disposal within the Las Vegas Valley, including the Las Vegas Valley disposal area, the Valley West Disposal area, and other legislatively authorized disposal areas. These lands are being transferred to the highest bidder through multiple auctions, and the lands will become available for development or other uses.

Nevada Test and Training Range Ongoing Actions

Approximately 846,000 acres of the Desert NWR are managed by the Department of Defense (DOD) and Department of Energy (DOE) as an aerial bombing and gunnery range (known as the NTTR). The NTTR overlay has been used since 1940 for testing armament and for training pilots in aerial warfare. Public Law 106–65 authorizes the U.S. Air Force (USAF) to use the NTTR (A) as an armament and high-hazard testing area; (B) for training for aerial gunnery, rocketry, electronic warfare, and tactical maneuvering and air support; (C) for equipment and tactics development and testing; and (D) for other defense-related purposes consistent with the purposes specified above. Use of this area is subject to the terms of a Memorandum of Understanding (MOU) between the Secretary of the Interior and the Secretary of the USAF.

In addition to ongoing actions, future actions may include more targets, increased sorties, more noise and sonic booms, and other improvements to the NTTR (USAF 2007a).

West-wide Energy Corridor

On August 8, 2005, the President signed into law the Energy Policy Act of 2005 (EPAct) (Public Law 109-58). In Section 368 of EPAct, Congress directed the Secretaries of Agriculture, Commerce, Defense, Energy, and the Interior to designate, under their respective authorities, corridors for oil, gas, and hydrogen pipelines and electricity transmission and distribution facilities on federal land in the 11 contiguous western states; perform any environmental reviews that may be required to complete the designation of such corridors; incorporate the designated corridors into the relevant agency land use and resource management plans; ensure that additional corridors for oil, gas, and hydrogen pipelines and electricity transmission and distribution facilities on federal land are promptly identified and designated as necessary; and expedite applications to construct or modify oil, gas, and hydrogen pipelines and electricity transmission and distribution facilities within such corridors. Congress further directed the Secretaries to take into account the need for upgraded and new electricity transmission and distribution facilities to improve reliability, relieve congestion, and enhance the capability of the national grid to deliver electricity. Finally, Congress specified that Section 368 corridors should specify the centerline, width, and compatible uses of the corridors.

A programmatic environmental impact statement (PEIS) that evaluates issues associated with the designation of energy corridors on federal lands in 11 western states was prepared by the involved agencies in accordance with the National Environmental Policy Act of 1969 (NEPA). The Department of Energy (DOE) and the BLM for the DOI were the lead agencies in preparation of this PEIS. The Department of Agriculture (USDA), Forest Service (FS); Department of Defense (DOD); and the Service were the cooperating federal agencies in preparation of the PEIS. The BLM and FS have issued Records of Decision which amended existing land use plans to designate the corridors. DOD will also be amending land use plans to designate corridors. However, due to the unique law, regulations, and policies that apply to the National Wildlife Refuge System, the Service will not amend land use plans to designate corridors. Future project proponents will need to comply with existing laws, policies, and regulations for ROW permits across Service-managed lands.

Other Development, Management Plans, and Recreational Facilities in Southern Nevada

Southern Nevada contains several growing communities, including Las Vegas, Pahrump, and Mesquite. Within each community, various development projects are ongoing to provide more housing and commercial opportunities for existing and new residents. The various public land management agencies in southern Nevada (National Park Service, BLM, USFS, and others) are continually managing their lands and identifying strategies to improve habitat and provide recreational opportunities. Local agencies, such as Clark County and the Cities of North Las Vegas and Las Vegas, are also expanding recreational opportunities in their communities. The Clark County Wetlands Park, for example, is undergoing improvements to provide more trails for public use.

5.9.2 Potential Cumulative Impacts

Physical Resources

Cumulative Impacts of Each Refuge's Actions

As described above, the preferred alternative for each refuge involves ground-disturbing activities that would have temporary effects on soils, water quality, and air quality. Because these impacts would be localized, they would not create cumulatively significant impacts on the Desert Complex.

Similarly, hydrology modifications on each refuge would also not contribute to cumulatively significant impacts because of the distances between each refuge and lack of surface water connectivity between the refuges.

Cumulative Impacts of Desert Complex Actions and Other Future Actions

Actions within the NTTR overlay in combination with other ground-disturbing activities on the Desert NWR could result in a temporary increase in soil erosion and air pollutant emissions, and adverse impacts on water quality. These impacts would be localized, but could result in cumulatively significant impacts if the actions are implemented at the same time. The Service would implement mitigation measures to reduce the impacts of each action.

Development, including construction activities and increased traffic, human activities, and related effects of development, as well as other projects involving ground disturbance or increased operations in the vicinity of each refuge, would add to the cumulative effects on soil disturbances, hydrology modifications, water quality impacts, increased air pollutants, and increased GHG emissions. Major developments, such as at Coyote Springs and in North Las Vegas, would create cumulatively significant impacts because of the large amount of affected land. The combination of all activities could contribute to climate change from increases in GHG emissions throughout southern Nevada.

Groundwater resources in the vicinity of each refuge could be adversely affected by increased groundwater use by new and expanding urban developments that use groundwater wells for water supply. Cumulative impacts on the groundwater aquifer could include increased drawdown of the groundwater aquifer, which could adversely affect vegetation or wildlife on the refuges and reduce the availability of groundwater resources for refuge use. This would be a significant cumulative groundwater impact.

Biological Resources

Cumulative Impacts of Each Refuge's Actions

As described above, the preferred alternative for each refuge involves ground-disturbing activities that would result in a loss of vegetation, potential impacts to sensitive plants on some refuges, and increased potential for invasive plants. Restoration activities proposed on each refuge would improve various habitats on the refuges and reduce the extent of invasive plants.

Habitat impacts would not be cumulatively significant because of the minimal amount of affected vegetation and the greater amount of habitat that would be restored at each refuge. Short-term impacts to sensitive plants would not be cumulatively significant because none of the sensitive plants are located on more than one refuge. Invasive plant removal and control efforts would be implemented on each refuge to help reduce the regional extent of invasive plant populations.

Cumulative Impacts of Desert Complex Actions and Other Future Actions

Actions within the NTTR overlay in combination with other ground-disturbing activities on the Desert NWR could result in minor losses of wildlife habitat. The Service would implement mitigation measures to reduce the impacts of each action. Restoration activities on the Desert NWR would result in cumulatively beneficial effects on habitat.

Development and other activities in the vicinity of each refuge would add to the cumulative effects on habitat, sensitive plant, and invasive plant impacts. Major developments, such as at Coyote Springs and in North Las Vegas, would create cumulatively significant impacts because of the large amount of affected land. Sensitive plant populations in affected areas could be at risk if measures are not implemented to protect or restore them on a regional basis.

Cultural Resources

Cumulative Impacts of Each Refuge's Actions

As described above, the preferred alternative for each refuge involves ground-disturbing activities that could result in adverse impacts on known and unknown cultural resources at each refuge. Increased visitation at each refuge also increases the potential for theft, vandalism, and other adverse impacts on the resources. These impacts would be cumulatively significant because the cultural resources in the Desert Complex provide important information on the history and prehistory of southern Nevada. Each activity would include measures to identify and avoid important resources, especially eligible resources, and protect known resources from adverse visitor impacts.

Cumulative Impacts of Desert Complex Actions and Other Future Actions

Actions within the NTTR overlay in combination with other ground-disturbing activities on the Desert NWR could result in adverse impacts to known and unknown cultural resources on the Refuge. Cumulative impacts to cultural resources could result from individually minor, but collectively significant, actions taking place over a period of time. Cumulative effects often occur to eligible districts where several minor changes to contributing properties, their landscaping, or to the setting over time could result in a significant loss of integrity. These impacts would be cumulatively significant because the resources on the Refuge may contribute to the history and prehistory of the area and provide important information on past uses. Mitigation measures would be implemented for each action to identify, avoid, or reduce impacts on important resources.

Development in the vicinity of each refuge would add to the cumulative effects on cultural resources and could result in adverse impacts to resources that provide important information on the history and prehistory of southern Nevada. Increased residential development in rural areas also increases the potential for adverse impacts on resources from vandalism and theft. Cultural resources could be destroyed if measures are not implemented as part of each action to protect them.

Social Values

Cumulative Impacts of Each Refuge's Actions

As described above, the preferred alternative for each refuge involves actions to improve recreational opportunities on each refuge and expand visitor services. Access to some refuges would be more controlled in order to protect resources, but improvements would be made to enhance visitor experience and provide more recreational opportunities. Temporary adverse impacts on aesthetics would occur on each refuge during ground-disturbing activities. Long-term changes in visual quality would occur as a result of new visitor facilities; however, these facilities would improve visitor experience and attract more visitors to the refuges. Local and refuge management economics would be improved through an increase in visitors and increased actions on each refuge. Cumulative impacts of each refuge's actions would be beneficial to the Desert Complex.

Cumulative Impacts of Desert Complex Actions and Other Future Actions

Development in the vicinity of each refuge would add to the cumulative effects on social values in southern Nevada. Access to recreational opportunities would be improved as new opportunities are provided on public lands and in new developments. Local and regional economics would be improved through new development and increased visitors to southern Nevada.

SE ROA 13056

Chapter 6. Compliance, Consultation, and Coordination with Others

Wildflowers on Gass Peak at Desert National Wildlife Refuge

SE ROA 13058

Chapter 6. Compliance, Consultation, and Coordination with Others

This chapter describes the efforts taken to ensure compliance with applicable laws, regulations, and federal guidance and to consult and coordinate with appropriate entities throughout the Comprehensive Conservation Plan (CCP) development process.

6.1 Compliance

The Environmental Impact Statement (EIS) is being prepared in accordance with the National Environmental Policy Act of 1969 (NEPA) (42 United States Code [USC] 4321 et seq.) and Council on Environmental Quality (CEQ) Regulations Implementing the Procedural Provisions of NEPA (40 Code of Federal Regulations [CFR] 1500–1508). The EIS scoping process was developed in accordance with the CEQ guidance for scoping under NEPA. Implementation of a CCP for the four refuges in the Desert National Wildlife Refuge Complex (Desert Complex) will require the U.S. Fish and Wildlife Service (Service) to comply with a variety of laws, Executive Orders (EOs), regulations, and other guidance pertinent to federal actions. A list of applicable regulations is provided in Appendix E.

6.2 Required Permits or Approvals

Prior to implementation of the various management actions, the Service may be required to obtain local, state, or federal permits or approvals. Typical permits or approvals that may be required include:

- Service—Ecological Services – Project level internal Section 7 consultations, as appropriate under the authorities of the Endangered Species Act (ESA), prior to the implementation of any actions that may affect federally listed endangered or threatened species.
- U.S. Army Corps of Engineers – Clean Water Act Section 404 Permits for wetland restoration projects or other actions that could discharge dredged or fill material into waters of the U.S.
- Nevada State Historic Preservation Office – Section 106 consultations under the authorities of the National Historic Preservation Act for any actions that may affect historic properties or cultural resources associated with listed properties (or those eligible for listing) on the National Register of Historic Places.
- Nevada Division of Environmental Protection – Construction Stormwater Permit for construction activities disturbing more than 1 acre; Section 401 Water Quality Certification or Waiver for projects requiring a Section 404 permit; and Air Quality Permits for various project types that result in emissions.

- Nevada Department of Transportation – Encroachment Permit for activities within state or U.S. highway rights-of-way; Sign Permit for directional signs within state or U.S. highway rights-of-way.
- State of Nevada – Air Quality Permits for ground-disturbance; Burn Permits for prescribed burns; Scientific Collection/Possession/Banding of Wildlife Permit; Conditional Permit for Disturbance or Destruction of Critically Endangered Species.
- Clark, Lincoln, and Nye Counties – Encroachment Permits for projects that encroach on county rights-of-way; Grading Permits for grading activities for facility construction.
- Clark County Department of Air Quality and Environmental Management – Dust Control Permits for construction activities in Clark County.

6.3 Consultation and Coordination with Others

6.3.1 Public Outreach

Federal Register Notices

The Service published a Notice of Intent (NOI) to prepare an EIS for the Desert Complex in the Federal Register on August 21, 2002. The NOI stated that the CCP/EIS process would help to identify potential issues, management actions, and concerns; significant problems or impacts; and opportunities to resolve them. The NOI also provided dates, times, and locations for the public scoping meetings. In addition, a public notice was published in the *Las Vegas Review Journal* on September 15, 2002, to announce the public scoping meetings and the initiation of the planning process for development of a CCP and preparation of an EIS for the Desert Complex.

Planning Updates

Planning updates were published to provide an update to the public on the status of the CCP process. Updates were made available to download from the Desert Complex Web site at http://www.fws.gov/desertcomplex/ccp.htm. The updates were published when certain milestones were achieved during the process.

The first planning update was made available in fall of 2002 to provide the public with background information on the refuges and CCP process and invite them to attend the public scoping meetings. It was mailed to 350 public citizens on September 3 and 4, 2002. The second planning update was made available in winter 2003 and provided a summary of the results of the public scoping meetings and a list of refuge activities occurring in 2003. This update was mailed out to interested members of the public in late February 2003. The third planning update was published in January 2007 to provide an update on the process and announce the preparation of a separate Environmental Assessment for the Desert National Wildlife Refuge (NWR) visitor center. A planning update will also be distributed prior to release of the public Draft EIS/CCP to inform the public of the anticipated release date and upcoming public meetings.

Public Scoping Meetings

Throughout the planning process, the public was invited to attend meetings, open houses, and workshops. The Draft EIS will be available to the public for a specified length of time (between 45 and 90 days) to allow interested individuals to comment on the document.

Prior to preparation of the EIS and CCP, a 60-day public comment period was initiated beginning August 21 and ending October 19, 2002, to identify issues important to the public. A news release was issued on September 4, 2002, to provide the public with information on the CCP. On September 15, 2002, a public notice was printed in the *Las Vegas Review Journal* with information on the dates and locations of the public scoping meetings. These meetings allowed the Service to provide the public with information on the CCP process and the refuges and allowed the public to provide input on the process and important resources or issues that should be addressed in the EIS. Five public meetings were held in 2002 in southern Nevada to solicit input from the public:

- September 16, 2002, 7–9 p.m., Moapa Community Center, Moapa Valley, Nevada
- September 17, 2002, 7–9 p.m., U.S. Fish and Wildlife Service Office, Las Vegas, Nevada
- September 18, 2002, 4–6 p.m. Amargosa Valley Multi-Purpose Building, Amargosa Valley, Nevada
- September 18, 2002, 7–9 p.m., Bob Ruud Community Center, Pahrump, Nevada
- September 19, 2002, 7–9 p.m., Alamo Annex Building, Alamo, Nevada

The public scoping meetings started with a presentation by the Service and their consultant. The presentation discussed the Service's role in the planning process, provided a description of the Desert Complex, and explained the CCP/EIS process. An open forum followed the presentation, allowing the public to ask questions and voice comments and concerns. Public comment forms were made available, and the public was urged to complete them and return them to the Service. Attendance at the five scoping meetings included members from the public and local, state, and federal agencies.

More than 400 comments were solicited from 53 members of the public during the public meetings. All attendees were asked to sign in upon entering the meeting and were provided a packet of information that included an agenda, information on each refuge, and a blank comment sheet for written comments. A public scoping report was prepared following the meetings to describe the methodology used to solicit and analyze input and to provide a summary of the results of the meetings. This report is available on the Desert Complex Web site at http://www.fws.gov/desertcomplex/ccp.htm.

6.3.2 Agency Coordination

The Service coordinated with several agencies to receive input on important resources that would need to be analyzed in the EIS. Two letters were mailed to federal, state, and local agencies having responsibility for, or special interest in, refuge resources and/or land use management strategies. The first letter was a notice of the Service's intention to prepare the CCP/EIS. The second letter was an invitation to the interagency scoping meeting, which was held on August 28, 2002, at the Service office in Las Vegas, Nevada. The interagency scoping meeting identified issues for each refuge as well as issues that encompass all four refuges. An additional meeting was held with staff members of the Nevada Department of Wildlife (NDOW) on September 23, 2002, at their headquarters in Reno, Nevada. The purpose of this meeting was to discuss coordination during the planning process and other topics relative to the Service's CCP efforts in Nevada.

An Interdisciplinary Team was formed among the lead and cooperating agencies, the project proponents, and the EIS preparers. The team met periodically to discuss the EIS, review interim work products, and provide guidance and direction for preparing the EIS. The team was formed with individuals from the following entities:

- U.S. Fish and Wildlife Service
- U.S. Air Force, Nellis Air Force Base
- Nevada Department of Wildlife, Las Vegas, Nevada

Members of the extended planning team, which provided input on the scope of the EIS and issues to be addressed, met periodically throughout the process. The planning team includes individuals from the following entities:

- U.S. National Park Service, Death Valley National Park
- U.S. National Park Service, Lake Mead National Recreation Area
- U.S. Bureau of Land Management, Region Three, Las Vegas, Nevada
- U.S. Department of Energy, Las Vegas, Nevada
- U.S. Forest Service, Spring Mountains National Recreation Area
- U.S. Department of Transportation, Federal Highway Administration, Central Federal Lands Division
- Nevada Division of Forestry, Las Vegas, Nevada
- Nevada State Historic Preservation Office
- Clark County Desert Conservation Program
- Clark County Federal Lands Program
- Lincoln County Commission
- Nye County
- Southern Nevada Water Authority
- City of Las Vegas
- City of North Las Vegas

6.3.3 Tribal Consultation/Coordination

Under the auspices of various federal laws and other legislation, the Service, as with all other federal agencies, is mandated to consult with affiliated Native American tribes to assure that Native American tribal governments and organizations whose interests might be affected have a sufficient opportunity for productive participation in planning and resource management decision-making. The development of the Desert Complex CCP and EIS provides an excellent opportunity for the Service to promote cooperation and participation by their Native American neighbors and thus strengthen their government-to-government relationships with the affiliated tribes.

A Native American Tribal Consultation Plan was developed in August 2000 to identify strategies that would allow more in-depth opportunities for participation of interested affiliated tribes in the planning process and during the reviewing and commenting periods for the CCP and EIS. The goals of the Native American Tribal Consultation Plan are to:

- Inform and educate interested affiliated Native American tribes about the CCP and the EIS process by providing clear, easily understood, factual information;
- Invite as many interested affiliated tribes as possible to participate in both the comprehensive conversation planning and environmental review processes;
- Provide meaningful and timely opportunities for tribal input;
- Identify key resource and land use issues relative to each refuge;
- Identify and eliminate from detailed study the cultural issues that are not significant;
- Consider and evaluate issues raised by interested affiliated tribes to assist in the preparation of the CCP;
- Consider tribal comments throughout the decision-making and review process; and
- Strengthen the government-to-government relationships between the Service and the affiliated tribes.

Tribal contact during the planning process has included the mailing of an initial consultation letter on June 26, 2002, which briefly discussed the Desert Complex CCP and EIS and invited the affiliated tribes to participate in the development process. This letter was mailed out to the Las Vegas Paiute Tribe, Pahrump Band of Paiutes, Big Pine Band of Owens Valley Paiute-Shoshone Indians, Bishop Paiute Tribe, Yomba Shoshone Tribe, Kaibab Paiute Tribe, Fort Mojave Tribe, Colorado River Indian Tribes, Timbisha Shoshone Tribe, Paiute-Shoshone Indians of the Lone Pine Community, Las Vegas Indian Center, Duckwater Shoshone-Paiute Tribe, Benton Paiute Indian Tribe, Chemehuevi Indian Tribe, Ely Shoshone Tribe, Moapa Paiute Tribe, Paiute Indian Tribes of Utah, and the Fort Independence Indian Community. Follow-up telephone calls were also made to all of the tribal representatives.

Following the consultation letter of June 26, 2002, the Service scheduled two public information/scoping meetings: one between November and December 2002 and the other between February and March 2003. Invitations were mailed out in September for the first public scoping meeting. The tribal governments responded by requesting separate meetings outside of the scheduled general public scoping meetings. The first of these meetings was held on January 29 and 30, 2003. The primary purpose of the first Native American Tribal Scoping Meeting, as well as individual presentations at tribal council meetings, was to 1) inform the affiliated tribes about the CCP/EIS process, 2) present options to the affiliated tribes regarding opportunities for participating in the process, and 3) scope out issues relative to refuge management actions and cultural resources protection and interpretation. The meetings also included a field trip to Corn Creek Field Station, where the inventory and testing work at Corn Creek was discussed.

A second tribal consultation meeting was held on May 8, 2003, as part of the annual Consolidated Group of Tribes and Organizations (CGTO) meeting sponsored by Nellis Air Force Base and Nevada Test and Training Range (NTTR). The primary purpose of the second meeting was to inform the affiliated tribes about the progress of the CCP/EIS process and other cultural resource conservation efforts and to encourage comments from tribal participants on the Draft CCP/EIS document. Another meeting was held June 22 and 23, 2006, to update the CGTO on the progress of the EIS/CCP and obtain input and recommendations on Service projects and planning efforts.

Affiliated tribes were also invited to participate at the biological and visitor services reviews. During the week of April 14–18, 2003, a biological review for Desert NWR and Ash Meadows NWR was held. The biological review for Moapa Valley NWR and Pahranagat NWR was held on May 27 and 28, 2003. A visitor services review was held on May 27 and 28, 2003. Various affiliated tribes participated in the reviews.

From July 15–17, 2003, Scott Aiken, the former regional Native American tribal liaison, met individually with various affiliated tribes. During the meetings, Mr. Aiken spoke with tribe members about the role of Native Americans in the review and editing of the Draft CCP/EIS cultural resources sections.

The CGTO's Document Review Committee participated in reviews of the Desert Complex's Cultural Resources Overview and Administrative Draft CCP/EIS. Comments received during these reviews have been addressed in the Draft CCP/EIS, as appropriate.

6.4 Comment/Response Process on Draft CCP/EIS

A Notice of Availability (NOA) was published in the Federal Register to initiate the public comment and review period for the Draft CCP/EIS. Planning Update No. 5 was mailed to those identified on the general mailing list and also posted to the project website. The planning update included notice of public meetings to be held during the week of August 4, 2008. The comment period was open from July 11 to September 9, 2008 (see Appendix D). The purpose of the public comment meetings was to solicit feedback on the Proposed Action, alternatives analysis, and issues addressed in the Draft CCP/EIS. In addition to comments received at the public meetings, we received 40 letters and/or comment forms. The comments and our responses are located in Appendix M.

6.5 Future Coordination with Others

As part of implementation of the CCP, the Service will coordinate closely with other agencies, affiliated tribes, and other entities to help manage the refuges. For example, the Service will work with affiliated tribes to develop strategies or actions to protect, recover, or monitor cultural resources and wildlife, as appropriate. For projects involving wildlife, the Service will work with NDOW to use their knowledge of the resources in southern Nevada, such as bighorn sheep and fish. Per the Memorandum of Understanding with the U.S. Air Force (USAF) for the Desert NWR, the Service will coordinate with the USAF regarding any management activities in the portion of the Refuge within the NTTR. In addition, because the Pahranagat NWR is under the Military Operations Area where military aircraft fly down to 100 feet above ground, the Service will coordinate with the USAF on projects that could increase bird populations higher than 100 feet above ground.