Case No. 84739

IN THE SUPREME COURT OF THE STATE OF NEVADA

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Elizabeth A. Brown
Clerk of Supreme Court

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

Appellants,

vs.

LINCOLN COUNTY WATER DISTRICT, et al.

JOINT APPENDIX

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Appendix A

Status of SNWA Data Collection Activities

A.1.0 STATUS OF SNWA DATA COLLECTION ACTIVITIES

In support of the Project, SNWA has been conducting various field activities to collect hydrologic, geologic, and water-chemistry data. Of particular interest to this report are the data obtained from drilling and aquifer testing for SNWA monitor and test wells and ongoing ET studies. These data collection activities are discussed within this section.

A.1.1 SNWA Monitor and Test Wells

Wells provide invaluable data in regard to regional and local hydrogeologic conditions. Numerous wells exist within the study area; however, most are completed within the basin-fill aquifer. SNWA has performed multiple drilling programs within the project basins (Figure A-1) with well completions in the basin-fill, carbonate and volcanic aquifers. In 2005, a monitor well program consisting of 10 monitor wells was conducted within Delamar (HA 182), Dry Lake (HA 181), Cave (HA 180), Pahranagat (HA 209), and Tikaboo North (HA 169A) valleys. From 2006 to 2008, eight 8-in.-diameter monitor and six 20-in.-diameter test wells were drilled in Spring Valley. An additional monitor and test well were drilled in Cave Valley in 2007. Prior to these programs, SNWA installed monitor wells in Coyote Spring Valley (HA 210) and Muddy River Springs Area (HA 219).

Geologic data within the study area were collected and evaluated using existing literature, well completion logs, SNWA geologic mapping, and surface geophysical surveys. Borehole lithology and fracture characteristics were evaluated through logging of cuttings and downhole geophysics. The monitor wells were pump tested for a short period, usually under eight hours, to evaluate general well performance characteristics, collect water-chemistry samples, and, in Spring Valley, assess the viability of a test well at the site.

Test wells were installed at six locations in Spring Valley and one location in Cave Valley. The purpose of the test wells was to collect more extensive hydrologic and water-chemistry data, perform a step-drawdown test, and conduct a 72- to 120-hr constant-rate test. The test wells are more extensively developed and hydraulically tested at a higher discharge rate than is possible in the smaller-diameter monitor wells.

A.1.1.1 Objectives

The primary objective of the well-drilling activities is to refine the current interpretations of the hydrogeologic framework and regional flow system through the acquisition and analysis of new data. These data include aquifer properties, geologic, water-chemistry, and water-level data. The wells provide monitoring points for collection of baseline and long-term data.

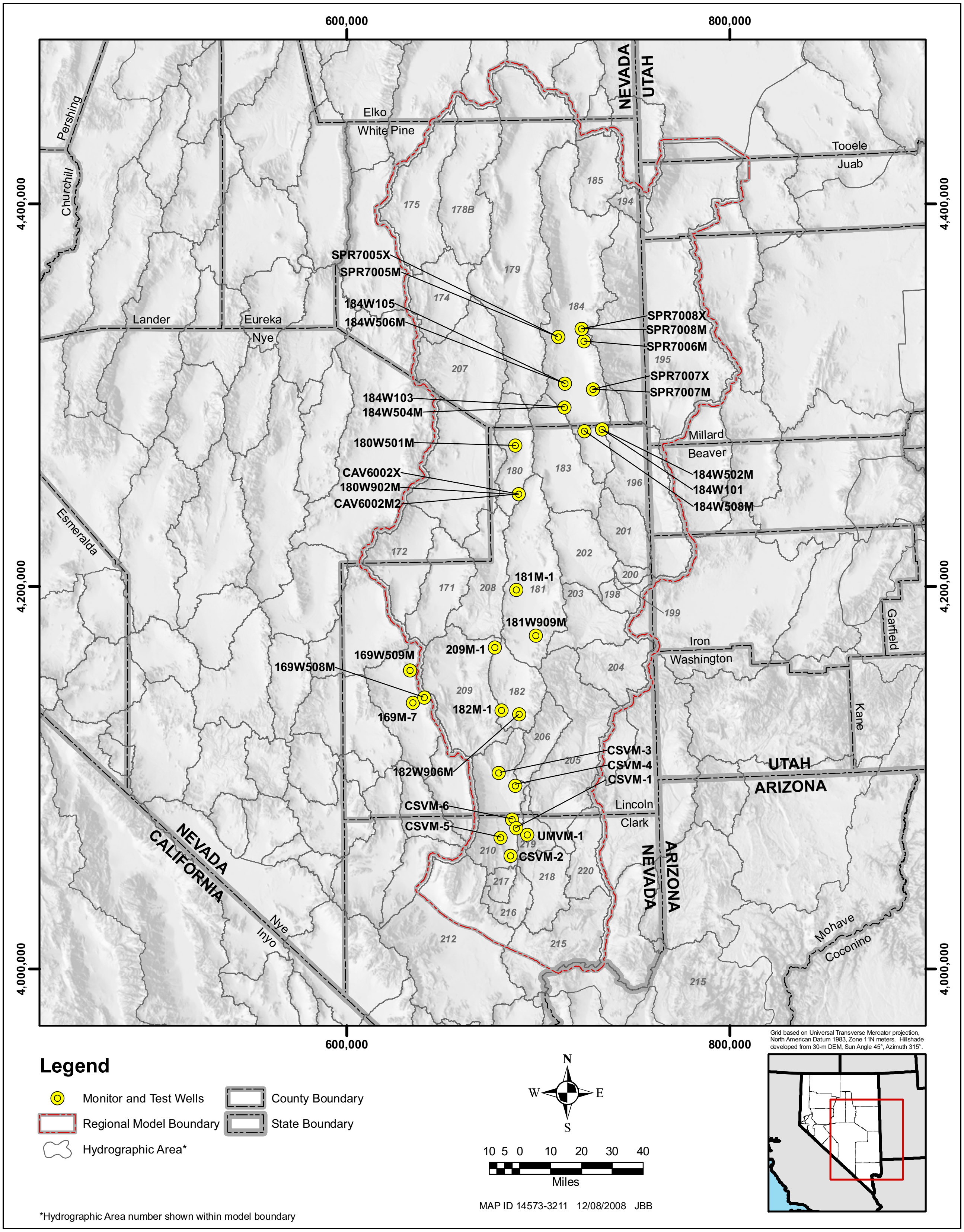

Figure A-1
Location of SNWA Wells within the Project Basins and Vicinity

SNWA has drilled 33 monitor and test wells within the following basins in the study area and vicinity (Figure A-1):

- Cave Valley: 3 monitor wells and 1 test well
- Coyote Spring Valley: 6 monitor wells
- Delamar Valley: 2 monitor wells
- Dry Lake Valley: 2 monitor wells
- Muddy River Springs Area: 1 monitor well
- Pahranagat Valley: 1 monitor well
- Spring Valley (Southern): 4 monitor wells and 3 test wells
- Spring Valley (Northern): 4 monitor wells and 3 test wells
- Tikaboo Valley North: 3 monitor wells

A.1.1.2 Well Status

A summary of monitor and test well locations and completion specifications are presented in Table A-1. Lithologic and downhole geophysical logging, including temperature logs, were performed during the drilling program. Temperature profile logs are available for all new wells. With a few exceptions, temperature logs were used in the analysis of thermal gradients in the study area and in the analysis conducted to estimate source depths for the major springs (Appendix G). Recent water-level data for each well are presented in Table A-2.

Short-term, single-well-pumping tests, generally seven to eight hours in duration, were performed at limited discharge rates at selected monitor wells after installation (Figure A-2). Water-chemistry samples were collected for a limited suite of chemical parameters at the end of the short-term test. Results of the short-term tests were used to assess the viability of a test well at the site for extended aquifer testing to evaluate aquifer properties. Test wells underwent extensive development after completion. A step-drawdown test, followed by a 72- to 120-hr constant-rate test, and recovery measurements were performed on each test well. Water-chemistry samples were collected during the constant-rate test for an extensive suite of chemical parameters; the resulting data are reported in SNWA (2008). Table A-3 presents a summary of the aquifer-test information for the test wells.

Data analysis has been completed for tests performed at Wells 184W101, 184W103, and 184W105. Analyses are currently being performed for the other tests. Additional test details and the preliminary estimates of aquifer properties derived from the data are presented in Appendix C.

A.1.2 Evapotranspiration Studies

In 2004, SNWA initiated a study to estimate groundwater ET within Spring and White River valleys in cooperation with the University of Nevada, Las Vegas (UNLV). The study was expanded to Snake Valley in 2007. Spring and Snake valleys were selected for the study because of their large discharge areas and their potential for water-resource development. White River Valley was included in the study because it is the largest discharge area of the WRFS. Descriptions of the objectives, locations, data collection methods, and data reduction methods are presented within this section. The resulting

Table A-1
SNWA Well Information

Well Name	HA Number	UTM Northing (m)	UTM Easting (m)	Surface Elevation (ft amsl)	Aquifer	Well Depth (ft bgs)	Hole Depth (ft bgs)	Screen Interval (ft bgs)
169M-7	169	4,139,267	634,523	4,290.93	Basin-Fill	1,490	1,500	995 to 1,480
169W508M	169	4,141,933	640,527	4,796.01	Carbonate	1,601	1,617	1,160 to 1,580
169W509M	169	4,156,097	632,997	5,157.81	Carbonate	1,558	1,560	1,448 to 1,548
180W501M	180	4,273,713	687,971	6,428.63	Carbonate	1,212	1,215	785 to 1,189
180W902M	180	4,248,356	689,816	5,984.89	Carbonate	903	915	196 to 882
CAV6002M2	180	4,248,366	689,783	5,982.81	Basin-Fill	887	893	159 to 882
CAV6002X	180	4,248,308	689,819	5,986.97	Carbonate	901	917	219 to 901
181M-1	181	4,198,200	688,535	4,963.07	Carbonate	1,472	1,501	765 to 1,451
181W909M	181	4,174,463	698,676	4,799.41	Basin-Fill	1,260	1,285	637 to 1,240
182M-1	182	4,135,293	680,867	4,597.78	Volcanic	1,321	1,345	996 to 1,300
182W906M	182	4,133,305	690,065	4,796.96	Volcanic	1,702	1,735	1,275 to 1,678
184W101	184	4,282,062	733,298	6,190.90	Carbonate	1,749	1,760	796 to 1,728
184W103	184	4,293,693	713,698	5,899.06	Carbonate	1,017	1,046	296 to 996
184W105	184	4,306,176	713,991	6,007.30	Carbonate	1,135	1,160	416 to 1,114
184W502M	184	4,282,116	733,294	6,189.72	Carbonate	1,800	1,828	495 to 1,779
184W504M	184	4,293,712	713,647	5,900.11	Carbonate	1,020	1,040	309 to 999
184W506M	184	4,306,214	713,940	6,014.04	Carbonate	1,140	1,160	430 to 1,120
184W508M	184	4,281,309	724,071	6,056.19	Volcanic	1,160	1,180	376 to 1,140
SPR7005M	184	4,330,472	710,372	6,395.68	Carbonate	1,404	1,412	663 to 1,383
SPR7005X	184	4,330,507	710,357	6,397.56	Carbonate	1,350	1,395	669 to 1,330
SPR7006M	184	4,328,163	723,873	6,525.18	Carbonate	1,700	1,720	980 to 1,680
SPR7007M	184	4,303,147	727,976	6,017.73	Basin-Fill	1,020	1,040	300 to 1,000
SPR7007X	184	4,303,152	727,946	6,017.53	Basin-Fill	1,020	1,040	299 to 1,000
SPR7008M	184	4,334,703	722,865	5,704.86	Basin-Fill	946	960	226 to 926
SPR7008X	184	4,334,728	722,848	5,703.98	Basin-Fill	960	970	240 to 940
209M-1	209	4,168,066	677,323	5,097.30	Carbonate	1,616	1,616	1,274 to 1,616
CSVM-1	210	4,073,793	688,602	2,160.60	Carbonate	1,040	1,060	320 to 1,020
CSVM-2	210	4,059,370	685,625	2,572.74	Carbonate	1,400	1,425	720 to 1,380
CSVM-3	210	4,102,600	679,319	2,650.68	Carbonate	1,200	1,220	380 to 1,180
CSVM-4	210	4,095,971	688,086	2,842.38	Carbonate	1,600	1,605	800 to 1,580
CSVM-5	210	4,068,774	680,295	3,130.70	Carbonate	1,780	1,783	1,020 to 1,760
CSVM-6	210	4,078,333	686,453	2,251.66	Carbonate	1,180	1,200	420 to 1,160
UMVM-1	219	4,070,248	694,305	2,061.88	Carbonate	1,780	1,785	960 to 1,760

Table A-2
Water-Level Measurements at SNWA Wells

Well Name	HA Name	HA Number	Surface Elevation (ft amsl)	Measuring Point (ft)	Measuring Point Elevation (ft amsl)	Date	Time	Water Depth (ft bgs)	Water Elevation (ft amsl)
169M-7	Tikaboo Valley	169	4,290.93	1.39	4,292.32	10/21/2008	10:15	837.99	3,452.94
169W508M	Tikaboo Valley	169	4,796.01	1.45	4,797.46	10/22/2008	9:20	1,104.79	3,691.22
169W509M	Tikaboo Valley	169	5,157.81	1.55	5,159.36	10/22/2008	11:00	1,431.91	3,725.90
180W501M	Cave Valley	180	6,428.63	2.41	6,431.04	10/21/2008	11:49	1,053.43	5,375.20
180W902M	Cave Valley	180	5,984.89	1.19	5,986.08	10/21/2008	13:23	139.91	5,844.98
CAV6002M2	Cave Valley	180	5,982.81	2.10	5,984.91	10/21/2008	13:45	137.51	5,845.30
CAV6002X	Cave Valley	180	5,987.97	1.00	5,988.97	10/21/2008	14:07	142.50	5,845.47
181M-1	Dry Lake Valley	181	4,963.07	1.55	4,964.62	10/21/2008	10:32	675.63	4,287.44
181W909M	Dry Lake Valley	181	4,799.41	1.21	4,800.62	10/21/2008	11:31	497.02	4,302.39
182M-1	Delamar Valley	182	4,597.78	1.88	4,599.66	10/21/2008	14:49	827.18	3,770.60
182W906M	Delamar Valley	182	4,796.96	2.88	4,799.84	10/21/2008	13:45	1,316.19	3,480.77
184W101	Spring Valley	184	6,190.90	1.98	6,192.88	9/25/2008	11:20	482.13	5,708.77
184W103	Spring Valley	184	5,899.06	2.13	5,901.19	9/25/2008	9:23	97.93	5,801.13
184W105	Spring Valley	184	6,007.30	1.85	6,009.15	9/23/2008	16:58	208.69	5,798.61
184W502M	Spring Valley	184	6,189.72	1.97	6,191.69	9/25/2008	11:10	481.12	5,708.60
184W504M	Spring Valley	184	5,900.11	1.33	5,901.44	9/25/2008	9:20	99.77	5,800.34
184W506M	Spring Valley	184	6,014.04	2.40	6,016.44	9/23/2008	16:47	215.35	5,798.69
184W508M	Spring Valley	184	6,056.19	1.67	6,057.86	9/25/2008	10:25	276.69	5,779.50
SPR7005M	Spring Valley	184	6,395.68	2.80	6,398.48	9/24/2008	8:36	493.61	5,902.07
SPR7005X	Spring Valley	184	6,397.56	2.78	6,400.34	9/24/2008	8:26	495.51	5,902.05
SPR7006M	Spring Valley	184	6,525.18	2.68	6,527.86	9/24/2008	13:40	769.65	5,755.53
SPR7007M	Spring Valley	184	6,017.73	2.08	6,019.81	9/24/2008	16:05	151.85	5,865.88
SPR7007X	Spring Valley	184	6,017.53	2.90	6,020.43	9/24/2008	16:17	151.77	5,865.76
SPR7008M	Spring Valley	184	5,704.86	2.80	5,707.66	9/24/2008	13:08	14.15	5,690.71
SPR7008X	Spring Valley	184	5,703.98	2.11	5,706.09	9/24/2008	13:16	13.86	5,690.12
209M-1	Pahranagat Valley	209	5,097.30	1.17	5,098.47	10/21/2008	9:16	1,200.52	3,896.78
CSVM-1	Coyote Spring	210	2,160.60	---	2,160.60	10/10/2008	10:30	340.24	1,820.36
CSVM-2	Coyote Spring	210	2,572.74	---	2,572.74	10/9/2008	8:17	749.3	1,823.44
CSVM-3	Coyote Spring	210	2,650.68	---	2,650.68	10/9/2008	11:37	443.1	2,207.58
CSVM-4	Coyote Spring	210	2,842.38	---	2,842.38,	10/9/2008	10:35	967.81	1,874.57
CSVM-5	Coyote Spring	210	3,130.70	---	3,130.70	10/9/2008	9:10	1083.73	2,046.97
CSVM-6	Coyote Spring	210	2,251.66	---	2,251.66	10/10/2008	9:25	433.68	1,817.98
UMVM-1	Muddy River Springs Area	219	2,061.88	---	2,061.88	10/10/2008	11:14	245.6	1,816.28

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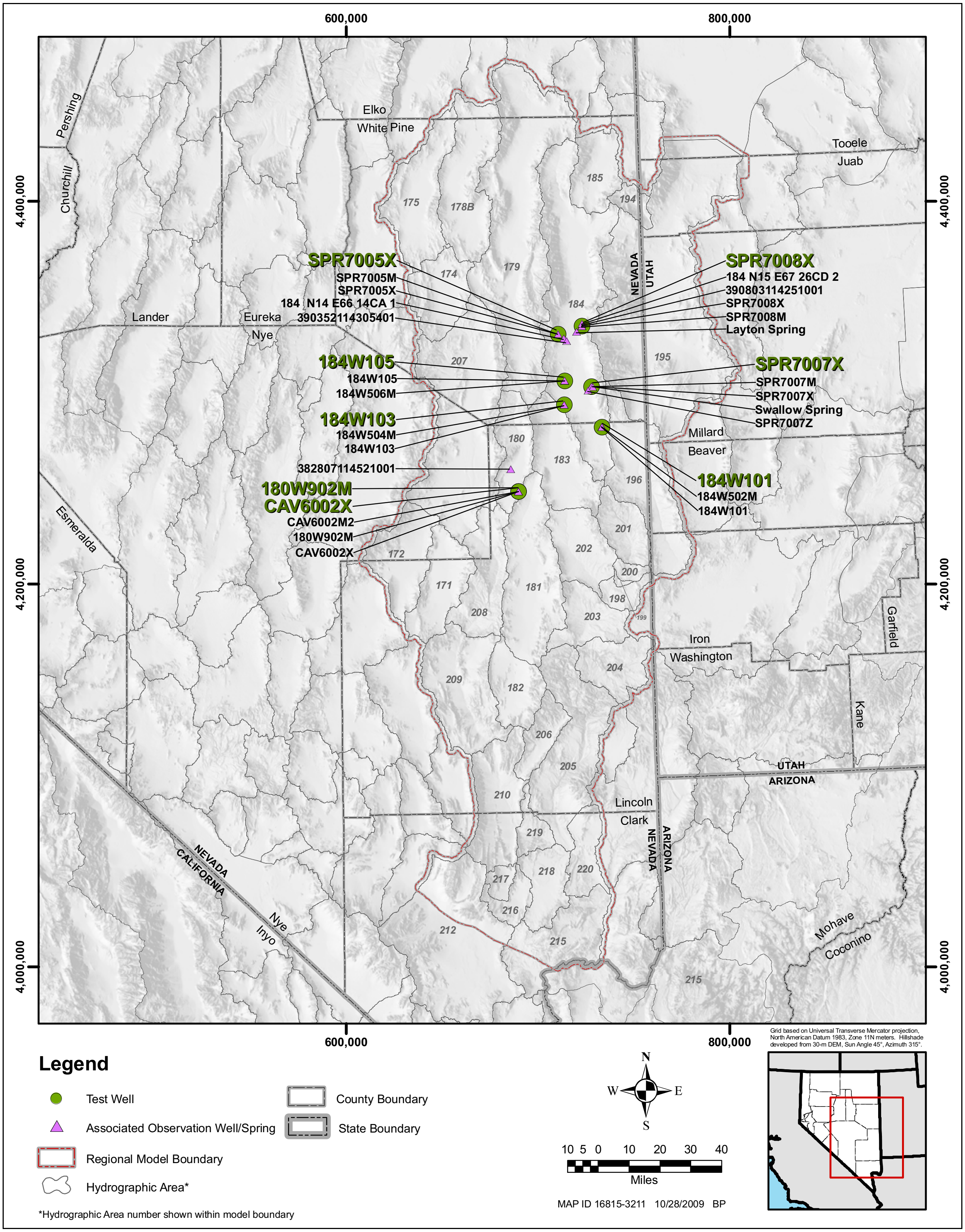

Figure A-2
Location of Wells Used in Aquifer Tests within the Project Basins and Vicinity

Table A-3
Aquifer-Test Data Summary for SNWA Wells
(Page 1 of 2)

Test Well Number	Associated Observation Well/Spring	Distance from Test Well (ft)	Specific Capacity (gpm/ft)	Constant-Rate Test: Duration (hours)	Constant-Rate Test: Flow Rate (gpm)	Step-Test Range (gpm)	Casing Diameter (in.)	Drill Depth (ft bgs)	Gravel Pack Interval (ft bgs)	Drawdown at end of Constant-Rate Test (ft)	Change in Spring Discharge
184W101	184W101	---	11.13	72	2,520	2,200 to 2,600	20	1,760	54 to 1,760	226.38	---
	184W502M	175	---				8	1,828	60 to 1,828[a]	21.12	---
	184W504M[b]	14 miles	---				---	---	---	0[c]	---
184W103	184W103	---	4.18	72	550	410 to 630	20	1,046	52 to 1,046	131.50	---
	184W504M	177	---				8	1,040	58 to 1,040[a]	3.92	---
	184W506M[b]	8 miles	---				---	---	---	0[c]	---
184W105	184W105	---	54.65	72	3,000	2,300 to 3,700	20	1,160	45 to 1,160	54.90	---
	184W506M	212	---				8	1,160	80 to 1,160[a]	4.63	---
	184W504M[b]	8 miles	---				---	--	---	0[c]	---
SPR7005X (184W111)	SPR7005X	---	111.1	120	3,000	2,000 to 3,800	20	1,395	509 to 1,350	39.82	---
	SPR7005M (184W512M)	129	---				8	1,412	452 to 1,406	2.88	---
	390352114305401	3.5 miles	---				2	160	Unknown (50 to 160)	0[c]	---
	184 N14 E66 14CA1	2.4 miles	---				8	372	50 to 372	0[c]	---
	184W506M	15 miles	---				8	1,160	80 to 1,160[a]	0[c]	---
SPR7007X (184W118)	SPR7007X	---	95.54	120	3,000	2,000 to 4,000	20	1,040	114 to 1,040	31.40	---
	SPR7007M (184W519M)	99	---				8	1,040	112 to 1,040	13.50	---
	390352114305401[b]	17 miles	---				2	160	Unknown (50 to 160)	0[c]	---
	Swallow Spring	2,300	---				---	---	---	---	(Discharge constant)[d]
	Minerva Spring Piezometer	1.7 miles	---				4	35	15 to 35	0[c]	---

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Table A-3
Aquifer-Test Data Summary for SNWA Wells
(Page 2 of 2)

Test Well Number	Associated Observation Well/Spring	Distance from Test Well (ft)	Specific Capacity (gpm/ft)	Constant-Rate Test Duration (hours)	Constant-Rate Test Flow Rate (gpm)	Step-Test Range (gpm)	Casing Diameter (in.)	Drill Depth (ft bgs)	Gravel Pack Interval (ft bgs)	Drawdown at end of Constant-Rate Test (ft)	Change in Spring Discharge
SPR7008X (184W120)	SPR7008X	---	11.78	72	2,000	1,500 to 3,300	20	970	109 to 970	169.71	---
	SPR7008M (184W521M)	100	---				8	960	69 to 960	42.74	---
	390803114251001	376	---				2	200	Unknown (50 to 200)	0.38	---
	390352114305401[b]	---	---				2	160	Unknown (50 to 160)	0[c]	---
	Layton Spring	2.5 miles	---				---	---	---	---	(Discharge constant)[e]
	MX Flowing Well	3,900	---				2	Unknown	Unknown	---	(Discharge constant)[e]
CAV6002X (180W103)	CAV6002X	---	4.78	72	1,200	800 to 1,500	20	917	55 to 917	191.82	---
	CAV6002M2 (180W504M)	225	---				6	893	50 to 893	6.93	---
	180W902M	157	---				12	915	0 to 915	7.06	---
	382807114521001	8 miles	---				10	460	Unknown (50 to 460)	0[c]	---
180W902M	180W902M	---	82.36	72	1,100	---	12	915	0 to 915	7.06	---
	CAV6002X	157	---				20	917	55 to 917	191.82	---
	CAV6002M2 (180W504M)	114	---				6	893	50 to 893	6.93	---
	382807114521001	8 miles	---				10	460	Unknown (50 to 460)	0[c]	---
SPR7023I	SPR7023I	---	10.60	120	987	600 to 1,200	20	1,220	162 to 1,220	93.75	---
	184 N13 E67 22BA	1 mile	---				---	550	---	0[c]	---

[a]Interval from bottom of conductor casing to total depth (open borehole).
[b]Background well.
[c]Drawdown as a result of the pump test. Actual water-level fluctuations due to barometric and tidal influences.
[d]Flow measured with 3-in. and 6-in. Parshall flumes downstream of the north and south orifices, respectively.
[e]Flow measured volumetrically.
Note: These are preliminary data and are subject to change.

data are incorporated in a summarized ET data set provided in Appendix E. Also, the results of the 3-year data collection period (2005 to 2007) are presented in Devitt et al. (2008).

A.1.2.1 Objectives

Initially, SNWA's primary objective for the ET study was to refine previous estimates of groundwater ET using newer methodologies. Several objectives have been added as the ET study has progressed. These include (1) monitoring the variability in ET rates among different vegetation communities; (2) gaining an understanding of plant water uptake from groundwater sources versus surface-water sources; and (3) developing relationships between ET and vegetation indices that represent plant community health using remote-sensing applications.

A.1.2.2 Locations

ET-monitoring site locations were selected to represent a range of the phreatophytic areas located on the valley bottoms of selected basins within the study area (Figure A-3 and Table A-4). In 2005, two towers were rotated among six sites in Spring and White River valleys (three sites in Spring Valley and three sites in White River Valley). Rotating the towers revealed the variability among the basins and provided a robust data set for extrapolating to basin ET. It did not, however, provide continuous data sets for any of the ET-monitoring sites. In 2006, the towers remained stationary at one site in each of the valleys (SV1 and WRV2). Four additional towers were monitored in 2007 (Table A-4); one monitoring location from 2005 (SV3) was re-equipped, and three sites (SV2b, SNVl, and SNV2) were added.

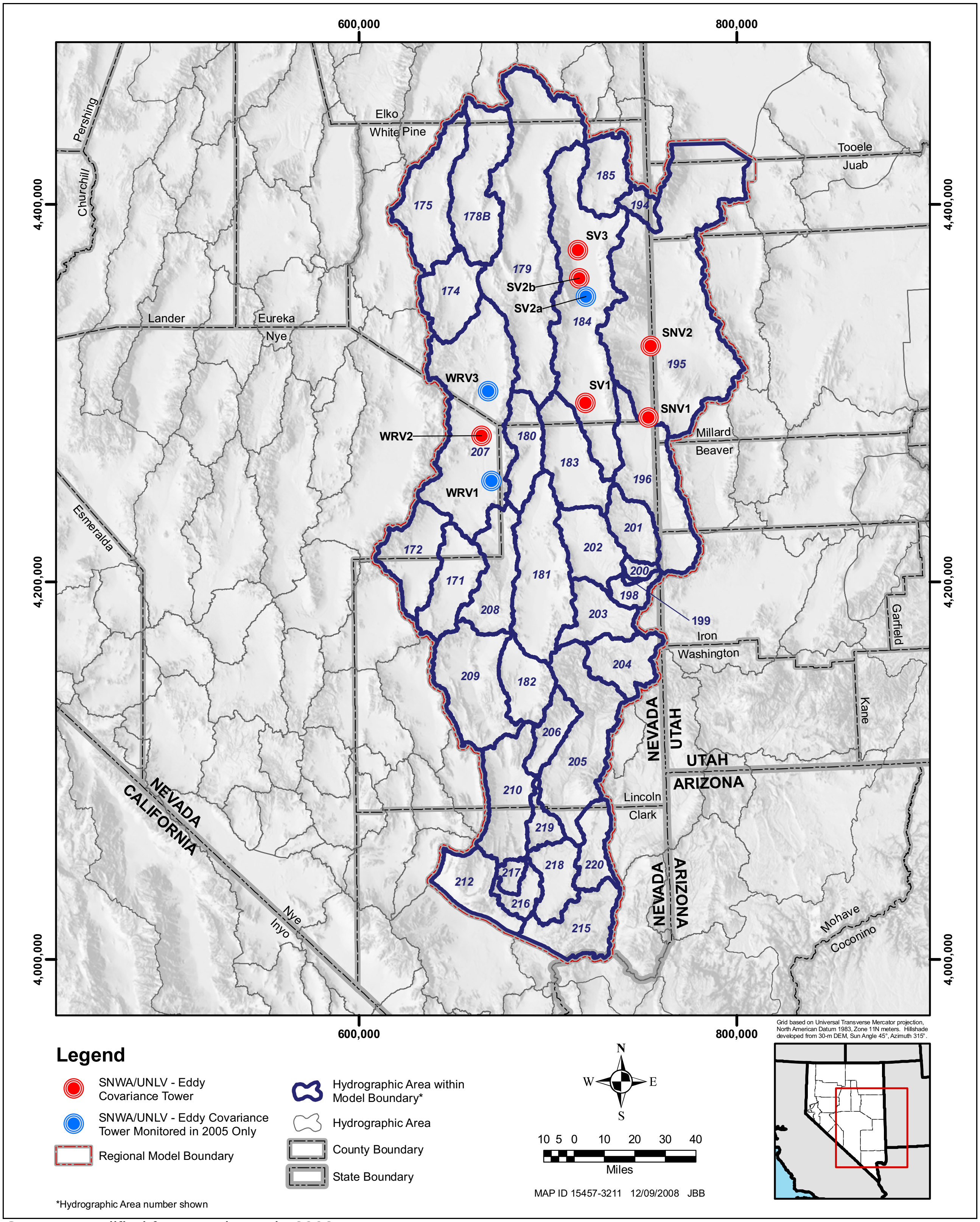
Species composition and percent cover within a 25 m × 25 m plot (size of Landsat satellite image pixel) at each site were evaluated by Devitt et a1. (2008). A brief description of the sites monitored between 2004 and 2007 is presented in Table A-4.

A.1.2.3 Data Collection Methods

Each ET site is equipped with an automated eddy covariance tower (ET towers), meteorological station, and groundwater monitor well for collection of ET, precipitation and PET data, and depth-to-water data, respectively. The ET towers are equipped with a 3D sonic anemometer and an infrared gas analyzer at a height of 1 m above average plant canopy height, with the exception of the pasture/grassland site (SV2b) where the height is 1.5 m above the grass. The towers are equipped with additional sensors to measure temperature, relative humidity, net radiation, rainfall, barometric pressure, saturated and actual vapor pressure, soil-heat flux, soil temperature, and volumetric water content. Continuous data are recorded on a l0Hz interval (every l0th of a second) with data downloads occurring on a 2- to 3-week rotation. All sensors are calibrated according to the manufacturer's guidelines.

A.1.2.4 Data Reduction Methods

ET rates are based on using the l0Hz measurement data and incorporating a series of post-processing adjustments to produce 30-minute totals. An ET data quality assurance/quality control flagging



Source: Modified from Devitt et al., 2008

Figure A-3
ET-Monitoring Site Locations

Table A-4
ET-Monitoring Site Information

Station Name	UTM Northing Zone 11 (m)	UTM Easting Zone 11 (m)	Monitoring Period	Vegetation Type	Percent Cover	Depth to Water (ft bgs)
SV1	4,294,917	719,920	2005 to present[a]	Predominantly sagebrush, rabbitbrush, and greasewood, minor amounts of shadscale and buckwheat	27	15
SV2a	4,351,204	720,177	2004 to 2005[b]	Mixed grasses, greasewood, and rabbitbrush	62	shallow
SV2b	4,360,829	716,743	2007 to present	Irrigated pasture, with perennial grasses	100	shallow
SV3	4,375,912	715,857	2007 to present	Predominantly greasewood and rabbitbrush, minor amounts of shadscale and pickleweed	32	17
SNV1	4,287,266	753,182	2007 to present	Predominantly greasewood, minor amounts of shadscale and sagebrush	62	19
SNV2	4,325,090	754,601	2007 to present	Mixed community of rabbitbrush, greasewood, sagebrush, and shadscale	13	30
WRV1	4,253,557	670,230	2005[c]	Predominantly greasewood and sagebrush, minor amounts of buckwheat	62	32[d]
WRV2	4,277,445	665,017	2005 to present	Predominantly sagebrush and greasewood, minor amounts of shadscale and rabbitbrush	55	19
WRV3	4,301,044	668,300	2005[e]	Predominantly greasewood and rabbitbrush, minor amounts of sagebrush, shadscale, cactus, and grass	42	41[f]

[a]2005 data were collected from 3/31/2005 to 5/26/2005 and 8/18/2005 to 12/22/2005.
[b]Data were collected from 8/18/2004 to 2/15/2005 and 7/7/2005 to 8/18/2005.
[c]Data were collected from 4/1/2005 to 5/27/2005 and 8/19/2005 to 9/5/2005.
[d]Data from Moreo et al. (2007).
[e]Data were collected from 5/27/2005 to 7/17/2005.
[f]Depth to water calculated for the period of 2004 to 2006.

system checks for data spikes and other anomalies by running each 30-minute total through a series of nine tests. These nine tests include checks on signal resolution, meteorological range of the data (range of acceptable numbers for this field of data collection), sampling errors, stationarity (statistical parameters varying in time), and fulfillment of requirements for a well-defined turbulence (needed for the eddy covariance approach).

A series of gap-filling techniques are employed after the data are visually inspected for any measurement gaps. Data gaps can occur anywhere from the 30-minute totals up to the yearly totals. The gap-filling technique employed depends on the magnitude of the missing data. These techniques include (1) assigning a flat rate from previous literature or (2) using linear regression or an unbiased average of the available data surrounding the data gap.

A.2.0 REFERENCES

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Moreo, M.T., Laczniak, R.J., and Stannard, D.I., 2007, Evapotranspiration rate measurements of vegetation typical of ground-water discharge areas in the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and adjacent areas in Nevada and Utah, September 2005–August 2006: U.S. Geological Survey Scientific Investigations Report 2007-5078, 48 p.

SNWA, see Southern Nevada Water Authority.

Southern Nevada Water Authority, 2008, Baseline characterization report for Clark, Lincoln, and White Pine Counties Groundwater Development Project: Southern Nevada Water Authority, Las Vegas, Nevada, 1146 p.

Appendix B

Additional Information in Support of the Simplified Hydrogeologic Framework

B.1.0 SIMPLIFIED HYDROGEOLOGIC FRAMEWORK DEVELOPMENT

This appendix contains information used to construct the simplified hydrogeologic framework. This includes a representation of the surface elevation as well as unit extent and structural contour maps for all RMUs (Figures B-1 through B-12).

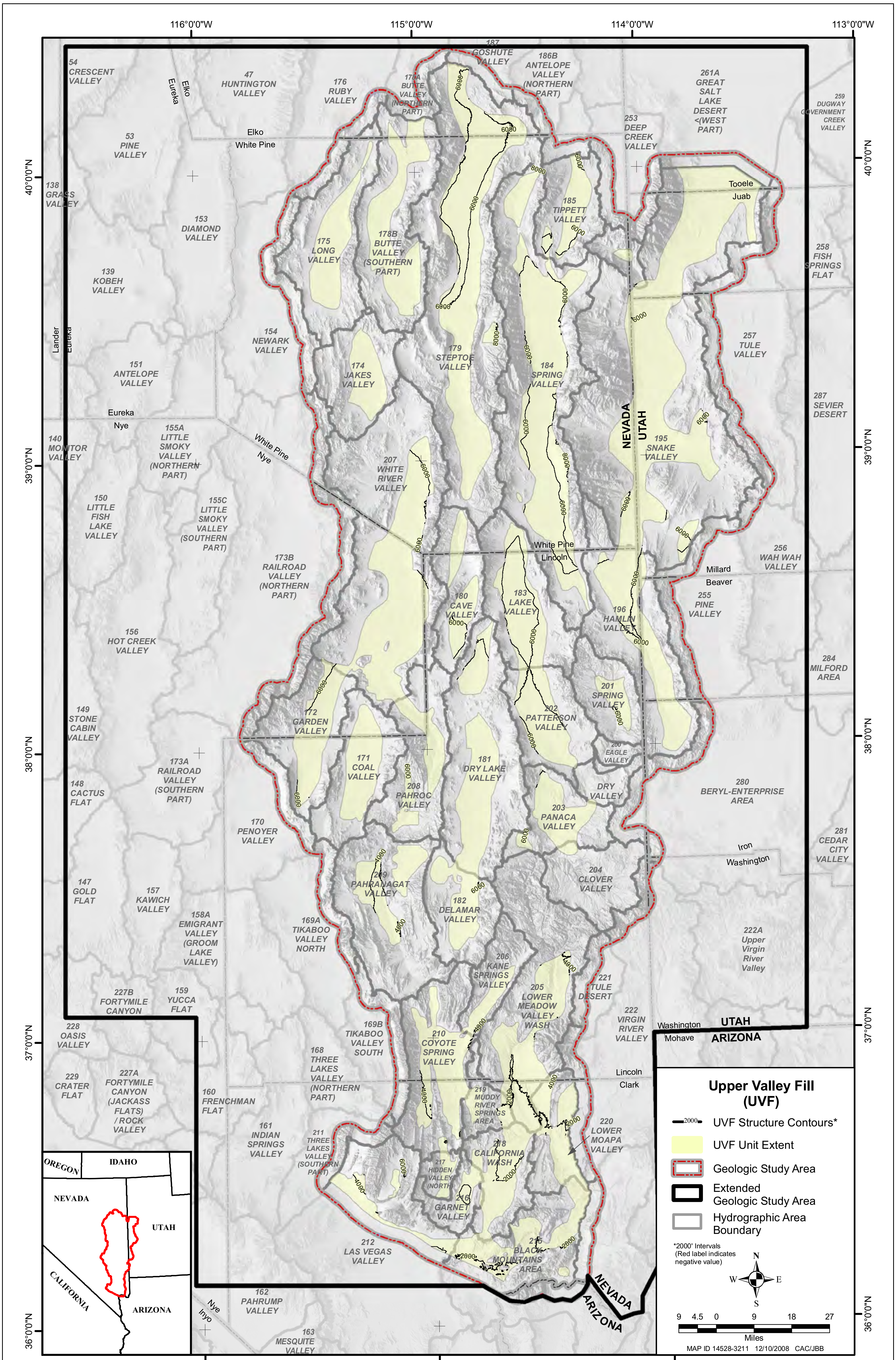

Figure B-1
Extent and Structural Contours of the Upper Valley Fill Regional Modeling Unit

SE ROA 50572

JA_15973

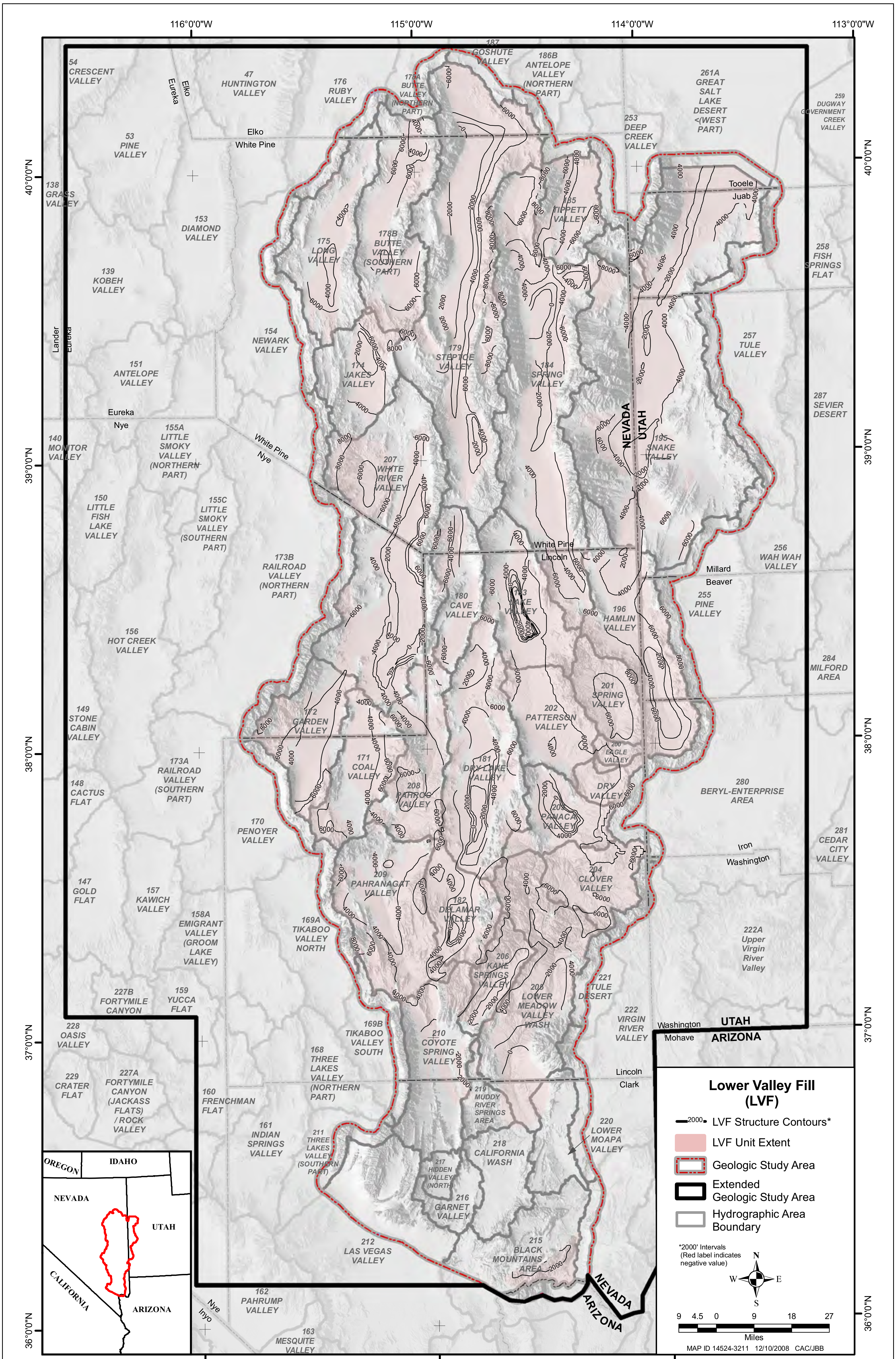

Figure B-2
Extent and Structural Contours of the Lower Valley Fill Regional Modeling Unit

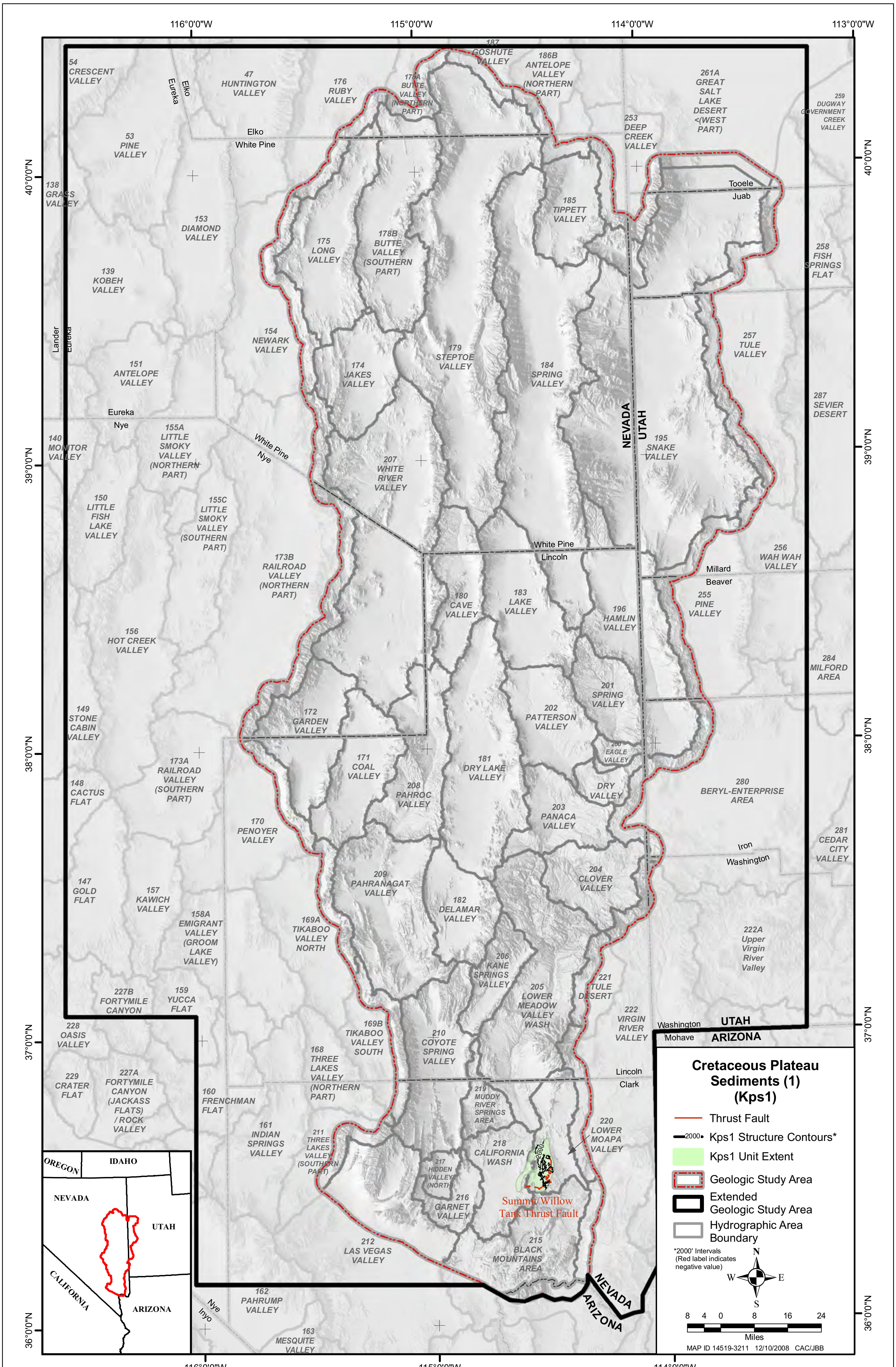

Figure B-3
Extent and Structural Contours of the Cretaceous Plateau Sediments (1) Regional Modeling Unit

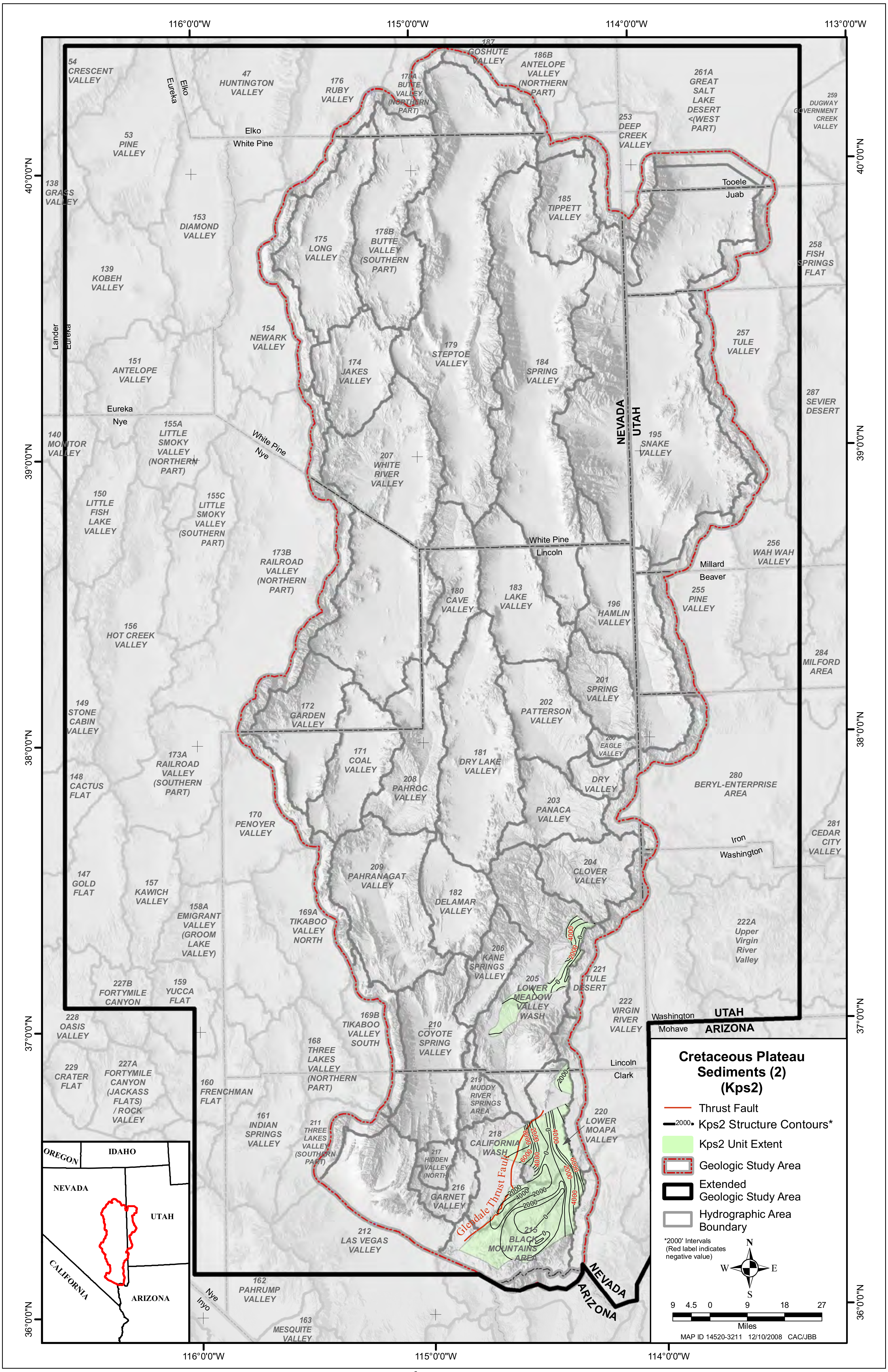

Figure B-4
Extent and Structural Contours of the Cretaceous Plateau Sediments (2) Regional Modeling Unit

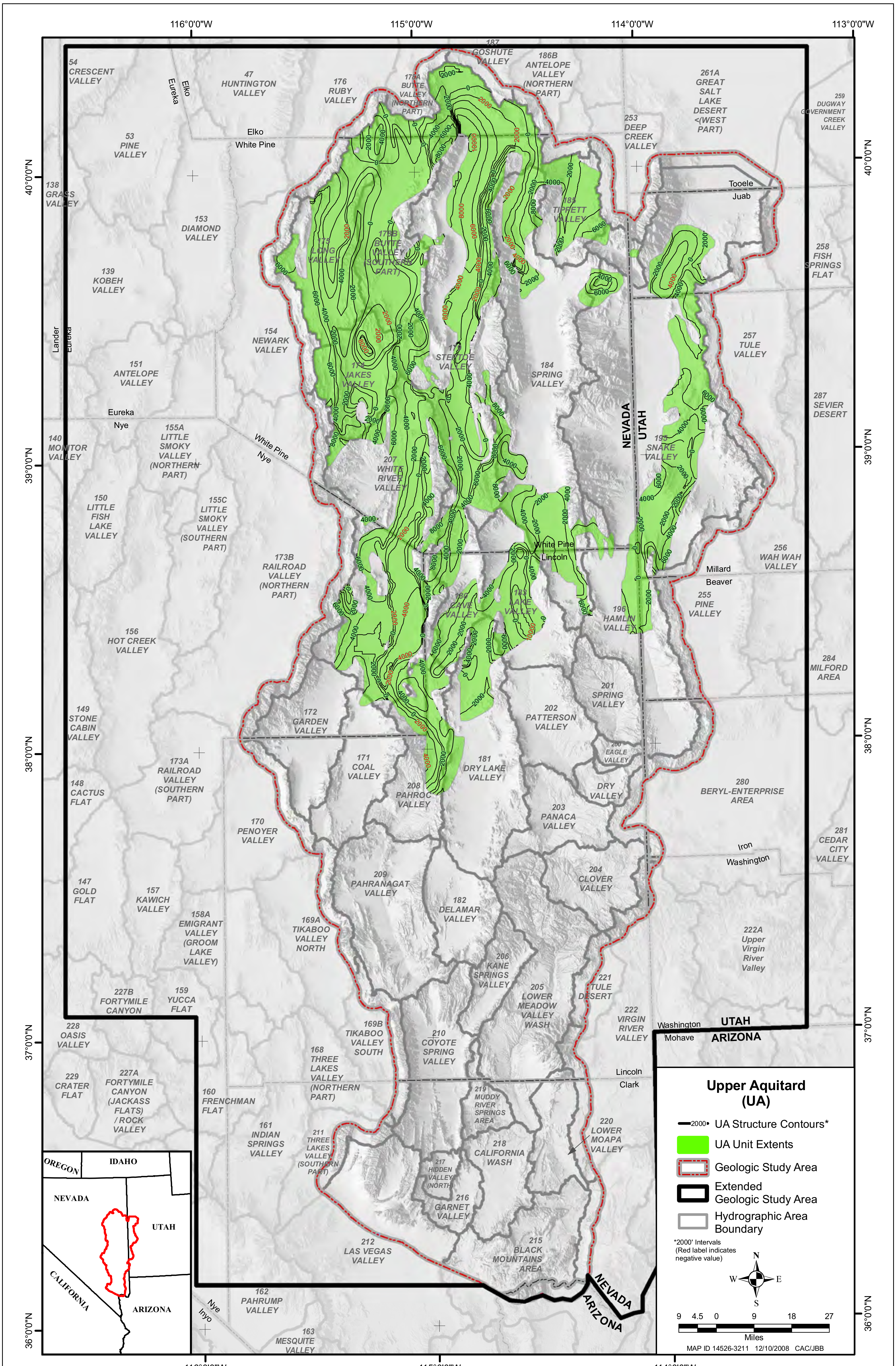

Figure B-5
Extent and Structural Contours of the Upper Aquitard Regional Modeling Unit

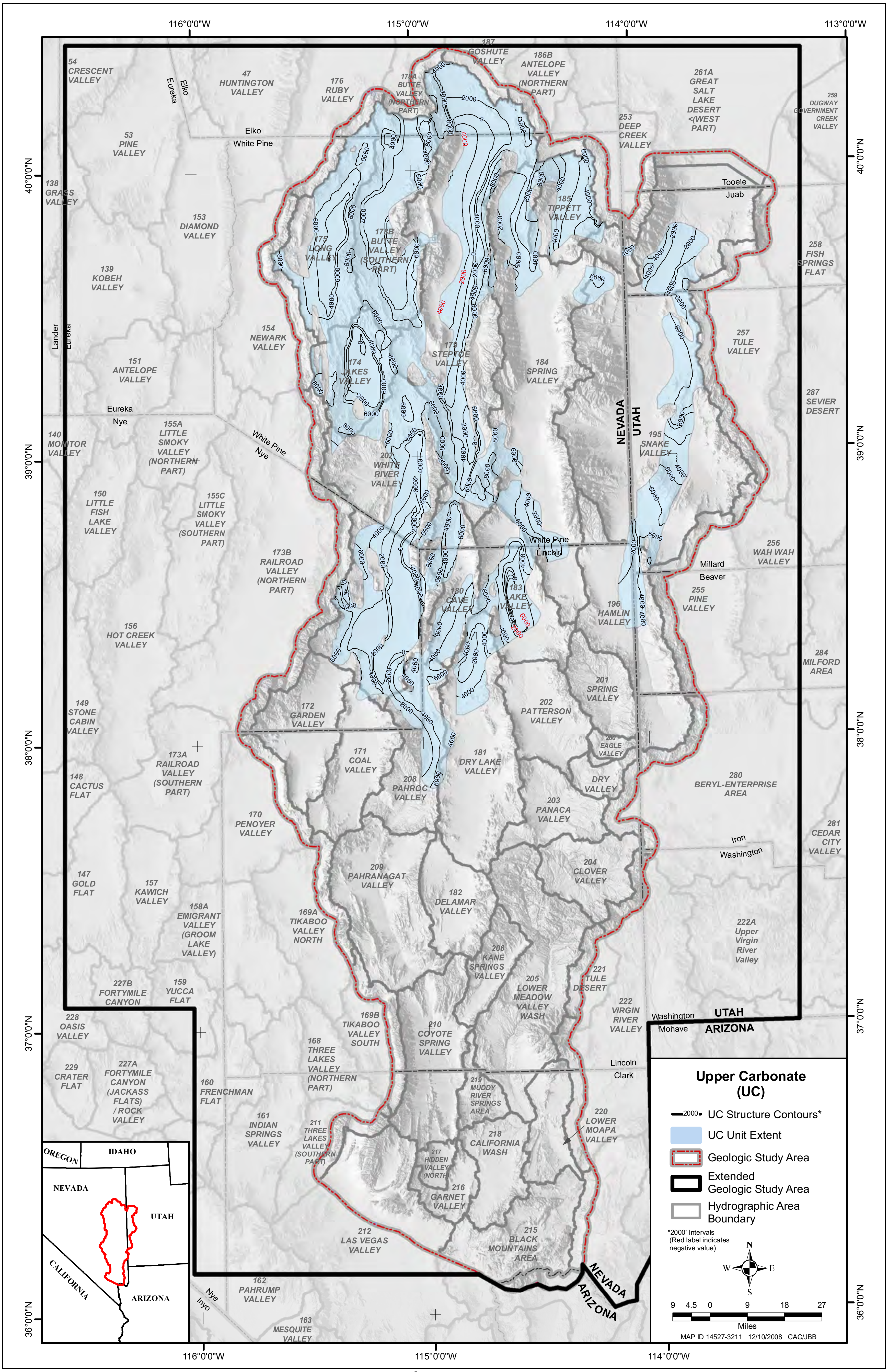

Figure B-6
Extent and Structural Contours of the Upper Carbonate Regional Modeling Unit

SE ROA 50577

JA_15978

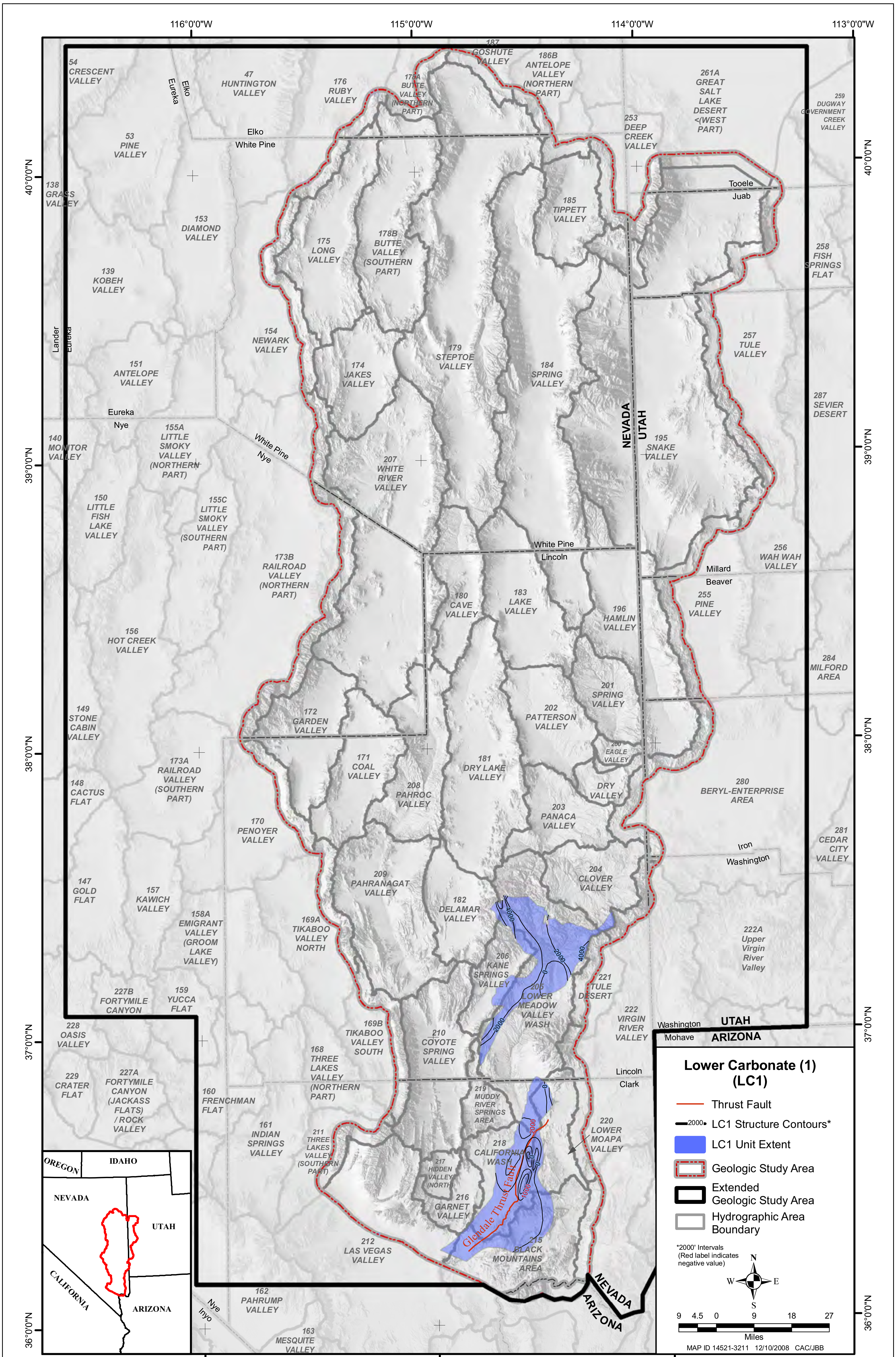

Figure B-7
Extent and Structural Contours of the Lower Carbonate (1) Regional Modeling Unit

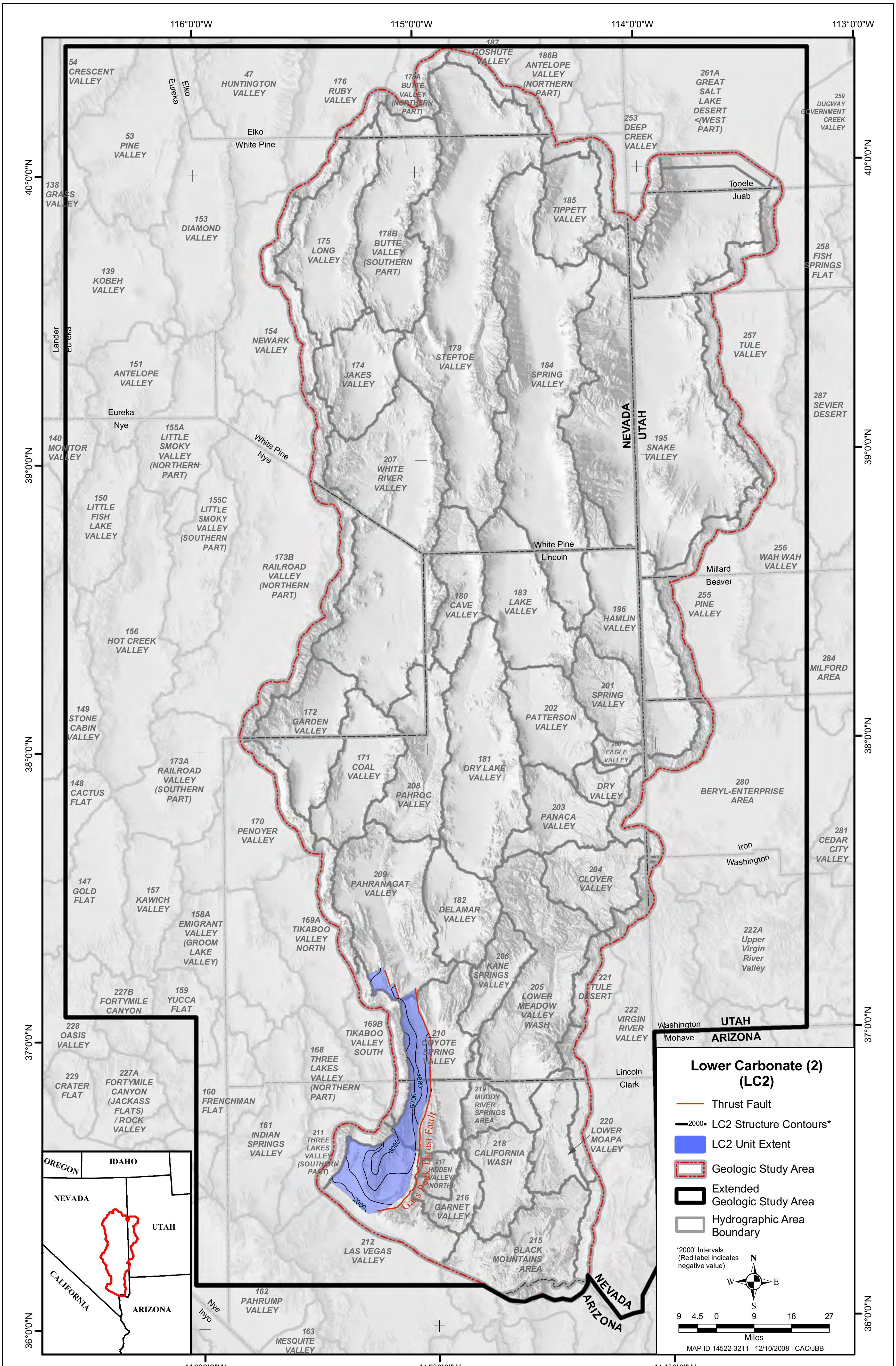

Figure B-8
Extent and Structural Contours of the Lower Carbonate (2) Regional Modeling Unit

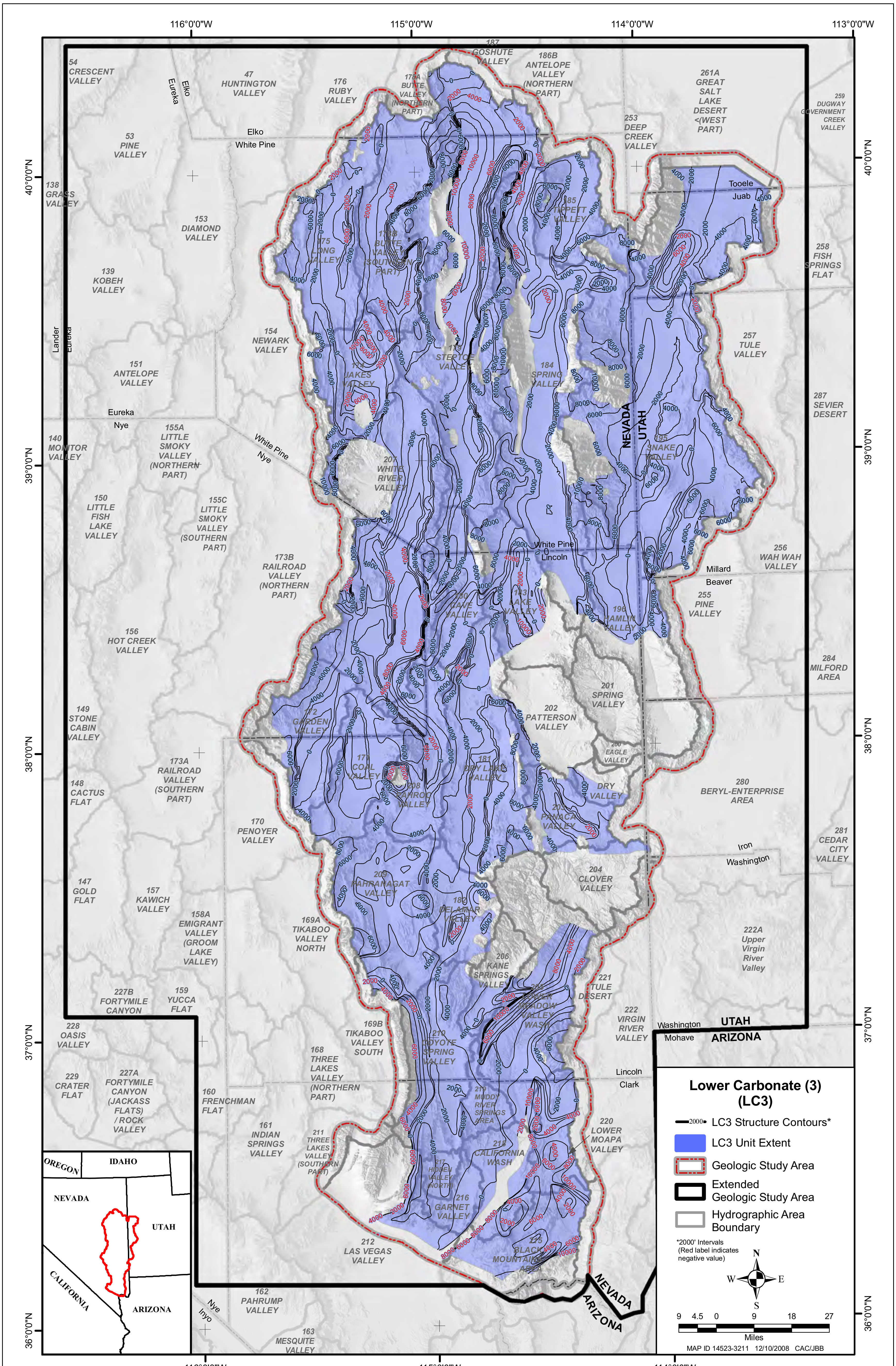

Figure B-9
Extent and Structural Contours of the Lower Carbonate (3) Regional Modeling Unit

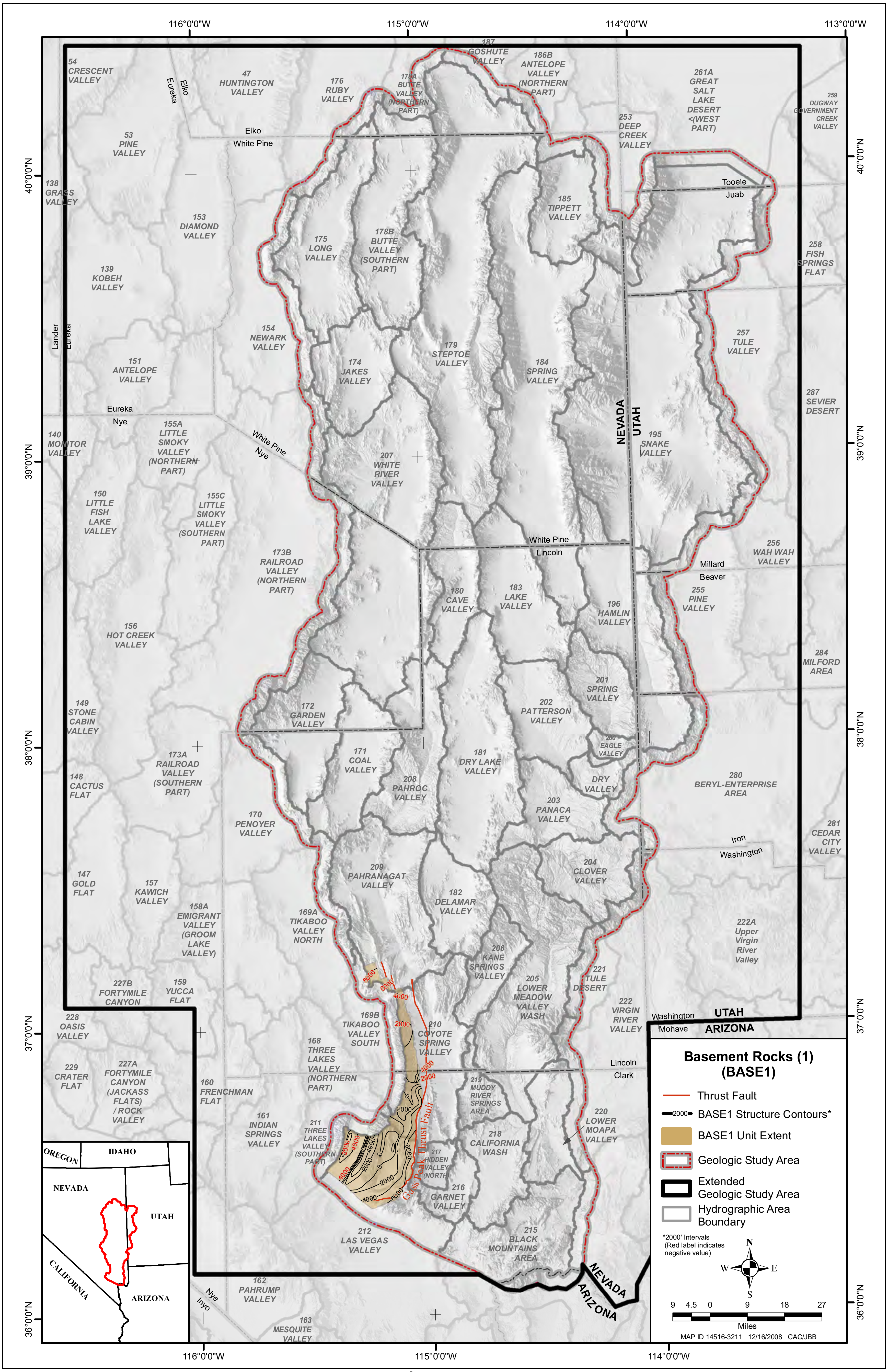

Figure B-10
Extent and Structural Contours of the Basement Rocks (1) Regional Modeling Unit

SE ROA 50581

JA_15982

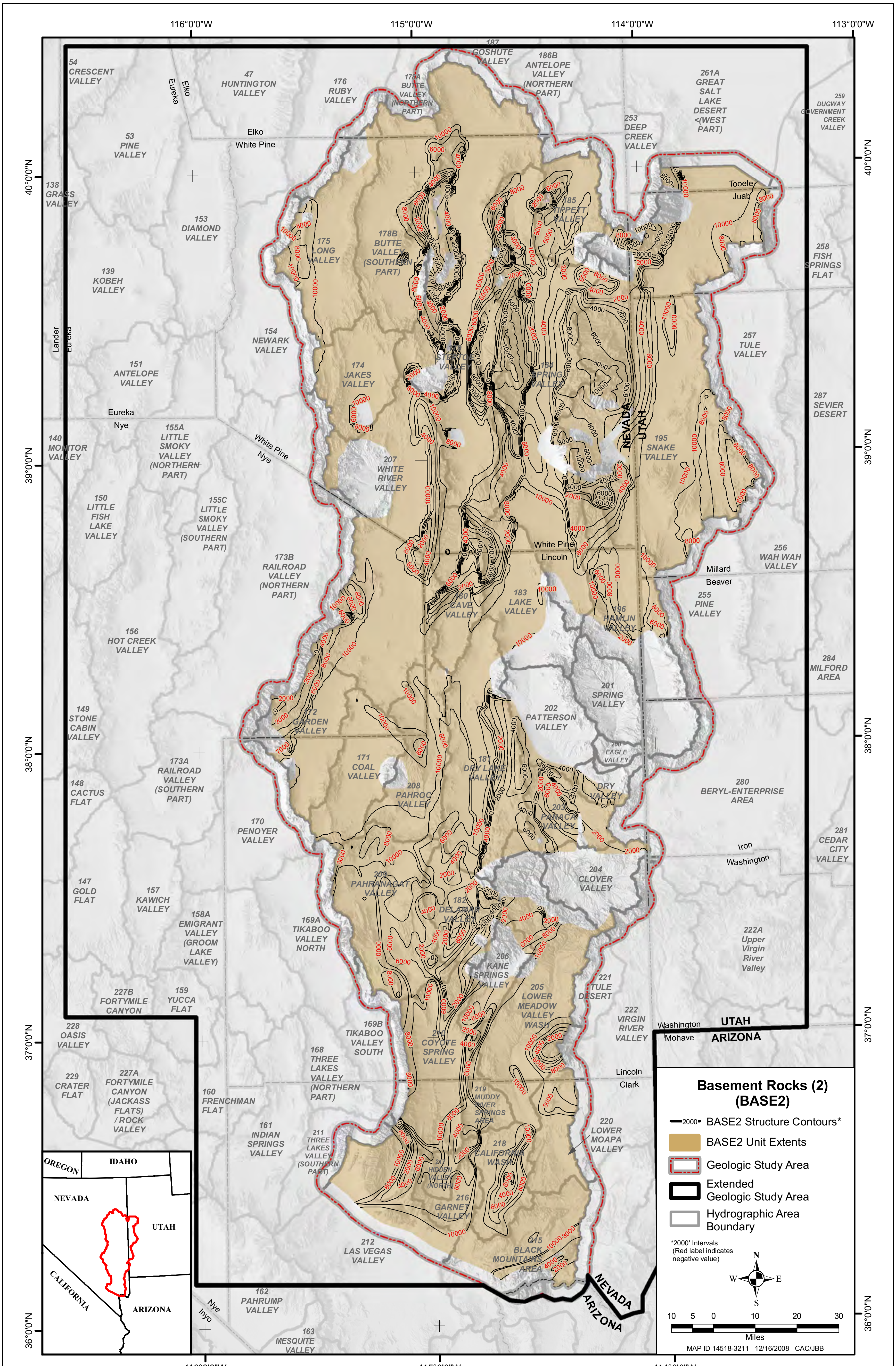

Figure B-11
Extent and Structural Contours of the Basement Rocks (2) Regional Modeling Unit

SE ROA 50582

JA_15983

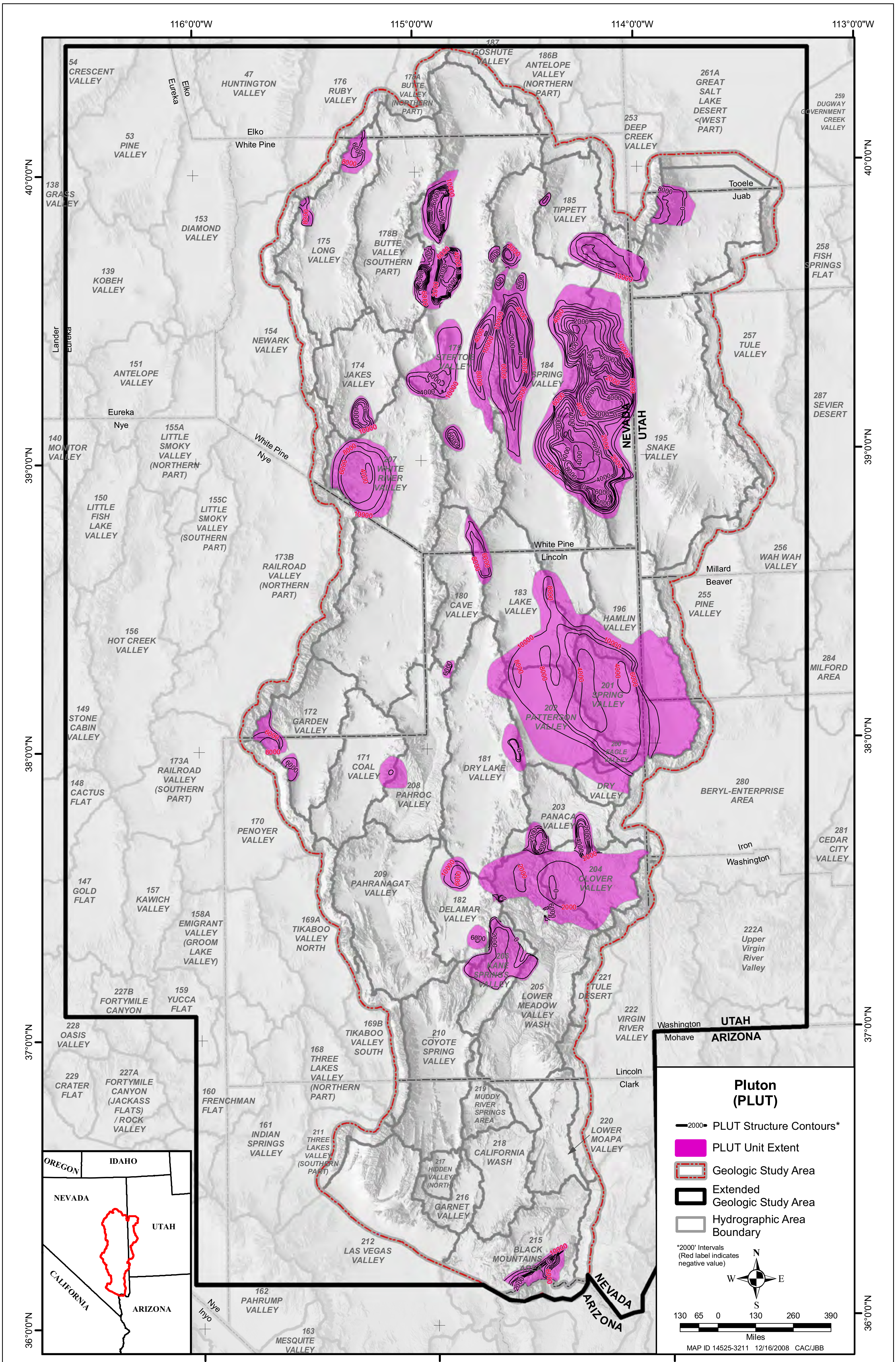

Figure B-12
Extent and Structural Contours of the Pluton Regional Modeling Unit

SE ROA 50583

JA_15984

Appendix C

Hydraulic-Property Data Analysis

C.1.0 HYDRAULIC-PROPERTY DATA ANALYSIS

This appendix describes the data analysis efforts conducted to derive estimates of hydraulic properties for the RMUs of the study area. Descriptions of previous relevant studies, the technical approach, and the data analysis are presented in this appendix, followed by a summary. The data analysis is presented in two subsections: (1) reported aquifer-test data and (2) preliminary SNWA data.

C.1.1 Relevant Studies

The study area for the Project is largely unpopulated and therefore has not been extensively studied. This section contains a description of previous site-specific and regional studies that are relevant to this investigation, followed by a description of the ongoing investigations conducted by SNWA.

C.1.1.1 Previous Site-Specific Studies

Previous investigations conducted within the general study area are termed site-specific and are summarized below.

C.1.1.1.1 LVVWD Cooperative Water Project Studies

LVVWD published a series of reports in the early to mid 1990s in support of groundwater applications filed in eastern and central Nevada. The reports document the environmental setting and hydrology of select basins within the region.

C.1.1.1.2 MX Well Studies

In the late 1970s and early 1980s, hydrogeologic investigations were completed for the MX missile-siting program. The data collected from MX Well Tests under the USAF MX Missile-Siting Investigation–Water Resources Program are described in reports by Ertec Western, Inc. (1981 a through c) and Bunch and Harrill (1984). The area of investigation for this project extends over Nevada and Utah. A number of wells were constructed and tested in 1980 and 1981 when the project was stopped. Most tests were single-well constant-rate tests that were conducted in the valley-fill aquifer with a few tests conducted in the carbonate aquifer.

C.1.1.1.3 Drill-Stem Tests

McKay and Kepper (1988) compiled, reviewed, and analyzed drill-stem test (DST) data collected from oil and gas wells in Nevada. Most of the wildcat wells reviewed are in the Railroad Valley and White River flow systems. McKay and Kepper (1988) calculated transmissivities for 20 wells with complete DST records for the carbonate aquifer. They found that DST transmissivity values were smaller than those derived from aquifer tests by as much as three orders of magnitude.

Since publication of McKay and Kepper (1988), 80 additional DSTs (1987 to 2003) have been conducted in Nevada. The data from these tests were not compiled or analyzed as part of this study.

C.1.1.1.4 White Pine Power Project

Leeds, Hill and Jewett, Inc., (1981b, 1983) describe well tests conducted as part of the White Pine Power Project. Aquifer-property data were derived from step-drawdown and pump tests. This study was conducted in three phases. Several wells were first installed and tested in the valley-fill and carbonate aquifers of Spring, Steptoe, and White River valleys. Then, a few more wells were installed and tested in Spring and Steptoe valleys.

C.1.1.1.5 NDWR Driller's Logs

The NDWR maintains an online database of driller's logs for many wells in Nevada (NDWR, 2004) and is a source of extensive information. In addition to location and well construction information, the driller's logs contain lithology and occasionally specific capacity data.

C.1.1.1.6 Other Site-Specific Studies

Other site-specific studies consist of reports on localized hydrological investigations of Coyote Spring Valley, Moapa Valley, Lower Meadow Valley Wash, and Garnet Valley. These reports include data derived from step-drawdown and constant-rate tests for wells completed in valley-fill, carbonate, and volcanic rocks.

C.1.1.2 Previous Regional Studies

For the most part, regional data were derived from studies associated with the Death Valley Flow System. This section briefly describes each of the regional studies.

C.1.1.2.1 Welch et al. (2008)

As part of BARCASS, Welch et al. (2008) derived estimates of hydraulic properties for their study area from the aquifer-test data set compiled by Belcher et al. (2001) for the DVFS. Welch et al. (2008) justified the use of DVFS data because of the lack of data specific to their study area and the similarity between rock types and HGUs within the DVFS.

Welch et al. (2008) grouped the horizontal hydraulic-conductivity data compiled by Belcher et al. (2001) by HGU and summarized the data statistically. They found that hydraulic-conductivity values for a given HGU vary by three to nine orders of magnitude and are affected by fracturing and chemical dissolution, at least for carbonate rocks.

C.1.1.2.2 Belcher et al. (2001)

Belcher et al. (2001) compiled an extensive aquifer-property data set from existing databases and the literature to support the USGS Death Valley Regional Flow System model (Belcher, 2004). Although most of the data compiled by Belcher et al. (2001) fall within the DVRFS model area, it also includes some data locations outside of the model boundary. The data set includes only "good quality" data as deemed by the authors of the report. The analyses performed by Belcher et al. (2001) included subdividing the carbonate aquifer based on rocks with extensive faulting, with or without karst development, and undisturbed rocks. The results of their analyses showed that faulted rocks had a geometric mean of the horizontal hydraulic conductivity of approximately 9.84 ft/day, whereas the undisturbed rocks had a geometric mean of 0.33 ft/day. The conclusion reached from this was that extensive faulting and karst development significantly increases the hydraulic continuity of the carbonate aquifers (Belcher et al., 2001).

C.1.1.2.3 NTS Studies

An aquifer-property data set was developed to support an earlier model of the regional groundwater flow model for the DVFS (IT, 1996), the NTS Regional Model (IT, 1997). This data set contains much of the regional data available at the time of the study, and each record in the data set was assigned a qualification flag.

In cooperation with the USGS, the Stoller-Navarro Joint Venture (SNJV) compiled raw slug-test data previously collected by the USGS for tests conducted on the NTS. SNJV analyzed the data for environmental restoration studies of the Pahute Mesa underground test area and published the results in a report discussing hydrologic data for Pahute Mesa (SNJV, 2004c).

Other NTS data are presented in hydrologic data-interpretation reports for wells or well clusters in the NTS and its vicinity conducted as part of the DOE Environmental Restoration Program (IT, 2002a through i; SNJV 2004a, b, d, and e).

C.1.1.2.4 Other Regional Studies

Other studies conducted within the region include data from the Nye County Early Warning Drilling Program (Questa Engineering, 1999a through c, 2000a and b, 2001, 2002a through c, and 2003). These studies include step-drawdown, constant-rate, and flow-logging tests for wells and multiple-well aquifer tests.

C.1.1.2.5 Ongoing SNWA Studies

As part of the Project, SNWA has been installing and testing several monitor and test wells within the study area (Appendix A). Aquifer tests have been conducted as part of the hydrologic data collection effort for some of these wells. A summary of the aquifer test results are presented in Section C.1.3.6.2.

C.1.2 Technical Approach

The role of aquifer properties, the types of data, and the objectives and approach for the hydraulic-property data analysis are described in this section.

C.1.2.1 Role of Aquifer Properties

Hydraulic properties include permeability and storage properties of geologic units. Permeability properties quantify the ability of fluids to flow through geologic media. Storage properties, as their name indicates, provide a measure of the storage capabilities of the geologic media.

In general, quantification of the permeability and storage properties of the geologic media is needed for several reasons: (1) it facilitates comparison of water-bearing geologic units; (2) it facilitates the identification of aquifers versus confining units; and (3) it is a requirement in flux calculations using simple analytical or complex numerical models of groundwater flow.

The aquifer-property data were used to support the development of a 3D numerical groundwater flow model by providing initial estimates and ranges of parameters. The numerical model was used to predict the potential effects of pumping from proposed production wells in the project basins (Figure 1-2).

C.1.2.2 Data Types

Data types of interest include (1) hydraulic properties, such as permeability and storage, derived directly from field or laboratory tests and (2) other types of data that may indirectly be used to estimate hydraulic properties or provide comparative estimates.

Permeability properties may be expressed as intrinsic permeability, hydraulic conductivity, or transmissivity. Intrinsic permeability is a measure of the ability of a geologic unit to transmit fluids under a hydraulic or potential gradient and is independent of the resident fluid properties (Fetter, 1988). This property is usually applied in the evaluation of oil and gas wells, where multiple fluids are usually present. Hydraulic conductivity is a measure of the ability of a geologic unit to transmit water and is a function of both the medium and the fluid (Fetter, 1988). Transmissivity is the rate at which water is transmitted through a unit width of an aquifer or confining bed under a unit hydraulic gradient and is a product of hydraulic conductivity and the thickness of the water-bearing geologic unit (Fetter, 1988). Hydraulic conductivity may vary with direction horizontally and vertically. Such variability is measured via anisotropy factors. Specific capacity is an expression of the productivity of a well that represents the well yield per unit of drawdown (Fetter, 1988) and may be used to derive estimates of transmissivity.

Storage properties include specific storage, storativity and specific yield. The storativity of an aquifer, also known as storage coefficient, is the volume of water that an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head (Fetter, 1988). Specific storage may be defined as the storativity per unit thickness. The specific yield is the ratio of water a rock or soil will yield by gravity drainage to the volume of rock or soil. The retained portion is called specific retention (Fetter, 1988).

Other types of data that may be used to estimate hydraulic properties are texture and permeability indicator information. Lithologic logs may be used to develop models of the spatial variability of texture within geologic units. These models may, in turn, be used to derive estimates of hydraulic conductivity. Permeability indicators are useful for carbonate aquifers. Such factors include geomorphic landforms, groundwater-level fluctuations, and variability of groundwater chemistry, among other factors (Rovey, 1994). Permeability indicators will not be discussed any further in this report.

Therefore, the types of data that may be used to estimate hydraulic properties are:

- Hydraulic conductivity
- Anisotropy ratios
- Hydraulic-conductivity variation with depth
- Transmissivity
- Specific capacity
- Storage coefficient/specific storage
- Specific yield

Spatially, hydraulic conductivity is log-normally distributed (Freeze and Cherry, 1979). The spatial distribution of transmissivity also follows a log-normal probability distribution. Anisotropy ratios and storage properties were assumed to be normally distributed for this study.

C.1.2.3 Objectives

The primary objectives for the hydraulic-property assessment were to:

1. Analyze the reported aquifer-testing data available for the study area and vicinity to:

   - Derive a range of hydraulic conductivity for each RMU.
   - Estimate horizontal-to-vertical anisotropy factors.
   - Derive a range of specific-yield values for all RMUs under unconfined conditions.
   - Estimate the range of specific storage for all RMUs under confined conditions.
   - Derive a relationship of hydraulic conductivity with depth for each RMU (aquifer units only).

2. Present preliminary aquifer-property data derived from SNWA tests conducted in the project basins.

C.1.2.4 Approach

The approach for this analysis is to compile the available existing aquifer-property information for the region. Data are handled and used differently depending on the process used to derive them.

Reported data derived from previous field and laboratory tests were compiled and reduced to a unified structure, ultimately creating a database. The database could then be queried based on RMU and statistically analyzed to obtain estimates of the range of hydraulic conductivity, specific yield, and specific storage by RMU. For hydraulic conductivity, the statistics were performed on the Log_{10} of the *K* values.

The partial results of the ongoing SNWA field data collection activities within the study area are reported but not incorporated in the data analysis because they are preliminary. They are presented separately and are to be used only as additional guides in the interpretation of the hydraulic properties of the RMUs at the local scale.

C.1.3 Reported Testing Data

The types of tests, the sources of data, the data reduction, the quality evaluation, and the analysis of the reported testing data are described in this section.

C.1.3.1 Type of Tests

Types of tests conducted to derive measurements of aquifer hydraulic properties include those that estimate hydraulic properties directly and those that estimate hydraulic properties in a quantitative or qualitative manner using other related data.

Methods of direct aquifer-property measurement include:

- Specific-capacity tests
- Constant-rate pumping tests
- Slug tests
- Packer tests
- Step-drawdown tests
- Drill-stem tests
- Permeameter tests

Specific capacity is typically calculated from short-duration pumping tests conducted immediately following drilling and is occasionally reported on the driller's log as the pumping rate and the total drawdown. Specific capacity may then be calculated as the ratio of the pumping rate to total drawdown. Estimates of transmissivity may be derived from specific-capacity values.

Constant-rate tests are most commonly conducted to estimate transmissivity or hydraulic conductivity and storage properties (storage coefficient or specific yield). Tests may include a single well or multiple wells and usually consist of a pumping phase and a recovery phase. Note that estimates of storage properties that are representative of the tested portion of the aquifer may be obtained only from the time-drawdown data collected from observation wells.

The pumping well is typically pumped at a constant rate for a period ranging from several hours to several days. The pumping phase involves measuring changes in water levels in the pumping well and observation wells (if any) while the well is being pumped. The recovery phase measures changes in water levels after pumping is stopped until the well recovers to pre-pumping conditions.

The resulting time-drawdown data are analyzed to derive estimates of transmissivity or hydraulic conductivity and storage properties if the test includes observation wells. The time-drawdown (or displacement) data are analyzed to derive estimates of transmissivity and storage properties.

Many methods are available for analyzing constant-rate test data in unconfined, confined, leaky, and fractured aquifers. These methods have been implemented in software packages, such as AQTESOLV. Analysis methods for constant-rate test data include Theis (1935), Theis residual drawdown (Theis, 1935), Cooper-Jacob (Cooper and Jacob, 1946), Hantush-Jacob (Hantush and Jacob, 1955), Hantush (1960, 1962), Papadopulos-Cooper (Papadopulos and Cooper, 1967), Neuman-Witherspoon (Neuman and Witherspoon, 1969), Neuman (1974), Streltsova (1974), and Moench (1984, 1985, 1993, 1996, 1997) methods.

Slug tests are usually conducted as single-well tests and provide estimates of hydraulic conductivity. During the process, a slug of water is either added to or removed from the well, and changes in water level are measured throughout the test. The resulting data are analyzed using one of the available data analysis methods. Confined-aquifer analysis methods include the Hvorslev (1951), Cooper et al. (1967), Bouwer and Rice (1976), and Hyder et al. (1994) methods. Unconfined-aquifer analysis methods include the Hvorslev (1951), Bouwer and Rice (1976), and Hyder et al. (1994) methods.

A slug test can also be conducted within a specific depth interval by isolating a section of the well using single or double packer(s). Changes in pressure are recorded using a transducer and converted to changes in hydraulic head or water level. These data are analyzed to derive estimates of transmissivity or hydraulic conductivity.

Step-drawdown tests are commonly conducted prior to constant-rate pumping tests. They are used to estimate well efficiency and optimal pumping rate. They are usually conducted with three to five consecutive short-duration pumped rates and provide estimates of the well's specific capacity, which can be used to derive an estimate of transmissivity. Step-drawdown-test data may be analyzed using the Theis (1935) step-test method.

DSTs are conducted to determine the potential of a producing oil or gas formation. The DST tool is placed on the bottom of the drill stem and lowered into the hole. Weight is applied to the tool to expand a hard rubber sealer (packer). To start the test, the tool ports are opened to the formation. A transducer records pressure versus time during pressure buildup. The time-pressure data may be analyzed to derive an estimate of transmissivity.

Permeameter tests are conducted on rock cores in the laboratory. A fluid (gas or liquid) is injected into the core at various pressures, and the differential pressure and flow rates are recorded. This information is then used in a Darcy's equation to calculate the permeability of the core sample. These tests provide small-scale estimates of permeability or hydraulic conductivity.

C.1.3.2 Data Sources

Data sources of aquifer-property data were subdivided into two main categories: (1) site-specific-testing data sources and (2) regional-testing data sources.

C.1.3.2.1 Site-Specific-Testing Data Sources

Site-specific-testing data sources are defined as reports or databases containing data for basins within the study area (Figure 1-1).

The main site-specific data sources cover more than one basin and are:

- MX Well tests (Ertec Western, Inc. reports, 1981 a through c; Bunch and Harrill, 1984)
- Driller's logs (NDWR, 2004; UDWR, 2005)
- Drill-stem tests (McKay and Kepper, 1988)
- White Pine Power Project well tests (Leeds, Hill, and Jewett, Inc., 1981a and b, 1983)

Other site-specific data sources cover a single basin located within the study area and are:

- Coyote Spring Valley (Berger et al., 1988; Johnson et al., 1998; Converse, 2002)
- Three Lakes Valley South (Converse, 1997, 1998a and b)
- Dry Lake Valley (SRK, 2001; Johnson, 2002)
- Meadow Valley (URS, 2001)
- Moapa Valley (Mifflin & Associates, 2001)
- Tule Desert (HydroSystems, 2002)

C.1.3.2.2 Regional-Testing Data Sources

Regional-testing data sources are defined as reports or databases containing data for regions including or located near the study area.

The main sources of regional data include:

- DVRFS Model data (Belcher et al., 2001)
- NTS Regional Model data (IT, 1996)
- Slug-test data (SNJV, 2004c)

Other sources of regional data are as follows:

- IT (2002 a through i)
- SNJV (2004a, b, d, and e)
- Questa Engineering (1999 a through c, 2000a and b, 2001, 2002a through c, 2003)
- Maurer et al. (2004)

C.1.3.3 Data Reduction

Data reduction for the hydraulic-property data set began with the calculation of hydraulic-conductivity estimates for the NDWR (2004) and UDWR (2005) specific-capacity data sets. All of the individual data sets were then formatted into the same fields of information, and all values were converted to a standard set of units. This formatting and standardization process included mapping the hydrogeologic or lithologic information to an RMU (Table 4-1). Formatting also involved the standardization of site names and the creation of a site-location table for unique locations. The individual data sets were then combined, and duplicate records were identified, flagged, and removed from the well-testing data set. Hydraulic conductivity was calculated when test interval thicknesses were available for transmissivity values. Finally, an aquifer-property database was constructed from the resulting location and property tables (SNWA, 2006). Figure C-1 shows the locations of aquifer-test data within the aquifer-property database.

C.1.3.4 Data-Quality Evaluation

The record documentation and the test type and scale were factors considered in the data-quality evaluation of each record of the combined data set as described in this section.

Record documentation includes the documentation of the test itself and the data analysis used to derive the aquifer properties. A data documentation evaluation flag was applied to each record in the well-testing data set. The levels of documentation are described below:

- Level 1: Data containing detailed information about how the properties were determined, including information on test type, dates of testing, pumping or injection rates, radius or interwell distances, transmissive intervals, lithologic or stratigraphic descriptions, analytical method, and source. This level also includes all of the data from Belcher et al. (2001).

- Level 2: Data containing all of the properties listed in Level 1 but missing the dates of testing.

- Level 3: Data containing most of the properties listed in Level 1 but missing multiple fields of relevant information, including dates, average pumping or injection rates, or radius or interwell distances.

- Level 4: Data missing information on analytical method, test types, or transmissive intervals. This level also includes NDWR and Utah Division of Water Rights Driller's Log information.

- Level 5: Data missing hydraulic-property values or the information required to calculate the values.

The type and scale of the test are extremely important when assessing the quality of a test for the intended purpose, especially for fractured HGUs. The following test types may be grouped according to their scales from largest to smallest: (1) multiple-well, constant-rate pumping tests; (2) single-well, constant-rate pumping tests; (3) specific-capacity and DSTs; (4) slug, packer, and step-drawdown tests; and (5) permeameter tests.

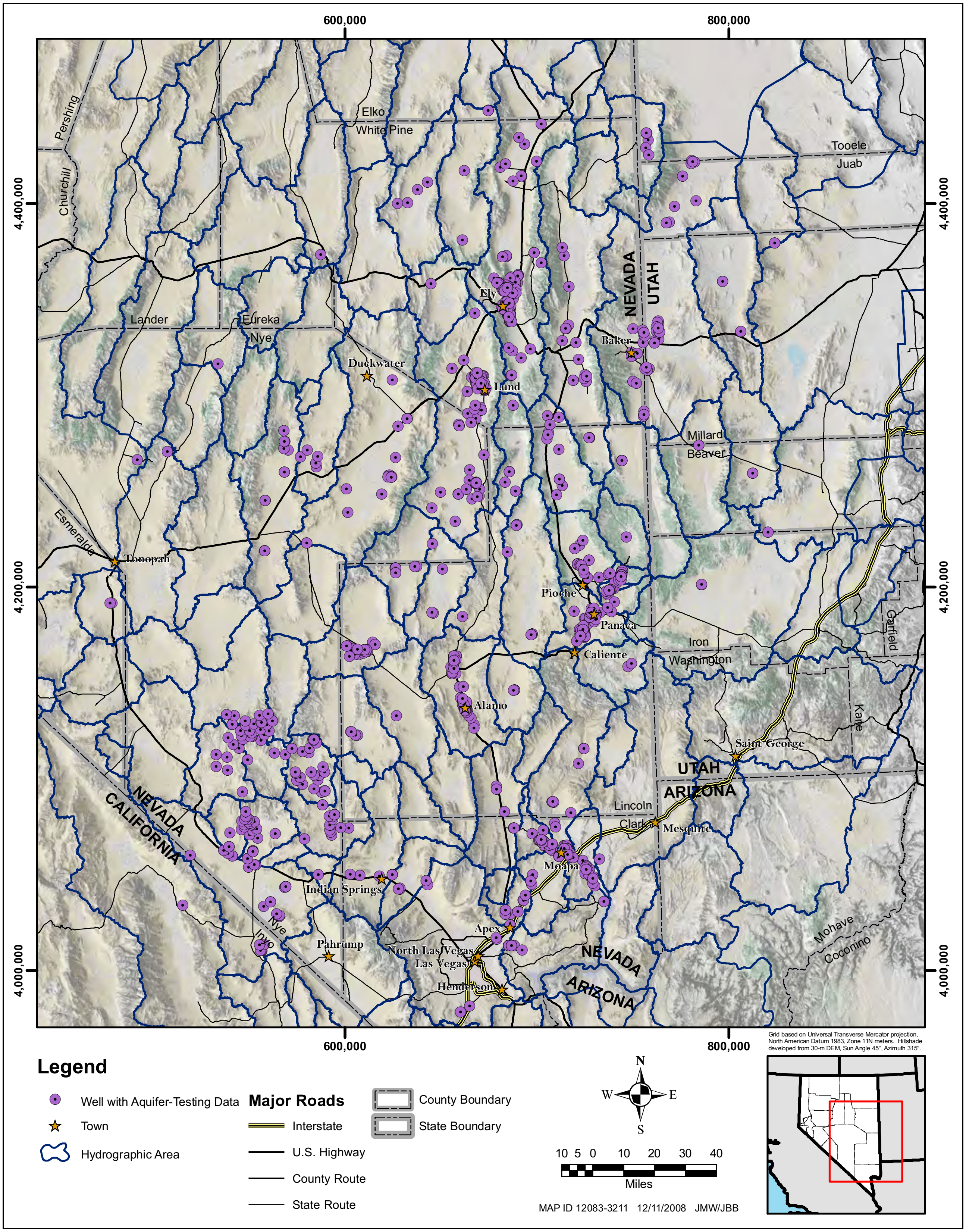

Figure C-1
Locations of Aquifer-Property Data

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C.1.3.5 Reported Test Data Limitations

General data limitations include:

- Limited data in project basins
- Limited tests from deep wells
- Limited number of multiple-well tests
- Limited number of long-term pumping tests
- Assumed thickness of the open interval
- Analytical methods based on aquifer assumptions

In addition, a positive bias for the average hydraulic conductivity is often observed because many wells are screened preferentially across more productive zones (Belcher et al., 2002).

C.1.3.6 Data Analysis

The analysis of the reported testing data is subdivided into four parts: (1) analysis of lithologic data from driller's logs, (2) statistical analysis of hydraulic properties, (3) analysis of hydraulic conductivity with depth, and (4) analysis of hydraulic conductivity versus depth.

C.1.3.6.1 Analysis of Lithologic Data

An attempt was made to use the available lithologic data contained in driller's logs to derive a spatial distribution of hydraulic conductivity using a method that converts lithologic data into texture, which is then converted to hydraulic conductivity. Driller's logs for wells drilled in the UVF RMU and for which lithologic data are available are shown in Figure C-2.

This texture analysis method was used by Burrow et al. (2004) for the Modesto, California, area. As part of the Modesto study, approximately 3,500 well logs were compiled for an area of approximately 900 mi^2. Geostatistical methods were then applied to develop a spatial correlation model of the percentage of coarse-grained texture. This model was created by converting the lithologic information in driller's logs into a bivariate distribution of texture, where a value of 100 percent was assigned to coarse-grained lithologies and 0 percent was assigned to fine-grained lithologies. The 1-m data were then re-sampled, and a 3D krigged model was created to show the percentage of coarse-grained material. This model was then used as a surrogate for hydraulic conductivity and demonstrated that, in the Modesto area, the composition of alluvial materials is significantly heterogeneous, and therefore the hydraulic conductivities would be heterogeneous.

A similar methodology was attempted with 964 driller's logs within the northern groundwater project study area as part of this study. The results of this work indicated that there were not enough data within the study area for this method to be useful. The spatial distribution of data was not sufficient for contouring, and there was a general lack of data within the project basins. The other problem encountered was that the valley fill in many of the study area basins is several thousands of feet thick, while the wells are generally drilled to the water table or slightly below. This results in a deficiency

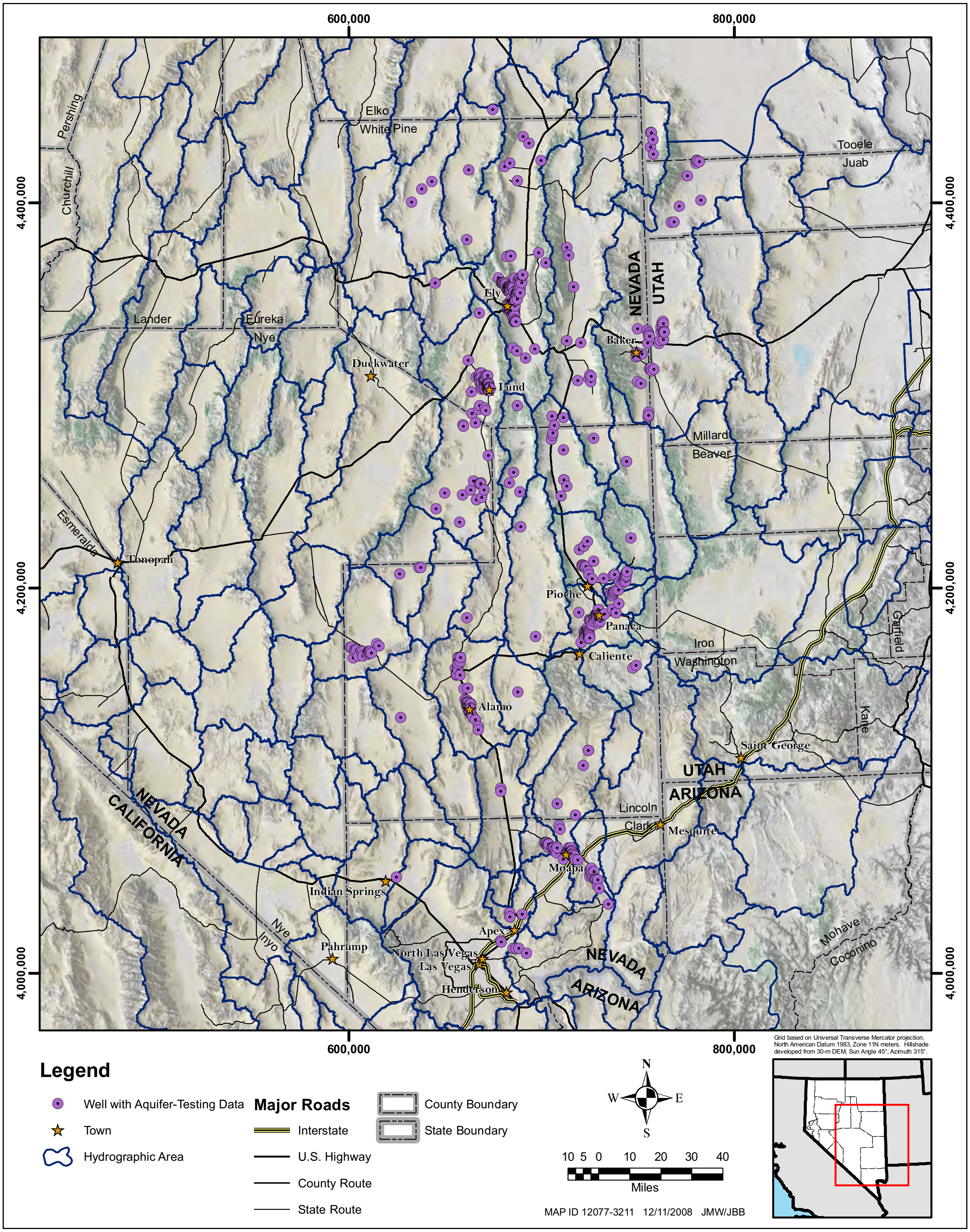

Figure C-2
Locations of Driller's Logs and Specific-Capacity Data for the UVF

of textural data for all but the uppermost alluvium. Therefore, this method was not used to determine hydraulic properties for this study.

C.1.3.6.2 Statistical Analysis of Hydraulic Properties

The data processing methodology and estimates of aquifer properties derived from the reported testing data are presented in this section. The data analysis does not include the preliminary results for the new SNWA monitor and test wells.

C.1.3.6.2.1 Methodology

Data analysis began with querying the aquifer-property database and extracting hydraulic-property information for all eight RMUs. The data were analyzed using two subsets of the data set, hydraulic conductivities and aquifer-storage properties, queried from the database:

The first subset was focused on hydraulic conductivity, as this property may be derived from all test types. However, this data subset was also used to derive estimates of other properties. The data were grouped by test type and quantity of available information. While duplicate records were removed before entry into the database, it was still possible to have multiple unique results for the same well interval. To keep these instances from creating a statistical bias, either a preferred value was accepted or the geometric mean of the values for the interval was calculated and applied. The data from Belcher et al. (2001) were considered to be high reliability and therefore were considered a preferred value. The higher weight applied to the Belcher et al. (2001) data stems from their re-analysis of tests before acceptance into their own data set. This processing reduced the data set to a set of records, each representing a single tested interval in a given well. Values of hydraulic conductivities were then transformed to Log_{10} values based on the assumption of a log-normal distribution for this property. Descriptive statistics, including the geometric means, standard deviations, minimum, and maximum, were calculated using the Log_{10} hydraulic-conductivity values for each RMU and test-type grouping. This reduced data set was also used to (1) conduct the analysis of the relationship of horizontal hydraulic conductivity with depth, (2) extract and summarize the few values of vertical anisotropy that are available, and (3) conduct a preliminary statistical analysis of the storativity and specific-yield data.

The estimates of storativity derived from the first data subset may not be representative of the aquifer units, as some of the records include estimates obtained from single-well aquifer tests. Aquifer-storage properties are most representative of the aquifer when they are derived from time-drawdown data collected from observation wells in multiple-well constant-rate aquifer tests. Thus, a second data subset was derived from the first subset. Because aquifer-storage properties are only needed for the aquifer RMUs, i.e., the UVF, LVF, and UC/LC RMUs, records for these RMUs corresponding to multiple-well constant-rate aquifer tests were extracted from the first data subset. This data subset was used to derive estimates of specific yield and specific storage. Because estimates of transmissivities in this data subset are also believed to be more representative of the tested aquifers, they were also statistically summarized from this data subset. Note that data records containing specific-yield values are identical in both data subsets because specific yield was only reported for observation wells.

C.1.3.6.2.2 Results

The results of the hydraulic-property data analysis are presented in this subsection. Statistics derived for horizontal hydraulic conductivity from the first data subset are presented in Table C-1 according to the type of test used to derive the estimates. The results of the analysis conducted using the second data subset are summarized in Table C-2. Analysis results for vertical anisotropy, specific yield, and storativity derived from the first data subset are presented by RMU in the following sections.

Table C-1
Hydraulic-Conductivity Estimates

Test Type	Log$_{10}$ Hydraulic Conductivity (ft/day)				
	Mean	Standard Deviation	Minimum	Maximum	Number of Analyses
Upper Valley Fill (UVF RMU)					
Constant-Rate Test	1.07	1.15	-3.71	3.56	132
Specific-Capacity Driller's Logs	1.11	0.81	-1.76	3.35	850
Step-Drawdown\Swabbing Recovery	0.49	0.90	-3.51	1.59	26
Slug Test	-1.05	1.56	-3.69	1.47	19
Bailing	-0.45	0.08	-0.51	-0.39	2
Lower Valley Fill (LVF RMU)					
Constant-Rate Test	0.29	1.04	-2.62	2.53	136
Drill-Stem Tests	-1.99	0.62	-2.79	-1.46	5
Slug Test	-2.10	1.07	-6.31	1.11	958
Borehole Flow Logging	1.05	1.12	-1.67	2.93	28
Laboratory	-4.40	1.56	-6.61	-0.17	118
Intrusive Rock (PLUT RMU)					
All Test Types	-1.50	1.39	-2.73	0.67	7
Cretaceous to Triassic Siliciclastic Rock (Kps RMU)					
Drill-Stem Tests	-2.20	0.85	-3.20	-0.04	16
Mississippian Siliciclastic Rock (UA RMU)					
Constant-Rate Test	-1.24	1.52	-2.96	1.17	6
Drill-Stem Tests	-2.60	0.67	-3.07	-2.13	2
Slug Test	-1.16	0.95	-2.14	0.10	5
Borehole Flow Logging	-2.25	0.46	-3.07	-1.24	32
Carbonate Rock (UC/LC RMU)					
Constant-Rate Test	0.73	1.24	-1.56	3.50	89
Step-Drawdown\Swabbing Recovery	1.61	1.65	-1.00	3.71	7
Drill-Stem Tests	-1.13	1.65	-5.03	1.26	17
Slug Test	-0.17	1.08	-1.25	3.00	21
Bailing	-0.68	0.25	-0.86	-0.50	2
Borehole Flow Logging	2.39	0.59	1.38	3.63	22

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Table C-2
Transmissivity, Specific-Yield, and Specific-Storage Values for Aquifer RMUs

RMU	Aquifer Property Name and Unit	Mean Value	Minimum Value	Maximum Value	Number of Data points
UVF	T (ft^2/d)	10,801	39	72,719	44
UVF	T (ft^2/d)[a]	5,039	39	72,719	44
UVF	Sy	0.0424	0.0004	0.2870	17
UVF	Ss (1/ft)	1.21E-04	1.72E-07	3.38E-03	36
LVF	T (ft^2/d)	8,711	43	34,432	11
LVF	T (ft^2/d)[a]	2,547	43	34,432	11
LVF	Sy	0.0023	0.0020	0.0030	3
LVF	Ss (1/ft)	6.75E-06	1.03E-07	3.44E-05	10
UC/LC	T (ft^2/d)	291,071	963	1,000,000	4
UC/LC	T (ft^2/d)[a]	48,809	963	1,000,000	4
UC/LC	Sy	0.0160	0.0012	0.0309	2
UC/LC	Ss (1/ft)	8.26E-06	4.67E-07	1.24E-05	3

[a]Values derived using Log_{10} values of transmissivity.

UVF RMU

Data available for the UVF RMU includes specific-capacity data and results of aquifer tests. Figure C-2 shows the distribution for driller's logs for which specific-capacity data are available, and Figure C-3 shows the distribution of all other test types in the UVF. Table C-1 contains a statistical summary for the horizontal hydraulic conductivity of the UVF. Table C-2 contains statistical summaries for the transmissivity, specific yield, and specific storage of the UVF.

Compared to the other RMUs, more site-specific hydraulic-property data are available for the UVF RMU. However, the available data (first data subset) are very spatially limited. Tested intervals for the constant-rate data include depths as great as 3,676 ft bgs; however, a majority of the tested depths were less than 1,000 ft deep. Based on 132 constant-rate tests, the mean K is 11.7 ft/day with a range of 0.0002 to 3,636 ft/day. Specific-yield estimates were available for 18 different wells or intervals for the UVF. Specific-yield estimates ranged from 0.0004 to 0.287 with an arithmetic mean of 0.043 after removing the suspect value of 0.0004. Belcher et al. (2001) removed the 0.0004 value from their statistics stating that the method used to derive it was not applicable. Storativity estimates were available for 58 different wells or intervals for the UVF and ranged from 1.04×10^{-15} to 0.7 with an arithmetic mean of 0.017. There are three tests in the UVF where the vertical anisotropy of hydraulic conductivity was measured. The vertical anisotropy factor, expressed as the horizontal-to-vertical hydraulic-conductivity ratio, ranges between 3 and 333.

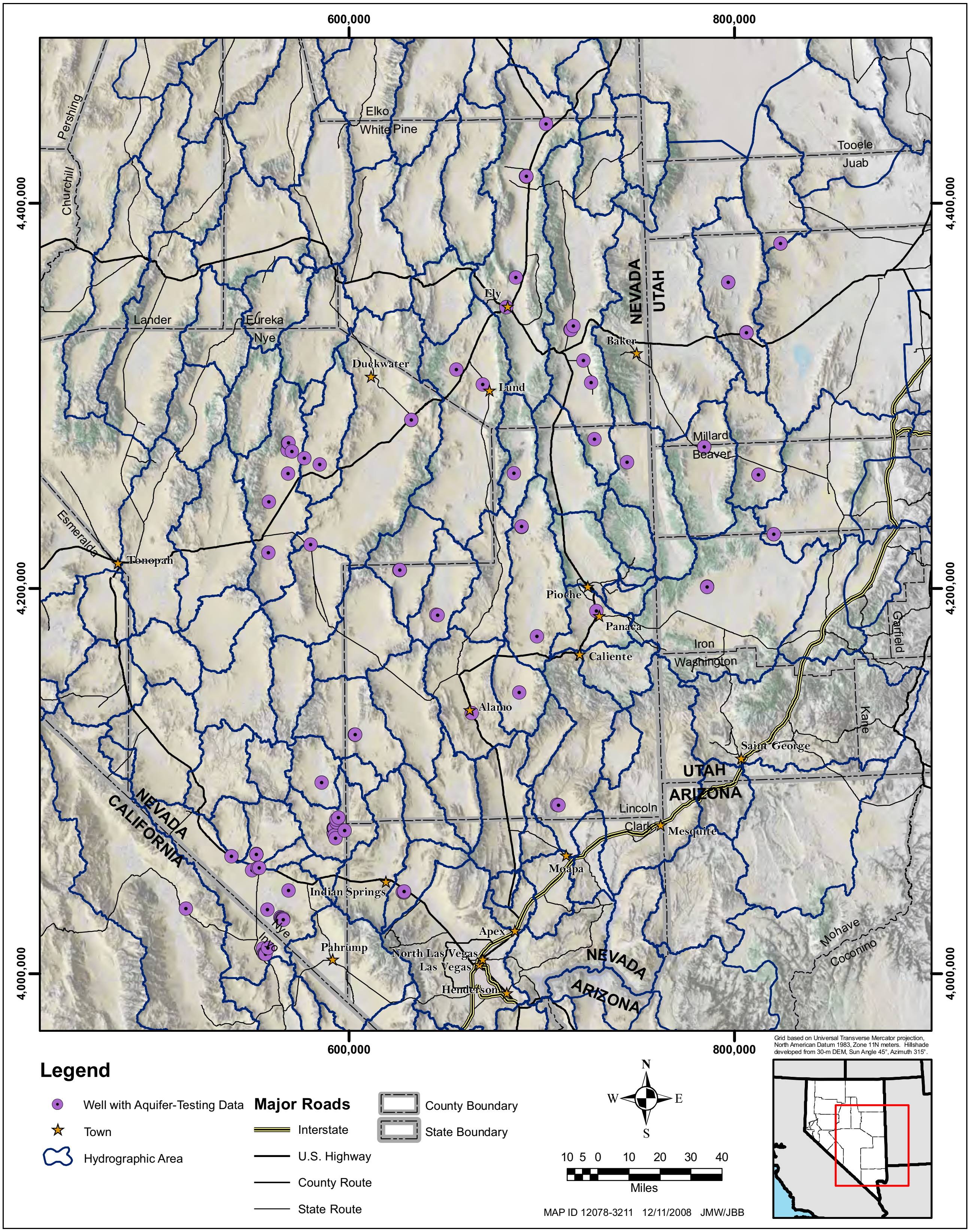

Figure C-3
Locations of Reported Aquifer-Property Data for the UVF

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LVF RMU

Most of the LVF data locations are clustered around the NTS and Yucca Mountain, although some data are within Lincoln and northern Nye counties (Figure C-4). Table C-1 contains a statistical summary for the horizontal hydraulic conductivity of the LVF. Table C-2 contains statistical summaries for the transmissivity, specific yield, and specific storage of the LVF.

Tested intervals for the constant-rate test data include depths as great as 13,689 ft bgs. Analyses of constant-rate test data yielded a mean horizontal hydraulic conductivity of 1.95 ft/day and a range of 0.002 to 339 ft/day. Seven tests to measure the vertical-to-horizontal anisotropy within this RMU were conducted in two boreholes completed in the LVF. The anisotropy factors (horizontal-to-vertical hydraulic-conductivity ratios) range from 0.5 to 40. Specific-yield estimates were available for 10 intervals within two wells for the LVF. Specific-yield estimates ranged from 0.001 to 0.2 with an arithmetic mean of 0.032. Storativity estimates were available for 308 intervals within 35 wells for the LVF. Storativity estimates ranged from 0.00001 to 0.04 with an arithmetic mean of 0.000665.

PLUT RMU

Very few aquifer tests have been performed in this RMU, and the data in the aquifer-property database come from tests performed at the NTS and at well UCE-1 in northern Nye County. Table C-1 contains a statistical summary for the horizontal hydraulic conductivity of the PLUT. Because there are only seven measurements, they were all incorporated as a single statistical output. The derived mean horizontal hydraulic conductivity is 0.032 ft/day. No information is available for vertical anisotropy, specific yield, or specific storage for the PLUT.

Kps RMU

Table C-1 contains a statistical summary for the horizontal hydraulic conductivity of the Kps. Only one DST in Virgin River Valley (HA 222) was conducted for the Kps RMU (Figures B-3 and B-4, Appendix B). Sixteen other tests were conducted in south-central Utah in sedimentary rocks of the Colorado Plateau. The Colorado Plateau data should be transferable to the study area because both areas contain some of the same formations with similar lithologies. The mean value of horizontal hydraulic conductivity is 0.006 ft/day. No data are available for vertical anisotropy, specific yield, or storativity for the Kps.

UA RMU

Most of the aquifer-property data for the UA (Figure C-5) come from tests conducted on the NTS, with a few additional tests in northern Nye and White Pine counties. Table C-1 contains a statistical summary for the horizontal hydraulic conductivity of the UA. The mean value of horizontal hydraulic conductivity derived from these data is 0.058 ft/day. No information is available for conductivity anisotropy, specific yield, or storativity for the UA.

LC and UC RMUs

The LC and UC have the second greatest number of site-specific test information with aquifer test data in northern Nye, Lincoln, and White Pine counties and the southern part of the study area (Figure C-6). Table C-1 contains a statistical summary for the horizontal hydraulic conductivity of

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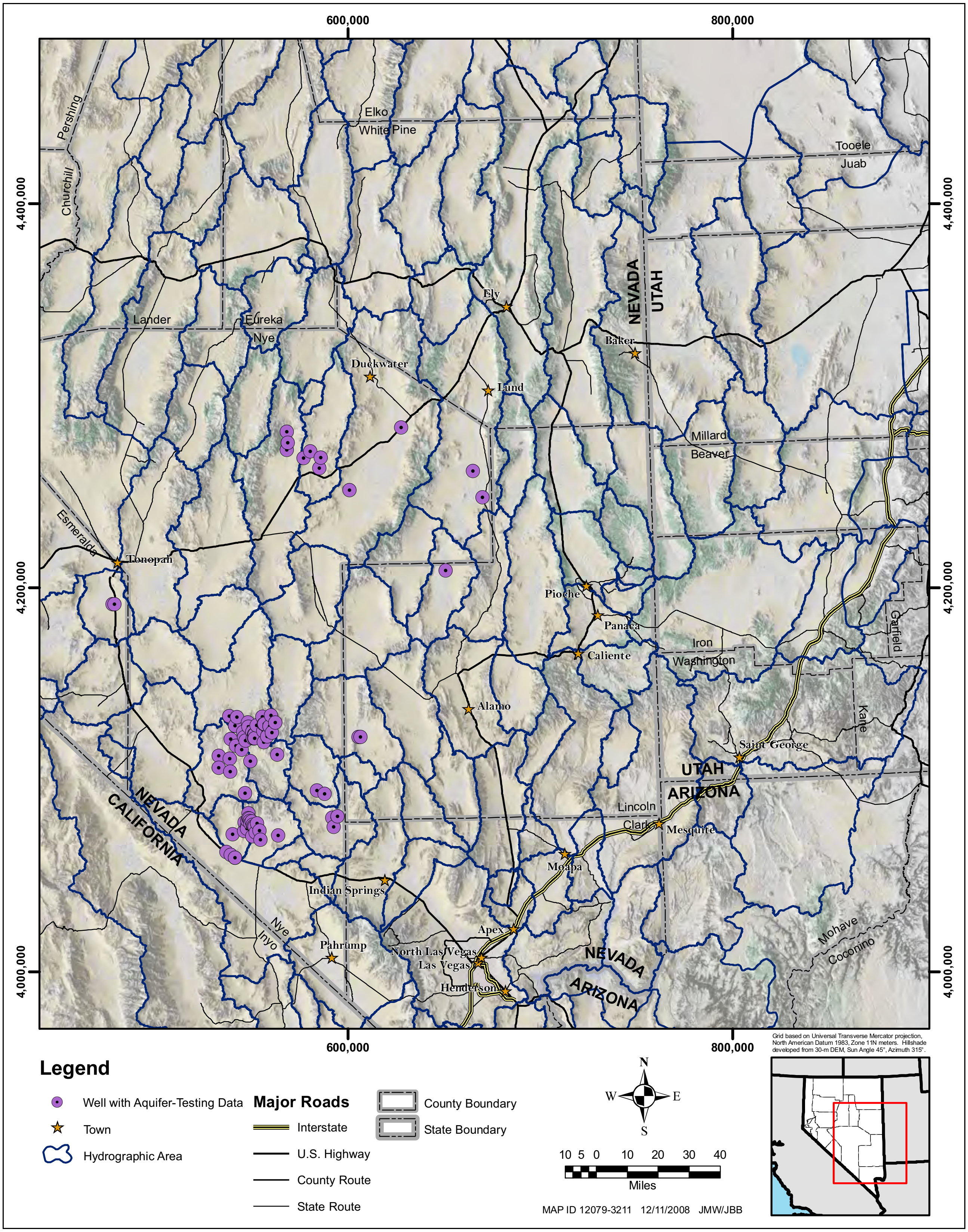

Figure C-4
Locations of Reported Aquifer-Property Data for the LVF

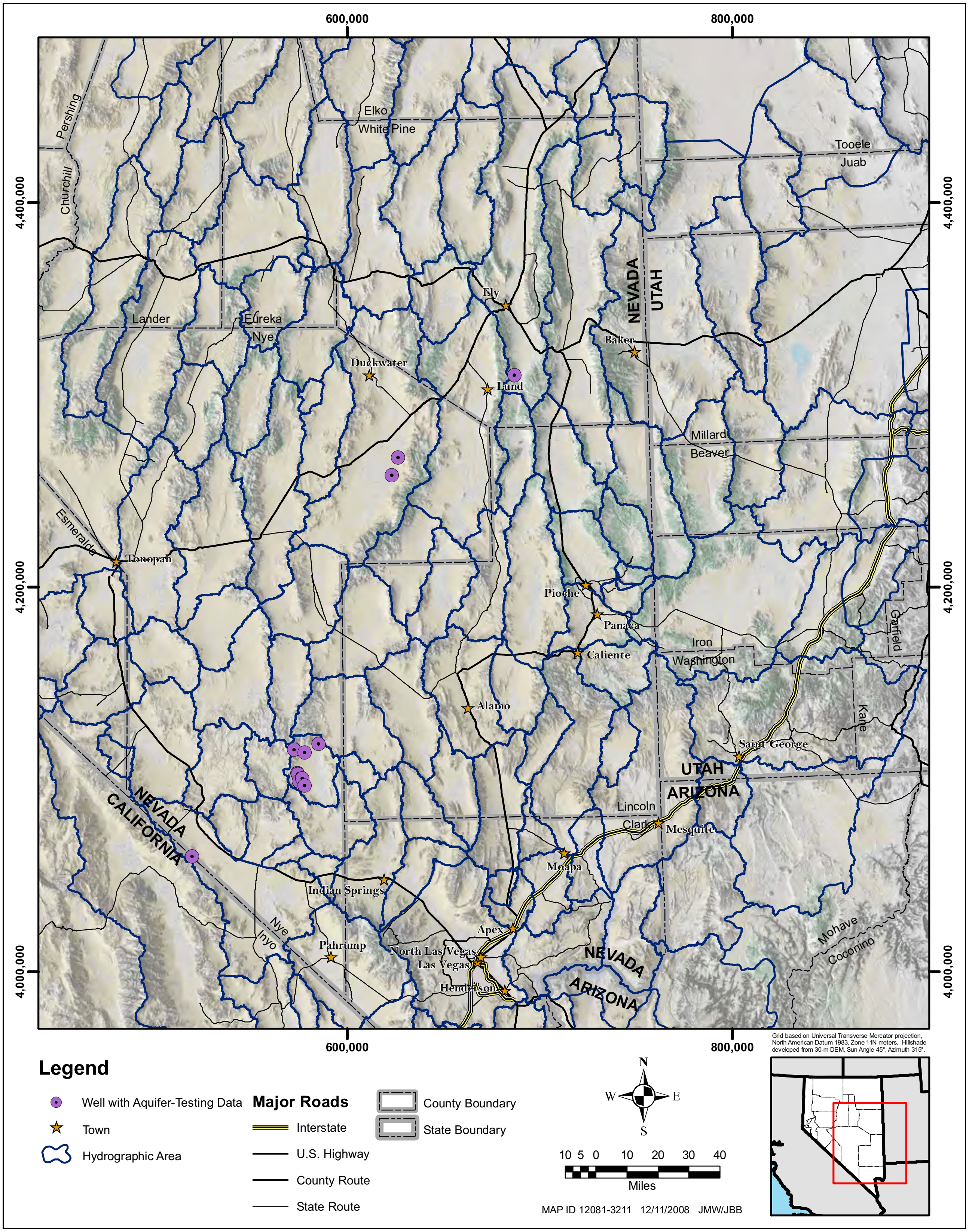

Figure C-5
Locations of Reported Hydraulic-Property Data for the UA

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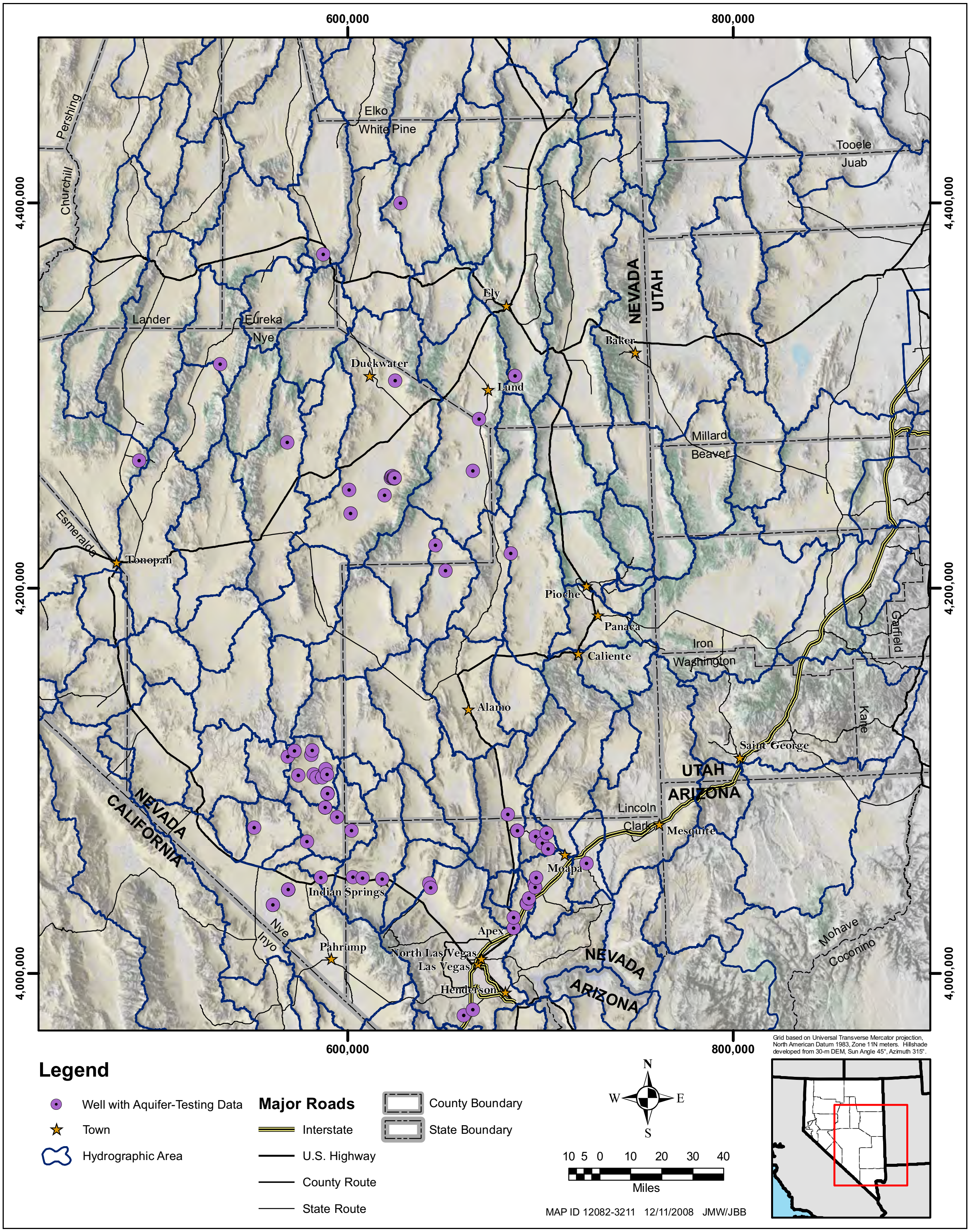

Figure C-6
Locations of Reported Aquifer-Property Data for the UC and LC

the LC and UC RMUs. Table C-2 contains statistical summaries for the transmissivity, specific yield, and specific storage of the UC and LC RMUs.

Tested intervals for the constant-rate data include depths as great as 5,923 ft bgs. The mean value of horizontal hydraulic conductivity derived from these data is 5.37 ft/day with a range of 0.028 to 3,158 ft/day. There are two tests in the carbonate rocks where the horizontal-to-vertical anisotropy was measured. These ratios range from 2 and 143. Specific-yield estimates were available for two wells in the UC and LC and were 0.001 and 0.031. There are 10 analyses of storativity for the UC and LC with a range of 1.7×10^{-9} to 8.14×10^{-3} and an arithmetic mean of 1.68×10^{-3}. The relatively large range of transmissivity listed in Table C-2 is probably more representative of faults, as the few data records were obtained from aquifer tests conducted in fault zones.

BASE RMU

No data exist in the aquifer-property database for the BASE unit.

C.1.3.6.3 Analysis of Hydraulic Conductivity with Depth

In theory, rock permeability decreases with depth resulting from the increasing pressure exerted by the overburden. In reality, many other factors also influence rock permeability. Nonetheless, as data are usually lacking for large depths, many studies attempted to define a relationship between permeability (or hydraulic conductivity) and depth. In this section, a literature review of selected studies is presented, followed by the analysis of the testing data versus depth.

C.1.3.6.3.1 Literature Review

The variability of permeability (or hydraulic conductivity) with depth has been studied for various reasons, including understanding the degassing of the Earth, locating and extracting oil, and modeling groundwater flow in the upper crust of the earth. Summaries of selected studies conducted by Ingebritsen and Manning (1999), Saar and Manga (2004), Bedinger et al. (1989), IT (1996, 1997), D'Agnese et al. (1997), Belcher et al. (2001), Belcher (2004), and SNJV (2008) are presented.

Some of the studies were performed using metric units. For consistency with the author's reports, the units will be left in the metric system. To convert from meters to feet, divide the value in meters by 0.3048 to obtain feet.

Ingebritsen and Manning (1999)

To understand the degassing of the Earth, Ingebritsen and Manning (1999) derived the following relationship between the permeability of the continental crust and depth, using geothermal data and calculated fluid flux during metamorphism:

$$\text{Log } k = 14 \ 3.2 \text{ Log } z \qquad \text{(Eq. C-1)}$$

where,

k = Permeability (m^2)
z = Depth below ground surface (km)

At crustal depths greater than about 5 km, the relationship was mainly derived from data from prograde metamorphic systems. Therefore, the relationship is applicable to orogenic belts where the Earth's crust is undergoing thickening and/or heating.

Saar and Manga (2004)

Using data from the Oregon Cascades, Saar and Manga (2004) studied the decrease in permeability with depth. They used four methods, each of which is applicable to a different depth scale:

- For depths of less than 0.1 km, they used spring discharge models to estimate horizontal permeabilities.
- For depths of less than 1 km, they used simulations of coupled heat and groundwater flow to estimate horizontal and vertical permeabilities.
- For depths of less than 5 km, they derived estimates of vertical permeability from statistical investigations of earthquakes believed to be triggered by groundwater recharge.
- For depths of less than 15 km, they derived estimates of vertical permeability from considerations of magma intrusion rates and water devolatilization.

Saar and Manga (2004) found that for depths greater than 0.8 km, their results are similar to the power law relationship derived by Ingebritsen and Manning (1999) Equation C-1. However, for depths shallower than or equal to 0.8 km and up to 2 km, Saar and Manga (2004) defined the following relationship:

$$k = 5 \times 10^{-13} \times e^{(-z/0.25)} \quad \text{(Eq. C-2)}$$

where,

k = Permeability (m^2)
z = Depth below ground surface (km)

Saar and Manga (2004) found that this relationship fits the data better than the relationship developed by Ingebritsen and Manning (1999). In addition, their relationship provided estimates of permeability for near-surface and zero depths. The two relationships, Equation C-1 and Equation C-2, are consistent at a depth of 0.8 km, yielding a smooth transition between the two.

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Bedinger et al. (1989)

In support of high-level radioactive-waste isolation studies, Bedinger et al. (1989) evaluated the hydraulic properties of rocks in the Basin and Range Province. For crystalline rocks below the weathered horizon, they found that permeability data from a single borehole do not usually display a consistent decrease with depth. However, they reported that in larger data sets, permeability values collected at depths of less than 1,000 m display a decrease with depth. Furthermore, they reported that the decrease in permeability is apparently greater for depths above 300 m than for larger depths. Bedinger et al. (1989) also derived distributions of hydraulic conductivity for the HGUs present in the region. Their distribution of hydraulic conductivity accounts for variations in rock properties caused by depth and degree of faulting.

IT Corporation (1996 and 1997)

As part of the development of the NTS regional model, IT (1996, 1997) used the data available at the time to derive relationships between hydraulic conductivity and depth to help estimate the total depth of the flow system and the hydraulic conductivities of the deeper units. A relationship was developed for each of the major aquifers: the Alluvial Aquifer, the Volcanic Aquifer, and the Lower Carbonate Aquifer. The relationships represent the decreasing linear trends observed in the logarithm of hydraulic conductivity with increasing depth. The relationships, therefore, exhibit an exponential decrease of hydraulic conductivity with depth and are provided by the following equation:

$$K_{depth} = K_h(10^{-Dd}) \qquad \text{(Eq. C-3)}$$

where,

K_{depth} = Horizontal hydraulic conductivity at specified depth
K_h = Horizontal hydraulic conductivity at land surface
D = Decay coefficient (calculated from linear regression)
d = Depth from land surface

The rate of decrease of K with depth is controlled by the decay coefficient. The values of the decay coefficient for the three aquifers are provided in Table C-3.

Table C-3
Hydraulic-Conductivity Decay Coefficients with Depth

Aquifer	Mean Decay Coefficient (1/day)	Mean *K* at Land Surface (m/day)
Alluvial Aquifer	0.00563	21.18
Carbonate Aquifer	0.00102	6.76
Volcanic Aquifer	0.00256	7.75

Source: DOE (1997)

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D'Agnese et al. (1997)

D'Agnese et al. (1997) developed a groundwater flow model for the DVFS. They used the findings of Bedinger et al. (1989) to incorporate a decrease in the hydraulic conductivity between depths of 300 to 1,000 m. Except in regional fault zones, they assumed that at depths greater than 1,000 m, permeability is probably representative of the rock matrix. At depths greater than 5,000 m, they assumed that faults and fractures are closed because of the overburden pressure (D'Agnese et al., 1997).

Belcher et al. (2001)

In support of the DVRFS model, Belcher et al. (2001) examined the relationship between hydraulic conductivity and depth for the HGUs of the Death Valley region. Similar to IT (1996), they found that the best correlation is provided by the log-transformed hydraulic-conductivity estimates versus the nontransformed depth values.

To evaluate the relative importance of HGUs and depth changes in the variations of hydraulic conductivity, they initially combined all data into a single data set. Using Analysis of Covariance (ANCOVA), they found that both depth and HGU are important factors at the same probability level of 0.025. Then they subdivided the data set by HGU and regressed each of the 15 data subsets separately (one for each HGU). Results from the ANCOVA showed a significant relationship between hydraulic conductivity and depth. The probability level was 0.025 for five of the HGUs, including the younger and older alluvial aquifers and the upper and lower carbonate aquifers. Belcher et al. (2001) observed that despite the relatively strong relationship with depth, hydraulic conductivity can greatly vary at any given depth. The variations are probably caused by factors other than depth, such as bedding, heterogeneity, or structural features. Belcher et al. (2001) also attributed some of the decreasing trend in hydraulic conductivity with depth to the process of deriving hydraulic conductivities from transmissivity values.

Belcher (2004)

Belcher (2004) developed the DVRFS model using MODFLOW-2000 where the *K* versus depth relationship was programmed into the hydrogeologic unit flow module of the program.

Several groundwater flow models developed by the DOE for the NTS and/or the Yucca Mountain Project used a hydraulic conductivity versus depth relationship of the form:

$$\text{Log } K = Ad + \text{Log } K_0 \qquad \text{(Eq. C-4)}$$

where,

K = Hydraulic conductivity at depth d
K_0 = Hydraulic conductivity projected to a reference surface
A = Depth-dependence coefficient, calculated from linear regression
d = Depth below the reference surface

SNJV (2008)

To address concerns about the apparent low correlation between hydraulic conductivity and depth previously derived from the available data (IT, 1996, 1997), SNJV (2008) developed an alternate method of data evaluation.

SNJV (2008) recognized that the variation of hydraulic conductivity within formations is due to two factors: natural variability and the effect of the overburden pressure (depth). The previous method (regression of $Log_{10}[K]$ versus depth) lumps the two factors to yield a measure of the overall variability. In the alternate method, after the regression is conducted, the derived equations are used to calculate hydraulic conductivity at the surface (K_0) for each data point. The resulting data set is then used to analyze the spatial variability of hydraulic conductivity.

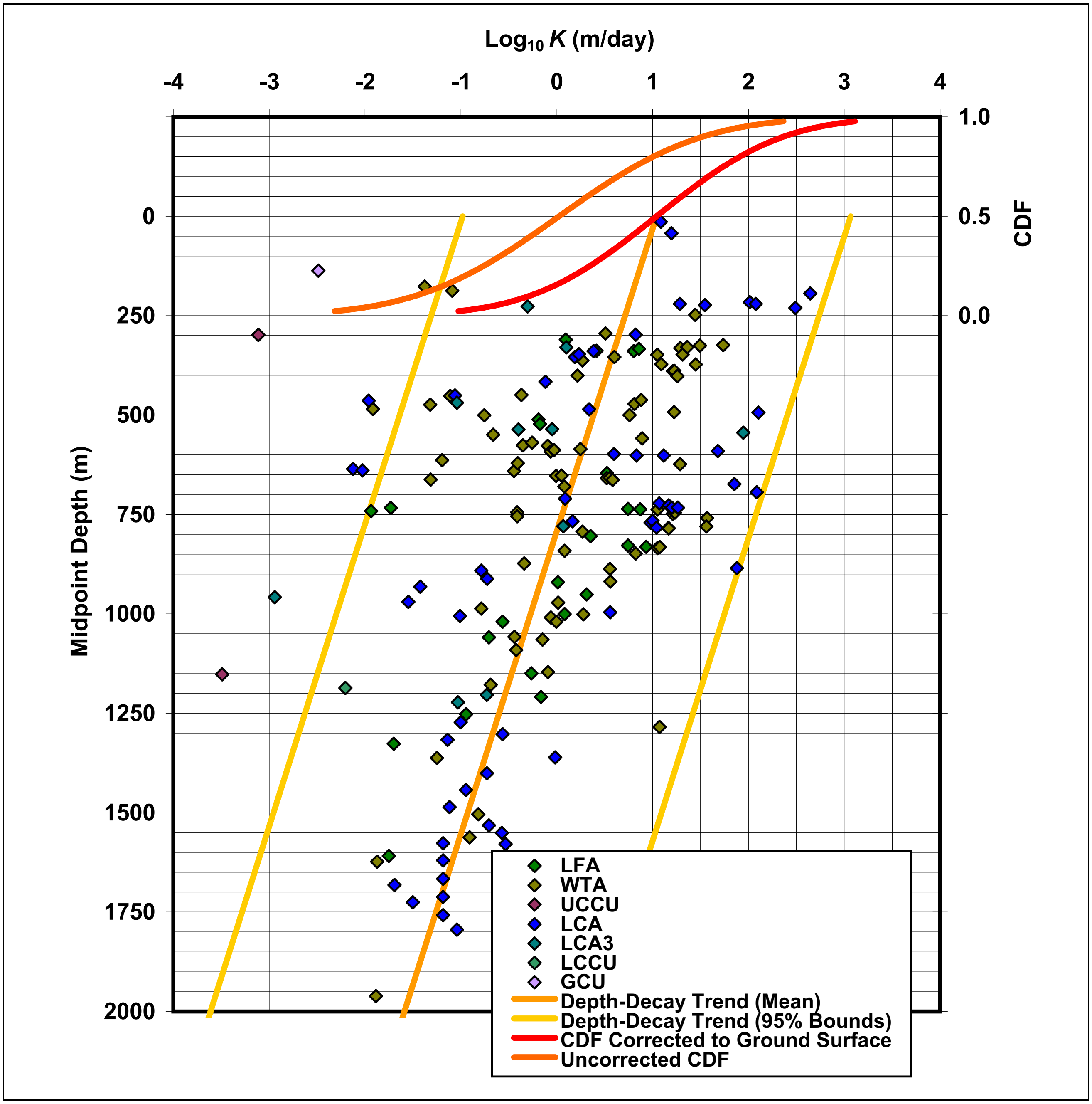
The HGUs were subdivided into two groups based on the effect of increasing overburden pressure on the formations:

- Brittle, fractured rocks
    - Granite Confining Unit (GCU)
    - Lava Flow Aquifer (LFA)
    - Lower Carbonate Aquifer (LCA/LCA3)
    - Lower Clastic Confining Unit (LCCU)
    - Upper Clastic Confining Unit (UCCU)
    - Welded Tuff Aquifer (WTA)
- Ductile, porous formations
    - Alluvial Aquifer (AA)
    - Older Alluvial Aquifer (OAA)
    - Playa Confining Unit (PCU)
    - Tuff-Confining Unit (TCU)

For the brittle group, the overburden pressure reduces fracture apertures. For the ductile group, the overburden pressure increases consolidation. The results of the linear regressions of $Log_{10}(K)$ versus depth, including the 95 percent confidence bounds, are shown on Figures C-7 and C-8. Both linear fits yielded the same correlation coefficient of -0.42. The probability distributions of all hydraulic conductivity values and of the hydraulic conductivity at the surface (K_0) are represented by cumulative density functions (CDFs) in Figures C-7 and C-8.

C.1.3.6.4 Analysis of Hydraulic Conductivity versus Depth

For this study, the relationship of hydraulic conductivity and depth was analyzed using the data within the aquifer-property database. The hydraulic-conductivity values were queried from the database and separated by RMU and test type. The hydraulic conductivities were then converted to Log_{10} and plotted against the midpoint of the depth interval they represent. Three plots were created to display the $Log_{10}(K)$ for the LC, LVF, and UVF RMUs (Figures C-9, C-10, and C-11). A linear trend line



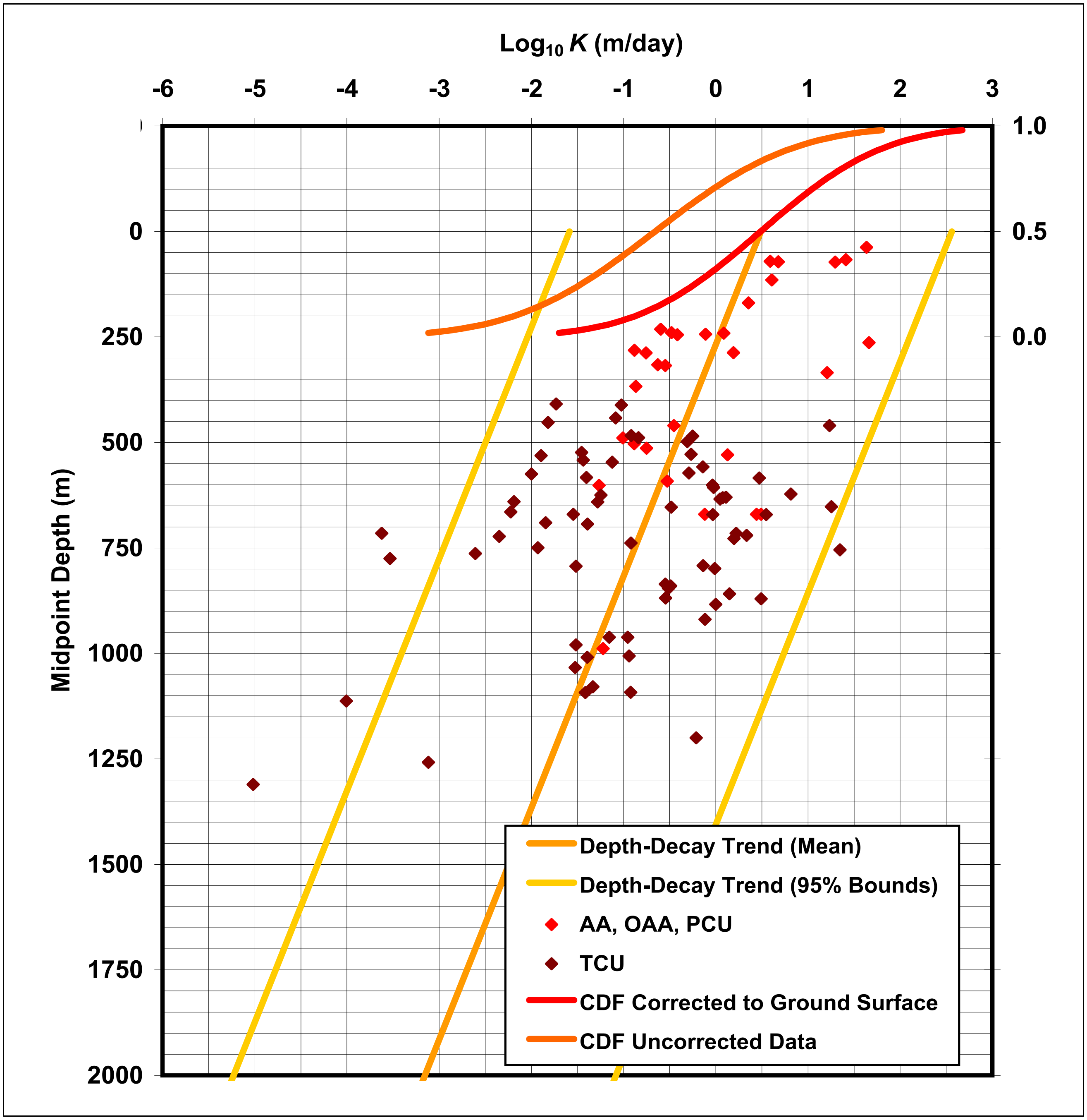
Source: SNJV, 2008

Notes:

1 - To convert from meters to feet, divide by 0.3048.

2 - To convert from $\text{Log}_{10}\,K$ (m/day) to K (ft/day), extract K (m/day) as K (m/day) = 10^{value}, then divide K by 0.3048 to obtain K (ft/day).

Figure C-7
Depth Decay for Brittle Rocks



Source: SNJV, 2008

Notes:

1 - To convert from meters to feet, divide by 0.3048.

2 - To convert from Log_{10} *K* (m/day) to *K* (ft/day), extract *K* (m/day) as *K* (m/day) = 10^{value}, then divide *K* by 0.3048 to obtain *K* (ft/day).

Figure C-8
Depth Decay for Ductile Rocks

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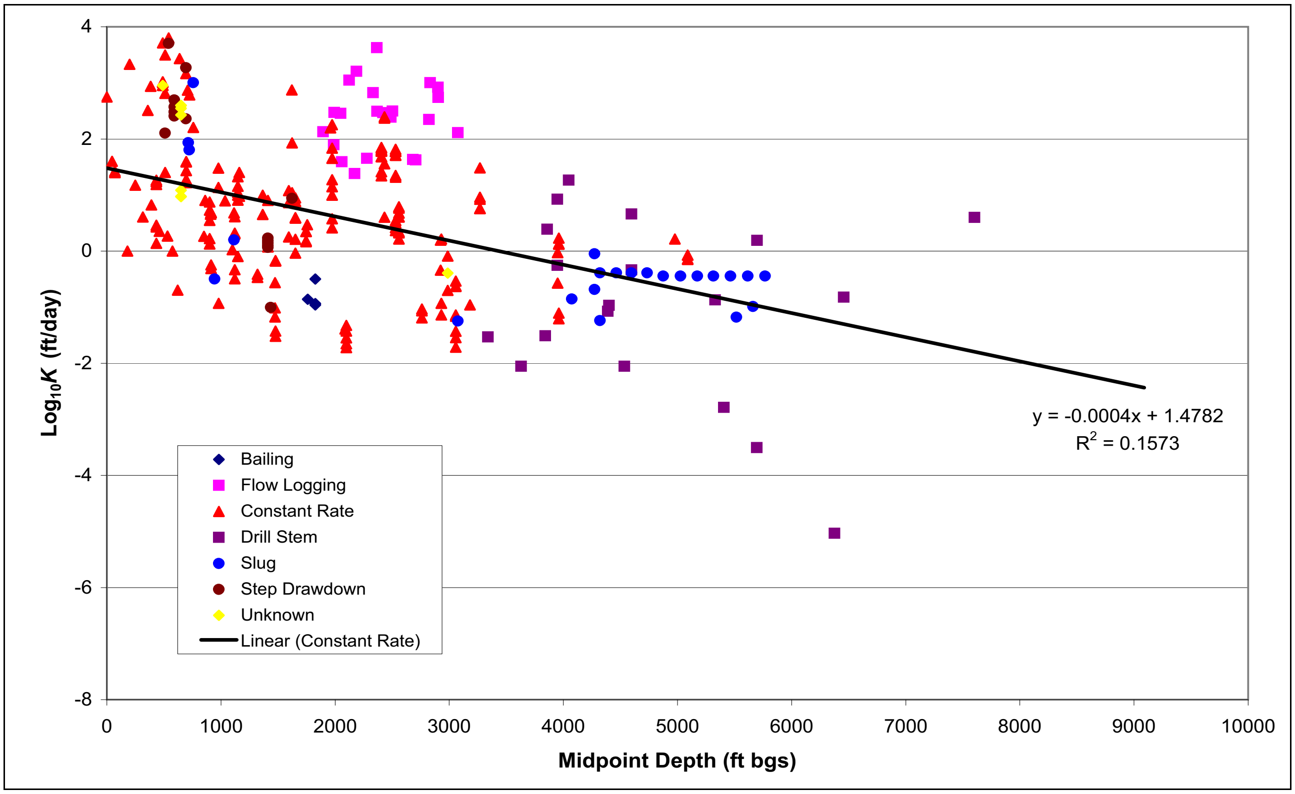

Figure C-9
Hydraulic Conductivity versus Depth for the LC

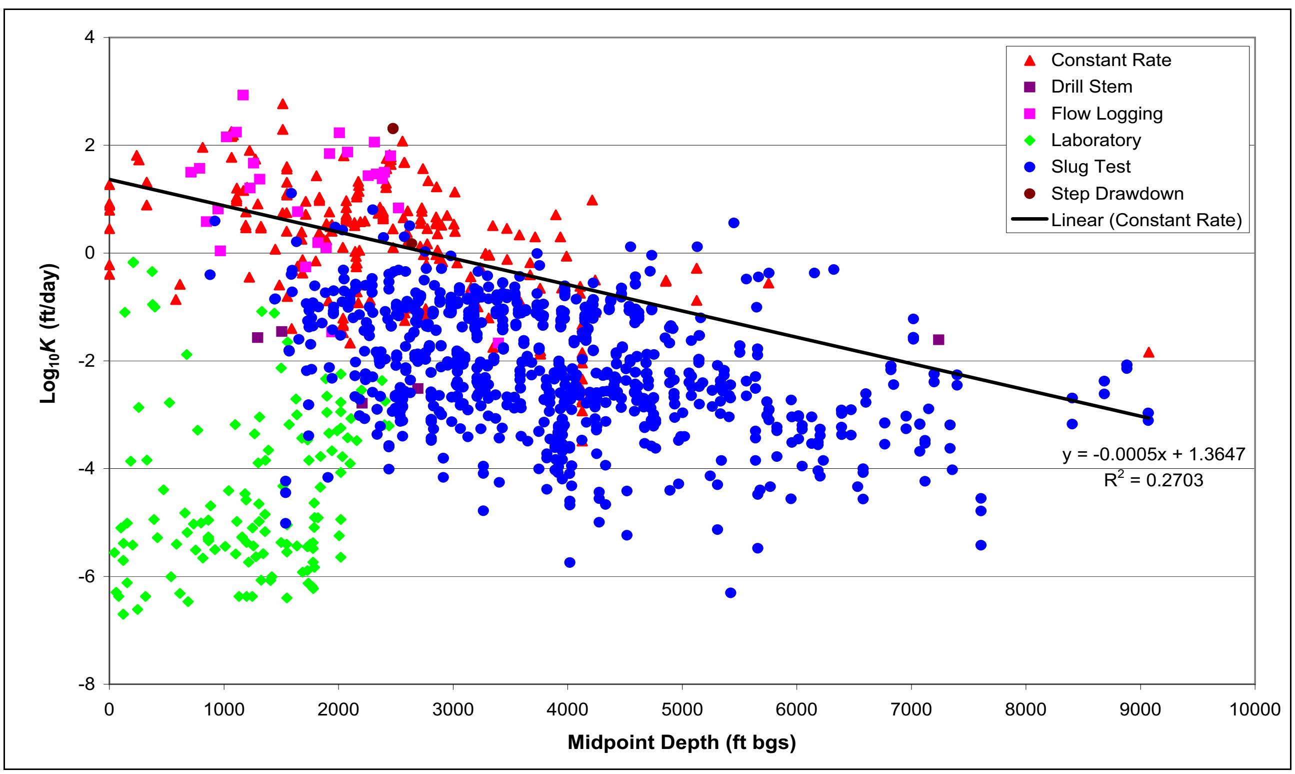

Figure C-10
Hydraulic Conductivity versus Depth for the LVF

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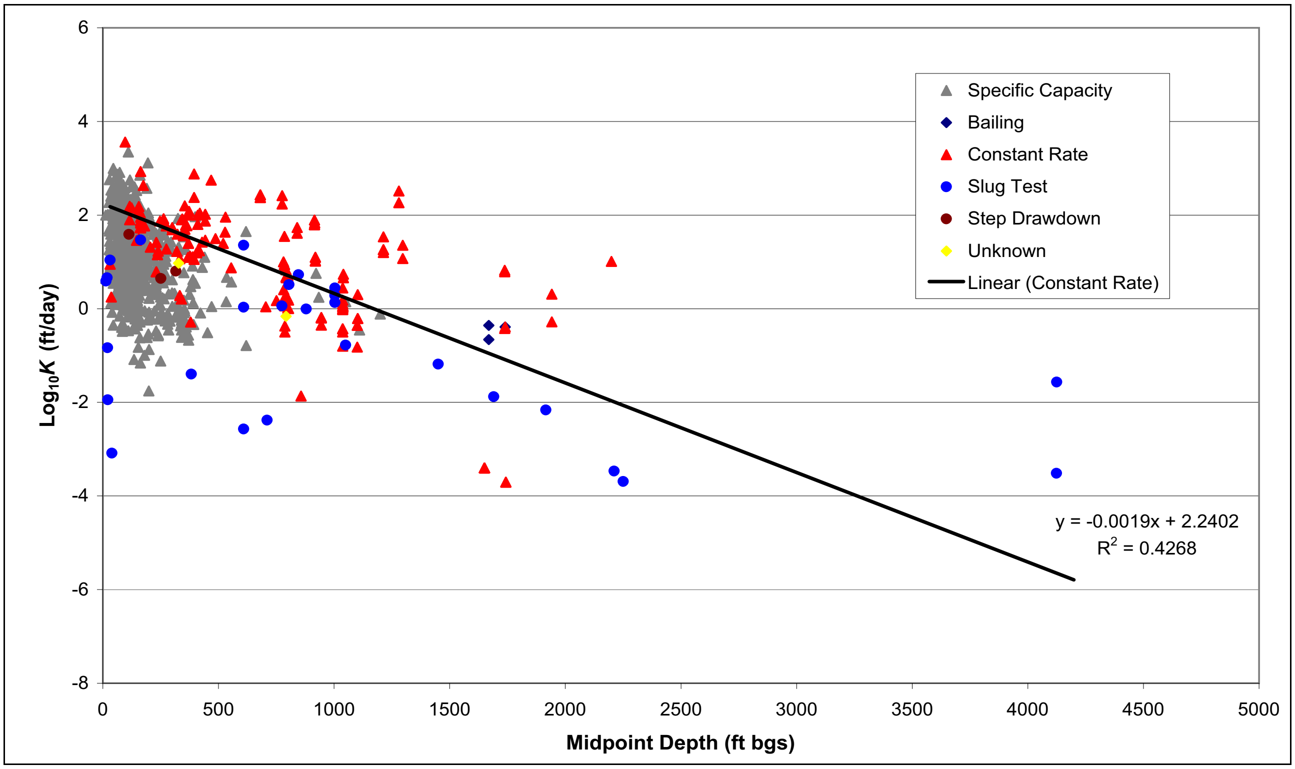

Figure C-11
Hydraulic Conductivity versus Depth for the UVF

was fitted to the constant-rate data for each of the RMUs, and the equation of the line was displayed on the plot. Each of the plots shows a decrease in *K* with depth, but with a large scatter in the data. The derived correlation coefficients between *K* and depth are 0.40 for the LC, 0.52 for the LVF, and 0.65 for the UVF. Although the results of this analysis show that some correlation exists between *K* and depth, the relationships are considered uncertain because of the large data scatter as well as the decrease in data with increasing depth.

C.1.4 Data from Ongoing SNWA Field Activities

This section contains a summary of the preliminary results obtained from aquifer testing at SNWA wells 184W101, 184W103, 184W105, SPR7005X, SPR7007X, SPR7008X, and SPR7023I. Results for CAV6002X are still pending. The location of each test site is presented in Figure A-1 (Appendix A). The carbonate-aquifer tests provided localized short-term results, which are consistent with increased formation hydraulic conductivity related to the fault structures and damage zones observed in carbonate aquifers compared with locations with limited fault influence in other areas.

C.1.4.1 Test Well 184W101 and Monitor Well 184W502M

An aquifer test was performed at Test Well 184W101 located in the southeast portion of Spring Valley approximately 14 mi southeast of Test Well 184W103. Test Well 184W101 was completed to a depth of approximately 1,760 ft bgs and has a static water level of approximately 470 ft bgs.

Hydrogeologic evaluation of the site indicated the presence of a fault structure, which was anticipated to be intersected by the test well.

Associated Monitor Well 184W502M, located approximately 175 ft from 184W101, was drilled first and encountered carbonates consisting of the Guilmette Formation and Simonson and Sevy dolomites. The borehole was initially planned to be terminated at approximately 1,300 ft bgs, but because the yield from the borehole above 1,300 ft bgs was very poor, the borehole was extended to 1,760 ft bgs. As a result, the borehole encountered the target fault structure with a higher density of open fractures, and the yield increased significantly.

A sustainable pumping rate of 2,520 gpm was maintained during the 72-hr constant-rate test. Drilling results, geophysical logs, and temperature data indicated that fractures associated with open fractures encountered between 1,300 and 1,700 ft bgs were the major source of well inflow.

Results from a 72-hr constant-rate and subsequent recovery aquifer test were evaluated using Barker Generalized Radial Flow Model (Barker GRFM) dual-porosity analysis and Cooper-Jacob analysis as the primary and secondary solutions, respectively. The primary solution indicated a composite optimal solution for hydraulic conductivity of approximately 7.6 to 8.0 ft/day using a saturated thickness over the length of the saturated interval of the borehole. However, considering the majority of inflow occurred from the zone consisting of the lower 20 percent of the well, an equivalent hydraulic conductivity would be approximately 40 ft/day over that interval of the borehole based on the Barker GRFM method. The secondary solution provided a wider range of hydraulic conductivities of 1.9 to 14 ft/day.

C.1.4.2 Test Well 184W103 and Monitor Well 184W504M

A 72-hr constant-rate and subsequent recovery aquifer test was performed at Test Well 184W103, located approximately 8 mi south of Test Well 184W105. This test well and associated monitor well are completed in the unconfined carbonate aquifer within the Arcturus Formation with drilled completion depths of 1,046 and 1,040 ft bgs, respectively. Static depth to water in these wells is approximately 100 ft bgs. Hydrogeologic reconnaissance and evaluation of this site indicated that the wells did not intersect significant fault structures and fractures were commonly clay filled. Results from the aquifer-test analysis using the Barker GRFM dual-porosity method and the Cooper-Jacob method as primary and secondary solutions, respectively, indicate a hydraulic conductivity of 5.0 to 12 ft/day.

C.1.4.3 Test Well 184W105 and Monitor Well 184W506M

Test well 184W105 and the associated monitor well 184W506M are completed in unconfined fractured carbonate, which was determined to be Pennsylvanian-Permian age limestone (Table C-4). Unsaturated Quaternary surface alluvium overlays the carbonate at this location to a depth of 15 to 35 ft bgs. Both wells were completed to a depth of 1,160 ft bgs, and the static depth to water at the site is approximately 214 ft bgs. The site location was selected after conducting a geologic reconnaissance of the area, including field mapping, review of geophysical and well log data, and

Table C-4
Summary of Preliminary Aquifer-Testing Results for SNWA Wells

Pumping Well	Observation Well(s)	Background Well(s)	Effective Saturated Thickness	Unit	Analytical Method	Hydraulic Conductivity	Fracture Hydraulic Conductivity	Matrix Hydraulic Conductivity	Transmissivity	Storativity or Specific Yield	Specific Storage (ft^{-1}) Fracture	Specific Storage (ft^{-1}) Matrix
	Distance From Pumping Well		(ft)			(ft/d)			(ft^2/d)			
184W101	184W502M - 175 ft	184W504M - 14 mi	1,280	Carbonate	1	7.6 to 8.0	7.6 to 8.0	1.1E-05 to 6.5E-05	9,700 to 10,000	0.03	4.2E-05 to 6.9E-07	3.9E-06 to 4.5E-06
					2	1.9 to 14	---	---	2,500 to 18,000	0.03	---	---
184W103	184W504M - 177 ft	184W506M - 8 mi	943		1	12	12	2.5E-05	11,000	0.018	7.7E-07	1.9E-05
					2	5.0	---	---	4,700	---	---	---
184W105	184W506M - 212 ft	184W504M - 8 mi	946		1	61 to 64	61 to 64	4.8E-04 to 6.3E-03	57,000 to 61,000	9.5E-03	1.3E-07 to 1.5E-07	1.0E-05
					2	56 to 58	---	---	53,000 to 55,000	2.1E-04	---	---
SPR7005X	SPR7005M - 129 ft	184W506M - 15 mi	856		1	---	2,700	1.8E-03	2,300,000[a] Open Fracture Fault	0.035	1.0E-06	4.1E-05
					2	35 to 48	---	---	30,000 to 41,000	---	---	---
SPR7007X	SPR7007M - 99 ft	390352114305401 - 17 mi	883	Alluvium	3, 4, 5	33 to 38	---	---	29,000 to 34,000	0.01 to 0.07	---	---
SPR7008X	SPR7008M - 100 ft	390352114305401 - 7 mi	800		5	4.2 to 5.9	---	---	3,300 to 4,700	0.2	---	---
SPR7023I	---	184 N13 E67 22BA	900		2, 3'	8.2 to 9.9	---	---	7,900 to 8,900	---	---	---

1 Barker GRFM dual porosity
2 Cooper Jacob
3 Theis
3' Theis Recovery
4 Neuman
5 Moench

[a]Transmissivity calculated for the fracture only. Not representative of the formation.

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evaluating surface structural features using aerial photography. Regional data and geologic mapping in the vicinity indicate the presence of faulting and related structures at the site.

The wells are located near several structures and are likely situated in the fault damage zone. A fault is visible with a strike of N42W approximately 500 ft northwest of the site along with an associated secondary north-south to N10W trending fault dipping 30 to 62 E. The northwest structures trend almost directly toward the wells. The test and monitor wells are believed to be located along the strike and within the damage zone of this exposed fault. This fault zone is estimated to be less than 500 ft wide at the surface and is part of a larger fault complex. An additional east-west fault trends through the hills west of the well site and is inferred to pass just north of Monitor Well 184W506M.

Significant fracture zones were identified using downhole geophysical methods at depths ranging from 790 to 850 ft bgs for Test Well 184W105, with less pronounced fracture zones identified in the range of 200 to 300 ft and 600 to 700 ft. Fracture zones were defined in Monitor Well 184W506M at depths of 200 to 300 ft and 480 to 880 ft.

A constant discharge rate of 3,000 gpm was used for the 72-hr test. The constant rate and subsequent recovery data were evaluated using Barker GRFM dual-porosity analysis as the primary solution and Cooper-Jacob analysis as the secondary solution. Results indicate an optimal solution for hydraulic conductivity of approximately 56 to 64 ft/day.

C.1.4.4 Test Well SPR7005X and Monitor Well SPR7005M

A 120-hr constant-rate aquifer test was performed at Test Well SPR7005X located at Cooper Canyon in Spring Valley. The pumping rate during the constant-rate test was 3,000 gpm. This well was sited based upon geologic reconnaissance and surface geophysics indicating the presence of faulting in Middle Cambrian limestone and dolomite. It was completed, along with associated Monitor Well SPR7005M, within a distinctive fault structure. Specific capacity of the test well was greater than 111 gpm/ft of drawdown at the end of the 120-hr test. Data are currently being analyzed. However, the hydraulic conductivity is expected to be at the higher range of the other carbonate aquifer tests performed in Spring Valley.

These results, while local, are consistent with higher hydraulic conductivities associated with fault structures compared to nonfaulted areas. Preliminary aquifer-property values reflect a composite value over the length of the communication interval between the aquifer and the well. Property values would vary within discrete vertical zones depending upon the fracture density and zone characteristics (Table C-4).

C.1.4.5 Test Well SPR7007X and Monitor Well SPR7007M

Test well SPR7007X is located approximately 100 ft north of Monitor Well SPR7007M. These wells are completed in Quaternary-Tertiary alluvium at depths of 1,040 ft bgs, and their static depth to water is approximately 156 ft bgs. Preliminary analysis using the Theis Recovery, Neuman Unconfined Solution, and Moench 1997 models indicate the hydraulic conductivity would range from 33 to 38 ft/day.

C.1.4.6 Test Well SPR7008X and Monitor Well SPR7008M

A 72-hr constant-rate test was performed on Test Well SPR7008X with a target discharge rate of 2,000 gpm. This well and associated Monitor Well SPR7008M were completed in the alluvial aquifer at a total depth of 970 and 960 ft bgs, respectively. The static depth to water at these wells is approximately 13 and 14 ft bgs, respectively. Moench confined and unconfined with leaky confining layers methods were used to evaluate the possible connection between the aquifer test interval, presumably a confined aquifer, and an upper unconfined aquifer. Preliminary results indicate a hydraulic conductivity of the test interval of 4.2 to 5.9 ft/day.

C.1.4.7 Irrigation Well SPR7023I

Irrigation Well SPR7023I is completed in the unconfined alluvial aquifer with a drilled depth of 1,200 ft bgs. The static water level is approximately 302 ft bgs. A 120-hr constant-rate pumping test was conducted at this well. The time-drawdown data were analyzed using the Cooper-Jacob straight-line and Theis recovery methods. These analyses indicate a hydraulic-conductivity range of 8.2 to 9.9 ft/day.

C.1.4.8 Summary

Estimates of aquifer properties are an essential component of the development of a conceptual groundwater flow model. These estimates served as the initial estimates used to constrain the hydraulic properties in the numerical groundwater flow model.

Data used in this report were obtained from many site-specific and regional reports and synthesized into a single aquifer-property database. The data were then queried from the database according to one of the eight RMUs that were developed as part of the hydrogeologic conceptual model for the study area. The data were then statistically analyzed by RMU to obtain estimates of aquifer properties, including hydraulic conductivity, storativity, and specific yield. The range in values provides a measure of the uncertainty in the property.

The relationship of hydraulic conductivity with depth was also analyzed as part of this study. Many previous investigators have shown a relationship between hydraulic conductivity and depth. In general, hydraulic conductivity decreases with depth as a result of confining pressures, sealing fractures and faults, and compressing sedimentary units. This study showed there was a trend of decreasing hydraulic conductivity with increasing depth in the UVF, LVF, and LC RMUs. Uncertainty in the use of this application stems from the large data scatter as well as the decrease in available data with increasing depth.

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Appendix D

Precipitation Station Data

D.1.0 PRECIPITATION STATION DATA

Precipitation station data were compiled and the period of record mean annual value was derived for each station. Data were compiled from the following sources:

- NDWR
- USGS
- Western Regional Climate Center (WRCC)
- National Climatic Data Center (NCDC)
- NRCS - SNOwpack TELemetry (SNOTEL).

Precipitation stations selected from these sources included stations qualified as climate normals by the NCDC. The average annual precipitation as reported by WRCC was used for these stations. Other stations, except for the Sheep Peak and Hayford Peak stations, have more than 20 "non-zero" years of reported annual precipitation (i.e., years in which the reported annual precipitation was greater than zero). Summary data for the stations located within and near the WRFS are listed in Table D-1.

Table D-1
Precipitation Station Information
(Page 1 of 2)

Station No.	Station Name	UTM Northing[a] (m)	UTM Easting[a] (m)	Altitude (ft amsl)	Annual Precipitation Mean (in.)	Min (in.)	Max (in.)	Period of Record	Period of Record (Number of Years)	NCDC Normal	Source
1	Connors Pass	4,323,835	703,315	7,732	14.72	2.90	26.30	1954 to 2005	52	No	NDWR
2	Current Creek	4,298,199	649,245	5,999	13.71	6.00	24.49	1954 to 2005	52	No	NDWR
3	Robinson Summit	4,365,136	665,201	7,800	14.05	0.55	27.30	1954 to 2005	52	No	NDWR
4	Schellbourne Pass	4,409,348	702,800	7,100	13.67	0.00	26.80	1954 to 2005	52	No	NDWR
5	Wilson Creek Summit	4,254,601	730,436	7,200	17.51	6.50	33.00	1954 to 2005	52	No	NDWR
6	Berry Creek	4,354,622	705,390	9,100	27.35	19.00	40.80	1981 to 2005	25	No	NRCS (SNOTEL)
7	Ward Mountain	4,333,562	677,114	9,200	24.22	13.30	38.80	1981 to 2005	25	No	NRCS (SNOTEL)
8	Cave Mountain	4,337,547	706,108	10,650	20.41	12.00	32.16	1984 to 2005	22	No	USGS
9	Cherry Creek Range	4,443,655	680,594	9,700	15.67	9.00	26.25	1984 to 2005	22	No	USGS
10	Hayford Peak	4,058,445	660,853	9,840	15.75	7.25	29.00	1986 to 2003	18	No	USGS
11	Mt. Washingon	4,309,377	732,764	10,440	26.13	12.00	46.00	1984 to 2005	22	No	USGS
12	Mt. Wilson	4,236,086	728,118	9,200	19.68	0.00	47.00	1984 to 2005	22	No	USGS
13	Sheep Peak	4,050,080	656,908	9,600	15.10	3.00	28.25	1986 to 2003	18	No	USGS
14	Unnamed Peak NW of Mt. Moriah	4,355,941	737,695	9,300	16.72	0.00	28.50	1984 to 2005	22	No	USGS
15	Adaven	4,219,700	624,110	6,250	12.73	4.42	23.64	1928 to 1982	55	No	WRCC
16	Caliente	4,166,179	719,105	4,400	9.10	1.84	18.73	1928 to 2007	80	30 yr	WRCC
17	Callao	4,421,801	780,345	4,330	5.80	0.94	10.59	1948 to 2007	60	30 yr	WRCC
18	Callville Bay	4,002,962	703,844	1,270	5.37	3.18	11.85	1989 to 2007	19	10 yr	WRCC
19	Desert Game Range	4,038,794	646,235	2,920	4.51	0.69	14.78	1948 to 2007	60	No	WRCC
20	Echo Bay	4,022,206	733,343	1,250	5.73	3.35	12.96	1989 to 2007	19	10 yr	WRCC
21	Elgin	4,136,549	718,409	3,420	12.23	3.72	24.98	1951 to 2007	57	10 yr	WRCC
22	Ely WBO	4,350,044	685,372	6,250	9.56	4.22	16.16	1897 to 2007	111	No	WRCC
23	Eskdale	4,334,515	763,613	4,980	6.39	3.18	12.57	1966 to 2007	42	30 yr	WRCC

Table D-1
Precipitation Station Information
(Page 2 of 2)

Station No.	Station Name	UTM Northing[a] (m)	UTM Easting[a] (m)	Altitude (ft amsl)	Annual Precipitation Mean (in.)	Annual Precipitation Min (in.)	Annual Precipitation Max (in.)	Period of Record	Period of Record (Number of Years)	NCDC Normal	Source
24	Fish Springs Refuge	4,415,084	808,023	4,340	7.89	3.89	12.64	1960 to 2007	48	30 yr	WRCC
25	Garrison	4,313,196	757,384	5,260	7.61	4.59	14.69	1951 to 1990	40	10 yr	WRCC
26	Geyser Range	4,282,815	706,113	6,020	8.67	1.65	15.49	1948 to 2002	55	No	WRCC
27	Great Basin National Park	4,320,446	740,673	6,830	13.27	7.37	21.20	1948 to 2007	60	10 yr	WRCC
28	Hiko	4,157,377	657,455	3,940	7.08	1.45	13.68	1989 to 2007	19	10 yr	WRCC
29	Key Pittman WMA	4,164,774	657,315	3,950	7.94	4.64	11.94	1964 to 1989	26	No	WRCC
30	Lages	4,436,011	702,945	5,960	8.20	4.83	13.20	1984 to 2007	24	10 yr	WRCC
31	Lake Valley Steward	4,243,927	705,365	6,350	15.69	9.39	28.29	1971 to 1998	28	No	WRCC
32	Logandale	4,049,785	726,628	1,410	5.14	3.23	9.81	1968 to 1992	25	No	WRCC
33	Lund, Nevada	4,302,024	673,483	5,570	10.20	4.99	18.83	1957 to 2007	51	30 yr	WRCC
34	Mcgill	4,363,530	691,944	6,300	8.81	3.76	16.21	1914 to 2007	94	30 yr	WRCC
35	Overton	4,047,975	728,168	1,290	4.40	0.71	8.94	1948 to 2007	60	No	WRCC
36	Pahranagat Wildlife Refuge	4,126,112	666,918	3,400	6.28	2.23	11.54	1964 to 2007	44	30 yr	WRCC
37	Partoun	4,391,336	767,708	4,780	6.68	2.03	12.21	1950 to 2007	58	30 yr	WRCC
38	Pioche	4,201,109	724,042	6,180	13.20	3.81	27.29	1948 to 2006	59	30 yr	WRCC
39	Ruth	4,350,154	673,938	6,840	12.04	6.68	19.46	1958 to 2007	50	10 yr	WRCC
40	Shoshone 5 N	4,311,105	725,336	5,930	9.65	5.48	14.56	1988 to 2007	20	10 yr	WRCC
41	Spring Valley State Park	4,212,891	747,440	5,950	12.17	5.05	23.48	1974 to 2007	34	10 yr	WRCC
42	Sunnyside	4,254,266	672,777	5,300	9.38	5.73	17.11	1948 to 2007	60	30 yr	WRCC
43	Valley of Fire State Park	4,034,875	722,534	2,000	6.55	1.66	16.90	1972 to 2007	36	30 yr	WRCC

[a]North American Datum of 1983 (NAD83), Zone 11

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Appendix E

ET Rates and Related Information

E.1.0 ET RATES AND RELATED INFORMATION

This appendix contains detailed information in support of the estimates of groundwater ET volume calculations. The information consists of the following:

- Observed ET rates
- Rooting depths of phreatophytic plants
- PET data and spatial distribution

E.1.1 Observed ET Rates

A literature survey for annual ET rates measured in the study area and vicinity was conducted, and the rates were compiled into the data set presented in Table E-1.

E.1.2 Rooting Depths of Phreatophytic Plants

The roots of phreatophytes in arid climates are extensive, covering a greater diameter and depth compared to those of plants in wetter climates. Because arid plants depend on their ability to tap groundwater for survival, the roots can exploit the soil/medium at greater depths to reach the water table (Lewis and Burghy, 1964). Therefore, understanding rooting depths of phreatophytes in arid climates would increase understanding of the extinction depth of groundwater ET.

Table E-2 lists rooting depths for different plants found in arid environments similar to that of the study area. The rooting depth information was obtained from different studies conducted in the southwestern United States or in similar environments. The rooting depths of phreatophytic plants extend from just below the ground surface to depths greater than 100 ft. SNWA field personnel have found plant roots hanging on a water-level logger during a routine monitor well run. The average depth to water at that particular well is about 18.6 ft. The well is surrounded by greasewood and rabbitbrush; therefore, it could be assumed that the roots could be from one of these phreatophytes. During a study performed in the southwestern United States, it was found that mesquite roots protruded to extreme depths, as deep as 175 ft (Phillips, 1963). This represents the maximum rooting depth found in the literature review.

Within a given phreatophytic area of reasonably homogeneous conditions, the maximum rooting depths correspond to the extinction depths of groundwater ET in that area. Groundwater ET is believed to decrease with increasing depth to water and reaches zero at the extinction depth (Shah et al., 2007). However, extinction depths are also influenced by other physical characteristics. Soil characteristics can have an impact on the maximum rooting depth. For instance, a phreatophyte in a sandy clay soil can have a greater extinction depth than in sandy loam (Shah et al., 2007). Conventionally, it was believed that the relationship between the extinction depth and groundwater

Table E-1
Summary of Reported ET Rates
(Page 1 of 7)

Report	Location	ET Unit Description	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Groundwater ET (ft/yr)
Lee (1912)	Independence area of Owens Valley, CA	Alfalfa	---	4.3	---	---
		Bare soil (Tank 1)	5.7 to 5.9	3.33	---	---
		Saltgrass (Tanks 2-7)	0.1 to 6.0	0.66 to 3.59	---	---
White (1932)	Escalante Valley, UT	Greasewood	1.3 to 3.3	0.99 to 2.1[a]	0.13 to 0.37[a]	---
		Alfalfa	2.3 to 3.3	1.92 to 2.16[a]	0.13 to 0.43[a]	---
		Saltgrass	0.92 to 2.3	0.76 to 1.88[a]	0.01 to 0.37[a]	---
Maxey and Eakin (1949)	White River Valley, NV	Native phreatophytes	---	---	---	0.8
		Cultivated plants	---	---	---	1.25
Gatewood et al. (1950)	Safford Valley, AZ	Saltcedar	3.13 to 7.79	3.3 to 8.6	0.0 to 0.22	---
		Cottonwood	5.01 to 6.86	3.4 to 8.7	0.0 to 0.22	---
		Baccharis	1.66 to 6.09	2.9 to 7.1	0.0 to 0.22	---
Eakin (1961)	Long Valley, NV	Mixed rabbitbrush and greasewood	10 to 40	---	---	0.2
Eakin (1962)	Cave Valley, NV	Main drainage channel	---	---	---	---
Eakin (1963a)	Dry Lake/Delamar valleys, NV	No phreatophytes, discharge from springs	---	---	---	---
Eakin (1963b)	Garden/Coal valleys, NV	Along stream channels and spring areas	---	---	---	---
Eakin (1963c)	Pahranagat/Pahroc valleys, NV	Phreatophytes, agriculture, and lakes	---	---	---	1.0 to 4.8
Rush and Eakin (1963)	Lake Valley, NV	Saltgrass and wetland meadow	<5	---	---	1.5
		Saltgrass and moderately wet meadow	<5	---	---	1.25
		Saltgrass and dry meadow	5 to 20	---	---	0.5
		Greasewood	20 to 25	---	---	0.25
		Greasewood and rabbitbrush mixed with big sage	25 to 50	---	---	0.1
Rush (1964)	Clover Valley, NV	Dry meadow	5 to 10	---	---	0.5
		Rabbitbrush	10 to 25	---	---	0.2
	Dry Valley, NV	Rabbitbrush and big sage	15 to 40	---	---	0.1
	Eagle Valley, NV	Dry meadow	---	---	---	0.5
		Rabbitbrush and big sage	10 to 15	---	---	0.3
	Lower Meadow Valley, NV	Saltbush	20 to 60	---	---	0.1
		Greasewood and rabbitbrush	20 to 50	---	---	0.1
		Greasewood, rabbitbrush, and creosote bush	---	---	---	0.1
		Cottonwood, willow, and saltcedar	0 to 5	---	---	3.0
	Panaca Valley, NV	Greasewood and rabbitbrush	10 to 20	---	---	0.1
		Rabbitbrush	15 to 25	---	---	0.2
	Patterson Valley, NV	Greasewood and rabbitbrush	20 to 30	---	---	0.1
	Rose Valley, NV	Rabbitbrush and big sage	20 to 25	---	---	0.1

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Table E-1
Summary of Reported ET Rates
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Report	Location	ET Unit Description	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Groundwater ET (ft/yr)
Rush (1964) cont.	Spring Valley, NV	Rabbitbrush	5 to 25	---	---	0.1
		Wetland meadow (very wet meadow and dry meadow)	0 to 10	---	---	0.5 to 1.5
Eakin (1964)	Coyote Spring, NV	Not delineated	---	---	---	---
	Kane Spring, NV	Not delineated	---	---	---	---
	Muddy River Springs, NV	Springs area	---	---	---	---
Rush and Kazmi (1965)	Spring Valley, NV	Wetland meadow and saltgrass	0 to 5	---	---	1.5
		Saltgrass, rabbitbrush, and moderately wet meadow	0 to 10	---	---	1.0
		Greasewood, saltgrass, meadow grass, and swamp cedar	5 to 15	---	---	0.5
		Greasewood and rabbitbrush	10 to 50	---	---	0.2
		Bare soil and sparse vegetation	5 to 15	---	---	0.1
		Cottonwood, willow, and wildrose	0 to 5	---	---	2.0
Hood and Rush (1965)	Snake Valley, NV and UT	Wetland meadow	0 to 5	---	---	1.75
		Meadow grass and rabbitbrush	2 to 10	---	---	0.5
		Greasewood and rabbitbrush	10 to 50	---	---	0.2
		Playas (flooded part of year)	0 to 15	---	---	0.75
		Playas (rarely flooded, but shallow water table)	0 to 30	---	---	0.1
Eakin (1966)	Jakes Valley, NV	Not delineated	---	---	---	---
Eakin et al. (1967)	Steptoe Valley, NV	Wetland meadow and saltgrass, including lowland spring areas	0	---	---	1.5
		Saltgrass, rabbitbrush, greasewood, and Goshute Lake playa	<10	---	---	0.5
		Greasewood, rabbitbrush, and saltgrass	<20	---	---	0.3
		Saltgrass, rabbitbrush, and greasewood	<12	---	---	0.1
Glancy (1968)	S. Butte Valley, NV	Open water	---	---	---	3.5
		Saltgrass	0 to 10	---	---	0.5
		Rabbitbrush and greasewood	10 to 35	---	---	0.2
		Greasewood	30 to 50+	---	---	0.1
Rush (1968)	Hidden Valley, NV	None	---	---	---	---
	Garnet Valley, NV	None	---	---	---	---
	California Wash Area, NV	Saltbush, saltgrass, saltcedar, mesquite, and cottonwood	2 to 50	---	---	1
	Lower Moapa Valley, NV	Saltbush, saltgrass, saltcedar, mesquite, cottonwood, and tules	2 to 50	---	---	2
	Black Mountains Area, NV	Tules, mesquite (Las Vegas Wash and Rogers Spring)	0 to 5	---	---	6
	Gold Butte Area, NV	Cottonwood, willow, grass, and tules near small springs	0 to 10	---	---	---
	Greasewood Basin, NV	Cottonwood, willow, grass, and tules near small springs	0 to 10	---	---	---

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Table E-1
Summary of Reported ET Rates
(Page 3 of 7)

Report	Location	ET Unit Description	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Groundwater ET (ft/yr)
Robinson (1970)	Humboldt River Valley, NV	Greasewood	5.0 to 7.8	1.14 to 1.81[a]	0.14 to 0.44[a]	---
		Rabbitbrush	5.0 to 6.2	1.07 to 2.19[a]	0.14 to 0.44[a]	---
		Bare soil	1.9 to 4.0	0.36 to 1.00[a]	0.14 to 0.44[a]	---
		Willow	3.5 to 5.8	2.07 to 3.94[a]	0.14 to 0.44[a]	---
		Wild Rose	4.2 to 6.1	1.23 to 2.13[a]	0.14 to 0.44[a]	---
Harrill (1971)	Tippet Valley, NV	No phreatophytes	>50	---	---	---
	Pilot Creek, NV	Greasewood, shadscale, and rabbitbrush	80 to 100	---	---	---
	Great Salt Lake Desert, UT	Playas (saltbrush)	80 to 100	---	---	---
		Bare soil on playas	<10	---	---	0.1
	Northern Antelope Valley, NV	Valley Floor (patches of greasewood)	80 to 100	---	---	---
Duell (1990)	Owens Valley, CA	Alkali meadow (sacaton and thistle)	10 to 15	2.71	---	---
		Alkali meadow (saltgrass, sacaton, and rabbitbrush)	7 to 9	2.05	---	---
		Alkali meadow (Nevada saltbush, sacaton, and rabbitbrush)	5 to 7	2.69	---	---
		Desert sink scrub (rabbitbrush, sacaton, and ephedra)	10 to 11	1.99	---	---
		Desert sink scrub (saltgrass and greasewood)	8 to 9	1.26	0.52	---
		Rabbitbrush meadow (saltgrass and rabbitbrush)	10 to 11	1.55	0.49	---
		Rush and sedge meadow (saltgrass, sacaton, and rush)	≤4	3.24	0.26	---
Malek et al. (1990)	Utah West Desert, UT	Pilot Valley playa, often salt covered	0 to 1	0.75	0.42	---
Carman (1993)	Smith Creek Valley and Carson Desert, NV	Soda Lake (greasewood)	25 to 30	0.59	0.49 to 0.66	---
		Smith Creek (rabbitbrush)	10 to 15	1.05	0.66 to 0.98	---
Nichols (1994) from Nichols (2000)	Northern Great Basin, NV	Smoke Creek desert (greasewood, salt brush, and sagebrush)	8.9	---	---	0.82[a]
		Smith Creek Valley (greasewood and rabbitbrush)	5.9	---	---	1.2[a]
		Railroad Valley (greasewood and salt brush)	5.9	---	---	0.2[a]
Lower Colorado River Accounting System (LCRAS) (BOR, 1997; 1998; 1999; 2000a,b; 2001; 2002; 2004a,b; 2005; 2007) Fort Mohave Reservation	Lower Colorado River, AZ	Marsh (cattail, bulrush, and phragmites [bamboo])	---	5.93	---	---
		Desert vegetation	---	1.34	---	---
		Barren (≤10% vegetation)	---	1.66	---	---
		Saltcedar (11 to 60%), arrowweed (≤25%)	---	4.36	---	---
		Saltcedar (61 to 100%), arrowweed (≤25%)	---	5.12	---	---
		Saltcedar (11 to 60%), mesquite (11 to 60%), arrowweed (≤25%)	---	5.45	---	---
		Saltcedar (≤75%), arrowweed (≥25%)	---	5.29	---	---
		Saltcedar (15 to 45%), mesquite (15 to 45%), arrowweed (20 to 40%)	---	5.43	---	---
		Screwbean/honey mesquite (11 to 60%), arrowweed (≤25%)	---	3.99	---	---
		Screwbean/honey mesquite (61 to 100%), arrowweed (≤25%)	---	4.99	---	---
		Mesquite (21 to 60%), arrowweed (31 to 60%), saltcedar (≤20%)	---	4.76	---	---

Table E-1
Summary of Reported ET Rates
(Page 4 of 7)

Report	Location	ET Unit Description	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Groundwater ET (ft/yr)
LCRAS - cont.	Lower Colorado River, AZ	Arrowweed (51 to 100%), trees (≤10%)	---	4.69	---	---
		Cottonwood and willow trees (61 to 100%)	---	4.96	---	---
		Low vegetation (phreatophyte vegetation >10% to ≤30%)	---	4.29	---	---
		Moist soil unit (flooded in winter and irrigated in summer)	---	5.03	---	---
		Seasonal wetland (flooded in winter and not irrigated in summer)	---	3.65	---	---
Nichols et al. (1997) from Nichols (2000)	Ash Meadows, NV	Ash Meadows 1 (salt grass)	1.6	---	---	2.45
		Ash Meadows 2 (salt grass and wiregrass)	0	---	---	2.52
Czarnecki (1997)	Franklin Lake Playa, CA	Seepweed, greasewood, and saltgrass (sparse)	<10	1.2 to 1.3	<0.16	---
Devitt et al. (1998)	Virgin River, NV	Riparian (mostly tamarix)	---	2.5 to 4.8		---
Laczniak et al. (1999)	Ash Meadows, NV	Open water body	---	8.6	0.21 to 0.35	---
		Submerged aquatic vegetation (shallow part of open water areas, includes sparse emergent vegetation)	---	8.6	0.21 to 0.35	---
		Dense grassland vegetation (grasses, short rushes, and trees)	---	3.5	0.21 to 0.35	---
		Sparse grassland vegetation (grasses)	---	1.3	0.21 to 0.35	---
		Moist bare soil (grasses)	---	2.6	0.21 to 0.35	---
		Dense wetland vegetation (reedy and rushy marsh plants)	---	3.9	0.21 to 0.35	---
		Dense meadow vegetation (trees, grasses, and shrubs)	---	3.4	0.21 to 0.35	---
Nichols (2000)	16 valleys in Great Basin, NV	Open water	---	---	---	---
		Playa / bare soil	---	---	---	0.15
		<10% plant cover	---	---	---	0.29 to 0.41
		10 to <20% plant cover	---	---	---	1.28 to 1.35
		20 to <35% plant cover	---	---	---	2.14 to 2.15
		35 to <50% plant cover	---	---	---	2.50 to 2.51
		≥50% plant cover	---	---	---	2.58
Laczniak et al. (2001)[b]	Death Valley Regional Flow System, primarily Ash Meadows and Oasis Valley, NV	Open water	0	8.4 to 8.8	---	---
		Submerged aquatic vegetation (shallow part of open water areas, includes sparse emergent vegetation)	0	8.1 to 8.5	---	---
		Sparse grassland vegetation (grasses and very low density shrubs)	few to 12	0.6 to 2.3	---	---
		Sparse woodland vegetation (mesquite)	10 to 40	0.7 to 1.8	---	---
		Dense meadow / forested vegetation (trees, grasses, and shrubs)	few to 20	3.0 to 4.0	---	---
		Sparse to moderate density shrubland vegetation (greasewood, rabbitbrush, wolfberry, and seepweed)	5 to 20	0.7 to 2.5	---	---
		Dense wetland vegetation (reedy and rushy marsh plants)	0	3.7 to 4.3	---	---
		Dense to moderate density grassland vegetation (saltgrass and/or short rushes with occasional tree or shrub)	< 5	2.5 to 3.7	---	---

Table E-1
Summary of Reported ET Rates
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Report	Location	ET Unit Description	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Groundwater ET (ft/yr)
Laczniak et al. (2001)[b] - cont.	Death Valley Regional Flow System, primarily Ash Meadows and Oasis Valley, NV	Moist bare soil (very sparse grasses)	< 5	2.2 to 3.0	---	---
		Open playa (bare soil)	5 to 40	0.1 to 0.7	---	---
Berger et al. (2001)	Ruby Lake National Wildlife Refuge Area, Ruby Valley, NV	Open water (submerged aquatic vegetation)	---	5.31[a]	0.65[a]	---
		Greasewood, rabbitbrush, wildrye, sagebrush (sparse to moderate)	17	1.33[a]	0.65[a]	0.68[a]
		Rabbitbrush, wildrye, greasewood, sagebrush (moderate)	5	1.33[a]	0.65[a]	0.68[a]
		Rabbitbrush, wildrye, greasewood, and sagebrush (moderate)	10	1.33[a]	0.65[a]	0.68[a]
		Saltgrass, rabbitbrush, wildrye, and greasewood (moderate)	<5	1.33[a]	0.65[a]	0.68[a]
		Desert shrub upland (moderate sagebrush and rabbitbrush)	>80	0.99[a]	0.65[a]	0.34[a]
		Bulrush marsh (moderate to dense bulrush and cattails)	1 to 3	4.19[a]	0.65[a]	3.54[a]
		Meadow (dense mixed sedges, rushes, and grasses)	<2	3.19[a]	0.65[a]	2.54[a]
		Saltgrass, rabbitbrush, wildrye, and greasewood (moderate)	<5	1.32[a]	0.65[a]	0.67[a]
		Grasslands	---	2.36[a]	0.65[a]	1.71[a]
		Playa/bare soil	---	0.80[a]	0.65[a]	0.15[a]
Reiner et al. (2002)[c]	Oasis Valley and Ash Meadows, NV	Open water body	---	8.6	0.50	8.1
		Submerged and sparse aquatic vegetation (shallow part of open water areas, includes sparse emergent vegetation)	0	8.6	0.50	8.1
		Dense wetland vegetation (Reedy and rushy marsh plants)	0	3.9	0.50	3.4
		Dense meadow and woodland vegetation (trees, grasses, shrubs)	0 to 20	3.3	0.50	2.8
		Moderate density to dense grassland (grasses, short rushes, occasional scattered trees.)	<10	3.2	0.50	2.7
		Sparse to moderate density grassland (grasses)	few to 10	2.0	0.50	1.5
		Moist bare soil (grasses)	≤5	2.6	0.50	2.1
		Sparse to moderate density shrubs (greasewood, rabbitbrush, and wolf-berry)	5 to 20	1.2	0.50	0.7
Harrington & Steinwand (2003, 2004)	Owens Valley, CA	Nevada saltbush scrub	13 to 14	0.59	0.35	0.25
		Rabbitbrush scrub	>16	0.31	0.11	0.19
		Nevada saltbush meadow	6.9 to 7.9	0.71 to 1.06	0.10 to 0.30	0.61 to 0.76
		Desert sink scrub	>13	0.49 to 0.80	0.10 to 0.50	0.31 to 0.38
		Rabbitbrush meadow	8.5 to 11	1.68	0.23	1.44
		Alkali meadow (sacaton, saltgrass, and wildrye)	6.6 to 11	1.37 to 2.25	0.11 to 0.99	0.87 to 2.18
DeMeo et al. (2003)	Death Valley, CA	Bare-soil playa	≤10	0.21 to 0.37	0.06 to 0.35	0.01 to 0.15
		Low density vegetation (salt grass, pickleweed, and shrub mesquite)	5 to 20	0.60	0.06	0.54
		Moderate density vegetation (grasses, arrowweed, mesquite, and pickleweed)	2 to 20	2.0	0.23	1.8

Table E-1
Summary of Reported ET Rates
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Report	Location	ET Unit Description	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Groundwater ET (ft/yr)
DeMeo et al. (2003) - cont.	Death Valley, CA	High density vegetation (Mesquite Flat)	≤20	2.9	0.16	2.7
		High density vegetation (Mesquite Flat and mixed grasses)	≤20	3.9	0.25	3.6
		Salt to encrusted playa	≤5	0.17 to 0.39	0.04 to 0.28	-1.40 to 0.13
Maurer et al. (2006)	Carson Valley and Douglas County, NV, and Alpine County, CA	Rabbitbrush and greasewood	3 to 5	1.9	---	---
		Flood-irrigated alfalfa	3 to 6	3.1	---	---
		Flood-irrigated pasture	2 to 5	3.2	---	---
		Flood-irrigated pasture	3 to 4	2.8	---	---
		Flood-irrigated alfalfa	40	3.0	---	---
		Non-irrigated pasture	6 to 7	1.7	---	---
		Bitterbrush and sage	60	1.5	---	---
		Flood-irrigated pasture	0 to 2	4.4	---	---
Cooper et al. (2006)	San Luis Valley, CO	Rush and saltgrass	3.0	1.34	0.60	0.74
		Greasewood and rabbitbrush	8.2	0.91	0.63	0.28
Laczniak et al. (2006)	Death Valley, CA	Saltgrass, grass, yerba mansa, arrowweed, desert baccharis, mesquite	0 to 15	2.28 to 2.68	0.05 to 0.49	2.1 to 2.3
Westenburg et al. (2006a)	Lake Mead, AZ and NV	Open water - Water Barge Cove	---	7.0	0.28 to 0.34[d]	---
		Open water - Sentinel Island	---	7.5	0.28 to 0.34[d]	---
		Open water - Virgin Basin	---	7.6	0.28 to 0.34[d]	---
		Open water - Overton Arm	---	6.8	0.28 to 0.34[d]	---
Westenburg et al. (2006b)	Topock Wash, Havasu area, Lower Colorado River, AZ	High density saltcedar - 2002	8	3.80	0.03	3.77
		Medium density (mesquite, saltcedar, saltgrass, arrowweed, baccharis, rush) - 2002	4 to 8	2.85	0.03	2.82
		Low to medium density arrowweed - 2002	8	2.87	0.03	2.84
		Barren soil - 2002	---	0.96	0.03	0.93
		High density saltcedar (saltcedar) - 2003	8	3.56	0.43	3.13
		Medium density (mesquite, saltcedar, saltgrass, arrowweed, baccharis, rush) - 2003	4 to 8	2.61	0.43	2.18
		Low to medium density arrowweed - 2003	8	2.65	0.43	2.21
		Barren soil - 2003	---	0.87	0.43	0.44
		High density saltcedar (saltcedar) - 2004	8	3.59	0.57	3.02
		Medium density (mesquite, saltcedar, saltgrass, arrowweed, baccharis, rush) - 2004	4 to 8	2.63	0.57	2.06
		Low to medium density arrowweed (arrowweed) - 2004	8	2.71	0.57	2.14
		Barren soil - 2004	---	0.88	0.57	0.31

Table E-1
Summary of Reported ET Rates
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Report	Location	ET Unit Description	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Groundwater ET (ft/yr)
Moreo et al. (2007)	Snake, Spring, and White River valleys, NV	Moderate density desert shrubland (greasewood)	17.16	0.836	0.52	0.32
		Sparse desert shrubland (greasewood and rabbitbrush)	9.78	0.835	0.72	0.12
		Moderate density desert shrubland (greasewood and rabbitbrush)	7.24	1.01	0.76	0.24
		Grassland/Meadowland (mixed grasses/meadow)	3.89	2.25	0.66	1.58
		Dense desert shrubland (greasewood)	32.39	1.06	0.74	0.32
		Moderate density desert shrubland (greasewood)	23.58	1.02	0.95	0.06
SNWA Project data	Snake, Spring, and White River valleys, NV	High density monotypic stand of greasewood (SNV1-2007)	19.31	1.65	0.37	1.28
		Moderate density monotypic stand of greasewood (SNV2-2007)	30.47	0.64	0.16	0.48
		Mixed shrubland; low density greasewood, sagebrush, rabbitbrush, shadscale, horsebrush (SV1-2006)	15.20	0.79	0.51	0.28
		Mixed shrubland; low density greasewood, sagebrush, rabbitbrush, shadscale, horsebrush (SV1-2007)	15.32	0.62	0.42	0.20
		Irrigated pasture/grassland; dense perennial grasses (SV2b-2007)	shallow	3.56	0.35	3.21
		Mixed shrubland; moderate density greasewood, rabbitbrush, shadscale (SV3-2007)	17.38	0.80	0.27	0.53
		Mixed shrubland; moderate density greasewood, sagebrush, rabbitbrush, shadscale, budsage (WRV2-2006)	18.95	1.38	0.87	0.51
		Mixed shrubland; moderate density greasewood, sagebrush, rabbitbrush, shadscale, budsage (WRV2-2007)	18.85	0.68	0.45	0.23
Devitt et al. (2008)	Snake, Spring, and White River valleys, NV	High density monotypic stand of greasewood (SNV1-2007)	19.31	1.64	0.12[a]	---
		Moderate density monotypic stand of greasewood (SNV2-2007)	30.47	0.70	0.04[a]	---
		Mixed shrubland; low density greasewood, sagebrush, rabbitbrush, shadscale, horsebrush (SV1-2006)	15.20	0.79	0.16[a]	---
		Mixed shrubland; low density greasewood, sagebrush, rabbitbrush, shadscale, horsebrush (SV1-2007)	15.32	0.66	0.11[a]	---
		Irrigated pasture/grassland; dense perennial grasses (SV2b-2007)	shallow	4.10	0.12[a]	---
		Mixed shrubland; moderate density greasewood, rabbitbrush, shadscale (SV3-2007)	17.38	0.89	0.10[a]	---
		Mixed shrubland; moderate density greasewood, sagebrush, rabbitbrush, shadscale, budsage (WRV2-2006)	18.95	1.39	0.24[a]	---
		Mixed shrubland; moderate density greasewood, sagebrush, rabbitbrush, shadscale, budsage (WRV2-2007)	18.85	0.90	0.20[a]	---

[a]Rates reflect growing season or less.
[b]Laczniak et al. (2001) rely on rates from previously published literature.
[c]Reiner et al. (2002) include data reported by Laczniak et al. (1999) for Ash Meadows.
[d]Average annual precipitation (1961 to 1990) measured at McCarran Airport, Las Vegas, NV (0.34 ft) and Overton, NV (0.28 ft) from DRI (Westenburg et al., 2006a).

Table E-2
Rooting Depths of Plants of the Southwestern United States

Plant	Rooting Depth (ft bgs)	Source
Alfalfa	12	Weaver (1926)
Alkali sacaton	25	Meinzer (1927)
Arrowweed	25	Meinzer (1927)
Big sage	5.9	Canadell et al. (1996)
Cottonwood	30	Robinson (1958)
Giant wildrye	≥12	Meinzer (1927)
Greasewood	60	Robinson (1958)
Mesquite	50	Meinzer (1927)
Mesquite	175	Phillips (1963); Canadell et al. (1996)
Pickleweed	≥20	Meinzer (1927)
Rabbitbrush	35	Mower and Nace (1957)
Rushes and sedges	A few feet	Meinzer (1927)
Saltbrush	62	Robinson (1958)
Saltcedar	11.8	Canadell et al. (1996)
Saltgrass	12	Meinzer (1927)
Wolfberry	30	USFS (2008)

ET is linear, but as mentioned above, different soil characteristics with different phreatophytes could generate different relationships. For example, Shah et al. (2007) found an exponential decline of groundwater ET with increasing depth to water.

E.1.3 PET Data and Spatial Distribution

A PET regression model was derived using estimates of PET reported in McCurdy and Albright (2004). McCurdy and Albright (2004) calculated PET for existing meteorological stations within the study area and vicinity using the Kimberly-Penman method (Wright, 1982) and the Hargreaves-Samani (Hargreaves and Samani, 1985) equation. The PET spatial distribution was derived from a multiple linear regression model of PET rates versus the latitude and altitude of the location where PET was measured. The regression model is expressed by the following equation:

$$PET = 104.3531 - 0.82922734Y - 0.004186006Z \qquad \text{(Eq. E-1)}$$

where,

PET = Potential ET rate (in./yr)
Y = Latitude (NAD, 1983)
Z = Altitude (ft amsl) (North American Vertical Datum of 1988)

Using GIS-gridding operations, the spatial distribution of PET was derived by applying Equation E-1 to a 100-m resolution DEM based on the USGS 30-m DEM (USGS, 2006). The meteorological station locations and their estimated PET values are depicted in Figure E-1 with the resultant PET distribution derived for the study area.

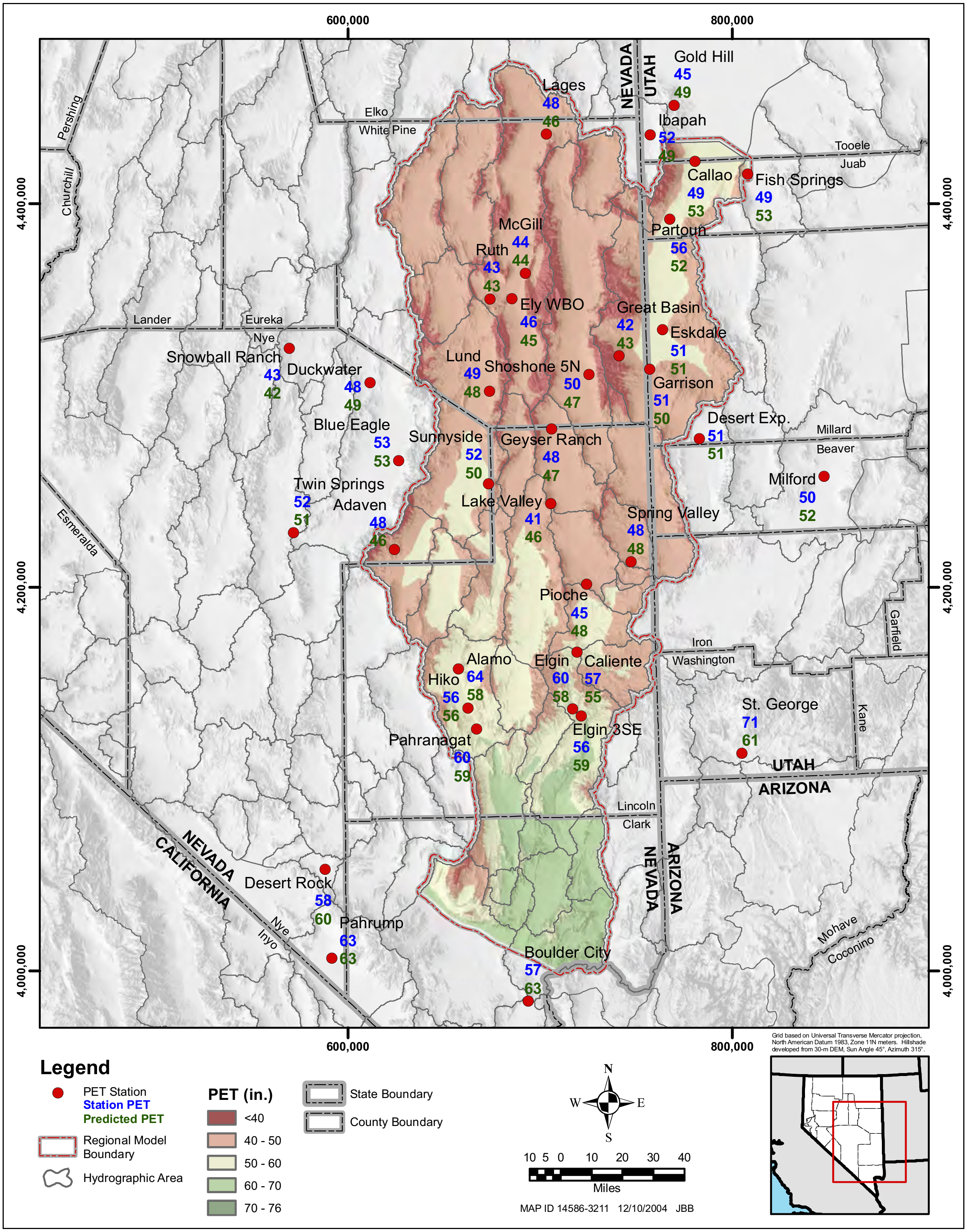

Figure E-1
Distribution of PET within the Flow System of the Study Area

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Appendix F

Details of Groundwater ET Estimates

F.1.0 DETAILS OF GROUNDWATER ET ESTIMATES

This appendix contains additional information in support of the groundwater ET estimates. This information consists of the details associated with the deterministic and stochastic groundwater ET estimates.

F.1.1 Deterministic Groundwater ET Estimates

Deterministic groundwater ET estimates were made for the entire study area using Method 1. Deterministic estimates were also made by Welch et al. (2008) for BARCASS using Method 2. The final estimates used in this study are a combination of Method 1 for the southern basins of the study area and Method 2 for the northern basins.

F.1.1.1 Method 1 Estimates

This section details the groundwater ET estimates derived by Method 1 and explains how the ET rates were selected, adjusted, and used in the calculations.

The literature ET rates presented in Appendix E were reviewed to select the most appropriate rates for each of the five ET-unit classes defined for this analysis. The rates selected for each class (Table F-1) were based on the similarities between the vegetation types and climate and the availability of supporting data, such as site coordinates, precipitation, and depth to water.

The selected literature ET rates were adjusted for use in the study area. The adjustment consisted of scaling the observed ET rates by the PET ratio (PET of ET area/PET at ET observation station). These adjusted rates were consistently applied to the study area with the following exceptions:

- ET rates for the medium-vegetation class in White River and Cave valleys were not scaled by the PET ratio. The average of the two basin-specific measured rates was used instead.

- Because the ET rate observed for the medium vegetation in Spring Valley was too low as compared to most of the medium vegetation that actually occurs in Spring Valley, this rate was not used. Instead, the mean value for dense desert shrubland derived for BARCASS, 1.24 ft/yr, was used.

- The basin-specific ET rate measured for bare soil in Snake Valley was used for that category without any scaling by PET.

Using the ET rates described above, the ET areas, and the 800-m PRISM precipitation grid presented in Section 5.0, the groundwater ET volumes were calculated using GIS tools. The calculations were

Table F-1
Method 1 - ET and PET Rates Used in the Derivation of Groundwater ET Estimates (Limited Station Data)

ET-Unit Class	Selected ET Site	Description of Selected ET Site	Total ET or Evaporation Rate (ft/yr)	Source	PET Rate Extracted from PET Grid (ft/yr)
Open Water	Peterson Reservoir	Open water supplied by spring discharge	8.60	Reiner et al. (2002)	5.42
Wetland/Meadow	SPV-3	Wetland/meadow land cover surrounding riparian corridors throughout the project area	2.25	Moreo et al. (2007)	4.00
Dense Meadow/ Riparian	Springdale and Carson Meadow	Area dominated by dense meadow and woodland vegetation, primarily trees, meadow and marsh grasses, or mixed trees, shrubs, and grasses; trees, desert ash and cottonwood, with some desert willow and mesquite; water table typically ranging from above land surface to about 20 ft bgs; soil wet to dry	3.30[a]	Reiner et al. (2002)	4.84
Medium-Density Phreatophytes	WRV-1, WRV-2, and SPV-2	Medium-density phreatophytes, greasewood and shrubs, such as sagebrush	1.03[b]	Moreo et al. (2007)	4.13
Bare Soil/ Low-Density Phreatophytes	Long-Term Mean Rate/BARCASS Region	Areas within the phreatophytic boundaries exhibiting ground cover densities of less than 20%, considered to be either bare soil or sparse vegetation cover	1.00[c]	Welch et al. (2008)	4.11

[a]Average ET rate from Springdale and Carson Meadow
[b]Average ET rate from WRV-1, WRV-2 and SPV-2
[c]Average of the area-weighted average annual ET for the sparse and moderately dense shrubland ET Units reported by Welch et al. (2008)

made following the 800-m PRISM grid and consisted of first subtracting the precipitation rate from the assigned ET rate, and second, multiplying the resulting groundwater ET rate by the area. For grid cells where the precipitation rates were larger than the ET rate, the difference was assumed to be zero. Thus, the corresponding groundwater ET volume was calculated as zero. The groundwater ET volumes calculated for the grid cells were then grouped by ET class for each basin where groundwater ET occurs. Table F-2 provides the results of these calculations. The table contains the scaled ET rates, the precipitation rates, and the groundwater ET areas.

The following are column-by-column descriptions of the information contained in Table F-2.

- HA Number: Hydrographic area number
- HA Name: Hydrographic area name
- ET Class Number: Class of groundwater ET within potential groundwater ET area
- Category 1 ET Area (acres): Area of groundwater ET categorized as likely using main groundwater system
- Category 2 ET Area (acres): Area of groundwater ET categorized as using uncertain groundwater system (may have partial or complete connection with main groundwater system
- Category 3 ET Area (acres): Area of groundwater ET categorized as likely using local groundwater system
- Total ET Area (acres): Total area of groundwater ET for categories 1, 2, and 3
- Scaled ET Rate (ft/yr): Total ET rates scaled by PET ratio
- Avg. Annual Precipitation PRISMV2 (ft/yr): Average precipitation rate for ET class within given basin derived from 800-m PRISM grid
- Category 1 Groundwater ET Volume (afy): Volume of groundwater ET calculated as (ET Rate – PRISMV2) × Category 1 ET area
- Category 2 Groundwater ET Volume (afy): Volume of groundwater ET calculated as (ET Rate – PRISMV2) × Category 2 ET area
- Category 3 Groundwater ET Volume (afy): Volume of groundwater ET calculated as (ET Rate – PRISMV2) × Category 3 ET area
- Total Groundwater ET Volume (afy): Total volume of groundwater ET (sum of Categories 1, 2, and 3)

Table F-2
Method 1 - Scaled ET Rates and Volumes of Groundwater ET by ET Class
(Page 1 of 4)

HA Number	HA Name	ET Class	ET Area Category 1	ET Area Category 2	ET Area Category 3	ET Area Total	Scaled ET Rate	Avg. Annual Precipitation PRISMV2	Groundwater ET Volume Category 1	Groundwater ET Volume Category 2	Groundwater ET Volume Category 3	Groundwater ET Volume Total
			(acres)				(ft/yr)		(afy)			
178B	Butte Valley South	1	2	0	0	2	5.95	0.96	10	0	0	10
		2	10,970	0	0	10,970	1.00	0.94	658	0	0	658
		3	38,321	0	0	38,321	1.16	0.94	8,431	0	0	8,431
		4	1,839	0	0	1,839	2.11	0.92	2,188	0	0	2,188
		178B Total	**51,132**	**0**	**0**	**51,132**			**11,287**	**0**	**0**	**11,287**
179	Steptoe Valley	1	129	0	4	133	6.07	0.83	676	0	21	697
		2	64,501	7	61	64,569	1.00	0.70	19,350	2	18	19,370
		3	51,050	171	846	52,067	1.19	0.73	23,483	79	389	23,951
		4	42,231	1,069	3,452	46,752	2.15	0.73	59,968	1,518	4,902	66,388
		179 Total	**157,911**	**1,247**	**4,363**	**163,521**			**103,477**	**1,599**	**5,330**	**110,406**
		GVFS Total	**209,043**	**1,247**	**4,363**	**214,653**			**114,764**	**1,599**	**5,330**	**121,693**
184	Spring Valley	1	278	0	0	278	6.36	0.72	1,568	0	0	1,568
		2	76,568	22	244	76,834	1.00	0.75	19,142	6	61	19,209
		3	68,916	62	272	69,250	1.24	0.80	30,323	27	120	30,470
		4	14,183	0	104	14,287	2.25	0.79	20,707	0	152	20,859
		6	11,505	0	0	11,505	0.71	0.79	0	0	0	0
		184 Total	**171,450**	**84**	**620**	**172,154**			**71,740**	**33**	**333**	**72,106**
185	Tippett Valley	2	7,554	0	5	7,559	1.00	0.78	1,662	0	1	1,663
		3	88	0	8	96	1.23	0.80	38	0	3	41
		4	130	0	34	164	2.22	0.80	185	0	48	233
		185 Total	**7,772**	**0**	**47**	**7,819**			**1,885**	**0**	**52**	**1,937**
194	Pleasant Valley	2	0	0	325	325	0.78	0.92	0	0	0	0
		3	0	0	1,213	1,213	1.19	0.98	0	0	255	255
		4	0	0	608	608	2.15	0.99	0	0	705	705
		194 Total	**0**	**0**	**2,146**	**2,146**			**0**	**0**	**960**	**960**
195	Snake Valley	1	336	0	2	338	6.75	0.71	2,029	0	12	2,041
		2	199,934	302	524	200,760	0.87	0.59	55,982	85	147	56,214
		3	18,855	688	667	20,210	1.32	0.69	11,879	433	420	12,732
		4	30,026	1,267	1,211	32,504	2.39	0.64	52,546	2,217	2,119	56,882
		6	58,009	0	0	58,009	0.71	0.55	9,281	0	0	9,281
		195 Total	**307,160**	**2,257**	**2,404**	**311,821**			**131,717**	**2,735**	**2,698**	**137,150**

Table F-2
Method 1 - Scaled ET Rates and Volumes of Groundwater ET by ET Class
(Page 2 of 4)

HA Number	HA Name	ET Class	ET Area: Category 1	ET Area: Category 2	ET Area: Category 3	ET Area: Total	Scaled ET Rate	Avg. Annual Precipitation PRISMV2	Groundwater ET Volume: Category 1	Groundwater ET Volume: Category 2	Groundwater ET Volume: Category 3	Groundwater ET Volume: Total
			(acres)				(ft/yr)		(afy)			
196	Hamlin Valley	1	0	0	0	0	6.45	0.73	0	0	0	0
		2	743	146	7	896	0.83	0.79	30	6	0	36
		3	1,918	293	117	2,328	1.26	0.77	940	144	57	1,141
		4	204	0	0	204	2.28	0.73	316	0	0	316
		196 Total	**2,865**	**439**	**124**	**3,428**			**1,286**	**150**	**57**	**1,493**
		GSLDFS Total	**489,247**	**2,780**	**5,341**	**497,368**			**206,628**	**2,918**	**4,100**	**213,646**
183	Lake Valley	1	58	0	0	58	6.26	0.86	313	0	0	313
		2	22,592	0	0	22,592	0.80	0.90	0	0	0	0
		3	21,112	0	0	21,112	0.98	0.91	1,478	0	0	1,478
		4	3,683	0	0	3,683	2.21	0.86	4,972	0	0	4,972
		183 Total	**47,445**	**0**	**0**	**47,445**			**6,763**	**0**	**0**	**6,763**
198	Dry Valley	1	33	0	0	33	6.68	1.08	185	0	0	185
		2	82	0	0	82	1.00	1.08	0	0	0	0
		3	1,182	0	0	1,182	2.87	1.07	2,128	0	0	2,128
		4	771	0	0	771	2.87	1.07	1,388	0	0	1,388
		198 Total	**2,068**	**0**	**0**	**2,068**			**3,701**	**0**	**0**	**3,701**
199	Rose Valley	2	0	0	0	0	1.00	1.12	0	0	0	0
		3	89	0	0	89	2.83	1.10	154	0	0	154
		4	255	0	0	255	2.83	1.10	441	0	0	441
		199 Total	**344**	**0**	**0**	**344**			**595**	**0**	**0**	**595**
200	Eagle Valley	2	3	0	0	3	1.00	1.14	0	0	0	0
		3	154	0	0	154	2.79	1.14	254	0	0	254
		4	477	0	0	477	2.79	1.15	782	0	0	782
		200 Total	**634**	**0**	**0**	**634**			**1,036**	**0**	**0**	**1,036**
201	Spring Valley	1	52	0	0	52	6.28	1.15	267	0	0	267
		2	7	3	0	10	1.00	1.14	0	0	0	0
		3	603	25	2	630	2.70	1.12	953	40	3	996
		4	1,528	52	77	1,657	2.70	1.10	2,445	83	123	2,651
		201 Total	**2,190**	**80**	**79**	**2,349**			**3,665**	**123**	**126**	**3,914**
202	Patterson Valley	3	771	0	0	771	2.81	1.06	1,349	0	0	1,349
		202 Total	**771**	**0**	**0**	**771**			**1,349**	**0**	**0**	**1,349**

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Table F-2
Method 1 - Scaled ET Rates and Volumes of Groundwater ET by ET Class
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HA Number	HA Name	ET Class	ET Area Category 1	ET Area Category 2	ET Area Category 3	ET Area Total	Scaled ET Rate	Avg. Annual Precipitation PRISMV2	Groundwater ET Volume Category 1	Groundwater ET Volume Category 2	Groundwater ET Volume Category 3	Groundwater ET Volume Total
			(acres)				(ft/yr)		(afy)			
203	Panaca Valley	2	343	0	0	343	1.00	0.86	48	0	0	48
		3	3,537	0	0	3,537	3.03	0.88	7,605	0	0	7,605
		4	5,224	0	0	5,224	3.03	0.88	11,232	0	0	11,232
		203 Total	**9,104**	**0**	**0**	**9,104**			**18,885**	**0**	**0**	**18,885**
204	Clover Valley	2	36	0	150	186	1.00	1.36	0	0	0	0
		3	136	0	1,641	1,777	2.90	1.42	201	0	2,429	2,630
		4	359	0	1,188	1,547	2.90	1.21	607	0	2,008	2,615
		204 Total	**531**	**0**	**2,979**	**3,510**			**808**	**0**	**4,437**	**5,245**
205	Lower Meadow Valley Wash	1	0	0	0	0	8.43	0.45	0	0	0	0
		2	528	0	0	528	1.00	0.48	275	0	0	275
		3	1,264	0	0	1,264	3.62	0.60	3,817	0	0	3,817
		4	6,024	0	0	6,024	3.62	0.67	17,771	0	0	17,771
		205 Total	**7,816**	**0**	**0**	**7,816**			**21,863**	**0**	**0**	**21,863**
		MVFS Total	**70,903**	**80**	**3,058**	**74,041**			**58,665**	**123**	**4,563**	**63,351**
172	Garden Valley	2	12	0	9	21	1.00	0.92	1	0	1	2
		3	483	0	69	552	2.82	0.94	908	0	130	1,038
		4	129	0	247	376	2.82	1.07	226	0	432	658
		172 Total	**624**	**0**	**325**	**949**			**1,135**	**0**	**563**	**1,698**
174	Jakes Valley	1	0	0	0	0	5.72	1.07	0	0	0	0
		2	0	0	4	4	1.00	1.06	0	0	0	0
		3	0	0	621	621	1.12	1.03	0	0	56	56
		4	0	0	346	346	2.02	1.05	0	0	336	336
		174 Total	**0**	**0**	**971**	**971**			**0**	**0**	**392**	**392**
175	Long Valley	2	6,727	13	0	6,740	1.00	0.95	336	1	0	337
		3	10,167	557	0	10,724	1.18	0.95	2,338	128	0	2,466
		4	131	0	0	131	2.14	0.95	156	0	0	156
		175 Total	**17,025**	**570**	**0**	**17,595**			**2,830**	**129**	**0**	**2,959**
180	Cave Valley	2	0	5,914	0	5,914	1.00	1.06	0	0	0	0
		3	814	8,763	74	9,651	1.03	1.05	0	0	0	0
		4	952	0	132	1,084	2.17	0.98	1,133	0	157	1,290
		180 Total	**1,766**	**14,677**	**206**	**16,649**			**1,133**	**0**	**157**	**1,290**

Table F-2
Method 1 - Scaled ET Rates and Volumes of Groundwater ET by ET Class
(Page 4 of 4)

HA Number	HA Name	ET Class	ET Area Category 1	ET Area Category 2	ET Area Category 3	ET Area Total	Scaled ET Rate	Avg. Annual Precipitation PRISMV2	Groundwater ET Volume Category 1	Groundwater ET Volume Category 2	Groundwater ET Volume Category 3	Groundwater ET Volume Total
			(acres)				(ft/yr)		(afy)			
207	White River Valley	1	313	1	0	314	6.63	0.80	1,825	6	0	1,831
		2	28,551	68	16	28,635	1.00	0.80	5,710	14	3	5,727
		3	86,764	637	385	87,786	1.04	0.83	18,220	134	81	18,435
		4	25,124	2,545	288	27,957	2.34	0.85	37,435	3,792	429	41,656
		207 Total	**140,752**	**3,251**	**689**	**144,692**			**63,190**	**3,946**	**513**	**67,649**
209	Pahranagat Valley	1	1,296	0	0	1,296	7.68	0.58	9,202	0	0	9,202
		2	260	0	0	260	1.00	0.61	101	0	0	101
		3	816	0	0	816	3.30	0.61	2,195	0	0	2,195
		4	6,285	0	0	6,285	3.30	0.59	17,032	0	0	17,032
		209 Total	**8,657**	**0**	**0**	**8,657**			**28,530**	**0**	**0**	**28,530**
215	Black Mountains Area	2	54	0	0	54	1.00	0.45	30	0	0	30
		3	244	0	0	244	3.88	0.46	834	0	0	834
		4	165	0	0	165	3.88	0.44	568	0	0	568
		215 Total	**463**	**0**	**0**	**463**			**1,432**	**0**	**0**	**1,432**
218	California Wash	2	37	0	0	37	1.00	0.45	20	0	0	20
		3	149	0	0	149	3.80	0.46	498	0	0	498
		4	1,194	0	0	1,194	3.80	0.46	3,988	0	0	3,988
		218 Total	**1,380**	**0**	**0**	**1,380**			**4,506**	**0**	**0**	**4,506**
219	Muddy River Springs Area	2	166	0	0	166	1.00	0.46	90	0	0	90
		3	214	0	0	214	3.77	0.46	708	0	0	708
		4	1,571	0	0	1,571	3.77	0.46	5,200	0	0	5,200
		219 Total	**1,951**	**0**	**0**	**1,951**			**5,998**	**0**	**0**	**5,998**
220	Lower Moapa Valley	1	137	0	0	137	9.06	0.45	1,180	0	0	1,180
		2	496	0	0	496	1.00	0.44	278	0	0	278
		3	907	0	0	907	3.89	0.44	3,129	0	0	3,129
		4	5,993	0	0	5,993	3.89	0.44	20,676	0	0	20,676
		220 Total	**7,533**	**0**	**0**	**7,533**			**25,263**	**0**	**0**	**25,263**
		WRFS Total	**180,151**	**18,498**	**2,191**	**200,840**			**134,017**	**4,075**	**1,625**	**139,717**
		Grand Total	**949,344**	**22,605**	**14,953**	**986,902**			**514,074**	**8,715**	**15,618**	**538,407**

F.1.1.2 Method 2 - BARCASS Estimates

The detailed estimates of groundwater ET derived for basins located in the BARCASS area are documented in four USGS reports:

- The final groundwater ET estimates are documented in the summary report titled *Water Resources of the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and Utah* prepared by Welch et al. (2008).

- The potential groundwater ET areas and their classification are documented in a report titled *Mapping Evapotranspiration Units in the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and Utah* by Smith et al. (2007).

- Field measurements of ET rates and ancillary information are documented in a report titled *Evapotranspiration Rate Measurements of Vegetation Typical of Ground-Water Discharge areas in the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and Utah* by Moreo et al. (2007).

- The agricultural areas are documented in a report titled *Irrigated Acreage within the Basin and Range Carbonate-Rock Aquifer System, White Pine County, Nevada, and Adjacent Areas in Nevada and Utah* by Welborn and Moreo (2007).

F.1.1.3 Combined Method 1 and Method 2 (BARCASS)

The estimates of groundwater ET are derived by Method 1 for the southern basins and Method 2 (BARCASS) for the northern basins to accomplish the following:

- Directly compare the ET rates and volumes derived using Methods 1 and 2 (BARCASS).
- Calculate and compare groundwater ET volumes for each category of ET area in each basin.
- Derive stochastic estimates of groundwater ET volumes using a single ET data set.

The resulting ET areas and annual volumes of groundwater ET for the 5 ET classes for the basins of the study area are listed in Table F-3 by category. This part of the data analysis was performed before the publication of DeMeo et al. (2008) and therefore does not include their estimates.

The combined ET data set was used, and the ET rates for equivalent classes in basins that are common to Methods 1 and 2 (BARCASS) were compared directly. As shown on Figure F-1, the rates derived using the two methods are comparable. The basin groundwater ET volumes derived by BARCASS are also comparable to those derived by Method 1. See Figure F-2 and Table F-3 for the volumes derived by the combined data set.

The consistent data set was used as the source of input parameters in the Monte Carlo analysis. The estimates of annual volumes of groundwater ET, derived from this Monte Carlo analysis, are described in the following section.

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Table F-3
Groundwater ET Areas and Volumes Using Combined Method 1 and Method 2 (BARCASS) Data Set
(Page 1 of 6)

HA Number	HA Name	Sub-Area Number	ET Class Number	ET Class Name	Category 1 Area (ac)	Category 1 Volume (afy)	Category 2 Area (ac)	Category 2 Volume (afy)	Category 3 Area (ac)	Category 3 Volume (afy)	Total Area (ac)	Total Volume (afy)
178B	Butte Valley (South)	N	1	Open Water	4	16	0	0	0	0	4	16
		N	2	Bare Soil/Low Vegetation	8,265	281	0	0	0	0	8,265	281
		N	3	Phreatophyte/Medium Vegetation	60,033	9,904	0	0	241	40	60,274	9,944
		N	4	Wetland/Meadow	1,092	1,559	0	0	65	93	1,157	1,652
				178B Total	**69,393**	**11,760**	**0**	**0**	**306**	**133**	**69,700**	**11,893**
172	Garden Valley	N	2	Bare Soil/Low Vegetation	12	1	0	0	9	1	21	2
		N	3	Phreatophyte/Medium Vegetation	483	906	0	0	69	130	552	1,036
		N	4	Wetland/Meadow	129	226	0	0	247	432	376	658
				172 Total	**624**	**1,133**	**0**	**0**	**325**	**563**	**949**	**1,696**
174	Jakes Valley	N	1	Open Water	0	0	0	0	26	110	26	110
		N	2	Bare Soil/Low Vegetation	0	0	0	0	6	0	6	0
		N	3	Phreatophyte/Medium Vegetation	0	0	0	0	930	384	930	384
		N	4	Wetland/Meadow	0	0	0	0	263	370	263	370
				174 Total	**0**	**0**	**0**	**0**	**1,225**	**864**	**1,225**	**864**
175	Long Valley	N	2	Bare Soil/Low Vegetation	4,858	194	45	2	0	0	4,903	196
		N	3	Phreatophyte/Medium Vegetation	12,939	2,041	440	69	0	0	13,379	2,110
		N	4	Wetland/Meadow	7	12	2	3	0	0	9	15
				175 Total	**17,804**	**2,247**	**487**	**74**	**0**	**0**	**18,291**	**2,321**
179	Steptoe Valley	1	1	Open Water	107	462	0	0	14	62	121	524
		1	2	Bare Soil/Low Vegetation	29,605	5,344	0	0	86	16	29,691	5,360
		1	3	Phreatophyte/Medium Vegetation	112,693	52,771	0	0	3,253	1,523	115,946	54,294
		1	4	Wetland/Meadow	13,136	26,521	0	0	1,439	2,906	14,575	29,427
		1	6	Playa	2,723	692	0	0	0	0	2,723	692
				Subtotal	**158,264**	**85,790**	**0**	**0**	**4,792**	**4,507**	**163,056**	**90,297**
		2	1	Open Water	296	1,238	0	0	22	94	318	1,332
		2	2	Bare Soil/Low Vegetation	398	32	14	1	4	0	416	33
		2	3	Phreatophyte/Medium Vegetation	6,417	2,783	293	127	316	137	7,026	3,047
		2	4	Wetland/Meadow	3,654	6,743	43	80	99	183	3,796	7,006
				Subtotal	**10,765**	**10,796**	**350**	**208**	**441**	**414**	**11,556**	**11,418**
				179 Total	**169,029**	**96,586**	**350**	**208**	**5,233**	**4,921**	**174,612**	**101,715**
180	Cave Valley	N	2	Bare Soil/Low Vegetation	5	0	3,548	0	2	0	3,555	0
		N	3	Phreatophyte/Medium Vegetation	1,061	56	7,542	395	136	7	8,739	458
		N	4	Wetland/Meadow	786	1,135	2	3	79	114	867	1,252
		N	6	Playa	0	0	194	0	0	0	194	0
				180 Total	**1,852**	**1,191**	**11,286**	**398**	**217**	**121**	**13,355**	**1,710**

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JA_16059

Table F-3
Groundwater ET Areas and Volumes Using Combined Method 1 and Method 2 (BARCASS) Data Set
(Page 2 of 6)

HA Number	HA Name	Sub-Area Number	ET Class Number	ET Class Name	Category 1 Area (ac)	Category 1 Volume (afy)	Category 2 Area (ac)	Category 2 Volume (afy)	Category 3 Area (ac)	Category 3 Volume (afy)	Total Area (ac)	Total Volume (afy)
					Groundwater ET							
183	Lake Valley	N	1	Open Water	26	106	0	0	0	0	26	106
		N	2	Bare Soil/Low Vegetation	16,303	0	0	0	0	0	16,303	0
		N	3	Phreatophyte/Medium Vegetation	36,478	1,094	0	0	0	0	36,478	1,094
		N	4	Wetland/Meadow	2,596	4,743	0	0	0	0	2,596	4,743
		N	6	Playa	94	1	0	0	0	0	94	1
				183 Total	**55,497**	**5,944**	**0**	**0**	**0**	**0**	**55,497**	**5,944**
184	Spring Valley	1	2	Bare Soil/Low Vegetation	235	40	94	16	36	6	365	62
		1	3	Phreatophyte/Medium Vegetation	2,213	954	186	80	147	63	2,546	1,097
		1	4	Wetland/Meadow	767	1,608	0	0	49	103	816	1,711
				Subtotal	**3,215**	**2,602**	**280**	**96**	**232**	**172**	**3,727**	**2,870**
184	Spring Valley	2	1	Open Water	6	27	0	0	0	0	6	27
		2	2	Bare Soil/Low Vegetation	20,208	3,435	0	0	10	2	20,218	3,437
		2	3	Phreatophyte/Medium Vegetation	40,930	16,176	0	0	398	157	41,328	16,333
		2	4	Wetland/Meadow	6,360	13,056	0	0	10	21	6,370	13,077
		2	6	Playa	17,651	5,500	0	0	0	0	17,651	5,500
				Subtotal	**85,155**	**38,195**	**0**	**0**	**418**	**180**	**85,573**	**38,374**
184	Spring Valley	3	2	Bare Soil/Low Vegetation	3,268	560	0	0	0	0	3,268	560
		3	3	Phreatophyte/Medium Vegetation	19,194	6,967	0	0	0	0	19,194	6,967
		3	4	Wetland/Meadow	319	501	0	0	0	0	319	501
		3	6	Playa	676	83	0	0	0	0	676	83
				Subtotal	**23,457**	**8,111**	**0**	**0**	**0**	**0**	**23,457**	**8,111**
184	Spring Valley	4	2	Bare Soil/Low Vegetation	11,870	2,255	0	0	2	0	11,872	2,255
		4	3	Phreatophyte/Medium Vegetation	49,270	17,042	0	0	58	20	49,328	17,062
		4	4	Wetland/Meadow	3,266	6,695	0	0	22	45	3,288	6,740
		4	6	Playa	529	23	0	0	0	0	529	23
				Subtotal	**64,935**	**26,015**	**0**	**0**	**82**	**65**	**65,017**	**26,080**
				184 Total	**176,762**	**74,923**	**280**	**96**	**732**	**417**	**177,774**	**75,435**
185	Tippett Valley	N	2	Bare Soil/Low Vegetation	1,624	292	0	0	0	0	1,624	292
		N	3	Phreatophyte/Medium Vegetation	5,551	1,325	0	0	35	8	5,586	1,333
		N	4	Wetland/Meadow	59	79	0	0	13	17	72	96
		N	6	Playa	497	6	0	0	0	0	497	6
				185 Total	**7,731**	**1,702**	**0**	**0**	**48**	**25**	**7,779**	**1,727**
194	Pleasant Valley	2	2	Bare Soil/Low Vegetation	0	0	0	0	118	37	118	37
		2	3	Phreatophyte/Medium Vegetation	0	0	0	0	759	512	759	512
		2	4	Wetland/Meadow	0	0	0	0	226	474	226	474
				194 Total	**0**	**0**	**0**	**0**	**1,103**	**1,023**	**1,103**	**1,023**

Table F-3
Groundwater ET Areas and Volumes Using Combined Method 1 and Method 2 (BARCASS) Data Set
(Page 3 of 6)

HA Number	HA Name	Sub-Area Number	ET Class Number	ET Class Name	Category 1 Area (ac)	Category 1 Volume (afy)	Category 2 Area (ac)	Category 2 Volume (afy)	Category 3 Area (ac)	Category 3 Volume (afy)	Total Area (ac)	Total Volume (afy)
195	Snake Valley	1	2	Bare Soil/Low Vegetation	13,604	2,585	300	57	0	0	13,904	2,642
		1	3	Phreatophyte/Medium Vegetation	4,006	2,383	266	158	0	0	4,272	2,541
		1	4	Wetland/Meadow	1,239	2,852	27	63	0	0	1,266	2,915
		1	6	Playa	56,065	4,205	7	1	0	0	56,072	4,206
				Subtotal	**74,914**	**12,025**	**600**	**279**	**0**	**0**	**75,514**	**12,304**
195	Snake Valley	2	1	Open Water	54	247	0	0	0	0	54	247
		2	2	Bare Soil/Low Vegetation	11,380	3,063	0	0	3	1	11,383	3,064
		2	3	Phreatophyte/Medium Vegetation	14,951	8,503	0	0	132	75	15,083	8,578
		2	4	Wetland/Meadow	1,439	3,188	0	0	1	3	1,440	3,191
		2	6	Playa	574	44	0	0	0	0	574	44
				Subtotal	**28,398**	**15,045**	**0**	**0**	**136**	**79**	**28,534**	**15,124**
195	Snake Valley	3	1	Open Water	65	297	0	0	6	27	71	324
		3	2	Bare Soil/Low Vegetation	104,340	31,885	38	12	140	43	104,518	31,940
		3	3	Phreatophyte/Medium Vegetation	68,151	37,546	429	236	1,679	925	70,259	38,707
		3	4	Wetland/Meadow	4,482	8,787	284	558	354	694	5,120	10,039
		3	6	Playa	7,092	1,314	0	0	0	0	7,092	1,314
				Subtotal	**184,130**	**79,829**	**751**	**806**	**2,179**	**1,689**	**187,060**	**82,324**
195	Snake Valley	4	1	Open Water	302	1,344	0	0	0	0	302	1,344
		4	2	Bare Soil/Low Vegetation	3,170	951	0	0	0	0	3,170	951
		4	3	Phreatophyte/Medium Vegetation	22,563	10,662	0	0	0	0	22,563	10,662
		4	4	Wetland/Meadow	3,126	6,643	0	0	0	0	3,126	6,643
				Subtotal	**29,161**	**19,600**	**0**	**0**	**0**	**0**	**29,161**	**19,600**
				195 Total	**316,603**	**126,499**	**1,351**	**1,085**	**2,315**	**1,768**	**320,269**	**129,352**
196	Hamlin Valley	N	2	Bare Soil/Low Vegetation	98	29	4	1	0	0	102	30
		N	3	Phreatophyte/Medium Vegetation	3,612	1,714	431	205	0	0	4,043	1,919
		N	4	Wetland/Meadow	60	102	2	3	0	0	62	105
				196 Total	**3,770**	**1,845**	**437**	**209**	**0**	**0**	**4,207**	**2,054**
198	Dry Valley	N	1	Open Water	33	183	0	0	0	0	33	183
		N	2	Bare Soil/Low Vegetation	82	0	0	0	0	0	82	0
		N	3	Phreatophyte/Medium Vegetation	1,182	2,133	0	0	0	0	1,182	2,133
		N	4	Wetland/Meadow	771	1,394	0	0	0	0	771	1,394
				198 Total	**2,068**	**3,710**	**0**	**0**	**0**	**0**	**2,068**	**3,710**
199	Rose Valley	N	2	Bare Soil/Low Vegetation	0	0	0	0	0	0	0	0
		N	3	Phreatophyte/Medium Vegetation	89	153	0	0	0	0	89	153
		N	4	Wetland/Meadow	255	441	0	0	0	0	255	441
				199 Total	**344**	**594**	**0**	**0**	**0**	**0**	**344**	**594**

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JA_16061

Table F-3
Groundwater ET Areas and Volumes Using Combined Method 1 and Method 2 (BARCASS) Data Set
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HA Number	HA Name	Sub-Area Number	ET Class Number	ET Class Name	Category 1 Area (ac)	Category 1 Volume (afy)	Category 2 Area (ac)	Category 2 Volume (afy)	Category 3 Area (ac)	Category 3 Volume (afy)	Total Area (ac)	Total Volume (afy)
					Groundwater ET							
200	Eagle Valley	N	2	Bare Soil/Low Vegetation	3	0	0	0	0	0	3	0
		N	3	Phreatophyte/Medium Vegetation	154	253	0	0	0	0	154	253
		N	4	Wetland/Meadow	477	780	0	0	0	0	477	780
				200 Total	**634**	**1,033**	**0**	**0**	**0**	**0**	**634**	**1,033**
201	Spring Valley	N	1	Open Water	52	266	0	0	0	0	52	266
		N	2	Bare Soil/Low Vegetation	7	0	3	0	0	0	10	0
		N	3	Phreatophyte/Medium Vegetation	603	955	25	40	2	4	630	999
		N	4	Wetland/Meadow	1,528	2,441	52	82	77	124	1,657	2,647
				201 Total	**2,190**	**3,662**	**80**	**122**	**79**	**128**	**2,349**	**3,912**
202	Patterson Valley	N	3	Phreatophyte/Medium Vegetation	771	1,346	0	0	0	0	771	1,346
				202 Total	**771**	**1,346**	**0**	**0**	**0**	**0**	**771**	**1,346**
203	Panaca Valley	N	2	Bare Soil/Low Vegetation	343	49	0	0	0	0	343	49
		N	3	Phreatophyte/Medium Vegetation	3,537	7,620	0	0	0	0	3,537	7,620
		N	4	Wetland/Meadow	5,224	11,226	0	0	0	0	5,224	11,226
				203 Total	**9,104**	**18,895**	**0**	**0**	**0**	**0**	**9,104**	**18,895**
204	Clover Valley	N	2	Bare Soil/Low Vegetation	36	0	0	0	150	0	186	0
		N	3	Phreatophyte/Medium Vegetation	136	225	0	0	1,641	2,710	1,777	2,935
		N	4	Wetland/Meadow	359	674	0	0	1,188	2,231	1,547	2,905
				204 Total	**531**	**899**	**0**	**0**	**2,979**	**4,941**	**3,510**	**5,840**
205	Lower Meadow Valley Wash	1	2	Bare Soil/Low Vegetation	21	1	0	0	0	0	21	1
		1	3	Phreatophyte/Medium Vegetation	257	316	0	0	0	0	257	316
		1	4	Wetland/Meadow	797	975	0	0	0	0	797	975
				Subtotal	**1,075**	**1,293**	**0**	**0**	**0**	**0**	**1,075**	**1,293**
205	Lower Meadow Valley Wash	2	2	Bare Soil/Low Vegetation	2	0	0	0	0	0	2	0
		2	3	Phreatophyte/Medium Vegetation	131	151	0	0	0	0	131	151
		2	4	Wetland/Meadow	710	808	0	0	0	0	710	808
				Subtotal	**843**	**959**	**0**	**0**	**0**	**0**	**843**	**959**
205	Lower Meadow Valley Wash	3	2	Bare Soil/Low Vegetation	30	6	0	0	0	0	30	6
		3	3	Phreatophyte/Medium Vegetation	124	169	0	0	0	0	124	169
		3	4	Wetland/Meadow	2,322	3,020	0	0	0	0	2,322	3,020
				Subtotal	**2,476**	**3,194**	**0**	**0**	**0**	**0**	**2,476**	**3,194**
205	Lower Meadow Valley Wash	4	1	Open Water	0	1	0	0	0	0	0	1
		4	2	Bare Soil/Low Vegetation	6	1	0	0	0	0	6	1
		4	3	Phreatophyte/Medium Vegetation	38	53	0	0	0	0	38	53
		4	4	Wetland/Meadow	834	1,161	0	0	0	0	834	1,161
				Subtotal	**878**	**1,216**	**0**	**0**	**0**	**0**	**878**	**1,216**

Table F-3
Groundwater ET Areas and Volumes Using Combined Method 1 and Method 2 (BARCASS) Data Set
(Page 5 of 6)

HA Number	HA Name	Sub-Area Number	ET Class Number	ET Class Name	Category 1 Area (ac)	Category 1 Volume (afy)	Category 2 Area (ac)	Category 2 Volume (afy)	Category 3 Area (ac)	Category 3 Volume (afy)	Total Area (ac)	Total Volume (afy)
205	Lower Meadow Valley Wash	5	1	Open Water	0	1	0	0	0	0	0	1
		5	2	Bare Soil/Low Vegetation	469	111	0	0	0	0	469	111
		5	3	Phreatophyte/Medium Vegetation	714	995	0	0	0	0	714	995
		5	4	Wetland/Meadow	1,360	1,899	0	0	0	0	1,360	1,899
				Subtotal	**2,543**	**3,006**	**0**	**0**	**0**	**0**	**2,543**	**3,006**
				205 Total	**7,815**	**9,668**	**0**	**0**	**0**	**0**	**7,815**	**9,668**
207	White River Valley	1	2	Bare Soil/Low Vegetation	14,564	3,043	134	28	0	0	14,698	3,071
		1	3	Phreatophyte/Medium Vegetation	79,383	27,705	2,228	778	99	35	81,710	28,518
		1	4	Wetland/Meadow	5,700	8,914	516	807	154	241	6,370	9,962
		1	6	Playa	77	7	0	0	0	0	77	7
				Subtotal	**99,724**	**39,669**	**2,878**	**1,613**	**253**	**276**	**102,855**	**41,558**
207	White River Valley	2	1	Open Water	685	2,967	0	0	0	0	685	2,967
		2	2	Bare Soil/Low Vegetation	30,226	6,488	0	0	4	1	30,230	6,489
		2	3	Phreatophyte/Medium Vegetation	37,999	12,967	0	0	822	280	38,821	13,247
		2	4	Wetland/Meadow	4,461	11,528	0	0	211	545	4,672	12,073
		2	6	Playa	907	112	0	0	0	0	907	112
				Subtotal	**74,279**	**34,062**	**0**	**0**	**1,037**	**826**	**75,315**	**34,888**
				207 Total	**174,003**	**73,731**	**2,878**	**1,613**	**1,290**	**1,102**	**178,170**	**76,446**
209	Pahranagat Valley	1	1	Open Water	384	2,693	0	0	0	0	384	2,693
		1	2	Bare Soil/Low Vegetation	97	33	0	0	0	0	97	33
		1	3	Phreatophyte/Medium Vegetation	262	689	0	0	0	0	262	689
		1	4	Wetland/Meadow	863	2,268	0	0	0	0	863	2,268
				Subtotal	**1,606**	**5,683**	**0**	**0**	**0**	**0**	**1,606**	**5,683**
209	Pahranagat Valley	2	2	Bare Soil/Low Vegetation	73	27	0	0	0	0	73	27
		2	3	Phreatophyte/Medium Vegetation	294	789	0	0	0	0	294	789
		2	4	Wetland/Meadow	2,934	7,885	0	0	0	0	2,934	7,885
				Subtotal	**3,301**	**8,701**	**0**	**0**	**0**	**0**	**3,301**	**8,701**
209	Pahranagat Valley	3	1	Open Water	464	3,302	0	0	0	0	464	3,302
		3	2	Bare Soil/Low Vegetation	37	16	0	0	0	0	37	16
		3	3	Phreatophyte/Medium Vegetation	87	239	0	0	0	0	87	239
		3	4	Wetland/Meadow	847	2,308	0	0	0	0	847	2,308
				Subtotal	**1,435**	**5,865**	**0**	**0**	**0**	**0**	**1,435**	**5,865**

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JA_16063

Table F-3
Groundwater ET Areas and Volumes Using Combined Method 1 and Method 2 (BARCASS) Data Set
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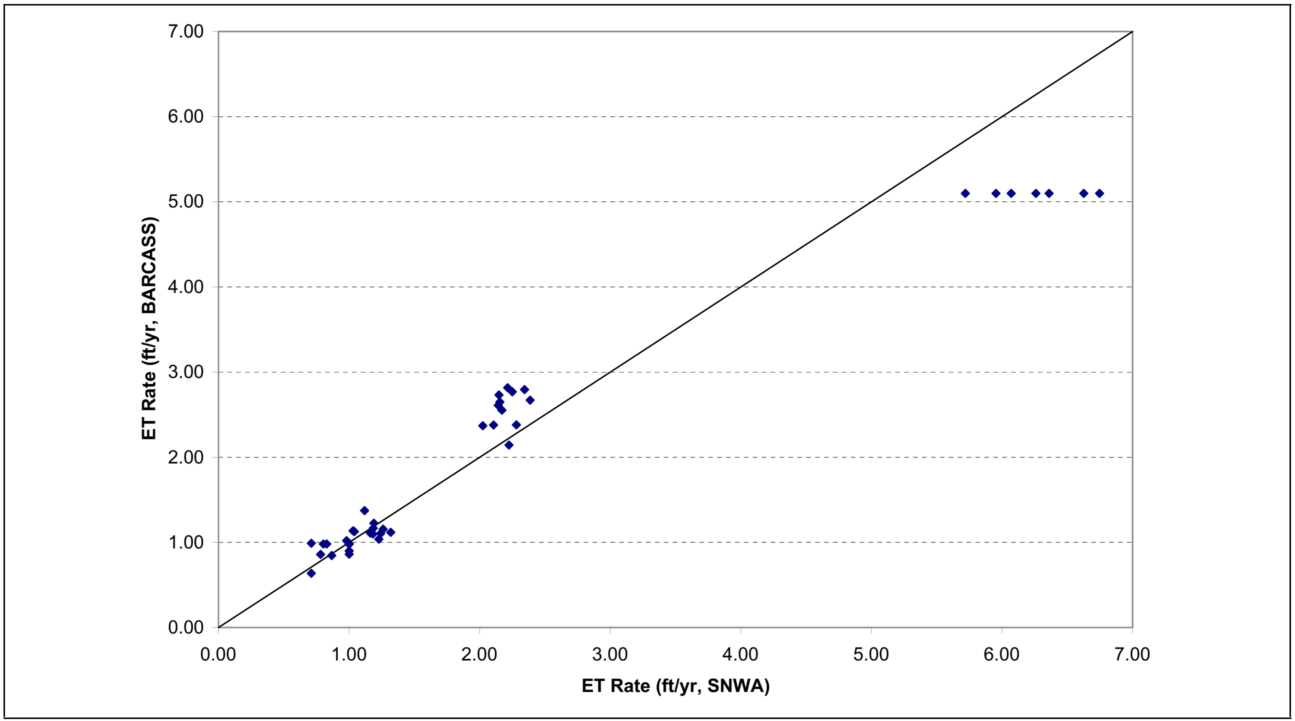
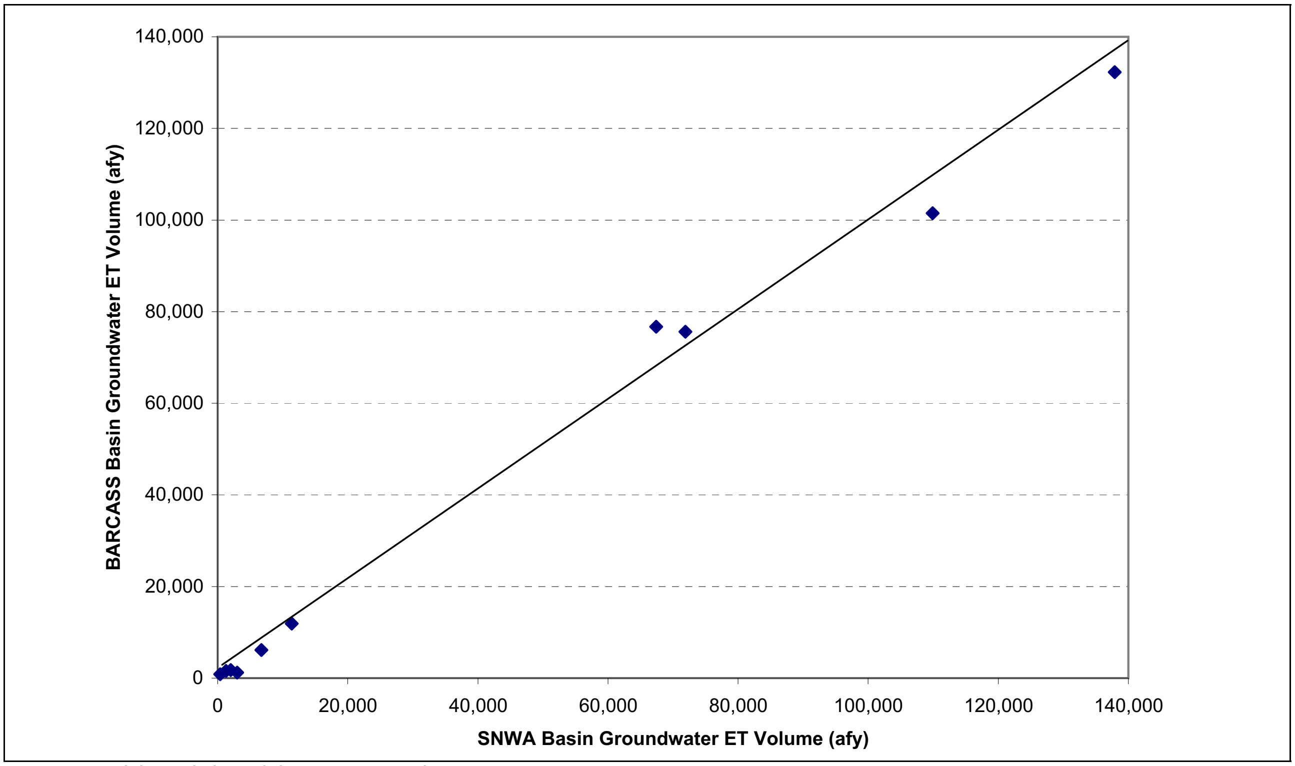
HA Number	HA Name	Sub-Area Number	ET Class Number	ET Class Name	Category 1 Area (ac)	Category 1 Volume (afy)	Category 2 Area (ac)	Category 2 Volume (afy)	Category 3 Area (ac)	Category 3 Volume (afy)	Total Area (ac)	Total Volume (afy)
					Groundwater ET							
209	Pahranagat Valley	4	1	Open Water	74	527	0	0	0	0	74	527
		4	2	Bare Soil/Low Vegetation	12	6	0	0	0	0	12	6
		4	3	Phreatophyte/Medium Vegetation	64	178	0	0	0	0	64	178
		4	4	Wetland/Meadow	900	2,492	0	0	0	0	900	2,492
				Subtotal	**1,050**	**3,203**	**0**	**0**	**0**	**0**	**1,050**	**3,203**
209	Pahranagat Valley	5	1	Open Water	375	2,686	0	0	0	0	375	2,686
		5	2	Bare Soil/Low Vegetation	41	20	0	0	0	0	41	20
		5	3	Phreatophyte/Medium Vegetation	108	301	0	0	0	0	108	301
		5	4	Wetland/Meadow	741	2,063	0	0	0	0	741	2,063
				Subtotal	**1,265**	**5,070**	**0**	**0**	**0**	**0**	**1,265**	**5,070**
				209 Total	**8,657**	**28,522**	**0**	**0**	**0**	**0**	**8,657**	**28,522**
215	Black Mountain Area	N	2	Bare Soil/Low Vegetation	54	30	0	0	0	0	54	30
		N	3	Phreatophyte/Medium Vegetation	244	835	0	0	0	0	244	835
		N	4	Wetland/Meadow	165	567	0	0	0	0	165	567
				215 Total	**463**	**1,432**	**0**	**0**	**0**	**0**	**463**	**1,432**
218	California Wash	N	2	Bare Soil/Low Vegetation	37	20	0	0	0	0	37	20
		N	3	Phreatophyte/Medium Vegetation	149	497	0	0	0	0	149	497
		N	4	Wetland/Meadow	1,194	3,988	0	0	0	0	1,194	3,988
				218 Total	**1,380**	**4,505**	**0**	**0**	**0**	**0**	**1,380**	**4,505**
219	Muddy River Springs Area	N	2	Bare Soil/Low Vegetation	166	89	0	0	0	0	166	89
		N	3	Phreatophyte/Medium Vegetation	214	706	0	0	0	0	214	706
		N	4	Wetland/Meadow	1,571	5,193	0	0	0	0	1,571	5,193
				219 Total	**1,951**	**5,988**	**0**	**0**	**0**	**0**	**1,951**	**5,988**
220	Lower Moapa Valley	N	1	Open Water	137	1,182	0	0	0	0	137	1,182
		N	2	Bare Soil/Low Vegetation	496	278	0	0	0	0	496	278
		N	3	Phreatophyte/Medium Vegetation	907	3,132	0	0	0	0	907	3,132
		N	4	Wetland/Meadow	5,993	20,719	0	0	0	0	5,993	20,719
				220 Total	**7,533**	**25,311**	**0**	**0**	**0**	**0**	**7,533**	**25,311**

N = Not defined



Source: Welch et al. (2008) for BARCASS data

Figure F-1
Comparison between ET Rates Derived by Methods 1 and 2 (BARCASS)



Source: Welch et al. (2008) for BARCASS data

Figure F-2
Comparison between SNWA and BARCASS ET Volumes

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F.1.2 Stochastic Estimates of Groundwater ET

Stochastic estimates of groundwater ET were derived for the study area using the consistent groundwater ET data set described in the previous section. The magnitude of the uncertainty in the calculated annual volumes of groundwater ET was estimated using Monte Carlo simulations implemented in the Crystal Ball software. Considering that the groundwater ET volume of each ET class was calculated as its area times the appropriate ET rate less the precipitation volume on the area, the uncertainty on the volumes of groundwater ET is due to the uncertainty in these three input parameters. The uncertainty in the input parameters used in the analysis and the detailed results are described here.

F.1.2.1 Uncertainty of Input Parameters

The Monte Carlo analysis requires estimates of the uncertainty on each of the three variables: potential ET area, ET rate, and precipitation rate. All three variables are assumed to be normally distributed. The ET rate is, however, dependent on the precipitation rate, as total ET is the sum of groundwater ET and precipitation. Therefore, these two variables are correlated. The information supporting the uncertainty estimated for each input variable (ET class area, precipitation rate, and ET rate) is described in the following text.

F.1.2.1.1 ET Class Areas

The potential groundwater ET areas needed are those reflecting predevelopment conditions. However, no records of these areas exist prior to the Reconnaissance Series. Thus, it was assumed that mean groundwater areas derived from previous studies and satellite imagery and modified to remove the agricultural areas would provide an approximate ET map representative of predevelopment conditions. Although this was determined to be the best approach, it has many limitations. Limitations relating to the creation of the current-condition and predevelopment groundwater ET maps are as follows:

- Ground truthing of areas of ET within the study area was conducted during the summer of 2004; however, the classification of the ET areas was determined from 2002 Landsat imagery. It is possible that vegetation communities and boundaries could change, especially because of drought, in a 2-year span; however, such changes are assumed to be minimal.

- Landsat scenes, with minimal cloud cover, within the months of June and July were chosen in order to represent maximum plant growth during the height of the growing season. Therefore, only one day in the life of the plants was used to support the development of the current-condition map. Thus, the NDVI analysis used in determining the land-classification scheme also represents a single day.

- A major limitation in creating the predevelopment map is the lack of historical imagery. Because historical imagery is nonexistent, creation of a predevelopment groundwater ET map representing steady-state conditions includes some subjective interpretations.

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The uncertainty on the ET class areas was estimated using previous estimates of the coefficient of variability (COV) by others (Zhu et al., 2007), differences in the estimates derived by this study and by other investigators, and the classification accuracy conducted by SNWA as a guide. In the Monte Carlo analysis conducted by DRI for BARCASS (Zhu et al., 2007), a COV of 10 percent was used for all ET units identified. Comparisons of previously reported extents of groundwater ET classes show that those of Open Water, Playa, Wetland/Meadow, and Medium Vegetation areas are more comparable than those of Bare Soil/Low Vegetation. This is well illustrated by the example of White River Valley. Estimates of the groundwater ET area made by previous investigators for White River Valley (Maxey and Eakin, 1949; Welch et al., 2008, and this study) vary by more than 100 percent. The results of the classification accuracy conducted by SNWA are provided in Table F-4. The reported accuracy provides a first estimate of the relative error (1-reported accuracy). An estimate of the COV may be obtained by dividing the relative error by 2. These crude estimates of the COV serve as a guide to deriving the final estimates of the COVs using the other available information. The COVs in Table F-4 indicate that the estimated COV for Open Water (ET Class 1) should be the lowest, the COVs for ET Classes 3, 4, and 5 should be about the same and slightly larger than for ET Class 1. The COV for ET Class 2 (Bare Soil/Low Vegetation) is the largest and should be at least twice as large as for the more densely vegetated areas.

Table F-4
Reported Accuracy and Relative Errors on ET Classification

ET Class Number	ET Class	Reported Accuracy	Relative Error	Estimated COV
1	Open Water	0.92	0.08	0.04
2	Bare Soil/Low Vegetation	0.78	0.22	0.11
3	Phreatophyte/Medium Vegetation	0.89	0.11	0.06
4	Wetland/Meadow	0.90	0.10	0.05
5	Agriculture	0.88	0.12	0.06

Note: COV is coefficient of variability

Coefficients of variability used for the ET classes are as follows:

- Wetland/Meadow and Medium Vegetation ET classes: The COV is 0.1 based on averages used by previous investigators and the accuracy assessment conducted by SNWA (Table F-3 and Table F-4).

- Open Water and Playa ET classes: These two classes are the most accurate and were assigned a COV of 0.05 based on the results of the classification accuracy results (Table F-4) and the fact that these two classes are easier to delineate.

- Bare Soil/Low Vegetation: This ET class has the largest uncertainty, as indicated by the classification accuracy results (Table F-4). However, the accuracy results do not provide an estimate of the full range of uncertainty. Furthermore, for this ET class, the uncertainty of the area increases with the size of the area. A COV of 0.5 was assumed for the largest areas (White River, Snake, Steptoe, and Spring valleys). A smaller COV of 0.25 was assigned to the areas of this type located in other basins.

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F.1.2.1.2 Precipitation Rates

The uncertainty on the precipitation rates used in the calculations of the groundwater ET was treated differently for the northern basins (Method 2-BARCASS) than for the southern basins (Method 1).

For the northern basins, the COVs derived for BARCASS (Welch et al., 2008) were used to represent the uncertainties associated with the mean values. This was appropriate because the mean precipitation rates used in the groundwater ET calculations are based on a different version of the PRISM grid (modified 4-km grid).

For the southern basins, the COVs were estimated using two main types of uncertainty that affect the precipitation rates: temporal and spatial. The temporal uncertainty stems from the use of 30 years of data (PRISM normal) to represent long-term mean precipitation rates. The temporal uncertainty was estimated from statistics, conducted on yearly station data over the period of record, for a station located within or near the relevant basin. If two or more stations were used for a given basin, a single COV was derived from the data by averaging the yearly data by year for all stations and then deriving the statistics. If no stations were present within the basin, the COV calculated using all the station data was assigned to the ET units within that basin. The spatial uncertainty stems from averaging the precipitation values spatially over a given ET area to obtain a mean value. The spatial uncertainty was derived from statistics conducted on the grid values falling within each ET class. The temporal and spatial uncertainties were combined to produce an estimate of the total uncertainty represented by an overall COV.

F.1.2.1.3 ET Rates

The detailed estimates of ET rates for the five combined ET classes and their correlation to precipitation are presented in this section. The observed ET rates and associated data compiled from the literature were classified by ET class and are listed in Table F-5. ET data for each ET class were then adjusted by the PET ratio to represent each of the ET classes within each sub-area of each basin.

A statistical analysis was conducted on the ET rate data to derive descriptive statistics for each ET class within each sub-area of each basin. Because of the limited number of data points in each class, the type of probability distributions cannot be clearly identified. As a simplification, the probability distributions were assumed to be normal. A COV was then derived from the mean and standard deviations of each class in each sub-area of each basin.

The correlation coefficient between the total ET and precipitation varies between 0 and 1. For areas where all ET is from the saturated zone, the correlation coefficient should be 0 (ET Class 1). Such is the case for open-water evaporation, assuming that the source of the open water is groundwater. For ET areas where all ET is from precipitation, the correlation coefficient is equal to 1. Such is the case for areas where the depth to water is greater than the maximum extinction depths of phreatophytes.

Table F-5
Reported ET Rates by ET Class
(Page 1 of 4)

ET Unit Description	UTM Northing (m)	UTM Easting (m)	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Source
Bare Soil/Low Vegetation						
Greasewood	4,381,357	338,222	25 to 30	0.59	0.49 to 0.66	Carman (1993)
Saltgrass (sparse to very sparse)	4,031,528	557,768	---	0.62	0.21 to 0.35	Laczniak et al. (1999)[a]
Sagebrush and rabbitbrush (moderate)	4,436,956	624,967	>80	0.99	0.65	Berger et al. (2001)[b]
Rabbitbrush and wolfberry (sparse)	4,101,973	527,189	5 to 20	0.62	0.50	Reiner et al. (2002)[c]
Saltgrass, pickleweed, and shrub mesquite (low density)	4,015,751	510,177	5 to 20	0.60	0.06	DeMeo et al. (2003)
Rabbitbrush scrub	4,136,441	380,459	>16	0.31	0.11	Harrington & Steinwand (2003, 2004)
Desert sink scrub	4,125,767	381,903	>13	0.49 to 0.80	0.10	
Nevada saltbush scrub	4,132,231	379,956	13 to 14	0.59	0.35	
Nevada saltbush meadow	4,131,124	379,763	6.9 to 7.9	0.71 to 1.06	0.10 to 0.30	
Barren (≤10% vegetation)	3,894,274	721,586	---	1.66	0.16[d]	BOR (1997-2007)[d]
Barren	3,853,458	723,745	---	0.96	0.03	Westenburg et al. (2006b)
Barren	3,853,458	723,745	---	0.87	0.43	
Barren	3,853,458	723,745	---	0.88	0.57	
Desert shrubland; greasewood (moderate)	4,336,424	753,927	17.16	0.836	0.52	Moreo et al. (2007)
Desert shrubland; greasewood and rabbitbrush (sparse)	4,295,186	719,949	9.78	0.835	0.72	
Desert shrubland; greasewood and rabbitbrush (moderate)	4,296,079	720,099	7.24	1.01	0.76	
Mixed shrubland (low density)	4,294,919	719,920	15.20	0.79	0.51	SNWA Project data
Mixed shrubland (low density)	4,294,919	719,920	15.32	0.62	0.42	
Greasewood, rabbitbrush, and shadscale (moderate)	4,375,912	715,857	17.38	0.80	0.27	
Monotypic stand of greasewood (moderate)	4,325,090	754,601	30.47	0.64	0.16	
Phreatophyte/Medium Vegetation						
Saltgrass and greasewood	4,107,584	388,935	8 to 9	1.26	0.52	Duell (1990)
Alkali meadow; sacaton and thistle	4,140,145	377,591	10 to 15	2.71	0.49[e]	
Saltgrass, sacaton, and rabbitbrush	4,093,688	390,978	7 to 9	2.05	0.39[e]	
Nevada saltbush, sacaton, and rabbitbrush	4,077,998	394,522	5 to 7	2.69	0.33[e]	
Rabbitbrush, sacaton, and ephedra	4,123,439	381,782	10 to 11	1.99	0.51[e]	
Saltgrass, rabbitbrush, sacaton, and greasewood	4,130,915	378,873	10 to 11	1.55	0.49	
Rabbitbrush	4,355,737	456,918	10 to 15	1.05	0.66 to 0.98	Carman (1993)
Saltgrass (sparse)	4,025,243	562,370	---	1.88	0.21 to 0.35	Laczniak et al. (1999)[a]
Saltgrass (sparse to moderate)	4,037,549	559,594	---	1.92	0.21 to 0.35	

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Table F-5
Reported ET Rates by ET Class
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ET Unit Description	UTM Northing (m)	UTM Easting (m)	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Source
Saltgrass, rabbitbrush, wildrye, and greasewood (moderate)	4,447,894	631,577	<5	1.33	0.65	Berger et al. (2001)[b]
Saltgrass, rabbitbrush, wildrye, and greasewood (moderate)	4,447,801	631,532	<5	1.32	0.65	
Rabbitbrush, wildrye, greasewood, and sagebrush (moderate)	4,461,364	634,578	5	1.33	0.65	
Rabbitbrush, wildrye, greasewood, and sagebrush (moderate)	4,444,761	632,318	10	1.33	0.65	
Greasewood, rabbitbrush, wildrye, sagebrush (sparse to moderate)	4,447,817	632,478	17	1.33	0.65	
Primarily greasewood (moderate to dense)	4,099,904	525,961	5 to 20	1.38	0.50	Reiner et al. (2002)[c]
Saltgrass (sparse to moderate)	4,100,119	525,664	few to 10	1.63	0.50	
Wire and saltgrass (sparse to moderate)	4,096,110	524,613	few to 10	2.49	0.50	
Grasses, arrowweed, mesquite, and pickleweed (moderate)	4,005,708	511,887	2 to 20	2.0	0.23	DeMeo et al. (2003)
Rabbitbrush meadow	4,093,461	391,331	8.5 to 11	1.68	0.23	Harrington & Steinwand (2003, 2004)
Desert vegetation	3,894,274	721,586	---	1.34	0.16[d]	BOR (1997-2007)[d]
Rush and saltgrass	4,211,928	1,500,833	3.0	1.34	0.60	Cooper et al. (2006)
Greasewood and rabbitbrush	4,211,928	1,500,833	8.2	0.91	0.63	
Saltgrass, grass, yerba mansa, arrowweed, desert baccharis, and mesquite	4,096,966	465,743	0 to 15	2.28 to 2.68	0.05 to 0.49	Laczniak et al. (2006)
Rabbitbrush and greasewood	4,323,822	257,119	3 to 5	1.9	0.66[f]	Maurer et al. (2006)
Bitterbrush and sage	4,310,759	254,378	60	1.5	0.66[f]	
Arrowweed (low to medium density)	3,853,458	723,745	8	2.87	0.03	Westenburg et al. (2006b)
Arrowweed (low to medium density)	3,853,458	723,745	8	2.65	0.43	
Arrowweed (low to medium density)	3,853,458	723,745	8	2.71	0.57	
Mixed vegetation (medium density)	3,850,483	726,385	4 to 8	2.85	0.03	
Mixed vegetation (medium density)	3,850,483	726,385	4 to 8	2.61	0.43	
Mixed vegetation (medium density)	3,850,483	726,385	4 to 8	2.63	0.57	
Desert shrubland; greasewood (dense)	4,253,549	670,158	32.39	1.06	0.74	Moreo et al. (2007)
Desert shrubland; greasewood (moderate)	4,278,646	665,098	23.58	1.02	0.95	
Mixed shrubland (moderate)	4,277,445	665,017	18.95	1.38	0.87	SNWA Project data
Mixed shrubland (moderate)	4,277,445	665,017	18.85	0.68	0.45	
Monotypic stand of greasewood (high density)	4,287,266	753,182	19.31	1.65	0.37	

Table F-5
Reported ET Rates by ET Class
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ET Unit Description	UTM Northing (m)	UTM Easting (m)	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Source
Playa						
Playa, often salt covered	4,434,212	764,573	0 to 1	0.75	0.42	Malek et al. (1990)
Playa; sparse seepweed, greasewood, and saltgrass	---	---	<10	1.2 to 1.3	<0.16	Czarnecki (1997)
Bunch grass (very sparse)	4,029,199	559,627	---	2.58	0.21 to 0.35	Laczniak et al. (1999)[a]
Bunch grass (sparse to very sparse)	4,025,676	562,516	---	2.60	0.21 to 0.35	Laczniak et al. (1999)[a]
Bare soil playa	4,437,735	627,276	---	0.80	0.65	Berger et al. (2001)[b]
Salt-encrusted playa	4,009,234	519,297	≤5	0.17 to 0.39	0.04 to 0.28	DeMeo et al. (2003)
Bare soil playa	4,007,757	520,249	≤10	0.21 to 0.37	0.06 to 0.35	DeMeo et al. (2003)
Wetland/Meadow						
Saltgrass, sacaton, and rush	4,071,453	394,441	≤4	3.24	0.26	Duell (1990)
Mixed grasses, clover, and scattered shrubs (dense)	4,030,891	559,192	---	3.44	0.21 to 0.35	Laczniak et al. (1999)[a]
Meadow; mixed sedges, rushes, and grasses (dense)	4,437,444	626,476	<2	3.19	0.65	Berger et al. (2001)[b]
Grasslands	4,437,444	626,476	---	2.36	0.65	Berger et al. (2001)[b]
Saltgrass (dense), surface periodically floods	4,037,732	559,269	---	3.07[i]	0.21 to 0.35	Reiner et al. (2002)[c]
Meadow and marsh grass (dense)	4,097,156	523,993	0 to 20	3.14	0.50	Reiner et al. (2002)[c]
Sacaton, saltgrass, and wildrye	4,084,272	389,787	6.6 to 11	1.37 to 2.25	0.11 to 0.99	Harrington & Steinwand (2003, 2004)
Grasses and mesquites (high density)	4,066,686	487,824	≤20	2.9	0.16	DeMeo et al. (2003)
Mixed grasses/meadow	4,312,948	723,534	3.89	2.25	0.66	Moreo et al. (2007)
Irrigated pasture; perennial grasses (dense)	4,360,829	716,743	---	3.56	0.35	SNWA Project data
Open water						
Open water body; submerged aquatic vegetation	4,033,564	558,128	---	8.6	0.21 to 0.35	Laczniak et al. (1999)[a]
Open water body; submerged aquatic vegetation	4,437,735	627,276	---	5.31	0.65	Berger et al. (2001)[b]
Lake Mead; Water Barge Cove	4,000,515	704,576	---	7.0	0.28 to 0.34[h]	Westenburg et al. (2006a)
Lake Mead; Sentinel Island	3,992,296	702,539	---	7.5	0.28 to 0.34[h]	Westenburg et al. (2006a)
Lake Mead; Virgin Basin	3,997,837	728,438	---	7.6	0.28 to 0.34[h]	Westenburg et al. (2006a)
Lake Mead; Overton Arm	4,021,370	735,435	---	6.8	0.28 to 0.34[h]	Westenburg et al. (2006a)
Riparian						
Riparian; mostly tamarix	4,051,962	738,583	---	2.5 to 4.8	0.35[g]	Devitt et al. (1998)
Cattails and reeds (dense)	4,037,793	559,173	---	3.91	0.21 to 0.35	Laczniak et al. (1999)[a]
Wiregrass and salt grass (sparse to moderate)	4,037,613	559,842	---	3.23	0.21 to 0.35	Laczniak et al. (1999)[a]

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Table F-5
Reported ET Rates by ET Class
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ET Unit Description	UTM Northing (m)	UTM Easting (m)	Depth to Water (ft bgs)	Total ET (ft/yr)	Precipitation (ft/yr)	Source
Moderate to dense bulrush and cattails	4,453,980	630,360	1 to 3	4.19	0.65	Berger et al. (2001)[b]
Grasses and mesquites (high density)	4,065,886	487,005	≤20	3.9	0.25	DeMeo et al. (2003)
Saltcedar (high density)	3,854,463	725,587	8	3.80	0.03	Westenburg et al. (2006b)
Saltcedar (high density)	3,854,463	725,587	8	3.56	0.43	
Saltcedar (high density)	3,854,463	725,587	8	3.59	0.57	
Seasonal wetland (flooded in winter and not irrigated in summer)	3,894,274	721,586	---	3.65	0.16[d]	BOR (1997-2007)[d]
Screwbean and honey mesquite (11% to 60%) and arrowweed (≤25%)	3,894,274	721,586	---	3.99	0.16[d]	
Low Vegetation - phreatophyte vegetation (>10% to ≤30%)	3,894,274	721,586	---	4.29	0.16[d]	
Saltcedar (11% to 60%) and arrowweed (≤25%)	3,894,274	721,586	---	4.36	0.16[d]	
Arrowweed (51% to 100%) and trees (≤10%)	3,894,274	721,586	---	4.69	0.16[d]	
Mesquite (21% to 60%), arrowweed (31% to 60%), and saltcedar (≤20%)	3,894,274	721,586	---	4.76	0.16[d]	
Cottonwood and willow trees (61% to 100%)	3,894,274	721,586	---	4.96	0.16[d]	
Screwbean and honey mesquite (61% to 100%), arrowweed (≤25%)	3,894,274	721,586	---	4.99	0.16[d]	
Moist soil unit (flooded in winter and irrigated in summer)	3,894,274	721,586	---	5.03	0.16[d]	
Saltcedar (61 to 100%), arrowweed (≤25%)	3,894,274	721,586	---	5.12	0.16[d]	
Saltcedar (≤75%), arrowweed (≥25%)	3,894,274	721,586	---	5.29	0.16[d]	
Saltcedar (15 to 45%), mesquite (15 to 45%), arrowweed (20 to 40%)	3,894,274	721,586	---	5.43	0.16[d]	
Saltcedar (11 to 60%), mesquite (11 to 60%), arrowweed (≤25%)	3,894,274	721,586	---	5.45	0.16[d]	
Marsh, cattail, bullrush, phragmites (bamboo)	3,894,274	721,586	---	5.93	0.16[d]	

[a]Evapotranspiration measured at an individual site (Laczniak et al., 1999).
[b]Rates for growing season only (or less).
[c]Evapotranspiration measured at an individual site (Reiner et al., 2002).
[d]Precipitation data are for the Mohave station (BOR, 2007) and ET data are averaged for 1995 to 2005 (BOR, 1997; 1998; 1999; 2000a and b; 2001; 2002; 2004a and b; 2005; and 2007).
[e]Estimated as the average of the precipitation reported for the two nearest sites (Duell, 1990).
[f]Precipitation reported for the test hole that is nearest to the evapotranspiration stations, CL-1 (Maurer, et al., 2006).
[g]Estimated as the average precipitation reported for 1994 to 1996 for the Overton, Nevada, station (WRCC, 2008).
[h]Average annual precipitation (1961 to 1990) measured at McCarran Airport, Las Vegas, Nevada (0.34 ft), and Overton, Nevada (0.28), from DRI (Westenburg et al., 2006a).
[i]Data reported from Reiner et al. (2002); data set for this site was more complete than that reported by Laczniak et al. (1999).

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For the three phreatophyte ET classes, the correlation of ET rates with precipitation rates was interpreted using the ET site data collected by SNWA. Monthly ET site data, including the ET and precipitation rates, were compiled (Table F-6). The site data were then grouped by ET class, and correlation coefficients were derived for the three ET classes represented by the data, i.e., Wetland/Meadow, Phreatophyte/Medium Vegetation and Bare Soil/Low Vegetation. The correlation coefficient derived for the Wetland/Meadow ET class is 0.2. The correlation coefficients calculated for the Phreatophyte/Medium Vegetation and Bare Soil/Low Vegetation, 0.57 and 0.54 respectively, were very similar and reversed, i.e., the Phreatophyte/Medium Vegetation ET rates should have a lower correlation to precipitation than the Bare Soil/Low Vegetation ET rates. Based on this observation, the four stations used to derive the two correlations (SV3, WRV2, SNV2, SV1) were combined to derive a single correlation. The resulting correlation coefficient is about 0.6 and was assumed to represent the Bare Soil/Low Vegetation ET class. The correlation coefficient for the Phreatophyte/Medium Vegetation ET class must be greater than 0.2 and less than 0.6. The middle of this interval, 0.4, was selected.

ET from wet playas generally consists of evaporation only and, given the same climatological conditions, it is highly variable depending on the depth to water. Therefore, the correlation coefficient is also variable depending on the depth to water. An average correlation coefficient of 0.5 was selected to accommodate all wet playas in the study area. The resulting correlation coefficients are presented in Table F-7.

F.1.2.2 Detailed Input Data

The uncertainty information for each input variable was estimated and is presented in Table F-8. Ten thousand (10,000) realizations were made using the random number method (seed = 999) and the input parameters listed in Table F-8.

Table F-6
Monthly ET Site Data Used to Estimate Correlation Coefficients between ET and Precipitation Rates

		SV2B		SNV1		SV3		WRV2		SNV2		SV1	
		Wetland/Meadow				Phreatophyte/ Medium Vegetation				Bare Soil/Low Vegetation			
Year	Month	ETA	P	ETA	P	ETA	P	ETA	P	ETA	P	ETA	P
2005	January	NA	NA	NA	NA	NA	NA	0.075	0.185	NA	NA	NA	NA
2005	February	NA	NA	NA	NA	NA	NA	0.130	0.129	NA	NA	NA	NA
2005	March	NA	NA	NA	NA	NA	NA	0.178	0.130	NA	NA	NA	NA
2005	April	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2005	May	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2005	June	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2005	July	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2005	August	NA	NA	NA	NA	NA	NA	0.148	0.042	NA	NA	NA	NA
2005	September	NA	NA	NA	NA	NA	NA	0.184	0.057	NA	NA	NA	NA
2005	October	NA	NA	NA	NA	NA	NA	0.081	0.065	NA	NA	NA	NA
2005	November	NA	NA	NA	NA	NA	NA	0.042	0.025	NA	NA	NA	NA
2005	December	NA	NA	NA	NA	NA	NA	0.031	0.018	NA	NA	NA	NA
2006	January	NA	NA	NA	NA	NA	NA	0.036	0.068	NA	NA	0.031	0.034
2006	February	NA	NA	NA	NA	NA	NA	0.040	0.081	NA	NA	0.044	0.046
2006	March	NA	NA	NA	NA	NA	NA	0.195	0.145	NA	NA	0.115	0.093
2006	April	NA	NA	NA	NA	NA	NA	0.227	0.111	NA	NA	0.094	0.070
2006	May	NA	NA	NA	NA	NA	NA	0.181	0.004	NA	NA	0.070	0.005
2006	June	NA	NA	NA	NA	NA	NA	0.115	0.043	NA	NA	0.079	0.015
2006	July	NA	NA	NA	NA	NA	NA	0.250	0.190	NA	NA	0.142	0.141
2006	August	NA	NA	NA	NA	NA	NA	0.111	0.002	NA	NA	0.087	0.001
2006	September	NA	NA	NA	NA	NA	NA	0.127	0.128	NA	NA	0.055	0.024
2006	October	NA	NA	NA	NA	NA	NA	0.036	0.081	NA	NA	0.039	0.073
2006	November	NA	NA	NA	NA	NA	NA	0.034	0.003	NA	NA	0.013	0.002
2006	December	NA	NA	NA	NA	NA	NA	0.036	0.015	NA	NA	0.020	0.008
2007	January	NA	NA	NA	NA	NA	NA	0.036	0.008	NA	NA	0.036	0.000
2007	February	NA	NA	NA	NA	NA	NA	0.041	0.038	NA	NA	0.038	0.074
2007	March	NA	NA	NA	NA	NA	NA	0.042	0.035	NA	NA	0.058	0.056
2007	April	0.216	0.019	NA	NA	0.048	0.012	0.079	0.063	NA	NA	0.070	0.041
2007	May	0.524	0.021	0.229	0.008	0.086	0.021	0.064	0.001	0.081	0.009	0.068	0.002
2007	June	0.673	0.002	0.262	0.005	0.119	0.000	0.073	0.023	0.077	0.001	0.059	0.002
2007	July	0.595	0.071	0.291	0.040	0.141	0.044	0.060	0.026	0.106	0.025	0.078	0.026
2007	August	0.560	0.051	0.257	0.075	0.141	0.058	0.151	0.137	0.074	0.013	0.100	0.083
2007	September	0.456	0.053	0.136	0.076	0.078	0.033	0.083	0.096	0.068	0.043	0.065	0.090
2007	October	0.222	0.062	0.044	0.001	0.045	0.029	0.040	0.011	0.028	0.001	0.029	0.003
2007	November	0.084	0.006	0.016	0.013	0.012	0.002	0.013	0.000	0.010	0.001	0.015	0.005

NA = Not Available

Table F-7
Correlation Coefficients for ET Rate and Precipitation

ET Class	Correlation Coefficient for Precipitation and ET Rate
Open Water	0.00
Bare Soil/Low Vegetation	0.60
Phreatophyte/Medium Vegetation	0.40
Wetland/Meadow	0.20
Playa/Moisture Soil	0.50

Table F-8
Groundwater ET Uncertainty Analysis - Monte Carlo Input Parameter Data
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HA Sub-Area	HA Name	ET Class	ET Rate Mean (ft/yr) (area weighted)	ET Rate COV (-)	ET Rate STD (ft/yr)	Precipitation Rate (ft/yr) (area weighted)	Precipitation Rate Spatial COV	Precipitation Rate Temporal COV	Precipitation Rate STD (ft/yr)	ET - P Correlation Coefficient	Groundwater ET Area (acre)	Groundwater ET Area COV (-)	Groundwater ET Area STD (acre)
172-N	Garden Valley	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.92	0.04	0.34	0.31	0.60	21	0.25	5
		Phreatophyte/Medium Vegetation	2.82	0.26	0.73	0.94	0.06	0.34	0.32	0.40	552	0.10	55
		Wetland/Meadow	2.82	0.24	0.67	1.07	0.13	0.34	0.39	0.20	377	0.10	38
174-N	Jakes Valley	Open Water	5.10	0.01	0.05	0.96	0.10	0.36	0.36	0.00	26	0.05	1
		Bare Soil/Low Vegetation	0.98	0.15	0.15	0.96	0.10	0.36	0.36	0.60	6	0.25	1
		Phreatophyte/Medium Vegetation	1.37	0.14	0.19	0.96	0.10	0.36	0.36	0.40	930	0.10	93
		Wetland/Meadow	2.37	0.11	0.26	0.96	0.10	0.36	0.36	0.20	263	0.10	26
175-N	Long Valley	Bare Soil/Low Vegetation	0.98	0.15	0.15	0.94	0.02	0.36	0.34	0.60	4,903	0.25	1,226
		Phreatophyte/Medium Vegetation	1.10	0.18	0.20	0.94	0.02	0.36	0.34	0.40	13,379	0.10	1,338
		Wetland/Meadow	2.61	0.09	0.24	0.94	0.02	0.36	0.34	0.20	9	0.10	1
179-1	Steptoe Valley	Open Water	5.10	0.01	0.05	0.77	0.14	0.28	0.24	0.00	121	0.05	6
		Bare Soil/Low Vegetation	0.86	0.17	0.15	0.68	0.12	0.28	0.20	0.60	29,691	0.50	14,846
		Phreatophyte/Medium Vegetation	1.16	0.17	0.20	0.69	0.12	0.28	0.21	0.40	115,946	0.10	11,595
		Wetland/Meadow	2.75	0.09	0.24	0.73	0.13	0.28	0.23	0.20	14,576	0.10	1,458
		Playa	0.92	0.14	0.13	0.67	0.11	0.28	0.20	0.50	2,723	0.05	136
179-2	Steptoe Valley	Open Water	5.10	0.01	0.05	0.92	0.10	0.28	0.27	0.00	319	0.05	16
		Bare Soil/Low Vegetation	0.88	0.17	0.15	0.80	0.13	0.28	0.25	0.60	416	0.50	208
		Phreatophyte/Medium Vegetation	1.26	0.16	0.20	0.83	0.12	0.28	0.25	0.40	7,026	0.10	703
		Wetland/Meadow	2.66	0.10	0.26	0.81	0.13	0.28	0.25	0.20	3,797	0.10	380
180-N	Cave Valley	Bare Soil/Low Vegetation	0.98	0.15	0.15	1.08	0.09	0.36	0.41	0.60	3,554	0.25	888
		Phreatophyte/Medium Vegetation	1.14	0.18	0.20	1.08	0.09	0.36	0.41	0.40	8,739	0.10	874
		Wetland/Meadow	2.55	0.10	0.26	1.11	0.02	0.36	0.40	0.20	867	0.10	87
		Playa	0.75	0.08	0.06	1.08	0.09	0.36	0.41	0.50	194	0.05	10
183-N	Lake Valley	Open Water	5.10	0.01	0.05	0.99	0.07	0.43	0.43	0.00	26	0.05	1
		Bare Soil/Low Vegetation	0.98	0.15	0.15	0.99	0.07	0.43	0.43	0.60	16,303	0.25	4,076
		Phreatophyte/Medium Vegetation	1.02	0.17	0.17	0.99	0.07	0.43	0.43	0.40	36,478	0.10	3,648
		Wetland/Meadow	2.82	0.09	0.24	0.99	0.07	0.43	0.43	0.20	2,596	0.10	260
		Playa	1.00	0.13	0.13	0.99	0.07	0.43	0.43	0.50	94	0.05	5

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Table F-8
Groundwater ET Uncertainty Analysis - Monte Carlo Input Parameter Data
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HA Sub-Area	HA Name	ET Class	ET Rate: Mean (ft/yr) (area weighted)	ET Rate: COV (-)	ET Rate: STD (ft/yr)	Precipitation Rate: (ft/yr) (area weighted)	Precipitation Rate: Spatial COV	Precipitation Rate: Temporal COV	Precipitation Rate: STD (ft/yr)	ET - P Correlation Coefficient	Groundwater ET Area: (acre)	Groundwater ET Area: COV (-)	Groundwater ET Area: STD (acre)
184-1	Spring Valley	Bare Soil/Low Vegetation	0.88	0.17	0.15	0.71	0.05	0.24	0.17	0.60	364	0.50	182
		Phreatophyte/Medium Vegetation	1.17	0.17	0.20	0.74	0.04	0.24	0.18	0.40	2,546	0.10	255
		Wetland/Meadow	2.87	0.09	0.25	0.77	0.03	0.24	0.19	0.20	816	0.10	82
184-2	Spring Valley	Open Water	5.10	0.01	0.05	0.69	0.05	0.24	0.17	0.00	6	0.05	0
		Bare Soil/Low Vegetation	0.86	0.17	0.15	0.69	0.05	0.24	0.17	0.60	20,218	0.50	10,109
		Phreatophyte/Medium Vegetation	1.09	0.18	0.19	0.69	0.05	0.24	0.17	0.40	41,328	0.10	4,133
		Wetland/Meadow	2.74	0.09	0.25	0.69	0.05	0.24	0.17	0.20	6,370	0.10	637
		Playa	1.00	0.13	0.13	0.69	0.05	0.24	0.17	0.50	17,651	0.05	883
184-3	Spring Valley	Bare Soil/Low Vegetation	0.87	0.17	0.15	0.70	0.05	0.24	0.17	0.60	3,268	0.50	1,634
		Phreatophyte/Medium Vegetation	1.06	0.19	0.20	0.70	0.05	0.24	0.17	0.40	19,194	0.10	1,919
		Wetland/Meadow	2.28	0.12	0.27	0.71	0.05	0.24	0.17	0.20	319	0.10	32
		Playa	0.81	0.15	0.13	0.69	0.05	0.24	0.17	0.50	676	0.05	34
184-4	Spring Valley	Bare Soil/Low Vegetation	0.98	0.15	0.15	0.79	0.03	0.24	0.19	0.60	11,873	0.50	5,936
		Phreatophyte/Medium Vegetation	1.14	0.17	0.20	0.79	0.03	0.24	0.19	0.40	49,327	0.10	4,933
		Wetland/Meadow	2.84	0.09	0.24	0.79	0.03	0.24	0.19	0.20	3,288	0.10	329
		Playa	0.83	0.15	0.13	0.79	0.03	0.24	0.19	0.50	529	0.05	26
185-N	Tippett Valley	Bare Soil/Low Vegetation	0.98	0.15	0.15	0.80	0.02	0.36	0.29	0.60	1,624	0.25	406
		Phreatophyte/Medium Vegetation	1.04	0.19	0.20	0.80	0.02	0.36	0.29	0.40	5,585	0.10	559
		Wetland/Meadow	2.14	0.13	0.27	0.80	0.02	0.36	0.29	0.20	72	0.10	7
		Playa	0.81	0.15	0.13	0.80	0.02	0.36	0.29	0.50	497	0.05	25
194-2	Pleasant Valley	Bare Soil/Low Vegetation	0.86	0.17	0.15	0.55	0.06	0.00	0.03	0.60	118	0.25	30
		Phreatophyte/Medium Vegetation	1.22	0.14	0.18	0.55	0.06	0.00	0.03	0.40	759	0.10	76
		Wetland/Meadow	2.65	0.09	0.24	0.55	0.06	0.00	0.03	0.20	226	0.10	23
195-1	Snake Valley	Bare Soil/Low Vegetation	0.74	0.20	0.15	0.55	0.05	0.27	0.15	0.60	13,904	0.50	6,952
		Phreatophyte/Medium Vegetation	1.14	0.16	0.18	0.55	0.05	0.27	0.15	0.40	4,272	0.10	427
		Wetland/Meadow	2.85	0.08	0.24	0.55	0.05	0.27	0.15	0.20	1,266	0.10	127
		Playa	0.63	0.20	0.12	0.55	0.05	0.27	0.15	0.50	56,072	0.05	2,804

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Table F-8
Groundwater ET Uncertainty Analysis - Monte Carlo Input Parameter Data
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HA Sub-Area	HA Name	ET Class	ET Rate			Precipitation Rate				ET - P Correlation Coefficient	Groundwater ET Area		
			Mean (ft/yr) (area weighted)	COV (-)	STD (ft/yr)	(ft/yr) (area weighted)	Spatial COV	Temporal COV	STD (ft/yr)		(acre)	COV (-)	STD (acre)
195-2	Snake Valley	Open Water	5.10	0.01	0.05	0.55	0.06	0.27	0.15	0.00	54	0.05	3
		Bare Soil/Low Vegetation	0.82	0.18	0.15	0.55	0.06	0.27	0.15	0.60	11,384	0.50	5,692
		Phreatophyte/Medium Vegetation	1.12	0.18	0.20	0.55	0.05	0.27	0.15	0.40	15,082	0.10	1,508
		Wetland/Meadow	2.77	0.08	0.23	0.55	0.06	0.27	0.15	0.20	1,440	0.10	144
		Playa	0.63	0.20	0.12	0.55	0.05	0.27	0.15	0.50	574	0.05	29
195-3	Snake Valley	Open Water	5.10	0.01	0.05	0.55	0.07	0.27	0.16	0.00	71	0.05	4
		Bare Soil/Low Vegetation	0.86	0.17	0.15	0.55	0.07	0.27	0.16	0.60	104,518	0.50	52,259
		Phreatophyte/Medium Vegetation	1.11	0.18	0.19	0.56	0.08	0.27	0.16	0.40	70,259	0.10	7,026
		Wetland/Meadow	2.52	0.10	0.26	0.56	0.08	0.27	0.16	0.20	5,120	0.10	512
		Playa	0.74	0.17	0.13	0.55	0.07	0.27	0.16	0.50	7,092	0.05	355
195-4	Snake Valley	Open Water	5.10	0.01	0.05	0.64	0.06	0.27	0.18	0.00	302	0.05	15
		Bare Soil/Low Vegetation	0.98	0.15	0.15	0.68	0.05	0.27	0.19	0.60	3,170	0.50	1,585
		Phreatophyte/Medium Vegetation	1.15	0.17	0.19	0.68	0.05	0.27	0.19	0.40	22,563	0.10	2,256
		Wetland/Meadow	2.80	0.09	0.25	0.68	0.05	0.27	0.19	0.20	3,126	0.10	313
196-4	Hamlin Valley	Bare Soil/Low Vegetation	0.98	0.15	0.15	0.68	0.05	0.00	0.03	0.60	102	0.25	25
		Phreatophyte/Medium Vegetation	1.15	0.17	0.20	0.68	0.05	0.00	0.03	0.40	4,043	0.10	404
		Wetland/Meadow	2.38	0.11	0.27	0.68	0.05	0.00	0.03	0.20	62	0.10	6
198-N	Dry Valley	Open Water	6.68	0.11	0.74	1.08	0.00	0.36	0.39	0.00	33	0.05	2
		Bare Soil/Low Vegetation	1.00	0.41	0.41	1.08	0.02	0.36	0.39	0.60	82	0.25	21
		Phreatophyte/Medium Vegetation	2.87	0.26	0.74	1.07	0.01	0.36	0.39	0.40	1,182	0.10	118
		Wetland/Meadow	2.87	0.24	0.68	1.07	0.01	0.36	0.39	0.20	771	0.10	77
199-N	Rose Valley	Bare Soil/Low Vegetation	1.00	0.41	0.41	1.12	0.00	0.36	0.41	0.60	0	0.25	0
		Phreatophyte/Medium Vegetation	2.83	0.26	0.73	1.10	0.01	0.36	0.40	0.40	89	0.10	9
		Wetland/Meadow	2.83	0.24	0.67	1.10	0.01	0.36	0.40	0.20	255	0.10	26
200-N	Eagle Valley	Bare Soil/Low Vegetation	1.00	0.41	0.41	1.14	0.02	0.36	0.41	0.60	3	0.25	1
		Phreatophyte/Medium Vegetation	2.79	0.26	0.72	1.14	0.02	0.36	0.42	0.40	154	0.10	15
		Wetland/Meadow	2.79	0.24	0.66	1.15	0.02	0.36	0.42	0.20	477	0.10	48

Table F-8
Groundwater ET Uncertainty Analysis - Monte Carlo Input Parameter Data
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HA Sub-Area	HA Name	ET Class	ET Rate: Mean (ft/yr) (area weighted)	ET Rate: COV (-)	ET Rate: STD (ft/yr)	Precipitation Rate: (ft/yr) (area weighted)	Precipitation Rate: Spatial COV	Precipitation Rate: Temporal COV	Precipitation Rate: STD (ft/yr)	ET - P Correlation Coefficient	Groundwater ET Area: (acre)	Groundwater ET Area: COV (-)	Groundwater ET Area: STD (acre)
201-N	Spring Valley	Open Water	6.28	0.11	0.70	1.15	0.01	0.38	0.44	0.00	52	0.05	3
		Bare Soil/Low Vegetation	1.00	0.41	0.41	1.14	0.06	0.38	0.44	0.60	10	0.25	2
		Phreatophyte/Medium Vegetation	2.70	0.26	0.70	1.12	0.03	0.38	0.43	0.40	630	0.10	63
		Wetland/Meadow	2.70	0.24	0.64	1.10	0.05	0.38	0.42	0.20	1,657	0.10	166
202-N	Patterson Valley	Phreatophyte/Medium Vegetation	2.81	0.26	0.72	1.06	0.00	0.36	0.39	0.40	771	0.10	77
203-N	Panaca Valley	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.86	0.05	0.36	0.32	0.60	343	0.25	86
		Phreatophyte/Medium Vegetation	3.03	0.26	0.78	0.88	0.05	0.36	0.32	0.40	3,537	0.10	354
		Wetland/Meadow	3.03	0.24	0.72	0.88	0.05	0.36	0.32	0.20	5,224	0.10	522
204-N	Clover Valley	Bare Soil/Low Vegetation	1.00	0.41	0.41	1.36	0.19	0.36	0.56	0.60	186	0.25	47
		Phreatophyte/Medium Vegetation	2.90	0.26	0.75	1.42	0.14	0.36	0.55	0.40	1,777	0.10	178
		Wetland/Meadow	2.90	0.24	0.69	1.21	0.19	0.36	0.50	0.20	1,547	0.10	155
205-1	Lower Meadow Valley Wash	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.84	0.01	0.67	0.57	0.60	21	0.25	5
		Phreatophyte/Medium Vegetation	3.62	0.26	0.93	0.84	0.01	0.67	0.56	0.40	257	0.10	26
		Wetland/Meadow	3.62	0.24	0.86	0.85	0.03	0.67	0.57	0.20	797	0.10	80
205-2	Lower Meadow Valley Wash	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.97	0.03	0.67	0.65	0.60	2	0.25	1
		Phreatophyte/Medium Vegetation	3.62	0.26	0.93	1.01	0.03	0.67	0.68	0.40	131	0.10	13
		Wetland/Meadow	3.62	0.24	0.86	1.05	0.07	0.67	0.71	0.20	710	0.10	71
205-3	Lower Meadow Valley Wash	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.55	0.02	0.67	0.37	0.60	30	0.25	7
		Phreatophyte/Medium Vegetation	3.62	0.26	0.93	0.54	0.02	0.67	0.36	0.40	124	0.10	12
		Wetland/Meadow	3.62	0.24	0.86	0.68	0.28	0.67	0.50	0.20	2,322	0.10	232
205-4	Lower Meadow Valley Wash	Open Water	8.43	0.11	0.94	0.45	0.07	0.67	0.30	0.00	0	0.05	0
		Bare Soil/Low Vegetation	1.00	0.41	0.41	0.49	0.08	0.67	0.33	0.60	6	0.25	1
		Phreatophyte/Medium Vegetation	3.62	0.26	0.93	0.47	0.07	0.67	0.32	0.40	38	0.10	4
		Wetland/Meadow	3.62	0.24	0.86	0.47	0.07	0.67	0.32	0.20	834	0.10	83

Table F-8
Groundwater ET Uncertainty Analysis - Monte Carlo Input Parameter Data
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HA Sub-Area	HA Name	ET Class	ET Rate Mean (ft/yr) (area weighted)	ET Rate COV (-)	ET Rate STD (ft/yr)	Precipitation Rate (ft/yr) (area weighted)	Precipitation Rate Spatial COV	Precipitation Rate Temporal COV	Precipitation Rate STD (ft/yr)	ET - P Correlation Coefficient	Groundwater ET Area (acre)	Groundwater ET Area COV (-)	Groundwater ET Area STD (acre)
205-5	Lower Meadow Valley Wash	Open Water	8.43	0.11	0.94	0.46	0.01	0.67	0.31	0.00	0	0.05	0
		Bare Soil/Low Vegetation	1.00	0.41	0.41	0.46	0.01	0.67	0.31	0.60	469	0.25	117
		Phreatophyte/Medium Vegetation	3.62	0.26	0.93	0.47	0.01	0.67	0.31	0.40	714	0.10	71
		Wetland/Meadow	3.62	0.24	0.86	0.46	0.01	0.67	0.31	0.20	1,360	0.10	136
207-1	White River Valley	Bare Soil/Low Vegetation	0.98	0.15	0.15	0.77	0.06	0.43	0.34	0.60	14,699	1.00	14,699
		Phreatophyte/Medium Vegetation	1.14	0.17	0.19	0.79	0.05	0.43	0.34	0.40	81,711	0.10	8,171
		Wetland/Meadow	2.38	0.11	0.27	0.82	0.05	0.43	0.36	0.20	6,370	0.10	637
		Playa	0.88	0.14	0.12	0.78	0.06	0.43	0.34	0.50	77	0.05	4
207-2	White River Valley	Open Water	5.10	0.01	0.05	0.77	0.06	0.43	0.34	0.00	685	0.05	34
		Bare Soil/Low Vegetation	0.98	0.15	0.15	0.77	0.06	0.43	0.33	0.60	30,230	1.00	30,230
		Phreatophyte/Medium Vegetation	1.11	0.18	0.20	0.77	0.06	0.43	0.33	0.40	38,821	0.10	3,882
		Wetland/Meadow	3.35	0.05	0.18	0.77	0.06	0.43	0.33	0.20	4,672	0.10	467
		Playa	0.89	0.14	0.12	0.77	0.06	0.43	0.34	0.50	907	0.05	45
209-1	Pahranagat Valley	Open Water	7.68	0.11	0.86	0.67	0.02	0.44	0.29	0.00	384	0.05	19
		Bare Soil/Low Vegetation	1.00	0.41	0.41	0.67	0.03	0.44	0.29	0.60	97	0.25	24
		Phreatophyte/Medium Vegetation	3.30	0.26	0.85	0.67	0.03	0.44	0.29	0.40	262	0.10	26
		Wetland/Meadow	3.30	0.24	0.78	0.67	0.02	0.44	0.29	0.20	863	0.10	86
209-2	Pahranagat Valley	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.63	0.03	0.44	0.27	0.60	73	0.25	18
		Phreatophyte/Medium Vegetation	3.30	0.26	0.85	0.62	0.04	0.44	0.27	0.40	294	0.10	29
		Wetland/Meadow	3.30	0.24	0.78	0.61	0.04	0.44	0.27	0.20	2,934	0.10	293
209-3	Pahranagat Valley	Open Water	7.68	0.11	0.86	0.56	0.01	0.44	0.24	0.00	464	0.05	23
		Bare Soil/Low Vegetation	1.00	0.41	0.41	0.57	0.01	0.44	0.25	0.60	37	0.25	9
		Phreatophyte/Medium Vegetation	3.30	0.26	0.85	0.57	0.02	0.44	0.25	0.40	87	0.10	9
		Wetland/Meadow	3.30	0.24	0.78	0.58	0.01	0.44	0.25	0.20	847	0.10	85
209-4	Pahranagat Valley	Open Water	7.68	0.11	0.86	0.52	0.01	0.44	0.23	0.00	74	0.05	4
		Bare Soil/Low Vegetation	1.00	0.41	0.41	0.54	0.02	0.44	0.23	0.60	12	0.25	3
		Phreatophyte/Medium Vegetation	3.30	0.26	0.85	0.54	0.02	0.44	0.23	0.40	64	0.10	6
		Wetland/Meadow	3.30	0.24	0.78	0.53	0.02	0.44	0.23	0.20	900	0.10	90

Table F-8
Groundwater ET Uncertainty Analysis - Monte Carlo Input Parameter Data
(Page 6 of 6)

HA Sub-Area	HA Name	ET Class	ET Rate Mean (ft/yr) (area weighted)	ET Rate COV (-)	ET Rate STD (ft/yr)	Precipitation Rate (ft/yr) (area weighted)	Precipitation Rate Spatial COV	Precipitation Rate Temporal COV	Precipitation Rate STD (ft/yr)	ET - P Correlation Coefficient	Groundwater ET Area (acre)	Groundwater ET Area COV (-)	Groundwater ET Area STD (acre)
209-5	Pahranagat Valley	Open Water	7.68	0.11	0.86	0.53	0.01	0.44	0.23	0.00	375	0.05	19
		Bare Soil/Low Vegetation	1.00	0.41	0.41	0.52	0.01	0.44	0.23	0.60	41	0.25	10
		Phreatophyte/Medium Vegetation	3.30	0.26	0.85	0.52	0.01	0.44	0.23	0.40	108	0.10	11
		Wetland/Meadow	3.30	0.24	0.78	0.52	0.01	0.44	0.23	0.20	741	0.10	74
215-N	Black Mountains Area	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.45	0.08	0.57	0.26	0.60	54	0.25	14
		Phreatophyte/Medium Vegetation	3.88	0.26	1.00	0.46	0.08	0.57	0.26	0.40	244	0.10	24
		Wetland/Meadow	3.88	0.24	0.92	0.44	0.08	0.57	0.25	0.20	165	0.10	16
218-N	California Wash	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.45	0.01	0.36	0.17	0.60	37	0.25	9
		Phreatophyte/Medium Vegetation	3.80	0.26	0.98	0.46	0.01	0.36	0.17	0.40	149	0.10	15
		Wetland/Meadow	3.80	0.24	0.90	0.46	0.01	0.36	0.17	0.20	1,194	0.10	119
219-N	Muddy River Springs Area	Bare Soil/Low Vegetation	1.00	0.41	0.41	0.46	0.02	0.36	0.17	0.60	166	0.25	42
		Phreatophyte/Medium Vegetation	3.77	0.26	0.97	0.46	0.02	0.36	0.17	0.40	214	0.10	21
		Wetland/Meadow	3.77	0.24	0.89	0.46	0.01	0.36	0.17	0.20	1,571	0.10	157
220-N	Lower Moapa Valley	Open Water	9.06	0.11	1.01	0.45	0.05	0.64	0.29	0.00	137	0.05	7
		Bare Soil/Low Vegetation	1.00	0.41	0.41	0.44	0.06	0.64	0.28	0.60	496	0.25	124
		Phreatophyte/Medium Vegetation	3.89	0.26	1.00	0.44	0.06	0.64	0.28	0.40	907	0.10	91
		Wetland/Meadow	3.89	0.24	0.92	0.44	0.05	0.64	0.28	0.20	5,993	0.10	599
178B-N	Butte Valley South	Open Water	5.10	0.01	0.05	0.95	0.05	0.36	0.35	0.00	4	0.05	0
		Bare Soil/Low Vegetation	0.98	0.15	0.15	0.95	0.05	0.36	0.35	0.60	8,265	0.25	2,066
		Phreatophyte/Medium Vegetation	1.11	0.18	0.20	0.95	0.05	0.36	0.35	0.40	60,274	0.10	6,027
		Wetland/Meadow	2.38	0.05	0.12	0.95	0.05	0.36	0.35	0.20	1,157	0.10	116

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Appendix G

Major Spring Discharge and Muddy River Stream Flow Gage Data

G.1.0 MAJOR SPRING DISCHARGE AND MUDDY RIVER STREAM FLOW GAGE DATA

This appendix contains detailed data and information for the major springs of the study area and historical stream flow measurements for two gaging stations located on the Muddy River. It is very important to note the relationship between all springs and seeps in the Muddy River Springs Area and stream flow in the Muddy River. In fact, under predevelopment conditions, the stream flow gage located on the Muddy River near Moapa measures total discharge from the springs and seeps located upstream and surface water runoff. The information presented here was used to derive mean predevelopment spring and stream flow rates.

G.1.1 Major Springs

The long-term mean discharge rates of major springs located in the study area are provided in this section, followed by descriptions of the methods used to derive temperature-depth relationships (geothermal gradients). These relationships were derived to support the depth estimates of the aquifers feeding the regional springs.

G.1.1.1 Long-Term Mean Discharge

Spring information, including mean spring flow rates and standard deviations derived from individual measurements, is listed in Table G-1. The individual, historical spring discharge measurements for gaged springs in the study area have been reported in SNWA (2008). Most of these springs are located in White River Valley, Pahranagat Valley, and the Muddy River Springs Area. Spring discharge measurements for the Muddy River Springs Area are reported as stream flow measurements on the Muddy River. Mean spring discharge estimates were also derived, using USGS data (USGS, 2008), for some of the springs listed in Table G-1. These estimates are provided in Table G-2.

G.1.1.2 Temperature-Depth Relationships

Temperature-depth relationships are used to estimate geothermal gradients. These relationships can be used to estimate the average flow depth of water discharging from the regional springs. For this method of depth estimation, groundwater temperatures measured at the surface are assumed to represent subsurface temperatures at the source of the water. This section describes the estimates of the geothermal gradients considered in this study. Estimates of the geothermal gradients for the study area are available from several sources, including Mifflin (1968), the Great Basin Center for Geothermal Energy (UNR, 2008a and b), and thermal logs obtained from monitor wells drilled by

Table G-1
Regional Springs and Selected Intermediate Springs Information
(Page 1 of 3)

HA Number	Spring ID	Local Number	Site Name	UTM Northing[a] (m)	UTM Easting[a] (m)	Elevation (ft amsl)	Number of Discharge Measurements	Average Discharge (gpm)	Discharge STD (gpm)
Regional Springs									
195	1953101	195 (C-10-14) 33C	Wilson Hot Spring 1	4,423,960	805,047	4,293	0	---	---
195	1953102	195 (C-10-14) 33CDC	Wilson Hot Spring 2	4,423,459	805,030	4,293	1	1	---
195	1953103	195 (C-10-14) 33CDD	Wilson Hot Spring 3	4,423,580	805,163	4,293	1	10	---
195	1953104	195 (C-10-14) 33DBA	Wilson Hot Spring 4	4,423,985	805,447	4,298	1	60	---
195	1953105	195 (C-10-14) 33DCB	Wilson Hot Spring 5	4,423,694	805,343	4,298	1	30	---
203	2030101	203 S02 E68 04BADD	Panaca Spring	4,187,657	730,624	4,799	15	1,455	1,677
207	2070501	207 N06 E61 18AADA	Hot Creek Spring	4,249,926	661,290	5,225	23	5,038	1,263
207	2071901	207 N06 E60 25BDAD	Moon River Spring	4,246,394	658,908	5,223	8	1,676	574
207	2071101	207 N09 E61 32DABC	Moorman Spring	4,273,440	662,053	5,299	26	522	944
207	2070901	207 N12 E61 02ACAB	Preston Big Spring	4,311,153	666,296	5,732	9	3,519	278
209	2090501	209 S06 E61 06BBBB	Ash Springs	4,147,834	659,848	3,622	3	7,831	800
209	2090401	209 S05 E60 10ADBB	Crystal Springs	4,155,349	656,168	3,803	3	5,724	73
209	2090101	209 S04 E60 14	Hiko Spring	4,162,744	657,549	3,875	17	2,583	399
219	2190401	219 S14 E65 16DB	Baldwin Spring	4,066,270	703,257	1,798	1	1,066	---
219	2190301	219 S14 E65 16DD	Jones Spring	4,065,661	703,714	1,784	12	517	227
219	2191701	219 S14 E65 16ABB 1	M-10	4,066,695	703,637	1,722	2	278	17
219	2190701	219 S14 E65 21AABB1	M-11	4,065,194	704,070	1,800	17	547	311
219	2190801	219 S14 E65 21AABB4	M-12	4,065,162	704,021	1,800	16	119	98
219	2190901	219 S14 E65 21AABB3	M-13	4,065,131	704,022	1,800	18	288	94
219	2191001	219 S14 E65 21AAAA1	M-15	4,065,200	704,318	1,780	14	714	257
219	2191101	219 S14 E65 21AAAB2	M-16	4,065,198	704,268	1,780	13	135	92
219	2191201	219 S14 E65 21AABB5	M-19	4,065,101	704,047	1,800	8	414	24
219	2191301	219 S14 E65 21 1	M-20	4,065,170	704,368	1,778	7	357	136
219	2190501	219 S14 E65 16DA	Muddy Spring	4,066,348	704,018	1,747	20	3,450	227
219	2190101	219 S14 E65 21BA	Pederson East Spring	4,065,062	703,965	1,800	4	94	6
219	2190201	219 S14 E65 21BA	Pederson Spring	4,065,088	704,008	1,811	17	101	11
219	2191401	219 S14 E65 21AAAA2	Warm Springs East	4,065,137	704,294	1,790	18	996	357
258	2580407	258 (C-11-14) 26AD	Crater Spring	4,415,708	808,950	4,305	0	---	---

Table G-1
Regional Springs and Selected Intermediate Springs Information
(Page 2 of 3)

HA Number	Spring ID	Local Number	Site Name	UTM Northing[a] (m)	UTM Easting[a] (m)	Elevation (ft amsl)	Number of Discharge Measurements	Average Discharge (gpm)	Discharge STD (gpm)
258	2580201	258 (C-11-14) 03DBD	Deadman Spring	4,420,367	807,286	4,310	2	53	67
258	2580401	258 (C-11-14) 23ACA	House Spring	4,417,323	808,385	4,315	1	850	---
258	2580404	258 (C-11-14) 26AAA	Lost Spring	4,415,980	808,796	4,310	1	1,100	---
258	2580403	258 (C-11-14) 23DDC	Middle Spring	4,416,434	808,564	4,315	1	5,400	---
258	2580408	258 (C-11-14) 23AD	Mirror Spring	4,417,204	808,509	4,315	0	---	---
258	2580101	258 (C-11-14) 03DBD	North Springs	4,421,366	806,770	4,303	1	3,140	---
258	2580406	258 (C-11-14) 26DAA	Percy Spring	4,415,332	808,823	4,315	1	1,700	---
258	2580405	258 (C-11-14) 26ADD	South Spring	4,415,581	808,860	4,310	1	3,600	---
258	2580402	258 (C-11-14) 23DBD	Thomas Spring	4,416,770	808,479	4,315	1	2,400	---
258	2580301	258 (C-11-14) 11CDB	Walter Spring	4,419,580	807,675	4,308	1	150	---
Intermediate Springs									
179	1792301	179 N23 E63 6C	Cherry Creek Hot Springs	4,417,460	679,565	6,250	3	37	7
179	1792601	179 N21 E63 12DC	Cold Spring	4,396,434	688,748	5,958	1	Dry	---
179	1792001	179 N16 E64 21	McGill Spring	4,364,930	691,168	6,104	14	4,734	734
179	1792501	179 N21 E63 25BA	Monte Neva Hot Springs	4,393,119	688,116	6,011	2	649	35
184	1846401	184 N11 E67 23DA	Blind Spring	4,297,977	724,792	5,773	2	Dry	---
184	1847001	184 N15 E67 30BD	Four Wheel Drive Spring	4,335,256	716,255	5,754	1	16	---
184	1847101	184 N18 E66 01DC	Keegan Spring	4,369,756	714,906	5,617	1	233	---
184	1845901	184 N14 E67 04DB	Layton Spring	4,331,794	720,204	5,698	4	<1	<1
184	1847201	184 N11 E67 12DB	Minerva Spring	4,301,025	726,101	5,825	2	272	40
184	1845701	184 N17 E67 25DB	North Millick Spring	4,353,981	725,760	5,590	4	283	61
184	1846001	184 N12 E67 18AD	North Spring	4,309,388	717,768	5,763	1	10	---
184	1846601	184 N21 E66 09BB	Osborne Springs	4,398,798	711,959	6,127	1	3	---
184	1845801	184 N15 E67 29	South Bastian Spring	4,334,865	718,388	5,660	3	3	2
184	1845802	184 N15 E67 29DC	South Bastian Spring 2	4,334,397	718,361	5,669	1	1	---
184	1845702	184 N17 E67 25CD	South Millick Spring	4,353,599	725,201	5,592	5	473	164
184	1847401	184 N22 E66 17CA	Stonehouse Spring	4,406,507	710,511	6,256	1	Dry	---
184	1847501	184 N12 E67 26AC	The Seep	4,306,263	724,060	5,764	1	5	---
184	1847701	184 N15 E67 09BBB	Unnamed 5 Spring	4,340,641	718,911	5,645	0	---	---

Table G-1
Regional Springs and Selected Intermediate Springs Information
(Page 3 of 3)

HA Number	Spring ID	Local Number	Site Name	UTM Northing[a] (m)	UTM Easting[a] (m)	Elevation (ft amsl)	Number of Discharge Measurements	Average Discharge (gpm)	Discharge STD (gpm)
184	1845601	184 N14 E67 32AC	Willard Springs	4,323,976	718,691	5,755	2	2	2
184	1845501	184 N21 E66 15BC	Willow Spring	4,397,068	713,830	5,982	3	14	19
195	1953202	195 (C-11-14) 04BBB	(C-11-14)4bbb-S1	4,422,636	803,797	4,298	1	20	---
195	1951901	195 N10 E70 33B	Big Springs	4,287,141	749,475	5,568	2	4,547	89
195	1952401	195 (C-19-20) 24 CB	Caine Spring	4,336,186	755,138	5,028	1	5	---
195	1953201	195 (C-11-14) 4AB	Cold Spring	4,422,428	804,999	4,310	0	---	---
195	1953401	195 (C-16-18) 16DAD	Foote Res. Spring	4,367,388	769,356	4,825	1	1,300	---
195	1953701	195 (C-17-19) 21	Kell Spring	4,356,001	759,929	4,910	1	120	---
195	1952701	195 (C-18-18) 16AB	Knoll Spring	4,348,105	769,378	4,869	2	3	<1
195	1954001	195 (C-16-18)22cab-S1	Twin Spring	4,366,197	770,137	4,826	1	1,795	---
195	1953901	195 (C-18-18) 08A	Unnamed Spring	4,350,397	768,130	4,853	1	2	---
195	1952001	195 (C-15-19) 31CB	Warm Creek near Gandy, UT	4,371,945	754,812	5,156	2	7,451	127
207	2070601	207 N12 E61 2DCCD	Arnoldson Spring	4,308,473	667,919	5,625	27	1,544	232
207	2071401	207 N07 E62 28ABDC	Butterfield Spring	4,256,472	673,530	5,320	23	1,222	193
207	2070701	207 N12 E61 12BDAD	Cold Spring	4,309,454	667,609	5,653	20	589	315
207	2072001	207 N09 E62 19DB	Emigrant Springs	4,276,841	669,895	5,480	12	852	281
207	2071303	207 N07 E62 33BCAB	Flag Springs 1	4,254,696	672,719	5,290	21	1,022	137
207	2071302	207 N07 E62 33BCCB	Flag Springs 2	4,254,570	672,576	5,280	21	1,294	200
207	2071301	207 N07 E62 33BCCC	Flag Springs 3	4,254,416	672,579	5,290	22	963	181
207	2071502	207 N09 E61 13CB	Hardy Spring NW	4,278,196	667,352	5,345	1	5	---
207	2071501	207 N09 E61 13CB	Hardy Springs	4,278,196	667,553	5,354	2	200	<1
207	2071001	207 N11 E62 04AABA	Lund Spring	4,302,019	673,266	5,608	29	3,516	871
207	2071601	207 N12 E61 12DBDD	Nicolas Spring	4,308,847	668,104	5,635	26	1,149	233
209	2090701	209 S05 E60 26DAD 1	Brownie Spring	4,149,897	658,088	3,695	1	224	---
215	2150301	215 S19 68E 07AB	Blue Point Spring	4,030,173	730,235	1,550	8	247	10
215	2150201	215 S18 E67 12DD	Rogers Spring	4,028,821	729,274	1,594	22	746	43
258	2580601	258 (C-12-14) 23DCC	Cane Spring	4,406,988	809,493	4,333	0	---	---

[a]North American Datum of 1983, Zone 11

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Table G-2
Statistics for USGS Discharge Measurements of Selected Springs

HA Number	Spring ID	Local Number	Site Name	Number of Discharge Measurements	Average Annual Discharge (gpm)	Discharge STD (gpm)
195	1951901	195 N10 E70 33B	Big Springs	2	4,547	89
195	1952001	195 (C-15-19) 31CB	Warm Creek near Gandy, UT	2	7,451	127
207	2070901	207 N12 E61 02ACAB	Preston Big Spring	9	3,519	278
209	2090501	209 S06 E61 06BBBB	Ash Springs	3	7,831	800
209	2090401	209 S05 E60 10ADBB	Crystal Springs	3	5,724	73
215	2150301	215 S19 68E 07AB	Blue Point Spring	8	247	10
215	2150201	215 S18 E67 12DD	Rogers Spring	22	746	43
219	2190101	219 S14 E65 21BA	Pederson East Spring	4	94	6
219	2190201	219 S14 E65 21BA	Pederson Spring	17	101	11
219	2190501	219 S14 E65 16DA	Muddy Spring	20	3,450	227

Source: USGS (2008)

SNWA. These methods are described, followed by the application of the selected method to the springs listed in Table G-1.

G.1.1.2.1 Interpretation by Mifflin (1968)

Mifflin (1968, p. 26) states that:

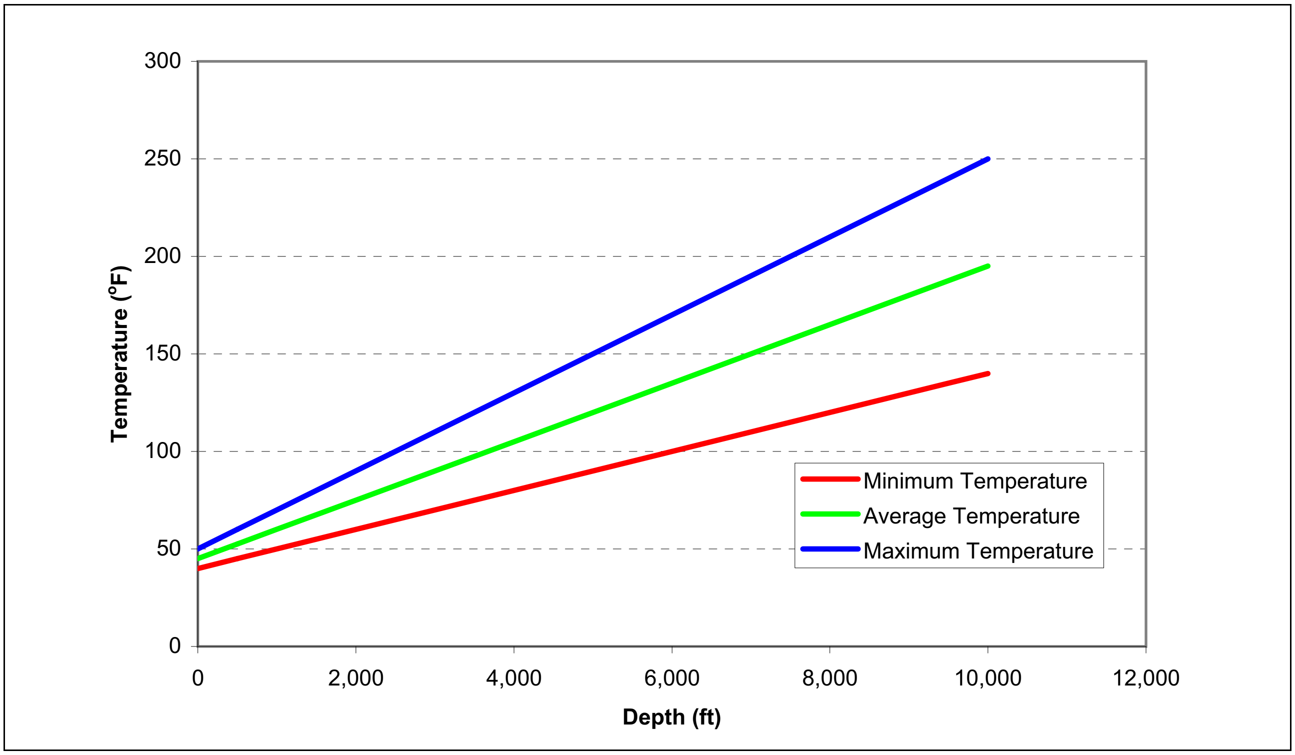
> Ground-water temperatures in Nevada are generally higher, by at least 5 to 10°F, than the mean annual air temperature at the point of sample. [and that] …within Nevada, ground-water temperatures observed in the 40's or 50's °F (temperatures which closely approximate mean annual air temperature) are most frequently found in the areas where saturation is relatively shallow, and active recharge to the system is often nearby or in the immediate vicinity of observation points.

These statements imply that the temperature of groundwater at the sampling point must be larger than about 45°F (mean air temperature in Nevada) to be affected by the geothermal gradient.

Mifflin (1968, p. 27) also states that:

> Many geothermal gradients could be illustrated in Nevada by picking the area. However, it seems likely that the gradients of 1°F to 2°F per 100 ft of depth are more common than 3°F per 100 feet or more.

Mifflin's interpretations of the mean geothermal gradient in Nevada may be depicted by three linear relationships of temperature versus depth that represent the mean trend and minimum and maximum trends. For the line representing the mean trend, the slope of the line is the average of the prevailing gradients in Nevada (i.e., 1.5°F per 100 ft or the middle of the range cited by Mifflin [1968]: 1°F to 2°F per 100 ft of depth). The intercept is the average air temperature in Nevada (i.e., 45°F or the middle of the range cited by Mifflin [1968]: 40°F to 50°F). The lower and upper ends of the ranges of thermal gradients and the mean air temperature provided by Mifflin (1968) form the basis of the minimum and maximum trends (Figure G-1).



Source: Interpreted from Mifflin (1968)

Figure G-1
Mifflin Geothermal Gradient Trends in Nevada

G.1.1.2.2 Great Basin Center Data

The Great Basin Center for Geothermal Energy is part of UNR. In support of research in the field of geothermal energy, the center conducts data compilation and analysis activities. Data types of interest include geologic, geochemical, geodetic, geophysical, and tectonic data. Data analysis products include maps and databases. Of particular interest to this study is the geochemistry database (UNR, 2008a) and the Temperature Gradient Map of the Great Basin (UNR, 2008b).

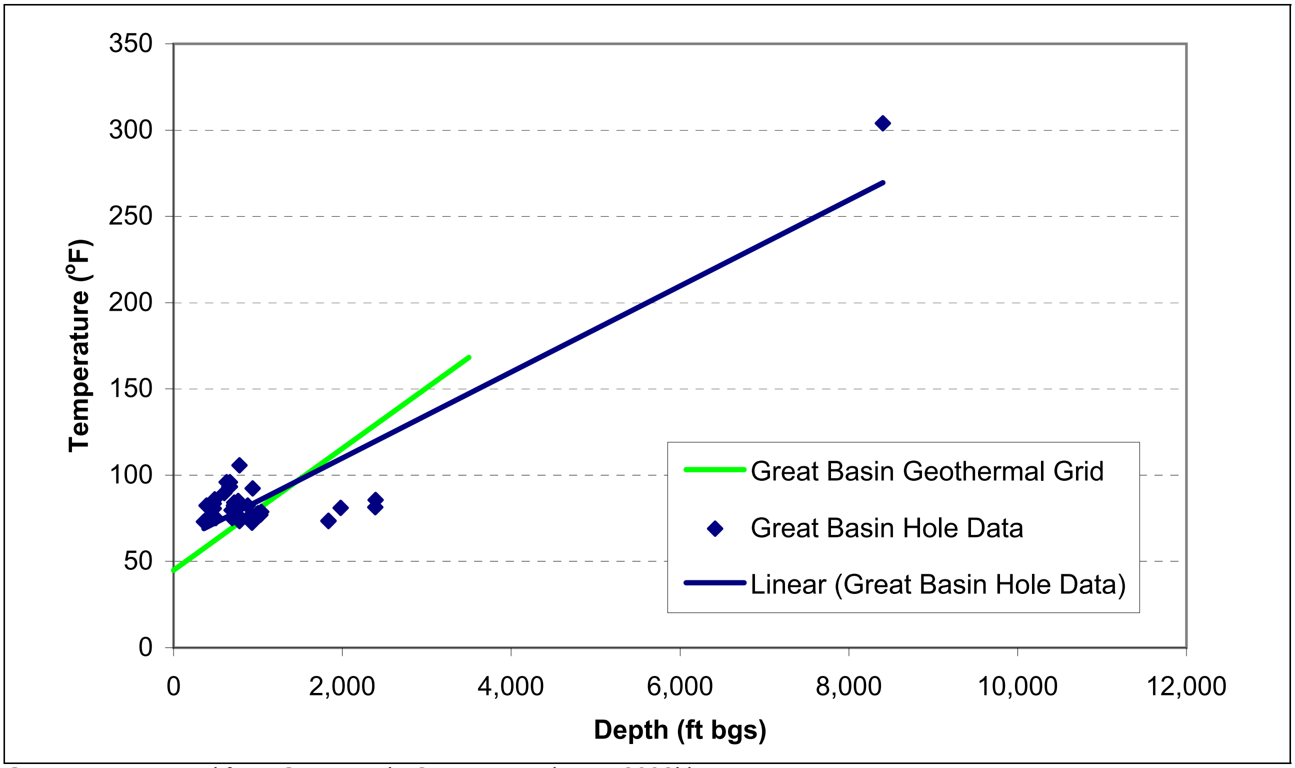
The geochemical database contains various types of information for fluids from wells and springs in the Great Basin. Hole depths and their respective water temperatures for boreholes located in Nevada were used to estimate a geothermal gradient for this study. Data points with temperatures less than 70°F and depths less than 100 m (328 ft) were first removed from the data set. The selected data are listed in Table G-3 and shown in blue on Figure G-2. A linear regression line through the data is also shown in blue on Figure G-2.

Average values of the geothermal gradient were derived from the Temperature Gradient Map of the Great Basin for each of the basins of the study area. The derived values are listed in Table G-4. The basin geothermal gradient values were averaged to obtain a mean value for the study area. The mean

Table G-3
Well Temperatures and Depths from UNR Great Basin Center for Geothermal Energy

Well Name	County	Hole Depth (m bgs)	Hole Depth (ft bgs)	Temperature (°C)	Temperature (°F)
Nellis 1 USAF	Clark	244	801	24	75
Nellis 12 (C) USAF	Clark	305	1,001	25	77
Nellis 12 (C) USAF	Clark	305	1,001	26	79
Nellis 13 (B) USAF	Clark	212	696	24	75
NWIS Well 209 S13 E63 23DD 1	Clark	204	669	34	93
NWIS Well 209 S13 E63 23DD 1	Clark	204	669	36	97
NWIS Well 212 N19 E60 04DAB 2 NV Division of Forestry	Clark	238	781	23	73
NWIS Well 215 S18 E63 14CBAC1	Clark	210	689	26	79
NWIS Well 215 S20 E64 29DADB1	Clark	149	489	30	86
NWIS Well 216 S18 E63 05AADB1	Clark	603	1,978	27	81
NWIS Well 216 S18 E63 11AAA 1	Clark	152	499	24	75
Railroad Well - Farrier, NV	Clark	110	361	23	73
USAF Lake Mead 3	Clark	313	1,027	25	77
USAF Lake Mead 3	Clark	313	1,027	25	77
USAF Lake Mead 4	Clark	268	879	28	82
USBLM SHV-1	Clark	280	919	25	77
USFWS DR-1	Clark	283	932	22	72
USFWS DR-1	Clark	284	932	25	77
USFWS SBH-1	Clark	220	722	29	84
USGS CSV-1	Clark	233	764	30	86
USGS CSV-2	Clark	146	479	27	81
USGS CSV-2	Clark	146	479	29	84
USGS CSV-3	Clark	238	781	41	106
USGS-MX CE-DT-5	Clark	192	630	36	97
USGS-MX CE-DT-6	Clark	286	938	34	93
North Dry Lake USGS-MX	Lincoln	730	2,395	30	86
NWIS Well 181 N03 E63 03DCC 1	Lincoln	729	2,392	28	82
NWIS Well 205 S04 E66 12AADC1	Lincoln	119	390	28	82
USGS Well VF-1, Desert NWR	Lincoln	218	715	28	82
Coal Valley Well USGS MX	Nye	560	1,837	23	73
Coal Valley Well USGS MX	Nye	560	1,837	23	73
Hans L. Anderson Water Well	White Pine	317	1,040	26	79
Henroid Well, D Henroid Ranch	White Pine	183	600	32	90
Shell Oil Co. NE Cherry Creek Unit No.1 Well	White Pine	2,562	8,406	151	304
USBLM Well, Shoshone Ponds	White Pine	124	407	24	75
USBLM Well, Shoshone Ponds	White Pine	134	440	24	75
Well at Alligator Ridge	White Pine	201	659	34	93

Source: UNR (2008a)
NWIS = National Water Information System



Source: Interpreted from Great Basin Center Data (UNR, 2008b)

Figure G-2
Great Basin Center Geothermal Gradient Trends

geothermal gradient calculated by this method is about 0.035°F/ft. This value was used to generate the corresponding temperature-depth relationship shown in green on Figure G-2.

G.1.1.2.3 SNWA Monitor Well Thermal Logs

SNWA conducted thermal logging in the monitor wells drilled as part of the Project. Their locations are provided on Figure A-1 (Appendix A). The thermal logs are shown on Figure G-3. These thermal logs were conducted before the wells were developed and conditions in the wells stabilized. Thus, groundwater was still mixed with drilling fluids, which may have resulted in cooler temperatures during the measurement period (Eastman, 2007a through g). A mean temperature-depth relationship was derived from these thermal logs by averaging the temperatures at each depth. The resulting relationship is shown on Figure G-4.

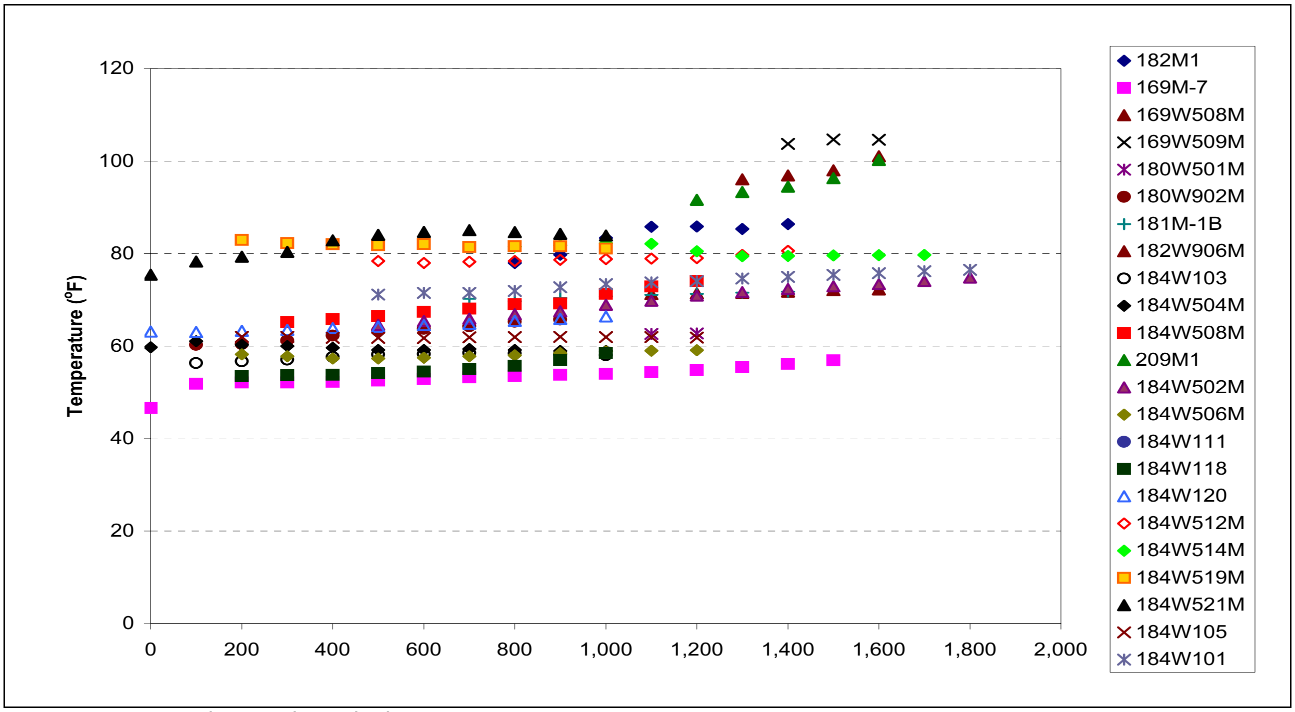
G.1.1.3 Spring Source Depth Estimates

Source aquifer depths were estimated for the selected regional and intermediate springs using the mean geothermal gradient interpreted by Mifflin (1968). Ranges of source depths were estimated when ranges of spring flow temperatures were available. The results are provided in Table G-5. These estimates constitute initial estimates only.

Table G-4
Average Basin Geothermal Gradients from the Temperature Gradient Map

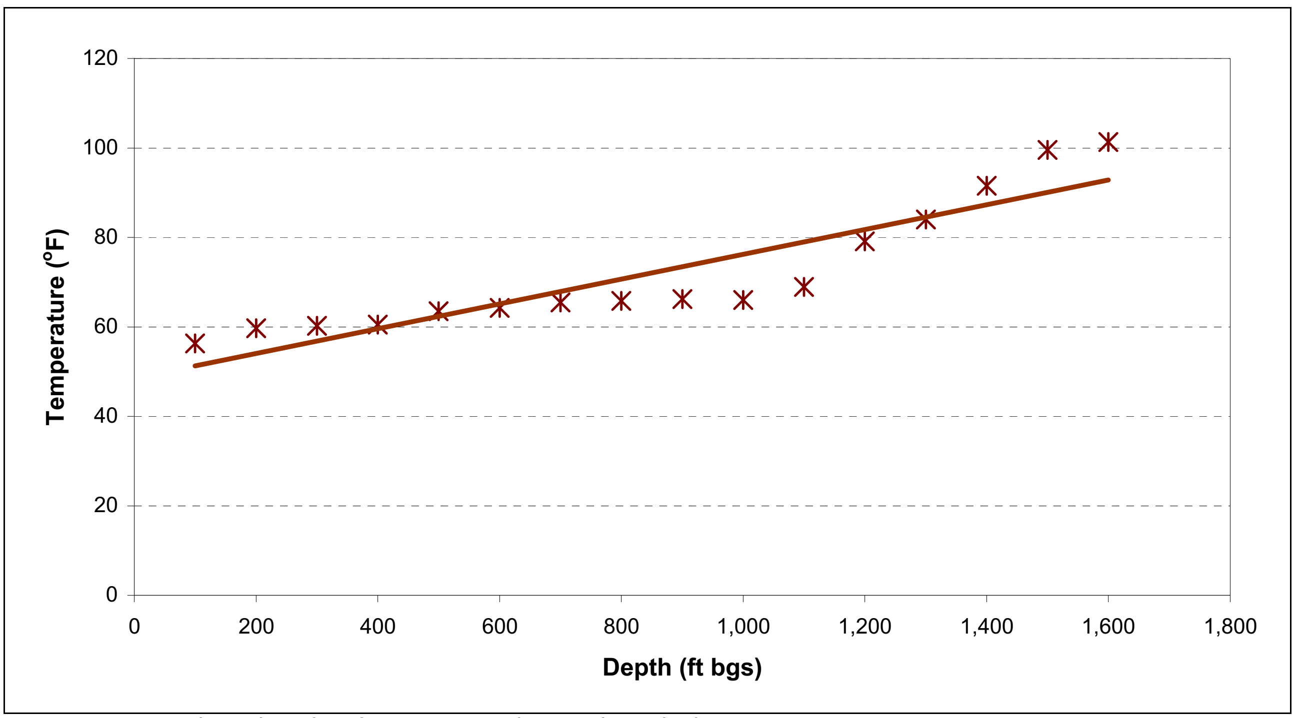
HA Number	Mean Gradient (°C/km)	Mean Gradient (°F/km)	Mean Gradient (°F/ft)
171	36.0	96.8	0.0295
172	41.3	106.3	0.0324
174	44.1	111.4	0.0339
175	43.1	109.7	0.0334
178B	49.2	120.6	0.0368
179	52.3	126.1	0.0384
180	37.8	100.1	0.0305
181	44.0	111.2	0.0339
182	48.1	118.6	0.0362
183	48.6	119.5	0.0364
184	50.0	121.9	0.0372
185	46.6	116.0	0.0353
194	38.0	100.4	0.0306
195	42.5	108.4	0.0330
196	43.5	110.3	0.0336
198	51.7	125.1	0.0381
199	50.3	122.5	0.0373
200	51.1	123.9	0.0378
201	48.3	118.9	0.0362
202	48.6	119.6	0.0364
203	46.9	116.4	0.0355
204	52.8	127.1	0.0387
205	49.8	121.7	0.0371
206	49.7	121.4	0.0370
207	46.3	115.4	0.0352
208	38.5	101.2	0.0308
209	42.3	108.2	0.0330
210	46.9	116.4	0.0355
212	44.6	112.3	0.0342
215	44.9	112.9	0.0344
216	49.0	120.2	0.0366
217	43.5	110.4	0.0336
218	49.3	120.8	0.0368
219	43.9	111.0	0.0338
220	46.0	114.8	0.0350
258	61.0	141.8	0.0432

Source: UNR (2008b)



Source: Eastman (2007a through g)

Figure G-3
Thermal Logs from SNWA Monitor Wells



Source: Average based on data from Eastman (2007a through g)

Figure G-4
Mean Temperature-Depth Relationship Based on
Thermal Logs from SNWA Monitor Wells

Table G-5
Spring Source Depths Estimated Using Mifflin's Mean Geothermal Gradient
(Page 1 of 2)

HA Number	Spring ID	Site Name	Temperature	Temperature Range (°C)	Temperature Range (°F)	Source Depth Range (ft bgs)
Regional Springs						
195	1953101	Wilson Hot Spring 1	Hot	60	141	6,394
195	1953102	Wilson Hot Spring 2	Hot	56	132	5,806
195	1953103	Wilson Hot Spring 3	Hot	59	138	6,202
195	1953104	Wilson Hot Spring 4	Hot	61	141	6,406
195	1953105	Wilson Hot Spring 5	Hot	60	140	6,334
203	2030101	Panaca Spring	Warm	NA	NA	NA
207	2070501	Hot Creek Spring	Warm	32	90	2,974
207	2071901	Moon River Spring	NA	33	91	3,094
207	2071101	Moorman Spring	Hot	37	99	3,622
207	2070901	Preston Big Spring	Warm	21	70	1,660
209	2090501	Ash Springs	Hot	32	90	2,974
209	2090401	Crystal Springs	Warm	28	82	2,434
209	2090101	Hiko Spring	Warm	27	80	2,356
219	2190401	Baldwin Spring	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2190301	Jones Spring	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2191701	M-10	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2190701	M-11	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2190801	M-12	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2190901	M-13	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2191001	M-15	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2191101	M-16	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2191201	M-19	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2191301	M-20	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2190501	Muddy Spring	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2190101	Pederson East Spring	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2190201	Pederson Spring	Warm	29 to 33	84 to 91	2,614 to 3,094
219	2191401	Warm Springs East	Warm	29 to 33	84 to 91	2,614 to 3,094
258	2580407	Crater Spring	NA	NA	NA	NA
258	2580201	Deadman Spring	Warm	23	73	1,894
258	2580401	House Spring	Warm	22	72	1,774
258	2580404	Lost Spring	Warm	26	78	2,224
258	2580403	Middle Spring	Warm	24	76	2,074
258	2580408	Mirror Spring	NA	NA	NA	NA
258	2580101	North Springs	Warm	24	74	1,954
258	2580406	Percy Spring	Warm	26	79	2,254
258	2580405	South Spring	Warm	24	76	2,044
258	2580402	Thomas Spring	Warm	26	79	2,254
258	2580301	Walter Spring	Cold	20	69	1,594

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Table G-5
Spring Source Depths Estimated Using Mifflin's Mean Geothermal Gradient
(Page 2 of 2)

HA Number	Spring ID	Site Name	Temperature	Temperature Range (°C)	Temperature Range (°F)	Source Depth Range (ft bgs)
Intermediate Springs						
179	1792301	Cherry Creek Hot Springs	Hot	47 to 57	117 to 135	4,774 to 5,974
179	1792601	Cold Spring	Cold	NA	NA	NA
179	1792001	McGill Spring	Warm	17	63	1,174
179	1792501	Monte Neva Hot Springs	Hot	77	171	8,422
184	1846401	Blind Spring	Cold	14	56	754
184	1847001	Four Wheel Drive Spring	Cold	15	58	898
184	1847101	Keegan Spring	Cold	13	56	706
184	1845901	Layton Spring	Cold	15	60	977
184	1847201	Minerva Spring	Cold	NA	NA	NA
184	1845701	North Millick Spring	Cold	15	59	949
184	1846001	North Spring	Warm	23	73	1,858
184	1846601	Osborne Springs	Cold	13	56	718
184	1845801	South Bastian Spring	Cold	12	54	628
184	1845802	South Bastian Spring 2	Cold	14	58	874
184	1845702	South Millick Spring	Cold	13	56	733
184	1847401	Stonehouse Spring	Cold	4	38	Negative
184	1847501	The Seep	Warm	24	74	1,966
184	1847701	Unnamed 5 Spring	Cold	14	58	841
184	1845601	Willard Springs	Cold	8	46	81
184	1845501	Willow Spring	Warm	13	56	709
195	1953202	(C-11-14)4bbb-S1	Cold	18	64	1,294
195	1951901	Big Springs	Cold	17	62	1,156
195	1952401	Caine Spring	Cold	14	58	862
195	1953201	Cold Spring	Cold	NA	NA	NA
195	1953401	Foote Res. Spring	NA	NA	NA	NA
195	1953701	Kell Spring	NA	NA	NA	NA
195	1952701	Knoll Spring	Cold	20	68	1,498
195	1954001	Twin Spring	Cold	20	68	1,534
195	1953901	Unnamed Spring	NA	NA	NA	NA
195	1952001	Warm Creek near Gandy, UT	Warm	26	80	2,305
207	2070601	Arnoldson Spring	Warm	22	72	1,786
207	2071401	Butterfield Spring	NA	NA	NA	NA
207	2070701	Cold Spring	Warm	22	71	1,738
207	2072001	Emigrant Springs	NA	20	68	1,534
207	2071303	Flag Springs 1	Warm	NA	NA	NA
207	2071302	Flag Springs 2	Warm	NA	NA	NA
207	2071301	Flag Springs 3	Warm	NA	NA	NA
207	2071502	Hardy Spring NW	Cold	17	63	1,174
207	2071501	Hardy Springs	Cold	17	63	1,174
207	2071001	Lund Spring	Cold	19	66	1,414
207	2071601	Nicolas Spring	Warm	70	159	7,594
209	2090701	Brownie Spring	NA	NA	NA	NA
215	2150301	Blue Point Spring	Warm	27	80	2,338
215	2150201	Rogers Spring	Warm	27	80	2,338
258	2580601	Cane Spring	Cold	20	68	1,534

NA = Not available

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G.1.2 Selected Muddy River Stream Gages

Mean annual stream flow measurements for the Muddy River near Moapa gage and the Muddy River near Glendale gage are provided in Table G-6. The mean annual stream flow values adjusted to remove water from flooding events are also provided in this table.

A graph of the adjusted stream flow rates at the Glendale gage and the Moapa gage for the periods of record shows a great correlation between the two gaging stations (Figure G-5). The data for the common period of record 1951 to 2004 (Table G-6), not including 1984, were used to derive a correlation coefficient between the two stations. A correlation coefficient of 0.92 was derived indicating a high degree of correlation between adjusted stream flow at the two gages.

Table G-6
Stream Flow Measurements (afy)
on the Muddy River near Moapa and Glendale
(Page 1 of 3)

Year	Mean Actual Value		Mean Adjusted Value[a]	
	Moapa Gage	Glendale Gage	Moapa Gage	Glendale Gage
1913	13,343[b]	---	---	---
1914	34,438	---	34,380	---
1915	13,625[b]	---	---	---
1916	33,819	---	33,819	---
1917	34,057	---	34,057	---
1918	---	---	---	---
1944	33,109	---	32,938	---
1945	33,938	---	33,761	---
1946	34,568	---	34,568	---
1947	33,583	---	33,583	---
1948	34,057	---	34,057	---
1949	33,454	---	33,454	---
1950	33,585	---	33,585	---
1951	33,920	31,908	33,920	31,542
1952	33,840	38,922	33,793	33,431
1953	33,325	33,305	33,251	33,253
1954	33,317	31,720	33,317	31,433
1955	34,184	39,708	33,899	34,215
1956	33,216	31,628	33,216	31,296
1957	34,507	34,935	33,928	33,841
1958	35,929	34,969	35,645	32,550
1959	35,384	32,598	35,100	32,208
1960	34,666	32,077	34,578	31,932
1961	33,493	43,967	32,646	33,505

Table G-6
Stream Flow Measurements (afy)
on the Muddy River near Moapa and Glendale
(Page 2 of 3)

Year	Mean Actual Value		Mean Adjusted Value[a]	
	Moapa Gage	Glendale Gage	Moapa Gage	Glendale Gage
1962	32,212	32,401	32,158	31,585
1963	32,335	29,056	32,335	28,810
1964	32,613	29,026	32,613	28,815
1965	31,419	31,999	31,327	31,258
1966	30,296	30,347	29,836	28,044
1967	33,333	32,749	30,416	29,127
1968	29,477	31,860	29,393	30,826
1969	30,907	39,462	30,507	30,543
1970	29,604	32,633	29,604	30,566
1971	27,602	30,784	27,412	29,846
1972	31,552	30,446	30,161	28,197
1973	32,928	32,039	31,643	29,582
1974	29,352	27,902	29,352	27,856
1975	28,874	29,422	28,834	28,519
1976	29,883	30,177	28,622	28,783
1977	27,130	27,645	26,170	25,601
1978	26,200	40,108	25,703	27,143
1979	28,370	30,641	26,926	26,184
1980	28,927	33,796	28,550	28,107
1981	27,452	32,463	27,176	24,677
1982	27,331	26,838	27,047	26,432
1983	28,493	39,796	28,104	27,704
1984	30,786	---	26,371	---
1985	27,662	26,568	27,579	26,220
1986	26,507	27,141	26,438	26,631
1987	27,247	27,026	27,247	27,027
1988	28,792	27,871	28,268	26,650
1989	24,397	22,270	24,397	22,269
1990	26,490	29,909	24,710	23,393
1991	26,111	25,968	25,801	24,371
1992	26,418	26,595	26,335	25,504
1993	28,668	39,265	27,563	26,992
1994	28,521	25,144	28,431	25,145
1995	25,770	23,760	25,770	23,760

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Table G-6
Stream Flow Measurements (afy)
on the Muddy River near Moapa and Glendale
(Page 3 of 3)

Year	Mean Actual Value		Mean Adjusted Value[a]	
	Moapa Gage	Glendale Gage	Moapa Gage	Glendale Gage
1996	24,332	22,663	24,332	22,663
1997	23,560	22,015	23,560	21,731
1998	25,210	39,777	24,782	25,652
1999	25,230	27,019	24,994	26,930
2000	25,073	28,862	24,727	25,125
2001	23,276	22,848	23,276	22,802
2002	22,665	22,919	22,665	22,919
2003	22,961	22,931	22,961	22,931
2004	22,059	23,266	22,059	23,266

[a]Removed water from flooding events.
[b]Reported values were identified as outliers.

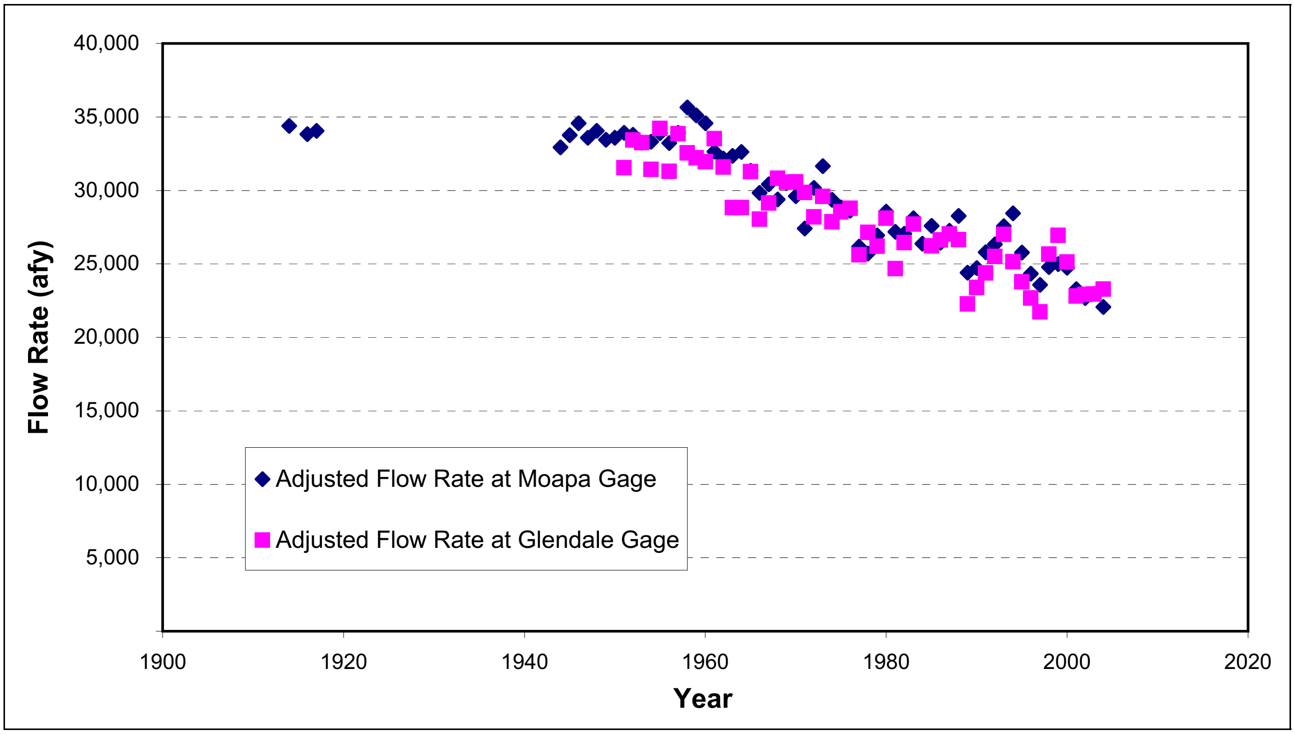

Figure G-5
Adjusted Stream Flow Rates at the Glendale and Moapa Gages on the Muddy River

G.2.0 References

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USGS, see U.S. Geological Survey.

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Appendix H

Interbasin Flow

H.1.0 INTERBASIN FLOW

This appendix contains reported estimates of interbasin flow for the basins in the study area and estimates of subsurface flow through the external boundary of the model area using the Monte Carlo method.

H.1.1 Reported Estimates of Interbasin Flow

A literature review was conducted to compile estimates of interbasin flow for all basins in the study area to support the discussion presented in the main text. The locations of interbasin flow are shown in Figure H-1. The reported values and overall ranges of flow across each segment boundary are presented in Table H-1.

H.1.2 External Boundary Flow–Monte Carlo Method

Interbasin flow volumes across most external boundaries of the model area were estimated using Darcy's equation and the Monte Carlo method. The method consisted of conducting Monte Carlo simulations using Crystal Ball software to generate stochastic estimates of total flux across each flow-boundary segment.

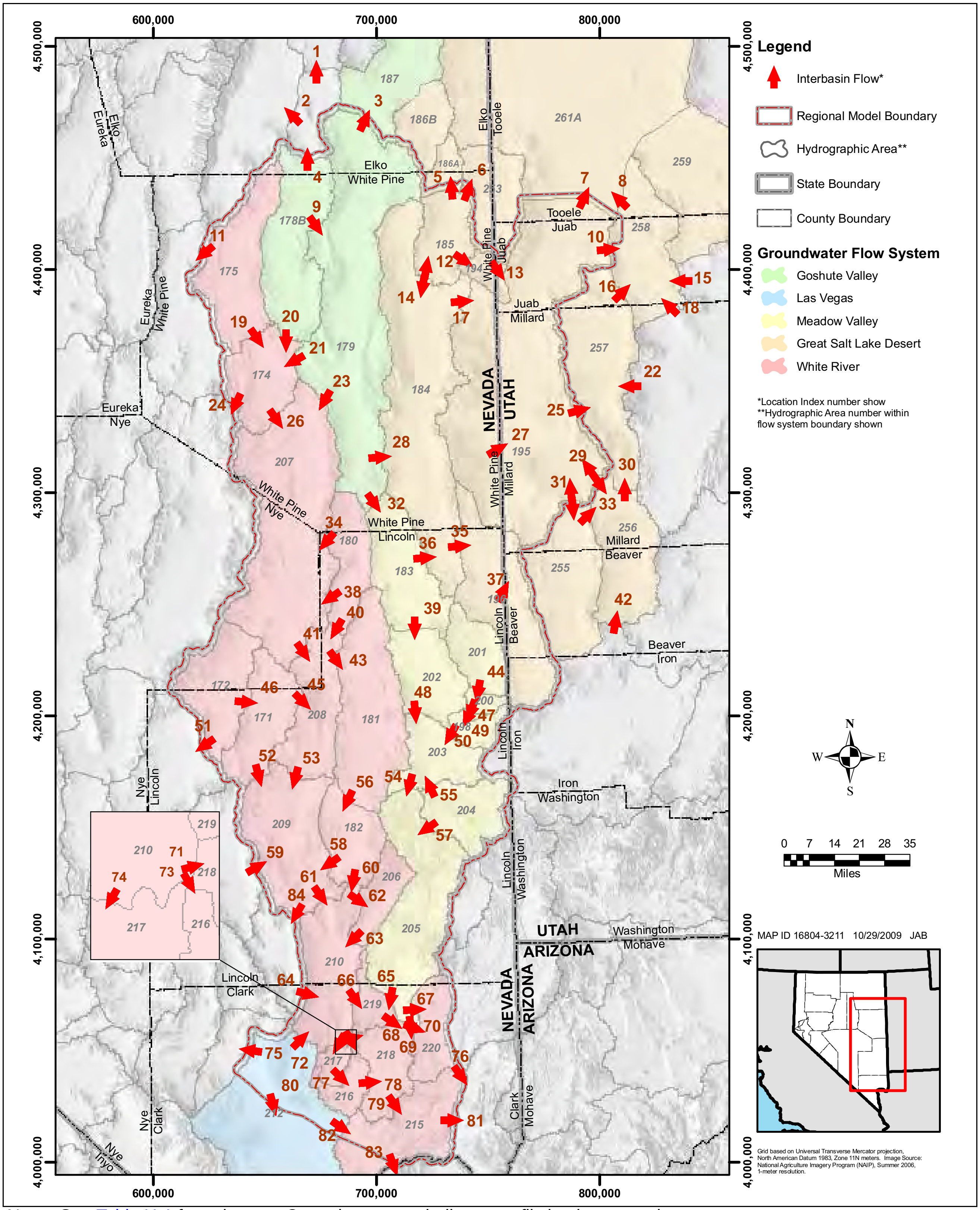
The analysis process included the following steps:

1. Began with the approximate locations of flow-boundary segments where groundwater flow is permissible (SNWA, 2008). Permissible means only that the flow-boundary segment is permeable, not that flow actually occurs through it under predevelopment conditions.

2. Extracted the RMU column from the simplified hydrogeologic framework model for each permeable flow-boundary segment.

3. Prepared input data (see Section H.1.3):

   - Estimated mean transmissivities and standard deviations using the available hydraulic head data.
   - Using the surficial RMU map and the available potentiometric maps, estimated the flow width of each permeable boundary segment.
   - Using the same maps as above and measured water levels, estimated the hydraulic gradient across each permeable flow-boundary segment.



Note: See Table H-1 for volumes. Opposing arrows indicate conflicting interpretations.

Figure H-1
Locations of Interbasin Flow within Study Area

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Table H-1
Reported Volumes of Interbasin Flow in Study Area
(Page 1 of 7)

Location Index[a]	Interbasin Flow Range (afy)	Interbasin Flow (afy)	Sources
1	22,500	22,500	Nichols (2000)
2	800 to 2,000	800	Scott et al. (1971)
		1,000	Harrill et al. (1988)
		2,000	Nichols (2000)
3	M to 7,000	M	Harrill et al. (1988)
		S	Scott et al. (1971)
		2,130 to 5,330	Frick (1985)
		4,000	Nichols (2000)
		7,000	Welch et al. (2008)
4	3,000 to 8,000	3,000	Glancy (1968)
		8,000	Welch et al. (2008)
5	3,000	3,000	Harrill et al. (1988)
6	2,000 to 12,000	2,000	Harrill et al. (1988)
		6,000	Nichols (2000)
		12,000	Welch et al. (2008)
7	3,500 to 29,000	3,500	Carlton (1985)
		10,000	Hood and Rush (1965)
		10,000	Gates and Kruer (1981)
		10,000	Harrill et al. (1988)
		29,000	Welch et al. (2008)
8	1,000 to 8,500	1,000	Harrill et al. (1988)
		8,500	Carlton (1985)
9	?	?	Harrill et al. (1988)
10	? to 18,500	?	Harrill et al. (1988)
		15,000?	Gates and Kruer (1981)
		18,500	Carlton (1985)
11	? to 12,700	?	Harrill et al. (1988)
		5,000	Welch et al. (2008)
		8,000	Thomas et al. (2001)
		10,000	Nichols (2000)
		12,700	Prudic et al. (1995)
12	3,600	3,600	Nichols (2000)
13	3,000	3,000	Scott et al. (1971)
14	-2,000 to 2,000	-2,000	Welch et al. (2008)
		2,000	Harrill (1971)
		2,000	Harrill et al. (1988)
15	6,000	6,000	Carlton (1985)
16	25,500 to 27,000	25,500	Carlton (1985)
		27,000	Harrill et al. (1988)
17	4,000 to 16,000	4,000	Nichols (2000)
		16,000	Welch et al. (2008)
18	?	?	Harrill et al. (1988)

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Table H-1
Reported Volumes of Interbasin Flow in Study Area
(Page 2 of 7)

Location Index[a]	Interbasin Flow Range (afy)	Interbasin Flow (afy)	Sources
19	8,000 to 19,000	8,000	Eakin (1961)
		8,000	Eakin (1966)
		8,000	Harrill et al. (1988)
		8,000	Scott et al. (1971)
		12,000	LVVWD (2001)
		12,000	Thomas et al. (2001)
		14,000	Nichols (2000)
		16,900	Thomas and Mihevc (2007)
		19,000	Welch et al. (2008)
20	16,000	16,000	Welch et al. (2008)
21	14,000	14,000	Welch et al. (2008)
22	5,500 to 9,000	5,500	Carlton (1985)
		9,000	Harrill et al. (1988)
23	8,000	8,000	Welch et al. (2008)
24	? to 700	?	Harrill et al. (1988)
		700	Nichols (2000)
25	15,000 to 42,000	15,000	Hood and Rush (1965)
		22,000 to 42,000	Harrill et al. (1988)
26	16,527 to 63,000	16,527 to 27,145	Kirk and Campana (1990)
		25,000	Eakin (1966)
		25,000	Scott et al. (1971)
		28,800	Thomas and Mihevc (2007)
		35,000	LVVWD (2001)
		35,000	Thomas et al. (2001)
		51,200	Nichols (2000)
		63,000	Welch et al. (2008)
27	30,000	30,000	Scott et al. (1971)
28	4,000	4,000	Welch et al. (2008)
29	-4,250 to 4,000	-4,250	Harrill et al. (1988)[b]
		4,000	Carlton (1985)
30	4,250 to 26,500	4,250	Harrill et al. (1988)[b]
		26,500	Carlton (1985)
31	-5,500 to 16,500	-5,500	Harrill et al. (1988)[b]
		16,500	Carlton (1985)
32	20,000	20,000	Welch et al. (2008)
33	5,500 to 30,000	5,500	Harrill et al. (1988)[b]
		30,000	Carlton (1985)
34	4,000 to 11,180	4,000	Thomas and Mihevc (2007)
		9,000	Welch et al. (2008)
		8,571 to 11,180	Kirk and Campana (1990)

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Table H-1
Reported Volumes of Interbasin Flow in Study Area
(Page 3 of 7)

Location Index[a]	Interbasin Flow Range (afy)	Interbasin Flow (afy)	Sources
35	4,000 to 33,000	4,000	Rush and Kazmi (1965)
		4,000	Gates and Kruer (1981)
		4,000	Harrill et al. (1988)
		4,000	Scott et al. (1971)
		10,000	Nichols (2000)
		33,000	Welch et al. (2008)
36	29,000	29,000	Welch et al. (2008)
37	10,000	10,000	Scott et al. (1971)
38	14,000 to 15,000	14,000	Eakin (1962)
		14,000	Eakin (1966)
		14,000	Harrill et al. (1988)
		14,000	Scott et al. (1971)
		15,000	LVVWD (2001)
39	3,000 to 17,000	3,000	Rush and Eakin (1963)
		3,000	Harrill et al. (1988)
		3,000	Scott et al. (1971)
		5,600	Thomas and Mihevc (2007)
		17,000	LVVWD (2001)
		17,000	Thomas et al. (2001)
40	9,400 to 15,000	9,400	Thomas and Mihevc (2007)
		15,000	Thomas et al. (2001)
41	6,400 to 40,000	6,400	Thomas and Mihevc (2007)
		17,000	Thomas et al. (2001)
		32,000	LVVWD (2001)
		39,000	Welch et al. (2008)
		40,000	Eakin (1966)
		40,000	Harrill et al. (1988)
		40,000	Scott et al. (1971)
42	1,500	1,500	Carlton (1985)
43	2,000	2,000	Thomas and Mihevc (2007)
44	M to 15,000	M	Scott et al. (1971)
		M	Harrill et al. (1988)
		7,200	Thomas and Mihevc (2007)
		15,000	LVVWD (2001)
		15,000	Thomas et al. (2001)
45	20,000 to 27,000	20,000	LVVWD (2001)
		27,000	Thomas and Mihevc (2007)
46	8,000 to 23,100	8,000	Eakin (1966)
		8,000	Harrill et al. (1988)
		8,000	Scott et al. (1971)
		14,000	LVVWD (2001)
		14,000	Thomas et al. (2001)
		23,100	Thomas and Mihevc (2007)

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Table H-1
Reported Volumes of Interbasin Flow in Study Area
(Page 4 of 7)

Location Index[a]	Interbasin Flow Range (afy)	Interbasin Flow (afy)	Sources
47	0 to 16,000	0	Scott et al. (1971)
		1,000	Harrill et al. (1988)
		8,300	Thomas and Mihevc (2007)
		16,000	LVVWD (2001)
		16,000	Thomas et al. (2001)
48	9,000 to 28,000	9,000	Harrill et al. (1988)
		9,000	Scott et al. (1971)
		14,900	Thomas and Mihevc (2007)
		28,000	LVVWD (2001)
		28,000	Thomas et al. (2001)
49	0 to 16,000	0	Scott et al. (1971)
		7,900	Thomas and Mihevc (2007)
		16,000	LVVWD (2001)
		16,000	Thomas et al. (2001)
50	7,400 to 16,000	7,400	Thomas and Mihevc (2007)
		16,000	LVVWD (2001)
		16,000	Thomas et al. (2001)
51	1,216 to 3,758	1,216	San Juan et al. (2004
		3,758	Faunt et al. (2004)
52	10,000 to 20,000	10,000	Eakin (1963)
		10,000	Eakin (1966)
		10,000	Harrill et al. (1988)
		10,000	Scott et al. (1971)
		20,000	Thomas et al. (2001)
53	1,330 to 59,000	1,330 to 1,970	Kirk and Campana (1990)
		39,000	Thomas et al. (2001)
		42,000	Eakin (1966)
		42,000	Harrill et al. (1988)
		42,000	Scott et al. (1971)
		45,300	Thomas and Mihevc (2007)
		59,000	LVVWD (2001)
54	M to 36,000	M	Harrill et al. (1988)
		8,900	Thomas and Mihevc (2007)
		27,000	LVVWD (2001)
		36,000	Thomas et al. (2001)
55	M to 9,000	M	Scott et al. (1971)
		9,000	Thomas et al. (2001)
56	5,000 to 17,700	5,000	Eakin (1966)
		5,000	Harrill et al. (1988)
		5,000	Scott et al. (1971)
		12,000	LVVWD (2001)
		12,000	Thomas et al. (2001)
		17,700	Thomas and Mihevc (2007)

Table H-1
Reported Volumes of Interbasin Flow in Study Area
(Page 5 of 7)

Location Index[a]	Interbasin Flow Range (afy)	Interbasin Flow (afy)	Sources
57	9,000 to 9,700	9,000	LVVWD (2001)
		9,700	Thomas and Mihevc (2007)
58	6,000	6,000	Eakin (1966)
		6,000	Harrill et al. (1988)
		6,000	Scott et al. (1971)
59	811 to 11,307	811	San Juan et al. (2004)
		11,307	Faunt et al. (2004)
60	16,000 to 24,100	16,000	Thomas et al. (2001)
		16,000	LVVVWD (2001)
		24,100	Thomas and Mihevc (2007)
61	22,300 to 35,000	22,300	Thomas and Mihevc (2007)
		27,247 to 29,370	Kirk and Campana (1990)
		28,000	LVVWD (2001)
		28,000	Thomas et al. (2001)
		35,000	Eakin (1966)
		35,000	Scott et al. (1971)
		35,000	Harrill et al. (1988)
62	S	S	Scott et al. (1971)
63	M to 6,000	M	Scott et al. (1971)
		M	Harrill et al. (1988)
		4,200	Thomas and Mihevc (2007)
		6,000	LVVWD (2001)
		6,000	Thomas et al. (2001)
64	? to 14,023	5,513	San Juan et al. (2004)
		14,023	Faunt et al. (2004)
		?	Harrill et al. (1988)
65	2,400 to 13,000	2,400 to 7,200	Buqo (2002)
		4,000	Thomas and Mihevc (2007)
		8,000	Thomas et al. (1996)
		5,500 to 9,000	Kirk and Campana (1990) as reported by Thomas et al. (1996)
		13,000	Prudic et al. (1995)
66	28,000 to 37,700	28,000	Thomas et al. (1996)
		37,000	Eakin (1966)
		37,000	Harrill et al. (1988)
		37,000	LVVWD (2001)
		37,000	Scott et al. (1971)
		37,000	Thomas et al. (2001)
		37,700	Thomas and Mihevc (2007)
67	32,000	32,000	LVVWD (2001)
		32,000	Thomas et al. (2001)

Table H-1
Reported Volumes of Interbasin Flow in Study Area
(Page 6 of 7)

Location Index[a]	Interbasin Flow Range (afy)	Interbasin Flow (afy)	Sources
68	M to 41,804	M	Rush (1968)
		M	Scott et al. (1971)
		1,700	Thomas and Mihevc (2007)
		32,000	LVVWD (2001)
		32,000	Thomas et al. (2001)
		34,700	Eakin (1966)
		35,843 to 41,804	Kirk and Campana (1990)
69	5,300 to 7,000	5,300	Thomas and Mihevc (2007)
		7,000	Rush (1968)
		7,000	Harrill et al. (1988)
		7,000	Scott et al. (1971)
70	M to 41,000	M[c]	Rush (1968)
		M[c]	Harrill et al. (1988)
		6,000	Thomas et al. (2001)
		18,900	Thomas and Mihevc (2007)
		41,000	LVVWD (2001)
71, 73, 74	15,000 to 16,000	15,000	Thomas and Mihevc (2007)
		16,000	Thomas et al. (2001)
		16,000	LVVWD (2001)
72	?	?	Harrill et al. (1988)
75	5,000	5,000	Harrill et al. (1988)
76	1,100 to 49,000	1,100	Scott et al. (1971)
		11,100[d]	Rush (1968)
		15,300	Thomas and Mihevc (2007)
		26,000	Thomas et al. (2001)
		49,000[e]	LVVWD (2001)
77	?,M to 15,000	?	LVVWD (2001)
		M	Harrill et al. (1988)
		300	Thomas et al. (2001)
		400	Rush (1968)
		400	Scott et al. (1971)
		15,000	Thomas and Mihevc (2007)
78	? to 17,000	?	LVVWD (2001)
		800	Rush (1968)
		800	Scott et al. (1971)
		1,000	Harrill et al. (1988)
		15,100	Thomas and Mihevc (2007)
		17,000	Thomas et al. (2001)
79	M to 4,000	M	Scott et al. (1971)
		2,000	Thomas and Mihevc (2007)
		2,300	LVVWD (2001)
		4,000	Thomas et al. (2001)
80	1,378	1,378	San Juan et al. (2004)

Table H-1
Reported Volumes of Interbasin Flow in Study Area
(Page 7 of 7)

Location Index[a]	Interbasin Flow Range (afy)	Interbasin Flow (afy)	Sources
81	600 to 1,000	600	Thomas and Mihevc (2007)
		1,000	LVVWD (2001)
82	400 to 1,200	400	Rush (1968)
		1,200	Harrill et al. (1988)
83	M to 2,000	M	Scott et al. (1971)
		2,000	Thomas et al. (2001)
84	4,000	4,000	Kirk and Campana (1990)

[a]Location of interbasin flow is shown on Figure H-1 with arrows.
[b]The reported interbasin flow was evenly distributed among multiple flowpaths.
[c]This value doesn't include stream flow.
[d]This value includes 10,000 afy of stream flow that is considered as groundwater here (Rush, 1968).
[e]This value includes 1,000 afy outflow from Black Mountains Area to Lake Mead.
? = Flow volume not specified.
M = Minor quantity. An amount which is either less than 500 afy, or small in comparison to other quantities in the particular hydrologic area (Scott et al., 1971).
S = Some quantity. Sufficient information is not currently available to make an estimate (Scott et al., 1971).

4. Set up an Excel® file containing all data necessary to calculate fluxes in the Crystal Ball software.

5. Ran 10,000 Monte Carlo simulations using the Crystal Ball software.

H.1.3 Description of Input Data Preparation

Estimates of lateral interbasin flow were derived for all external boundaries, except Las Vegas Valley, using the available information. The required data consist of estimates of the probability distributions of the transmissivity, flow widths, and hydraulic gradients across the flow-boundary segment.

Probability distributions of transmissivities were derived from the hydraulic-property database described in Appendix C. Records in the database containing transmissivity values were extracted to form a data subset. If several records were available for a single location, they were reduced to one value by averaging. The reduced data set was then sorted by RMU, and the derived data were analyzed by RMU.

For RMUs with sufficient constant-rate pumping tests, records of other types of tests were removed from the data set. All records were kept for all other RMUs. Except for the carbonate aquifer, the remaining data sets were used for the statistical analyses. For the carbonate aquifers, low and high values were eliminated from the reduced data set prior to the analysis. Low transmissivity values represent matrix-only carbonate rocks, and high transmissivity values represent faults or highly fractured carbonate rocks. For RMUs with sufficient data records, the probability distributions were confirmed to be log-normal. The statistics, means, and standard deviations were as calculated. For other RMUs, the probability distributions were assumed to also be log-normal.

The flow widths across permeable segments of the model boundary were identified from a combination of information: (1) the map of permissible flow segments, (2) the regional

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potentiometric map (Prudic et al., 1995), and (3) the hydrogeology map including the locations of major structural features. The three maps were superposed, and the most probable flow width was identified and measured. The probability distribution was assumed to be normal with COV values ranging from 0.5 to 1.

Hydraulic gradients across permeable-segment boundaries were derived from a combination of water-level data and previous interpretations of the potentiometric surface. Potentiometric contours for the entire region (Prudic et al., 1995) were used to identify the approximate directions of groundwater flow. Water-level data were used to actually calculate the hydraulic gradients. To approximate the regional hydraulic gradient between basins, water levels from the central parts of the basins were used rather than water levels on the mountain blocks. Because of the scarcity of carbonate wells, water levels in the central parts of the basins were assumed to represent regional potentiometric levels, i.e., carbonate aquifer is connected to alluvial aquifers. Also, water levels from groups of wells rather than single-well measurements were preferred to capture the magnitude of the mean gradient. The probability distribution was assumed to be normal with COV values ranging between 0.5 and 1.

The input data are presented in Table H-2. The last column is not part of the input but provides a deterministic Darcy flux value of the flow rate across each boundary segment and each RMU, using the listed input data.

Table H-2
Input Data for Monte Carlo Simulations of Boundary Fluxes

Boundary Segment	HGU	Transmissivity (ft^2/day)		Hydraulic Gradient (ft/ft)		Flow Width (ft)		Flux (ft^3/day)
		Geometric Mean	STD	Mean	STD	Mean	STD	
Snake Valley to Tule Valley	LC3	6,000	10	0.0045	0.0034	65,617	49,213	1,772,029
Butte Valley South to Butte Valley North	UVF	3,500	10	0.0014	0.0010	19,685	14,764	93,763
	LVF	1,500	10	0.0014	0.0010	19,685	14,764	40,184
	UC	6,000	10	0.0014	0.0010	19,685	14,764	160,737
	UA	50	30	0.0014	0.0010	19,685	14,764	1,339
	LC3	6,000	10	0.0014	0.0010	19,685	14,764	160,737
Steptoe Valley to Goshute Valley	UVF	3,500	10	0.0025	0.0013	16,404	8,202	143,789
	LVF	1,500	10	0.0025	0.0013	16,404	8,202	61,624
	UC	6,000	10	0.0025	0.0013	16,404	8,202	246,495
	UA	50	30	0.0025	0.0013	16,404	8,202	2,054
	LC3	6,000	10	0.0025	0.0013	16,404	8,202	246,495
Tippett Valley to Antelope Valley	UVF	3,500	10	0.0028	0.0021	32,808	24,606	319,695
	LVF	1,500	10	0.0028	0.0021	32,808	24,606	137,012
	UC	6,000	10	0.0028	0.0021	32,808	24,606	548,049
	UA	50	30	0.0028	0.0021	32,808	24,606	4,567
	LC3	6,000	10	0.0028	0.0021	32,808	24,606	548,049
Snake Valley to Great Salt Lake Desert	UVF	3,500	10	0.0004	0.0004	262,467	262,467	346,228
	LVF	1,500	10	0.0004	0.0004	262,467	262,467	148,383
	LC3	6,000	10	0.0004	0.0004	262,467	262,467	593,534
Tikaboo Valley South to Coyote Springs Valley	LC2	6,000	10	0.0076	0.0038	12,467	6,234	570,147
Lower Moapa Valley to Lake Mead	UVF	3,500	10	0.0030	0.0015	39,370	19,685	413,386
	LVF	1,500	10	0.0030	0.0015	39,370	19,685	177,165
	Kps2	1	10	0.0030	0.0015	39,370	19,685	118
	LC3	6,000	10	0.0030	0.0015	39,370	19,685	708,661
Lower Moapa Valley to Colorado River (pre-Lake Mead)	UVF	3,500	10	0.0040	0.0020	39,370	19,685	551,181
	LVF	1,500	10	0.0040	0.0020	39,370	19,685	236,220
	Kps2	1	10	0.0040	0.0020	39,370	19,685	157
	LC3	6,000	10	0.0040	0.0020	39,370	19,685	944,882

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Appendix I

Flow System Budget Solutions

I.1.0 FLOW SYSTEM BUDGET SOLUTIONS

The groundwater-balance method was used to derive recharge efficiencies and was implemented using the Excel® Solver. The solver is designed to find optimal solutions to numerical problems such as the one at hand, in which the main variables requiring a solution are the recharge efficiencies for the flow systems in the study area. The solver finds an optimal value for a formula in one cell of the worksheet called the target cell. The solver works with a group of cells that are related, either directly or indirectly, to the formula in the target cell. Values in these cells are called parameters, which the solver adjusts to produce the desired result defined by the target-cell formula. Constraints can be added to restrict the values of the parameters the solver uses. Additional information on the Excel® Solver, including examples, can be found in the Excel® 2003 version help menu and/or the "Microsoft Excel® 2003 Bible" (Walkenbach, 2003).

To initialize and run the solver, the target cell, parameters, constraints, and initial conditions must first be defined. To do so, the necessary data were compiled and analyzed to estimate values for these inputs. This included compiling the following information and data:

- Precipitation station data and a spatial distribution for the area encompassing the study area
- Hydrologic data for the flow system to assist in defining constraints
- Geologic information and data to assist in identifying likely areas of interbasin flow
- Maps delineating groundwater discharge areas and ET classes
- ET rate data, PET data, and a PET distribution encompassing the groundwater discharge areas
- Estimates of boundary inflow and outflow
- Digital elevation model

This section presents details on the application of the Excel® Solver and solution process used to derive the groundwater budgets for each flow system in the study area. Also presented are the estimated recharge volumes and comparisons to those reported in the literature and the resulting detailed groundwater budgets.

I.1.1 Solver Application Process

The solver was used in conjunction with the PRISM precipitation grid (Section 6.0) and boundary flow estimates (Section 8.0) to calculate recharge efficiencies for 1-in. precipitation intervals (Section 9.0) and boundary fluxes from the flow systems. The derived recharge distribution, along with estimates of interbasin flow at selected locations, were used to construct groundwater budgets for individual basins within the flow systems. The data processing and analyses performed to estimate these efficiencies, including the solver setup, targets, parameters, and constraints, are described in the following sections.

I.1.1.1 Delineation of Areas of Potential Recharge

For the purpose of this study, areas of potential recharge are defined as areas where most of the in-place recharge occurs and mountain-front runoff is generated. This area of potential recharge is used to estimate the recharge distribution at the basin scale, not at the local scale. For example, the recharge that may result from infiltration of mountain-front runoff is not distributed to the actual areas where it may occur. For a given basin, potential recharge is assumed to occur in all areas of a given basin except (1) the valley floor, (2) groundwater discharge areas, and (3) areas where the precipitation is less than 8 in.

The valley floor was delineated for each basin of the study area using the USGS DEM (USGS, 2006) and was subsequently excluded as an area of potential recharge. Land-surface slopes were calculated using the DEM grid, and the relatively flat areas of each basin were identified and excluded if the slopes were less than 2 percent. Alluvial fans were not included in the delineation of the valley floor areas because they are typically composed of coarse-grained material that can accommodate recharge if the precipitation is significant (i.e., greater than 8 in.).

It was assumed that groundwater ET areas are not areas of potential recharge. This is consistent with the calculation of estimated groundwater ET where the precipitation is deducted from the total ET estimate. Removing the precipitation volume necessarily leads to the removal of any recharge that may occur there.

It was also assumed that a minimum of 8 in. of precipitation is necessary before groundwater recharge may occur. The first 8 in. of precipitation are assumed to satisfy the soil-moisture deficit and losses to the atmosphere (ET) (Anderson et al., 1992). This assumption is consistent with the Maxey-Eakin (1949) method, which assumes that recharge is zero below 8 in. of precipitation. Thus, areas receiving less than 8 in. of precipitation are not considered to be areas of potential recharge.

The resulting potential recharge areas are depicted in Plate 1. The union of the valley floors, groundwater discharge areas, and areas receiving less than 8 in. of precipitation are considered "areas of no recharge" only for the purpose of this report. As stated before, direct recharge from precipitation may actually occur in these areas, depending on local conditions.

I.1.1.2 Preparation of Precipitation Data

The PRISM precipitation distribution serves as the basis for the solver calculations and the derivation of the spatial distribution of recharge. The PRISM grid for the study area was contoured to generate 1-in. precipitation intervals starting from a minimum depth of 3 in. to the maximum depth occurring within the flow system. Next, the area corresponding to each interval was calculated, and then adjusted as necessary to exclude the areas of no recharge, as defined in the previous section. For each basin, the adjusted areas were then exported to Excel® to create a table containing the precipitation rate and corresponding area for each 1-in. interval within the basin. This table forms the basis of the calculations performed by the solver.

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I.1.1.3 Solver Target

In the solver, the target is represented by the estimated value of total groundwater ET for a flow system. The target cell contains a formula relating groundwater ET to the other components of the budget as follows:

$$ET_{gw} = R_T + Inflow - Outflow \quad \text{(Eq. I-1)}$$

where,

ET_{gw} = Total groundwater ET for the flow system (afy)
R_T = Total recharge for the flow system (afy)
$Inflow$ = Total groundwater inflow to the flow system (afy)
$Outflow$ = Total groundwater outflow from the flow system (afy)

I.1.1.4 Solver Parameters

Parameters represent the flow system variables that require a solution. For this analysis, the primary parameters are the recharge efficiencies and interbasin flow rates for selected basin boundaries of the flow system. The parameter solutions are determined through an optimization process in which the recharge efficiencies and boundary flows are adjusted within the predefined constraints, described in Section I.1.1.5, to ensure that the total recharge is equal to the sum of the total groundwater discharge and outflow, less the groundwater inflow as shown in Equation I-1 above.

Considering that the solution to the problem depends on many variables, but only a few of them are known within reasonable bounds of uncertainty, the solution is nonunique, and many possible representations exist. For example, the solver may identify solutions that are mathematically feasible but not reasonable given what is understood about the physical aspects of the flow system. It is, therefore, important to provide reasonable initial estimates for all parameters.

I.1.1.4.1 Recharge Efficiencies

Recharge efficiency, by definition, is the ratio of recharge to precipitation. For this analysis, recharge is expressed as a function of effective precipitation (Kumar and Seethapathi, 2002) as follows:

$$R = a(P-8)^b \quad \text{(Eq. I-2)}$$

where,

R = Recharge (in./yr)
a = Power function constant
b = Power function exponent
P = Precipitation (in./yr)
$P-8$ = Effective precipitation (in./yr)

For this analysis, it was assumed that precipitation contributes to recharge (effective precipitation), starting at 8 in./yr where the effective precipitation and recharge are assumed to be zero. The effective precipitation and recharge increases with increasing precipitation. This equation is also similar to that of Contor (2004) and Anderson et al. (1992), except these authors express recharge as a function of total precipitation rather than effective precipitation.

To calculate the recharge efficiencies for use in the solver, each side of Equation I-2 is divided by precipitation, P, to yield the following equation expressing recharge efficiency:

$$Eff = \frac{[a \times (P - 8)^b]}{P} \qquad \text{(Eq. I-3)}$$

where,

Eff = Recharge efficiency or R/P as a fraction
a = Power function constant
b = Power function exponent
P = Precipitation (in./yr)
$P - 8$ = Effective precipitation (in./yr)

Equation I-3 was used in the solver for direct calculation of the recharge efficiencies. The primary parameters are the coefficients of the power function (i.e., the constant a and the exponent b). Initial estimates for these two primary parameters were derived from a power function derived from the step-function defined by the standard Maxey-Eakin efficiencies. They are as follows:

- Power function constant: $a = 8.0 \times 10^{-5}$
- Power function exponent: $b = 3.62$

Details on how these initial estimates were derived using the Maxey-Eakin recharge efficiencies are provided in Appendix E of SNWA (2007).

I.1.1.4.2 Interbasin Flow Volumes

The interbasin flow volumes for each flow system are the secondary solver parameters. Initial estimates of the interbasin flow volumes for each flow system are presented in Section 8.0.

I.1.1.5 Solver Constraints

Constraints were placed on the coefficients of the power function, the maximum recharge efficiency, and the volumes of subsurface flow at the selected interbasin flow locations used as secondary parameters in the solver. The common constraints are as follows:

- Power function constant, a is positive.
- Power function exponent, b is positive.
- Maximum recharge efficiency is less than or equal to 0.63.

The constraint imposed on the recharge efficiency was derived from a literature review of maximum recharge efficiencies estimated for the region of the study area (Watson et al., 1976). The maximum reported value of 63 percent or 0.63 was selected as the constraint value.

I.1.2 Solution Process

The solution process includes two major steps: (1) the Excel® Solver was used to derive a recharge distribution, and (2) the resulting recharge distribution was used to derive basin budgets.

I.1.2.1 Derivation of Recharge Distribution

The solver was used to inversely solve for the recharge efficiencies and the selected underflow volumes using the target ET estimates, the parameters, and the constraints. Because there is more than one unknown parameter, the derived solution is not unique. To converge to a solution, the solver uses an iterative process and successive values of all parameters while seeking a solution. Values of the primary parameters and the power function coefficients, *a* and *b*, are used to calculate recharge for each 1-in. precipitation band. This recharge value is then divided by precipitation to obtain a recharge efficiency, which in turn, is used to calculate recharge volumes. The calculated recharge volumes and values of the secondary parameters are tested in the budget. Once the calculated recharge volumes yield a total groundwater ET value that matches the target value, a solution is reached. The final values of all parameters are part of the solution and are used to estimate the final recharge distribution.

I.1.2.2 Derivation of Basin Groundwater Budgets

The process of deriving a groundwater budget for each basin in a flow system is conducted in Excel®, but outside of the solver. The solver provides a recharge distribution for each basin. Assuming that each basin is under predevelopment conditions, a groundwater budget may be derived for each basin. The process starts from the most up-gradient basin of the flow system and ends at the most down-gradient basins. For each basin, any inflow to the basin is added to the estimate of basin recharge, and the basin's groundwater ET value is then subtracted. The remainder is the outflow to the next contiguous basin(s) located down-gradient. For basins having more than one outflow boundary, independent estimates of selected outflow boundaries were made.

I.1.3 Solver Input Information and Solutions

Summary tables of the information used for the four flow systems and the solver solution are provided in Tables I-1 through I-4. No separate solution was sought for the small portion of Las Vegas Valley located within the model area. Recharge for this area was calculated using the solution derived for the nearest flow system, namely the WRFS.

I.1.3.1 Recharge Solutions and Detailed Comparisons to Reported Values

The estimated recharge volumes and previously reported estimates are provided in Tables I-5 and I-6. Table I-5 contains estimates reported prior to 2004, and Table I-6 contains values reported starting in 2004. The annual recharge volume for the portion of Las Vegas Valley contained within the model area was calculated using the recharge efficiencies derived for the WRFS and is included in the groundwater budgets presented in the next section.

I.1.3.2 Groundwater Budgets

The detailed groundwater budgets derived using the Excel® Solver are presented in Table I-7. The portion of Las Vegas Valley contained within the model area was added to the budget. In this budget, the recharge was assumed to flow out to Three Lakes Valley. The groundwater budgets for the flow systems with solutions are shown on four separate maps depicting the regional flow patterns within each of the flow systems in the following order: GVFS, GSLDFS, MVFS, and WRFS (Figures I-1 through I-4). The regional direction of groundwater flow is represented by arrows on basin boundaries where interbasin flow was interpreted to occur.

Table I-1
GVFS: Solver Information

Target: Groundwater ET	113,373 afy
Parameters	*a*
	b
	Outflow through northern HA boundary of Steptoe Valley
	Outflow from Butte Valley South to Butte Valley North
Constraints	Total outflow: 3,000 to 18,000 afy
	Inflow from Butte Valley South to Steptoe Valley: ≥ 0 afy
	Outflow from northern Butte Valley South: 1,000 to 8,000 afy
	Outflow from northern Steptoe Valley: 2,000 to 10,000 afy
	$a \geq 0$
	$b \geq 0$
	a initial: 0.00008
	b initial: 3.62
	Maximum efficiency: ≤ 0.63
Solution: *a*	0.01670
Solution: *b*	2.2232
Solution: Outflow through northern HA boundary of Steptoe Valley	2,000 afy
Solution: Outflow from Butte Valley South to Butte Valley North	1,000 afy

Table I-2
GSLDFS: Solver Information

Target: Groundwater ET	209,642 afy
Parameters	*a*
	b
	Outflow through Confusion Range
	Outflow through northern Snake Valley
	Inflow to Spring Valley from Tippett Valley
Constraints	Outflow from Snake Valley to Tule Valley: 1,000 to 52,000 afy (this range was adjusted to 15,000 to 52,000 afy following preliminary testing)
	Outflow from northern Snake Valley: 1,000 to 30,000 afy
	Outflow to Tule Valley is 1.6 times that to the north as determined using the outflow means from the Monte Carlo analysis
	Outflow from Tippett Valley to north: 3,000 to 29,000 afy
	Inflow to Spring Valley from Tippett Valley: $\geq$ 0 afy
	Recharge of volcanic area in southern Hamlin: 23,921 afy
	$a \geq 0$
	$b \geq 0$
	a initial: 0.00008
	b initial: 3.62
	Maximum efficiency: $\leq$ 0.63
Solution: *a*	0.0151
Solution: *b*	2.2364
Solution: Outflow through Confusion Range	15,000 afy
Solution: Outflow through northern Snake Valley	9,375 afy
Solution: Inflow to Spring Valley from Tippett Valley	0 afy

Table I-3
MVFS: Solver Information

Target: Groundwater ET	54,228 afy
Parameters:	*a*
	b
Constraints	Total outflow: 2,400 to 13,000 afy
	$a \geq 0$
	$b \geq 0$
	a initial: 0.00008
	b initial: 3.62
	Maximum efficiency: ≤ 0.63
Solution: *a*	0.00008
Solution: *b*	4.1811

Table I-4
WRFS: Solver Information

Target: Groundwater ET	147,791 afy
Parameters	*a*
	b
	Total outflow
	Inflow from Tikaboo Valley to Coyote Spring Valley
	Outflow from Coyote Spring Valley to Hidden Valley, Garnet Valley, and California Wash
	Outflow from Coyote Spring Valley to Muddy River Springs Area
Constraints	Total outflow: 13,000 to 37,000 afy
	Outflow from Coyote Spring Valley to Hidden Valley, Garnet Valley, and California Wash: ≥ 2,000 afy
	Inflow to White River Valley from Cave Valley: 4,000 afy
	Outflow from White River Valley to Pahroc Valley: 0 to 40,000 afy
	Outflow from Pahroc Valley to Dry Lake Valley: 2,000 afy
	Inflow to Muddy River Springs Area from Coyote Spring Valley and Lower Meadow Valley Wash: ≥ 28,000 afy and ≤40,000 afy
	Inflow from Tikaboo Valley: 1,000 to 12,000 afy
	Inflow from Lower Meadow Valley Wash to Muddy River Springs Area: 1,346 afy
	Inflow from Lower Meadow Valley Wash to California Wash: 1,749 afy
	$a \geq 0$
	$b \geq 0$
	a initial: 0.00008
	b initial: 3.62
	Maximum efficiency: ≤ 0.63
Solution: *a*	0.00285
Solution: *b*	3.0173
Solution: Total Outflow	22,082 afy
Solution: Inflow from Tikaboo Valley	7,200 afy
Solution: Outflow from Coyote Spring Valley to Muddy River Springs Area	40,000 afy
Solution: Coyote Spring Valley to Hidden Valley, Garnet Valley and California Wash Inflow	16,002 afy

Table I-5
Comparison of Estimated Recharge Volumes to Reported Values Prior to 2004 in afy
(Page 1 of 2)

HA Number	HA Name	This Study	Reconnaissance Series and Scott et al. (1971)	Gates and Kruer (1981)	Frick (1985)	Carlton (1985)	Dettinger (1989)	Kirk and Campana (1990)	Brothers et al. (1993a and b; 1994; 1996)	Nichols (2000)	LVVWD (2001) and Thomas et al. (2001)
Goshute Valley Flow System											
178B	Butte Valley South	24,688	15,000	---	---	---	12,165	---	---	---	---
179	Steptoe Valley	91,685	85,000	---	98,900	---	---	---	---	131,469	---
	Total	**116,373**	**100,000**								
Great Salt Lake Desert Flow System											
184	Spring Valley	81,339	75,000	---	---	---	61,636	---	72,000	103,569	---
185	Tippett Valley	5,616	6,900	---	---	---	---	---	---	12,389	---
194	Pleasant Valley	5,388	---	---	---	---	---	---	---	---	---
195	Snake Valley	104,210	---	---	---	---	---	---	---	---	---
196	Hamlin Valley	41,358	---	---	---	---	---	---	---	---	---
254	Big Snake	150,956	100,000	100,000	---	104,000	---	---	110,000	---	---
	Total	**237,911**	**181,900**								
Meadow Valley Flow System											
183	Lake Valley	9,861	13,000	---	---	---	---	---	---	---	41,320
198	Dry Valley	1,953	1,300	---	---	---	---	---	---	---	4,237
199	Rose Valley	79	<100	---	---	---	---	---	---	---	352
200	Eagle Valley	1,465	1,100	---	---	---	---	---	---	---	2,349
201	Spring Valley	9,644	10,000	---	---	---	---	---	---	---	16,151
202	Patterson Valley	5,656	6,000	---	---	---	---	---	---	---	15,761
203	Panaca Valley	2,381	1,500	---	---	---	---	---	---	---	9,041
204	Clover Valley	15,110	1,700	---	---	---	---	---	---	---	10,557
205	Lower Meadow Valley Wash	8,078	1,300	---	---	---	---	---	---	---	22,823
	Total	**54,227**	**35,900**								**122,591**
White River Flow System											
171	Coal Valley	4,020	2,000	---	---	---	---	---	---	---	7,002

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Table I-5
Comparison of Estimated Recharge Volumes to Reported Values Prior to 2004 in afy
(Page 2 of 2)

HA Number	HA Name	This Study	Reconnaissance Series and Scott et al. (1971)	Gates and Kruer (1981)	Frick (1985)	Carlton (1985)	Dettinger (1989)	Kirk and Campana (1990)	Brothers et al. (1993a and b; 1994; 1996)	Nichols (2000)	LVVWD (2001) and Thomas et al. (2001)
White River Flow System (Continued)											
172	Garden Valley	25,292	10,000	---	---	---	---	10,994	---	---	19,153
174	Jakes Valley	12,658	17,000	---	---	---	---	17,999	---	38,203	24,194
175	Long Valley	20,496	10,300	---	---	---	---	5,011	---	47,740	31,112
180	Cave Valley	15,044	14,000	---	---	---	---	10,994	13,000	---	19,595
181	Dry Lake Valley	16,208	5,000	---	---	---	---	7,491	5,000	---	13,254
182	Delamar Valley	6,627	1,000	---	---	---	---	1,994	1,000	---	4,597
206	Kane Springs Valley	4,329	500	---	---	---	---	997	---	---	6,757
207	White River Valley	42,037	38,000	---	---	---	---	35,000	---	---	62,133
208	Pahroc Valley	4,705	2,200	---	---	---	---	1,994	---	---	7,545
209	Pahranagat Valley	5,726	1,800	---	---	---	---	1,508	---	---	7,407
210	Coyote Spring Valley	2,215	1,900	---	---	---	---	5,011	---	---	4,000
215	Black Mountains Area	0	<100	---	---	---	---	---	---	---	438
216	Garnet Valley	101	400	---	---	---	---	---	---	---	393
217	Hidden Valley	45	400	---	---	---	---	---	---	---	339
218	California Wash	0	<100	---	---	---	---	---	---	---	311
219	Muddy River Springs Area	41	<100	---	---	---	---	---	---	---	237
220	Lower Moapa Valley	35	<50	---	---	---	---	---	---	---	1,354
	Total	**159,579**	**104,500**								**197,227**
Las Vegas Flow System											
212	Las Vegas Valley (Partial)	2,843	---	---	---	---	---	---	---	---	---
	Total (Project Study Area)	**570,933**	---	---	---	---	---	---	---	---	---

Table I-6
Comparison of Estimated Recharge Volumes to Reported Values Starting in 2004 in afy
(Page 1 of 2)

HA Number	HA Name	This Study	Flint et al. (2004) BCM-Mean Year	Flint et al. (2004) BCM-Time Series	Epstein (2004) Maxey-Eakin Method Evaluation	Epstein (2004) Nichols Method Evaluation	Epstein (2004) Bootstrap Brute-Force Model	Epstein (2004) Numeric Maxey-Eakin Method	Epstein (2004) Numeric Nichols Method	SNWA (2006, 2007)	Welch et al. (2008)	Mizell et al. (2007)	Halford (2008)
Goshute Valley Flow System													
178B	Butte Valley South	24,688	22,240	18,284	30,360	34,310	28,535	20,758	55,029	---	35,345	33,000	22,369
179	Steptoe Valley	91,685	111,419	94,391	115,106	117,586	101,338	84,885	171,952	---	154,068	121,000	129,126
	Total	**116,373**	**133,659**	**112,675**	**145,466**	**151,896**	**129,873**	**105,643**	**226,981**	**---**	**189,413**	**154,000**	**151,495**
Great Salt Lake Desert Flow System													
184	Spring Valley	81,339	66,987	56,179	66,402	93,840	92,965	53,335	139,194	87,000	93,128	62,000	98,764
185	Tippett Valley	5,616	9,717	7,659	7,569	10,502	9,269	5,752	18,418	---	12,357	---	4,282
194	Pleasant Valley	5,388	---	---	5,833	7,721	2,931	4,267	10,756	---	---	---	5,016
195	Snake Valley	104,210	---	---	40,500	63,767	66,265	34,697	88,194	---	---	---	106,556
196	Hamlin Valley	41,358	---	---	8,773	28,294	18,547	6,451	39,322	---	---	---	50,269
254	Big Snake	150,956	92,728	81,955	55,106	99,782	87,743	45,415	138,272	---	111,337	37,000	161,841
	Total	**237,911**	**169,432**	**145,793**	**129,077**	**204,124**	**189,977**	**104,502**	**295,884**	**---**	**216,822**	**---**	**264,887**
Meadow Valley Flow System													
183	Lake Valley	9,861	14,718	12,353	16,831	44,694	23,740	10,875	62,123	---	13,092	34,000	20,686
198	Dry Valley	1,953	2,192	1,815	4,444	9,712	4,263	2,644	14,055	---	---	---	1,791
199	Rose Valley	79	48	43	69	1,006	380	98	1,541	---	---	---	85
200	Eagle Valley	1,465	890	999	1,822	5,327	1,960	1,144	7,509	---	---	---	1,300
201	Spring Valley	9,644	10,874	8,930	15,783	35,206	14,716	8,892	43,969	---	---	---	15,942
202	Patterson Valley	5,656	6,643	6,759	9,347	35,885	15,579	6,608	51,852	---	---	---	14,453
203	Panaca Valley	2,381	4,741	4,984	2,127	17,344	10,354	2,945	28,408	---	---	---	4,939
204	Clover Valley	15,110	16,274	14,389	3,750	35,336	14,071	3,528	46,946	---	---	---	5,714
205	Lower Meadow Valley Wash	8,078	11,683	20,092	5,047	26,854	17,864	6,779	44,841	---	---	---	4,120
	Total	**54,227**	**68,063**	**70,364**	**59,220**	**211,364**	**102,927**	**43,513**	**301,244**	**---**	**---**	**---**	**69,030**

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Table I-6
Comparison of Estimated Recharge Volumes to Reported Values Starting in 2004 in afy
(Page 2 of 2)

HA Number	HA Name	This Study	Flint et al. (2004) BCM-Mean Year	Flint et al. (2004) BCM-Time Series	Epstein (2004) Maxey-Eakin Method Evaluation	Epstein (2004) Nichols Method Evaluation	Epstein (2004) Bootstrap Brute-Force Model	Epstein (2004) Numeric Maxey-Eakin Method	Epstein (2004) Numeric Nichols Method	SNWA (2006, 2007)	Welch et al. (2008)	Mizell et al. (2007)	Halford (2008)
White River Flow System													
171	Coal Valley	4,020	3,839	3,110	5,104	4,446	7,789	4,683	12,107	3,857	---	---	2,095
172	Garden Valley	25,292	17,974	15,559	6,098	20,900	17,342	5,331	32,223	24,818	---	---	21,770
174	Jakes Valley	12,658	10,974	8,310	20,266	18,989	13,653	11,834	30,405	12,288	15,680	39,000	7,242
175	Long Valley	20,496	16,289	13,536	30,664	33,249	22,398	20,851	52,736	19,928	24,665	---	15,451
180	Cave Valley	15,044	10,264	9,380	21,838	32,507	15,166	13,592	45,913	14,659	10,859	33,000	8,964
181	Dry Lake Valley	16,208	10,627	11,298	9,159	28,559	20,187	8,947	50,389	15,667	---	---	12,470
182	Delamar Valley	6,627	7,764	6,404	3,119	12,930	10,248	3,567	21,442	6,401	---	---	4,186
206	Kane Springs Valley	4,329	5,421	6,328	460	9,680	6,184	1,429	13,864	4,189	---	---	2,305
207	White River Valley	42,037	34,925	30,759	46,671	53,286	42,392	35,507	89,570	41,065	35,243	59,000	35,436
208	Pahroc Valley	4,705	4,432	4,832	4,561	9,044	10,251	4,934	19,362	4,507	---	---	3,791
209	Pahranagat Valley	5,726	7,043	7,186	2,968	6,271	10,209	5,996	15,979	5,507	---	---	2,253
210	Coyote Spring Valley	2,215	5,184	5,951	535	3,892	5,815	3,077	8,331	2,128	---	---	1,369
215	Black Mountains Area	0	54	1,470	94	0	3,178	3,644	1,338	0	---	---	34
216	Garnet Valley	101	294	1,000	0	164	976	591	679	96	---	---	49
217	Hidden Valley	45	188	571	0	35	521	288	327	42	---	---	52
218	California Wash	0	23	652	0	0	1,738	1,467	732	0	---	---	8
219	Muddy River Springs Area	41	12	207	0	0	509	360	214	38	---	---	1
220	Lower Moapa Valley	35	0	147	0	49	1,454	1,027	778	33	---	---	24
	Total	**159,579**	**135,307**	**126,700**	**151,537**	**234,001**	**190,010**	**127,125**	**396,389**	**155,223**	**---**	**---**	**117,500**
Las Vegas Flow System													
212	Las Vegas Valley (Partial)	2,843	---	---	11,923	28,130	24,004	15,246	43,865	---	---	---	---
	Total (Project Study Area)	**570,933**	**506,461**	**455,532**	**497,223**	**829,515**	**636,791**	**396,029**	**1,264,363**	**---**	**---**	**---**	**602,912**

Table I-7
Detailed Groundwater Budgets Derived Using Excel® Solvers
(Page 1 of 2)

HA Number	HA Name	Recharge (afy)	Groundwater ET (afy)	Inflow (afy)	Inflow From	Outflow (afy)	Outflow To
178B	Butte Valley South	24,688	11,876	0	---	11,812	Steptoe Valley (HA 179)
						1,000	Butte Valley North (HA 178A)
179	Steptoe Valley	91,685	101,497	11,812	Butte Valley South (HA 178B)	2,000	Out of model boundary
---	Goshute Valley Flow System (partial)	116,373	113,373	0	---	3,000	Out of model boundary
184	Spring Valley	81,339	75,615	0	---	5,724	Hamlin Valley (HA 196)
185	Tippett Valley	5,616	1,742	0	---	3,874	Out of model boundary
194	Pleasant Valley	5,388	912	0	---	4,476	Snake (HA 195)
195	Snake Valley	104,210	129,041	49,226	Hamlin and Pleasant valleys (HAs 196 and 194)	24,395	Out of model boundary
196	Hamlin Valley	41,358	2,333	5,724	Spring Valley (HA 184)	44,749	Snake (HA 195)
254	Big Snake	150,956	132,285	5,724	Spring Valley (HA 184)	24,395	Out of model boundary
---	Great Salt Lake Desert Flow System (partial)	237,911	209,642	0	---	28,270	Out of model boundary
183	Lake Valley	9,861	6,134	0	---	3,727	Patterson Valley (HA 202)
198	Dry Valley	1,953	3,709	5,647	Rose Valley (HA 199)	3,891	Panaca Valley (HA 203)
199	Rose Valley	79	594	6,163	Eagle Valley (HA 200)	5,647	Dry Valley (HA 198)
200	Eagle Valley	1,465	1,034	5,731	Spring Valley (HA 201)	6,163	Rose Valley (HA 199)
201	Spring Valley	9,644	3,913	0	---	5,731	Eagle Valley (HA 200)
202	Patterson Valley	5,656	1,346	3,727	Lake Valley (HA 183)	8,037	Panaca Valley (HA 203)
203	Panaca Valley	2,381	18,895	21,198	Dry, Patterson, and Clover valleys (HAs 198, 202, and 204)	4,684	Lower Meadow Valley Wash (HA 205)
204	Clover Valley	15,110	5,840	0	---	9,270	Panaca Valley (HA 203)
205	Lower Meadow Valley Wash	8,078	9,668	4,684	Panaca Valley (HA 203)	3,095	Muddy River Springs Area and California Wash (HAs 219 and 218)
---	Meadow Valley Flow System	54,227	51,133	0	---	3,095	Out of MVFS
171	Coal Valley	4,020	0	23,596	Garden Valley (HA 172)	27,615	Pahroc Valley (HA 208)
172	Garden Valley	25,292	1,696	0	---	23,596	Coal Valley (HA 171)
174	Jakes Valley	12,658	858	19,263	Long Valley (HA 175)	31,063	White River Valley (HA 207)
175	Long Valley	20,496	1,233	0	---	19,263	Jakes Valley (HA 174)

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Table I-7
Detailed Groundwater Budgets Derived Using Excel® Solvers
(Page 2 of 2)

HA Number	HA Name	Recharge (afy)	Groundwater ET (afy)	Inflow (afy)	Inflow From	Outflow (afy)	Outflow To
180	Cave Valley	15,044	1,550	0	---	13,494	White River and Pahroc valleys (HAs 207 and 208)
181	Dry Lake Valley	16,208	0	2,000	Pahroc (HA 208)	18,208	Delamar Valley (HA 182)
182	Delamar Valley	6,627	0	18,208	Dry Lake Valley (HA 181)	24,835	Coyote Spring Valley (HA 210)
206	Kane Springs Valley	4,329	0	0	---	4,329	Coyote Spring Valley (HA 210)
207	White River Valley	42,037	76,701	35,063	Jakes and Cave valleys (HAs 174 and 180)	398	Pahroc Valley (HA 208)
208	Pahroc Valley	4,705	0	37,507	Coal, Cave and White River valleys (HAs 171, 180, and 207)	42,212	Dry Lake and Pahranagat valleys (HAs 181 and 209)
209	Pahranagat Valley	5,726	28,516	40,212	Pahroc (HA 208)	17,423	Coyote Spring Valley (HA 210)
210	Coyote Spring Valley	2,215	0	53,787	Delamar, Kane Springs, Pahranagat valleys (HAs 182, 206, and 209), and Tikaboo Valley South (HA 169B)	56,002	Muddy River Springs Area, Hidden and Garnet valleys and California Wash (HAs 219, 216, 217, and 218)
215	Black Mountains Area	0	1,432	2,000	California Wash (HA 218)	568	Out of model boundary
216	Garnet Valley	101	0	10,713	Hidden and Coyote Spring valleys (HAs 217 and 210)	10,814	California Wash (HA 218)
217	Hidden Valley (North)	45	0	5,334	Coyote Spring Valley (HA 210)	5,379	Garnet Valley (HA 216)
218	California Wash	0	4,505	53,295	Lower Meadow Valley Wash, Garnet Valley, and Muddy River Springs Area (HAs 205, 216, and 219)	48,790	Black Mountains Area (HA 215) and Lower Moapa Valley (HA 220)
219	Muddy River Springs Area	41	5,989	41,346	Lower Meadow Valley Wash and Coyote Spring Valley (HAs 205 and 210)	35,398	California Wash (HA 218)
220	Lower Moapa Valley	35	25,311	46,790	California Wash (HA 218)	21,515	Out of model boundary
---	White River Flow System	159,579	147,791	10,295	Lower Meadow Valley Wash (HA 205) and Tikaboo Valley South (HA 169B)	22,083	Out of model boundary
---	**Total Four Flow Systems**	**568,090**	**521,940**	**7,200**	**Tikaboo Valley South (HA 169B)**	**53,352**	**Out of model boundary**
---	**Las Vegas (Partial)**	**2,843**	**0**	**0**	**---**	**2,843**	**Three Lakes Valley**
---	**Project Model**	**570,933**	**521,940**	**7,200**	**Tikaboo Valley South (HA 169B)**	**56,196**	**Out of model boundary**

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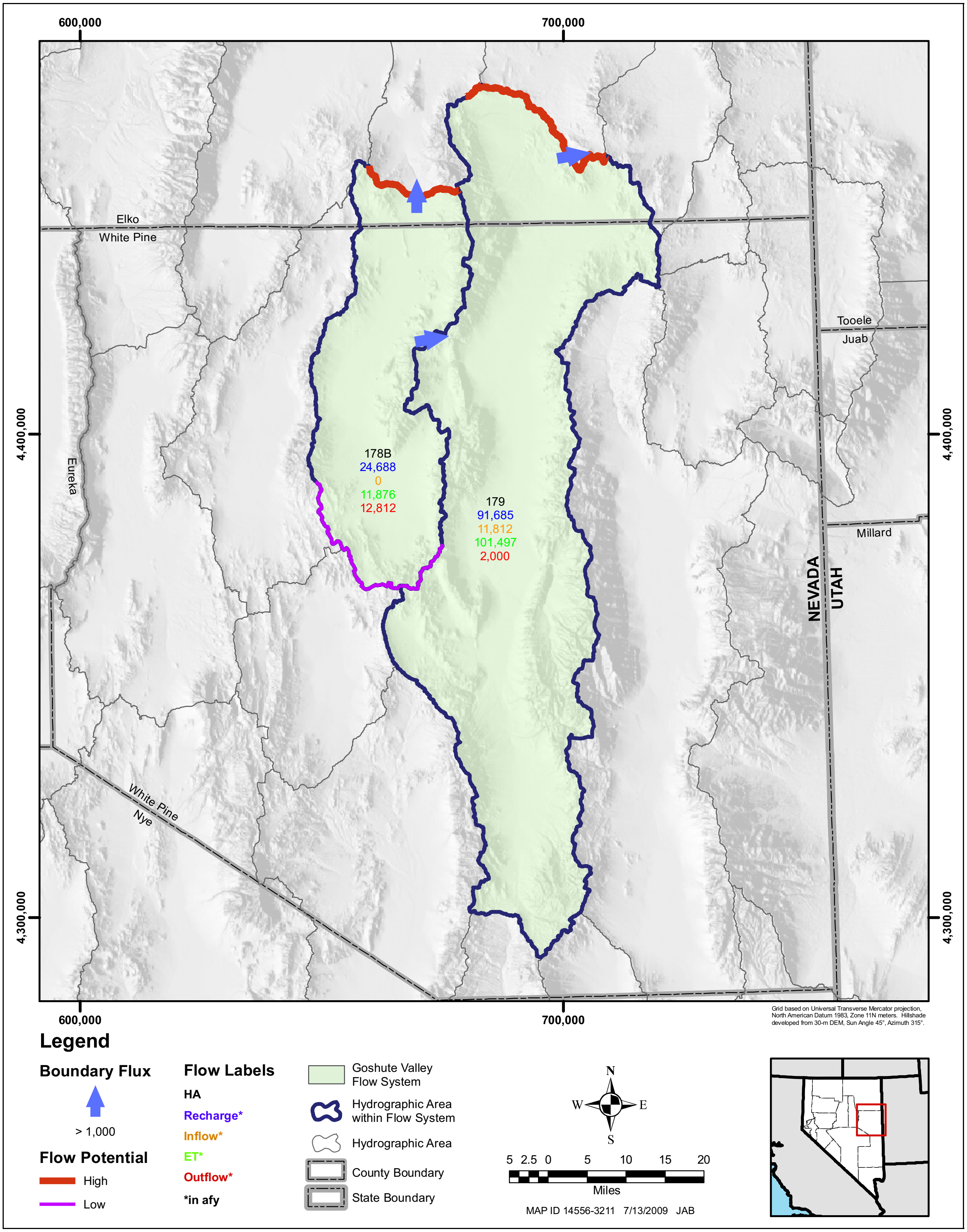

Figure I-1
Regional Groundwater Flow in Goshute Valley Flow System

SE ROA 50737

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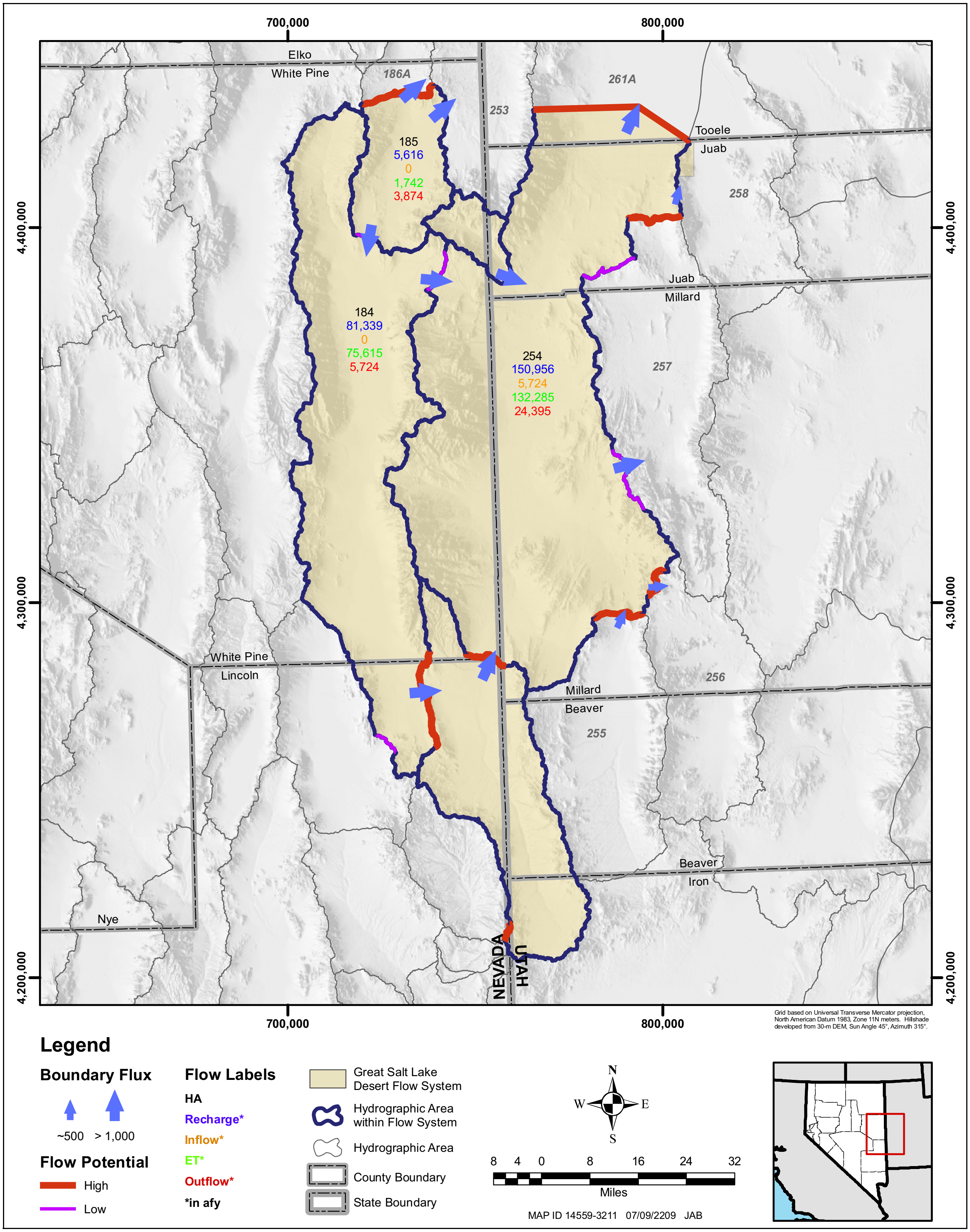

Figure I-2
Regional Groundwater Flow in the Great Salt Lake Desert Flow System

SE ROA 50738

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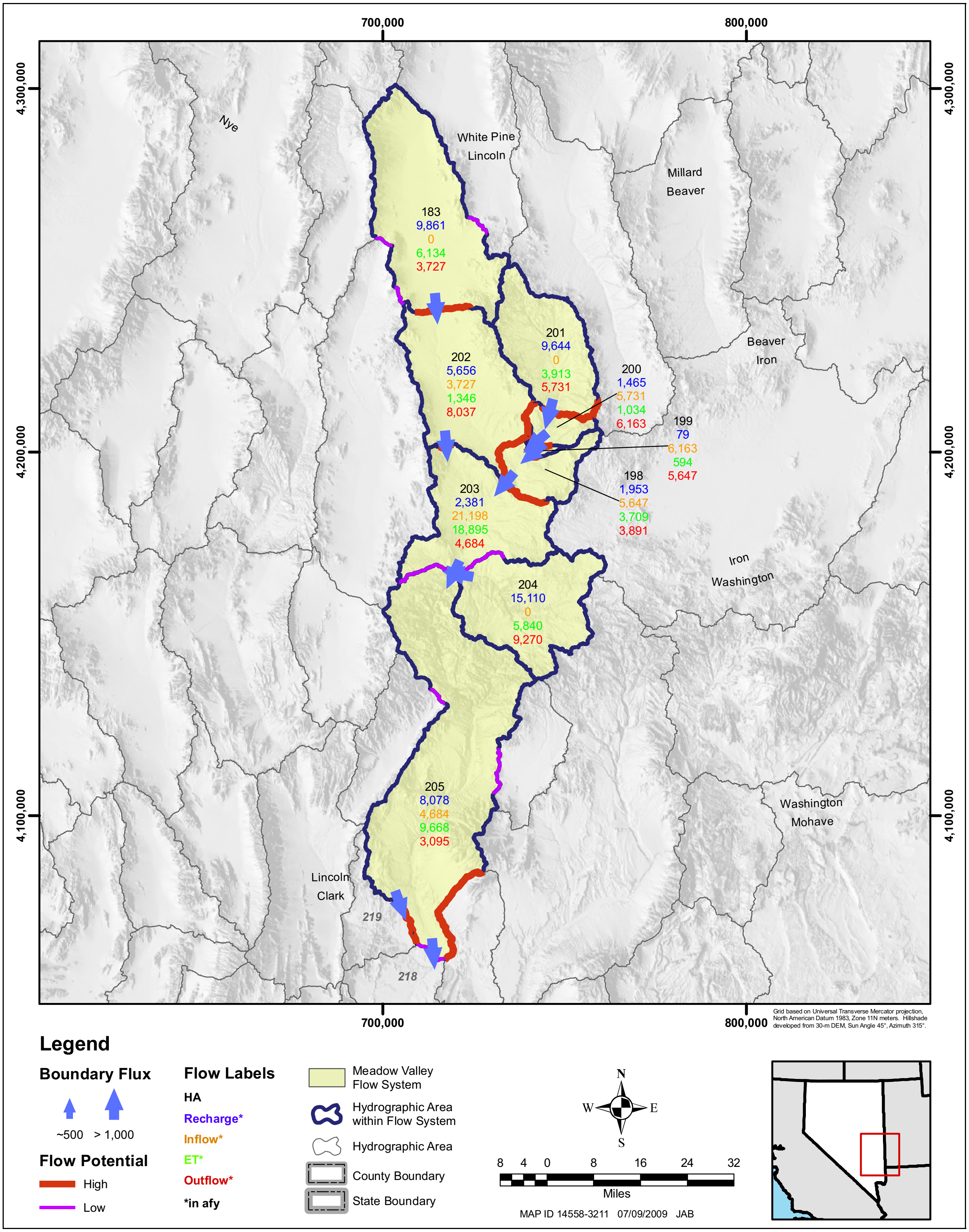

Figure I-3
Regional Groundwater Flow in Meadow Valley Flow System

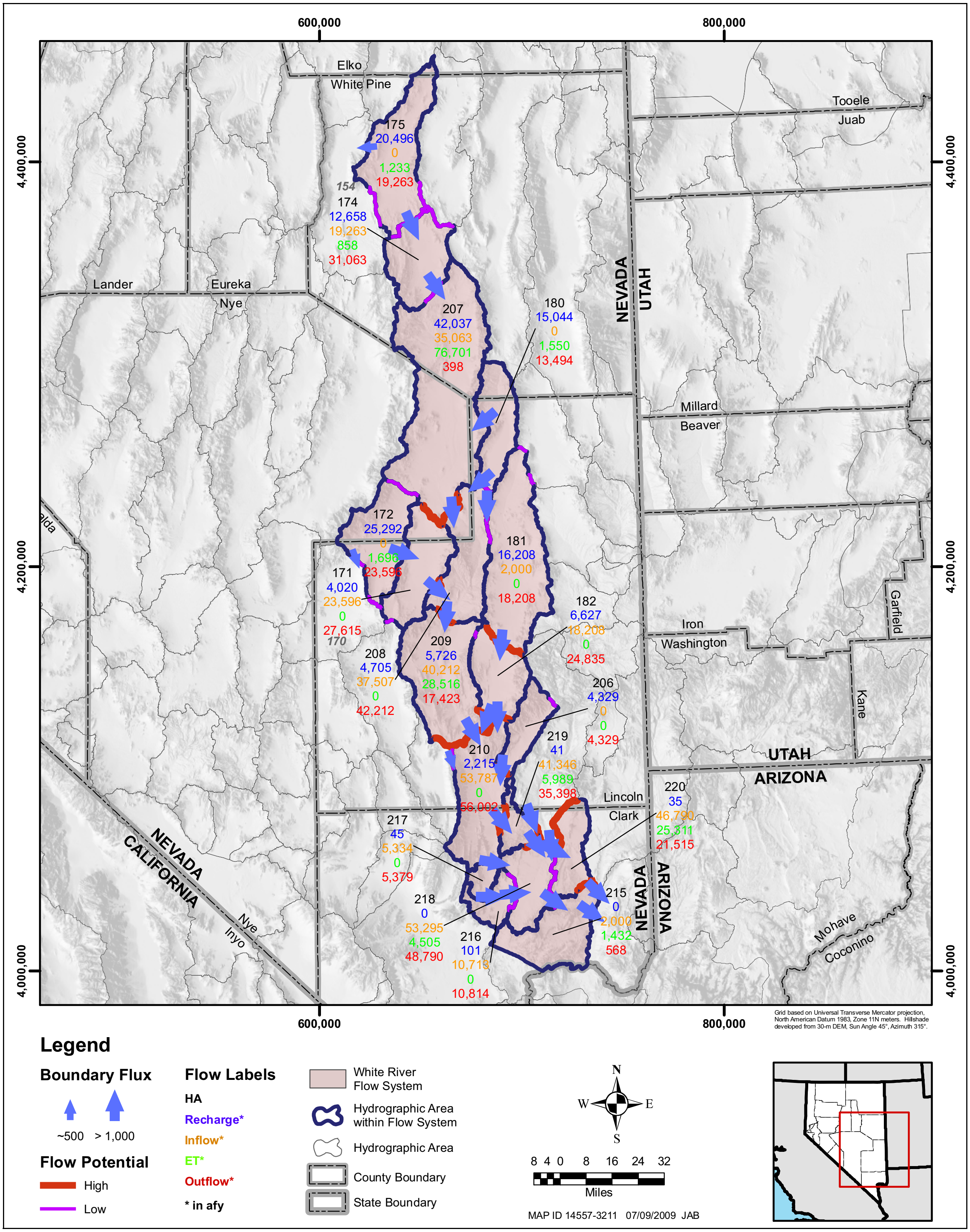

Figure I-4
Regional Groundwater Flow in White River Flow System

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Plates

PLATE 1. MAJOR FEATURES OF THE CONCEPTUAL GROUNDWATER FLOW SYSTEM

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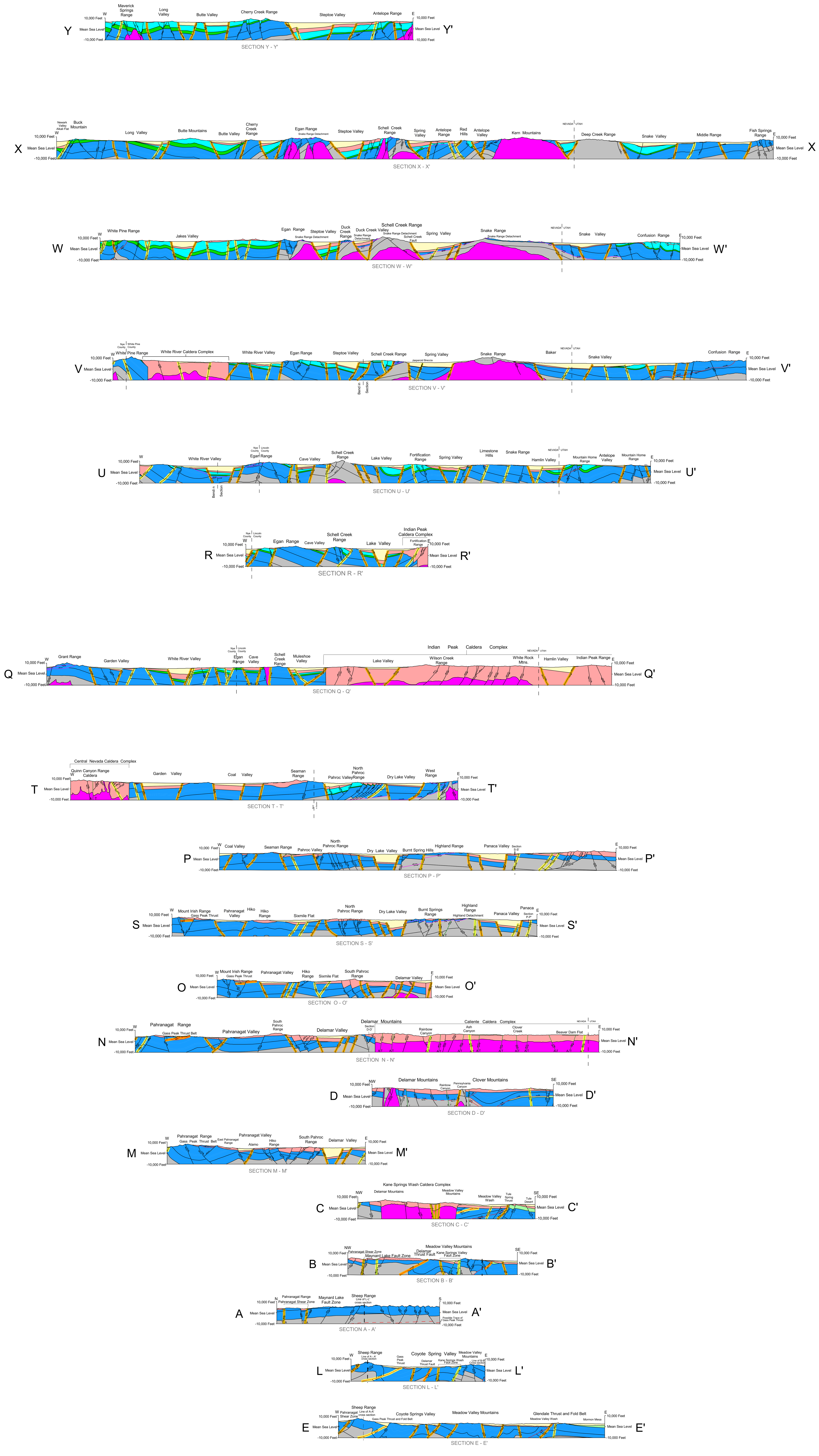
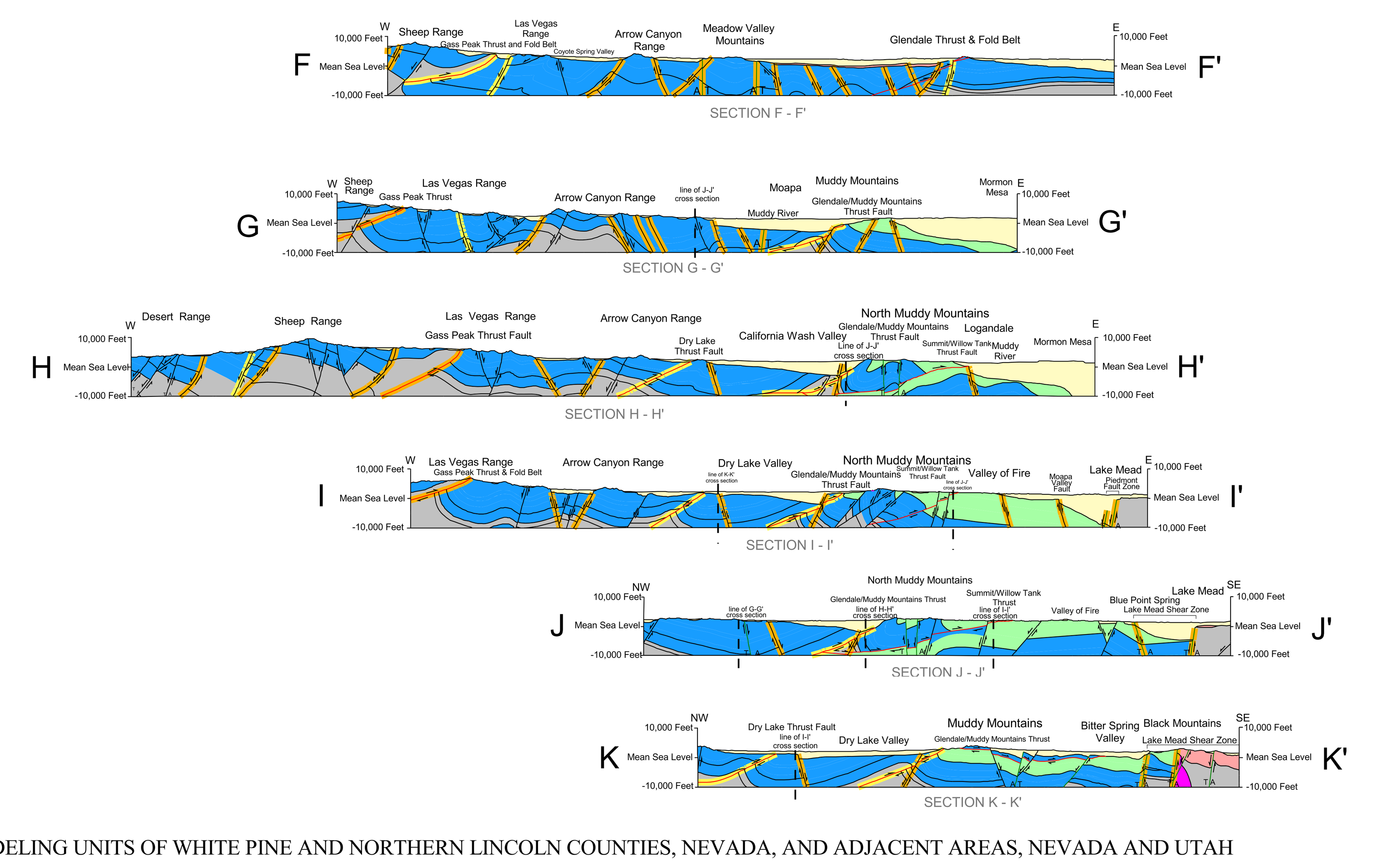
PLATE 2. SURFICIAL REGIONAL MODELING UNITS OF WHITE PINE AND NORTHERN LINCOLN COUNTIES, NEVADA, AND ADJACENT AREAS, NEVADA, UTAH, AND ARIZONA





Legend

Regional Modeling Units

- UVF - Upper Valley Fill (QTs, QTb)*
- LVF - Lower Valley Fill (Tv, Tos)*
- PLUT - Plutonic Rock (TJi)*
- Kps - Cretaceous Plateau Sediments (KTRs)*
- UC - Upper Carbonate Aquifer (PIPc)*
- UA - Upper Aquitard (Ms)*
- LC - Lower Carbonate Aquifer (MOc, €c)*
- BASE - Basement Rock (€p€s, p€m)*

Faults

- Normal Fault
- Thrust Fault
- Strike-slip Fault
- Detachment Fault
- Structurally Significant Fault
- Less Structurally Significant Fault

SCALE 1:500,000
NO VERTICAL EXAGGERATION

* Corresponding hydrogeologic units
Note: See Plate 2 for cross-section locations.
Many small faults and thin basin-fill sediments are not illustrated on cross sections.

PLATE 3. CROSS SECTIONS SHOWING REGIONAL MODELING UNITS OF WHITE PINE AND NORTHERN LINCOLN COUNTIES, NEVADA, AND ADJACENT AREAS, NEVADA AND UTAH

Southern Nevada Water Authority

SE ROA 50748

MAP ID 14950-3211 12/09/2008 JMB/JBB

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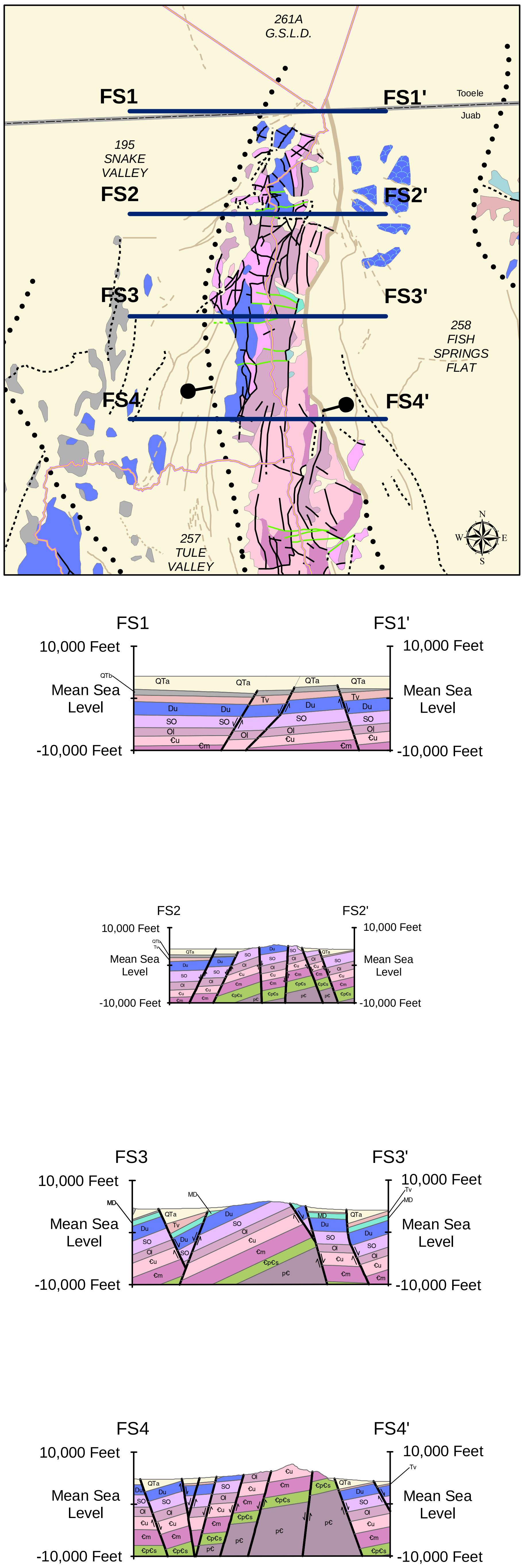
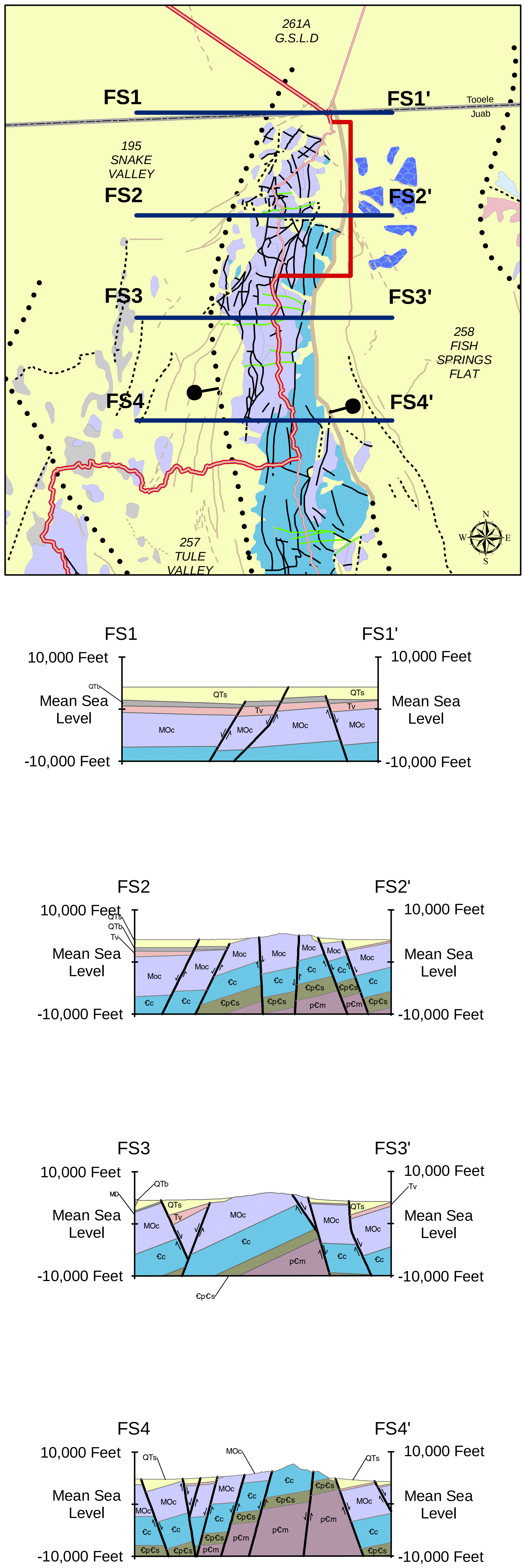
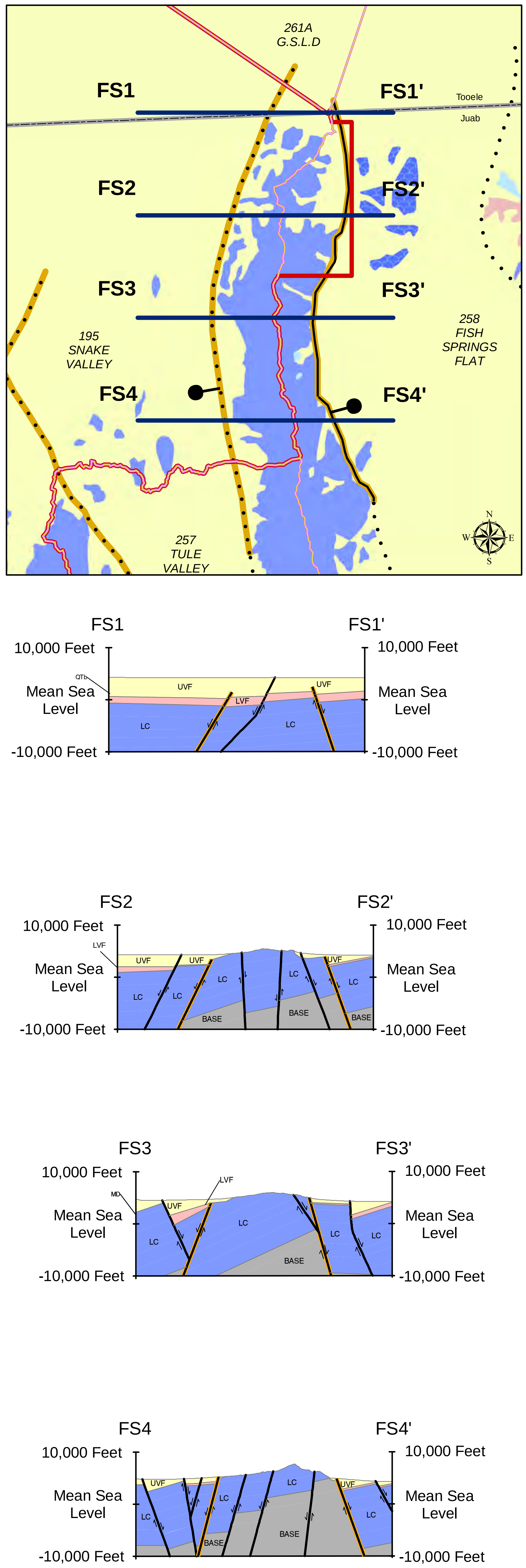
Geologic Units



Hydrogeologic Units



Regional Modeling Units



Geologic Units

- QTa — Quaternary and Tertiary basin-fill deposits
- QTb — Quaternary and Tertiary thin basalt flows and cinder cones
- Tv — Tertiary volcanic rocks
- Tt2 — Tertiary poorly-densely welded ash-flow tuff and interbedded airfall tuff
- IP — Pennsylvanian Ely limestone
- MD — Lower Mississippian to upper Devonian limestone and shale
- Du — Devonian carbonate sedimentary rocks, undivided
- SO — Silurian and Ordivician sedimentary rocks, undivided
- SOu — Silurian and Upper Ordovician dolomite, undivided
- Ol — Middle and Lower Ordovician, mostly eureka Quartzite and Pogonip Goup
- Ꞓu — Lower Ordovician? And Upper Cambrian limestone and shale, undivided
- Ꞓm — Upper and Middle Cambrian limestone
- ꞒpꞒs — Middle Cambrian to late Proterozoic sedimentary rocks
- pꞒ — Late to Early Proterozoic metamorphosed and crystalline Precambrian basement rocks

Hydrogeologic Units

- QTs — Quaternary-Tertiary sediments
- QTb — Quaternary-Tertiary basalts
- Tv — Tertiary volcanic rocks
- PIPc — Permian-Pennsylvanian carbonate rocks
- MOc — Mississippian-Ordovician carbonate rocks
- Ꞓc — Cambrian carbonate rocks
- ꞒpꞒs — Cambrian-Precambrian siliciclastic rocks
- pꞒm — Precambrian metamorphic rocks

Regional Modeling Units

(shown with corresponding Hydrogeologic Units)

- UVF — Upper Valley Fill (QTs, QTb)
- LVF — Lower Valley Fill (Tv, Tos)
- UC — Upper Carbonate Aquifer (PIPc)
- LC — Lower Carbonate Aquifer (MOc, Ꞓc)
- BASE — Basement Rock (ꞒpꞒs, pꞒm)
- Open Water

Regional Faults

Normal Fault

Solid where known; dashed where inferred; dotted where concealed. Bar and ball are on downthrown side of fault. Highlighted where structurally significant (RMU only).

Quaternary Normal Fault

Solid where known; dashed where inferred; dotted where concealed.

Subsidiary Faults

Normal Fault

Solid where known; dashed where inferred; dotted where concealed.

Strike-Slip and Oblique-Slip Fault

Solid where known; dashed where inferred; dotted where concealed.

Quaternary Normal Fault

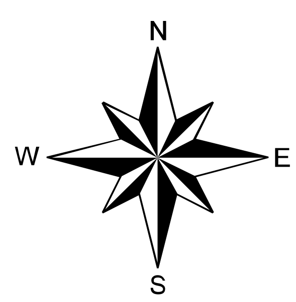
Solid where known; dashed where inferred; dotted where concealed.

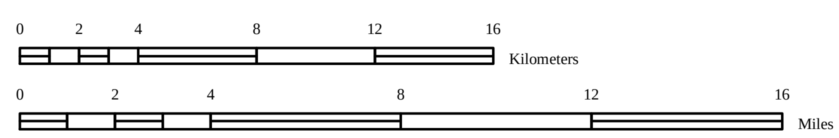
Hydrographic Basin

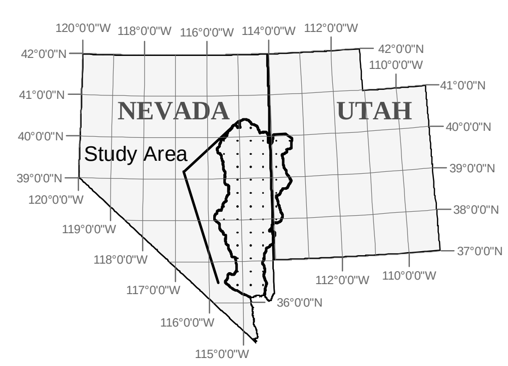
Regional Model Boundary

County Boundary

Cross Section







MAP ID 15080-3211 12/09/2008 CAC/JBB

PLATE 4. SURFACE GEOLOGY, HYDROGEOLOGY, AND REGIONAL MODELING UNITS AND ASSOCIATED CROSS SECTIONS, FISH SPRINGS RANGE, JUAB COUNTY, UTAH

SE ROA 50749

JA_16150