APPENDIX A
GEOCHEMICAL AND ISOTOPIC CONSTRAINTS ON GROUNDWATER FLOW

A1. PURPOSE

The purpose of the work described in this appendix is to provide an analysis of groundwater recharge rates, flow directions and velocities, and mixing proportions of water from different source areas based on groundwater geochemical and isotopic data. The analysis of hydrochemical and isotopic data is intended to provide a basis for evaluating the hydrologic system at Yucca Mountain independently of evaluations that are based purely on hydraulic arguments. In this way, this appendix is intended as an independent corroboration of the saturated zone flow model presented in the main text of this report.

This appendix is based on the previous revision of this report (BSC 2004 [DIRS 170037]) in that many of the same analyses and techniques were used to estimate generalized flow directions from hydrochemical data. However, several updates are made to the analyses including:

1. Analyze new data to determine chemical reactions in the groundwater system, the evolution of groundwater as it moves from upgradient source areas to downgradient areas of potential groundwater withdrawal, groundwater mixing relationships, and chemical and isotopic distributions of strontium and uranium.

2. Correct groundwater ^{14}C ages for water/rock interactions.

3. Provide an analysis of groundwater recharge rates, flow directions and velocities, and mixing proportions of water from different source areas.

4. Compare patterns of groundwater movement produced by the SZ flow model with flow patterns inferred from hydrochemical and isotopic data.

Information supporting the resolution of several technical issues related to the saturated zone was also developed in this appendix:

1. Groundwater residence times based on ^{14}C

2. Flow path lengths in alluvium and tuff.

Addressing these and related issues will help in determining the performance of the saturated zone as a natural barrier to radionuclide migration by providing validation information for the SZ site-scale flow model.

The physical and hydrochemical parameters summarized in this appendix are important controls on the transport of dissolved and colloidal species in the saturated zone. This information can be used in the SZ site-scale flow and SZ transport models to simulate the transport of radionuclides as breakthrough curves. These breakthrough curves are then used as input in the TSPA-LA calculations.

This appendix was left largely untouched from the previous revision of this report (BSC 2004 [DIRS 170037]) and that it is presented here to provide historical context. Appendix B represents analyses of the latest geochemical data, none of which contradict the findings in this appendix.

A2. NOT USED

A3. SOFTWARE CODES

Software uses in this appendix are considered a corroboration activity that provides indirect support for validation of the SZ site-scale flow model as described in Section 7. The computer code, PHREEQC V2.3 (STN: 10068-2.3-00; [DIRS 155323]), used directly in this appendix, is public-domain geochemical software whose description is summarized in Table A3-1. The software was obtained from Software Configuration Management (SCM) and is appropriate for the license application. The code was used only within its range of validation as required by LP-SI.11Q-BSC, *Software Management*. Input files for this appendix are identified in Section A4; technical data numbers of the associated modeling results are listed in Section A7.2.

Table A3-1. Software Used in Support of this Scientific Analysis

Software Name and Version (V)	Software Tracking Number (STN)	Description/ Section Where Used	Computer and Platform Identification	Reference	Date Baselined
PHREEQC, V2.3	10068-2.3-00	Used to speciate elements in groundwater, calculate mineral saturation indices, and calculate mixing fractions and chemical reactions required to produce observed groundwater compositions. PHREEQC is a C-language program developed by the U.S. Geological Survey (USGS). Used in Sections A6.3.5 and A6.3.6.6.2, A6.3.8 and A6.3.9	Windows 95/98/NT; Compaq professional workstation AP400	[DIRS 155323]	03/29/01
FEHM V2.20*	10086-2.20-00	Flow modeling/flow and transport modeling used to illustrate groundwater flow paths. Used in Section A6.3.10.	Sun workstation SunOS v. 5.7-5.8	[DIRS 161725]	01/28/03
reformat_sz V1.0	11079-1.0-00	Used to reformat hydrochemical and isotopic data originally in a text format for input into PHREEQC. Written in Fortran 77. Used in Sections A6.3.5, A6.3.6.6.2, and A6.3.8.	Solaris 2.7, 2.8	[DIRS 164652]	05/21/03
maketrac V1.1	11078-1.1-00	Used to create *trac* macro for FEHM. Used in Section A6.3.10.	Sun workstation SunOS v. 5.7-5.8	[DIRS 164653]	07/02/03
fehm2tec V1.0	11092-1.0-00	Used to reformat FEHM output for plotting with TECPLOT, V 8.0. Used in Section A6.3.10.	Sun workstation Solaris 2.7, 2.8	[DIRS 164654]	06/26/03

*NOTE: FEHM v2.20 was used throughout Appendix A because the analyses documented in this Appendix were not updated for revision 03 of this modeling report. Reference to FEHM v2.20 and its modeling results as documented in revision 2 of the SZ site-scale flow model remain in this document for historical accuracy.

The range of hydrochemical and isotopic data used in PHREEQC V2.3 (STN: 10068-2.3-00; [DIRS 155323]) is indicated by Tables A6-1 and A6-2. The results of all calculations using PHREEQC were checked with order-of-magnitude estimations.

FEHM V2.20 (STN: 10086-2.20-00; [DIRS 161725]) was used to illustrate groundwater flow paths predicted by the SZ flow model (DTN: LA0304TM831231.002 [DIRS 163788]), as documented in *Saturated Zone Site-Scale Flow Model* (BSC 2004 [DIRS 170037]).. The reformat_sz was used to reformat hydrochemical and isotopic data for input into PHREEQC; output from reformat_sz V1.0 (STN: 11079-1.0-00; [DIRS 164652]) was verified by visual inspection. Maketrac V1.1 (STN: 11078-1.1-00; [DIRS 164653]) was used to help create the trac macro for FEHM, and fehm2tec V1.0 (STN: 11092-1.0-00; [DIRS 164654]) was used to reformat FEHM output for plotting with TECPLOT. The output from the maketrac and fehm2tec codes was verified by visual inspection of the FEHM results.

Software use documented in historical versions of Appendix A and listed above in Table A3-1 is not listed in Table 3-1 because it is indirect-use software for the hydrochemistry analysis to conduct a corroboration activity and provides only validation support to the SZ site-scale flow model.

A4. INPUTS

This appendix summarizes hydrochemistry data to ultimately derive hydrochemically inferred flow pathways. The data evaluations, including the derived flow pathways, are used to corroborate information put forth in the main body of this report. As such, this appendix does not require direct inputs nor does it produce qualified technical outputs. Output developed within this appendix is considered unqualified intermediary output.

Input data used in this appendix come from several sources, as summarized in Table A4-1 and Table A4-2. Table A4-3 lists the types of chemical and isotopic groundwater data presented by the sources in Table A4-1 and A4-2, including local data for the Yucca Mountain area and regional data for the Death Valley flow system and Nevada Test Site (NTS). The input data referenced in Tables A4-1, A4-2 and Table A4-3 represent geochemical and isotopic characteristics of perched water and groundwater near Yucca Mountain and hence are appropriate for the intended use. Data from the Death Valley flow system immediately surrounding Yucca Mountain are also presented to provide evidence for potential sources of groundwater found near Yucca Mountain and place the Yucca Mountain groundwater system within a regional perspective. The data presented for the area around Yucca Mountain within the SZ site-scale flow model domain (Figure A6-1) include representative historical data sets collected in the 1960s through the 1990s, as well as more recent data from newly drilled wells. In the immediate Yucca Mountain area, nearly all data collected since Yucca Mountain came under consideration as a repository were evaluated. Data from the outlying areas were selected to provide more complete geographic coverage but are not nearly as comprehensive as the data sets in the Yucca Mountain area. When both new data (1990s and later) and historical data sets were available in an area, emphasis was generally given to the newer data sets because they were typically more comprehensive in terms of the suite of chemicals and isotopes that were analyzed. This emphasis was especially true for the areas north of Yucca Mountain in the Timber Mountain, Beatty Wash, Fortymile Canyon and Oasis Valley areas. In the west-central Amargosa Desert, the data represent a blend of historic and recently collected data because of uncertainty in the effects of recent groundwater development on groundwater compositions. Elsewhere (for example, in Amargosa Flats), historical data sets were used where they provided the only representative hydrochemical data for an area.

Data contained in the DTNs and other sources listed in Tables A4-1, A4-2 and A4-3 are summarized for each sample/well location in Section A6.3 (Tables A6-1 and A6-2) where areal distributions and scatterplots of the hydrochemical and isotopic data are discussed and portrayed on figures. Where multiple sets of data were available for a location/sample, these data were averaged to derive the values shown in those tables, and it is these compiled values that are plotted in the figures of Section A6.3. Groundwater samples taken from different depth intervals in the same well were evaluated to examine the trends of groundwater composition with depth in the well (see Section A6.3.3). Groundwater sample depths and information on the geologic units present in the sampled interval are given in Table A4-3 to aid in understanding the causes of similarities or differences in groundwater compositions from particular geographic areas. Tables A4-1 to A4-3 provide the DTN links back to the original data used to generate the compiled and plotted values listed and shown in Section A6.

Table A4-1. Sources of Data

DTN Description	DTN	Tables Used[2]
Chemical and isotopic data from borehole TW-5	MO0007GNDWTRIS.004 [DIRS 151494] [1]	S00368_001
	MO0007MAJIONPH.002 [DIRS 151507] [1]	S00352_001
Chemical data from the Nye County EWDP Wells in Amargosa Valley, Nevada, collected between 12/11/98 and 11/15/99.	MO0007MAJIONPH.015 [DIRS 151532] [1]	S00365_001
Chemical data from borehole NDOT collected 5/17/95	MO0007MAJIONPH.009 [DIRS 151522] [1]	S00359_001
Chemical and isotopic data from boreholes WT-7, WT-10, WT#12, WT#14, and WT#15	MO0007GNDWTRIS.006 [DIRS 151496] [1]	S00370_001
	MO0008MAJIONPH.017 [DIRS 151534] [1]	S00383_001
Stable isotope ratios and radiocarbon data for WT#12, WT#14, and WT#15	MO0007GNDWTRIS.007 [DIRS 151497] [1]	S00371_001
Chemical and isotopic data from test well UE-25 p#1, Yucca Mountain area, Nye County, Nevada	MO0007GNDWTRIS.008 [DIRS 151508] [1]	S00372_001
	MO0007MAJIONPH.010 [DIRS 151523] [1]	S00360_001
Chemical and isotopic data for groundwater in the Yucca Mountain area, Nevada 1971 to 1984	MO0007GNDWTRIS.009 [DIRS 151509] [1]	S00373_001
	MO0007MAJIONPH.011 [DIRS 151524] [1]	S00361_001
	MO0007GNDWTRIS.010 [DIRS 151500] [1]	S00374_001
Chemical composition of groundwater from ONC#1	MO0007MAJIONPH.004 [DIRS 151516] [1]	S00354_001
Chemical and isotopic data from perched groundwater at selected YMP boreholes	MO0007MAJIONPH.016 [DIRS 151533]	S00378_001
	MO0007GNDWTRIS.013 [DIRS 151504] [1]	S00377_001
Chemical analyses of water from selected wells and springs in the Yucca Mountain area, Nevada, and southeastern California	MO0007MAJIONPH.012 [DIRS 151529] [1]	S00362_001
Chemical composition of groundwater in the Yucca Mountain area	MO0007MAJIONPH.013 [DIRS 151530] [1]	S00363_001
Chemical and isotopic data for groundwater in the west-central Amargosa Desert, Nevada	MO0007GNDWTRIS.011 [DIRS 151501] [1]	S00375_001
	MO0007MAJIONPH.014 [DIRS 151531] [1]	S00364_001
Selected groundwater data for Yucca Mountain region, southern Nevada, through December 1992	MO0007GNDWTRIS.005 [DIRS 151495] [1]	S00369_001
	MO0007MAJIONPH.008 [DIRS 151521] [1]	S00358_001
Hydrochemical database for the Death Valley Region	MO0007MAJIONPH.006 [DIRS 151518] [1]	S00356_001
Chemical and isotopic data for groundwater samples collected at boreholes USW UZ-14, UE-25 WT#3, and USW WT-17	MO0007GNDWTRIS.003 [DIRS 151493] [1]	S00367_001
	MO0007MAJIONPH.005 [DIRS 151517] [1]	S00355_001
Chemical composition of groundwater from UZ#16	MO0007MAJIONPH.007 [DIRS 151519] [1]	S00357_001
Chemical and isotopic data for borehole USW G-2	MO0007GNDWTRIS.002 [DIRS 151492] [1]	S00366_001
	MO0007MAJIONPH.003 [DIRS 151513] [1]	S00353_001
Chemical and isotopic data from the CIND-R-LITE well samples collected on 5/17/95 and 9/6/95	GS000700012847.001 [DIRS 150842] [1]	S00446_001

Table A4-1. Sources of Data (Continued)

DTN Description	DTN[1]	Tables Used[2]
Field, chemical, and isotopic data describing water samples collected in Death Valley National Monument and at various boreholes in and around Yucca Mountain, Nevada, between 1992 and 1995	GS950808312322.001 [DIRS 148114] [1]	S96068_001 to S96068_003, S96068_010, S96068_011, S96068_015 to S96068_018, S96068_032, S96068_036 to S96068_040, S96068_042, S96068_043
$\delta^{18}O$ and δD stable isotope analyses of borehole waters from GEXA Well 4 and VH-2	GS970708312323.001 [DIRS 145405] [1]	S97550_001 S97550_002
Uranium concentrations and $^{234}U/^{238}U$ ratios from spring, well, runoff, and rainwater collected from the NTS and Death Valley vicinities and analyzed between 01/15/98 and 08/15/98	GS980908312322.009 [DIRS 118977] [1]	S99222_001
Water chemistry and sample documentation for two samples from Amargosa Valley (formerly Lathrop Wells) cone and USW VH-2	GS930108315213.002 [DIRS 148109] [1]	S98045_002 to S98045_010, S98045_023, S98045_029
Uranium isotopic analyses of groundwater from SW Nevada–SE California	GS930108315213.004 [DIRS 145525] [1]	S96290_001 S96290_002
Stable isotopic data for water samples collected between 02/20/98 and 08/20/98 in the Yucca Mountain area, Nye County, Nevada	GS021008312322.002 [DIRS 162913] [1]	S02343_001 S02343_002
Field and isotopic data from groundwater samples from wells in the Amargosa Valley and NTS	GS990808312322.001 [DIRS 149393] [1]	S99384_001 S99384_002
Chemical and isotopic data from groundwater samples collected from wells in the Amargosa	GS990808312322.002 [DIRS 162917] [1]	S99385_001 S99385_002
Field, chemical, and isotopic data from wells in the Yucca Mountain area, Nye County, Nevada, collected between 12/11/98 and 11/15/99	GS010308312322.003 [DIRS 154734] [1]	S01053_001 S01053_002 S01053_004
Field and chemical data collected between 1/20/00 and 4/24/01 and isotopic data collected between 12/11/98 and 11/6/00 from wells in the Yucca Mountain area, Nye County Nevada	GS011108312322.006 [DIRS 162911] [1]	S01174_001 S01174_002
Uranium and thorium isotope data for waters analyzed between January 18, 1994, and September 14, 1996	GS010608315215.002 [DIRS 156187] [1]	S01134_001
Uranium and uranium isotope data for water samples from wells and springs in the Yucca Mountain vicinity collected between December 1996 and December 1997	GS010808312322.004 [DIRS 156007] [1]	S01132_001
Uranium concentrations and $^{234}U/^{238}U$ ratios for waters in Yucca Mountain region	GS940908315213.005 [DIRS 164673]	S96241_002 S96241_003

Table A4-1. Sources of Data (Continued)

DTN Description	DTN[1]	Tables Used[2]
Hydrochemical data obtained from water samples collected at water well ER-30-1 on 1/31/95 and 2/1/95	GS960908312323.005 [DIRS 162916] [1]	S97098_002 to S97098_005, S97098_013, S97098_017 to S97098_021, S97098_028 to S97098_031
Strontium isotope ratios and isotope dilution data for strontium for two samples collected at UE-25 c#3, 12/4/96 and 2/19/97	GS970708315215.008 [DIRS 164674] [1]	S97527_001 S97527_002
Tritium analyses of pore water from USW UZ-14, USW NRG-6, USW NRG-7A, and UE-25 UZ#16 and of perched water from USW SD-7, USW SD-9, USW UZ-14, and USW NRG-7A from 12/09/92 to 5/15/95	GS951208312272.002 [DIRS 151649]	S01175_002
Chloride, bromide, sulfate and chlorine-36 analyses of springs, groundwater, pore water, perched water, and surface runoff	LAJF831222AQ98.011 [DIRS 145402]	S98328_001
SZ site-scale flow model, FEHM files for SZ site-scale flow model	LA0304TM831231.002 [DIRS 163788]	—
Thermodynamic characteristics input file required to run PHREEQC	MO0309THDPHRQC.000 [DIRS 165529]	S03316_001
Uranium activity ratios of pore waters from upper lithophysal unit of Topopah Spring tuff	MO0012URANISOT.000 [DIRS 153384]	—
Field, chemical, and isotopic data from a precipitation sample collected behind the service station in area 25 and groundwater samples collected at boreholes UE-25 c#2, UE-25 c#3, USW UZ-14, UE-25 WT#3, USW WT-17, and USW WT-24, between 10/06/97 and 07/01/98	GS980908312322.008 [DIRS 145412]	S98383_001, 003, 005 to 007, 009, 014, 016, 018, 022, 024, 025, 028, 031, 038, 041 to 044, 046
Uranium Concentrations and 234U/238U Ratios from Spring, Well, Runoff, and Rain Waters Collected from the Nevada Test Site and Death Valley Vicinities and Analyzed between 01/15/98 and 08/15/98 (Only the data for Water Well 8 and c#3 were used as input from this DTN).	GS040208312322.003 [DIRS 172396]	S04101_001

[1]DTNs that reference this footnote are acquired-data sources used as input for developed-data DTN: LA0309RR831233.001 [DIRS 166546], which is cited as one of the sources for data shown in Tables A6-1 and A6-2. In this case, the acquired-data DTN has not been listed separately as a source for data in the footnotes of those two tables.

[2]Names of the tables within each DTN that were sources of data.

Table A4-2. Sources of Data and Other Information

Information Used	Reference (DTN)[1]	Source of Data Used
Chloride, bromide, sulfate, and chlorine-36 analyses of ESF porewaters	LA9909JF831222.010 [DIRS 122733]	S99410_001
Chloride, bromide, and sulfate analyses of pore water extracted from ESF Niche 3566 (Niche #1) and ESF 3650 (Niche #2) drill core	LA9909JF831222.012 [DIRS 122736]	S99412_001
Apparent infiltration rates in alluvium from USW UZ-N37, USW UZ-N54, USW UZ-14, and UE-25 UZ#16, calculated by chloride mass-balance method	LA0002JF831222.001 [DIRS 147077]	S00142_001
Apparent infiltration rates in PTn units from USW UZ-7A, USA UZ-N55, USW UZ-14, UE-25 UZ#16, USW NRG-6, USW NRG-7A, and USW SD-6, SD-7, SD-9, and SD-12 calculated by the chloride mass-balance method	LA0002JF831222.002 [DIRS 147079]	S00143_001 S00143_002 S00143_003
Uranium and thorium isotopic data from secondary minerals in the ESF collected between 02/15/97 and 09/15/97	GS970808315215.012 [DIRS 145921]	S97566_001 S97566_003 S97566_006
Chemical and isotopic data from wells in Yucca Mountain area, Nye County, Nevada collected between 12/11/98 and 11/15/99	GS010308312322.002 [DIRS 162910] [1]	S01052_001
Uranium concentrations and $^{234}U/^{238}U$ activity ratios analyzed between August 1998 and April 2000 for saturated-zone well water, springs, and runoff collected between April 1998 and November 1999	GS010208312322.001 [DIRS 162908] [1]	S01051_001
Chemical and isotopic data describing water samples collected from 11 springs and one stream within Death Valley National Park in 1993, 1994, and 1995	GS960408312323.002 [DIRS 162915] [1]	S00176_001
Field, chemical, and isotopic data from a precipitation sample collected behind the service station in area 25 and groundwater samples collected at boreholes UE-25 c#2, UE-25 c#3, USW UZ-14, UE-25 WT#3, USW WT-17, and USW WT-24, between 10/06/97 and 07/01/98	GS980908312322.008 [DIRS 145412] [1]	S98383_001, S98383_003, S98383_005, S98383_006, S98383_007, S98383_009, S98383_014, S98383_016, S98383_018, S98383_022, S98383_024, S98383_025, S98383_028, S98383_031, S98383_038, S98383_041 to S98383_044, S98383_046
Selected groundwater data for Yucca Mountain region, southern Nevada, and eastern California, through December 1992	GS931100121347.007 [DIRS 149611] [1]	S96375_006, S96375_007

Table A4-2. Sources of Data and Other Information (Continued)

Information Used	Reference (DTN) [1]	Source of Data Used
Water chemistry data from samples collected at borehole USW WT-24 between 10/06/97 and 12/10/97	GS980108312322.005 [DIRS 149617] [1]	S98308_001, S98308_006, S98308_007, S98308_009, S98308_010, S98308_015, S98308_019, S98308_026, S98308_027, S98308_029, S98308_031, S98308_033, S98308_036 S98308_038
Chemical composition of groundwater and the locations of permeable zones in the Yucca Mountain area	GS930308312323.001 [DIRS 145530] [1]	S97314_008, S97314_017, S97314_018
Chemical composition of groundwater in the Yucca Mountain area, Nevada, 1971 to 1984	GS920408312321.003 [DIRS 105937]	S97126_009, S97126_018, S97126_019
Selected groundwater hydrochemical and isotopic data from Geochem02.mdb—the Department of Energy's comprehensive water quality database for groundwater in the vicinity of the Nevada Test Site (Rev. 4)	LA0311EK831232.001 [DIRS 166068]	—
Hydrochemical data from field tests and lab analyses of water samples collected at field stations USW VH-1, JF3, UE-29 UZN#91, Virgin Spring, Nevares Spring, UE-25 J#12, UE-25 J#13, UE-22 Army#1, and USW UZ-14	GS930908312323.003 [DIRS 145404]	S96076_001
Isotopic compositions of pore water from boreholes USW UZ-14 and USW NRG-6	GS990308312272.002 [DIRS 145692]	S00254_001
Groundwater strontium isotope data from selected Nye County Early Warning Drilling Program borehole	LA0311EK831232.002 [DIRS 166069]	—
Chemical composition of groundwater in the Yucca Mountain area, Nevada, 1971-1984	Benson and McKinley 1985 [DIRS 101036]	Tables 1 and 5
Hydrochemical database for the Yucca Mountain area, Nye County, Nevada	Oliver and Root 1997 [DIRS 100069], *yucca.xls*	Hydrochemical, isotope and summary worksheets
$^{234}U/^{238}U$ evidence for local recharge and patterns of groundwater flow in the vicinity of Yucca Mountain	Paces et al. 2002 [DIRS 158817]	Table 1, Appendix A
Sources and mechanisms of recharge for groundwater in the west-central Amargosa Desert, Nevada—a geochemical interpretation	Claassen 1985 [DIRS 101125]	Table 1

Table A4-2. Sources of Data and Other Information (Continued)

Information Used	Reference (DTN)[1]	Source of Data Used
Chemical and isotopic data for groundwater in southern Nevada.	Rose et al. 1997 [DIRS 144725]	Tables 2, 3, and 4
Preliminary report on the isotope hydrology investigations at the Nevada Test Site: Hydrologic Resources Management Program, FY 1992–1993	Davisson et al. 1994 [DIRS 162939]	Tables 1 and 2
Groundwater chemistry at the Nevada Test Site: data and preliminary interpretations	Chapman and Lyles 1993 [DIRS 162940]	Appendix B, Figs. 10, 12, and 14
Well completion summary information for the Nye County EWDP, Phases I and II	LA0311EK831223.001 [DIRS 165985]	—
Well completion data and spring discharge area lithologies for the PM-OV area	Rose et al. 2002 [DIRS 162938]	Appendix A
UTM coordinates for selected Amargosa Desert wells	LA0309EK831223.001 [DIRS 165471]	spreadsheet Claassen_coord.xls
Borehole data from water-level analysis for the SZ site-scale flow and transport model	GS010908312332.002 [DIRS 163555][2]	*mean312411.xls* (columns C and D only)
Uranium isotopic data for saturated- and unsaturated-zone waters collected by non-YMP personnel between May 1989 and August 1997	GS980208312322.006 [DIRS 146065]	S98201_001 S98201_002
Uranium concentrations and $^{234}U/^{238}U$ ratios for groundwater samples from boreholes ER-EC-7, ER-18-2, and UE-18r, collected between December 1999 and June 2000	GS031108312322.003 [DIRS 166467]	—

[1] DTNs that reference this footnote are acquired-data sources used as input for developed-data DTN: LA0309RR831233.002 [DIRS 166548], which is cited as one of the sources for data shown in Tables A6-1 and A6-2. In this case, the acquired-data DTN has not been listed separately as a source for data in the footnotes of those two tables.

[2] This DTN was only used to establish well locations consistent with the flow model. Water-level data were not used to develop the geochemical flowpaths.

Table A4-3. Summary of Groundwater Wells and Data Sources

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[e]	Geologic Unit[c,e]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data[d]
Oasis Valley/Northwest Amargosa									
ER-EC-08	ER-EC-08	1	532764	4106142	OV/NWA	Oasis Valley/Northwest Amargosa	(192.6 to 320.0) (423.1 to 474.9) (495.6 to 606.6)[4]	Tfb Tmaw Tmap[4]	DTN: LA0311EK831232.001 [DIRS 166068], 7/23/99, 6/28/00 and 7/12/00 samples
ER-OV-01	ER-OV-01	2	528417	4104084	OV/NWA	Oasis Valley/Northwest Amargosa	(45.7 to 51.8)[8]	Tuff[8]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/8/97 sample; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
ER-OV-06a	ER-OV-06a	3	528417	4104084	OV/NWA	Oasis Valley/Northwest Amargosa	(154.2 to 160.3)[8]	Tuff[8]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/7/97 and 11/8/97 samples; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
ER-OV-05	ER-OV-05	4	520280	4099809	OV/NWA	Oasis Valley/Northwest Amargosa	(51.8 to 57.9)[8]	Alluvium[8]	DTN: LA0311EK831232.001 [DIRS 166068], 11/7/97 sample
ER-OV-02	ER-OV-02	5	526310	4098716	OV/NWA	Oasis Valley/Northwest Amargosa	(51.8 to 57.9)[8]	colluvial and alluvial gravel[8]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/11/97 sample); GS010808312322.004 [DIRS 156007], U concentrations and isotopes
Springdale Upper Well (10S/47E-32adc)	Springdale Upper Well (10S/47E-32adc)	6	523522	4097506	OV/NWA	Oasis Valley/Northwest Amargosa	open borehold (depth not reported)	tuff breccia or alluvium[4]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/12/97 sample; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
Goss Springs North (11S/47E-10bad)	Goss Springs North (11S/47E-10bad)	7	526100	4094647	OV/NWA	Oasis Valley/Northwest Amargosa	0.0 (spring)	not reported	DTNs: LA0311EK831232.001 [DIRS 166068], 11/13/97 sample; GS010808312322.004 [DIRS 156007], U concentrations and isotopes

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Oasis Valley/Northwest Amargosa (Continued)									
ER-OV-03a	ER-OV-03a	8	526299	4094587	OV/NWA	Oasis Valley/Northwest Amargosa	(67.1 to 73.2)[8]	tuff[8]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/9/97 sample; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
ER-OV-03a3	ER-OV-03a3	9	526299	4094587	OV/NWA	Oasis Valley/Northwest Amargosa	(34.4 to 40.5)[8]	Tma, tuff[8]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/9/97 sample; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
ER-OV-03a2	ER-OV-03a2	10	526299	4094587	OV/NWA	Oasis Valley/Northwest Amargosa	(183.5 to 189.6)[8]	Not reported	DTNs: LA0311EK831232.001 [DIRS 166068], 11/9/97 sample; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
Goss Spring (11S/47E-10bcc)	Goss Spring (11S/47E-10bcc)	11	526061	4093440	OV/NWA	Oasis Valley/Northwest Amargosa	0.0 (spring)[2]	Tv[2]	DTN: LA0311EK831232.001 [DIRS 166068], 9/7/95 sample
ER-OV-04a	ER-OV-04a	12	525671	4089316	OV/NWA	Oasis Valley/Northwest Amargosa	(33.8 to 39.9)[8]	Alluvium[8]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/7/97 sample;GS010808312322.004 [DIRS 156007], U concentrations and isotopes
Beatty Well no. 1 (Wat&Sanit Distr)	Beatty Well no. 1 (Wat&Sanit Distr)	13	521378	4085329	OV/NWA	Oasis Valley/Northwest Amargosa	(30.0 to 48.8)	Not reported	DTN: LA0311EK831232.001 [DIRS 166068], 2/11/97 and 4/28/97 samples

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Oasis Valley/Northwest Amargosa (Continued)									
Bond Gold Mining #1	Bond Gold Mining #1	14	516203	4074502	OV/NWA	Oasis Valley/Northwest Amargosa	Not reported	Qal[13]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, Alk, ions, $\delta^{18}O$, δD, $\delta^{13}C$); GS011108312322.006 [DIRS 162911], ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; GS010308312322.002 [DIRS 162910], U concentrations
US Ecology MW-313	US Ecology MW-313	15	527666	4069293	OV/NWA	Oasis Valley/Northwest Amargosa	open borehole (depth not reported)	Qal[13]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, Alk, ions, $\delta^{18}O$, δD, $\delta^{13}C$; GS011108312322.006 [DIRS 162911], ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; GS010308312322.002 [DIRS 162910], U concentrations
US Ecology MW-600	US Ecology MW-600	16	527666	4069293	OV/NWA	Oasis Valley/Northwest Amargosa	open borehole (depth not reported)	Qal[13]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, Alk, ions, $\delta^{18}O$, δD, $\delta^{13}C$; GS011108312322.006 [DIRS 162911], ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; GS010308312322.002 [DIRS 162910], U concentrations

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Oasis Valley/Northwest Amargosa (Continued)									
Nucl. Eng. Co.	NEC Well	17	527519	4068738	OV/NWA	Oasis Valley/Northwest Amargosa	open borehole (86 to 180)[3]	QTal[2]	DTNs: MO0007GNDWTRIS.011 [DIRS 151501). $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C
US Ecology MR-3	US Ecology MR-3	18	527395	4068707	OV/NWA	Oasis Valley/Northwest Amargosa	open borehole (depth not reported)	Qal[13]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, Alk, $\delta^{18}O$, δD, $\delta^{13}C$; GS011108312322.006 [DIRS 162911], $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; GS010308312322.003 [DIRS 154734], ^{14}C; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
Timber Mountain									
UE-18r	UE-18r	19	549322	4109762	TM	Timber Mountain	509[4,6]	Tm, debris flow[4]	DTNs: LA0311EK831232.001 [DIRS 166068], 7/11/91,8/11/92 and 12/9/99 samples; GS031108312322.003 [DIRS 154734], U isotopes
ER-18-2	ER-18-2	20	555725	4106389	TM	Timber Mountain	(411.9 to 758.0)[4]	Tmar[4]	DTNs: LA0311EK831232.001 [DIRS 166068], 3/21/00 sample; GS031108312322.003 [DIRS 154734], U isotopes
ER-EC-05	ER-EC-05	21	538702	4106389	TM	Timber Mountain	(356.3 to 439.8) (559.3 to 654.1) (688.7 to 755.9)[4]	Ttc Tfbr,Tfbw Tmap[4]	DTNs: LA0311EK831232.001 [DIRS 166068], 7/8/99,5/4/00, and 5/25/00 samples; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
Coffer's Ranch Windmill Well	Coffer's Ranch Windmill Well	22	539421	4095192	TM	Timber Mountain	(109.8 to 146.3)[4]	Not reported	DTNs: LA0311EK831232.001 [DIRS 166068], samples from 1994 through 1997; GS010808312322.004 [DIRS 156007], U concentrations and isotopes

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Timber Mountain (Continued)									
ER-OV-03c	ER-OV-03c	23	535494	4094374	TM	Timber Mountain	(156.1 to 162.2)[4,8]	Tma[4]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/10/97 sample; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
ER-EC-07	ER-EC-07	24	546484	40931217	TM	Timber Mountain	(272.8 to 312.4) (351.4 to 399.3)[4]	Tfb,Tfl[4]	DTNs: LA0311EK831232.001 [DIRS 166068], 8/7/99, 4/28/2000 and 6/5/00 samples; GS031108312322.003 [DIRS 166467], U isotopes
Fortymile Wash – North									
Water Well 8	Water Well 8	25	563113	4113275	FMW-N	Fortymile Wash – North	377[6]	Tv[2]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/4/97 sample; GS040208312322.003 [DIRS 172396], U concentrations and isotopes
Test Well 1 (USGS HTH #1)	Test Well 1 (USGS HTH #1)	26	569000	4112499	FMW-N	Fortymile Wash – North	624[6]	Tv[5]	DTN: LA0311EK831232.001 [DIRS 166068], 8/13/92 sample
UE-18t	UE-18t	27	559591	4109095	FMW-N	Fortymile Wash – North	(577.9 to 792.5)[4]	Tm[4]	DTN: LA0311EK831232.001 [DIRS 166068], 9/23/88 sample
ER-30-1 (upper)	ER-30-1 (upper)	28	560805	4100463	FMW-N	Fortymile Wash – North	(179.1 to 185.2)[4]	Basaltic lava[4]	DTNs: GS960908312323.005 [DIRS 162916], ions and most isotopes; GS950808312322.001 [DIRS 148114], T, pH, Alkalinity, $^{87}Sr/^{86}Sr$
ER-30-1 (lower)	ER-30-1 (lower)	29	560805	4100463	FMW-N	Fortymile Wash – North	(227.2 to 233.3)[4]	Gravelly sand[4]	DTNs: GS960908312323.005 [DIRS 162916], ions and most isotopes; GS950808312322.001 [DIRS 148114], T, pH, Alkalinity, $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – North (Continued)									
UE-29 a#2	a#2(dp)	30	555753	4088351	FMW-N	Fortymile Wash – North	247 to 354[1]	Th[2]	DTNs: MO0007GNDWTRIS.010 [DIRS 151500], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.013 [DIRS 151530], C; GS010808312322.004 [DIRS 156007], U concentrations and isotopes; GS930308312323.001 [DIRS 145530], T, F^-, $Sr2^+$
	a#2(sh)	31					87 to 213[1]	Th[2]	
UE-29a#1 HTH	UE-29a#1 HTH	32	555758	4088341	FMW-N	Fortymile Wash – North	(10.7 to 65.5)[4]	Rhyolite[4]	DTNs: LA0311EK831232.001 [DIRS 166068], 11/6/97 sample; GS010808312322.004 [DIRS 156007], U concentrations and isotopes
UE-25 WT#15	WT#15	33	554034	4078702	FMW-N	Fortymile Wash – North	Open borehole (354 to 415)[9]	Tpt[9]	DTNs: MO0007GNDWTRIS.007 [DIRS 151497], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007GNDWTRIS.006 [DIRS 151496], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0008MAJIONPH.017 [DIRS 151534], C
UE-25 WT#14	WT#14	34	552630	4077330	FMW-N	Fortymile Wash – North	open borehole (346 to 399)[9]	Tpt,Tac[9]	
UE-25 J-13	J-13	35	554017	4073517	FMW-N	Fortymile Wash – North	(303 to 424) (820 to 1,009)[9]	Tpt Tct,Tlr[9]	DTNs: MO0007GNDWTRIS.010 [DIRS 151500). $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.013 [DIRS 151530], C; GS930108315213.004 [DIRS 145525], U concentrations and isotopes; GS930308312323.001 [DIRS 145530], T, F^-, $Sr2^+$; LA0311EK831232.001 [DIRS 166068], 87Sr/86Sr
UE-25 J-12	J-12	36	554444	4068774	FMW-N	Fortymile Wash – North	open borehole (227 to 271)[9]	Tpt[9]	

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – North (Continued)									
UE-25 JF#3	JF#3	37	554498	4067974	FMW-N	Fortymile Wash – North	open borehole (216 to 347)[15]	Tv[15]	DTNs: MO0007GNDWTRIS.005 [DIRS 151495], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.008 [DIRS 151521], C; GS930908312323.003 [DIRS 145404], F^-, Sr^{2+}; GS930108315213.004 [DIRS 145525], U concentrations and isotopes; LA0311EK831232.001 [DIRS 166068], $^{87}Sr/^{86}Sr$
Solitario Canyon Wash									
USW H-6	H-6(bh)	38	546188	4077816	SCW	Solitario Canyon Wash	open borehole (526 to 1,220)[1]	Tcb/Tct[2]	DTNs: MO0007GNDWTRIS.010 [DIRS 151500], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.013 [DIRS 151530], C; GS930308312323.001 [DIRS 145530], (T, F^-, Sr^{2+});
	H-6(Tct)	39					753 to 835[1]	Tct[2]	DTN: MO0007GNDWTRIS.010 [DIRS 151500], ($\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C); MO0007MAJIONPH.012 [DIRS 151529], (C);Benson and McKinley 1985 [DIRS 101036], T, F^-, Sr^{2+}
	H-6(Tcb)	40					608 to 646[1]	Tcb[2]	

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Solitario Canyon Wash (Continued)									
USW WT-7	WT-7	41	546151	4075474	SCW	Solitario Canyon Wash	open borehole (421 to 491)[9]	Tpt,Tcp[9]	DTNs: MO0007GNDWTRIS.006 [DIRS 151496], $\delta^{18}O$, $\delta^{13}C$; MO0008MAJIONPH.017 [DIRS 151534], C; LA0311EK831232.001 [DIRS 166068], F^-, Sr^{2+}, $^{87}Sr/^{86}Sr$; Paces et al. 2002 [DIRS 158817], Table 1, U concentrations and isotopes
USW WT-10	WT-10	42	545964	4073378	SCW	Solitario Canyon Wash	open borehole (347 to 431)[9]	Tpt[9]	DTNs: MO0007GNDWTRIS.006 [DIRS 151496], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0008MAJIONPH.017 [DIRS 151534], C; DTN: LA0311EK831232.001 [DIRS 166068], (F^-, Sr^{2+}, $^{87}Sr/^{86}Sr$); Paces et al. 2002 [DIRS 158817], Table 1, U concentrations and isotopes
Yucca Mountain – Crest									
USW G-2	G-2	43	548143	4082542	YM-CR	Yucca Mountain – Crest	533 to 792[10]	Tpt,Tac[10]	DTNs: MO0007GNDWTRIS.002 [DIRS 151492], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.003 [DIRS 151513], C; GS010608315215.002 [DIRS 156187], U concentrations and isotopes; LA0311EK831232.001 [DIRS 166068], F^-, Sr^{2+}, $^{87}Sr/^{86}Sr$
USW WT-24	USW WT-24	44	548691	4081898	YM-CR	Yucca Mountain – Crest	688[11]	Not reported	DTN: GS980908312322.008 [DIRS 145412], 4/24/98 sample; Paces et al. 2002 [DIRS 158817], Table 1

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – Crest (Continued)									
USW UZ-14	UZ-14 (sh)	45	548032	4080260	YM-CR	Yucca Mountain – Crest	bailed (579)[11]	Tcp	DTNs: MO0007GNDWTRIS.003 [DIRS 151493], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.005 [DIRS 151517], C; GS980908312322.008 [DIRS 145412], T, F^-, Sr^{2+}, SiO_2, HCO_3^-, and $\delta^{34}S$
	UZ-14 (dp)	46					bailed (655)[11]	Tcb	
USW H-1	H-1(Tcp)	47	548727	4079926	YM-CR	Yucca Mountain – Crest	572-687[1]	Tcp[2]	DTNs: MO0007GNDWTRIS.010 [DIRS 151500], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.013 [DIRS 151530], C; GS930308312323.001 [DIRS 145530], T, F^-, Sr^{2+}
	H-1(Tcb)	48					687 to 1829[1]	Tcb[2]	
USW H-5	H-5	49	547668	4078841	YM-CR	Yucca Mountain – Crest	open borehole (704 to 1220)[1]	Tcb/Tct[2]	DTNs: MO0007GNDWTRIS.010 [DIRS 151500], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.013 [DIRS 151530], C; GS930308312323.001 [DIRS 145530], T, F^-, Sr^{2+}
USW SD-6	USW SD-6	50	547592	4077514	YM-CR	Yucca Mountain – Crest	open borehole (depth not reported)	Not reported	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$; GS011108312322.006 [DIRS 162911], $\delta^{13}C$, $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
USW H-3	H-3	51	547562	4075759	YM-CR	Yucca Mountain – Crest	open borehole (822 to 1,220)[1]	Tct[2]	DTNs: MO0007GNDWTRIS.009 [DIRS 151509], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.011 [DIRS 151524], C; MO0007MAJIONPH.012 [DIRS 151529], C; GS920408312321.003 [DIRS 105937], T, F^-, Sr^{2+}

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – Central									
USW G-4	G-4	52	548933	4078602	YM-C	Yucca Mountain – Central	open borehole (541 to 915)[1]	Tct	DTNs: MO0007GNDWTRIS.010 [DIRS 151500], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C); MO0007MAJIONPH.013 [DIRS 151530], (C); GS930308312323.001 [DIRS 145530], (T, F^-, Sr^{2+})
UE-25 b#1	b#1(Tcb)	53	549949	4078423	YM-C	Yucca Mountain – Central	863-875[1]	Tcb[2]	DTNs: MO0007GNDWTRIS.010 [DIRS 151500], ($\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.013 [DIRS 151530], C; GS930308312323.001 [DIRS 145530], T, F^-, Sr^{2+}
	b#1(bh)	54					open borehole (470-1220)[1]	Th/Tct[2]	
USW H-4	H-4	55	549188	4077309	YM-C	Yucca Mountain – Central	open borehole (519 to 1,220)[1]	Tcb/Tct[2]	DTNs: MO0007GNDWTRIS.010 [DIRS 151500], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.013 [DIRS 151530], C; GS930308312323.001 [DIRS 145530], T, F^-, Sr^{2+}
UE-25 UZ#16	UZ#16	56	549484.9	4076986	YM-C	Yucca Mountain – Central	490 to 492	Tcp	DTN: MO0007MAJIONPH.007 [DIRS 151519], C
Yucca Mountain – Southeast									
UE-25 ONC#1	ONC#1	57	550479.9	4076608	YM-SE	Yucca Mountain – Southeast	open borehole (433 to 469)[15]	Th/Tcp[15]	DTN: MO0007MAJIONPH.004 [DIRS 151516], C; Oliver and Root 1997 [DIRS 100069], Sr^{2+} and $^{87}Sr/^{86}Sr$
UE-25 c#1	c#1	58	550955	4075933	YM-SE	Yucca Mountain – Southeast	open borehole (400 to 914)[1]	Tcb/Tct[2]	DTNs: MO0007GNDWTRIS.009 [DIRS 151509], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.011 [DIRS 151524], C; MO0007MAJIONPH.012 [DIRS 151529], C; GS920408312321.003 [DIRS 105937], T, F^-, Sr^{2+}; LA0311EK831232.001 [DIRS 166068], $^{87}Sr/^{86}Sr$ for c#1

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – Southeast (Continued)									
UE-25 c#3	c#3	59	550930	4075902	YM-SE	Yucca Mountain – Southeast	open borehole (402 to 913)[1]	Tcb/Tct[2]	DTNs: MO0007GNDWTRIS.009 [DIRS 151509], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.011 [DIRS 151524], C; MO0007MAJIONPH.012 [DIRS 151529], C; GS920408312321.003 [DIRS 105937], T, F^{-}, Sr^{2+}
	c#3(95-97)	60							DTNs: GS950808312322.001 [DIRS 148114], C, $\delta^{18}O$, δD; GS010808312322.004 [DIRS 156007); GS010608315215.002 [DIRS 156187]; GS040208312322.003 [DIRS 172396]; U concentrations and isotopes; [DIRS 172396] GS980908312322.008 [DIRS 145412], $\delta^{34}S$; GS970708315215.008 [DIRS 164674], $^{87}Sr/^{86}Sr$ for c#3
UE-25 c#2	c#2	61	550955	4075871	YM-SE	Yucca Mountain – Southeast	open borehole (401 to 913)[1]	Tcb[2]	DTNs: MO0007GNDWTRIS.009 [DIRS 151509], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.011 [DIRS 151524], C; MO0007MAJIONPH.012 [DIRS 151529], C; GS920408312321.003 [DIRS 105937], T, F^{-}, Sr^{2+}; GS980908312322.008 [DIRS 145412], $\delta^{34}S$ for c#2

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – Southeast (Continued)									
UE-25 p#1	p#1(v)	62	551501	4075659	YM-SE	Yucca Mountain – Southeast	381-1197[1]	tuff[2]	DTNs: MO0007GNDWTRIS.009 [DIRS 151509], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.011 [DIRS 151524], C; MO0007GNDWTRIS.008 [DIRS 151508], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.010 [DIRS 151523], C; GS930108315213.004 [DIRS 145525], U concentrations and isotopes; GS920408312321.003 [DIRS 105937], T, F^-, Sr^{2+}; LA0311EK831232.001 [DIRS 166068], $^{87}Sr/^{86}Sr$
	p#1(c)	63					1,297 to 1,805[1]	Srm/ DSlm[2]	
USW WT-17	WT-17	64	549905	4073307	YM-SE	Yucca Mountain – Southeast	open borehole (393 to 443)[9]	Tcp[9]	DTNs: MO0007GNDWTRIS.003 [DIRS 151493], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.005 [DIRS 151517], C; GS980908312322.008 [DIRS 145412], T, F^-, Sr^{2+}, and $\delta^{34}S$; GS980908312322.009 [DIRS 118977], U concentrations and isotopes
UE-25 WT#3	WT#3	65	552090	4072550	YM-SE	Yucca Mountain – Southeast	open borehole (301 to 348)[9]	Tcb[9]	DTNs: MO0007GNDWTRIS.003 [DIRS 151493], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.005 [DIRS 151517], C; GS980908312322.008 [DIRS 145412], T, F^-, Sr^{2+}, and $\delta^{34}S$); GS980908312322.009 [DIRS 118977], U concentrations and isotopes

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – Southeast (Continued)									
UE-25 WT#12	WT#12	66	550168	4070659	YM-SE	Yucca Mountain – Southeast	open borehole (345 to 399)[9]	Tpt/Tac[9]	DTNs: MO0007GNDWTRIS.007 [DIRS 151497], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007GNDWTRIS.006 [DIRS 151496], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0008MAJIONPH.017 [DIRS 151534], C; GS010608315215.002 [DIRS 156187], U concentrations and isotopes; LA0311EK831232.001 [DIRS 166068], $^{87}Sr/^{86}Sr$; Oliver and Root 1997 [DIRS 100069], F^-, Sr^{2+}
Jackass Flats									
UE-25 J-11	UE-25 J-11	67	563798	4071073	JF	Jackass Flats	open borehole (317 to 405)[9]	Tb, Tpt[9]	DTNs: GS010308312322.003 [DIRS 154734], pH, alkalinity, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], ions; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
Crater Flat									
GEXA Well 4	GEXA Well 4	68	534069	4086110	CF	Crater Flat	(244 to 488)[4]	TV[4,15]	DTNs: GS970708312323.001 [DIRS 145405], $\delta^{18}O$, δD; MO0007MAJIONPH.008 [DIRS 151521], C; GS980208312322.006 [DIRS 146065], U concentrations and isotopes; Oliver and Root 1997 [DIRS 100069], T, F^-, Sr^{2+}, $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Crater Flat (Continued)									
USW VH-1	VH-1	69	539976	4071714	CF	Crater Flat	open borehole (184 to 762)[1]	Tcb[2]	DTNs: MO0007GNDWTRIS.010 [DIRS 151500], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.013 [DIRS 151530], C; GS930308312323.001 [DIRS 145530], T, F^-, Sr^{2+}; LA0311EK831232.001 [DIRS 166068], $^{87}Sr/^{86}Sr$; Paces et al. 2002 [DIRS 158817], Table 1, U concentrations and isotopes
Crater Flat - Southwest									
USW-VH-2	VH-2	70	537738	4073214	CF-SW	Crater Flat – Southwest	open borehole (164 to 1,219)[15]	Tv[15]	DTNs: GS930108315213.002 [DIRS 148109], C; GS970708312323.001 [DIRS 145405], $\delta^{18}O$, δD; MO0007MAJIONPH.008 [DIRS 151521], C; GS930108315213.004 [DIRS 145525], U concentrations and isotopes; LA0311EK831232.001 [DIRS 166068], F^-, Sr^{2+}, $^{87}Sr/^{86}Sr$
NC-EWDP-7S	NC-EWDP-7S	71	539558	4064318	CF-SW	Crater Flat – Southwest	(8.5 to 12.2)[7]	Paleospring deposits[7]	DTN: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$
NC-EWDP-7SC	NC-EWDP-7SC	72	539558	4064320	CF-SW	Crater Flat – Southwest	Open borehole (7.6 to 237.3)[7]	Paleospring deposits, Tertiary sediments and volcanic rock[7]	DTN: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Crater Flat – Southwest (Continued)									
NC-EWDP-1DX	NC-EWDP-1DX	73	536768	4062503	CF-SW	Crater Flat – Southwest	Open borehole (16.8 to 762)[7]	Paleospring deposits, alluvium, Tertiary sediments[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, $\delta^{18}O$, δD, $\delta^{13}C$; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], F^-, Sr^{2+}; MO0007MAJIONPH.015 [DIRS 151532], C; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
NC-EWDP-1DX Zone 2	NC-EWDP-1DX Zone 2	74	536768	4062503	CF-SW	Crater Flat – Southwest	(658.4 to 682.8)[7]	Tertiary sediments[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-1S Zone 1	NC-EWDP-1S Zone 1	75	536771	4062499	CF-SW	Crater Flat – Southwest	(48.8 to 54.9)[7]	Tertiary welded tuff[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Crater Flat – Southwest (Continued)									
NC-EWDP-1S Zone 2	NC-EWDP-1S Zone 2	76	536771	4062499	CF-SW	Crater Flat – Southwest	(64.0 to 82.3)[7]	Tertiary welded tuff[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-1S	NC-EWDP-1S	77	536771	4062499	CF-SW	Crater Flat – Southwest	Open borehole (15.8 to 103.6)	Tertiary welded tuff[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, $\delta^{18}O$, δD, $\delta^{13}C$; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], ions; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
NC-EWDP-12PA	NC-EWDP-12PA	78	536906	4060766	CF-SW	Crater Flat – Southwest	(99.0 to 117.2)[7]	Tertiary Reworked tuff[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-12PB	NC-EWDP-12PB	79	536863	4060794	CF-SW	Crater Flat – Southwest	(99.1 to 117.3)[7]	Tertiary Reworked tuff[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Crater Flat – Southwest (Continued)									
NC-EWDP-12PC	NC-EWDP-12PC	80	536872	4060809	CF-SW	Crater Flat – Southwest	(51.8 to 70.0)[7]	Alluvium[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
Yucca Mountain - South									
NC-EWDP-09SX	NC-EWDP-09SX	81	539039	4061004	YM-S	Yucca Mountain – South	Open borehole (30.2 to 121.0)	Valley fill, Alluvium, Tertiary volcanic rock[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, $\delta^{18}O$, δD, $\delta^{13}C$; GS011108312322.006 [DIRS 162911], $\delta^{13}C$, $\delta^{34}S$; MO0007MAJIONPH.015 [DIRS 151532], C; GS010308312322.002 [DIRS 162910], F^-, Sr^{2+}; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-09SX Zone 1	NC-EWDP-09SX Zone 1	82	539040	4061006	YM-S	Yucca Mountain – South	(27.4 to 36.6)[7]	Alluvium[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], ^{14}C, $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – South (Continued)									
NC-EWDP-09SX Zone 2	NC-EWDP-09SX Zone 2	83	539040	4061006	YM-S	Yucca Mountain – South	(42.7 to 48.8)[7]	Alluvium[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-09SX Zone 3	NC-EWDP-09SX Zone 3	84	539040	4064006	YM-S	Yucca Mountain – South	(76.2 to 88.4)[7]	Tertiary tuff[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-09SX Zone 4	NC-EWDP-09SX Zone 4	85	539040	4061006	YM-S	Yucca Mountain – South	(100.6 to 103.7)[7]	Tertiary tuff[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)		Area[b]	Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – South (Continued)									
NC-EWDP-03D	NC-EWDP-03D	86	541273	4059444	YM-S	Yucca Mountain – South	(159 to 292)[7]	Alluvium, Tertiary sedimentary and volcanic rocks[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], F^-, Sr^{2+}; MO0007MAJIONPH.015 [DIRS 151532], C; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
NC-EWDP-3S Zone 2	NC-EWDP-3S Zone 2	87	541273	4059444	YM-S	Yucca Mountain – South	(103.6 to 128.0)[14]	Tertiary tuff and sediments[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-3S Zone 3	NC-EWDP-3S Zone 3	88	541273	4059444	YM-S	Yucca Mountain – South	(146.3 to 160.0)[14]	Tertiary tuff and sediments[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{18}O$, $\delta^{34}S$; GS010308312322.002 [DIRS 162910], U concentration data; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – South (Continued)									
CIND-R-LITE	CIND-R-LITE	89	544027	4059809	YM-S	Yucca Mountain – South	not reported	Tv[15]	DTNs: GS930108315213.002 [DIRS 148109], C; MO0007MAJIONPH.006 [DIRS 151518], C; GS000700012847.001 [DIRS 150842], C, I; GS930108315213.004 [DIRS 145525], U concentrations and isotopes; LA0311EK831232.001 [DIRS 166068], F^-, Sr^{2+}, $^{87}Sr/^{86}Sr$
NC-EWDP-15P	NC-EWDP-15P	90	544848	4058158	YM-S	Yucca Mountain – South	(61.0 to 79.2)[7]	Alluvium[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-02D	NC-EWDP-02D	91	547744	40571647	YM-S	Yucca Mountain – South	Open borehole (95.1 to 493.2)[7]	Alluvium[7]	DTNs: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010308312322.002 [DIRS 162910], F^-, Sr^{2+}; MO0007MAJIONPH.015 [DIRS 151532], C; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
NC-EWDP-19D	NC-EWDP-19D	92	549238	4058265	YM-S	Yucca Mountain – South	Open borehole (106.1 to 443.9)[7]	Alluvium, Tertiary tuff and sediments[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Yucca Mountain – South (Continued)									
NC-EWDP-19P	NC-EWDP-19P	93	549250	4058287	YM-S	Yucca Mountain – South	(109.5 to 139.8)[7]	Alluvium[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-19D (alluvial)	NC-EWDP-19D (alluvial)	94	549238	4058265	YM-S	Yucca Mountain – South	(125.9 to 242.4) (assumed to be combined depth range of screened intervals 1 to 4)	Alluvium[7]	DTN: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$
NC-EWDP-19D (zone #1)	NC-EWDP-19D (zone #1)	95	549238	4058265	YM-S	Yucca Mountain – South	(125.9 to 131.4)[7]	Alluvium[7]	DTN: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$
NC-EWDP-19D (zone #2)	NC-EWDP-19D (zone #2)	96	549238	4058265	YM-S	Yucca Mountain – South	(151.8 to 157.3)[7]	Alluvium[7]	DTN: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$
NC-EWDP-19D (zone #3)	NC-EWDP-19D (zone #3)	97	549238	4058265	YM-S	Yucca Mountain – South	(176.1 to 206.0)[7]	Alluvium[7]	DTN: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$
NC-EWDP-19D (zone #4)	NC-EWDP-19D (zone #4)	98	549238	4058265	YM-S	Yucca Mountain – South	(220.2 to 242.4)[7]	Alluvium[7]	DTN: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$
Amargosa Valley									
NC-EWDP-4PB	NC-EWDP-4PB	99	553202	4056768	LW	Amargosa Valley	(225.4 to 255.8)[7]	Alluvium[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-4PA	NC-EWDP-4PA	100	553167	4056766	LW	Amargosa Valley	(123.5 to 147.9)[7]	Alluvium[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Amargosa Valley (Continued)									
Desert Farms Garlic Plot	Desert Farms Garlic Plot	101	553295	4055305	LW	Amargosa Valley	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
15S/50E-18ccc	15S/50E-18ccc	103	553710	4055273	LW	Amargosa Valley	open borehole (105 to 102)[2]	Qal[2]	DTN: MO0007MAJIONPH.006 [DIRS 151518], C; Oliver and Root 1997 [DIRS 100069], F^-, Sr^{2+}
NDOT	NDOT	104	553685	4055242	LW	Amargosa Valley	open borehole (105 to 151)	Qal[13]	DTNs: MO0007MAJIONPH.008 [DIRS 151521], C; MO0007MAJIONPH.009 [DIRS 151522], C; GS940908315213.005 [DIRS 164673], U concentrations and isotopes; Oliver and Root 1997 [DIRS 100069], F^- and $^{87}Sr/^{86}Sr$
15S/50E-18cdc	15S/50E-18cdc	105	553934.3	4055151	LW	Amargosa Valley	open borehole (105 to 120)[2]	Qal[2]	DTN: MO0007MAJIONPH.006 [DIRS 151518], C; Claassen 1985 [DIRS 101125], Table 1, sample 34, T

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Amargosa Valley (Continued)									
Airport Well	Airport Well	106	552846	4054904	LW	Amargosa Valley	open borehole (76 to 229)[15]	Qal[15]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, alkalinity); GS010308312322.003 [DIRS 154734], ions, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; Paces et al. 2002 [DIRS 158817], Table 1, U concentrations and isotopes
15S/50E-19b1	15S/50E-19b1	107	553862.5	4054720	LW	Amargosa Valley	open borehole (103 to 110)[15]	Qal[13]	DTN: MO0007MAJIONPH.006 [DIRS 151518], C
Amargosa River									
16S/48E-8ba	16S/48E-8ba	108	536979	4048129	AR	Amargosa River	open borehole (34-80)[2]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 45
16S/48E-7bba	16S/48E-7bba	109	534791	4048366	AR	Amargosa River	open borehole (0 to 38)[2]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 46, T
16S/48E-7cbc	16S/48E-7cbc	110	534546	4047441	AR	Amargosa River	open borehole (23 to 46)[2]	Qal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 47, T
16S/48E-18bcc	16S/48E-18bcc	111	534827	4045747	AR	Amargosa River	open borehole (27 to 110)[2]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Amargosa River (Continued)									
16S/48E-17ccc	16S/48E-17ccc	112	536122	4045106	AR	Amargosa River	open borehole (depth not reported)	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C
16S/48E-18dad	16S/48E-18dad	113	536069	4045814	AR	Amargosa River	open borehole (depth not reported)	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$; MO0007MAJIONPH.014 [DIRS 151531], C
16S/48E-8cda	16S/48E-8cda	114	537063	4045941	AR	Amargosa River	open borehole (40 to unknown)[2]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 51, T
16S/48E-17abb	16S/48E-17abb	115	537035	4046681	AR	Amargosa River	open borehole (31 to 90)[3]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 52, T
Barrachman Dom/Irr.	Barrachman Dom/Irr.	116	534951	4048117	AR	Amargosa River	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Amargosa River (Continued)									
McCracken Domestic	McCracken Domestic	117	537372	4047061	AR	Amargosa River	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, alkalinity, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
Fortymile Wash – West									
16S/48E-15ba	16S/48E-15ba	118	539670	4046693	FMW-W	Fortymile Wash – West	open borehole (30 to 50)[3]	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 37, T
16S/48E-10cba	16S/48E-10cba	119	539766	4047463	FMW-W	Fortymile Wash – West	open borehole (depth not reported)	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 25, T
16S/48E-15aaa	16S/48E-15aaa	120	540763	4046852	FMW-W	Fortymile Wash – West	open borehole (29 to 50)[3]	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 23, T

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – West (Continued)									
Selbach Domestic	Selbach Domestic	121	539256	4046506	FMW-W	Fortymile Wash – West	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
16S/48E-15dda	16S/48E-15dda	122	540893	4045620	FMW-W	Fortymile Wash – West	open borehole (depth not reported)	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C
16S/49E-23add	16S/49E-23add	123	551958	4045217	FMW-W	Fortymile Wash – West	open borehole (depth not reported)	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C
16S/48E-23bdb	16S/48E-23bdb	124	541469	4044729	FMW-W	Fortymile Wash – West	open borehole (29 to 100)[3]	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 24, T
16S/48E-23da	16S/48E-23da	125	542391	4044729	FMW-W	Fortymile Wash – West	open borehole (24 to 100)[3]	Qal[13]	DTN: MO0007MAJIONPH.006 [DIRS 151518], C; Claassen 1985 [DIRS 101125], Table 1, sample 53, T

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – West (Continued)									
Funeral Mountain Ranch Irrig	Funeral Mountain Ranch Irrig	126	541406	4043314	FMW-W	Fortymile Wash – West	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
Fortymile Wash – South									
16S/49E-05acc	16S/49E-05acc	127	546664.5	4049439	FMW-S	Fortymile Wash – South	open borehole (21 to 90)[3]	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Oliver and Root 1997 [DIRS 100069], F^-, Sr^{2+}
16S/49E-8abb	16S/49E-8abb	128	546695	4048453	FMW-S	Fortymile Wash – South	open borehole (45 to 60)[3]	Qtal[3]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 5, T
16S/49E-8acc	16S/49E-8acc	129	546723	4047806	FMW-S	Fortymile Wash – South	open borehole (45 to 60)[3]	Qtal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 6, T

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – South (Continued)									
16S/49E-18dc	16S/49E-18dc	130	545144	4045579	FMW-S	Fortymile Wash – South	open borehole (33 to 110)[3]	Qtal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C
16S/48E-24aaa	16S/48E-24aaa	131	544077	4045235	FMW-S	Fortymile Wash – South	open borehole (29 to 150)[3]	Qtal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 12, T
16S/49E-19daa	16S/49E-19daa	132	545777	4044535	FMW-S	Fortymile Wash – South	open borehole (30 to 90)[3]	Qtal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 11, T
DeLee Large Irrigation	DeLee Large Irrigation	133	544975	4043727	FMW-S	Fortymile Wash – South	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
16S/48E-25aa	16S/48E-25aa	134	544160	4043602	FMW-S	Fortymile Wash – South	open borehole (26 to 50)[3]	QTal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 13, T

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – South (Continued)									
16S/48E-36aaa	16S/48E-36aaa	135	544168	4042031	FMW-S	Fortymile Wash – South	open borehole (21 to 50)[3]	Qal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C, MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, MO0007MAJIONPH.014 [DIRS 151531], C
Bray Domestic	Bray Domestic	136	546665	4040701	FMW-S	Fortymile Wash – South	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
Amargosa Estates #2	Amargosa Estates #2	137	544634	4040394	FMW-S	Fortymile Wash – South	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], pH, ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
17S/48E-1ab	17S/48E-1ab	138	544152	4040182	FMW-S	Fortymile Wash – South	open borehole (16 to 60)[3]	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – South (Continued)									
17S/49E-7bb	17S/49E-7bb	139	544758	4038645	FMW-S	Fortymile Wash – South	open borehole (12 to 150)[3]	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 16, T
17S/49E-8ddb	17S/49E-8ddb	140	547575	4037612	FMW-S	Fortymile Wash – South	open borehole (15 to 100)[3]	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, T
17S/49E-35ddd	17S/49E-35ddd	141	552739	4031202	FMW-S	Fortymile Wash – South	0.0 (Ash Tree Spring)[3]	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 20, T
Fortymile Wash – East									
15S/49E-22a1	15S/49E-22a1	142	550086.3	4054974	FMW-E	Fortymile Wash – East	open borehole (90 to 174)[15]	Qal[15]	DTN: MO0007MAJIONPH.006 [DIRS 151518], C; Oliver and Root 1997 [DIRS 100069], F^-
15S/49E-22dcc	15S/49E-22dcc	143	549672.5	4053523	FMW-E	Fortymile Wash – East	open borehole (78 to 148)[3]	Qal[13]	DTNs: MO0007MAJIONPH.006 [DIRS 151518], C; MO0007GNDWTRIS.011 [DIRS 151501], I, “Amargosa well 3”; Oliver and Root 1997 [DIRS 100069], F^-, Sr^{2+}

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – East (Continued)									
15S/49E-27acc	15S/49E-27acc	144	549552.9	4052722	FMW-E	Fortymile Wash – East	open borehole (73 to 467)[2]	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Oliver and Root 1997 [DIRS 100069], F^-, Sr^{2+}
O'Neill Domestic	O'Neill Domestic	145	547304	4047893	FMW-E	Fortymile Wash – East	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
16S/49E-9cda	16S/49E-9cda	146	548168	4047291	FMW-E	Fortymile Wash – East	open borehole (46 to 90)[3]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 7, T
16S/49E-9dcc	16S/49E-9dcc	147	548343	4047045	FMW-E	Fortymile Wash – East	open borehole (49 to 60)[3]	Qal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 8, T
16S/49E-16ccc	16S/49E-16ccc	148	547508	4045222	FMW-E	Fortymile Wash – East	open borehole (depth not reported)	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Fortymile Wash – East (Continued)									
Ponderosa Dairy #1	Ponderosa Dairy #1	149	549382	4038747	FMW-E	Fortymile Wash – East	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], (U concentrations and isotopes
17S/49E-9aa	17S/49E-9aa	150	549382	4038262	FMW-E	Fortymile Wash – East	open borehole (5 to 6)[2]	Qal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C
17S/49E-15bbd	17S/49E-15bbd	151	549843	4036855	FMW-E	Fortymile Wash – East	open borehole (17 to 110)[3]	Qal[13]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 19, T
M. Gilgan Well	M. Gilgan Well	152	549550	4036791	FMW-E	Fortymile Wash – East	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
17S/49E-15bc	17S/49E-15bc	153	549870	4036577	FMW-E	Fortymile Wash – East	open borehole (15 to 157)[2]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 38, T

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Gravity Fault									
NC-EWDP-5S	NC-EWDP-5S	154	555676	4058229	GF	Gravity fault	(183.3 to 237.7)[7]	Alluvium[7]	DTNs: GS010308312322.003 [DIRS 154734], T, $\delta^{18}O$, δD; GS010308312322.002 [DIRS 162910], F^-, Sr^{2+}, SiO_2; MO0007MAJIONPH.015 [DIRS 151532], pH, C; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
NC-EWDP-5SB	NC-EWDP-5SB	155	555678	4058216	GF	Gravity fault	(115.6 to 149.0)[7]	Alluvium[7]	DTNs: GS011108312322.006 [DIRS 162911], T, pH, ions, ^{14}C, $\delta^{18}O$, δD, $\delta^{13}C$, $\delta^{34}S$; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$
16S/50E-7bcd	16S/50E-7bcd	156	553932	4047540	GF	Gravity fault	open borehole (43 to 60)[3]	Qal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C
Nelson Domestic	Nelson Domestic	157	553683	4047702	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
16S/49E-12ddd	16S/49E-12ddd	158	553834	4047386	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Gravity Fault (Continued)									
Lowe Domestic	Lowe Domestic	159	552116	4047002	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
16S/49E-15aaa	16S/49E-15aaa	160	550556	4046842	GF	Gravity fault	open borehole (51 to 120)[3]	Qal[2]	DTNs: MO0007MAJIONPH.012 [DIRS 151529], C; MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$; MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 29, T
Anvil Ranch Irrigation	Anvil Ranch Irrigation	161	548906	4043723	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
16S/49E-36aaa	16S/49E-36aaa	162	553569	4042053	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTNs: MO0007GNDWTRIS.011 [DIRS 151501], $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; MO0007MAJIONPH.014 [DIRS 151531], C
16S/49E-35baa	16S/49E-35baa	163	551307	4042040	GF	Gravity fault	open borehole (26 to 100)[3]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 33, T

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Gravity Fault (Continued)									
Payton Domestic	Payton Domestic	164	553134	4041977	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
16S/49E-36aba	16S/49E-36aba	165	553222	4041836	GF	Gravity fault	open borehole (depth not reported)	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C
16S/49E-35aaa	16S/49E-35aaa	166	551980	4041520	GF	Gravity fault	open borehole (35 to 52)[2]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C
Oettinger Well	Oettinger Well	167	551698	4040954	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
Amargosa Motel (b)	Amargosa Motel (b)	168	551720	4038945	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Gravity Fault (Continued)									
17S/49E-11ba	17S/49E-11ba	169	551873	4038623	GF	Gravity fault	open borehole (20 to 56)[2]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 36, T
Spring Meadows Well #8	Spring Meadows Well #8	170	560913	4038129	GF	Gravity fault	open borehole (depth not reported)	Not reported	DTN: LA0311EK831232.001 [DIRS 166068], 10/15/70 sample
17S/50E-19aab	17S/50E-19aab	171	555998	4035691	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 58, T
USFWS - Five Springs Well	USFWS - Five Springs Well	172	561126	4035571	GF	Gravity fault	open borehole (depth not reported)	Not reported	DTN: LA0311EK831232.001 [DIRS 166068], 8/24/90, 4/28/92, 8/18/92, and 9/22/96 samples; the 1990 and 1992 samples are also in DTN: GS931100121347.007 [DIRS 149611)
Spring Meadows Well #10	Spring Meadows Well #10	173	556916	4034042	GF	Gravity fault	open borehole (depth not reported)	Not reported	DTN: LA0311EK831232.001 [DIRS 166068], 8/15/62 sample
18S/49E-1aba	18S/49E-1aba	174	554035	4031056	GF	Gravity fault	0 (Spring)[3]	Qal[13]	DTN: MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 40, T
18S/50E-6dac	18S/50E-6dac	175	556035	4029960	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C
18S/50E-7aa	18S/50E-7aa	176	556040	4029158	GF	Gravity fault	open borehole (depth not reported)	Qal[13]	DTN: MO0007MAJIONPH.014 [DIRS 151531], C; Claassen 1985 [DIRS 101125], Table 1, sample 59, T

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Amargosa River/ Fortymile Wash									
16S/48E-36dcc	16S/48E-36dcc	177	543530	4040395	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (13 to 120)[3]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 26, T
Crane Domestic	Crane Domestic	178	543587	4037930	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
27N/4E-27bbb	27N/4E-27bbb	179	541520	4034130	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (14 to 90)[3]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 54, T
IMV on Windjammer	IMV on Windjammer	180	548115	4033603	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
17S/49E-29acc	17S/49E-29acc	181	547349	4033420	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (depth not reported)	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 44, T
17S/49E-28bcd	17S/49E-28bcd	182	548370	4033395	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (depth not reported)	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Amargosa River/ Fortymile Wash (Continued)									
18S/49E-2cbc	18S/49E-2cbc	183	551377	4030023	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (22 to 160)[3]	Qal[2]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 41, T
Mom's Place	Mom's Place	184	551996	4029417	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (depth not reported)	Qal[13]	DTNs: GS990808312322.001 [DIRS 149393], T, pH, $\delta^{18}O$, δD, $\delta^{13}C$; GS990808312322.002 [DIRS 162917], ions and ^{14}C; GS021008312322.002 [DIRS 162913], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes
18S/49E-11bbb	18S/49E-11bbb	185	551307	4029283	AR/FMW	Amargosa River/ Fortymile Wash	open borehole (depth not reported)	Qal[13]	DTN: MO0007MAJIONPH.012 [DIRS 151529], C; Claassen 1985 [DIRS 101125], Table 1, sample 42, T
Skeleton Hills									
TW-5	TW-5	186	562604	4054686	SH	Skeleton Hills	open borehole (207 to 244)[15]	Protozoic clastic rocks[16]	DTNs: MO0007MAJIONPH.006 [DIRS 151518], C; MO0007GNDWTRIS.004 [DIRS 151494], $\delta^{18}O$, δD; MO0007MAJIONPH.002 [DIRS 151507], C; Oliver and Root 1997 [DIRS 100069], F^-, Sr^{2+}, $^{87}Sr/^{86}Sr$
Unnamed Well 15S/50E-22-7	Unnamed Well 15S/50E-22-7	187	559605	4053895	SH	Skeleton Hills	open borehole (depth not reported)	Not reported	DTN: LA0311EK831232.001 [DIRS 166068], 11/20/72 sample

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Amargosa Flat									
Amargosa Tracer Hole #2	Amargosa Tracer Hole #2	188	569158	4043531	AF	Amargosa Flat	open borehole (12 to 252)[2]	Paleozoic carbonate rocks[2]	DTN: LA0311EK831232.001 [DIRS 166068], 9/17/66, 10/7/67, 2/15/88 and 2/16/68 samples
Cherry Patch Well, 17S/52E-08cdb	Cherry Patch Well, 17S/52E-08cdb	189	576207	4038588	AF	Amargosa Flat	open borehole (10 to 122)[2]	Qal (limestone)[2]	DTN: LA0311EK831232.001 [DIRS 166068], 8/24/90, 3/24/92, 9/5/91,and 5/15/97 samples; the 1990 through 1992 data are also in DTN: GS931100121347.007 [DIRS 149611]
USDOE-MSH-C shallow Well	USDOE-MSH-C shallow Well	190	565396	4039700	AF	Amargosa Flat	open borehole (depth not reported)	Not reported	DTN: LA0311EK831232.001 [DIRS 166068], 9/27/96 sample
Mine Mountain									
UE-17a	UE-17a	191	574116	4103157	MM	Mine Mountain	Bailed from 254 Open borehole (194 to 354)[6]	Not reported	DTN: LA0311EK831232.001 [DIRS 166068], 6/9/93 sample; also in Rose et al. 1997 [DIRS 144725], samples 56 to 58
UE-1a	UE-1a	192	578395	4100387	MM	Mine Mountain	Bailed from 168 Open borehole (167 to 171)[6]	Tv[5]	DTN: LA0311EK831232.001 [DIRS 166068], 9/1/92 sample; also in Davisson et al. 1994 [DIRS 162939]; Rose et al. 1997 [DIRS 144725], sample 46
UE-1b	UE-1b	193	579004	4100389	MM	Mine Mountain	Bailed from 207 Open borehole (198 to 382)[6]	Paleozoic carbonate rocks[5]	DTN: LA0311EK831232.001 [DIRS 166068], 9/1/92 sample; also in Davisson et al. 1994 [DIRS 162939]; Rose et al. 1997 [DIRS 144725], sample 45
UE-16f	UE-16f	194	574100	4098960	MM	Mine Mountain	Bailed from 395 Open borehole (112 to 422)[6]	Eleana Fm.[5]	DTN: LA0311EK831232.001 [DIRS 166068], 7/12/93; Rose et al. 1997 [DIRS 144725], sample 42, sulfate, SO_4^{2-} and Na^+

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Mine Mountain (Continued)									
UE-14b	UE-14b	195	575427	4087304	MM	Mine Mountain	Not reported	Tv[5]	DTN: LA0311EK831232.001 [DIRS 166068], 9/1/88 and 7/24/91 samples; the 9/1/88 sample is in Chapman and Lyles 1993 [DIRS 162940], p. 39
Pluto 1	Pluto 1	196	579238	4075338	MM	Mine Mountain	Possibly perched[5]	Tv[5]	DTN: LA0311EK831232.001 [DIRS 166068], 11/2/84 sample; also in Chapman and Lyles 1993 [DIRS 162940], p. 38
Pluto 5	Pluto 5	197	579263	4074977	MM	Mine Mountain	Possibly perched[5]	Tv[5]	DTN: LA0311EK831232.001 [DIRS 166068], 9/26/88 sample; also in Chapman and Lyles 1993 [DIRS 162940], p. 38
USGS Test Well F (HTH)	USGS Test Well F (HTH)	198	578858	4068348	MM	Mine Mountain	Not reported	Tv[5]	DTN: LA0311EK831232.001 [DIRS 166068], 5/21/75,2/2/76, and 3/12/80 samples
Funeral Mountains									
Woodcamp Spring	Woodcamp Spring	199	502027	4091249	FMt	Funeral Mountains	0.0 (spring discharge)[12]	Tertiary volcanic rock[12]	DTN: GS960408312323.002 [DIRS 162915], C, I
Bond Gold Mining #13	Bond Gold Mining #13	200	519383	4059841	FMt	Funeral Mountains	open borehole (depth not reported)	Qal[13]	DTN: GS010308312322.003 [DIRS 154734], T, pH, alkalinity, ions, $\delta^{18}O$, δD, $\delta^{13}C$, ^{14}C; GS011108312322.006 [DIRS 162911], $\delta^{34}S$; GS010208312322.001 [DIRS 162908], U concentrations and isotopes; GS010308312322.002 [DIRS 162910], U concentrations; LA0311EK831232.002 [DIRS 166069], $^{87}Sr/^{86}Sr$

Table A4-3. Summary of Groundwater Wells and Data Sources (Continued)

Well Identifier	Abbreviation Used in Appendix	Figure A6-5	UTM-X[a] (m)	UTM-Y[3] (m)	Area[b]		Approximate Interval Sampled (m)[d]	Geologic Unit[c,d]	Reference for Sampled Depth and Chemical (C) and Isotopic (I) Data
Funeral Mountains (Continued)									
Nevares Spring	Nevares Spring	201	516068	516068	FMt	Funeral Mountains	0.0 (spring discharge)[12]	Travertine[12]	DTN: GS960408312323.002 [DIRS 162915], C, I
Travertine Spring	Travertine Spring	202	515211	4032657	FMt	Funeral Mountains	0.0 (spring discharge)[12]	Qal[12]	DTN: GS960408312323.002 [DIRS 162915], C, I

[a] Coordinate data are from (1) LA0311EK831232.001 [DIRS 166068], (2) GS010908312332.002 [DIRS 163555], (3) GS010208312322.001 [DIRS 162908], (4) Paces et al. 2002 [DIRS 158817], (5) GS010808312322.004 [DIRS 156007], and (6) LA0309EK831223.001 [DIRS 165471]. These sources do not always identify whether coordinates are reported relative to North American Datum (NAD) 1927 or 1983, and the coordinates listed may represent a mixture of both coordinate systems. Because of uncertainty in the reference system used in any source, an uncertainty of approximately 100 m results in the coordinates of boreholes listed. Because of the scale at which data are presented, this uncertainty has a negligible effect on the interpretation of groundwater geochemical patterns and flow paths given in this appendix.

[b] See Figure A6-5 and Section A6.3.2 for a definition of subareas near Yucca Mountain. The subareas used in this appendix may differ from subareas used in DTNs that begin MO000…, which are associated with the earlier analysis model report version of this appendix.

[c] Geologic units: Qal Quaternary alluvium; QTal Quaternary-Tertiary alluvium; Tv Tertiary volcanic rocks; Tb Tertiary basalts; Tpt Tertiary Topopah Spring Member of Paintbrush tuff; Tct Tertiary Crater Flat tuff; Th Tertiary tuffaceous beds of Calico Hills; Tac Tertiary Calico Hills Formation; Tcb Tertiary Bullfrog Member of Crater Flat tuff; Tcp Tertiary Prow Pass Member of Crater Flat tuff; Tlr Tertiary Lithic Ridge tuff; DSlm Devonian and Silurian Lone Mountain Dolomite; Srm Silurian Roberts Mountain Dolomite; Tfb (and its subunits Tfbr and Tfbw) are volcanic rocks of the Tertiary Beatty Wash Formation; Tm is the Tertiary Timber Mountain tuff; Tma (and its subunits Tmaw, Tmap and Tmar) are the Tertiary Ammonia Tanks tuff; Tft is a basalt; and Ttc is the Tertiary commendite of Ribbon Cliff). Geologic units are defined in Oliver and Root 1997 [DIRS 100069], p. 5; Buesch et al. 1996 [DIRS 100106], Table 4; McKinley et al. 1991 [DIRS 116222], pp. 5 to 6; Day et al. 1998 [DIRS 101557], map sheet 2; Slate et al. 1999 [DIRS 150228]. Also, see stratigraphic column in Figure A6-2.

[d] C: the DTN or reference was the source for chemical data for this well; I: the DTN or reference was the source for isotopic data for this well. References to sample identifiers in Claassen 1985 [DIRS 101125], Table 1 provide traceability between identifiers used in the listed DTNs and those listed in column 1 of this table. As indicated in footnotes for Tables A4-1 and Table A4-2, many of the data sources listed in this table were used as input for developed-data DTNs: LA0309RR831233.001 [DIRS 166546] and LA0309RR831233.002 [DIRS 166548], which are cited as the sources for the bulk of the data listed in Tables A6-1 and A6-2. In this case, the acquired-data sources have not been listed separately as sources for data in the footnotes of those two tables.

[e] Sources of data on interval depths and geologic units sampled are (1) Benson and McKinley 1985, [DIRS 101036], Table 1, (2) McKinley et al. 1991 [DIRS 116222], Tables 1 and 5, (3) Claassen 1985 [DIRS 101125], Table 1), (4) Rose et al. 2002 [DIRS 162938], Table A-1, (5) Chapman and Lyles 1993 [DIRS 162940], Figures 11, 13, 16), (6) Davisson et al. 1994 [DIRS 162939], Table 1, (7) DTN: LA0311EK831223.001 [DIRS 165985], (8) Robledo et al. 1998 [DIRS 165986], Tables 1 and 4, (9) Graves et al. 1998 [DIRS 155411], throughout report, (10) O'Brien 1998 [DIRS 101278], Table 2, (11) DTN: GS980908312322.008 [DIRS 145412], (12) Steinkampf and Werrell (2001 [DIRS 158818], pp. 11 to 14), (13) lithology estimated from Figure 1 of Claassen 1985 [DIRS 101125], (14) GS010308312322.003 [DIRS 154734], (15) Oliver and Root 1997 [DIRS 100069], *yucca.xls*, (16) Winograd and Thordarson 1975 [DIRS 101167], Plate 1).

A5. ASSUMPTIONS

The scientific analyses presented in this appendix sometimes required that assumptions be made about certain aspects of the hydrochemical or hydrologic system. Typically, these assumptions were made (1) to simplify a problem so that a solution could be approximated, (2) to obtain bounding estimates, or (3) because no relevant data were available at the time the analysis was made.

Table A5-1. Assumptions

	Assumption	Rationale for Assumption
1	To provide an initial assessment of flow directions indicated by the hydraulic gradient in Figure A6-3, flow vectors are drawn parallel to this gradient, implicitly assuming the hydraulic conductivity of the rocks is isotropic.	In spite of the likely anisotropy introduced by the presence of north and northwest trending faults in the Yucca Mountain area, this assumption was made to get an initial sense of the flow directions indicated by the hydraulic gradients. The likelihood that actual flow directions may be more aligned with fault orientations than indicated by these flow lines is acknowledged in the text. This assumption does not influence the conclusions herein that are based solely on groundwater geochemical and isotopic data.
2	The dissolved aluminum concentration of groundwater in the Yucca Mountain area is in equilibrium with kaolinite.	The assumption that groundwater aluminum concentrations are controlled by equilibrium with kaolinite was supported by calculating dissolved aluminum concentrations in equilibrium with a variety of secondary minerals with PHREEQC (Parkhurst and Appelo 1999 [DIRS 159511]) and comparing these calculated concentrations with concentrations measured at a subset of wells in the Yucca Mountain area (Figure A6-30). This assumption affects calculation of mineral saturation indices in Table A6.3-5.
3	For the purpose of calculating mineral saturation indices, the temperature of groundwater samples can be approximated either from published maps of water table temperatures at Yucca Mountain, or, in the Amargosa Desert, can be assumed to be 25°C.	The use of a contour map of water table temperatures (Fridrich et al. 1994 [DIRS 100575], Figure 8) to estimate groundwater sample temperatures at Yucca Mountain is an acceptable approximation because most of the samples for which this approximation was made are from the upper part of the saturated zone (see Table A4-3 for sampled depths and Figure A6-5 for locations of samples 33, 34, 41, 56, 57, and 66). Likewise, the assumption that groundwater samples in the Amargosa Desert with no measured temperatures are at 25°C is an acceptable approximation because most of the measured groundwater sample temperatures are in the range of 20°C to 30°C (see temperature data for samples from the Amargosa Valley (rows 99-107), Amargosa River (rows 108-117), Fortymile Wash—West (rows 118 to 126), Fortymile Wash—South (rows 127 to 141), Fortymile Wash—East (rows 142 to 153), Gravity Fault (rows 154 to 176), and Amargosa River/Fortymile Wash (rows 177-185) in Table A6-1).
4	The chemical and isotopic composition of the groundwater sample from the carbonate aquifer at borehole p#1 (sample p#1(c) in Tables A6-1 and A6-2) and, in particular, its Cl^- and SO_4^{2-} concentrations, are representative of the composition of groundwater in carbonate aquifer at Yucca Mountain.	Borehole p#1 is the only borehole near Yucca Mountain where groundwater was directly sampled from the carbonate aquifer, so this assumption is made out of necessity. The Cl^- and SO_4^{2-} concentrations of groundwater at p#1 (28 and 160 mg/L, respectively) are similar to the concentrations of these ions in groundwater from the carbonate aquifer at Ash Meadows where Cl^- ranges from 21 to 27 mg/L and SO_4^{2-} ranges from 80 to 111 mg/L (Winograd and Pearson 1976 [DIRS 108882], Table 1). The variability in the concentrations of Cl^- and SO_4^{2-} in the carbonate aquifer at Ash Meadows may indicate the extent of the variability that could be expected at Yucca Mountain.

Table A5-1. Assumptions (Continued)

	Assumption	Rationale for Assumption
5	The chloride mass-balance (CMB) method is assumed to be applicable to the estimation of recharge rates at Yucca Mountain. The CMB method assumes one-dimensional, downward piston flow in the soil zone, no run-on or runoff, no Cl^- source other than precipitation, and no Cl^- sink (e.g. the formation of halite is negligible).	The absence of chloride sources and sinks is indicated by the absence of halite or other chloride-bearing minerals in the soils and rocks at Yucca Mountain. The departures of actual flow conditions from the assumption of one-dimensional piston flow are mitigated somewhat for the calculations done on the basis of the saturated-zone chloride data. This result is because, for Yucca Mountain as a whole, flow can be assumed to be vertical between the ground surface and the water table, even though lateral flow in the unsaturated zone could redistribute water on a more local scale. Similarly, when using the saturated-zone data with the CMB method, the effects of nonpiston flow are mitigated because hydrodynamic mixing and mixing in the well bore when groundwater is pumped tend to average the Cl^- concentrations of fast- and slow-moving water percolating through fractures and matrix in the unsaturated zone. Run-on and runoff both can redistribute Cl^- locally at Yucca Mountain. However, although run-on is a factor to consider for wells near Fortymile Wash, run-on from other areas to Yucca Mountain does not occur, and so the total Cl^- balance for Yucca Mountain itself is not affected by this process. Runoff from Yucca Mountain to Fortymile Wash would tend to cause the actual Cl^--deposition rates at Yucca Mountain to be less than those assumed in the calculations and, thus, cause the estimated Yucca Mountain recharge to overestimate the actual recharge.
6	The estimated range of annual deposition rates for chloride at Yucca Mountain encompasses the present-day rate as well as the rates that prevailed when the sampled pore waters infiltrated below the soil zone.	Several independent lines of evidence support this assumption. First, the range of deposition rates assumed for Yucca Mountain reflect the present-day wet and dry chloride deposition rates estimated for sites at Red Rock Canyon and Kawich Range, Nevada (BSC 2002 [DIRS 160247]), which represent climates that are drier and wetter, respectively, than that prevailing at Yucca Mountain today. The second line of evidence is the constancy of the $^{36}Cl/Cl$ ratio throughout the Holocene, based on packrat midden data (Plummer et al. 1997 [DIRS 107034]). Finally, the nearly uniform Cl concentrations in the perched water and SZ groundwater beneath Yucca Mountain also support the assumption. Section A6.3.6.5 addresses the uncertainty in the deposition rate and propagation of that uncertainty through the resulting estimates of recharge obtained by the chloride mass-balance method.
7	The chemical and isotopic composition of deep-perched water from boreholes UZ-14 and SD-7 is representative of local recharge at Yucca Mountain.	A possible conceptual model for the formation of perched water at Yucca Mountain is that perched water originates when local infiltration rates exceed the hydraulic conductivity of the perching layer, so that deep infiltration begins to pond at the top of the layer. The perched water then moves toward the water table to become recharge either by (1) seeping slowly through the matrix of the perching layer, (2) moving laterally down-dip along the top of the perching layer, or (3) by draining down faults where these intersect the perching layer, depending on local structural conditions. Although some additional water/rock interactions such as cation exchange may occur in the deep UZ between the surface and perched-water horizons, the deep perched water already incorporates the effects of evaporative processes and water/rock/gas interactions in the soil zone that dominate the chemical and isotopic compositions of unsaturated-zone waters (Meijer 2002 [DIRS 158813]). The compositions of the deep-perched waters are therefore a good approximation of the water compositions of local recharge.

Table A5-1. Assumptions (Continued)

	Assumption	Rationale for Assumption
8	Carbon isotope exchange is not a significant process affecting ^{14}C activities of groundwater near Yucca Mountain.	The age-correction models (Section A6.3.6.6.2) did not consider the process of carbon-isotope exchange, a process that alters the carbon-isotope composition of groundwater without increasing the net concentrations of elements contained in the carbon-bearing solid phases. Isotope exchange is important to consider where the groundwater is already saturated with calcite and additional interaction between groundwater and calcite that might alter the isotopic composition (^{14}C and $\delta^{13}C$) of the dissolved carbon would not be reflected by a change in the concentration of the total dissolved carbon. The groundwater in the carbonate aquifer is already saturated with calcite, and thus, exchange reactions are important to consider in this environment. In the volcanic aquifer, almost all groundwater samples for which age corrections were made were under saturated with calcite. Any interaction between groundwater and calcite in the volcanic aquifer should, therefore, be reflected by an increase in the dissolved carbon concentrations in the groundwater, a process already considered by the mass-balance approach embedded in the modeling.
9	The $\delta^{13}C$ of calcite in alluvium is similar to the $\delta^{13}C$ of pedogenic calcite in the unsaturated zone of Yucca Mountain (about –4 per mil).	No data presently exists on the isotopic composition of calcite contained in alluvium south and southeast of the repository area at Yucca Mountain. Late-stage fracture-lining calcite from the unsaturated zone has a distribution with a mode of about –6 per mil, whereas intermediate-stage calcite is more uniformly distributed and has a mode of about –2 per mil (Whelan et al. 1998 [DIRS 108865], p. 179). An average value of –4 per mil approximates an average value for the intermediate and late-stage fracture-lining calcite in the unsaturated zone at Yucca Mountain.
10	It is assumed for the purpose of tracing flow lines from chemical and isotopic data that, once in the saturated-zone groundwater system, δD, $\delta^{18}O$, Cl^-, SO_4^{2-}, and $\delta^{34}S$ are sufficiently conservative (i.e., nonreactive) to identify likely flow paths and groundwater mixing relationships.	This assumption is sound for δD and $\delta^{18}O$ because these constitute the water molecule; thus, large amounts of water/rock interaction are required to alter their composition. This assumption is acknowledged in the text as an approximation for Cl^- and SO_4^{2-}. Changes in the input concentrations of these constituents as a result of climate change or modifications due to water/rock interaction will result in variability along a flow path. However, in most cases, this effect is expected to be small. Regardless, the areal contrast in concentrations between these constituents is large enough that meaningful inferences about flow directions can be made.
11	The chemical composition of groundwater at borehole J-11 is representative of groundwater in central Jackass Flats.	Because borehole J-11 is the only borehole that has been drilled and sampled in central Jackass Flats, this is a necessary assumption.
12	A straight-line distance was assumed in evaluating transport times between wells based on ^{14}C.	The straight-line distance assumption allows for straightforward calculation of transport times and results in the fastest transport time. It is therefore a conservative assumption.
13	No correction was made to estimated ^{14}C transport times in fractured volcanics for matrix diffusion.	Corrections for diffusion of ^{14}C into the matrix of fractured volcanics would tend to increase the calculated groundwater transport times because the matrix pore waters tend to have lower pmc values. However, detailed data on the ^{14}C content of pore waters along potential pathways are lacking.
14	No additional ^{14}C is added to groundwater from downgradient recharge as a groundwater moves from an upgradient to a downgradient well defining a flow-path segment.	The data on oxygen and hydrogen isotopes for groundwater sampled in downgradient wells generally indicate lighter isotope ratios as water is sampled from wells progressively further downgradient. The lighter isotope ratios represent older waters (Pleistocene). The lack of modern hydrogen and oxygen isotope ratios in downgradient locations is evidence of minimal modern recharge at these locations.

A.6. SCIENTIFIC ANALYSIS

A6.1 OBJECTIVES

The objective is to provide an analysis of groundwater recharge rates, flow directions and velocities, and mixing proportions of water from different source areas based on groundwater geochemical and isotopic data. An analysis of these processes based on geochemical data can provide an independent basis for evaluating the interpretation of the flow system provided by the SZ site-scale flow model.

The analysis is structured as follows: Section A6.2 provides background information regarding geographic, geologic and hydrologic setting as well as a summary of over twenty five years of geologic and hydrologic research that has taken place in the region. Information within these sections is continually used and evaluated throughout this appendix. Sections A6.3.1 through A6.3.5 provide an overview of the hydrochemical setting in the study area. A discussion of hydrochemical trends with depth for some boreholes provided in Section A6.3.3, areal distribution plots of hydrochemical and isotopic data discussed in Section A6.3.4, and calculated geochemical parameters presented in Section A6.3.5 provide the initial hydrochemical framework for evaluating the hydraulic system. Particular attention is provided in Section A6.3.6 to evaluate the sources and evolution of water beneath Yucca Mountain. Sections A6.3.7 through A6.3.10 then evaluate flow away from Yucca Mountain. Section A6.3.7 evaluates mixing patterns evident in some areas, and Section A6.3.8 describes PHREEQC models of groundwater mixing and evolution. Section A6.3.9 uses ^{14}C groundwater ages to evaluate flow velocities, and Section A6.3.10 confirms the consistency of flow models using FEHM and flow models derived from hydrochemical arguments. Finally, Section A6.3.11 integrates all the above sections to produce a map describing regional flow pathways.

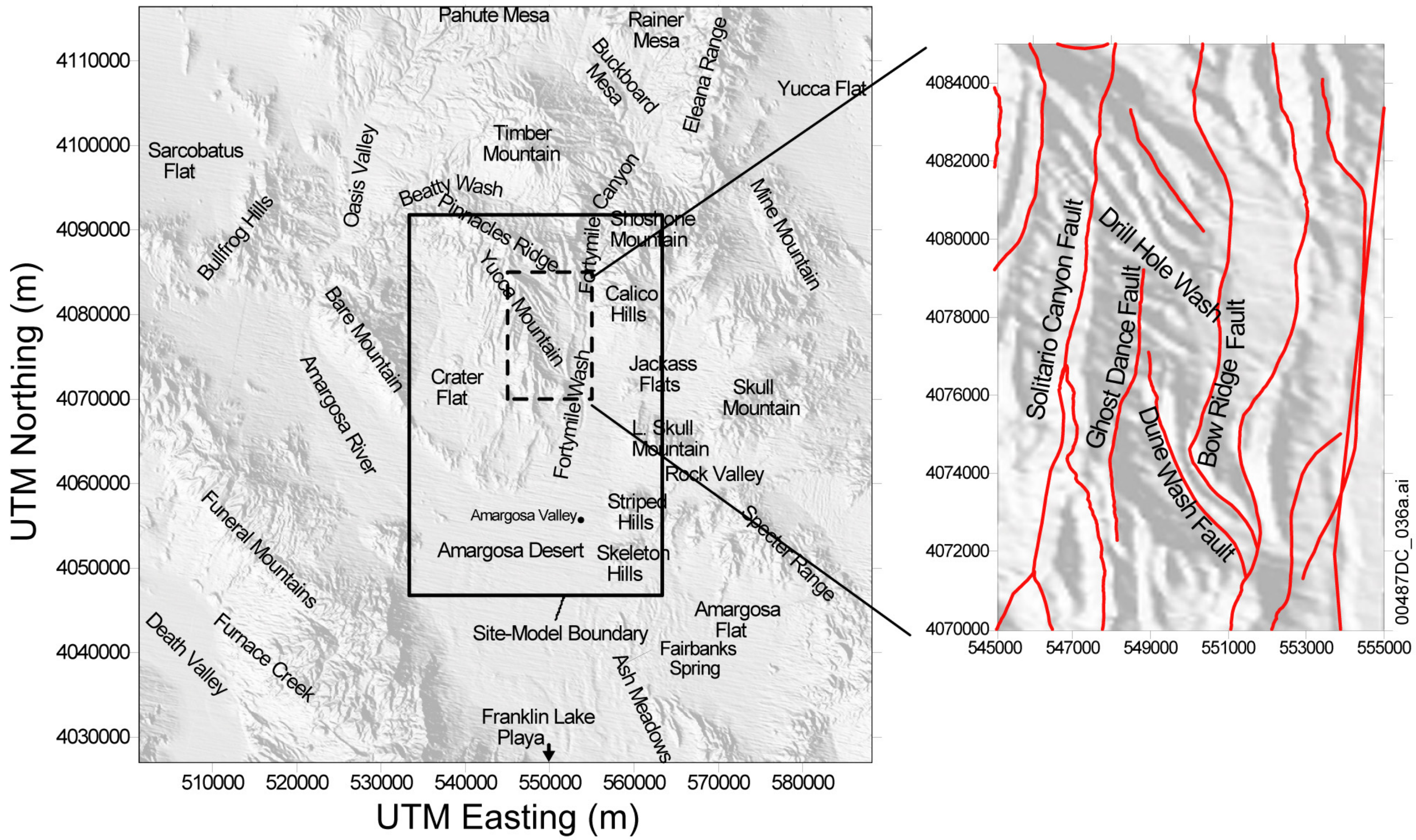
A6.2 INTRODUCTION AND PREVIOUS WORK

A6.2.1 Geography, Geology, and Physical Hydrology

Yucca Mountain is located in the Great Basin about 150 km northwest of Las Vegas, Nevada. The mountain consists of a series of fault-bounded blocks of ash-flow and ash-fall tuffs and a smaller volume of lava deposited between 14 and 11 Ma (million years before present) from a series of calderas located a few to several tens of kilometers to the north in the vicinity of Timber Mountain (Sawyer et al. 1994 [DIRS 100075], Figure 1). Volcanic rocks erupted from these calderas typically thin to the south and eventually pinch out beneath alluvium in the Amargosa Desert (Figure A6-1). Yucca Mountain itself extends southward from Pinnacles Ridge toward the Amargosa Desert (Figure A6-1). Volcanic units on Yucca Mountain typically dip 5 to 10 degrees to the east. Crater Flat is west of Yucca Mountain and separated from it by Solitario Canyon, which is the surface expression of the Solitario Canyon fault—a steeply dipping scissors fault with down-to-the-west displacement of as much as 500 m in southern Yucca Mountain (Day et al. 1998 [DIRS 101557], pp. 6 and 7). Underlying Crater Flat is a thick sequence of alluvium, lava, and tuff that has been locally cut by faults and volcanic dikes. East of Yucca Mountain, and separated from it by Fortymile Wash, is Jackass Flats, which is also underlain by a thick sequence of alluvium and volcanic rocks. Timber Mountain, approximately 25 km to the north of the repository area, is a resurgent dome within the larger caldera complex that erupted the tuffs at Yucca Mountain.

The central block of Yucca Mountain is bounded by Drill Hole Wash on the north, the Solitario Canyon fault on the west, the Bow Ridge fault on the east, and is dissected by the Ghost Dance and Dune Wash faults (Figure A6-1). Topography north of the central block at Yucca Mountain is controlled by long, northwest-trending, fault-controlled washes. Within and south of the central block, washes are shorter and trend eastward. Topography in the southern part of Yucca Mountain is controlled by south-trending faults.

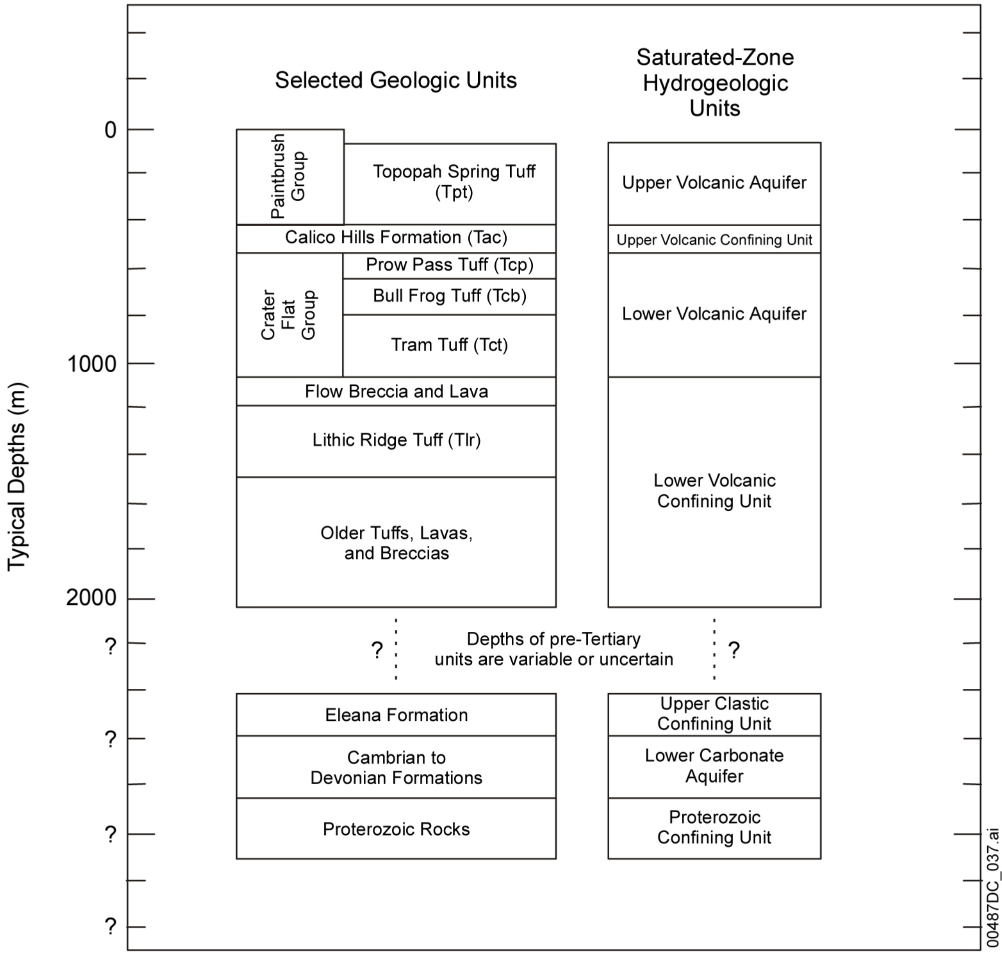
Based on similarities in their core-scale hydrologic and mechanical properties, saturated volcanic units at Yucca Mountain were grouped into two confining layers and two aquifers by Luckey et al. (1996 [DIRS 100465], pp. 17 to 19) (Figure A6-2). Figure A6-2 represents a simplification of the more detailed hydrostratigraphic framework presented in DTN: GS030208312332.001 [DIRS 163087] and used in the SZ site-scale flow model DTN: LA0304TM831231.002 [DIRS 163788] and is shown here only to provide a broad overview of the site hydrostratigraphy. In general, the confining units are zeolitic, nonwelded tuffs and the uppermost aquifers are fractured, welded, and devitrified tuffs (the Upper Volcanic Aquifer) or include intervals of fractured, welded, and devitrified tuffs (the Lower Volcanic Aquifer). Most zeolite formation took place before approximately 11 Ma (Broxton et al. 1987 [DIRS 102004], p. 101; Bish 1989 [DIRS 101194], pp. 31 and 33) and was concentrated in the originally permeable, nonwelded vitric tuffs; zeolitization was less intense in the partly to densely welded, devitrified tuffs that are present in the interiors of the Prow Pass and Bullfrog tuffs of the Crater Flat group. Zeolitization and clay alteration is more intense and zeolite facies alteration occurs higher in the section in northern Yucca Mountain because of the high paleotemperature gradients that existed near the calderas (Broxton et al. 1987 [DIRS 102004], pp. 107 to 108; Bish 1989 [DIRS 101194], p. 35). Regionally, argillite of the Eleana Formation is a confining layer, and the Paleozoic carbonate rocks are an important aquifer (Winograd and Thordarson 1975 [DIRS 101167], Table 1, columns 6, 7; Laczniak et al. 1996 [DIRS 103012], Table 1). The Eleana Formation is inferred to be present in northern Yucca Mountain based on areal magnetic data (Luckey et al. 1996 [DIRS 100465], p. 20), though it has not been penetrated by drill core. The carbonate aquifer was penetrated at borehole p#1 (the correspondence between well identifiers and borehole abbreviations is given in Table A4-3), but its continuity and thickness in this part of southern Nevada, and consequently its importance as a regional aquifer, is thought to be less near Yucca Mountain than in areas farther to the east (Thomas et al. 1996 [DIRS 101933], Figure 17).



DTN: GS010908314221.001 [DIRS 145263] (Tertiary faults).

NOTE: The solid rectangle is the boundary of the SZ site-scale flow and transport model. UTM=Universal Transverse Mercator.

Figure A6-1. Important Physiographic Features near Yucca Mountain

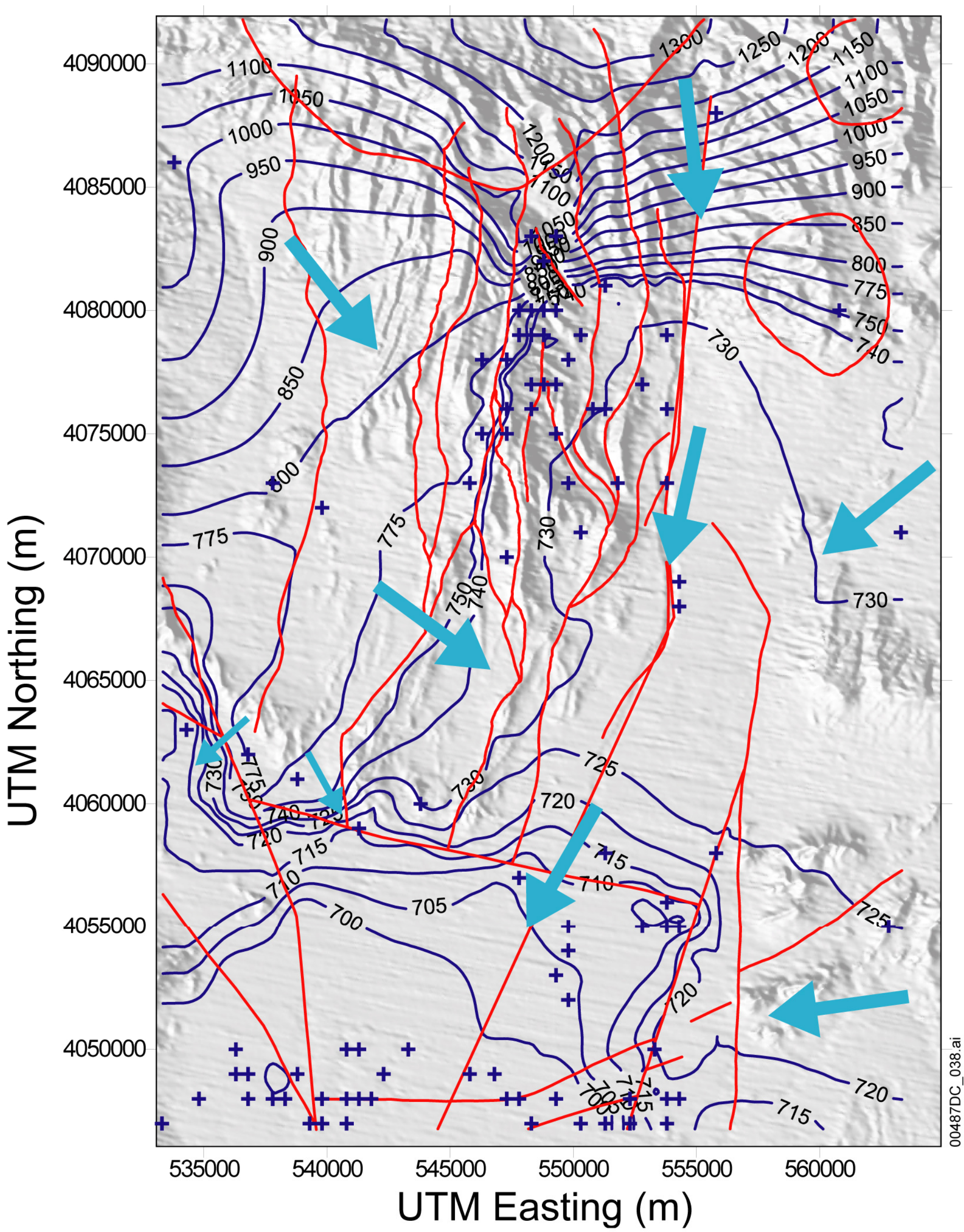


Source: Luckey et al. 1996 [DIRS 100465], Figure 7.

NOTE: Valley Fill of variable age, consisting of sands, gravels, clays, freshwater limestones, and basaltic lavas, overlies various units of the Tertiary volcanic rocks and pre-Tertiary rocks in basins to the west, east, and south of Yucca Mountain. For example, see Kilroy 1991 [DIRS 103010], Figure 3.

Figure A6-2. Selected Geologic and Hydrogeologic Units for the Saturated Zone at Yucca Mountain

A map of the potentiometric surface in the Yucca Mountain area was developed as part of an associated analysis report (USGS 2001 [DIRS 154625], Figure 1-2) based on average water–level data collected from 1985 to 1995 (Figure A6-3). The potentiometric-surface elevations at individual boreholes are based on composite water levels in the volcanic units or, at boreholes where heads were measured at multiple depths in the units, on the shallowest head measurement. (USGS 2001 [DIRS 154625], p. 18). The water levels have been influenced by local pumping in the southern part of the model area (USGS 2001 [DIRS 154625], p. 23).



Source: USGS (2001 [DIRS 154625], Figure 1-2); DTNs: GS010908314221.001 [DIRS 145263] (Tertiary faults); GS000508312332.001 [DIRS 149947] (Water-level contours).

NOTE: The inferred groundwater flow directions are based on Assumption 1 in Table A5-1. The circular areas outlined in red near the Calico Hills in the northeast corner of the map are zones of hydrothermal alteration associated with granitic intrusions, and the semicircular area along the central northern portion of the map is the southern boundary of the Claim Canyon caldera (BSC 2004 ([DIRS 170037], Table 6-17; BSC 2004 [DIRS 170008], Figure 6-3; and Zyvoloski et al. 2003 [DIRS 163341], Figure 2b). The other red lines are selected faults; blue crosses indicated the location of hydraulic head measurements. Blue lines are contours showing elevation (in meters above sea level) of the potentiometric surface; contour intervals vary. UTM=Universal Transverse Mercator. For illustrative/historical perspective purposes only.

Figure A6-3. Potentiometric Surface and Inferred Flow Directions (light blue arrows) for Yucca Mountain and Vicinity

Several possible flow directions were defined by drawing arrows parallel to the gradient in the potentiometric surface (Figure A6-3). The flow directions were drawn under the assumption that hydraulic conductivity and transmissivity are isotropic (Assumption 1 in Table A5-1). In fractured-rock aquifers, such as those at Yucca Mountain, hydraulic conductivity probably is anisotropic (Luckey et al. 1996 [DIRS 100465], p. 36). Nonetheless, this assumption provides a starting point for evaluating the possible flow pathways of groundwater in the Yucca Mountain area. Groundwater models of the site that account for the effects of faults and anisotropy on the flow paths may indicate paths substantially different than those drawn from Figure A6-3.

The flow paths shown in Figure A6-3 indicate that water may flow from the north and northwest under Yucca Mountain. In Figure A6-3, some of the flow from the north is predicted to flow southeastward toward Fortymile Wash in northern Yucca Mountain, an area dominated by northwest-trending, fault-controlled washes. The inferred flow directions indicate that groundwater flows southeast from Yucca Mountain and southwest from Jackass Flats toward the Fortymile Wash area. Groundwater from the Fortymile Canyon area flows south and then southwest in the southern part of the site model area. Flow in the southern part of Yucca Mountain is predominantly southeastward toward Fortymile Wash rather than south toward the Amargosa Desert (Figure A6-3). The faults in the southern part of Yucca Mountain do not seem to exert an observable effect on the potentiometric surface, but this may reflect the sparseness of boreholes and small hydraulic gradient in this area.

A6.2.2 Previous Hydrochemical Investigations

Yucca Mountain has been under investigation as a repository site since the early 1980s, and an extensive body of literature exists concerning its groundwater hydrochemical and isotopic characteristics. The following summary of that literature is not exhaustive but represents the range of interpretations that have been made concerning groundwater flow at and near Yucca Mountain. Literature data were used to create and evaluate conceptual models, corroborate existing models, and to enhance the database of hydrochemistry data obtained by the Project.

Several published studies (White and Chuma 1987 [DIRS 108871]; Benson and Klieforth 1989 [DIRS 104370]; Stuckless et al. 1991 [DIRS 101159]; Fridrich et al. 1994 [DIRS 100575]; Luckey et al. 1996 [DIRS 100465]; Campana and Byer 1996 [DIRS 126814]; Paces et al. 2002 [DIRS 158817]) have focused on the origin and flow paths of groundwater in the vicinity of Yucca Mountain. These authors primarily differed with respect to the extent of recharge occurring through Yucca Mountain or along Fortymile Wash, the residence time of groundwater beneath Yucca Mountain, and the extent of mixing between the volcanic and carbonate aquifers.

Based on δD and $\delta^{18}O$ data for the Yucca Mountain region, Benson and Klieforth (1989 [DIRS 104370], p. 48) proposed that groundwater beneath Yucca Mountain could be a mixture of overland flow along Fortymile Wash and groundwater flow from upland areas to the north (Pahute Mesa). Benson and Klieforth (1989 [DIRS 104370], pp. 48 and 49, Figure 11) reported that the $\delta^{18}O$ values of groundwater in the vicinity of Yucca Mountain were lower for water with apparent ^{14}C ages between 18.5 and 9 ka (thousand years before present) and were higher and constant since then, a relation that was attributed to global climate change and accompanying changes in the paths of storms bringing moisture to southern Nevada prior to 9 ka. Benson and Klieforth (1989 [DIRS 104370], p. 42) also argued that groundwater ^{14}C ages in the

Yucca Mountain area do not require substantial correction to account for the dissolution of calcite, based on geochemical modeling of three wells in Fortymile Wash by White and Chuma (1987 [DIRS 108871], Table 2, Figure 23) and the observation that surface runoff in Fortymile Wash was saturated with calcite and yet still had a ^{14}C activity of 100% modern carbon (pmc).

Groundwater in the volcanic aquifers in the Yucca Mountain area was interpreted by Stuckless et al. (1991 [DIRS 101159], p. 1,414) to be a mixture of at least three end members. One source of groundwater in the volcanic aquifer, represented by groundwater from borehole UE-29 a#2 in Fortymile Canyon, is characterized by isotopically light ^{13}C ($\delta^{13}C$), a high ^{14}C activity, and isotopically heavy δD. This groundwater is either mixed with a second source of groundwater from the Paleozoic carbonate aquifer having an isotopically heavy $\delta^{13}C$ and a low ^{14}C activity or, alternatively, is modified by calcite derived from the carbonate aquifer with these isotopic characteristics. A third, poorly constrained end member with a $\delta^{13}C$ value and ^{14}C activity intermediate between that of the first and second sources and having a lighter δD value than the first source was hypothesized to explain the scatter in the $\delta^{13}C$ and ^{14}C about a possible mixing trend line (Stuckless et al. 1991 [DIRS 101159], Figure 4). Groundwater at Pahute Mesa from borehole UE-20 a#2 has these characteristics and it was suggested by Stuckless et al. (1991 [DIRS 101159], p. 1,414) as a possible third source for the groundwater at Yucca Mountain.

Fridrich et al. (1994 [DIRS 100575], pp. 153 to 159) used the spatial variability in $\delta^{13}C$, water table temperature, magnetic data, and unsaturated zone heat flux to infer that groundwater in the northern part of Yucca Mountain entered the deep carbonate aquifer and reemerged into the shallow volcanic aquifer along faults in the central and southern parts of the mountain. Luckey et al. (1996 [DIRS 100465], p. 44) noted the downgradient increase in the calcium-to-sodium ratio from west to east across Yucca Mountain and speculated that it might reflect either upwelling from the underlying carbonate aquifer through faults on the east side of Yucca Mountain or mixing of water flowing from the west with calcium-rich water recharged from Fortymile Wash.

Campana and Byer (1996 [DIRS 126814], p. 465) presented a steady-state mixing-cell model of the NTS regional groundwater flow system that used corrected ^{14}C ages to determine flow volumes and directions and recharge rates in the regional flow system. Their results indicated that between 28% and 88% of the groundwater beneath Yucca Mountain originated as local recharge, which was estimated to be between 1.9 mm/yr^{-1} to 4.2 mm/yr^{-1} as an annual average distributed evenly across the cell's surface area (Campana and Byer 1996 [DIRS 126814], p. 473). In their model, the remainder of the flow beneath Yucca Mountain originated from the west in Crater Flat. Flow from upland areas north of Yucca Mountain was diverted eastward toward Fortymile Canyon and Fortymile Wash before reaching Yucca Mountain. Groundwater beneath Yucca Mountain was interpreted by Campana and Byer (1996 [DIRS 126814], Figure 5) to be a mixture of groundwaters having different ^{14}C activities, with a mean age of 10.9- to 16.0-ka and a median age of 6.3- to 6.5-ka (Campana and Byer 1996 [DIRS 126814], Table 7). Approximately 20% to 25% of the total recharge in their regional model domain originated from the Fortymile Canyon and Wash area, where areally distributed recharge rates were estimated to be 26 to 32 mm/yr^{-1} (5.3×10^6 to 6.6×10^6 m^3/yr^{-1}) (Campana and Byer 1996 [DIRS 126814],

p. 476). Water in the Amargosa Desert originated from groundwater flow from Fortymile Canyon and Wash area and Crater Flat.

Based on $^{234}U/^{238}U$ activity ratios in perched water and the underlying groundwater, Paces et al. (2002 [DIRS 158817]) concluded that at least some of the shallow groundwater presently beneath Yucca Mountain appears to have been recharged locally. Paces et al. (2002 [DIRS 158817], p. 770) suggested a conceptual model that explains the presence of high $^{234}U/^{238}U$ data in the saturated zone beneath Yucca Mountain. The hydraulic barriers that cause the comparatively large hydraulic gradients in the northern and western parts of Yucca Mountain inhibit underflow from upgradient areas, thereby allowing the chemical and isotopic composition of a small amount of local recharge to exert a prominent influence on the isotopic and chemical composition of the groundwater. Likewise, because both the present-day recharge rates and rates of groundwater flow from upgradient areas are small, hydraulic gradients beneath Yucca Mountain are relatively flat and groundwater that was recharged at Yucca Mountain in the late Pleistocene continues to persist in the groundwater beneath the Yucca Mountain (Paces et al. 2002 [DIRS 158817], p. 770). The absence of high $^{234}U/^{238}U$ activity ratios in groundwater downgradient from Yucca Mountain could reflect the hydraulic isolation of Yucca Mountain, dilution by Fortymile Wash groundwater or other Yucca Mountain recharge with lower $^{234}U/^{238}U$ activity ratios (bulk-rock dissolution seems to have lowered $^{234}U/^{238}U$ activity ratios in perched water at borehole USW SD-7 (Paces et al. 2002 [DIRS 158817], p. 768)), water/rock interactions that incorporate other sources of uranium, or the upwelling of small amounts of groundwater from the carbonate aquifer.

Winograd and Thordarson (1975 [DIRS 101167], p. C111) concluded from chemical data that groundwater in the central Amargosa Desert (Figure A6-1) originates from at least three sources: (1) water dominated by calcium, magnesium, sodium, and bicarbonate that flows across the hydraulic barrier responsible for springs at Ash Meadows; (2) water southwest of Amargosa Valley (formerly, Lathrop Wells) dominated by sodium, potassium, and bicarbonate that probably flows from western Jackass Flats; and (3) water in the west-central and northwestern Amargosa Desert that flows from Oasis Valley. In addition, Winograd and Thordarson (1975 [DIRS 101167], p. C112) noted the dilute nature of the groundwater near Fortymile Wash and interpreted the low dissolved solids content of this water to indicate an origin from paleorecharge along the channel rather than underflow from areas north of Jackass Flats. Winograd and Thordarson (1975 [DIRS 101167], p. C112) also noted the higher dissolved solids content in wells at and south of Amargosa Valley, which they attributed to small amounts of groundwater leaking upward from the carbonate aquifer into the valley fill near the Gravity fault.

Claassen (1985 [DIRS 101125]) and White and Chuma (1987 [DIRS 108871]) presented different hypotheses regarding the origin of water in the northern Amargosa Desert near the present-day Fortymile Wash drainage. Claassen (1985 [DIRS 101125], p. F30) argued that groundwater near surface drainages was predominantly derived from surface runoff during the Pleistocene and the very early Holocene based on its apparent ^{14}C age (Claassen 1985 [DIRS 101125], Figure 15), and on the high ratio of calcium plus magnesium to sodium plus potassium [(Ca + Mg)/(Na + K)] of groundwater from the northern Amargosa Desert compared to groundwater from upgradient locations (Claassen 1985 [DIRS 101125], p. F13, Figure 9). The $^{234}U/^{238}U$ activity ratios and δD values of groundwater near Fortymile Wash in the northern Amargosa Desert were also later interpreted as supportive of this hypothesis (Paces et al. 2002

[DIRS 158817], p. 767). In contrast, White and Chuma (1987 [DIRS 108871], p. 578) argued that groundwater in the northern Amargosa Desert evolved chemically from groundwater that had recharged upgradient in Fortymile Canyon. The ^{14}C age of groundwater in the northern Amargosa was used to calculate groundwater velocities beneath Fortymile Wash of between 3 and 30 m yr^{-1} over an average distance of about 15 km extending southward from borehole J-13 to the north-central Amargosa Desert (White and Chuma 1987 [DIRS 108871], p. 578).

A6.3 ANALYSIS OF HYDROCHEMICAL AND ISOTOPIC DATA

This section presents the results of the analysis of the hydrochemical and isotopic data in the vicinity of Yucca Mountain in eleven major subsections. Section A6.3.1 discusses factors affecting the chemical and isotopic composition of groundwater. In section A6.3.2 all groundwater samples evaluated in this appendix are assigned to a specific grouping to facilitate interpretation and discussion. Section A6.3.3 discusses depth-dependent trends in the chemical and isotopic composition of groundwater. Section A6.3.4 presents areal distribution maps of hydrochemical data and discusses geographic trends shown by these data. Section A6.3.5 presents areal distribution maps showing calculated geochemical parameters such as mineral saturation indices. Section A6.3.6 presents an evaluation of the evidence regarding local recharge at Yucca Mountain. Also discussed in this subsection are evaluations of the evidence for the timing and magnitude of recharge. Section A6.3.7 presents an evaluation of mixing relations among groundwaters. Section A6.3.8 presents an analysis of mixing and water rock interactions using PHREEQC V2.3 (BSC 2001 [DIRS 155323]). Section A6.3.9 addresses groundwater flow velocities. Section A6.3.10 presents results of the site-scale saturated zone groundwater flow model for a portion of the study area. Section A6.3.11 presents an analysis of groundwater flow paths in the Yucca Mountain region based on cumulative evidence presented in the previous sections.

The data derived from the DTNs and other sources are summarized here for each sample/well location for the major ions (Table A6-1) and for the isotopes and trace elements (Table A6-2). Where multiple sets of data were available for a location/sample, these data were averaged to derive the values shown in these two tables, and the areal distribution of the hydrochemical and isotopic data discussed in this section and portrayed on figures of the area of study uses the compiled values of Tables A6-1 and A6-2. All analytical data have uncertainty associated with the individual values, as fully described in Sections A7.3.1 and A7.3.2. Because these samples were collected over a time-span of several decades by different organizations using different methods, analytical precision and accuracy may be variable for particular analytes. In many cases, the original data sources do not provide an indication of the precision or accuracy. However, a sense of the uncertainties associated with historic measurements can be obtained from data that are more recently collected; uncertainties in historic data are probably higher than the values listed below because of recent developments in measurement technology.

Analytical accuracy for recent measurements are (Section A7.3.1):

- Ten percent for major anions, cations and strontium concentration, except for fluoride, for which accuracy is estimated as better than ±15%. In some cases, strontium was determined by isotope dilution, mass spectrometry methods, for which data are more precise (e.g., ±0.5%)

- ±3.0 per mil for δD, ±0.2 per mil for $\delta^{18}O$, $\delta^{13}C$, and $\delta^{34}S$, and ±0.1 pmc for ^{14}C
- Better than 1% for uranium concentrations and from 0.09% to 4.5% (with a mean of 0.73%) for $^{234}U/^{238}U$
- ±0.00001 for $^{87}Sr/^{86}Sr$, which translates to an uncertainty of approximately 0.01 per mil in $\delta^{87}Sr$ units.

An additional guide to the reliability of individual water analyses is also provided by the calculated charge-balance errors listed in Table A6-3. Groundwaters from most sites used in this analysis, especially those near Yucca Mountain itself, have charge-balance errors less than ± 5%. However, groundwaters from some outlying areas that were used as data in this analysis have charge-balance errors as high as 10% to 20%. These sample sites are located primarily in the Mine Mountain group of samples and did not have a significant influence on the conclusions derived in this analysis.

Table A6-1. Field Parameters and Major Ion Composition

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Oasis Valley/NW Amargosa													
ER-EC-08	1	38.2	8.0	10.3	0.9	120.0	5.6	50.7	84.8	176.8	—[d]	5.3	49.1
ER-OV-01	2	25.7	8.3	6.2	0.1	139.7	6.8	45.6	82.7	196.9	1.7	2.1	70.0
ER-OV-06a	3	28.6	8.3	2.1	0.7	144.5	7.5	48.5	80.0	197.9	3.0	3.1	52.9
ER-OV-05	4	21.9	7.8	21.5	4.4	103.5	10.0	37.7	55.6	235.6	—	1.7	82.4
ER-OV-02	5	18.9	8.2	14.3	0.6	143.0	4.1	51.2	88.1	227.1	—	2.3	57.4
Springdale Upper Well (10S/47E-32adc) (11/12/97)	6	23.6	7.7	22.0	4.1	130.0	8.7	37.2	67.7	292.8	—	2.1	69.9
Goss Springs North (11S/47E-10bad) (11/13/97)	7	17.7	8.2	16.4	1.2	107.0	5.0	43.0	76.4	180.1	—	2.4	53.2
Er-OV-03a	8	17.5	8.1	14.0	1.0	118.0	5.2	42.6	76.0	183.6	—	2.3	54.7
ER-OV-03a3	9	21.2	8.3	13.3	1.1	120.5	5.7	44.9	81.2	184.2	—	2.1	55.1
ER-OV-03a2	10	20.0	9.2	5.7	1.0	331.0	84.7	262.0	295.0	186.2	41.6	—	20.0
Goss Spring (11S/47E-10bcc)	11	22.0	7.7	17.5	1.3	116.5	5.1	45.0	78.1	181.0	—	2.8	50.4
ER-OV-04a (11/07/97)	12	23.7	8.4	8.7	0.1	98.8	7.8	28.2	59.9	162.4	2.2	2.8	68.9
Beatty Well no. 1 (Wat&Sanit Distr)	13	22.2	8.0	39.2	5.5	126.3	8.5	48.4	113.0	203.0	—	1.4	—
Bond Gold Mining #1	14	—	8.3	23.0	6.0	65.0	7.3	40.0	52.0	161.0	0.0	0.6	29.0
US Ecology MW-313	15	—	7.5	54.0	16.0	146.0	13.0	69.0	205.0	336.0	0.0	5.0	68.0
US Ecology MW-600	16	—	7.9	20.0	11.5	167.5	8.8	67.5	153.0	296.0	0.0	5.2	62.5
NECWell	17	—	7.6	54.9	14.1	170.1	10.2	79.1	190.2	328.3	0.0	—	70.3
US Ecology MR-3	18	—	7.7	—	—	—	—	—	—	325.0	0.0	—	—
Timber Mountain													
UE-18r	19	30.6	8.2	18.5	0.7	73.3	2.7	6.8	19.7	202.8	5.2	2.7	48.6
ER-18-2	20	55.2	7.6	5.8	0.2	351.7	3.1	13.2	54.0	730.0	—	12.8	42.8
ER-EC-05	21	29.9	8.0	20.3	0.6	73.9	1.7	16.2	35.5	176.8	—	4.7	40.9
Coffer's Ranch Windmill Well	22	20.1	8.3	16.2	0.2	70.6	0.9	7.5	30.2	184.0	—	3.4	40.2
ER-OV-03c	23	22.2	8.2	15.1	0.4	79.7	1.3	17.4	43.6	161.5	—	4.5	42.9
ER-EC-07	24	30.0	7.9	21.6	1.7	36.8	3.1	6.0	18.3	148.8	—	1.5	44.0

Table A6-1. Field Parameters and Major Ion Composition (Continued)

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Fortymile Wash—North													
Water Well 8	25	24.2	7.3	7.9	1.2	31.1	3.3	7.3	15.0	78.0	—	0.7	50.0
Test Well 1 (USGS HTH #1)	26	26.6	8.7	1.2	0.0	51.3	0.5	3.2	8.7	104.0	—	—	19.5
UE-18t	27	—	8.6	22.2	1.0	141.0	8.2	64.4	10.8	331.0	—	—	7.0
ER-30-1 (upper)	28	22.9	9.4	3.5	0.1	62.0	1.8	6.2	12.0	87.5	22.1	1.7	29.0
ER-30-1 (lower)	29	24.3	9.2	2.1	0.1	65.0	1.0	6.5	9.9	106.3	11.1	1.4	25.0
a#2(dp)	30	25.1	7.2	10.0	0.2	44.0	1.1	11.0	22.0	107.0	0.0	1.0	44.0
a#2(sh)	31	22.7	7.0	10.0	0.3	44.0	1.3	8.8	21.0	107.0	0.0	0.9	44.0
UE-29a#1 HTH	32	22.9	7.6	15.0	2.3	36.5	4.1	7.9	16.2	108.9	0.0	0.6	57.2
WT#15	33	33.0[b]	7.5	12.0	1.7	62.0	4.6	12.0	16.0	166.0	0.0	—	52.0
WT#14	34	30.0[b]	7.3	10.0	0.8	45.0	5.0	8.2	22.0	119.0	0.0	—	57.0
J-13	35	31.0	7.2	12.0	2.1	42.0	5.0	7.1	17.0	124.0	0.0	2.4	57.0
J-12	36	27.0	7.1	14.0	2.1	38.0	5.1	7.3	22.0	119.0	0.0	2.1	54.0
JF#3	37	26.6	7.7	18.0	3.1	38.0	8.9	10.0	30.0	120.0	0.0	1.6	56.0
Solitario Canyon Wash													
H-6(bh)	38	37.8	8.1	4.1	0.1	86.0	1.3	7.6	29.0	182.0	0.0	4.7	48.0
H-6(Tct)	39	41.6	8.3	1.4	0.0	88.0	1.3	7.2	25.0	217.0	0.0	3.9	47.0
H-6(Tcb)	40	37.2	8.3	4.7	0.1	88.0	1.4	7.4	32.0	234.0	0.0	4.7	49.0
WT-7	41	34.0[b]	8.7	2.6	0.2	97.0	2.1	13.0	7.2	252.0	0.0	—	20.0
WT-10	42	38.5	8.4	2.6	0.1	94.5	1.0	7.8	33.5	186.0	0.0	3.7	46.5
Yucca Mountain—Crest													
G-2	43	34.2	7.5	7.7	0.5	46.0	5.3	6.5	15.0	121.0	0.0	1.0	51.0
USW WT-24	44	—	7.9	0.3	0.036	59.0	1.6	6.7	15.0	119.0	0.0	0.9	53.0
UZ-14(sh)	45	25.7	8.4	0.48	0.023	70.0	1.9	6.7	14.0	133	2.7	6.3	44
UZ-14(dp)	46	27.5	8.4	0.2	0.030	74.0	1.9	7.7	14.0	137.0	3.0	6.7	47
H-1(Tcp)	47	33.0	7.7	4.5	>01	51.0	2.4	5.7	18.0	115.0	0.0	1.2	47.0
H-1(Tcb)	48	34.7	7.7	6.2	>0.1	51.0	1.6	5.8	19.0	122.0	0.0	1.0	40.0
H-5	49	35.9	7.9	2.0	0.0	60.0	2.1	6.1	16.0	126.5	0.0	1.4	48.0

Table A6-1. Field Parameters and Major Ion Composition (Continued)

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Yucca Mountain—Crest (Continued)													
USW SD-6	50	35.0	8.4	0.4	0.0	90.6	1.5	6.8	26.7	181.8	2.5	4.7	45.6
H-3	51	26.5	9.2	0.8	0.0	120.0	1.1	9.5	31.0	274.0	0.0	5.5	43.0
Yucca Mountain—Central													
G-4	52	35.6	7.7	13.0	0.2	57.0	2.1	5.9	19.0	139.0	0.0	2.5	45.0
b#1(Tcb)	53	37.2	7.1	18.0	0.7	46.0	2.8	7.5	21.0	133.0	0.0	1.6	51.0
b#1(bh)	54	36.0	7.3	18.0	0.7	49.5	3.6	10.8	23.0	156.0	0.0	1.6	52.5
H-4	55	34.8	7.4	17.0	0.3	73.0	2.6	6.9	26.0	173.0	0.0	4.6	46.0
UZ#16	56	30.0[b]	—	11.4	1.6	79.2	—	10.6	29.1	210.0	0.0	—	36.2
Yucca Mountain—Southeast													
ONC#1	57	31.0[b]	8.7	13.0	1.1	51.0	3.6	7.1	24.0	115.0	8.8	—	27.0
c#1	58	41.5	7.6	11.0	0.3	56.0	2.0	7.4	23.0	151.0	0.0	2.1	56.0
c#3	59	40.8	7.7	11.0	0.4	55.0	1.9	7.2	22.0	137.0	0.0	2.0	53.0
c#3(95-97)	60	40.8[c]	7.7	11.0	0.3	57.0	1.9	6.5	19.0	141.0	0.0	—	58.0
c#2	61	40.5	7.7	12.0	0.4	54.0	2.1	7.1	22.0	139.0	0.0	2.1	54.0
p#1(v)	62	44.3	6.8	37.0	10.0	92.0	5.6	13.0	38.0	344.0	0.0	3.4	49.0
p#1(c)	63	56.0	6.6	100.0	39.0	150.0	12.0	28.0	160.0	694.0	0.0	4.7	41.0
WT-17	64	28.7	7.1	8.9	0.9	49.0	2.6	6.4	17.5	129.5	0.0	2.0	39.0
WT#3	65	31.8	7.6	11.2	1.0	49.0	3.9	6.0	18.3	138.5	0.0	2.3	56.2
WT#12	66	33.0[b]	7.6	15.0	0.3	66.0	2.6	7.8	28.0	167.0	0.0	3.1	47.0
Jackass Flats													
UE-25 J-11	67	—	8.1	76.5	15.0	154.0	17.0	17.5	479.5	82.0	0.0	1.2	57.5
Crater Flat													
GEXA Well4	68	31.8	7.9	11.5	0.4	71.0	3.3	13.5	45.5	150.0	0.0	3.2	48.0
VH-1	69	35.4	7.6	10.3	1.5	79.0	1.9	10.3	44.3	164.7	0.0	2.7	49.7
Southwest Crater Flat													
VH-2	70	32.8	7.1	78.5	29.8	70.8	8.1	16.0	142.5	391.8	0.0	1.1	26.3
NC-EWDP-7S	71	21.5	7.3	77.0	37.0	86.0	8.2	19.5	167.0	420.0	0.0	1.0	23.0

Table A6-1. Field Parameters and Major Ion Composition (Continued)

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Southwest Crater Flat (Continued)													
NC-EWDP-7SC	72	—	7.2	83.0	38.0	90.7	4.3	22.0	179.0	429.0	0.0	0.9	23.7
NC-EWDP-1DX	73	—	7.2	55.5	31.0	73.5	10.0	16.0	136.0	369.0	0.0	0.7	46.5
NC-EWDP-1DX Zone 2	74	28.6	6.7	40.0	11.0	329.7	6.2	49.7	112.3	1011.5	0.0	11.0	51.3
NC-EWDP-1S Zone 1	75	26.7	7.4	57.5	30.5	65.0	9.0	15.5	128.5	360.0	0.0	0.6	50.5
NC-EWDP-1S Zone 2	76	27.6	7.3	55.5	30.5	64.5	8.9	15.5	126.0	356.0	0.0	0.6	48.5
NC-EWDP-1S	77	27.8	7.3	59.0	31.0	67.5	8.6	15.0	127.0	358.0	0.0	0.6	55.0
NC-EWDP-12PA	78	28.5	6.8	30.3	8.2	146.0	27.0	14.0	102.3	414.5	0.0	4.1	69.3
NC-EWDP-12PB	79	29.3	6.9	30.5	8.2	140.5	27.0	14.0	105.0	396.5	0.0	4.2	68.0
NC-EWDP-12PC	80	28.6	7.5	53.0	27.5	72.0	10.0	14.0	123.5	323.0	0.0	1.0	55.5
Southern Yucca Mountain													
NC-EWDP-09SX	81	28.4	8.0	20.3	7.7	76	4.3	11.0	61.7	212.3	0.0	2.2	52.7
NC-EWDP-9SX Zone 1	82	26.0	8.3	17.5	5.8	76.5	5.5	15.0	57.5	193.5	1.9	2.2	40.5
NC-EWDP-9SX Zone 2	83	27.6	7.9	18.0	7.2	73.0	4.5	11.3	59.3	203.5	0.0	2.1	44.7
NC-EWDP-9SX Zone 3	84	27.5	8.1	17.5	7.1	71.5	4.2	10.0	58.0	207.0	0.0	2.2	42.5
NC-EWDP-9SX Zone 4	85	27.9	8.0	18.3	7.2	70.3	3.8	9.9	58.3	208.7	0.0	2.1	46.3
NC-EWDP-03D	86	34.3	8.4	0.5	0.1	113.0	3.0	9.0	45.0	223.3	6.2	2.9	54.0
NC-EWDP-3S Zone 2	87	32.2	8.7	0.8	0.1	127.5	1.8	18.0	47.5	224.5	11.7	3.0	59.0
NC-EWDP-3S Zone 3	88	32.4	8.9	0.8	0.1	134.7	3.0	10.2	47.3	255.5	23.5	4.2	47.7
CIND-R-LITE	89	50.0[b]	7.8	12.3	6.2	71.7	4.0	9.2	46.0	193.7	0.0	2.5	54.3
NC-EWDP-15P	90	29.9	7.8	10.0	2.5	80.0	3.3	8.7	44.0	188.0	0.0	2.2	49.3
NC-EWDP-02D	91	—	7.5	19.0	1.2	42.0	4.1	6.1	22.0	149.0	0.0	1.6	49.0
NC-EWDP-19D	92	30.2	8.7	1.8	0.1	107.8	3.6	6.2	27.8	219.3	13.5	2.2	61.0
NC-EWDP-19P	93	29.2	8.7	14.0	0.9	44.0	3.7	8.9	24.0	110.0	7.4	1.7	57.0
NC-EWDP-19D (alluvial)	94	30.9	8.6	2.3	0.2	96.5	3.4	6.3	22.0	202.5	17.5	2.2	57.0
NC-EWDP-19D (zone #1)	95	32.0	8.6	3.7	0.3	91.5	3.7	6.1	22.0	189.0	12.5	2.0	58.0
NC-EWDP-19D (zone #2)	96	28.9	8.3	10.7	1.0	60.5	3.8	6.3	21.5	153.0	0.0	1.7	60.5
NC-EWDP-19D (zone #3)	97	30.8	8.5	1.3	0.1	99.0	3.2	6.3	26.0	204.0	7.4	2.0	55.0

Table A6-1. Field Parameters and Major Ion Composition (Continued)

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Southern Yucca Mountain (Continued)													
NC-EWDP-19D (zone #4)	98	31.3	8.9	0.9	0.0	107.3	3.4	5.6	18.7	212.0	21.5	2.7	59.7
Amargosa Valley													
NC-EWDP-4PB	99	24.2	9.5	6.7	0.0	67.0	1.9	5.5	34.7	63.0	40.7	1.7	32.0
NC-EWDP-4PA	100	24.3	8.2	12.5	0.3	55.0	2.9	7.4	52.5	108.5	0.0	1.2	32.5
Desert Farms Garlic Plot	101	26.2	7.8	30.0	2.1	71.0	5.1	13.0	117.0	125.0	0.0	0.8	40.0
15S/49E-13dda	102	—	—	—	—	—	—	—	—	—	—	—	—
15S/50E-18ccc	103	—	8.4	16.8	0.5	93.1	3.9	13.1	100	157	0.0	2.1	34.3
NDOT	104	27.3	8.0	16.3	0.8	101.3	3.8	14.7	110.0	160.0	0.0	1.9	43.7
15S/50E-18cdc	105	25.1	8.0	12.0	0.5	93.0	3.9	13.1	100.0	157.0	0.0	1.9	34.0
Airport Well	106	27.6	8.7	5.6	0.1	69.0	1.5	6.6	45.0	116.0	6.2	1.8	38.0
15S/50E-19b1	107	23.9	8.1	20.0	3.9	107.5	6.0	17.5	127.5	167.5	0.0	1.4	43.0
Amargosa River													
16S/48E-8ba	108	25.0	7.9	58.5	6.3	180.5	12.9	79.8	202.7	295.9	0.0	—	37.9
16S/48E-7bba	109	24.7	7.4	52.9	9.5	140.0	10.2	63.1	179.6	250.8	0.0	—	69.1
16S/48E-7cbc	110	24.2	7.7	46.9	16.0	130.1	9.4	62.0	179.6	239.2	0.0	—	64.3
16S/48E-18bcc	111	—	8.0	54.9	10.9	150.1	11.7	61.0	190.2	271.5	0.0	—	79.9
16S/48E-17ccc	112	—	7.7	66.1	10.9	169.9	12.1	83.0	235.3	239.2	0.0	—	77.5
16S/48E-18dad	113	—	7.7	52.9	8.5	149.9	10.6	63.1	187.3	236.1	0.0	—	76.9
16S/48E-8cda	114	23.3	7.6	48.1	6.8	160.0	10.2	67.0	179.6	264.2	0.0	—	67.9
16S/48E-17abb	115	24.0	7.4	60.1	7.8	157.0	12.1	69.1	178.7	302.0	0.0	—	75.1
Barrachman Dom/Irrigation	116	19.0	7.5	53.0	12.0	128.0	10.0	62.0	179.0	286.0	0.0	1.8	66.0
McCracken Domestic	117	21.7	7.5	83.0	12.0	194.0	12.0	123.0	266.0	243.0	0.0	1.7	73.0
Fortymile Wash—West													
16S/48E-15ba	118	25.0	8.0	60.1	7.8	147.1	9.8	65.6	198.8	264.2	0.0	—	37.3
16S/48E-10cba	119	24.5	8.3	9.2	3.9	60.9	5.5	8.2	32.7	166.0	0.0	—	64.3
16S/48E-15aaa	120	25.5	8.1	9.6	3.2	57.9	5.9	7.4	27.9	153.2	0.0	—	67.9
Selbach Domestic	121	23.9	8.0	23.0	8.1	90.0	6.6	36.0	96.0	178.0	0.0	1.4	68.0

Table A6-1. Field Parameters and Major Ion Composition (Continued)

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Fortymile Wash—West (Continued)													
16S/48E-15dda	122	—	8.0	20.0	5.8	70.8	7.4	17.4	37.5	175.7	0.0	—	71.5
16S/49E-23add	123	—	8.2	16.0	1.7	55.9	6.6	8.9	34.6	126.9	0.0	—	76.3
16S/48E-23bdb	124	24.0	7.3	9.2	1.0	66.0	6.6	8.9	26.9	156.2	0.0	—	73.9
16S/48E-23da	125	27.8	8.2	22.0	2.2	69.0	6.6	26.6	67.2	134.2	0.0	—	—
Funeral Mountain Ranch Irrigation	126	22.2	8.2	12.0	2.4	80.0	7.0	12.0	43.0	200.0	0.0	2.3	87.0
Fortymile Wash—South													
16S/49E-05acc	127	—	8.1	29.0	2.2	35.0	5.1	6.0	26.0	135.0	0.0	1.0	62.0
16S/49E-8abb	128	23.0	7.5	30.1	2.7	37.0	5.5	7.8	29.8	151.9	0.0	—	54.1
16S/49E-8acc	129	25.8	7.9	22.8	2.4	37.0	6.6	6.0	28.8	137.9	0.0	—	58.3
16S/49E-18dc	130	—	8.1	20.0	2.7	42.1	9.0	7.4	27.9	150.1	0.0	—	58.9
16s/48E-24aaa	131	27.0	8.1	18.0	0.7	54.0	7.0	7.8	29.8	147.1	0.0	—	78.7
16S/49E-19daa	132	26.4	8.2	24.0	1.2	36.1	8.2	6.7	32.7	134.2	0.0	—	75.1
DeLee Large Irrigation	133	14.6	8.0	24.0	1.1	37.0	8.4	6.2	25.0	135.0	0.0	1.1	76.5
16S/48E-25aa	134	26.5	8.1	18.8	0.7	43.0	7.4	9.2	27.9	133.0	0.0	—	72.1
16S/48E-36aaa	135	—	8.4	16.8	1.9	40.0	6.3	6.7	25.0	133.0	0.0	—	78.7
Bray Domestic	136	20.9	8.0	22.0	1.8	35.0	8.8	7.9	25.0	131.0	0.0	1.0	74.0
Amargosa Estates #2	137	24.0	8.1	20.0	2.1	38.0	6.8	6.5	22.0	134.0	0.0	1.6	79.0
17S/48E-1ab	138	—	8.2	18.8	1.5	40.0	7.0	6.4	25.0	134.9	0.0	—	78.7
17S/49E-7bb	139	—	8.3	24.0	1.7	48.0	7.4	9.6	30.7	153.2	0.0	—	79.9
17S/49E-8ddb	140	24.0	8.4	20.8	2.7	36.1	7.4	6.4	26.9	123.3	0.0	—	80.8
17S/49E-35ddd	141	23.0	8.0	15.2	4.6	50.6	8.2	6.7	40.3	157.4	0.0	—	81.1
Fortymile Wash—East													
15S/49E-22a1	142	27.8	8.0	25.0	2.4	41.0	5.2	8.0	33.0	145.0	0.0	1.4	52.0
15S/49E-22dcc	143	29.5	6.7	27.0	2.0	43.0	4.6	8.5	33.0	149.0	0.0	1.0	49.0
15S/49E-27acc	144	44.1	7.8	22.0	1.6	48.0	2.9	7.3	36.0	151.0	0.0	0.9	19.0
O'Neill Domestic	145	19.5	7.9	26.0	2.4	44.0	7.6	7.4	43.0	141.0	0.0	0.8	65.0
16S/49E-9cda	146	24.0	7.6	30.5	3.4	51.0	8.6	12.1	64.4	143.4	0.0	—	65.5

Table A6-1. Field Parameters and Major Ion Composition (Continued)

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Fortymile Wash—East (Continued)													
16S/49E-9dcc	147	23.3	8.2	22.8	2.7	56.1	9.0	9.9	67.2	140.9	0.0	—	72.1
16S/49E-16ccc	148	—	7.9	30.1	1.9	39.8	4.3	8.2	50.9	132.4	0.0	—	76.9
Ponderosa Dairy #1	149	28.3	8.0	30.0	4.5	59.0	11.0	16.0	93.0	145.0	0.0	1.2	74.0
17S/49E-9aa	150	—	8.0	24.8	3.6	48.0	9.8	9.9	69.2	131.2	0.0	—	70.3
17S/49E-15bbd	151	22.5	8.1	20.8	3.9	31.3	8.2	9.9	34.6	120.2	0.0	—	72.7
M. Gilgan Well	152	24.5	8.2	19.0	2.3	41.0	7.5	8.0	28.0	129.0	0.0	1.6	77.0
17S/49E-15bc	153	24.0	8.2	21.6	1.0	39.1	6.6	10.6	27.9	122.0	0.0	—	—
Gravity Fault													
NC-EWDP-5S	154	—	8.3	17.0	3.5	149.0	11.0	39.0	146.0	—	—	1.0	3.7
NC-EWDP-5SB	155	23.4	7.6	14.0	1.7	107.0	6.9	32.0	61.0	211.0	0.0	1.2	21.0
16S/50E-7bcd	156	30.6	7.6	47.7	17.5	111.5	12.9	29.1	151.8	291.7	0.0	—	28.8
Nelson Domestic	157	29.4	7.5	43.0	16.0	110.0	11.5	26.5	154.0	308.0	0.0	3.8	25.5
16S/49E-12ddd	158	—	7.6	45.7	17.0	120.0	4.3	24.1	160.4	288.6	0.0	—	20.4
Lowe Domestic	159	18.5	7.7	44.0	11.0	111.0	11.0	30.0	147.0	274.0	0.0	1.4	43.0
16S/49E-15aaa	160	23.8	7.7	40.9	7.5	80.0	9.8	23.0	129.7	195.3	0.0	—	46.3
Anvil Ranch Irrigation	161	20.5	7.9	47.0	5.8	68.0	13.0	40.0	120.0	138.0	0.0	1.1	71.0
16S/49E-36aaa	162	—	7.8	52.1	22.1	120.0	18.0	26.9	168.1	314.3	0.0	—	37.9
16S/49E-35baa	163	24.0	7.4	53.3	18.0	113.1	13.3	31.2	170.0	302.7	0.0	—	37.9
Payton Domestic	164	20.2	7.6	51.0	19.0	107.0	16.0	41.0	155.0	290.0	0.0	3.9	36.0
16S/49E-36aba	165	—	7.7	44.9	19.9	110.1	16.8	24.1	155.6	292.9	0.0	—	42.7
16S/49E-35aaa	166	—	7.7	44.1	16.0	120.0	16.0	29.1	147.9	271.5	0.0	—	36.7
Oettinger Well	167	25.2	7.5	50.0	16.0	103.0	15.0	29.0	157.0	291.0	0.0	3.3	39.0
Amargosa Motel (b)	168	24.0	7.6	49.5	18.0	97.5	14.0	27.0	151.0	286.0	0.0	3.0	43.5
17S/49E-11ba	169	22.0	8.1	40.1	14.1	97.0	14.1	28.0	160.4	209.9	0.0	—	52.9
Spring Meadows Well #8	170	21.0	—	22.0	10.9	110.0	14.9	21.9	73.9	295.8	—	2.1	31.0
17S/50E-19aab	171	16.0	8.6	7.6	8.5	252.0	27.4	69.8	175.8	415.5	0.0	—	42.7
USFWS – Five Springs Well	172	33.5	7.5	47.0	20.0	67.5	7.9	23.3	82.0	304.0	—	1.6	21.8

Table A6-1. Field Parameters and Major Ion Composition (Continued)

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Gravity Fault (Continued)													
Spring Meadows Well #10	173	19.5	—	2.8	2.9	250.0	14.9	25.8	105.1	494.0	—	3.2	67.0
18S/49E-1aba	174	17.5	8.6	24.0	11.9	94.9	19.2	18.1	99.9	263.0	0.0	—	72.7
18S/50E-6dac	175	—	8.2	23.6	11.9	102.5	13.7	20.6	106.6	230.0	0.0	—	80.5
18S/50E-7aa	176	13.0	8.4	25.7	9.5	140.9	19.2	37.6	147.0	261.2	0.0	—	47.5
Amargosa River/Fortymile Wash													
16S/48E-36dcc	177	26.0	7.2	54.9	9.7	100.0	12.9	33.0	110.5	300.2	0.0	—	70.3
Crane Domestic	178	26.3	7.2	64.0	18.0	147.0	16.0	41.0	138.0	451.0	0.0	3.3	45.0
27N/4E-27bbb	179	22.0	7.8	58.1	19.0	134.0	19.2	31.9	106.6	438.1	0.0	—	72.1
IMV on Windjammer	180	23.5	7.5	45.0	9.9	100.0	11.0	30.5	89.0	303.0	0.0	2.8	67.5
17S/49E-29acc	181	21.0	7.6	54.1	15.1	160.0	19.9	69.8	186.4	275.8	0.0	—	72.1
17S/49E-28bcd	182	—	7.6	42.9	10.0	100.0	12.1	24.1	89.3	294.7	0.0	—	70.3
18S/49E-2cbc	183	23.8	7.8	28.9	11.9	120.0	9.8	19.9	74.0	352.1	0.0	—	58.9
Mom's Place	184	22.8	7.8	27.0	6.7	77.0	9.4	14.0	55.0	236.0	0.0	2.6	75.0
18S/49E-11bbb	185	25.0	7.6	34.1	8.5	99.1	11.7	30.8	90.3	224.6	0.0	—	78.1
Skeleton Hills													
TW-5	186	30.0	7.9	33.0	17.0	130.0	12.0	21.0	99.0	395.0	0.0	3.4	19.0
Unnamed Well 15S/50E-22-7	187	—	6.7	27.0	2.0	43.0	4.6	8.5	33.0	148.8	—	0.9	49.0
Amargosa Flat													
Amargosa Tracer Hole #2	188	30.5	8.0	42.8	18.5	63.8	7.5	21.0	68.7	279.2	—	1.9	22.0
Cherry Patch Well, 17S/52E-08cdb	189	26.2	7.3	76.0	38.8	272.5	9.6	122.5	485.0	344.7	—	1.7	25.5
USDOE-MSH-C shallow Well	190	20.5	8.0	16.0	17.0	81.0	9.4	17.0	58.0	261.0	—	1.7	34.0
Mine Mountain													
UE-17a	191	27.0	7.6	41.0	29.9	80.0	3.0	27.7	95.5	200.0	—	0.9	11.8
UE-1a	192	25.4	7.4	48.5	23.9	50.5	8.7	26.3	—	402.5		—	19.3
UE-1b	193	27.4	7.4	37.4	13.7	31.3	10.7	5.9	—	184.0		—	80.9
UE-16f	194	29.4	8.9	1.8	1.9	421.2	5.0	18.8	423.0	900.0	33.0	5.2	4.5
UE-14b	195	—	8.4	10.5	0.2	77.5	1.5	7.1	80.8	116.0		—	43.8

Table A6-1. Field Parameters and Major Ion Composition (Continued)

Well Name[a]	Figure A6-5 Sample	Temperature (°C)	pH	Ca^{2+} (mg/L)	Mg^{2+} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	Cl^{-} (mg/L)	SO_4^{2-} (mg/L)	HCO_3^{-} (mg/L)	CO_3^{2-} (mg/L)	F^{-} (mg/L)	SiO_2 (mg/L)
Mine Mountain (Continued)													
Pluto 1	196	—	8.0	40.5	9.8	36.2	7.7	23.7	46.9	150.0	—	—	54.0
Pluto 5	197	—	7.9	55.0	21.6	26.4	4.3	11.5	54.2	218.0	—	—	58.0
USGS Test Well F (HTH)	198	64.5	6.9	46.0	16.7	63.0	9.1	12.9	79.3	254.2	—	3.2	36.4
Funeral Mountains													
Woodcamp Spring	199	19.2	7.2	23.0	3.3	38.0	14.0	24.0	24.0	122.0	—	0.2	57.0
Bond Gold Mining #13	200	32.4	7.3	144.5	79.5	85.5	7.0	63.5	621.5	274.5	0.0	0.6	16.5
Nevares Spring	201	39.4	7.4	42.0	20.0	140.0	11.0	37.0	170.0	353.0	—	3.2	26.0
Travertine Spring	202	35.3	7.4	33.0	18.0	140.0	12.0	37.0	150.0	343.0	—	3.7	30.0

Sources: Primarily DTNs: LA0309RR831233.001 [DIRS 166546] and LA0309RR831233.002 [DIRS 166548]; and others as documented in Table A4-3.

[a] dp = deep sample, sh = shallow sample, Tcp = sample from Prow Pass tuff, Tcb = sample from Bullfrog tuff, bh = sample from entire borehole, ’95 = sample from 1995, v = sample from volcanic aquifer, c = sample from carbonate aquifer, Tct = sample from Tram Member or Crater Flat tuff. Where not otherwise indicated, sample is from entire open interval of borehole.

[b] The groundwater temperature was estimated from the map of water table temperature shown in Fridrich et al. 1994 [DIRS 100575], Figure 8.

[c] The groundwater temperature for this sample was assumed to be the same as for the c#3 sample.

[d] The symbol “—“ indicates the data are not available.

Table A6-2. Isotope and Trace Element Composition

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (μg)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (μg)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Oasis Valley/NW Amargosa											
ER-EC-08	1	−1.0	8.7	−116.0	−14.8	—	4.4	—	—	0.70864	−0.8
ER-OV-01	2	−2.0	5.0	−112.5	−14.7	—	9.4	3.7	4.9	0.71058	1.9
ER-OV-06a	3	−2.2	6.0	−113.0	−14.7	—	5.2	3.3	10.6	0.70932	0.2
ER-OV-05	4	−3.1	17.3	−106.0	−13.7	—	2.2	2.8	192.0	0.70976	0.8
ER-OV-02	5	−2.6	16.2	−112.0	−14.7	—	18.3	2.5	46.0	0.71006	1.2
Springdale Upper Well (10S/47E-32adc)	6	−1.7	10.8	−104.0	−13.9	—	2.6	5.4	291.0	0.71026	1.5
Goss Springs North (11S/47E-10bad)	7	−2.9	21.8	−110.0	−14.7	—	9.23	2.9	88.0	0.71039	1.7
Er-OV-03a	8	−3.0	16.3	−111.0	−14.7	—	9.1	2.9	75.2	0.71029	1.5
ER-OV-03a3	9	−2.8	16.5	−110.0	−14.6	—	9.1	2.9	76.8	0.71003	1.2
ER-OV-03a2	10	−5.0	21.0	−109.0	−14.5	—	9.8	5.4	167.0	0.70809	−1.6
Goss Spring (11S/47E-10bcc)	11	—	20.8	−111.7	−14.7	—	9.2	2.9	90.0	0.71050	1.8
ER-OV-04a	12	−3.4	8.0	−109.5	−14.8	—	3.0	3.0	22.0	0.71006	1.2
Beatty Well no. 1 (Wat & Sanit Distr)	13	—	—	—	—	—	8.8	—	155.3	—	—
Bond Gold Mining #1	14	−8.8	12.8	−100.0	−13.8	15.7	0.1	3.5	150.0	—	—
US Ecology MW-313	15	−6.1	17.0	−109.0	−14.1	21.8	7.8	3.2	361.0	—	—
US Ecology MW-600	16	−8.4	19.3	−108.3	−14.4	19.5	4.9	2.5	340.0	—	—
NECWell	17	−5.9	28.8	—	—	—	—	—	—	—	—
US Ecology MR-3	18	−6.5	323.0	−109.0	−14.5	20.1	6.5	3.2	—	—	—
Timber Mountain											
UE-18r	19	−1.7	7.7	−110.0	−14.7	—	5.1	6.1	116.5	0.70903	−0.2
ER-18-2	20	−0.7	1.6	−112.0	−14.7	—	8.0	12.7	224.3	0.70872	−0.7
ER-EC-05	21	−2.5	6.3	−113.0	−14.9	—	3.2	6.4	140.1	0.70916	−0.1
Coffer's Ranch Windmill Well	22	−3.9	9.6	−103.9	−13.5	—	5.5	4.9	162.1	0.70922	0.0
ER-OV-03c	23	−3.2	6.8	−109.0	−14.7	—	4.2	5.4	99.0	0.70924	0.1
ER-EC-07	24	−6.3	36.5	−98.0	−13.2	—	1.8	7.2	123.1	0.70938	0.2
Fortymile Wash—North											
Water Well 8	25	−11.6	25.0	−103.0	−13.5	—	0.4	3.9	5.2	0.71025	1.5

Table A6-2. Isotope and Trace Element Composition (Continued)

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (μg /L)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (μg /L)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Fortymile Wash—North (Continued)											
Test Well 1 (USGS HTH #1)	26	−10.2	30.1	—	−14.7	—	0.6	—	15.0	0.70892	−0.4
UE-18t	27	—	—	—	—	—	—	—	—	—	—
ER-30-1 (upper)	28	−6.3	—	−93.2	−12.4	—	—	—	13.0	0.70778	−2.0
ER-30-1 (lower)	29	−6.0	—	−86.7	−11.8	—	—	—	7.0	0.70807	−1.59
a#2(dp)	30	−12.6	62.3	−93.5	−12.8	—	—	—	39.0	—	—
a#2(sh)	31	−13.1	60.0	−93.0	−12.8	—	0.7	4.0	33.0	—	—
UE-29a#1 HTH	32	−10.5	75.7	−91.0	−12.6	—	1.5	3.6	54.7	0.71105	2.6
WT#15	33	−11.8	21.6	−97.5	−13.2	—	—	—	—	—	—
WT#14	34	−12.8	24.1	−97.5	−12.8	—	—	—	—	—	—
J-13	35	−7.3	29.2	−97.5	−13.0	—	0.6	7.2	20.0	0.71146	3.2
J-12	36	−7.9	32.2	−97.5	−12.8	—	0.3	5.5	10.0	0.71164	3.4
JF#3	37	−8.6	30.7	−97.0	−13.2	—	0.8	4.1	—	0.71133	3.0
Solitario Canyon Wash											
H-6(bh)	38	−7.5	16.3	−106.0	−13.8	—	—	—	8.0	—	—
H-6(Tct)	39	−7.3	10.0	−105.0	−14.0	—	—	—	3.0	—	—
H-6(Tcb)	40	−7.1	12.4	−107.0	−14.0	—	—	—	8.0	—	—
WT-7	41	−9.0	—	—	−14.0	—	0.1	4.8	—	0.71027	1.5
WT-10	42	−6.1	7.3	−103.0	−13.8	—	2.8	4.8	4.0	0.71007	1.2
Yucca Mountain—Crest											
G-2	43	−11.8	20.5	−98.8	−13.3	—	1.2	7.6	10.0	0.71070	2.1
USW WT-24	44	−10.6	27.3	−101.1	−13.2	—	1.1	6.4	1.5	—	—
UZ-14(sh)	45	−14.1	24.6	−100.4	−14.0	11.4	—	—	57.0	—	—
UZ-14(dp)	46	−14.4	21.1	−100.6	−14.0	—	—	—	32.0	—	—
H-1(Tcp)	47	—	19.9	−103.0	−13.4	—	—	—	5.0	—	—
H-1(Tcb)	48	−11.4	23.9	−101.0	−13.5	—	—	—	20.0	—	—
H-5	49	−10.3	19.8	−102.0	−13.6	—	—	—	6.5	—	—

Table A6-2. Isotope and Trace Element Composition (Continued)

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (µg /L)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (µg /L)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Yucca Mountain—Crest (Continued)											
USW SD-6	50	−9.4	—	−105.3	−14.4	12.5	5.0	3.9	>1.0	—	—
H-3	51	−4.9	10.5	−101.0	−13.9	—	—	—	1.0	—	—
Yucca Mountain—Central											
G-4	52	−9.1	22.0	−103.0	−13.8	—	—	—	17.0	—	—
b#1(Tcb)	53	−8.6	18.9	−99.5	−13.5	—	—	—	47.0	—	—
b#1(bh)	54	−10.6	16.7	−100.3	−13.4	—	—	—	41.0	—	—
H-4	55	−7.4	11.8	−104.0	−14.0	—	—	—	27.0	—	—
UZ#16	56	—	—	—	—	—	—	—	—	—	—
Yucca Mountain—Southeast											
ONC#1	57	—	—	—	—	—	—	—	1720.0	0.71040	1.7
c#1	58	−7.1	15.0	−102.0	−13.5	—	—	—	30.0	0.71040	1.7
c#3	59	−7.5	15.7	−103.0	−13.5	—	—	—	44.0	—	—
c#3(95-97)	60	—	—	−99.7	−13.4	10.8	1.2	8.1	60.0	0.70981	0.9
c#2	61	−7.0	16.6	−100.0	−13.4	10.9	—	—	45.0	—	—
p#1(v)	62	−4.2	3.5	−106.0	−13.5	—	—	—	180.0	—	—
p#1(c)	63	−2.3	2.3	−106.0	−13.8	—	13.3	2.3	450.0	0.71177	3.6
WT-17	64	−8.3	16.2	−101.9	−13.7	10.5	1.1	7.6	—	—	—
WT#3	65	−8.2	22.3	−102.1	−13.6	10.8	0.8	7.2	32.0	—	—
WT#12	66	−8.1	11.4	−102.5	−13.8	—	2.5	7.2	23.0	0.70991	1.0
Jackass Flats											
UE-25 J-11	67	−11.0	12.3	−105.3	−13.5	8.8	2.0	1.5	264.0	—	—
Crater Flat											
GEXA Well4	68	—	—	−105.6	−14.1	—	3.0	5.1	34.0	0.70974	0.8
VH-1	69	−8.5	12.2	−108.0	−14.2	—	3.6	5.5	66.7	0.71096	2.5
Southwest Crater Flat											
VH-2	70	—	—	−99.5	−13.5	—	3.0	3.1	570.0	0.71300	5.4
NC-EWDP-7S	71	−4.9	8.4	−98.0	−13.0	14.3	—	—	630.0	—	—

Table A6-2. Isotope and Trace Element Composition (Continued)

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (µg /L)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (µg /L)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Southwest Crater Flat (Continued)											
NC-EWDP-7SC	72	—	—	—	—	—	—	—	558.0	—	—
NC-EWDP-1DX	73	−4.5	—	−101.3	−13.5	14.6	5.1	3.9	510.0	—	—
NC-EWDP-1DX Zone 2	74	−2.1	2.5	−105.7	−14.7	28.3	0.0	3.0	981.0	0.71293	5.3
NC-EWDP-1S Zone 1	75	−5.8	7.7	−101.3	−13.6	14.8	8.6	4.5	568.0	0.71279	5.1
NC-EWDP-1S Zone 2	76	−5.6	7.2	−100.8	−13.7	15.2	7.6	4.5	533.0	0.71288	5.2
NC-EWDP-1S	77	−5.6	—	−99.6	−13.8	14.5	8.6	4.5	557.0	—	—
NC-EWDP-12PA	78	−3.4	4.7	−103.8	−13.6	16.9	—	—	302.0	0.71561	9.0
NC-EWDP-12PB	79	−3.6	4.5	−100.5	−13.6	16.7	—	—	296.0	0.71460	7.6
NC-EWDP-12PC	80	−5.3	9.0	−101.8	−13.4	14.7	—	—	462.0	0.71269	4.9
Southern Yucca Mountain											
NC-EWDP-09SX	81	−6.5	—	−104.2	−14.0	13.3	5.1	5.0	151.3	0.71250	4.7
NC-EWDP-9SX Zone 1	82	−7.1	12.2	−102.0	−14.3	14.2	4.6	4.9	129.0	0.71247	4.6
NC-EWDP-9SX Zone 2	83	−7.0	11.4	−104.7	−14.3	13.9	4.6	5.0	149.0	0.71239	4.5
NC-EWDP-9SX Zone 3	84	−6.8	10.9	−104.5	−14.1	14.4	4.4	5.0	144.5	0.71246	4.6
NC-EWDP-9SX Zone 4	85	−6.2	11.0	−105.0	−14.2	13.8	4.6	5.0	146.7	0.71254	4.7
NC-EWDP-03D	86	−6.8	10.0	−105.6	−14.4	11.2	2.0	3.4	1.3	—	—
NC-EWDP-3S Zone 2	87	−8.4	21.5	−104.8	−14.3	10.9	2.6	3.2	2.5	0.71032	1.6
NC-EWDP-3S Zone 3	88	−5.0	8.4	−106.2	−14.2	9.8	7.4	2.9	3.7	0.71100	2.5
CIND-R-LITE	89	—	—	−102.0	−13.6	—	2.8	4.7	108.0	0.71221	4.2
NC-EWDP-15P	90	−6.3	12.0	−106.3	−13.8	13.2	—	—	50.0	0.71222	4.3
NC-EWDP-02D	91	−8.3	23.5	−104.0	−14.1	11.9	1.2	4.8	53.0	—	—
NC-EWDP-19D	92	−7.6	12.4	−106.1	−13.8	9.0	—	—	3.5	0.71056	1.9
NC-EWDP-19P	93	−9.5	23.5	−103.5	−13.6	11.7	—	—	57.0	0.71133	3.0
NC-EWDP-19D (alluvial)	94	−7.1	12.4	−108.8	−13.8	10.7	—	—	7.5	—	—
NC-EWDP-19D(zone #1)	95	−7.0	17.6	−109.0	−13.9	10.1	—	—	15.0	—	—
NC-EWDP-19D(zone #2)	96	−7.6	21.0	−104.0	−13.6	10.6	—	—	36.0	—	—

Table A6-2. Isotope and Trace Element Composition (Continued)

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (µg /L)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (µg /L)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Southern Yucca Mountain (Continued)											
NC-EWDP-19D(zone #3)	97	−9.4	12.5	−106.3	−13.5	10.9	—	—	3.0	—	—
NC-EWDP-19D(zone #4)	98	−6.4	11.2	−110.2	−13.9	11.7	—	—	2.0	—	—
Amargosa Valley											
NC-EWDP-4PB	99	−10.0	15.9	−108.5	−13.9	9.6	—	—	36.0	0.71021	1.4
NC-EWDP-4PA	100	−10.5	23.1	−101.3	−13.3	8.9	—	—	62.5	0.70949	0.4
Desert Farms Garlic Plot	101	−9.1	8.8	−106.4	−13.1	8.8	1.3	3.4	144.0	—	—
15S/49E-13dda	102	—	—	—	—	—	—	—	—	—	—
15S/50E-18ccc	103	—	—	—	—	—	—	—	80.0	—	—
NDOT	104	—	—	—	—	—	2.5	2.5	—	0.71081	2.3
15S/50E-18cdc	105	—	—	—	—	—	—	—	—	—	—
Airport Well	106	−10.3	10.5	−106.2	−13.2	8.7	0.6	3.1	24.0	—	—
15S/50E-19b1	107	—	—	—	—	—	—	—	—	—	—
Amargosa River											
16S/48E-8ba	108	—	—	—	—	—	—	—	—	—	—
16S/48E-7bba	109	—	—	—	—	—	—	—	—	—	—
16S/48E-7cbc	110	−6.2	31.4	−102.0	−13.1	—	—	—	—	—	—
16S/48E-18bcc	111	—	—	—	—	—	—	—	—	—	—
16S/48E-17ccc	112	—	—	—	—	—	—	—	—	—	—
16S/48E-18dad	113	−5.7	—	−104.0	−13.6	—	—	—	—	—	—
16S/48E-8cda	114	—	—	—	—	—	—	—	—	—	—
16S/48E-17abb	115	—	—	—	—	—	—	—	—	—	—
Barrachman Dom/Irr.	116	−5.8	17.9	−107.4	−13.5	20.9	5.2	3.4	473.0	—	—
McCracken Domestic	117	−12.1	32.9	−102.7	−12.9	18.5	5.2	3.3	600.0	0.71456	7.6
Fortymile Wash—West											
16S/48E-15ba	118	—	—	—	—	—	—	—	—	—	—
16S/48E-10cba	119	−5.6	15.6	−102.0	−13.4	—	—	—	—	—	—
16S/48E-15aaa	120	−7.1	17.1	−103.0	−13.4	—	—	—	—	—	—

Table A6-2. Isotope and Trace Element Composition (Continued)

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (µg /L)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (µg /L)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Fortymile Wash—West (Continued)											
Selbach Domestic	121	−8.1	30.7	−103.2	−12.9	10.9	2.7	4.2	217.0	—	—
16S/48E-15dda	122	—	—	—	—	—	—	—	—	—	—
16S/49E-23add	123	−8.4	27.4	−99.0	−13.2	—	—	—	—	—	—
16S/48E-23bdb	124	—	—	—	—	—	—	—	—	—	—
16S/48E-23da	125	—	—	—	—	—	—	—	—	—	—
Funeral Mountain Ranch Irrigation	126	−5.5	6.5	−106.6	−13.7	13.2	1.3	2.9	114.0	—	—
Fortymile Wash—South											
16S/49E-05acc	127	−7.1	19.3	−103.0	−13.2	—	—	—	50.0	—	—
16S/49E-8abb	128	−6.8	21.4	−99.5	−13.2	—	—	—	—	—	—
16S/49E-8acc	129	—	—	—	—	—	—	—	—	—	—
16S/49E-18dc	130	—	28.4	−102.0	−12.6	—	—	—	—	—	—
16s/48E-24aaa	131	—	—	—	—	—	—	—	—	—	—
16S/49E-19daa	132	—	20.8	−101.0	−13.1	—	—	—	—	—	—
DeLee Large Irrigation	133	−8.4	20.5	−104.1	−13.3	9.5	1.5	3.2	109.5	—	—
16S/48E-25aa	134	—	19.3	−102.0	−13.0	—	—	—	—	—	—
16S/48E-36aaa	135	—	—	−98.5	−12.6	—	—	—	—	—	—
Bray Domestic	136	−10.0	23.5	−103.5	−13.2	9.3	1.5	3.1	101.0	—	—
Amargosa Estates #2	137	−10.6	21.6	−104.3	−13.1	10.2	1.3	3.0	129.0	—	—
17S/48E-1ab	138	—	18.4	−104.0	−13.0	—	—	—	—	—	—
17S/49E-7bb	139	—	10.0	−104.0	−12.7	—	—	—	—	—	—
17S/49E-8ddb	140	—	27.8	−102.0	−13.0	—	—	—	—	—	—
17S/49E-35ddd	141	—	13.8	−102.0	−12.4	—	—	—	—	—	—
Fortymile Wash—East											
15S/49E-22a1	142	—	—	—	—	—	—	—	—	—	—
15S/49E-22dcc	143	—	—	—	—	—	—	—	65.0	—	—
15S/49E-27acc	144	—	—	—	—	—	—	—	65.0	—	—
O'Neill Domestic	145	−6.7	17.7	−101.8	−13.2	9.6	1.7	2.8	109.0	—	—

Table A6-2. Isotope and Trace Element Composition (Continued)

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (µg /L)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (µg /L)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Fortymile Wash—East (Continued)											
16S/49E-9cda	146	—	—	—	—	—	—	—	—	—	—
16S/49E-9dcc	147	−7.3	21.9	−103.0	−13.4	—	—	—	—	—	—
16S/49E-16ccc	148	−5.2	24.8	−97.5	−13.2	—	—	—	—	—	—
Ponderosa Dairy #1	149	−7.2	14.2	−105.5	−13.3	16.6	2.3	2.9	248.0	—	—
17S/49E-9aa	150	—	18.9	−105.0	−12.8	—	—	—	—	—	—
17S/49E-15bbd	151	—	40.3	—	—	—	—	—	—	—	—
M. Gilgan Well	152	−9.0	27.9	−100.1	−13.0	9.4	0.8	3.0	155.0	—	—
17S/49E-15bc	153	—	—	—	—	—	—	—	—	—	—
Gravity Fault											
NC-EWDP-5S	154	—	—	−107.0	−14.0	—	0.04	6.7	361.0	0.71206	4.0
NC-EWDP-5SB	155	−1.5	4.0	−107.0	−13.3	17.8	—	—	204.0	0.71232	4.4
16S/50E-7bcd	156	−3.6	7.0	−105.0	−13.8	—	—	—	—	—	—
Nelson Domestic	157	−2.0	0.9	−110.2	−13.8	22.6	1.7	3.2	829.5	—	—
16S/49E-12ddd	158	—	—	—	—	—	—	—	—	—	—
Lowe Domestic	159	−3.0	1.2	−103.7	−13.8	21.5	2.8	3.3	724.0	—	—
16S/49E-15aaa	160	−3.4	—	−105.0	−13.8	—	—	—	—	—	—
Anvil Ranch Irrigation	161	−10.4	11.8	−103.3	−13.1	13.2	2.1	2.8	319.0	—	—
16S/49E-36aaa	162	−4.4	10.3	−104.0	−13.7	—	—	—	—	—	—
16S/49E-35baa	163	—	—	—	—	—	—	—	—	—	—
Payton Domestic	164	−2.7	3.3	−109.7	−13.8	21.7	1.0	3.6	1069.0	—	—
16S/49E-36aba	165	—	—	—	—	—	—	—	—	—	—
16S/49E-35aaa	166	—	—	—	—	—	—	—	—	—	—
Oettinger Well	167	−2.6	1.4	−108.5	−13.8	21.8	1.5	3.3	915.0	—	—
Amargosa Motel (b)	168	−3.0	1.9	−109.0	−13.7	22.0	1.6	3.2	954.0	—	—
17S/49E-11ba	169	—	—	—	—	—	—	—	—	—	—
Spring Meadows Well #8	170	—	—	—	—	—	—	—	—	—	—
17S/50E-19aab	171	—	—	—	—	—	—	—	—	—	—

Table A6-2. Isotope and Trace Element Composition (Continued)

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (μg /L)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (μg /L)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Gravity Fault (Continued)											
USFWS – Five Springs Well	172	—	—	−104.0	−13.6	—	—	—	860.0	—	—
Spring Meadows Well #10	173	—	—	—	—	—	—	—	—	—	—
18S/49E-1aba	174	—	—	—	—	—	—	—	—	—	—
18S/50E-6dac	175	—	—	—	—	—	—	—	—	—	—
18S/50E-7aa	176	—	—	—	—	—	—	—	—	—	—
Amargosa River/Fortymile Wash											
16S/48E-36dcc	177	—	—	—	—	—	—	—	—	—	—
Crane Domestic	178	−4.3	7.9	−108.8	−13.4	22.3	4.0	3.3	674.0	—	—
27N/4E-27bbb	179	—	—	—	—	—	—	—	—	—	—
IMV on Windjammer	180	−5.0	6.6	−104.0	−13.4	19.3	3.6	3.0	430.0	—	—
17S/49E-29acc	181	—	—	—	—	—	—	—	—	—	—
17S/49E-28bcd	182	—	—	—	—	—	—	—	—	—	—
18S/49E-2cbc	183	—	—	—	—	—	—	—	—	—	—
Mom's Place	184	−4.9	11.4	−105.5	−13.2	17.1	1.9	3.0	346.0	—	—
18S/49E-11bbb	185	—	—	—	—	—	—	—	—	—	—
Skeleton Hills											
TW-5	186	—	—	−113.2	−15.4	—	—	—	1509.0	0.71505	8.2
Unnamed Well 15S/50E-22-7	187	—	—	—	—	—	—	—	80.0	—	—
Amargosa Flat											
Amargosa Tracer Hole #2	188	−6.0	4.6	—	−13.6	—	—	—	790.0	—	—
Cherry Patch Well, 17S/52E-08cdb	189	—	—	—	—	—	1.8	2.9	1500.0	—	—
USDOE-MSH-C shallow Well	190	—	—	−108.0	−14.1	—	—	—	540.0	—	—
Mine Mountain											
UE-17a	191	−9.9	4.9	−100.0	−13.3	—	0.4	—	829.0	0.71020	1.5
UE-1a	192	−8.6	60.5	−103.0	−13.5	—	4.3	—	630.0	0.70957	0.5
UE-1b	193	−4.5	16.0	−105.0	—	—	4.3	—	470.0	0.70950	0.4
UE-16f	194	−11.7	3.4	−104.0	−13.5	—	—	—	550.0	0.71138	3.1

Table A6-2. Isotope and Trace Element Composition (Continued)

Well Name	Figure A6-5 Sample	$\delta^{13}C$ (per mil)	^{14}C (pmc)	δD (per mil)	$\delta^{18}O$ (per mil)	$\delta^{34}S$ (per mil)	U (µg /L)	$^{234}U/^{238}U$ (AR)	Sr^{2+} (µg /L)	$^{87}Sr/^{86}Sr$ (ratio)	$\delta^{87}Sr$ (per mil)
Mine Mountain (Continued)											
UE-14b	195	—	—	—	—	—	—	—	—	—	—
Pluto 1	196	—	—	—	—	—	—	—	—	—	—
Pluto 5	197	—	—	—	—	—	—	—	—	—	—
USGS Test Well F (HTH)	198	—	—	—	—	—	—	—	570.0	—	—
Funeral Mountains											
Woodcamp Spring	199	−12.2	78.0	−91.6	−12.4	—	—	—	20.0	0.70871	−0.7
Bond Gold Mining #13	200	−7.5	8.1	−100.6	−13.3	29.3	8.1	1.9	2140.0	0.72732	25.5
Nevares Spring	201	−5.5	3.0	−101.0	−13.5	—	1.3	2.1	1100.0	0.71679	10.7
Travertine Spring	202	−3.8	3.3	−102.0	−13.5	—	3.3	2.4	1100.0	0.71734	11.5

Sources: Primarily DTNs: LA0309RR831233.001[DIRS 166546]; LA0309RR831233.002 [DIRS 166548], and LA0311EK831232.002 [DIRS 16606 9]; and others as documented in Table A4-3.

AR = activity ratio

A6.3.1 Factors Affecting the Chemical and Isotopic Composition of Groundwater

This section will summarize the study of Meijer (2002 [DIRS 158813]) that describes the effects of: (1) precipitation composition, (2) evaporation, (3) precipitation/dissolution reactions, (4) adsorption and ion-exchange reactions, and (5) climate change on the chemical composition of groundwater. Additional details are presented in Meijer (2002 [DIRS 158813]) and in the *Yucca Mountain Site Description* (BSC 2004 [DIRS 169734], Sections 5.2.2, 8.2.7, and 8.3.6).

A6.3.1.1 Factors Affecting the Chemical Composition of Groundwater

The main processes that control groundwater chemistry are:

- Precipitation (atmospheric) quantities and compositions
- Surface water quantities and compositions in recharge areas and along stream courses
- Soil-zone processes in recharge areas and along flow paths between the soil and saturated zone
- Rock-water interactions in the unsaturated zone
- Rock-water interactions in the saturated zone
- Temperature and pressure effects in the unsaturated and saturated zones
- Mixing of groundwater from different flow systems.

Although all the processes listed above may affect the groundwater chemistry, mixing and rock-water interactions generally are the most dominant in determining changes to the major-ion composition of recharge after it has reached the saturated zone.

Processes that affect infiltrating waters in the soil zone or the unsaturated zone include evapotranspiration, mineral and gas dissolution reactions, gas ex-solution and mineral-precipitation reactions, and ion-exchange reactions. The dominant changes to the water compositions that result from these processes in the volcanic rock in the Yucca Mountain area are increases in the concentration of all chemical species and major relative increases in SiO_2, Na^+, and HCO_3^- compared to the composition of precipitation.

The dominant water-rock reactions that impact the water chemistry after the shallow unsaturated-zone or soil-zone reactions are SiO_2-precipitation reactions and ion-exchange reactions involving minerals such as zeolites and clays. The cation-hydrogen ion-exchange reaction will also continue to be of significance. The ion-exchange reactions lead to increased Na^+ concentrations and decreased Ca^{2+}, Mg^{2+}, and K^+ concentrations in the waters. However, changes in the concentrations of these ions will only occur if zeolites and/or clays are present in adequate quantities in rock units through which the waters migrate. The Na^+–H^+ ion-exchange reaction will continue to increase the Na^+ content of the waters until thermodynamic equilibrium is achieved with the host rock.

The primary controls on the pH of groundwater in the saturated zone are the partial pressure of CO_2 and the rate at which hydrogen ions are consumed by the rock-mineral matrix. In the saturated zone, access to the CO_2 reservoir in the gas phase of the unsaturated zone becomes progressively more difficult with depth. Therefore, unless a secondary source of H_2CO_3 or another source of acidity (e.g., sulfide minerals) exists in the saturated zone, the reaction of hydrogen ions with the rock mineral matrix will eventually consume the available acidity, leading to increased pH.

Winograd and Thordarson (1975 [DIRS 101167], pp. C97 to C102, Plate C) identified six hydrochemical facies in the vicinity of the Nevada Test Site. Where the host rocks are limestone and dolomite, as in the case of the carbonate aquifer, the dominant ions are Ca^{2+}, Mg^{2+}, and HCO_3^-. Tuffaceous aquifers are characterized by groundwater having Na^+, K^+ and HCO_3^- as the dominant ions. Groundwater of mixed compositions occurs where groundwater flows from one aquifer type into another, or from alluvium derived from one rock type into alluvium derived from another rock type. Groundwater mixing can also produce groundwaters that are intermediate in compositions between the carbonate and tuffaceous aquifers. In the alluvial valley fill deposits, the host rocks consist of fragments that reflect the rock composition in the upland sediment source areas. For example, in the west central Amargosa Desert, a central region of predominantly tuffaceous valley fill is flanked to the east and west by zones containing significant proportions of carbonate-rock detritus (Claassen 1985 [DIRS 101125], p. F5, Figure 1), which greatly affect the major-ion composition of the groundwater. This lateral sedimentary facies relationship is further complicated in the Amargosa Desert by the local presence of playa deposits (Claassen 1985 [DIRS 101125], pp. F5 and F30). Groundwater in the vicinity of playa deposits typically contains greater concentrations of SO_4^{2-} and Cl^-, which were concentrated in the playa deposits through earlier cycles of evaporation (Claassen 1985 [DIRS 101125], p. F18).

A6.3.1.2 Factors Affecting the Isotopic Composition of Groundwater

The main processes that control the isotopic chemistry of SZ groundwaters have some common ground with those that control major-ion chemistry; however, major differences exist between these chemical regimes. As with major-ion content, precipitation quantity and composition are the starting point for the isotopic evolution of groundwater.

A6.3.1.2.1 Hydrogen and Oxygen

Hydrogen and oxygen isotope ratios are useful for tracing groundwater movement where spatial differences in their concentrations exist. Both hydrogen and oxygen are composed of more than one stable isotope. The stable hydrogen isotopes of interest here are ^1H and ^2H. The latter isotope is commonly referred to as deuterium with the chemical symbol D. The ratio of these two isotopes is measured and is generally reported in δ notation as follows, with units of per mil:

$$\delta D = [(D/^1H)_{sample}/(D/^1H)_{standard} - 1] \times 1{,}000 \qquad \text{(Eq. A6-1)}$$

The standard used for these measurements is known as Vienna Standard Mean Ocean Water (Clark and Fritz 1997 [DIRS 105738], p. 8).

The stable oxygen isotopes of interest here are ^{16}O and ^{18}O. The ratio of these isotopes is measured and also reported in δ notation as follows, with units of per mil:

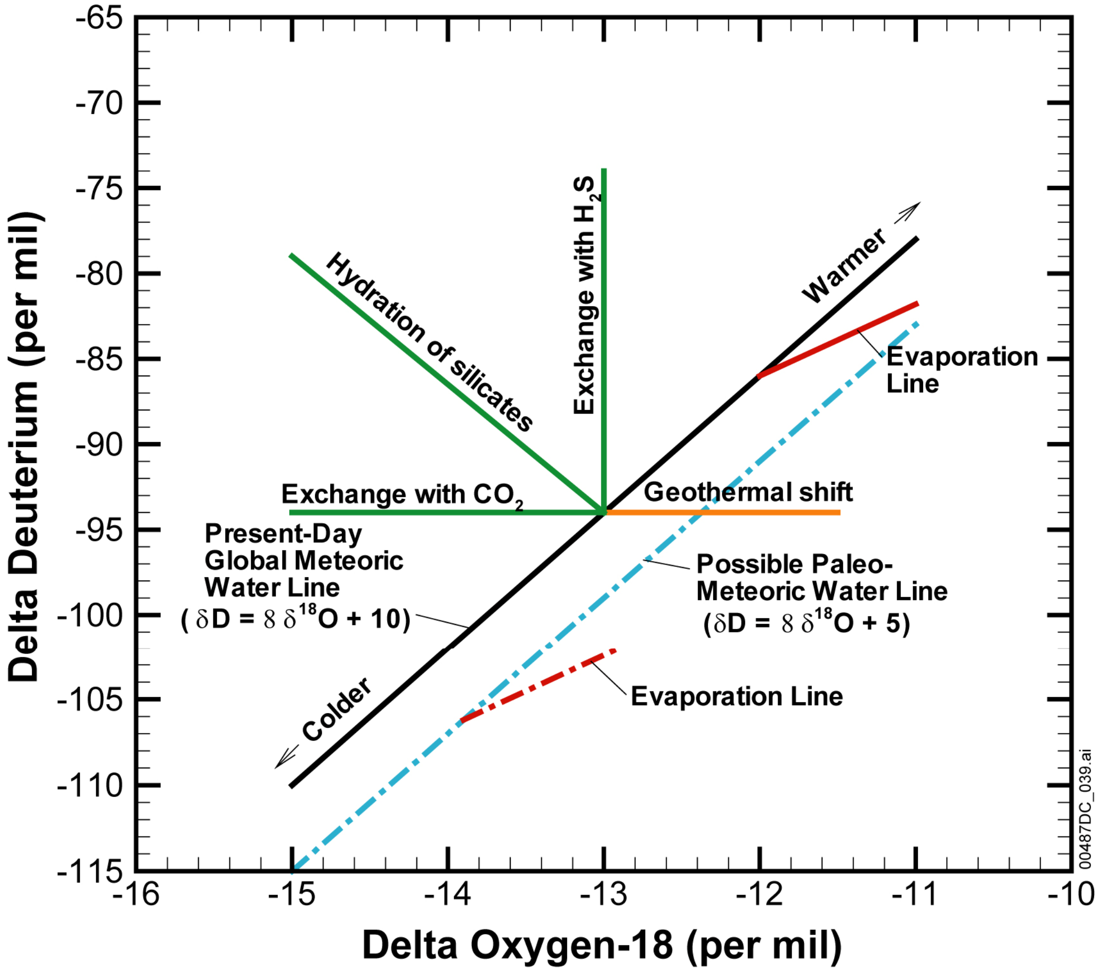
$$\delta^{18}O = [(^{18}O/^{16}O)_{sample}/(^{18}O/^{16}O)_{standard} - 1] \times 1{,}000 \qquad \text{(Eq. A6-2)}$$

Vienna Standard Mean Ocean Water is also used as the standard for oxygen isotope measurements (Clark and Fritz 1997 [DIRS 105738], p. 8).

The ^{2}H and ^{18}O atoms are part of the water molecule and, at low temperatures, are generally unaffected by water-rock interactions. The values of δD and $\delta^{18}O$ in precipitation, fresh surface water, and groundwater are typically negative because of fractionation between the heavy and light isotopes of hydrogen and oxygen during evaporation over the initial moisture source area and because the residual water vapor becomes progressively more depleted in the heavier isotopes (^{2}H and ^{18}O) during successive precipitation events. A detailed discussion of all the processes affecting the isotopic composition of precipitation and recharge, and possible effects of water-rock interactions, is beyond the scope of this report. A summary of these processes is available in textbooks, such as Clark and Fritz (1997 [DIRS 105738], Sections 2 to 4, 9). Some of the net effects of these processes are depicted in Figure A6-4.

The values of δD and $\delta^{18}O$ in precipitation are strongly correlated on a global basis. This correlation has been termed the "global meteoric water line." The equation for this line is $\delta D = 8\,\delta^{18}O + 10$ (Clark and Fritz 1997 [DIRS 105738], p. 36). The slope of the line is related to the ratio of the equilibrium fractionation factors for ^{2}H and ^{18}O, which are approximately 8.2 at 25ºC (Clark and Fritz 1997 [DIRS 105738], p. 50). Locally, the isotopic composition of precipitation may follow a line with a somewhat different slope and intercept. Such lines have been referred to as the "local meteoric water line." The deuterium "excess" is the intercept in the meteoric water line when the slope is eight. This "excess" is inversely related to the relative humidity of the air in the moisture source area (Clark and Fritz 1997 [DIRS 105738], p. 45; Merlivat and Jouzel 1979 [DIRS 126847], p. 5,029).

One of the primary factors affecting the isotopic composition of precipitation is condensation temperature, which is a function of season, elevation, and climate. Precipitation falling during periods when temperatures are low has more negative ("depleted") δD and $\delta^{18}O$ values than precipitation falling during warm periods. Because average surface temperatures are correlated with elevation, precipitation falling at higher elevations tends to have more negative isotope ratios than precipitation falling at lower elevations. Late Pleistocene groundwater, identified by ^{14}C age dating or other techniques, is often more isotopically depleted compared to modern waters because it was recharged under conditions that were cooler than at present. Also, because of the inverse relation between the value for the deuterium excess and relative humidity of the moisture source areas, data for old groundwaters recharged during pluvial periods in the Pleistocene sometimes plot below the present-day global or local meteoric water line (Clark and Fritz 1997 [DIRS 105738], pp. 198 to 199, Figure 8-2).



Source: Based on Clark and Fritz 1997 [DIRS 105738], Figures 2-1, 2-9, 2-11, and 9-1.

NOTE: The possible paleometeoric water line for the Amargosa Desert area is based on arguments of White and Chuma 1987 [DIRS 108871], p. 573.

Figure A6-4. Effects of Different Processes on Delta Deuterium and Delta Oxygen-18 Composition of Subsurface Water

Despite seasonal variations in the δD and δ^{18}O composition of precipitation, the isotopic composition of the recharge water in humid regions is generally close to the average volume-weighted isotopic composition of precipitation. In arid climates, the isotopic composition of the recharge can be substantially different from the average volume-weighted isotopic composition of precipitation because of the preferential recharge of winter precipitation (see, for example, Ingraham et al. 1991 [DIRS 145088], p. 256) and because of evaporation prior to recharge. Generally, evaporation shifts the δD and δ^{18}O composition of the infiltrating water to the right of the meteoric water line. The slope of the evaporation line increases with increasing relative humidity of the air (Clark and Fritz 1997 [DIRS 105738], Figure 2-8). The slope of the evaporation line ranges between 3.9 and 4.5 for relative humidities between 0 and 50%, which encompasses the range of relative humidities typical of Yucca Mountain during the summer months. Like evaporation, transpiration by plants increases the salinity of soil moisture; however, transpiration is a nonfractionating process and does not result in isotopic enrichment of the residual soil moisture (Clark and Fritz [DIRS 105738], pp. 80 and 94). The relative importance of evaporation and transpiration on soil water loss can be evaluated by examining if increases in soil-water salinity are accompanied by corresponding increases in δD and $\delta^{18}O$ compositions along an evaporation trend.

Once in the ground, interaction between groundwater and the solid surfaces in soil or rock can cause the $\delta^{18}O$ composition of groundwater to be shifted horizontally to the right of the meteoric water line. This interaction is facilitated by high temperatures such as those associated with known geothermal fields (Clark and Fritz 1997 [DIRS 105738], pp. 250 to 255). At low temperatures, these interactions are kinetically inhibited. However, under special circumstances, interactions between groundwater and silicate minerals, or between groundwater and subsurface gases, may cause the isotopic compositions of groundwater to be shifted to the left of the meteoric water line (Clark and Fritz 1997 [DIRS 105738], Figure 9-1). The special circumstances typically involve alteration of rock to clays at high rock/water ratios or, in the case of gases, proximity to gas vents associated with volcanoes. Note that hydrogen isotope ratios are not generally affected as much by water/rock interactions as oxygen isotope ratios because rocks generally contain much less hydrogen than water on a volume-to-volume basis.

A6.3.1.2.2 Carbon

Carbon has two stable isotopes ^{12}C and ^{13}C and a third isotope, ^{14}C, which is radioactive. Carbon-14 is produced in the atmosphere by interactions of nitrogen and cosmic rays that bombard the earth constantly. The reaction can be described as $^{14}N\ (n,p) \Rightarrow {}^{14}C$. ^{14}C is rapidly mixed in the atmosphere and incorporated into the CO_2 molecule where it is then available for incorporation into terrestrial carbonaceous material. The radioactive decay of ^{14}C, with a half-life ($t_{1/2}$) of 5,730 years (Clark and Fritz 1997 [DIRS 105738], Table 1-3), forms the basis for radiocarbon dating. The ^{14}C age of a sample is calculated by the following equation:

$$t = (-1/\lambda)\ \ln\ ({}^{14}A/{}^{14}A_0) \qquad \text{(Eq. A6-3)}$$

where

t is the mean groundwater age (yr)

λ is the radioactive decay constant, equal to $\ln(2)/t_{1/2}$: $1.21 \times 10^{-4}\ yr^{-1}$ (Clark and Fritz 1997 [DIRS 105738], p. 201)

^{14}A is the measured ^{14}C activity

$^{14}A_0$ is the assumed initial activity.

^{14}C ages are typically expressed in percent modern carbon (pmc). A ^{14}C activity of 100 pmc is taken as the ^{14}C activity of the atmosphere in the year 1890, before the natural ^{14}A of the atmosphere was diluted by large amounts of ^{14}C-free carbon-dioxide gas from the burning of fossil fuel (Clark and Fritz 1997 [DIRS 105738], p. 18).

Theoretically, the activity of ^{14}C in a groundwater sample reflects the time at which the water was recharged. Unfortunately, precipitation is generally very dilute and has a high affinity for dissolution of solid phases in the soil zone, unsaturated zone, and/or saturated zone. In particular, in the transition from precipitation compositions to groundwater compositions, the bicarbonate + carbonate concentration in the water commonly increases by orders of magnitude (Langmuir 1997 [DIRS 100051], p. 292, Table 8.7; Meijer 2002 [DIRS 158813]). Because bicarbonate is the principal ^{14}C-containing species in most groundwaters, the source of this additional bicarbonate can have a major impact on the "age" calculated from the ^{14}C activity of a given water sample. If the source is primarily decaying plant material in an active soil zone, the calculated "age" for the water sample should be close to the real age. On the other hand, if the source of the bicarbonate is dissolution of old ($\geq 10^4$ yr) calcite with low ^{14}C activity, the calculated age for the sample will be too old.

A useful measure of the source of the carbon in a water sample is the $\delta^{13}C$ value of the sample because this value is different for organic materials compared to calcites. The $\delta^{13}C$ value is defined as follows, and expressed in units of per mil:

$$\delta^{13}C = [(^{13}C/^{12}C)_{sample}/(^{13}C/^{12}C)_{standard} - 1] \times 1000 \qquad \text{(Eq. A6-4)}$$

The standard used for reporting stable carbon isotope measurements is carbon from a belemnite fossil from the Cretaceous Pee Dee Formation in South Carolina (Clark and Fritz 1997 [DIRS 105738], p. 9).

The $\delta^{13}C$ values of carbon species typical of the soil waters in arid environments range from –25 to –13 per mil (Forester et al. 1999 [DIRS 109425], p. 36). At Yucca Mountain, pedogenic carbonate minerals have $\delta^{13}C$ values that generally are between –8 and –4 per mil, although early formed calcites are also present that have $\delta^{13}C$ values greater than 0 per mil (Forester et al. 1999 [DIRS 109425], Figure 16; Whelan et al. 1998 [DIRS 137305], Figure 5). Paleozoic carbonate rocks typically have $\delta^{13}C$ values close to 0 per mil (Forester et al. 1999 [DIRS 109425], Figure 16; Whelan et al. 1998 [DIRS 137305], Figure 5).

A6.3.1.2.3 Sulfur

Four stable isotopes of sulfur occur in nature; of these ^{32}S and ^{34}S are the most abundant. The sulfur isotopes are fractionated as a result of reduction of sulfate and by isotope exchange reactions. The isotopic composition of sulfur is expressed in terms of delta-^{34}S ($\delta^{34}S$) as defined by:

$$\delta^{34}S = [(^{34}S/^{32}S)_{sample}/(^{34}S/^{32}S)_{standard} - 1] \times 1{,}000 \qquad \text{(Eq. A6-5)}$$

The standard used for reporting $\delta^{34}S$ is the troilite (FeS) phase of the Canon Diablo meteorite (CDT), which has a $^{34}S/^{32}S$ ratio of 0.0450. Analytical precision is generally greater than ±0.3 per mil (Clark and Fritz 1997 [DIRS 105738], p. 11).

In groundwater, sulfur is transported principally as the conservative ion SO_4^{2-} and thus is a potentially useful indicator of groundwater mixing. Dissolution of solids containing sulfur can also readily change the $\delta^{34}S$ of groundwater. Of particular importance for this study is the fact the early Paleozoic marine carbonate that forms the carbonate aquifer near Yucca Mountain and, presumably, the groundwater from this aquifer, should both have distinctly high $\delta^{34}S$ values (25 to 30 per mil) compared to volcanic aquifer groundwater (Clark and Fritz 1997 [DIRS 105738], pp. 138 to 148, Figures 6-1 and 6-2). The $\delta^{34}S$ in volcanic environments is about 0 ±2 per mil where the sulfur is in a reduced oxidation state and ranges from about 3 to 15 per mil in more oxidizing environments (Clark and Fritz 1997 [DIRS 105738], Figure 6-1).

A6.3.1.2.4 Uranium

^{234}U ($t_{1/2}$ = 2.45 × 10^5 yr) (Cheng et al. 2000 [DIRS 153475], p. 17) is part of the ^{238}U ($t_{1/2}$ = 4.47 × 10^9 yr) radioactive decay series (Clark and Fritz 1997 [DIRS 105738], Table 1-3). The $^{234}U/^{238}U$ activity ratio in rocks is generally close to the secular equilibrium value 1. However, ^{234}U is typically enriched relative to ^{238}U in groundwater (Activity ratios > 1; Osmond and Cowart 1992 [DIRS 145190], Figure 9.1). The primary causes for this enrichment are: preferential dissolution of ^{234}U from crystallographic defects caused by alpha decay; the tendency for ^{234}U atoms to be converted to the more soluble uranyl ion due to the effects of radiation-induced ionization (Gascoyne 1992 [DIRS 127184], Section 2.5.1), and direct ejection of ^{234}Th (which decays in about 24 days to ^{234}U) into groundwater by alpha recoil. Uranium activity ratios may be lowered by release of uranium from rock and minerals with $^{234}U/^{238}U$ ratios near secular equilibrium through dissolution. Consequently, the $^{234}U/^{238}U$ activity ratios are the result of the competing effects of enrichment processes and dissolution of uranium-bearing material. Given the long half-life of ^{234}U relative to groundwater ages in this region, changes in the $^{234}U/^{238}U$ activity ratio due to ^{234}U decay are insignificant. Removal of uranium from solution by precipitation or sorption decrease U concentrations, but these processes do not affect the isotopic ratio. Therefore, the isotopic ratio should be relatively constant along a groundwater pathway unless additional U is added to the groundwater through mixing or by mineral or glass dissolution, or recoil-related processes.

A6.3.1.2.5 Strontium

Strontium is a trace constituent in groundwaters, with concentrations typically ranging from 10 µg/L to 1,000 µg/L. Strontium has four naturally occurring isotopes, ^{84}Sr, ^{86}Sr, ^{87}Sr and ^{88}Sr, all of which are stable. The absolute abundances of ^{84}Sr, ^{86}Sr and ^{88}Sr do not change. In contrast, the absolute abundance of ^{87}Sr is continually increasing because this nuclide is produced from decay of ^{87}Rb. Therefore, the $^{87}Sr/^{86}Sr$ ratios of rocks and minerals continually increase; the present day $^{87}Sr/^{86}Sr$ ratio depends on the relative abundances of Rb to Sr and on their age (Faure 1986 [DIRS 105559], Section 8). Strontium in groundwater is acquired from the materials through which the water passes. The $^{87}Sr/^{86}Sr$ ratios in groundwater will evolve toward the isotopic composition of the host material along its flow path as water-rock reaction progresses. Strontium isotope ratios can therefore provide a record of groundwater sources, flow pathways, and water-rock interaction.

Strontium isotope ratios are commonly expressed using the delta notation relative to a standard value according to the equation:

$$\delta^{87}Sr = [(^{87}Sr/^{86}Sr)_{sample}/(^{87}Sr/^{86}Sr)_{standard} - 1] \times 1{,}000 \qquad \text{(Eq. A6-6)}$$

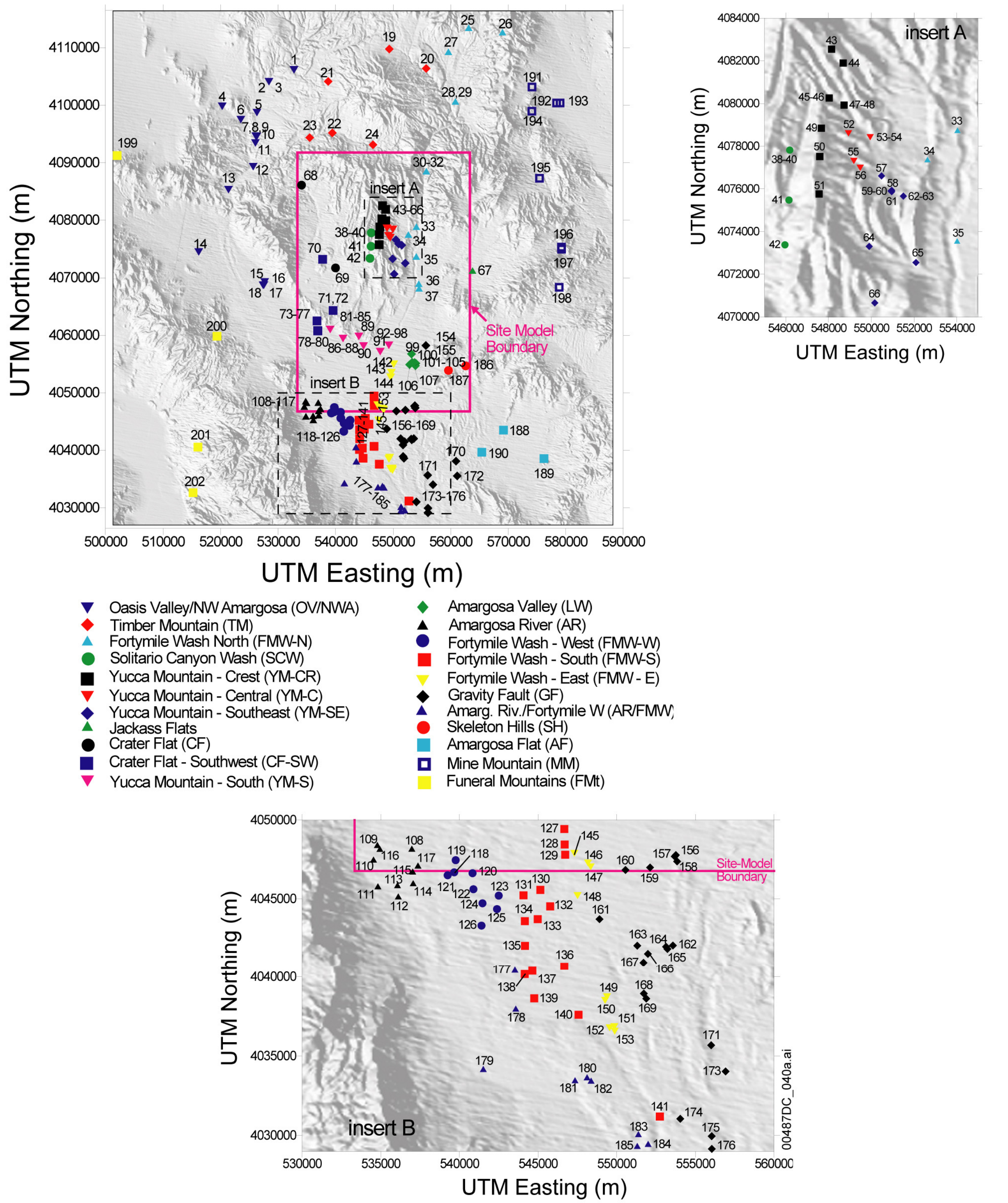
where the $(^{87}Sr/^{86}Sr)_{standard}$ value is modern seawater with a ratio of 0.7092.

Strontium in the oceans has a residence time of about 5,000,000 years, considerably longer than oceanic mixing times, which are on the order of 1,000 yrs (Faure 1986 [DIRS 105559], Section 11). As a result, the $^{87}Sr/^{86}Sr$ ratio of strontium in the open oceans is consistent globally. This ratio, however, has changed throughout the Phanerozoic in response to the relative contributions of the different rock types that are exposed to chemical weathering. The variations of the $^{87}Sr/^{86}Sr$ ratios throughout the Phanerozoic have been determined by analyzing unaltered samples of marine carbonate (e.g., Burke et al. 1982 [DIRS 162906]). This work and subsequent refinements by a number of other studies have produced a detailed history of the variations in oceanic $^{87}Sr/^{86}Sr$ ratios throughout the Phanerozoic. Such information can be quite useful when interpreting $^{87}Sr/^{86}Sr$ ratios of groundwater that has interacted with marine carbonate rock.

A6.3.2 Assignment and Description of Hydrochemical Groupings in the Vicinity of Yucca Mountain

Hydrochemical and isotopic data from over 200 groundwater samples are presented in this appendix. The locations of wells cited in this section are shown in Figure A6-5, with insets to show greater detail. As these maps show, the data are unevenly distributed throughout the Yucca Mountain region, with clusters of wells in central and northern Yucca Mountain, farming areas of the Amargosa Desert, and along U.S. Highway 95. Elsewhere, data are relatively sparse, particularly to the west and east of Yucca Mountain in Crater Flat and Jackass Flats, respectively. An important data gap also exists at Yucca Mountain itself, between the cluster of wells in central and northern Yucca Mountain, and the line of wells along U.S. Highway 95. The potential impact of these gaps in data coverage is to make mixing trends among groundwaters separated by the gaps less obvious.

To facilitate interpretation and discussion, these samples are assigned to 22 different groups. Each group is identified by a unique symbol and color, which are used in plots throughout. Samples are numbered sequentially within groups. Numbering within and between groups generally increases from north to south, with the exception of the last three groups, Mine Mountain, Amargosa Flat, and Funeral Mountains. All groupings are based largely on geographic distribution, or geographic affiliation. Hydrochemical similarities and/or trends were also considered in the group assignments. Accordingly, some groups show a relatively uniform hydrochemical composition, whereas others show a spread in hydrochemistry and were grouped to emphasize this transition. A brief geographic and hydrochemical description of each group follows. Hydrochemistry of all samples is shown on trilinear (Piper) and scatter plots (Figures A6-6 through A6-8), with the groups divided into three separate figures for clarity.



NOTES: The figure has color-coded data points and should not be read in a black and white version. The upper right panel corresponds to the area marked "insert A"; the lower panel corresponds to the area marked "insert B." Borehole numbers correspond to the names in Table A6-2.

UTM = Universal Transverse Mercator.

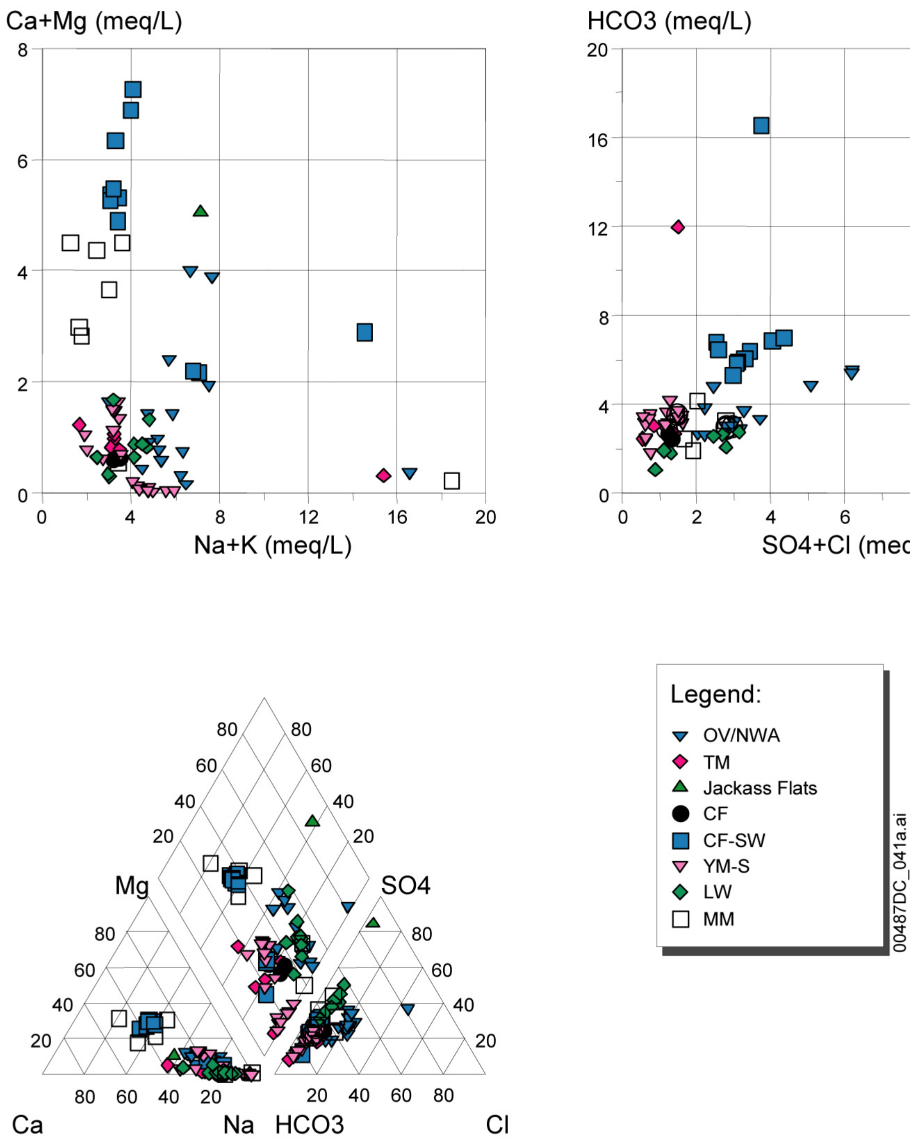
Figure A6-5. Locations of Boreholes in the Vicinity of Yucca Mountain and the Northern Amargosa Desert

The Oasis Valley/northwest Amargosa Desert group (OV/NWA) comprises boreholes located from the northern part of Oasis Valley extending southward along the course of the Amargosa River to the west and south of Bare Mountain. Boreholes drilled as part of the Nye County Early Warning Drilling Program (NC-EWDP) are located along the southern edge of Crater Flat and extend southeasterly into Fortymile Wash. Most of these wells have been assigned into two groupings, Crater Flat–southwest (CF-SW) and Yucca Mountain-south (YM-S), on the basis of geographic position and hydrochemistry. Two boreholes with similar chemistry comprise the Crater Flat group (CF). Boreholes to the north of Yucca Mountain are assigned to the Timber Mountain group (TM). A single borehole, though one with unique hydrochemical characteristics comprises the Jackass Flats group. Several tightly grouped boreholes along U.S. Highway 95 are assigned to the Amargosa Valley (formerly Lathrop Wells) group (LW). Finally, the boreholes in the northeast part of the study area are assigned to the Mine Mountain group.

Most groundwaters from these regions are a sodium-bicarbonate type (Figure A6-6). Notable exceptions are those samples from the SW Crater Flat Group and the Mine Mountain Group, which contain greater Ca^{2+} + Mg^{2+} relative to Na^{+} + K^{+}. These groundwaters either originate from the regional carbonate aquifer or have contacted alluvium derived from carbonate rocks and their greater Ca^{2+} + Mg^{2+} contents reflect the composition of these rock. The hydrochemical characteristics of groundwater beneath the broad area of Jackass Flats are represented by data from a single borehole (J-11), which has a unique chemical signature that may or may not be representative of regional groundwater flow in this area.

Boreholes at Yucca Mountain were divided into (1) a western group designated Solitario Canyon Wash (SCW), which includes samples from west of the Solitario Canyon fault, (2) a group of samples that encompasses the crest of Yucca Mountain (Yucca Mountain-Crest YM-CR), (3) a central group (Yucca Mountain Central, YM-C), which includes boreholes located within the central block of Yucca Mountain, and (4) a southeastern group (Yucca Mountain-Southeast, YM-SE), which includes boreholes along and south of Dune Wash. Boreholes near Fortymile Wash east and northeast of Yucca Mountain are assigned to a northern Fortymile Wash North group (FMW-N), distinguishing them from samples along the course of the Fortymile Wash in the Amargosa Desert (discussed below).

These groundwater are mostly sodium-bicarbonate water, typically with low total dissolved solids (TDS) (Figure A6-7). An important exception to this is the borehole p#1(c) sample from the YM-SE group (site 63), which penetrates to the carbonate aquifer. This sample is distinct from those from the volcanic aquifer in that it has higher calcium, magnesium, and TDS. The contribution of carbonate water in sample p#1(v) from the volcanic aquifer (site 62) is also evident in Figure A6-7. It was estimated that about 28.6% of the groundwater in this sample originated from upward flow in the borehole from the carbonate aquifer (Craig and Robison 1984 [DIRS 101040], p. 49).



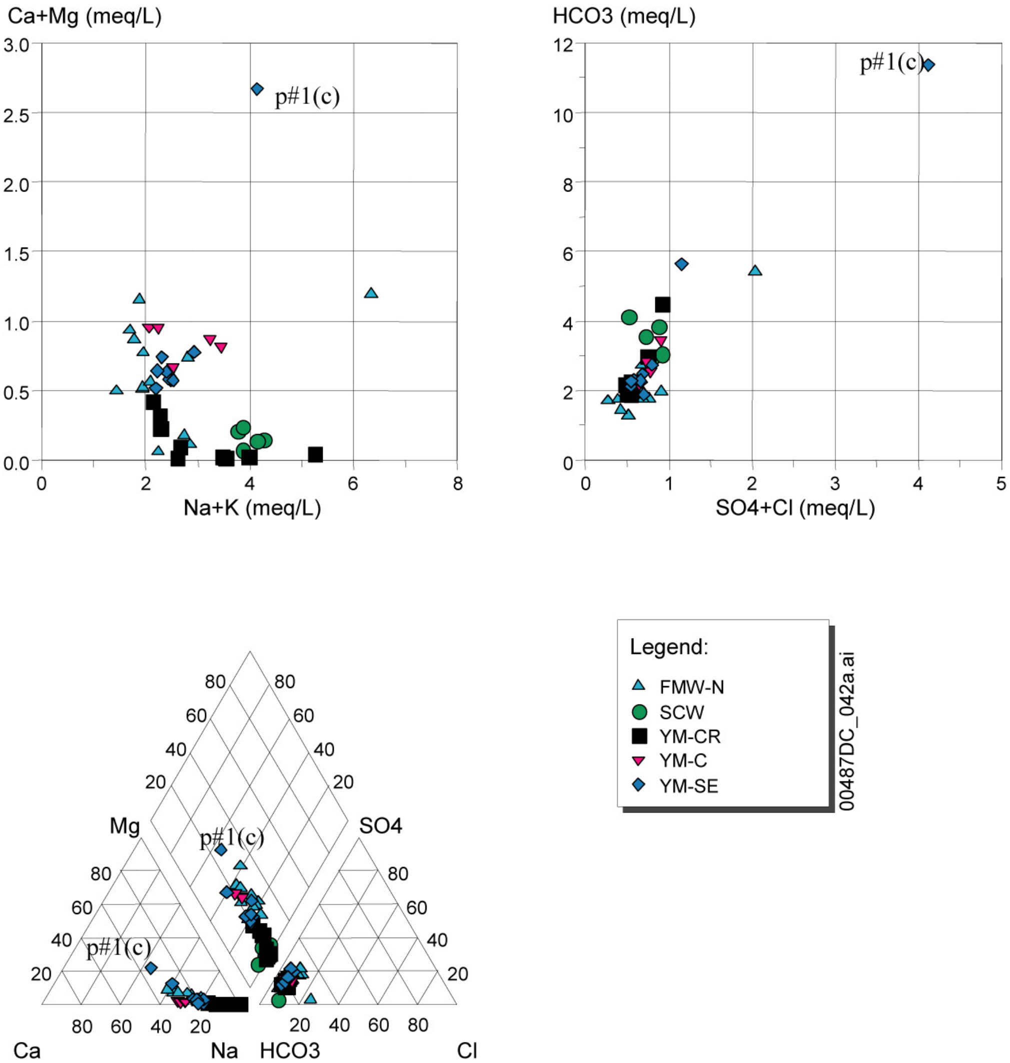
Source: Table A6-1.

NOTE: Units for the trilinear plots are percent milliequivalents per liter. Legend explained in Figure A6-5.

Figure A6-6. Trilinear and Scatter Plots for Samples that Surround Yucca Mountain But Are Generally North of the Amargosa Valley

Figure A6-8 shows hydrochemical characteristics from boreholes located south of U.S. Highway 95. The Amargosa River (AR) and Gravity fault (GF) groupings constitute boreholes located on the west and east sides of the Amargosa Desert, respectively. Groundwater from these groupings is typically sodium-calcium-bicarbonate-sulfate water type with higher TDS than samples in the central Amargosa Desert. Boreholes located along and near the main channel of Fortymile Wash in the Amargosa Desert are assigned to the Fortymile Wash-south (FMW-S) grouping. These are relatively dilute sodium-bicarbonate waters. The Amargosa River, Gravity fault and FMW-S groups, in general, represent three end-members of the hydrochemistry displayed in the Amargosa Desert region. Boreholes of the

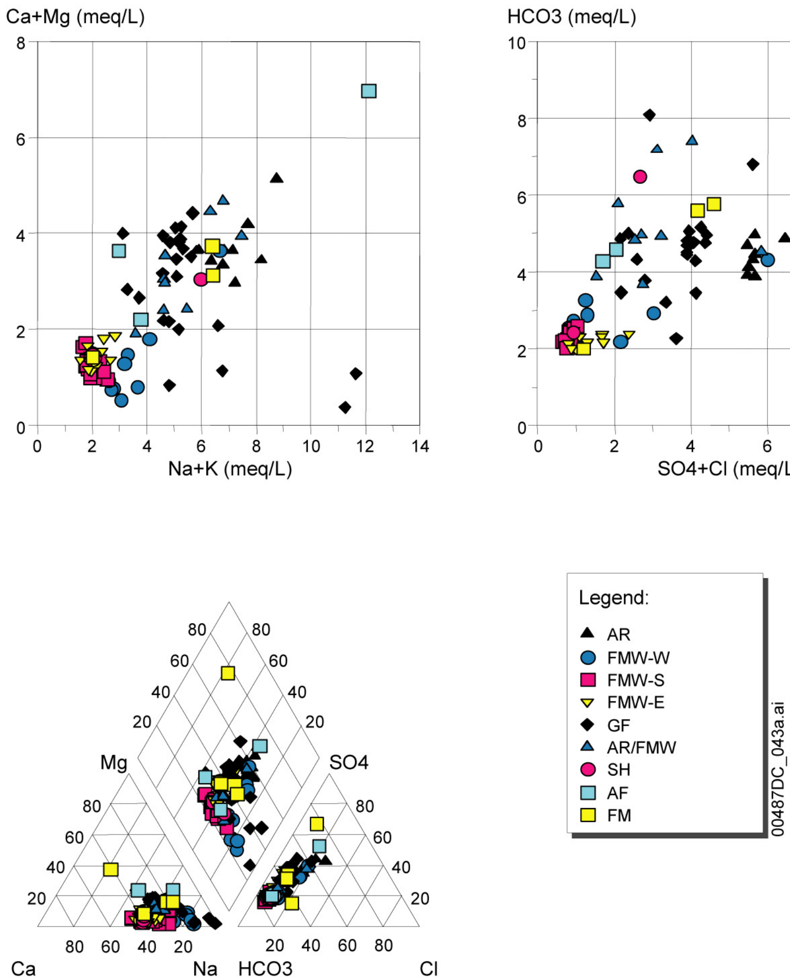
Fortymile Wash-East (FMW-E), Fortymile Wash-West (FMW-W) and Amargosa River/Fortymile Wash (AR/FMW) groupings are transitional between these end members. Boreholes near the Skeleton Hills and Specter Range Thrust fault are grouped together as Skeleton Hills (SH). Boreholes in the far east of the study area are assigned to the Amargosa Flat group (AF), and finally, the widely spaced samples along the western part of the study area are grouped as the Funeral Mountains (FMt) group.



Source: Table A6-1.

NOTE: Units for the trilinear plots are percent milliequivalents per liter. Legend explained in Figure A6-5.

Figure A6-7. Trilinear and Scatter Plots for Samples from the Yucca Mountain Area



Source: Table A6-1.

NOTE: Units for the trilinear plots are percent milliequivalents per liter. Legend explained in Figure A6-5.

Figure A6-8. Trilinear and Scatter Plots for Samples from Groupings in the Amargosa Desert Region

A6.3.3 Depth-Dependent Trends in the Chemical and Isotopic Composition of Groundwater

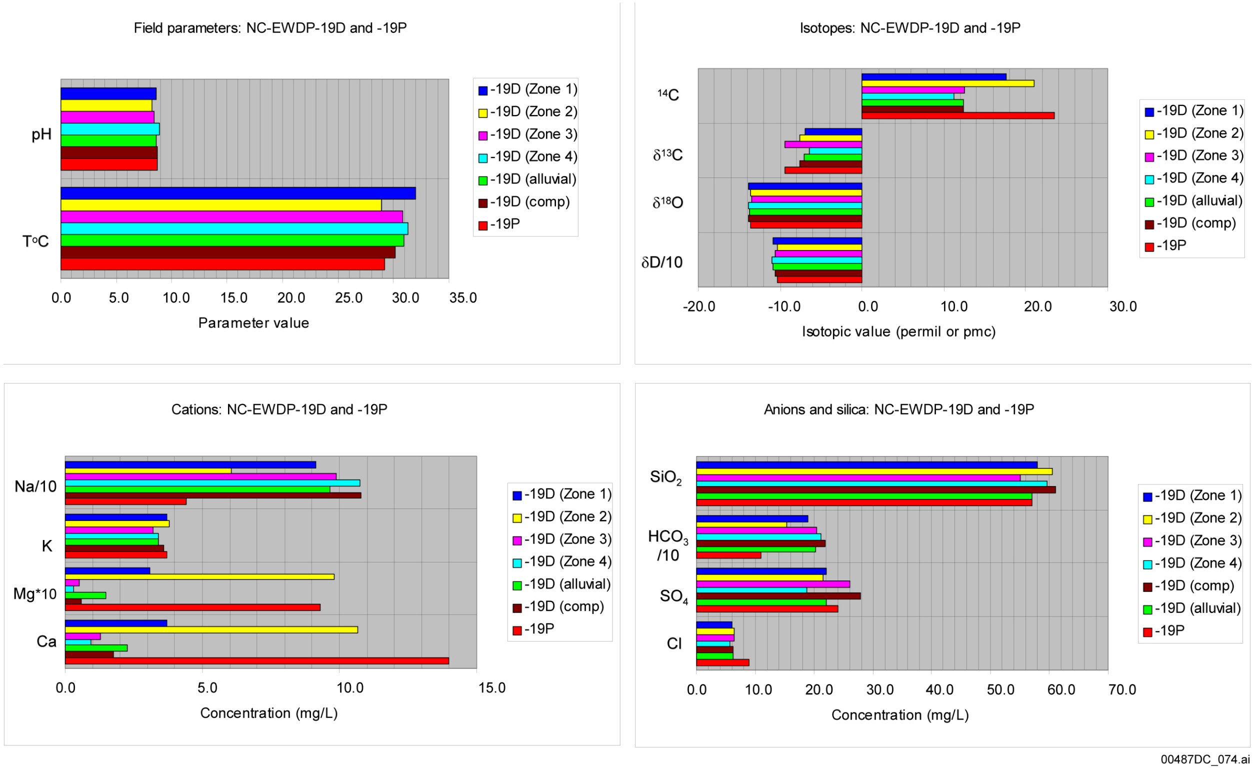
This section describes groundwater samples from different depth intervals in single well or closely spaced wells to evaluate the relationship between hydrochemistry and depth and/or aquifer rock type. For most wells in the Yucca Mountain area, groundwater samples were obtained by pumping from an open borehole. In some boreholes, flow logs made during pumping indicate that much of the groundwater came from a relatively narrow depth interval, whereas in other boreholes, flow logs indicate the mixing of groundwater from different depth intervals. Sampling groundwater from an open borehole produces a groundwater composition that is naturally weighted by the permeability of the producing zones and which may be representative of the average composition of groundwater flowing past the open interval of the borehole (see Section A6.3.4). However, it may also result in artificial mixing of groundwaters that would not otherwise mix and thereby obscure compositional differences that reflect different groundwater sources and rates of groundwater movement. This section examines data from the

NC-EWDP wells obtained from discrete-interval sampling or from closely spaced wells and piezometers completed at different depths to assess the magnitude and importance of these differences.

A6.3.3.1 Boreholes NC-EWDP-19D and -19P

Groundwater samples were collected at borehole NC-EWDP-19D (Site 92) from the open borehole ("composite" sample), from the saturated alluvial section (Site 94), from zones 1 to 4 at different depth intervals within the alluvium (Sites 95–98), and from the alluvium at nearby piezometer NC-EWDP-19P (Site 93). The screened interval in NC-EWDP-19P (109.5– to 139.8-m depth) is slightly higher but overlaps with Zone 1 of NC-EWDP-19D (125.9 –131.4 m). The open borehole sample from NC-EWDP-19D included contributions from a lithic ash flow tuff between depths of 251 and 379 m, whereas the remainder of the groundwater samples originated from the alluvium overlying the tuffs (DTN: LA0311EK831223.001 [DIRS 165985]). The compositions of groundwater from the open-hole and the composite alluvial interval likely reflect the relative amounts of inflow from different zones into the borehole during pumping.

All of the groundwater samples from NC-EWDP-19D and -19P are characterized by low Cl-concentrations compared to Crater Flat area groundwater and very light $\delta^{18}O$ compared to northern Fortymile Wash area (FMW-N) groundwater found at boreholes J-13, J-12, and JF-3 (Tables A6-1 and A6-2). Samples from wells NC-EWDP-19P and -19D (Zone 2) have higher concentrations of Ca^{2+} and Sr^{2+} (not shown, see Table A6-2), lower concentrations of Na^{+} and HCO_3^{-}, heavier δD, and higher ^{14}C activity compared to other alluvial groundwater from well NC-EWDP-19D (Figure A6-9). These compositional characteristics are compatible with less water-rock interaction and short residence times of groundwater in this interval compared with other intervals in the alluvium. However, hydraulic testing (BSC 2004 [DIRS 170010]) at NC-EWDP-19D indicated that Zone 4 was the most permeable zone in the immediate vicinity of the borehole.



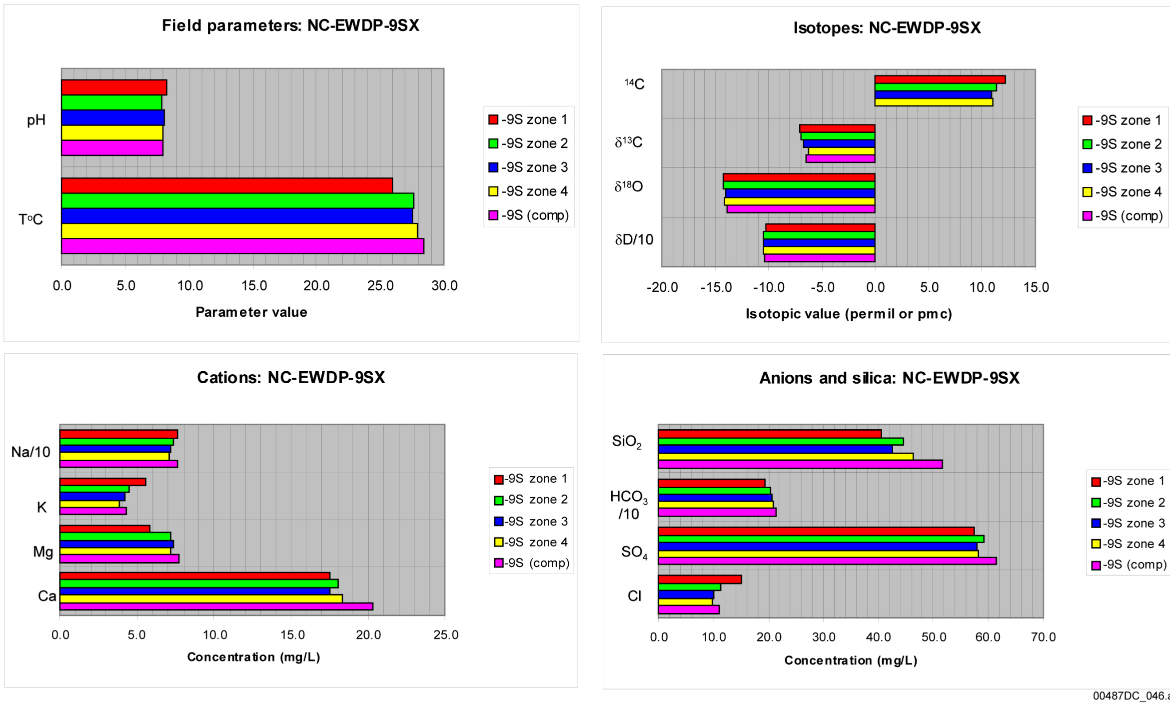
Source: Tables A6-1 and A6-2.

NOTE: For plotting purposes only, Mg^{2+} concentration has been multiplied by 10, and the values for Na^{+}, δD, and HCO_3^{-} have been divided by 10.

Figure A6-9. Plots of Selected Hydrochemical Constituents for the Different Depth Intervals of Boreholes NC-EWDP-19D and -19P

A6.3.3.2 Borehole NC-EWDP-9SX

Groundwater from four depth intervals in borehole NC-EWDP-9SX (Sites 82 to 85) originates from the upper 91 m of the SZ just south of Crater Flat. The groundwater over this relatively narrow depth range is similar in all four-depth intervals (Figure A6-10). In general, ^{14}C, $\delta^{13}C$, δD, Na^{+}, K^{+}, and Cl^{-} decrease slightly and HCO_3^{-} increases with depth in the borehole, but overall, there is relatively little chemical or isotopic variability within the depth range spanned by sampling Zones 1 to 4. In addition to the data shown in Figure A6-10, the Sr^{2+} concentration in Zone 1 is slightly less than in the other zones, but the $\delta^{87}Sr$, $\delta^{34}S$, and $^{234}U/^{238}U$ activity ratio data are very similar in all four zones (Table A6-2). The composite sample from borehole NC-EWDP-9SX (Site 81) has a composition that is similar to that of the individual zones but with slightly higher concentrations of Ca^{2+}, Mg^{2+}, Na^{+}, SO_4^{2-}, SiO_2, and Sr^{2+}. The remainder of the chemical and isotopic species of the composite sample is similar or intermediate to those of the four individual zones.



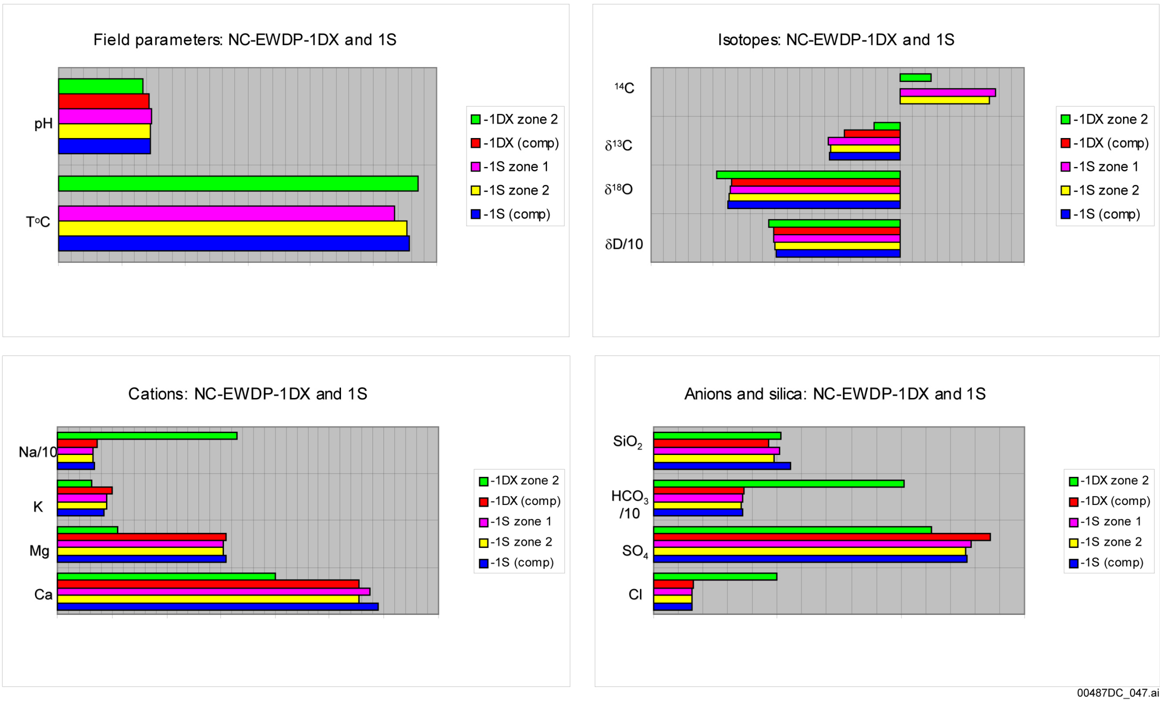
Sources: Tables A6-1 and A6-2.

NOTE: For plotting purposes only, the values for Na^+, δD, and HCO_3^- have been divided by 10.

Figure A6-10. Plots of Selected Hydrochemical Constituents for the Different Depth Intervals of Borehole NC-EWDP-9SX

A6.3.3.3 Boreholes NC-EWDP-1DX and -1S

Groundwater from shallow intervals (48.8–54.9 and 64.0–82.3 m) in borehole NC-EWDP-1S (Sites 75 to 76) shows large differences in both chemical and isotopic composition compared to deep groundwater (658.4 to 682.8 m) from Zone 2 (Site 74) in borehole NC-EWDP-1DX (Figure A6-11). Chemically, groundwater from Zone 2 in NC-EWDP-1DX has much higher Na^+, Sr^{2+} (not shown, see Table A6-2), Cl^-, F^- (not shown, see Table A6-2), and HCO_3^- concentrations and has lower pH and lower Ca^{2+} and SO_4^{2-} concentrations than the shallower groundwater from NC-EWDP-1S. The deep groundwater from Zone 2 of borehole NC-EWDP-1DX is heavier in $\delta^{13}C$ and $\delta^{34}S$ (not shown, see Table A6-2), lighter in $\delta^{18}O$ and δD, and has a lower $^{234}U/^{238}U$ activity ratio (not shown, see Table A6-2) than the shallow zones in NC-EWDP-1S (Figure A6-11 and Table A6-2). The composite groundwater samples from boreholes NC-EWDP-1S (Site 77) and NC-EWDP-1DX (Site 73) have similar isotopic and chemical compositions to the shallow groundwater samples from NC-EWDP-1S.



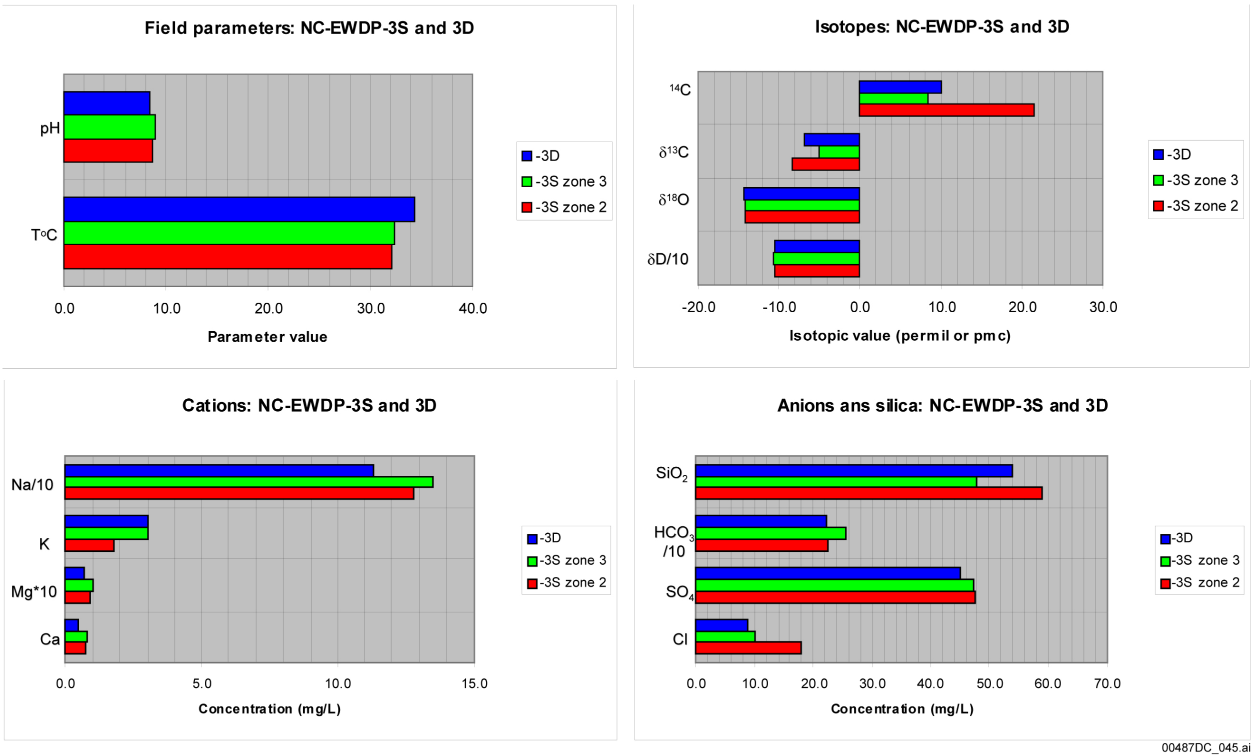
Sources: Tables A6-1 and A6-2.

NOTE: For plotting purposes only, the values for Na^+, δD, and HCO_3^- have been divided by 10.

Figure A6-11. Plots of Selected Hydrochemical Constituents for the Different Depth Intervals of Boreholes NC-EWDP-1S and -1DX

A6.3.3.4 Boreholes NC-EWDP-3D and -3S

Groundwater at NC-EWDP-3S was sampled from Zone 2 between depths of 103.6 and 128.0 m (site 87) and from Zone 3 between depths of 146.3 and 160.0 m (Site 88) (DTN: GS010308312322.003 [DIRS 154734]). Well NC-EWDP-3D (Site 86) was drilled to 762 m but was open between 159 to 292 m (DTN: LA0311EK831223.001 [DIRS 165985]). The groundwaters from these three sample locations have similar concentrations in most major ions with the exception that the sample from Zone 2 of NC-EWDP-3S is higher in Cl^- concentration, has higher ^{14}C, and is lighter in $\delta^{13}C$ compared to the other two samples (Figure A6-12). Compared to other wells in the YM-S group, groundwater samples from NC-EWDP-3D and -3S are very low in divalent cations, including Ca^{2+}, Mg^{2+}, and Sr^{2+} (not shown, see Table A6-2).



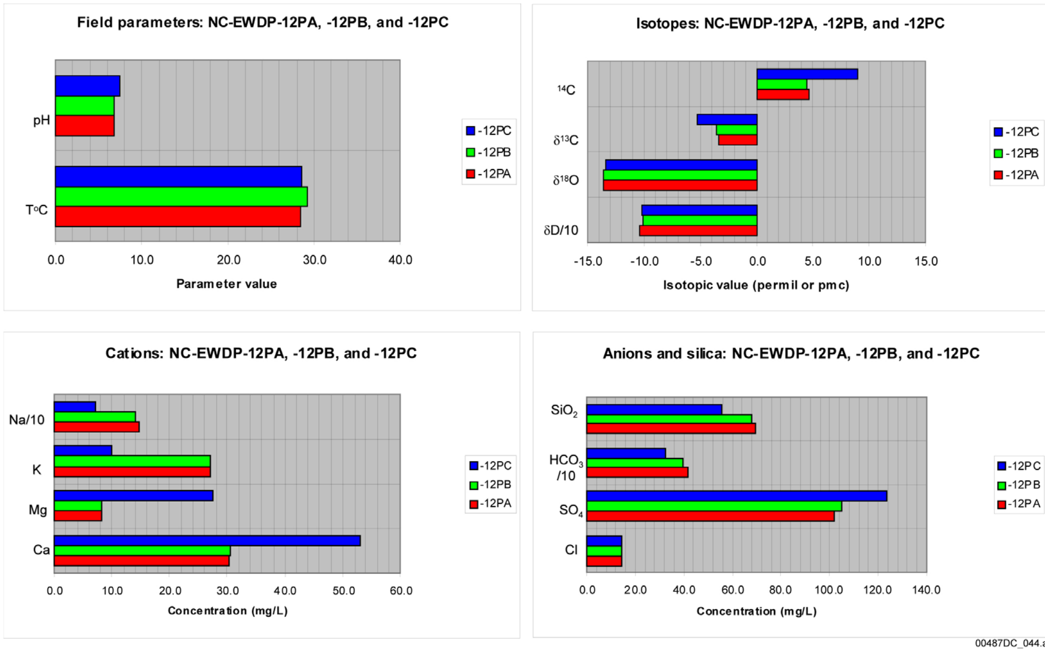
Sources: Tables A6-1 and A6-2.

NOTE: For plotting purposes only, Mg^{2+} concentration has been multiplied by 10, and the values for Na^{+}, δD, and HCO_3^{-} have been divided by 10.

Figure A6-12. Plots of Selected Hydrochemical Constituents for the Different Depth Intervals of Boreholes NC-EWDP-3S and -3D

A6.3.3.5 Boreholes NC-EWDP-12PA, -12PB, and -12PC

Boreholes NC-EWDP-12PA (Site 78), -12PB (Site 79), and -12PC (Site 80) form a piezometer nest in the northern Amargosa Desert just south of western Crater Flat. As shown in Table A4-3, the open intervals of the piezometers in boreholes NC-EWDP-12PA and NC-EWDP-12PB are located about 46 m below the open interval in NC-EWDP-12PC. Groundwater from boreholes NC-EWDP-12PA and NC-EWDP-12PB is very similar with respect to almost all chemical species and isotopes (Figure A6-13). The shallower groundwater from NC-EWDP-12PC is higher in ^{14}C, Ca^{2+}, Mg^{2+}, and SO_4^{2-}, lower in K^{+}, Na^{+}, HCO_3^{-}, F^{-} (not shown, see Table A6-2), and SiO_2, and lighter in $\delta^{13}C$ than groundwater from the other boreholes. The lower ^{14}C and heavier $\delta^{13}C$ of the groundwater in boreholes NC-EWDP-12PA and -12PB indicates the deep groundwater has interacted with more carbonate rocks. The geologic map of the NTS and vicinity shows that a slide block of carbonate sedimentary rock from Bare Mountain outcrops along the low ridge bordering southern Crater Flat just north of these boreholes (Slate et al. 2000 [DIRS 150228], Plate 1, p. 13). The groundwater at all three boreholes has similar $\delta^{18}O$ and δD to groundwater at borehole VH-2 in western Crater Flat (Table A6-2).



Sources: Tables A6-1 and A6-2.

NOTE: For plotting purposes only, the values for Na^+, δD, and HCO_3^- have been divided by 10.

Figure A6-13. Plots of Selected Hydrochemical Constituents for the Different Depth Intervals of Boreholes NC-EWDP-12PA, -12PB and -12PC

A6.3.3.6 Summary of Depth-Dependent Trends in Groundwater Compositions

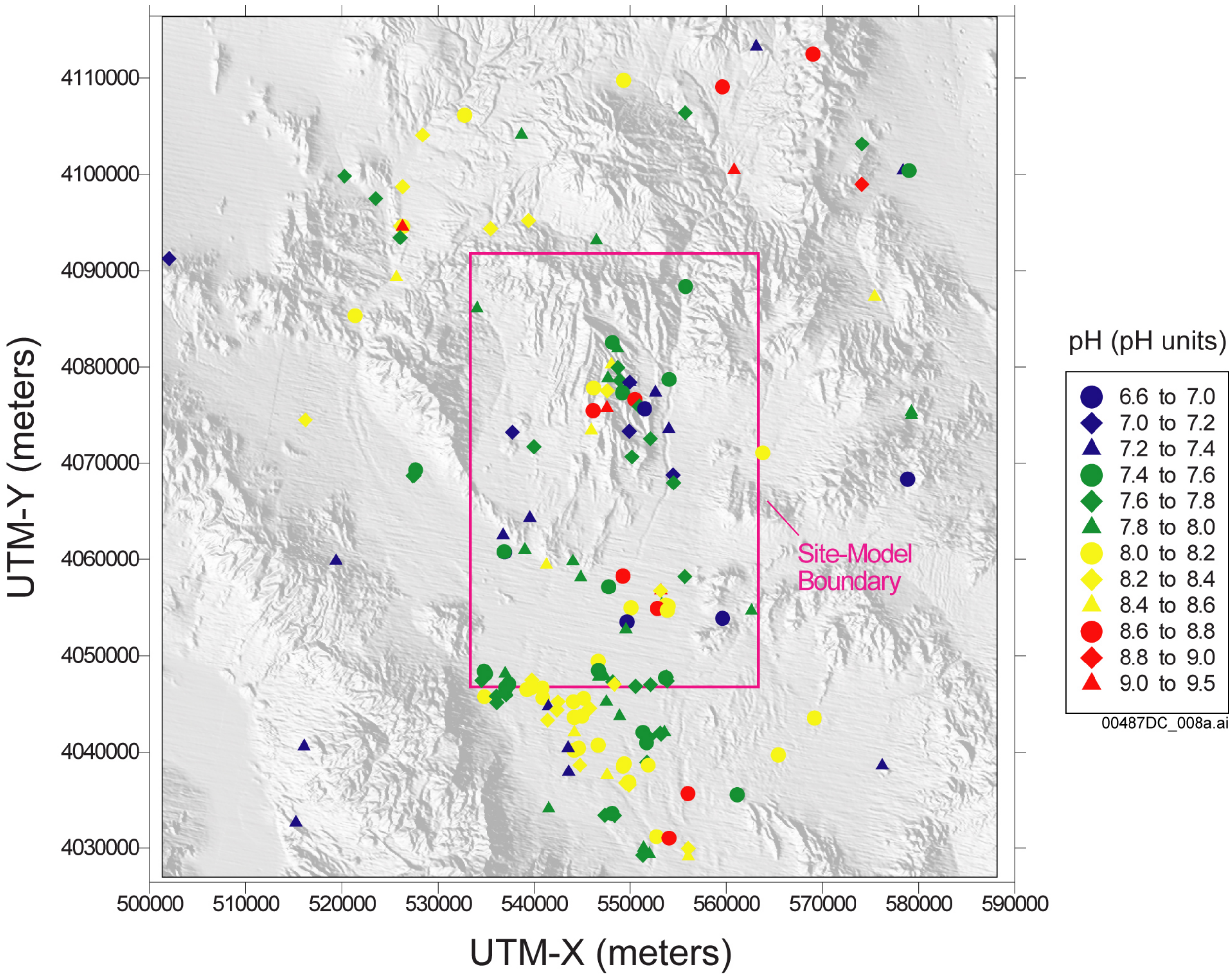
Groundwater geochemical and isotopic data from five groups of NC-EWDP wells and piezometers along U.S. Highway 95 were examined to determine the extent of compositional changes with sampling depth. The changes with depth for most constituents were small at wells NC-EWDP-9SX, piezometers NC-EWDP-12PA, NC-EWDP-12PB and NC-EWDP-12PC, and wells NC-EWDP-3D and NC-EWDP-3S. This may be due, in part, to the relatively small range of depths sampled within each of these groups. For these groups, the composition of the groundwater sampled from the open borehole within the group does not substantially differ from any of the samples taken from a narrower depth interval. For wells NC-EWD-1DX and NC-EWD-1S, the deep (658.4–682.8 m) sample from Zone 2 of NC-EWDP-1DX (Site 74) is very different from the other samples in this group. However, groundwater from Zone 2 does not appear to contribute significantly to the composition of groundwater pumped from the open interval of NC-EWDP-1DX (Site 73), which more closely resembles shallow groundwater from nearby well NC-EWDP-1S. This observation indicates that the deep groundwater from Zone 2 at NC-EWDP-1DX may be relatively stagnant and not representative of the flowing groundwater composition at this location. Groundwaters from wells NC-EWDP-19D and NC-EWDP-19P have significant compositional variations with depth that indicate possible differences in groundwater sources, flow rates, or extent of water/rock interactions. The shallow groundwater from piezometer NC-EWDP-19P (Site 93) represents the composition of the shallowest and, perhaps, youngest groundwater in this area. The composite alluvial sample from well NC-EWDP-19D (Site 94) approximates the average composition of alluvial groundwater in this area.

A6.3.4 Areal Distributions of Chemical and Isotopic Species

In this section, areal distributions of values measured for the concentrations of major cations and anions and for isotopic ratios are presented, along with some preliminary analysis. The discussions of areal trends in individual chemical and isotopic constituents presented in this section are intended to be somewhat general in character. More detailed discussions are presented below. Many boreholes, particularly the Nye County-EWDP boreholes along U.S. Highway 95 (Yucca Mountain-South grouping) have numerous sampled intervals as discussed previously. In these cases, one value, which is considered to best represent the average value for that borehole and to best represent regional hydrochemical trends is plotted. Typically, data for groundwater samples pumped from the entire open interval of borehole are plotted in figures in Sections A6.3.4 and A6.3.5. Thus, the sampled groundwater compositions are naturally weighted toward the compositions in the most permeable intervals of the well, and the compositions of groundwater from less permeable zones attain less emphasis. These composite samples thus provide a good indication of the flux-weighted composition of groundwater actually moving past the well in the aquifer. (Note: One exception to this generalization exists in the case of NC-EWDP-19D, where the composite alluvial sample, rather than the composite borehole sample, was used.) Nonetheless, vertical heterogeneity displayed among the samples is recognized as an important element in evaluating the flow system. Although groundwater pumped from the open interval of a borehole may be representative of the average flowing composition, more detailed depth sampling, like that available for well NC-EWDP-19D (Section A6.3.3.1), does suggest that in some locations groundwaters may originate from different sources, travel at different velocities, or undergo different degrees of water/rock interaction. These groundwaters can become artificially mixed in samples pumped from large open intervals, partially obscuring details of the flow system.

A6.3.4.1 pH

Groundwater pH at Yucca Mountain varies between about 7 and 9 (Figure A6-14). Some of the higher pH values are found in the vicinity of Yucca Crest, with similarly high pH values found in groundwater associated with Solitario Canyon Wash. Groundwater in the carbonate aquifer at borehole p#1 (Site 63) has a distinctly lower pH value (6.6) compared to groundwater in the volcanic aquifer at Yucca Mountain. Groundwater to the north and northeast of Yucca Mountain also has a pH range of 7 to 9, with the highest values present in the northernmost part of Fortymile Wash. South of the northern boundary of the site model, groundwater pH along Fortymile Wash shows an overall increase from values of about 7.2 to 7.6 directly east of Yucca Mountain to values greater than 8 near Fortymile Wash in the Amargosa Desert. Groundwater pH values less than 8 generally are typical of the groundwater associated with the Amargosa River and Gravity fault areas (Figure A6-14).



Source: Table A6-1.

NOTES: This figure has color-coded data points and should not be read in a black and white version. The pH is –log[H^+] where [H^+] is the activity of hydrogen ion in moles/L.

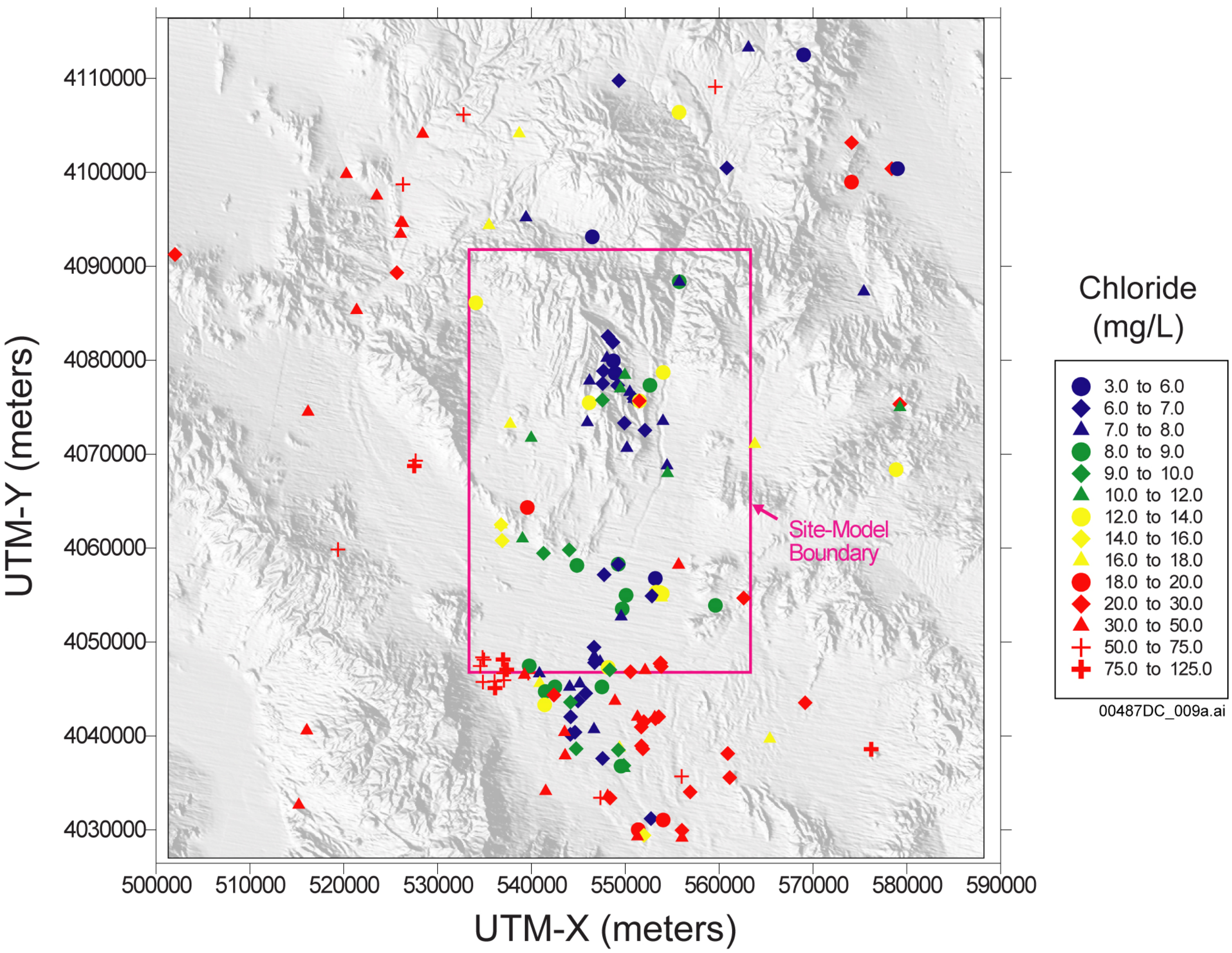
UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-14. Areal Distribution of pH in Groundwater

A6.3.4.2 Chloride

The chloride (Cl^-) concentrations of groundwater samples in the Yucca Mountain vicinity are shown in Figure A6-15. The areal distribution clearly shows coherent spatial patterns in Cl^-concentrations. Except for borehole p#1, where groundwater was sampled from the carbonate aquifer (Site 62) and from deep in the volcanic section (Site 62) where groundwater seems to be mixed with groundwater from the carbonate aquifer, the Cl^- concentrations of groundwater in the Yucca Mountain area generally are low (less than 9 mg/L) compared to areas to the west and east. Several wells to the north of Yucca Mountain in the Timber Mountain area have similarly low Cl^- concentrations. Groundwater from the Oasis Valley to the northwest of the site model area generally has Cl^- concentrations of 20 to 50 mg/L. These concentrations are slightly lower than the Cl^- concentrations of 50 mg/L or more measured in groundwater near the Nuclear Engineering Company (NEC) wells west of Bare Mountain or in groundwater in the southwest corner of the site model boundary. Groundwater to the northeast and east of the site model boundary shows considerable variability between closely spaced wells, so that it is difficult to make generalizations about Cl^- concentrations in these areas.

Groundwater in eastern Crater Flat has low Cl^- concentrations compared to groundwater in western Crater Flat, a distinction that is preserved at the south end of Crater Flat at the NC-EWDP boreholes. One borehole at the southern end of Crater Flat (Site 71 – NC-EWDP-7S) has a relatively high Cl^- concentration of 18 to 20 mg/L. The depth to groundwater at this borehole is only about 7 m and groundwater in this area, like the shallow groundwater in Oasis Valley, may have been affected by evapotranspiration. Low Cl^- concentrations associated with the Fortymile Wash area east of Yucca Mountain extend southward into the Amargosa Desert, where the low-concentration zone is bounded by areas having substantially higher Cl^- concentrations.



Source: Table A6-1.

NOTE: This figure has color-coded data points and should not be read in a black and white version.
UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-15. Areal Distribution of Chloride in Groundwater

A6.3.4.3 Sulfate

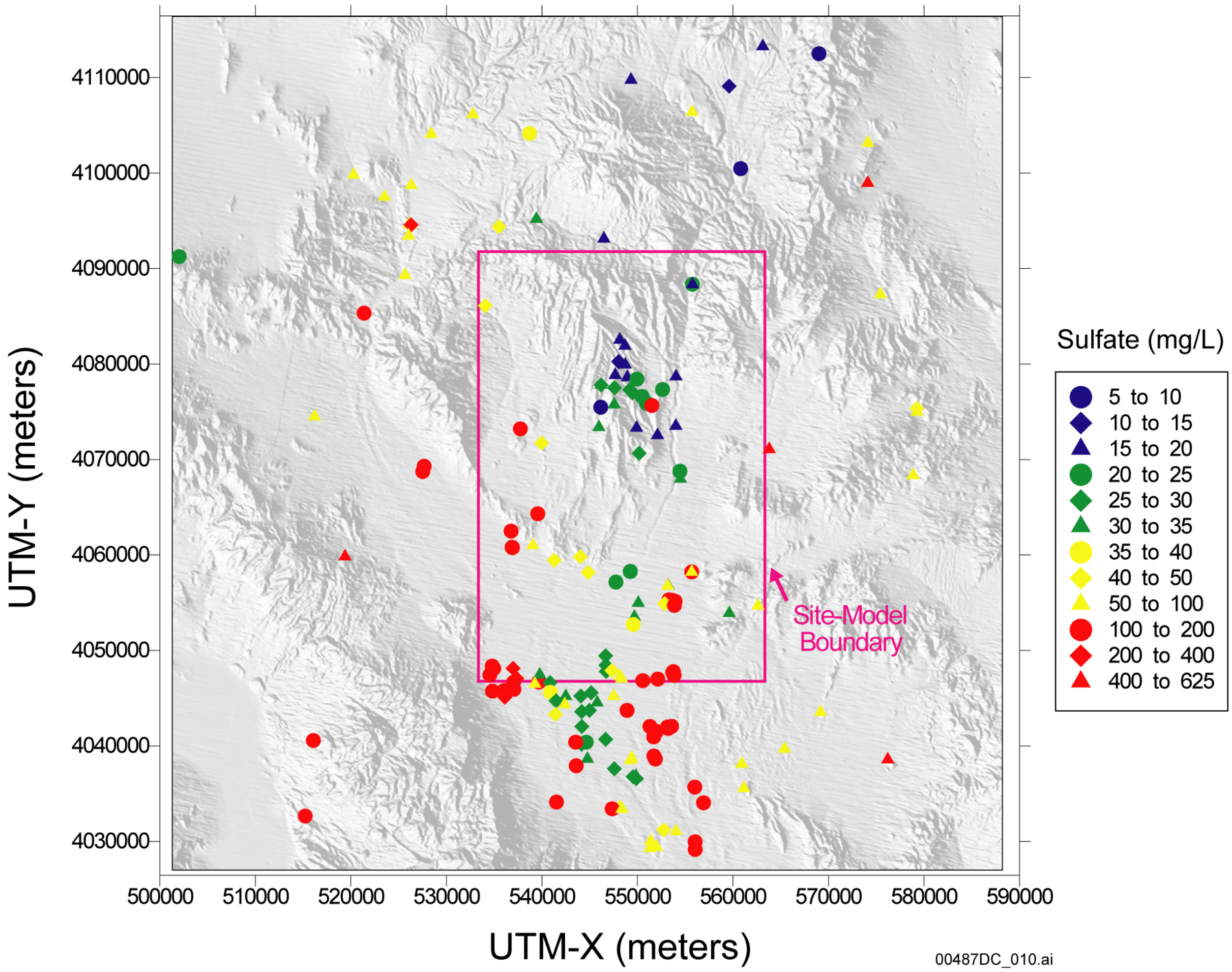
The areal distribution of sulfate (SO_4^{2-}) (Figure A6-16) has patterns similar to those described for Cl^- (Figure A6-15). Except at borehole p#1 where the SO_4^{2-} concentrations are much higher, groundwater at Yucca Mountain generally has SO_4^{2-} concentrations less than 35 mg/L, whereas SO_4^{2-} concentrations west and east of Yucca Mountain are moderately to substantially higher. Borehole J-11 (Site 67) in central Jackass Flat has a SO_4^{2-} concentration of 479 mg/L. Groundwater north of Yucca Mountain at Timber Mountain and in the upper part of Fortymile Wash near Rainer Mesa has SO_4^{2-} concentrations in the same range as those found at Yucca Mountain. Groundwater SO_4^{2-} concentrations north of the site model area increase toward Oasis Valley. The compositional differences between groundwater in western and eastern Crater Flat observed in Cl^- concentrations are also evident in SO_4^{2-} concentrations, with the difference that the SO_4^{2-} concentration at Gexa Well 4 (Site 68) in the northwest corner of the site model area more closely resembles groundwater in eastern Crater Flat at borehole VH-1 (Site 69) rather than western Crater Flat at borehole VH-2 (Site 70). As is the case for Cl^-, the low SO_4^{2-} groundwater associated with Fortymile Wash east of Yucca Mountain also extends southward into the Amargosa Desert, where it is surrounded by groundwater having distinctly higher SO_4^{2-} concentrations. Unlike Cl^-, however, groundwater SO_4^{2-} concentrations increase toward the south along Fortymile Wash.

The groundwater with high Cl^- concentrations near the southwest corner of the site model area also has relatively high (100 to 200 mg/L) SO_4^{2-} concentrations. Groundwater to the north of this area in western Crater Flat and to the northwest in southern Oasis Valley has similarly high SO_4^{2-} concentrations.

A6.3.4.4 Bicarbonate

The areal distribution of bicarbonate (HCO_3^-) is shown in Figure A6-17. The areal patterns for HCO_3^- are similar to those described for SO_4^{2-} and Cl^- with some differences. Groundwater with high (greater than 200 mg/L) HCO_3^- concentrations is present in easternmost Crater Flat and western Yucca Mountain near Solitario Canyon. Elsewhere at Yucca Mountain, groundwater generally has HCO_3^- concentrations less than 175 mg/L. Groundwater near the Fortymile Wash drainage in the Amargosa Desert (FMW-S group) has much lower (less than 160 mg/L) HCO_3^- concentrations than groundwater in the surrounding areas in the GF, AR, and AR/FMW groups but has slightly higher HCO_3^- concentrations than groundwater upgradient along Fortymile Wash (FMW-N group).

Most groundwater in the TM group has HCO_3^- concentrations of 170 mg/L or greater with the exception of Site 24 (well ER-EC-07) in Beatty Wash, which has a concentration (148.8 mg/L) similar to that typically found in northern Yucca Mountain (120 to 140 mg/L). The moderately high HCO_3^- concentrations found in the Oasis Valley area increase southeastward along the Amargosa River toward the AR and AR/FMW group wells.



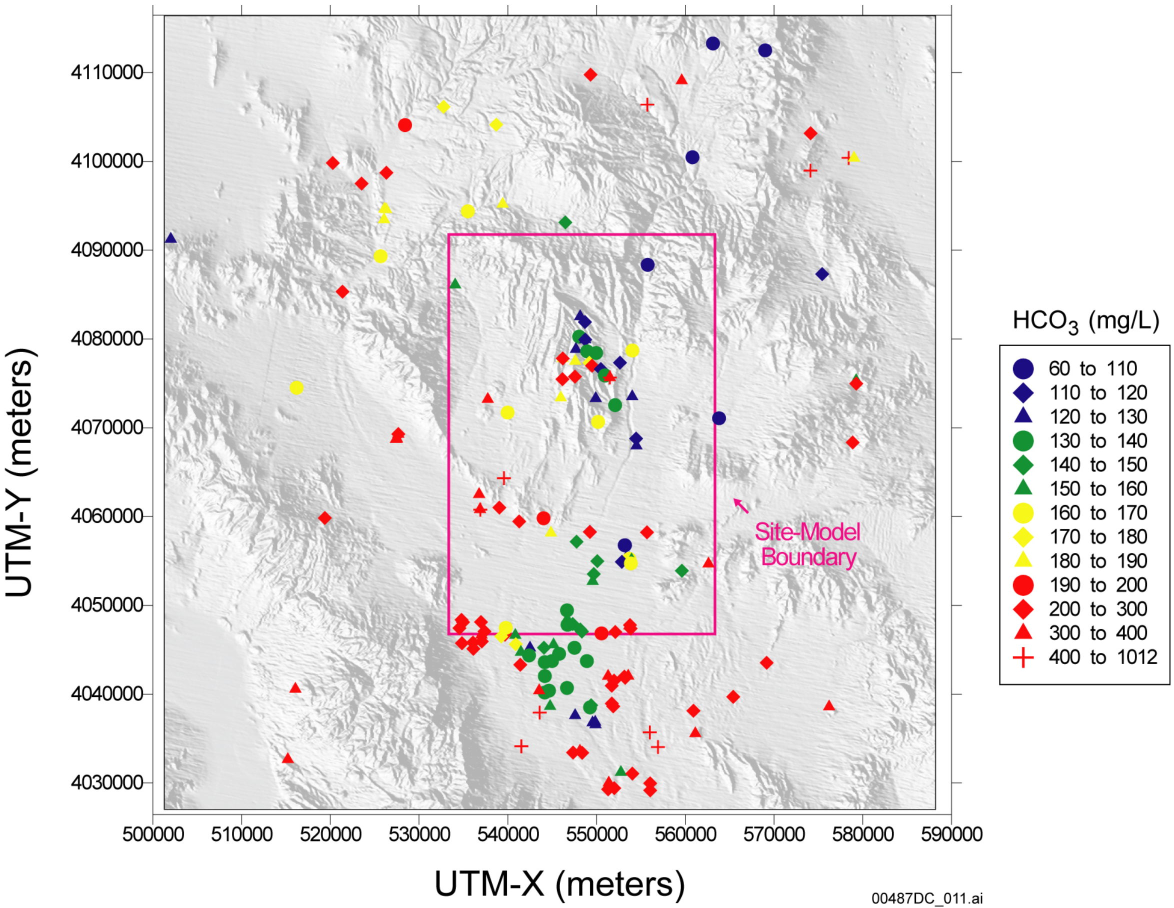
Source: Table A6-1.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting and UTM-Y = UTM-Northing. UTM = Universal Transverse Mercator.

Figure A6-16. Areal Distribution of Sulfate in Groundwater

Groundwater in southwestern Crater Flat (CF-SW group) has higher HCO_3^- than groundwater in the CF grouping. Bicarbonate concentrations at site NC-EWDP-7S (Site 71) are particularly high, possibly reflecting the location of this well in a paleospring deposit or evaporative effects associated with a shallow water table (Table A6-1). Groundwater in central Jackass Flats at borehole J-11 (Site 67), where the high SO_4^{2-} was noted previously, has one of the lowest HCO_3^- concentrations (82 mg/L) in the map area. Similarly low HCO_3^- concentrations are found in some of the LW group wells to the southwest of borehole J-11.



Source: Table A6-1.

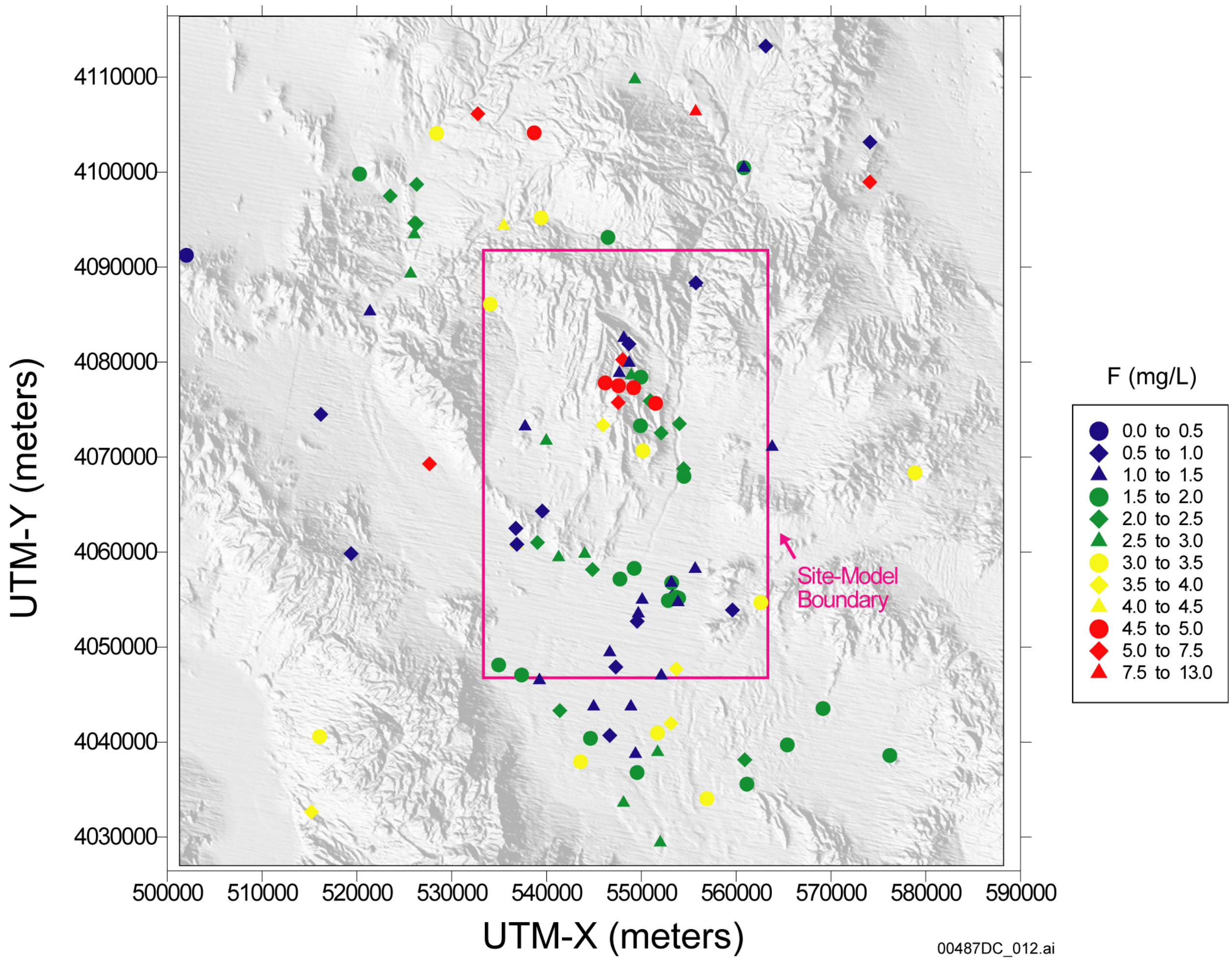
NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-17. Areal Distribution of Bicarbonate in Groundwater

A6.3.4.5 Fluoride

Few data for F^- concentrations are available for the Yucca Mountain. (Figure A6-18). These data are consistent with the concentration distributions for other anions like Cl^- (Figure A6-15) in this area, with dilute concentrations found near Fortymile Wash and concentrations that increase to the west and east of the wash. Groundwater fluoride concentrations at Yucca Mountain have a variability that is comparable to the variability found in the Yucca Mountain region as a whole (Figure A6-18). The F^- concentrations in northern Yucca Mountain are low compared to other areas of Yucca Mountain. Relatively high F^- concentrations of 4.5 to 13.0 mg/L are found in groundwater at several wells along Yucca Crest (YM-CR group), in the Solitario Canyon Wash (SWC) group, and in the carbonate aquifer at well p#1 (Sites 62 and 63). Groundwater along Fortymile Wash has F^- concentrations that generally vary between 1 and 2 mg/L, with no systematic north–south variations evident. Groundwater in southwest Crater Flat has lower F^- concentrations than groundwater in eastern Crater Flat or in the NC-EWDP wells farther to the east.



Source: Table A6-1.

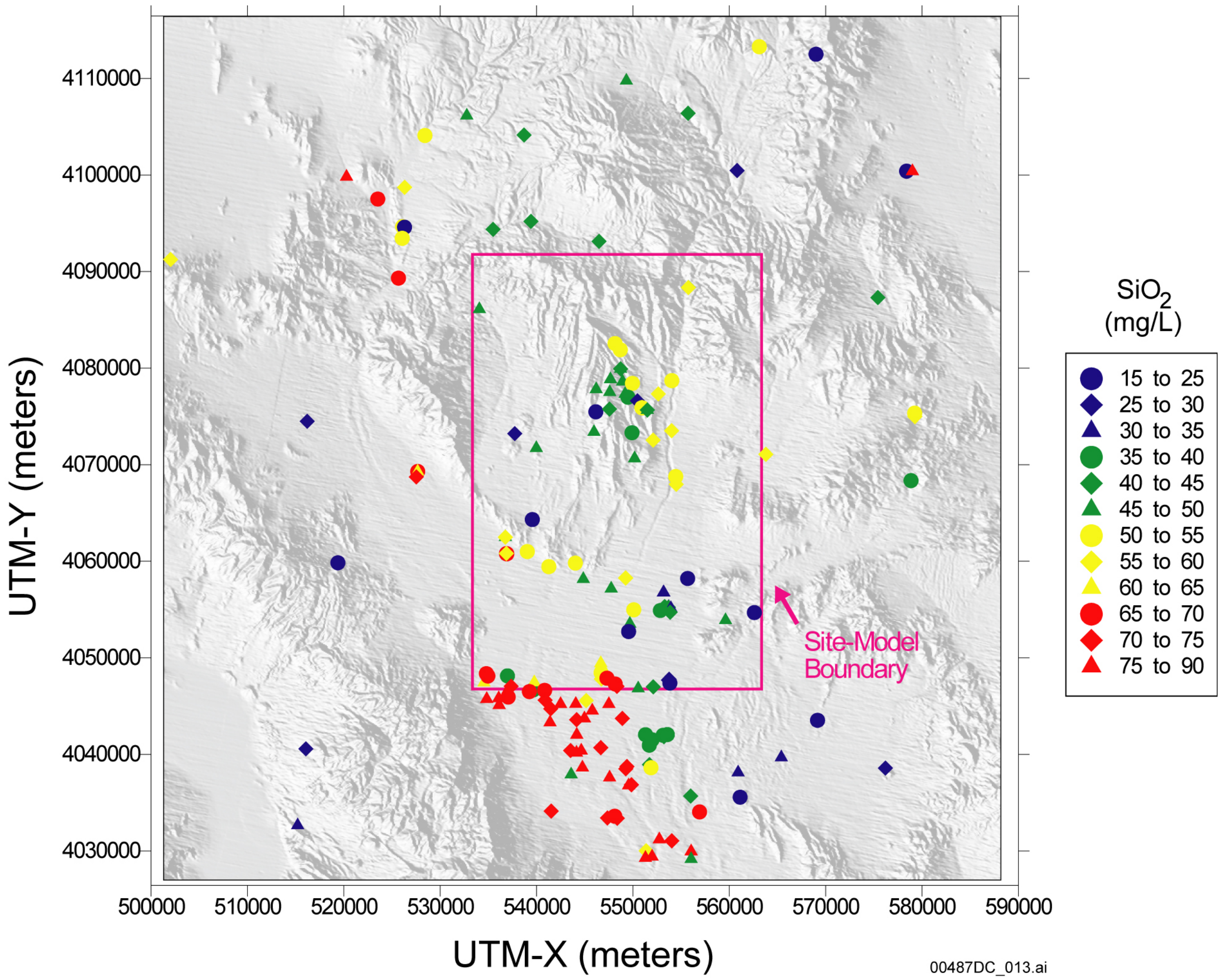
NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-18. Areal Distribution of Fluoride in Groundwater

A6.3.4.6 Silica

Groundwater in northern and central Yucca Mountain has SiO_2 concentrations that range from 30 to 60 mg/L (Figure A6-19). Groundwater beneath Fortymile Wash east of Yucca Mountain has SiO_2 concentrations that are approximately 50 to 60 mg/L. Southward from Yucca Mountain and along Fortymile Wash, SiO_2 concentrations in groundwater near the southern site model boundary increase abruptly. Relatively high SiO_2 concentrations (65 to 90 mg/L) characterize groundwater throughout most of Amargosa Desert and can also be traced southeastward from the Oasis Valley area through the northwest Amargosa Desert. An exception to this general trend is the area near the Gravity fault where SiO_2 concentrations are considerably lower. Most groundwater in the alluvium near the Gravity Fault is thought to originate from the lower carbonate aquifer where this aquifer abuts low permeability alluvium along the Gravity Fault. Groundwater from the carbonate aquifer typically contains lower SiO_2 concentrations (median, 8 to 31 mg/L) compared to groundwater in the volcanic aquifer (median, 44 to 85 mg/L) (comparison of SiO_2 in Facies I and III to that in Facies II, Winograd and Thordarson 1975 [DIRS 101167], Table 8). This interpretation is also consistent with the generally higher bicarbonate, Ca, and Mg concentrations, and heavier stable carbon isotope ratios, in groundwater in the alluvium near the fault (as discussed in Sections A6.3.4.4, A6.3.4.7, A6.3.4.8, and A6.3.4.14, respectively).



Source: Table A6-1.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

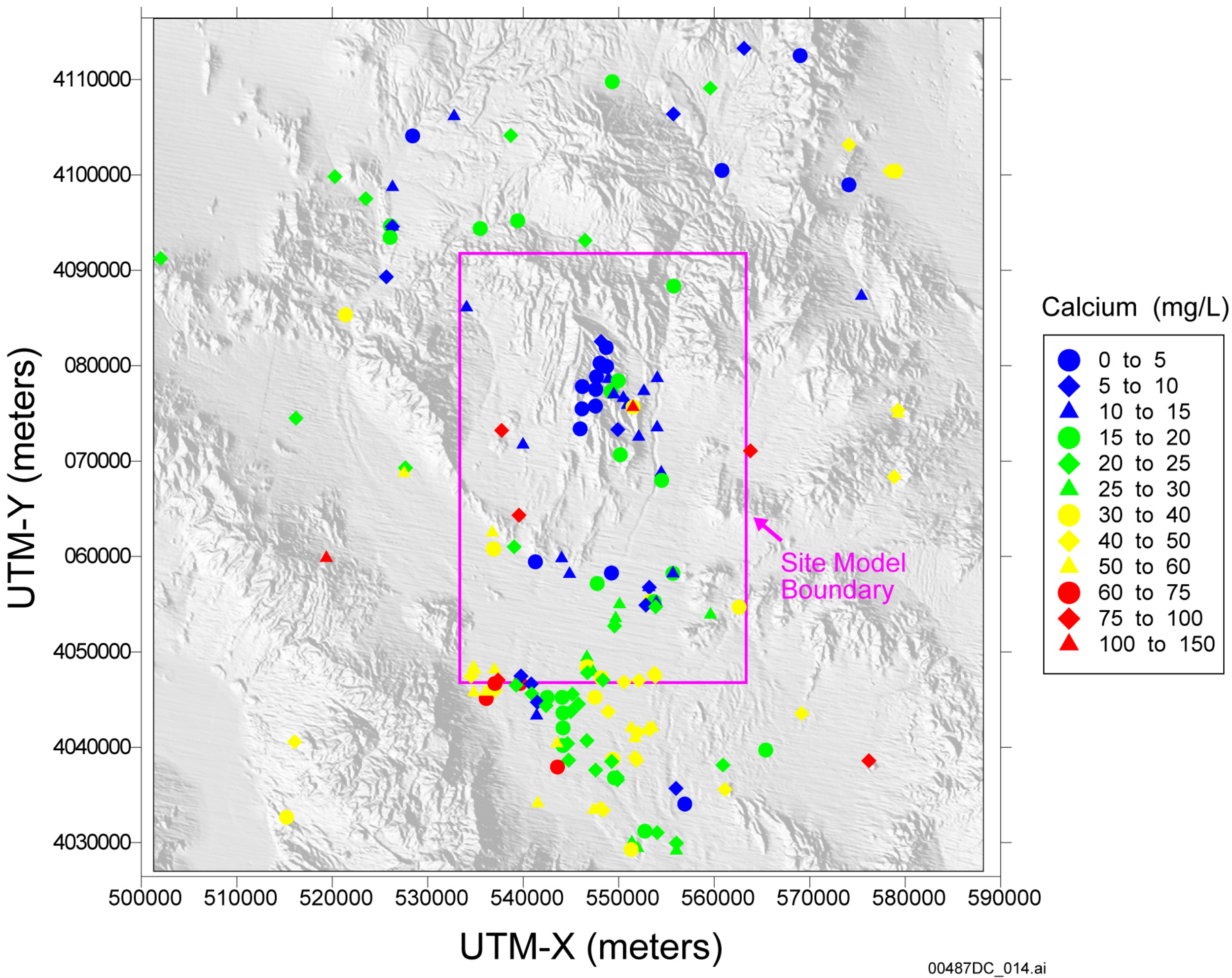
UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-19. Areal Distribution of Silica in Groundwater

A6.3.4.7 Calcium

The calcium (Ca^{2+}) concentrations of groundwater at Yucca Mountain are generally less than 20 mg/L (Figure A6-20), except at borehole p#1 (Site 63), where groundwater from the carbonate aquifer has a concentration of 100 mg/L. Along the eastern edge of Crater Flat and in western Yucca Mountain, Ca^{2+} concentrations are less than 5 mg/L. The Ca^{2+} concentration is higher in western Crater Flat at borehole VH-2 (Site 70) than in eastern Crater Flat at borehole

VH-1 (Site 69). The Ca^{2+} concentration at Gexa Well 4 in the northwest corner of the site model area is similar to the value at VH-1 and at NC-EWDP wells southeast of Crater Flat (Yucca Mountain-South group). The Ca^{2+} concentration is relatively high (82 mg/L) at borehole J-11 (Site 67) in central Jackass Flats, where SO_4^{2-} is also relatively high (Figure A6-16). The Ca^{2+} concentration along Fortymile Wash is between 10 and 20 mg/L east and northeast of Yucca Mountain and increases to values generally between 20 and 30 mg/L in the Amargosa Desert.



Source: Table A6-1.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

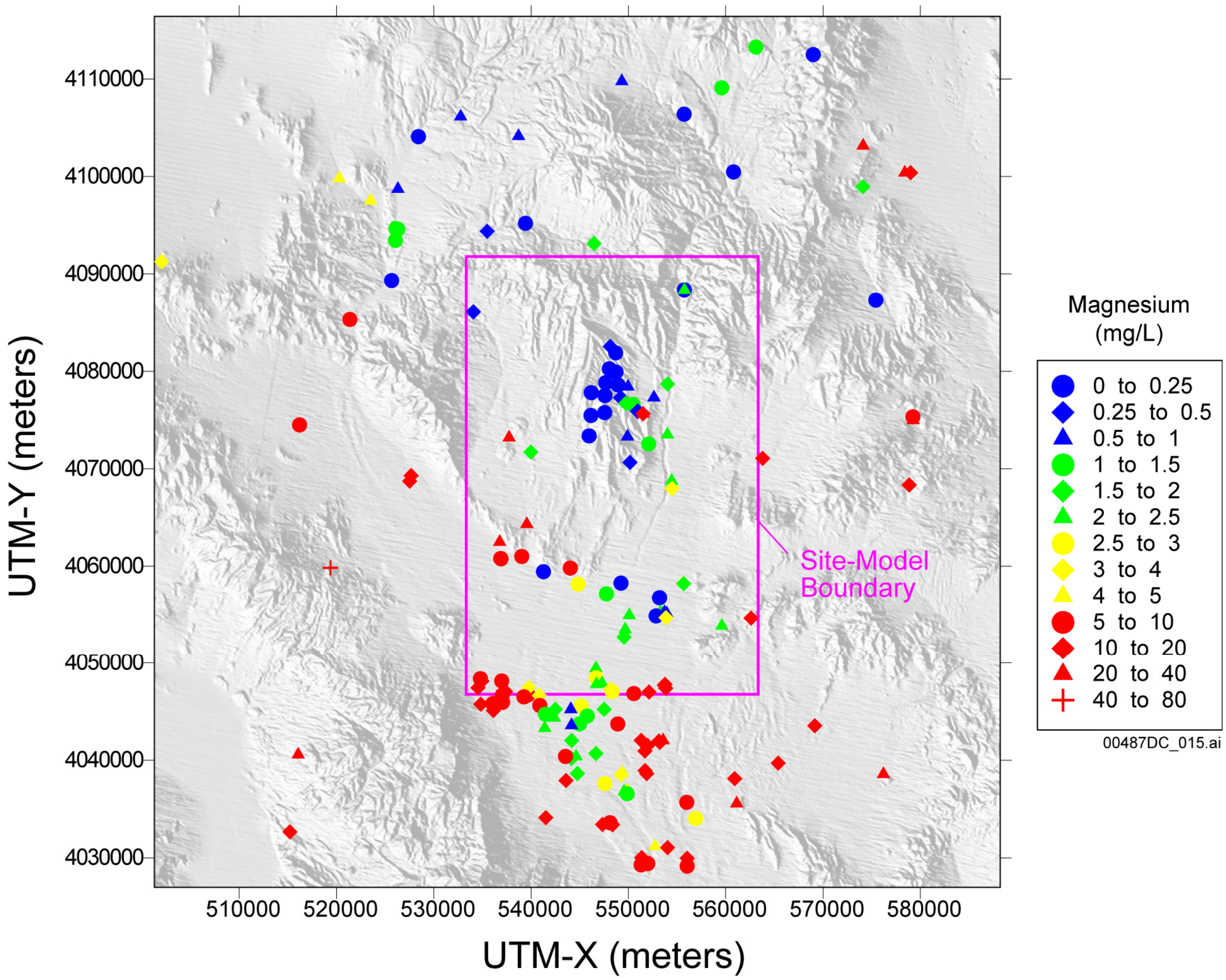
UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-20. Areal Distribution of Calcium in Groundwater

The Ca^{2+} concentration increases to the west and the east of Fortymile Wash in the Amargosa Desert. Groundwater Ca^{2+} concentrations in the southwest corner of the site model area (Amargosa River group) are generally higher than Ca^{2+} concentrations in upgradient areas in western Crater Flat, west of Bare Mountain, and in the Oasis Valley.

A6.3.4.8 Magnesium

The areal distribution of magnesium (Mg^{2+}) concentrations (Figure A6-21) display a pattern that is similar, in terms of relative concentrations, to that of Ca^{2+}. Magnesium concentrations in groundwater at Yucca Mountain range from 0.1 to 1.6 mg/L, except at borehole p#1 where the Mg^{2+} concentration is 10 mg/L in the volcanic aquifer and 39 mg/L in the carbonate aquifer. The Mg^{2+} concentration in groundwater in western Crater Flat at borehole VH-2 (Site 70) is high (30 mg/L) compared to the concentration of 1.5 mg/L measured in groundwater at borehole VH-1 (Site 69). In Nye County-EWDP wells south and southeast of Crater Flat (SW Crater Flat and Yucca Mountain-South groups), Mg^{2+} concentrations are quite variable with concentrations generally increasing to the northwest. Concentrations of Mg^{2+} are generally low (less than 1.5 mg/L) at Timber Mountain and in upper Fortymile Canyon, but are generally between 2 and 3 mg/L along the length of Fortymile Wash east of Yucca Mountain and in the Amargosa Desert. Magnesium concentrations on the east and west side of the Amargosa Desert are considerably higher with values typically between 5 and 20 mg/L. In the southwest corner of the model area (Amargosa River group), Mg^{2+} concentrations generally are between 5 to 10 mg/L, but a few samples have concentrations between 10 and 20 mg/L, similar to the concentration of groundwater at the sites 15 to 17 west of Bare Mountain (11.5 to 16 mg/L), but higher than those in Oasis Valley. The concentration of Mg^{2+} is 13 mg/L at borehole J-11 (Site 67) in central Jackass Flats.



Source: Table A6-1.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-21. Areal Distribution of Magnesium in Groundwater

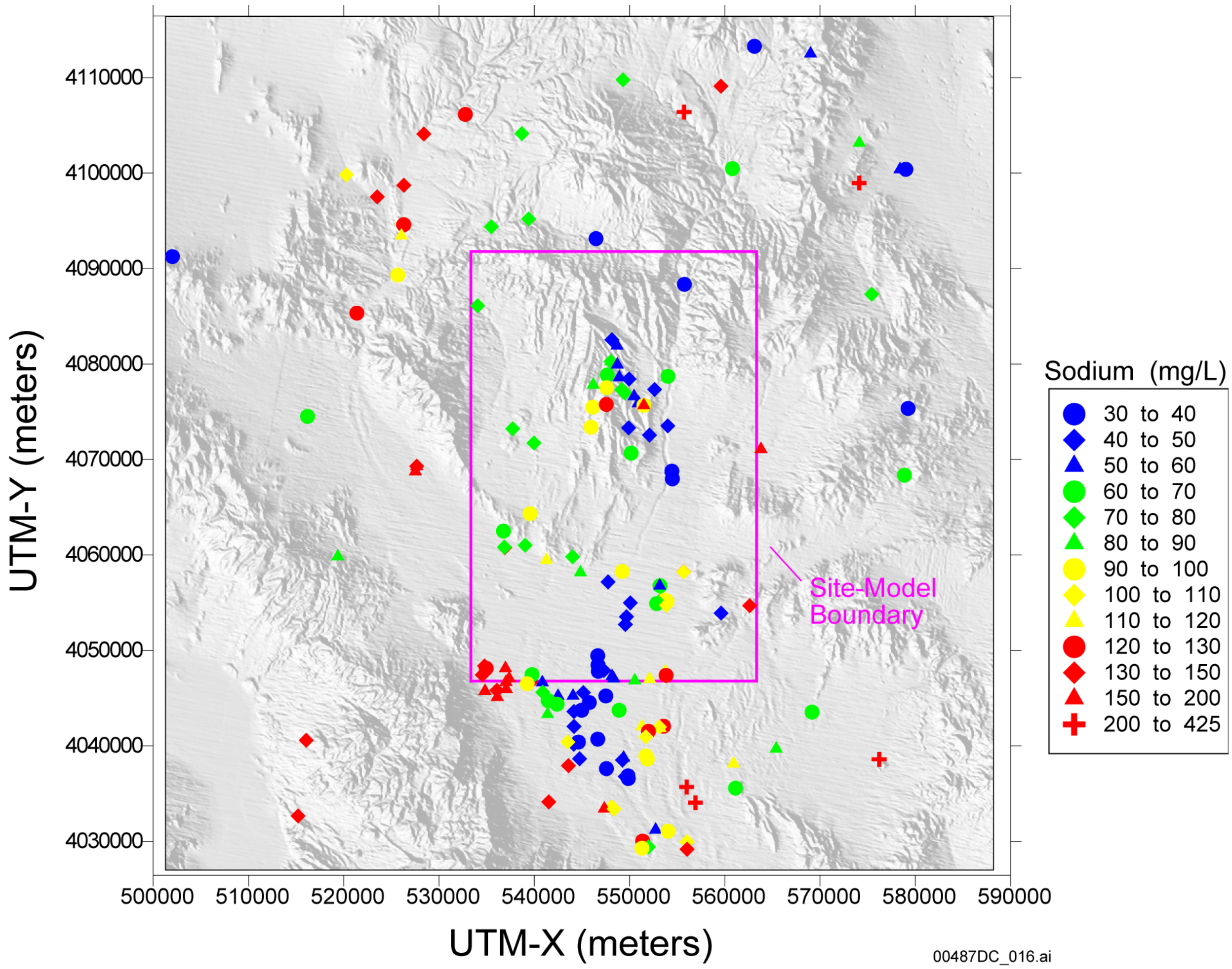
A6.3.4.9 Sodium

The areal distribution of sodium (Na^+) is shown in Figure A6-22. Excluding data from the carbonate aquifer (borehole p#1), the Na^+ concentrations of groundwater at Yucca Mountain range between 46 and 130 mg/L with the higher values from samples in the western part of Yucca Mountain (Solitario Canyon Wash and Yucca Crest groups). A zone of relatively low Na^+ concentrations (less than 60 mg/L) extends southeastward from northern Yucca Mountain toward lower Dune Wash and Fortymile Wash. The Na^+ concentrations of groundwater in the NC-EWDP boreholes west of Fortymile Wash are generally between 40 and 100 mg/L, except at boreholes NC-EWDP-3D and NC-EWDP-3S (Sites 86 to 88) where the Na^+ concentration was anomalously high (113 to 135 mg/L). The Na^+ concentrations of groundwater at borehole NC-EWDP-5S (Site 154) west of the Striped Hills and at well J-11 (Site 67) in central Jackass Flats are also high (149 and 154 mg/L, respectively [Table A6-1]). Note that the value of

149 mg/L at NC-EWDP-5S listed in Table A6-1 is obscured in Figure A6-22 by the somewhat lower value of 107 mg/L at nearby Site 155. Most of the groundwater samples along Fortymile Wash have Na^+ concentrations between 35 and 50 mg/L; there are not any obvious trends in the Na^+ concentrations of groundwater beneath Fortymile Wash east of Yucca Mountain and beneath the wash in the Amargosa Desert. In the Amargosa Desert, Na^+ concentrations in groundwater increase away from Fortymile Wash in both eastward and westward directions. Groundwater in the southwest corner of the site model area (Amargosa River group) has high Na^+ concentrations (130 to 180 mg/L), similar to those of sites 15 to 17 west of Bare Mountain and groundwater in Oasis Valley.

A6.3.4.10 Potassium

Potassium (Figure A6-23) concentrations in groundwater at Yucca Mountain range between 1 and 6 mg/L, except in the carbonate aquifer at borehole p#1 (Site 63) where the K^+ concentration is 12 mg/L. Groundwater from the Solitario Canyon and Yucca Crest groups typically has smaller K^+ concentration when compared to groundwater farther east at Yucca Mountain in the FMW-N group. The K^+ concentrations in groundwater in western Crater Flat at borehole VH-2 (Site 70) is high (8 mg/L). Similarly high K^+ concentrations are found south of VH-2 in Nye County-EWDP wells 1S (Site 77) and 1DX (Site 73) and even higher concentrations exist at NC-EWDP-12PA (Site 78) and -12PB (Site 79). Concentrations of K^+ are generally low (less than 5 mg/L) in northern Fortymile Canyon but are generally between 5 and 8 mg/L along the length of Fortymile Wash east of Yucca Mountain and in the Amargosa Desert. In the eastern and western parts of the Amargosa Desert, K^+ concentrations are typically higher than those in groundwater near the adjacent reach of Fortymile Wash. However, even among the FMW-S samples along Fortymile Wash, K^+ concentrations are two to three times higher than K^+ concentrations in upgradient areas in the southern Yucca Mountain (YM-S) group. Potassium concentrations in the Amargosa River (AR) group are similar to those of groundwater at Sites 15 through 17 west of Bare Mountain and somewhat higher than those found in Oasis Valley.



Source: Table A6-1.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

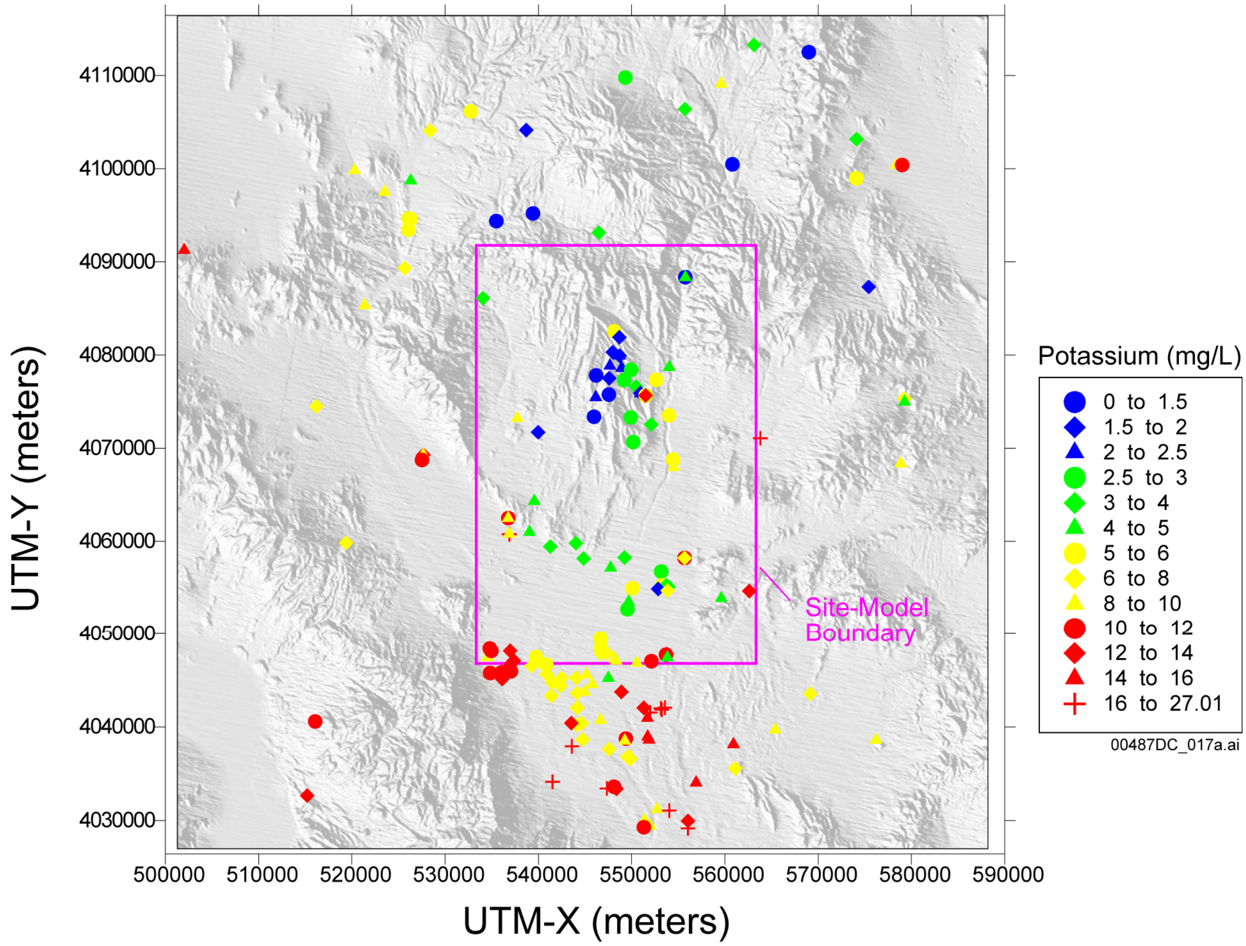
UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-22. Areal Distribution of Sodium in Groundwater

A6.3.4.11 Delta Deuterium

The areal distribution of delta deuterium (δD) values is shown in Figure A6-24 (this isotopic parameter is defined and discussed in Section A6.3.1.2). The δD values in groundwaters from the Yucca Mountain area range from about –105 per mil at borehole USW SD-6 (Site 50) to about –99 per mil at borehole G-2 (Site 43). In Crater Flat, the δD values of –108 and –106 per mil measured in water from borehole VH-1 (Site 69) and from Gexa Well 4 (Site 68) are substantially lighter (i.e., more negative) than the δD value of –99 per mil measured in groundwater from borehole VH-2 (Site 70), but similar to the extremely light values found in Oasis Valley and lower Beatty Wash. The δD values at borehole NC-EWDP-1DX (Site 73) of –101.3 per mil and at borehole NC-EWDP-3D (Site 86) of –105.6 per mil are generally similar to the values at upgradient boreholes VH-2 and VH-1 (–99.5 and –108.0, respectively).

The groundwater δD value of –98.0 per mil at Site 71 (NC-EWDP-7S) is also relatively heavy and comparable to the value at borehole VH-2.



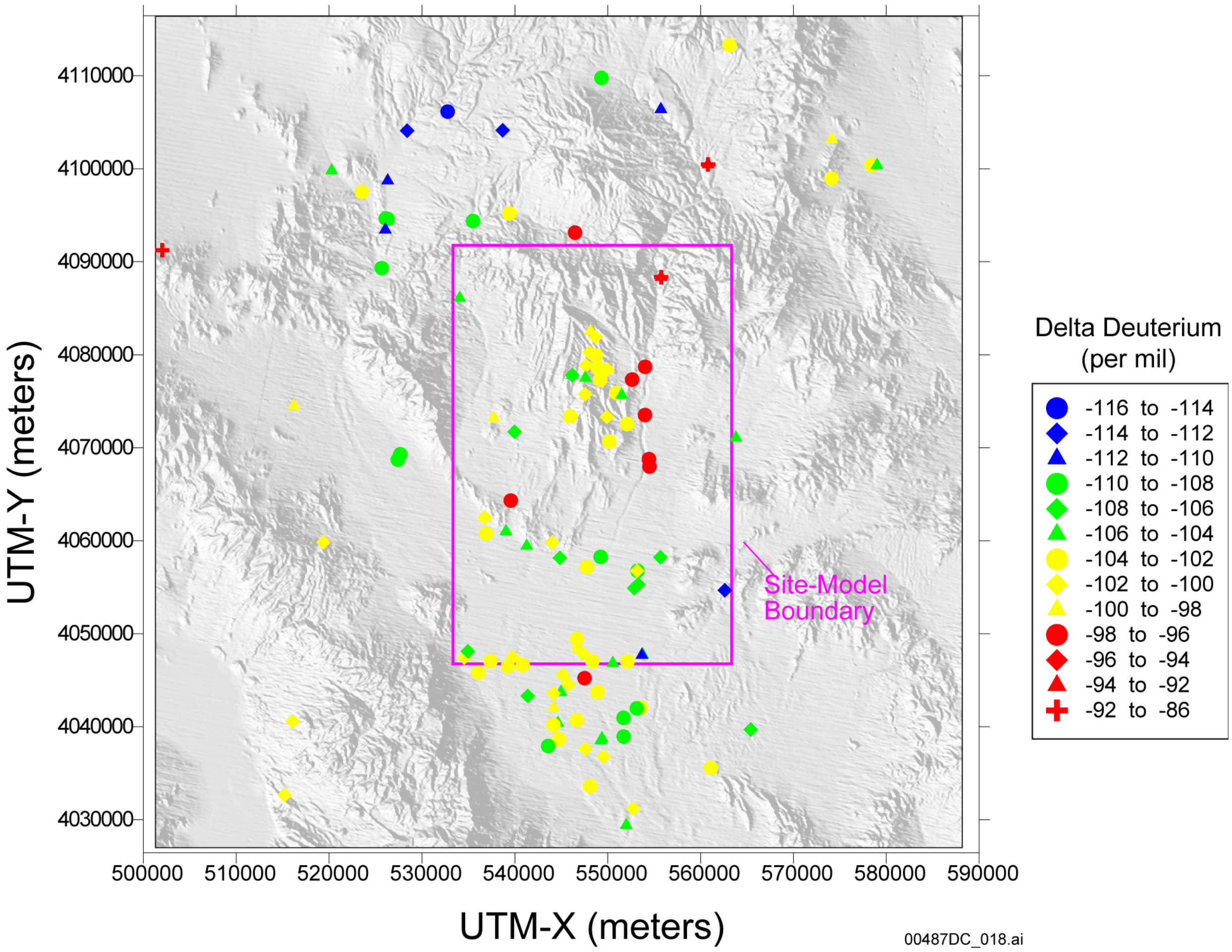
Source: Table A6-1.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-23. Areal Distribution of Potassium in Groundwater

The δD values of groundwater near Fortymile Wash show a general trend toward more depleted values from north to south, ranging from about –93 to –91 per mil at boreholes UE-29 a#1 and a#2 (Sites 30 to 32) near the northern boundary of the site model area to values that are generally –100 per mil or less near the southern boundary of the model area. East of Yucca Mountain, groundwater beneath Fortymile Wash has δD values of about –97 per mil. The δD values of –104 per mil of groundwater at boreholes NC-EWDP-2D (Site 91)) and δD values of –110 to –104 per mil at well NC-EWDP-19D (Sites 92 and 94 to 98) are substantially lighter than in groundwater associated with Fortymile Wash in the FMW-N group. Groundwater in the Amargosa Desert has variable values, and spatial patterns are not as regular as for other chemical species, but groundwater in the eastern part of the Amargosa Desert is generally lighter in δD than groundwater farther to the west near Fortymile Wash.



Source: Table A6-2.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

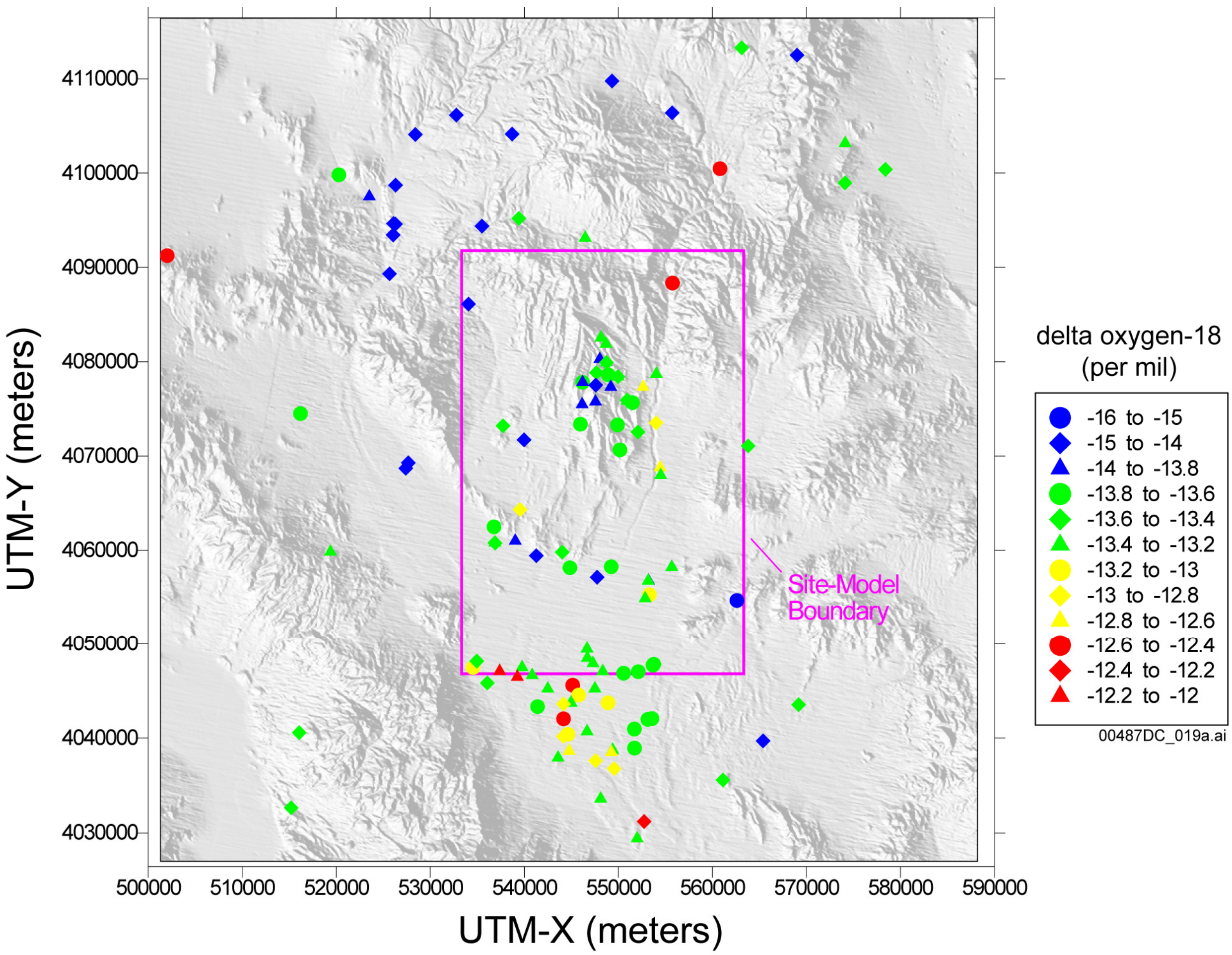
Figure A6-24. Areal Distribution of Delta Deuterium in Groundwater

Groundwater δD values at Timber Mountain are quite variable, ranging from about –114 to -96 per mil, with the heaviest value found in upper Beatty Wash at Site 24 (well ER-EC-07). The groundwater δD values near Oasis Valley are among the lightest in the vicinity of Yucca Mountain (–116 to –108 per mil). Groundwater δD values lighter than –108 per mil are also found at sites 15 to 18 (Figure A6-5) west of Bare Mountain in the northwest Amargosa Desert. Southeast of these sites along the Amargosa River, groundwater from the AR and AR/FMW well groups has δD values that are typically heavier than values from wells to the northwest.

A6.3.4.12 Delta ^{18}O

Figure A6-25 shows the areal distribution of δ^{18}O values for the Yucca Mountain area (this isotopic parameter is defined and discussed in Section A6.3.1.2). Groundwater at Yucca Mountain has δ^{18}O values between –13.3 and –14.4 per mil, with groundwater in western Yucca

Mountain near Solitario Canyon having values that fall toward the lighter end of this range. Groundwater at borehole VH-1 (Site 69) in Crater Flat has a $\delta^{18}O$ value of –14.2 per mil, similar to the $\delta^{18}O$ value of –14.1 per mil of groundwater at Gexa Well 4 (Site 68) and at Site 23 (well ER-OV-03c) in lower Beatty Wash. Groundwater in southwestern Crater Flat has substantially heavier $\delta^{18}O$ values, with groundwater at VH-2 (Site 70) having a $\delta^{18}O$ value of –13.4 per mil. Groundwaters sampled from the NC-EWDP wells along the southern edge of Crater Flat generally have $\delta^{18}O$ values that are similar to those in wells directly to the north at boreholes VH-1 and VH-2. However, the groundwater $\delta^{18}O$ value at site 71 (NC-EWDP-7S) has a somewhat heavier $\delta^{18}O$ value than upgradient groundwater, perhaps reflecting the effects of evapotranspiration due to the shallow water table (7 m) at this well.



Source: Table A6-2.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

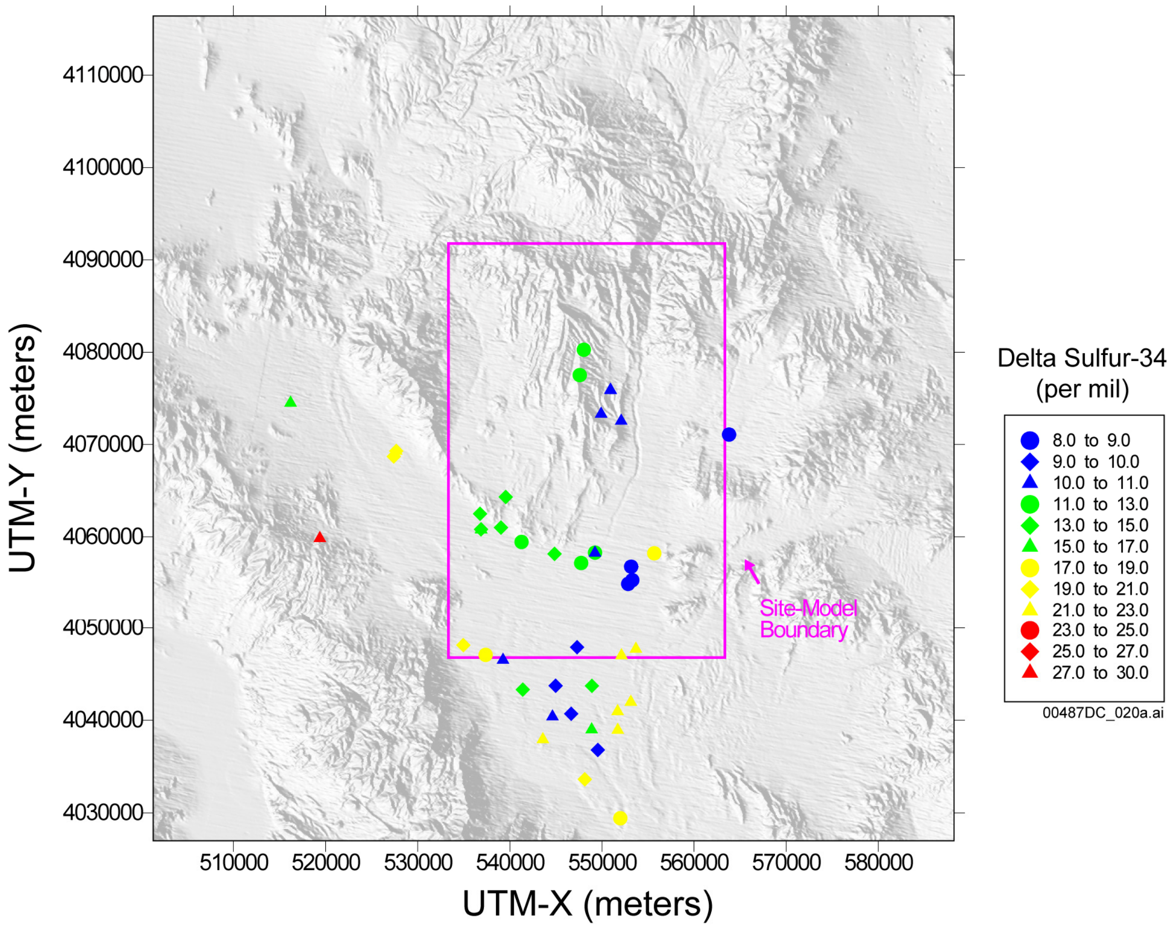
Figure A6-25. Areal Distribution of $\delta^{18}O$ in Groundwater

The groundwater $\delta^{18}O$ values at Sites 28 to 32 (Figure A6-5) in the FMW-N group are relatively heavy (–12.8 to –11.8 per mil) compared to wells to the south within this group and to most groundwater in the FMW-S group (Table A6-2). (The apparent range of values on Figure A6-25 is somewhat less because not all data are evident in the figure). Groundwater within the FMW-N group is distinctly heavier in $\delta^{18}O$ than groundwater to the west at Yucca Mountain. In the Amargosa Desert, the $\delta^{18}O$ of groundwaters near Fortymile Wash generally are distinct from those of groundwater farther east or west from the Wash, although near the southern boundary of the site model area, this distinction becomes less well defined.

The groundwater $\delta^{18}O$ at Timber Mountain are generally lighter than most groundwater found at Yucca Mountain, except for groundwater found directly north of Yucca Mountain in upper Beatty Wash. Groundwater $\delta^{18}O$ values become lighter toward the west in Beatty Wash. Relatively light groundwater $\delta^{18}O$ values are found in Oasis Valley and in the northwest Amargosa Desert west of Bare Mountain at Sites 15 to 18. As with δD values, groundwater $\delta^{18}O$ increase downstream along the Amargosa River toward the AR and AR/FMW sites.

A6.3.4.13 Delta ^{34}S

Groundwater data for $\delta^{34}S$ were not collected from the Yucca Mountain area and Amargosa Desert before the late 1990s, nor have they been collected in areas north of Yucca Mountain. Consequently, areal coverage is not as complete as for most other ions and isotopes. The limited data from Yucca Mountain shows that groundwater from two wells along Yucca Crest have higher $\delta^{34}S$ values than groundwater in the YM-SE grouping near Dune Wash (Figure A6-26). Groundwater from wells in the CF-SW and YM-S groupings near U.S. Highway 95 generally show an overall increase toward the west. Groundwaters in the easternmost wells of the YM-S grouping (wells NC-EWDP-2D, NC-EWDP-19D, and NC-EWDP-19P) have $\delta^{34}S$ values that span a range similar to that defined by the groundwater samples from Yucca Crest and Dune Wash. In the Amargosa Desert, groundwater associated with the Amargosa River and the Gravity fault has substantially higher $\delta^{34}S$ values than groundwater associated with Fortymile Wash, perhaps reflecting the presence of alluvium derived from carbonate rocks in these areas. As discussed in Section A6.3.1.2.3, marine sulfates from the early Paleozoic have $\delta^{34}S$ values near 30 per mil, values that are considerably higher than the values of 0 to 15 typical of sulfur of a volcanic origin. Some of the lowest groundwater $\delta^{34}S$ values are found in Jackass Flat at well J-11 (Site 67) and in several of the LW-group wells in the Amargosa Valley area.



Source: Table A6-2.

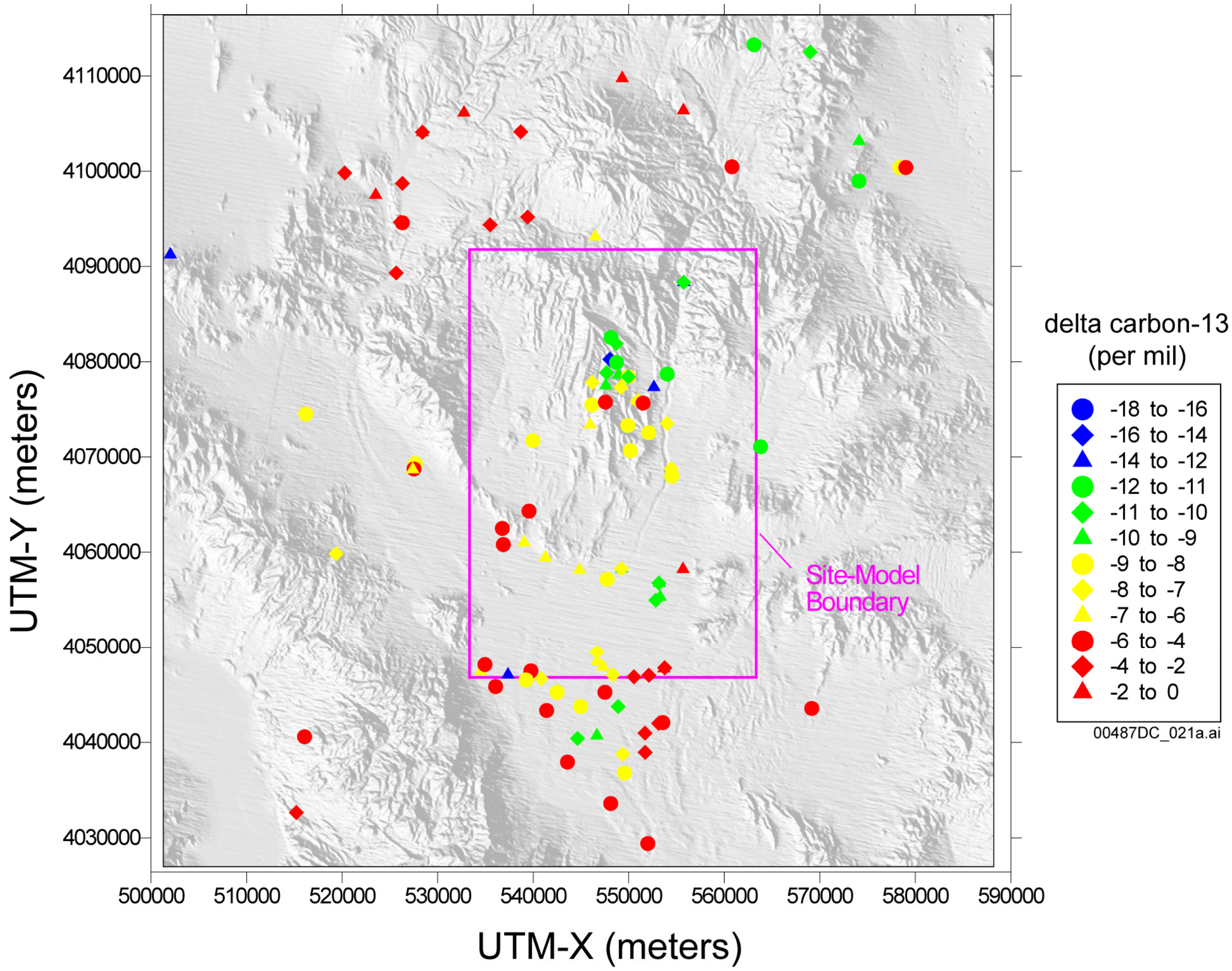
NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-26. Areal Distribution of $\delta^{34}S$ in Groundwater

A6.3.4.14 Delta ^{13}C

The areal distribution of $\delta^{13}C$ values is shown in Figure A6-27 (this isotopic parameter is defined and discussed in Section A6.3.1.2). Excluding the data from borehole p#1 (Sites 62 and 63), where groundwater has $\delta^{13}C$ values of –2.3 per mil in the carbonate aquifer and –4.2 per mil in the volcanic aquifer, the $\delta^{13}C$ values of groundwater at Yucca Mountain vary between –14.4 per mil at borehole UZ-14 (Sites 45 and 46) to –4.9 per mil at borehole H-3 (Site 51). Although patterns are complex on a borehole-by-borehole basis, groundwater in the northern most part of Yucca Mountain is generally lighter in $\delta^{13}C$ than groundwaters found toward the central and southern parts of the mountain. North of Yucca Mountain, groundwater $\delta^{13}C$ values are generally considerably heavier than the groundwater $\delta^{13}C$ values found at Yucca Mountain. Only groundwater from well ER-EC-07 (Site 24) in Beatty Wash has a $\delta^{13}C$ within the range of values found at Yucca Mountain, in the Solitario Canyon Wash area, or in Crater Flat at borehole VH-1 (Site 69). Overall, the $\delta^{13}C$ values of groundwater in the Nye County-EWDP boreholes at the southern edge of Crater Flat increase toward the west, reflecting the increasing proximity of groundwater to carbonate rocks with relatively heavy $\delta^{13}C$ values.



Source: Table A6-2.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-27. Areal Distribution of $\delta^{13}C$ in Groundwater

The $\delta^{13}C$ values of groundwater near Fortymile Wash generally increase between the north and south boundaries of the site model area, although local reversals in this trend are evident. The groundwater $\delta^{13}C$ values near Fortymile Wash are generally lower than the $\delta^{13}C$ values toward the western and eastern parts of the Amargosa Desert, where groundwater $\delta^{13}C$ values reflect the proximity to carbonate rocks of the southern Funeral Mountains and discharge from the carbonate aquifer across the Gravity fault, respectively. Several of the $\delta^{13}C$ values of groundwater near the southwest corner of the site model area are similar to the values measured in groundwater at sites 15 to 18 west of Bare Mountain and in wells and springs in Oasis Valley. Groundwater in Jackass Flats and some groundwater at Amargosa Valley have relatively light

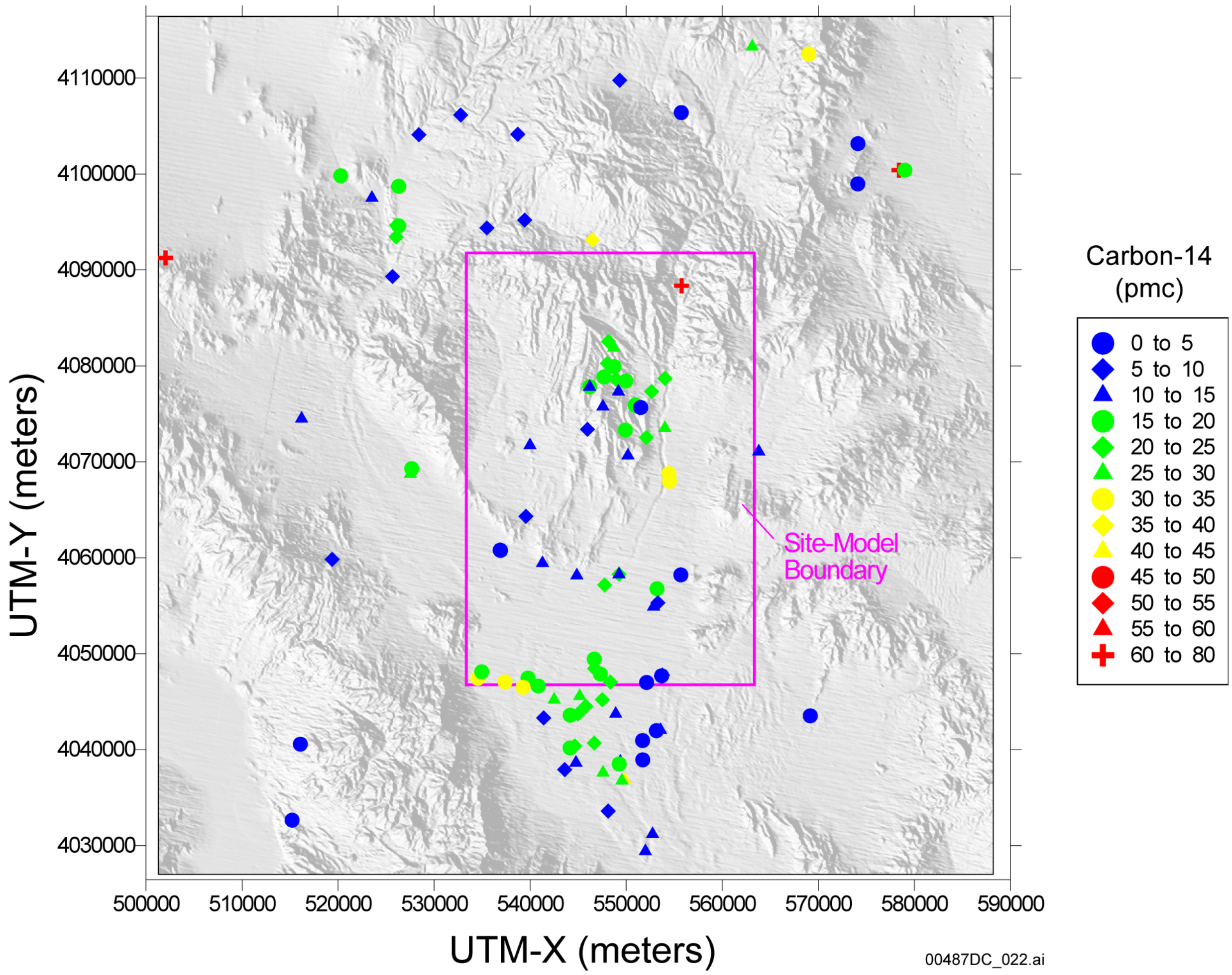
$\delta^{13}C$ values, despite the proximity of the Amargosa Valley (LW) group to groundwater near the Gravity fault with considerably heavier $\delta^{13}C$ values.

A6.3.4.15 ^{14}C Activity

The areal distribution of ^{14}C activity in pmc is shown in Figure A6-28. This hydrochemical parameter is discussed in Section A6.3.1.2. Excluding groundwater from borehole p#1 (Sites 62 and 63), which has a ^{14}C activity of 2.3 pmc in the carbonate aquifer and 3.5 pmc in the volcanic aquifer, the ^{14}C activity of groundwater at Yucca Mountain ranges from 10.5 pmc at borehole H-3 (Site 51) to 27 pmc at borehole WT-24 (Site 44) in northern Yucca Mountain. Groundwater at the eastern edge of Crater Flat near Solitario Canyon has some of the lowest ^{14}C activities of groundwater in the map area, with values as low as 7.3 pmc at borehole WT-10 (Site 42) and 10 pmc in a sample from borehole H-6 (Site 34). Groundwater ^{14}C activities are slightly higher (12 pmc) farther to the west in Crater Flat at borehole VH-1 (Site 69). Groundwater at several Nye County-EWDP wells in the YM-S grouping to the south of borehole VH-1 has similar ^{14}C activities. The groundwater at boreholes NC-EWDP-2D (Site 91), NC-EWDP-19P (Site 93), and some zones in NC-EWDP-19D (i.e. Site 96) have ^{14}C activities of 20 pmc or more, similar to the ^{14}C activities of groundwater in Dune Wash and Fortymile Wash.

Groundwater near Fortymile Wash has ^{14}C activities that range from about 76 pmc at borehole a#1 (Site 32) near the northern boundary of the model area to values less than 20 pmc near the southern boundary of the model area, with local reversals in this overall trend among the FMW-N group of samples. Southward from this area along Fortymile Wash, groundwater ^{14}C activities are lower but also do not show an obvious north-to-south trend. South of the southern boundary of the site model area, groundwater ^{14}C activities near Fortymile Wash range from 10 to 40 pmc. Elsewhere in the Amargosa Desert, several groundwater ^{14}C activities measured in the southwest corner of the site model area are approximately 30 pmc, which is considerably higher than the values of groundwater to the north and moderately higher than the values measured to the northwest at sites 15 to 18 west of Bare Mountain and in Oasis Valley.

In general, it can be noted that where relatively high groundwater $\delta^{13}C$ values indicate water/rock interactions with isotopically heavy carbonate rock (Figure A6-27), the groundwater ^{14}C activities are generally low compared to other areas. These carbonate-rock-affected groundwaters are present at Timber Mountain, near Bare Mountain in the CF-SW area, near the southern Funeral Mountains in some AR and AR/FMW groundwaters, and near the GF samples. The highest ^{14}C activities are associated with major drainages, including the Amargosa River in the southwest corner of the site model area, upper Beatty Wash, and along Fortymile Wash, suggesting that these major washes are important areas of Holocene recharge.



Source: Table A6-2.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

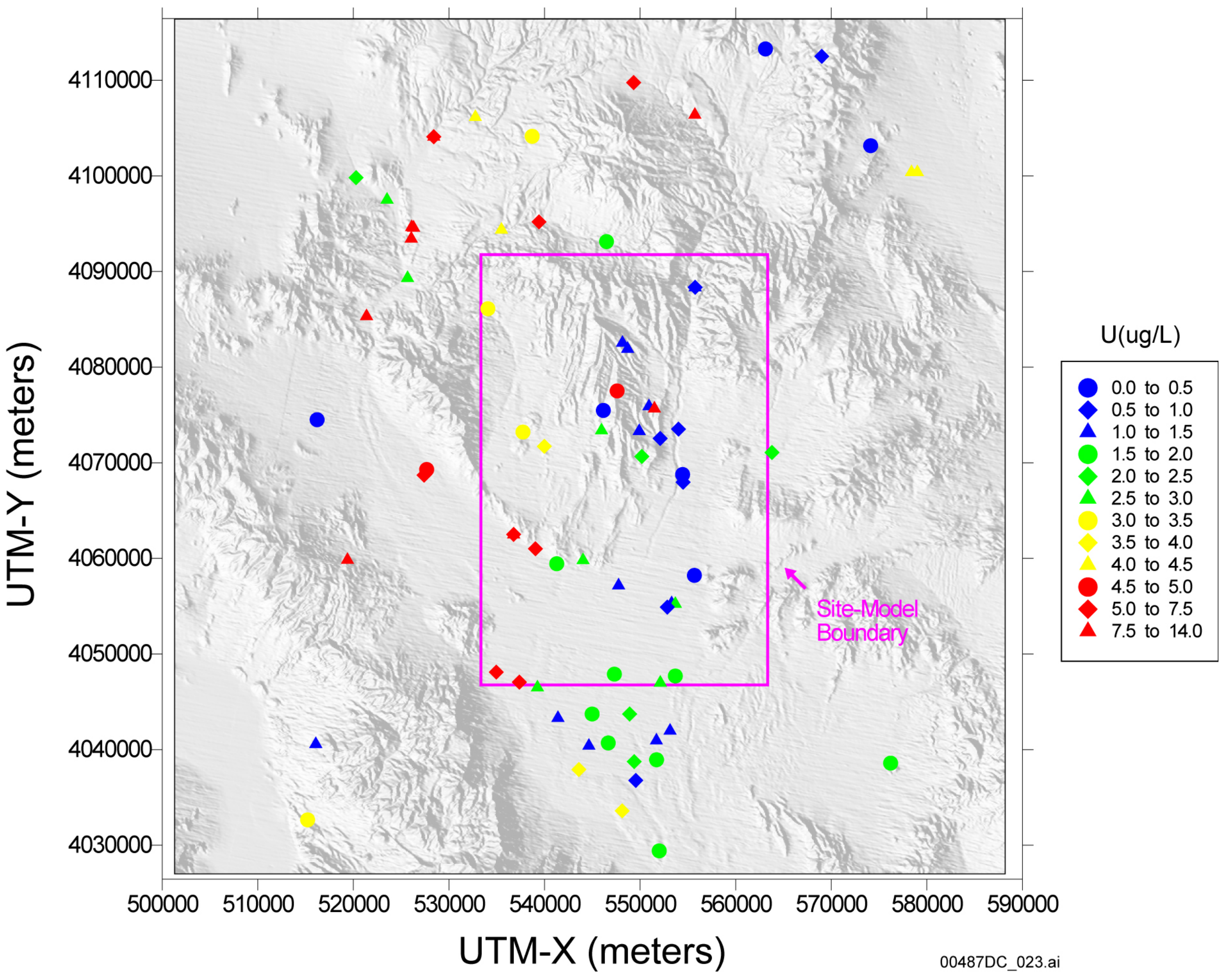
UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-28. Areal Distribution of ^{14}C in Groundwater

A6.3.4.16 Uranium Concentration and $^{234}U/^{238}U$ Activity Ratios

Uranium concentration and $^{234}U/^{238}U$ activity ratio data are shown in Figures A6-29 and A6-30 respectively. Processes affecting uranium concentrations and $^{234}U/^{238}U$ activity ratios are discussed in Section A6.3.1.2 and in Paces et al (2002 [DIRS 158817]). Some of the highest activity ratios in the region are found at Timber Mountain (TM group) and in northern and southeastern Yucca Mountain (YM-CR and YM-SE groups). Samples in the YM-CR and YM-SE with these elevated $^{234}U/^{238}U$ activity ratios also have relatively small uranium concentrations (less than 2.5 µg/L, but most approximately 1 µg/L), whereas groundwaters from the TM group (except for Site 24 in upper Beatty Wash) have somewhat higher uranium concentrations (Figure A6-29). In addition to different uranium concentrations, other hydrochemical attributes of the Timber Mountain and Yucca Mountain groundwaters, such as Na^+ (Figure A6-22), HCO_3^- (Figure A6-17), and $\delta^{13}C$ (Figure A6-27), are also generally different, suggesting the groundwaters from these areas are not necessarily related, despite their similar $^{234}U/^{238}U$ activity ratios. Data from borehole p#1 (Site 63) at Yucca Mountain indicate the carbonate aquifer has comparatively high uranium concentrations (13.3 µg/L) and low $^{234}U/^{238}U$ activity ratios (2.3) compared to some shallow groundwater at Yucca Mountain.

Uranium activity ratios decrease southward along Fortymile Wash from a value as high as 7 at well J-13 (Site 35) to values below 3.0 in the northern Amargosa Desert. Paces et al. (2002 [DIRS 158817], p. 769) suggested that significant groundwater pumping from well J-13 and nearby well J-12 (Site 36) may have disrupted natural flow patterns and induced Yucca Mountain groundwater with high $^{234}U/^{238}U$ activity ratios to flow eastward toward Fortymile Wash. Measurements of archived water samples from well J-12 indicated its $^{234}U/^{238}U$ activity ratio in 1971 was 5.5, supporting the authors' contention that the $^{234}U/^{238}U$ activity ratios at well J-13 may have initially been lower than recent measurement at that well have indicated.



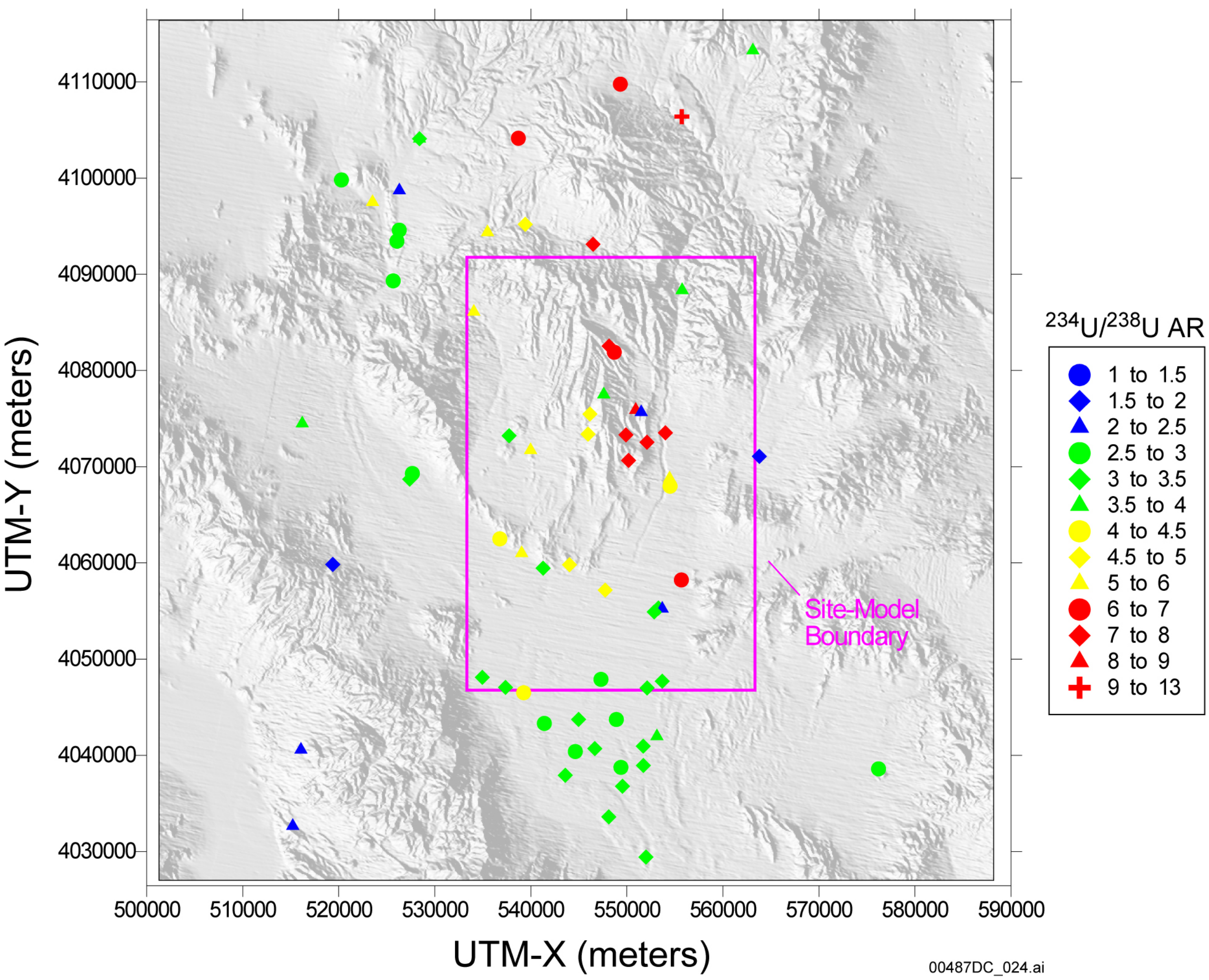
Source: Table A6-2.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-29. Areal Distribution of Uranium in Groundwater

Uranium concentrations and $^{234}U/^{238}U$ activity ratios in the Amargosa Desert region have a relatively narrow range with concentrations typically between 1 and 4 μg/L and activity ratios mostly between 2.5 and 3.5. Borehole NC-EWDP-5S (Site 154) has an anomalously high $^{234}U/^{238}U$ activity ratio for this location of 6.6 and a very low uranium concentration of 0.04 μg/L. From east to west of Yucca Mountain through the Crater Flat area into the Oasis Valley, $^{234}U/^{238}U$ activity ratios generally decrease whereas uranium concentrations increase.



Source: Table A6-2.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

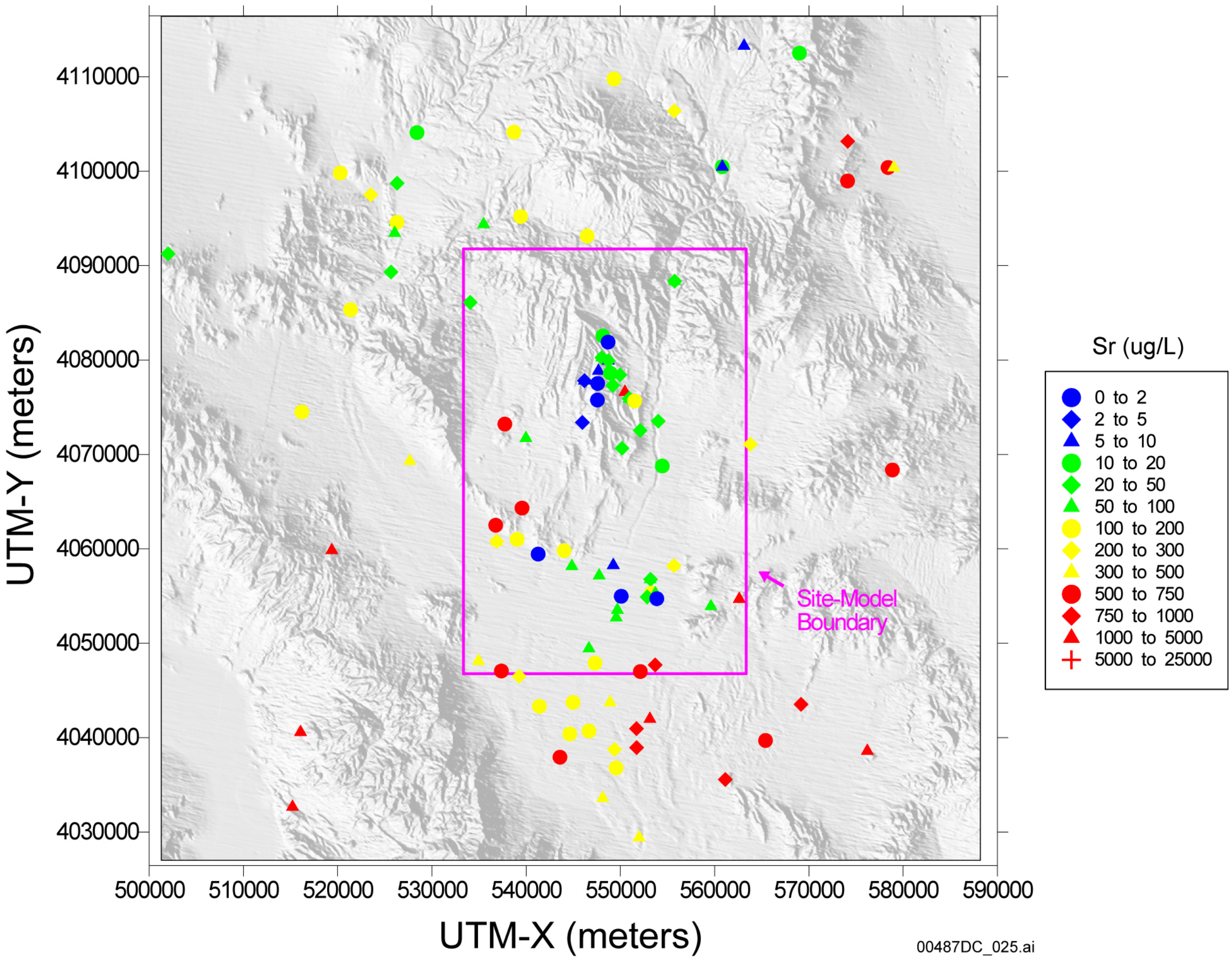
UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-30. Areal Distribution of $^{234}U/^{238}U$ Activity Ratios in Groundwater

A6.3.4.17 Strontium Concentrations and Delta Strontium-87

Strontium concentrations from groundwater at Yucca Mountain vary considerably with values between 1.0 and 1,720 μg/L; most values, however, are between 10 and 50 μg/L. In general, groundwater near Fortymile Wash has lower Sr^{2+} concentrations than groundwater to the east or west of the wash. Strontium concentrations in the FMW-N group are low (values mostly less than 50 μg/L) relative to those in the FMW-S group (most values greater than 100 μg/L). Sr^{2+} concentrations in Beatty Wash are one-to-two orders of magnitude higher that Sr^{2+} concentrations in northern Yucca Mountain in the YM-CR group, which are among the lowest in the region. Groundwater from p#1(c) has a relatively high Sr^{2+} concentration of 450 μg/L. Similarly high values also characterize groundwater that is likely to have contacted Paleozoic carbonate rocks elsewhere in the area (e.g., samples from SW Crater Flat, Gravity fault, Funeral Mountains, and Amargosa Flat groupings). Groundwater in the Timber Mountain area has Sr^{2+} concentrations between about 99 and 224 μg/L.

Strontium isotope-ratio data (expressed as $\delta^{87}Sr$) are unevenly distributed throughout the area with numerous values to the north of Yucca Mountain, some in the Yucca Mountain area and along U.S. Highway 95, and none in the Amargosa Desert region. Very low $\delta^{87}Sr$ values are found in groundwater in Beatty Wash, in the Timber Mountain area, and in Oasis Valley (less than 1.8 per mil, with some negative values). Generally higher values exist to the south of the TM and upper FMW-N groups, although some Yucca Mountain groundwaters also have comparably low $\delta^{87}Sr$ values. Interestingly, $\delta^{87}Sr$ values of groundwater from the carbonate aquifer or from boreholes that have a component of water from the carbonate aquifer (e.g. p#1(c), SW Crater Flat, Funeral Mountains) have high $\delta^{87}Sr$. These waters also typically have high strontium concentrations. Reaction with the Paleozoic carbonate aquifer rock cannot explain this trend as these rocks are expected to have $\delta^{87}Sr$ values of less than zero. A possible explanation is that these waters have reacted with Paleozoic or Precambrian clastic rocks, which are expected to have high $\delta^{87}Sr$ due to their composition and age of the original detrital material (Peterman and Stuckless 1993 [DIRS 101149], p. 1,561).

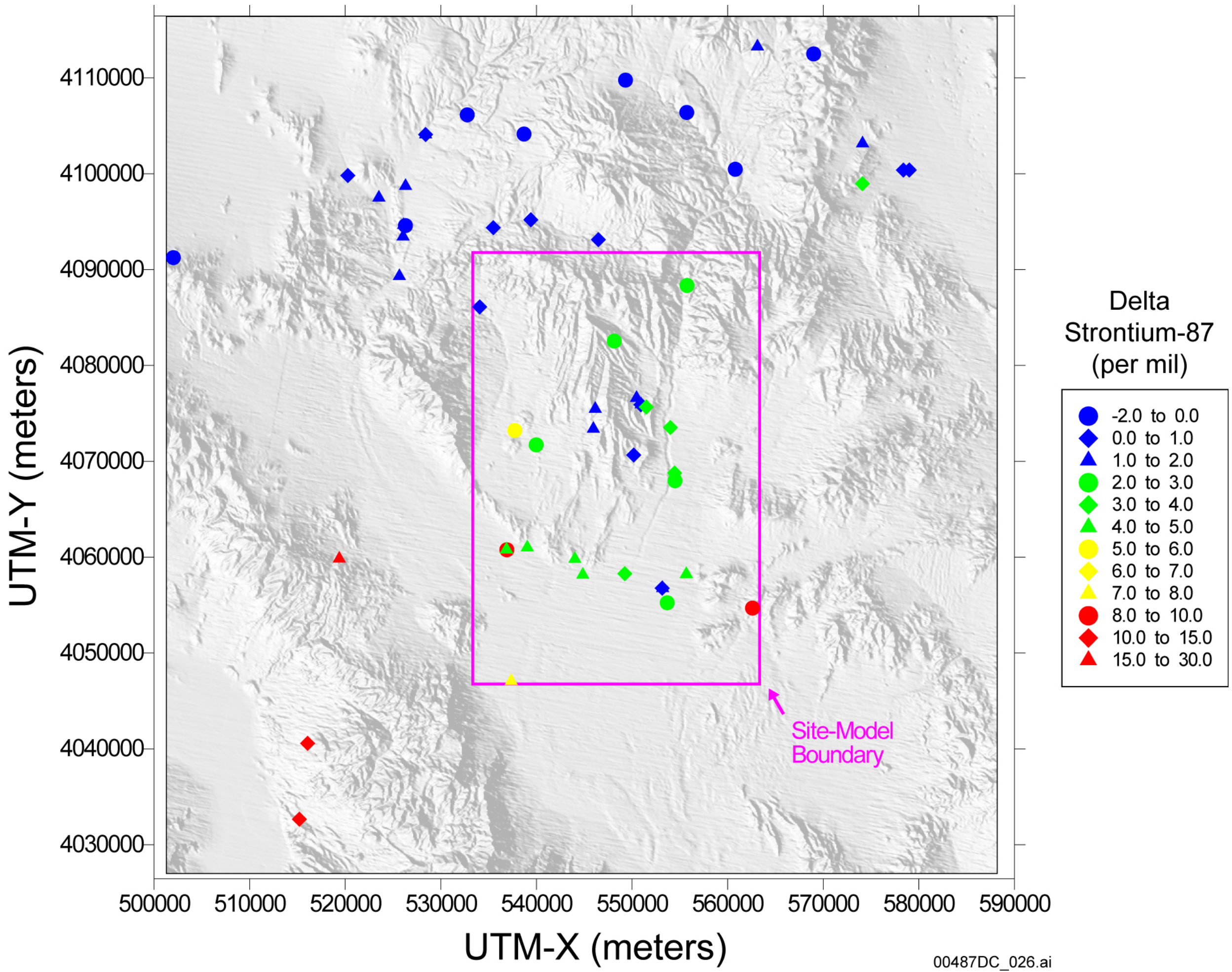


Source: Table A6-2.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting; UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-31. Areal Distribution of Strontium in Groundwater



Source: Table A6-2.

NOTE: This figure has color-coded data points and should not be read in a black and white version.

UTM-X = UTM-Easting, UTM-Y = UTM-Northing; UTM = Universal Transverse Mercator.

Figure A6-32. Areal Distribution of δ^{87}Sr in Groundwater

A6.3.5 Areal Distribution of Calculated Geochemical Parameters

The following subsections describe the areal distribution of the calculated geochemical parameters, including a brief summary of how the calculated parameters would be expected to reflect the relative state of evolution of the groundwater. A number of geochemical parameters were calculated with PHREEQC V2.3 (STN: 10068-2.3-00 [DIRS 155323]; Parkhurst and Appelo 1999 [DIRS 159511]) to further characterize groundwater in the Yucca Mountain area. These parameters include charge balance error, ionic strength, dissolved inorganic carbon (DIC), the logarithm of dissolved carbon-dioxide partial pressure (log P_{CO_2}), and the saturation indices of many minerals identified at Yucca Mountain (Table A6-3 below). The charge-balance errors are helpful in evaluating the reliability of hydrochemical analyses given in Table A6-1 of this report. The calculated DIC concentrations are used for evaluating the extent of calcite dissolution Yucca Mountain recharge undergoes as it moves through the saturated zone

(Section A6.3.6.6) and in mixing models involving ^{14}C (Sections A6.3.6.7 and A7.3.6). The saturation indices are used to help constrain the possible reactions in inverse mixing and water/rock interaction models presented in Section A6.3.8.

The saturation indices of many common minerals such as K-feldspar, amorphous silica [SiO_2(a)], and calcite were based on thermodynamic data contained in the *phreeqc.dat* database provided with PHREEQC (Parkhurst and Appelo 1999 [DIRS 159511], Table 55). In addition, the specific chemical formulas and thermodynamic data for Ca- and Na-clinoptilolite and smectite that have been identified at Yucca Mountain were used in PHREEQC to compute saturation indices. The chemical formulas of these minerals and the Gibbs free-energies **(ΔG^O_f)** and enthalpies (**ΔH^O_f)** of formation estimated for these minerals are listed in Table A6-4.

For the purpose of calculating mineral saturation indices, when field temperature measurements are unavailable, the temperature of groundwater samples was approximated either from published maps of water table temperatures at Yucca Mountain or, in the Amargosa Desert, was assumed to be 25°C. The use of a contour map of water table temperatures (Fridrich et al. 1994 [DIRS 100575], Figure 8) to estimate groundwater sample temperatures at Yucca Mountain is an acceptable approximation because most of the samples for which this approximation was made are from the upper part of the saturated zone (see Table A4-3 for sampled depths and Figure A6-5 for locations of samples 33, 34, 41, 57, and 66). Likewise, the assumption that groundwater samples in the Amargosa Desert with no measured temperatures are at 25°C is an acceptable approximation because most of the measured groundwater sample temperatures are in the range of 25°C to 30°C (see temperature data for samples from the Amargosa Valley (rows 99 to 107), Amargosa River (rows 108 to 117), Fortymile Wash—West (rows 118 to 126), Fortymile Wash—South (rows 127 to 141), Fortymile Wash—East (rows 142 to 153), Gravity Fault (rows 154 to 176), and Amargosa River/Fortymile Wash (rows 177 to 185) in Table A6-1.

The calculation of saturation indices for alumino-silicate minerals such as those listed in Table A6-4 requires measurements of dissolved Al^{3+} concentrations in the groundwater. Although recent groundwater samples from the Yucca Mountain area have reported dissolved Al^{3+} concentrations, historic data from the Yucca Mountain area are generally lacking this information. To get an estimate of the saturation indices of alumino-silicate minerals throughout the Yucca Mountain area, dissolved Al^{3+} concentrations for each sample were assumed to be in equilibrium with kaolinite (see Table A5-1, Assumption 2). This assumption provides estimates of dissolved Al^{3+} concentrations that are in good agreement with measured Al^{3+} concentrations at sites where these data are available (Figure A6-33). Estimates of Al concentrations made by assuming groundwater equilibrium with other Al^{3+}-bearing minerals such as gibbsite, smectite, clinoptilolite, and K-feldspar did not produce nearly as good a match to the available Al^{3+} data. Other factors affecting the calculated saturation indices are discussed in Section A7.3.2. These factors include uncertainty in thermodynamic data use to calculate the mineral solubility constants, variability in mineral compositions and particle sizes, and slow reaction rates relative to the groundwater residence times.