DOE/NV/11718--1064

A Hydrostratigraphic Framework Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Clark, Lincoln and Nye Counties, Nevada

Prepared for
U.S. Department of Energy
National Nuclear Security Administration
Nevada Site Office
Las Vegas, Nevada

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September 2005

This manuscript was prepared by Bechtel Nevada under Contract No. DE-AC08-96NV11718 with the U.S. Department of Energy.

Healey, D. L., M. A. Pistrang, and H. Barnes, 1967. *Proposed Ue5m Test Area, Southwest Frenchman Flat, Nevada Test Site*. U.S. Geological Survey Technical Letter NTS-189.

Healey, D. L., R. N. Harris, D. A. Ponce, and H. W. Oliver, 1987. *Complete Bouguer Gravity Map of the Nevada Test Site and Vicinity, Nevada*. U.S. Geological Survey Open-File Report 87-506, scale: 1:100,000.

Hinrichs, E. N., 1968. "Geologic Map of the Camp Desert Rock Quadrangle Nye County, Nevada." U.S. Geological Survey Quadrangle Map G-726, scale 1:24,000.

Hinrichs, E. N., and E. J. McKay, 1965. "Geologic Map of the Plutonium Valley Quadrangle, Nye and Lincoln Counties, Nevada." U.S. Geological Survey Geologic Quadrangle Map 384, scale 1:24,000.

Hudson, M. R., 1992. "Paleomagnetic Data Bearing on the Origin of Arcuate Structures in the French Peak-Massachusetts Mountain Area of Southern Nevada." *Geological Society of America Bulletin*, v. 104: 581-594.

Hudson, M. R., 1997. *Structural Geology of the French Peak Accommodation Zone, Nevada Test Site, Southwestern Nevada*. U. S. Geological Survey Open File Report 97-56.

IT, see IT Corporation.

IT Corporation, 1996a. *Groundwater Flow Model Documentation Package* (*Phase I Data Analysis Documentation, Volume VI).* ITLV/10972-181. Prepared for the U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV.

IT Corporation, 1996b. *Hydrologic Parameter Data Documentation Package (Phase I Data Analysis Documentation, Volume IV*), ITLV/10972-181. Prepared for the U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV.

IT Corporation, 1996c. *Regional Geologic Model Documentation Package (Phase I Data Analysis Documentation, Volume I, Parts 1 and 2*). ITLV/10972-181. Prepared for the U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV.

IT Corporation, 1996d. *Groundwater Recharge and Discharge Data Documentation Package (Phase I Data Analysis Documentation, Volume III).* ITLV/10972-181. Prepared for the U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV.

IT Corporation, 1997. *Value of Information Analysis Corrective Action Unit No. 98 for Frenchman Flat.* IT Report ITLV/10972-192.

IT Corporation, 1998. *Underground Test Area Subproject, Corrective Action Unit 98: Frenchman Flat Data Analysis Task, Volume I- Hydrostratigraphic Model Documentation Package, Draft.* ITLV/13052-044.

IT Corporation, 1999a. Digital Elevation Model Database for the NTS and Vicinity. Las Vegas, NV.

IT Corporation, 1999b. *External Peer Review Group Report on Frenchman Flat Data Analysis and Modeling Task, Underground Test Area Project.* ITLV/13052--077. Las Vegas, NV

IT Corporation, 1999c. Written communication. Subject: *Underground Test Area Project Corrective Action Unit 98: Frenchman Flat, Vol. III - Groundwater Flow and Contaminant Transport Model Data Documentation Package.* Prepared for U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV.

IT Corporation, 2000. *Frenchman Flat Hydrogeologic Investigation Wells Drilling and Completion Criteria.* ITLV/13052–094. Las Vegas, Nevada.

IT Corporation, 2001. *Addendum to Frenchman Flat Hydrogeologic Investigation Wells Drilling and Completion Criteria.* ITLV/13052–094-Rev.1-ADD. Las Vegas, Nevada.

IT Corporation, 2002. Written communication. Subject: *Integrated Data Report for the Multiple-Well Aquifer Test at Frenchman Flat Well Cluster ER-5-3.* Las Vegas, NV.

Jachens, R. C. and B. C. Moring, 1990. *Maps of the Thickness of Cenozoic Deposits and the Isostatic Residual Gravity Over Basement for Nevada.* U.S. Geological Survey Open File Report 90-0404, 15 p, scale: 1:1,000,000.

Kirchoff-Stein, K. S., D. A. Ponce, and B. A. Chuchel, 1989. *Preliminary Aeromagnetic Map of the Nevada Test Site and Vicinity, Nevada*. U.S. Geological Survey Open File Report 89-446, scale: 1:100,000.

Laczniak, R. J., J. C. Cole, D. A. Sawyer, and D. A. Trudeau, 1996. *Summary of Hydrogeologic Controls on the Movement of Groundwater at the Nevada Test Site, Nye County, Nevada*. U.S. Geological Survey, Water-Resources Investigations Report 96-4109. Carson City, NV.

Marsh, K. V., 1992. *Hydrology and Radionuclide Migration Program 1988 Progress Report.* Lawrence Livermore National Laboratory Report, UCRL-53779-88. Livermore, CA.

McCafferty, A. E., and F. J. Grauch, 1997. *Aeromagnetic and Gravity Anomaly Maps of the Southwestern Nevada Volcanic Field, Nevada and California.* U.S. Geological Survey Geophysical Investigation Map GP-1015, scale 1:250,000.

McKeown, F. A., D. L. Healey, and C. H. Miller, 1976. "Geologic Map of the Yucca Lake Quadrangle, Nye County, Nevada." U.S. Geological Survey GQ-1327, scale 1:24,000.

Miller, C. H., and D. L. Healey, 1986. *Gravity Interpretation of Frenchman Flat and Vicinity, NTS*. U.S. Geological Survey Open File Report 86-211.

Miller, J. J., D. L. Gustafson, and K. E. Snyder, 1993. "Lineaments Identified in Northern Frenchman Flat, Nye, Lincoln, and Clark Counties, Nevada." Map Scale 1:24,000. Las Vegas, NV: Raytheon Services Nevada.

Naeser, C. W., and F. Maldonado, 1981. *Fission-Track Dating of the Climax and Gold Meadows Stocks, Nye County, Nevada*. In: Short Contributions to Geochronology: U.S. Geological Survey Professional Paper 1199E, pp. 45-47.

National Geophysical Company, Inc, 1966. *Seismic Survey Report on the Frenchman Flat Area, Nevada Test Site Areas 5 and 11, Nye County, Nevada*. Dallas, TX: National Geophysical Company, Inc.

Nevada Bureau of Mines and Geology, 1996. *County Digital Geologic Mapping Project- Final Report.* Open-File Report 97-1. Scale 1:250,000.

Pawloski, G.A., 1996. Written communication. Subject: *Review of Data in Frenchman Flat, with Special Emphasis on Alluvium and Porosity*. Lawrence Livermore National Laboratory informal report. Livermore, CA.

Phelps, G. A., and S. E. Graham, 2002. *Preliminary Gravity Inversion Model of Frenchman Flat Basin, Nevada Test Site, Nevada.* U.S. Geological Survey Open-File Report 02-363.

Phelps, G. A., L. Justet, B. C. Moring, and C. W. Roberts, 2005. *A Preliminary Investigation of the Structure of Southern Yucca Flat, Massachusetts Mountain, and CP Basin, Nevada Test Site, Nevada, Based on Geophysical Modeling*. U.S. Geological Survey Open-File Report (in press).

Ponce, D. A., R. N. Harris, and H. W. Oliver, 1988. *Isostatic Gravity Map of the Nevada Test Site and Vicinity, Nevada*. U.S. Geological Survey Open File Report 88-664, scale: 1:100,000.

Ponce, D. A., E. A. Mankinen, J. G. Davidson, R. L. Morin, and R. J. Blakely, 1999. *Digital Isostatic Gravity Map of the Nevada Test Site Area, Nye, Lincoln, and Clark Counties, Nevada and Inyo County, California.* U.S. Geological Survey Open File Report 99-554c, CD-ROM, scale 1:100,000.

Ponce, D. A., 1999. *Digital Aeromagnetic Map of the Nevada Test Site Area, Nye, Lincoln, and Clark Counties, Nevada and Inyo County, California.* U.S. Geological Survey Open File Report 99-55413, CD-ROM, scale 1:100,000.

Poole, F. G., 1965. "Geologic Map of the Frenchman Flat Quadrangle, Nye, Lincoln, and Clark Counties, Nevada." U.S. Geological Survey Geologic Quadrangle Map GC-456, scale 1:24,000.

Poole, F. G., F. N. Houser, and P. P. Orkild, 1961. *Eleana Formation of Nevada Test Site and Vicinity, Nye County, Nevada.* U. S. Geological Survey Professional Paper 424-D, pp. D104-D111.

Poole, F. G., R. E. Davis, and J. R. Ege, and D. L. Hoover, 1963. *Geology of a Strip Between Cane Spring Road and Mara Wash, Nevada Test Site*. U.S. Geological Survey Technical Letter NTS-52.

Poole, F. G., D. P. Elston, and W. J. Carr, 1965. "Geologic Map of the Cane Spring Quadrangle, Nye County, Nevada," U.S. Geological Survey Geologic Quadrangle Map GQ-455, scale 1:24,000.

Prothro, L. B., and S. L. Drellack, Jr., 1997. *Review and Reconnaissance of the Hydrogeology of Tertiary Sedimentary Rocks in the Vicinity of Frenchman Flat, Nevada Test Site*, DOE/NV/11718-155. Bechtel Nevada. Las Vegas, NV.

Prothro, L. B., 2002. Written communication. Subject: *Geologic Interpretation of the Frenchman Flat 3-D Seismic Data*. Bechtel Nevada. Las Vegas, NV.

Pullammanappallil, S. K., and J. N. Louie, 1994. Written communication. Subject: *Seismic Refraction Analysis of the Cane Spring Fault, Southern Nevada*. Project Report to Raytheon Services Nevada. Reno, NV: University of Nevada-Reno, Mackay School of Mines.

Raytheon Services Nevada, 1990. *Nevada Test Site Drilling and Mining Summary*. Las Vegas, NV.

Raytheon Services Nevada, 1994. Written communication. Subject: *Summary of Volcanic Activity at the Area 5 Radioactive Waste Management Site, DOE/Nevada Test Site, Nye County, Nevada*. Las Vegas, NV.

REECo, see Reynolds Electrical & Engineering Co., Inc.

Reynolds Electrical & Engineering Co., Inc., 1993a. *Hydrogeologic Data for Existing Excavations at the Area 5 Radioactive Waste Management Site, Nevada Test Site, Nye County, Nevada*. DOE/NV/11432-40, UC 721. Las Vegas, NV.

Reynolds Electrical & Engineering Co., Inc. 1993b. *Hydrogeologic Data for Science Trench Boreholes at the Area 5 Radioactive Waste Management Site, Nevada Test Site, Nye County, Nevada*. DE-AC08-94-NV11432, UC 721. Las Vegas, NV.

RSN, see Raytheon Services Nevada.

Sawyer, D. A., R. J. Fleck, M. A. Lamphere, R. G. Warren, and D. E. Broxton, 1994. "Episodic Caldera Volcanism in the Miocene Southwest Nevada Volcanic Field: Revised Stratigraphic Caldera Framework, 40Ar/39Ar Geochronology and Implications for Magmatism and Extension." *Geological Society of America Bulletin*, v. 67, n. 10: 1304-1318.

Scott, J. H., 1962. *Shallow Electrical Resistivity Measurements of Alluvium in Frenchman Flat, NTS*, U.S. Geological Survey Technical Letter, Small Boy-002.

Scott, J. H., and R. A. Black, 1962. *Deep Electrical Resistivity Measurements at Frenchman Flat, NTS*, U.S. Geological Survey Technical Letter, Small Boy-004.

Shott, G. J., C. J. Muller, L. E. Barker, D. E. Cawlfield, F. T. Lindstrom, D. G. Linkenheil, M. J. Sully, L. McDowell-Boyer, and D.J. Thune, 1995. *Performance Assessment for the Area 5 Radioactive Waste Management Site at the Nevada Test Site, Nye County, Nevada*. DOE/NV/11432-196.

Shott, G. J., L. E. Barker, S. E. Rawlinson, M. J. Sully, and B. A. Moore, 1998. Written communication. Subject: *Performance Assessment of the Area 5 RWMS at the NTS, Nye County, Nevada, Revision 2.1*. DOE/NV/11718--176. Prepared by Bechtel Nevada for U.S. Department of Energy, Nevada Operations Office. Las Vegas, NV.

Slate, J. L., M. E. Berry, P. D. Rowley, C. J. Fridrich, K. S. Morgan, J. B. Workman, O. D. Young, G. L. Dixon, V. S. Williams, E. H. McKee, D. A. Ponce, T. G. Hilderbrand, WC Swadley, S. C. Lundstrom, E. B. Ekren, R. G. Warren, J. C. Cole, R. J. Fleck, M. A. Lanphere, D. A. Sawyer, S. A. Minor, D. J. Grunwald, R. J. Laczniak, C. M. Menges, J. C. Yount and A. S. Jayko, 1999. *Digital Geologic Map of the Map of the Nevada Test Site and Vicinity, Nye, Lincoln, and Clark Counties, Nevada and Inyo County, California.* U.S. Geological Survey Open-File Report 99B554BA, scale 1:120,000.

SNJV, see Stoller-Navarro Joint Venture.

Snyder, K. E., D. L. Gustafson, J. J. Miller, and S. E. Rawlinson, 1994. *Geologic Components of Site Characterization and Performance Assessment for a Radioactive Waste Management Facility at the Nevada Test Site*. DOE/NV/10833-20. Las Vegas, NV: Raytheon Services Nevada.

Snyder, K. E., D. L. Gustafson, H. E. Huckins-Gang, J. J. Miller, and S. E. Rawlinson, 1995. *Surficial Geology and Performance Assessment for a Radioactive Waste Management Facility at the Nevada Test Site.* DOE/NV/10833-25. Las Vegas, NV: Raytheon Services Nevada

Stewart, J. H., and J. E. Carlson, 1978. *Geologic Map of Nevada.* Scale 1:500,000. U.S. Geological Survey, Reston, VA.

Stewart, J. H., 1998. "Regional Characteristics, Tilt Domains, and Extensional History of the Late Cenozoic Basin and Range Province, Western North America." In: Faulds, J. E., and J. H. Stewart, eds., *Accommodation Zones and Transfer Zones: The Regional Segmentation of the Basin and Range Province.* Geological Society of America Special Paper 323. Boulder, CO.

Stoller-Navarro Joint Venture, 2004a. Written communication. Subject: *Interpretation of Hydraulic Test and Multiple-Well Aquifer Test Data at Frenchman Flat Well Cluster ER-5-3.* Las Vegas, NV.

Stoller-Navarro Joint Venture, 2004b. *Phase II Hydrologic Data for the Groundwater Flow and Contamination Transport Model of CAU Unit 98: Frenchman Flat, Nye County, Nevada.* S-N/99205-032, Revision 0. Las Vegas, NV.

Stoller-Navarro Joint Venture, 2005a. *Phase II Contaminant Transport Parameters for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Nye County, Nevada*. Prepared for the U.S. Department of Energy. Report Number S-N/99205--043. Las Vegas, NV.

Stoller-Navarro Joint Venture, 2005b. Written communication. Subject: *Unclassified Source Term and Radionuclide Data for Corrective Action Unit 98: Frenchman Flat, Nevada*. Las Vegas, NV

Sully, M. J., D. E. Cawlfield, D. O. Blout, L. E. Barber, B. L. Dozier, and D. P. Hammermeister, 1993. Written communication. Subject: *Characterization of the Spatial Variability of Hydraulic Properties at the Area 5 Radioactive Waste Management Site*. Las Vegas, NV: Reynolds Electrical & Engineering Co., Inc.

Sweetkind, D., R. P. Dickerson, R. J. Blakely, and P. D. Denning, 2001. *Interpretive Geologic Cross Sections for the Death Valley Regional Flow System and Surrounding Areas, Nevada and California.* U.S. Geologic Survey Misc. Field Studies Map MF-2370.

Trexler, J. H., Jr., J. C. Cole, and P. H. Cashman, 1996. *Middle Devonian-Mississippian Stratigraphy on and near the Nevada Test Site: Implications for Hydrocarbon Potential*. American Association of Petroleum Geologists Bulletin, v. 80, n. 11, pp. 1736-1762. Tulsa, OK.

Tschanz, C. M., and E. H. Pampeyan, 1970. "Geology and Mineral Deposits of Lincoln County, Nevada, Recently Dated as Miocene." In: *Nevada Bureau of Mines and Geology Bulletin 73*.

Twiss, R. J. and E. M. Moores, 1992. *Structural Geology*. W. H. Freeman and Company, New York, 530 pp.

U.S. Department of Energy, Nevada Operations Office, 1998. *Routine Radiological Environmental Monitoring Plan,* Report DOE/NV/11718--244. Prepared by Bechtel Nevada. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office, 1999. *Corrective Action Investigation Plan for Corrective Action Unit 98: Frenchman Flat, Nevada Test Site, Nevada*, DOE/NV-478-Rev. 1. Prepared by IT Corporation. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office, 2000a. *Addendum to Revision 1 of the Corrective Action Investigation Plan for Corrective Action Unit 98: Frenchman Flat, Nevada Test Site, Nevada*. DOE/NV-478-Rev. 1-Add. Prepared by IT Corporation. Las Vegas, NV.

U.S. Department of Energy, Nevada Operations Office, 2000b. *United States Nuclear Tests, July 1945 through September 1992*. DOE/NV-209, Revision 15. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, 2004. *Nevada Test Site Environmental Report 2003.* DOE/NV/11718--971. Prepared by Bechtel Nevada. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, 2005a. *Well Completion Report for Well Cluster ER-5-3.* Report DOE/NV/11718--1093. Prepared by Bechtel Nevada. Las Vegas, NV.

U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office, 2005b. *Well Completion Report for Well Cluster ER-5-4.* Report DOE/NV/11718--998. Prepared by Bechtel Nevada. Las Vegas, NV

USGS, see U.S. Geological Survey.

Waddell, R. K., Jr., J. H. Robison, and R. K. Blankennagel, 1984. *Hydrology of Yucca Mountain and Vicinity, Nevada-California: Investigative Results Through Mid-1983,* USGS-WRIR-84-4267, Water Resources Investigation Report. Denver, CO: U.S. Geological Survey.

Wagoner, J. L., and W. Richardson, 1986. *Stratigraphic Contacts from Drill Holes at the Nevada Test Site,* Lawrence Livermore National Laboratory Report, UCID-20790. Livermore, CA.

Wahl, R. R., U.S. Geological Survey, 1995. Written communication to Ed Price, HSI-GeoTrans, "Analysis of Gravity Data Along Profile KR1, Frenchman Flat, Nevada." November 2,1995. Golden, CO.

Wahl, R. R., D. A. Sawyer, S. A. Minor, M. D. Carr, J. C. Cole, WC Swadley, R. J. Laczniak, R. G. Warren, K. S. Green, and C. M. Engle, 1997. "Digital Geologic Map Database of the Nevada Test Site area, Nevada." U.S. Geological Survey Open-File Report 97-140, CD-ROM, scale 1:100,000.

Warren, R.G., Los Alamos National Laboratory, 1995. Personal communication to S. L. Drellack, Bechtel Nevada, regarding the hydrology of the Wahmonie Formation in Frenchman Flat. Los Alamos, NM.

Warren, R. G., F. C. Benedict Jr., T. P. Rose, D. K. Smith, S. J. Chipera, E. C. Kluk, and K. M. Raven, 2002. *Alluvial Layering and Distribution of Reactive Phases within Drill Holes ER-5-4 and UE-5n of Frenchman Flat.* Los Alamos National Laboratory Report LA-UR-02-6206.

West, L. R., and M. S. Garber, 1961. *Abridged Log of Ground-Water Test Well F, 410 Area, Nevada Test Site, Nevada.* U.S. Geological Survey Technical Letter NTS-12.

Winograd, I. J., and W. Thordarson, 1975. *Hydrogeologic and Hydrochemical Framework, South-Central Great Basin, Nevada-California, with Special Reference to the Nevada Test Site.* U.S. Geological Survey Professional Paper 712-C.

Workman, J. B., C. Menges, W. R. Page, E. Taylor, E. B. Ekren, P. D. Rowley, G. L. Dixon, R. A. Thompson, and L. A. Wright, 2002. *Geologic Map of the Death Valley Groundwater Basin and Surrounding Areas, Nevada and California.* U.S. Geologic Survey Misc. Field Studies Map No. MF 2381-A, Scale 1:250,000.

Yount, J. C. U.S. Geological Survey, 1996. Verbal communication to L. B. Prothro regarding the rocks of Winapi Wash.

Zavarin M., S. K. Roberts, T. P. Rose, and D. L. Phinney, 2002. *Validating Mechanistic Sorption Model Parameters and Processes for Reactive Transport in Alluvium.* Lawrence Livermore National Laboratory Report UCRL-ID-149728, Livermore, CA.

Zavarin M., S. F. Carle, and R. M. Maxwell, 2004. *Upscaling Radionuclide Retardation - Linking the Surface Complexation and Ion Exchange Mechanistic Approach to a Linear Kd Approach.* Report on work performed for the UGTA program, Lawrence Livermore National Laboratory Report UCRL-TR-214713, Livermore, CA.

Zonge Engineering and Research Organization, Inc., 1990. Written communication prepared for Holmes and Narver, Inc. Subject: *Final Report: Vector CSAMT Survey, Frenchman Flat Project, Nevada Test Site*. Tucson, AZ.

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APPENDIX A

Geologic and Hydrostratigraphic Drill Hole Database for the Frenchman Flat Model Area

Appendix A.
Hydrostratigraphic Database for Drill Holes in the Frenchman Flat Area.

Hole Name	Strat[1]	Lith[1]	Major Alter.[1]	HGU[2]	HSU[3]	Depth Top[4] (ft)	Depth Top[4] (m)	Elev. Top[5] (ft)	Elev. Top[5] (m)	TD[6](ft)	TD[6](m)
ER-5-3	QTa	AL	CC	AA	AA3[10]	0.0	0.0	3,334.3	1,016.3	2,610.0	795.5
ER-5-3	QTa	AL	CC/ZE	AAA	OAA	590.0	179.8	2,744.3	836.5		
ER-5-3	Tybf	BS	DV	LFA	BLFA	903.0	275.2	2,431.3	741.1		
ER-5-3	QTa	AL	CC/ZE	AAA	OAA1[12]	933.0	284.4	2,401.3	731.9		
ER-5-3	Ttp	BED	GL/ZE	VTA	OAA1	1,665.0	507.5	1,669.3	508.5		
ER-5-3	QTa	AL	CC/ZE	AAA	OAA1	1,682.0	512.7	1,651.4	503.3		
ER-5-3	Tmar	MWT	DV	WTA	TM-WTA	2,042.0	622.4	1,292.3	393.9		
ER-5-3	Tmar	DWT	DV	WTA	TM-WTA	2,130.0	649.2	1,204.3	367.1		
ER-5-3	Tmar	MWT	DV	WTA	TM-WTA	2,176.0	663.2	1,158.3	353.1		
ER-5-3	Tmap	PWT	GL/ZE	VTA	TM-WTA	2,262.0	689.5	1,072.3	326.8		
ER-5-3	Tmab	BED	GL/ZE	VTA	TM-WTA	2,306.0	702.9	1,028.3	313.4		
ER-5-3	Tmrr	NWT/PWT	ZE	TCU	TM-WTA	2,334.0	711.4	1,000.3	304.9		
ER-5-3	Tmrr,Tmrp	PWT/MWT	DV/VP	WTA	TM-WTA	2,370.0	722.4	964.3	293.9		
ER-5-3	Tmrp	MWT/DWT	DV	WTA	TM-WTA	2,510.0	765.1	824.3	251.3		
ER-5-3	Tmrp	DWT	DV	WTA	TM-WTA	2,530.0	771.1	804.3	245.2		
ER-5-3	Tmrp	MWT	DV/VP	WTA	TM-WTA	2,590.0	789.4	744.3	226.9		
ER-5-3#2	QTa	AL	CC	AA	AA3	0.0	0.0	3,334.3	1,017.2	5,683.0	1732.2
ER-5-3#2	QTa	AL	CC/ZE	AAA	OAA	590.0	178.8	2,744.3	836.5		
ER-5-3#2	Tybf	BS	DV	LFA	BLFA	910.0	277.4	2,424.3	738.9		
ER-5-3#2	QTa	AL	CC/ZE	AAA	OAA1	940.0	286.5	2,394.3	729.8		
ER-5-3#2	Ttp	BED	GL/CC	VTA	OAA1	1,680.0	512.1	1,654.3	504.2		
ER-5-3#2	QTa	AL	CC/ZE	AAA	OAA1	1,695.0	516.6	1,639.3	499.7		
ER-5-3#2	Tmar	MWT	DV	WTA	TM-WTA	2,060.0	627.9	1,274.3	388.4		
ER-5-3#2	Tmar	DWT	DV/VP	WTA	TM-WTA	2,140.0	652.3	1,194.3	364.0		
ER-5-3#2	Tmar	MWT	DV	WTA	TM-WTA	2,190.0	667.5	1,144.3	348.8		
ER-5-3#2	Tmap	PWT	GL/ZE/VP	VTA	TM-WTA	2,270.0	691.9	1,064.3	324.4		
ER-5-3#2	Tmab	BED	GL/ZE	VTA	TM-WTA	2,310.0	704.1	1,024.3	312.2		
ER-5-3#2	Tmrr	NWT/PWT	ZE	TCU	TM-WTA	2,340.0	713.2	994.3	303.1		
ER-5-3#2	Tmrr,Tmrp	PWT/MWT	DV/VP	WTA	TM-WTA	2,370.0	722.4	964.3	293.9		
ER-5-3#2	Tmrp	MWT/DWT	DV/QC	WTA	TM-WTA	2,520.0	768.1	814.3	248.2		
ER-5-3#2	Tmrp	DWT	DV/QC	WTA	TM-WTA	2,540.0	774.2	794.3	242.1		
ER-5-3#2	Tmrp	MWT	DV/VP	WTA	TM-WTA	2,600.0	792.5	734.3	223.8		
ER-5-3#2	Tmrp	PWT/NWT	DV/ZE	VTA	TM-LVTA	2,710.0	826.0	624.3	190.3		
ER-5-3#2	Tmrp	NWT	ZE	TCU	UTCU	2,780.0	853.4	554.3	169.0		
ER-5-3#2	Tmrh	BED	ZE	TCU	UTCU	2,807.0	855.6	527.3	160.7		

Appendix A.
Hydrostratigraphic Database for Drill Holes in the Frenchman Flat Area.

Hole Name	Strat[1]	Lith[1]	Major Alter.[1]	HGU[2]	HSU[3]	Depth Top[4] (ft)	Depth Top[4] (m)	Elev. Top[5] (ft)	Elev. Top[5] (m)	TD[6](ft)	TD[6](m)
ER-5-3#2	Tpt	NWT	GL	WTA	TSA	2,862.0	872.3	472.3	144.0		
ER-5-3#2	Tpt	MWT/DWT	DV/QTZ/VP	WTA	TSA	2,891.0	881.2	443.3	135.1		
ER-5-3#2	Tpt	PWT	DV/QZ/ZE	WTA	TSA	2,960.0	902.2	374.3	114.1		
ER-5-3#2	Tpt	NWT	DV/GL/ZE	VTA	TSA	3,000.0	914.4	334.3	101.9		
ER-5-3#2	Th	BED	ZE	TCU	LTCU	3,024.0	921.7	310.3	94.6		
ER-5-3#2	Twlb	NWT/PWT	ZE	TCU	LTCU	3,055.0	931.2	279.3	85.1		
ER-5-3#2	Twlb	BED/NWT/PWT	ZE/QTZ	TCU	LTCU	3,164.0	964.4	170.3	51.9		
ER-5-3#2	Twls	BED/NWT/PWT	ZE/CC/QZ	TCU	LTCU	3,315.0	1,010.4	19.3	5.9		
ER-5-3#2	Tcb	BED/NWT/PWT	ZE/CC/QZ	TCU	LTCU	3,796.0	1,157.0	-461.7	-140.7		
ER-5-3#2	Pz	DM	CC	CA	LCA	4,678.0	1,425.9	-1,343.7	-409.6		
ER-5-3#3	QTa	AL	CC/ZE	AA	AA3	0.0	0.0	3,334.3	1,016.0	1,800	548.6
ER-5-3#3	QTa	AL	CC/ZE	AAA	OAA	610.0	185.9	2,724.3	830.4		
ER-5-3#3	Tybf	BS	DV	LFA	BLFA	910.0	277.4	2,424.3	738.9		
ER-5-3#3	QTa	AL	CC/ZE	AAA	OAA1	950.0	289.6	2,384.3	726.7		
ER-5-4	QTa	AL	CC	AA	AA3	0.0	0.0	3,131.7	954.5	3,732.0	1137.5
ER-5-4	QTp	P	CC	PCU	PCU1U[7]	2,312.0	704.7	819.7	249.8		
ER-5-4	Ttp	BED	GL	VTA	PCU1U	2,702.0	823.6	429.7	131.0		
ER-5-4	QTp	P	CC	PCU	PCU1U	2,707.0	825.1	424.7	129.5		
ER-5-4	QTa	AL	CC	AA	AA1	2,940.0	869.1	191.7	58.4		
ER-5-4	Tma	PWT	DV	WTA	TM-WTA	3,670.0	1,118.6	-538.3	164.1		
ER-5-4#2	QTa	AL	CC/ZE	AA	AA3	0.0	0.0	3,131.7	954.5	7,000.0	2133.6
ER-5-4#2	QTp	P	CC	PCU	PCU1U	2,312.0	704.7	819.7	249.8		
ER-5-4#2	Ttp	BED	GL	VTA	PCU1U	2,702.0	823.6	429.7	131.0		
ER-5-4#2	QTp	P	CC	PCU	PCU1U	2,707.0	825.1	424.7	129.5		
ER-5-4#2	QTa	AL	CC	AA	AA1	2,940.0	869.1	191.7	58.4		
ER-5-4#2	Tma	PWT	DV/GL/ZE	VTA	TM-WTA	3,676.0	1,120.4	-544.3	-165.9		
ER-5-4#2	Tma	MWT	DV	WTA	TM-WTA	3,730.0	1,136.9	-598.3	-182.4		
ER-5-4#2	Tma	PWT	DV	WTA	TM-WTA	3,830.0	1,167.4	-698.3	-212.8		
ER-5-4#2	Tma	NWT	GL	VTA	TM-WTA	3,890.0	1,185.7	-758.3	-231.1		
ER-5-4#2	Tmab	BED	GL	VTA	TM-WTA	3,928.0	1,197.3	796.3	-242.7		
ER-5-4#2	Tmr	NWT	GL/DV	VTA	TM-WTA	3,980.0	1,213.1	-848.3	-285.6		
ER-5-4#2	Tmr	PWT	DV	WTA	TM-WTA	4,020.0	1,225.3	-888.3	-270.8		
ER-5-4#2	Tmr	MWT	DV	WTA	TM-WTA	4,102.0	1,250.3	-970.3	-295.8		
ER-5-4#2	Tmr	PWT	GL	WTA	TM-LVTA	4,306.0	1,312.5	-1,174.3	-357.9		
ER-5-4#2	Tmr	NWT	GL	VTA	TM-LVTA	4,320.0	1,316.0	-1,188.3	-362.2		

Appendix A.
Hydrostratigraphic Database for Drill Holes in the Frenchman Flat Area.

Hole Name	Strat[1]	Lith[1]	Major Alter.[1]	HGU[2]	HSU[3]	Depth Top[4] (ft)	Depth Top[4] (m)	Elev. Top[5] (ft)	Elev. Top[5] (m)	TD[6](ft)	TD[6](m)
ER-5-4#2	pre-Tmr/ post-Tw	NWT/BED		VTA	TM-LVTA	4,356.0	1,327.7	-1,224.3	-373.2		
ER-5-4#2	Tw	NWT/BED	ZE	TCU	LTCU	4,472.0	1,363.1	-1,340.3	-408.5		
ER-5-4#2	Tw	LA	DV/QZ	LFA	LTCU	6,072.0	1,850.7	-2,940.3	-896.2		
ER-5-4#2	Tw	NWT	ZE	TCU	LTCU	6,134.0	1,869.6	-3,002.3	-915.1		
ER-5-4#2	Tcb	NWT	ZE	TCU	LTCU	6,306.0	1,922.1	-3,174.3	-967.5		
ER-5-4#2	Tw	NWT	ZE	TCU	LTCU	6,730.0	2,051.3	-3,598.3	-1,096.8		
U-5a	QTa	AL	CC	AA	AA3[9]	0.0	0.0	3,086.0	940.6	628.0	191.4
WW-5A	QTa	AL	CC	AA	AA3	0.0	0.0	3,093.0	942.7	910.0	277.4
WW-5A	QTp	P	CC	PCU	PCU2T[8]	80.0	24.4	3,013.0	918.4		
WW-5A	QTa	AL	CC	AA	AA2	550.0	167.6	2,543.0	775.1		
WW-5A	QTa	AL	CC	AA	AA2	585.0	178.3	2,508.0	764.4		
U-5b	QTa	AL	CC	AA	AA3	0.0	0.0	3,095.0	943.4	675.0	205.7
WW-5B	QTa	AL	CC	AA	AA3	0.0	0.0	3,092.0	942.4	900.0	274.3
WW-5B	QTp	P		PCU	PCU2T	57.0	17.4	3,035.0	925.1		
WW-5B	QTa	AL	CC	AA	AA2	432.0	131.7	2,660.0	810.8		
U-5c	QTa	AL	CC	AA	AA3	0.0	0.0	3,100.0	944.9	675.0	205.7
WW-5C	QTa	AL	CC	AA	AA3	0.0	0.0	3,081.0	939.1	1,200.0	365.8
WW-5C	QTp	P		PCU	PCU2T	10.0	3.5	3,071.0	936.0		
WW-5C	QTa	AL	CC/QZ	AA	AA	732.0	223.1	2,349.0	716.0		
UE-5cWW	QTa	AL	CC	AA	AA	0.0	0.0	3,216.0	980.2	2,682.0	817.5
UE-5cWW	Tw	NWT	ZE	TCU	LTCU	1,350.0	411.5	1,866.0	568.8		
U-5d	QTa	AL	CC	AA	AA3	0.0	0.0	3,120.0	951.0	685.0	208.8
U-5e	QTa	AL	CC	AA	AA3	0.0	0.0	3,137.0	956.2	1,000.0	304.8
UE-5f	QTa	AL	CC	AA	AA3	0.0	0.0	3,301.0	1,006.1	1,100.0	335.3
U-5g	QTa	AL	CC	AA	AA3	0.0	0.0	3,085	940.3	90.0	27.4
U-5i	QTa	AL	CC	AA	AA3	0.0	0.0	3,395.0	1,034.8	820.0	249.9
U-5i	QTa	AL	CC/ZE	AAA	OAA	550.0	167.6	2,877.0	876.9		
UE-5i	QTa	AL	CC	AA	AA2	0.0	0.0	3,427.0	1,044.6	2,124.0	647.4
UE-5i	QTa	AL	CC/ZE	AAA	OAA	550.0	167.6	2,877.0	876.9		
UE-5i	Tybf	BS	CC	LFA	BLFA	880.0	268.2	2,547.0	776.3		
UE-5i	QTa	AL	CC/ZE	AAA	OAA1	950.0	289.6	2,477.0	755.0		
UE-5i	Ttp	NWT	V	VTA	OAA1	1,065.0	324.6	2,362.0	719.9		
UE-5i	QTc	AL	CC/ZE	AA	OAA1	1,090.0	332.2	2,337.0	712.3		
UE-5i	Tma	MWT/DWT	DV	WTA	TM-WTA	1,100.0	335.3	2,327.0	709.3		

Appendix A.
Hydrostratigraphic Database for Drill Holes in the Frenchman Flat Area.

Hole Name	Strat[1]	Lith[1]	Major Alter.[1]	HGU[2]	HSU[3]	Depth Top[4] (ft)	Depth Top[4] (m)	Elev. Top[5] (ft)	Elev. Top[5] (m)	TD[6](ft)	TD[6](m)
UE-5i	Tmab	BED	GL	VTA	TM-WTA	1,368.0	417.0	2,059.0	627.6		
UE-5i	Tmr	NWT	V	VTA	TM-WTA	1,398.0	426.1	2,029.0	618.4		
UE-5i	Tmr	DWT	DV	WTA	TM-WTA	1,700.0	518.2	1,727.0	526.4		
UE-5i	Tmr	PWT/NWT	V	VTA	TM-LVTA	2,010.0	612.6	1,417.0	431.9		
UE-5i	Tmr	NWT	ZE	TCU	UTCU	2,040.0	621.8	1,387.0	422.8		
UE-5i	Tmrh/Ta	BED	ZE	TCU	UTCU	2,120.0	646.2	1,307.0	398.4		
U-5i#1	QTa	AL	CC	AA	AA3	0.0	0.0	3,404.0	1,037.5	835.0	254.5
UE-5j	QTa	AL	CC	AA	AA3	0.0	0.0	3,578.0	1,090.6	1,242.0	378.6
UE-5j	Tma	DWT	DV	WTA	TM-WTA	1,090.0	332.0	2,488.0	758.3		
UE-5j	Tmr	MWT	DV	WTA	TM-WTA	1,235.0	376.4	2,343.0	714.2		
U-5k	QTa	AL	CC	AA	AA3	0.0	0.0	3,349.0	1,020.8	905.0	275.8
U-5k	QTa	AL	CC/ZE	AAA	OAA	575.0	175.0	2,774.0	845.5		
UE-5k	QTa	AL	CC	AA	AA3	0.0	0.0	3,349.0	1,020.8	1,728.0	526.7
UE-5k	QTa	AL	CC/ZE	AAA	OAA	575.0	175.3	2,774.0	845.5		
UE-5k	Tybf	BS		LFA	BLFA	950.0	289.6	2,399.0	731.2		
UE-5k	QTa	AL	CC/ZE	AAA	OAA1	1,000.0	304.8	2,349.0	716.0		
UE-5k	Tma	DWT	DV	WTA	TM-WTA	1,660.0	506.0	1,689.0	514.8		
U-5L	QTa	AL	CC	AA	AA3	0.0	0.0	3,323.0	1,012.9	120	36.6
U-5Ls	QTa	AL	CC	AA	AA3	0.0	0.0	3,324.0	1,013.2	835.0	254.5
UE-5m	QTa	AL	CC	AA	AA3	0.0	0.0	3,500.0	1,066.8	1,504.0	458.4
UE-5m	Tw	NWT/BED	ZE	TCU	WCU	165.0	50.3	3,335.0	1,016.5		
UE-5m	Tws	FB		LFA	WCU	430.0	131.1	3,070.0	935.7		
UE-5m	Tc	TUF	ZE	TCU	LTCU1[13]	1,100.0	335.3	2,400.0	731.5		
UE-5m	Tgp	TUF/SS	AR	TCU/AA/CA	VCU	1,280.0	390.1	2,220.0	676.7		
UE-5n	QTa	AL	CC	AA	AA3	0.0	0.0	3,112.0	948.5	1,687.0	514.2
RNM#1	QTa	AL	CC	AA	AA3	0.0	0.0	3,136.0	955.9	1,302.0	396.8
RNM#2	QTa	AL	CC	AA	AA3	0.0	0.0	3,132.0	954.6	935.0	285.0
RNM#2s	QTa	AL	CC	AA	AA3	0.0	0.0	3,133.0	954.9	1,156.0	352.3
RNM#3	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	100.0	30.5
RNM#4	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	72.0	21.9
RNM#5	QTa	AL	CC	AA	AA3	0.0	0.0	3,111.0	948.2	150.0	45.7
U5Rc1	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	46.0	14.0
U5R4c	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	118.0	36.0
U5R5	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	55.0	16.8
U5R5u	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	118.0	36.0

Appendix A.
Hydrostratigraphic Database for Drill Holes in the Frenchman Flat Area.

Hole Name	Strat[1]	Lith[1]	Major Alter.[1]	HGU[2]	HSU[3]	Depth Top[4] (ft)	Depth Top[4] (m)	Elev. Top[5] (ft)	Elev. Top[5] (m)	TD[6](ft)	TD[6](m)
U5R6u	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	117.0	35.7
U5R7c	QTa	AL	CC	AA	AA3	0.0	0.0	3,195.0	973.8	120.0	36.6
U5R8c	QTa	AL	CC	AA	AA3	0.0	0.0	3,194.0	973.5	120.0	36.6
U5R9u	QTa	AL	CC	AA	AA3	0.0	0.0	3,190.0	972.3	120.0	36.6
U5R10u	QTa	AL	CC	AA	AA3	0.0	0.0	3,190.0	972.3	117.0	35.7
U5R11u	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	119.0	36.3
U5R12u	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	119.0	36.3
RCRA#1	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	120.0	36.6
TH5#4	QTa	AL	CC	AA	AA3	0.0	0.0	3,405.0	1,037.8	172.0	52.4
TH5#4	Tw	FB/LA		TCU	WCU	129.0	39.3	3,276.0	998.5		
TH5#5	QTa	AL	CC	AA	AA3	0.0	0.0	3,233.0	985.4	461.0	140.5
TH5#5	Tw	FB/LA	AR	TCU/LFA	WCU	134.0	40.8	3,099.0	944.6		
U5GCDT1	QTa	AL	CC	AA	AA3	0.0	0.0	3,242.0	988.2	119.0	36.3
TH5#1	QTa	AL	CC	AA	AA3	0.0	0.0	3,178.0	968.7	60	18.3
TH5#1A	QTa	AL	CC	AA	AA3	0.0	0.0	NA	NA	120.0	36.6
TH5#2	QTa	AL	CC	AA	AA3	0.0	0.0	3,188.0	971.7	86	26.2
UE-5PW-1	QTa	AL	CC	AA	AA3	0.0	0.0	3,180.0	969.3	839.0	255.7
UE-5PW-2	QTa	AL	CC	AA	AA3	0.0	0.0	3,248.0	990.0	919.5	280.3
UE-5PW-3	QTa	AL	CC	AA	AA3	0.0	0.0	3,298.0	1,005.2	955.0	291.1
UE-5PW-3	Tma	PWT	V	WTA	TM-WTA	617.0	188.1	2,681.0	817.2		
UE-5PW-3	Tmab	BED	V	VTA	TM-WTA	917.0	279.5	2,381.0	725.7		
UE-5PW-3	Tmr	PWT	DV	WTA	TM-WTA	955.0	291.1	2,343.0	714.2		
SB5 AP1	QTa	AL	CC	AA	AA3	0.0	0.0	3,199.5	975.2	275.0	83.8
SB5 AP2	QTa	AL	CC	AA	AA3	0.0	0.0	3,199.3	975.2	275.0	83.8
SB5 RP1	QTa	AL	CC	AA	AA3	0.0	0.0	3,169.3	966.0	150.0	45.7
SB5 RP2	QTa	AL	CC	AA	AA3	0.0	0.0	3,169.1	965.9	150.0	45.7
SB5 NN1	QTa	AL	CC	AA	AA3	0.0	0.0	3,204.9	976.9	200.0	61.0
SB5 NE1	QTa	AL	CC	AA	AA3	0.0	0.0	3,196.6	974.3	200.0	61.0
SB5 NW1	QTa	AL	CC	AA	AA3	0.0	0.0	3,177.7	968.6	200.0	61.0
SB5 NS1	QTa	AL	CC	AA	AA3	0.0	0.0	3,171.2	966.6	200.0	61.0
WW6-4	QTa	AL	CC	AA	AA3	0.0	0.0	3,602.0	1,097.9	1,479.0	450.8
WW6-4	Tma	MWT/DWT	DV	WTA	TM-WTA	520.0	158.5	3,082.0	939.4		
WW6-4	Tmr	NWT	GL/DV	VTA	TM-WTA	740.0	225.6	2,862.0	872.3		
WW6-4	Tmr	MWT	DV	WTA	TM-WTA	790.0	240.8	2,812.0	857.1		
WW6-4	Tmr	DWT	DV	WTA	TM-WTA	940.0	286.5	2,662.0	811.4		

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Hydrostratigraphic Database for Drill Holes in the Frenchman Flat Area.

Hole Name	Strat[1]	Lith[1]	Major Alter.[1]	HGU[2]	HSU[3]	Depth Top[4] (ft)	Depth Top[4] (m)	Elev. Top[5] (ft)	Elev. Top[5] (m)	TD[6](ft)	TD[6](m)
WW6-4	Tmr	MWT	DV	WTA	TM-WTA	1,060.0	323.1	2,542.0	774.8		
WW6-4	Tmr	NWT	GL	VTA	TM-LVTA	1,190.0	362.7	2,412.0	735.2		
WW6-4	Tmrh/Ta	RWT	DV	VTA	TM-LVTA	1,210.0	368.8	2,392.0	729.1		
WW6-4	Tpt	MWT/DWT	GL/VP/VT	WTA	TSA	1,250.0	381.0	2,352.0	716.9		
WW6-4	Th	RWT/NWT/PWT	ZE	TCU	LTCU	1,340.0	408.4	2,262.0	689.5		
WW6-4A	QTa	AL	CC	AA	AA3	0.0	0.0	3,606.0	1,099.1	1,516.0	462.1
WW6-4A	Tma	PWT/MWT	GL	WTA	TM-WTA	765.0	233.2	2,841.0	865.9		
WW6-4A	Tmab	BED	GL	VTA	TM-WTA	970.0	295.7	2,636.0	803.5		
WW6-4A	Tmr	NWT	GL	WTA	TM-WTA	980.0	298.7	2,626	800.4		
WW6-4A	Tmr	MWT	GL	WTA	TM-WTA	1,050.0	320.0	2,556	779.1		
WW6-4A	Tmr	DWT	GL	WTA	TM-WTA	1,160.0	353.6	2,446	745.5		
WW6-4A	Tmr	MWT	GL	WTA	TM-WTA	1,255.0	382.5	2,351	716.6		
WW6-4A	Tmr	NWT	GL	VTA	TM-LVTA	1,270.0	387.1	2,336	712.0		
WW6-4A	Tmrh/Th	BED	GL	VTA	TM-LVTA	1,305.0	397.8	2,301.0	701.3		
WW6-4A	Tpt	DWT	GL	WTA	TSA	1,325.0	403.9	2,281.0	695.3		
WW6-4A	Th	BED	ZE	TCU	LTCU	1,450.0	442.0	2,156.0	657.2		
UE-11a	QTa	AL	CC	AA	AA3	0.0	0.0	3,547.0	1,081.1	1,400.0	426.7
UE-11a	Tma	DWT	DV	WTA	TM-WTA	550.0	167.6	2,997.0	913.5		
UE-11a	Tma	PWT	DV	WTA	TM-WTA	765.0	233.2	2,782.0	848.0		
UE-11a	Tma	NWT	GL	VTA	TM-WTA	850.0	259.1	2,697.0	822.1		
UE-11a	Tmab	BED	GL	VTA	TM-WTA	890.0	271.3	2,657.0	809.9		
UE-11a	Tmr	NWT	GL	VTA	TM-WTA	900.0	274.3	2,647.0	806.8		
UE-11a	Tmr	PWT	DV	WTA	TM-WTA	950.0	289.6	2,597.0	791.6		
UE-11a	Tmr	DWT	DV	WTA	TM-WTA	1,128.0	343.8	2,419.0	737.3		
UE-11a	Tmr	PWT	DV	WTA	TM-WTA	1,140.0	347.5	2,407.0	733.7		
U-11b	QTa	AL	CC	AA	AA3	0.0	0.0	3,586.0	1,093.0	980.0	298.7
U-11b	Tmr	PWT/DWT	DV	WTA	TM-WTA	190.0	57.9	3,396.0	1,035.1		
U-11b	Tmrh/Th	BED	GL	VTA	TM-LVTA	630.0	192.0	2,956.0	901.0		
U-11b	Tp	BED	GL	VTA	TM-LVTA	978.0	298.1	2,608.0	794.9		
UE-11b	QTa	AL	CC	AA	AA3	0.0	0.0	3,586.0	1,093.0	1,303.0	397.2
UE-11b	Tmr	PWT	DV	WTA	TM-WTA	190.0	57.9	3,396.0	1,035.1		
UE-11b	Tmr	DWT	DV	WTA	TM-WTA	260.0	79.3	3,326.0	1,013.8		
UE-11b	Tmr	NWT	GL	VTA	TM-LVTA	515.0	157.0	3,071.0	936.0		
UE-11b	Tmrh/Ta	BED	GL	VTA	TM-LVTA	630.0	192.0	2,956.0	901.0		
UE-11b	Tp	BED	GL	VTA	TM-LVTA	978.0	298.1	2,608.0	794.9		

Appendix A.
Hydrostratigraphic Database for Drill Holes in the Frenchman Flat Area.

Hole Name	Strat[1]	Lith[1]	Major Alter.[1]	HGU[2]	HSU[3]	Depth Top[4] (ft)	Depth Top[4] (m)	Elev. Top[5] (ft)	Elev. Top[5] (m)	TD[6](ft)	TD[6](m)
UE-11b	Tpt	VT/ DWT	GL/DV	WTA	TSA	1,020.0	310.9	2,566.0	782.1		
UE-11b	Th	BED	GL	VTA	LVTA	1,240.0	378	2,346.0	715.1		
UE-11b	Th	BED	ZE	TCU	LTCU	1,290.0	393.2	2,296.0	699.8		
U-11c	QTa	AL	CC	AA	AA3	0.0	0.0	3,381.0	1,030.5	835.0	254.5
U-11c	QTa	AL	CC/ZE	AAA	OAA	650.0	198.1	2,731.0	832.4		
U-11c#1[14]	QTa	AL	CC	AA	AA3	0.0	0	3,380.0	1030.2	1,860.0	566.9
U-11c#1	QTa	AL	CC	AA	AA3	519.0	158.2	2,861.0	872.0		
U-11c#1	QTa	AL	CC/ZE	AAA	OAA	680.0	207.3	2,700.0	823.0		
U-11c#1	Tma	DWT	DV	WTA	TM-WTA	1,590.0	484.6	1,790.0	545.6		
U-11d	QTa	AL	CC	AA	AA3	0.0	0.0	3,385	1,031.80	40	12.2
U-11e	QTa	AL	CC	AA	AA3	0.0	0.0	3,385.0	1,031.8	835.0	254.5
U-11f	QTa	AL	CC	AA	AA3	0.0	0.0	3,393.0	1,034.2	910.0	277.4
U-11g	QTa	AL	CC	AA	AA3	0.0	0.0	3,405.0	1,037.8	910.0	277.4
U-11g	QTa	AL	CC/ZE	AAA	OAA	570.0	173.7	2,835.0	864.1		
U-11g#1	QTa	AL	CC	AA	AA2	0.0	0.0	3,405.0	1,037.8	860.0	262.1
U-11g#1	QTa	AL	CC/ZE	AAA	OAA	610.0	185.9	2,795.0	851.9		
U-11g Ex1	QTa	AL	CC	AA	AA3	0.0	0.0	3,405.0	1,037.0	1,155.0	352.0
U-11g Ex1	QTa	AL	CC/ZE	AAA	OAA	617.0	188.1	2,788.0	849.8		
U-11g Ex1	Tmr	DWT	DV/VP	WTA	TM-WTA	1,120.0	341.4	2,285.0	696.5		
TW-F	Tw	TUF	AR	TCU	WCU	0.0	0.0	4,143.0	1,262.8	3,400.0	1036.3
TW-F	Tws	TUF	AR	TCU	WCU	1,110.0	338.3	3,033.0	924.5		
TW-F	Tc	BED	ZE	TCU	LTCU	1,482.0	451.7	2,661.0	811.1		
TW-F	Tgp	SLT	AR	TCU/AA	VCU	1708	520.6	2,435.0	742.2		
TW-F	Pz	CA		CA	LCA	3137	956.0	1006	306.6		
WW-1	QTa	AL	CC	AA	AA3	0.0	0.0	3,100.0	944.9	870.0	265.2
WW-1	QTp	P	CC	PCU	PCU2T	20.0	6.1	3,080.0	938.8		
WW-1	QTa	AL	CC	AA	AA2	519.0	158.2	2,581.0	786.7		
HTH#3	QTa	AL	CC	AA	AA3	0	0.0	3,477.0	1,059.8	1,860.0	566.9
HTH#3	Op	LS		CA	LCA	157	47.9	3320	1,011.9		

Explanation:

Strat = Stratigraphic unit. See Table 4-1 in the main document for abbreviations.
Lith = Lithology

AL = alluvium	P = playa
BS = basalt	PWT = partially welded tuff
BED = bedded tuff	RWT = reworked tuff
DM = dolomite	SLT = siltstone
DWT = densely welded tuff	TS = tuffaceous sandstone
FB = flow breccia	TUF = tuff
LA = lava	unk = unknown
MWT = moderately welded tuff	VT = vitrophyric tuff
NWT = nonwelded tuff	LS = limestone

Major Alteration

AR = argillic	QZ = silicic
CC = calcite	unk = unknown
DM = dolomite	VP = vapor phase
DV = devitrified	ZE = zeolitic
GL = vitric	

1 Stratigraphic assignments, lithology, and major alteration compiled from Drellack (1997) and well-specific completion reports. See Section 2 of main document.
2 HGU = Hydrogeologic unit. See Table 4-3 in the main document for abbreviations.
3 HSU = Hydrostratigraphic unit. See Table 4-4 in the main document for abbreviations.
4 Depth Top = Distance from ground surface to top of unit.
5 Elev. Top = Elevation (above mean sea level) of unit top.
6 TD = Hole total depth below ground level.
7 PCU1U = Older subsurface playa deposits.
8 PCU2T = Youngest (at surface) playa deposits.
9 AA3 = Alluvial deposits overlying the subsurface extension of the modern playa (PCU2). Equivalent to the AA. Refer to Figure 4-7.
10 AA2 = Alluvial deposits overlying the OAA. Equivalent to the AA. Refer to Figure 4-10.
11 AA1 = Alluvial deposits beneath older playa (PCU1U). Equivalent to the AA. Refer to Figure 4-7.
12 OAA1 = Older alluvial deposits beneath the basalt lava flow aquifer (BLFA). Equivalent to the OAA. Refer to Figure 4-10.
13 LTCU1 = Zeolitic bedded tuffs (TCU) beneath the WCU. Equivalent to the LTCU. Refer to Figure 4-20.
14 U-11c#1 = Also called UE-11c.

APPENDIX B

Graphical Presentations for Selected UGTA Wells in the Frenchman Flat Model Area Showing Stratigraphy, Lithology, Alteration, and Hydrogeologic Units

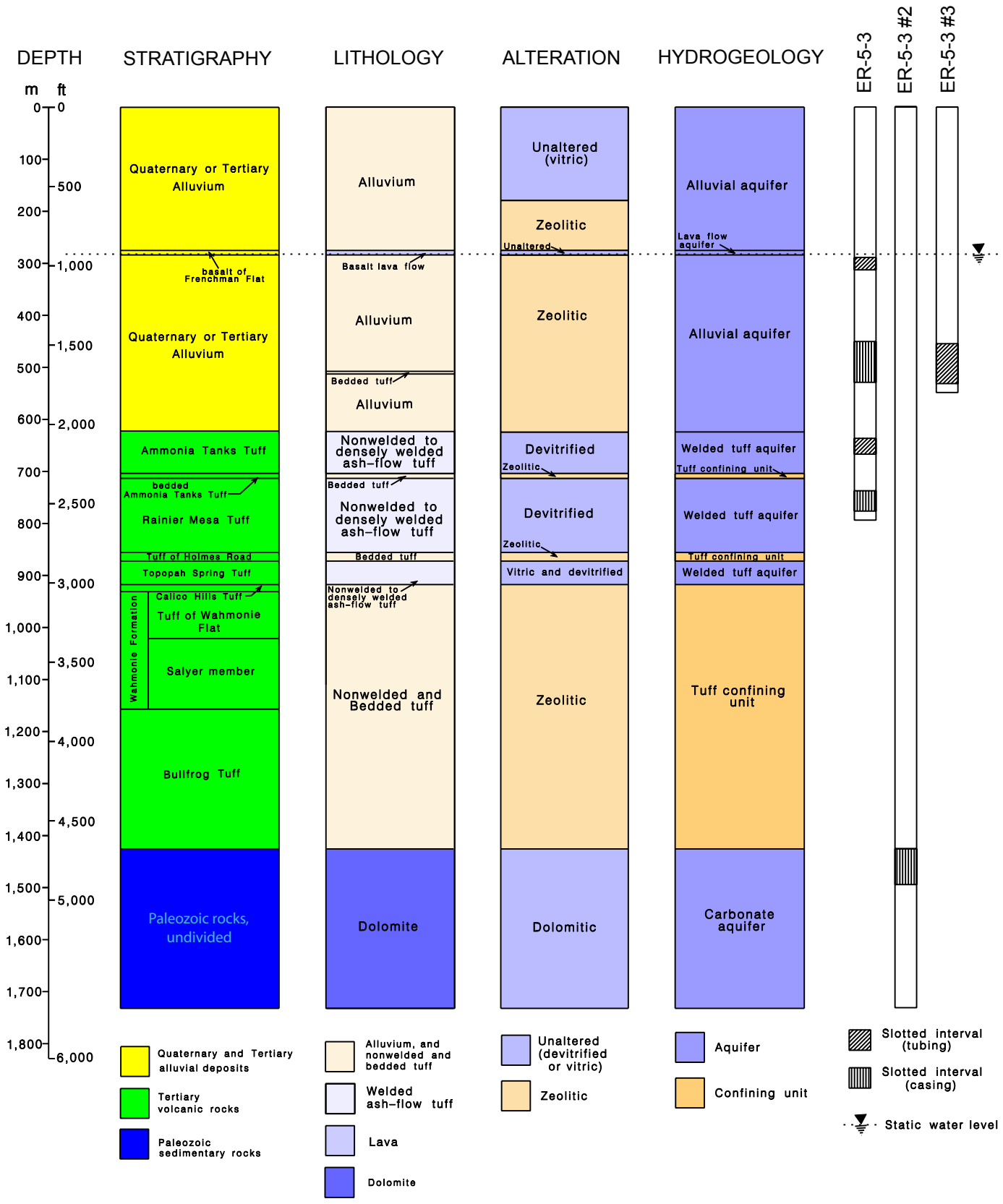


Figure B-1
Geology and Hydrogeology of Well Cluster ER-5-3

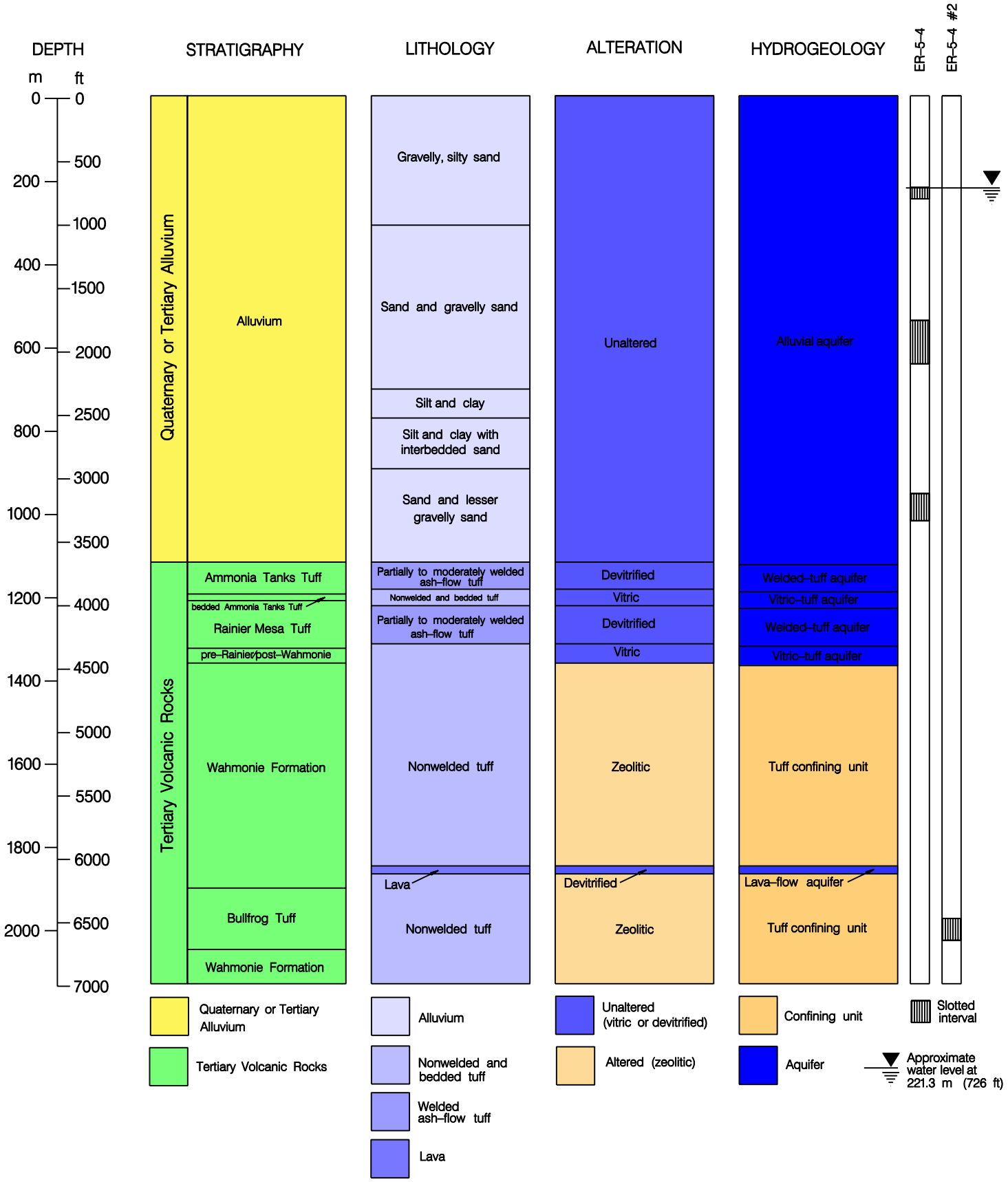


Figure B-2
Geology and Hydrogeology of Well Cluster ER-5-4

APPENDIX C

Hydrostratigraphic Profiles through the Frenchman Flat Model Area

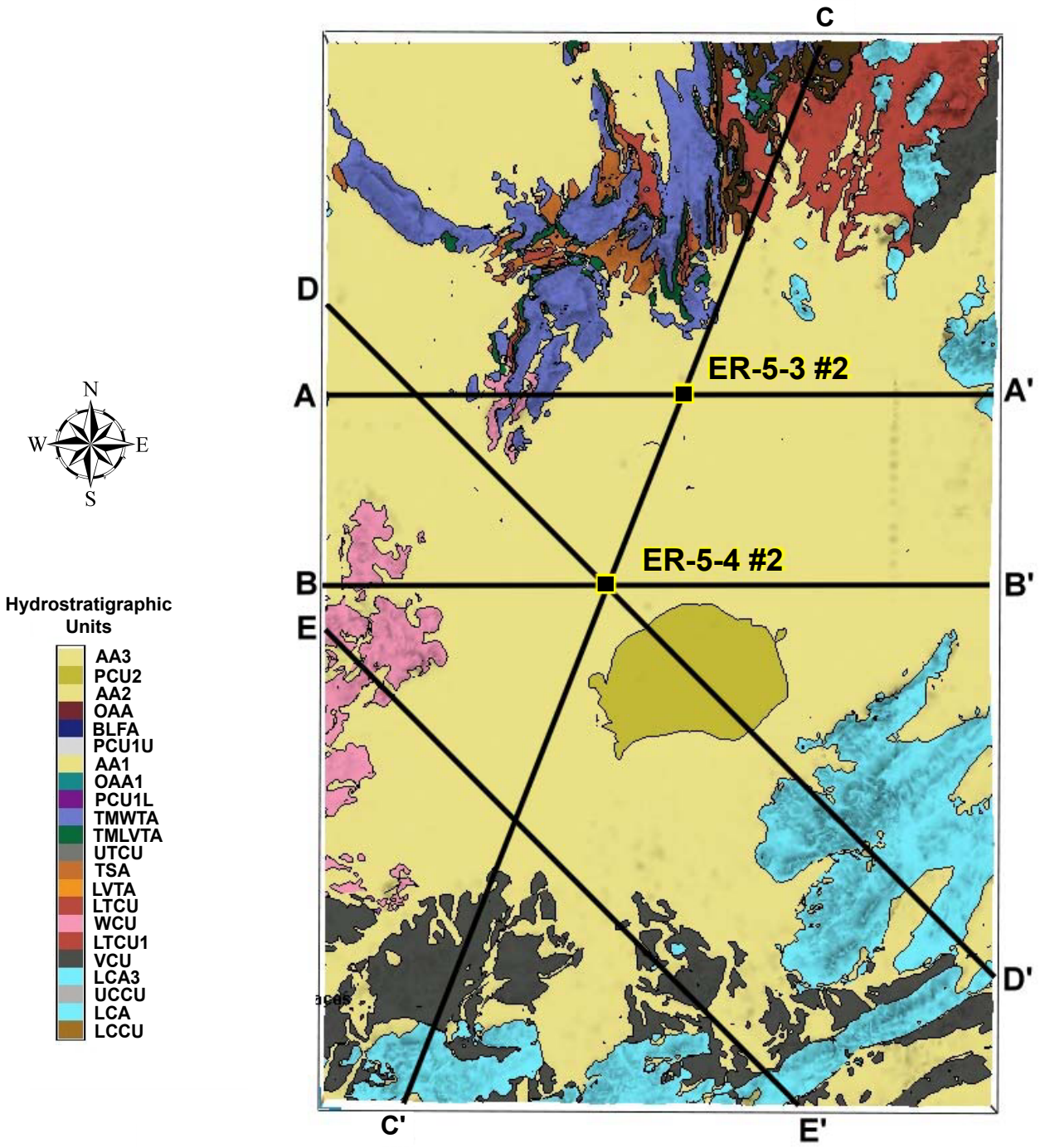
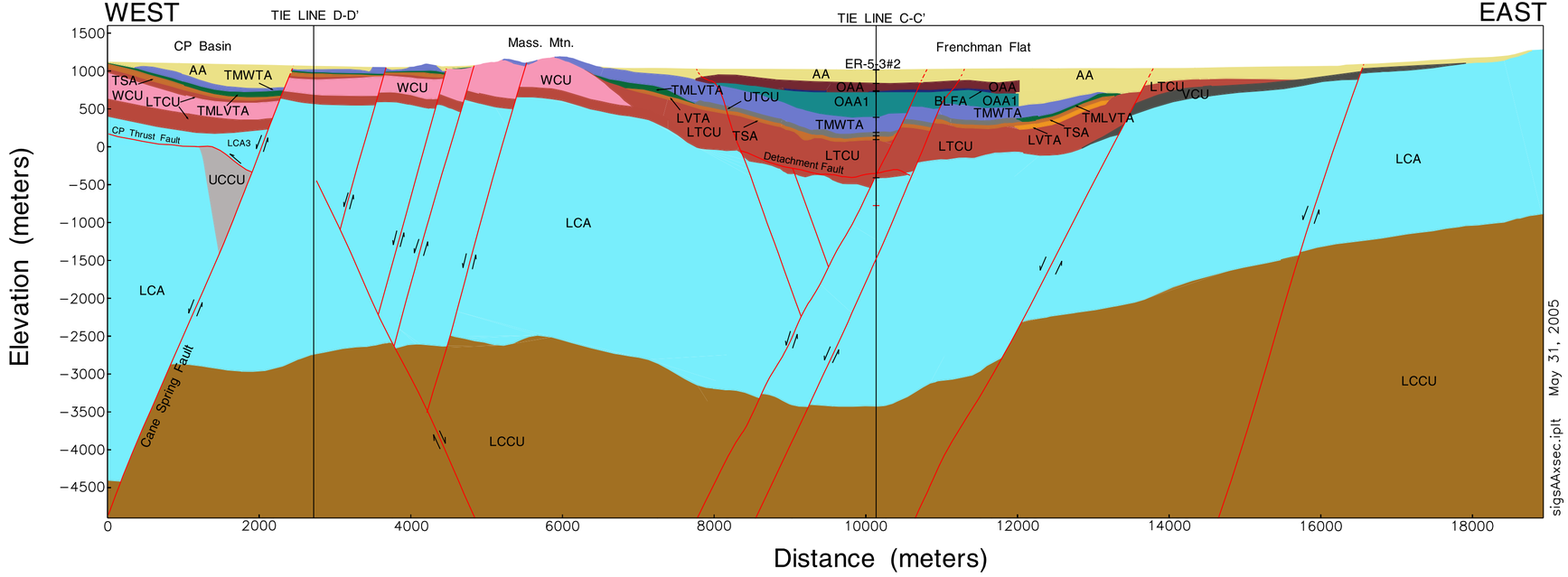


Figure C-1
Locations of Model Profiles from the Frenchman Flat Hydrostratigraphic Model

West - East Model Profile (A-A') through Northern Frenchman Flat at Well ER-5-3#2

Scale: 1:48,000

No Vertical Exaggeration



sigsAAxsec.iplt May 31, 2005

A Hydrostratigraphic Framework Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Clark, Lincoln, and Nye Counties, Nevada

Bechtel Nevada Report DOE/NV/11718-1064

September 2005

Hydrostratigraphic Units

- AA3
- PCU2T
- AA2
- OAA
- BLFA
- PCU1U
- AA1
- OAA1
- PCU1L
- TMWTA
- TMLVTA
- UTCU
- TSA
- LVTA
- LTCU
- WCU
- LTCU1
- VCU
- LCA3
- UCCU
- LCA
- LCCU

LEGEND

ER-5-3#2 — Drill hole in the line of profile. Black tick marks represent tops of hydrostratigraphic units determined from drill hole data. Red tick mark indicates total depth of hole.

Fault with sense of displacement shown.

Tie Line C-C' — Tie line indicates location where another profile intersects this profile.

Note: See report for definitions of hydrostratigraphic units.

A Hydrostratigraphic Framework Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98:
Frenchman Flat, Clark, Lincoln, and Nye Counties, Nevada
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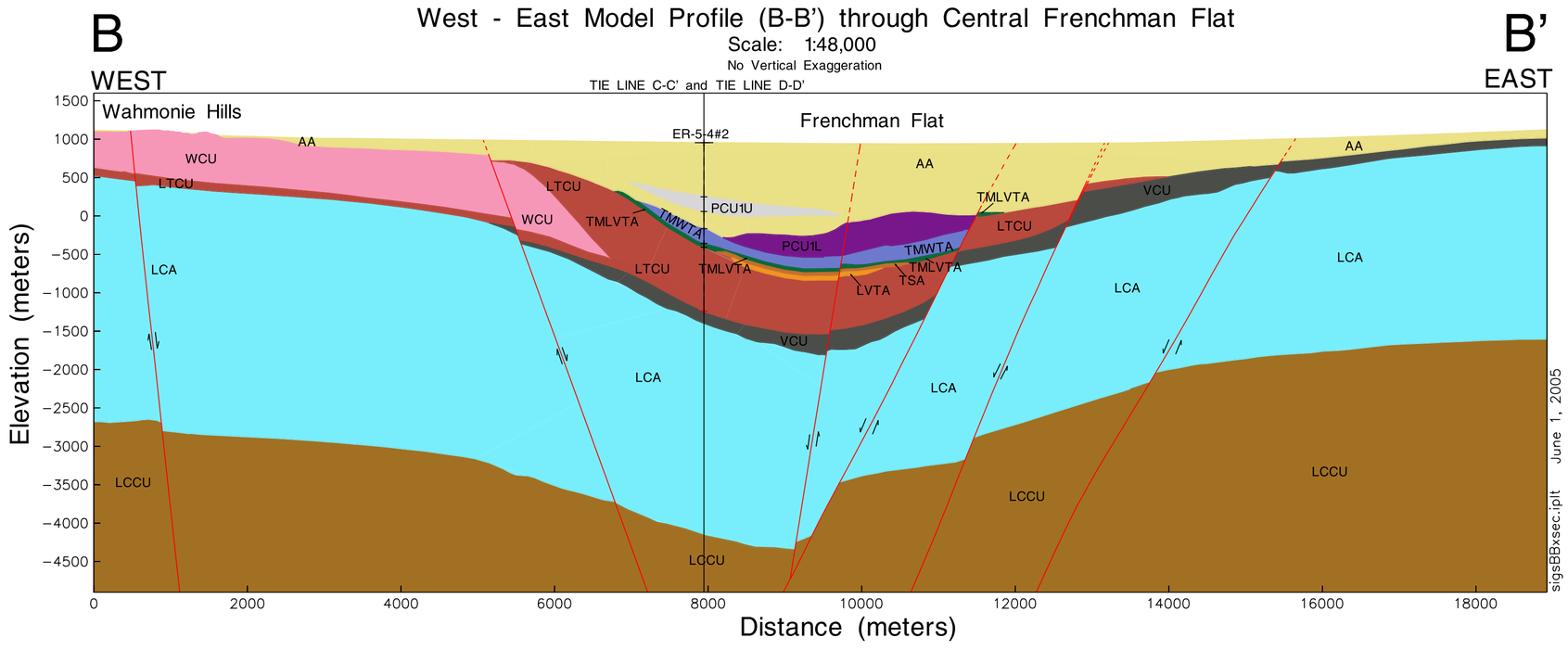
September 2005

West - East Model Profile (B-B') through Central Frenchman Flat

Scale: 1:48,000

No Vertical Exaggeration

TIE LINE C-C' and TIE LINE D-D'



Hydrostratigraphic Units

- AA3
- PCU2T
- AA2
- OAA
- BLFA
- PCU1U
- AA1
- OAA1
- PCU1L
- TMWTA
- TMLVTA
- UTCU
- TSA
- LVTA
- LTCU
- WCU
- LTCU1
- VCU
- LCA3
- UCCU
- LCA
- LCCU

LEGEND

ER-5-4#2 — Drill hole in the line of profile. Black tick marks represent tops of hydrostratigraphic units determined from drill hole data. Red tick marks indicate total depth of hole.

Fault with sense of displacement shown.

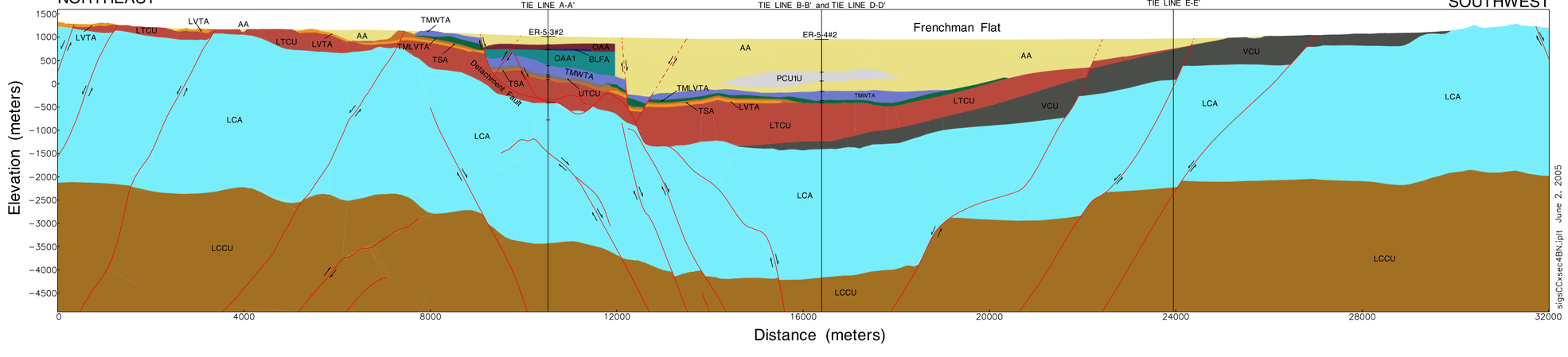
Tie Line C-C' — Tie line indicates location where another profile intersects this profile.

Note: See report for definitions of hydrostratigraphic units

Northeast - Southwest Model Profile (C-C') at Well ER-5-3#2 and Well ER-5-4#2

Scale: 1:48,000

No Vertical Exaggeration



A Hydrostratigraphic Framework Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Clark, Lincoln, and Nye Counties, Nevada

Bechtel Nevada Report DOE/NV/11' 18-1064

September 2005

Hydrostratigraphic Units

- AA3
- PCU2T
- AA2
- OAA
- BLFA
- PCU1U
- AA1
- OAA1
- PCU1L
- TMWTA
- TMLVTA
- UTCU
- TSA
- LVTA
- LTCU
- WCU
- LTCU1
- VCU
- LCA3
- UCCU
- LCA
- LCCU

LEGEND

ER-5-4#2 — Drill hole in the line of profile. Black tick marks represent tops of hydrostratigraphic units determined from drill hole data. Red tick marks indicate total depth of hole.

Fault with sense of displacement shown.

Tie Line C-C'

Tie line indicates location where another profile intersects this profile.

Note: See report for definitions of hydrostratigraphic units

Northwest - Southeast Model Profile (D-D') at Well ER-5-4#2

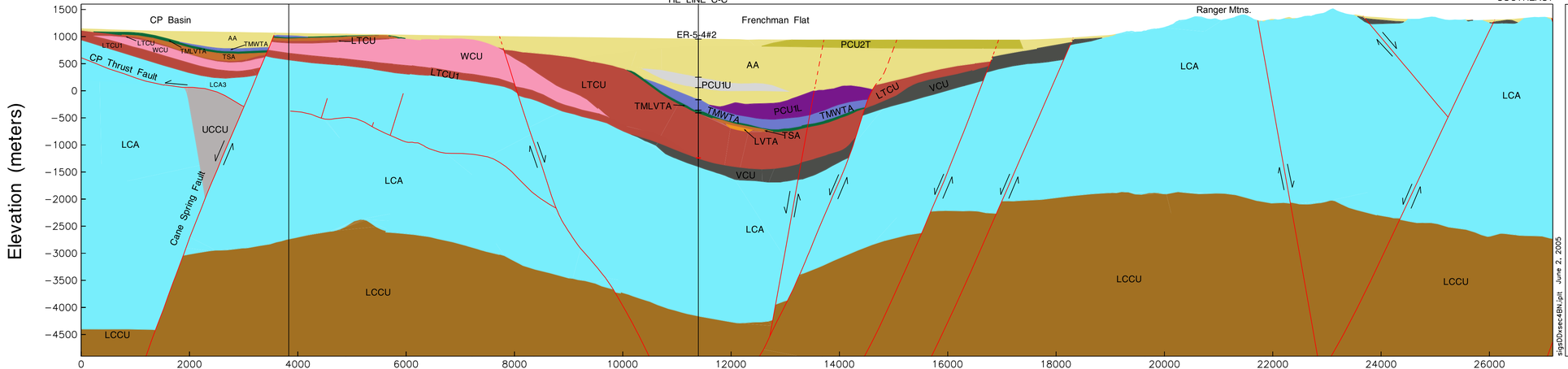
Scale: 1:48,000

No Vertical Exaggeration

A Hydrostratigraphic Framework Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Clark, Lincoln, and Nye Counties, Nevada

Bechtel Nevada Report DOE/NV/11718-1064

September 2005



sigsDDsec4BN.jpt June 2, 2005

Hydrostratigraphic Units

- AA3
- PCU2T
- AA2
- OAA
- BLFA
- PCU1U
- AA1
- OAA1
- PCU1L
- TMWTA
- TMLVTA
- UTCU
- TSA
- LVTA
- LTCU
- WCU
- LTCU1
- VCU
- LCA3
- UCCU
- LCA
- LCCU

LEGEND

ER-5-4#2 — Drill hole in the line of profile. Black tick marks represent tops of hydrostratigraphic units determined from drill hole data. Red tick marks indicate total depth of hole.

Fault with sense of displacement shown.

Tie Line C-C' — Tie line indicates location where another profile intersects this profile.

Note: See report for definitions of hydrostratigraphic units.

A Hydrostratigraphic Framework Model and Alternatives for the Groundwater Flow and Contaminant Transport Model of Corrective Action Unit 98: Frenchman Flat, Clark, Lincoln, and Nye Counties, Nevada

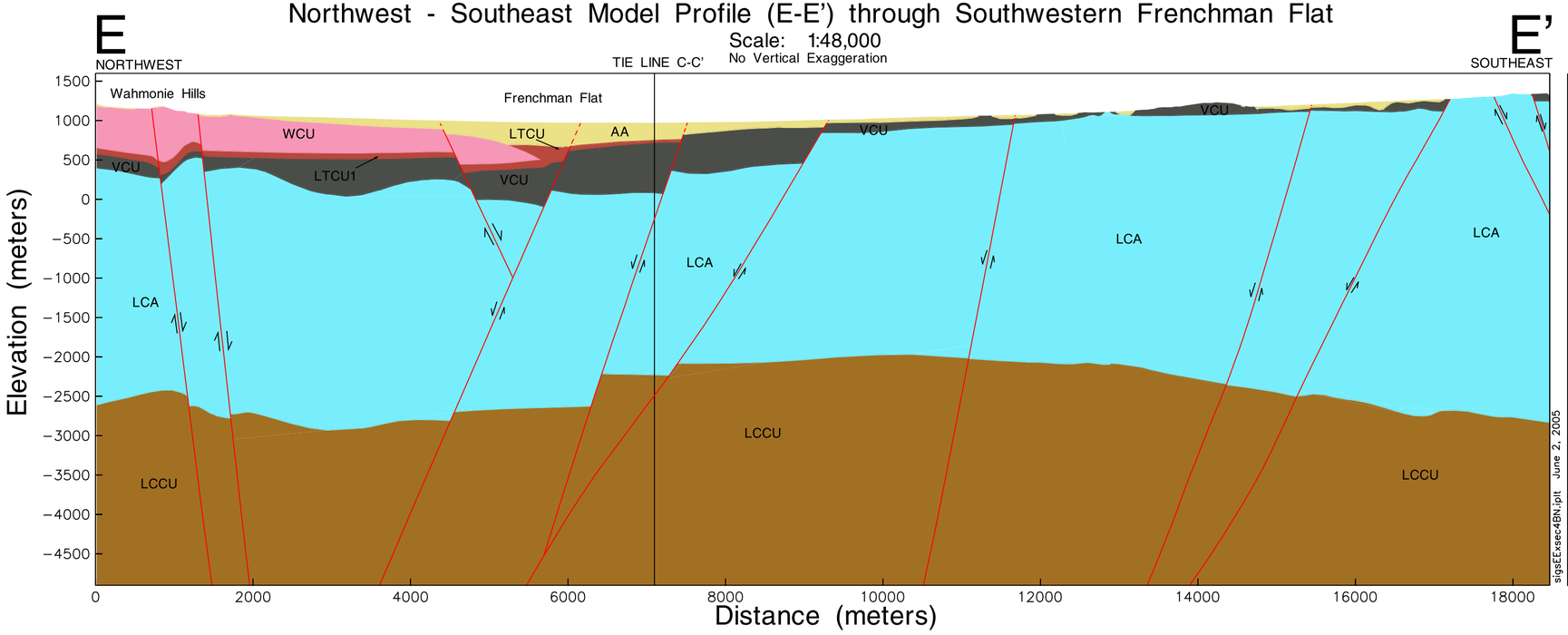
Bechtel Nevada Report DOE/NV/11718-1064

September 2005

Northwest - Southeast Model Profile (E-E') through Southwestern Frenchman Flat

Scale: 1:48,000

No Vertical Exaggeration



Hydrostratigraphic Units

- AA3
- PCU2T
- AA2
- OAA
- BLFA
- PCU1U
- AA1
- OAA1
- PCU1L
- TMWTA
- TMLVTA
- UTCU
- TSA
- LVTA
- LTCU
- WCU
- LTCU1
- VCU
- LCA3
- UCCU
- LCA
- LCCU

LEGEND

ER-5-4#2 — Drill hole in the line of profile. Black tick marks represent tops of hydrostratigraphic units determined from drill hole data. Red tick marks indicate total depth of hole.

Fault with sense of displacement shown.

Tie Line C-C' — Tie line indicates location where another profile intersects this profile.

Note: See Report for definitions of hydrostratigraphic units.

APPENDIX D

3-D Seismic Survey in Frenchman Flat

Frenchman Flat 3-D Seismic Survey

by

Carl Schaftenaar, Great Basin Exploration Consultants, Inc.
Jerome B. Hansen, Great Basin Exploration Consultants, Inc.
Lance Prothro, Bechtel Nevada

September 2004

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All figures are found at the end of each section.

List of Tables

List of Acronyms and Abbreviations

3-D	three-dimensional
BN	Bechtel Nevada
BOA	base of alluvium
BWZ	base of welded zone
ft	feet
GBEC	Great Basin Exploration Consultants, Inc.
km	kilometer(s)
m	meter(s)
mi	mile(s)
NNSA/NSO	National Nuclear Security Administration, Nevada Site Office
NTS	Nevada Test Site
Pz	top of Paleozoic rocks
UGTA	Underground Test Area Project
Vector	Vector Seismic Data Processing, Inc.

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D.1.0 Introduction

A 35.8 square-kilometer (13.8-square mile) three-dimensional (3-D) seismic reflection survey was conducted for the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office (NNSA/NSO) in support of the Nevada Environmental Restoration Project at the Nevada Test Site (NTS), Nye County, Nevada (Prothro, 2001). The seismic survey was conducted as part of the hydrogeologic investigation program for Frenchman Flat. This program is part of the NNSA/NSO Environmental Restoration Division's Underground Test Area (UGTA) project at the NTS. The goals of the UGTA project include evaluating the nature and extent of contamination in groundwater due to underground nuclear weapons testing, and establishing a long-term groundwater monitoring network. As part of the UGTA project, scientists are developing computer models to predict groundwater flow and contaminant migration within and near the NTS. To build and test these models, it is necessary to collect geologic, geophysical, and hydrologic data to help define groundwater migration pathways, migration rates, and quality.

The seismic survey area is located in the northern and central portions of Frenchman Flat and includes all the sites of underground nuclear weapons tests conducted in Frenchman Flat (Figure D.1-1). Project management and technical oversight were provided by Bechtel Nevada (BN). Data acquisition was performed by Subsurface Exploration Company. Vector Seismic Data Processing, Inc. processed the seismic data. Collection and processing of gravity data for static corrections were performed by Opfer Exploration, Inc. Great Basin Exploration Consultants, Inc. (GBEC) functioned as technical advisor to BN. Interpretation of the seismic data was performed by BN and GBEC.

D.1.1 Purpose and Scope

The goal of the Frenchman Flat 3-D seismic survey was to acquire subsurface geologic information to better constrain the distribution of hydrostratigraphic units and major structural features in the vicinity of underground nuclear test locations in Frenchman Flat. Specific objectives included:

- Determine the depth to the top of the Paleozoic-age rocks which form the regional aquifer
- Identify faults
- Determine the extent of the welded volcanic units that form the volcanic aquifers
- Map the base of the alluvial basin fill which forms the alluvial aquifer.

The seismic data and interpretations allow for more accurate modeling of groundwater flow and radionuclide migration in the region, and a more realistic evaluation of potential "short-circuit" groundwater pathways from the higher basin aquifers where underground nuclear tests were conducted to the deeper regional aquifer.

D.1.2 Geologic Setting

Frenchman Flat is a hydrographically closed, Cenozoic-age basin formed in response to Basin and Range tectonism. Topographically, the basin is roughly oval-shaped, elongated in a northeast direction, and contains a playa lake in the southeast which marks the topographic low point of the basin (see Figure D.1-1).

Rocks exposed in the highlands around the margins of Frenchman Flat consist of Tertiary-age volcanic and tuffaceous sedimentary rocks that overlie complexly folded and faulted Paleozoic-age sedimentary rocks (Hinrichs and McKay, 1965; Poole, 1965; Poole et al., 1965; Hinrichs, 1968; McKeown et al., 1976; Barnes et al., 1982). The volcanic rocks are mostly Miocene-age tuffs of generally rhyolitic composition erupted from large calderas located 40 kilometers (km) (25 miles [mi]) northwest of Frenchman Flat, and intermediate-composition tuffs, lavas, and debris flows from the Wahmonie volcanic center located adjacent to Frenchman Flat on the west. Tuffaceous sedimentary rocks appear to occur within a rather narrow, linear, northeast-trending depositional area that generally corresponds to the topographic axis of the basin (Prothro and Drellack, 1997). These rocks are exposed along the southern margin of the basin where they consist of a diverse assemblage of fluvial and lacustrine sandstone and mudrocks, freshwater limestone, conglomerate, and volcanic tuff. The tuffaceous sedimentary rocks appear to be partly coeval with the older volcanic rocks and thus likely interfinger with the volcanic rocks beneath Frenchman Flat. Paleozoic-age sedimentary rocks are exposed along the south and east sides of Frenchman Flat and consist mostly of carbonate rocks ranging in age from Cambrian to Mississippian.

Drilling and geophysical data from Frenchman Flat indicate that many of the rocks exposed along the margins of the basin are present beneath Frenchman Flat, and have been buried by thick aprons of alluvial debris shed from the exposed highlands during basin development. At its deepest point the basin is filled with approximately 1,500 meters (m) (5,000 feet [ft]) of Tertiary and Quaternary alluvium that overlies approximately 1,300 m (4,300 ft) of Tertiary volcanic and tuffaceous sedimentary rocks. Figure D.1-2 is a simplified stratigraphic column for the Frenchman Flat area.

The formation of Frenchman Flat is directly related to the northeastern termination of the Rock Valley strike-slip fault zone within an extensional imbricate fan (Figure D.1-3). The formation of this fan structure has resulted in a series of oblique-slip faults that flare out to the north and northwest from the Rock Valley fault zone in the southern portion of Frenchman Flat. These faults drop the basin down along the south, east, and north forming an east-tilted half-graben. The resulting basin, as illustrated on Bouguer gravity contours, is tear-drop shaped and elongated in the northeast-southwest direction.

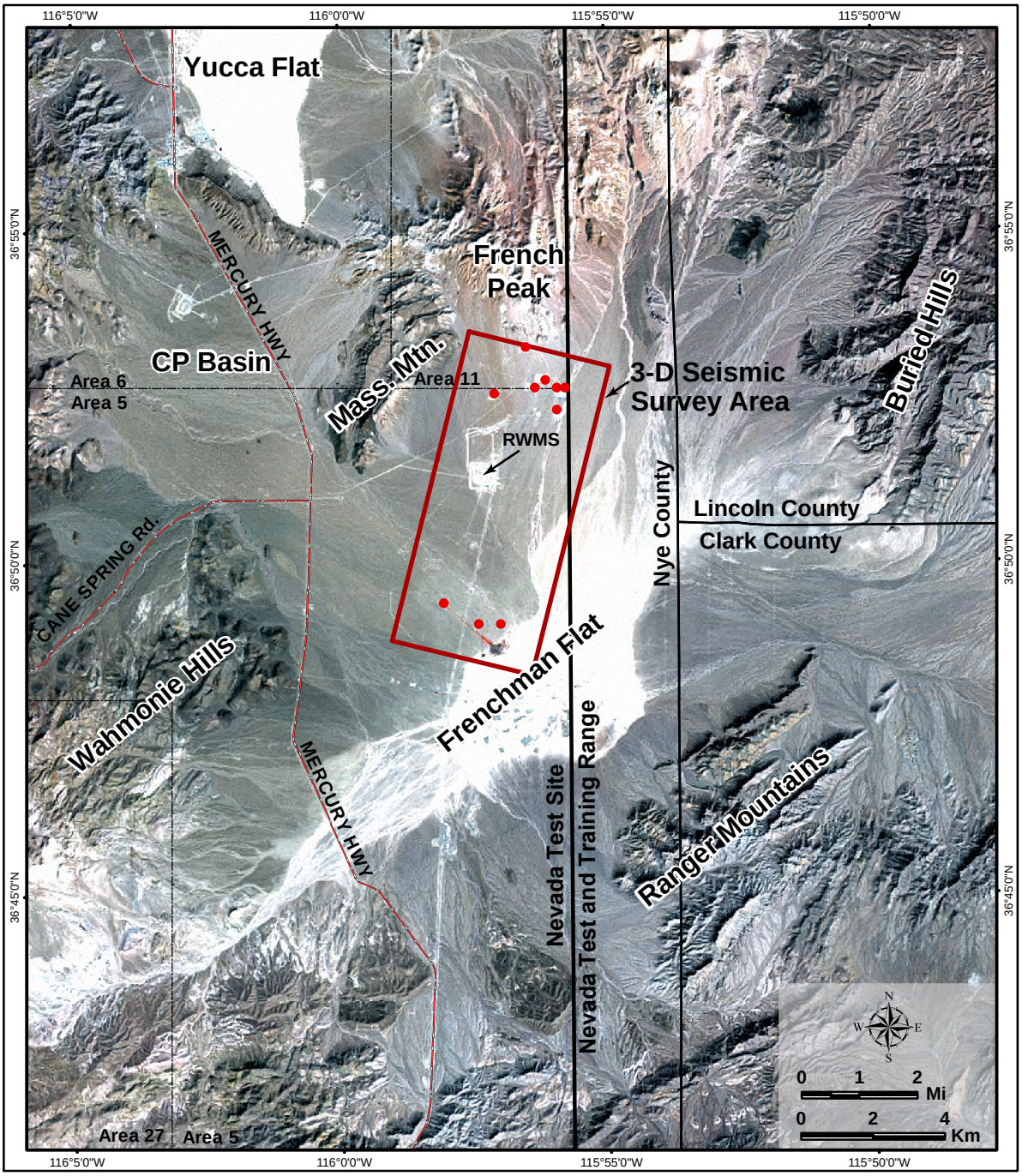


Figure D.1-1
Satellite Image of the Frenchman Flat Area
Showing Location of the 3-D Seismic Survey Area
Red dots are locations of expended underground nuclear tests.

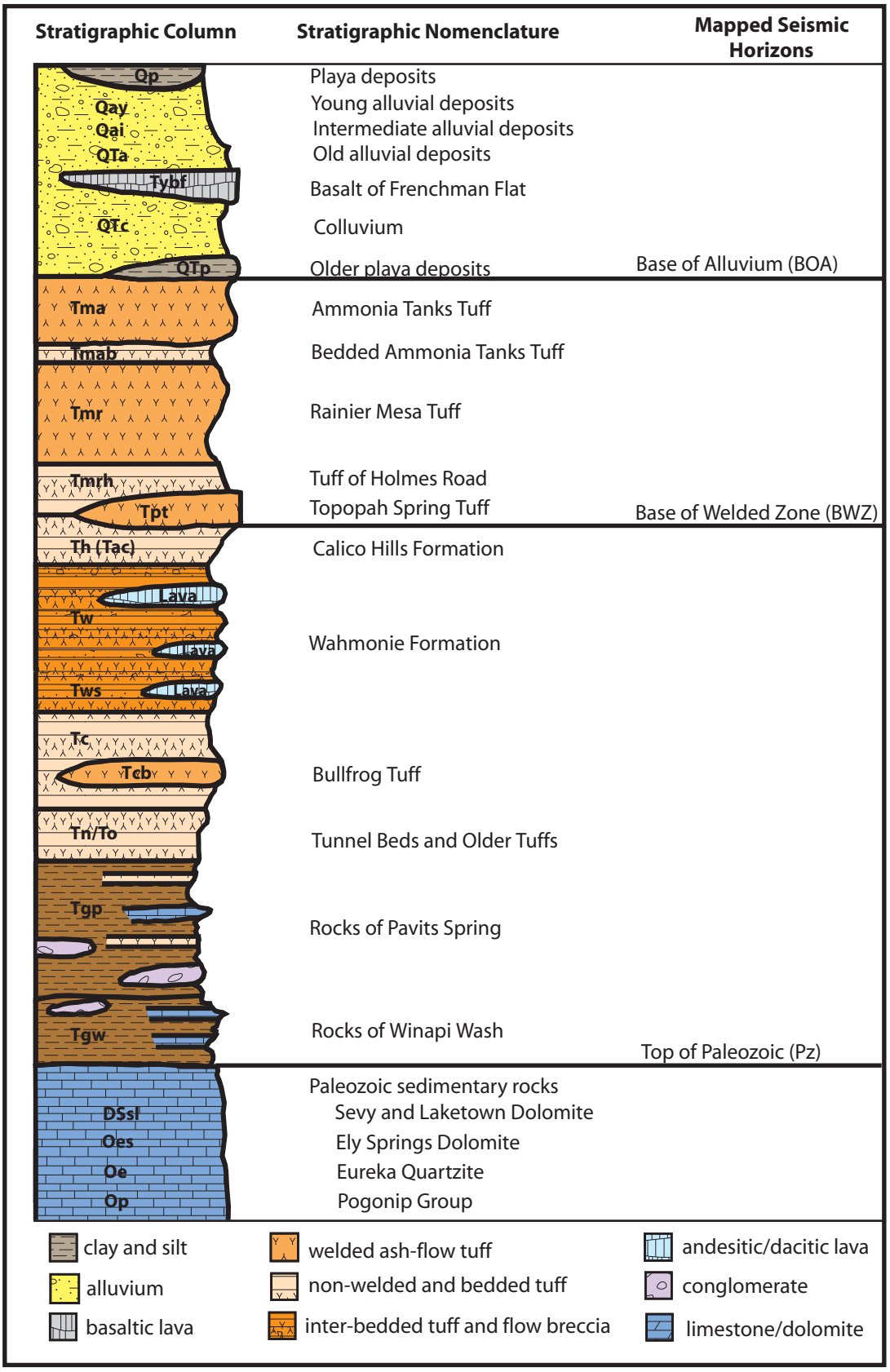
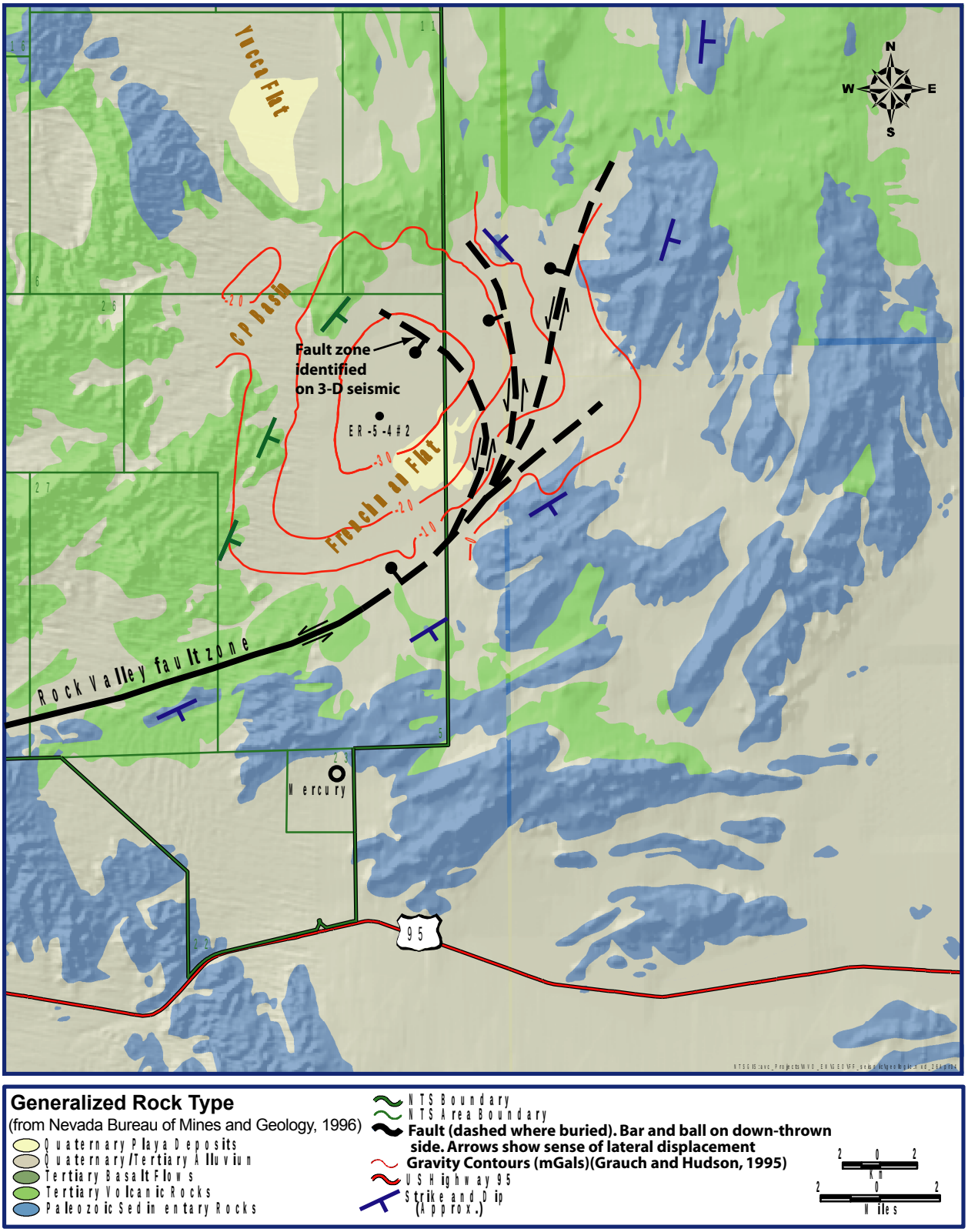


Figure D.1-2
Stratigraphic Column for Frenchman Flat



Generalized Rock Type
(from Nevada Bureau of Mines and Geology, 1996)

- Quaternary Playa Deposits
- Quaternary/Tertiary Alluvium
- Tertiary Basalt Flows
- Tertiary Volcanic Rocks
- Paleozoic Sedimentary Rocks

- NTS Boundary
- NTS Area Boundary
- **Fault (dashed where buried). Bar and ball on down-thrown side. Arrows show sense of lateral displacement**
- **Gravity Contours (mGals)(Grauch and Hudson, 1995)**
- US Highway 95
- Strike and Dip (Approx.)

2 0 2
Km
2 0 2
Miles

Figure D.1-3
Simplified Geologic Map of Frenchman Flat and Vicinity showing the General Structural Model of the Basin

D.2.0 Survey Design and Data Acquisition

The Frenchman Flat 3-D seismic survey was designed to record seismic data over all underground nuclear test locations within the basin (see Figure D.1-1). This was accomplished within in a rectangular-shaped layout 8.9 km (5.5 mi) long and 4.0 km (2.5 mi) wide with the long axis oriented north-northeast. Target depths of the survey were from 300 to 3,660 m (1,000 to 12,000 ft) below ground surface (0.35 to 2.5 seconds). Table 2-1 lists acquisition parameters. The original survey design called for an 18.3 m x 18.3 m (60 ft x 60 ft) bin spacing. However, because of the acquisition company's standard cable length of 30.5 m (100 ft), it was decided to change the source and receiver spacing to 30.5 m (100 ft) to accommodate the shorter cable lengths. This produced a higher resolution 15.2 m x 15.2 m (50 ft x 50 ft) bin design at no additional cost. Because the source and receiver lines had already been established and cleared for archeological and biological resources, line spacing was not changed, which resulted in a more randomly spaced data set.

Data acquisition was conducted from August to December, 2001. Access within the survey area was generally good; however, some areas were inaccessible due to subsidence craters, radiological surface contamination, and a radioactive waste management facility.

A high spatial frequency gravity survey was also conducted in conjunction with the seismic survey to provide gravity-derived static corrections to the seismic data. Gravity measurements were made at every third receiver and source point resulting in a total of 2,991 gravity measurements.

Table D.2-1
Acquisition Parameters for the Frenchman Flat 3-D Seismic Survey

Survey area:	35.8 square kilometers (13.8 square miles)
Target depths:	300 - 3,660 m (1,000 - 12,000 ft)
Target times:	0.35 - 2.5 seconds
Total number of receiver lines:	28
Receiver line spacing:	329.2 m (1,080 ft)
Receiver point interval:	30.5 m (100 ft)
Live channels per line:	132
Number of live receiver lines:	12
Total live channels:	1,584
Number of receiver points:	3,723
Number of geophones per receiver point:	6
Geophone array:	3.0-m (10-foot) circle centered on flag
Source line spacing:	402.3 m (1,320 ft) (284.4 m [933 ft] normal to source lines)
Source line orientation:	45 degrees to receiver lines
Source point interval:	30.5 m (100 ft) (43.1 m [141.4 ft] along source lines)
Number of source points:	2,930
Maximum inline offset:	2,176.3 m (7,140 ft)
Maximum crossline offset	1,959.9 m (6,430 ft)
Maximum offset (diagonal)	2,928.8 m (9,609 ft)
Source type:	Vibroseis (30,000 pounds peak force)
Source array:	4 vibrators in a box pattern
Number of sweeps per source point:	8
Sweep length:	12 seconds
Listen time:	4 seconds
Frequency range:	10 - 80 hertz
Sample interval:	2 milliseconds
Correlated record length:	4 seconds
Approximate number of traces recorded:	4,500,000
Bin size:	15.2 m x 15.2 m (50 ft x 50 ft)
Number of bins:	153,855
Maximum fold:	30

D.3.0 Data Processing

Vector Seismic Data Processing, Inc. (Vector) performed the data processing to produce the stacked and migrated data volumes using ProMAX® by Landmark Graphics Corporation and Vector proprietary software. The basic processing steps used on the Frenchman Flat data are summarized in Table 3-1. The processing steps that proved particularly important with regards to the Frenchman Flat data included velocity analysis and NMO correction, determination of mutes, and post-stack noise filtering such as FXY deconvolution and Tau-p filtering.

Because of the great thickness of low velocity material in the valley fill alluvium, stacking velocities were low and increased very slowly with time/depth. Therefore, very small incremental changes in stacking velocities were required to analyze and determine the appropriate stacking velocities.

Much of the coherent reflection signal on the resulting stack came from the mid- to far-offset range. The near offsets were dominated by source generated noise, while the longest offsets were contaminated by reverberating first arrival energy. Because of the strong first arrival energy, the top mute was picked very carefully to remove first arrival energy but leave far offset reflections in the stack.

After stacking, a strong pattern of linear noise was noticed on the data. This noise pattern originated from stacking of source generated noise in certain directions and attenuation of source generated noise in other directions. This resulted in source generated noise stacking to form an "acquisition footprint" on the stacked data. Vector devised a form of their proprietary Tau-p filter in order to successfully filter the linear noise from the data as a post-stack process.

Table D.3-1
Processing steps performed on the Frenchman Flat 3-D seismic data

Reformat from SEG-Y
Geometry Application
Trace Edits
True Amplitude Correction
Shot Balance
Deconvolution
Spectral Whitening
Datum Statics
Velocity Analysis
Autostatics
NMO Correction
Trace Balance
Top Mute
Shift to Final datum
Stack
Trace Balance
FXY Deconvolution
Migration

Additional Processing
Gravity-Derived Static Corrections (pre-stack)
Tau-p Filter (post-stack)

D.4.0 Interpretation

D.4.1 Data Utilized

Seismic data in Nevada tend to be difficult to interpret due to the discontinuous nature of the continental sediments which can produce discontinuous and incoherent seismic reflections. In addition, thick deposits of relatively low-velocity alluvium that fill basins like Frenchman Flat can seriously attenuate the seismic signal, particularly the higher frequencies, thus reducing the strength of the seismic signal reflecting from deeper horizons. The top of the Paleozoic rocks can be particularly difficult to image because of its greater depth and the uneven nature of this eroded surface. Very few coherent reflections are observed within the Paleozoic rocks in the Frenchman Flat 3-D data or on two-dimensional seismic data from Yucca Flat located just north of Frenchman Flat. This is likely due to the weak signal at these depths, the lack of acoustic contrasts in this section typically dominated by carbonate rocks, and complex structure.

In spite of the difficulties described above, the seismic data set from Frenchman Flat, although somewhat noisy overall, is adequate for interpretation. In places, such as at the top of the Paleozoic rocks in the northeast corner of the survey area, the quality of the data is very good.

Five processed seismic data sets from the Frenchman Flat 3-D survey were available for interpretation, including the final unmigrated stack, migration before FXY filtering, migration after FXY filtering, migration after Tau-p filtering, migration after Tau-p filtering, and gravity statics. The migration after Tau-p filtering was judged to be the most coherent of these data volumes, and the interpretation was made on this volume. The other data volumes were utilized to clarify interpretations and evaluate seismic travel times.

Amplitude was the primary seismic attribute utilized during the interpretation process. However, other attributes such as frequency, reflection strength, average energy, and phase were also utilized in various instances to help clarify and refine interpretations.

Other types of geologic and geophysical data were also utilized and integrated into the seismic interpretation. These included the following:

- Surface geologic maps (Poole, 1965; Hinrichs and McKay, 1965; Slate et. al., 1999).
- Geophysical data and interpretations from gravity, aeromagnetic, and surface magnetic investigations (Slate et. al., 1999; Grauch and Hudson, 1995; Carr et. al., 1975).
- Information from 35 drill holes, including lithologic descriptions, formation tops, well logs, and check shot surveys.

D.4.2 Interpretation Methods

Interpretation of the seismic data was performed using the seismic interpretation software application 2d/3dPAK® by Seismic Micro-Technology, Inc. The basic workflow for interpreting the Frenchman Flat seismic data consisted of a four step process as described below.

Step 1 - Development of an integrated geologic - geophysical base map.

A variety of spatial data were imported into 2d/3d PAK® to produce an integrated geologic and geophysical base map. Each data set could be turned on or off (i.e., displayed or hidden) on the base map as desired during interpretation of the seismic data. A digital version of the Slate et al. (1999) geologic map was imported to provide lateral outcrop control for interpretation (Figure D.4.1). Additional strike and dip information from geologic quadrangle maps (Poole, 1965; Hinrichs and McKay, 1965) were digitized and also incorporated into the base map. Other data included aeromagnetic contours (Grauch and Hudson, 1995), limits of buried basalt flows as defined by surface magnetics (Carr et al., 1975), geophysically inferred structures from Slate et al. (1999), and Bouguer gravity contours (Grauch and Hudson, 1995).

Step 2 - Integration of geologic, well log, and velocity data from area drill holes into the 3-D seismic volume.

Time-depth curves and synthetic seismograms were developed from density and sonic logs and from check shot surveys to tie the well data with the seismic data, and subsequently to identify seismic reflections based on the formation tops. The locations of the wells are shown on the index map of the seismic survey, Figure D.4-2.

Velocity information is available for ten wells within, and immediately adjacent to, the Frenchman Flat 3-D Survey (Table D.4-1, Figure D.4-2). The velocity data are from various sources including check shot surveys, velocity logs and sonic logs, or estimated from density logs.

Synthetic seismograms for nine of the wells were created and time-depth curves for the logged portion of all ten of the holes were calculated. Because the upper portions of drill holes ER-5-3#2 and ER-5-4#2 were not logged, the ER-5-3 and ER-5-3#2 logs were combined to represent the borehole at the ER-5-3#2, and the ER-5-4 and ER-5-4#2 logs were combined to represent the borehole at the ER-5-4#2 . The synthetic seismograms were computed using a 5-10-25-30 hertz, zero-phase wavelet to visually approximate the bandwidth of the seismic data. The synthetic seismograms are shown in Figures D.4-3 to D.4-9.