2.6.2.2 Seismic Source Zones

Geologic, tectonic, and seismic evidence indicates that three seismic source zones may be used to adequately characterize the region. These are well approximated by the Basin and Range subregion, the Permian Basin subregion exclusive of the Central Basin Platform, and the Central Basin Platform itself. Specific boundaries are taken from a 1976 study by Algermissen and Perkins ***(1976)*** of earthquake risks throughout the United States. Additional details on this study are in ***CCA*** Appendix GCR, Section 5.3.2.

Site region seismic source zones are shown in Figure 2-~~48~~***58***. Superposed on these zones are the earthquake epicenters of Figure 2-~~47~~***57***. The zonation presented generally conforms with historical seismicity. The source zonation of Figure 2-~~48~~***58*** has no explicit analog to the Permian Basin subregion exclusive of the Central Basin Platform. This is considered part of the broad background region.

For the purposes of this study, some minor modifications of the Algermissen and Perkins ***(1976)*** source zones were made. Geologic and tectonic evidence suggests that the physiographic boundary between the Basin and Range and Great Plains provinces provides a good and conservative approximation of the source zones (***CCA*** Appendix GCR). In addition, information from the Kermit seismic array (Appendix to Rogers and Malkiel 1979) indicates that the geometry used to model the limits of the Central Basin Platform source zone may be modified somewhat from the original analogous Algermissen and Perkins ***(1976)*** zone. These modifications are shown in Figure 2-~~49~~***59*** and constitute the preferred model for the WIPP site region seismic source zones in this study. This model is preferred because it more completely considers geologic and tectonic information, as well as seismic data, and because it results in a more realistic development of risks at the WIPP facility.

With regard to earthquake focal depth, there is little doubt that the focal depths of earthquakes in the WIPP facility region should be considered shallow. Early instrumental locations were achieved using an arc intersection method employing travel-time-distance curves calculated from a given crustal model, and the assumption of focal depths of 5 km (3.1 mi), 10 km (6.2 mi), or, for later calculations, 8 km (5 mi). Good epicentral locations could generally be obtained under these assumptions. For conservatism, a focal depth of 5 km (3.1 mi) is used in all source zones of this study including that of the site. For smaller hypocentral distances, the form of the

attenuation law adopted here severely exaggerates the importance of small, close shocks in the estimation of probabilistic acceleration at the WIPP site. Additional discussion is included ~~in this application~~ in ~~Chapter 5 of~~ ***CCA*** Appendix GCR***, Chapter 5***.

2.6.2.3 Source Zone Recurrence Formulas and Maximum Magnitudes

The risk calculation procedure used in this study requires that earthquake recurrence rates for each seismic source zone be specified. This is done formally by computing the constants a and b in the equation

$$\log N = a - bM \,, \qquad (2.4)$$

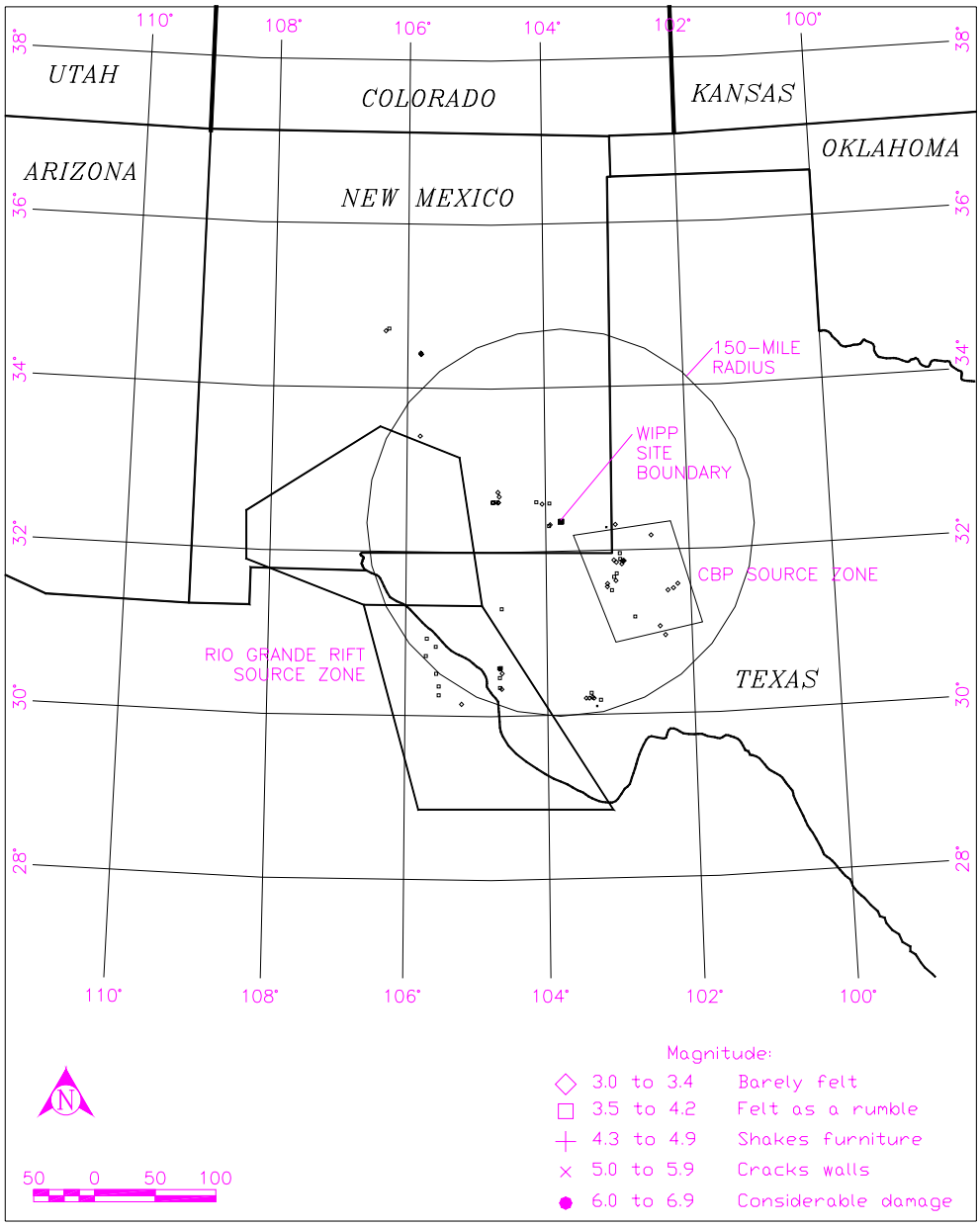


Figure 2-48*58*. Seismic Source Zones

where N is the number of earthquakes of magnitude greater than or equal to M within a specified area occurring during a specified period.

For the WIPP facility region, three formulas of this type are needed: one for the province west and southwest of the site (the Basin and Range subregion or Rio Grande ***R***ift source zone), another for the province of the WIPP facility exclusive of the Central Basin Platform (the Permian Basin subregion or background source zone), and a final one for the Central Basin Platform. In practice, the difficulties in finding meaningful recurrence formulas for such small areas in a region of low historical earthquake activity are formidable.

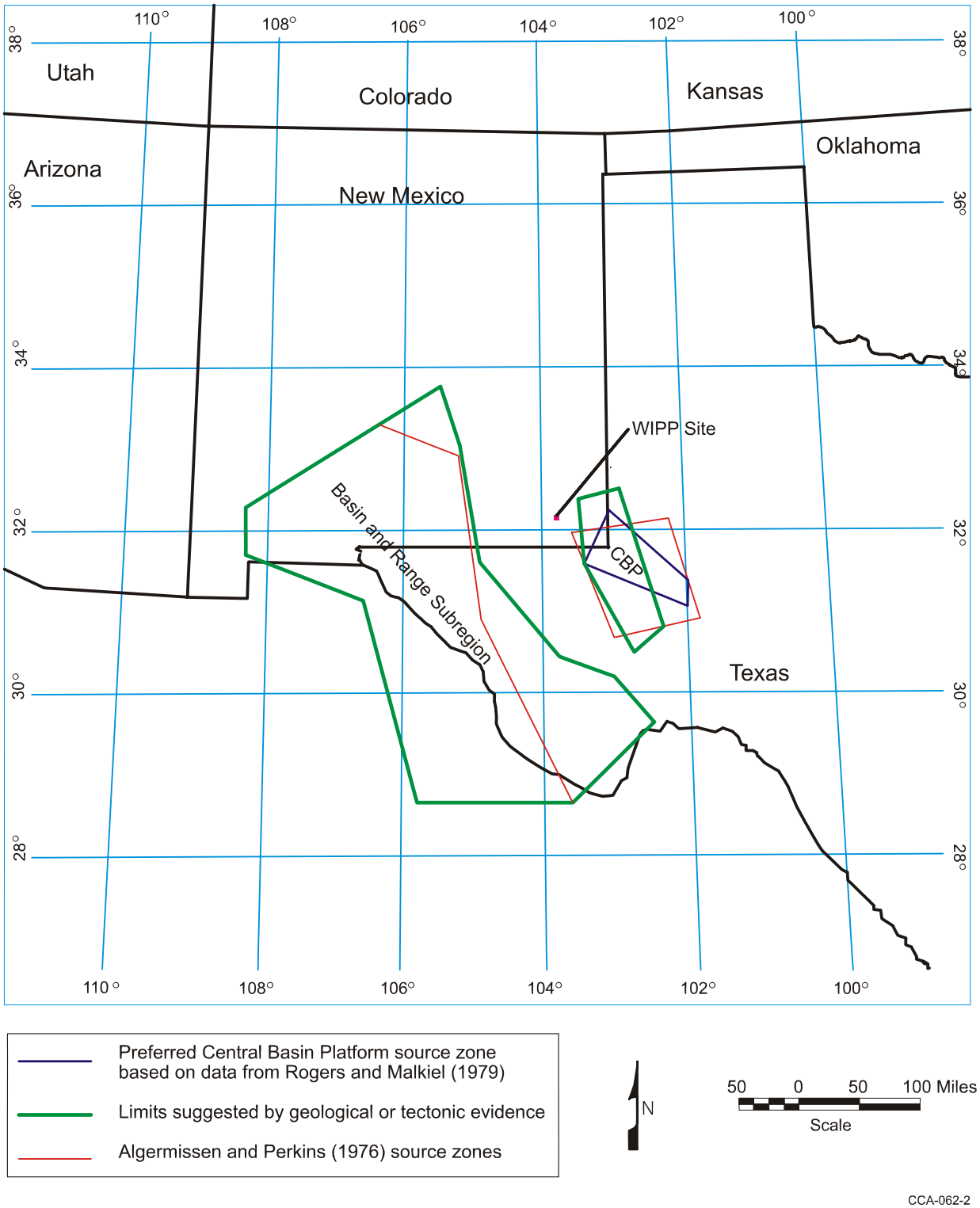


Figure 2-~~49~~59. Alternate Source Geometries

The formulas have been determined to be

- $\log N = 2.43 - M_{CORR}$ Site source zone (background) ***(2.5)***
- $\log N = 3.25 - M_{CORR}$ Basin and Range subregion ***(2.6)***
- $\log N = 3.19 - 0.9\ M_{CORR}$ Central Basin Platform ***(2.7)***

The rationale for their development and the relationship used to determine M_{CORR} can be found in ***CCA*** Appendix GCR, Section 5.3.

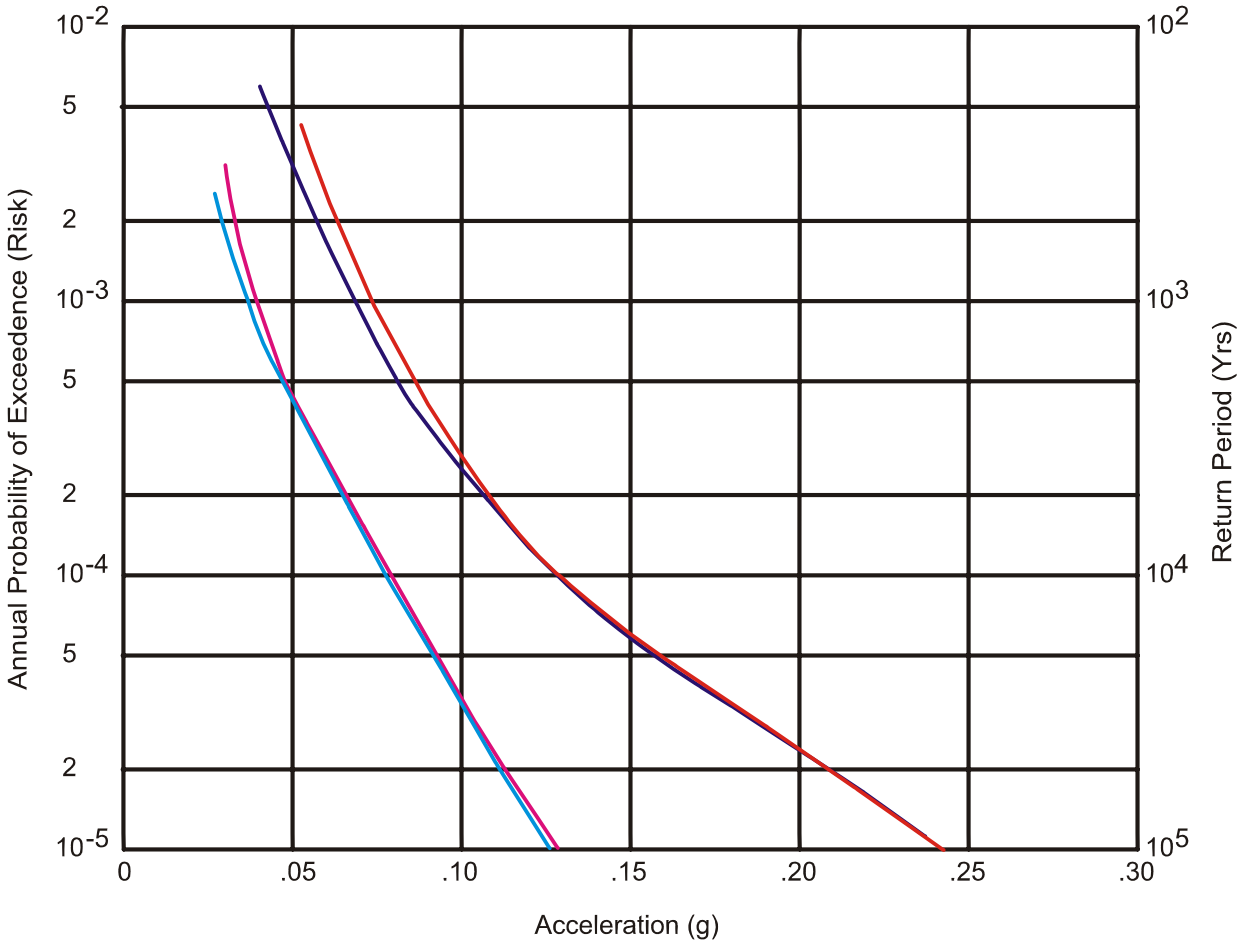
2.6.2.4 Design Basis Earthquake

The term Design Basis Earthquake (DBE) is used for the design of surface confinement structures and components at the WIPP facility. As used here, the DBE is equivalent to the design earthquake used in Regulatory Guide 3.24 (Nuclear Regulatory Commission [NRC] 1974). That is, in view of the limited consequences of seismic events in excess of those used as the basis, the DBE is such that it produces ground motion at the WIPP facility with a recurrence interval of 1,000 years. In practice, the DBE is defined in terms of the 1,000-year acceleration and design response spectra.

The generation of curves expressing probability of occurrence or risk as a function of peak WIPP facility ground acceleration is discussed in detail in ***CCA*** Appendix GCR, Section 5.3***,*** for a number of possible characterizations of WIPP facility region source zones and source zone earthquake parameters. The most conservative (and the least conservative) risk curves are shown in Figure 2-~~50~~***60***.

From this figure, the most conservative calculated estimate of the 1,000-year acceleration at the WIPP facility is approximately 0.075 g. The geologic and seismic assumptions leading to this 1,000-year peak acceleration include the consideration of a Richter magnitude 5.5 earthquake at the site, a 6.0 magnitude earthquake on the Central Basin Platform, and a 7.8 magnitude earthquake in the Basin and Range subregion. These values, especially the first two, are considered quite conservative, as are the other parameters used in the 0.075-g derivation. For additional conservatism, a peak design acceleration of 0.1 g is selected for the WIPP facility DBE. The design response spectra for vertical and horizontal motions are taken from Regulatory Guide 1.60 (NRC 1973) with the high-frequency asymptote scaled to this 0.1-g peak acceleration value.

This DBE and the risk analysis that serves an important role in its definition are directly applicable to surface confinement structures and components at the WIPP facility. Underground structures and components are not subject to DBE design requirements because according to Pratt et al. (1979), mine experience and studies on earthquake damage to underground facilities show that tunnels are not damaged at sites having peak surface accelerations below 0.2 g.



Curve 1	———	Risk from site source zone assuming a maximum magnitude of 4.5.
Curve 2	———	Risk from site and Central Basin Platform source zones assuming maximum magnitudes of 4.5 and 5.0, respectively.
Curve 3	———	Risk from the site source zone assuming a maximum magnitude of 5.0.
Curve 4	———	Risk from the site and Central Basin Platform source zones assuming a maximum magnitude of 5.0 for both.

Note: Risk curves generated by using worst and best case assumption from the parameter variation considered for site region source zones. See Appendix GCR, Figure 5.3-7 for further details.

CCA-063-2

Figure 2-~~50~~*60*. Total WIPP Facility Risk Curve Extrema

REFERENCES

Adams, J.E. 1944. "Upper Permian Ochoa Series of the Delaware Basin, West Texas and Southeastern New Mexico." *American Association of Petroleum Geologists Bulletin*, Vol. 28, No. 11, 1596-1625.

Algermissen, S.T., and Perkins, D.M. 1976. *A Probabilistic Estimate of Maximum Ground Acceleration in the Contiguous United States.* Open-file Report 76-416, pp. 1 – 45. U.S. Geological Survey.

Anderson, R.Y. 1978. *Deep Dissolution of Salt, Northern Delaware Basin, New Mexico.* Report to Sandia National Laboratories, Albuquerque, NM. ***ERMS #229530.***

Anderson, R.Y., and Kirkland, D.W. 1980. Dissolution of Salt Deposits by Brine Density Flow. *Geology*, Vol. 8, No. 2, pp. 66 – 69.

Anderson, R.Y. 1981. "Deep-Seated Salt Dissolution in the Delaware Basin, Texas and New Mexico." In *Environmental Geology and Hydrology in New Mexico,* S.G. Wells and W. Lambert, eds., Special Publication No. 10, pp. 133 - 145. New Mexico Geological Society.

Anderson, R.Y. 1993. "The Castile as a 'Nonmarine' Evaporite." In *Carlsbad Region, New Mexico and Texas, New Mexico Geological Society, Forty-Fourth Annual Field Conference, Carlsbad, NM, October 6-9, 1993*, D.W. Love et al., eds., pp. 12 - 13. New Mexico Geological Society, Socorro, NM.

Anderson, R.Y., Dean, W.E., Jr., Kirkland, D.W., and Snider, H. I. 1972. "Permian Castile Varved Evaporite Sequence, West Texas and New Mexico." *Geological Society of America Bulletin*, Vol. 83, No. 1, pp. 59 - 85.

Anderson, R.Y., and Powers, D.W. 1978. "Salt Anticlines in the Castile-Salado Evaporite Sequence, Northern Delaware Basin, New Mexico." In *Geology and Mineral Deposits of Ochoan Rocks in Delaware Basin and Adjacent Areas*, G.S. Austin, ed., Circular 159. pp. 79 - 83. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM.

Anderson, R.Y., Kietzke, K.K., and Rhodes, D.J. 1978. "Development of Dissolution Breccias, Northern Delaware Basin, New Mexico and Texas." In *Geology and Mineral Deposits of Ochoan Rocks in Delaware Basin and Adjacent Areas*, G.S. Austin, ed., Circular 159. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM.

Bachman, G.O. 1973. *Surficial Features and Late Cenozoic History in Southeastern New Mexico.* Open-File Report 4339-8. U.S. Geological Survey, Reston, VA.

Bachman, G.O. 1974. *Geologic Processes and Cenozoic History Related to Salt Dissolution in Southeastern New Mexico.* Open-File Report 74-194. U.S. Geological Survey, Denver, CO.

Bachman, G.O. 1976. "Cenozoic Deposits of Southeastern New Mexico and an Outline of the History of Evaporite Dissolution." *Journal of Research*, Vol. 4, No. 2, pp. 135 - 149. U.S. Geological Survey.

Bachman, G.O. 1980. *Regional Geology and Cenozoic History of Pecos Region, Southeastern New Mexico.* Open-File Report 80-1099. U.S. Geological Survey, Denver, CO.

Bachman, G.O. 1981. *Geology of Nash Draw, Eddy County, New Mexico.* Open-File Report 81-31. U.S. Geological Survey, Denver, CO.

Bachman, G.O. 1984. *Regional Geology of Ochoan Evaporites, Northern Part of Delaware Basin.* Circular 184, pp. 1 - 22. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM.

Bachman, G.O. 1985. *Assessment of Near-Surface Dissolution at and Near the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico*. SAND84-7178. Sandia National Laboratories, Albuquerque, NM. ***ERMS #224609.***

Barrows, L.J., Shaffer, S.E., Miller, W.B., and Fett, J.D. 1983. *Waste Isolation Pilot Plant (WIPP) Site Gravity Survey and Interpretation.* SAND82-2922. Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L., Hassinger, B.W., and Kleiber, J.A. 1983. *Basic Data Report for Borehole Cabin Baby-1 Deepening and Hydrologic Testing, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico*. WTSD-TME-020. United States Department of Energy, Albuquerque, NM.

Beauheim, R.L. 1986. *Hydraulic-Test Interpretations for Well DOE-2 at the Waste Isolation Pilot Plant (WIPP) Site.* SAND86-1364. Sandia National Laboratories, Albuquerque, NM. ***ERMS #227656.***

Beauheim, R.L. 1987a. *Interpretations of Single-Well Hydraulic Tests Conducted at and Near the Waste Isolation Pilot Plant (WIPP) Site, 1983–1987.* SAND87-0039. Sandia National Laboratories, Albuquerque, NM. ***ERMS #227679.***

Beauheim, R.L. 1987b. *Analysis of Pumping Tests of the Culebra Dolomite Conducted at the H-3 Hydropad at the Waste Isolation Pilot Plant (WIPP) Site.* SAND86-2311. Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L. 1987c. *Interpretation of the WIPP-13 Multipad Pumping Test of the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site*. SAND87-2456. Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L. 1989. *Interpretation of H-141b4 Hydraulic Tests and the H-11 Multipad Pumping Test of the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site*. SAND89-0536. Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L. 2002. "Analysis Plan for Evaluation of the Effects of Head Changes on Calibration of Culebra Transmissivity Fields, AP-088, Rev. 1," ERMS #524785. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Beauheim, R.L. 2000. "Appendix E, Summary of Hydraulic Tests Performed at Tracer-Test Sites," in Interpretations of Tracer Tests Performed in the Culebra Dolomite at the Waste Isolation Pilot Plant Site, Meigs, L.C., Beauheim, R.L., and Jones, T.L., eds. SAND97-3109. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., and Holt, R.M. 1990. "Hydrogeology of the WIPP Site." In *Geological and Hydrological Studies of Evaporites in the Northern Delaware Basin for the Waste Isolation Pilot Plant (WIPP), New Mexico, Geologic Society of America 1990 Annual Meeting Field Trip #14 Guidebook*, pp. 131 -179. Dallas Geologic Society, Dallas, TX.

Beauheim, R.L., and Roberts, R.M. 2002. "Hydrology and Hydraulic Properties of a Bedded Evaporite Formation," Journal of Hydrology, v. 259, pp. 66-88.

Beauheim, R.L., and Ruskauff, G.J. 1998. Analysis of Hydraulic Tests of the Culebra and Magenta Dolomites and Dewey Lake Redbeds Conducted at the Waste Isolation Pilot Plant Site. SAND98-0049. Albuquerque, NM: Sandia National Laboratories.

Beauheim, R.L., Roberts, R.M., Dale, T.F., Fort, M.D., and Stensrud, W.A. 1993. *Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Second Interpretive Report.* SAND92-0533. Sandia National Laboratories, Albuquerque, NM. ***ERMS #223378.***

Beauheim, R.L., Saulnier, G.J., ***Jr.*** and Avis, J.D. 1991***a***. *Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report.* SAND90-0083. Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L., Dale, T.F., and Pickens, J.F. 1991b. Interpretations of Single-Well Hydraulic Tests of the Rustler Formation Conducted in the Vicinity of the Waste Isolation Pilot Plant Site, 1988-1989. SAND89-0869. Sandia National Laboratories, Albuquerque, NM.

Beauheim, R.L., Meigs, L.C., Saulnier, G.J., ***Jr.*** and Stensrud, W.A. 1995. *Culebra Transport Program Test Plan: Tracer Testing of the Culebra Dolomite Member of the Rustler Formation at the H-19 and H-11 Hydropads on the WIPP Site*. ***ERMS #230156. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.***

Bechtel National Inc. 1979. "Soils Design Report – Volume 1 Plant Site Near-Surface Structures," Doc. No. Dr-22-V-01. San Francisco, CA: Bechtel National Inc.

Becker, M.L., Rasbury, E.T., Meyers, W.J., and Hanson, G.N. 2002. U-Pb calcite age of the Late Permian Castile Formation, Delaware Basin: a constraint on the age of the Permian-Triassic boundary (?): Earth and Planetary Science Letters, v. 203, p. 681-689.

Blackwell, D.D., Steele, J.L., and Carter, L.S. 1991. "Heat-Flow Patterns of the North American Continent; A Discussion of the Geothermal Map of North America." In *Neotectonics of North America,* D.B. Slemmons, E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, eds., pp. 423 - 436. Geological Society of America, Boulder, CO.

Bodine, Jr., M.W. 1978. "Clay-Mineral Assemblages from Drill Core of Ochoan Evaporites, Eddy County, New Mexico." In *Geology and Mineral Deposits of Ochoan Rocks in Delaware Basin and Adjacent Areas*, G.S. Austin, ed., Circular 159. pp. 21 - 31. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM.

Borns, D.J. 1987. *The Geologic Structures Observed in Drillhole DOE-2 and Their Possible Origins: Waste Isolation Pilot Plant.* SAND86-1495. Sandia National Laboratories, Albuquerque, NM.

Borns, D.J., Barrows, L.J., Powers, D.W., and Snyder, R.P. 1983. *Deformation of Evaporites Near the Waste Isolation Pilot Plant (WIPP) Site.* SAND82-1069. Sandia National Laboratories, Albuquerque, NM.

Borns, D.J. 1985. *Marker Bed 139: A study of Drillcore from a Systematic Array*. SAND85-0023. Sandia National Laboratories, Albuquerque, NM.

Borns, D.J., and Shaffer, S.E. 1985. *Regional Well-Log Correlation in the New Mexico Portion of the Delaware Basin.* SAND83-1798. Sandia National Laboratories, Albuquerque, NM.

Brausch, L.M., Kuhn, A.K., and Register, J.K. 1982. *Natural Resources Study, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico*. TME 3156. Albuquerque, NM: U.S. Department of Energy, Waste Isolation Pilot Plant.

Brokaw, A.L., Jones, C.L., Cooley, M.E., and Hays, W.H. 1972. *Geology and Hydrology of the Carlsbad Potash Area, Eddy and Lea Counties, New Mexico.* Open-File Report 4339-1. U.S. Geological Survey, Denver, CO.

Brookins, D.G. 1980. "Polyhalite K-Ar Radiometric Ages from Southeastern New Mexico." In *Isochron/West*, No. 29, pp. 29 - 31.

Brookins, D.G. 1981. "Geochronologic Studies Near the WIPP Site, Southeastern New Mexico." In *Environmental Geology and Hydrology in New Mexico*, S.G. Wells, and W. Lambert, ed., Special Publication 10, pp. 147 - 152. New Mexico Geological Society.

Brookins, D.G., and Lambert, S.J. 1987. "Radiometric Dating of Ochoan (Permian) Evaporites, WIPP Site, Delaware Basin, New Mexico, USA." *Scientific Basis for Nuclear Waste Management X, Materials Research Society Symposia Proceedings, Boston, MA, December 1-4, 1986*, J.K. Bates and W.B. Seefeldt, eds., Vol. 84, pp. 771 - 780, Materials Research Society, Pittsburgh, PA.

Brookins, D.G., Register, J.K, Jr., and Krueger, H.W. 1980. "Potassium-Argon Dating of Polyhalite in New Mexico." *Geochimica et Cosmochimica Acta*, Vol. 44, No. 5, pp. 635 - 637.

Butcher, B.M. 1997. A Summary of the Sources of Input Parameter Values for the Waste Isolation Pilot Plant Final Porosity Surface Calculations. SAND97-0796. Albuquerque, NM: Sandia National Laboratories.

Calzia, J.P., and Hiss, W.L. 1978. "Igneous Rocks in Northern Delaware Basin, New Mexico, and Texas." In *Geology and Mineral Deposits of Ochoan Rocks in Delaware Basin and Adjacent Areas*, G.S. Austin, ed., Circular 159, pp. 39 - 45. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM.

Cartwright, Jr., L.D. 1930. Transverse Section of Permian Basin, West Texas and Southeastern New Mexico. *American Association of Petroleum Geologists Bulletin*, Vol. 14.

Casas, E., and Lowenstein, T.K. 1989. Diagenesis of Saline Pan Halite: Comparison of Petrographic Features of Modern, Quaternary and Permian Halites. *Journal of Sedimentary Petrology*, Vol. 59.

Chapman, J.B. 1986. Stable Isotopes in the Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP Area. EEG-35, DOE/AL/10752-35. Environmental Evaluation Group, Santa Fe, NM.

Chapman, J.B. 1988. Chemical and Radiochemical Characteristics of Groundwater in the Culebra Dolomite, Southeastern NM. EEG-39. Environmental Evaluation Group, Santa Fe, NM.

Chugg, J.C., Anderson, G.W., Kink, D.L., and Jones, L.H. 1952. Soil Survey of Eddy Area, New Mexico. U.S. Department of Agriculture.

~~Chugg, J.C., Anderson, G.W., Kink, D.L., and Jones, L.H. 1971. *Soil Survey of Eddy Area, New Mexico*. Prepared by the U.S. Soil Conservation Service in cooperation with New Mexico Agricultural Experiment Station. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.~~

Claiborne, H.C., and Gera, F. 1974. *Potential Containment Failure Mechanisms and Their Consequences at a Radioactive Waste Repository in Bedded Salt in New Mexico.* ORNL-TM 4639. Oak Ridge National Laboratories, Oak Ridge, TN.

Corbet, T.F. and Knupp, P.M. 1996. *The Role of Regional Groundwater Flow in the Hydrogeology of the Culebra Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico*. SAND96-2133. Sandia National Laboratories: Albuquerque, NM.

Crawley, M.E., and Nagy, M. 1998. Waste Isolation Pilot Plant RCRA Background Groundwater Quality Baseline Report. DOE/WIPP 98-2285. Albuquerque, NM: IT Corporation for Westinghouse Electric Corporation.

Davies, P.B. 1984. "Deep-Seated Dissolution and Subsidence in Bedded Salt Deposits." Ph.D. Thesis. Stanford University, Palo Alto, CA.

Davies, P.B. 1989. *Variable-Density Ground-Water Flow and Paleohydrology in the Waste Isolation Pilot Plant (WIPP) Region, Southeastern New Mexico.* Open-File Report 88-490. U.S. Geological Survey, Albuquerque, NM.

Deal, D.E., and Case, J.B. 1987. *Brine Sampling and Evaluation Program Phase I Report*. DOE-WIPP 87-008. Westinghouse Electric Corporation, Carlsbad, NM.

Deal, D.E., Case, J.B., Deshler, R.M., Drez, P.E., Myers, J., and Tyburski, J.R. 1987. *Brine Sampling and Evaluation Program Phase II Report*. DOE-WIPP-87-010. Westinghouse Electric Corporation, Carlsbad, NM.

Deal, D.E., Abitz, R.J., Belski, D.S., Case, J.B., Crawley, M.E., Deshler, R.M., Drez, P.E., Givens, C.A., King, R.B., Lauctes, B.A., Myers, J., Niou, S., Pietz, J.M., Roggenthen, W.M., Tyburski, J.R., and Wallace, M.G. 1989. *Brine Sampling and Evaluation Program, 1988 Report.* DOE-WIPP-89-015. Carlsbad, NM: Westinghouse Electric Corporation.

Deal, D.E., Abitz, R.J., Belski, D.S., Clark, J.B., Crawley, M.E., and Martin, M.L. 1991a. *Brine Sampling and Evaluation Program, 1989 Report.* DOE-WIPP-91-009. Carlsbad, NM: Westinghouse Electric Corporation.

Deal, D.E., Abitz, R.J., Myers, J. Case, J.B., Martin, M.L., Roggenthen, W.M., and Belski, D.S. 1991b. *Brine Sampling and Evaluation Program, 1990 Report*. DOE-WIPP-91-036. Prepared for U.S. Department of Energy by IT Corporation and Westinghouse Electric Corporation. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Deal, D.E., Abitz, R.J., Myers, J., Martin, M.L., Milligan, D.J., Sobocinski, R.W., Lipponer, P.P.J., and Belski, D.S. 1993. *Brine Sampling and Evaluation Program, 1991 Report.* DOE-WIPP-93-026. Carlsbad, NM: Westinghouse Electric Corporation.

Deal, D.E., Abitz, R.J. Belski, D.S., Case, J. B., Crawley, M.E., Givens, C. A., James Lipponer, P.P.J., Milligan, D.J., Myers, J., Powers, D. W., and Valdivia, M. A. 1995. Brine Sampling and Evaluation Program, 1992-1993 Report and Summary of BSEP Data Since 1982, DOE-WIPP 94-011. Carlsbad, NM: Westinghouse Electric Corporation.

Domski, P.S., Upton, D.T., and Beauheim, R.L. 1996. *Hydraulic Testing Around Room Q: Evaluation of the Effects of Mining on the Hydraulic Properties of Salado Evaporites*. SAND96-0435. Sandia National Laboratories, Albuquerque, NM.

Duke Engineering and Services (DES). 1997. Exhaust Shaft: Phase 2 Hydraulic Assessment Data Report Involving Drilling, Installation, Water-Quality Sampling, and Testing of Piezometers 1-12. DOE/WIPP97-2278. Carlsbad, NM: Westinghouse Electric Corporation.

Eager, G.P. 1983. Core from the Lower Dewey Lake, Rustler, and Upper Salado Formation, Culberson County, Texas. In *Permian Basin Cores*, R.L. Shaw and B.J. Pollen, eds., P.B.S.-S.E.P.M. Core Workshop No. 2, pp. 273 - 283. Permian Basin Section, Society of Economic Paleontologists and Mineralogists, Midland, TX.

Earth Technology Corporation. 1988. *Final Report for Time Domain Electromagnetic (TDEM) Surveys at the WIPP Site.* SAND87-7144. Albuquerque, NM: Sandia National Laboratories.

Elliot Geophysical Company. 1976. *A Preliminary Geophysical Study of a Trachyte Dike in Close Proximity to the Proposed Los Medaños Nuclear Waste Disposal Site, Eddy and Lea Counties, New Mexico.* Elliot Geophysical Company, Tucson, AZ.

Environmental Science and Research Foundation (ESRF), Inc. 2000. Waste Isolation Pilot Plant 1999 Site Environmental Report. DOE/WIPP 00-2225, ESRF-039. Idaho Falls, ID: ESRF.

Environmental Science and Research Foundation (ESRF), Inc. 2001. Waste Isolation Pilot Plant CY 2000 Site Environmental Report. DOE/WIPP 01-2225, ESRF-045. Idaho Falls, ID: ESRF.

Environmental Science & Research Foundation (ESRF). 2002. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 2001, DOE/WIPP 02-2225, Carlsbad, NM.

Ewing, T.E. 1993. "Erosional Margins and Patterns of Subsidence in the Late Paleozoic West Texas Basin and Adjoining Basins of West Texas and New Mexico," New Mexico Geological Society Guidebook, 44th Field Conference, Carlsbad Region New Mexico and West Texas, D.W. Lowe et al., eds., pp. 155 - 166.

Foster, R.W. 1974. *Oil and Gas Potential of a Proposed Site for the Disposal of High-Level Radioactive Waste.* BNL/SUB-44231/1. Ridge National Laboratory, Oak Ridge, TN. Available from NTIS. NTIS Accession number: ORNL/SUB-4423-1.

Freeze, R.A., and Witherspoon, P.A. 1967. "Theoretical Analysis of Regional Groundwater Flow: 2. Effect of Water-Table Configuration and Subsurface Permeability Variation," Water Resources Research. Vol. 3, No. 2, pp. 623 - 634.

FWS (U.S. Fish and Wildlife Service). 1989. Letter from John C. Peterson, Field Supervisor, Albuquerque, NM, to Jack B. Tillman, Project Manager, U.S. DOE–Carlsbad, May 25, 1989.

Geohydrology Associates. 1978. Ground-Water Study Related to Proposed Expansion of Potash Mining near Carlsbad, New Mexico. Contractor Report to Bureau of Land Management, Denver, CO, Contract No. YA-512-CT7-217. Albuquerque, NM: Geohydrology Associates.

Hale, W.E., Hughes, L.S., and Cox, E.R. 1954. *Possible Improvement of Quality of Water of the Pecos River by Diversion of Brine at Malaga Bend, Eddy County, NM.* Pecos River Commission New Mexico and Texas, in cooperation with United States Department of the Interior, Geological Survey, Water Resources Division, Carlsbad, NM.

Harland, W.B., Armstrong, R.L., Cox, A.V., Craig, L.E., Smith, A.G., and Smith, D.G. 1989. A Geologic Time Scale 1989. Cambridge Earth Science Series. Cambridge University Press.

Harms, J.C., and Williamson, C.R. 1988. "Deep-Water Density Current Deposits of Delaware Mountain Group (Permian), Delaware Basin, Texas and New Mexico." American Association of Petroleum Geologists Bulletin, Vol. 72.

Haug, A., Kelley, V.A., LaVenue, A.M., and Pickens, J. F. 1987. Modeling of Ground-Water Flow in the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site: Interim Report. SAND86-7167. Sandia National Laboratories, Albuquerque, NM.

Hawley, J.W. 1993. "The Ogallala and Gatuña Formations in the Southeastern New Mexico Region, a Progress Report." In *Carlsbad Region, New Mexico and West Texas, New Mexico Geological Society, Forty-Fourth Annual Field Conference, Carlsbad, NM, October 6-9, 1993*, D.W. Love et al., eds., pp. 261 - 269. New Mexico Geological Society, Socorro, NM.

Hayes, P.T., and Bachman, G.O. 1979. *Examination and Reevaluation of Evidence for the Barrera Fault, Guadalupe Mountains, New Mexico.* Open-File Report 79-1520. U.S. Geological Survey, Denver, CO.

Hazen, R.M., and Roedder, E. 2001. "How Old are Bacteria from the Permian Age?" Nature, v. 411, p. 155.

Hills, J.M. 1984. Sedimentation, Tectonism, and Hydrocarbon Generation in Delaware Basin, West Texas and Southeastern New Mexico. *American Association of Petroleum Geologists Bulletin*, Vol. 68.

Hiss, W.L. 1975. "Stratigraphy and Ground-Water Hydrology of the Capitan Aquifer, Southeastern New Mexico and Western Texas." PhD dissertation. University of Colorado, Department of Geological Sciences, Boulder, CO.

Hiss, W.L. 1976. *Structure of the Premium Guadalupian Capitan Aquifer, Southeast New Mexico and West Texas.* Resource Map. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM.

Holt, R.M. 1997. Conceptual Model for Transport Processes in the Culebra Dolomite Member, Rustler Formation. SAND97-0194. Albuquerque, NM: Sandia National Laboratories.

Holt, R.M., and Powers, D.W. 1984. *Geotechnical Activities in the Waste Handling Shaft Waste Isolation Pilot Plant (WIPP) Project Southeastern New Mexico.* WTSD-TME-038. U.S. Department of Energy, Carlsbad, NM.

Holt, R.M., and Powers, D.W. 1986. *Geotechnical Activities in the Exhaust Shaft.* DOE-WIPP-86-008. U.S. Department of Energy, Carlsbad, NM.

Holt, R.M., and Powers, D.W. 1988. *Facies Variability and Post-Depositional Alteration Within the Rustler Formation in the Vicinity of the Waste Isolation Pilot Plant, Southeastern New Mexico.* DOE/WIPP 88-004. U.S. Department of Energy, Carlsbad, NM. (~~This document is included as~~ ***CCA*** Appendix GCR.)

Holt, R.M., and Powers, D.W. 1990***a***. *Geologic Mapping of the Air Intake Shaft at the Waste Isolation Pilot Plant.* DOE/WIPP 90-051. U.S. Department of Energy, Carlsbad, NM.

Holt, R.M, and Powers, D.W. 1990b. "Halite Sequences within the Late Permian Salado Formation in the Vicinity of the Waste Isolation Pilot Plant," in Powers, D.W., Holt, R.M., Beauheim, R.L., and Rempe, N., eds., Geological and Hydrological Studies of Evaporites in the Northern Delaware Basin for the Waste Isolation Pilot Plant (WIPP): Guidebook 14, Geological Society of America (Dallas Geological Society), pp. 45-78.

Holt, R.M., and Powers, D.W. 2002. "Impact of Salt Dissolution on the Transmissivity of the Culebra Dolomite Member or the Rustler Formation, Delaware Basin, Southeastern New Mexico" Abstracts with Program, v. 34, no. 6, p. 215.

Holt, R.M. and Yarbrough, L. 2002. Analysis Report Task 2 of AP-088 – Estimating Base Transmissivity Field. Sandia National Laboratories, WIPP Records Center. ERMS #523889. WIPP Records Center.

Howard, K.A., Aaron, J.M., Brabb, E.E., Brock, M.R., Gower, H.D., Hunt, S.J., Milton, D.J., Muehlberger, W.R., Nakata, J.K., Plafker, G., Prowell, D.C., Wallace, R.E., and Witkind, I.J. 1971 [reprinted 1991]. *Preliminary Map of Young Faults in the United States as a Guide to Possible Fault Activity.* Miscellaneous Field Studies Map MF-916, 1:5,000,000. 4 maps on 2 sheets. U.S. Geological Survey, Denver, CO.

Hubbert, M.K. 1940. "The Theory of Ground-Water Motion," The Journal of Geology. Vol. 48, no. 8, pt. 1., pp. 785 - 944.

Hunter, R.L. 1985. *A Regional Water Balance for the Waste Isolation Pilot Plant (WIPP) Site and Surrounding Area.* SAND84-2233. Sandia National Laboratories, Albuquerque, NM.

INTERA. 1997a. Exhaust Shaft Hydraulic Assessment Data Report. DOE-WIPP 97-2219. Carlsbad, NM: WIPP Management and Operating Contractor.

INTERA. 1997b. Exhaust Shaft Data Report: 72-Hour Pumping Test on C-2506 and 24-Hour Pumping Test on C-2505. Carlsbad, NM: Waste Isolation Pilot Plant.

IT Corporation. 2000. Addendum 1, Waste Isolation Pilot Plant RCRA Background Groundwater Quality Baseline Update Report. Prepared for Westinghouse Electric Corporation, Carlsbad, NM.

Izett, G.A., and Wilcox, R.E. 1982. *Map Showing Localities and Inferred Distribution of the Huckleberry Ridge, Mesa Falls, and Lava Creek Ash Beds in the Western United States and Southern Canada.* Misc. Investigations Map I-1325, scale 1:4,000,000. U.S. Geological Survey.

Jarolimek, L., Timmer, M.J., and McKinney, R.F. 1983. *Geotechnical Activities in the Exploratory Shaft—Selection of the Facility Interval, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico.* TME 3178. U.S. Department of Energy, Albuquerque, NM.

Jones, C.L., Bowles, C.G., and Bell, K.G. 1960. *Experimental Drillhole Logging in Potash Deposits of the Carlsbad District, New Mexico.* Open-File Report. U.S. Geological Survey, Denver, CO.

Jones, C.L., Cooley, M.E., and Bachman, G.O. 1973. *Salt Deposits of Los Medaños Area, Eddy and Lea Counties, New Mexico.* Open-File Report 4339-7. U.S. Geological Survey, Denver, CO.

Jones, C.L. 1978. *Test Drilling for Potash Resources: Waste Isolation Pilot Plant Site, Eddy County, New Mexico.* Open-File Report 78-592. Vols. 1 and 2. U.S. Geological Survey, Denver, CO.

Jones, C.L. 1981. *Geologic Data for Borehole ERDA-6, Eddy County, New Mexico.* Open-File Report 81-468. U.S. Geological Survey, Denver, CO.

Jones, T.L., Kelley, V.A., Pickens, J.T., Upton, D.T., Beauheim, R.L., and Davies, P.B. 1992. *Integration of Interpretation Results of Tracer Tests Performed in the Culebra Dolomite at the Waste Isolation Pilot Plant Site*. SAND92-1579. Sandia National Laboratories, Albuquerque, NM.

Keesey, J. J. 1976. *Hydrocarbon Evaluation, Proposed Southeastern New Mexico Radioactive Material Storage Site, Eddy County, New Mexico.* SAND71-7033. Vols. I and II. Sipes, Williamson, and Aycock, Midland, TX.

Kehrman, R.F. 2002. Compliance Recertification Application Monitoring Data, Volume Two. Carlsbad, NM: Westinghouse TRU Solutions LLC. Copy on file in the Sandia WIPP Records Center under ERMS# 527193.

Kelley, V.A. 1971. *Geology of the Pecos Country, Southeastern New Mexico.* Memoir 24. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM.

Kelley, V.A., and Saulnier, Jr., G.J. 1990. *Core Analyses for Selected Samples from the Culebra Dolomite at the Waste Isolation Pilot Plant Site.* SAND90-7011. Sandia National Laboratories, Albuquerque, NM.

King, P.B. 1948. *Geology of the Southern Guadalupe Mountains, Texas.* Professional Paper 215. U.S. Geological Survey, Washington, D.C.

Krumhansl, J.L., Kimball, K.M. and Stein, C.L. 1991. Intergranular Fluid Compositions from the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico. SAND90-0584. Albuquerque, NM: Sandia National Laboratories.

Lambert, S.J. 1983a. *Dissolution of Evaporites in and around the Delaware Basin, Southeastern New Mexico and West Texas*. SAND82-0461. Sandia National Laboratories, Albuquerque, NM.

Lambert, S.J. 1983b. "Evaporite Dissolution Relevant to the WIPP Site, Northern Delaware Basin, Southeastern New Mexico." In *Scientific Basis for Nuclear Waste Management VI, Materials Research Society Symposia Proceedings, Boston, MA, November 1-4, 1982*, SAND82-1416C. D.G. Brookins, ed., pp. 291 - 298. Elsevier Science Publishing Company, New York, NY.

Lambert, S.J. 1987. *Feasibility Study: Applicability of Geochronologic Methods Involving Radiocarbon and other Nuclides to the Groundwater Hydrogeology of the Rustler Formation, Southeastern New Mexico.* SAND86-1054. Sandia National Laboratories, Albuquerque, NM.

Lambert, S.J. 1991. "Isotopic Constraints on the Rustler and Dewey Lake Groundwater Systems," in Siegel, M.D., Lambert, S.J., and Robinson, K.L., eds. Hydrogeochemical Studies of the Rustler Formation and Related Rocks in the Waste Isolation Pilot Plant Area, Southeastern New Mexico. SAND88-0196. Sandia National Laboratories, Albuquerque, NM.

Lambert, S.J., and Carter, J.A. 1987. *Uranium-Isotope Systematics in Groundwaters of the Rustler Formation, Northern Delaware Basin, Southeastern New Mexico. I. Principles and Preliminary Results.* SAND87-0388. Sandia National Laboratories, Albuquerque, NM.

Lambert, S.J., and Harvey, D.M. 1987. *Stable-Isotope Geochemistry of Groundwaters in the Delaware Basin of Southeastern New Mexico.* SAND87-0138. Sandia National Laboratories, Albuquerque, NM.

Lang, W.B. 1935. "Upper Permian Formation of Delaware Basin of Texas and New Mexico." American Association of Petroleum Geologists Bulletin, Vol. 19, pp. 262 - 276.

Lang, W.B. 1939. Salado Formation of the Permian Basin. *American Association of Petroleum Geologists Bulletin,* Vol. 23, pp. 1569 - 1572.

Lang, W.B. 1942. Basal Beds of Salado Formation in Fletcher Potash Core Test near Carlsbad, New Mexico. *American Association of Petroleum Geologists Bulletin*, Vol. 26.

Lang, W.B. 1947. "Occurrence of Comanche Rocks in Black River Valley, New Mexico," American Association of Petroleum Geologists Bulletin, Vol. 31, pp. 1472 - 1478.

Lappin, A.R., Hunter, R.L., Garber, D.P., and Davies, P.B., eds, 1989. Systems Analysis, Long -Term Radionuclide Transport, and Dose Assessments, Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico; March 1989. SAND89-0462. Sandia National Laboratories, Albuquerque, NM.

LaVenue, A.M., Haug, A., and Kelley, V.A. 1988. *Numerical Simulation of Ground-Water Flow in the Culebra Dolomite at the Waste Isolation Pilot Plant (WIPP) Site: Second Interim Report.* SAND88-7002. Sandia National Laboratories, Albuquerque, NM.

LaVenue, A.M., Cauffman, T.L., and Pickens, J.F. 1990. Ground-Water Flow Modeling of the Culebra Dolomite. Volume 1: Model Calibration. SAND89-7068/1. Sandia National Laboratories, Albuquerque, NM.

Lee, W.T. 1925. "Erosion by Solution and Fill." In Contributions to Geography in the United States: USGS Bulletin, 760-C.

Lord, K.J., and Reynolds, W.E., eds. 1985. *Archaeological Investigations of Three Sites within the WIPP Core Area.* Prepared for the U.S. Army Corps of Engineers (COE), Albuquerque District in NM. Eddy County, NM, Chambers Consultants and Planner, Albuquerque, NM.

Lowenstein, T.K. 1987. *Post Burial Alternation of the Permian Rustler Formation Evaporites, WIPP Site, New Mexico: Textural Stratigraphic and Chemical Evidence*. EEG-36, New Mexico Health and Environment Department, Santa Fe, New Mexico.

Lowenstein, T.K. 1988. "Origin of Depositional Cycles in a Permian Saline Giant: The Salado (McNutt Zone) Evaporites of New Mexico and Texas." *Geological Society of America Bulletin*, Vol. 100, No. 4, pp. 20 - 21, 592 - 608.

Lucas, S.G., and Anderson, O.J. 1993a. "Triassic Stratigraphy in Southeastern New Mexico and Southwestern Texas." In *Carlsbad Region, New Mexico and West Texas, New Mexico Geological Society, Forty-Fourth Annual Field Conference, Carlsbad, NM, October 6-9, 1993.* D.W. Love et al., eds., pp. 231 - 235. New Mexico Geological Society, Socorro, NM.

Lucas, S.G., and Anderson, O.J. 1993b. "Stratigraphy of the Permian-Triassic Boundary in Southeastern New Mexico and West Texas." In *Geology of the Carlsbad Region, New Mexico and West Texas*, D.W. Love et al., eds., Forty-Fourth Annual Field Conference Guidebook. New Mexico Geological Society, Socorro, NM.

Machette, M.N. 1985. "Calcic Soils of the Southwestern United States." In *Soils and Quaternary Geology of the Southwestern United States*, D.L. Weide and M.L. Faber, eds., Special Paper Vol. 203, pp. 1 - 21. Geological Society of America, Denver, CO.

Madsen, B.M., and Raup, O.B. 1988. Characteristics of the Boundary between the Castile and Salado Formations near the Western Edge of the Delaware Basin, Southeastern New Mexico. *New Mexico Geology*, Vol. 10, No. 1.

Maley, V.C., and Huffington, R.M. 1953. "Cenozoic Fill and Evaporite Solution in the Delaware Basin, Texas and New Mexico." Geological Society of America Bulletin, Vol. 64.

McGowen, J.H., and Groat, C.G. 1971. *Van Horn Sandstone, West Texas: An Alluvial Fan Model for Mineral Exploration.* Report of Investigations No. 72. Bureau of Economic Geology, Austin, TX.

McGuire, R.K. 1976. *FORTRAN Computer Program for Seismic Risk Analysis*. Open-File Report No. 76-67, pp. 1 - 68. U.S. Geological Survey.

Meigs, L.C., and Beauheim, R.L. 2001. "Tracer Tests in a Fractured Dolomite, 1. Experimental Design and Observed Tracer Recoveries," Water Resources Research, Vol. 25, No. 5, pp. 1113-1128.

Meigs, L.C., Beauheim, R.L., and Jones, T.L. eds. 2000. Interpretation of Tracer Tests Performed in the Culebra Dolomite at the Waste Isolation Pilot Plant. SAND97-3109. Albuquerque, NM: Sandia National Laboratories.

Mercer, J.W. 1983. *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medaños Area, Southeastern New Mexico.* Water Resources Investigation Report 83-4016. U.S. Geological Survey, Albuquerque, NM. (***CCA*** Appendix HYDRO.)

Mercer, J.W., Beauheim, R.L., Snyder, R.P., and Fairer, G.M. 1987. *Basic Data Report for Drilling and Hydrologic Testing of Drillhole DOE-2 at the Waste Isolation Pilot Plant (WIPP) Site.* SAND86-0611. Sandia National Laboratories, Albuquerque, NM.

Miller, D.N. 1955. *Petrology of the Pierce Canyon Formation, Delaware Basin, Texas and New Mexico* [Ph.D. Dissertation]. University of Texas, Austin.

Miller, D.N. 1966. Petrology of Pierce Canyon Redbeds, Delaware Basin, Texas and New Mexico. *American Association of Petroleum Geologists Bulletin*, Vol. 80.

Molecke, M.A. 1983. A Comparison of Brines Relevant to Nuclear Waste Experimentation. SAND83-0516. Albuquerque, NM: Sandia National Laboratories.

Muehlberger, W.R., Belcher, R.C., and Goetz, L.K. 1978. Quaternary Faulting on Trans-Pecos, Texas. *Geology*, Vol. 6, No. 6, pp. 337 - 340.

Neill, R.H., Channell, J.K., Chaturvedi, L., Little, M.S., Rehfeldt, K., and Spiegler, P. 1983. Evaluation of the Suitability of the WIPP Site. EEG-23. Environmental Evaluation Group, Santa Fe, NM.

New Mexico Bureau of Mines and Mineral Resources ***(NMBMMR)***. 1995. *Final Report Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site*. Vols. 1 to 4.

Nicholson, Jr., A., and Clebsch, Jr., A. 1961. *Geology and Ground-Water Conditions in Southern Lea County, New Mexico*. Ground-Water Report 6. New Mexico Bureau of Mines and Mineral Resources, Socorro, NM.

Nuttli, O.W. 1973. Design Earthquakes for the Central United States. Miscellaneous Paper S-73-1, pp. 1 - 45. U.S. Army Waterways Experiment Station, Vicksburg, MS.

Olive, W.W. 1957. "Solution-Subsidence Troughs, Castile Formation of Gypsum Plain, Texas and New Mexico." Geological Society of America Bulletin, Vol. 68.

O'Neill, J.R., Johnson, C.M., White, L.D., and Roedder, E. 1986. "The Origin of Fluid in the Salt Beds of the Delaware Basin, New Mexico and Texas," Applied Geochemistry, v. 1, pp. 265-271.

Palmer, A.R. 1983. "The Decade of North American Geology 1983 Geologic Time Scale." *Geology*, Vol. 11, No. 9, pp. 503 -504.

Piper, A.M. 1973. *Subrosion in and about the Four-Township Study Area near Carlsbad, New Mexico.* Report to Oak Ridge National Laboratories, Oak Ridge, TN.

Piper, A.M. 1974. *The Four-Township Study Area near Carlsbad, New Mexico: Vulnerability to Future Subrosion.* Report to Oak Ridge National Laboratories, Oak Ridge, TN.

Popielak, R.S., Beauheim, R.L., Black, S.B., Coons, W.E., Ellingson, C.T., and Olsen, R.L. 1983. *Brine Reservoirs in the Castile Formation, Waste Isolation Pilot Plant (WIPP), Project*

Southeastern New Mexico. TME-3153. ~~Vols. 1 and 2.~~ Westinghouse Electric Corporation, Carlsbad, NM.

Powers, D.W. 1997. Geology of Piezometer Holes to Investigate Shallow Water Sources under the Waste Isolation Pilot Plant, in INTERA, 1997, Exhaust Shaft Hydraulic Assessment Data Report, DOE/WIPP 97-2219. Carlsbad, NM: US DOE

Powers, D.W. 2002a. Analysis Report for Task 1 of AP-088 – Construction of Geologic Contour Maps: ERMS #522086. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Powers, D.W. 2002b. "Addendum to Analysis Report Task 1 of AP-088 Construction of Geologic Contour Maps." ERMS #523886. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Powers, D.W. 2002c. Basic Data Report for Drillhole C-2737 (Waste Isolation Pilot Plant – WIPP): DOE/WIPP 01-3210. Carlsbad, NM: US DOE.

Powers, D.W. 2003a. Addendum 2 to Analysis Reports Task 1 of AP-088, Construction of Geologic Contour Maps. ERMS #525199. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Powers, D.W. 2003b. Geohydrological conceptual model for the Dewey Lake Formation in the vicinity of the Waste Isolation Pilot Plant (WIPP). Test Plan TP02-05. ERMS# 526493. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Powers, D.W., and Hassinger, B.W. 1985. "Synsedimentary Dissolution Pits in Halite of the Permian Salado Formation, Southeastern New Mexico," Journal of Sedimentary Petrology, Vol. 55, pp. 769-773.

Powers, D.W. and Holt, R. 1990. *Sedimentology of the Rustler Formation Near the Waste Isolation Pilot Plant (WIPP) Site.* pp. 77 -106. GSA Field Trip #14. Geological Society of America 1990 Annual Meeting. October 29 - November 1, 1990. Dallas, TX.

Powers, D.W., and Holt, R.M. 1993. "The Upper Cenozoic Gatuña Formation of Southeastern New Mexico." In *Carlsbad Region, New Mexico and West Texas, New Mexico Geological Society, Forty-Fourth Annual Field Conference, Carlsbad, NM, October 6-9, 1993,* D.W. Love et al., eds., pp. 271-282. New Mexico Geological Society, Roswell, NM.

Powers, D.W., and Holt, R.M. 1995. *Regional Geological Processes Affecting Rustler Hydrogeology*. Prepared for U.S. Department of Energy by IT Corporation, Albuquerque, NM.

Powers, D.W., and Holt, R.M. 1999. "The Los Medaños Member of the Permian Rustler Formation," New Mexico Geology, Vol. 21, No. 4, pp. 97-103.

Powers, D. W., and R. M. Holt. 2000. "The Salt That Wasn't There: Mudflat Facies Equivalents to Halite of the Permian Rustler Formation, Southeastern New Mexico," Journal of Sedimentary Research, Vol. 70, No. 1, pp. 29-36.

Powers, D.W., and Stensrud, W.A. 2003. Basic Data Report for Drillhole C-2811 (Waste Isolation Pilot Plant–WIPP). DOE/WIPP 02-3223. Carlsbad, NM: US DOE.

Powers, D.W., Lambert, S.J., Shaffer, S.E., Hill, L.R., and Weart, W.D., eds. 1978. *Geological Characterization Report for the Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico.* SAND78-1596, Vols. I and II. Sandia National Laboratories, Albuquerque, NM. (~~This document is included as~~ ***CCA*** Appendix GCR.)

Powers, D.W., Sigda, J.M., and Holt, R.M. 1996. "Probability of Intercepting a Pressurized Brine Reservoir Under the WIPP." ***ERMS #523414. Carlsbad, NM: Sandia National Laboatories. WIPP Records Center.***

Powers, D.W., Vreeland, R.H., and Rosenzweig, W.D. 2001. How Old are Bacteria from the Permian Age? Nature, Vol. 411, pp. 155-156.

Powers, D.W., Holt, R.M., Beauheim, R.L., and McKenna, S.A. 2003. "Geological Factors Related to the Transmissivity of the Culebra Dolomite Member, Permian Rustler Formation, Delaware Basin, Southeastern New Mexico," in Johnson, K.S., and Neal, J.T., eds., Evaporite karst and engineering/environmental problems in the United States: Oklahoma Geological Survey Circular 109, pp. 211-218.

Pratt, H.R., Stephenson, D.E., Zandt, G., Bouchon, M., and Hustrulik, W.A. 1979. Earthquake Damage to Underground Facilities. *Proceedings of the 1979 RETC,* Vol. 1. AIME, Littleton, CO.

Ramey, D.S. 1985. *Chemistry of Rustler Fluids.* EEG-31. New Mexico Environmental Evaluation Group, Santa Fe, NM.

Rawson, D., Boardman, C., and Jaffe-Chazan, N. 1965. *The Environment Created by a Nuclear Explosion in Salt*. PNE-107F. U.S. Atomic Energy Commission Plowshare Program, Project Gnome, Carlsbad, NM.

Register, J.K. 1981. *Rubidium-Strontium and Related Studies of the Salado Formation, Southeastern New Mexico.* SAND81-7072. Sandia National Laboratories, Albuquerque, NM.

Register, J.K., and Brookins, D.G. 1980. "Rb-Sr Isochron Age of Evaporite Minerals from the Salado Formation (Late Permian), Southeastern New Mexico." *Isochron/West,* No. 29, pp. 39 - 42.

Reiter, M., Barroll, M.W., and Minier, J. 1991. "An Overview of Heat Flow in Southwestern United States and Northern Chihuahua, Mexico." In *Neotectonics of North America,* D.B. Slemmons, E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, eds., pp. 457 - 466. Geological Society of America, Boulder, CO.

Renne, P.R., Sharp, W.D. and Becker, T.A. 1998. "$^{40}Ar/^{39}Ar$ Dating of Langbeinite [$K_2Mg_2(SO_4)_3$] in Late Permian Evaporites of the Salado Formation, Southeastern New Mexico, USA," Mineralogy Magazine, Vol. 62A, pp. 1253-1254

Renne, P.R., Steiner, M.B., Sharp, W.D., Ludwig, K.R., and Fanning, C.M. 1996. "^{40}40/^{39}Ar and U/Pb SHRIMP Dating of Latest Permian Tephras in the Midland Basin, Texas," Eos, Transactions, American Geophysical Union, Vol. 77, p. 794.

Richardson, G.B. 1904. "Report of a Reconnaissance of Trans-Pecos Texas, North of the Texas and Pacific Railway." *Texas University Bulletin 23*. Var Boeckmann-Jones Company, Austin, TX.

Richey, S.F. 1989. *Geologic and Hydrologic Data for the Rustler Formation Near the Waste Isolation Pilot Plant, Southeastern New Mexico.* Open-File Report 89-32. U.S. Geological Survey, Albuquerque, NM.

Richter, C.F. 1958. *Elementary Seismology*. W.H. Freeman & Co., San Francisco, CA.

Roberts, R.M., Beauheim, R.L., and Domski, P.S. 1999. Hydraulic Testing of Salado Formation Evaporites at the Waste Isolation Pilot Plant Site: Final Report. SAND98-2537. Sandia National Laboratories, Albuquerque, NM.

Robinson, T.W., and Lang, W.B. 1938. "Geology and Ground-Water Conditions of the Pecos River Valley in the Vicinity of Laguna Grande de la Sal, New Mexico, with Special Reference to the Salt Content of the River Water." *Twelfth and Thirteenth Biennial Reports of the State Engineer of New Mexico for the 23rd, 24th, 25th, and 26th Fiscal Years, July 1, 1934 to July 30, 1938.* State Engineer, Santa Fe, NM.

Robinson, J.Q., and Powers, D.W. 1987. "A Clastic Deposit within the Lower Castile Formation, Western Delaware Basin, New Mexico." In *Geology of the Western Delaware Basin, West Texas and Southeastern New Mexico,* D.W. Powers, and W.C. James, eds., El Paso Geological Society Guidebook 18, pp. 66 -79. El Paso Geological Society, El Paso, TX.

Roedder, E. 1984. "The Fluids in Salt," American Mineralogist, v. 69, pp. 413-439.

Rogers, A.M., and Malkiel, A. 1979. A Study of Earthquakes in the Permian Basin of Texas–New Mexico. *Bulletin of the Seismological Society of America*, Vol. 69, pp. 843 - 865.

Rosholt, J.N., and McKinney, C.R. 1980. *Uranium Series Disequilibrium Investigations Related to the WIPP Site, New Mexico (USA), Part II. Uranium Trend Dating of Surficial Deposits and Gypsum Spring Deposits Near WIPP Site, New Mexico.* Open-File Report 80-879. U.S. Geological Survey, Denver, CO.

Salvador, A. 1985. "Chronostratigraphic and Geochronometric Scales in Colorado SUNA Stratigraphic Correlation Charts of the United States." American Association of Petroleum Geologists Bulletin, Vol. 69.

Sandia National Laboratories. 2000. "Sandia National Laboratories Annual Compliance Monitoring Parameter Assessment, WBS 1.3.5.2.1.1, Pkg. No. 510062." ERMS #512733. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Sandia National Laboratories. 2001. "Sandia National Laboratories Annual Compliance Monitoring Parameter Assessment, WBS 1.3.5.3.1, Pkg. No. 510062, October 2001." ERMS #519620. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Sandia National Laboratories. 2002. "Sandia National Laboratories Annual Compliance Monitoring Parameter Assessment for 2002, WBS 1.3.5.3.1, Pkg. No. 510062, November 2002." ERMS #524449. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Sandia National Laboratories. 2003a. "Sandia National Laboratories Technical Baseline Reports, WBS 1.3.5.3, Compliance Monitoring; WBS 1.3.5.4, Repository Investigations, Milestone RI 03-210, January 31, 2003." ERMS #526049. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Sandia National Laboratories. 2003b. "Program Plan, WIPP Integrated Groundwater Hydrology Program, FY03-FY09, Revision 0, March 14, 2003." ERMS #526671. Carlsbad, NM: Sandia National Laboratories, WIPP Records Center.

Sanford, A.R., Jaksha, L.H., and Cash, D.J. 1991. "Seismicity of the Rio Grand Rift in New Mexico." In *Neotectonics of North America,* D.B. Slemmons, E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, eds., pp. 229 - 244. Geological Society of America, Boulder, CO.

~~Saulnier, Jr., G.J., and Avis, J.D. 1988. *Interpretation of Hydraulic Tests Conducted in the Waste Handling Shaft at the Waste Isolation Pilot Plant (WIPP) Site.* SAND88-7001. Sandia National Laboratories, Albuquerque, NM. WPO 24164.~~

Satterfield, C.L., Lowenstein, T.K., Vreeland, R, and Rosenzweig, W. 2002. "The Search for Microorganisms in Brine Inclusions in Halite: an Update," Abstracts with Programs, Geological Society of America, Annual Meeting, v. 34, no. 6, p. 19.

Schiel, K.A. 1988. "The Dewey Lake Formation: End Stage Deposit of a Peripheral Foreland Basin." Master's thesis. University of Texas at El Paso, El Paso, TX.

Schiel, K.A. 1994. "A New Look at the Age, Depositional Environment and Paleogeographic Setting of the Dewey Lake Formation (Late Permian)." *West Texas Geological Society Bulletin*, Vol. 33, No. 9, pp. 5 - 13.

Sergent, Hauskins & Beckwith, 1979. Subusrface Exploration & Laboratory Testing. Plant Site: Waste Isolation Pilot Plant. Vols I & II. Phoenix, AZ: Sergent, Hauskins & Beckwith (Copy on file at the U.S. Department of Energy, WIPP Information Center, Carlsbad, NM).

Sewards, T., Williams, M.L., and Keil, K. 1991. *Mineralogy of the Culebra Dolomite Member of the Rustler Formation.* SAND90-7008. Sandia National Laboratories, Albuquerque, NM.

Siegel, M.D., Lambert, S.J., and Robinson, K.L., eds. 1991. *Hydrogeochemical Studies of the Rustler Formation and Related Rocks in the Waste Isolation Pilot Plant Area, Southeastern New Mexico*. SAND88-0196. Sandia National Laboratories, Albuquerque, NM.

Silva, M.K. 1996. Fluid Injection for Salt Water Disposal and Enhanced Oil Recovery as a Potential Problem for WIPP: Proceedings of a June 1995 Workshop and Analysis. EEG-62. Albuquerque, NM: Environmental Evaluation Group.

Snider, H.I. 1966. "Stratigraphy and Associated Tectonics of the Upper Permian Castile-Salado-Rustler Evaporite Complex, Delaware Basin, West Texas and Southeast New Mexico." Ph.D. dissertation. University of New Mexico, Albuquerque, NM.

Snyder, R.P. 1985. *Dissolution of Halite and Gypsum, and Hydration of Anhydrite to Gypsum, Rustler Formation, in the Vicinity of the Waste Isolation Pilot Plant, Southeastern New Mexico.* Open-File Report 85-229. U.S. Geological Survey, Denver, CO.

Snyder, R.P., Gard, Jr., L.M., and Mercer, J.W. 1982. *Evaluation of Breccia Pipes in Southeastern New Mexico and Their Relation to the Waste Isolation Pilot Plant (WIPP) Site, with Section on Drill-Stem Tests.* Open-File Report 82-968. U.S. Geological Survey, Denver, CO.

Stein, C.L., and Krumhansl, J.L. 1988. "A Model for the Evolution of Brines in Salt from the Lower Salado Formation, Southeastern New Mexico," Geochimica et Cosmochimica Acta, v. 52, pp. 1037-1046.

~~Stensrud, W.A. 1995. *Culebra Transport Program Test Plan: Hydraulic Tests at Wells WQSP-1, WQSP-2, WQSP-3, WQSP-4, WQSP-5, WQSP-6 and WQSP-6a at the Waste Isolation Pilot Plant (WIPP) Site.* On file in the Sandia WIPP Central Files.~~

Swift, P.N. 1992. *Long-Term Climate Variability at the Waste Isolation Pilot Plant, Southeastern New Mexico, USA.* SAND91-7055. Sandia National Laboratories, Albuquerque, NM. (~~This document is included as~~ ***CCA*** Appendix CLI.)

TerraTek, Inc. 1996. "Physical Property Characterization of Miscellaneous Rock Samples, Contract AA-2896." Contractor Report TR97-03 to Sandia National Laboratories. ERMS #238234. Salt Lake City, UT.

Thompson, G.A. and Zoback, M.L. 1979. Regional Geophysics of the Colorado Plateau. *Tectonophysics,* Vol. 61, Nos. 1 - 3, pp. 149 - 181.

Tóth, J., 1963. "A Theoretical Analysis of Groundwater Flow in Small Drainage Basins," Journal of Geophysical Research. Vol. 68, No. 16, pp. 4795 - 4812.

UNM (University of New Mexico). 1984. *A Handbook of Rare and Endemic Plants of New Mexico.* New Mexico Native Plants Protection Advisory Committee, eds. University of New Mexico Press, Albuquerque, NM.

Urry, W.E. 1936. Post-Keweenawan Timescale. Exhibit 2, pp. 35 - 40. National Research Council, Report Committee on Measurement of Geologic Time 1935 -36.

U.S. Congress. 1992. *Waste Isolation Pilot Plant Land Withdrawal Act*. Public Law 102-579, October 1992. 102nd Congress, Washington, D.C.

~~U.S. Department of Commerce. 1980. *Census of Population, General Population Characteristics of New Mexico.* Bureau of the Census.~~

U.S. Census Bureau. 2000. Census 2000 at http://www.census.gov/main/www/access.html.

U.S. Department of Commerce. 1990. *Census of Population, General Population Characteristics of New Mexico.* Bureau of the Census.

U.S. Department of Energy (DOE). 1980. *Final Environmental Impact Statement, Waste Isolation Pilot Plant.* DOE/EIS-0026, Vols. 1 and 2. Office of Environmental Restoration and Waste Management, Washington, D.C.

U.S. Department of Energy (DOE). 1983. Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program. WIPP-DOE-161. Carlsbad, NM: Waste Isolation Pilot Plant.

U.S. Department of Energy (DOE). 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant, DOE/CAO-1996-2184, October 1996, Carlsbad Field Office, Carlsbad, NM.

U.S. Department of Energy (DOE). 1999. Exhaust Shaft: Phase III Hydraulic Assessment Data Report, October 1997 –- October 1998. DOE-WIPP 99-2302. Carlsbad, NM: Waste Isolation Pilot Plant.

U.S. Department of Energy (DOE). 2002a. Delaware Basin Monitoring Annual Report. DOE/WIPP-99-2308, Rev. 03. Carlsbad, NM: Department of Energy.

U.S. Department of Energy (DOE). 2002b. Geotechnical Analysis Report for July 2000 -June 2001. DOE/WIPP 02-3177, Vol. 1. Carlsbad, NM: Department of Energy.

U.S. Department of Energy (DOE). 2003. Strategic Plan for Groundwater Monitoring at the Waste Isolation Pilot Plant. DOE/WIPP-03-3220, United States Department of Energy. Carlsbad, NM: February 2003.

U.S. Environmental Protection Agency (EPA). 1988. "40 CFR Parts 124, 144, 146, and 148 Underground Insertion Control Program: Hazardous Waste Disposal Injection Restrictions; Amendments to Technical Requirements for Class 1 Hazardous Waste Injection Wells, and Additional Monitoring Requirements Applicable to All Class 1 Wells." *Federal Register*, Vol. 53, 28188, July 26, 1988.

U.S. Environmental Protection Agency (EPA). 1993. 40 CFR Part 191 Environmental Radiation Protection Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule. *Federal Register*, Vol. 58, No. 242, pp. 66398 - 66416, December 20, 1993. Office of Radiation and Indoor Air, Washington, D.C.

U.S. Environmental Protection Agency (EPA). 1996. *40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; Final Rule*. *Federal Register*, Vol. 61, No. 28,

pp. 5224 - 5245, February 9, 1996. Office of Air and Radiation, Washington, D.C. In NWM Library as KF70.A35.C751.

U.S. Environmental Protection Agency (EPA). 1996. Docket A-93-02, Item II-I-01, Enclosure 1, Letter from EPA to DOE, December 19, 1996 technical issues raised by EPA.

U.S. Nuclear Regulatory Commission ***(NRC***). 1973. Design Spectra for Seismic Design of Nuclear Power Plants, Revision 1. *Regulatory Guide* 1.60, December 1973.

Vine, J.D. 1963. "Surface Geology of the Nash Draw Quadrangle, Eddy County, New Mexico." *U.S. Geological Survey Bulletin 1141-B*. U.S. Government Printing Office, Washington, DC.

Washington Regulatory & Environmental Services (WRES). 2003. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 2002, DOE/WIPP 03-2222, Carlsbad, NM.

Waste Isolation Pilot Plant Management and Operating Contractor (WIPP MOC). 1995. Basic Data Report for WQSP 1, WQSP 2, WQSP 3, WQSP 4, WQSP 5, WQSP 6, WQSP 6a, DOE/WIPP 95-2154. WIPP MOC, Carlsbad, NM.

Weart, W.D. 1983. *Summary Evaluation of the Waste Isolation Pilot Plant (WIPP) Site Suitability*. SAND83-0450. Albuquerque, NM: Sandia National Laboratories.

Westinghouse Electric Corporation ***(WEC)***. 1991a. *Waste Isolation Pilot Plant Groundwater Monitoring Program Plan and Procedures Manual.* WP02-1. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation ***(WEC)***. 1991b. *Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1990.* DOE/WIPP 91-008. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation ***(WEC)***. 1992. *Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1991.* DOE/WIPP 92-007. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation ***(WEC)***. 1993. *Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1992.* DOE/WIPP 93-017. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation ***(WEC)***. 1994. *Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1993.* DOE/WIPP 94-2003. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation ***(WEC)***. 1995. *Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1994.* DOE/WIPP 95-Draft-2094. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation (WEC). 1996. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1995, DOE/WIPP 96-2182, Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation (WEC). 1997. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1996, DOE/WIPP 97-2225, Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Electric Corporation (WEC). 1998. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1997, DOE/WIPP 98-2225, Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Westinghouse Government Environmental Services Company (WGESC), LLC. 1999. Waste Isolation Pilot Plant Site Environmental Report for Calendar Year 1998, DOE/WIPP 99-2225, Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

Wolfe, H.G., et al., eds. 1977. *An Environmental Baseline Study of the Los Medaños Waste Isolation Pilot Plant (WIPP) Project Area of New Mexico: A Progress Report.* SAND77-7017. Sandia National Laboratories, Albuquerque, NM.

Wood, B.J., Snow, R.E., Cosler, D.J., and Haji-Djafari, S. 1982. *Delaware Mountain Group (DMG) Hydrology—Salt Removal Potential, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico.* TME 3166. U.S. Department of Energy, Albuquerque, NM.

Zoback, M.L., and Zoback, M.D. 1980. "State of Stress in the Conterminous United States." *Journal of Geophysical Research,* Vol. 85, No. B11, pp. 6113 - 6156.

Zoback, M.L., Zoback, M.D., Adams, J., Bell, S., Suter, M., Suarez, G., Estabrook, C., and Magee, M. 1991. *Stress Map of North America.* Continent Scale Map CSM-5, Scale 1:5,000,000. Geological Society of America, Boulder, CO.

Zoback, M.D., and Zoback, M.L. 1991. "Tectonic Stress Field of North America and Relative Plate Motions." In *Neotectonics of North America,* D.B. Slemmons, E.R. Engdahl, M.D. Zoback, and D.D. Blackwell, eds., pp. 339 - 366. Geological Society of America, Boulder, CO.

INDEX

40 CFR Part 191 2-1
accessible environment 2-85, 2-87, 2-115
actinide
  Culebra 2-105
  transport 2-105
advection 2-12, 2-45, 2-105, 2-110
analysis
  probabilistic 2-182, 2-186
anhydrite 2-22, 2-24, 2-29, 2-31, 2-32, 2-44, 2-45, 2-48, 2-51, 2-69, 2-74, 2-76, 2-85, 2-92, 2-95, 2-99, 2-102, 2-109, 2-112, 2-115, 2-117, 2-119
anthropogenic 2-120, 2-121, 2-123
archaeology 2-140, 2-145
area
  controlled 2-101, 2-136, 2-143
assurance requirements 2-85
barriers 2-11
  engineered 2-2
  natural 2-11
Bell Canyon 2-18, 2-21, 2-22, 2-24, 2-25, 2-26, 2-27, 2-71, 2-77, 2-80, 2-85, 2-91, 2-92, 2-93, 2-125
borehole ... 2-2, 2-13, 2-14, 2-15, 2-24, 2-27, 2-35, 2-39, 2-47, 2-56, 2-65, 2-71, 2-73, 2-76, 2-78, 2-80, 2-83, 2-85, 2-91, 2-92, 2-95, 2-117, 2-119, 2-128, 2-135, 2-139
boundary conditions 2-1, 2-110
breccia pipes 2-8, 2-74, 2-77, 2-80, 2-125
brine 2-2, 2-27, 2-31, 2-33, 2-35, 2-73, 2-77, 2-80, 2-85, 2-90, 2-92, 2-93, 2-96, 2-98, 2-101, 2-128, 2-133, 2-135
  aquifer 2-33, 2-77, 2-126, 2-128
brine reservoirs 2-7, 2-28, 2-74, 2-91, 2-92, 2-93, 2-95
  volume 2-92
calcite 2-28, 2-31
calibrate 2-115
Capitan Limestone 2-22, 2-24, 2-29, 2-59, 2-71, 2-73, 2-78, 2-80, 2-85, 2-92, 2-123, 2-131
carbonates 2-11, 2-21, 2-36, 2-39, 2-123
Castile 2-22, 2-24, 2-27, 2-28, 2-29, 2-31, 2-58, 2-71, 2-73, 2-74, 2-76, 2-77, 2-80, 2-85, 2-88, 2-90, 2-91, 2-92, 2-93, 2-95, 2-96, 2-98, 2-125, 2-135
Cenozoic 2-50, 2-63, 2-68, 2-80
Central Basin Platform 2-17, 2-63, 2-69, 2-180, 2-183, 2-184, 2-186
channeling 2-33, 2-51, 2-97
Cherry Canyon 2-22
climate 2-99, 2-110, 2-135, 2-162
colloid 2-105
Compliance Certification Application (CCA) 2-2, 2-10, 2-11, 2-12, 2-13, 2-17, 2-18, 2-21, 2-22, 2-24, 2-27, 2-28, 2-29, 2-31, 2-32, 2-33, 2-35, 2-39, 2-42, 2-44, 2-45, 2-47, 2-48, 2-50, 2-57, 2-58, 2-63, 2-69, 2-71, 2-73, 2-76, 2-78, 2-80, 2-85, 2-88, 2-89, 2-91, 2-93, 2-95, 2-97, 2-99, 2-101, 2-103, 2-105, 2-106, 2-107, 2-110, 2-111, 2-112, 2-114, 2-115, 2-116, 2-117,

2-119, 2-120, 2-125, 2-126, 2-127, 2-128, 2-133, 2-135, 2-136, 2-139, 2-140, 2-145, 2-147, 2-160, 2-180, 2-182, 2-183, 2-186
computational model.....2-2, 2-12
conceptual model..... 2-1, 2-11, 2-12, 2-17, 2-28, 2-36, 2-44, 2-58, 2-78, 2-85, 2-93, 2-98, 2-101, 2-102, 2-103, 2-110, 2-116, 2-117, 2-126
consequence analysis..... 2-58
controlled area..... 2-101, 2-136, 2-143
creep closure..... 2-36
Cretaceous..... 2-67
Culebra .. 2-11, 2-13, 2-16, 2-18, 2-33, 2-36, 2-42, 2-44, 2-45, 2-46, 2-47, 2-48, 2-66, 2-67, 2-68, 2-74, 2-81, 2-85, 2-87, 2-88, 2-90, 2-101, 2-102, 2-103, 2-105, 2-106, 2-108, 2-112, 2-116, 2-119, 2-120, 2-140
model.....2-103, 2-115
cuttings 2-48
data
quality 2-13
deformation 2-7, 2-11, 2-24, 2-27, 2-29, 2-32, 2-45, 2-51, 2-59, 2-65, 2-71, 2-74, 2-76, 2-92
Delaware Basin 2-11, 2-14, 2-21, 2-22, 2-24, 2-27, 2-28, 2-29, 2-31, 2-32, 2-35, 2-36, 2-63, 2-65, 2-69, 2-71, 2-76, 2-80, 2-85, 2-86, 2-87, 2-95, 2-98, 2-123, 2-125, 2-136, 2-139, 2-140, 2-147
Delaware Mountain Group.....2-18, 2-22
demographics 2-134, 2-140
Devonian..... 2-21
Dewey Lake 2-51, 2-52, 2-53, 2-55, 2-58, 2-66, 2-68, 2-69, 2-71, 2-85, 2-87, 2-88, 2-89, 2-90, 2-91, 2-99, 2-119, 2-120, 2-121, 2-122, 2-123
diapirism..... 2-7
diffusion.....2-45, 2-104
dike..... 2-35, 2-69, 2-72
discharge..... 2-9, 2-89, 2-92, 2-99, 2-102, 2-105, 2-111, 2-128, 2-131
disposal system
performance 2-11, 2-36, 2-58, 2-112
dissolution.. 2-8, 2-9, 2-10, 2-11, 2-14, 2-24, 2-27, 2-29, 2-32, 2-34, 2-39, 2-44, 2-48, 2-50, 2-59, 2-62, 2-63, 2-69, 2-71, 2-74, 2-76, 2-78, 2-80, 2-90, 2-99, 2-102, 2-107, 2-114, 2-123, 2-125, 2-126, 2-135
disturbed rock zone (DRZ).....2-2, 2-73, 2-87, 2-96, 2-98
Dockum Group.....2-53, 2-66
double porosity 2-12
drainage.....2-55, 2-59, 2-62, 2-83, 2-89, 2-99, 2-128, 2-133
drilling . 2-12, 2-13, 2-21, 2-24, 2-44, 2-48, 2-53, 2-55, 2-69, 2-73, 2-74, 2-77, 2-85, 2-96, 2-107, 2-123, 2-126, 2-134, 2-138, 2-143, 2-146
engineered
barriers 2-2
erosion 2-9, 2-10, 2-14, 2-17, 2-51, 2-57, 2-58, 2-59, 2-62, 2-63, 2-66, 2-81, 2-91, 2-107
exposure pathways 2-159
facility design.....2-2, 2-55
fault.....2-7, 2-24, 2-63, 2-73, 2-147, 2-164, 2-180, 2-181

fauna 2-10, 2-51, 2-160
features, events, and processes (FEPs) 2-1, 2-7, 2-13, 2-58, 2-136
natural 2-2, 2-7, 2-13
fluvial 2-9, 2-39, 2-51, 2-55, 2-160
Forty-niner 2-36, 2-39, 2-50, 2-88, 2-117
fractures 2-7, 2-28, 2-32, 2-42, 2-45, 2-46, 2-51, 2-66, 2-77, 2-92, 2-97, 2-101, 2-104, 2-114, 2-119, 2-128
future events 2-182
Gatuña 2-50, 2-56, 2-59, 2-68, 2-71, 2-80, 2-160
glaciation 2-10, 2-160
groundwater 2-8, 2-9, 2-24, 2-32, 2-35, 2-45, 2-51, 2-58, 2-78, 2-91, 2-95, 2-99, 2-100, 2-101, 2-103, 2-109, 2-115, 2-117, 2-119, 2-120, 2-121, 2-125, 2-126, 2-134, 2-140, 2-159
monitoring 2-85, 2-91, 2-111, 2-115, 2-119, 2-120
Guadalupian Series 2-22
human intrusion 2-14, 2-83, 2-85
hummock 2-57, 2-59
hunting 2-143, 2-144
hydraulic
potential 2-98
hydraulic conductivity 2-87, 2-91, 2-99, 2-102, 2-116, 2-121, 2-123
hydraulic gradient 2-91, 2-92, 2-104, 2-112, 2-117, 2-125, 2-126
potential 2-99
hydrostatic 2-92, 2-98
independent review 2-13
infiltration 2-9, 2-51, 2-58, 2-83, 2-88, 2-89, 2-112, 2-120, 2-123, 2-125, 2-147
interbed 2-29, 2-36, 2-45, 2-97
inventory 2-146
karst 2-33, 2-59, 2-76, 2-78, 2-80, 2-101
Lamar limestone 2-22, 2-24
Land Withdrawal Act (LWA) 2-143
land withdrawal area 2-143
Leonardian Series 2-22
lithofacies 2-55
Livingston Ridge 2-33, 2-62, 2-143
loading 2-63, 2-67, 2-114
Los Medaños 2-36, 2-39, 2-44, 2-88, 2-102
Magenta 2-11, 2-17, 2-18, 2-36, 2-48, 2-50, 2-85, 2-88, 2-101, 2-111, 2-116, 2-117
Malaga Bend 2-99, 2-126, 2-133
McNutt Potash Zone 2-29, 2-135
Mescalero Caliche 2-55, 2-57, 2-59, 2-160
metamorphic 2-8, 2-14
Mississippian 2-21
Mississippian Limestone 2-21
model
computational 2-2, 2-12

conceptual.....2-1, 2-11, 2-12, 2-17, 2-28, 2-36, 2-44, 2-45, 2-47, 2-58, 2-78, 2-85, 2-93, 2-98, 2-101, 2-102, 2-110, 2-116, 2-117, 2-126
Culebra.....2-103, 2-115
numerical.....2-101
monitoring.....2-13, 2-16, 2-17, 2-18, 2-85
environmental.....2-122, 2-162
groundwater.....2-91, 2-103, 2-110, 2-115, 2-116, 2-117, 2-119, 2-120
mudstone.....2-32, 2-33, 2-48, 2-49, 2-102, 2-107, 2-115
Nash Draw.....2-88, 2-99, 2-116, 2-121, 2-123, 2-126, 2-131, 2-160
natural barriers.....2-11
numerical model.....2-101
Ochoan.....2-21, 2-24, 2-51, 2-63, 2-78
Ogallala Formation.....2-55, 2-59, 2-62, 2-65, 2-68, 2-69, 2-76, 2-131
oil and gas.....2-24, 2-69, 2-134, 2-139, 2-143, 2-144
Ordovician.....2-21, 2-63
Paleozoic.....2-18, 2-21, 2-63
parameter...2-1, 2-11, 2-14, 2-18, 2-28, 2-36, 2-44, 2-63, 2-81, 2-97, 2-109, 2-116, 2-117, 2-121, 2-139, 2-182, 2-186
value.....2-2, 2-47, 2-48, 2-53, 2-93, 2-103, 2-105
Pecos River.....2-55, 2-59, 2-62, 2-69, 2-83, 2-99, 2-125, 2-126, 2-128, 2-133, 2-144, 2-160
Pennsylvanian.....2-21, 2-63
performance assessment (PA).....2-1, 2-2, 2-11, 2-12, 2-14, 2-36, 2-53, 2-85, 2-88, 2-93, 2-95, 2-97, 2-99, 2-101, 2-104, 2-114, 2-136, 2-143
permafrost.....2-10
permeability.....2-87
Permian.....2-21, 2-57
Basin.....2-63, 2-64, 2-183, 2-184
Period.....2-35, 2-63
plugging.....2-139
polyhalite.....2-29, 2-31, 2-32, 2-35, 2-71
possible futures.....2-136
potash resources.....2-12, 2-77
Precambrian.....2-14, 2-21, 2-69
precipitation.....2-10, 2-58, 2-83, 2-89, 2-122, 2-131, 2-133, 2-161, 2-162, 2-166
pressure
gradient.....2-90
probabilistic analysis.....2-182, 2-183, 2-186
probability.....2-28, 2-58, 2-63, 2-74, 2-93, 2-123, 2-138, 2-182, 2-186
Project Gnome.....2-147
quality assurance (QA).....2-12
Quaternary.....2-57, 2-63, 2-69, 2-80
ranching.....2-144
recharge.....2-9, 2-78, 2-88, 2-89, 2-99, 2-110, 2-112, 2-119, 2-125
records packages.....2-13
resources.....2-2, 2-76, 2-143
potash.....2-12, 2-77

Richter scale *2-164, 2-180*
risk *2-134, 2-182, 2-183, 2-186*
Rustler.... *2-11, 2-28, 2-31, 2-33, 2-36, 2-38, 2-39, 2-41, 2-42, 2-43, 2-44, 2-48, 2-49, 2-50, 2-51, 2-53, 2-58, 2-69, 2-71, 2-73, 2-77, 2-78, 2-80, 2-85, 2-87, 2-88, 2-90, 2-99, 2-101, 2-102, 2-103, 2-107, 2-112, 2-119, 2-126, 2-128*
Salado.... *2-10, 2-22, 2-24, 2-27, 2-30, 2-31, 2-33, 2-34, 2-35, 2-36, 2-42, 2-44, 2-58, 2-63, 2-71, 2-73, 2-74, 2-77, 2-78, 2-80, 2-81, 2-83, 2-85, 2-87, 2-88, 2-89, 2-90, 2-91, 2-92, 2-95, 2-96, 2-97, 2-98, 2-99, 2-101, 2-102, 2-107, 2-108, 2-109, 2-112, 2-125, 2-126, 2-128, 2-135, 2-147*
San Simon Sink *2-77*
San Simon Swale *2-62*
Santa Rosa *2-51, 2-54, 2-55, 2-68, 2-69, 2-88, 2-90, 2-99, 2-119, 2-120, 2-121, 2-125*
scarps *2-59, 2-69*
scenarios *2-1, 2-85, 2-135*
seals *2-164*
seismic *2-7, 2-8, 2-27, 2-63, 2-73, 2-146, 2-164, 2-180, 2-183, 2-186*
shafts *2-36, 2-48, 2-74, 2-87, 2-107, 2-111, 2-119, 2-120*
siliciclastic *2-32, 2-39, 2-44*
siltstone *2-33, 2-48, 2-51, 2-102, 2-115, 2-117, 2-121*
Silurian *2-21*
Simpson *2-21*
site characterization *2-1, 2-11, 2-13, 2-59, 2-120*
sorption *2-105*
stratigraphy *2-36, 2-38*
subsidence *2-7, 2-59, 2-62, 2-63, 2-77, 2-80, 2-102*
surface
  drainage *2-89, 2-128*
  structures *2-13, 2-88, 2-109, 2-120, 2-121, 2-122, 2-123*
  water *2-9, 2-83, 2-89, 2-119, 2-147, 2-159*
sylvite *2-31, 2-32, 2-35, 2-135, 2-136*
syndeposition *2-33, 2-35, 2-45, 2-48, 2-51, 2-74, 2-77*
Tamarisk *2-36, 2-39, 2-47, 2-48, 2-78, 2-88, 2-103, 2-110, 2-115*
tectonic *2-7, 2-58, 2-68, 2-69, 2-71, 2-78, 2-164, 2-181, 2-183*
threshold pressure *2-97*
time-domain electromagnetic (TDEM) *2-93*
transmissivity *2-12, 2-85, 2-87, 2-88, 2-90, 2-102, 2-114, 2-116, 2-117, 2-119, 2-126*
  Culebra *2-42, 2-103, 2-106, 2-108, 2-116*
transport *2-10, 2-12, 2-39, 2-45, 2-50, 2-81, 2-87, 2-89, 2-95, 2-103, 2-110, 2-112, 2-115*
transuranic (TRU) waste *2-80*
Triassic *2-28, 2-51, 2-53, 2-66, 2-80*
uncertainty *2-1, 2-42, 2-111, 2-115*
underground *2-12, 2-164, 2-186*
  facilities *2-87, 2-164, 2-186*
  source of drinking water (USDW) *2-88, 2-140*
undisturbed performance (UP) *2-83*
unloading *2-63, 2-67, 2-114*
unnamed lower member *2-29, 2-36, 2-44, 2-102*

uplift ***2-63, 2-68, 2-69***
Upper Devonian Woodford Shale ***2-21***
vug ***2-44, 2-45, 2-104***
Wolfcampian Series ***2-21***