2.1.3.5.1 ~~Unnamed Lower Member~~ ***Los Medaños Member***

The unit formerly referred to as the unnamed lower member has been named the Los Medaños Member. The ~~unnamed lower member~~ ***Los Medaños*** rests on the Salado with apparent conformity at the WIPP site. It consists of significant proportions of bedded and burrowed siliciclastic sedimentary rocks with cross-bedding and fossil remains. These beds record the transition from strongly evaporative environments of the Salado to saline lagoonal environments. The upper part of the ~~unnamed lower member~~ ***Los Medaños*** includes halitic and sulfatic beds within clastics. ~~Holt and Powers (~~***CCA*** Appendix FAC, p***p.*** 6-8~~)~~ ***and Powers and Holt (1999)*** interpret these as facies changes within a saline playa or lagoon environment, not dissolution residues from postdepositional dissolution.

According to ~~Holt and Powers (~~***CCA*** Appendix FAC, Figure 4-4, the ~~unnamed lower member~~ ***Los Medaños*** ranges in thickness from about 29 to 38 m (96 to 126 ft) within the site boundaries. The maximum thickness recorded during that study was 63 m (208 ft) southeast of the WIPP site. An isopach of the ~~unnamed lower member~~ ***Los Medaños*** is shown as Figure 4-7 in ***CCA*** Appendix FAC.

Halite is present in the M1/H1 unit of the ~~unnamed lower member~~***Los Medaños*** west of most of the site area (see ~~Figure 2-10~~ ***Figure 2-15*** for an illustration of the halite margins). ***The drilling initiated during CRA-2004 preparation to investigate Culebra transmissivity variations based on overburden and Salado dissolution will develop additional detailed information about distribution of halite in the Los Medaños.*** Cross-sections based on geophysical log interpretations by Holt and Powers (***CCA Appendix FAC) and Powers and Holt (2000)*** show that the unit is thicker to the east where the halite is more abundant. The ~~unnamed lower member~~ ***Los Medaños*** is incorporated into the conceptual model as described in Section 6.4.6.1. Model parameters are in Appendix ***PA, Attachment*** PAR, Table PAR-~~31~~ ***27***.

2.1.3.5.2 The Culebra ***Dolomite Member***

The Culebra rests with apparent conformity on the ~~unnamed lower member,~~***Los Medaños***, though the underlying unit ranges from claystone to its lateral halitic equivalent in the site area. West of the WIPP site, in Nash Draw, the Culebra is disrupted from dissolution of underlying halite. Holt and Powers (***CCA*** Appendix FAC, Section 8.9.3) principally attribute this to dissolution of Salado halite, ***noting the presence of sedimentologic features in the lower Rustler (see also Powers and Holt 1999).*** ~~while Snyder (1985, 6) indicates that salt was dissolved postdepositionally from the unnamed lower member. These alternative interpretations offer differing explanations of how the existing Rustler hydrologic system developed and might continue to develop~~. Culebra hydrology and its significance to disposal system performance are discussed in detail in Section 2.2.1.4.1.2.

The Culebra was described by Robinson and Lang (1938, ***p.*** 83) as a dolomite 11 m~~eters~~ (35 ~~feet~~ ***ft***) in thickness. The Culebra is generally brown, finely crystalline, locally argillaceous and arenaceous dolomite with rare to abundant vugs with variable gypsum and anhydrite filling; Adams (1944, ***p.*** 1614) noted that oölites are present in some outcrops as well. Holt and Powers (***CCA*** Appendix FAC, ***pp.*** 5 ***-*** 11) describe the Culebra features in detail, noting that most of the Culebra is microlaminated to thinly laminated, while some zones display no depositional fabric.

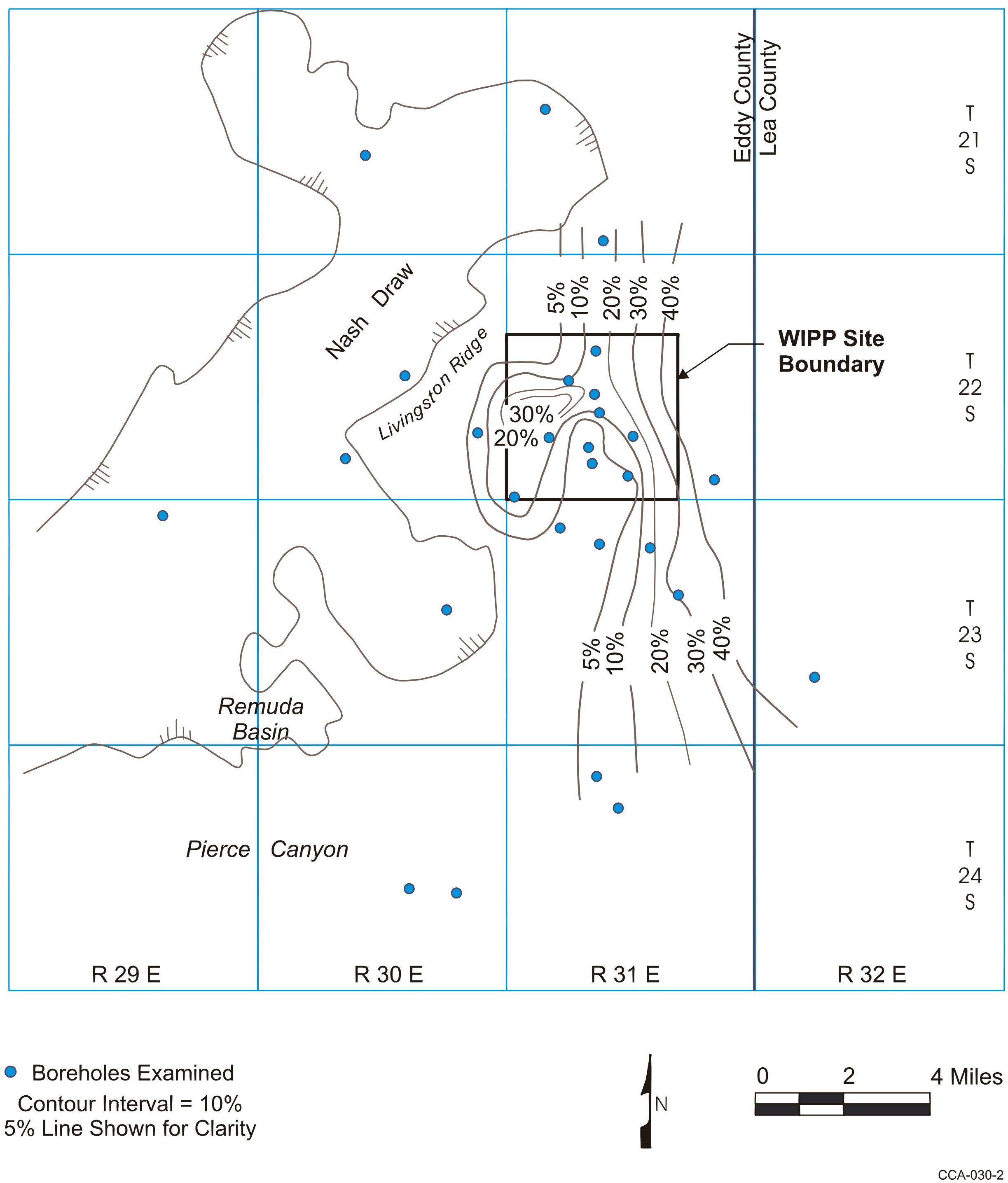
Holt and Powers (1984) described an upper interval of the Culebra consisting of medium brown, microlaminated carbonate that thickens up to ***0***.6 m (2 ft) in the vicinity of dome structures and is of probable algal origin. This is underlain by a ***0***.64-to-~~2.56~~***2.54***-cm- (***0***.25-to-1-in.-) thick bed of cohesive black claystone. Because of the unique organic composition of this thin layer, Holt and Powers ***(1988)*** did not include it in the Culebra for thickness computations, and this will be factored into discussions of Culebra thickness. Based on core descriptions from the WIPP project, Holt and Powers (***CCA*** Appendix FAC) concluded that there is very little variation of depositional sedimentary features throughout the Culebra.

Vugs are an important part of Culebra porosity. They are commonly zoned parallel to bedding. In outcrop, vugs are commonly empty. In the subsurface, vugs range from open to partially filled or filled with anhydrite, gypsum, or clay (Holt and Powers 1990a, ***pp.*** 3-18 to 3-20). Lowenstein (1987, ***pp.*** 19 ***-*** 20) noted similar features. Holt and Powers (***CCA*** Appendix FAC) attributed vugs partly to syndepositional growth as nodules and partly as later replacive textures. Lowenstein (1987, ***pp.*** 29 ***-*** 31) also described textures related to later replacement and alteration of sulfates. Vug or pore fillings vary across the WIPP site and contribute to the porosity structure of the Culebra. As pointed out by Holt and Powers (see ***CCA*** Appendix FAC, Section 8.8), natural fractures filled with gypsum are common east of the WIPP site center and in a smaller area west of the site center (Figure 2-~~12~~***17***). Section 2.1.5.2 discusses Culebra fracture mechanisms. Additional discussion of Culebra fractures and their role in groundwater flow and transport is in Section 2.2.1.4.1.1, Appendix ***PA, Attachment*** MASS, Sections MASS.14.~~2~~***4*** and MASS.15.

Holt (1997) reexamined geological and hydrological data for the Culebra and developed a conceptual model for transport processes. In this document, Holt (1997) recognized several porosity types for the Culebra, and separated four Culebra units (CU) informally designated CU-1 through CU-4 from top to bottom. CU-1 differs from underlying units because it has been disrupted very little by syndepositional processes. Microvugs and interbeds provide most of the porosity, and the permeability of CU-1 is relatively limited. CU-2 and CU-3 likely contribute most of the flow in the Culebra, and the significant difference is that CU-2 includes more persistent silty dolomite interbeds. CU-2 and CU-3 include "small-scale bedding-plane fractures, networks of randomly oriented small-scale fractures and microfractures, discontinuous silty dolomite interbeds, large vugs hydraulically connected with microfractures and small-scale fractures, microvugs hydraulically connected with microfractures and intercrystalline porosity, blebs of silty dolomite interconnected with microfractures and intercrystalline porosity, and intercrystalline porosity" (Holt 1997, p. 2-19). Bedding-plane fractures dominate CU-4 at the base of the Culebra, and the unit shows some brittle deformation. CU-4 has not been isolated for hydraulic testing.

Holt (1997, p. I) also related porosity and solute transport, conceptualizing the medium "as consisting of advective porosity, where solutes are carried by the groundwater flow, and fracture-bounded zones of diffusive porosity, where solutes move through slow advection or diffusion." Holt (1997) noted that length or time scales will govern how each porosity type will contribute to solute transport.

Sewards et al. (1991, ***pp.*** IX-1) report that the Culebra is primarily dolomite with some quartz and clay. Clay minerals include corrensite, illite, serpentine, and chlorite. Clay occurs in bulk



Source: Beauheim and Holt (1990)

Figure 2-~~12~~*17*. Percentage of Natural Fractures in the Culebra Filled with Gypsum

rock and on fracture surfaces. Even though these clays occur, the conceptual model discussed in Section 6.4.6.2.1 takes no credit for their presence.

In the WIPP area, the Culebra varies in thickness. Depending on the area considered and the horizons chosen for the upper and lower boundaries of the Culebra, different data sources provide varying estimates (Table 2-3). Holt and Powers (***CCA*** Appendix FAC, ***p.*** 4-4) considered the organic-rich layer at the Culebra-Tamarisk contact separately from the Culebra in interpreting geophysical logs.

Comparing data sets, Holt and Powers (***CCA*** Appendix FAC) typically interpret the Culebra as being about 1 m (about 3 ft) thinner than do other interpretations. In general, this reflects the difference between including or excluding the unit at the Culebra-Tamarisk contact. ~~Holt and Powers~~ ***The*** isopach of the Culebra is shown as Figure 4.8 in ***CCA*** Appendix FAC.

LaVenue et al. (1988, Table B.1) calculated a mean thickness of 7.7 m~~eters~~ (25 ~~feet~~ ***ft***) for the Culebra within their model domain based on thicknesses measured in 78 boreholes. Mercer (1983, reproduced ~~here~~ as ***CCA*** Appendix HYDRO) reported a data set similar to that of LaVenue et al ~~(Table 1 of Appendix HYDRO)~~. The borehole database for the region of interest is provided in ***CCA*** Appendix BH.

The treatment of the Culebra in the conceptual model is discussed in Section 6.4.6.2 and associated parameter values in Table 6-20. A more thorough discussion of Culebra features, such as fractures, is provided in Appendix ***PA, Attachment*** MASS, Section MASS.15.

Table 2-3. Culebra Thickness Data Sets

Source	Data Set Location								
	T22S, R31E			T21-23S, R30-32E			Entire Set		
	n	ave	std dev	n	ave	std dev	n	ave	std dev
Richey (1989)	7	7.5 m	1.04 m	115	7.9 m	1.45 m	633	7.7 m	1.65 m
CCA Appendix FAC	35	6.4 m	0.59 m	122	7.0 m	1.26 m	508	6.5 m	1.89 m
LaVenue et al. (1988)							78	7.7 m	
Source	**WIPP Potash Drillholes**								
Jones (1978)				21	7.5 m	0.70 m			
CCA Appendix FAC				21	6.3 m	0.50 m			

Legend:

n number of boreholes or data points
ave average or mean
std dev standard deviation
m meters

2.1.3.5.3 The Tamarisk ***Member***

Vine (1963, B14) named the Tamarisk for outcrops near Tamarisk Flat in Nash Draw. Outcrops of the Tamarisk are distorted, and subsurface information was used to establish member characteristics. Vine reported two sulfate units separated by a siltstone, about 1.5 m (5 ft) thick, interpreted by Jones et al. in 1960 as a dissolution residue.

The Tamarisk is generally conformable with the underlying Culebra. The transition is marked by an organic-rich unit interpreted as being present over most of southeastern New Mexico. The Tamarisk around the WIPP site consists of lower and upper sulfate units separated by a unit that varies from mudstone (generally to the west) to mainly halite (to the east). Near the center of the WIPP site, the lower anhydrite was partially eroded during deposition of the middle mudstone unit, as observed in the WIPP waste-handling and exhaust shafts. The lower anhydrite was completely eroded at WIPP-19. Before shaft exposures were available, the lack of the Lower Tamarisk anhydrite at WIPP-19 was interpreted as the result of dissolution and the mudstone was considered a cave filling.

Jones ***(1978)*** interprets halite to be present east of the center of the WIPP site based on geophysical logs and drill cuttings. Based mainly on cores and cuttings records from the WIPP potash drilling program, Snyder prepared a map ~~in 1985~~ showing the halitic areas of each of the noncarbonate members of the Rustler (Snyder 1985, Figure 4). A very similar map based on geophysical log characteristics was prepared by Holt and Powers (1988).

~~Holt and Powers (~~***CCA*** Appendix FAC~~)~~ describe***s*** the mudstones and halitic facies in the middle of the Tamarisk and postulate that the unit formed in a salt-pan-to-mudflat system. ~~Holt and Powers~~ ***Powers and Holt (2000)*** cited sedimentary features and the lateral relationships as evidence of syndepositional dissolution of halite in the marginal mudflat areas. ~~In contrast, other investigators interpreted the lateral decrease in thickness and absence of halite to the west as evidence of postdepositional dissolution (see, for example, Jones et al. 1960, Jones 1978, and Snyder 1985).~~

The Tamarisk thickness varies greatly in southeastern New Mexico, principally as a function of the thickness of halite in the middle unit. Within T22S, R31E, the thickness ranges from 26 to 56 m (84 to 184 ft) for the entire Tamarisk and from 2 to 34 m (6 to 110 ft) for the interval of mudstone-halite between lower and upper anhydrites (***CCA*** Appendix FAC, Figures 4-9 and 4-11). Expanded geophysical logs with corresponding lithology illustrate some of the lateral relationships for this interval (Figure 2-~~13~~***18; see also Powers and Holt 2000).***

The Tamarisk is modeled as discussed in Section 6.4.6.3. Tamarisk parameter values are given in Appendix ***PA, Attachment*** PAR, Table PAR-~~29~~***24***.

2.1.3.5.4 The Magenta ***Dolomite Member***

Adams (1944, ***p.*** 1614) attributes the name Magenta Member to Lang, based on a feature named Magenta Point north of Laguna Grande de la Sal. According to ~~Holt and Powers~~ ***CCA*** ~~(~~Appendix FAC~~),~~ the Magenta is a gypsiferous dolomite with abundant primary sedimentary structures and well-developed algal features. It does not vary greatly in sedimentary features

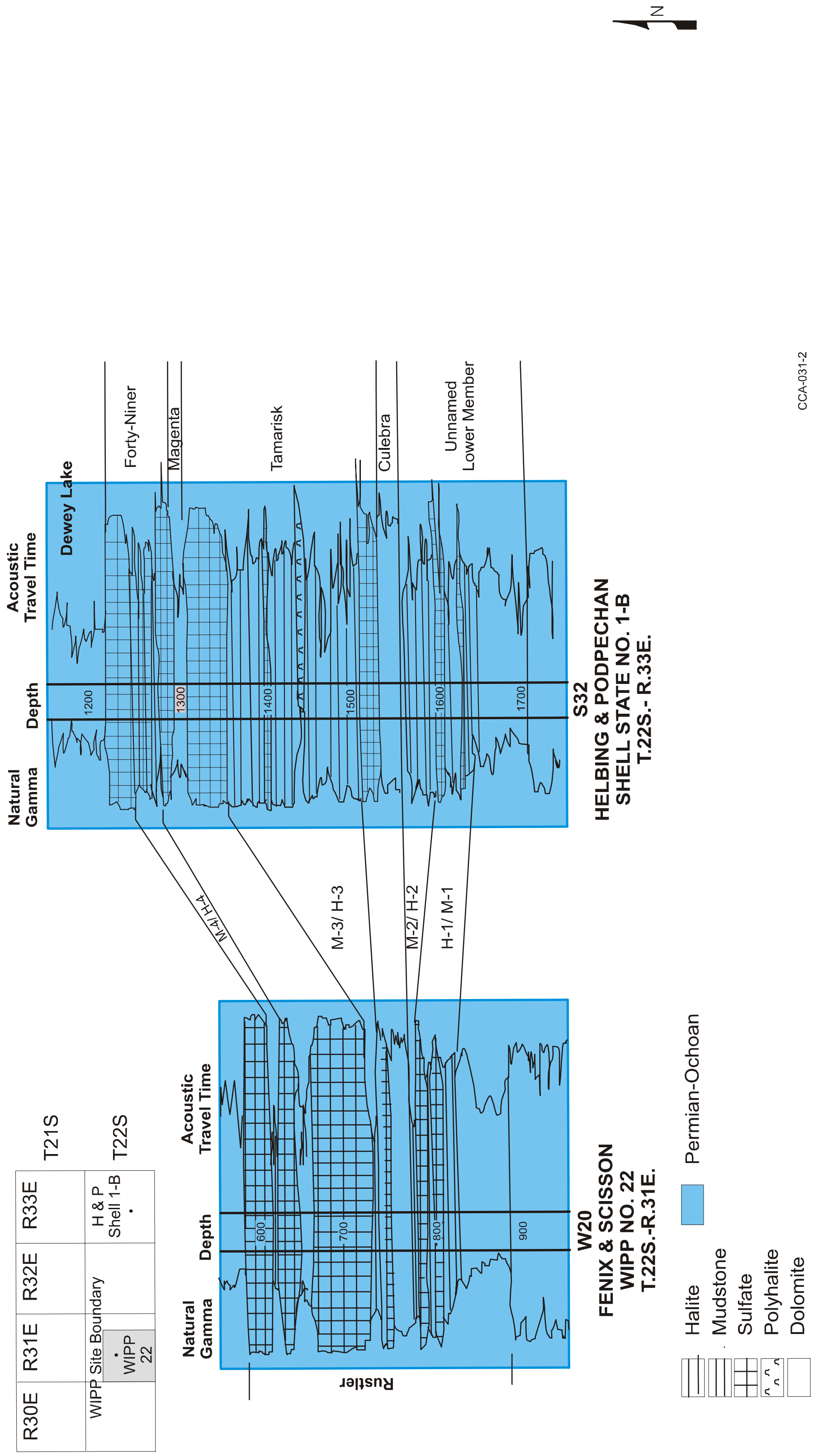


Figure 2-~~13~~*18*. Log Character of the Rustler Emphasizing Mudstone-Halite Lateral Relationships

across the site area. ~~Holt and Powers (~~*CCA* Appendix FAC, 5-22~~)~~ reported that the Magenta varies from 7.0 to 8.5 m (23 to 28 ft) around the WIPP site. ~~Holt and Powers~~ ***CCA Appendix FAC*** did not ~~prepare~~ ***include*** a regional Magenta isopach. Additional detail on the Magenta can be found in Section 4.3.2 of ***CCA*** Appendix GCR and in Sections 4.1.4, 4.2.4, and 5.4 of ***CCA*** Appendix FAC. The Magenta is included in the conceptual model as discussed in Section 6.4.6.4. Modeling values are in Table 6-24.

2.1.3.5.5 The Forty-niner ***Member***

Vine (1963) named the Forty-niner for outcrops at Forty-niner Ridge in eastern Nash Draw, but the unit is poorly exposed there. In the subsurface around the WIPP, the Forty-niner consists of basal and upper sulfates separated by a mudstone. It is conformable with the underlying Magenta. As with other members of the Rustler, geophysical log characteristics can be correlated with core and shaft descriptions to extend geological inferences across a large area ***(Holt and Powers 1988)***.

The Forty-niner varies from 13 to 23 m (43 to 77 ft) thick within T22S, R31E. East and southeast of the WIPP, the Forty-niner exceeds 24 m (80 ft), and some of the geophysical logs from this area indicate that halite is present in the beds between the sulfates. A regional isopach map of the Forty-niner is in ***CCA*** Appendix FAC (Figure 4-13). ***See also Powers and Holt (2000).***

Within the waste-handling shaft, the Forty-niner mudstone displayed sedimentary features and bedding relationships indicating sedimentary transport. ~~The mudstone has commonly been interpreted as a residue from the dissolution of halitic beds because it is thinner where there is no halite.~~ These beds are not known to have been described in detail prior to mapping in the waste-handling shaft at WIPP, and the features found there led Holt and Powers (***CCA*** Appendix FAC) to reexamine the available evidence for, and interpretations of, dissolution of halite in Rustler units.

The inclusion of the Forty-niner in the conceptual model is discussed in Section 6.4.6.5.

2.1.3.6 The Dewey Lake ~~Redbeds~~

The nomenclature for rocks included in the Dewey Lake ***Formation*** was introduced during the 1960s to clarify relationships between these rocks assigned to the Upper Permian and the Cenozoic Gatuña Formation ~~(hereafter referred to as the Gatuña)~~.

There are three main sources of data about the Dewey Lake in the area around WIPP. Miller reported the petrology of the unit in 1955 and 1966. Schiel (1988) described outcrops in the Nash Draw areas and interpreted geophysical logs of the unit in southeastern New Mexico and west Texas to infer the depositional environments and stratigraphic relationships in 1988 and 1994. Holt and Powers (1990a) were able to describe the Dewey Lake in detail at the AIS for WIPP in 1990, confirming much of Schiel's ***(1988)*** information and adding data regarding the Lower Dewey Lake.

The Dewey Lake overlies the Rustler conformably, though local examples of the contact (for example, the AIS described by Holt and Powers ~~in~~ ***(***1990a) show minor disruption by dissolution of some of the upper Rustler sulfate. The formation is predominantly reddish-brown fine sandstone to siltstone or silty claystone with greenish-gray reduction spots. Thin bedding, ripple cross-bedding, and larger channeling are common features in outcrops, and additional soft sediment deformation features and early fracturing from the lower part of the formation are described by Holt and Powers ***(1990a)***. Schiel (1988, ***p.*** 143; 1994, ***p.*** 9) attributed the Dewey Lake to deposition on "a large, arid fluvial plain subject to ephemeral flood events."

There is ~~little~~ ***no*** direct faunal or radiometric evidence of the age of the Dewey Lake ***in the vicinity of the WIPP site.*** It is assigned to the Ochoan Series***, considered historically to be*** ~~of~~ Late Permian ***in*** age, and it is regionally correlated with units of similar lithology and stratigraphic position. Schiel (1988, 1994) reviewed the limited radiometric data from lithologically similar rocks (Quartermaster Formation) and concluded that much of the unit could be Early Triassic in age. ***Renne et al. (1996) resampled tephra from the Quartermaster in the Texas panhandle area and found that radiometric data support the idea that the Quartermaster is mainly Triassic in age rather than Permian. Others have begun to infer as well that the Dewey Lake in the vicinity of the WIPP may be mostly Triassic (e.g., Powers and Holt 1999). These age relationships continue to be of academic interest because of the geologic significance of the Permo-Triassic boundary, but there is no significance for waste isolation at the WIPP.***

Near the center of the WIPP site, Holt and Powers (1990a, Figure 5) mapped 152 m (498 ft) of the Dewey Lake (Figure 2-~~14~~***19***). The formation is thicker to the east (Schiel 1994, Figure 2) of the WIPP site, in part because western areas were eroded before the overlying Triassic rocks were deposited.

The Dewey Lake contains fractures, which are filled with minerals to varying degrees. Both cements and fracture fillings have been examined and used to infer groundwater infiltration. Holt and Powers (1990a, ***pp.*** 3-10) described the Dewey Lake as cemented by carbonate above 50 m (164.5 ft) in the AIS; some fractures in the lower part of this interval were also filled with carbonate, and the entire interval surface was commonly moist. Below this point, the cement is harder ***and more commonly anhydrite (Powers 2003b)***, the shaft is dry, and fractures are filled with gypsum. ***Powers (2002c; 2003b) reports core and geophysical log data supporting these vertical changes in natural mineral cements in the Dewey Lake over a larger region at a horizon that is believed to underlie known natural groundwater occurrences in the Dewey Lake. In areas where the Dewey Lake has been exposed to weathering after erosion of the overlying Santa Rosa, this cement boundary tends to generally parallel the eroded upper surface of the Dewey Lake, suggesting that weathering has affected the location of the boundary. Where the Dewey Lake has been protected by overlying rocks of the Santa Rosa, the cement change appears to be stratigraphically controlled but the data points are too few to be certain.*** Holt and Powers (1990a, ***pp.*** 3 - 11, Figure 16) suggested that the cement change might be related to infiltration of meteoric water. They also determined that some of the gypsum-filled fractures are syndepositional. Dewey Lake fractures include horizontal to subvertical trends, some of which were mapped in detail (Holt and Powers 1986, Figures 6, 7, and 8).

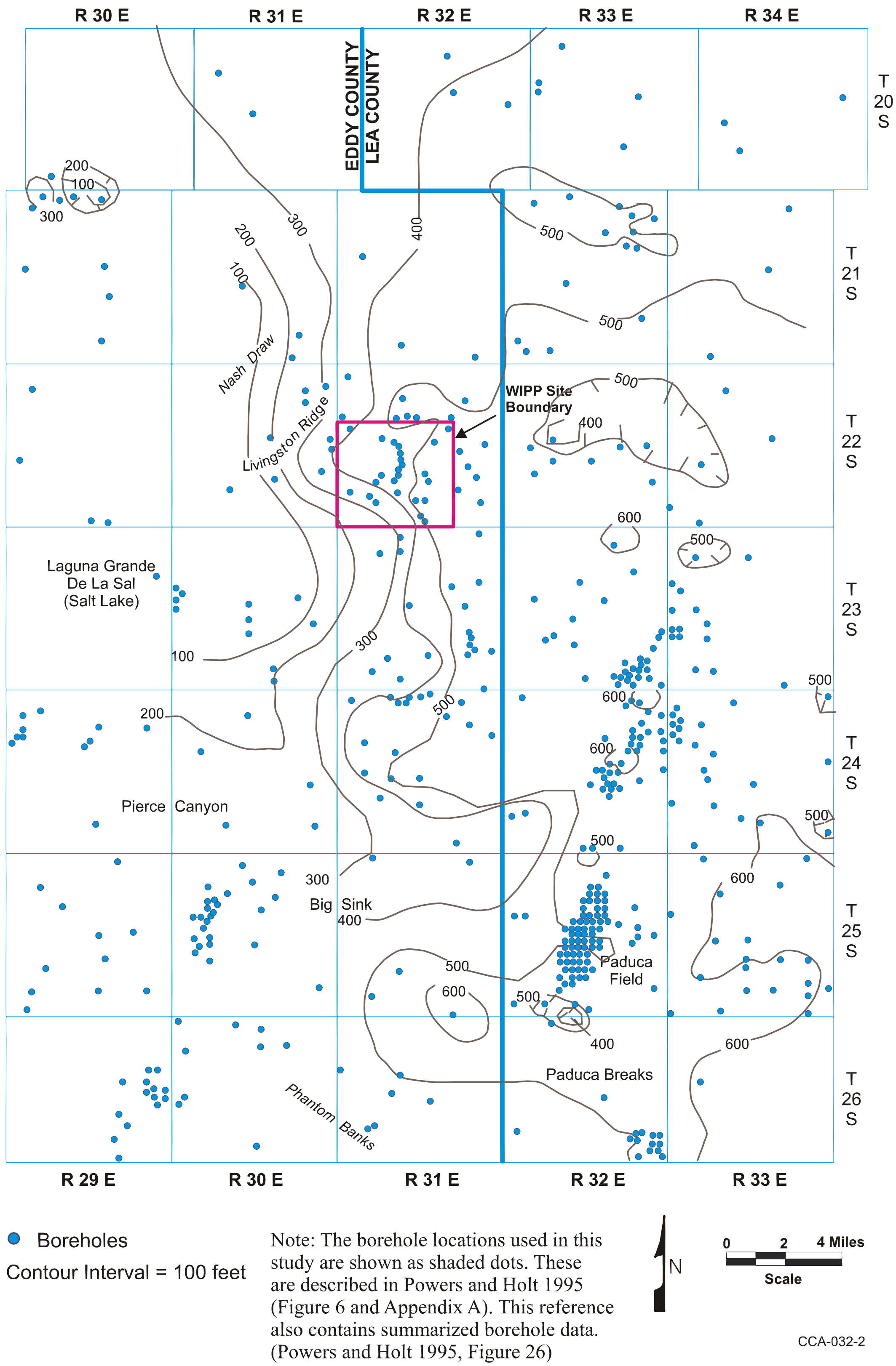


Figure 2-~~14~~*19*. Isopach of the Dewey Lake

Lambert ~~(in Siegel et al.~~ ***(***1991, ***pp.*** 5 ***-*** 65) analyzed the deuterium/hydrogen (D/H) ratios of gypsum in the Rustler and gypsum veins in the Dewey Lake. He suggest~~s~~ that none of the gypsum formed from evaporitic fluid such as Permian seawater but that the D/H ratios all show influence of meteoric water. Furthermore, Lambert (~~in Siegel et al.~~1991, 5 – 66) infers that the gypsum D/H ratio is not consistent with modern meteoric water; it may, however, be consistent with older meteoric fluids. There is no obvious correlation with depth to indicate infiltration. Strontium isotope ratios ($^{87}Sr/^{86}Sr$) indicate no intermixing or homogenization of fluids between the Rustler and the Dewey Lake, but there may have been lateral movement of water within the Dewey Lake (***Lambert*** ~~Siegel et al.~~ 1991, ***pp.*** 5 ***-*** 54). Dewey Lake carbonate-vein material shows a broader range of strontium ratios than does surface caliche, and the ratios barely overlap.

The treatment of the Dewey Lake in the conceptual model can be found in Section 6.4.6.6. Dewey Lake parameter values are in Table 6-25.

2.1.3.7 The Santa Rosa

There have been different approaches to the nomenclature of rocks of Triassic age in southeastern New Mexico. Bachman ***(1974)*** generally described the units ~~in 1974~~ as "Triassic, undivided" or as the Dockum Group, without dividing it. Vine ~~in~~ ***(***1963***)*** used "Santa Rosa Sandstone," and Santa Rosa has become common usage. Lucas and Anderson (1993a, 1993b) import other formation names that are unlikely to be useful for WIPP.

The Santa Rosa has been called disconformable over the Dewey Lake by Vine (1963, B25). These rocks have more variegated hues than the underlying uniformly colored Dewey Lake. Coarse-grained rocks, including conglomerates, are common, and the formation includes a variety of cross-bedding and sedimentary features (Lucas and Anderson 1993a, ***pp.*** 231 ***-*** 235).

Within the WIPP site boundary, the Santa Rosa is relatively thin to absent (Figure 2-~~15~~***20***). At the AIS, Holt and Powers (1990a, Figure 5) attributed about 0.6 m (2 ft) of rock to the Santa Rosa. The Santa Rosa is a maximum of 78 m (255 ft) thick in potash holes drilled for WIPP east of the site boundary. The Santa Rosa is thicker to the east. ***The geologic data from design studies (Sergent et al. 1979) were incorporated with data from drilling to investigate shallow subsurface water in the Santa Rosa to provide structure and thickness maps of the Santa Rosa in the vicinity of the WIPP surface structures area (Powers 1997). These results are consistent with the broader regional distribution of the Santa Rosa.***

The Santa Rosa and younger rocks are modeled in the WIPP ***PA*** as a single region as discussed in Section 6.4.6.7. The model parameters for this supra-Dewey Lake region are given in Table 6-26.

2.1.3.8 The Gatuña ~~Formation~~

Lang (in Robinson and Lang 1938, ***p.*** 84) named the Gatuña for outcrops in the vicinity of Gatuña Canyon in the Clayton Basin. Rocks now attributed to the Gatuña in Pierce Canyon were once included in the Pierce Canyon Formation with rocks now assigned to the Dewey Lake. The

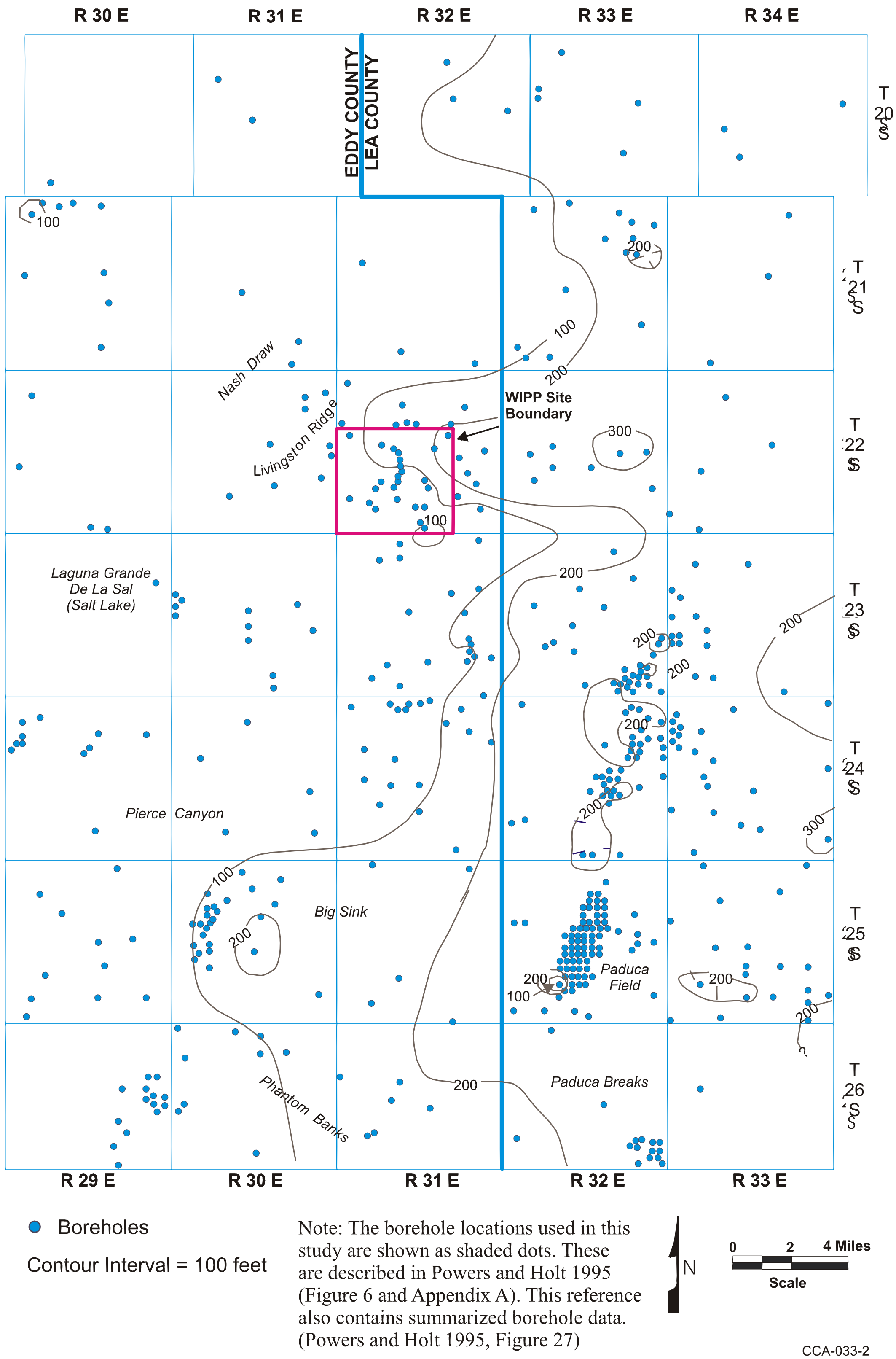


Figure 2-~~15~~*20*. Isopach of the Santa Rosa

formation has been mapped from the Santa Rosa, New Mexico, area south to the vicinity of Pecos, Texas. It is unconformable with underlying units.

Vine (1963) and Bachman (1974) provided some limited description of the Gatuña. The most comprehensive study of the Gatuña is based on WIPP investigations and landfill studies for the City of Carlsbad and Eddy County (Powers and Holt 1993). Much of the formation is colored light reddish-brown. It is broadly similar to the Dewey Lake and the Santa Rosa, though the older units have more intense hues. The formation is highly variable, ranging from coarse conglomerates to claystones with some highly gypsiferous sections. Sedimentary structures are abundant. Analysis of lithofacies indicates that the formation is dominantly fluvial in origin with areas of low-energy deposits and evaporitic minerals.

The thickness of the Gatuña is not very consistent regionally, as shown in Figure 2-~~16~~***21***. ~~Thicknesses range up to about 300 feet (91 meters) at Pierce Canyon, with thicker areas generally subparallel to the Pecos River.~~ ***The thickness of the Gatuña ranges up to 91 m (300 ft) at Pierce Canyon, with thicker areas generally subparallel to the Pecos River.*** To the east, the Gatuña is thin or absent. Holt and Powers (1990a) reported about 2.7 m (9 ft) of undisturbed Gatuña in the AIS at WIPP. ***Powers (1997) integrated data from facility design geotechnical work (Sergent et al. 1979) and drilling to investigate shallow water to develop maps of the Gatuña in the vicinity of the WIPP surface facility. These maps are consistent with the broader regional view of the distribution of the Gatuña.***

The Gatuña has been considered Pleistocene in age based on a volcanic glass in the Upper Gatuña along the eastern margin of Nash Draw that has been identified as the Lava Creek B ash, dated at 0.6 million years by Izett and Wilcox (1982). This upper-limit age is corroborated by the age determinations from the Mescalero caliche (hereafter referred to as the Mescalero) that overlies the Gatuña (see Section 2.1.3.9). An additional volcanic ash from the Gatuña in Texas yields consistent K-Ar and geochemical data, indicating that it is about 13 million years old at that location (Powers and Holt 1993, ***p.*** 271). Thus, the Gatuña ranges in age over a period of time that may be greater than that spanned by the Ogallala Formation (hereafter referred to as the Ogallala) on the High Plains east of WIPP.

2.1.3.9 Mescalero Caliche

The Mescalero caliche is an informal stratigraphic unit apparently first differentiated by Bachman in 1974, though Bachman (1973, ***p.*** 17, ***p.*** 27) described the caliche on the Mescalero Plain. He differentiated the Mescalero from the older, widespread Ogallala caliche or caprock on the basis of textures, noting that breccia and pisolitic textures are much more common in the Ogallala caliche. The Mescalero has been noted over significant areas in the Pecos drainage, including the WIPP area, and it has been formed over a variety of substrates. Bachman (1973) described the Mescalero as a two-part unit: (1) an upper dense laminar caprock and (2) a basal, earthy-to-firm, nodular calcareous deposit. Machette (1985, ***p.*** 5) classified the Mescalero as having Stage V morphologies of a calcic soil (the more mature Ogallala caprock that occurs east of the WIPP site reaches Stage VI).

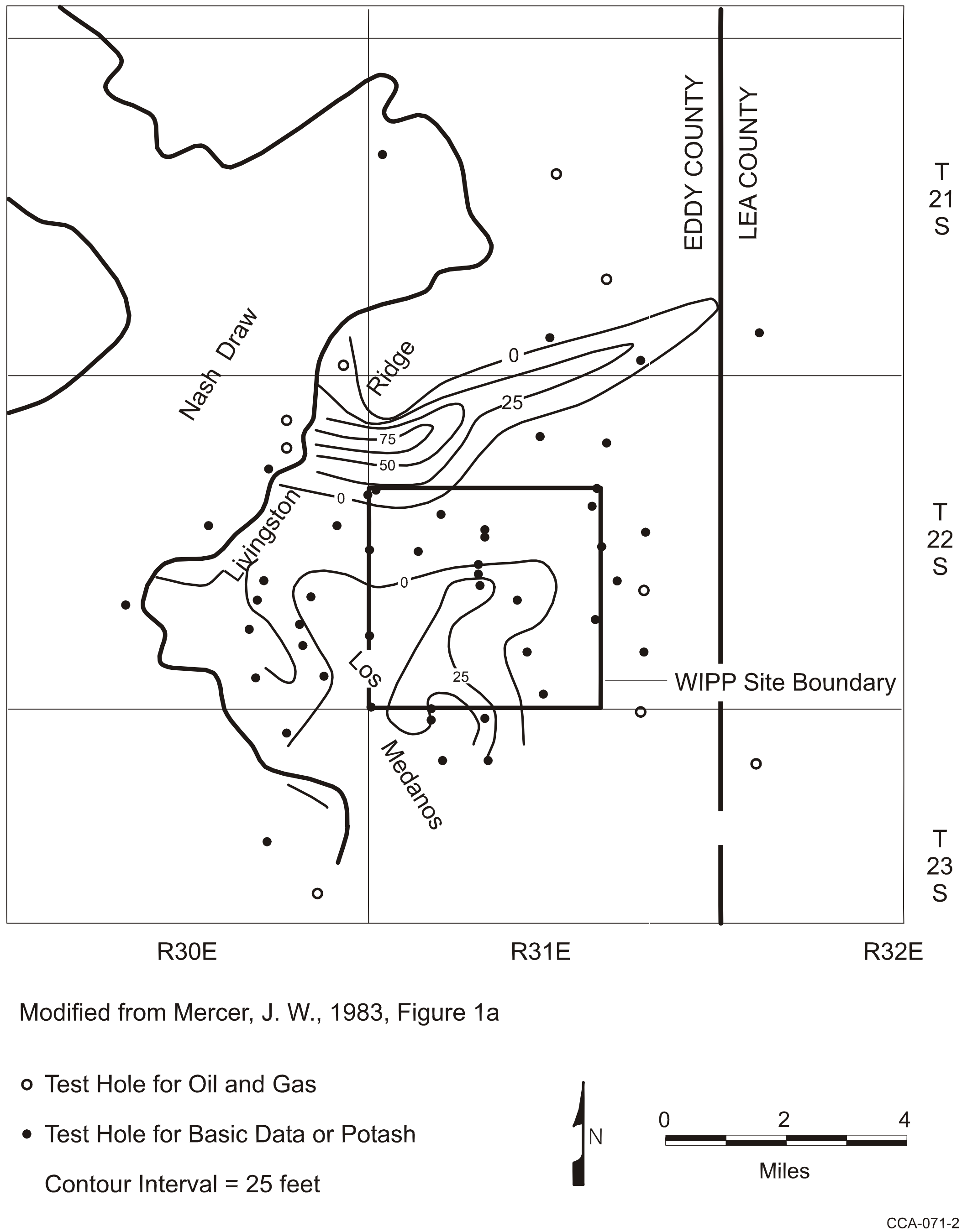


Figure 2-~~16~~*21*. Isopach of the Gatuña

Bachman (1976, Figure 8) provided structure contours on the Mescalero caliche for a large area of southeastern New Mexico, including the WIPP site. From the contours and Bachman's discussion of the Mescalero as a soil, it is clear that the Mescalero is expected to be continuous over large areas. Explicit WIPP data are limited mainly to boreholes, though some borehole reports do not mention the Mescalero. The unit may be as much as 3 m (10 ft) thick.

The Mescalero overlies the Gatuña and was interpreted by Bachman (1976) on basic stratigraphic grounds as having accumulated during the early-to-middle Pleistocene. Samples of the Mescalero from the vicinity of the WIPP were studied using uranium-trend methods.

Based on early written communication from Rosholt, Bachman (1985, ***p.*** 20) reports that the basal Mescalero began to form about 510,000 years ago and the upper part began to form about 410,000 years ago; these ages are commonly cited in WIPP literature. The samples are interpreted by Rosholt and McKinney (1980, Table 5) in the formal report as indicating ages of 570,000 ± 110,000 years for the lower part of the Mescalero and 420,000 ± 60,000 years for the upper part.

According to Bachman (1985, ***p.*** 19), where the Mescalero is flat-lying and not breached by erosion, it is an indicator of stability or integrity of the land surface over the last 500,000 years. An additional discussion of the Mescalero caliche can be found in ***CCA*** Appendix GCR, Section 4.2.2.

2.1.3.10 Surficial Sediments

Soils of the region have developed mainly from Quaternary and Permian parent material. Parent material from the Quaternary System is represented by alluvial deposits of major streams, dune sand, and other surface deposits. These are mostly loamy and sandy sediments containing some coarse fragments. Parent material from the Permian System is represented by limestone, dolomite, and gypsum bedrock. Soils of the region have developed in a semiarid, continental climate with abundant sunshine, low relative humidity, erratic and low rainfall, and a wide variation in daily and seasonal temperatures. Subsoil colors are normally light brown to reddish brown but are often mixed with lime accumulations (caliche) that result from limited, erratic rainfall and insufficient leaching.

A soil association is a landscape with a distinctive pattern of soil types (series). It normally consists of one or more major soils and at least one minor soil. There are three soil associations within 8.3 km (5 mi) of the WIPP site: the Kermit-Berino, the Simona-Pajarito, and the Pyote-Maljamar-Kermit. Of these three associations, only the Kermit-Berino soil series has been mapped across the WIPP site by Chugg et al. (1952, Sheet No. 113). These are sandy soils developed on eolian material. The Kermit-Berino soils include active dune areas. The Berino soil has a sandy A horizon; the B horizons include more argillaceous material and weak-to-moderate soil structures. A and B horizons are described as noncalcareous, and the underlying C horizon is commonly caliche. Bachman (1980, ***p.*** 44) interpreted the Berino soil as a paleosol that is a remnant B horizon of the underlying Mescalero. Rosholt and McKinney (1980, Table 5) applied uranium-trend methods to samples of the Berino soil from the WIPP site area. ~~They~~ ***Rosholt and McKinney (1980)*** interpreted the age of formation of the Berino soil as 330,000 ± 75,000 years.

Generally, the Berino Series, which covers about 50 percent of the site, consists of deep, noncalcareous, yellow-red to red sandy soils that developed from wind-worked material of mixed origin. These soils are described as undulating to hummocky and gently sloping (***zero*** to ***three*** percent slopes). The soils are the most extensive of the deep, sandy soils in the Eddy County area. Berino soils are subject to continuing wind and water erosion. If the vegetative cover is seriously depleted, the water-erosion potential is slight, but the wind-erosion potential is very high. These soils are particularly sensitive to wind erosion in the months of March, April, and May, when rainfall is minimal and winds are highest. These soil characteristics are a consideration for the design of long-term passive controls such as monuments and markers (see ***CCA*** Appendix PIC, Section III).

The Kermit Series consists of deep, light-colored, noncalcareous, excessively drained loose sands, typically yellowish-red fine sand. The surface is undulating to billowy (from 0 to 3 percent slopes) and consists mostly of stabilized sand dunes. Kermit soils are slightly to moderately eroded. Permeability is very high, and, if vegetative cover is removed, the water-erosion potential is slight, but the wind-erosion potential is very high.

Surface soils appear to play a role in the infiltration of precipitation. Mercer (***CCA*** Appendix HYDRO) points out that where surface deposits are thickest, they may contain localized perched zones of groundwater. A more thorough discussion of this topic can be found in ***CCA*** Appendix HYDRO.

2.1.3.11 Summary

The stratigraphy and lithology at the WIPP site has been summarized from the lowermost pre-Cambrian units to the surface soils. While these are important for an understanding of the site and its stability, not all of these units are important to the performance of the disposal system. As a result, the DOE has developed a conceptual model that describes the lithology as ***13*** discrete model regions ranging from the Castile to a region that generally includes units above the Dewey Lake. In this model, emphasis is placed on the Castile, the Salado, the five members of the Rustler, the Dewey Lake, and the supra-Dewey Lake units. The Salado is divided into five stratigraphic units to capture the variations in properties near the horizon of the repository (see ~~Section 6.4.2.1~~***Figure 6-14***). The identification and definition of the appropriate modeling units is based on the identification of FEPs that can impact the performance of the disposal system. Details of the conceptual model can be found in Section 6.4.2.

2.1.4 Physiography and Geomorphology

In this section, the DOE presents a discussion of the physiography and geomorphology of the WIPP site and surrounding area. This information is taken from DOE 1980 (***pp.*** 7-21 to 7-23). Geomorphology and physiography are determined by the DOE ***(1980)*** to be features that are potentially important to disposal system performance. They are included in the consequence analysis through consideration of the topography and its influence on the regional water table. (See discussion of regional water table characteristics in Section 2.2.1.) Consequently, topographic information is presented in this section. In addition, several geomorphological processes have been screened out on the basis of either low consequence or low probability, as discussed in Appendix ***PA, Attachment*** SCR. These include weathering, erosion, sedimentation, and soil development. Information is presented in this section to support this screening. In order to perform this screening, such factors as slopes, proximity to watercourses, dissection, and historic and existing processes are important. These are presented in this section in terms of the regional and local physiographic and geomorphological characteristics. Tectonic processes that may alter the physiography of the region or site area are discussed in Section 2.1.5. In addition, Section 2.1.6 presents more specific details on nontectonic processes identified during site characterization as having the potential for affecting the repository over the longer term and as requiring detailed investigation. These include halite deformation and dissolution.

2.1.4.1 Regional Physiography and Geomorphology

The WIPP site is in the Pecos Valley section of the southern Great Plains physiographic province (Figure 2-~~17~~***22***), a broad, highland belt sloping gently eastward from the Rocky Mountains and the Basin and Range Province to the Central Lowlands Province. The Pecos Valley section itself is dominated by the Pecos River Valley, a long north-south trough that is from 8.3 to 50 km (5 to 30 mi) wide and as much as 305 m (1,000 ft) deep in the north. The Pecos River System has evolved from the south, cutting headward through the Ogallala sediments and becoming entrenched some time after the Middle Pleistocene. It receives almost all the surface and subsurface drainage of the region; most of its tributaries are intermittent because of the semiarid climate. The surface locally has a karst terrain containing sinkholes, dolines, and solution-subsidence troughs from both surface erosion and subsurface dissolution. The valley has an uneven rock- and alluvium-covered floor with widespread solution-subsidence features, the result of dissolution in the underlying Upper Permian rocks. The terrain varies from plains and lowlands to rugged canyonlands, and contains such erosional features as scarps, cuestas, terraces, and mesas. The surface slopes gently eastward, reflecting the underlying rock strata. Elevations vary from more than 1,829 m (6,000 ft) in the northwest to about 610 m (2,000 ft) in the south.

The Pecos Valley section is bordered on the east by the virtually uneroded plain of the Llano Estacado. The Llano Estacado is part of the High Plains section of the Great Plains physiographic province and is a poorly drained eastward-sloping surface covered by gravels, wind-blown sand, and caliche that has developed since early-to-middle Pleistocene time. Few and minor topographic features are present in the High Plains section, formed when more than 152 m (500 ft) of Tertiary silts, gravels, and sands were laid down in alluvial fans by streams draining the Rocky Mountains. In many areas, the nearly flat surface is cemented by a hard caliche layer.

To the west of the Pecos Valley section are the Sacramento Mountains and the Guadalupe Mountains, part of the Sacramento section of the Basin and Range Province. The Capitan escarpment along the southeastern side of the Guadalupe Mountains marks the boundary between the Basin and Range and the Great Plains provinces. The Sacramento section has large basinal areas and a series of intervening mountain ranges (DOE 1980).

2.1.4.2 Site Physiography and Geomorphology

The land surface in the area of the WIPP site is a semiarid, wind-blown plain sloping gently to the west and southwest, and is hummocky with sand ridges and dunes. A hard caliche layer (Mescalero rocks) is typically present beneath the sand blanket and on the surface of the underlying Gatuña. Figure 2-~~18~~***23*** is a topographic map of the area. ~~Detailed topographic maps are attached at the end of this volume.~~ Elevations at the site range from 1,088 m (3,570 ft) in the east to 990 m (3,250 ft) in the west. The average east-to-west slope is 9.4 m~~eters~~ per kilometer (50 ft/mi).

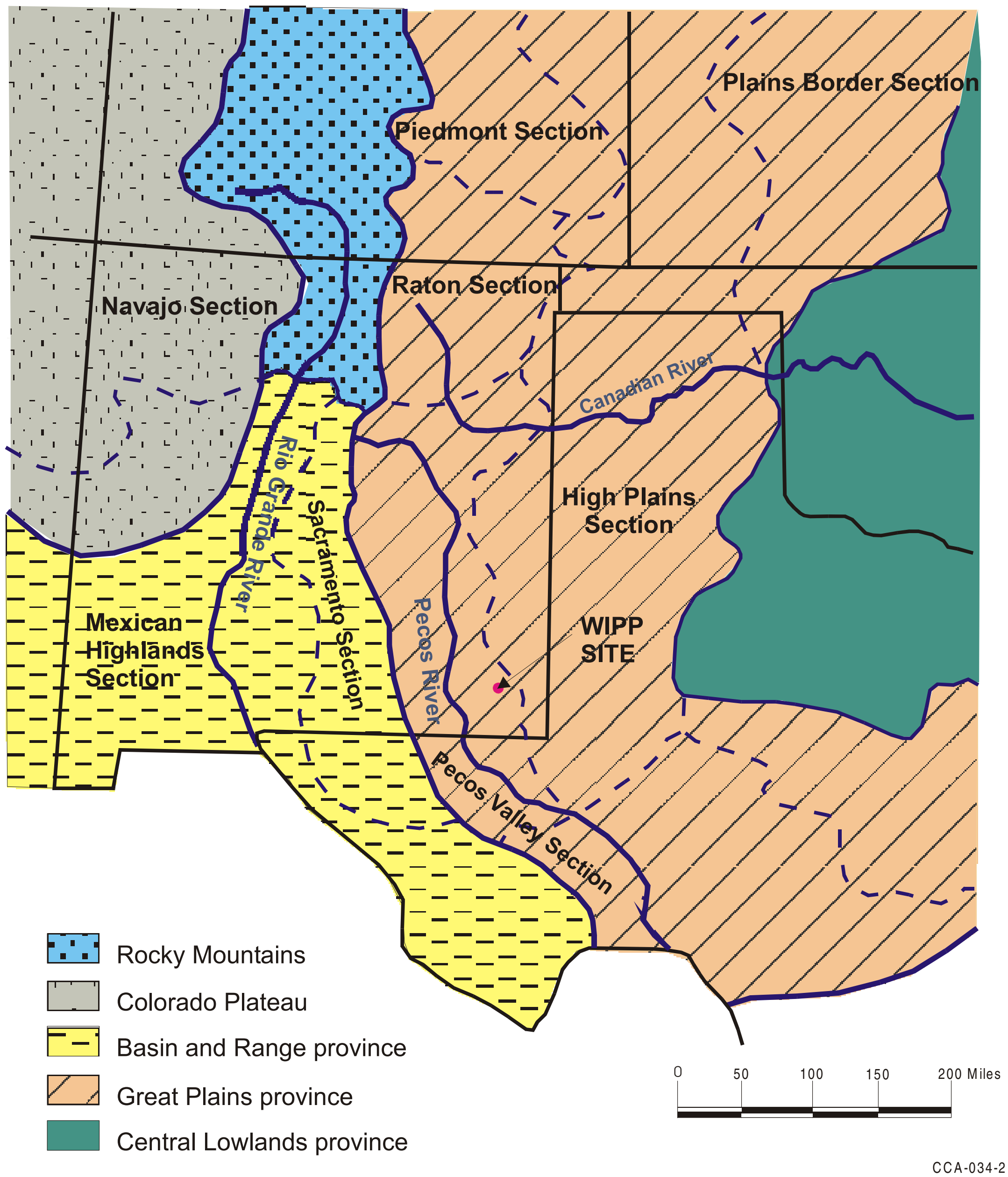


Figure 2-~~17~~*22*. Physiographic Provinces and Sections

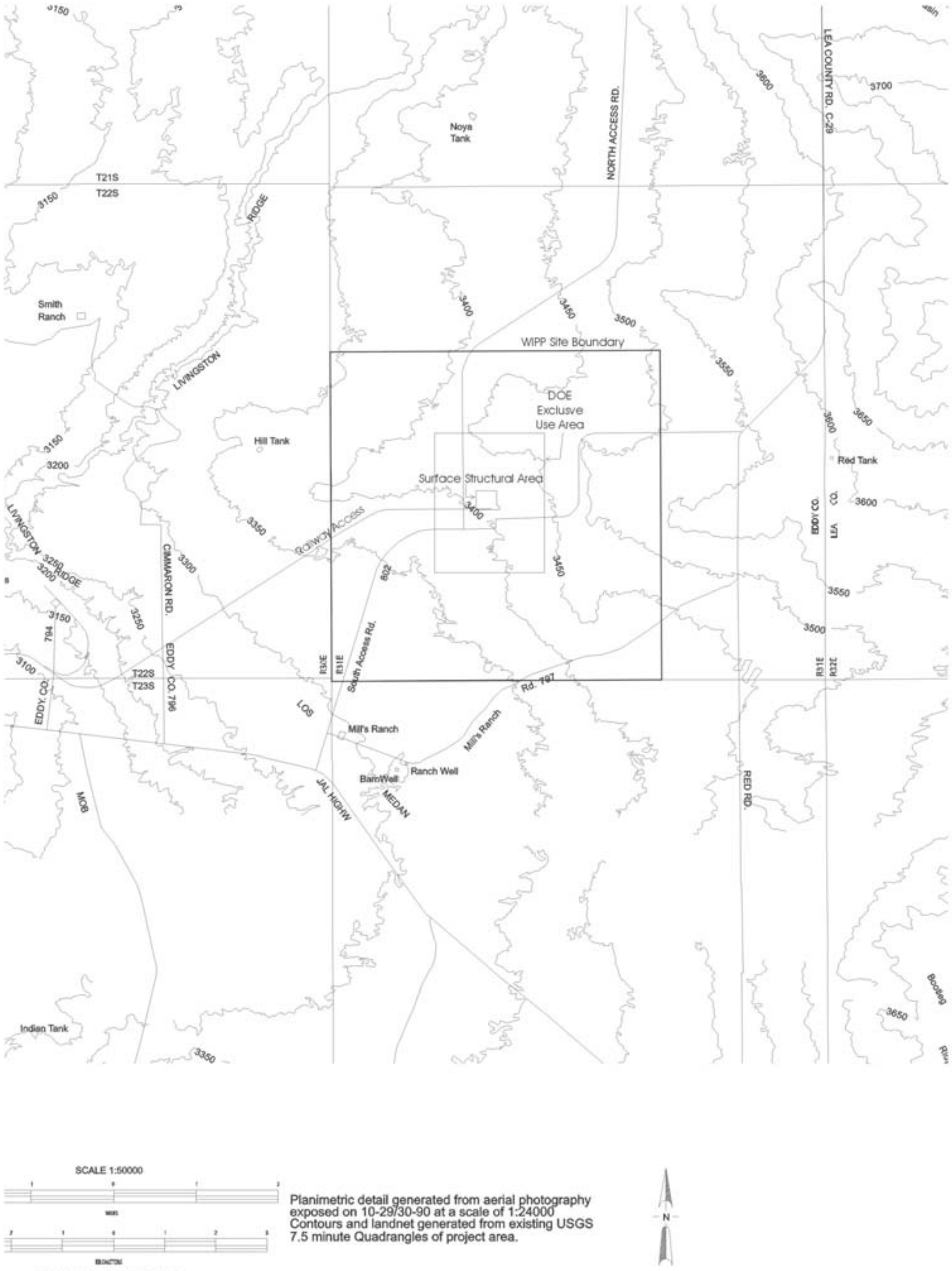


Figure 2-*23*~~25.~~ ***Topographic Map of the Area Around the WIPP Site***