MONTGOMERY WATSON
Mining Group

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February 5, 2000 (Via: FedEx)

New Mexico Environmental Department (NMED)
Hazardous and Radioactive Materials Bureau
2044 Galisteo
P.O. Box 26110
Sante Fe, New Mexico 87502

Attn: Ms. Stephanie Kruse

Re: Revised Draft of Section 3
Triassic Park Waste Disposal Facility - Part B Permit Application
Gandy Marley Inc. (GMI)

Dear Ms. Kruse:

Attached is a hard copy of revised Section 3. This section address comments we received from NMED after we incorporated our responses to the RSI request and the approved Groundwater Monitoring Waiver Request. We understand that after you have reviewed these sections, we will submit electronic copies that will be incorporated into your permit modules. A draft of the Vadose Zone Monitoring Plan that is referenced in Section 3 will be submitted during the week of February 6, 2000.

If you have any questions or require any additional information, please contact the undersigned or Mr. Dale Gandy.

Sincerely,

Montgomery Watson

Patrick Corser, P.E.
Principal

cc: Dale Gandy - GMI
Jim Bonner – InfiMedia
Steve Pullen – NMED
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3.0 GROUNDWATER PROTECTION

Section 3.0 presents historical and acquired field data, which demonstrate that the proposed landfill at the Facility will not impact groundwater resources. The EPA's RCRA Groundwater Monitoring Technical Enforcement Guidance Document was used in the preparation of this material.

The proposed Facility is located in a remote portion of eastern Chaves County, New Mexico, 36 miles from the city of Tatum (see Figure 3-1). Section 3.1, Geographical Setting and Topography, describes the favorable physical attributes of the proposed site location.

Climatic conditions, which are favorable for the efficient and environmentally safe operations of the proposed landfill and the ability to provide long-term isolation of hazardous waste, are described in Section 3.2. Data in this section were obtained from the National Oceanic and Atmospheric Administration's (NOAA's) recording station at Roswell, New Mexico.

Section 3.3, Soils and Land Use, describes soils, ranching, and other land uses in the area surrounding the proposed site. This section shows that the proposed hazardous waste disposal activities should have no impact on the existing occupational or recreational use of the surrounding land.

The regional and local geologic setting of the proposed landfill site is detailed in Section 3.4. Sediments of the Dockum Group of Triassic age are proposed as host rocks for this Facility. These unsaturated and low permeability sediments represent a stable geologic barrier to potential migration of contaminants from the proposed site.

Section 3.5, Surface Water, describes surface waters at the proposed site.

Regional and local aquifers are described in Section 3.6. This section documents the lack of groundwater present in the proposed Triassic host rocks.

Section 3.7, Groundwater Protection Requirements summarizes the results of the Facility's Groundwater Monitoring Waiver.

Section 3.8, Summary and Conclusions, summarizes the detailed technical data, which demonstrate that the proposed Facility is situated in a hydrologic setting that will assure long-term isolation of hazardous wastes from the environment. Technical data to support this conclusion are contained in the appendices included with this application in Volume II.

3.1 GEOGRAPHICAL SETTING AND TOPOGRAPHY

The proposed site is located in a remote portion of eastern Chaves County in New Mexico. The proposed Facility area is located in the eastern half of Section 18 and western half of Section 17, T11S, R31E, encompassing 480 acres.

This site is approximately 4 miles south of U.S. Highway 380, which provides the main access to the property. Roswell, New Mexico is approximately 43 miles west of the proposed site, and Tatum, New Mexico is approximately 36 miles to the east. Other New Mexico communities in the region include Lovington (42 miles to the southeast) and Artesia (50 miles to the southwest).

3.1.1 Physiographic Setting

The proposed site lies within a region of transition between the northern extension of the Chihuahuan Desert and the Southern High Plains. The Caprock escarpment, located approximately 2 miles east of the proposed site, delineates the western boundary of the Southern High Plains province, which, in west Texas and eastern New Mexico, is known as the Llano Estacado. The Llano Estacado is a flat-lying elevated plain, whose grass-covered surface is remarkably different from the wind-blown, sandy desert environment to the west.

3.1.2 Topography

The proposed site is located on the far eastern flank of the Pecos River Basin. The land surface gently slopes to the west at approximately 40 to 50 feet per mile toward the river. This sloping plain is characterized by low-relief hummocky wind-blown deposits, sand ridges, and dunes. The average elevation above sea level of the proposed site is 4,150 feet.

The Caprock escarpment (or Mescalero Rim) is one of the most prominent topographic features in southeastern New Mexico. East of the proposed site, the escarpment has approximately 200 feet of relief. On top of the Caprock, the land surface consists of low-relief undulating plains.

Figure 3-2 contains a portion of the USGS topographic map coverage of the proposed site. The Caprock escarpment is well illustrated in the southeastern corner of the mapped area. The proposed site and surrounding area are covered by two USGS 7½° quadrangle maps: Mescalero Point and Mescalero Point NE.

3.2 CLIMATE

The information used to evaluate the climate of the project area was obtained from climatological data summaries from the Class A recording station in Roswell, New Mexico. This recording station is part of the National Climatic Center of NOAA. The local climatological data summaries provided extreme and normal values of the meteorological parameters (for the period of record at the Roswell Municipal Airport and more recent data from the Roswell Industrial Air Center) that were used to characterize the area's climate.

The climate of the region is semiarid, with generally mild temperatures, low precipitation and humidity, and a high evaporation rate. Winds are most commonly from the south and moderate. During the winter, the weather is dominated by a high-pressure system often situated in the central portion of the western United States and a low-pressure system commonly located in north-central Mexico. During the summer, the region is affected by a low-pressure system normally situated over Arizona.

3.2.1 Temperatures

Moderate temperatures are typical throughout the year, although seasonal changes are distinct. Mean annual temperatures in southeastern New Mexico are near 60°F (Eagleman, 1976). Temperatures in December through February show a large diurnal variation, averaging 36°F at Roswell. On approximately 75 percent of winter mornings, temperatures are below freezing, and afternoon maximum temperatures average in the high fifties. Afternoon winter temperatures of 70°F or more are not uncommon. Nighttime lows average near 23°F, occasionally dipping as low as 14°F. Generally, there are only two or three winter days when the temperature fails to rise above freezing.

Table 3-1 shows the average monthly and average daily maximum/minimum temperatures recorded for Roswell for a typical year.

3.2.2 Precipitation

Precipitation is light and unevenly distributed throughout the year and averages 10 to 13 inches. Winter is the season of least precipitation, averaging less than 0.6 inch of rainfall per month. Snow averages about 5 inches per year at the site and seldom remains on the ground for more than a day because of the typically above-freezing temperatures in the afternoon. Approximately half the annual precipitation comes from frequent thunderstorms in June through September. Rains are usually brief but occasionally intense when moisture from the Gulf of Mexico spreads over the region.

Precipitation for the project area varies greatly from year to year. For example, Roswell's record low annual precipitation is 4.35 inches. The maximum 24-hour rainfall was 5.65 inches in October 1901. The record annual high is 32.92 inches. Most years are either "wet" or "dry"; few are "average." An average precipitation rate for Roswell, for a 107-year period from 1878 to 1982, is 10.61 inches per year. Table 3-2 shows monthly precipitation rates for the Roswell area for a five-year period and compares annual rates to the average precipitation.

3.2.3 Wind

Prevailing winds are from the south, with a normal mean wind speed at Roswell of 9.6 mph. An annual wind rose for a four-year period is shown in Figure 3-3. This wind rose shows the predominant southerly winds occurring 14 percent of the time.

3.3 SOILS AND LAND USE

The proposed site is located in a rural portion of Chaves County, New Mexico. This section describes soil profiles of the land surface in this area, existing vegetation, and the current land usage.

3.3.1 Soil Profiles

Information on soil profiles at the proposed site has been obtained from the National Cooperative Soil Survey. This survey covers Chaves County and was made cooperatively by the Soil Conservation Service, the BLM, and the New Mexico Agricultural Experiment Station.

There are two types of soils present on the proposed site. The Roswell-Faskin-Jalmar Association is present on the sandy slopes throughout the property. The Alama Series is restricted to topographically lower drainage areas and is associated with flood plain deposits.

3.3.1.1 Roswell-Faskin-Jalmar Association

This association consists of excessively drained and well-drained soils with slopes of 0 to 15%. The association is about 40% Roswell soils, 25% Faskin soils, 15% Jalmar soils, and the remainder being a mixture of various soil types. The soils of this association are used for grazing and wildlife habitat. Vegetation is mainly sand dropseed, little bluestem, sand bluestem, sandbur, three-awn, shinnery oak, yucca, and sand sagebrush. Elevation ranges from 3,500 to 4,100 feet. The frost-free season ranges from 190-205 days per year.

Roswell soils are deep, gently undulating to rolling, and rapidly permeable. They are found in hummocky or billowy areas of deep sands. They consist of a surface layer of light brown fine sand. The underlying material is pink fine sand.

Faskin soils are deep, level to nearly level, and moderately permeable. They are intermingled with Roswell soils in depressions. They have a surface layer of brown and strong brown fine sand and loamy fine sand. The subsoil is yellowish red sandy clay loam and reddish brown clay loam.

Jalmar soils are deep, evenly deposited, and moderately permeable. They are intermingled with Roswell soils in depressions. They consist of a surface layer of brown, reddish yellow, and yellowish red fine sand and loamy fine sand. The subsoil is light reddish brown, heavy loamy fine sand, and sandy clay loam.

3.3.1.2 Alama Series

The Alama Series consists of deep, well-drained soils formed in alluvium on flood plains. Slopes are 1% to 3%. Elevation is 3,400 to 3,600 feet. These soils are used for grazing, watershed, and wildlife habitat. Vegetation is mainly tobosa, buffalo grass, vine-mesquite, mesquite, and cactus. The frost-free season ranges from 200-215 days per year.

In a representative profile, the surface layer of these soils is brown loam about 3 inches thick. The subsoil is reddish brown clay loam and silty clay loam about 16 inches thick. The substratum is stratified reddish brown and light reddish brown sandy clay loam, silty clay loam, and loam to a depth of 69 inches or more. The soil profile is strongly calcareous and moderately alkaline throughout.

Permeability is moderately slow, and available water capacity is 11 to 12 inches. Effective rooting depth is 69 inches or more.

3.3.2 Land Ownership and Use

The property for the proposed site is owned by Marley Ranches, Ltd. Adjacent lands are both federally and privately owned. Generally, lands to the west are owned by the BLM, and lands to the east are privately owned.

The predominant land use in this area is grazing. With existing vegetation, approximately one section of land is required to sustain five animal units year-long. Intermittently, the land is the site of exploratory drilling for gas and oil wells, but there are no abandoned well sites within the proposed Facility boundary, and the nearest production well is approximately 3 miles from the proposed site.

The BLM has developed a recreation area known as Mescalero Sands approximately 2 miles northwest of the proposed site. The recreation area allows hikers and recreational vehicles in the sand dunes.

3.4 GEOLOGY

This section describes the regional and geologic setting of the proposed landfill.

3.4.1 Regional Geology

The geologic formations present within the region range in age from Quaternary through Triassic. Those include Quaternary alluvium, Tertiary Ogallala Formation, and the Triassic Dockum Group. Permian sediments do not outcrop in this region but, because they underlie the proposed host sediments, they are also discussed in this section.

3.4.1.1 Regional Stratigraphy

The stratigraphic relationship of the formations discussed in this section is illustrated in Figure 3-4. Information concerning formation tops and thicknesses was obtained from well logs from the New Mexico OCD office in Hobbs, New Mexico. Appendix B presented in Volume II contains a representative oil well log.

Quaternary

The surface throughout the project area is covered by alluvial deposits of Quaternary age. These deposits are comprised of fine-grained, red-brown sands, interbedded with red-brown silts and clays. A major source of these sediments was the topographically higher Ogallala Formation, as evidenced by the abundant granitic cobbles, chert pebbles, and fragments of petrified wood found throughout this unit. The thickness of these alluvial deposits along the eastern flank of the Pecos River Basin in Chaves County varies from a few feet to as much as 50 feet.

Tertiary

The "Caprock," which is the surface expression of the Tertiary Ogallala Formation, unconformably overlies Triassic sediments in southeastern New Mexico. This flat-lying sandstone and conglomeritic unit is approximately 300 to 400 feet thick. It consists of fluviatile sand, silt, clay, and gravel capped by caliche. The sand deposits of the Ogallala Formation consist of fine- to medium-grained quartz grains, which are silty and calcareous. Bedding features range from indistinctly bedded to massive to crossbedded. The formation varies from unconsolidated to weakly cohesive and contains local quartzite lenses. The sand intervals of the Ogallala Formation occur in various shades of gray and red.

Ogallala Formation silt and clay deposits are reddish brown, dusky red, and pink and contain caliche nodules. Gravels occur as basal conglomerates in intra-formational channel deposits and consist primarily of quartz, quartzite, sandstone, limestone, chert, igneous rock, and metamorphic rock. There are abundant petrified wood fragments throughout this unit.

Triassic

Triassic sediments are the potential host rocks for the proposed Facility and, as such, are described in more detail than the other formations. The Depositional Framework of the Lower Dockum Group (Triassic), Texas Bureau of Economic Geology, No. 97, 1979, by McGowen was used as a major reference for gathering information on the characteristics of Triassic sediments.

Triassic sediments unconformably overlie Permian sequences in Texas and New Mexico and have been classified as the Triassic Dockum Group. The Dockum Group is comprised of a complexly interrelated series of fluvial and lacustrine mudstone, siltstone, sandstone, and silty dolomite deposits that can be as much as 2,000 feet thick in this part of the Permian Basin. These sediments accumulated in a variety of continental depositional settings, including braided and meandering streams, alluvial fan deltas, lacustrine deltas, lacustrine systems, and mud flats.

The Triassic Dockum Group is divided into an Upper and Lower Unit. The Upper Dockum Unit is very near the surface within the project boundary, covered only by a thin veneer of Quaternary sediments. The character of this unit, also know as the Chinle Formation, is a series of fluvial sediments. These sediments conformably overlie the Lower Dockum Unit and consist of red-green micaceous mudstones, interbedded with thin, discontinuous lenses of siltstone and silty sandstones. A continental fluvial depositional environment predominated during Upper Dockum time, when the Triassic basin was filled with lacustrine sediments. The Chinle Formation is widespread in the southwestern United States.

The Lower Dockum accumulated in a fluvial lacustrine basin defined by the Amarillo Uplift on the north and the Glass Mountains on the south (Figure 3-5). As presented in this basin map, the Lower Dockum represents sediments from a large, regional depositional system. For any given portion of this basin, these sediments tend to be very homogeneous and not subject to abrupt local changes.

This basin was peripherally filled, receiving sediment from the east, south, and west. Chief sediment sources were Paleozoic sedimentary rocks. Lowlands to the east and west were traversed chiefly by meandering streams. Higher gradient streams with flashy discharge existed at northern and southern ends of the basin. The large shallow lake (or lakes) was the last portion of the basin to be filled. The lacustrine sediments that accumulated here consist primarily of low-energy mudstone.

The proposed site, situated on the western flank of the Triassic paleobasin, is underlain by thick sequences of Lower Dockum mudstones. In Triassic times this area was dominated by meandering streams. The former tectonic belts were more than 200 miles away, and the regional slopes were relatively low. Surface exposures today in these areas consist of thick sequences of maroon-red-purple variegated mudstones with thin discontinuous layers of siltstones and silty sandstones.

The stratigraphy of Lower Dockum sediments in east-central New Mexico is significantly different from that of the proposed site. Figure 3-6, a subsurface sand percent map of this unit, was compiled from drill hole data from more than 1,500 oil wells throughout the basin. Thick sequences of sandstones at the northern and southern portions of the basin are shown projecting inward toward the center of the basin. In the New Mexico portion of this basin, these sand accumulations are related to the occurrence of the Santa Rosa Sandstones. This medium-to-coarse grained, white to buff sandstone represents the lowermost Triassic depositional unit and is a major aquifer in this portion of New Mexico.

Figure 3-6 illustrates a great accumulation of Santa Rosa Sands filling the northern portion of the Triassic paleobasin. During the Lower Dockum time, the Facility site was part of a low-relief area with very little of this luvial deposition. The McGowen report specifies sand percentages of the Lower Dockum group in the Facility site area to be in the 10-20% range. This is consistent with data gathered from the two deeper drill holes completed north and south of the site boundary. The basal sand unit in the Lower Dockum below the site, is characteristically different from but depositionally related to the Santa Rosa Sandstone.

Permian

Permian sediments are important to the geologic setting because they are immediately below the proposed Triassic host rocks. The deeper formations of Permian age were deposited in a restricted-marine environment and thus contain salt deposits, which make the groundwater produced from them too brackish for use.

Permian sediments underlying the Triassic units in the project area are assigned to the Artesia Group. Oil well logs from the New Mexico OCD in Hobbs, New Mexico, have provided sufficient data to identify the Dewey Lake Formation, Rustler Formation, and Yates Formation from the upper portion of this group. Geologic literature describes these Permian sediments to be gently dipping to the east. This fact was confirmed by using oil well log data to construct a graphic 3-point solution, as shown in Figure 3-7. Using the top of the anhydrite (Rustler) as a marker bed, the following simple calculations were made:

Known Point Elevations of Marker Bed

A = Lowest elevation - 2,975 feet
C = Highest elevation - 3,148 feet
B = Middle elevation - 3,091 feet

Strike Determination

Strike is defined as the direction of a horizontal line along the bedding plane and is calculated as follows:

D = point along AC with the same elevation as B (BD is strike)

$$AD = AC \times \frac{\text{difference in elevation between A and B}}{\text{difference in elevation between A and C}}$$

$$AD = 18{,}500 \text{ ft} \times \frac{3091 - 2975}{3148 - 2975} = 12{,}405 \text{ ft}$$

$$CD = 18{,}500 \text{ ft} - 12{,}405 \text{ ft} = 6{,}095 \text{ ft}$$

BD = direction of strike = N6°E

Dip Determination

Dip is defined as the angle of the bedding plane measured from a horizontal line perpendicular to the strike and is calculated as follows:

E = point along strike, therefore, E(elevation) = B(elevation)

$$\text{Tangent of dip angle} = \frac{\text{E(elevation) - A(elevation)}}{\text{AE}}$$

$$\text{Tangent of dip angle} = \frac{3091 \text{ ft} - 2975 \text{ ft}}{7520 \text{ ft}} = \frac{116 \text{ ft}}{7520 \text{ ft}} = .015$$

$$\text{Dip angle} = \text{Tangent}^{-1}(.015)$$

Dip angle = 0°52'

These calculations indicate a north-south strike and a dip of less than 1° to the east. These results are consistent with the reported regional dip for Permian (and Triassic) sediments along the western flank of the Permian Basin.

Dewey Lake Formation—The uppermost Permian sediments underlying the Triassic sequence in the project area correlate to the Dewey Lake Formation. These sediments are predominately red to red-brown mudstones and siltstones and are virtually indistinguishable from the overlying Triassic sediments. Geologic literature reports a conformable relationship between these sediments and the overlying Triassic sediments. There are approximately 240 feet of Permian redbeds in this section.

Rustler Formation—The top of the Rustler Formation was identified on OCD well logs and corresponds to the top of a 40-foot bed of anhydrite. These anhydrites are visible in outcrop on the hills immediately east of the Pecos River drainage east of Roswell, New Mexico. Underlying the anhydrite are approximately 500 feet of halite (salt). The Rustler Formation represents the youngest anhydrite sequence in the Permian Basin.

Yates Formation—Unconformably underlying the Rustler, the Yates Formation is composed primarily of interbedded sandstone with minor dolostone and limestone. The sands are light gray and fine to very fine grained. Limestone is white to very light gray microcrystalline lime mudstone with a chalky texture. Dolostone is pink to light gray and microcrystalline.

3.4.1.2 Regional Structure

The tectonic setting and seismic activity are discussed in this section.

Tectonic Setting

The proposed Facility site is located on the western flank of the Permian Basin of west Texas. Because of the distance from tectonic centers and the minimal seismic activity, this is considered one of the more geologically stable regions within the United States.

The region underwent intense deformation, however, during late Paleozoic times. As shown in Figure 3-5, major uplifting occurred along the Ouachita Tectonic Belt and the Wichita System of Texas and Oklahoma. The Sacramento and Sangre de Cristo uplifts in northeastern New Mexico were also active during late Paleozoic time. The overall structural configuration of the Permian Basin was established at this time.

This period of intense deformation was followed by a long period of gradual subsidence. The sea covered the region, and throughout the remainder of Permian era, the Permian Basin was slowly filled with several thousand feet of evaporites, carbonates, and shales. As discussed in Section 3.4.1.1, non-marine deposition began in Triassic time with the accumulation of lacustrine/fluvial sediments into a large shallow lake.

During the late Cretaceous to early Tertiary Laramide Orogeny, there was renewed uplifting along the Sacramento, Sangre de Cristo, and other ranges within the Rocky Mountains. This orogeny uplifted the region to its present position and supplied sediments for the Tertiary Ogallala Formation.

Seismic Activity

The Permian Basin is an area of moderate to low seismic activity. Data obtained from the National Geophysical Data Center of NOAA indicate a total of 102 observed earthquakes within a 250-km (155-mile) radius of the proposed site. These data reflect observations made from 1930 to 1993.

As shown in Figure 3-8, there were no recorded earthquakes with a magnitude greater than 3.9 within 70 miles of the proposed site and no recorded seismic activity within a radius of 45 miles. The distance from any tectonic centers and the low recorded seismic activity suggest that the proposed site is located in an extremely stable environment where activity is not expected. Consequently, little damage from earthquake activity is anticipated.

3.4.2 Site Geology

Figure 3-9 illustrates the surficial geology on and adjacent to the proposed site. This section will provide detailed descriptions of the proposed Triassic host sediments and the Quaternary alluvium that overlies these sediments only.

3.4.2.1 Site Stratigraphy

Specific data for this section was obtained through drilling activities described in Section 3.4.3. Figure 3-10 is a stratigraphic cross-section based on this drilling, illustrating relationships between the proposed Triassic host sediments and adjacent formations. Other site-specific cross-sections are located in Volume II, Appendix G.

Quaternary

The thickness of Quaternary alluvial deposits at the site varies from less than 10 feet to 35 feet. The upper portion of these sediments consists of fine to very fine, wind-blown yellow-brown sands. Below this sand are varying thicknesses of red-brown to yellow-brown siltstones and silty mudstones.

Scattered throughout these sediments are small chert pebbles and granitic cobbles derived from the Tertiary Ogallala Formation.

A caliche zone (Mescalero Caliche) is present in most of this unit. The caliche is found immediately under the top wind-blown sands and coats and fills fractures within the more consolidated siltstones. Where the Quaternary alluvium is quite thin, this caliche is found coating Triassic sediments.

Triassic

Drilling at the site has delineated 1,175 feet of Dockum sediments. Two distinct units can be identified in these sediments: the Upper Dockum (475 feet thick) and the Lower Dockum (700 feet thick). Within the proposed Facility boundary the thickness of the Upper Dockum unit never exceeds 100 feet. Upper Dockum sediments are in contact with the overlying Quaternary alluvium throughout the project area.

Upper Dockum— This unit consists of variegated (red-brown-green) mudstones interbedded with reddish gray siltstones and reddish-gray-green sandy siltstones. The siltstones are micaceous (predominantly muscovite), indicating they were part of a relatively active fluvial system capable of transporting material into the basin from distant source rocks.

From examination of lithology and down-hole electric logs, it is estimated that 30 percent of the unit is comprised of mudstones. Lithologies of the remainder of the unit are evenly divided between siltstones and sandy siltstones. However, as the geotechnical properties of these two lithologies are very similar, this geologic discussion will simply refer to them both as siltstone. Mudstones were found to have an average permeability of 2.45×10^{-7} cm/s, and the siltstones average 1.22×10^{-5} cm/s.

These sediments were deposited in a fluvial environment. Mudstone and siltstone bodies are very lenticular and are found to pinch out abruptly. Accordingly, individual lithologies are not correlatable over significant distances (thousands of feet).

Cross-sections prepared from the close-spaced drilling within the proposed Facility boundary establish an understanding of the fluvial nature of this unit (see Appendix G in Volume II). Figure 3-11 shows the locations of drill holes for the close-spaced drilling pattern and provides an index of cross-sections that illustrate the character of the Upper Dockum Unit. Also shown on Figure 3-11 is the location of the "most favorable" area for the construction of the proposed landfill. As shown in the cross-section on Figure 3-12, the lithology of this area (centered on drill hole PB-4) is predominantly mudstone, with thin beds of siltstones. The lenticular nature of the mudstone and siltstone bodies is also shown in these cross-sections. Cross-sections 3-1 and 3-2, in Appendix G (Volume II), show the facies relationships of the "most favorable" area.

The fluvial nature of the Upper Dockum Unit has led to the scouring of channels into the underlying Lower Dockum Unit. This scouring and the pinching-out of fluvial sediments have resulted in the local development of an undulatory surface on top of the Lower Dockum Unit. This phenomenon is well illustrated in Cross-sections 3-3, 3-4, and 3-5, in Appendix G (Volume II). Figure 3-13 is a structure contour map developed on the top of the Lower Dockum Unit. This figure shows the irregular nature of the contact between these two Dockum units.

Lower Dockum — The Lower Dockum Unit, described in Section 3.4.1.1, has a completely different character from the upper unit. The lower unit represents a time of relatively quiet lacustrine deposition, which resulted in the accumulation of thick sequences of predominantly mudstones interbedded with thin siltstones. These sediments are very homogeneous, in contrast with the abrupt facies changes present in the more active Upper Dockum depositional system.

Most of the close-spaced drilling within the proposed Facility boundary "bottomed" in Lower Dockum mudstones. These mudstones were consistently a moderate reddish brown color, which according to McGowen (1979), is associated with low stand lacustrine and mud flat deposition. Some drilling was conducted to specifically examine this unit. PB-36 encountered 64 feet of this unit, PB-37 encountered 55 feet, and PB-38 encountered 18 feet. Ten feet of core of Lower Dockum were collected from PB-36 at a depth of 138 to 148 feet and 7 feet of Lower Dockum were collected from PB-37 at a depth of 148 to 155 feet. Four representative samples of this core were sent to AGRA Earth & Environmental laboratories for permeability analyses. The results of these analyses confirm the Lower Dockum to be a very impermeable unit (average permeability of 5.7×10^{-8} cm/s), capable of performing as a geologic barrier to downward migration from the proposed landfill. Following are the results of the core analyses:

Core Interval	Permeability (cm/sec)
PB-36 (144'-145')	5.2×10^{-8}
PB-36 (147'-148')	6.8×10^{-8}
PB-37 (150'-151')	5.8×10^{-8}
PB-37 (154'-155')	4.9×10^{-8}

3.4.2.2 Site Structure

There are no identified faults within the project area. As previously discussed, the proposed site is located in a geologically stable area. There are no mapped faults on or adjacent to the project area. Color air photos of the area were examined for surface lineations, which can reflect faulting in the subsurface. All surface lineations observed on these photos were attributed to man-made features (i.e., fences, roads, etc.).

Subsurface drilling did not encounter displacement or repeating of geologic sequences that would be indicative of faulting. In the Upper Dockum Unit, there are abrupt changes in lithologies, but these are attributed to depositional processes associated with an active fluvial system.

3.4.3 Site Investigation Activities

Triassic sediments in eastern Chaves County were initially identified as excellent host rocks for proposed hazardous waste disposal because they (1) contain thick sequences of low permeability clays; (2) occur in remote, unpopulated areas; and (3) produce virtually no groundwater. This section describes the series of exploration activities undertaken to verify and document the suitability of the site for hazardous waste disposal.

As part of this permit application, a total of 51 drill holes were completed. The lithologies of these holes were recorded and a geophysical log was run on each drill hole. Forty of these drill holes were completed within the project boundary (Figure 3-14).

3.4.3.1 Preliminary Evaluation Activities

The first phase in determining an appropriate disposal site was to identify potential sites with exposed or near-surface Triassic sediments. To identify such sites, color aerial photos were obtained of areas underlain by Triassic sediments in eastern Chaves County (Figure 3-15). The areas exhibiting the characteristic coloration associated with the Triassic sediments on the photos were then plotted on topographic maps. The locations with desirable geology were screened for additional factors, including accessibility and land ownership. From this process, a prioritization of sites was developed and a shallow drilling program designed.

In July and September 1993, two shallow drilling programs were conducted to examine Triassic sediments underlying the Quaternary alluvium. Average depth of these holes was 40 to 60 feet, and the drilling was conducted on a spacing of approximately 1,000 feet between holes. As shown in Figure 3-16, three areas encompassing seven sections were examined. The objective of this drilling was to identify an area where the Triassic sediments were unsaturated, were situated close to the surface, and contained low permeability clays. An Ingersol Rand 1500 air rotary drill was used to perform this work. This air rotary technique was used because of the high quality of drill cuttings it produces and because the presence of any subsurface water can be easily detected.

Of all areas investigated, the surface and near-surface geology in the vicinity of Red Tank (the proposed site) was found to be the most favorable. Over most of this area, the thickness of Quaternary alluvium averaged approximately 10 feet, and the shallow drilling indicated the presence of unsaturated mudstones underlying the alluvium. Five shallow core holes were completed, adjacent to rotary air holes, to obtain preliminary geotechnical data on the near-surface Triassic sediments. As a result of the shallow depth of these sediments, many of the clays were very dry and brittle. This presented some difficulty in obtaining "undisturbed" core samples. Despite these difficulties, materials testing results showed low permeabilities for Triassic clays, ranging from 1×10^{-7} to 3×10^{-8} cm/s. These values, along with the local geologic setting, established the Red Tank area as an area conducive to more detailed site characterization.

Two deep holes (WW-1 and WW-2) were drilled to the base of the Dockum Group in November 1993. These holes encountered an unsaturated thickness of 600 to 650 feet of Lower Dockum mudstones consisting primarily of reddish brown, maroon, and purple mudstones with thin intervals of reddish brown silts.

Lithologic logs developed from cuttings samples and down-hole geophysical logs (gamma and thermal neutron) confirm the homogeneity of this thick mudstone interval. In addition, samples of drill cuttings from one of the deep holes (WW-2) were taken to the University of New Mexico's Diagnoses Laboratory for a grain size analysis. This analysis showed a remarkably constant grain size distribution throughout the sequence, which is consistent with the technical definition of a mudstone. This procedure involved desegregating, centrifuging, drying, wet sieving, and weighing the samples. A complete procedure and the results of this analysis are contained in Volume II, Appendix F.

The 600- to 650-foot mudstone interval rests on a basal sandstone unit that is approximately 50 feet thick. This basal unit is present in oil well logs in the area as a clean to a silty sand. The deep drilling did not retrieve any cuttings from this basal unit. The drilling was performed with air, and the moisture in this unit prevented the return of cuttings to the surface. Casing was placed in these holes, and water levels were taken (Section 3.6.2).

WW-1 and WW-2 were drilled north and south of the project boundary to characterize the nature of the Lower Dockum. Because of the consistent, continuous depositional environment within the lacustrine sediments at the Lower Dockum, it was decided (and approved by the NMED) that is was unnecessary to penetrate the entire Lower Dockum sediments within the site boundary. Such penetration would have certainly violated the integrity of the formation in the area of the planned hazardous waste landfill and in all likelihood would not have provided additional geologic information.

3.4.3.2 1994 Site Characterization Activities

In June 1994, a drilling plan for site characterization activities at the proposed site was prepared and submitted to the Hazardous and Radioactive Materials Bureau of the New Mexico Environment Department. The plan identified drilling locations, depths and methods, proposed geotechnical tests and methods, and down-hole geophysical logging methods. The 100-foot depth was sufficient to penetrate the base of the Upper Dockum (with the exception of the easternmost portion of the site). The plan was approved as submitted.

Drilling operations commenced on July 17, 1994 and a total of 36 drill holes were completed. There were three distinct phases of this drilling program: (1) close-spaced pattern drilling in the area of the proposed site (to a depth of 100 feet) to obtain detailed lithologic and hydrologic information for the design of a landfill, (2) stratigraphic drilling across the project area (to a depth of 200 feet) to correlate the site geology with the regional setting, and (3) selected core drilling in the proposed site for geotechnical samples. Samples of drill cuttings were collected and logged for each hole (see Volume II, Appendix C). Southwest Geophysical Services, Inc. conducted down-hole geophysical logging of each drill hole. These electrical surveys consisted of thermal neutron and gamma logs. The electric logs provide lithologic information from unsaturated drill holes to supplement and verify the lithologic interpretations based on drill cuttings. Copies of all geophysical logs can be found in Volume II, Appendix D.

A rotary air rig (Ingersol Rand 1500) was used for this work. Drilling with air provides cleaner drill cuttings than drilling with water, and usually a good indication of water saturation. However, in the case of the Upper Dockum sediments on the Facility site, this drilling technique was not always successful in identifying water saturation. This failure was a result of the low to very low permeabilities of the silty sands and the low amount of water saturation. The pressure of the air from the drilling process prevented water from immediately entering the holes. If groundwater was present, it was not always detected until the hole had stabilized and a geophysical log was taken. Geophysical logs on all drill holes within the site boundary encountered no saturated Upper Dockum sediments.

Three core holes were completed and a total of 85 feet of core recovered. A CME-55 hollow-stem auger rig using a continuous sampler was used to collect these samples. The dry, brittle nature of these shallow, unsaturated sediments made the recovery of undisturbed core samples difficult.

Representative core samples of mudstones, siltstones, and sandy siltstones were sent to materials testing laboratories for measurement of geotechnical parameters to be used in the Facility design and contaminant transport modeling. In addition to core samples, 11 backhoe pits were dug adjacent to drill holes for the collection of bulk samples. Proctor tests were performed on these bulk samples to provide information required for design studies. All geotechnical results are contained in Volume II, Appendix E.

3.4.3.3 1995 Confirmation Drilling Program

In order to confirm the unsaturated nature of the Upper Dockum sediments on the eastern boundary of the proposed Facility, a drilling plan was submitted to Mr. Bob Sweeney of NMED on June 26, 1995. This plan was modified and verbally approved by Mr. Ronald A. Kern, on July 12, 1995. A three-hole drilling program was conducted on the GMI site on July 24 & 25, 1995. Mr. Bob Sweeney visited the site and observed the drilling operations on Monday, July 24, 1995.

Holes PB-36, PB-37, and PB-38 were completed as an extension to an existing east-west line of drill holes. The westernmost drill hole was located on the eastern boundary of the proposed landfill. The other two holes were drilled 1,000 feet apart and examined the area immediately east of the proposed landfill. All surface locations for these drill holes were surveyed.

No groundwater saturation was encountered. All holes were completed with air so that saturated sediments could have easily been detected. Lithology logs describing drill hole cuttings were prepared in the field and down-hole geophysical logs were run on each hole. The geophysical logs included gamma ray, thermal neutron, and caliper profiles.

3.4.3.4 1999 Confirmation Drilling Program

In August 1999, a drilling program was conducted by Gandy Marley, Inc., at the request of NMED, to further clarify the subsurface stratigraphy and groundwater conditions underlying and adjacent to the proposed site. A total of ten (10) drill holes were completed as part of this program. All drilling activities were performed in accordance with an approved Work Plan and were documented in a Final Report for 1999 Stratigraphic and Groundwater Characterization Program, Triassic Park Waste Disposal Facility, September 1999.

Stratigraphic Characterization Program - Nine additional stratigraphic holes (Figure 3-17) were drilled in the northern portion of the proposed site in the area of the proposed operations area. To provide a complete picture of the drilling coverage, this figure also shows previous drill holes. All 1999 holes penetrated the entire existing Upper Dockum section and were bottomed in the Lower Dockum mudstones. Accordingly, the contact between these two units was identified in both cuttings and geophysical logs. An average of 25 feet of mudstones were displayed at the bottom of the 1999 drill holes.

Table 3-3, Summary of Stratigraphic Drilling Results, presents a summary of the 1999 stratigraphic drilling:

TABLE 3-3
SUMMARY OF STRATIGRAPHIC DRILLING RESULTS

Hole No	Depth	Depth to Contact[1]	Depth of Lower Dockum Penetrated
PB-39	120 ft	96 ft	24ft
PB-40	90 ft	68 ft	22 ft
PB-41	75 ft	55 ft	20 ft
PB-42	90 ft	62 ft	28 ft
PB-43	100 ft	74 ft	26 ft
PB-44	110 ft	78 ft	32 ft
PB-45	120 ft	100 ft	20 ft
PB-46	120 ft	89 ft	31 ft
PB-47	130 ft	108 ft	22 ft

[1]Contact between upper and lower Dockum, based on visual logging of cuttings and geophysical log.

No groundwater was encountered within the Upper Dockum or Lower Dockum sediments in the 1999 drilling. These stratigraphic drilling results demonstrated that the subsurface stratigraphy underlying the proposed site is both continuous with and predictable from previous drilling results. There were no unexplainable features within the depositional environment. In all cases, the depth of the contact between the Upper Dockum and the Lower Dockum sediments was encountered where it was estimated to be and all sediments were unsaturated.

Groundwater Characterization Program - This program consisted of the drilling of one drill hole (PB-48) east of the proposed site in an attempt to locate saturation within the Upper Dockum sediments. This drill hole was located 1000 feet north and 2000 feet east of drill hole PB-38, approximately ¾ of a mile from the proposed Phase I Landfill. The contact between the Upper Dockum and Lower Dockum sediments was encountered at a depth of 165 feet. The hole was completed to a depth of 210 feet. There was no saturation observed in the drill cuttings or on the geophysical log. This drill hole was plugged and abandoned. This drilling demonstrated that the limited saturation encountered one mile northeast of the site in the Upper Dockum was an isolated occurrence of perched groundwater. Upper Dockum sediments underlying the site and extending ¾ mile downgradient have been examined by over 40 drill holes and found to be unsaturated.

3.5 SURFACE WATER

There are no perennial stream drainages on or near the proposed site. The nearest surface drainage is the Pecos River, approximately 30 miles to the west.

There is one small stock tank (Red Tank) within the proposed Facility boundary and several additional tanks on adjacent lands. These tanks are approximately 200 feet by 200 feet and contain water for livestock. The tanks are clay-lined and retain water from run-off or receive water from an underground pipeline. Water in the underground pipeline is supplied from three water wells on the Marley Ranch located in Section 10, T11S, R31E. These wells are east of the Mescalero Rim and produce water from the Ogallala Formation. In the past, water from the springs along the Caprock excarpment was used in this pipeline, but now water is pumped from the Ogallala Formation. The pipeline is personally owned and maintained by the Marley Ranch to provide water to cattle operations below the Caprock.

In the 1999 drilling program, surface water from a small pond was found infiltrating into the adjacent alluvial sediments. This observation was made after completing drill hole PB-39, which was located approximately 120 from a excavated gravel pit. There was an impermeable clay layer at the bottom of this pit, and a pond had formed due to the heavy precipitation in the area this year. In the 30 hours following the completion of this drill hole, many measurements were taken and water levels were found to rise to within 22 feet of the surface. It was believed that this water was migrating along the top of the impermeable clays and entering the hole at a depth of fifteen feet.

To resolve the source of this water, a 30-foot deep offset hole was drilled. This offset hole penetrated the 15-foot thick alluvium sequence and bottomed in the 15-foot sequence of mudstone. This hole was drilled 20 feet east of PB-39, between it and the gravel pit. Water levels were measured in both PB-39 and the offset hole. The water had now dropped to a depth of 47 feet in PB-39 and it stood at 12 feet in the offset hole. In addition, the water level in the gravel pit was noticeably lower. Moss that had been floating on top of the water was now draped over approximately five feet of mud. Water levels remained at 47 feet (PB-39) and 12 feet (offset hole) for 24 hours. There was concurrence with the site HRMB representative that the source of the water had been the gravel pit.

The phenomena of impounded surface water migrating through alluvial sediments will have no impact on the proposed development activities. All water tanks or gravel pits existing within or adjacent to the landfill will be lined or filled. Once the site is designated as a disposal area, cattle operations on this property will cease and the Marley Ranch will stop using Red Tank. They will also re-route their personal pipeline, as appropriate, to avoid landfill operations and continue to supply water to their cattle operations below the Caprock. In addition, the Facility's perimeter ditches, designed for surface water control, will divert any surface water within these alluvial sediments.

3.6 GROUNDWATER

This section describes regional and local aquifers.

3.6.1 Regional Aquifers

In the region surrounding the proposed site, there are two geologic units that have produced groundwater, the Triassic and the Tertiary Ogallala Formation. Very minor amounts of groundwater have been produced from Triassic sediments; but the Tertiary Ogallala Formation is a major aquifer in southeastern New Mexico, west Texas, and several other western states.

A listing of the locations of all water wells within a 4-mile radius of the proposed site was obtained from the New Mexico State Engineer's office. Sixteen water wells were reported, fourteen from the Ogallala Formation and two from the Triassic. Of the two Triassic wells, one is now reported to be dry and the other is actually located more than 6 miles west of the proposed site. These water wells, along with oil well locations and the locations for all site investigation drilling activities, are shown in Figure 3-18.

3.6.1.1 Ogallala Aquifer

The Ogallala Aquifer is the primary freshwater aquifer within the regional study area and serves as the principal source of groundwater in the Southern High Plains. The saturated thickness of the Ogallala Aquifer ranges from a few feet to approximately 300 feet in the Southern High Plains. Groundwater within the Ogallala Aquifer is typically under water table conditions, with a regional hydraulic gradient toward the southeast ranging from approximately 10 feet/mile to 15 feet/mile. The average hydraulic conductivity of the Ogallala Aquifer ranges from 1 foot/day to 27 feet/day.

The Ogallala Aquifer is recharged primarily through the infiltration of precipitation. The rate of recharge is believed to be less than 1 inch/year. Groundwater discharge from the Ogallala Aquifer occurs naturally through springs, underflow, evaporation, and transpiration, but groundwater is also removed artificially through pumpage and catchment. Currently, the rate of withdrawal exceeds the rate of recharge for much of the Ogallala Aquifer.

3.6.1.2 Triassic

Regionally, the only aquifer within Triassic sediments is the Lower Dockum Aquifer. However, because the Upper Dockum is known to have permeable facies that locally produce low quantities of poor quality water, it is included in this section.

<u>Lower Dockum Aquifer</u>

The major aquifer within the Lower Dockum is the Santa Rosa Sandstone. This sandstone is present along the northern and southern flanks of the Permian Basin and is a principal source of groundwater in Roosevelt and Curry Counties, New Mexico. The Lower Dockum along the western flank of the Permian Basin, which includes the proposed site, is equivalent to but not described as the Santa Rosa Sandstone.

Where the Santa Rosa Aquifer has been studied, hydrochemical analyses and groundwater oxygen isotopes indicate that it is distinctly different from the Ogallala Aquifer. The thick, impermeable clays within the Triassic section have been sufficiently impermeable to prevent hydraulic communication between these aquifers.

In the region of the proposed site, Lower Dockum sands (equivalent to the Santa Rosa Sandstone) provide limited groundwater production. Figure 3-19 is a map of ten water wells developed in Triassic sediments within a 10-mile radius of the proposed site. This information was obtained from the New Mexico State Engineer's office and represents the results of a records search of six townships surrounding the proposed site (T11S through T13S and R29E through R30E). Six of these wells these wells are shallow completions (100 feet or less) from the 1910's and 1940's. They are used in conjunction with windmills to supply water to livestock and wildlife. The numbers of these wells are RA-8585 through RA-8589 and RA-8363.

The other four wells range in depth from 560 to 640 and have been completed within the past seven years. These wells would have penetrated the Lower Dockum sediments including the Santa Rosa Sandstone equivalent). Following is a description of these wells:

- RA-8577 was drilled to a depth of 614 feet in 1992. Its initial production was 4 gallons per minute
- RA-9320 was drilled in 1996 to a depth of 560 feet. The estimated yield was 6 gallons per minute, however, the water was determined to be not potable. The well was plugged and abandoned on 11/25/96.
- RA-9568 was drilled to a depth oe 640 feet in 1998. It was a dry hole and was plugged and abandoned on 08/14/98.
- RA-9670 was drilled in 1998 to a depth of 587 feet. The esimated yield was 2 gallons per minute.

Upper Dockum Aquifer

There is no regional aquifer developed within Upper Dockum sediments. In local areas, recharge to the Upper Dockum is provided through vertical infiltration from overlying aquifers which are water-bearing units within the Ogallala Formation. This relationship has been illustrated in Figure 3-10.

3.6.2 Site Groundwater

Potential Triassic host sediments within the proposed Facility boundary are unsaturated. Detailed drilling within this boundary has encountered no groundwater. Drilling outside the proposed Facility boundary has identified saturated zones in both the Upper and Lower Dockum Units. The following subsections contain descriptions of these saturated zones.

3.6.2.1 Ogallala Aquifer

The western boundary of the Ogallala Aquifer, represented by the Caprock escarpment, is located topographically/stratigraphically above and 2 miles east of the proposed site. At the base of the escarpment, along the contact of the Ogallala Formation and the underlying Upper Dockum, are numerous springs, which are a result of downward-migrating Ogallala groundwater coming into contact with low permeability zones within the Upper Dockum and being diverted to the surface.

3.6.2.2 Upper Dockum - Perched Water

As previously discussed in Section 3.6.2.1, several springs are present where the Ogallala Formation crops out, two miles east of the Facility site, along the 200-foot high Caprock escarpment. These springs are present where the Ogallala sands unconformably overlie impermeable Dockum mudstones and claystones and the groundwater moves laterally to the surface. Where these water-bearing Ogallala sands are in contact with more permeable units of the Upper Dockum, saturation of these underlying sediments occurs. The result, as illustrated in Figure 3-10, is the formation of a groundwater divide east of the proposed site. The majority of the groundwater entering the Upper Dockum flows to the east, conforming to the regional dip of the unit. There is also an intermittent flow component which slopes away from the unconformable contact, resulting in scattered perched water. There is no perched water beneath the Facility site. But as shown in Figure 3-20, northeast of the site, holes WW-1, PB-1 and PB-26 are saturated.

Where groundwater has been observed in the Upper Dockum, not all lithologies within the unit are saturated. Air drilling through these sediments found the mudstones to be unsaturated. The more permeable sandy siltstone facies were water-bearing below depths of 135 to 150 feet. These saturated lithologies were encountered only in one small area northeast of the proposed landfill site, beyond the proposed Facility boundary (Figure 3-20). It is extremely significant that this saturation does not extend beneath the Facility site. All 40 drill holes within the site boundary, as shown on Figure 3-14, were unsaturated. For this reason, there were no groundwater production tests conducted.

Exploratory drilling west of the proposed Facility boundary (updip), near the outcrop of the Upper Dockum Unit, the small sandy hills located along the section line between Section 18, T11S, R31E and Section 13, T11S, R30E, encountered an isolated occurrence of saturation (Figure 3-20 and Cross-section 3-3). In a single drill hole (PB-14), at a depth of 42 feet, a small accumulation of groundwater was found in a depression developed on the surface of the underlying Lower Dockum mudstones. This depression is consistent with the "scouring" of the Upper Dockum fluvial sediments into the Lower Dockum mudstones (Section 3.4.3.2). Closer spaced drilling in the vicinity of this occurrence encountered no other such accumulations. This isolated "pooling" is most likely a result of surface run-off entering the subsurface from the nearby outcrop and being caught in a small "stratigraphic trap."

Because of the identification of groundwater in borehole PB-14, an offset (borehole PB-14o) was completed 400 feet to the east (down-gradient). This borehole location was in addition to those pre-approved by the NMED, but determining the potential extent of groundwater saturation was important. Borehole 14o was drilled to a depth of 100 feet.

There was no saturation observed while drilling this offset, but the geophysical log indicated the presence of fluid at the bottom of this borehole. The top of the fluid was observed to be at a depth of 92.0 feet, indicating a maximum apparent concentration of 3.5 feet. This is an apparent concentration because a 2.25 inch probe will displace approximately one-half of the volume of the hole. Regardless of all of these factors, there was approximately one gallon of fluid in the bottom of this borehole introduced by a heavy rainfall that occurred after the hole was drilled and before it could be logged. Due to the impermeable nature of the Lower Dockum mudstones, the water did not infiltrate into the formation and was trapped in the bottom of the hole.

The hole was cased with 3-inch plastic tubing and monitored for several weeks. No additional water entered the hole, and, in fact, the gallon of water eventually dispersed into the Lower Dockum. An examination of the log for PB-14o shows the bottom of the sandy silt unit (Upper Dockum) to be a depth of 36 feet. If the Upper Dockum was the source of the water, the hole would have equilibrated or filled to a depth of at least 36 feet. The fluid did not migrate upward through several hundred feet of Lower Dockum mudstones; therefore, there is no apparent subsurface source for the small quantity of water shown in the log for this hole.

Water Level Measurements— After the stratigraphically trapped water (Cross-section 3-3, Appendix G, Volume II) was encountered, temporary casing was placed in the drill hole (PB-14) so that piezometric water levels could be measured. For the first six weeks after casing the drill hole, the water was pumped from the hole weekly. After each pumping event, the water returned to a static level of 42 feet. Subsequent water level measurements have confirmed a static water level in this drill hole.

In addition to casing drill hole PB-14, nine other drill holes, located downdip, were also cased. Although the Upper Dockum is unstaturated in these other drillholes, the holes were examined weekly for six weeks. No water was observed except for that previously described in PB-14o. The drill holes that were cased with 3-inch plastic casing and the perforated intervals for these holes are as follows:

Hole No.	Perforated Zone	Base of Upper Dockum
PB-14	30-80	42'
PB-14o	20-40	36'
PB-33	20-55	52'
PB-18	60-80	78'
PB-16	60-80	79'
PB-15	30-65	62'
PB-13	30-50	48'
PB-9	40-80	72'
PB-7	20-40	38'
PB-17	60-85	80'

The intent of installing casing in these 10 holes was to allow any groundwater in the vicinity of these drill holes to collect for detection purposes. The depths of the cased intervals varied because there is an approximate 1° regional dip to the east. All cased intervals extend down to the bottom of the Upper Dockum sand. Slits were cut in the PVC casing every foot throughout the perforated zones.

Water Quality— Preliminary water quality data were obtained from limited chemical analyses on a sample of the stratigraphically trapped groundwater from drill hole PB-14. These results include the following measurements:

Total Dissolved Solids	4,920 mg/L
Alkalinity	396 mg/L
Sodium	1,640 mg/L
Magnesium	103 mg/L

These preliminary data indicate that water from the Upper Dockum is of poor quality. The most significant parameter is total dissolved solids (TDS); water with TDS values of greater than 5,000 mg/L is considered to be unfit for human consumption.

3.6.2.3 Lower Dockum Aquifer - "Uppermost Aquifer"

For the purpose of this application, the uppermost aquifer is considered to be the Lower Dockum Unit because the Ogallala Aquifer is not present at the site. The EPA has defined the uppermost aquifer as the geologic formation, group of formations, or part of a formation that is the aquifer nearest to the ground surface capable of yielding a significant amount of groundwater to wells or springs. While the Lower Dockum Unit does not yield a significant amount of groundwater, preliminary drilling adjacent to the site area and in the region has found this unit to be water-bearing and to possess consistent hydrologic characteristics.

The basal sandstone of the Lower Dockum Unit is the water-bearing portion of this unit. The recharge area for the Lower Dockum Aquifer is the Pecos River drainage to the west. Groundwater flow direction is easterly, along the regional dip of this unit. This unit is overlain by a thick sequence (600 to 650 feet) of low permeability mudstones that act as an aquitard. Most of the shallow drilling in the site area has "bottomed" in the upper portion of the aquitard. Two holes (WW-1 and WW-2) were drilled to approximately the base of the Triassic section and encountered water from the Lower Dockum Aquifer (Figure 3-20). Hole WW-1 also penetrated a saturated zone in the Upper Dockum Unit, resulting in a mixing of these groundwaters in this drill hole.

Both holes were drilled with an air rotary rig and drill cutting samples were collected. WW-1 was completed to a depth of 820 feet and, at the time of drilling, no water saturation was apparent in the drill cuttings. WW-2 was completed to a depth of 710 feet; however, circulation was lost at a depth of 645 feet. Loss of circulation commonly occurs when drill cuttings are too wet for the air pressure of the rig to remove the cuttings from the hole. It is likely that the basal sandstone of the Lower Dockum Unit was penetrated at this depth.

Water Level Measurements— Temporary plastic casing was placed in each of the two holes immediately after completion. In July 1994, geophysical logs were run for each hole, and water levels were identified. WW-1 had a water level of 155 feet. This level is 20 feet above the Upper/Lower Dockum contact, and it is likely that groundwaters from both units are present in this drill hole. A water level of 467 feet was observed for WW-2. This finding indicates that there is a hydrostatic head pressure within the Lower Dockum Aquifer of 178 feet.

Both of these cased holes were pumped and allowed to recover. After a sufficient recovery period, a static water level (155 feet for WW-1 and 467 feet for WW-2) was maintained.

Water Quality— Two sources of data have been used to evaluate water quality data for the Lower Dockum, 1) United States Geological Survey (USGS) Multistation Analyses and 2) site-specific analyses.

The USGS works in conjunction with the State of New Mexico to establish, sample and analyze ground water from monitor wells throughout the state. A request for data was made to the USGS for water quality information on wells penetrating Triassic sediments in the area of the proposed site. This search area encompassed 12 townships - T9S through T12S and R29E through R31E.

Data from a total of nine monitoring wells within the search area were received. Of these nine wells, only two could be confirmed as penetrating Dockum sediments (the Beadle well and the Winsor well). The Windor well is shown on Figure 3-19 , while the Beadle well is an additional two miles to the northwest of the map's boundary. Ten separate analyses were conducted on samples from these wells. Total results can be reviewed in **Appendix- ??**. For this section, to be consistent with results of site specific analyses, only values for Total Dissolved Solids, Magnesium and Sodium are presented.

	Beadle well	Winsor well
Total Dissolved Solids	38,400 mg/L	14,000 mg/L
Sodium	11,000 mg/L	3,200 mg/L
Magnesium	625 mg/L	519 mg/L

Preliminary water quality data are presented only for WW-2. This drill hole encountered groundwater from the Lower Dockum. Because groundwater from the Upper Dockum and Lower Dockum was mixed in drill hole WW-1, preliminary water quality data from WW-1 do not accurately characterize either aquifer and are not presented. The results from WW-2 include the following:

Total Dissolved Solids	18,800 mg/L
Alkalinity	83 mg/L
Sodium	7,030 mg/L
Magnesium	87 mg/L

The character of the regional and site-specific data appear to be very similar. Both indicate that the water quality of the Lower Dockum is very low. The extremely high TDS values are indicative of long formation retention times, which reflects low groundwater flow and low permeability conditions within the Lower Dockum aquifer.

3.7 GROUNDWATER PROTECTION REQUIREMENTS

The Gandy-Marley Corporation was issued a Groundwater Monitoring Waiver for its proposed Triassic Park Waste Disposal Facility by the Hazardous and Radioactive Materials Bureau (HRMB) of the New Mexico Environment Department (NMED) on January 12, 2000. This request was based on a demonstration that the site-specific geologic and hydrologic conditions at the site, combined with the engineered barriers in the regulated units at the Facility will prevent migration of liquids from the regulated unit to the uppermost aquifer.

3.7.1 Groundwater Monitoring Waiver

The Gandy Marley Corporation considers the monitoring of the Lower Docukum aquifer not to be protective of human health and the environment and requests a waiver from these monitoring requirements for the following reasons:

1. The thick sequence (600-650 feet) of low permeability Lower Dockum mudstones provide a sound geologic barrier to the downward migration of contaminants.

2. The installation of monitoring wells in the Lower Dockum aquifer would violate the integrity of geologic barrier provided by the thick sequence of mudstones and possibly create an avenue for contaminant migration.

3. The Lower Dockum aquifer has artesian characteristics as demonstrated through a site specific investigation.

4. A commitment exists from Gandy Marley to construct hazardous waste management units (HWMU) with leachate and release monitoring and retrieval systems.

NMED's authority to grant a groundwater monitoring waiver lies in the New Mexico Hazardous Waste Management Regulations (20 NMAC 4.1.500), which adopts by reference 40 CFR § 264.90(b)(4). The relevant regulation states that the owner or operator of regulated units are not subject to regulations of 40 CFR 264.90 for releases into the uppermost aquifer under this part if:

> *The Regional Administrator finds that there is no potential for migration of liquid from a regulated unit to the uppermost aquifer during the active life of the regulated unit (including the closure period) and the post-closure care period specified under § 264.117. This demonstration must be certified by a qualified geologist or geotechnical engineer. In order to provide an adequate margin of safety in the prediction of potential migration of liquid, the owner or operator must base any predictions made under this paragraph on assumptions that maximize the rate of liquid migration.*

This demonstration evaluated the potential for migration of hazardous waste or hazardous waste constituents from the facility to the uppermost aquifer, through:

- A water balance of precipitation, evapotranspiration, runoff, and infiltration; and
- Unsaturated zone contaminant transport modeling
- Vadose zone monitoring

3.7.1.1 Water Balance

This information is useful for assessing the potential migration of contaminants released at or near the surface to groundwater. Groundwater recharge rate is directly related to the potential for contaminants spilled or leaked at the surface to reach groundwater. In areas with little or no groundwater recharge, there is less potential for groundwater contamination form releases of hazardous substances than in high recharge areas because the mechanisms to transport potential contamination are limited.

Groundwater recharge at the proposed site can be estimated by summing precipitation, infiltration from surface water bodies and irrigation at the site and subtracting evapotranspiration and surface run-off. As no natural surface water bodies or irrigation occur at the site, groundwater recharge is estimated as the difference between direct precipitation and evapotranspiration. This assumes no surface run-off at the site.

As previously described in section 3.2.2, precipitation data collected at the Roswell weather station indicate that mean annual precipitation is 10.61 inches. This annual mean is used as the average precipitation at the proposed site.
Evapotranspiration refers to the processes that return water to the atmosphere by a combination of direct evaporation and transpiration by plants and animals. It is the largest item in the water budget because most of the precipitation that falls in the area returns almost immediately to the atmosphere without becoming part of the surface water or groundwater systems. In a regional water balance conducted in southeastern New Mexico, it was estimated that approximately 96 percent of total precipitation is lost to evapotransiration (Hunter, 1985). This number corresponds to data presented for the Rio Grande Basin by Todd (1983), that estimated that 95.4 percent of total precipitation was being lost to evapotranspiration.

Assuming a mean annual precipitation rate of 10.61 inches, of which 96 percent is lost to evapotransporation, the net recharge to groundwater is estimated as 0.42 inch per year. This low groundwater recharge rate is a reflection of the arid climate of the region and significantly reduces the potential for groundwater contamination from spills or leaks at the proposed Facility. The low recharge rate appears to be reasonable given the unsaturated conditions of the Upper Dockum within the site boundaries. Using the highest recorded annual precipitation value of 32.92 inches yields onlyu a slightly higher rate of 1.32 inches (assuming an evapotranspiration rate of 0.96). This short-term (1 year) increase in recharge is unlikely to have a significant impact on the unsaturated flow regime at the proposed site.

3.7.1.2 Contaminant Transport Modeling

Contaminant transport modeling was performed to calculate the travel time required for a potential leak from the proposed landfill to reach the uppermost aquifer (the Santa Rosa Sandstone equivalent). Numerous discussions were held with NMED regarding the modeling requirements for a waiver demonstration. Based on these discussions, the following criteria for the modeling effort were developed.

- A one-dimensional flow and transport model, MULTIMED, should be used to evaluate the potential travel times through the Lower Dockum
- A travel time of 800 years should be considered as a minimum to justify a waiver from groundwater monitoring.
- Conservative input parameters should be utilized for all modeling runs.
- Develop a simplistic approach that is easily verified and understandable.

Two MULTIMED simulations calculated the travel times through the Lower Dockum using different infiltration rates as boundary conditions.

- Assumes an infiltration rate equal to the net recharge of 0.42 in/yr for this site. This is based on a regional water balance assessment that does not account for any of the liner or cover barrier layers in the landfill. This approach more accurately models the long-term annual conditions at the site, but is still considered conservative.

- Assumes an infiltration rate equal to the saturated hydraulic conductivity of 0.84 in/yr. This approach is considered the most conservative and assumes that the formation has access to as much leachate as it can physically accept.

Applying the realistic, but still conservative infiltration rate of 0.42 in/yr, it was calculated that it would require 3211 years for a potential leak to penetrate the Lower Dockum mudstones and reach the uppermost aquifer. The most conservative approach, using the maximum infiltration rate of 0.84 in/yr yielded a travel time of 1606 years for contaminants to reach the uppermost aquifer. The low permeability and thickness of the Lower Dockum mudstones, in conjunction with the arid conditions, make this site an ideal location for the proposed landfill activities.

3.7.1.3 Vadose Zone Monitoring System

Due to the extremely long travel times in the lower Dockem and along the Upper Dockum/Lower Dockum contact, groundwater monitoring data from the Santa Rosa formation or the perched aquifer downgradient of the site will not provide meaningful information concerning potential releases from the proposed facility. It is therefore proposed that a Vadose Zone Monitoring System (VZMS) be used to detect potential releases from the facility. The VZMS will provide the most effective method for detecting potential releases from the facility. Before potential contamination can reach the uppermost aquifer, these systems can detect leaks and help to initiate corrective actions for preventing impacts to the environment.

Details of the VZMS are presented in Appendix __. This includes specifics on the number and location of vadose zone monitoring points in the landfill and evaporation pond sumps and the vadose zone monitoring wells. Monitoring strategies are also presented that indicate steps that will be taken to characterize fluids if they are found in the sumps or wells.

3.8 SUMMARY AND CONCLUSIONS

The proposed location of the Facility landfill in eastern Chaves County, New Mexico is ideal. It is located in an unpopulated portion of the county, on privately owned land, and more than 36 miles from the nearest community. The semiarid climate of this region with its high evaporation rate and lack of surface water, will play an important role in the proposed site's ability to confine and control material placed in the landfill.

Large-scale ranching is the primary land use for this portion of Chaves County. However, setting aside the 480 acres proposed for the Facility will have no impact on the ranching industry in the region, as these acres support fewer than five animal units year-long. Since the economic stimulation provided by landfill-related jobs will greatly offset the minimal economic impact of the loss of grazing land, the project has the support of the surrounding community.

A geologic setting for the Facility was selected that will enable the proposed landfill to be developed in an environment that will protect groundwater resources and ensure long-term isolation of wastes. The host rocks for this Facility are the sediments of the Dockum Group of Triassic age. Because these sediments are unsaturated and of low permeability, they represent a stable geologic barrier to the potential migration of contaminants from the proposed landfill.

The proposed landfill will be developed within sediments of the Upper Dockum unit. These sediments, consisting of fluvial, interbedded mudstones (30 percent) and siltstones (70 percent Underlying these sediments is the Lower Dockum, consisting of a 600-foot thickness of homogeneous, lacustrine mudstones overlying a thin basal sandstone. This thick sequence of unsaturated, low permeability mudstones represents a geologic barrier to the potential downward migration of contaminants from the proposed landfill.

The hydrologic setting of the Facility is extremely protective of groundwater resources. The nearest groundwater production comes from the Tertiary Ogallala Aquifer. The western boundary of this aquifer forms a topographic feature called the Caprock, which is approximately two miles east and several hundred feet higher than the proposed site. A small area of perched groundwater has been identified northeast of the site boundary. The source of this groundwater is infiltration from the overlying Ogallala Aquifer. Underlying and downgradient of the proposed landfill, the Upper Dockum is unsaturated.

The Lower Dockum unit is designated as the uppermost aquifer for the purposes of this permit application. NMED has issued a Groundwater Monitoring Waiver for this aquifer. Monitoring of this unit was not considered to be protective of human health and the environment due to due to its low production of poor quality groundwater. In addition, conservative contaminant transport modeling calculated that a potential leak from the Facility would require travel times of 1606 to 3211 years to reach this aquifer. In lieu of groundwater monitoring, Gandy Marley will implement a vadose zone monitoring system.

The description of the proposed Facility, as presented in this permit application is a result of six years of investigation to identify an environmentally sound site in southeastern New Mexico where hazardous wastes could be safely disposed. The location, geology and hydrology of the proposed site present a unique setting, where natural geologic barriers, combined with a well-conceived landfill design, will ensure long-term isolation of hazardous wastes from the environment.

TABLE 3-1
TEMPERATURES AT ROSWELL, 1977 TO 1978

Month	Monthly Average (°F)	Average Daily Maximum (°F)	Average Daily Minimum (°F)
January	38.1	55.4	20.8
February	42.9	60.9	24.8
March	49.3	57.7	30.9
April	59.7	78.2	41.2
May	68.5	86.4	50.5
June	77.0	94.2	59.8
July	79.2	94.7	63.7
August	77.9	93.4	62.3
September	70.4	86.5	54.3
October	59.6	77.0	42.2
November	46.9	64.8	29.0
December	39.3	56.8	21.8
Annual	**59.1**	**76.3**	**41.8**

TABLE 3-2
MONTHLY AND ANNUAL PRECIPITATION SUMMARY FOR ROSWELL (INCHES)
1977 THROUGH 1982

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1977	0.07	0.36	0.27	1.25	2.43	0.25	0.46	4.45	0.29	0.62	0.48	0.02	10.95
1978	0.50	0.48	0.39	0.02	1.81	4.31	0.52	3.49	3.58	1.47	1.25	0.43	18.25
1979	0.41	0.44	0.13	0.32	1.25	1.56	1.44	2.28	0.15	0.18	T	0.37	8.53
1980	0.85	0.19	0.00	1.06	0.85	0.29	0.01	2.45	6.58	T	0.77	0.15	13.20
1981	0.27	0.17	0.10	0.79	3.35	4.55	6.27	4.73	2.70	1.02	0.25	0.13	24.33
1982	0.66	0.20	0.12	0.41	0.20	0.76	1.03	0.93	2.00	0.20	0.92	1.62	9.05
Normal = 10.61 T = trace													

TABLE 3-3
TRIASSIC PARK HELP MODEL RESULT SUMMARY FOR CELL FLOOR

Time (years)	LCRS Operational Beyond 30 Years Post Closure			LCRS Not Operational Beyond 30 Years Post Closure		
	Liner Leakage (gal/acre/day)	Cap Leakage (gal/acre/day)	Final Waste Moisture Content (vol/vol)	Liner Leakage (gal/acre/day)	Cap Leakage (gal/acre/day)	Final Waste Moisture Content (vol/vol)
0	1.3781	NA	0.1410	1.3781	NA	0.1410
20	0.9400	0.0454	0.1222	.9400	0.0454	0.1222
30	0.2735	0.0430	0.1181	0.2735	0.0430	0.1181
50	0.1927	0.0450	0.1125	3.4579	0.0450	0.1125
70	0.1329	0.0450	0.1087	8.0071	0.0450	0.1098
90	0.1007	0.0439	0.1059	9.1465	0.0439	0.1083
100	0.0775	0.0442	0.1049	8.5811	0.0442	0.1076
120	0.0744	0.0453	0.1029	8.8612	0.0453	0.1062
140	0.0629	0.0461	0.1013	8.6989	0.0461	0.1048
160	0.0547	0.0442	0.0999	8.5494	0.0442	0.1034
180	0.0482	0.0442	0.0987	8.4178	0.0442	0.1021
200	0.0431	0.0431	0.0976	8.2818	0.0442	0.1008

NA - Not Applicable

TABLE 3-4
TRIASSIC PARK HELP MODEL RESULT SUMMARY FOR CELL SLOPE(1)

Time (years)	LCRS Operational Beyond 30 Years Post Closure			LCRS Not Operational Beyond 30 Years Post Closure		
	Liner Leakage (gal/acre/day)	Cap Leakage (gal/acre/day)	Final Waste Moisture Content (vol/vol)	Liner Leakage (gal/acre/day)	Cap Leakage (gal/acre/day)	Final Waste Moisture Content (vol/vol)
0	173.0000	NA	0.1410	173.0000	NA	0.1414
20	123.0000	0.0453	0.1221	123.0000	0.0453	0.1223
30	53.5373	0.0442	0.1182	53.5373	0.0442	0.1182
50	37.0011	0.0453	0.1152	37.0282	0.0453	0.1152
70	24.5001	0.0461	0.1087	24.5114	0.0452	0.1087
90	18.0529	0.0442	0.1059	18.0583	0.0449	0.1059
100	13.6143	0.0425	0.1049	13.6174	0.0430	0.1049
120	12.9000	0.0443	0.1029	12.9032	0.0450	0.1029
140	10.7627	0.0439	0.1013	10.7642	0.0450	0.1013
160	9.2002	0.0457	0.0999	9.2030	0.0439	0.0999
180	8.0161	0.0462	0.0987	8.0178	0.0457	0.0987
200	7.0994	0.0461	0.0976	7.1002	0.0462	0.0976

Note: (1) Initial HELP Modeling Results were based on landfill liner system without double liner system on side slopes. These should not be confused with HELP results presented in the Engineering Report.
NA - Not Applicable

TABLE 3-5
INPUT PARAMETERS FOR UNSATURATED FLOW MODELING

	β	Ko			Q		α	Source Coordinates (m)		
Unit	**(m)**	**(m/day)**	**Sr**	**Sm**	**(m^3/day)**	**n**	**1/m**	**x[1]**	**y[1]**	**z[1]**
Lower Dockum	0.373	4.90E-05	0.279	1	8.00E-05	3	8.042	0, 33, 66, 99, 132, 165, 193, 231, 264, 297, 330, 363, 396, 429, 462	0	0
Upper Dockum	0.2076	1.05E-02	0.161	1	3.80E-05	3	14.45	5.5, 11, 16.5, 22, 27.5, 33, 38.5, 44, 49.5, 55, 60.5, 66, 71.5, 77	0	24.5, 22.6, 20.72, 18.84, 16.96, 15.07, 13.19, 11.31, 9.42, 7.54, 5.[illegible] 3.77, 1.88, 0
Clay Berm	0.37	8.64E-05	0.126[a]	1	3.80E-05	3	8.108	0, 5.5, 11	0	3.77, 1.88, 0
Quaternary Alluvium	0.0726[a]	8.64E-02	0.0458[a]	1	3.80E-05	3	41.32	0, 5.5, 11	0	3.77, 1.88, 0

Key:
β = bubbling pressure; typical values reported by Bumb and Mckee et al. (1988)
Ko = saturated hydraulic conductivity; site-specific means values
Sm = maximum saturation; assumed
Sr = residual saturation; site-specific mean values
Q = leakage rate; based on HELP modeling results
n = curve fitting parameter based on pre size index (Mckee and Bumb, 1988)
α = n/β
1 = Typical values reported by Bumb and Mckee et al (1988)
a = typical values reported by Bumb and Mckee et al. (1988)
b = assumed values

Insert Figure 3-1, Index Map Proposed Site

Insert Figure 3-2, Topography South East New Mexico

Insert Figure 3-3, Wind Rose South East New Mexico

Insert Figure 3-4, Stratigraphic Column

Insert Figure 3-5, Triassic Basin - Paled Map

Insert Figure 3-6, Triassic Basin Subsurface

Insert Figure 3-7, Project Area

Insert Figure 3-8, Seismic Activity - South East New Mexico

Insert Figure 3-9, Surface Geology Project Area

Insert Figure 3-10, Stratigraphic Cross-Section

Insert Figure 3-11, Close-Spaced Drilling Pattern - South East New Mexico

Insert Figure 3-12, Proposed Disposal Site

Insert Figure 3-13, Cross Section 1995 Drill Holes

Insert Figure 3-14, Total Drill Holes

Insert Figure 3-15, Air Photo - South East New Mexico

Insert Figure 3-16, Project Area

Insert Figure 3-17, Drill Hole Locations

Insert Figure 3-18, Upper Dockum Groundwater

Insert Figure 3-19, Landfill Profile

Insert Figure 3-20, Steady State Effect Saturation vs. Distance

Insert Figure 3-21, Steady State Effect Conductivity vs. Distance

Insert Figure 3-22, Steady State Effect Velocity vs. Distance

Insert Figure 3-23, Steady State Effect Leakage vs. Distance

Insert Figure 3-24, Steady State Effect Leakage vs. Lateral