BACKGROUND AND SITE-SPECIFIC GEOLOGY AND HYDROLOGY FOR THE LOVING LANDFILL SITE

prepared for

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by

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ABSTRACT

The Loving, NM, landfill site has been closed, and geological and hydrological studies of the landfill site and area have been conducted. Regional to area information has been summarized, and six wells were drilled, described, and completed for hydrological monitoring.

The landfill site is located in the western Delaware Basin, which accumulated thick sequences of sediments through the Paleozoic Era. The last deposits in this sequence, evaporitic units in several formations, underlie the site. Dissolution of salt has created evaporitic karst in the area, affecting surface features and hydrology.

More recent deposits of sediments eroded from the Guadalupe Mountains cover areas west of the landfill site. The Pecos River valley and drainage from the Guadalupes by the Black River and other draws have modified the topography further. There is no surficial evidence in this area of recent tectonic faulting, and structure contours on the top of the Bell Canyon Formation around the site area indicate a general, modest eastward dip with no offsets.

Regional ground water data indicate that flow under the site would probably be generally from west to east. Ground water depth was estimated at 75 to 100 ft below the surface at the site based on existing data; total dissolved solids were greater than 1000 ppm for all analyses of nearby ground water.

Six monitor wells drilled at the landfill site encountered the Pleistocene(?) Gatufía Formation to total depth. Lithologies ranged from claystones to sandstones and gravelly to conglomeratic sandstones or conglomerates. Sedimentary structures were
fewer than in Gatunia outcrops and cores from other locations, but they were consistent
with features found in other locations. The Gatunia is more gypsiferous than it is in
outcrops and cores to the north and northeast of the site. Dips and deformation
indicate the Gatunia has been disturbed by dissolution of underlying beds since being
deposited (probably about 500,000 years ago).

The geological data indicate general stability of the site over periods of tens to
perhaps hundreds of thousands of years. The principal threat to geological stability
appears to be further dissolution of underlying beds. No active karst is apparent at
the site.

Ground water was found immediately in three monitor wells (M-2, M-4, M-6) in the
southeastern part of the site, and water soon reached elevations of about 3060 ft in
each. Three wells (M-1, M-3, M-5) in the northern and western part of the site have
not reached similar elevations and may not have reached equilibrium. Apparent confined
conditions for ground water in at least the three southeastern wells and fine grained
sediments in each borehole suggest small potential for vertical recharge at the site.

Further testing of ground water gradients and chemistry should be deferred until
water levels in the monitor wells are believed to have stabilized.
BACKGROUND INFORMATION

Purpose of Report

This report provides both the general background and detail of the geology and hydrology of the Loving, NM, landfill site. It is provided to JOAB, Inc., for use in applying for a closure permit for the landfill.

Site Location

The Loving landfill site is located in the northeast ¼ of section 32, T.23S., R.28E. The landfill is approximately 1 mile south of Loving and about 10 miles southeast of Carlsbad (Figure 1).

General Physiographic Setting

The Loving landfill is located in the Pecos Valley section of the southern Great Plains physiographic province defined by Fenneman (1931). The Great Plains province is the western part of the Interior Plains major physiographic division.

The Pecos Valley physiographic section extends from the north end of the Pecos River and a part of the Canadian River valley to the south where the Pecos River enters the Edwards Plateau area. From there, the Pecos River has cut a deeper and narrower channel through the plateau until it empties into the Rio Grande River. The Pecos Valley physiographic section is a broad trough, oriented mainly north-south, due mainly to headward erosion by the Pecos River of the High Plains physiographic section, which once extended as a gently sloping plain to the mountain ranges west of the Pecos Valley section. Thus, the Pecos Valley section was developed later than the High Plains section and was superimposed on it by headward erosion.
The Pecos Valley section expresses a wide variety of topography from nearly flat plains to more extreme local relief. Several terrace levels are identifiable along the Pecos Valley, especially in the Roswell area (Kelley, 1971). Broad fan deposits have also developed along the western side of the Pecos Valley as clasts are redistributed in response to the erosional lowering and migration of the Pecos River. The entire area is drained either by the Pecos River, arroyos which lead to the Pecos, or the Black River and its tributaries, all of which also drain to the Pecos.

A triangular area between U.S. Highways 62/180 and 285 and bounded on the south by the Black River includes the Loving landfill site in its southeastern part (Figure 1). Most of the area lies between elevations of 3300 and 3000 ft above mean sea level.

The western part of the triangle is commonly underlain by gently sloping limestone gravels and conglomerates deposited in broad fans from the Guadalupe Mountains to the west. Near the Guadalupe Mountains, local outcrops of the Rustler Formation, especially the Culebra Dolomite Member, hold up some hills within the area of sloping gravels and conglomerates. East of the coarser detritus, the slope decreases and the surface is characterized by finer grained calcareous and gypsiferous soils.

The southeastern part of the triangle is slightly more irregular topographically and is underlain by gypsum of the Rustler Formation which is weathered into gypsiferous soils.

General Geological Setting

General Geological History

The Loving landfill site is set in the ancient structural and depositional feature called the Delaware Basin. The Delaware Basin dominated the region throughout the Paleozoic Era, accumulating thousands of feet of marine sediments which include several units yielding hydrocarbons. The Paleozoic Era, and the Delaware Basin, culminated...
Figure 1
General Location and Topography,
Loving Landfill Site

C = Carlsbad, L = Loving, M = Malaga. Contours are in ft and are partial. U.S. Highway numbers are 62/180 and 285. Modified from Carlsbad Sheet, 1:250,000.

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with the deposition of thick (about 3000 ft) evaporites, which immediately underlie the landfill site, and red siltstones.

During the Mesozoic and most of the Cenozoic Eras, this area was mainly subject to erosion. There is a record in the eastern part of the Delaware Basin of late Triassic redbeds (Dockum Group) more than 1000 ft thick. The remnants of the Dockum Group can still be found east of the longitude of Loving, within 20 miles of the landfill, at both the surface and in the subsurface. It is quite likely that the landfill site was at one time covered with Dockum Group rocks, though perhaps not as thick as now exist in the eastern part of the basin. In addition, along Black River, Lang (1947) and Bachman (1980) noted localities with marine fossils of early Cretaceous age, indicating that some rocks of this age covered areas which probably include the landfill site. Given facies changes in Cretaceous rocks to the south and east in Texas, it is doubtful if these rocks were very thick at the landfill site. The local gap in the rock record extends from these lower Cretaceous rocks to rocks of late Tertiary age. Plio-Pleistocene (?) Gatuña Formation deposits immediately west of the landfill site in sections 31 and 32 overlie Rustler Formation units. There are no preserved Miocene Ogallala Formation rocks here, and it is difficult to estimate how much, if any, of this High Plains deposit may have extended into the area. To the north of Carlsbad, the Pecos Valley is interpreted as having been erosional cut into the Ogallala. Ogallala deposits are rare and thinner east and southeast of Loving, however, weakening inferences about the presence or extent of Ogallala at the landfill site.

Since the end of the Permian Period, then, the landfill site has been subject mainly to erosion during the following periods: early Triassic, all of the Jurassic, most of the Cretaceous, and most of the Cenozoic. These times of erosion may account for 80 to 90% of the 250 million year geological history of the area since the end of the Permian Period and Paleozoic Era.
The times of erosion, especially after the Triassic rocks were removed, probably also contributed to dissolution of the underlying evaporites, as discussed in a later detailed section.

**General Structural Setting**

Deeper rocks under the evaporites in the Delaware Basin commonly strike nearly due north-south and dip eastward at about 100 ft/mile (e.g. Grauten, 1965; Powers and others, 1978; Borns and Shaffer, 1985). The tilt of the Delaware Basin has been attributed by some mainly to a late Cenozoic, Basin and Range event (Anderson, 1978). Others suggest a series of tilting events, beginning with two events during deposition of the Permian evaporites and including tilting events during the Mesozoic and Cenozoic Eras (Bachman, 1980; Adams, 1944).

Structure contours on the top of the Delaware Mountain Group (Figure 2), which immediately underlies the evaporites, show the deeper rocks underlying the land fill site have the same regional north-south strike, but the limited data indicate that the dip might be slightly less than the average through the western part of the Delaware Basin.

Faults due to tectonic events are not known to be later than the Permian in the western Delaware Basin area. That is, there are a few faults which appear to displace some of the lower evaporites (e.g. Powers and others, 1978), but there are none known in this area which displace the full section. On the east side of the basin, Holt and Powers (1988) interpreted significant displacement through the Rustler Formation, and possibly Dewey Lake Formation, along the western margin of the Central Basin Platform. The Triassic units do not appear to be displaced. Along the western margin of the Capitan reef and associated rocks, Kelley (1971) reported displacement along the Carlsbad and Barrera faults. These alleged faults were further examined by Hayes and Bachman (1979), who believe these linear features along the base of the eastern
Figure 2
Structure Contours of
Bell Canyon/Castile Contact

Contours in feet. L# refers to well number in Table 1; nearby number refers to elevation of Bell Canyon/Castile contact. Small numbers refer to section numbers.

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Table 1

Well Data for Bell Canyon(BC)/Castile Contact

<table>
<thead>
<tr>
<th>Well ID</th>
<th>Location (T,R,Sec.)</th>
<th>Reference Elevation (ft)</th>
<th>Depth to BC/ Castile (ft)</th>
<th>BC/Castile Elevation (ft)</th>
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<tr>
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<td>2595</td>
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Logs were interpreted by Dennis Powers.
Guadalupe escarpment as mainly vegetation and erosional features with no demonstrable faulting or displacement.

Within the Delaware Basin, however, there are local areas which show faults at the surface which appear attributable to subsidence and collapse of overlying rocks when the underlying evaporite rocks are dissolved. It is more common that rocks overlying the evaporites are deformed and distorted by subsidence rather than being noticeably faulted. Bachman (1980, 1981) mapped and reported on these features in Nash Draw and along the Pecos River valley, including areas east and southeast of the Loving landfill site. Along the Black River, south of the landfill site area, probable Salado and Rustler units are distorted and deformed by subsidence due to dissolution. South and southeast of Malaga, the surface shows many domal to synclinal forms in the exposed Rustler Formation units due to the same processes. Though these rocks are only sparingly exposed nearer to the Loving landfill site, it is most probable that the near-surface rocks will also be similarly deformed due to dissolution and collapse.
SITE AREA GEOLOGY

Introduction

The site area geology has been examined by including information from several square miles around the landfill. Most of this information is from outcrops and from geophysical logs of boreholes drilled for hydrocarbon exploration. These are readily interpreted for deeper stratigraphic units; the units above the Castile Formation are more disturbed by both depositional variations (Holt and Powers, 1984, 1988) and dissolution processes, and they are less readily interpreted. The rock unit relationships of most importance for the site and area are presented in Figure 3.

Units Underlying the Evaporite Beds (sub-Castile)

Precambrian crystalline "basement" rocks are not known to have been drilled in the vicinity of the Loving landfill site. About 1.5 mile west southwest of the landfill, Mobil Oil Corporation Pardue #1 well (L10, Table 1) was drilled to a total depth of 13,906 feet. Sub-Castile rocks in this borehole are 11,484 feet thick. About 3 miles east of the landfill site, Phillips Petroleum Company Malaga C #1 (L11, Table 1) was drilled to a total depth of 13,468 feet. Sub-Castile rocks in this borehole are 10,813 feet thick. The Mobil well appears to be drilled to Silurian age rocks just below the Devonian Woodford Shale. Near the WIPP site, Powers and others (1979) estimated the depth to Precambrian below the Woodford to be about 2,400 feet. The depth to the base of apparent Woodford Shale in the Mobil well is about 13,750 feet. The 2,400 feet thickness of the sub-Woodford is a reasonable approximation of the same interval at the Mobil well. From this, we can infer a total depth of about 16,150 to the Precambrian at the Mobil well and a sub-Castile sedimentary rock thickness of about 13,725 feet. These estimates are reasonably applied to the Loving landfill site.
Figure 3
Important Stratigraphic Relationships
at and near the Loving Landfill Site

Site and Area

Plio (?) - Pleistocene
Gutna Formation

Regional Relationships

Mescalero caliche

Dockum Group
(Santa Rosa Sandstone)

Dewey Lake Formation

Rustler Formation
Forty-niner Member
Magenta Dolomite Member
Tamarisk Member
Culebra Dolomite Member
unnamed lower member

Salado Formation

Castile Formation

Capitan Limestone (aquifer)

Delaware Mountain Group
Bell Canyon Formation

Vertical lines indicate units not present at the site. The Mescalero caliche is not well represented near the site. Units below the Bell Canyon Fm are omitted.

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Pre-Permian rocks in this area are about 5,000 feet thick, based on inferences from geophysical logs and data included in Hills (1984), Haigler (1962), and Powers and others (1978). Basal sedimentary units are expected to be the Ellenburger Dolomite of Ordovician and possible late Cambrian age. The Simpson and Montoya Groups are also included in the Ordovician System. Silurian age rocks, dominantly dolomite and limestone, may be unnamed or attributed to the Fusselman Dolomite. The Devonian System in the area are attributed to the Thirtyone Formation (Hills, 1984) and Woodford Shale. The Mississippian System includes a lower, thicker limestone which commonly is unnamed and an upper unit called the Barnett Shale. The Pennsylvanian System consists of more heterogeneous units of sandstone, siltstone, and limestone commonly named the Morrow, Atoka, and Strawn Series from bottom to top. These units are important hydrocarbon producers in the Delaware Basin and site area.

The Permian System is divided into four series in the Delaware Basin: Wolfcampian, Leonardian, Guadalupian, and Ochoan Series, from base to top. The first three series include the pre-Castile formations. The Ochoan Series includes the evaporite and overlying redbeds of Permian age. Ochoan Salado and Rustler Formations are at the surface and in the near-subsurface around the Loving landfill site.

The Wolfcampian Series consists of heterogeneous rocks of shale and carbonate with minor sandstones on the order of 1000 feet thick. The Leonardian Series consists of beds of sandstone and limestone about 3000 feet thick. Part or all of the series is commonly called the Bone Spring Limestone. The Guadalupian Series in the area is very well known from different facies in the basin, under the site area, and in the Guadalupe Mountains. In the Guadalupe Mountains, the series is represented by formations which expose the reef to backreef facies made famous over the years by numerous studies (e.g. Newell and others, 1953) and the development of the Carlsbad Caverns in the reef rocks. Along the eastern escarpment of the Guadalupe Mountains,
rocks are exposed showing the transition from the backreef to reef to basin facies. The basin facies are named the Delaware Mountain Group, which is subdivided into the Brushy Canyon, Cherry Canyon, and Bell Canyon Formations from base to top. The Delaware Mountain Group is commonly about 4000 feet thick in the basin.

Evaporite Formations

The Ochoan Series in the northern Delaware Basin is divided into four formations: Castile, Salado, Rustler, and Dewey Lake Formations, from base to top. The Dewey Lake Formation has not been observed in the vicinity of the site, though it is well known and mapped east of the Pecos River. About one mile west of the landfill site, the depth to the base of the Castile is about 2520 feet in Citation Oil and Gas Company Watts Federal #1 well (L9, Table 1). The natural gamma and density log through most of this interval is inside casing; though not very reliable as a basis for interpretation, the log shows what appears to be a relatively intact evaporite section below about 950 feet depth. This section is probably mostly equivalent to the Castile Formation. The upper 950 feet are not reliable for basic interpretation of the stratigraphy. Bachman (1984, Fig. 3, p. 9) shows an isopach of the Castile of about 1600 feet at the landfill site location. This is consistent with the better geophysical logs from around the site.

From exposures and drilling around the site, the Salado and Rustler Formations immediately underlie the surface of the site. West of the site, along the county road, sulfate outcrops most probably belong to the Rustler Formation, although outcrops and site drilling (see later section) reveal considerable gypsum in the Gatuna Formation. Two small hills, about ½ and 1 mile west of the site and along the south side of the road, expose mostly red siltstones and sandstones of the Gatuna Formation of probable Plio-Pleistocene age (see below).
Surficial and Near-Surface Geology

The surficial and near-surface geology of the Loving landfill site is dominated by the erosion, solution, and weathering of the late Permian evaporite beds of the Salado and Rustler Formations. The Gatuña Formation deposited a veneer of sediments more recently (?Pliocene to Pleistocene), and these beds have also been subsequently distorted by solution of the underlying evaporites. The soils and surface deposits reflect both less soluble constituents of the evaporites, the fan-like deposits off the Guadalupe Mountains, and the influence of Pecos River drainage system.

Sulfatic beds are exposed both within the trench of the Loving landfill (late in 1991, now filled), along the road ditch west of the landfill site, and as outcrops and boulders in a borrow pit west of the landfill. There are no specific internal features to identify uniquely some of these beds. At distances of a few miles around the landfill site, lower Rustler units and upper Salado units are exposed, though deformed by dissolution and collapse. The Culebra Dolomite Member of the Rustler is identifiable in outcrops, and the broader structure on this units indicates it underlies the Loving site. I have identified neither outcrop nor clasts of the higher Magenta Dolomite Member of the Rustler Formation, indicating it was probably erosionally removed before the Gatuña was deposited. Nearby gypsum beds, to the west, are interpreted as possible Tamarisk Member of the Rustler Formation, while noting the gypsum encountered in the Gatuña Formation during drilling.

Within the landfill, the sulfate crops out as a large block which is probably rotated from horizontal. This is a possible clast of Rustler gypsum incorporated during collapse. In the nearby borrow pit, outcrops of the Gatuña also appear to be rotated, perhaps as much as 90° from original position; these rocks are also highly gypsiferous. The rocks are deformed by dissolution and collapse, as the underlying Bell Canyon and Castile Formations show no evidence of tectonic features other than the regional eastward dip.
The Gatuña Formation unconformably rests on several formations in the Delaware Basin. West of the landfill, the Gatuña rests on apparent Rustler sulfate beds. In the landfill, the Gatuña consists of thinly bedded sandstone and sandy siltstone, some thin gypsum beds and fracture fillings, and some argillaceous siltstones. These beds are rotated as much as $90^\circ$ from the horizontal, but the dip is not uniform even through the length of the trench. The Gatuña crops out on two hills approximately $\frac{1}{2}$ and 1 mile west of the landfill site. At both of these locations, the Gatuña is mainly siltstones and claystones. At the hill about $\frac{1}{2}$ mile west of the landfill site, the Gatuña appears to be about horizontal and is capped by gravel and conglomerate composed of mainly Permian limestone clasts from the Guadalupes. The gravel and conglomerate does not appear to be rotated or distorted. It is possibly the same age as the Mescalero caliche or younger based on cementation. The Gatuña at the more westerly location ranges from apparently horizontal to dipping to the west. Blocks of conglomerate near the middle of the borrow pit at this hill overlie the Gatuña in apparent conformity. The gravel may have been deposited in a low or channel through a collapsed or collapsing area on the Gatuña, though it may also have been modestly and uniformly lowered since gravel deposition.

The implication of these formations is that solution of the underlying evaporites, while hardly continuous or uniform, occurred both before and after the deposition of the Gatuña Formation. In Nash Draw, the Mescalero caliche (which began to form about 570,000 years ago; Rosholt and McKinney, 1980) overlies the Gatuña, indicating the Gatuña there was deposited by this time. Without other evidence, that is taken as the most likely upper limit to the age of the Gatuña in the landfill area. It can be inferred then that the most recent episode of solution and collapse around the landfill area may have occurred as recently as about 500,000 years ago. It may have been earlier, as the Gatuña is clearly of variable age. Significant solution and collapse
seems unlikely to be much more recent than a half million years ago in the immediate area, as I have observed no evidence of modern collapse features (sinkholes, karst). The cemented gravels (conglomerates) do not indicate rotation either, and these beds were likely cemented at the same time as the Mescalero caliche or later.

Soils

The soils of the landfill site area are mapped as the Reeves-Gypsum (RG) complex, with slopes of less than 3% (Chugg and others, 1971; sheet 119). The surrounding areas are also commonly mapped as part of the Reeagan association. The Reeves complex developed on gypsiferous units of the Rustler Formation, while the Reagan soils locally reflect the more calcareous alluvial source material from the Guadalupes brought in and deposited over the remains of the Rustler Formation.

Geomorphology

The site lies near the eastern end of a low ridge area or topographic high without well-developed drainage. The topography is due to both the local areas of more resistant highly cemented conglomerates and the remains of the Rustler sulfate beds. The sulfates continue to be weathered rapidly in geological time, and the low relief and fluffy soils are a consequence. Cass Draw, to the north, and Black River, to the south, are well integrated drainages from the west, drawing virtually all runoff from the Guadalupe Mountain area upslope of the landfill site. The site thus is protected from runoff and the underlying rocks are weathered mainly by direct precipitation and infiltration. For the immediate geological future, this topographic high will continue to exist. Secondary drainage from Cass Draw and the Black River will eventually form to remove runoff from direct precipitation and accelerate the weathering, solution, and erosion of these rocks, but this development will require considerable time (tens to hundreds of thousands of years) barring greatly increased precipitation.
West of the site, a gravel apron or fan developed off the Guadalupe Mountains during the Quaternary. Parts of the apron became highly cemented by carbonate and hold up high points parallel to Cass Draw. The rest of the gravel apron is being modified by erosion and reworking, mainly by Cass Draw, to lower positions as Cass Draw adjusts to the Pecos River.

Areas north, south, and east of the landfill site show evidence of evaporite karst developed on the Rustler Formation (Bachman, 1980). Rustler carbonate units hold up rounded hills or surround crescent shaped lows. These karst mounds and domes (Bachman, 1980) developed from the resistant plugs of former collapse areas (mounds) or as remaining highs (domes) as the surrounding areas underwent dissolution and collapse. The most obvious examples of these features exist southeast of Malaga in the Queen Lake area. In the far future, erosion is likely to expose some of these same features in the general area of the landfill, though there is no direct evidence. These features are not considered to be actively forming in this area today.

SITE AREA HYDROLOGY

The site hydrology can be generally inferred from the study by Hendrickson and Jones (1952).

As indicated above, the surface hydrology is dominated to the north by Cass Draw and to the south by Black River. Both are tributaries to the Pecos River about 4 miles east of the site. Because these two tributaries drain the Guadalupes uphill of the landfill site, there is little likelihood of a new, major drainage developing across the site. Instead, minor and poorly developed drainage from the site area can drain into these larger drainages. Given the low rainfall and nature of the soils, the site area is not expected to develop significant additional drainage in a short time (less than tens to hundreds of thousands of years).
Hendrickson and Jones (1952, Fig. 7) show the depth to water under the landfill site to be in the range from 75 to 100 ft. The depth to water decreases to the east, toward the Pecos River, and increases to the west under the sediment apron in front of the Guadalupe Mountains. The elevation of the water table also increases to the west, however, and Hendrickson and Jones (1952, Pl. 3) infer a northeasterly flow direction for the shallow ground water to the site area and thence east to the Pecos River. Almost all of the wells in the site area are reported within alluvial sediments. At greater depths, the Culebra Dolomite is also likely to transmit water, though its characteristics for this area were practically unknown at the time Hendrickson and Jones completed their study. Geohydrology Associates, Inc. (1978) report no information useful for this landfill site beyond that provided by Hendrickson and Jones (1952).

Hendrickson and Jones (1952, Table 3) report water quality for several wells in T.23S., R.27 and 28E. All of the reported wells were between 1,000 and 10,000 ppm total dissolved solids, exceeding present standards for human consumption but usable for irrigation. In the vicinity of Malaga Bend on the Pecos River, water quality can be much poorer, especially on the east side of the Pecos River. This stretch of the Pecos River is in the general direction Hendrickson and Jones (1952) expected shallow ground water to flow.

The Capitan aquifer, at considerable distance to the west and north of the landfill site, is geologically isolated from the shallow and deeper hydrology of the landfill site. The Capitan limestone, formed as a reef, fringes and helps define the Delaware Basin. There appears to be very little interconnection between the Capitan and equivalent rocks, the Delaware Mountain Group, in the basin. The Delaware Mountain Group underlies the site at a depth of about 2500 ft. The gradient would also cause flow from Capitan to the site area (Mercer, 1983, Fig. 9), if any flow exists.
SITE GEOLOGY AND HYDROLOGY

The site specific geology and hydrology reported here (see Appendices 1 and 2 for details) have been developed through the drilling program for establishing monitor wells and subsequent measurements of water levels. The drilling and completion program was carried out under the general plan (Appendix 3) for monitor wells provided to the Environment Department prior to beginning field work.

Drilling included both coring and rotary drilling with tricone bits. The geological data are based on core descriptions as well as more general descriptions of cuttings which were obtained from the return air/ fluid flow. Coring was limited as the principal purpose of the program was to develop monitor wells. Rocks exposed in the sides of trenches were also inspected during the drilling program.

The rocks penetrated during the drilling at the Loving landfill site are all attributed to the Pleistocene (?) Gatuña Formation. The Rustler Formation and/or Salado Formation residues are expected to underlie the Gatuña, but neither is believed to have penetrated during the drilling.

Gatuña Formation

The Gatuña Formation was originally proposed by Lang (in Robinson and Lang, 1938) as a formation based on deposits in the Gatuña Canyon area of Clayton Basin. Bachman (1974) described a type section about 54.5 ft thick in the canyon. More recently, Powers (in Holt and others, in prep.) described Gatuña outcrops and lithologic associations from the type area to Pierce Canyon; Powers (1992) also described cores of Gatuña from the geologic and borehole drilling during characterization of the Sand Point site being investigated as a potential landfill site for Eddy County and
Grid line markers are at 100 ft intervals; initial point (0,0) is southwest corner of fenced portion marked by solid lines. M-# refers to monitor well number. Modified from base map by Wehran EnviroTech for JOAB, Inc. Small numbers near well location refer to total depth drilled.

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are interpreted to be beds of gypsum within the Gatuña. The alternatives are to interpret the unit as partially belonging to the lower Rustler or Salado Formations, or to interpret these as possible blocks transported from nearly outcrops. The attendant lithologies and sedimentary structures are much more consistent with interpreting these as lithofacies of the Gatuña rather than as unusual deposits within the other formations. The minor sandstones and relatively rare conglomerates or gravels in the monitor wells are consistent with the Gatuña as well, and they are not consistent with other units in the area.

Available cores and trench exposures reveal zones with extensive parallel laminae to thin beds, a single cross-bedded unit, some concretions, some wavy bedding, minor bioturbation and MnO₂. These features are consistent with the Gatuña. Some of these features are found in other units, such as the Dewey Lake Formation, but the combination is only consistent with the Gatuña. Diagnostic features of the Dewey Lake are not present, however.

Site Hydrology

The regional hydrology suggests that ground water should be about 75 to 100 ft below the landfill surface if the hydrology of the Pecos valley fill continues under the site. The general flow regime is estimated to be from west to east under the site. Initial drilling was planned for an upgradient (west) borehole and downgradient (east/southeast) boreholes. The wells were drilled and completed under the provisions of the monitor well drilling plan (Appendix 2, Figures 2-1 through 2-5; Appendix 3).

During drilling, three boreholes (M-1, M-3, M-5) did not show any immediate evidence of ground water. Each of these monitor wells has subsequently produced water, and the water levels have been measured several times (Table 2). Three boreholes (M-2, M-4, and M-6) returned water to the surface during drilling, and the water level in
each reached approximate equilibrium very quickly (Table 2), based on several
measurement since the well completion.

M-2, M-4, and M-6 all show ground water level to have risen relatively rapidly
(within hours) to levels above the depth at which water was first observed. M-2 and
M-6 rose about 70 to 50 ft, respectively, above the initial encounter, while the level
in M-4 rose less than 5 ft above the depth at which water was encountered. At least in
M-2 and M-6, the ground water behaves as a confined aquifer. M-4 is also probably
confined, but it is less obvious. During the final drilling of M-6, pressure in the
borehole built up after ground water was initially observed. The water level in M-2

### Table 2
**Summary of Recent Measurements of Ground Water Levels, Loving Landfill**

<table>
<thead>
<tr>
<th>Borehole</th>
<th>Shroud Cap Elevation (JOAB - Magee) ft</th>
<th>09/29/92 (time)</th>
<th>Ground Water Depths (ft) 10/05/92 (time)</th>
<th>10/14/92 (time)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL M-1</td>
<td>3113.91</td>
<td>112.12 (1714)</td>
<td>111.88 (1429)</td>
<td>111.51 (0901)</td>
</tr>
<tr>
<td>LL M-2</td>
<td>3110.73</td>
<td>50.52 (1743)</td>
<td>50.42 (1407)</td>
<td>50.71 (0845)</td>
</tr>
<tr>
<td>LL M-3</td>
<td>3113.12</td>
<td>84.58 (1752)</td>
<td>84.47 (1358)</td>
<td>84.26 (0837)</td>
</tr>
<tr>
<td>LL M-4</td>
<td>3110.50</td>
<td>50.47 (1737)</td>
<td>50.34 (1411)</td>
<td>50.51 (0852)</td>
</tr>
<tr>
<td>LL M-5</td>
<td>3113.11</td>
<td>111.88 (1722)</td>
<td>110.52 (1433)</td>
<td>110.03 (0907)</td>
</tr>
<tr>
<td>LL M-6</td>
<td>3114.22</td>
<td>53.92 (1731)</td>
<td>53.83 (1439)</td>
<td>54.10 (0913)</td>
</tr>
</tbody>
</table>

All water depths were measured by Dennis Powers with the same probe supplied by JOAB, Inc. Depths were
based on repeated changes in strength of audio signal, and the measurement was by sighting across the top
of the well shroud in each well.

The shroud elevations were measured by Marvin Magee of JOAB, Inc.
was observed to rise during the pressure buildup and to fall when the pressure was removed. The ground water level was not observed to change in M-4 during this pressure increase in M-6. This indicates very good hydraulic connections between M-2 and M-6, possibly through a fracture system within the isolated (confined) unit. M-1, M-3, and M-5 systems may require additional development and testing after ground water levels have stabilized to determine if the units are interconnected.

**DISCUSSION AND IMPLICATIONS**

The broad geology of the Loving site indicates it has a common geological history with much of southeastern New Mexico. Permian age evaporites deposited within the Delaware Basin are a controlling feature of the present landscape and geological processes because they are now at or near the surface. These units are rather soluble compared to other minerals, resulting in local evaporite karst and deformation features unrelated to broader tectonic processes. The evaporites are also likely to prevent or minimize the possibility of earthquakes fracturing the rock units to provide hydrological continuity between deeper units and near surface units. There are no nearby faults known to be recent and of tectonic origin.

The geology of the Loving landfill site indicates that main geological processes in the last few hundreds of thousands to a few (1 or 2?) million years have been weathering and erosion of the then exposed Rustler Formation, dissolution of soluble minerals from the Rustler with attendant deformation and collapse, and deposition of sediments, first as the Gatufia Formation and later as debris from the Guadalupe Mountains forming an apron of sediment to the west of the site area. At least local dissolution of beds under the Gatufia resulted in deformation of the Gatufia, probably about 500,000 years ago. The Pecos River continued reworking alluvium and integrating the drainage from the Guadalupe.
The time bounds on dissolution in the site area are provided by the presence of the Gatufia Formation and carbonate-cemented conglomerates inferred to be the age of the Mescalero caliche or younger (570,000 years or less). West of, and near, the site, the Gatufia (including conglomerates) is apparently undisturbed, indicating locally that post-Gatufia dissolution is minimal. Within the landfill site, the Gatufia is considerably disturbed, showing that later dissolution and collapse has occurred. There is no evidence of active karst at the site.

The surface hydrology of the site area is broadly predictable from the geomorphology of the site and indicates it should not change significantly for geological periods of time. The near-surface hydrology is dominated by alluvium around the site, with ground water expected to move to the northeast and east. At the site, the Gatufia produces ground water in each of the six monitor wells drilled. Three of the monitor wells indicate ground water at about 50 ft below the surface; these monitor wells in the southeast part of the landfill are probably all showing the same ground water system. The other three boreholes, in the north and northwest part of the landfill site, are not yet known to have reached equilibrium and are not yet determined to belong to the same ground water system. The ground water elevations in these boreholes range from about 3060 ft (in monitor wells with apparently stabilized ground water levels) to about 3000 ft (in two wells with apparently rising ground water levels). Contours of ground water elevations at the site by Hendrickson and Jones (1952) are 3020 to 3040 ft (to the west). The observations at the site show ground water higher than projected by Hendrickson and Jones; the ground water flow direction is not yet established and may be more complex than estimated from contours provided in Hendrickson and Jones.

Each of the monitor wells drilled showed intervals of claystone or argillaceous rocks with little obvious porosity. The data from M-2, M-4, and probably M-6, of
confined ground water, combined with impermeable beds, suggest there is little potential for vertical recharge at the landfill site.

**CONCLUSIONS**

The geology and hydrology of the Loving landfill site and immediate surroundings indicate this site should remain relatively stable or unaltered by natural processes for tens to hundreds of thousands of years. The major threat over that period of time will be further dissolution and the development of deeper surface drainage. Increased rainfall, as has occurred in the geological past, could accelerate these processes:

The hydrology of the Loving landfill site clearly reveals ground water at relatively shallow depths (about 50 ft below the surface), though three wells do not appear yet to have reached an equilibrium level. These wells will need to reach equilibrium for satisfactory demonstration of ground water levels and testing to determine probable direction of ground water flow. Fine-grained beds in each monitor well, and probable confined ground water in at least three wells, strongly suggest little, if any, vertical recharge of ground water at the landfill site.

**RECOMMENDATIONS**

Testing of hydraulic parameters and sampling for ground water chemistry/quality should be deferred until hydrological consultants have determined that ground water in the monitor wells has reached static or near-static levels. This will permit an initial estimate of gradients and whether the ground water sources are well-connected. Premature sampling in M-1, M-3, and M-5 may cause considerable delays in reaching static levels, given the slow rise in levels.
It is also recommended that the water in the monitor wells be tested for ground water quality and specific gravity in initial samples before any bailing. In southeastern New Mexico, local changes in specific gravity due to dissolution and modest mixing in relatively impermeable beds can be large and can significantly alter computed ground water gradients and flow directions.

A plan for monitoring ground water levels in the monitor wells should be implemented soon. It is recommended that levels should be measured at intervals of 1 to 2 months until static or apparent static water levels have been reached.

If the gradients finally established for this location are predominantly from east to west, as indicated by water levels which have so far been measured, an older landfill to the east of Higby Hole Road should be considered as a potential source of contaminants in eastern, upgradient wells. There is no known monitoring of this former landfill. Initial planning of water quality sampling as well as monitor locations should consider the possibility that upgradient (if to the east) water quality could be affected by this landfill.
REFERENCES CITED


Bureau of Economic Geology, 1976, Geologic atlas of Texas, Pecos Sheet: Bureau of Economic Geology, Austin, Texas, scale: 1:250,000.


Powers, D.W., 1992, Summary of site selection and preliminary site characterization for the Sand Point site, Eddy County, NM: draft report (09/02/92) to JOAB, Inc.


Robinson, T.W., and Lang, W.B., 1938, Geology and ground-water conditions of the Pecos River valley in the vicinity of Laguna Grande de la Sal, New Mexico, with special reference to the salt content of the river water: Twelfth and Thirteenth Biennial Reports of the State Engineer of New Mexico, p. 77-118.

Appendix 1

Loving Landfill Closure

Monitor Well Descriptions and Graphics

Introduction and Explanation of Symbols

The monitor well graphic logs presented here were prepared from the field descriptions and logs. Several notes are provided below. The approximate locations for each borehole in section 32 (T.23S, R.28E.) are given relative to fence corners or fenced boundaries of the landfill site.

Explanation of Symbols

- **Gypsum or gypsiferous rock**
- **Claystone**
- **Siltstone**
- **Sandy siltstone**
- **Sandstone**
- **Conglomerate**
- **Bioturbation** (mainly rootcasts)
- **Ripple cross-bedding**
- **Laminar bedding**
- **Wavy bedding**
- **Soji deformation**
- **Fibrous gypsum in fracture**

Abbreviations: f - fracture; MnO₂ - manganese oxide stain; sl - slickensides; calc - calcareous; 2.5YR 4/6 - numbers refer to colors based on Munsell Soil Color Chart.

The descriptions are based only on field study; estimates of the average grain size are not precision analyses of the rocks and have been given to show trends and relative sizes. Grain size estimates are included in some zones from cuttings where confidence in representative cuttings is better. Poor or no recovery is indicated by placing no graphic symbols. Graphic symbols may be arbitrarily placed in a coring interval where core loss occurs but cannot be exactly placed. Depths are in feet.

Line symbols for size estimates and unit contacts are continuous, dashed, or dotted; continuous lines indicate good sorting or sharp contacts while dots indicate poor sorting and gradational contacts.
<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Cg Sd St Cl</td>
<td>Possible disturbed fill to 6 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Siltstone, argillaceous and white to clear crystalline gypsum.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gatuna Formation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gypsum in subvertical zones, some slight MnO₂; some root material of possible recent or modern origin.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No root zones apparent 10-20 ft. Some fractures about 60°, may be due to drilling.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Crystalline gypsum in apparent nodules as well as in subvertical to subhorizontal zones about 1/16 to 1/4 inch wide. Forms roughly continuous network on core surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Fracture has root casts, possible clay illuviation.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Carbonate nodules to about 1 inch diameter from about 24-28 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rare coarse sand particle of chert.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No gypsum, 34.5 to 36.5 ft. Slickensides, MnO₂.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Gypsum, very coarse, to about ½ inch; may be displacive.</td>
</tr>
</tbody>
</table>

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40-69: Siltstone, argillaceous, with gypsum in pods, zones; gypsum from 40-45 generally < ¼ inch diameter, in continuous network along core.

Slight whitish mottling from carbonate at 47 ft to nodules at about 52 ft.

Mainly crystalline gypsum with argillaceous siltstone from 53-55 ft.

61-65: unit becomes more sandy, less gypsum.

Gravel, siltstone, mudstone at base of recovered core.

69-85: Sandstone, with silt and rare small pebbles (generally < ¼ inch) from 69 to 75 ft or granules and some gypsum. Poorly consolidated, soft. No bedding observed.
### MONITOR WELL GEOLOGICAL LOG
**LOVING LANDFILL SITE**

**Drillhole No.: LL M-1**

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>Poorly developed calcareous nodules to about 1/4 inch and displacive gypsum to about 1/2 inch from 80-85 ft.</td>
</tr>
<tr>
<td>85-97</td>
<td></td>
<td></td>
<td>85-97: Siltstone, sandy, argillaceous, with displacive and some fibrous gypsum. Calcareous nodules, poorly developed.</td>
</tr>
</tbody>
</table>

97 ft. End coring, begin rotary drilling.
Graphics and notes based on cuttings recovered. Depths based on depth of bit at time of recovery.

106-116: White gypsum powder.

116-126: Pebbles, gravels of rounded to broken light brown to gray limestones.

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<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>120-130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>130-140</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>140-150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150-160</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

126: Siltstone, brown, with gypsum.

145-150: Gravels and pebbles.

150: Gypsum with siltstone.

---

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160-205: Gypsum and very dark brown sticky mud, with rare clasts or fragments of rounded chert and limestone.

205-220: Mainly gypsum, some yellowish mud.

End drilling. T.D. 220 ft.
<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size Cg Sd St Cl</th>
<th>Description</th>
</tr>
</thead>
</table>
| 0-30      |          |                        | Gatunña Formation.  
|           |          |                        | 0-30: Sandstone, with argillaceous siltstone and gypsum in thin laminae along bedding. Sand is very fine to medium, subangular to subround, < 1% dark grains. Thin laminae and ripple-scale cross-beds abundant. |
|           |          |                        | More gypsiferous 10-20 ft. |
| 22        |          |                        | 22: Clay clasts, purplish and yellow. |
| 29        |          |                        | 29: Dip 5-10°. |
| 30-40     |          |                        | 30-40: Thin laminae of sandstone, sandstone and siltstone, some thin clay interlaminae. Gypsum is along bedding, as probable cement, also as thin (2-4 mm) fracture fillings at 10-45° opposite dip. Clay clasts at 30 and 36 ft. |

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**Monitor Well Geological Log**

**Loving Landfill Site**

**Drillhole No.: LL M-2**  
**Location: 100 ft, 50 fc of SE corner**  
**Date: 06/27/92**

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>40-60</td>
<td></td>
<td></td>
<td>40-60: similar to above. More argillaceous zones from 40-50, rare MnO₂ along bedding. Crinkled bedding at 40-42 ft as well as dips on planar beds. Clay clasts at 47 ft. Detail at 41 ft.</td>
</tr>
<tr>
<td>50-60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60-70</td>
<td></td>
<td></td>
<td>60-T.D.: sticking at 60 ft; rotary with 5 inch bit with air from surface. Graphics and discussion reflect cuttings.</td>
</tr>
<tr>
<td>70-80</td>
<td></td>
<td></td>
<td>70: Sandstone, fine, siltstone with argillaceous zones, gypsiferous.</td>
</tr>
</tbody>
</table>

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### MONITOR WELL GEOLOGICAL LOG

**LOVING LANDFILL SITE**

**Drillhole No.:** LL M-2  **Location:** 100 ft, 50 ft of SE corner  **Date:** 06/27/92

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-92</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>80-92: Siltstone, sandy, and claystone, gypsiferous, soft.</td>
</tr>
<tr>
<td>92-97</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>92-97: as above, harder, more grayish brown.</td>
</tr>
<tr>
<td>97-120</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>97-120: similar to 80-92 ft. Some gravel, pebble fragments at 118 ft. Water returned to surface while drilling at 118 ft.</td>
</tr>
<tr>
<td>120-128</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>120-128: Siltstone, argillaceous, soft, dark brown.</td>
</tr>
<tr>
<td>128-130</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>128-130: Siltstone, gypsiferous, harder than above, grayish brown.</td>
</tr>
<tr>
<td>130-132</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>130-132: Gypsum.</td>
</tr>
<tr>
<td>132-135</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>132-135: Siltstone and claystone, soft, brown.</td>
</tr>
<tr>
<td>135-140</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>135-140: Siltstone, hard, grayish brown, gypsum cemented. Similar to 92-97 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End drilling. T.D. 140 ft.</td>
</tr>
</tbody>
</table>

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## Monitor Well Geological Log

### Loving Landfill Site

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size Cg Sd St Cl</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-40</td>
<td></td>
<td></td>
<td>Gatuña Formation. Rotary drilling with air. Graphics and descriptions from cuttings. 0-31: Siltstone, sandy, gypsiferous, light brown to medium brown. Includes slightly more argillaceous zones, including 22-31.</td>
</tr>
<tr>
<td>31-33</td>
<td></td>
<td></td>
<td>31-33: Gypsum. Similar to zone above gypsum. Reddish-brown siltstone and claystone with gypsum.</td>
</tr>
<tr>
<td>80</td>
<td></td>
<td></td>
<td>80: no moisture in tubing after 35 minute shutdown.</td>
</tr>
</tbody>
</table>

*Drillhole No.: LL M-3  Location: 100 ft, 50 ft of NE corner  Date: 06/27/92*

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<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-153:</td>
<td>Siltstone/claystone, gray, with gypsum stringers or between between 90-100 ft; gypsum interbeds and some gypsiferous zones 100-153 ft. Some zones slightly more grayish brown, brownish gray below 100 ft.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>153-158:</td>
<td>Mostly gypsum.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>158-161:</td>
<td>Gypsum with siltstone.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
161-200: Siltstone/claystone, grayish brown, with gypsum throughout. Zone may be slightly more moist at about 174 ft. Becomes very sticky at 198-200 ft. No apparent fluid production during 30 minute observation period.

Begin coring.

# Monitor Well Geological Log

**Loving Landfill Site**

**Drillhole No.: LL M-3**
**Location:** 100 ft, 50 ft of NE corner
**Date:** 06/28/92

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size Cg Sd St Cl</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>240</td>
<td></td>
<td></td>
<td>End drilling. T.D. at 248 ft.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cg Sd St Cl</th>
</tr>
</thead>
</table>

---

D.W. Powers, Ph.D.  
*Star Route Box 87*  
*Anthony, TX 79821*

Consulting Geologist  
(915) 877-2417
<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-18</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>Rotary drilling with air; cuttings used for graphics and description.</td>
</tr>
<tr>
<td>18-19</td>
<td></td>
<td></td>
<td>Gatunha Formation</td>
</tr>
<tr>
<td>19-38</td>
<td></td>
<td></td>
<td>0-18: Sandstone with gypsum, upper part is disturbed by landfill activities.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>18-19: Gravel, sand, somewhat moist.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>19-38: Sandstone and gypsum with siltstone.</td>
</tr>
<tr>
<td>38-40</td>
<td></td>
<td></td>
<td>38-40: Claystone and siltstone, soft, reddish brown.</td>
</tr>
<tr>
<td>40-60</td>
<td></td>
<td></td>
<td>40-60: Interbedded gypsum and siltstone.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No return of cuttings at 50 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water return to surface.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End drilling. T.D. 60 ft.</td>
</tr>
</tbody>
</table>

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**MONITOR WELL GEOLOGICAL LOG**
LOVING LANDFILL SITE

**Drillhole No.: LL M-5**  
**Location:** 200 ft, 50 ft of NW corner  
**Date:** 06/29/92

<table>
<thead>
<tr>
<th>Lathology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>Rotary drilling with air; cuttings used for graphics and description. <strong>Gatun Formation</strong></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cg Sd St Cl</td>
<td>0-34: Claystone and siltstone, reddish brown, with zones or blocks of gypsum. Soft, cuttings molded during drilling.</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td>30: Sticky zone.</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td>34-37: Gypsiferous claystone and siltstone.</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td>37-38: Conglomerate, limestone clasts.</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td></td>
<td>38-58: Gypsiferous siltstone and claystone.</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
<td>58-60: Gravel, limestone clasts.</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td>60-74: Gypsiferous siltstone and claystone, grayish brown.</td>
</tr>
<tr>
<td>70</td>
<td></td>
<td></td>
<td>74-78: Gravelly zone.</td>
</tr>
</tbody>
</table>

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*(915) 877-2417*
<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>90</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>130</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>140</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>150</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>160</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

78-112: Siltstone and claystone, reddish brown, with gypsum or gypsiferous zones and beds. Becomes more grayish brown in color below 87 ft.

112-119: Sand, gravel, gypsum, yellowish.


160: Claystone, gray, soft.
### MONITOR WELL GEOLOGICAL LOG
#### LOVING LANDFILL SITE

**Drilling No.: LL M-5**  
**Location:** 200 ft, 50 fs of NW corner  
**Date:** 06/29/92

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>160-200</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>160-200: Claystone and siltstone, grayish brown, soft, with zones/beds of gypsum. Unit generally more gypsférous from 181-185.</td>
</tr>
<tr>
<td>200</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>End drilling. T.D. 200 ft.</td>
</tr>
</tbody>
</table>

---

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**MONITOR WELL GEOLOGICAL LOG**
**LOVING LANDFILL SITE**

**Drillhole No.: LL M-6**  **Location: 100 ft, 150 ft of SE corner**  **Date: 06/29/92**

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td></td>
<td>Rotary drilling with air; cuttings used for graphics and description.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cg Sc St Cl</td>
<td>Gatuna Formation</td>
</tr>
<tr>
<td>0-75</td>
<td></td>
<td></td>
<td>0-75: Siltstone and claystone, reddish brown, soft, with fibrous gypsum and gypsiferous zones. Sandy zone from about 28-38 ft. Gypsum zone at 43 ft. Clasts at 57 ft.</td>
</tr>
<tr>
<td>75-79</td>
<td></td>
<td></td>
<td>75-79: Claystone, greenish gray, with brown claystone and siltstone.</td>
</tr>
<tr>
<td>79-80</td>
<td></td>
<td></td>
<td>79-80: Coarse gypsum fragments.</td>
</tr>
</tbody>
</table>

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*Star Route Box 87*
*Anthony, TX 79821*
<table>
<thead>
<tr>
<th>Lithology</th>
<th>Features</th>
<th>Grain Size</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>80-100</td>
<td></td>
<td>Cg Sd St Cl</td>
<td>80-100: Siltstone/claystone, gray and brown.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Blew water from borehole at about 95 ft.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>End drilling. T.D. 120 ft.</td>
</tr>
</tbody>
</table>
Appendix 2
Loving Landfill Closure
Monitor Hole Histories

General
The hole histories for the drilling of monitor wells for closure of the Loving landfill site are compiled from field notes by Dennis Powers and Marvin Magee. The borehole histories are a chronological record of the daily events in drilling and completion of each borehole. Where minor differences in records existed, they have been reconciled based on the best apparent record; these generally reflect minor variations in data about times of events or exact depths. The main report includes generalized illustrations of the features of each borehole as completed.

The drilling contractor was Stewart Brothers, Inc., Grants, NM; a four man crew utilized a Chicago Pneumatic 650, top head drive, rotary drilling rig. The crew and rig arrived on site June 25, 1992; the last well was completed on July 1 and surface shrouds were finished July 2, 1992.

The program for the Loving landfill was implemented to establish wells for monitoring ground water levels and quality following closure of the landfill. Drillholes were cored through various intervals to establish the fundamental geology. Drilling was conducted with air when possible; some conditions required use of foam or water. The wells were established as piezometers to monitor initial ground water level recover, provide for sampling, and enable bailing or other testing of hydrologic parameters, if necessary.
Drillhole LL M-1

LL M-1 was located about 20 ft inside the western fenceline of the landfill, approximately at the middle of the boundary line. The surface elevation of LL M-1 is about 3112 ft.

June 25
1500-1545 Moved rig onto landfill site and set up to drill M-1.
1545-1830 Drilling and coring with air, using 94 mm wireline system, from ground surface to 70 ft with good but variable recovery of Gatuña Formation.

June 26
0700-0705 Checked borehole with water detector; borehole dry.
0705-0740 Cored to 76 ft, using air; drilling difficult from 74-76 ft.
0740-0900 Reamed hole to 5" diameter with tricone bit to 76 ft. Rerigged for coring.
0900-1030 Cored using air to 97 ft with variable recovery. Put 5 gal water into drillhole from surface while drilling at 95 ft. Coring difficult; changed to rotary drilling with examination of cuttings.
1030-1745 Rotary drilling in Gatuña Formation from 97 to 220 ft. Foam was used in drilling from about 160 ft to TD. No detectable fluid in borehole. Removed drilling string from borehole and shut down rig. Major electrical storm north and south threatening site.

June 27
0700-0940 Checked for water in M-1; possible fluid level at 215-216 ft below surface and bottom of borehole at 225 ft. Bailed hole "dry", waited 20 minutes, bailed again; estimated 15 gal of soapy water and muck (mainly mud clasts and gypsum). Decided to move to another location and allow borehole to stand.

July 1
Set 2 inch schedule 40 FJ PVC tubing as follows: screen from 200 to 170 ft, riser from 170 ft to surface. Completed monitor well with sand pack (10-20 size) from 240 (TD) to 160 ft, benseal from 160 to 122 ft, and cemented from 122 ft to surface with 15 lb neat cement. Set well shroud.

Drillhole LL M-2

LL M-2 was located about 50 ft east and 100 ft north of the southwest corner of the landfill. The surface elevation of LL M-2 is about 3109 ft.

June 27
0940-1010 Moved to location for LL M-2 and set up to core.
1010-1155 Core with air with good recovery from ground surface to 60 ft. Probable condensation in core barrel and sticking from 50-60 ft.

1155-1445 Standby and rotary drilling with 5" tricone bit from 60 to 118 ft, using air. Recover cuttings of Gatufia Formation. At 118 ft, cuttings stopped returning, pressure in drill string rose, and then water began blowing from air return.

1445-1515 Continued drilling hole to 140 ft TD with rotary tricone bit (5") to provide sump for tubing.

1515-1530 Rig down to move to M-3 location.

June 30
Set 2 inch schedule 40 FJ PVC tubing as follows: blank tubing from 140-130 ft, screen from 130 to 110 ft, riser from 110 ft to surface. Completed monitor well with sand pack (10-20 size) from 140 (TD) to 94 ft, benseal from 94 to 78 ft, and cemented from 78 ft to surface with 15 lb neat cement.

July 2
Set shroud.

Drillhole LL M-3

LL M-3 was located about 50 ft east and 100 ft south of the northeastern fence corner of the landfill. The surface elevation of LL M-3 is about 3111 ft.

June 27
1530-1615 Moved to M-3 location and set up to drill.

1615-1845 Rotary drilled with air using 5" tricone bit from surface to 140 ft depth. Cuttings from Gatufia Formation primarily finer-grained siltstone/claystone with variable gypsum content. Checked water level in M-2 (57.2 ft below surface).

June 28
0700 Checked water levels in M-2 (48 ft below surface) and M-3 (no fluid detected) at 140 ft.

0700-0900 Rotary drilled with air to 200 ft; sticky clay and difficult drilling from 198-200 ft.

0900-0915 Halted drilling and removed drill string for observation of any fluid entry.

0915-0945 Monitored borehole with water detector at 200 ft; no fluid entry detected.

0945-1350 Re-entered borehole with wireline coring system and bit. Cored slowly with to TD at 248 ft with excellent recovery.

1350-1445 Observed borehole for fluid entry; no water detected.

1445 Rig down for move to M-4.
June 30
Set 1¼ inch tubing as follows: screen from 240 to 220 ft, riser from 220 ft to surface. Completed monitor well with sand pack (10-20 size) from 245 (TD) to 175 ft, benseal from 175 to 157 ft, and cemented from 157 ft to surface with 15 lb neat cement.

July 2
Set shroud.

Drillhole LL M-4

LL M-4 was located about 250 ft east of southwest fence corner and 50 ft south of the south fence line of the landfill. The surface elevation of LL M-4 is about 3108 ft.

June 28
1445-1515 Rig down and move from M-3 to M-4. Set up and prepare for rotary drilling with 5" tricone bit.
1515-1615 Rotary drill to 60 ft. No cuttings returned from about 50 ft, damp to wet cuttings from 51 ft, moisture blowing from hole from 53 ft (1555 hours). Cuttings from gypsum at 60 ft.
1615-1745 Shut down drilling, observed fluid level rise from about 53.6 (1620 hours) to 51.6 ft (1655 hours) (levels measured from top of drill pipe, about 3 ft above ground level). Bailed about 30 gal to 1730 hours. Measured about 10" recovery in water level from 1733 to 1745 hours.
1745-1800 Pulled rig off hole and shut down operations.

June 29
0710-0805 Checked water levels at M-1,2,3, and 4.

June 30
Set 2 inch schedule 40 FJ PVC tubing as follows: screen from 60 to 40 ft, riser from 40 ft to surface. Completed monitor well with sand pack (10-20 size) from 60 (TD) to 35 ft, benseal from 35 to 20 ft, and cemented from 20 ft to surface with 15 lb neat cement.

July 2
Set shroud.

Drillhole LL M-5

LL M-5 was located about 25 ft south of approximate midpoint of north fence line of the landfill. The surface elevation of LL M-5 is about 3112 ft.

June 29
0805-1155 Rotary drilled with air using 5" tricone bit from surface to 200 ft. Gatuña Formation indicated by cuttings to TD. No fluid or moist zones identified.
Rig down, move to M-6 location and set up for drilling.

Move rig back to M-5 to install tubing for monitor well. Set 1¼ inch tubing as follows: screen from 193 (TD) to 183 ft, riser from 183 ft to surface. Placed sand pack (10-20 size) from 193 to 174 ft, benseal from 174-156 ft, and cemented from 156 ft to surface with 15 lb neat cement.

July 1

Set well shroud.

**Drillhole LL M-6**

LL M-6 was located about 150 north and 100 ft west of the southeast fence corner of the landfill. The surface elevation of LL M-6 is about 3113 ft.

**June 29**

1235-1630

Rotary drilled with air, using 5" tricone bit, from surface to 120 ft in Gatuná Formation. Possible fluid entry at 90 ft, probable fluid production from fracture at 115 ft. Pressure increase within drillstring in M-6 coincided with fluid level rise in M-2. Lowered pressure in M-6 and fluid production coincided with lowering of fluid level in M-2. Blew fluid from borehole. Monitored fluid level rise briefly; rigged down for rig move.

**June 30**

Set 2 inch schedule 40 FJ PVC tubing as follows: screen from 120 to 90 ft, riser from 90 ft to surface. Completed monitor well with sand pack (10-20 size) from 120 (TD) to 84.8 ft, benseal from 84.8 to 72 ft, and cemented from 72 ft to surface with 15 lb neat cement.

**July 1**

Set well shroud.
Table 2-1
Well Reference and
Early Ground Water Elevations,
Loving Landfill Monitor Wells

<table>
<thead>
<tr>
<th>Monitor Well</th>
<th>Date:</th>
<th>July 2</th>
<th>August 6</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Ground Water Elevation (Depth)</td>
<td></td>
</tr>
<tr>
<td>LL M-1</td>
<td>3113.9</td>
<td>2979.1 (134.75)</td>
<td>2997.3</td>
</tr>
<tr>
<td>LL M-2</td>
<td>3110.7</td>
<td>3060.2 (49.9)</td>
<td>3060.8</td>
</tr>
<tr>
<td>LL M-3</td>
<td>3113.1</td>
<td>2890.1 (223.0)</td>
<td>3026.3</td>
</tr>
<tr>
<td>LL M-4</td>
<td>3110.5</td>
<td>3070.8 (39.7)</td>
<td>3060.6</td>
</tr>
<tr>
<td>LL M-5</td>
<td>3113.1</td>
<td>&lt; 2917.1 (dry to 196)</td>
<td>2984.3</td>
</tr>
<tr>
<td>LL M-6</td>
<td>3114.2</td>
<td>3060.9 (53.3)</td>
<td>3060.9</td>
</tr>
</tbody>
</table>

Note: All measurements provided by Marvin Magee (JOAB, Inc.).
### Table 2-2

**Loving Landfill Hydrological Data Obtained During Drilling Program**

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Depth</th>
<th>Reference Point</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LL M-1</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 26</td>
<td>0700</td>
<td>70'</td>
<td>drill pipe</td>
<td>Dry to TD @ 70'</td>
</tr>
<tr>
<td>June 27</td>
<td>1530</td>
<td>190?</td>
<td>surface</td>
<td>Questionable fluid level or mud; TD 220'.</td>
</tr>
<tr>
<td>June 28</td>
<td>0700</td>
<td>215-216'</td>
<td>surface</td>
<td>Possible water; bottom @ 225'</td>
</tr>
<tr>
<td></td>
<td>0910</td>
<td>193?</td>
<td>surface</td>
<td>Possible fluid level</td>
</tr>
<tr>
<td>June 29</td>
<td>about 0715</td>
<td>170.3</td>
<td>surface</td>
<td>Fluid level; bottom 216'</td>
</tr>
<tr>
<td><strong>LL M-2</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 27</td>
<td>1445</td>
<td>118'</td>
<td>drill pipe</td>
<td>Blow water from hole while drilling</td>
</tr>
<tr>
<td>June 27</td>
<td>1555</td>
<td>84'</td>
<td>surface</td>
<td>Fluid level; TD 120'.</td>
</tr>
<tr>
<td></td>
<td>1723</td>
<td>63.5'</td>
<td>surface</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>1744</td>
<td>61.5'</td>
<td>surface</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>1849</td>
<td>57.2'</td>
<td>surface</td>
<td>*</td>
</tr>
<tr>
<td>June 28</td>
<td>0703</td>
<td>48.0'</td>
<td>surface</td>
<td>*</td>
</tr>
<tr>
<td></td>
<td>0900</td>
<td>48</td>
<td>surface</td>
<td>*</td>
</tr>
<tr>
<td>June 29</td>
<td>about 0725</td>
<td>47.0</td>
<td>surface</td>
<td>Fluid level; level rise to &lt;42' with pressure buildup in M-6; level drop with pressure release in M-6</td>
</tr>
<tr>
<td></td>
<td>about 1500</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>LL M-3</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 27</td>
<td>1750</td>
<td>80</td>
<td>Drill pipe</td>
<td>No fluid after 35 min; TD 80'</td>
</tr>
<tr>
<td>June 28</td>
<td>0945</td>
<td>200</td>
<td>Drill floor</td>
<td>No fluid after 30 min; TD 200'</td>
</tr>
<tr>
<td></td>
<td>1445</td>
<td>248</td>
<td>Drill floor</td>
<td>No fluid detected at TD 248'</td>
</tr>
<tr>
<td>June 29</td>
<td>about 0735</td>
<td>190'</td>
<td>Surface</td>
<td>Damp mud?</td>
</tr>
<tr>
<td><strong>LL M-4</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 28</td>
<td>1600</td>
<td>53'</td>
<td>Drill pipe</td>
<td>Blow water from borehole while drilling</td>
</tr>
<tr>
<td></td>
<td>1620</td>
<td>53.63'</td>
<td>Drill pipe</td>
<td>Drill pipe about 3' above surface</td>
</tr>
<tr>
<td></td>
<td>1625</td>
<td>52.54</td>
<td>Drill pipe</td>
<td>as above</td>
</tr>
<tr>
<td></td>
<td>1630</td>
<td>52.17</td>
<td>Drill pipe</td>
<td>as shown</td>
</tr>
<tr>
<td></td>
<td>1635</td>
<td>52.0</td>
<td>Drill pipe</td>
<td>as above</td>
</tr>
<tr>
<td></td>
<td>1640</td>
<td>51.90</td>
<td>Drill pipe</td>
<td>as above</td>
</tr>
<tr>
<td></td>
<td>1645</td>
<td>51.79</td>
<td>Drill pipe</td>
<td>as above</td>
</tr>
</tbody>
</table>
Table 2-2, cont.  
Loving Landfill Hydrological Data Obtained During Drilling Program

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Depth</th>
<th>Reference Point</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>LL M-4</td>
<td>cont.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 28</td>
<td>1650</td>
<td>51.71</td>
<td>Drill pipe</td>
<td>as above</td>
</tr>
<tr>
<td></td>
<td>1655</td>
<td>51.63</td>
<td>Drill pipe</td>
<td>as above</td>
</tr>
<tr>
<td></td>
<td>1700-1730</td>
<td>51.63</td>
<td>Drill pipe</td>
<td>bailed about 30 gal</td>
</tr>
<tr>
<td></td>
<td>1733</td>
<td>54.33</td>
<td>Drill pipe</td>
<td>see above</td>
</tr>
<tr>
<td></td>
<td>1735</td>
<td>54.08</td>
<td>Drill pipe</td>
<td>see above</td>
</tr>
<tr>
<td></td>
<td>1740</td>
<td>53.71</td>
<td>Drill pipe</td>
<td>see above</td>
</tr>
<tr>
<td></td>
<td>1745</td>
<td>53.48</td>
<td>Drill pipe</td>
<td>see above</td>
</tr>
<tr>
<td>June 29</td>
<td>about 0745</td>
<td>47.90</td>
<td>Surface</td>
<td>surface about 3' lower than drill pipe</td>
</tr>
<tr>
<td></td>
<td>about 1500</td>
<td>47.90</td>
<td>Surface</td>
<td>No change in level with pressure buildup and release in M-6</td>
</tr>
<tr>
<td>LL M-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 29</td>
<td>1200</td>
<td>200'</td>
<td>Drill pipe</td>
<td>Dry to TD @ 200'</td>
</tr>
<tr>
<td>LL M-6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>June 29</td>
<td>1412</td>
<td>95'</td>
<td>Drill pipe</td>
<td>Blew water from borehole; TD @ 120'. Pressure buildup in M-6 produced fluid level rise in M-2; pressure release resulted in M-2 drop. M-4 showed no effects.</td>
</tr>
</tbody>
</table>
Figure 2-1

As-Built Configuration of LL M-1

<table>
<thead>
<tr>
<th>Well I.D.</th>
<th>LL M-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Loving Landfill</td>
</tr>
<tr>
<td>Type</td>
<td>Piezometer</td>
</tr>
<tr>
<td>Elevation*</td>
<td>3113.91 ft</td>
</tr>
</tbody>
</table>

- Top of well shroud without locking cap
- Not to scale

- Locking Cap
- Reference Level (0 ft)
- Well Shroud
- Concrete Cap
- Reference Level (0 ft)
- Ground Surface
- Drill Hole Diameter 5 in.
- Neat Cement with 3% gel
- 15 lb/gal
- Well 2 in Sched. 40
- Flush Threaded PVC
- Water Level 111.51 ft (10/14/92)
- 122 ft
- 160 ft
- 170 ft
- Benseal
- Screen 0.020 in. Slot
- Sand Pack 10-20 Silica Sand
- Bottom Cap
- Total Depth 220 ft

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Figure 2-2

As-Built Configuration of LL M-2

Well I.D.: LL M-2
Location: Loving Landfill

-定了强电
-表层位移
-锁紧盖
-井套管
-混凝土盖
-钻孔
-直径5英寸
-清水水泥
-带有3%凝胶
-15磅/加仑

-井
-2英寸
-标准40
-冲程螺纹PVC

-万能

-网
-0.020英寸
-槽
-砂包
-10-20硅砂
-空白
-底部盖

-水位50.71英尺（10/14/92）
-总深度140英尺

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**Figure 2-3**

As-Built Configuration of LL M-3

| Well I.D.: | LL M-3 |
| Location: | Loving Landfill |
| Type: | Piezometer |
| Elevation*: | 3113.12 |

Not to scale

- Reference Level (0 ft)
- Ground Surface
- Water Level 84.26 ft (10/14/92)
- Total Depth 248 ft

Diameter 5 in.

- Neat Cement with 3% gel
- 15 lb/gal

- Drill Hole Diameter 5 in.
- Well 1¼ in Sched. 80 Flush Threaded PVC
- Benseal
- Screen 0.020 in. Slot
- Sand Pack 10-20 Silica Sand
- Bottom Cap

Not to scale

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Figure 2-4
As-Built Configuration of LL M-4

Well I.D.: LL M-4
Location: Loving Landfill
Type: Piezometer
Elevation*: 3110.50

*Top of well shroud without locking cap

Not to scale

Locking Cap
Reference Level (0 ft)
Well Shroud
Concrete Cap
Ground Surface
Drill Hole
Diameter 5 in.
Neat Cement
with 3% gel
15 lb/gal
Well
2 in Sched. 40
Flush Threaded PVC
Benseal
Screen
0.020 in. Slot
Sand Pack
10-20 Silica Sand

Water Level 50.51 ft (10/14/92)

Bottom Cap
Total Depth 60 ft

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Figure 2-5
As-Built Configuration of LL M-5

<table>
<thead>
<tr>
<th>Well I.D.: LL M-5</th>
<th>Type: Piezometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location: Loving Landfill</td>
<td>Elevation*: 3113.11</td>
</tr>
</tbody>
</table>

Not to scale

- Locking Cap
- Well Shroud
- Concrete Cap
- Reference Level (0 ft)
- Ground Surface
- Drill Hole Diameter 5 in.
- Neat Cement with 3% gel 15 lb/gal
- Well 1¼ in Sched. 80 Flush Threaded PVC
- Benseal
- Screen 0.020 in. Slot
- Sand Pack 10-20 Silica Sand
- Bottom Cap

- Total Depth 200 ft
- Water Level 110.03 ft (10/14/92)

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Figure 2-6
As-Built Configuration of LL M-6

Well I.D.: LL M-6
Location: Loving Landfill
Type: Piezometer
Elevation*: 3114.22

Locking Cap
Well Shroud
Concrete Cap

Drill Hole
Diameter 5 in.

Neat Cement
with 3% gel
15 lb/gal

Not to scale

Well
2 in Sched. 40
Flush Threaded PVC

Water Level 54.10 ft (10/14/92)

72 ft
84.8 ft
90 ft
120 ft

Total Depth 120 ft

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Appendix 3
Loving Landfill Closure

Monitor Well Plan
Loving Landfill Site
06/22/92

by

Dennis W. Powers, Ph.D.
Consulting Geologist
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Monitor Well Plan
Loving Landfill Site

This plan is provided as a guideline to drilling and establishing ground water monitoring wells following closure of the Loving landfill site. This plan is for conceptual purposes and does not attempt to establish all of the field operational details or variables which may develop as the monitor wells are established. These will be reported following completion of the monitor wells.

Objective: Three or more locations will be drilled at the Loving landfill site to serve for long-term monitoring of ground water in the general upgradient and downgradient positions.

Background Hydrology: No wells in the immediate vicinity of the landfill site are known to encounter the saturated zone. A shallow drillhole (< 50 ft depth) east of the landfill boundary and immediately south of the transfer point has not indicated any standing fluid in repeated testing with an electric ground water tester.

On a larger scale, the Pecos valley and floodplain has numerous wells for domestic and irrigation purposes. Data reported by Jones and Hendrickson (1952) from the vicinity show that ground water, generally exceeding limits for human consumption but suitable for irrigation, is at depths < 100 ft and show ground water depth contours at the landfill site between 75 and 100 ft. From the information available, we anticipate a generally easterly flow direction for ground water under the landfill site. There is uncertainty about the flow direction because there are no data points at the site, and the surface topography could be influencing the local ground water depth. Somewhat more southerly or northerly flow directions are possible.

Background Landfill Conditions: The information available about the landfill indicates the following conditions:

- dead animal pits along the northern half of the western boundary and around the northeastern corner of the site, and several north-south (lengthwise) trenches filled with other waste.
- In addition, the western boundary abuts property not owned by Eddy County, while the property immediately south and east of the landfill proper is owned by the County.

Basic Plan to Establish Monitor Wells: In view of some uncertainty about the ground water gradient at the landfill, the drilling and completion plan considers options to minimize expenses if initial locations are not adequate to monitor up- or downgradient ground water flow. In addition, the landfill site is small, and monitor well locations will only be separated by distances of about 500 ft or less. The gradient may be so slight that it can only be determined with confidence after a period of monitoring. If the gradient is very slight, the initial well sites may not be adequate monitoring points, even though located on the basis of the available information from initial drilling. The agencies involved need to recognize that additional monitor wells may need to be established in the future to adequately test up- and/or downgradient flow. It may also be necessary to delay periodic sampling if static water levels in any monitor well are recovering too slowly, due to low productivity, to securely establish gradients between sampling intervals.
The following steps are the basic plan for establishing monitor wells:

1. Drill the first three locations (see figure) without completing as monitor wells if the boreholes will stay open. Establish preliminary ground water levels, using temporary tubing if appropriate. Drilling will be without fluids, if possible, and initial bailings will be minimized to provide least disturbed conditions to the static water level.

2. If the locations are appropriate as up- and downgradient monitor wells or if the gradient is too slight to be certain, complete last drilled location as a monitor well. Relocate over other two monitor locations successively and complete as monitor wells.

2a. If any or all of the original locations can be determined to be inappropriate for up- and/or downgradient monitoring, cement these boreholes to the surface. Drill and complete monitor wells in alternate locations.

3. Obtain final survey of reference elevation points.

4. Develop well as necessary and take initial samples for analysis.

5. If the gradients can only be determined after extensive monitoring and prove the ground water flow is not adequately sampled by the well locations, additional monitor holes will have to be drilled and completed.

**Initial Locations:** Based on the general evidence of west to east ground water flow, three initial locations have been chosen (see attached figure). The upgradient monitor well (LL M-1) is located inside the landfill site within 30 ft of the western boundary at about the north-south midpoint (coordinates about 20E, 275N on attached figure). The M-1 locations is south of the dead animal disposal pit near the northwestern corner of the site. The second monitor well (LL M-2), in a downgradient position, will be located outside the fenced eastern boundary (coordinates about 350N, 500E). The third monitor well (LL M-3) is also located in the downgradient position (coordinates about 100N, 500E).

**Procedures:** Monitor wells will be drilled in accordance with procedures in the regulations. The drillrig, pipe, and tools will be cleaned prior to drilling. Operations will avoid, as much as possible, use of drilling fluids, hydrocarbons or other materials which may be tested for in ground water samples as evidence of waste transport.

The surface completion will include a small cement pad, protective casing, and padlocks to prevent surface inflow or tampering.

The first borehole will be cored as possible. The second borehole (in the downgradient direction) will be rotary drilled with regular examination of cuttings. Coring will be optional. The third borehole will be cored if variability in the second borehole warrants it; it is probable that geological information will be adequate to characterize the rocks based on rotary drilling of the last two boreholes. Cores will be described, photographed, and maintained in coreboxes for a period of at least one year, until monitoring baselines have been established.

**Reference Cited**
Hendrickson, G.E., and Jones, R.S., 1952, Geology and ground-water resources of Eddy County, New Mexico: Ground-water Report 3, New Mexico Bureau of Mines & Mineral Resources, Socorro, NM.