The Sand Point well site, Eddy County, New Mexico

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Summary
of
Site Selection
and
Preliminary Site Characterization

for the
Sand Point Site, Eddy County, NM

Prepared for

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ABSTRACT

Dwindling capacity of Carlsbad landfills and new (1991) state regulations necessitate finding a new landfill site for Carlsbad and Eddy County, NM. Three sites close to Carlsbad were examined and rejected as unsuitable during the work reported here. **Section 16** (T.21S., R.27E.), north of Carlsbad is deemed unsuitable because of active sinkholes in the immediate vicinity and because of probable shallow ground water. The **Becker site** was proven to have ground water at less than 50 ft and was rejected. The **motocross site** (section 5, T.21S., R.27E.) appears to include bedrock, has a large amount of "cultural features" such as pipelines, and also is likely to have ground water at less than 100 ft below ground surface. This site was also rejected.

Large areas of Eddy County are unsuitable by virtue of rock outcrops and national park/forest land (western part), river and floodplain areas with shallow ground water (along the Pecos River), and areas with active karst/sinkholes (commonly along the eastern side of the Pecos River and south of the Black River).

Three broader locations were examined for background hydrological and geological suitability. The **Old Caverns Hwy** location south of Carlsbad appears marginal at best for ground water depth and is poorly located for ownership and some cemented conglomerates. It has been eliminated. The **Laguna Grande location** northwest of Laguna Grande has been examined and three augur holes attempted. Ground water is likely to be shallow, but prior studies also indicate that the groundwater is likely of poor quality (> 10,000 ppm TDS). Parts of the location are also underlain by hard bedrock at shallow depths. This location remains a possible alternative location, but it is a longer distance for haulage. The **Sand Point location** (six square miles) was

examined at the same time as the Laguna Grande location. A review of background data and drilling two augur holes showed no evidence of negative features, and the location was further considered.

Additional background hydrological and geological data about Sand Point were obtained and analyzed, indicating the possibility of regional ground water and further structural changes of the Rustler Fm under the location. Based on the broader geological and hydrological data, areas along the northern part of the location are more suitable, while the southern part of the location may be unsuitable because of ground water depths and karst. The areas suitable in view of background geological and hydrological data were reviewed; engineering and location data were preferable for the NW¼ of section 11 (T.21S., R.28E), and this site was chosen for preliminary characterization.

Of eight drilling locations proposed and reviewed around the perimeter of the site, four were chosen for preliminary characterization. The locations were drilled from late May to late June (1992). Each location was cored as possible as an objective record of the geology. Ground water was intercepted at each location, ranging in depths from about 170 ft to about 220 ft below the surface. The boreholes were completed with screens and tubing as piezometer wells. The annulus of each well was filled with sand, bentonite, and grout, over appropriate intervals, to provide good inflow conditions and prevent surface inflow. The boreholes are completed with surface casing in cement and a secure cover.

The geology encountered by drilling at Sand Point shows near-surface Mescalero caliche of variable induration and thickness. The (?Plio-Pleistocene) Gatuña Formation ranges in thickness from a minimum of about 220 ft to about 290 ft. Three boreholes intercepted the Permian Dewey Lake Formation, and one drillhole was drilled an additional 155 ft in the Dewey Lake without reaching the underlying Rustler Formation.

The Gatuña is thicker at Sand Point than it is in most nearby outcrops, but it does not exceed regional outcrops. The Dewey Lake is also somewhat thicker than expected. These conditions are interpreted as evidence of significant pre-Gatuña solution of salt from the upper Salado Formation. Salt solution is a regionally significant process, but there is no indication of surface sinks or karst suggesting enhanced vertical permeability.

Ground water levels in the boreholes appear to have nearly stabilized by early August. The levels are more than 150 ft below the ground surface, exceeding the minimal requirements of new regulations. The ground water gradient appears to be toward the east or northeast, based on present water levels. No water quality samples have been taken from the observation wells to provide any necessary revisions due to density differences in the fluids.

Based on the existing geological and hydrological evidence from the Sand Point site, it is recommended that the site be selected for further characterization leading to a permit application.

1.0 INTRODUCTION

New regulations by the State of New Mexico and the capacity of existing landfills utilized by the city of Carlsbad and Eddy County, NM, require closure of landfills in the near future and development of new landfills. This report documents the geological studies, mostly by Dennis Powers, by which current activities have reached the stage of recommending further geological and hydrological characterization of the Sand Point site east of Carlsbad. Plans for further characterization leading to applying for a landfill permit, as well as closure plans and data for existing landfills, will be covered in separate documents.

1.1 Objective of Report

This report is intended as a comprehensive summary of the geological and hydrological activities during which several possible sites were rejected, the Sand Point site was selected for preliminary characterization, and four holes were drilled as part of preliminary characterization. It replaces several draft reports provided to JOAB earlier as evidence of progress and which have provided a basis for recommending a course of action to Carlsbad and Eddy County. The substance of most of these draft reports is incorporated in this report.

1.2 Topics Covered

Several specific sites and general locations were examined during the work I completed and are covered in this report in approximate chronological order: examination of section 16, T.21S., R.27E.; the "Beker site"; the "motocross site", the "Old Caverns Highway location"; the "Laguna Grande location"; general data acquisition for the "Sand Point location;" and preliminary selection/characterization of the Sand Point site. Some of these potential sites were examined at the specific request of Carlsbad and Eddy County.

1.3 General Flow of Activities

Some activities developed in response to specific requests by Carlsbad and Eddy County. Three sites (listed above) were rejected before broader screening was considered. After these specific sites were rejected, the activities assumed a pattern for developing a site from a more general search to specific site investigation. Three general locations (listed above), including Sand Point, were considered based on broad siting characteristics, personal knowledge of the regional geology, and readily available information. For the Sand Point site, the activities followed more nearly a conceptual outline from initial screening through preliminary characterization (Table 1).

Preliminary location/site screening and site location to identify the Sand Point area were based on generally available geological and hydrological information as well as personal knowledge of the regional geology. From this information and modest site examination, no factors were apparent which would cause rejection of the location without more specific information. From a more general 6 square mile location, we (JOAB employees and I) located a potential site (¼ section or ¼ square mile), combining good geological and hydrological characteristics with engineering factors, for further investigation. We have recently completed field investigations as part of the *Preliminary Location/Site Characterization* phase. As a result of the preliminary site characterization, I conclude that the site is acceptable; I will recommend, at the end of the report, that the Sand Point site be selected and that investigations leading to a permit application be planned and conducted.

Table 1
General Phases of Landfill Site Investigations, Carlsbad & Eddy County Landfill

Preliminary Location/Site Screening

- based on broad siting criteria and regulations - avoid areas obviously in conflict with regulations
- examined broader area around Carlsbad for potential locations/sites
- included reconnaissance of area and exam of proposed sites such as Beker site
- this phase may continue if region-wide work is necessary

Preliminary Location/Site Selection

- obtain and summarize available information
- consider relative merits of locations or sites from screening
- include basic engineering and other qualifications:
  - haulage distance
  - "culture", i.e. pipelines, oil wells, etc
- select principal and backup locations/sites for initial characterization

Preliminary Location/Site Characterization

- conduct initial detailed field investigations of site or location
- concentrate on most likely flaws or anomalies at site/location
- conduct mapping, drilling, initial hydrology studies
  - establish basic geology conditions in the near-surface (<1000 ft)
  - establish initial hydrology conditions for site
    - depth to groundwater (gradient, flow velocity)
    - groundwater quality

Site Selection

- mainly confirms that information from preliminary characterization is still consistent with locating a site
- constitutes a formal decision to proceed with more detailed investigations which are expected to lead to permitting process
- if questions at this stage are significant, alternate or backup site might be chosen for preliminary characterization

Site Characterization

- investigated in detail all necessary aspects of geology and hydrology, as well as engineering and construction, to prepare for the permit application
- more detailed geology of the upper 140-150 ft
- more detailed hydrology
  - monitoring wells are established
  - more sophisticated testing and observation of wells
  - may include slug, pumping, or other tests

Permit Application

Construction

Operation

Closure and Monitoring

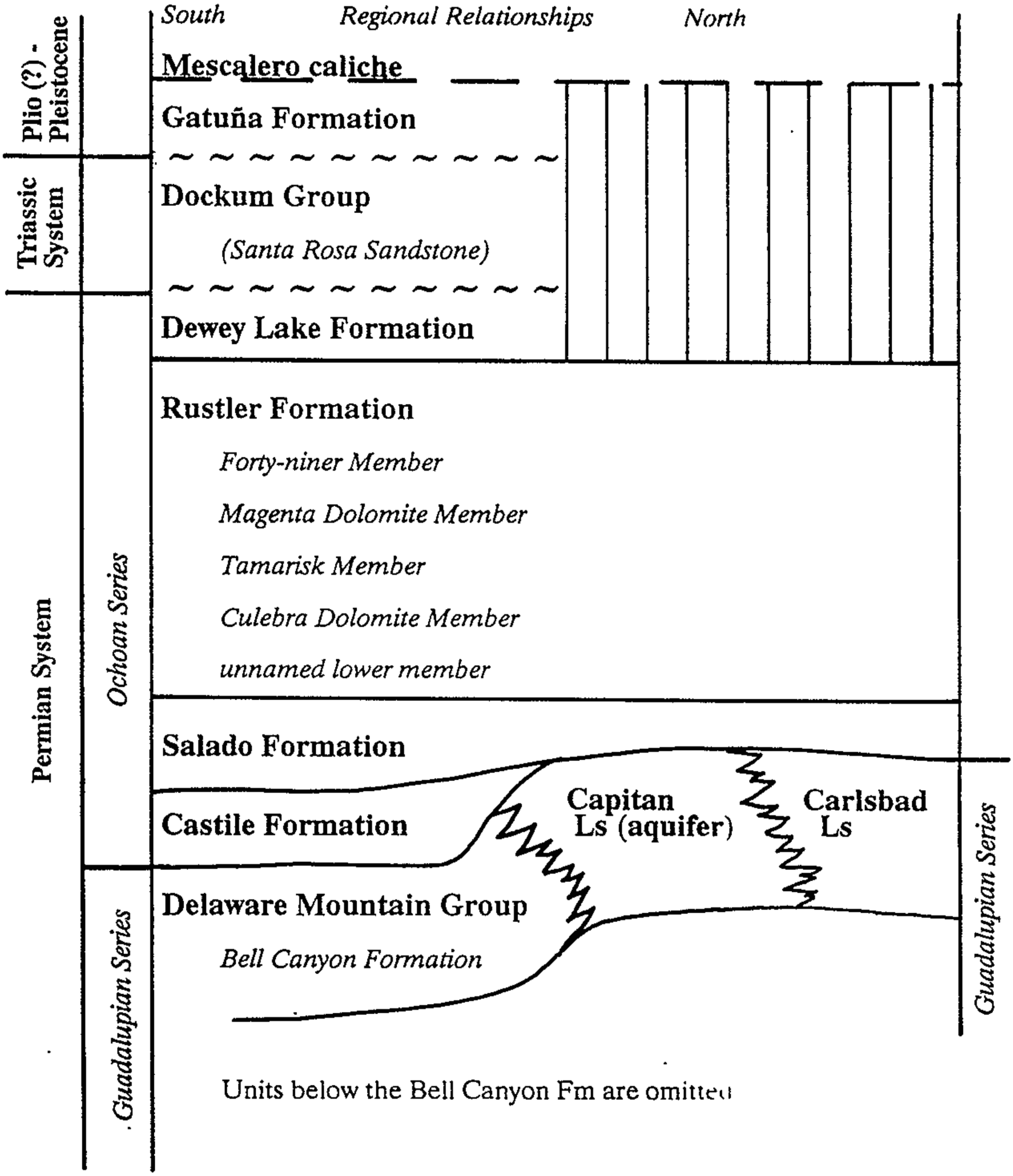
1.4 Brief Overview of Relevant Geology

Much of the geology of surficial and near-surface rocks in Eddy County and the area around Carlsbad is dominated by a general series of events: 1) the geological setting for deposits of Permian age (about 250 million years old) evaporites, 2) subsequent mild tectonic events and erosion, 3) solution of carbonates and soluble evaporites, and 4) late Tertiary to Holocene age deposits on the irregular surfaces formed by dissolution and erosion. Major units of the area examined during this study are shown in their stratigraphic relationships in Figure 1.

From south to north, through a line passing through Carlsbad, Eddy County is underlain by a major basin (south), a transition from basin to major reef rocks (Carlsbad), and shallower shelf carbonate rocks (north). The basin filled with evaporite rocks (Castile Formation) which lap onto (were deposited over) much of the shelf to the north (Salado and Rustler Formations). By the end of the Permian, the basin and shelf areas were covered with fine-grained sediment brought in by intermittent or slow-flowing rivers or streams (Dewey Lake Formation). The Dewey Lake and Rustler Formations crop out or are near the surface in the eastern part of the county where most of the search for a new landfill is concentrated.

During the early Triassic, much of this area was subject to erosion. Coarser sandstones and conglomerates were deposited over the eastern part of Eddy County and are thicker to the east. Following these events, most of this area was subject to erosion through much of Mesozoic and Cenozoic time. In one or more events following the deposition of Permian evaporites, the basin and much of the shelf was gently tilted to the east, with the latest tilting in late Miocene time. The Ogallala Formation was deposited on the high plains following this tilting. It is uncertain how much of the Eddy County area was covered by Ogallala sediments.

Figure 1
Important Stratigraphic Relationships Among Units in the Area Covered by this Report



During the Pleistocene, at least, erosion by the Pecos system progressed, developing the major drainage of the area. Solution of the underlying evaporites caused local subsidence at least, affecting the Pecos drainage. Features such as Nash Draw also developed by combined erosion/solution processes. The Gatuña Formation was deposited during the early development of these drainage and solution features. It shows mainly fluvial deposits incorporating clasts from Ogallala and older local formations as well as clasts of igneous rocks from the Sierra Blanca (New Mexico) area (Bachman, 1974). The Gatuña includes gypsiferous deposits to the south and locally in Nash Draw, demonstrating local intermittent ponding and probable saturated soil conditions. The Gatuña displays tilted and cross-cutting relationships in some areas (e.g., Pierce Canyon) which indicate the underlying rocks were also being dissolved while the Gatuña was being deposited. Highly variable Gatuña thicknesses accumulated depending on both local relief and differential subsidence from dissolution.

The Mescalero caliche (about ½ million years old; see Szabo and others, 1980) overlies the Gatuña and other formations over large areas in eastern Eddy County, indicating the degree of stability over that period. The caliche forms over a period of time and will be affected by tilting/subsidence associated with dissolution.

The rocks over most of Eddy County broadly tilt to the east; erosion of higher areas to the west exposed large areas of carbonate which are unsuitable for landfill purposes and which have been set aside in national forest and park lands. Along the Pecos and general longitude of Carlsbad, evaporites and their residues crop out and are subject to both erosion and solution. Further east, outcrops are dominated by clastic rocks which are insoluble, though affected when underlying evaporites are dissolved.

The Pecos River and floodplain have deposits of alluvium with shallow ground water underneath. Reef and shelf carbonates yield groundwater at varying depths from very shallow around Carlsbad to much deeper to the east. Clastic rocks have variable water resources at moderately predictable depths and stratigraphic positions.

2.0 PRELIMINARY SITE SELECTION ACTIVITIES

2.1 Preliminary Site Investigations

Several specific sites were proposed by Carlsbad and Eddy County and were examined individually for suitability as a landfill site. These were rejected after limited geological and hydrological investigations revealed unsuitable characteristics; some concerns were based on regulations now in force in New Mexico. Each of these investigations is covered in this report as evidence of the activities leading to the selection of the Sand Point site.

Broad screening criteria (Table 2) were applied to areas within Eddy County; these are partially based on recent regulations established by the state (State of New Mexico Environment Department, 1991). These screening criteria consider various specific geological, hydrological, and socioeconomic factors (e.g., presence of pipelines and other "cultural" features). To find a potential site, priority factors included distance from Carlsbad and suitable geological and hydrological conditions.

Portions of Eddy County are rejected without examination: much of the western part consists of rock outcrops and national park areas, the Pecos valley flood plain also has shallow groundwater, and outcrops of some formations east of the Pecos valley as well as south of Whites City are more likely subject to sinkhole/karst development (Figure 2).

It does not appear that any of the sites or locations are located within or near a floodplain. The final determination would be made on the basis of Federal maps designating floodplain areas. None of the sites or locations appear to include wetlands based on National Wetlands Maps (pers. comm, M. Magee).

Each of the sites or locations includes areas which show evidence of occasional flow of water as in the definition of a watercourse supplied in state regulations. A large part of the **Beker site** is affected by a drainage into Lone Tree Draw. The "**motocross site**" has short arroyos and low areas of drainage. The **Quahada Ridge** area includes some areas with developed drainage, but large portions do not show such drainages. Large parts of the **Old Cavern Hwy** area do not show significant drainage development. The **Laguna Grande locations** show areas with some drainage channel development; local areas drain into Laguna Grande de la Sal while some areas eventually drain into the Pecos River. The **Sand Point location** slopes

Table 2

SCREENING CRITERIA

Several criteria of general use help focus on the relative merits of these sites:

depth to groundwater:	more than 100 ft below landfill excavation depth
quality of groundwater:	preferred to exceed 10,000 mg/liter (ppm)
construction quality:	minimal or no bedrock in upper 30 ft. prefer higher clay content as infiltration barrier
topographic features:	no active sinkholes or probable karst moderate slopes
land ownership:	no state land private or BLM ownership preferred
"cultural features":	minimize oil/gas wells, pipelines minimize power lines, but nearby source desirable nearby good road desirable
distance for haulage:	minimize haulage distance for appropriate sources.

Of the above criteria, the most stringent are groundwater, bedrock, sinkholes, and land ownership. Other factors, such as pipe lines and power lines, might be overcome by rerouting if necessary, but the costs of overcoming such obstacles would have to be weighed relative to other costs.

Additional exclusions in proposed state regulations were partially considered during reconnaissance of sites and locations and were applied more stringently if potential site survived initial screening:

no floodplain locations, not within 500 ft of wetlands or within 200 ft of watercourses;

not within 200 ft of a fault that has had displacement within the last 11,000 yrs;

not within historically or archeaeologically significant sites, unless in compliance with various legislation (the Cultural Properties Action, Section 18-6-1 to 18-6-23 NMSA 1978; the Prehistoric and Historic Sites Preservation Act, Sections 18-8-1 to 180808 NMSA 1978); or

not in an active alluvial fan.

generally to the south. Drainage along the northern part is generally broad, and drainage becomes better defined southward through parts of the middle of the location. Draws then carry surface runoff to the south where some drainage becomes diffuse or poorly channelized, especially where the Rustler Fm crops out and has apparently developed some karst drainage.

There is no known evidence of any tectonic fault in the area of these sites or locations with displacement in the last 11,000 years. Kelley (1971) observed a lineament which he designated as two faults, called the Carlsbad and Barrera faults, along the general escarpment of the Guadalupe Mountains south of Carlsbad and Whites City. Hayes and Bachman (1979) re-examined these outcrops and concluded there was no faulting; vegetation along the escarpment edge creates the appearance of a lineament. The nearest known faulting due to tectonic forces and of probable Quaternary age is along the western escarpment of the Guadalupe Mountains where normal faulting created the west Texas salt flat graben (e.g. King, 1948; Muehlberger and others, 1978). This faulting is about 30 miles from the closest area considered in this report.

The archeological and historical site criteria are not addressed here. Preliminary information can be obtained through Federal agencies; the Bureau of Land Management has been consulted and has located potential archeological sites for Sand Point.

None of the sites or locations were located on an alluvial fan.

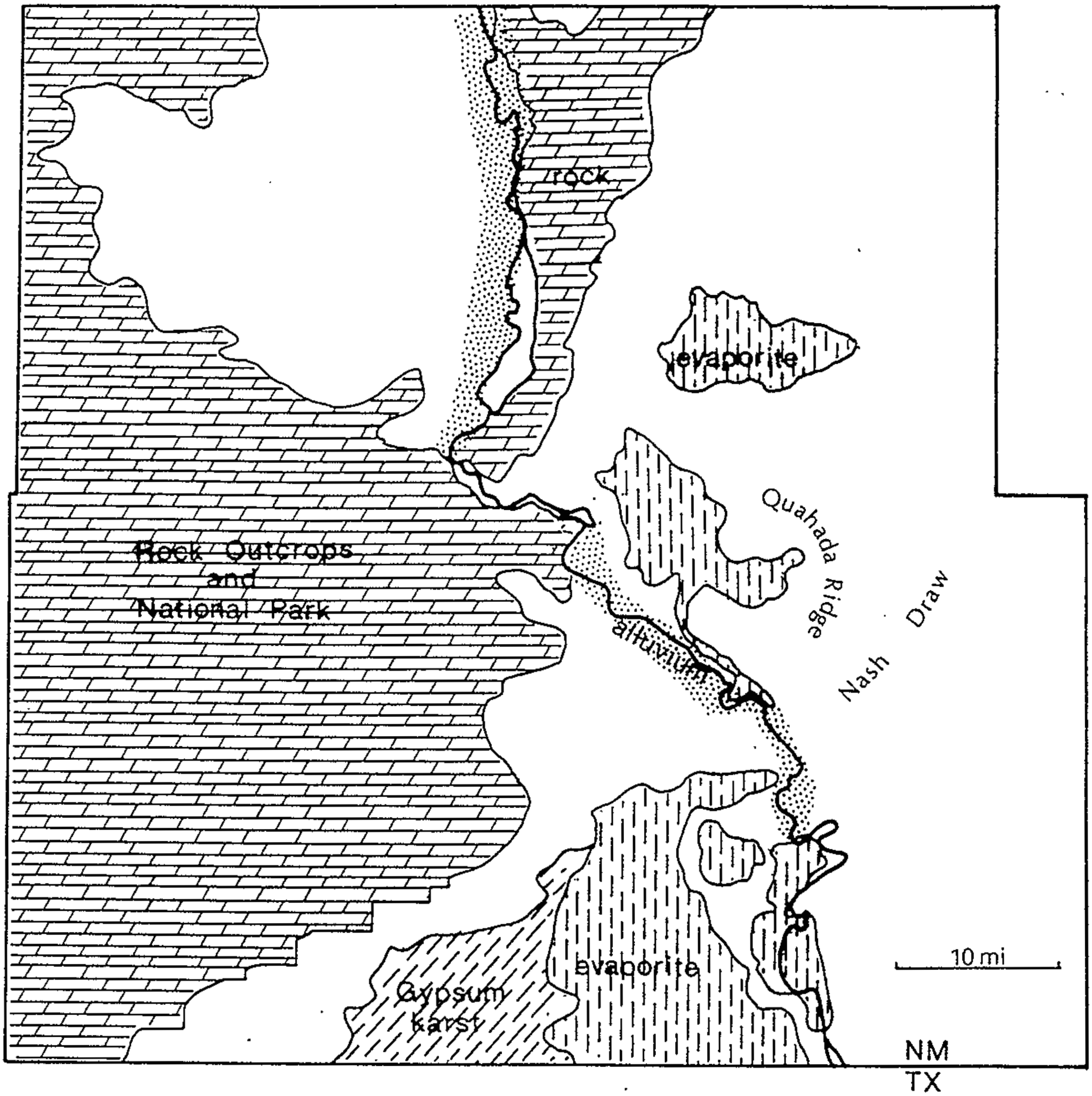
The principal geological and hydrological factors for the sites and locations examined included the presence of sinkholes/karst and depth to ground water.

<u>2.1.1 Southern Half, Section 16, T.21S., R.27E.</u>

2.1.1.1 Objective

The objective of this program was to conduct a limited field investigation of a potential site for a new landfill for the city of Carlsbad, NM, to determine the

Figure 2
Generalized Geohydrological Screening, Eddy County, NM



Basic source is Geologic Map of New Mexico (Dane and Bachman, 1965); general knowledge of area is factored in to eliminate areas generally unsuitable by virtue of surface outcrops or shallow water.

stability and potential for karst and related dissolution features. Basic information about stratigraphic units and their distribution was also desired. A limited study was conducted in the field and reported to convey the results of these field investigations. The site had been preselected on the basis of location and potential for argillaceous units which might be utilized for natural liner for a landfill.

The investigation concentrated mainly on the southern half of section 16 (T.21S., R.27E.); the northern half and areas around the sides of section 16 were also examined briefly to add insight into the features present in the southern half of section 16 and processes responsible for those features.

2.1.1.2 Methods

The field area (sec. 16, T.21S., R.27E.) was examined on October 9 and 11, 1991, and a basic geologic map (Figure 3) was developed showing the units exposed at the surface. Particular sites which might have developed as a consequence of solution and collapse were examined more closely for evidence of active swallowholes or other features helpful in determining the stability of the site.

The photography and mapping for the soil survey of Eddy County (Chugg and others, 1971) was also consulted to locate features not represented by contours on the Carlsbad East Quadrangle (1:24,000; provisional edition, 1985).

2.1.1.3 Geological Units

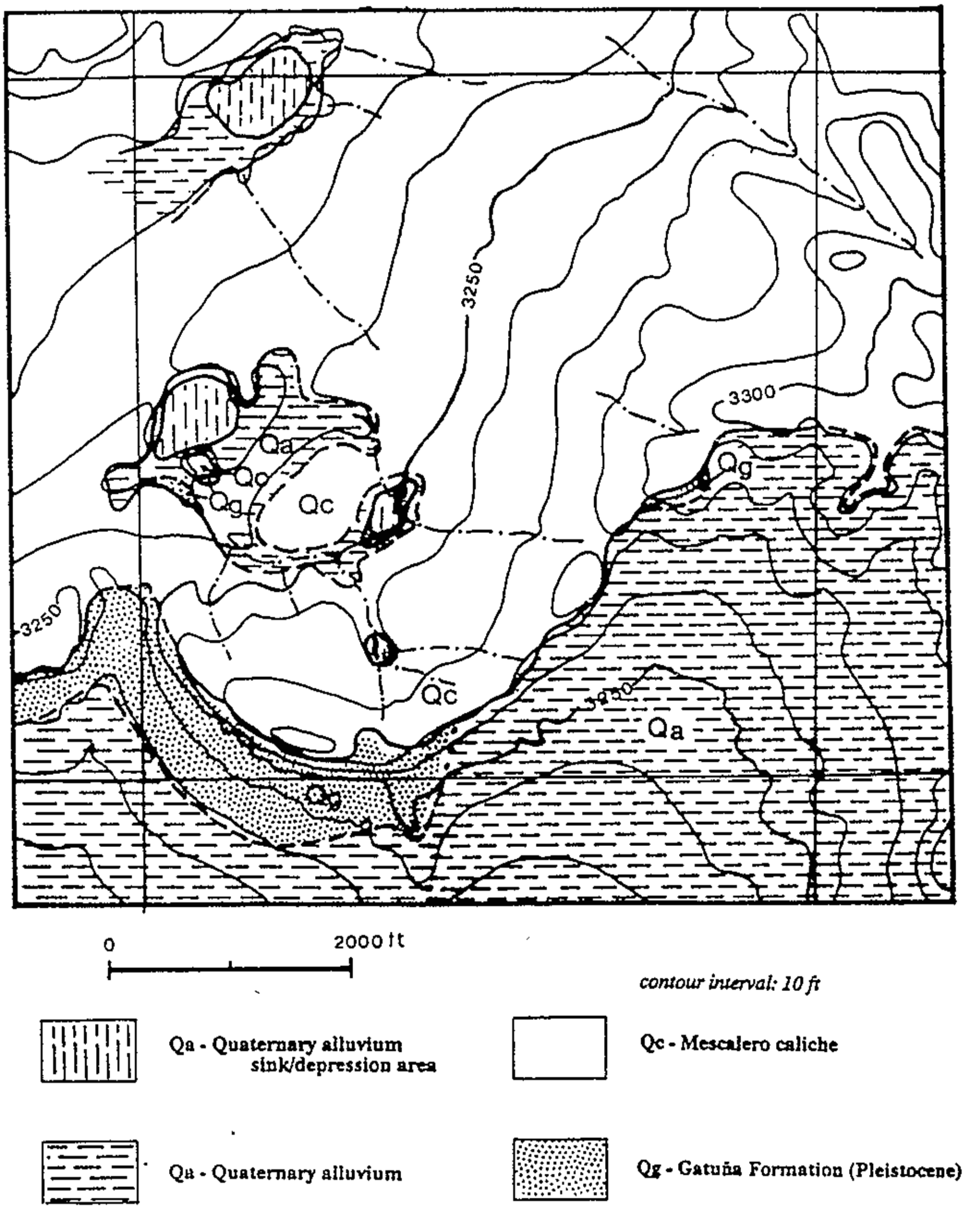
2.1.1.3.1 Gatuña Formation

There are three basic geologic units to be mapped within the boundaries of section 16 (Figure 3). The oldest exposed unit is interpreted as part of the Gatuña Formation of late Tertiary to Pleistocene age. Along Nash Draw, about 25 miles east-southeast, the Gatuña is demonstrated to be mostly older than about 500,000 years (Bachman, 1980). The volcanic ash in the upper part of the formation is 600,000 years old, and the overlying Mescalero caliche has been dated by uranium-series methods as about 500,000 years old (Szabo and others, 1980). The age of the basal Gatuña has not been determined.

The Gatuña Formation is identified by position and lithology. No underlying units were identified within the field area, but the lithology and appearance of the Gatuña are generally diagnostic. (There is a slight possibility these rocks represent a claystone unit laterally equivalent to mudstones of the Tamarisk Member of the Rustler Formation.) The Gatuña commonly differs in lithology and color from the Permian Dewey Lake Formation and the Triassic units (frequently called the Santa Rosa Sandstone). The Dewey Lake is a more uniform dark reddish brown siltstone and fine grained sandstone with green reduction spots. The Santa Rosa is variegated, with very dark reddish-brown (with a purplish cast) sandstones as well as lighter hued sandstones and conglomerates consisting of mainly quartzites and cherts. The Gatuña is brown to medium reddish brown siltstones and sandstones with lesser amounts of conglomerate and claystone beds. Gatuña conglomerates include variable proportions of quartzite and chert clasts derived from the Triassic beds, Permian limestone pebbles to cobbles, Tertiary volcanic pebbles, and Ogallala caliche clasts, depending on location. Some outcrop areas along the southern edge of section 16 show erosional remnants of Gatuña conglomerates.

The Gatuña Formation along the southern edge of section 16 apparently consists of about 20 to 40 ft of dark reddish brown silty claystone with minor amounts of siltstone and a few remnants of conglomerate. There are very small outcrops of medium brown sandy siltstone around the edge of the depression midway along the western boundary of section 16. At this more northern exposure, there is no surficial evidence to confirm or reject the continuation of the claystone units of the southern part of the section.

Figure 3
Surface Map
Section 16, T.21S., R.27E.



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It is not possible to predict from the outcrop how extensive the claystone is because the Gatuña is quite variable laterally in areas further to the east where I have described it in several profiles. The thickness of the argillaceous unit suggests it may have considerable extent as well, but there is no evidence the reddish claystone continues west much beyond the southwest corner of section 16. Along the southern edge of section 17, some light greenish argillaceous units and minor reddish siltstones of the Gatuña crop out.

2.1.1.3.2 Mescalero caliche

The Mescalero caliche is the informal name for a pedogenic carbonate unit of Quaternary age which is developed over large areas of southeastern New Mexico west of the High Plains escarpment. It is a moderately well developed unit, with soil pisolites to laminar zones developed in different areas. Further east, the Mescalero is overlain by a soil unit (Berino soil) with a uranium-series age of about 350,000 years (Bachman, 1980). Thus, the Mescalero probably developed over a period of about 150,000 years. Soil units, and caliche in particular, indicate a period of stability for the surface during which the soil developed. The Mescalero is, therefore, an indicator of geologic and geomorphic stability during that time, and its structure, thickness, and continuity can attest to reasonable stability since about 350,000 years ago.

The Mescalero is well developed locally within section 16, showing well plugged laminar zones of a mature caliche. In other areas, the Mescalero shows more modest development or possible disruption, as it reveals nodules and powdery carbonate without evidence of complete plugging of porosity in the profile. Other areas are indeterminate; additional soil may either cover the caliche or poor outcrops may signify last remnants of caliche from weathering. The maximum observed thickness of Mescalero is about 6 ft. It appears more commonly to be less than about 3 ft thick.

Only the highest topographic areas show clear outcrops of persistent, well developed Mescalero caliche. Some areas where Mescalero likely underlies the surface, based on irregular patches of obvious caliche or concentration of eroded Mescalero clasts, have been included within the Mescalero with boundaries marked by dashed contacts.

2.1.1.3.3 Quaternary alluvium

In low areas and along drainages, alluvium has accumulated from erosion and weathering of more upland areas. In areas mapped as alluvium, neither Mescalero caliche nor Gatuña are apparent. Both Quaternary alluvium and Gatuña have been mapped relatively conservatively while Mescalero caliche map areas include some questionable areas.

The Quaternary alluvium is of unknown thickness in depressions and drainage areas. The large proportion of clay minerals in the alluvium might make it useful for a clay liner, though the thickness is not great. The alluvium is probably better used for the soil cover for reclamation.

2.1.1.4 Structure

The Mescalero caliche is resistant to erosion and is the only real surface indicator of structure in section 16. There are apparent dips to the north and northwest in the area. The topography follows this dip in general, which allows the dip to be inferred. These dips are of the order of 1-2°; they are not reliably measured on an individual outcrop. In the south part of the section, the dips are more or less to the north. In the southeastern quarter of section 16 the dips appear to be more northwestward.

Deeper units in this region generally dip to the east, and there is local deformation in the backreef region. These may be reflected in the sub-Gatuña erosional surface but are not predictable based on these outcrops.

2.1.1.5 Surface Features

2.1.1.5.1 Drainage

The drainage in most of the south half of section 16 is toward the closed depression located at about the midpoint of the western boundary of the section. Much of the northern half of the section drains to a depression located near the northwestern corner of section 16. Part of the southeastern quarter as well as the southern edge of the section drains to the south-southwest along an unnamed draw at the edge of the Alacran Hills.

Much of the drainage channels in section 16 could be classified as first-order, without identifiable tributary channels. Some second order channels exist, but they consist of the confluence of poorly developed first-order channels.

Most of the drainage shows poorly developed channels with little or no cutting below gradient of adjacent slopes. Most drainages have grass or grass clumps and show local evidence of recent unchannelized or sheet flow on the order of 4 inches deep based on debris. Nearer the center of section 16, some short stretches of channels are scoured to about 3 ft wide and about 1 ft deep. Most of the drainage is not now downcutting the southern part of the section, due to a combination of lack of runoff, small catchment area, surficial or very shallow caliche, sediment available for transport, and stable baselevel.

The localized drainages are marked by heavier vegetation; mesquite and some other woody plants are almost exclusively present along drainage or depressions.

2.1.1.5.2 Depressions

There are four depressions or sedimentation points to consider in section 16:

A) SE ¼, SW ¼,
B) NE ¼, SW ¼,
C) SW ¼, SW ¼, NW ¼, and
D) NW ¼, NW ¼, NW ¼.

Depression A is a modest low area marked in part by an excursion in the 3260 ft contour line. Three first order drainages converge at this low point, which shows a wider, flatter valley profile compared to either the incoming or draining channel. I observed no swallowholes or other evidence of current infiltration and downward drainage consistent with an active sinkhole. It appears to have once been a closed depression, and it is highly probable that it was a sinkhole at one time.

The draining channel from depression A is narrower as it exits the depression. It appears to have cut the outlet drainage once the depression sufficiently was plugged and became inactive. It appears that inflow is passed through the depression and is not currently significantly draining through the base of the depression.

Depression B is similar to depression A, though larger. I did not find any evidence of swallowholes or other features indicating significant downward drainage in the depression. It also appears that depression B may have drained through a surface channel to the west at an earlier time. This drainage is the same as that for depression A. The present-day drainage for depression B is to the north and then to the west to depression C. Depression B is covered with more abundant grass than the surrounding slopes and has more woody vegetation, including mesquite, than the surrounding slopes and drainage areas.

Depression C is an irregularly shaped sink area oriented roughly northeast-southwest. It accumulates most of the runoff from the southern half of section 16, including the runoff through depressions A and B. The caliche in the broader area around depression C generally slopes into the depression and is more or less flat on the west in section 17. There are open swallowholes generally about 1 ft across in the northern central part of depression C, showing that the silt and clay sediment in the bottom of the depression has not succeeding in plugging the drainage from this area.

It is probable that drainage in depression C connects through underlying sediments (?Permian limestones) to the drainage of the arroyo approximately ¼ mile to the northwest.

Depression D was not observed in great detail. It is also a sink area, but I have not examined it sufficiently to determine if there are active swallowholes.

2.1.1.6 Conclusions

The southern half of section 16 includes part or all of three features (depressions A, B, and C) which range from nearly certain to certain sinkhole features. Two of them (A and B) are very likely plugged and inactive for some period of time, and surficial drainage has developed to remove inflow. Depression C continues to be active as a sinkhole.

The Gatuña claystones present at the south end of the section may not be present in the middle of the section. The very limited Gatuña in depression C is of different lithology, though it does not necessarily signify that the claystones are absent. The presence of both plugged and active sinkholes suggest to me that the Gatuña is less likely to be present, as it would have helped retard or prevent the development of sinkholes. A short auger or drillhole would demonstrate the presence or absence of this thicker Gatuña section in the central part of section 16. The Gatuña is likely to be of intermediate thickness (30 ft or less) along the eastern side of section 16 under the caliche escarpment. Surface outcrops indicate it may be less argillaceous to the east.

The volume of Gatuña claystone under the south central part of section 16 probably exceeds 1.9 million yd^3. This takes the volume as a triangular wedge 10 yd high, 440 yd wide (north to south), and 880 yd long (east to west). This volume, if present, would be sufficient to provide a layer 2.5 yd thick over a half square mile. Auguring holes in a few places should be sufficient to establish the quality and quantity of these beds.

Based on surface extent, morphology, and position, I speculate that depressions C, B, and A developed approximately in that order. I think depression B may have plugged and began to drain to the west initially but then began to drain to the north. Depression A may have plugged slightly later than channel B; as it cut a channel to the northwest, it then intersected and occupied the former westward drainage from depression B and continued to cut it slightly to the present day.

Both depressions A and B would have to be explored further to determine the likelihood they could be reactivated if disturbed by surface activities. Certainly drainage could be engineered to avoid accumulating surface fluids in those areas, but if the plug to these depressions is fragile, some circulating water from depression C might cause additional collapse and re-establish surface drainage through a landfill.

It seems likely that a large part of the half section could be developed while avoiding direct disturbance to the areas which have been sinkholes. The possibilities of such a plan could also be considered.

2.1.1.7 Hydrogeology

Hendrickson and Jones (1952, p. 107) show depth to ground water as 81.4 ft in a well in the SW¼, SW¼ of section 9, about ½ mile north of the area examined. No well in the same township showed depth to water as much as 100 ft below surface.

2.1.1.8 Recommendations

Some preliminary field activities would suffice to demonstrate probable major problems with using part or all of the southern half of section 16.

The presence and quality of Gatuña claystones can be estimated with three to four augur holes or core holes.

The stability of depressions A and B would have to be investigated with 1 to 3 short coreholes (probably 150 - 300 ft maximum) in each depression and subsequent hydrotests. In addition, a soil examination pit in each depression would help determine soil development and a better estimate of time in which the depression has been inactive as a sink. These pits might yield samples for pollen or radiocarbon analysis.

Two to four other pits would be appropriate to determine the condition of Mescalero caliche on some of the slopes in the vicinity of depressions A and B.

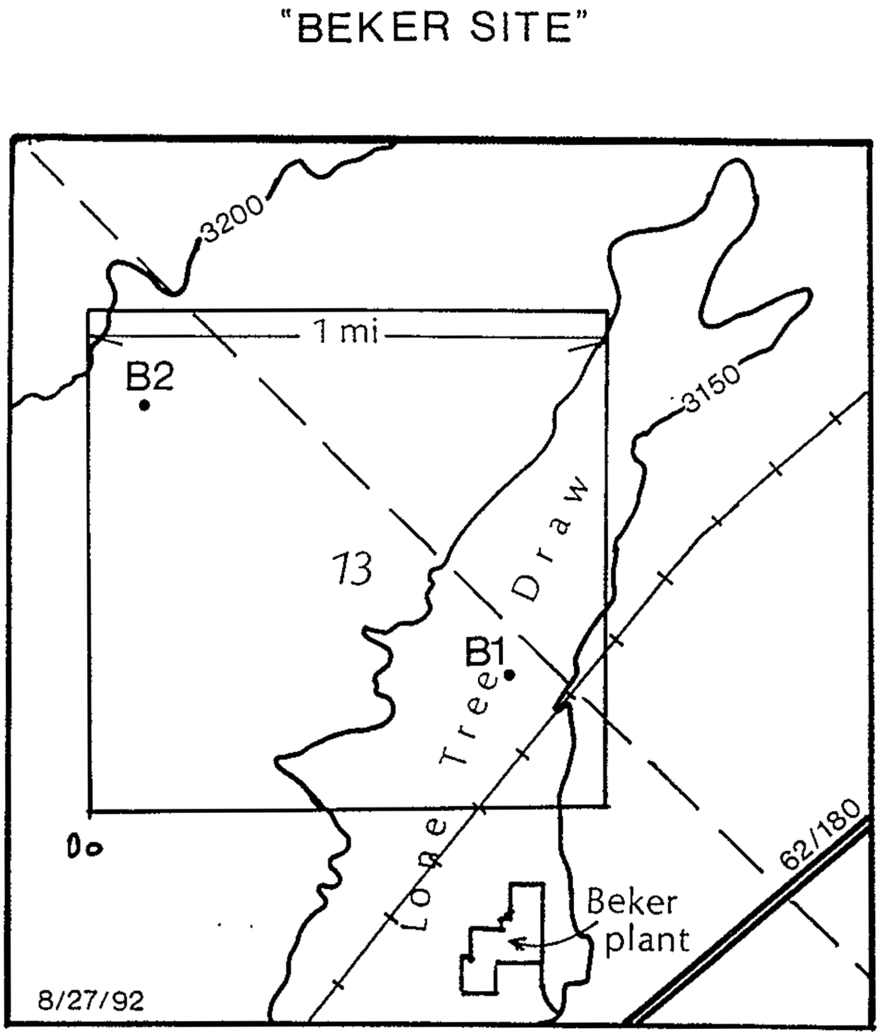
As groundwater is probably less than 100 ft below the surface at section 16 and the surface shows evidence of nearby active sinks/karst, this site is not considered acceptable for a landfill based on new regulations from the State of New Mexico.

2.1.2 Beker Site

2.1.2.1 Objective

The *Beker site*, located in the western half of section 13, T.21S., R.27E., (Figure 4) was examined first by field reconnaissance and then with augur drilling to determine if site characteristics were generally acceptable under state regulations. The field examinations were also intended to show additional features of the local geology and hydrology not readily available through published documents and sources. Maps and other sources do not reveal the full and current extent of cultural problems (pipelines, oil or gas wells, etc.). The Beker site was evaluated at the request of city/county administrations.

Figure 4
"Beker Site"
Section 13, T.21S., R.27E.



B1 and B2 are augur holes at Beker site. Elevation contours are in feet. NW-SE dashed line is a pipeline. Railroad crosses southeast corner of section 13.

Dennis W. Powers, Ph.D.
Consulting Geologist
12/28/92

2.1.2.2 Review of Beker Site Geology and Hydrology

Data available from the literature and from field reconnaissance indicate the Beker site is unacceptable because of shallow groundwater and carbonate rock outcrops.

The western half of section 13 consists of relatively low topography including a draw draining much of the area into low and possibly closed basin areas in the eastern part of the section (Lone Tree Draw). Along the western part of the section and in section 14 to the west, the Culebra Dolomite Member of the Permian Rustler Formation (see Figure 1 for stratigraphic relationships) crops out and holds up the hill areas. A small ridge trends southeast from the northwestern corner of section 13; its geology is uncertain, though caliche may be holding up the topography.

The depth to groundwater under the western half of section 13 is not known from literature review. The high point of the site is between 50 and 60 feet above Lone Tree Draw, which shows local signs of small topographically closed areas which may pond at times, clay-rich alluvium, and abundant grass and some phreatophytes. These are common indicators of well watered areas. Small (questionable) swallowholes and lack of soluble salts indicate significant infiltration. A windmill very close to the eastern boundary of section 13 shows a water level at an elevation of about 3140 ft, about 60 feet below the highest point in section 13 and about the elevation of the surface of Lone Tree Draw. Hendrickson and Jones (1952) report total dissolved solids (TDS) from this well as 6090 ppm and sulfate as an important dissolved constituent. This is consistent with the local geology. Richey (1989) reports water level at an elevation of 3084 ft in a shallow well in the east-central part of section 24, just south of the Beker plant. Richey (1989) reports the Rustler Formation as the water source.

Hiss (1976) showed information on the elevation of the top of the Capitan reef aquifer and water quality from the Capitan. There is no specific Capitan information from this particular site. The general contours, however, indicate the Capitan is at least 500 feet below the surface. Water quality for this aquifer is contoured on the basis of *minimum* values. The site falls between contours for 5000 and 10000 ppm chloride ion concentration, though local values may exceed 10000 ppm (Hiss, 1975).

A portion of the western margin of the proposed site is unsatisfactory because the Culebra Dolomite is at the surface. The thickness of the Culebra throughout much of the area ranges between 25 and 35 feet, and an outcrop in section 14 indicates at least 20 feet. As a consequence, construction through that area would be both difficult and expensive. In general, the Rustler in the area dips to the east at a rate of about 100 feet per mile. The sulfate units along the eastern boundary of section 13 most probably belong to the Tamarisk Member of the Rustler, just above the Culebra. Unless the Culebra has significantly collapsed through the proposed site area, it probably underlies the alluvium in the site area at shallow depths (less than 30 feet).

Culebra bedrock certainly crops out in part of the site and probably underlies much of the site at depths less than 30 feet. It is expected to be a significant obstacle to construction; any testing of this site should immediately determine depth/extent of the Culebra.

The site topography does not indicate any active sinkholes or modern karst. An arroyo drains through much of the site and into Lone Tree Draw. The arroyo would have to be partially rerouted along the margins of the site. Slopes within the site area are generally moderate.

Land in this section is privately owned.

Only one oil/gas well is known in the proposed site: Monsanto Lone Tree F26. A field inspection on 01/30/92 shows that the well has been capped. Power sources are relatively nearby. The site center is about 2 miles north of Hwy 62/180.

This site would be 7-8 miles from the center of Carlsbad if a new road was constructed from Hwy 62/180 north along the line of the western section boundary west of the Beker plant.

2.1.2.3 Beker Site Specific Investigation

2.1.2.3.1 Description of Boreholes and Results

Two holes were augured in section 13, T.21S., R.27E., to test the depth to groundwater and/or bedrock at this site (Fig. 4). Hole B-1 was located in the southeast quarter of the section near the lowest areas of Lone Tree Draw. The elevation of the location, based on the topographic map, is approximately 3138 ft. Hole B-2 was located near an arroyo in the northwest quarter of the section, at an elevation of about 3185 ft.

B-1 was drilled about 15 ft deep. The lithology consisted of two basic units:

0-3 ft	Black silty clay, moderately calcareous.
3-15 ft	Light brown gypsum and gypsum mud, slightly calcareous.

Details are included in Appendix 1. The cuttings were wet from a drilling depth of about 7 ft below the surface, and water began filling the borehole when the augur was removed. Water levels below the surface were measured as follows:

10:30 am	7 ft 2 in	(2.18 m)
10:40 am	6 ft 4 in.	(1.93 m)
2:07 pm	5 ft 9 in.	(1.75 m)

The water elevation at the last observation would therefore be about 3132 ft. A sample of the water showed an in field temperature of 13.5^{o}C (56.3^{o}F) and a specific gravity (measured by hydrometer) of 1.005 gm/cc.

B-2 was drilled about 55 ft deep. The lithology consisted generally of reddish brown silt and sandy silt with some zones containing siliceous pebbles and granules. Based on induration and color changes, the upper 11 ft appear to be recent alluvium from the arroyo; the lower 44 ft are tentatively assigned to the Plio(?)-Pleistocene Gatuña Formation. Details are included in Appendix 1.

The cuttings returned from B-2 became moist at a drilling depth of about 46 ft and became wet mud and muck from the interval of 53 to 55 ft depth. The open hole was allowed to stand for about 30 minutes. The water levels were measured as follows:

1:15 pm 46 ft 9 in
1:25 pm 46 ft 4 in.

A water sample taken from 55 ft right after drilling was very small and muddy. Water temperature was measured at the surface as 18.5°C (65.3°F). A water sample taken after water had reached 46 ft 4 in was measured at the surface as 20°C (68°F). Specific gravity was not measured from either sample.

2.1.2.3.2 Significance of Beker Site Results

B-1 demonstrates the expectable shallow groundwater in Lone Tree Draw with relatively good quality (non-potable). B-2, drilled in the western half of the section where a landfill would have been considered, shows the presence of groundwater less than 100 ft below the surface. The alluvial fill and Gatuña Fm in this location is greater than anticipated from the preliminary examination. Nearby outcrops of the Culebra Dolomite and projects suggested that these limestones would be encountered at this location at depth perhaps less than 30 ft. Soluble materials have been removed in greater volumes, lowering the Culebra more than anticipated. The preservation of the Gatuña implies that the solution and subsidence occurred during or soon after the Gatuña. Though thicker Gatuña would be favorable for construction materials (compared to Culebra Dolomite), the presence of shallow groundwater, probably with less than 10,000 ppm TDS, rules out this site.

2.1.2.4 Recommendations for Beker Site

The Beker site was rejected on the basis of shallow ground water. No further examination of the Beker site was recommended.

2.1.3 "Motocross Site"

2.1.3.1 Objective

The *"motocross" site* is located in the southern half of section 5, T.21S., R.27E., and possibly includes the northern edge of section 8. The site was briefly examined to determine surficial characteristics and presence of "cultural" features. Some literature data are also available concerning the site. The site has been called the "motocross" site because of recreational activities. The site was examined at the request of city/county administrators.

2.1.3.2 Review of "Motocross" Site Geology and Hydrology

There are no surface indicators of local groundwater concentration in the southern part of section 5 and northern edges of section 8. A well drilled just southeast of the center of section 5 had a measured depth to water (1974) of 199 feet from a surface elevation of 3280 ft (Geohydrology Associates, Inc., 1978). The source of water is believed to be the Capitan limestone. A stock well about 1 mile west (in section 6) had a measured depth to water of 34 ft in 1948 from a surface elevation of 3190 ft. This well is located in a broad draw draining into Lake Avalon. At the center of section 4, about 1 mile east, Alkali Lake occupies the center of a large depression about a half square mile in area. Near-surface groundwater (less than 100 ft in depth) is not indicated at the site, though a perched zone might be encountered.

Hiss (1976) shows an analysis of 3800 ppm for water from a well in the Capitan aquifer (probably the same well reported by Geohydrology Associates).

The area of this site shows both caliche and bedrock carbonates (probably Rustler Formation, though there is some question) cropping out along the western slopes and higher areas. The topography is most likely held up by bedrock. Eolian sands have draped the leeward (eastern) slopes of the area, but bedrock should not be at great depth. Construction would be a problem with the amount of bedrock. It's not clear there would be significant softer construction material under the bedrock.

There are no observable active sinkholes or karst under this site. East of the site about 1 mile, a string of playas in depressions is strong evidence of past karst and sinkhole development, though these depressions now hold water. There is considerable relief locally.

The land is believed owned by the Bureau of Land Management.

This site area has particular problems because of "cultural features." At least three longer pipelines cross parts of this site, and several drillholes are known in the southern half. At least one drillhole appears relatively recent. Good roads pass within 1 mile on both south and west sides of this site area. Power lines exist within 2 miles of the site area.

This site would require about 7-8 miles of haulage from the center of Carlsbad.

2.1.3.3 Recommendations

It was recommended that this site receive no further consideration. "Cultural" features such as pipelines are particularly abundant and would require extensive and expensive relocation/rerouting. In addition, shallow ground water to the west and east may also indicate shallow groundwater under the site, ruling out use of the site. Bedrock outcrops would cause operational difficulties and expense.

2.1.4 Old Caverns Highway

2.1.4.1 Objective

An area south of Carlsbad and west of Loving was considered as a possible location within which a site might be found based on general characteristics from available information. The area, called here **Old Caverns Hwy** is located in the area of southeastern corner T.23S., R.26E., and southwestern corner T.23S., R.27E. (south and east of former Chuckwagon Restaurant).

2.1.4.2 General Geological and Hydrologic Characteristics

Depth of groundwater, based on Hendrickson and Jones (1952) appears to be marginally greater than 100 ft, though data are sparse in this area. Some perched groundwater may also be present, as much of the underlying rock is either Gatuña Formation or clasts from a now-abandoned fan deposit off the Guadalupe Mountains. The Culebra Dolomite Member of the Rustler will be at relatively shallow depths and may also be able to serve as a local aquifer. East of this location, boreholes drilled recently for closure monitor wells at the Loving landfill site have encountered ground water levels less than 50 ft below the surface.

Water quality is not available from Hendrickson and Jones (1952).

The main obstacle to construction, depending on location, would be heavily cemented conglomerates. These can be observed in a borrow pit in section 18 (T.23S., R.26E.), but they are either limited or buried by more modern alluvium in much of the area. The Gatuña, as it crops out closer to Loving, ranges from an argillaceous siltstone to a sandstone. Local construction materials may be sufficient to form a barrier to infiltration but are not predictable from available data.

The relief and slopes are modest throughout this area. There is considerable evidence near Black River and further south of active evaporite karst which should be avoided. Older evaporite karst features are common well to the east and southeast of the area. No sinks or swallowholes are known in the area to indicate active karst.

Land ownership is a major obstacle, as only a strip along the county road (Bounds Road) in southern T.23S., R.27E., is known to be under BLM control. Most of the remaining properties in this area are private or state-owned.

"Cultural features" are generally minimal in this area. Roads are good. A power line runs through the eastern part of the area.

Haul distance from the center of Carlsbad would be 10 to 12 miles.

2.1.4.3 Recommendations

No further investigations are recommended of this general location because of the probable shallow ground water and land ownership obstacles.

2.1.5 Laguna Grande

2.1.5.1 Objective

A generalized location northwest of Laguna Grande de la Sal was examined both for information in the literature and from some preliminary auguring to determine broad geological characteristics. The Laguna Grande location was investigated because of potentially favorable near surface lithology (areas of Gatuña Fm) and because depth to ground water may be favorable or ground water quality very low. Parts of Nash Draw and the area around Laguna Grande are underlain by the "brine aquifer," a very saline water-bearing unit generally located in a solution residue above the uppermost salt in the Salado Fm. If ground water occurs at shallow depths under parts of the area, it is possible that the high salinity and internal drainage toward Laguna Grande would provide acceptable conditions for locating a landfill.

2.1.5.2 General Location Information

The dominant recent geological processes in the vicinity of Laguna Grande and through Nash Draw have been solution of Salado halite, subsidence of the overlying units, erosion and deposition in subsided areas, and the formation of internal drainage, including Laguna Grande. These processes have been discussed in Bachman (1980) and Vine (1963), while Bachman (1981) and Vine also provided maps of the surface geology of Nash Draw. Much of the location more specifically considered here is adjacent to the areas mapped by these investigators. Earlier work by Robinson and Lang (1938) defined basic hydrogeological information for the area because of apparent increasing salinity of water in irrigation wells near the Pecos after a potash refinery began to discharge additional brine into Laguna Grande in the 1930's. A salinity alleviation project near Malaga Bend was related to the saline ground water, but little of that information appears directly relevant.

Hydrological information is more sparce northwest away from Laguna Grande itself. A study by Geohydrology Associates (1978) shows water at marginally acceptable depths about 1 mile west of the general location. In addition, the salinity gradient away from the area of the lake is poorly defined to unknown in this area; the area of interest underlain by brine (> 10,000 ppm TDS) is not known.

2.1.5.3 Specific Location Information

Three locations were chosen northwest of Laguna Grande de la Sal to examine the possible geology and hydrology in this area (Figure 5). LG-1 was located in the SW¼, NE¼, section 5, T.23S., R.29E. near the drilling pad of Eastland Carthel Federal #2 and a railroad trestle over a small arroyo. The elevation for this location is about 3000 ft based on the topographic map. LG-2 was located near the northwest corner of section 8, T.23S., R. 29E., adjacent to a road leading to the United Salt Corporation works on Laguna Grande de la Sal. The elevation of this location is about 3015 ft based on the topographic map. LG-3 was located near the center of the NW¼, section 6, T.23S., R.29E., in a small borrow pit and adjacent to a small arroyo. LG-3 is at an elevation of about 3060 ft based on the topographic map.

LG-1 was augured and cored to refusal at 33 ft. The lithology can be described as three basic units, with details provided in Appendix 1:

0-10 ft	Surface wash and fill including clasts of Magenta Dolomite Member of the Rustler Formation. Some of the upper material may have been alterred during pad construction nearby.
10-29? ft	Mixed unit of reddish brown sand, silt, and some silty claystone and soft gray gypsum. Some probable smeared intraclasts at 16-19.5. This unit represents the remains of the Tamarisk Member of the Rustler Formation.
29?-33 ft	Mainly ground gypsum and clasts of very light gray carbonate. This unit is harder drilling and is the upper part of the Culebra Dolomite Member of the Rustler Formation, though the carbona has been altered somewhat.

No water was detected in this borehole using a water depth gauge.

LG-2 revealed about 1 ft of dark gray soil with caliche clasts before reaching the top of the well lithified Mescalero caliche. Auguring was not possible, and the attempt was abandoned.

LG-3 was augured and drilled to refusal at a total depth of 46.5 ft. The lithology of the hole can be described as three basic units, with details provided in Appendix 1:

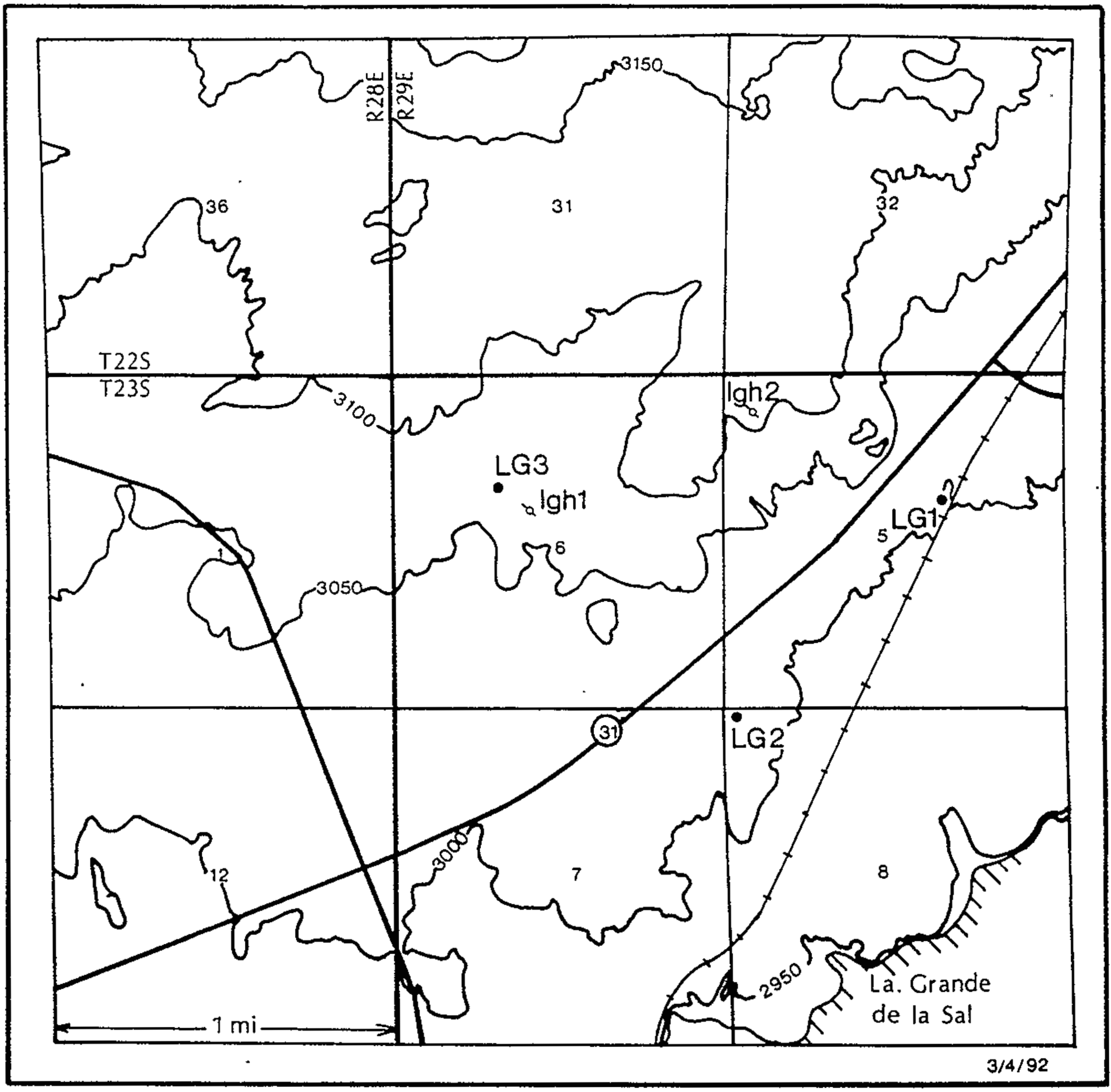
0-10 ft	Arroyo fill and upper Gatuña Fm overprinted by pedogenic carbonate (Mescalero caliche).
10-35?ft	Mixed sandstone, siltstone, and claystone, mainly reddish brown, with zones of sandstone including well rounded siliceous granules and pebbles. Some siltstones and claystones include considerable bioturbation from rootlets and have blocky texture with MnO_2 stains along vertical fractures. (Gatuña Formation) Hard drilling zone augured without coring from 30-35 ft is probably a continuation of pebbly zones recovered in zone from 25-30 ft.
35?-46.5 ft	Hard drilling. Cuttings return very calcareous matrix and pebbles of vuggy light gray dolomite (Culebra Dolomite Member of the Rustler Formation).

No water or moist zones were detected in the borehole with a water level gauge or in cuttings.

2.1.5.4 Discussion of Drilling Results

Both LG-1 and the outcrops in the immediate area suggest that the local geology of the Rustler is highly disturbed as a consequence of solution of Rustler sulfate units and upper Salado salt. In the areas nearer the lake, we should anticipate that these units will be much less predictable from a structural view; significant auguring would be necessary to understand whether hard rock will crop out in excavation for a landfill. Though groundwater was not encountered to the upper Culebra Dolomite Member, it is highly probable that either the Culebra or underlying sediment will yield shallow saline water or brine at this location. There may also be fresher water lenses included, as Robinson and Lang (1938) found in drilling in the lake itself. This location is not suggested as a site itself, in view of the railroad, gas well, and arroyo. It was chosen as a drilling site to obtain information about the underlying geology and groundwater and was successful in indicating the geology.

Figure 5
Laguna Grande de la Sal
Location and Drilling Sites



LG1 through 3 are augur sites described in the report. lgh1 and 2 are proposed locations for additional drilling if the Laguna Grande de la Sal location was investigated further as an alternate location to Sand Point. Elevations on contours are in feet.

LG-2 is in an area with well-developed Mescalero caliche. This unit shows laminar development under the present soil, indicating its state of induration. Such locations can be expected to have 3 to 6 ft of hard soil carbonate, which can be a significant obstacle to construction. The hydrologic situation should be similar to that at LG-1, though it is untested at the moment.

LG-3 shows that the Culebra Dolomite is at very shallow depths and is overlain by the Gatuña. The Dewey Lake and upper Rustler have been stripped from this area. The Culebra is at nearly the same elevation in this hole as it is at Culebra Bluffs along the Pecos River about 2 miles west southwest of LG-3. As construction material, the overlying Gatuña may be suitable to difficult (depending on the extent and lithification of the hard pebbly to conglomeratic sandstones in the Gatuña) to work.

It is possible that the Culebra bears some fluid in this area, though a drillhole for the BLM (Geohydrology and Associates, 1979) about 1 mile west northwest of LG-3 likely penetrated the Culebra between 31 and 63 ft depth apparently without encountering fluid. That hole (23.28.1.11) was drilled to 300 ft depth with temporary lost circulation zones at 70 and 270 ft. The hole was dry when drilled. Four months later (February, 1979) the water level was 161 ft below land surface. From the lithology of that borehole, the fluid-bearing zone is within the solution residue of the Salado Formation, and the water level rose to approximately the base of the Rustler Formation. The elevation of the fluid would be between about 2890 and 2900 ft, given the topography of the general borehole location on the topographic map. This would be about 60-70 ft below the level of the Pecos River to the southwest.

The area for the Laguna Grande investigation includes higher topographic area comprised of Gatuña overlain by Mescalero caliche. The Dewey Lake is known to occur along southern Quahada Ridge, but nearer the Pecos has mostly been eroded prior to depositing the Gatuña. Auguring helped establish correctly the depth of some units in the general area, but was not able to establish the depth to groundwater or presence of brine in the area. Deeper drilling will be required to establish the groundwater depth and composition. In terms of the factors examined in the preliminary report, this location (Figure 5) is still apparently suitable. Its major drawbacks, at this time, appear to be longer distance of transport and less certainty of the depth to hard rock for construction. Groundwater is neither established for its depth nor for its quality. Some parts of the area may be more subject to erosion.

2.1.5.5 Recommendations

The Laguna Grande location may be acceptable, but has several drawbacks. As a consequence, no further immediate investigations are recommended, though it is still possible the location would serve as an alternate if the Sand Point site and location ultimately proved unacceptable. The location is not conveniently located, considering Carlsbad as a major source for the landfill. Drilling shows variable depth to hard ground conditions, with Culebra and Magenta Dolomite Members commonly at very shallow depths. In addition, ground water depth and quality still remains poorly defined and possibly marginal (depthwise) under much of the location. There is no assurance that poor ground water quality will lessen regulatory requirements if ground water is less than 100 ft.

In the event this location is further examined in the future, the first step is to acquire any additional information which can be made available through BLM (Roswell office) and collate the available information into a reasonable database to project the geology and hydrology for further investigations of the area. The geology at this location is not well exposed, in general, and appears to be somewhat less predictable (than Sand Point) due to more extensive dissolution. The depth to groundwater may be less than at Sand Point, though perhaps well in excess of 100 ft in many areas and very possibly of greater salinity than at Sand Point.

Two tentative locations have been plotted (Figure 5) for hydrologic investigations if further investigation of this location is desired. These well sites have been chosen for the following reasons:

lgh-1 This location was chosen to determine the depth and quality of groundwater in a possible downgradient area from possible landfill sites in the area. The first probable groundwater zone would be the Culebra Dolomite Member of the Rustler, at a depth expected to be less than 100 ft below the surface, based on the shallow depth to Culebra in nearby LG3. The upper part of the Culebra in LG3 did not yield water, but the remainder of the dolomite was untested. The next probable fluid bearing zone would be at the base of the Rustler, in solution residue of the upper Salado. About 1 mile west northwest, a hole for BLM yielded water from this interval. This general location should also provide a reasonable check of the area underlain by high salinity water (> 10,000 ppm TDS) from either zone.

lgh-2 The location for lgh-2 overlies a thicker Gatuña zone, at higher elevation, in an area more likely to be chosen for a landfill site. This location should also provide a good check of the area underlain by high salinity groundwater.

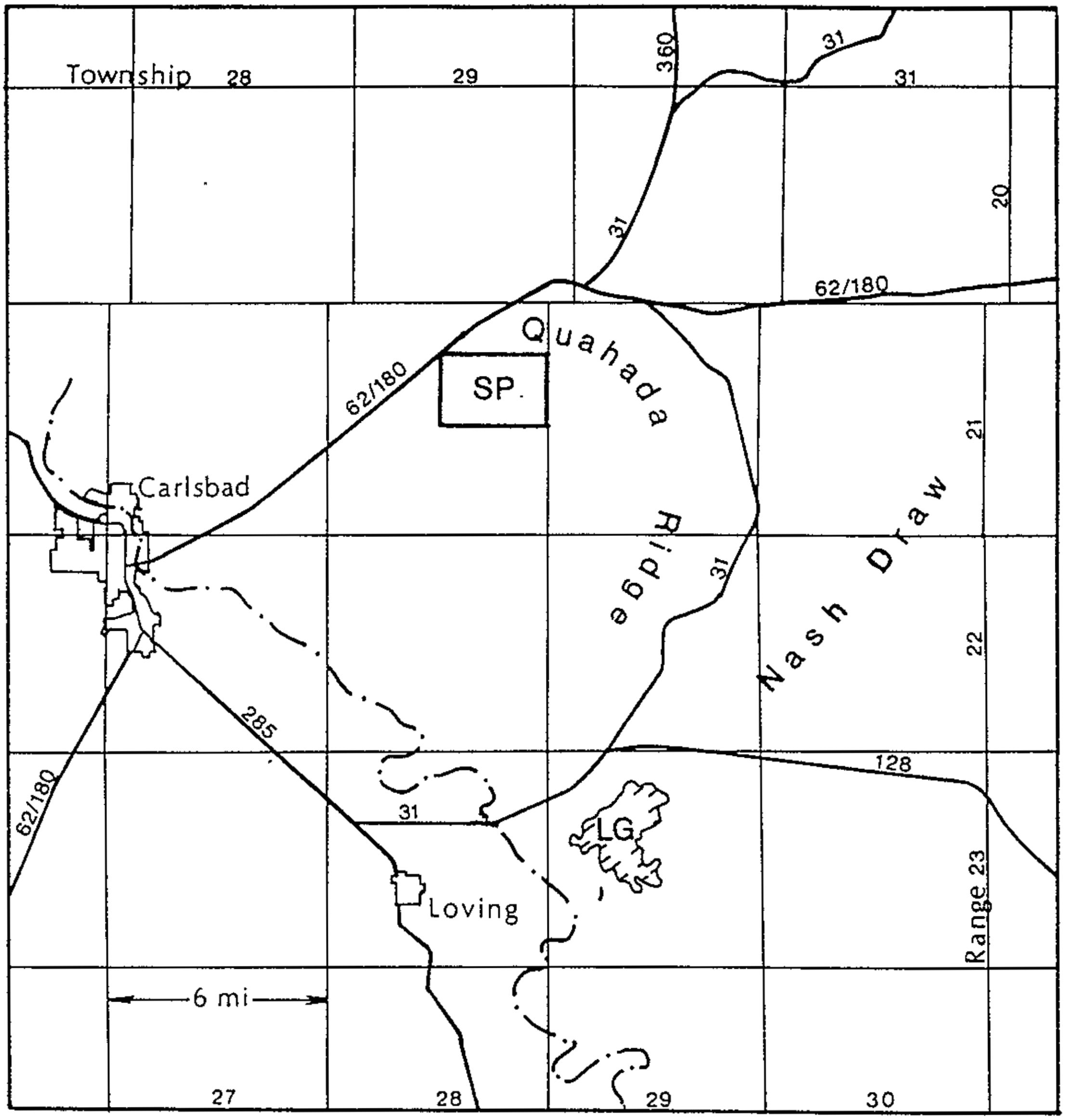
The two hydrologic boreholes would provide a first good hydrologic test of this general location. Further boreholes may be necessary, but sites should probably not be chosen until data are available from one or both of these boreholes. The general drilling and testing program for these boreholes should be similar to that for Sand Point.

2.1.6 Sand Point Location (Quahada Ridge)

2.1.6.1 Objective

Quahada Ridge is a topographic high which bounds the western side of Nash Draw and bends back to the west at its north end (Figure 6). The ridge is covered in many areas by the Mescalero caliche, which is as much as 6 ft thick in some parts. The remainder of the ridge consists of either the Plio-Pleistocene Gatuña Formation, commonly a few feet to a several tens of feet of brownish to slightly reddish brown sandstone and siltstone, or the Permian Dewey Lake Formation, a reddish brown siltstone ranging in thickness to about 600 ft to the east of Nash Draw. A broader location (sections 10-15, T.21S., R.28E.) was examined on the northwestern end of Quahada Ridge at and around Sand Point (section 10) to determine if general conditions were suitable for a landfill.

Figure 6
Regional Setting
Sand Point Location



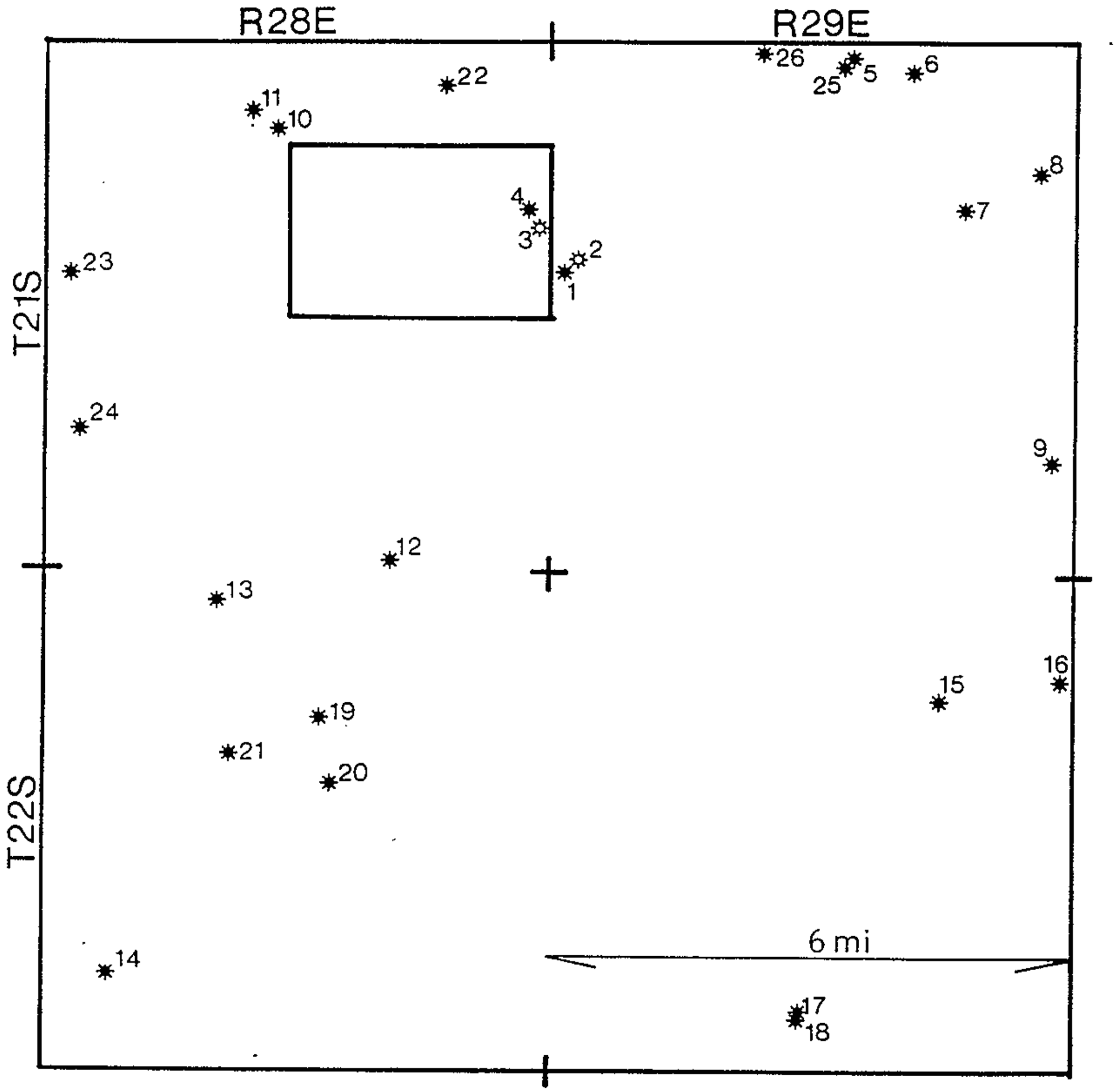
SP identifies Sand Point location (six square miles). LG is the location of Laguna Grande de la Sal. Highway numbers are shown along the highway line.

This location was chosen for further investigation because of relative proximity to Carlsbad, apparent regional depth to ground water, and favorable nearsurface lithologies for construction. An area of 6 sections (square miles) was designated for investigation to include possible favorable and adjacent areas.

2.1.6.2 Background Geological and Hydrological Data

There are no observed shallow hydrologic wells in the six sections examined as a possible location for a landfill site (Figure 7; Table 3). A livestock well ("Lusk east well") located in section 18 (T.21S., R.29E.), just east of the common section line with section 12, is reported by Hendrickson and Jones (1952) as having water at a depth of 135 feet below a land surface elevation of 3290 feet. The calculated elevation of the water is 3155 ft. Richey (1989) reports the water elevation in this well as 3156 ft in 1983. This well ("Lusk east well") was inoperable when inspected (01/30/92). Geohydrology Associates, Inc. (1978) report a second well in section 18 (21.29.18.123) with a water depth of 100 to 120 ft. This location presents two problems: 1) no well has been found at this location and 2) the map topography, plus indicated water depth, would indicate the elevation of the top of ground water varies here by 25 to 55 ft above the elevation of the "Lusk east well." The "Lusk east well" should be between ½ and ¼mile from this reported location. Geohydrology Associates, Inc. (1978) also reported an "industrial" well in the southeastern corner of section 12 which could not be found despite intensive field inspections. It is likely this well location is reported incorrectly and is instead a water supply well drilled near and for Bass Big Eddy Unit #36; the water supply well is located 810 ft fel (from east line) and 1850 fsl in section 12 at a ground level of 3356 ft according to data obtained from the Bureau of Land Management in Roswell. The elevation data (3358 ft) reported by Geohydrology Associates is consistent with this location but not with the

Figure 7
Background Hydrological Data Sources, Sand Point Location



Numbers refer to arbitrary well number entries in Table 7. Table 7 includes elevation, water depth, and other data for each well with water data.

Table 3
Background Hydrological Data
Sand Point Location

(Figure 7)

Well Number	Source	Surface Elevation	Water Depth	comments
1	A,B,D*	3290	135	21.29.18.130; "Lusk east well"; measured depth (date) 135'
2	B	3310(map)	100-120	21.29.18.123; not found at given location
3	B	3358	205	21.28.12.444; not found at given location; interpreted as well number 4 based on elevation and other information
4	D	3358	not given	Water water for nearby oil well Big Eddy 36; depth may be 205; see above
5	A,B	3380	210+	21.29.03.120; Wayne Cowden well
6	C	3422	274	21.29.02.14; BLM test well
7	B,C	3311	175	21.29.11.421
8	B,C	3485	280	21.29.12.211
9	C	3314	68	21.29.25.423; Pue domestic well; nearby well in ref B.
10	B,C,D	3235	80	21.28.04.442; water depth 105+ in 1992
11	B,C,D	3207	23	21.28.04.413; water depth
12	B,C	3160	137	21.28.35.333; may be same well as 22.28.111 in B,C
13	B	3142	131	22.28.04.130
14	A,B	3042	14	22.28.30.443
15	A,B	3230	278	22.29.11.000
16	A,B	3140	119	22.29.12.224
17	B,C	3018	54	22.29.33.214
18	A,B	3020	56	22.29.33.240
19	B	3986	28?	22.28.10.33
20	B,C	3096	75	22.28.15.323
21	B,C	3083	52	22.28.16.113
22	B	3367	210	21.28.02.24
23	B	3150	19	21.28.18.130
24	B,C	3181	90	21.28.30.141
25	B	3396	225	21.29.03.141
26	B	3380	183	21.29.04.121

* A= Hendrickson and Jones, 1952; B= Geohydrology Associates, 1978; C= Geohydrology Associates, 1978; D= measurement made or location obtained during Sand Point investigation.

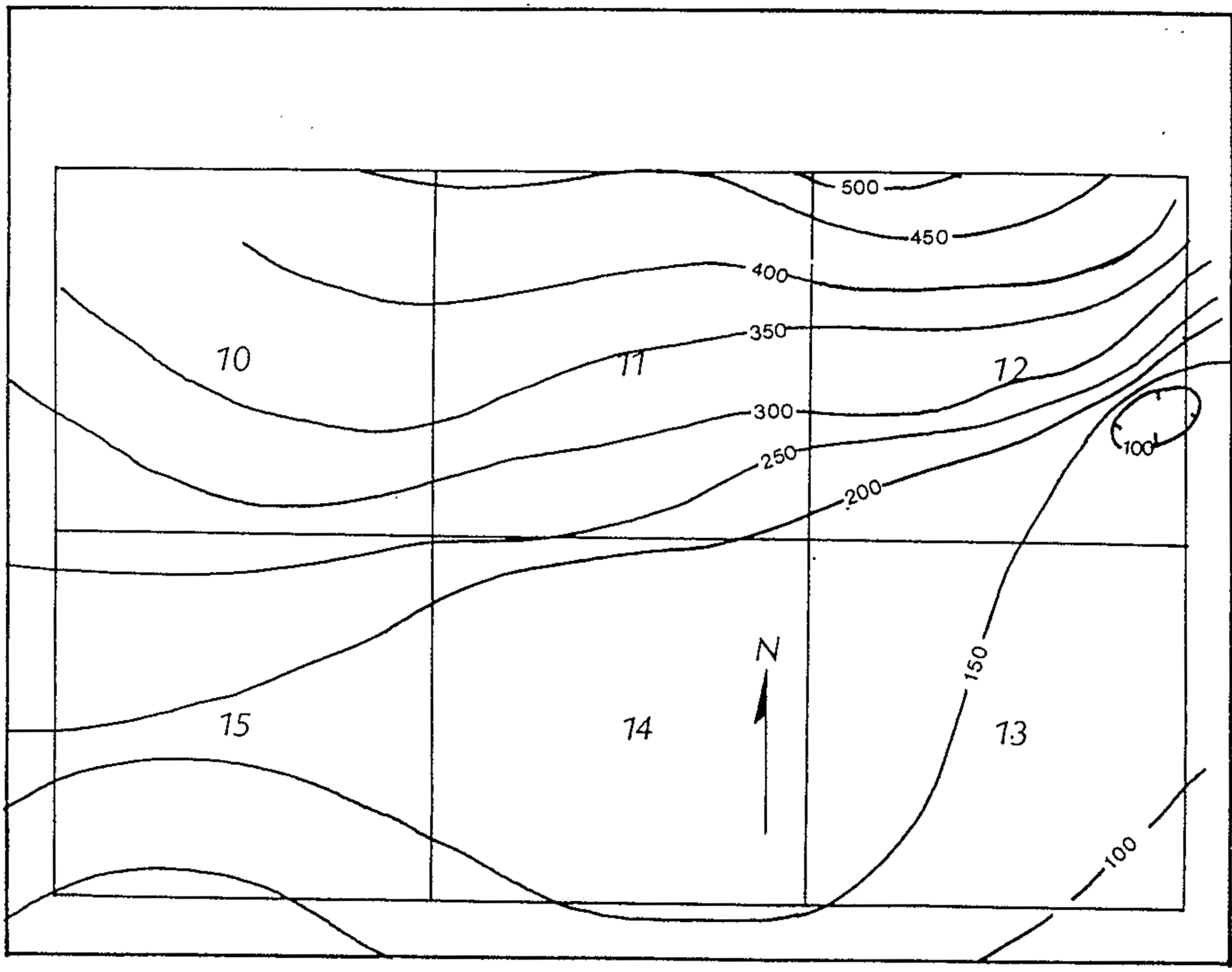
reported southeastern corner of the section. Depth data for the well is reported by Geohydrology Associates, Inc. (1978) as 275 feet, identical to the Bass water supply well. These inconsistencies have not been resolved, though the problem is believed to be the location provided by Geohydrology Associates. Geohydrology Associates report water depth as 205 ft which can be calculated as a water elevation of 3153 ft. Geohydrology Associates, Inc. (1978) also report the elevation (3367 ft) and depth to water (210 ft) for a stock well near the center of section 2, less than 1 mile north of the prime section (11) for this location. The water elevation for this well is 3157 ft. For all practical purposes the calculated elevations on the water in these three wells are the same. Background data for other wells in the general area of the Sand Point location are included in Table 3 for locations shown in Figure 7.

Hendrickson and Jones (1952) report specific conductance of 6,220 micromhos and TDS of 4,880 ppm for the "Lusk east well." Geohydrology Associates, Inc. (1978) report the second well (not located on the ground) in section 18 has a specific conductance of 4320 micromhos, indicating that TDS would probably be less than 4000 ppm.

The Dewey Lake Formation is known to include unpredictable zones of perched groundwater, most commonly near the base of the formation where it overlies the relatively impermeable sulfates of the upper Rustler Formation. The Dewey Lake crops out along this part of Quahada Ridge; no ready evidence has been found of drilling which encountered such zones, but potash drilling records have not been examined.

A preliminary and generalized map of depth to top of Rustler Formation has been prepared based on structure contours from a larger area and the topographic contours (Figure 8). The map contours indicate that most of sections 10, 11, and 12 should have depth of more than 250 ft to the top of the Rustler, improving the possibility that any unpredictable perched water in the lower Dewey Lake Formation will be more than 100 ft below the ground surface. Elevations (structure contours) on the top of the Rustler

Figure 8
Estimated Depth Below Surface of Top of Rustler Formation
(T.21S., R.28E.)



Contours in feet. Depths derived by subtracting general structure contours on Rustler (Figure 9a) from elevation where major contours intersect. Resultant data have been contoured. Contours in northern area based on few structure data points.

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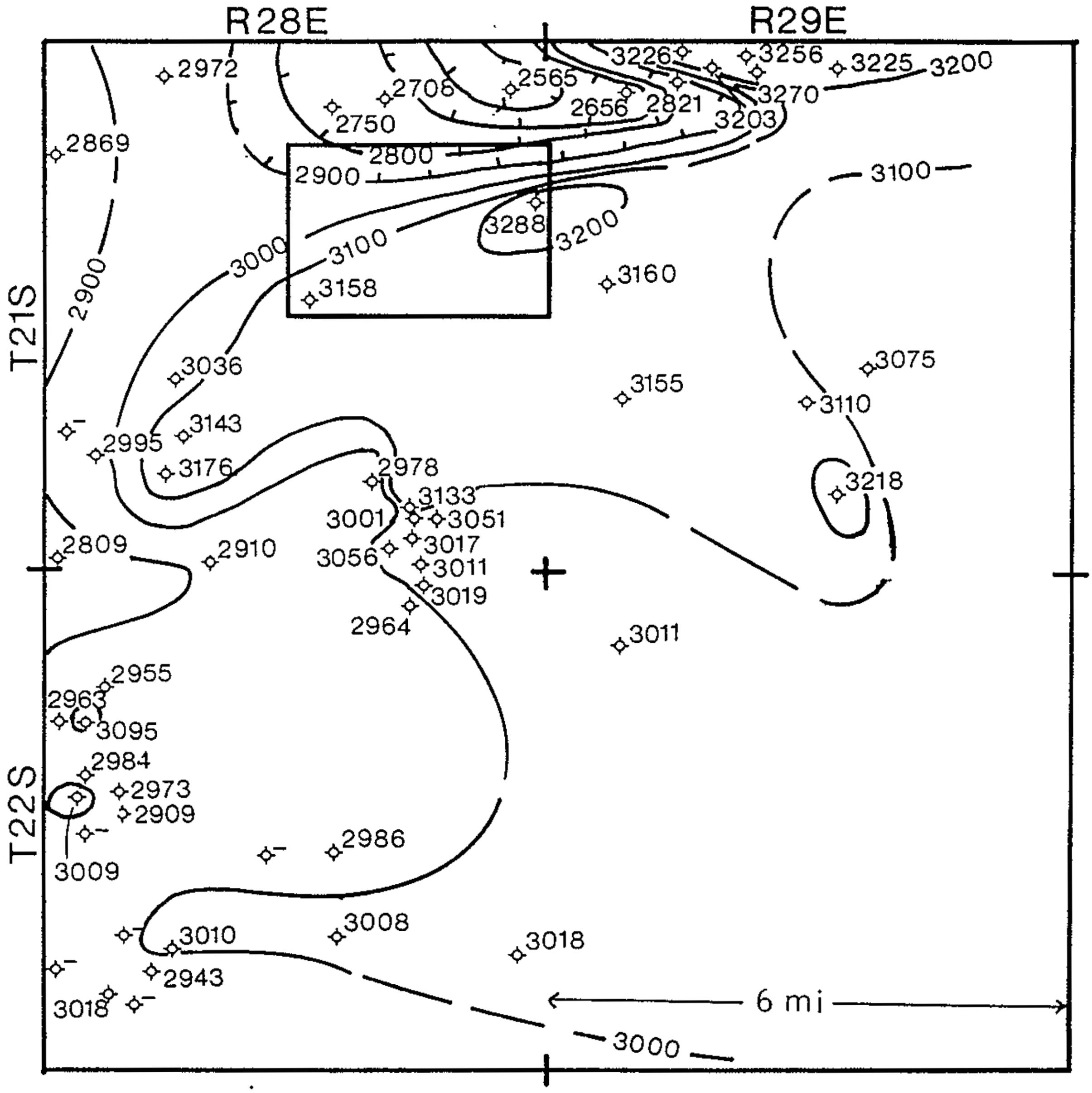
Formation (Figure 9) show that the Rustler is much affected by karst to the north in the area north of the Hobbs highway (Highway 62/180). It is probable that the contours do not impinge on the northern part of the 6 section location as drastically as shown in this map. The map was drawn conservatively to enhance this structure, but the dips in units exposed along the Hobbs highway suggest these contours may not begin dipping to the north within the boundaries of the location (Figure 9). Some additional drillholes exist in this area, but the information is apparently not yet in the public domain. The main effect of such structure would be to redirect subsurface flow within the Rustler and lower Dewey Lake to the north rather than to the south.

The Mescalero caliche which covers much of the higher elevations in this area ranges from thick and well indurated to moderately indurated. The Plio-Pleistocene Gatuña Formation and Permian Dewey Lake Formations which underlie the caliche are usually moderately to poorly indurated and have weathered and fractured extensively near the surface. It is questionable whether these materials, in this area, will provide a suitable barrier to infiltration, but they should not be a serious obstacle to construction.

No sinkholes or evidence of probable karst were observed in these sections. Further west and south, the Rustler Formation crops out or is weathering in the near surface. Closed depressions and swallowholes have been observed north, west, and south of the location, but are not known to be a problem within sections 10-15. A closed depression occurs adjacent to the Sand Point location in section 9. The depression may indicate solution of salt or of sulfate beds. At the location, salt is still present in the Salado Formation underlying the Rustler, indicating solution has.

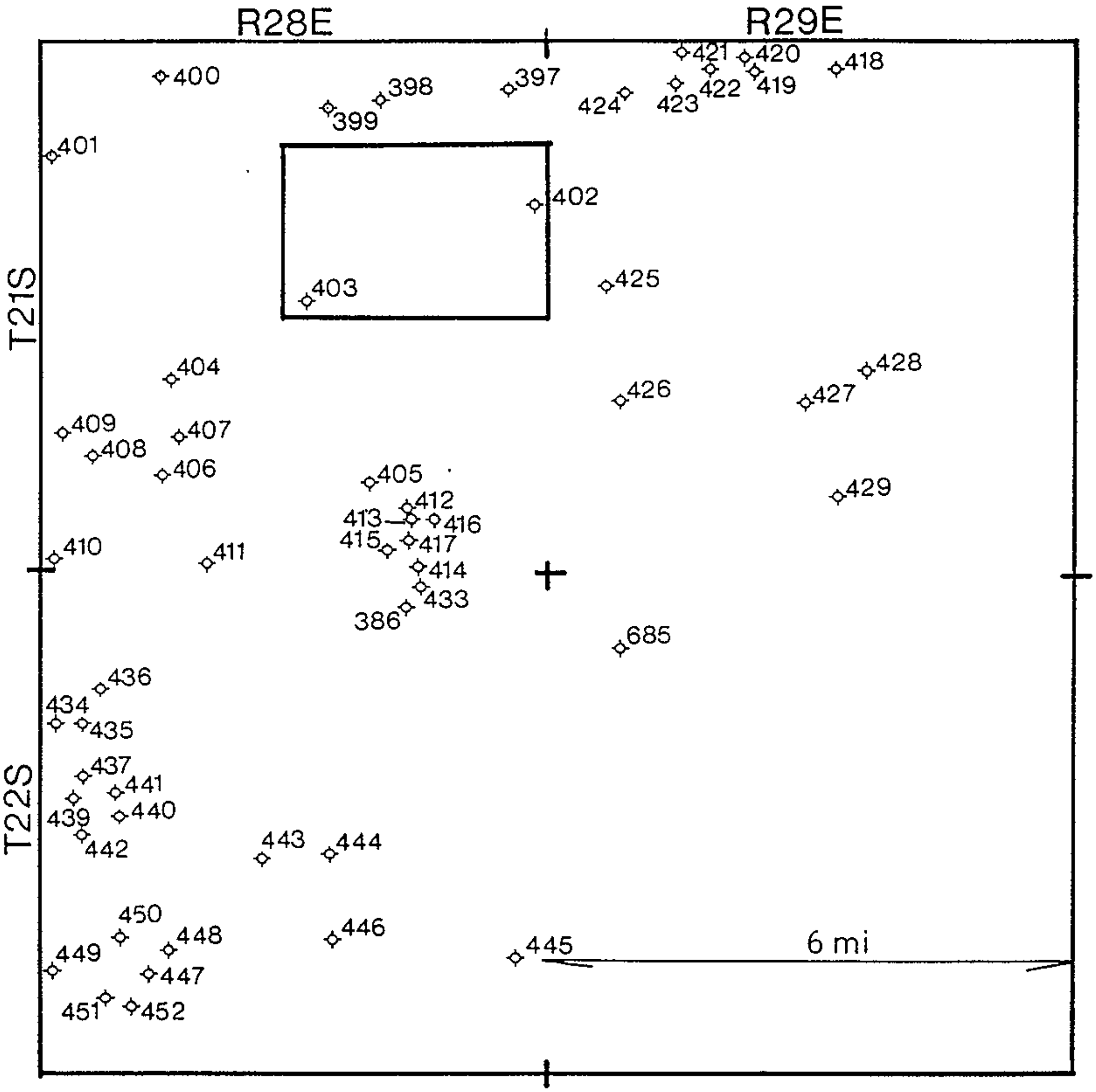
The relief and slopes in this area are not great. Local drainages connect to Indian Draw and Flats to the southwest, but it should be possible to locate a large site without including any significant drainage system.

Figure 9A
Regional Structure Contours, Top of Rustler Formation, Sand Point Location



Elevations in feet. Source of data: Richey (1987). See Figure 9B for borehole identifiers and Table 4 for data set.

Figure 9B
Borehole Locations and Identifiers,
Regional Data for Rustler Formation,
Sand Point Location



Numbers are equivalent to "FFG" numbers in Richey (1987). See Figure 9A for structure contours on top of Rustler and Table 4 for data set.

Table 4
Preliminary Stratigraphic Data
(Richey, 1989)

Arranged by T,R

FFG #	Location (T.R.sec)	Ref. Elevation feet	Ref. Elevation (meters)	Depth Top Rustler feet	Depth Top Rustler (meters)	Depth Top Salado feet	Depth Top Salado (meters)	Elevation Top Rustler feet	Elevation Top Rustler (meters)	Elevation Top Salado feet	Elevation Top Salado (meters)
397	21.28. 1	3401	(1036.9)	835	(254.8)		( )	2565	(782.1)		( )
398	21.28. 2	3318	(1011.6)	609	(185.9)		( )	2708	(825.7)		( )
399	21.28. 3	3285	(1001.6)	534	(163.1)		( )	2750	(838.5)		( )
400	21.28. 5	3216	(980.5)	243	(74.1)		( )	2972	(906.4)		( )
401	21.28. 7	3189	(972.3)	319	(97.5)		( )	2869	(874.8)		( )
402	21.28.12	3355	(1023.1)	67	(20.6)		( )	3288	(1002.5)		( )
403	21.28.15	3264	(995.2)	105	(32.2)	486	(148.3)	3158	(963.0)	2777	(846.9)
404	21.28.20	3203	(976.6)	166	(50.9)		( )	3036	(925.7)		( )
405	21.28.27	3182	(970.2)	204	(62.2)	473	(144.5)	2978	(908.0)	2708	(825.7)
406	21.28.29	3176	(968.4)	0	(0.0)		( )	3176	(968.4)		( )
407	21.28.29	3181	(969.9)	38	(11.6)		( )	3143	(958.3)		( )
408	21.28.30	3165	(965.0)	169	(51.8)	450	(137.2)	2995	(913.2)	2715	(827.8)
409	21.28.30	3183	(970.5)		( )		( )		( )		( )
410	21.28.31	3118	(950.7)	308	(94.0)	733	(223.6)	2809	(856.7)	2384	(727.1)
411	21.28.33	3141	(957.7)	230	(70.4)	553	(168.6)	2910	(887.3)	2588	(789.1)
412	21.28.35	3182	(970.2)	48	(14.9)	410	(125.3)	3133	(955.3)	2771	(844.9)
413	21.28.35	3177	(968.7)	175	(53.6)	437	(133.5)	3001	(915.1)	2739	(835.2)
414	21.28.35	3167	(965.8)	156	(47.7)	516	(157.4)	3011	(918.1)	2651	(808.4)
415	21.28.35	3163	(964.4)	106	(32.6)	376	(114.9)	3056	(931.8)	2786	(849.5)
416	21.28.35	3185	(971.1)	133	(40.8)	429	(130.8)	3051	(930.3)	2756	(840.3)
417	21.28.35	3170	(966.7)	152	(46.6)	421	(128.6)	3017	(920.1)	2748	(838.1)
418	21.29. 3	3391	(1033.9)	165	(50.6)		( )	3225	(983.3)		( )
419	21.29. 4	3452	(1052.5)	182	(55.5)		( )	3270	(997.0)		( )
420	21.29. 4	3427	(1045.1)	171	(52.4)		( )	3256	(992.7)		( )
421	21.29. 5	3434	(1047.0)	207	(63.4)	549	(167.6)	3226	(983.6)	2884	(879.4)
422	21.29. 5	3458	(1054.3)	254	(77.7)		( )	3203	(976.6)		( )
423	21.29. 5	3466	(1057.0)	645	(196.9)	981	(299.3)	2821	(860.1)	2485	(757.7)
424	21.29. 6	3469	(1057.7)	812	(247.8)		( )	2656	(809.9)		( )
425	21.29.18	3292	(1003.7)	131	(40.2)	518	(158.2)	3160	(963.5)	2773	(845.5)
426	21.29.19	3267	(996.1)	111	(34.1)	457	(139.6)	3155	(962.0)	2809	(856.5)
427	21.29.21	3420	(1042.7)	309	(94.5)	544	(166.1)	3110	(948.2)	2875	(876.6)
428	21.29.22	3439	(1048.5)	363	(110.9)	674	(205.7)	3075	(937.6)	2764	(842.8)
429	21.29.34	3424	(1044.2)	206	(63.1)	526	(160.6)	3218	(981.1)	2898	(883.6)
386	22.28. 2	3155	(961.9)	190	(58.2)	502	(153.3)	2964	(903.7)	2652	(808.6)
433	22.28. 2	3175	(968.0)	155	(47.5)	495	(151.2)	3019	(920.5)	2679	(816.8)

FFG number is a reference number assigned by Richey (1989) for each borehole. Location data given as xx.xx.xx refer in order to township, range, and section.

Table 4, cont.
Preliminary Stratigraphic Data
(Richey, 1989)

434	22.28. 7	3098	(944.6)	134	(41.1)	387	(118.2)	2963	(903.5)	2710	(826.4)
435	22.28. 7	3095	(943.7)	0	(0.0)	309	(94.5)	3095	(943.7)	2785	(849.2)
436	22.28. 7	3094	(943.4)	138	(42.2)	394	(120.3)	2955	(901.2)	2699	(823.1)
437	22.28.18	3076	(937.9)	91	(27.9)	389	(118.7)	2984	(910.0)	2686	(819.2)
439	22.28.18	3087	(941.2)	78	(23.8)		( )	3009	(917.4)		( )
440	22.28.18	3078	(938.5)	168	(51.5)	393	(120.1)	2909	(887.0)	2684	(818.4)
441	22.28.18	3079	(938.8)	105	(32.3)	395	(120.7)	2973	(906.5)	2683	(818.1)
442	22.28.19	3073	(937.0)		( )		( )		( )		( )
443	22.28.21	3064	(934.2)		( )	372	(113.7)		( )	2691	(820.5)
444	22.28.22	3094	(943.4)	107	(32.8)	387	(118.2)	2986	(910.6)	2706	(825.2)
445	22.28.25	3151	(960.7)	132	(40.5)	437	(133.5)	3018	(920.2)	2713	(827.2)
446	22.28.27	3073	(937.0)	64	(19.8)	352	(107.6)	3008	(917.2)	2720	(829.4)
447	22.28.29	3025	(922.3)	82	(25.0)	324	(98.8)	2943	(897.3)	2701	(823.5)
448	22.28.29	3031	(924.2)	20	(6.4)	356	(108.8)	3010	(917.8)	2674	(815.4)
449	22.28.30	3056	(931.8)		( )	369	(112.5)		( )	2687	(819.3)
450	22.28.30	3036	(925.7)		( )	348	(106.4)		( )	2687	(819.3)
451	22.28.31	3048	(929.3)	29	(9.1)	349	(106.7)	3018	(920.2)	2698	(822.6)
452	22.28.31	3064	(934.2)		( )	415	(126.8)		( )	2648	(807.4)
685	22.29. 6	3291	(1003.5)	280	(85.4)	583	(177.8)	3011	(918.1)	2708	(825.7)

FFG number is a reference number assigned by Richey (1989) for each borehole. Location data given as xx.xx.xx refer in order to township, range, and section.

It is believed Bureau of Land Management controls all sections (10 through 15) in the general Sand Point location.

Two subparallel pipelines running northeast-southwest cross parts of this location. One pipeline affects sections 13 and the southeastern part of section 14. The other pipeline cuts through section 12 and the southeastern part of section 11. Section 10 is not affected. Drilling has been minor. There are no nearby power lines. Potential sites range from about 1 to 2 1/2 miles from Hwy 62/180.

The haul distance from the center of Carlsbad would be about 11-12 miles, depending on location of a site.

Based on conditions indicated by background data, the northern part of the Sand Point location appears to be favorable and some initial auguring was completed.

2.1.6.3 Sand Point Augur Results

Two holes were augured and partially sampled in this general location (Fig. 10). SP-1 was drilled about 20 ft from the road in the SW¼, NW¼, section 11, T.21S., R.28E. The location is at the lower end of a borrow pit for sand. The elevation of the surface at SP-1 is about 3320 ft, based on the topographic map. Borehole SP-2 was augured in the SW¼, SE¼, section 12, T.21S., R.28E., adjacent to the road. The elevation of SP-2 is about 3350 ft, based on the topographic map.

SP-1 was augured to refusal at a depth of 81 ft. The lithology can be described as three basic units, with detail provided in Appendix 1:

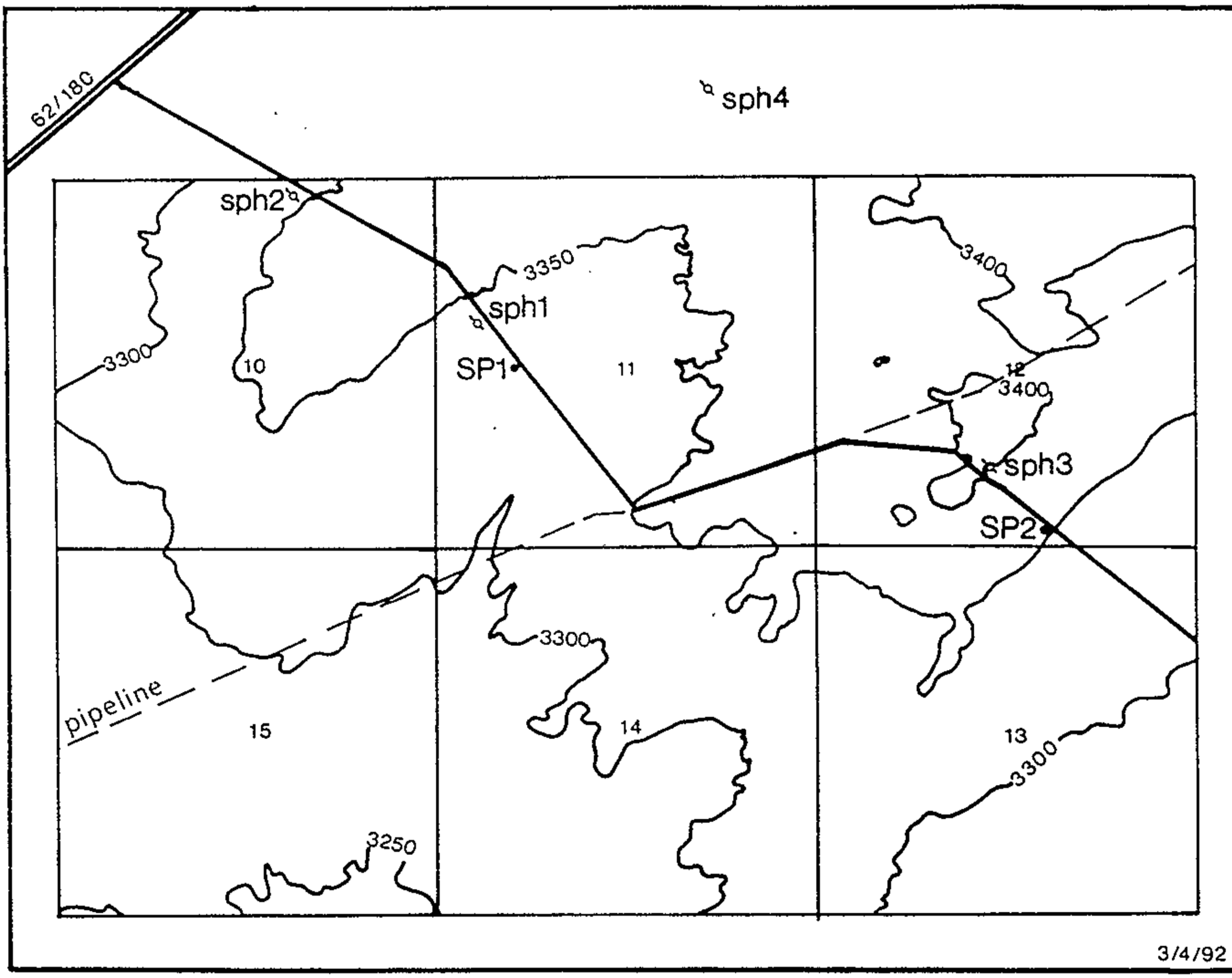
0-6 ft	Reddish brown argillaceous sand of eolian origin.
6-16 ft	White caliche clasts in light brown sandy to granular matrix (Mescalero caliche) overlying sandy silt and silty sand with pedogenic carbonate from the Mescalero.
16-81 ft	Reddish brown calcareous silty sand and sandstone with zones of thin bedding and zones with extensive open porosity and MnO stains from rootlets in weak paleosols (Gatuña Formation).

No moisture was detected in this borehole. Cuttings returned to the surface from a drilling depth of about 8 ft were moist enough to hold together when pressed. Sampling from 11 to 16 feet returned material which was slightly moist as well. No moisture collected overnight in the hole to a depth of 60 ft.

SP-2 was augured to a total depth of 56 ft to refusal. The lithology consists of four units, with detail provided in Appendix 1:

0-2 ft	Loose dark brown sand with pebbles (surface wash and soil).
2-5 ft	Light brown to white calcareous matrix and caliche pebbles (Mescalero caliche).
5-53 ft	Reddish brown siltstone and fine sandstone with greenish reduction spots (Dewey Lake Formation). Drilling and recovery became variable from about 38 ft, and the augur assembly was not in solid rock through some zones. Drilling became difficult at 53 ft. No coring from 45-55 ft.
53-56 ft	TD in hard, slightly pinkish, white gypsum (Rustler Formation). Sample included some porous sandy carbonate chunks. Based on drilling difficulty, the top of Rustler is estimated to be at 53 ft.

Figure 10
Sand Point Location, Augur Holes and Potential Exploratory Drillhole Locations



Topographic contours in feet. **SP#** refers to augur hole number. **sph#** refers to potential exploratory drillhole location for general examination of the location geology and hydrology.

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No moisture was detected in this borehole using a water depth gauge. There were neither cuttings nor core indicating any moist zones.

Based on the preliminary data and augur results, it was concluded that available records should be further researched as a basis for possible preliminary site characterization.

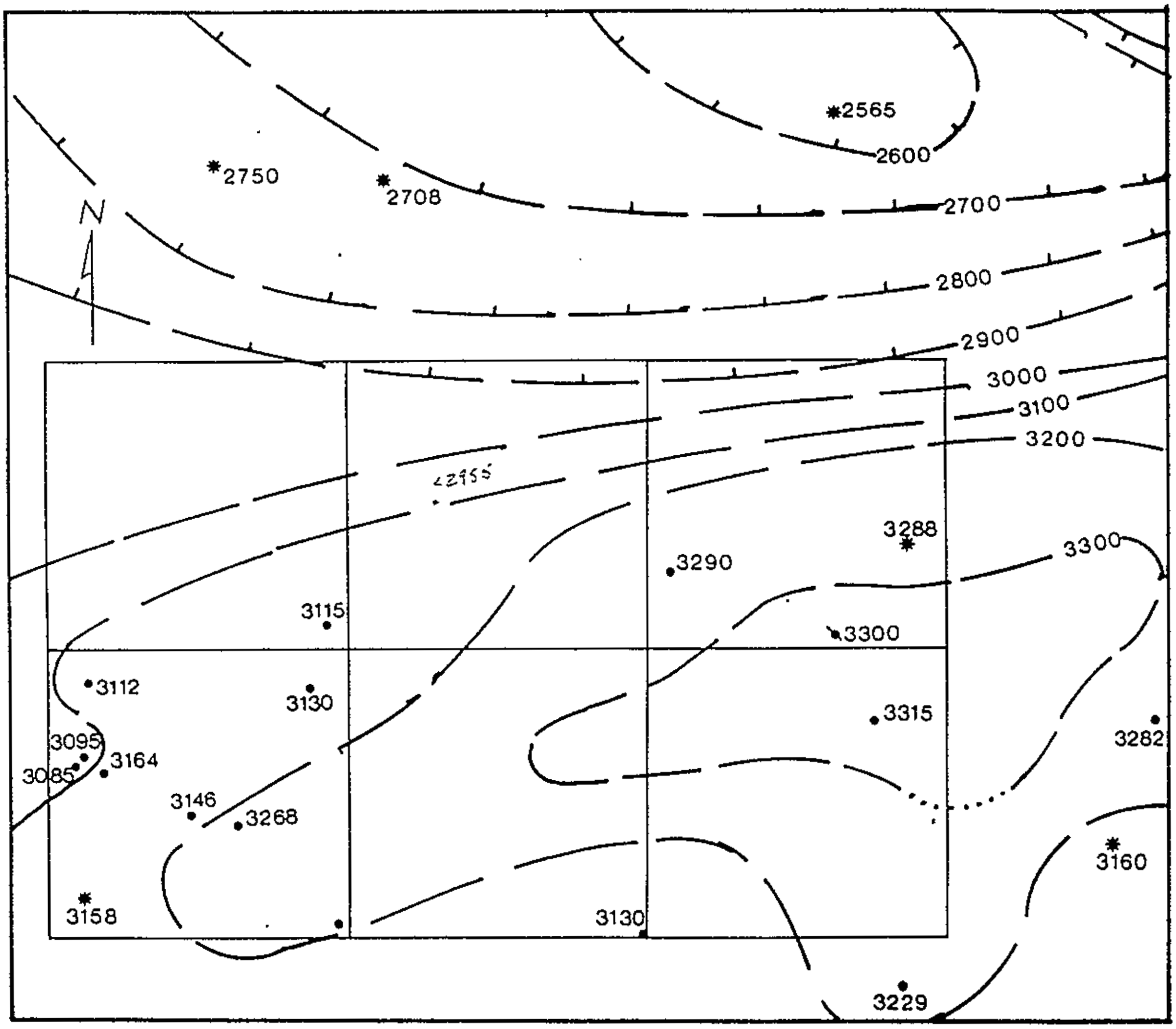
2.1.6.4 Additional Background Data, Sand Point Location

The Bureau of Land Management in Roswell made available information from potash or other drilling for the Sand Point location and surroundings where that information is releasable to the public. The requested information included stratigraphic information on units to the top of Salado or Salado salt and any hydrologic data which may have been recorded (lost circulation zones, moist zones, water level, water quality). Appendix 2 summarizes data from various boreholes.

A preliminary structure contour map (Figure 9) of the top of the Rustler Fm was constructed with basic data obtained from Richey (1989) (Table 4). Depth below surface of the top of the Rustler (Figure 8) was estimated by contouring the difference between structure contours and topographic contours at intersections of major contour lines. With the additional potash and hydrocarbon drillhole data within and around the 6 square mile Sand Point location, the structure contour map of the top of the Rustler Fm was revised (Figure 11), demonstrating some anticlinal structure oriented generally east-west. The elevation of the top of Salado halite (Figure 12) was estimated through the location with data along the south and by extrapolating along general structure contours of the overlying Rustler Fm.

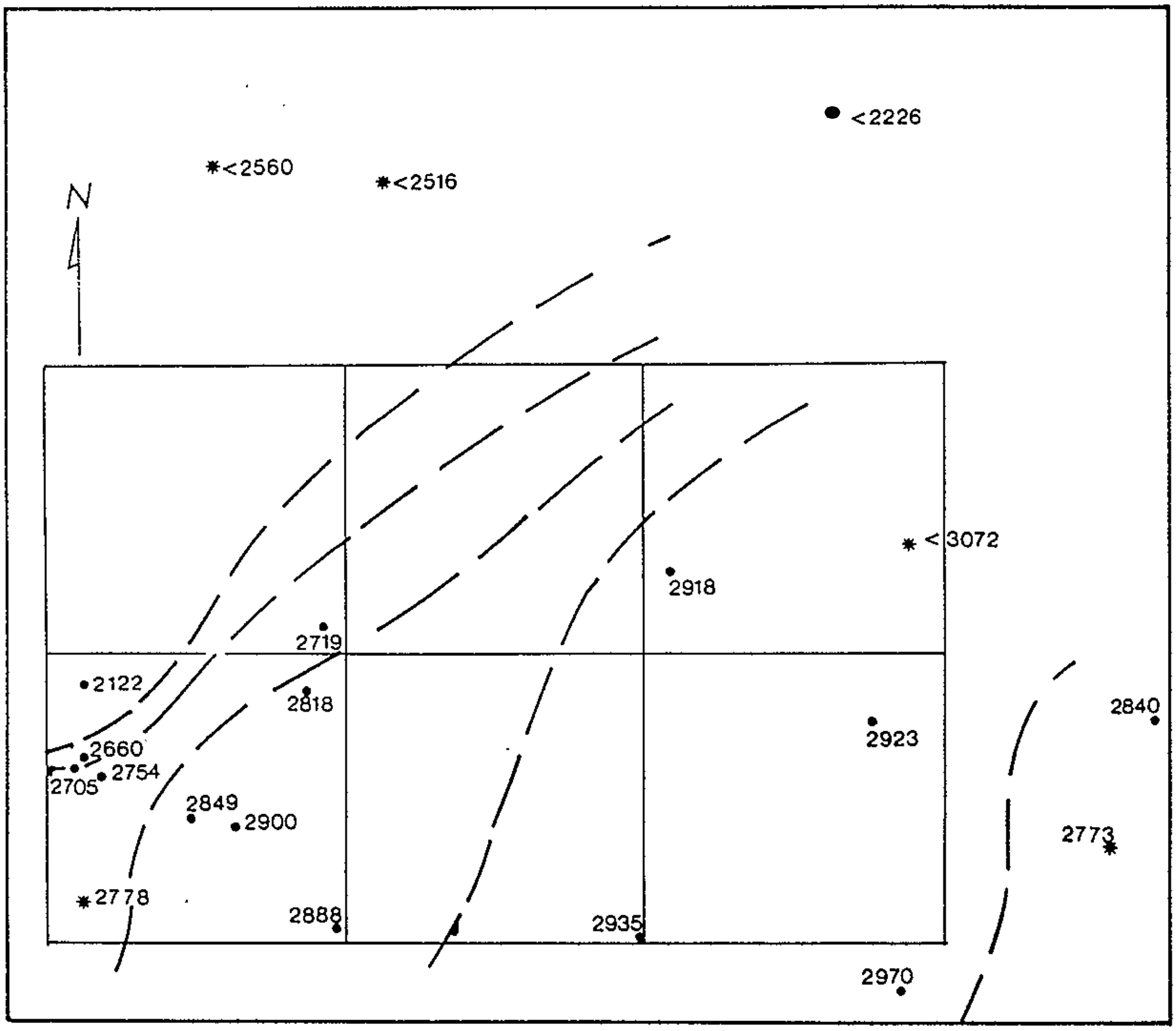
Some hydrological data were obtained from potash and hydrocarbon exploration in the area to add to regional data reported by Geohydrology Associates, Inc. (1978). In section 12 (T.21S., R.28E.), a potash hole log reported water encountered at a depth of

Figure 11
Revised Structure Contours on Top of Rustler Formation, Sand Point Location



Data from Richey (1987) indicated by ✷; reported in Table 4 and shown in Figure 9a. Data from Bureau of Land Management (Roswell office) files indicated by •; basic data are reported in Appendix 2. SP-2 augur hole is indicated by ↘•.

Figure 12
Estimated Elevation Contours, Top of Salado Formation Halite Sand Point Location



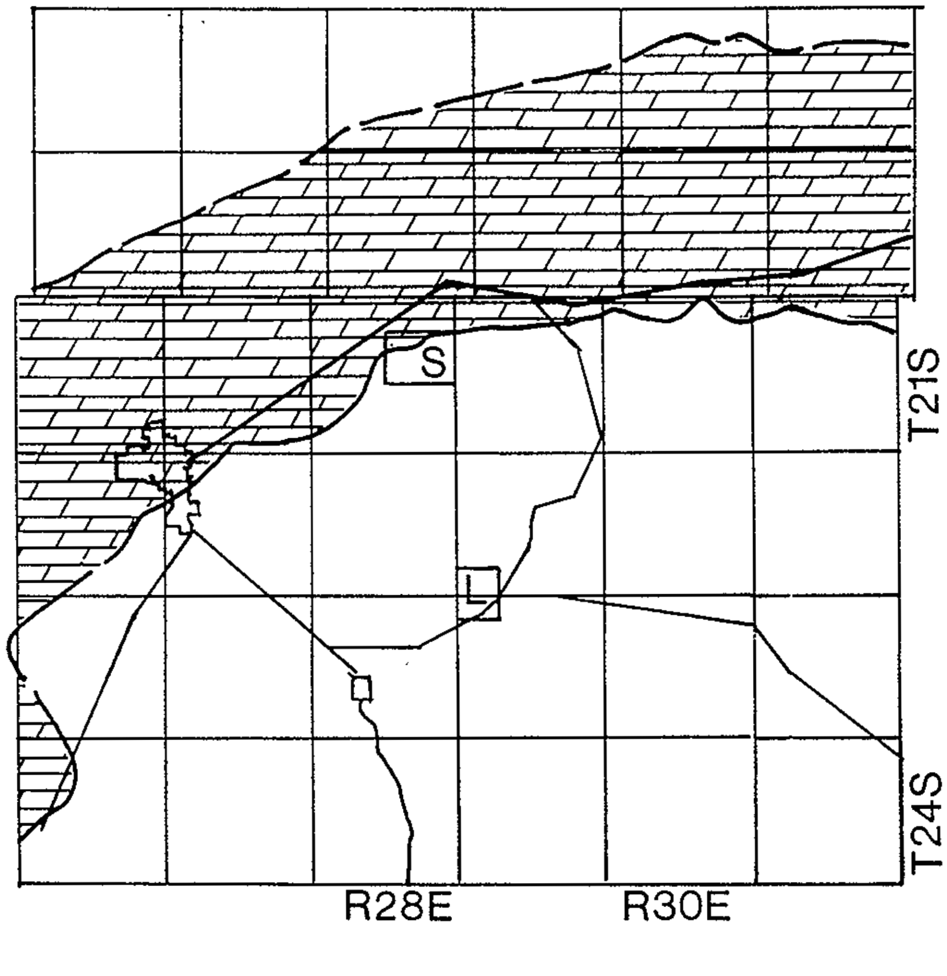
Data from Richey (1987) indicated by ✱; reported in Table 4 and shown in Figure 9a. Data from Bureau of Land Management (Roswell office) files indicated by •; basic data are reported in Appendix 2.

280 ft, within the upper Culebra Dolomite Member of the Rustler Fm or in basal gypsum of the Tamarisk Member. In the southwestern part of the six square mile location, potash drillholes were reported to have encountered water at varying depths, even in adjacent boreholes. The depths and geologic information reported suggest that these intervals may correspond to Culebra Dolomite or unnamed lower member of the Rustler and the interval above Salado halite. It cannot be determined if water-bearing units were undetected during some drilling or if there exists highly variable and isolated fluid-bearing zones in this area. These data have been conservatively (i.e., assuming less favorable conditions) estimated to indicate an unconfined water-bearing unit at an elevation of about 3150 ft through much of the northern part of the location.

The base of data gathered from various sources, as well as field investigations, shows that the northern three sections (10-12) have little direct information from drilling. This is an area where changes in the underlying structure are significant, as interpolated between boreholes in the southern three sections (13-15) and those north of the location. The lack of drilling and apparent lack of underlying resources is advantageous for a landfill, but it also signifies less confidence about the underlying geology.

According to Hiss's maps (1976) the Capitan aquifer could underlie much of section 10 and northern halves of sections 11 and 12 (Figure 13). The map conservatively moves the boundary toward the basin. Given the locations of boreholes with and without Capitan, the Capitan could also be north of all of these sections. Until further information is obtained, the more conservative, more southerly position underlying part of the Sand Point location is assumed correct. The Capitan is not a factor in site selection, as the depth to the Capitan is much greater than other fluid-bearing zones at the location.

Figure 13
Location of Capitan aquifer Relative to Sand Point and Laguna Grande Locations



The Sand Point location is designated by **S**, and the Laguna Grande location is designated by **L**. Representative townships and ranges are given for orientation. Modified from Hiss (1976).

The nearest wells to the west and north show elevations of 2222 ft, 1944 ft, and 1884 ft on top of the Capitan. Even assuming the 2222 ft elevation continued under the Sand Point location would indicate minimum depths to Capitan in excess of 900 ft throughout the location. The eastward dip of the Capitan in the area also is of the order of 100+ ft/mi, indicating the Capitan should be even deeper, if present at all.

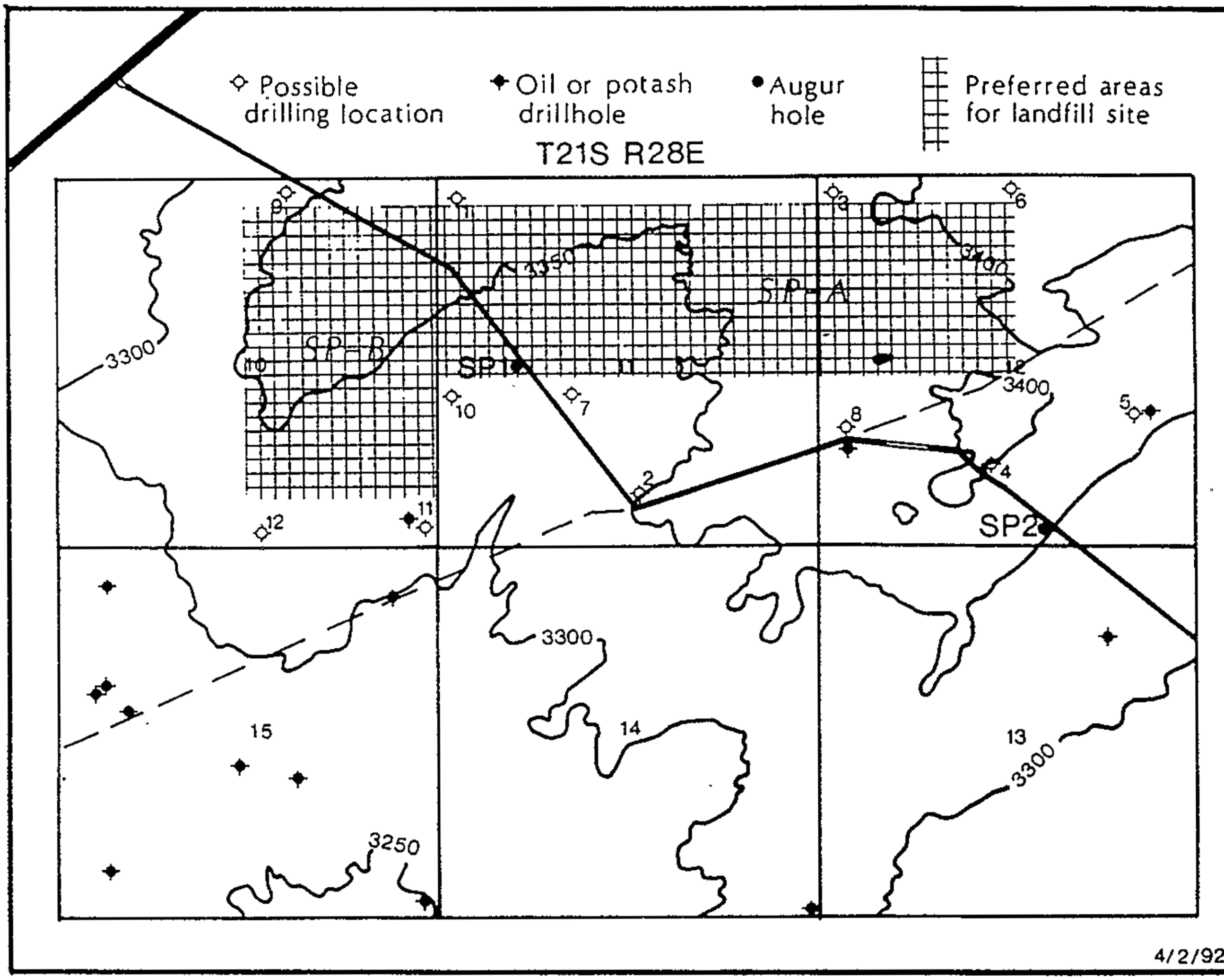
2.1.6.5 Preliminary Site Characterization Plan, Sand Point

A general plan for preliminary site characterization of the Sand Point location was prepared and discussed. That plan, edited for this report, is included here in sections 2.1.6.5.1 through 2.1.6.5.9. As implemented, the drilling plan and methods were revised, especially the order of drilling holes. The numbers and figures originally used have been revised to match identifiers for each borehole as constructed. Section 2.1.6.5.10 describes the significant alterations to the plan and to field operations as actually carried out.

2.1.6.5.1 Preliminary Site Selection

The Sand Point location of 6 square miles included areas not likely to be suitable. The southern row of 3 sections (13-15) were eliminated for further characterization based on probable depth to groundwater and outcrops or nearsurface beds of the Rustler Fm, which may be difficult construction material. Of the remaining 3 sections, the southeastern ¼ to ½ of section 12 and some of the southern areas of section 11 appeared less favorable, though possibly suitable for a landfill. From a geological and hydrological viewpoint, the NW¼ of section 12, north ½ of section 11, and eastern ½ of section 10 appear to be the most favorable areas (Figure 14). The northern parts of sections 11 and 12 was termed SP-A, while the eastern half of section 10 was termed SP-B. SP-A would appear to have modest geological and hydrological advantages over SP-B. Based only on the existing geological and hydrological data, a sequence of 12 drillhole locations was proposed (Figure 14) which would develop data to permit a smaller site to be selected from among the possibilities.

Figure 14
Preferred Site Areas,
Sand Point Location



SP-A and SP-B preferred site areas are based on background geological and hydrological data available prior to preliminary site characterization. Potential drilling locations would provide general information to identify preferred site.

The NW¼ of section 11 was chosen from among the possibilities within SP-A and SP-B for preliminary site characterization based on factors of site visibility, road access and distance, and preliminary concepts of design and construction.

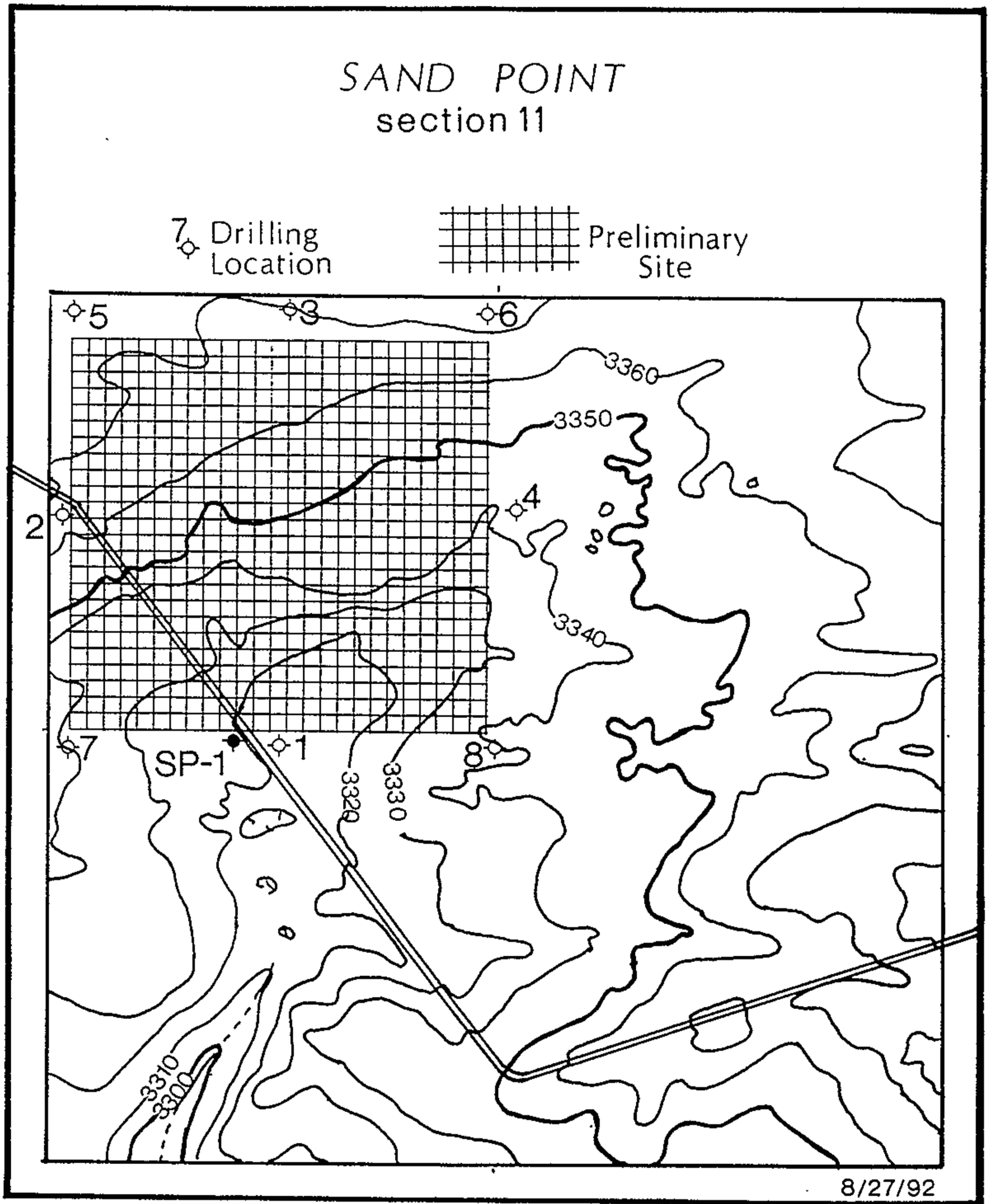
2.1.6.5.2 Introduction

Eight general drilling locations (Fig. 15) and information were examined for maximum flexibility during *preliminary site characterization*. Only a few of the locations (probably 4 or 5) were expected to be drilled, and the principal targets were the uppermost saturated zone and the upper Rustler units. In the unlikely event a drillhole showed no significant evidence of any saturated zones, the drilling was to be continued to the top of halite in the Salado. I estimated probable drilling depths for coreholes and hydrological monitoring for drilling locations based on preliminary selection of the NW¼, section 11, T.21S., R.28E., Eddy County, NM (Table 5). These locations and data modified broader plans and locations (see above) based on the fact that the northern half of sections 11 and 12, as well as the eastern half of section 10, were of generally equal quality from the existing geological and hydrological data. Engineering factors and archeological potential of the area suggest that the NW¼ of section 11 is the preferred initial site for characterization. Other alternatives within sections 10, 11, or 12 can be considered if the NW¼ of 11 proves undesirable.

2.1.6.5.3 Overall Drilling Plan

I anticipate drilling 4 or 5 holes (see details below) for *preliminary site characterization* of the NW¼, section 11. Drilling will be halted immediately if conditions are found to reject the site (e.g., groundwater less than 100 ft below the surface). Locations around the perimeter of the site have been selected and will be cleared for drilling as alternatives if the on-site situation requires it. The expense of idling equipment while clearing alternatives justifies selecting possible alternatives before mobilizing equipment and personnel.

Figure 15
Location Map of Potential Drillholes, Preliminary Site Characterization NW ¼, Section 11, Sand Point



SP-1 shows location of augur hole. Numbered locations are described in Table 5.

Table 5
Potential Drilling Locations and Specifics
(DWP, 5/13/92; revised 8/04/92)

Hole ID (revised)	Location (Approximate)	Surface Elevation	Depth/Target
SP G/H-1	1300' fwl, 2600 fsl	about 3315'	190' to top Rustler* 215' test possible regional water table** 350' to Culebra Dolomite*** 585' + to top of halite
SP G/H-2	1300' fnl, 200' fwl	about 3365'	265' test possible regional water table 390' to top Rustler 550' to Culebra Dolomite 765' to top of halite
SP G/H-3	200' fnl, 1300' fwl	about 3370'	270' test possible regional water table 475' to top Rustler 635' to Culebra Dolomite 770' to top of halite
SP G/H-4	1300' fnl, 2600 fel	about 3342'	245' test possible regional water table 340' to top Rustler 500' to Culebra Dolomite 620' to top of halite
SP G/H-5	200' fnl & fwl	about 3375'	275' test possible regional water table 475' to top Rustler 635' to Culebra Dolomite 825' to top of halite
SP G/H-6	200' fnl, 2600 fwl	about 3372'	275' test possible regional water table 475' to top Rustler 635' to Culebra Dolomite 725' to top of halite
SP G/H-7	200' fwl, 2600 fsl	about 3340'	240' test possible regional water table 260' to top Rustler 420' to Culebra Dolomite 650' + to top of halite
SP G/H-8	2600' fsl & fwl	about 3340'	240' test possible regional water table 210' to top Rustler 370' to Culebra Dolomite 550' to top of halite

* Depths to the Rustler and other stratigraphic units are general estimates based on available information and conservative assumptions. The first drillholes (especially SP G/H-2 & -4) will provide information to modify structural data and revise these initial forecasts for later drillholes.(SP G/H-3 or alternatives).

** If present, regional water table is indicated at about 3150' ± 25'. The drilling depths for testing the possible regional water table are uniformly to a depth corresponding to an elevation of 3100' to assure first testing will include this zone even if there are no indications of fluid.

*** Culebra Dolomite depth is taken as 160' below top of Rustler. This will vary where earlier dissolution or erosion has removed part of the upper Rustler.

The targets for drilling are the groundwater nearest the surface and stratigraphic information of major shallow units. In the unlikely event no saturated zone is encountered in a drillhole, drilling would be stopped when halite at the top of the Salado Formation is encountered. Normal drilling will be to the level of the uppermost water detected or the upper Rustler Formation, whichever is deeper. The main target is a possible groundwater zone at an elevation of about 3150 ft, ranging from about 215 to 275 ft below the surface at drilling locations around the site perimeter (Table 5). Depths for other possible drilling targets have also been estimated and are provided for planning (Table 5).

The locations (Fig. 15) and drilling/testing objectives (Table 5) provide initial and alternative drilling locations to develop a data base on the hydrology and geology around the perimeter of the preliminary site. The data base should support further planning for detailed site characterization and hydrological monitoring when the preliminary characterization is complete and the site remains acceptable.

2.1.6.5.4 Geological Objectives

There are three main geological objectives for this drilling plan:

1) *obtain lithologic and stratigraphic information to confirm or modify extrapolations of structure and extent of units from surrounding boreholes,*
2) *examine geological data for evidence of continuing or recent processes which might be detrimental to a landfill site, such as karst or recent collapse due to dissolution, and,*
3) *obtain an objective sample record of the geology and lithology of the site.*

The initial estimated drilling depths to reach stratigraphic markers (Table 5) are based on data in drillholes around the prospective site. Because the shallow geology has not been directly explored at the prospective site and because the upper Salado has been partially dissolved in the geologic past, these stratigraphic markers can not be precisely predicted. The data and interpretations do not indicate geological conditions are likely to eliminate this site. The first three drillholes should greatly increase accuracy of predictions for the remaining drilling.

2.1.6.5.5 Hydrological Objectives

There are three main hydrological objectives for this drilling plan:

1) *obtain depth to groundwater and water quality data,*
2) *determine preliminary groundwater flow directions, and*
3) *utilize data to establish the appropriate locations for permanent hydrological monitoring wells.*

The hydrological data, like the geology, are both sparse and poorly constrained for the prospective site, though there is no indication that depth to groundwater will be reason to reject the site. As with the geology, the first three boreholes will greatly improve our knowledge of the hydrology of this site. Table 5 provides depth estimates.

2.1.6.5.6 Order of Drilling

The probable order of drilling (locations and numbers in Table 5) at Sand Point is:

SP G/H-1 This is approximately the low point in the topography adjacent to the site; it is expected to be an immediate test for possible stray saturated zones at shallow depths.

SP G/H-2 This location will help define the existence of any regional saturated zone; it will extend out from our data from the better defined geology and hydrology along the southern edge of the Sand Point location. It should also be important in defining downgradient directions.

SP G/H-3 This location is expected to help define the upgradient hydrology and will more fully explore any possibility of a hydrologic divide and the degree to which past subsidence of the Rustler and Dewey Lake Formations may affect local hydrology.

SP G/H-4 This location is similar to 2, and it could be drilled interchangeably with 2 as the second borehole.

SP G/H-5 & 6

May be drilled as alternatives to location 3 or 4 if the evidence from drillholes 1 and 2 warrant more detail than is expected from 3 alone.

2.1.6.5.7 Drilling Requirements

A primary objective is to obtain data about fluid-bearing zones, including zones which may yield little fluid. As a consequence, the boreholes should be drilled as much as possible without water.

In the unlikely event that no fluid is observed in any of the possible fluid-bearing zones under this site, drilling will not proceed further than the highest intercepted halitic units. Depths to Salado halite have been estimated for each drilling location for this contingency.

To obtain an objective record of strata and samples for testing, each of the locations for this phase should be cored to the extent possible. Cores should be 1.5-2 inches in diameter or greater for best information. In the event of conflict between hydrologic and geologic objectives and drilling requirements, hydrologic data will generally have priority. The geologist/hydrologist on site will have responsibility for determining the best course of action in consultation with the drillers and on-site JOAB management.

At least one observation period will be required for each borehole. Several observation depths and periods may be required if no fluid is observed in different zones. The initial observation period will be when drilling indicates the presence or reasonable possibility of a saturated zone above 3100 ft elevation or at a depth corresponding to an elevation of about 3100 ft above mean sea level even if there is no indication of a saturated zone. This observation period of the interval above 3100 ft elevation tests the possibility of an unconfined regional saturated zone at an elevation of about 3150 ft at the site as indicated in work by Geohydrology Associates, Inc. for the Bureau of Land Management (Geohydrology Associates, Inc., 1978, 1979). The observation period will be at least one hour, and the hole will be tested for fluid with an electrical water depth tester.

Similar observation periods will be undertaken at other possible fluid-bearing zones at the direction of the on-site geologist/hydrologist. If no fluid is detected, additional observations will at least be made at the Culebra Dolomite and when halite is encountered, in addition to the 3100 ft elevation observation. Further details of observation periods and tests may be provided by Daniel B. Stephens and Associates.

Each borehole should be prepared as a piezometer hole, with PVC placed to permit ready access for sampling and measuring recovery of fluid head. Sand packs and grouting may be required to obtain most satisfactory information. Where consistent with other test objectives, the tubing should have an inside diameter of about 1.5 inches or greater to permit obtaining natural gamma logs from the USGS. Neutron and other logs require diameters approaching 2 inches. The geophysical logs are not necessary, but may be an option for the future, as USGS Water Resources Division personnel are committed at this time to other projects.

2.1.6.5.8 Sampling Requirements

Fluid samples will be obtained, where possible, for initial specific conductance measurements. There will be limited or no bailing of the hole, as the principal data will be recovered head elevation. Water temperature will be measured in the field from the recovered sample. Immediate field measurement of specific gravity is optional.

Fluid samples should be placed in Nalgene bottles or equivalent. Each bottle will require a unique sample number and be marked with the following data at a minimum:

sample number (SP G/H-#-H#) (1st # is hole number; 2nd # is hydro sample #)

date, time

depth

name of sample collector

other (temperature, specific gravity)

Coring will be continuous, if possible, from the surface. If samples are friable or poorly lithified, representative samples will be bagged and identified for appropriate intervals, generally about 2 ft. Core will generally be marked and described while it remains in the opened split core barrel. It may be photographed in the core barrel or in the core box. Where the core is adequately lithified, it may be laid out in approximately 5 ft intervals in wooden troughs for marking and photography before being boxed. Such core will be marked with permanent marker with arrows <u>pointing downward</u>, in the direction the hole is advancing. Cores will be photographed, in approximately 5 ft intervals or by the box (generally 10 ft sections), in color under natural light. Each photograph will include: scale, drillhole identifier, depths, date, and a color scale.

Core will be described as soon after being obtained as possible. Onsite descriptions will include basic lithology, color (using standard color chart), thickness of units (depths), observable primary and secondary features, observable cementation, degree of lithification, and any other miscellaneous observations. The onsite geologist will maintain a record of samples selected for any further testing. A letter or other form indicating chain of custody should accompany such samples.

Core will be preserved in boxes which have clear and complete data including borehole identifier and depth interval. Core should be placed with the highest part to the upper left and deepest segment to the lower right part of the box. Boxes will be taped with reinforced tape before being transported. Core will be placed in a reasonably secure facility, with limited access and protected from the elements, and stacked a maximum of 10 boxes high.

Where appropriate, cores should be sampled to analyze saturated hydraulic conductivity and moisture content. Samples for chloride mass balances will be collected pending the results of initial testing. A log of these samples will be maintained onsite as indicated above. Sampling and testing requirements and protocols for hydraulic conductivity, moisture content, and chloride mass balances will be provided as necessary by Daniel B. Stephens and Associates.

2.1.6.5.9 On-Site Responsibility

On-site decisions regarding testing or variations from the general drilling, coring and testing plan will be the responsibility of the on-site manager for JOAB, Inc. (Marvin Magee). Marvin Magee will designate the onsite geologist or hydrologist making decisions in his absence. Major variations will normally be decided by on-site personnel in consultation with various parties responsible for scientific data (Powers, Stephens and Associates, Turnbough), management (Magee for JOAB), or drilling contractor.

2.1.6.5.10 Modifications to Preliminary Site Characterization Plan

As preliminary site characterization was conducted, some planned activities were modified to reflect the on-site and drilling conditions. The major modifications are described here.

Drilling proved difficult through some zones. Some units did not core well or were not very stable in the borehole. Foaming agents and water were necessary for drilling in these zones, though their use was minimized as possible. Core recovery was somewhat irregular, reducing the sampling for possible laboratory tests. Core commonly could not be marked with marking pens with arrows as planned. Small wooden blocks were marked and placed at the top and bottom of core intervals and where samples were removed.

2.2 Preliminary Site Characterization of Sand Point

The preliminary site characterization consists principally of drilling five boreholes at four locations around the perimeter of the NW¼ of section 11. The holes were drilled to obtain geological data and to determine the presence and level of ground water at the site. The boreholes were drilled in general accordance with the plan presented in section 2.1.6.5, with program modifications noted in that section. Borehole drilling and completion histories, and details of the geology and hydrology, are presented in several appendices while the broader information and interpretation is presented in this section.

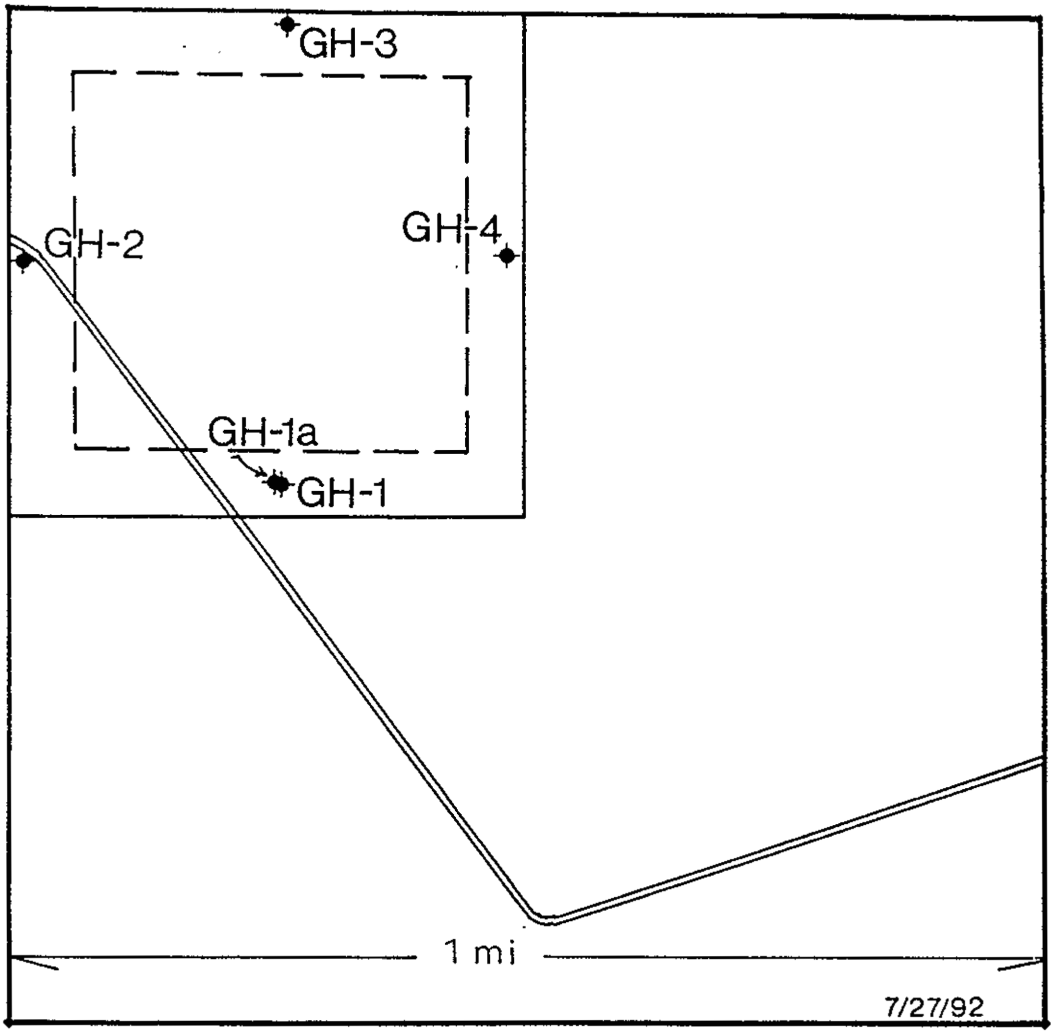
2.2.1 Sand Point Drilling

Four locations (Figure 16) were chosen for initial drilling from among eight proposed locations around the NW¼ of section 11. These locations, near the midpoints along the side boundaries of the quarter section, to provide probable upgradient and downgradient testing of the ground water level as well as to test general concepts of stratigraphy and structure at the proposed site. Details of borehole histories and basic drilling data are presented in Appendix 3.

The four locations (SP G/H-1 through 4) were drilled in order: G/H-1 along the center of the south line, G/H-2 along the center of the west line, G/H-3 along the center of the north line, and G/H-4 along the center of the east line. Initial

Figure 16
General Location Map of Drillholes for Preliminary Site Characterization Sand Point Location

Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology well completed.

Dennis W. Powers, Ph.D.
Consulting Geologist
12/28/92

drilling of G/H-1 did not clearly establish the presence of ground water due to difficult drilling conditions through the interval which later proved to yield water. G/H-1A was drilled about 12 ft from the G/H-1 location after G/H-4 was completed. G/H-1A was rotary drilled to the zone predicted based on ground water levels in G/H-2, -3, and -4.

Most of the drilling used a coring bit about 5 inches in diameter with a wireline core barrel inside. For intervals with poor stability, some rotary drilling with a tricone bit about 5 inches in diameter was necessary. For further stability, some of the holes were reamed with a 7 7/8 inch tricone bit; temporary casing 5½ inches in diameter was used as well in some holes. The casing permitted coring and drilling inside it while maintaining stability. Some water and foaming agent were necessary for lubrication while drilling some intervals.

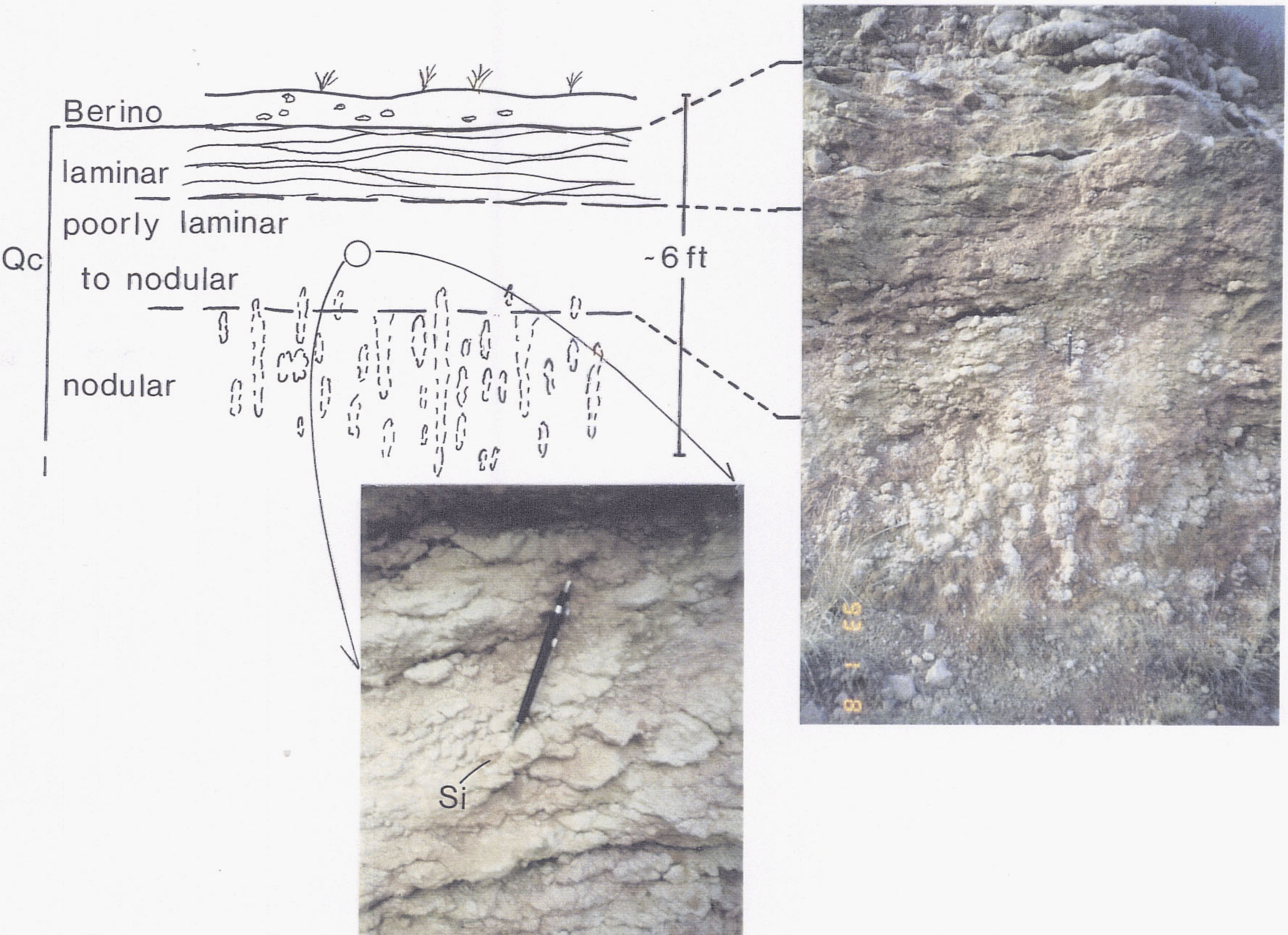
Core recovery ranged from excellent to no recovery for some drilling intervals. For drillholes G/H-1 through G/H-4, respectively, the recovery was 59%, 57%, 40%, and 60% (see Appendix 3). G/H-1A was not cored. For the first four holes, the total drilled interval was 1193 ft. Coring was attempted through 860 ft, about 72% of the total drilling for these four holes. About 487 ft of core were recovered, representing about 54.5% recovery over the 860 ft through which coring was attempted. Some intervals of sand, as well as deeper intervals, proved impractical to attempt to core.

The core was photographed, sampled as necessary, and stored in core boxes after being described. Color prints of the core photographs are available for reference.

2.2.2 Sand Point Geology

2.2.2.1 General Information

Drilling at Sand Point encountered three geologic units known from this area (Table 6). Each of the four locations showed the informal unit called the Mescalero caliche


Berino
laminar
poorly laminar
to nodular
Qc
nodular
~6 ft
Si

at the surface or immediately underlying surficial soil and/or eolian sand. Each of the drillholes showed a considerable thickness of the Plio(?)-Pleistocene Gatuña Formation below the Mescalero. The Gatuña ranged in thickness from a minimum of about 208 ft in G/H-1 to about 280 ft each in G/H-2 and G/H-3. The Gatuña is at least 220 ft thick in G/H-4, but the basal contact was apparently not encountered at total depth of 230 ft. The first three boreholes showed Permian Dewey Lake Formation below the Gatuña. The thickness of Dewey lake drilled was about 155 ft, 10 ft, and 5 ft, respectively, in G/H-1, G/H-2, and G/H-3. The deepest drilling, at 368 ft in G/H-1, was still in the Dewey Lake Formation.

Table 6
Stratigraphic Units and Thickness*
Sand Point Drillholes

Stratigraphic Unit	*SP G/H-1A*	*SP G/H-2*	*SP G/H-3*	*SP G/H-4*
Mescalero caliche	1' +	4'	9'	5'
Gatuña Formation	196' +	281'	283'	220' +
Dewey Lake Formation	155' +	10' +	3' +	not intercepted

* Thicknesses are minimum demonstrated by coring and cuttings. Some surfical intervals did not return sufficient sample to determine Mescalero caliche thicknesses. Drilling did not completely penetrate Dewey Lake or Gatuña in some boreholes.

2.2.2.2 Surficial Deposits

Surficial sand of eolian origin overlies the caliche at locations for G/H-1, -2, and -4. A very thin veneer of dark brown soil overlies caliche at G/H-3. Because of pad construction and poor sampling, these suficial soils were not described. The middle of the quarter section clearly displays stabilized to unvegetated eolian dune sand which is apparently quite thick, perhaps more than 10 ft.

2.2.2.3 Mescalero caliche

The Mescalero caliche is best developed on the higher, flatter surface along the northern and northwestern parts of the quarter section. G/H-3, located on this surface, proved hardest to drill. Sampling was poor, at best, through this unit in all holes. Surface exposures at G/H-3 showed a compact petrocalcic or K horizon in Stage III to IV (in the sense of Giles and others, 1981) or in Stage VI (in the sense of Machette, 1985). Here the fabrics are very dense, well indurated, and show carbonate brecciation and recementation. The caliche has apparently been under some brecciation and forms cobble-sized packed fragments. It is not clear from modest examination whether the caliche is currently being recemented or is still in the process of brecciation. At the other three locations, the caliche clearly has been degraded and ranges from clasts and moderate cementing to softer calcareous matrix with harder nodules or clasts. These were poorly sampled during drilling. The Mescalero more nearly corresponds in these three locations to stages II and III (Machette, 1985), as no calcareous laminae were detected to cap the K horizon.

2.2.2.4 Gatuña Formation (Plio?-Pleistocene)

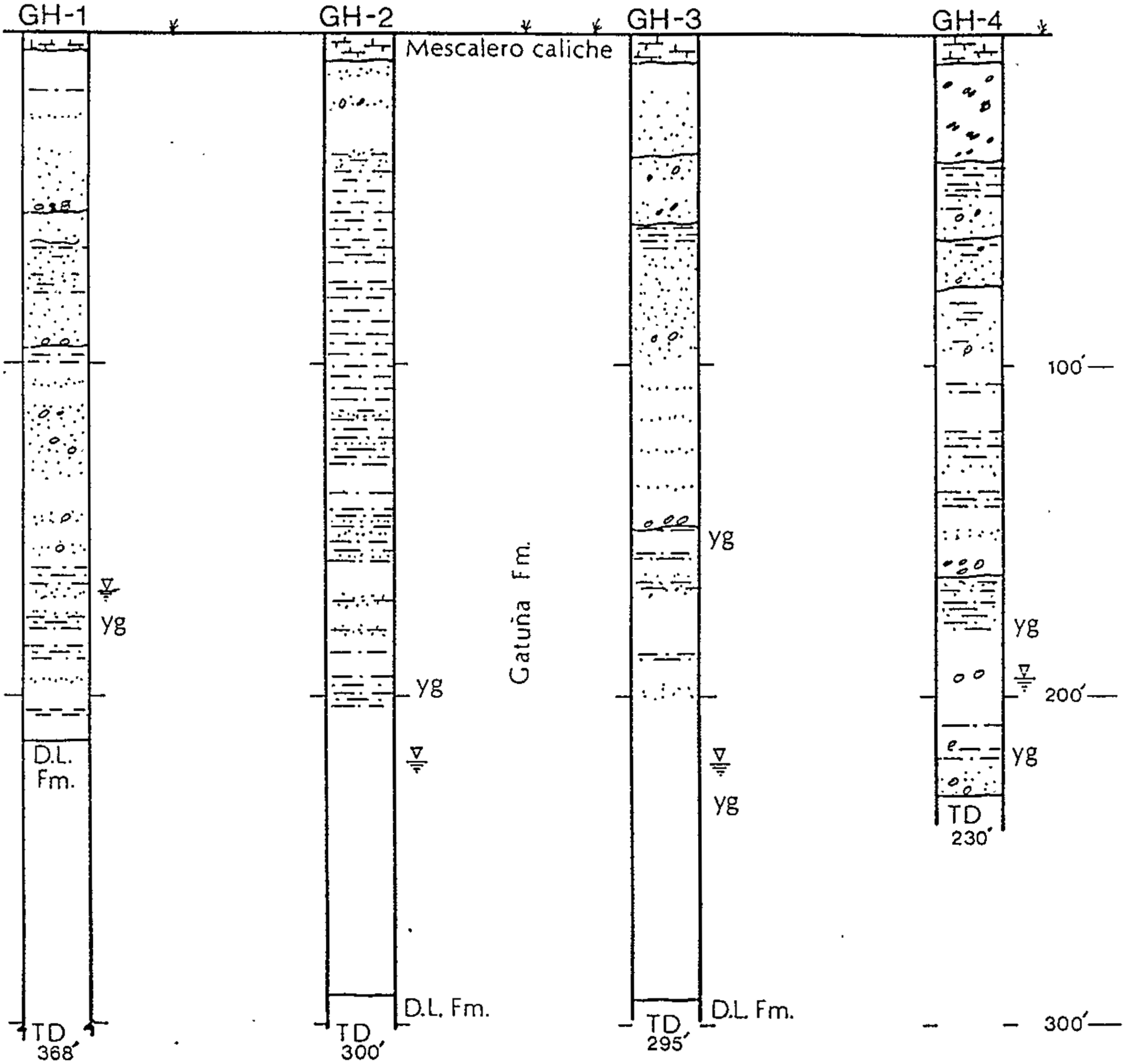
Detailed lithological sequences and sedimentary structures of the Gatuña Fm. are presented in Appendix 4. An overview of the unit is presented here with discussion of some particulars.

The Gatuña Fm (Figure 17) at Sand Point, as found in the cores from the four drillholes, is similar in lithology and depositional environments to most of the Gatuña outcrops from Clayton Basin (T.20S., R.30E.) to Pierce Canyon (T.24S., R.29 and 30E.) in southeastern New Mexico. The cored thickness is greater than that exposed in individual outcrops except at the head (eastern) of Pierce Canyon. Further south, and somewhat to the west as well, the Gatuña is thicker and commonly includes gypsum and gypsiferous beds which are not represented at Sand Point. I have intensively studied the Gatuña outcrops over much of this area for a project in progress on the hydrogeology of the Rustler Formation for the Waste Isolation Pilot Plant; Gatuña descriptions and interpretations from that report being drafted are considered in the comments about the Gatuña.

A common sedimentary sequence in the Gatuña is a fining upward cycle. The base of the cycle is coarser sediment (may include pebbles) overlies a sharp contact which may have some relief in outcrop. The coarser sand may be one or more ft in thickness with some evidence of bedding. It is overlain by finer-grained siltstones, sandy siltstones, and/or silty claystones which commonly are thinly bedded to laminar. Clay content and finer-grained beds can increase upward. Some of these fining upward cycles are topped by siltstone/claystone with few or no sedimentary structures but having evidence of bioturbation (especially root casts), black staining (Mn?), and possible ped structures and clay illuviation. These fining upward cycles were deposited in fluvial environments and floodplains with some soil development on the floodplain.

The basic fining upward cycle has variations depending on the environmental circumstances. Channel areas may develop thicker coarse deposits, while areas more distal from the channel may develop thicker fine-grained interbedded deposits. Soil development will depend on the length of exposure time before additional sediment is added.

Figure 17
General Geology and Stratigraphy
Drillholes for Preliminary Site Characterization
Sand Point Location
Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology drillhole. Graphic log is shown relative to depth. Symbols: yg = yellowish green siltstones, D.L. Fm. = Dewey Lake Fm., T.D. = total depth. Groundwater symbol ( ) is at approximate depth. Lithologic symbols are standard; they are not shown where core not recovered.

In different locations, the Gatuña displays thick (up to 6 or 8 ft thick) conglomerates of pebble to cobble size. In the type area in Clayton Basin, the upper Gatuña shows beds with foresets at acute angles to the basal contact implying braided stream deposits. To the south, in eastern Pierce Canyon, conglomerates are more tabular and appear to have deposited on a wider, flatter plain. A deeper channel-filling conglomerate also crops out in the western part of Pierce Canyon. Gravelly to pebbly beds at Sand Point appear to be dominated by sand with a small portion of coarser clasts. These deposits do not apparently form framework supported thick units at Sand Point. High-energy environments were apparently limited at Sand Point.

The upper part of the Gatuña in the type section and elsewhere commonly is formed by deposits of mainly sandstone with the following features: disseminated (matrix-supported) clasts of coarser grains (mainly granule to pebble) in some beds, few or no sedimentary structures, bioturbation (mainly root casts), general calcareous cement, black staining (?Mn) on bioturbation and fractures, probable ped structures at the top of some beds, and color that tends to be brown with lesser reddish hues than the rest of the Gatuña. This unit shows definite signs of pedogenic development, and the matrix-supported clasts suggest these deposits may also have partly originated as small mud flow or debris flow deposits on local slopes.

The first three drillholes (G/H-1, -2, and -3) included zones of poorly indurated or unindurated sand, especially in the interval above the Dewey Lake. Returns to the surface, as well as limited material in the core barrel, commonly showed moderately well sorted and well rounded sand. The sand from G/H-1 was slightly coarse and more "orange" in color than was most of the sand from G/H-2 and G/H-3. These "orange sands" are quite similar to sands which crop out in some exposures of the Gatuña, especially at Remuda Basin, to the southeast of Sand Point several miles. In those outcrops, and here at Sand Point, these sands are interpreted to have formed as probable eolian sand or eolian sand reworked by fluvial environments.

The Sand Point cores each included sections of distinctive yellowish to greenish-gray laminar to thin-bedded claystone or silty claystone interbedded with very thin beds or laminae of siltstone or fine-grained sandstone. These distinctive sections are in the lower part of each core but occur at different depths and positions above the base of the unit. G/H-3 appears to have two such sections based on cores and deeper cuttings returned. G/H-4 shows two zones more closely spaced near the bottom of the drillhole. These deposits are interpreted to have formed on the floodplain, probably in somewhat lower locations which may have remained flooded longer and were somewhat reducing environments rather than oxidizing, as in the reddish-brown deposits and paleosol sections. A similar interval occurs in the type section in Gatuña Canyon near the base of exposures. These distinctive rocks are not interpreted as lacustrine deposits because: 1) they do not appear to show continuity or even close stratigraphic equivalence and 2) the interbedding and rare hints of rippling and crosscutting suggest more common floodplain environments.

Each of the four drillholes cored through Gatuña has a generally distinct overall sequence reflecting the fact that the Gatuña was deposited in a fluvial-dominated environment with considerable lateral as well as vertical changes. The westernmost drillhole (G/H-2) includes a thick section of interbedded siltstones in the upper 200 ft. G/H-3 included more sand and a few thin pebbly units. Both G/H-1 and G/H-4 show several zones of pebbly sandstones, but G/H-4 shows a thicker unit near the top of the core. There is no evident correlation from one location to another of specific units. The most consistent lithologies or parts of the Gatuña are: 1) poorly indurated to unlithified sand in G/H-1, -2, and -3 in the section just above the Dewey Lake Fm and 2) the "McDonald Ranch member" just below the Mescalero caliche in G/H-2 and -3. It isn't known if G/H-4 reached the broadly equivalent section of loose sand just above the Dewey Lake.

The Gatuña is thicker at Sand Point than at most outcrops and drillholes in the area, though the Gatuña is even thicker further south. The Gatuña lithologies at Sand Point are like the Gatuña elsewhere, though sequences differ from each other as a consequence of variable depositional environments.

2.2.2.5 Dewey Lake Formation (Permian)

The Dewey Lake Formation was partially drilled in each of the first three boreholes (G/H-1, -2, and -3). The Dewey Lake was observed only through cuttings in G/H-1 and -3; about 9.7 ft of core from the top of the Dewey Lake were recovered from G/H-2. Cuttings and core are typical lithologies for the Dewey Lake as observed elsewhere in outcrops and underground (e.g., description of lithology on air intake shaft walls at Waste Isolation Pilot Plant; Holt and Powers, 1991). The Dewey lake is dominated by fine grained sandstone and siltstone in thinly bedded units with thin bedding and cross-bedding. The Dewey Lake is a rather uniform reddish brown (2.5YR4/4; Munsell Soil Color Chart, 1971 ed.) with hues and color value somewhat more intense than the Gatuña. Another distinctive character of the Dewey Lake is the common grayish (5Y7/3, pale yellow; Munsell Soil Color Chart, 1971 ed.) "reduction spots" of varying size; even cuttings commonly are distinctive reddish brown siltstone/sandstone with grayish spots.

The Dewey Lake generally decreases thickness from east to west across the northern Delaware Basin. Different episodes of erosion, beginning during the early Triassic, have affected the Dewey Lake. Sand Point and Quahada Ridge provide some of the more westerly outcrops of the Dewey Lake. Based on preliminary field auguring, background data available, and regional trends, the thickness of Dewey Lake (as well as Gatuña) was anticipated to be somewhat less than has been found through drilling. The Dewey

Lake is at least 155 ft thick at G/H-1; drilling at G/H-2 and -3 was discontinued after reaching depths of less than about 10 ft in the uppermost Dewey Lake. The known thickness of Dewey Lake here is still only a fraction of the full section (> 600 ft) known to exist in the eastern Delaware Basin.

Core from G/H-2 shows Dewey Lake bedding inclined about 15 to 20° from the axis of the drillhole. some portions of Gatuña core showed modest inclination, but most is near horizontal.

2.2.2.6 Discussion of Geological Features

The thicknesses of Gatuña and Dewey Lake encountered in the drillholes are significant features of the Sand Point location and require further inferences about structure and geological history of the site area.

The thicknesses differ from those estimated from background data as a guide to drilling. To the south and southeast, the Dewey Lake and Gatuña are much thinner, and the Rustler is closer to the surface. In section 12, the supra-Rustler deposits are about 100 ft thick. To the north, the Rustler has been affected by solution of Salado halite as well as by solution of sulfates within the Rustler. The site area was a relatively unknown location between these areas.

The thickness of Gatuña and Dewey Lake under the site area indicates the Rustler Fm is structurally displaced downward more than was expected before drilling. The estimated drilling depths to Rustler (Table 5) was interpolated based on thinner overlying units and a more gradual estimated change in the structure than apparently exists. It appears that the inclination of the Rustler in the southern half of secton 11 (south of the site) and to the southeast and east is more abrupt than expected. The topography of the southeastern quarter of section 11 may partly reflect the deeper structure. The dipping Dewey Lake bedding in G/H-2 is generally consistent with the structural changes in the site area but is unlikely to be representative of the entire area. Some areas may show less and others greater dip.

Thicker Dewey Lake preserved under the site area indicates that the Dewey Lake was lowered prior to some stages of erosion in the area. It was apparently lowered mostly prior to deposition of the Gatuña, in view of the Gatuña, because the Gatuña displays basically flat-lying bedding. Thicker Gatuña also implies that the locale was either lower throughout the period of deposition or was being lowered some during deposition. Even the easternmost borehole (G/H-4) shows few, if any, lithologies or structures likely to indicate the site or location was being lowered during deposition. The lowermost pebbly zone and uppermost coarse clastics might indicate some syndepositional changes or normal depositional environment variations. In contrast, Gatuña lithologies at the eastern end of Pierce Canyon (study in progress) clearly show thick units of cross-cutting and matrix-supported clasts in dipping units deposited during a time when some of the area was also subsiding, most probably in response to dissolution of underlying salt beds. The Sand Point lithologies do not show features similar in scale and lithology.

The Mescalero caliche differs in thickness and induration over the site. It is well preserved in the northwestern and northern part of the site. The rest of the site shows caliche with less development of diagnostic horizons or with diagnostic horizons being destroyed by slope and climate changes. The geomorphology of the site, with a narrow channel cutting through a ridge to the south of the site. This channel drains runoff from the site area, though drainage is very poorly developed over the site. This small channel appears to have cut down through the ridge. Caliche also drapes some of the slopes south and east of the site, indicating it developed relatively well over a broader area. The southern part of the site, then, is being eroded somewhat, and this is disturbing the caliche and preventing further formation.

There are two somewhat different explanations of the present condition of the caliche and geomorphic expression in the southern part of section 11 and part of the site. Simple erosion by the drainage system could explain the general geomorphology of the southern part of the site. Caliche draping the slopes along the south and southeastern part of section 11, however, suggests that that area subsided modestly during the last 500,000 years. The drainage channel cut down through the small southern ridge as the area just to the north was let down slightly. This preserved elements of the caliche but subjected it to erosion/solution during part of the period it would normally have formed.

The changes at the site are mainly attributed to pre-Gatuña subsidence due to dissolution of some of the salt in the upper Salado Formation. A thicker Dewey Lake was preserved, and space was provided for a thicker Gatuña deposit. Some post-Gatuña, and possibly post-Mescalero caliche, further subsidence may have contributed to the present geomorphology. Erosion processes in recent geologic time does not appear to be very effective in the site area, as dune sand, both unstabilized and vegetated, has accumulated and is not being carried out of the site area. Good infiltration and evapotranspiration, as well as limited rainfall and runoff area, limit immediate potential for erosion of the site area. The prospect of further subsidence due to dissolution of salt like that which has apparently occurred at the site area is slight over the near-geological future. If subsidence occurred, it would further lower the landfill topography and decrease the potential for erosion.

2.2.3 Sand Point Hydrology

2.2.3.1 Summary of Background Hydrology

From regional hydrologeological surveys and from more local information from potash and hydrocarbon exploration, the Culebra Dolomite Member of the Rustler Formation bears water to the south and southeast. The "Lusk east well" is most likely producing from the Culebra. It is possible that the Culebra is confined within a mile of the site.

To the north and west, water-bearing units may include the Gatuña or karst in the Rustler Fm and they are more likely to be unconfined. It was estimated that, if a regionally connected water-bearing unit occurs at the site, it would show a ground water surface at an elevation of about 3150 ft. Under this assumption, borehole locations around the site were estimated to have ground water at depths of 215 to about 275 ft below the ground surface.

2.2.3.2 Summary of Initial Sand Point Hydrology

The first drillhole (G/H-1) was not obviously yielding water during drilling because borehole conditions required that some water and foam be used from about 49 ft depth. It was noted that fluid was present at 170 ft, but it could not be determined at the time if the borehole had intercepted a water-bearing zone or if the water/foam used in drilling was returning to the borehole. Later redrilling (G/H-1A) a few ft away demonstrated this was a producing zone. Cautious testing and observation on G/H-2 was necessary to determine the water-producing zone; G/H-3 and -4 were more easily interpreted as producing water because of experience in earlier drilling.

Each of the four locations drilled around the sides of the site was completed as a piezometer (Figures 18-21) (completion details in Appendix 1) to be used for observation or ground water levels and future sampling. In general, the wells were completed with a short blank tubing to collect sediment below 30 ft of screen placed across the estimated general water level in the borehole. Riser pipe to the surface was capped for protection. A sand pack was placed around the lower pipe and screen to about 10 ft above the top of the screen. Granulated and powdered Wyoming bentonite was put above the sand pack with a thickness of about 20 ft. The borehole was then cemented back to the surface with approximately 14 lb/gal cement with a small amount of bentonite added. The surface was completed with a protective casing cemented in place

Figure 18
As-Built Configuration SP G/H-1A

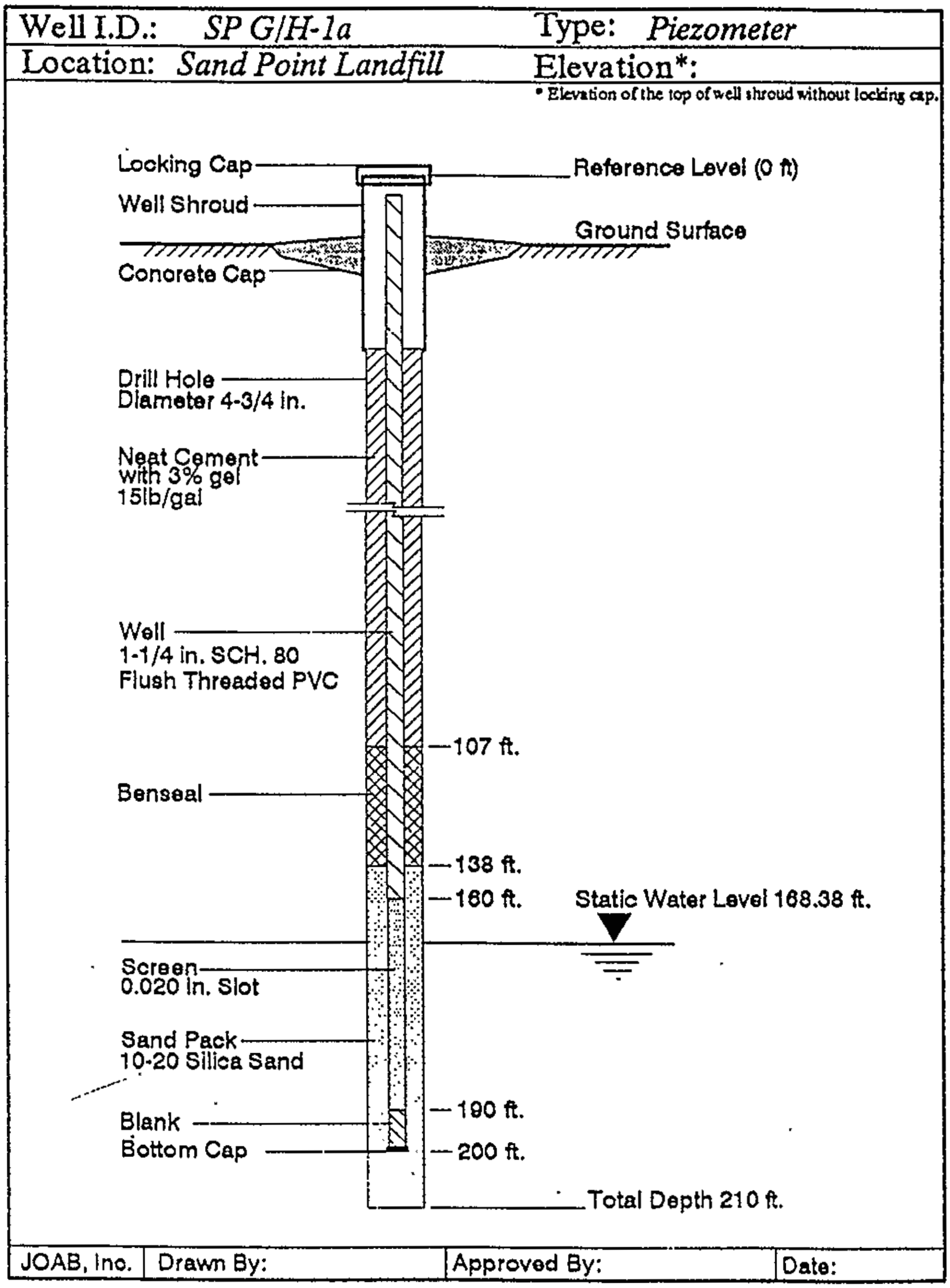


Figure 19
As-Built Configuration SP G/H-2

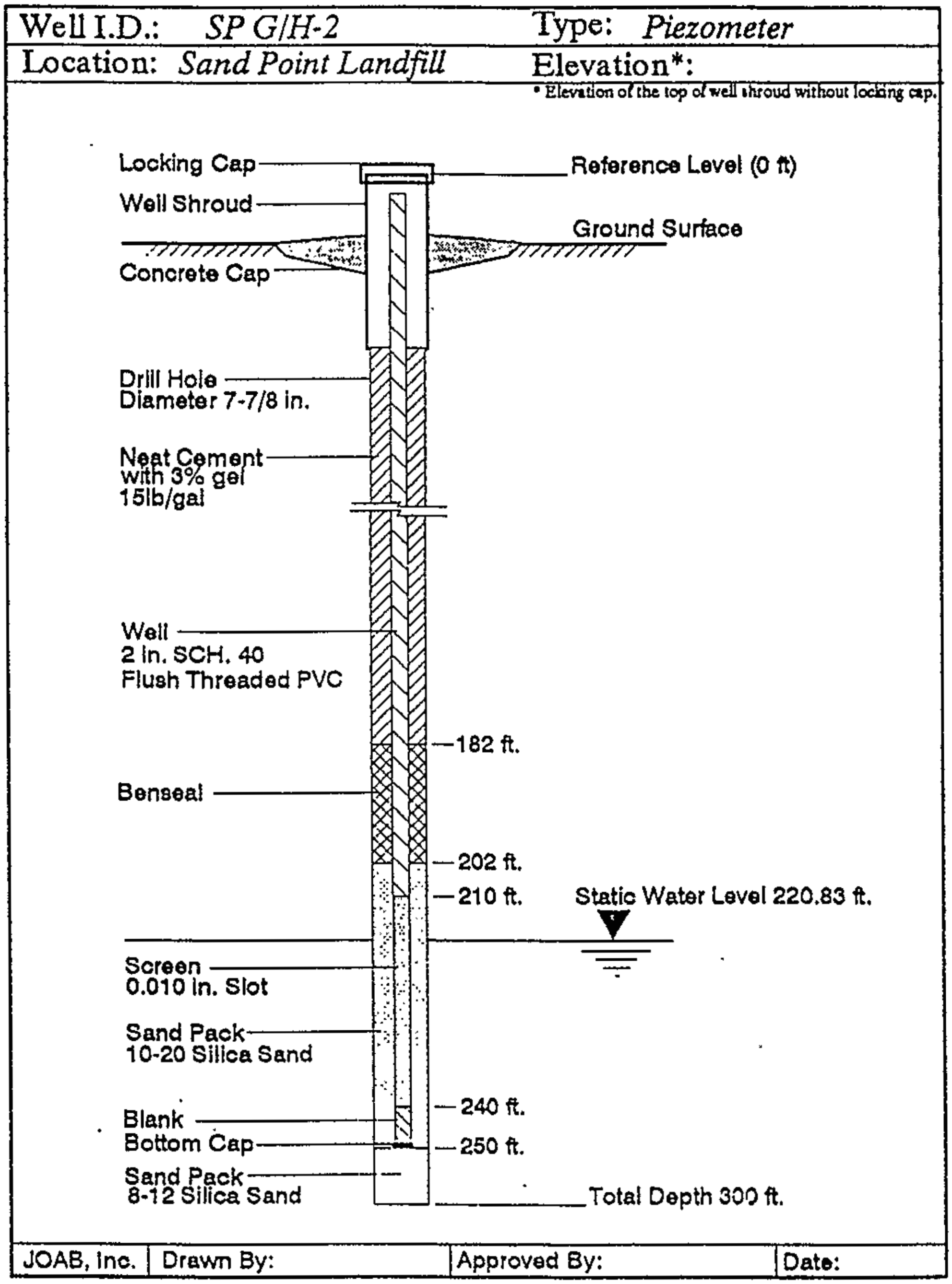


Figure 20
As-Built Configuration SP G/H-3

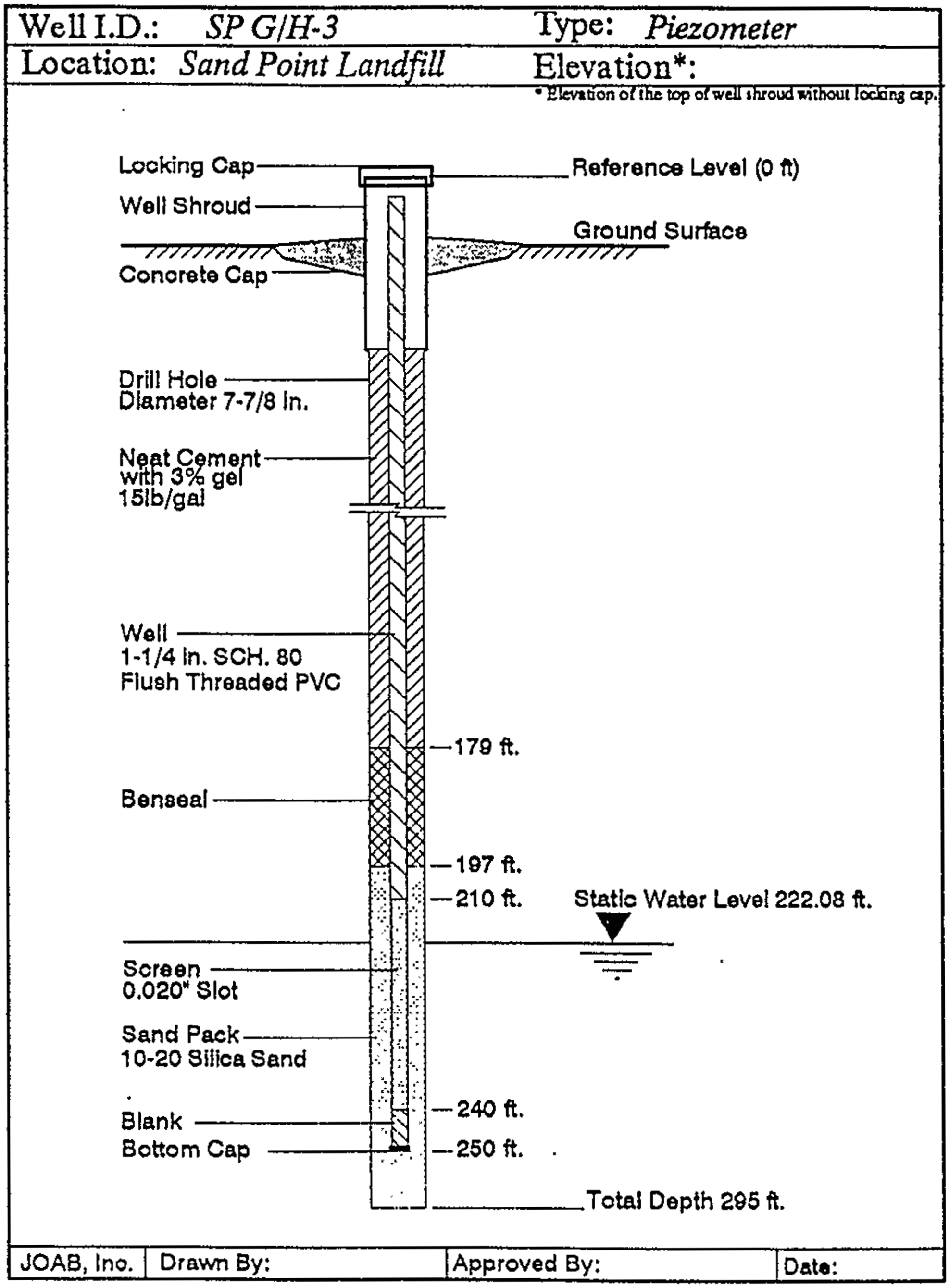
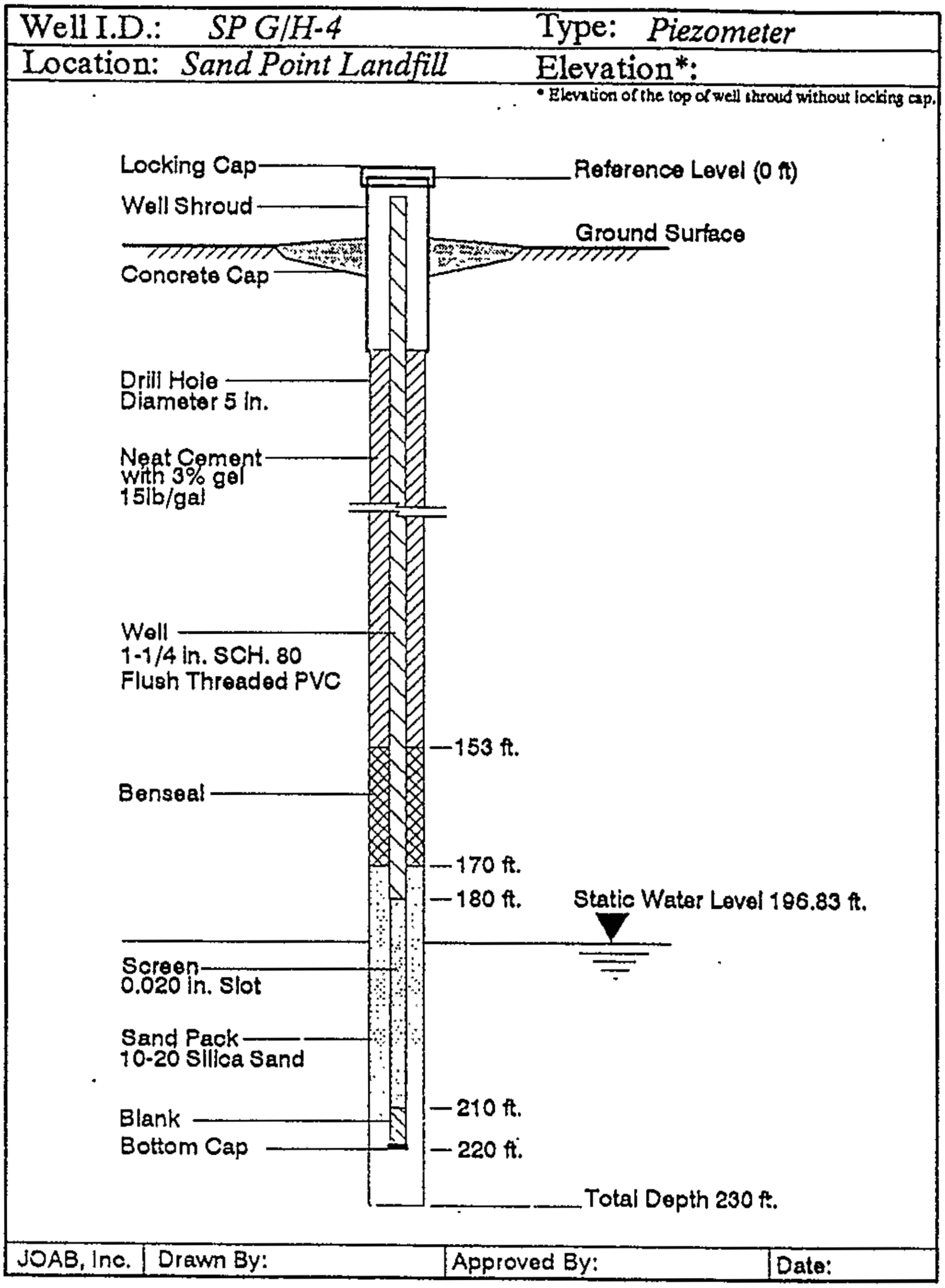


Figure 21
As-Built Configuration SP G/H-4



with a small cement pad to protect the top of the borehole from surface inflow. The protective casing has a cap and padlock for further security. Each borehole protective casing was surveyed as a reference point for measuring water depth.

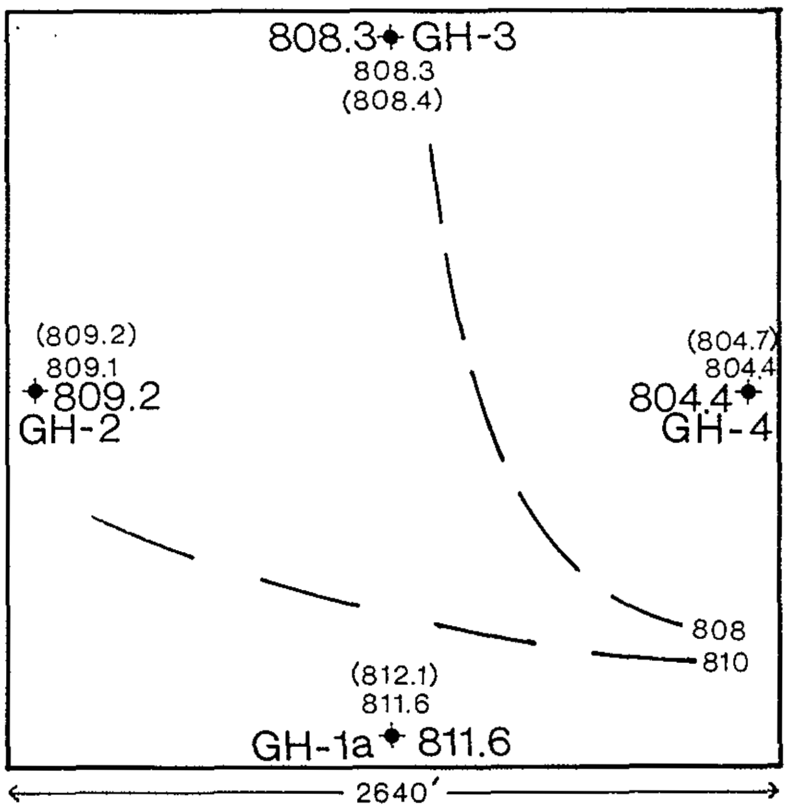
During drilling, modest amounts of water and sediment were bailed from the boreholes. An estimated 50 gal was bailed from G/H-3, more than from other drillholes. Both fluid used for drilling and bailing/production were minimized as possible to provide the minimum disturbance to ground water level.

After each drillhole was completed, water levels were checked irregularly while drilling continued at other locations (Table 7). Each water level was measured July 2, July 22, and August 6, 1992, as a further preliminary baseline because most levels appeared to be changing relatively little (Table 8) (Figure 22). Water levels were measured again from September 9 through October 14, 1992, demonstrating modest changes (Table 9) (Figure 23). The most recent measurements are relative to measured elevations of each well shroud. The observation wells will be remeasured again to establish the lack of changes before any sampling/testing program is undertaken.

2.2.3.3 Discussion of Preliminary Hydrological Data

The data on ground water elevations available at this time indicates that ground water movement would be towards the east and northeast. It is assumed that the ground water in each borehole is interconnected. There is no clear evidence indicating that the ground water in any borehole is confined, though the water level has generally risen modestly above the drilling depth at the time water in the borehole became evident. This effect is attributed to delay in circulation and delay in water entering the drillhole from borehole surface effects. If there is confined ground water, it is most likely to exist in G/H-4, where drilling encountered laminated claystone to siltstone in the lower part of the drillhole, and where water apparently delayed

Figure 22
Location Map of Drillholes for Preliminary Site Characterization and Preliminary Elevations (Arbitrary) of Ground Water, Sand Point Location
Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology well completed. Elevation of groundwater is relative to point of turning (POT) established at center of section and assigned *an arbitrary elevation of 1000.00 ft.* Top of ground water measured July 2 ( ), July 21, and August 6(bold), 1992, by Marvin Magee (JOAB, Inc.).

Table 7
Sand Point Hydrological Data Obtained During Drilling Program

Date	Time	Depth (fluid or hole)	Reference Point	Comment
SP G/H-1				
May 29	0700	180'	drill pipe	Foam/water in bailer
May 30	0700	170'	drill pipe	Possible water
SP G/H-1				
June 1	1345	120'	drill pipe	No fluid detected over 20 minutes
June 1	1545	125'	drill pipe	No fluid detected
June 2	0715	170'	drill pipe	No fluid detected
June 3	1905	245'	drill pipe	Top of fluid level
June 4	0730	224.9'	drilling floor	Sand at 253'. Removed 4 bailers of fluid (about 1 to 2 gallons total)
June 4	after 1330	235'	top of casing	
June 9	0830	222'	top of casing	Sand at 245-250'. Bailed about 1 gallon.
June 10	0715	232.15		Water level
June 11	1000	220.5	top tubing	Measured inside tubing
June 13	0703	220.3	top tubing	Measured inside tubing
June 23	1235	220.5	top tubing	Measured inside tubing
SP G/H-3				
June 12	0705	92'	top drill string	No fluid detected at TD
June 12	0835	97'	top drill string	No fluid detected at TD
June 12	1115	130'	top drill string	No fluid detected at TD
June 13	0705	200'	top drill string	No fluid detected at TD
June 13	1830	230'	top drill string	No fluid detected at TD
June 14	0715	221'	top drill string	Erratic indications of fluid
June 14	1245	292?'	top drill string	Uncertain indications of fluid
June 14	1340	230	top drill string	Possible water level
June 14	1502	234.0	top drill string	Measured water level
	1519	232	top drill string	Measured water level
	1541	230	top drill string	Measured water level
	1600	229.25	top drill string	Measured water level
June 15	0710	222	drilling floor (14.25" below string)	Measured water level
	0820	223	top tubing	Measured water level
June 23	1210	222.25	top well shroud	Measured water level

Table 7, cont.
Sand Point Hydrological Data
Obtained During Drilling Program

Date	Time	Depth (fluid or hole)	Reference Point	Comment
SP G/H-4				
June 17	0700	130'	top drill pipe	No fluid detected
	1145	160	top drill pipe	No fluid detected
	1645	199.7	drilling floor	Final fluid level
June 18	0705	195	drilling floor	Fluid level
	0845	203	top drill pipe	No fluid detected
	1025	228.1	top drill pipe	Measured fluid level
	1240	216.3	top drill pipe	Measured fluid level
	1320	214.5	top drill pipe	Measured fluid level
June 23	0800	193	drilling floor	Measured fluid level
June 24	0800	196.3	top of tubing	Measured fluid level
	1755	196.2	top of tubing	Measured fluid level
SP G/H-1A				
June 24	0700	172		Uncertain signal
	1345	178	top drill pipe	Measured fluid level
June 25	0800	168.7	top of tubing	Measured fluid level

Notes: These measurements are reported as part of the history of drilling. Bailing, drilling, or other activities may have occurred between successive measurements. The borehole histories in Appendix 1 show the range of activities; Appendix 3 includes the measurements of fluid levels during drilling.

entering the borehole. Higher ground water levels to the south, shown by G/H-1A, may be related to more effective recharge at some time along the drainage area in the southern half of section 11. Discharge to the east or northeast, indicated by lower ground water levels at G/H-4, does not clearly relate to ground water elevations further to the southeast. "Lusk east well" appears to have a ground water surface which may be 10 or more ft above the level in G/H-4, pending final survey of elevations at the Sand Point exploratory boreholes. As a consequence, the eastward flow direction may not be accurate far beyond the site. In addition, the boreholes need to be observed long enough to confirm stability for the ground water levels in each borehole, though data through July indicate the levels may have nearly reached a stable level.

From regional information, the ground water surface appears to generally slope southward. This may still be the overall direction of flow, though the site appears more complex. Neither hydraulic properties nor chemical quality have been determined for these observation wells, and gradient and velocity calculations will require knowledge of these properties.

2.2.4 Other Sand Point Characteristics

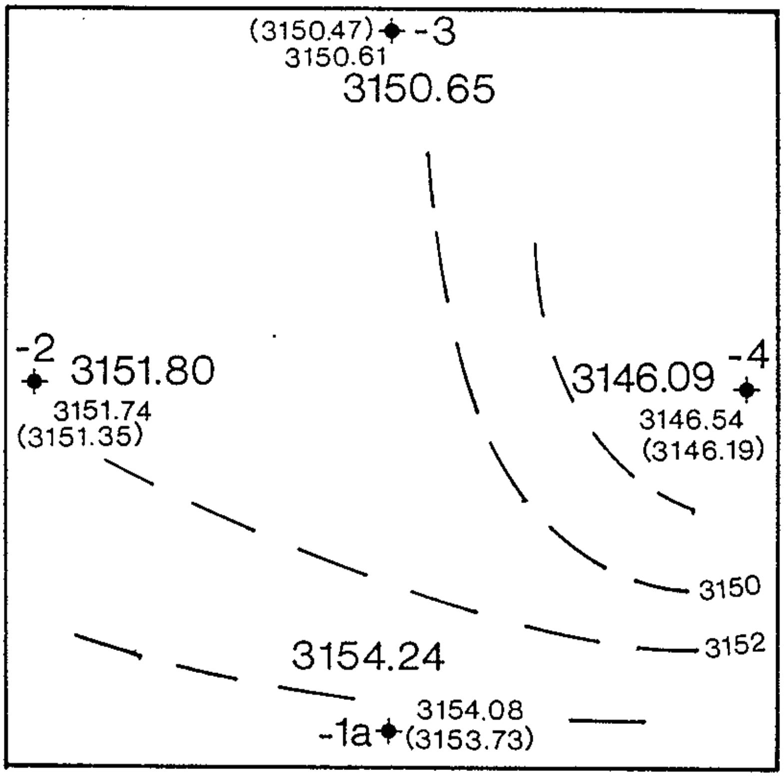
Several other relevant geological conditions or factors for site selection remain as found during checking of background data for the site. There is no evidence of faulting underlying the site or of any alluvial fan. Though salt under the site has evidently been partially dissolved by regional processes, the site shows no karst features.

Table 8
Measured Water Levels* 7/2 - 8/6
Sand Point

Date	*SP G/H-1A*	*SP G/H-2*	*SP G/H-3*	*SP G/H-4*
July 2	812.1	809.2	808.4	804.7
July 21	811.6	809.1	808.3	804.4
August 6	811.6	809.2	808.3	804.4
August 28	811.4	809.1	808.3	804.2

* Measured water levels are given a reference elevation which is relative to a point of turning (POT) established at the center of section 11. The POT has been given an arbitrary elevation 1000.00 ft until it is surveyed relative to another established benchmark. Gradients should remain unchanged pending confirmation of surveys of the reference point on each well shroud. Measurements provided by Marvin Magee, JOAB, Inc.

Figure 23
Preliminary Elevations of Ground Water, Sand Point Location
Northwest ¼, Section 11, T.21S., R.28E.
(9/29/92 - 10/14/92)



GH-# represents geology/hydrology well completed. Elevation of ground water is relative to surveyed elevation of shroud cap (Skyline Engineering) (see Table 9). Top of ground water measured 9/29 ( ), 10/05, and 10/14/92 (**bold**) by Dennis Powers.

Table 9
Summary of Recent Measurements
Ground Water Levels
Sand Point

Borehole	Shroud Cap Elevation (Skyline Eng.) ft	Ground Water Elevations (ft) / Ground Water Depths (time) 09/29/92	10/05/92	10/14/92
SP G/H-1A	3322.68	**3153.73** 168.95 (1300)	**3154.08** 168.60 (1629)	**3154.24** 168.44 (1700)
SP G/H-2	3372.72	**3151.35** 221.37 * (1245)	**3151.74** 220.98 (1619)	**3151.80** 220.92 (1710)
SP G/H-3	3372.99	**3150.47** 222.52 (1334)	**3150.61** 222.38 (1653)	**3150.65** 222.34 (1720)
SP G/H-4	3343.56	**3146.19** 197.40 (1315)	**3146.54** 197.02 (1639)	**3146.09** 196.91 (1637)

* G/H-2 was sucking air when opened on 9/29/92.

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 cap elevation was measured by Skyline Engineering, Inc., and reported to JOAB, Inc. The measurement in each case is on the top of the shroud cap. This measured elevation *on the top of the cap* will be slightly above the top of the well shroud used as a depth reference. The slight difference in elevation (<.05 ft) will not change gradient calculations as the shroud caps are of the same design and dimensions for each well.

3.0 Conclusions and Selection of Sand Point as Potential Landfill Site

3.1 Summary of Sand Point Characteristics

Critical factors for preliminary site selection include exclusionary geohydrological factors based on new state regulations (State of New Mexico, 1991). The site is not located on a floodplain, nor is it located within 200 ft of watercourses. The site is not within 200 ft of a fault with displacement within the last 11,000 years. The depth to groundwater exceeds 100 ft below designed (preliminary) landfill excavation. Groundwater quality is not determined; it is probably better quality than 10,000 mg/l, but this does not disqualify the site. Caliche near the surface can be moderately well lithified but should not present significant construction difficulties; there is no hard bedrock within the excavation depth. Clay content in the construction zone is variable, but probably does not meet qualifications for a natural liner. There are no known sinkholes or karst within the site. Slopes are moderate and suited to construction.

The Sand Point site meets known geohydrologic criteria based on background data and preliminary site characterization.

3.2 Recommendation to Pursue Permitting Activities

Based on preliminary site characterization, I recommend that the Sand Point site be selected for complete site characterization necessary to apply for a permit to operate a landfill. A borehole drilling program has been developed for site characterization (Appendix 5). The drilling program is an alternative plan submitted according to state regulation.

4.0 REFERENCES CITED

Bachman, G.O., 1980, *Regional geology and Cenozoic history of [the] Pecos region, southeastern New Mexico:* Open-file Report 80-1099, U.S. Geological Survey, Denver, CO.

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

Chugg, J.C., Anderson, G.W., King, D.L., and Jones, L.H., 1971, *Soil survey of Eddy area, New Mexico:* U.S. Department of Agriculture, Soil Conservation Service.

Dane, C.H., and Bachman, G.O., 1965, *Geologic Map of New Mexico:* U.S. Geological Survey.

Geohydrology Associates, Inc., 1978, *Collection of hydrologic data eastside Roswell range EIS area New Mexico:* report to Bureau of Land Management, Denver, Co.

Geohydrology Associates, Inc., 1979, *Water-resources study of the Carlsbad potash area, New Mexico:* report to Bureau of Land Management, Denver, Co.

Gile, L.H., Hawley, J.W., and Grossman, R.B., 1981, *Soils and geomorphology in the Basin and Range area of southern New Mexico - Guidebook to the Desert Project:* Memoir 39, New Mexico Bureau of Mines & Mineral Resources, Socorro, NM, 222 p.

Hayes, P.T., and Bachman, G.O., 1979, *Examination and reevaluation of evidence for the Barrera Fault, Guadalup Mountains, New Mexico:* Open-file report 79-1520, US Geological Survey, Denver, CO.

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 and Mineral Resources, Socorro, NM, 169 p.

Hiss, W.L., 1975, *Chloride-ion concentraion in ground water in Permian Guadalupian rocks, southeast New Mexico and west Texas:* Resource Map 4, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM, 1 sheet.

Hiss, W.L., 1976, *Structure of the Permian Guadalupian Capitan aquifer, southeast New Mexico and west Texas:* Resource Map 7, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM, 1 sheet.

Holt, R.M., and Powers, D.W., 1991, *Geologic mapping of the air intake shaft at the Waste Isolation Pilot Plant:* DOE/WIPP 90-051, U.S. Department of Energy, Carlsbad, NM.

Kelley, V.C., 1971, *Geology of the Pecos country, southeastern New Mexico:* New Mexico Bureau of Mines and Mineral Resources, Mem. 24, 75 p.

King, P.B., 1948, *Geology of the southern Guadalupe Mountains, Texas:* U.S. Geological Survey Prof. Paper 480.

Machette, M.N., 1985, *Calcic soils of the southewestern United States in Soils and Quaternary Geology of the southwestern United States, Weide, D.L., ed.:* Special Paper 203, Geological Society of America, pp. 1-21.

Muehlberger, W.R., Belcher, R.C., and Geotz, L.K., 1978, *Quaternary faulting in Trans-Pecos Texas:* Geology, v. 6, no. 6, p. 337-340.

Richey, S.F., 1989, *Geologc and hydrologic data for the Rustler Formation near the Waste Isolation Pilot Plant, southeastern New Mexico:* Open-file report 89-32, U.S. Geological Survey, Albuquerque, NM, 72 p.

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.

State of New Mexico Environment Department, 1991, *New Mexico Solid Waste Management Regulations.*

Szabo, B.J., Gottschall, W.C., Rosholt, J.N., and McKinney, C.R., 1980, *Uranium Series Disequilibrium Investigations related to the WIPP site, New Mexico, Part II: Uranium trend dating of surficial deposits and gypsum spring deposit near WIPP site, New Mexico:* Open-file report 80-879, U.S. Geological Survey, Denver, CO.

Vine, J.D., 1963, Surface geology of the Nash Draw quadrangle, Eddy County, New Mexico: U.S. Geological Survey Bulletin 1141-B.

APPENDIX 1

Augur Drilling Data

Prior to Sand Point Characterization

Descriptions of the following augur holes are based on cuttings returned to surface and, where available, cores taken through the augur with a split barrel corer. Samples were examined visually, were tested with 10% HCl, and were described for basic color using either the GSA Rock Color Chart (Beker site) or Munsell Soil Color Chart (1971 Ed.) for other sites. The descriptions here more nearly reflect a geological than an engineering approach, so that a rock name including the word "stone", as in sandstone, reflects enough lithification to hold a sample together for examination; this is not a reference to engineering properties. The descriptions begin with basic lithology, followed by modifiers of decreasing significance and color. Color chart names which differ from a perceived color are included with the hue and associated numbers while the perceived color is used as a general description. As an example, an apparent light brown or reddish brown color may have an official color somewhat different, for example (pink: 5YR 8/4). Other features are then described.

Basic Descriptions of Augur Holes at Beker Site

B-1
NE1/4, SE1/4, Section 13, T.21S., R.27E.
Augured 2/26/92

Depth (ft)	**Description**
0-3	Silty clay, black with streaks of reddish-brown. Moderately calcareous.
3-15	Unlithified gypsum mud, light brown (10YR8/4). Very moist below 7' to saturated at 15'. Slightly calcareous from 3-7', noncalcareous below 7'. Reddish brown calcareous silty claystone was stuck in lower 1-2' of augur.

9

B-2
NW1/4, NW1/4, Section 13, T.21S., R.27E.
Augured 2/26/92

Depth (ft)	Description
Surface	Soft sandy, pebbly, argillaceous silt. Light brown (5YR 6/4) on dry surface, moderate brown (5YR 4/4) moist. Wash from higher topography.
0-4	Argillaceous silt, sandy, pebbly, generally light brown (5YR 6/4). Moist to slightly sticky. Very calcareous, but not indurated.
4-8	Sandy silt, pebbly, argillaceous, generally about 5YR 6-7/4 (light brown and interpolated color between chips).
8-11	As above, slightly less pebbly, slightly darker color interpolated (5YR 5/4).
	probable top of Gatuña Formation
11-12	Pebbly sand, silty, generally moderate brown (about 5YR 4/4). Very calcareous.
12-14	Silty sandstone to sandy siltstone, generally moderate brown (about 5YR 4/4). Very calcareous, moderately well indurated.
14-46	Sandy silt and silty sand with rare pebbles. Becomes more reddish with depth to 10R 5/6 or 10R 6/6 (mderate reddish orange) from about 30' down.
46 to TD	Similar to above, but with additional clay, possibly as claystone layers or claystone balls in silt and sand. Moist. Returns of wet mud and muck at 53-55' (TD).

Rock and Cuttings Sample List

Sample #	Depth Interval (ft)
B2-1	0-4
B2-2	4-5
B2-3	8-9
B2-4	13-14
B2-5	about 16
B2-6	about 18
B2-7	26-28
B2-8	33
B2-9	38
B2-10	43
B2-11	48
B2-12	about 53
B2-13	about 55

Basic Descriptions of Augur Holes at Sand Point

SP-1
NW1/4, SW1/4, Section 11, T.21S., R.28E.
Augured 2/26 and 2/27/92

Depth (ft)	**Description**
0-6	Argillaceous sand, reddish brown (5YR 4/4).
6-8	"Caliche" -pebble and smaller size, somewhat rounded white (5YR 8/1) clasts in light brown (pink: 5YR 8/4) sandy to granular matrix. Very calcareous.
8-11	Sandy silt, argillaceous, reddish yellow (5YR 6/6). Very calcareous, includes granules of white caliche. Moist, forms weak ball.
begin coring	**probable Gatuña Formation**
11-15	Silty sand, fine to medium grain, light brown (pink: 7.5YR 7/4), with minor granule-sized caliche and very minor clay illuviation. Very calcareous. Slightly moist, forms very weak ball.
15-16	as 11-15'.
	top of unalterred Gatuña Formation
16-19.5	Claystone with minor sand and silt, reddish brown (2.5YR 5/4). Shows dark stains (manganese oxide) on fractures and white material around root casts.
19.5-28	as 11-15' in general, light red (2.5YR 6/8).
28-29	Sand and sandstone, fine to medium grain, silty, with more argillaceous and calcareous zone at 28'; moderately well indurated.
29-30	Sand, fine to medium, with subvertical fracture about 1/8 inch wide filled with reddish brown clay stained black (manganese oxide) on surfaces.
30-30.7	Sandstone, thinly bedded, light brown (pink: 5YR 7/4), calcareous.
30.7-35	as 29-30.
35-40	Sandstone, silty, argillaceous, calcareous, yellowish red (5YR 5/8). Thin beds or partings from 36-29'. Also shows extensive small (< 1/16 inch) open bioturbation from probable root zone stained black. Unbedded, less calcareous in lower foot.
40-40.5	Sandstone, calcareous, bedded, similar to 36-39'.
40.5-45	Sand, silty, argillaceous, calcareous, similar to above, not indurated except for thin zones. Includes possible intraclasts of Gatuña.
45-50	similar to 36-39 and 40-40.5.

50-55	lithology similar to above, with less clay, no evidence of bedding, poorly lithified to friable. Lower 1' is loose sand with rare granule-sized clay clasts. Granule to pebble-sized, rounded clasts of Dewey Lake. Thin zones (< 6") are more calcareous and lithified.
55-56	Sand, with some evidence of crossbedding.
56-60	Sandstone, silty and slightly argillaceous, very calcareous, red (10R 5/8). Includes root casts and black staining. Beds are thin (about 1/4 inch).
60-61	Sand, fine, silty, slightly calcareous, red (2.5YR 5/8). May include slight amount of clay.
61-64.5	Claystone, very silty and slightly sandy, to argillaceous, sandy siltstone, light reddish brown (2.5YR 6/4). Abundant fine interconnected porosity from rootlets, modest dark stains on some rootcasts. Very calcareous. Platy to thinly bedded.
64.5-68	Sand, similar to 60-61' with slightly more silt and clay, reddish brown (2.5YR 5/4). Includes tan pebble or nodule of sandy crystalline limestone at 68' with porosity and rootcasts. May be secondary caliche or clast penetrated by bioturbation.
68-69	Claystone, silty, similar to 61-64.5 in lithology and structure. Light reddish brown (2.5YR 6/4).
69-72	Sand, silty, similar to 60-61'. Becomes sandier downward (fines upward) to medium sand at 72' with 5-10% opaques, some mica. Subangular to subrounded grains. Calcareous. Becomes lighter in color downward to red (2.5YR 5/6).
72-76	Argillaceous siltstone to sandy siltstone at base (fining upward), very calcareous, red (2.5YR 4/6). Shows block to slightly platy structure, open porosity due to rootlets, some dark staining on fractures and pores.
76-81 (TD)	similar unit to 72-76', slightly more argillaceous at base. Red (2.5YR 4/6).

SP-2
SW1/4, SE1/4, Section 12, T.21S., R.28E.
Augured 2/27/92

<u>Depth</u> (ft)	<u>Description</u>
0-2	Loose dark brown sand with pebbles.
2-5	Light brown to whitish carbonate matrix and pebble-sized caliche clasts (Mescalero caliche).
begin coring	
	top of Dewey Lake Formation
5-10	Sandstone, very fine to fine grained, silty, slightly argillaceous, dark reddish brown to reddish brown (2.5YR 3/4 to 4/4) with small greenish gray spots. Very calcareous, especially along fractures. Upper 1' more calcareous from overlying caliche. Blocky to somewhat play, well indurated. No observable finer bedding.

10-15	as above, with zones (< 1 ft) with more clay. Subvertical fractures show slight carbonate film. Some subhorizontal fractures show both carbonate films and black stains.
15-20	as above, with carbonate decreasing downward.
20-25	as above. 2 inch "purplish" argillaceous unit at 23'. Drilling harder through part of interval.
25-30	as above.
30-35	as above. Variable carbonate content from none to mildly effervescent. Zone from 33-35' slightly more argillaceous. Greenish reduction spots somewhat larger.
35-40	as above. Drilling became easier from about 38'. 80% core recovery.
40-45	as above. Drilling very easy last 3', augur not solid on bottom. About 25% core recovery, sample very loose.
begin auguring only	
45-55	No sample, augur only. Drilling became hard at 53'.
begin coring	
55-56 (TD)	Core returned small sample of white to slightly pinkish gypsum and irregular porous sandy carbonate chunks alterred by solution. **Top of Rustler Formation** (probably at 53'); most likely Forty-niner Member gypsum; possibly Magenta Dolomite Member represented by carbonate with gypsum from top of Tamarisk Member.

Rock Sample List

Sample #	Depth Interval
SP2-1	5-10
SP2-2	10-15
SP2-3	15-20
SP2-4	20-25
SP2-5	25-30
SP2-6	30-35
SP2-7	35-40
SP2-8	40-45

Basic Descriptions of Augur Holes at Laguna Grande de la Sal Location

LG-1
SE1/4, SW1/4, Section 5, T.23S., R.29E.
Augured 2/27/92

Depth (ft)	Description
augured	
	Rustler Formation, Magenta Dolomite Member
0-10	Surface wash, probable fill from drill pads, clasts of Magenta Dolomite Member of Rustler Formation in augur and surface returns.
begin coring	
	residue of Tamarisk Member
10-11	Argillaceous silty sandstone (fine to medium), brown and dark gray.
11-14.5	Sand, fine, silty, slightly argillaceous, with small white powdery gypsum spots. Very calcareous.
14.5-16	Silty claystone, dark reddish brown (2.5YR 3/4). Noncalcareous or slightly calcareous. Slickensides on claystone.
16-19.5	Silt, sandy, argillaceous, reddish brown (2.5YR 4/4). Moderately calcareous, slightly indurated. White or gray spots (about 1/16 inch). Mottled due to clasts included; may be smeared intraclasts.
19.5-24.5	Gypsum, gray (10YR 8/1), calcareous, soft, finely granular.
24.5-25	Gypsum, as above, along high angle (about 75°) contact with reddish brown siltstone and gypsum mix. Includes granules of harder gypsum.
25-30	Gypsum, soft, calcareous; includes some porous "clasts" of Culebra Dolomite Member and brown silt mixed with gypsum from 28-29'.
	top of Culebra Dolomite Member
30-33 (TD)	Gypsum and Culebra Dolomite. Little porosity in Culebra. Lithified, parts in platy sections. Subvertical fracture from 31-32'.

LG-2
near NW corner, Section 8, T.23S., R.29E.
Augured 2/27/92

Depth (ft)	Description
	augured approximately 1 ft through soil to refusal on Mescalero caliche.

LG-3
SE1/4, NW1/4, Section 6, T.23S., R.29E.
Augured 2/27-28/92

Depth (ft)	Description
augur only	
0-10	Fill and Gatuña Formation overprinted by caliche.
begin coring	
	unaltered Gatuña Formation
10-15	Sandstone, silty, in upper 1', and siltstone, argillaceous from 11-12'. Very calcareous. Includes rare pebbles of chert. Some black stain on vertical fractures or planes in siltstone.
15-21	Sandstone, generally fine to medium grained, silty near top and pebbly near base (fining upward), light red (2.5YR 6/6). Bedding or parting on 1/2 inch scale through much of core. Poorly indurated in pebbly zone near base. Sharp base to pebbly zone.
21-22	Claystone, sandy and silty, reddish brown (2.5YR 4/4). Black stain on horizontal planes and fractures.
22-23	Claystone, sandy to sandstone downward, very calcareous.
23-25.5	Pebbly sand and sandstone, fining slightly upward, light reddish brown (2.5YR 6/6).
25.5-26	Pebbly sandstone with silt and clay, greenish (light gray: 10YR 7/2). Pebbles of chert, quartzite. Open porosity from root casts.
26-27+ (30)	Pebbly sandstone and siltstone, light red (2.5YR 6/6). Shows open root casts.
augur from 27' with hard drilling	
30-35	Augur returns as above.
	Culebra Dolomite Member of Rustler Formation
35-46.5 (TD)	Augur returns mainly carbonate flour and pebble size Culebra clasts.

APPENDIX 2

Summary of Background Data from Potash and other Drilling for the Sand Point Location

Available files of potash and hydrocarbon exploration for the Sand Point location and immediate surroundings were reviewed at Bureau of Land Management offices in Roswell. Appropriate information was copied for files for future reference. Each of the descriptive logs or other data were reviewed to determine available information pertaining to the following:

location and elevation data,

stratigraphy of units from the surface to the upper Salado Formation,

presence of halite in the upper Salado, and

evidence of fluid-bearing zones.

These data were compiled on forms for each borehole, and the data from these forms are summarized here.

Borehole Name	Location (T.R.s)	Ref. Elev.	Depth (ft) to top of: Dewey Lake	Rustler	Magenta	Tamarisk	Culebra	Unnamed lower mbr	Salado	salt	water
USP 66	21.28.10 396fsl, 414fel	3313*	120	220	320?	340?	405	430	520?	616	nr
USP 37	21.28.12 1625fsl, 452fwl	3390		100	150	1980	280	298	400?	472	280
Big Eddy 36 water source well	21.28.12	3356	N.I.								
USP 31	21.28.13 1320fnl, 1320fel	3326		10	50	87	180	238	300	402	180 (gyp)
IMC 382	21.38.14 94 N79°W from SE corner	3320		190						385	nr
IMC 412	21.28.15 164fsl, 234fel	3245								357	nr
Fren Oil Friess Fenton 1	21.28.15 660fnl, 660fel	3310		45	204?	208?	310	335	435?	492	204-208
Ingram 1	21.28.15 2270fsl, 2310fwl	3291		145	263?		345	355?		442	nr
Nix & Curtis Muse 2	21.28.15 2080fnl, 630fwl	NA		195			355?	375?		575	165-175 220-225
Nix & Curtis Muse 1	21.28.15 NA	3294		130			395	435	495?	540	323-330
Schuster &Mess-inger Page 2	21.28.15 660fnl & fwl	3287		175						1165	575-790
Schuster & Mess-inger 1	21.28.15 1980fnl, 660fwl	NA		180			392?			615	nr
Fulton Friess 1	21.28.15 1980fsl & fel	3270*		0?-100?						370?	355-370

Borehole Name	Location (T.R.s)	Ref. Elev.	Depth (ft) to top of: Dewey Lake	Rustler	Magenta	Tamarisk	Culebra	Unnamed lower mbr	Salado	salt	water
USP 35	21.28.24 NA	3355		36	102?	120?	125	144	211	285	120
IMC 379	21.28.25 2575fel, 250fnl	3230								300	nr (lost circ zone)
USP 36	21.29.18 1050fnl, 1376fel	3320*		38	75	110	210	250	370	480	200-210
IMC 380	21.29.19 2636fel, 1610fnl	3270					487?	497?		516	nr (lost circ zone)
Southern Union 4	21.29.29 2640fsl, 100fwl	3276	106	168	225?	245?	334	358	451	451	nr
IMC 381	21.29.20 2840 e of w¼ corner	3330								465	nr (lost circ zone)

*Elevation from topographic map. NA = not available. nr = not reported.

Appendix 3
Sand Point Hole Histories
and Basic Data

General

The hole histories for Sand Point are compiled from the field notes by Marvin Magee, Dennis Powers, and Mark Miller as a chronological record of the daily events in the drilling and completion of each hole. Minor differences in notes have been reconciled based on best apparent record; these generally reflect slight differences in records of such data as times when events occurred or slight differences in depths. Some times are blank where an observer was not on site at a specific time. Generalized illustrations, showing the features of each borehole as completed, have been included in the main report (Figures 18-21).

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 was mobilized May 26, 1992, and drilling at Sand Point began May 27, 1992. The rig and crew was demobilized June 25, 1992, for this project and moved to Loving for a drilling program at the Loving landfill site.

The basic program at Sand Point was to establish the near-surface geological and hydrological character and construct piezometers to establish the elevation of groundwater under the Sand Point location. Drillholes were cored as possible, using air unless drilling conditions required foam or water. The piezometers also permit sampling for water quality and the possibility of bailing fluid to determine hydrological properties of the saturated zone.

Drillhole SP G/H-1

SP G/H-1 was located about 2600 ft from the north line and about 1300 ft from the west line (section 11, T.21S., R28E.) at an elevation of about 3315 feet.

May 27

0700-0800 Mobilized to Sand Point from Carlsbad.

0800-0930 Set up; began drilling with split spoon to 5 ft, became hard, recovered Mescalero caliche; continued drilling to 15 ft with no recovery 5-15 ft. Changed to 94 mm wireline core system.

0930-1730 Coring with variable recovery from 15 ft to 90 ft; Pleistocene Gatuña Formation. Began with foaming agent and water at 49 ft for hole control in loose sand and sandstone. Foaming agent is STAFOM 202 supplied by Western Mud Services, Silver City, NM.

1730-1930 Stewart Bros. rig work.

May 28

0700-1430 Coring with wireline system from 90 ft to 170 ft using foam and water assist. Variable recovery. Loose sand and sandstone running in on hole causing problems.

1430-1600 Change over drill string and ream hole to 170 ft with 5¼ inch tricone bit.

1600-1730 Change over drill string for wireline system. Core from 170-180 ft using foam and water assist, modest recovery.

May 29

0700-1300 Checked borehole with bailer. Recovered foam-water from drilling. Cored with wireline system from 180 to 210 ft with wireline system using foam or foam-water assist with variable recovery. Sand running in hole causing problems.

1300-1730 Change over to tricone bit, rotary from 210 ft to 368 ft. Return cuttings from Dewey Lake Formation from about 213 ft to TD. Pulled pipe from borehole, removed bit, and ran open pipe in hole. Blew with air to remove foam, capped pipe to let pressure dissipate slowly. Left pipe in borehole. Total fluid used in borehole about 3200 gal water and 4 gal STAFOM with minor bentonite and polymer(50% active water free liquid grade anionic acrylamide copolymer) from Western Mud Services, Silver City, NM.

May 30

0700-0730 Checked borehole for fluid. Indicates possible fluid in borehole to 170 ft with sand at 220 ft. Could not determine if hole is producing water or if fluid may be from drilling and sand inflow. Decided to plug and abandon borehole, based on following:
1) poor information on stratigraphy and hydrology in lower section,
2) re-entering not likely to improve information with hole collapse and fluid used in drilling,
3) hole conditions make it difficult to proceed deeper to check for Rustler.
Location to be reoccupied later using different drilling technique.

0730-1330 Pulled drill string. Cemented hole with 55 sacks of cement and 2 bags of bentonite producing about 15 lb/gal cement.

1330-1530 Rigged down, moved rig to next site.

Drillhole SP G/H-2

SP G/H-2 was located about 1300 ft from the north line and about 50 ft from the west line at an elevation of about 3365 feet.

May 30

1530-1600 Set up. Core with air to 4 ft with split spoon to Mescalero caliche.

1600-1800 Core with wireline system, using air, to 40 ft with partial recovery. Through Mescalero caliche and into Gatuña Fm.

May 31

0700-0845 Cored with air to 60 ft with partial recovery. Hole caving in, making drilling difficult.

0845-0945 Changed to 5¼ inch tricone bit and reamed hole to 60 ft.

0945-1530 Shut down for rig repair.

1530-1630 Cored from 60 to 70 ft with partial recovery. Added estimated 10-15 gal water to hole to remove stuck pipe. Shut down operations for day.

June 1

0700-0945 Reamed hole 7 7/8 inch diameter to 35 ft depth. 31 ft of 6 5/8 inch casing to be set in hole was dropped in hole when hole depth was miscalculated as 31 ft. Casing fished out, section was added, and casing set at 35 ft. Hole reamed to 70 ft with 5¼ inch tricone bit using air.

0945-1345 Core with wireline system from 70 to 124 ft using air. Variable core recovery. Drilling rate slowed from about 110 ft in more argillaceous units. Checked borhole for fluid entry over 20 minute period; no fluid detected.

1345-1550 Changed bits. Reamed hole with 5¼ inch tricone to 125 ft using air. Changed to wireline coring system. Checked borehole for fluid using sounder; borehole dry.

1550-1800 Cored from 125 to 170 ft with air. Variable recovery. Shut down for day.

June 2

0700-0720 Checked borehole for fluid using sounder; borehole dry. Prepare for drilling.

0720-0745 Cored from 170 to 175 ft, using air, with partial recovery. No cuttings returning to surface, indicating probable loose, unsaturated sand.

0745-0840 Cored from 175 to 188 ft, using foam assist. Poor core recovery.

0840-1050 Cored from 188 to 220 ft, using foam and mud assist; poor returns to surface. Poor to no core recovery. Fine sand may be coming into hole.

1050-1400 Reamed hole with 5¼ inch tricone to 220 ft, drilled additional 10 ft to 230. Sand coming in hole. Decided to ream hole with 7 7/8 bit and use 5½ inch (o.d.) casing in hole for control.

June 11

0700-1000	Bailed well with difficulty. Yielded about 20 gal muddy and soapy water. Water level about 220.5 to top of tubing, hole clear to 250 ft.
1000-1200	Cemented hole back to surface, rigged down to move.
June 12/13	Finished surface fittings: cement pad with steel casing, hinged metal cap, padlock.

Sand Point SP G/H-3

G/H-3 is located about 50 ft from the north line and 1300 ft from the west line at an elevation of about 3370 ft.

June 11

1200-1230	Move onto location, set up to drill.
1230-1430	Core with wireline system, using air, to 50 ft with variable recovery through Mescalero caliche and into Gatuña Fm. Core barrel stuck in drill string between 40 and 50 ft, was dropped while trying to retrieve core.
1430-1600	Remove drill string, separate core barrel and bit, replace bit split by core barrel, prepare to continue drilling.
1600-1815	Cored from 50 to 90 ft in the Gatuña Fm, using air, with good recovery.

June 12

0700-0705	Ran electric water detector in borehole to TD; no fluid detected.
0705-0830	Cored from 90 to 97 ft with difficulty, partial recovery. Core barrel moist inside, believed due to condensation from very warm air compressed to remove cuttings. Core barrel and core very cool, causing condensation.
0830-0835	Ran electric water detector in borehole to TD and observed for 2 minutes; no fluid detected.
0835-0945	Changed bits to 5¼ inch tricone, reamed hole to 100 ft, changed to wireline coring system.
0945-1115	Cored from 100 to 130 ft, with air, poor recovery in Gatuña sand and sandstone. Core barrel and recovered core continue to be moist. Ran electric moisture detector to TD; no fluid detected.
1115-1155	Cored from 130 to 140 ft, with air, poor recovery.
1155-1515	Prepared to use foam assist to try to improve coring and hole conditions. Cored from 140 to 190 ft, using foam, with variable to no recovery in Gatuña sands. Sand may be coming in borehole.
1515-1900	Removed drill string and coring system from borehole. Reamed with 7 7/8 inch tricone bit to 200 ft using foam assist.

June 13

0700-0705	Ran electric moisture detector to TD; no fluid detected.

1400-	Pulled drilling string, removed casing, reamed 7 7/8 inch hole to 120 ft. Shut down for day.
June 3	
0700-1100	Ream 7 7/8 inch hole from 120 to 240 ft and wait casing.
1100-1500	Install 5½ inch casing to 249 ft.
1500-1900	"Drilled" with corebarrel inside casing to 270 ft, blowing mainly moist, very fine sand. Added 21 ft of casing. Corebarrel dripping water and contained about 6 inches of very wet sand when removed from inside casing. Measured water level at 245 ft below top of casing at 1905 hours.
June 4	
0700-0730	Measured water level at 224.9 ft below top of drilling floor, sand at about 253 ft.
0730-0830	Bailed approximately 2 gal of water and sand from inside borehole. Took samples for conductivity. Measured water temperature of 21.5°C, specific gravity about 1.000 g/cc.
0830-1330	Drilled from 270 to 275 with difficulty, poor or no air or fluid return to surface. Pulled drilling string and drove casing to 272 ft. Drill string in hole to re-establish circulation. Removed drill string from hole and shut down for 4 day break in operations. Water level at about 235 ft.
June 9	
0815-0830	Measure water level at 222 ft, mud or sand at 245-250 ft. Bailed about 1 gal water; temperature 21.5°C, sp. grav. about 1.000 g/cc.
0830-1020	Ran drill string in hole with 4 3/4 inch tricone bit.
1020-1100	Shut down rig and installed discharge pipe system.
1100-1345	Blew sand and fluid out of hole. Drilled inside casing to 290 ft using air. Recovered cuttings of Dewey Lake Fm from about 290 ft.
1345-1600	Rigged up for wireline coring.
1600-1715	Cored Dewey Lake Formation from 290 to 300 ft, using air, with variable recovery.
June 10	
0700-0715	Measured fluid level at 232.15 ft below drilling floor, about 3' above ground surface.
0715-1900	Pulled drilling pipe from borehole. Filled hole from 300 ft to about 250 ft with 8-12 silica sand. Set 250 ft piezometer of two inch diameter, flush threaded PVC: 10 ft blank, 30 ft of screen with 0.010 inch slots, 210 ft of riser pipe. Sand pack (10-20 sand) installed to 202 ft while pulling about 79 ft of outer casing. Set 20 ft bentonite seal using 7 sacks of bentonite. Final bentonite seal about 180 ft below grade. Grouted to 79 ft with approximately 15 lb/gal neat cement before running out of cement. Tried to bail well with 1 9/16 inch diameter, 4 ft long, stainless steel bailer but could not get past about 210 ft. Tubing must be slightly crooked. Used 3 ft plastic bailer yielding water from 22-25°C, 2130-2380 millimhos. Water level 220.9 ft below top tubing about 30 min after bailed.

0705-1315 Installed 5½ inch casing to 197 ft. Ran 4 3/4 inch tricone bit inside casing to TD, drilled to 220 ft in Gatuña sand and sandstone. Casing following drilling to 219 ft.

1400-1830 Blew damp sand from borehole, may indicate fluid-bearing zone. Drilled to 240 ft and set casing at 220 ft. Removed bit from hole and tested for water. No water indicated, but bottom of hole at only 230 ft.

June 14

0700-0820 Checked for water in borehole with electric water detector. Possible fluid level approximately 221 ft, erratic signal. Attempted to bail hole with small PVC pipe bailer, encountered wet mud but no fluid. Ball free in bailer indicating proper operation. Prepared to continue rotary drilling with 4 3/4 inch bit inside casing.

0820-1245 Drilled with foam from 230 to 295 ft. Loose sand common; sticky mud around 247 ft. Harder drilling and cuttings from about 292 ft indicate base of Gatuña and top of Dewey Lake Formation. Removed drilling string from borehole to check for fluid.

1245-1300 No fluid detected with certainty in borehole. Drill pipe without bit put into hole to 260 ft, stopped for observation.

1300-1340 Standby period for observation. Possible water level detected at 235 ft with bottom of hole 1 to 3 ft below this level.

1340-1500 Attempted to bail hole with small PVC bailer. Three runs yielded about 2 quarts of watery mud. Made up 20 ft steel bailer using tremie pipe. Bailed estimated 50 gal water, sand, and mud from borehole.

1500-1615 Observed water levels (depth below top of drillpipe, 14.25 inches above drilling floor): 234.0 ft @ 1502 hrs, 232 @ 1519 hrs, 230.0 @ 1541 hrs, 229.25 @ 1600 hrs. Bottom of borehole at about 255 ft. Shut down for overnight observation.

June 15

0700-0710 Measure water depth at about 222 ft below drilling floor. Bottom of hole at 253 ft, inside casing (to 260 ft).

0710-0820 Put 1¼ inch schedule 80, flush threaded, PVC piezometer tubing into hole: 10 ft blank, 30 ft screen with 0.020 inch slots, 210 ft riser pipe to surface. Tubing touched bottom with top about 1½ ft below top of drilling string. Top of tubing pulled slightly above top of drilling string. Water level inside tubing measured at 223 ft below top of tubing; about 3 to 5 ft sediment inside blank.

0820-1330 Placed sand pack (11 sacks, 50 pounds each, 10-20 size) inside casing, alternating putting sand in, drawing drill string up, and measuring top of sand pack. Withdrew all drill string from borehole with casing at about 220 ft. Removed 40 ft casing. Final measurement of sand pack top at 197 ft below drilling floor with 180 ft casing in hole.

1330-1430 Installed clay plug using 2 buckets (50 pounds each) of "Pure Gold" and 7 sacks (50 pounds each) of WyoBen Enviroplug #8. Final clay plug top measured at 179 ft below drilling floor for 18 ft plug. Added about 15 gal Carlsbad city water inside casing to expand clay. Pulled remaining casing from borehole.

1430-1800 Ran tremie pipe in borehole. Mixed and placed 28 bags of cement mixed with 8 to 10 pounds high yield bentonite per 480 pounds cement. Cement run finished at about 1600 without return to surface. Partially pulled tremie pipe, indicating top of grout about 73 ft below drilling floor. Second cement round using 28 additional bags of cement mixed as before, circulated grout to surface. Withdrew tremie pipe, grout subsided a few feet below surface. Drilling operations complete at G/H-3.

June 16/17 Finished surface fittings: cement pad with steel casing, hinged metal cap, padlock.

Sand Point SP G/H-4

G/H-4 is located about 1300 ft from the north line and about 2600 ft from the west line of section 11 at an elevation of about 3342 ft.

June 16

0700-0945 Moved drilling rig from SP G/H-3 to SP G/H-4 and set up for drilling.

0945-1400 Coring with split spoon from 0 to 17 ft, using air; variable recovery. Drilled through sand, Mescalero caliche, upper Gatuña Fm. Changed to wireline coring system from 17 to 80 ft, using air, with generally good core recovery.

1430-1715 Cored from 80 to 130 ft in Gatuña Fm using air with good to variable recovery. Poured 2 to 3 gal water inside drilling string due to sticking at about 120 ft.

June 17

0700-0900 Used electric water detector to check for fluid at TD; none detected. Reamed borehole with 5 inch tricone bit to 130 ft using air.

0900-1115 Re-entered borehole with wireline core system and cored, with air, from 130 to 160 ft. Core wet from 140-150 ft.

1115-1145 Standby to observe for water; electric water detector indicates no water in borehole. Damp core barrel apparently due to condensation from very warm and humid air pumped into borehole to return cuttings.

1145-1530 Core from 160 to 210 ft, using air and slight amount of water added at sticking points, with variable to poor recovery. Very moist core. Shut down drilling to observe fluid levels.

1530-1645 Observed fluid level at 199.7 ft below drilling floor.

1645-1745 Cored from 210 to 230 ft, using foam assist, with partial recovery. TD in Gatuña Fm. Shut down for overnight recovery of fluid level.

June 18

0700-0915 Measured water level at about 195 ft below drilling floor with hole bottom at about 203-204 ft. Removed drill string to take off core bit. Put drill string back to 230 ft; sand at 203 ft inside drill string. No water detectable. Blew sand from hole with foam. Measured bottom at 228 ft.

0915-1025 Bailed soap, sand, slime, fluid from borehole with steel bailer made from tremie pipe.

1025-1320 Observed fluid rise from 228 ft to 214.5 ft below drilling string.

1320-1415 Bailed about 11-12 gal fluid from hole, shut down and secured rig for four day break.

June 23

0800- Measured water level at 193 ft below drill floor with hole open to 230 ft. Installed 1¼ inch flush threaded PVC piezometer tubing: 20 ft blank, 30 ft screen (0.020 inch slot), and 180 ft riser pipe to surface. Placed sand pack from 230 to 170 ft, benseal from 170 to 153 ft, grouted back to surface with cement/bentonite mixture. Moved rig from G/H-4 to G/H-1A (alternate location to G/H-1).

June 25 Finished surface fittings: cement pad with steel casing, hinged metal cap, padlock.

Sand Point SP G/H-1A

G/H-1A is located a few feet from SP G/H-1.

June 23

Rotary drilled G/H-1A to 200 ft. Shut down for overnight observation of fluid level.

June 24

0700-1310 Initial water level indicated at 172 ft below drilling floor. Bailed sand and fluid from hole; sand at 160 ft after bailing. Used foam and pressure to rotate open string to about 208 ft. Stopped to relieve pressure in hole.

1345-1800 Fluid level measured at 178 ft below top of drill pipe, bottom at about 210 ft. Set 1¼ inch, flush threadded, PVC piezometer tubing: 10 ft blank, 30 ft screen (0.020 inch slots), 160 ft riser pipe to surface. Center of screen at about 175 ft. Used 4 bags (100 pounds) of sand (10-20 size) for pack, with final sand level about 138 ft below top of drill string. Drill string pulled as sand pack added. Used 2 buckets (50 pound) Pure Gold (¼ inch) volclay tablets and 2 bags (50 pound) Enviroplug #8 to bring clay pack to 107 ft (31 ft thick) with drill pipe at 100 ft. Pulled remaining drill pipe. Installed tremie pipe. Circulated cement/bentonite grout to surface. Pulled tremie pipe. Shut down rig for move off site.

June 25

0700-1030 Final preparations for moving off site.

Finished surface fittings: cement pad with steel casing, hinged cap, padlock.

Sand Point
Coring Statistics

Borehole	Total Depth	Cored Thickness	Total Core Recovered	Percent Recovery
SP G/H-1	*368 ft*	*210 ft*	*123.7 ft*	*59%*
SP G/H-2	*300 ft*	*230 ft*	*131.2 ft*	*57%*
SP G/H-3	*295 ft*	*190 ft*	*75.3 ft*	*40%*
SP G/H-4	*230 ft*	*230 ft*	*138.4 ft*	*60%*
SP G/H-1A	*210 ft*	*not cored*		

Sand Point
Preliminary Fluid Level Data

The following data reflect preliminary evidence of fluid levels during the drilling efforts and during the period of establishing piezometers. As such, they should be interpreted with great caution. The information is provided in the event they should later be useful in explaining any static water levels or data obtained during the period of more precise and undisturbed measurements following completion of each piezometer.

The elevations used here are based on an arbitrary reference elevation of 1000.00 ft for the top of the turning point marker recently established at approximately the center of section 11, T.21S., R.28E. Conversions to elevations above mean sea level will be provided following further ties to level lines in the area. Final surveys will provide the most accurate elevation data on each point.

Most depths established here will be relative to the drilling table or floor (d.f.). These points were surveyed during drilling, but were frequently shifted by several inches during drilling. Consequently, different epochs of measuring water depths in a single hole may only be accurate to about ± 1 ft, though consecutive or successive measurements may have a precision of ± 0.1 ft.

The relative elevation of the final permanent casing, used as a measuring point since early July, 1992, has also been provided here.

All measurements have been provided by Marvin Magee, JOAB, Inc., and are to be used only as interim elevations until a final survey can be provided.

Preliminary Reference Elevation Points

Borehole	Reference Elevation	Description of Point
SP G/H-1	979.33	Top of rig table.
SP G/H-1A	980.0	Top of permanent casing.
SP G/H-2	1029.9	Top of rig table.
	1030.0	Top of permanent casing.
SP G/H-3	1030.1	Top of rig table.
	1030.4	Top of permanent casing.
SP G/H-4	1000.4	Top of rig table.
	1001.2	Top of permanent casing.

Above reference elevation points for drilling table may be used for approximate conversion of water depths determined during drilling to reference elevations.

Sand Point Hydrological Data Obtained During Drilling Program

Date	Time	Depth (fluid or hole)	Reference Point	Comment
SP G/H-1				
May 29	0700	180'	drill pipe	Foam/water in bailer
May 30	0700	170'	drill pipe	Possible water
SP G/H-2				
June 1	1345	120'	drill pipe	No fluid detected over 20 minutes
June 1	1545	125'	drill pipe	No fluid detected
June 2	0715	170'	drill pipe	No fluid detected
June 3	1905	245'	drill pipe	Top of fluid level
June 4	0730	224.9'	drilling floor	Sand at 253[. Removed 4 bailers of fluid (about 1 to 2 gallons total)
June 4	after 1330	235'	top of casing	
June 9	0830	222'	top of casing	Sand at 245-250'. Bailed about 1 gallon.
June 10	0715	232.15		Water level
June 11	1000	220.5	top tubing	Measured inside tubing
June 13	0703	220.3	top tubing	Measured inside tubing
June 23	1235	220.5	top tubing	Measured inside tubing
SP G/H-3				
June 12	0705	92'	top drill string	No fluid detected at TD
June 12	0835	97'	top drill string	No fluid detected at TD
June 12	1115	130'	top drill string	No fluid detected at TD
June 13	0705	200'	top drill string	No fluid detected at TD
June 13	1830	230'	top drill string	No fluid detected at TD
June 14	0715	221'	top drill string	Erratic indications of fluid
June 14	1245	292?'	top drill string	Uncertain indications of fluid
June 14	1340	230	top drill string	Possible water level
June 14	1502	234.0	top drill string	Measured water level
	1519	232	top drill string	Measured water level
	1541	230	top drill string	Measured water level
	1600	229.25	top drill string	Measured water level
June 15	0710	222	drilling floor (14.25" below string)	Measured water level
	0820	223	top tubing	Measured water level
June 23	1210	222.25	top well shroud	Measured water level

==

Sand Point Hydrological Data, cont.
Obtained During Drilling Program

Date	Time	Depth (fluid or hole)	Reference Point	Comment
SP G/H-4				
June 17	0700	130'	top drill pipe	No fluid detected
	1145	160	top drill pipe	No fluid detected
	1645	199.7	drilling floor	Final fluid level
June 18	0705	195	drilling floor	Fluid level
	0845	203	top drill pipe	No fluid detected
	1025	228.1	top drill pipe	Measured fluid level
	1240	216.3	top drill pipe	Measured fluid level
	1320	214.5	top drill pipe	Measured fluid level
June 23	0800	193	drilling floor	Measured fluid level
June 24	0800	196.3	top of tubing	Measured fluid level
	1755	196.2	top of tubing	Measured fluid level
SP G/H-1A				
June 24	0700	172		Uncertain signal
	1345	178	top drill pipe	Measured fluid level
June 25	0800	168.7	top of tubing	Measured fluid level

Notes: These measurements are reported as part of the history of drilling. Bailing, drilling, or other activities may have occurred between successive measurements. The borehole histories in the appendix show the range of activities including the measurements of fluid levels.

APPENDIX 4

Borehole Graphic Logs and Descriptions, Sand Point Preliminary Characterization

The borehole graphic logs presented here were prepared from the field descriptions and logs. Several notes are appropriate. The approximate locations for each borehole in section 11 are given for reference and are not based on precise surveys. The descriptions, including estimates of the average grain size, are based on field study only and show trends; they are not precision analyses of the rocks.

Explanation of Symbols

Limestone or calcareous rock

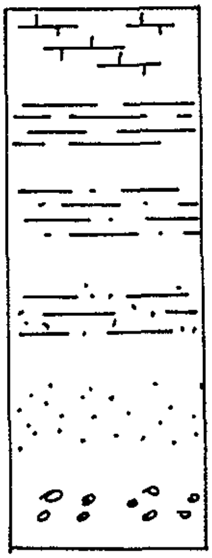
Claystone

Siltstone

Sandy siltstone

Sandstone

Conglomerate



Bioturbation (mainly rootcasts)

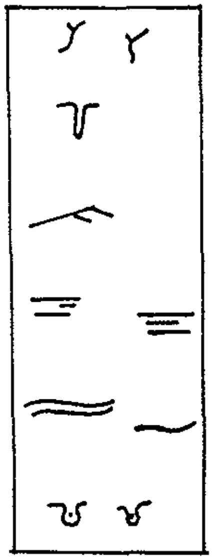
Desiccation crack

Ripple cross-bedding

Laminar bedding

Wavy bedding

Soft deformation

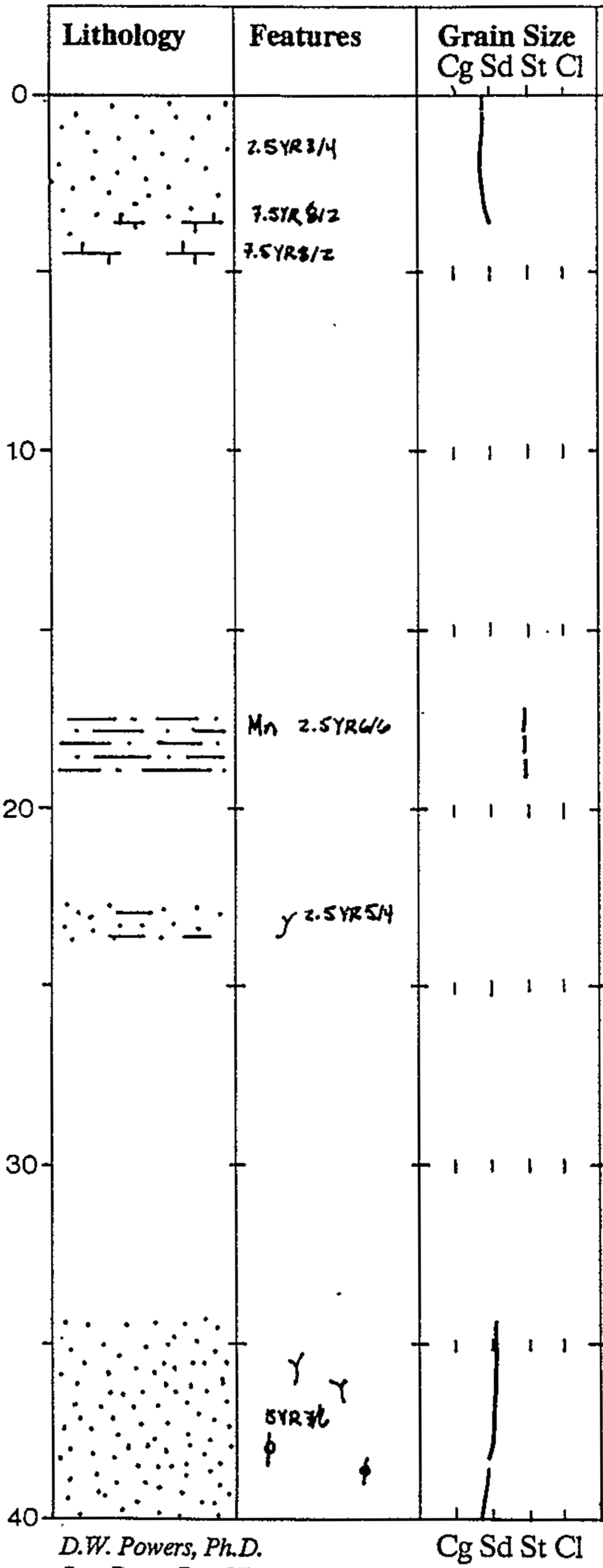


Abbreviations: f - fracture; Mn - manganese oxide stain; sl - slickensides; calc - calcareous; 2.5YR 4/6 - numbers refer to colors based on Munsell Soil Color Chart.

No symbols indicates poor or no recovery. Graphic symbols may be arbitrarily placed in a coring interval where core loss occurs but cannot be exactly placed.
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.

DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-1 *Location: ~1400fwl, 2600fnl* *Drilling Date: 05/27/92*



Description

Sand, fine to medium, slightly silty and slightly argillaceous. Dark reddish brown (2.5YR 3/4). Includes light brown (7.5YR 8/2: pinkish white) calcareous sand to soft, sandy limestone. Sand is subangular to well rounded, mainly subround with about 1% dark grains.

top Mescalero caliche
"Limestone," sandy, soft. Light brown (7.5YR 8/2: pinkish white).

Gatuña Formation
Siltstone, sandy, argillaceous; light red (2.5YR 6/6). Blocky ped structure. Poorly lithified, cores poorly. Very calcareous. Black (MnO_2) stain on blocks, illuvial clays along fractures; tiny open pores. No bedding or primary sedimentary structures.

Sandstone, silty, very calcareous; reddish brown (2.5YR 5/4). Moderately well indurated in samples; cores poorly. Open porosity as rootcasts, some coated with carbonate. No bedding apparent. Sand is fine to medium, subrounded to well rounded; grains appear coated.

24-34: No core. Blowing sand from borehole; fine to medium, round to well rounded, uncemented. May be equivalent to "orange sands" found in Gatuña in Remuda Basin.

34-52.9: Sand and sandstone, with basal conglomeratic sand- stone. Sand is generally fine to medium, loose to moderately well indurated; subround to well rounded, < 1% dark grains. No bedding observed. Narrow (<< 1 mm) porosity from root casts. Calcareous nodules or clasts from 38-39'. Coarsens slightly downward to conglomeratic base; rare clasts of carbonate and siltstone throughout. Clasts to about ½ inch diameter in conglomerate: Dewey Lake, chert, Permian limestone. Basal unit may be inbricated. Color is generally reddish yellow (5YR 7/6), becoming slightly lighter in value downward.

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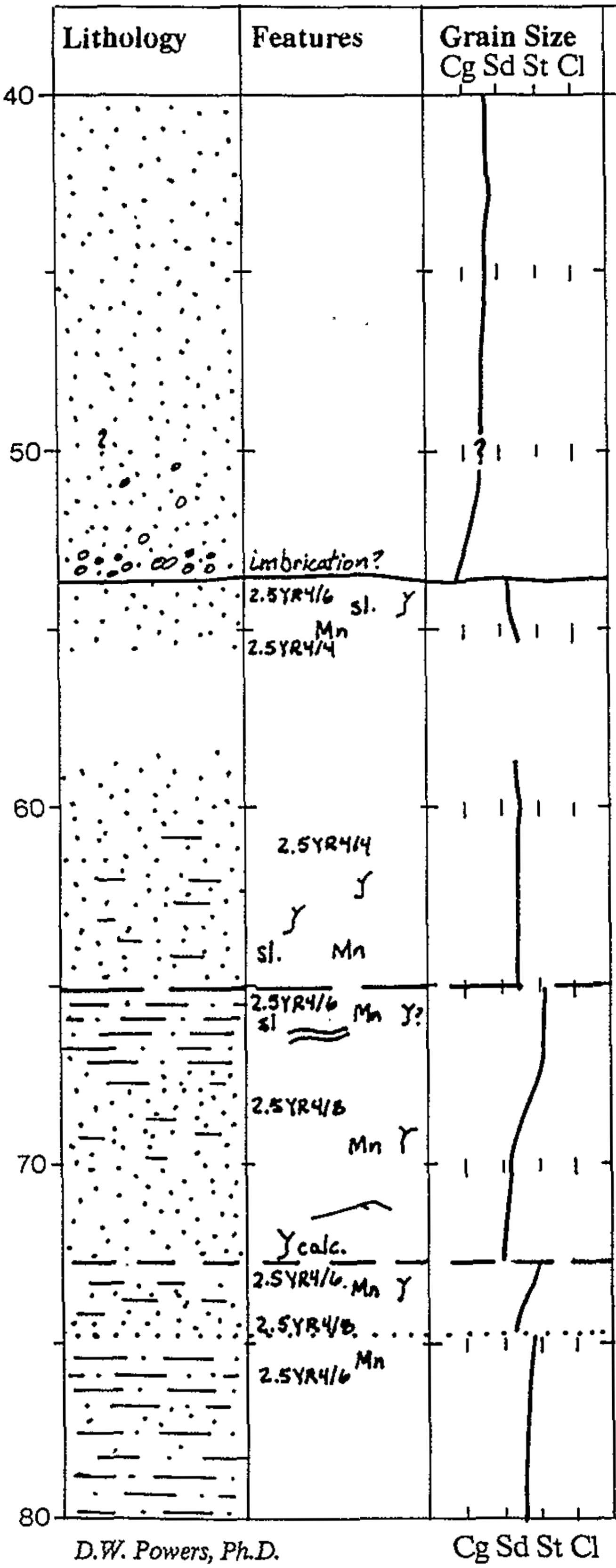
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-1 *Location: ~ 1400fwl, 2600fnl* *Drilling Date: 05/27/92*



Description

52.9-65: Sandstone, silty and argillaceous, calcareous. Subhorizontal slickensided surfaces in upper part. MnO_2 on vertical and horizontal fractures, with white calcareous stain on Mn stain in lower part. Minor porosity from root bioturbation throughout. Sand is fine to medium, subrounded to well rounded; poorly cemented and indurated at top, increasing clay, silt and induration downward. Moist colors: red (2.5YR 4/6) at top to reddish brown (2.5YR 4/4) from about 55' down.

65-67.5: Siltstone, argillaceous, slightly sandy. Slickensided on subhorizontal fractures; MnO_2 on irregular vertical fractures or possible root casts. Very calcareous; moderately well indurated. Thin beds to laminae at 66'. Red (2.5YR 4/6) when moist.

67.5-72.5: Sandstone, silty and argillaceous in upper half. Sand is very fine to medium, subrounded to well rounded, few opaque grains. MnO_2 and possible rootcasts at 69-70'; no clear bedding in upper half. Sandstone at base with calcareous rootcasts to 2-3 mm diameter. Probable ripple cross-laminae at 72'. Red (2.5YR 4/6) when moist.

72.5-75: Sandstone to siltstone, fining upward. Fine to medium sandstone at base, slightly sandy siltstone at top with MnO_2 stains and probable root casts. Very calcareous and moderately well indurated. Red (2.5YR 4/6 at top to 2.5YR 4/8 at bottom) when moist.

75-81.5: Sandstone fining up to siltstone, slightly sandy and argillaceous. Sand is fine to medium at base. Thin bedding or platy fracture at 80'. MnO_2 stains and a few root casts at top. Very calcareous, moderately well indurated at top. Red (2.5YR 5/6 at bottom to 2.5YR 4/6 at top).

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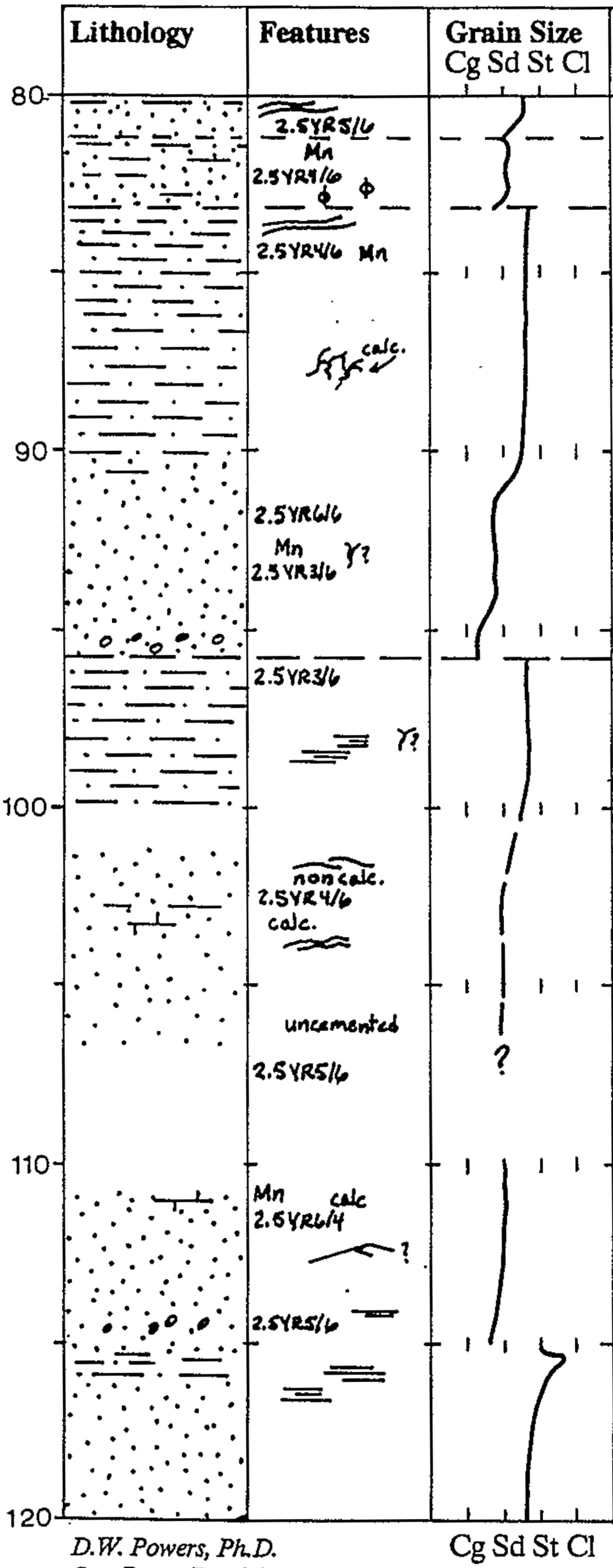
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-1 *Location: ~1400fwl, 2600fnl* *Drilling Date: 05/27-28/92*



Description

81.5-83: Sandstone fining upward to siltstone; red. Calcareous nodules or pebbles at top of sandy part. Very minor MnO_2 stains and rootcasts in siltstone.

83-90: Siltstone, argillaceous slightly sandy, red. Some possible bedding near top. MnO_2 stains and rootcasts. White carbonate network, possibly outlining ped structures, at 87-89'.

90-95.5: Pebbly sandstone, dark red, fining upward to sandstone, slightly silty, light red. Sand fine to some coarse, subangular to well rounded; dark grains 2-5%. Very calcareous, moderately well indurated. Pebbles at base are about 1 inch maximum and are Dewey Lake and Permian limestone. MnO_2 stains and possible rootcasts at about 93'.

95.5-100: Siltstone, very sandy, and argillaceous siltstone interlaminated in zones with sandy siltstone; dark red. Sand is fine to very fine. White calcareous network at 98' may be outlining fractures or bioturbation. Moderately well indurated.

102-106: Sandstone, silty, and sand; red. Sand ranges from very fine to medium, subangular to well rounded; 1-2% dark grains. Finer grained units show vague evidence of laminar bedding. Calcareous zone at about 103' shows some nodular development; calcite probably accumulated from overlying 6 inch zone which is non-calcareous. Laminae (< ½ inch) below calcareous zone. Lower part of unit is uncemented "orange sand" with minor silt and clay.

111-115: Sandstone, silty, light reddish brown. Very coarse sand and small granules at 114.5; fine to medium with some coarse above; 1-2% dark grains. Some bedding or possible ripples. Minor MnO_2 at top. Moderate to poor induration.

115-132: Sandstone, silty and argillaceous, with small pebbles to granules in lower part, fining upward to siltstone, sandy, with argillaceous laminae; red. Coarser clasts from Dewey Lake as well as nondiagnostic carbonate clasts of either Gatuña or

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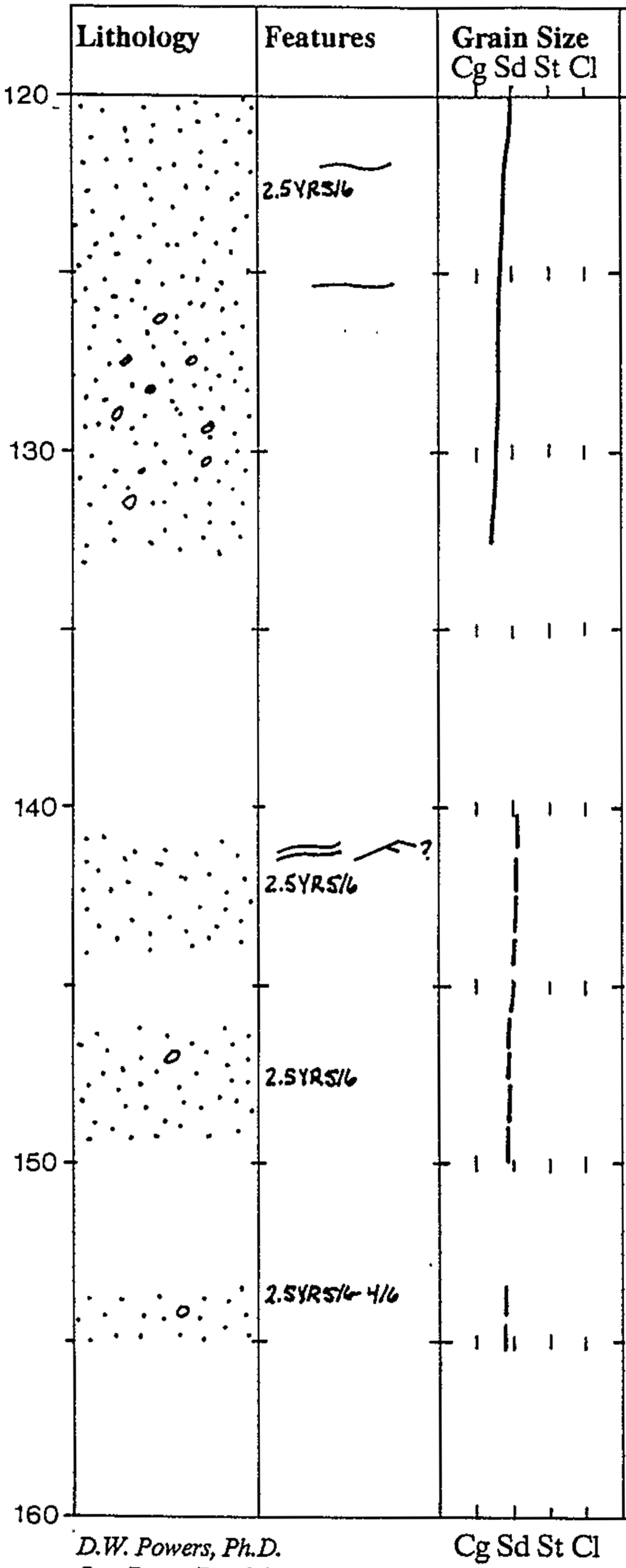
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-1 *Location: ~1400fwl, 2600fnl* *Drilling Date: 05/28/92*



Description

115-132, cont: Permian limestone. Sand in lower part is fine to very coarse, subangular to rounded; 2-5% dark grains. Sand grains higher are very fine to medium, subangular to subrounded upward; about 5% dark grains. Argillaceous zone and laminae near top are slightly calcareous, show thin beds to laminae ½ to 1 inch thick. Horizontal, planar parting with minor slickensides on parting.

141.5-150: Sand and sandstone, red. Calcareous, but poorly indurated. Coarser sand, some granules and rare small pebbles with 1-2% dark grains in lower part; fine to medium, subangular to subround, about 1% dark grains in upper part. Laminar to ripple (?) bedding at top.

153-155: As above, with small pebble of white, calcite-cemented sandstone near bottom of recovered sample.

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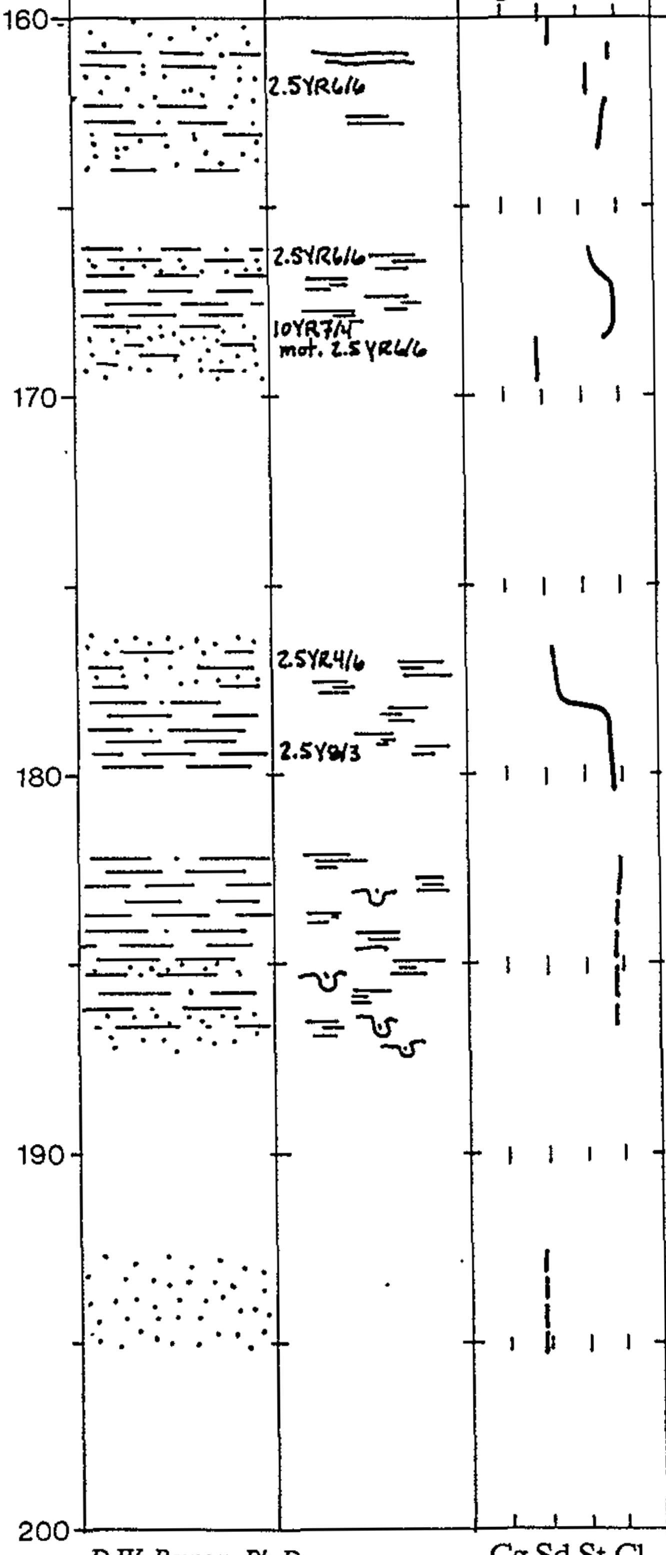
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-1 *Location: ~1400fwl, 2600fnl* *Drilling Date: 05/28-29/92*

Lithology	Features	Grain Size Cg Sd St Cl	Description



160-163: Sand, silty sand, and poorly indurated silty claystone, light red. Sand is very fine to medium, with 1% dark grains. Sand also occurs in better sorted thin zones or laminae without silt. Calcareous. Clay consolidates sediment. Argillaceous zones appear to have vague horizontal bedding and thin sandy laminae.

166-169: Silty argillaceous sand, silty claystone, and sandy siltstone (bottom to top), very pale brown to light red. Lower sand is very fine to coarse, subangular to subround; 1-2% dark grains. Upper part has very fine to medium sand, subangular to subround; about 1% dark grains in very fine sand to silt size. Sandy siltstone and claystone are thinly bedded to thinly laminar (about 1/16 inch) with a zone of possible ripple cross-laminae. No apparent bedding in sand. Calcareous in sand, slightly calcareous in claystone.

177-178: Sandstone, silty, red. Very fine to fine with laminae to medium grain size. Calcareous, fair induration; porous. Interlaminated downward with siltstone and claystone.

178-180: Siltstone and silty claystone, pale yellow. Interlaminated at about 1/16 to 3/8 inch scale. Includes thin laminae of sand with black (?)organic matter. Unit is similar to lower part of Gatuña type section.

182-187: Thin to very thin (1/16 to about ½ inch) laminae of claystone, siltstone to claystone, and very fine sandstone to siltstone or claystone. Many thin laminae grade upwards to claystone. Random thin laminae of white carbonate or sandy limestone (<3/8 inch). Several sandstone or sandy units show probable incipient ball and pillow soft sediment deformation. Color also interlaminated red and pale yellow.

193-196: Sand, loose, "orange". Fine to medium, subangular to well rounded, moderately well sorted. Dark grains about 1%, slightly finer size. Grains slightly coated.

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DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-1 *Location: ~1400fwl, 2600fnl* *Drilling Date: 05/29/92*

Depth	Lithology	Features	Grain Size (Cg Sd St Cl)	Description
200				
				202-204: Laminar claystone pieces and loose sand similar to interval above.
210				
				top of Dewey Lake Formation
				Cuttings: clasts of Dewey Lake Formation and Gatuña returned, less than ½ inch diameter. Drilling is harder from 213'.
				Total Depth: 368'.
220				
230				
370				

Cg Sd St Cl

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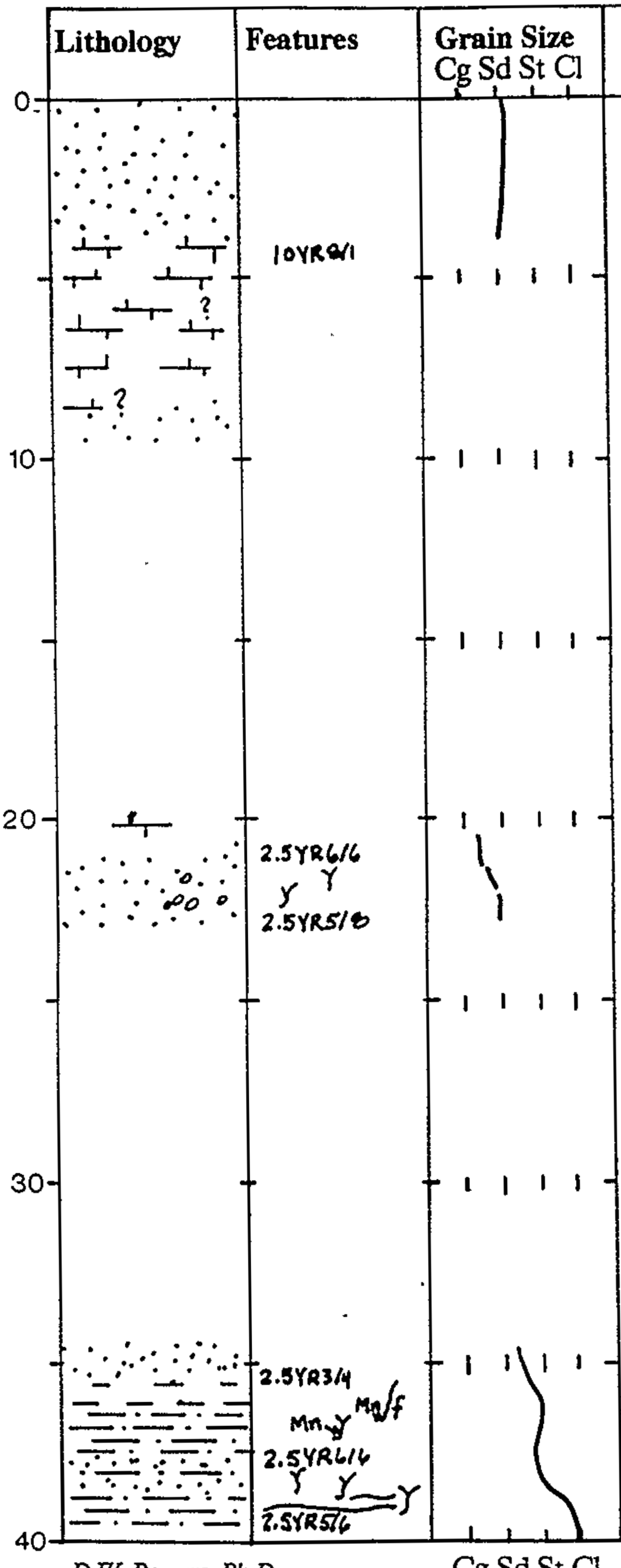
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-2 *Location: ~50fwl, 1300fnl* *Drilling Date: 05/30/92*



Description

0-4: Sand, silty, some clay. Unconsolidated pad fill and eolian dune sand. Very fine to medium sand, dark brown and moist.

top of Mescalero caliche
4-10: Limestone (caliche), sandy, white. Includes reddish brown sandstone of Gatuña Fm in sample and cutting. Samples show some evidence of laminar (V) phase as well as some brecciation (stage VI). Cuttings indicate same general lithology to 10'.

10-20 Cuttings: dark reddish brown sandstone; "McDonald Ranch member" of Gatuña Fm.

20-22: Sandstone, granular, light red to red. Sand is fine to very coarse with small granules of mainly siliceous material. Sandstone mottled with white carbonate. Abundant pores to 1/8 inch. Cylindrical, vertical concretion or rootcast at 22.5'. Less well indurated at 23-25 based on core sample and cuttings. No apparent bedding.

35-47: Sandstone, silty, and sandy siltstone, mainly red to light red with dark reddish brown at top. Sand mainly very fine to fine, coarser near top. Very calcareous, moderately well indurated. Poor bedding @ 39'; also zones with more sand. Rootcasts; MnO_2 mottling and on pores from rootcasts.

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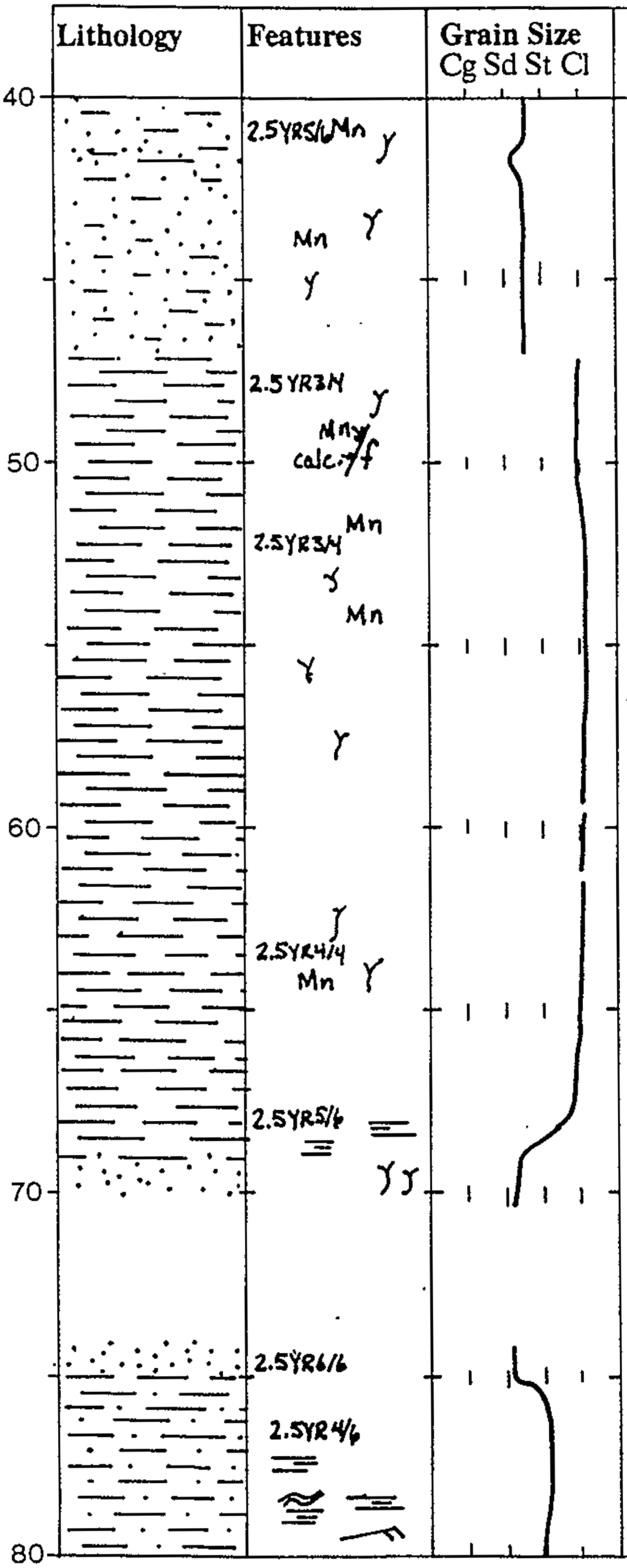
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-2 *Location: ~50fwl, 1300fnl* *Drilling Date: 05/31-06/01/92*



Description

47-68: Claystone, silty, slightly calcareous, dark reddish brown to reddish brown. Moderately well indurated. Thin bedding to laminae with some deformation and possible crossbedding in slightly sandier basal rock. Rootcasts common. MnO_2 mottling and on pores from rootcasts. Strong Mn stain on fractures 49-50' and strong subhorizontal slickensides.

68-75?: Sandstone to sand, light red; "orange sand". Sand is fine to medium, subround to well rounded, well sorted; < 1% dark grains. Not calcareous to slightly calcareous; friable to poorly indurated. Very little bedding. Rootcasts; possible burrow at top.

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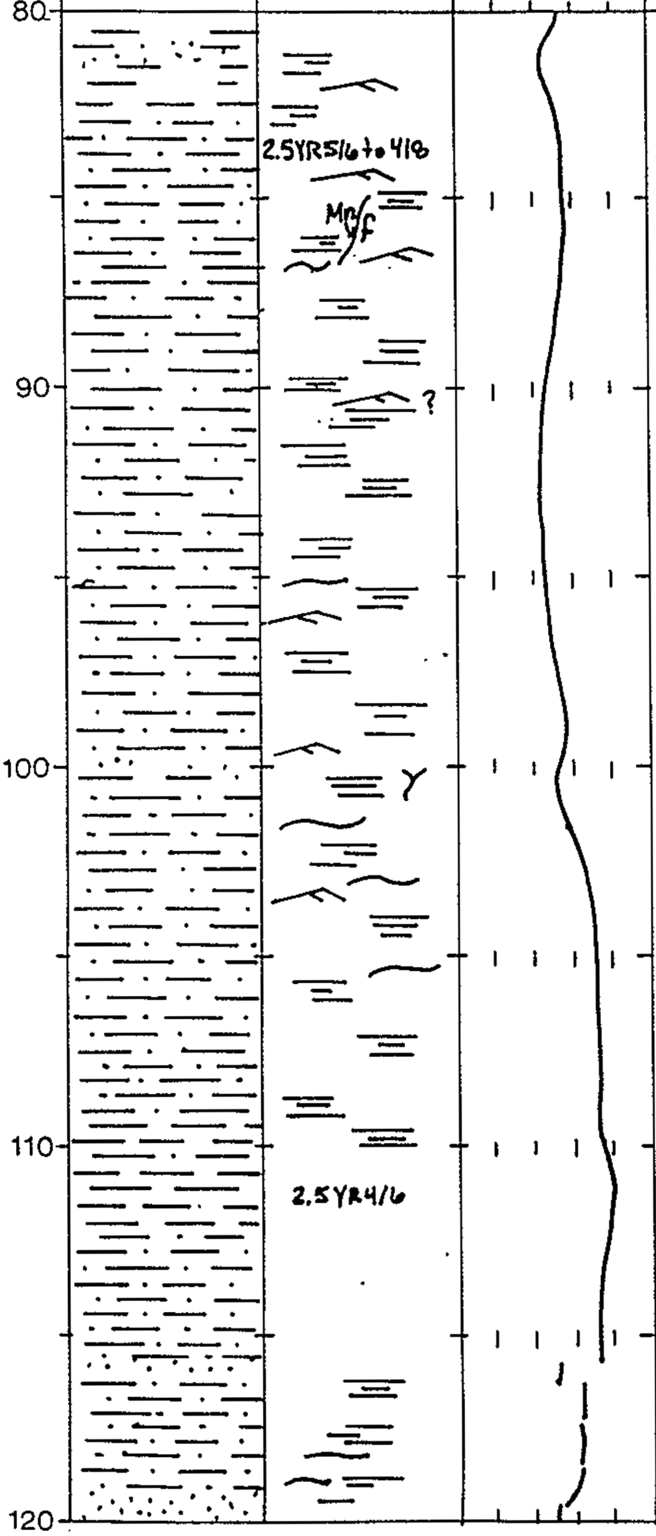
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-2 *Location: ~50fwl, 1300fnl* *Drilling Date: 06/01/92*

Lithology	Features	Grain Size Cg Sd St Cl	Description



75-125: Laminar to thinly bedded siltstone, claystone, and minor sandstone, red. Siltstone is argillaceous to sandy; claystone generally silty. Sandstone is generally very fine to fine grained, some medium sand in thin laminae. Ripple crossbedding; some wavy bedding or soft deformation. MnO_2 on fracture at 86' and horizontal surfaces at 92'. Burrow (1/8 inch wide) at 100.2'.

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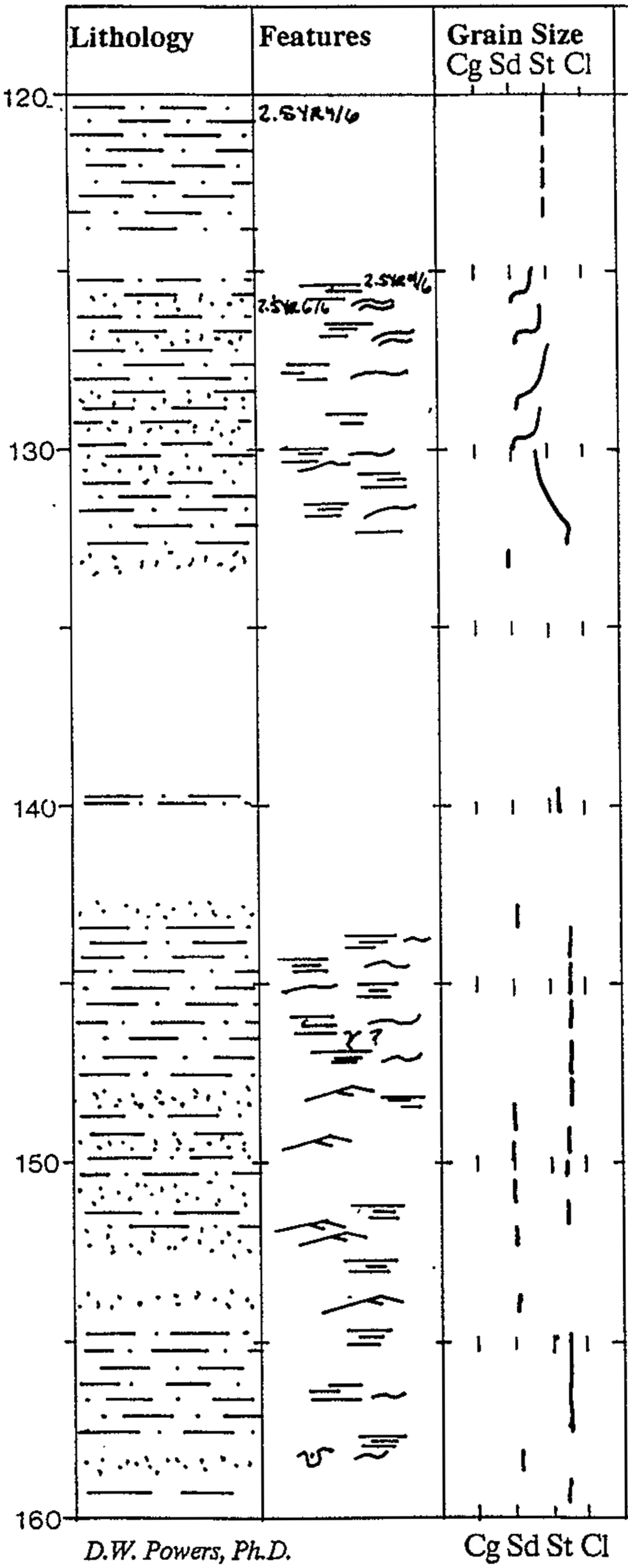
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-2 *Location: ~50fwl, 1300fnl* *Drilling Date: 06/01/92*



Description

125-133: Interbedded thin sandstone (about 1 inch thick) and sandy to argillaceous siltstone and silty claystone; red to light red (ss). Very calcareous, moderately well indurated. Sand is very fine to medium, mainly fine. Siltstone and claystone are laminated to very thinly laminated (½ to < 1/16 inch), with color and lithologic changes to 1/16 inch scale. Laminae show minor soft sediment deformation, slight cross-cutting. Loose sand (?"orange sand") at base of core above plug of claystone (from 140').

143-161: Interbedded sandstone (and sand), siltstone, and claystone, light red. Sand generally fine to coarse, rarely very coarse; subrounded to well rounded, moderately well sorted. Unit is calcareous, variably indurated. Middle of unit shows common small ripple cross-laminae; horizontal laminae common throughout. Some wavy bedding, possible ball and pillow (159'). Possible burrows (about 1/8 inch) @ 146-147'.

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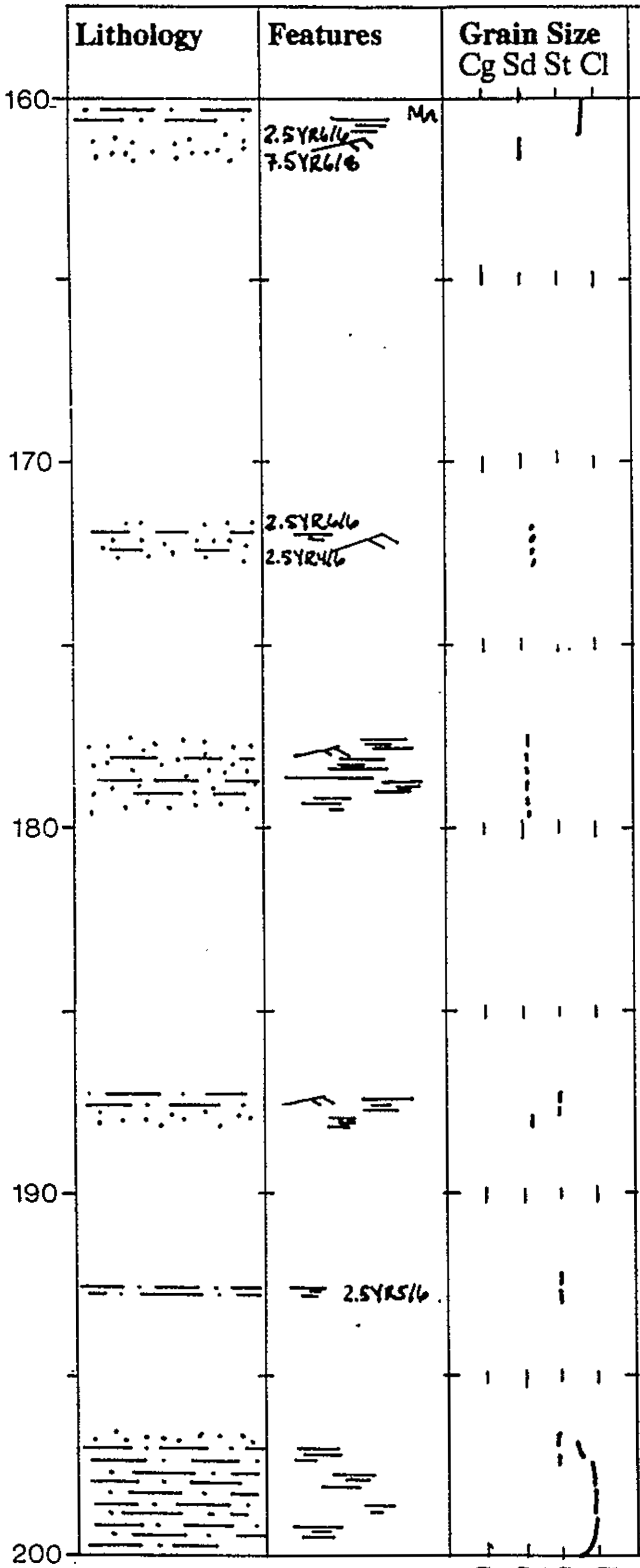
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-2 *Location: ~50fwl, 1300fnl* *Drilling Date: 06/01-02/92*



Description

161-162: Sandstone and sand, silty, reddish yellow. Sand very fine to medium, very porous. Poor to no induration. Some ripple crosslaminae.

172-173: Sandstone and sand interbedded with siltstone and silty claystone, red to light red (ss). Sand very fine to medium, rare coarse grains; subangular to well rounded; <1% dark grains. Thin beddng and probable ripple cross-laminae. Very porous.

177-180: Similar to 172-173; sand more abundant and horizontal planar bedding more dominant.

187-188: Similar to 172-173; 60-70% claystone. Sandstone includes yellow zones (10YR 7/8) as well as some black laminae bases. Minor cross-bedding.

192.5-193: Similar to 172-173; horizontal planar laminae dominate. Very slight soft sedimenent deformation.

197-206: Interbedded silty claystone, argillaceous siltstone, and sandstone; red with some pale olive sandstones. Claystone dominates (up to 75% of parts). Laminae generally thin (< 1/16 inch), horizontal. Some deformed laminae near base of sample (206').

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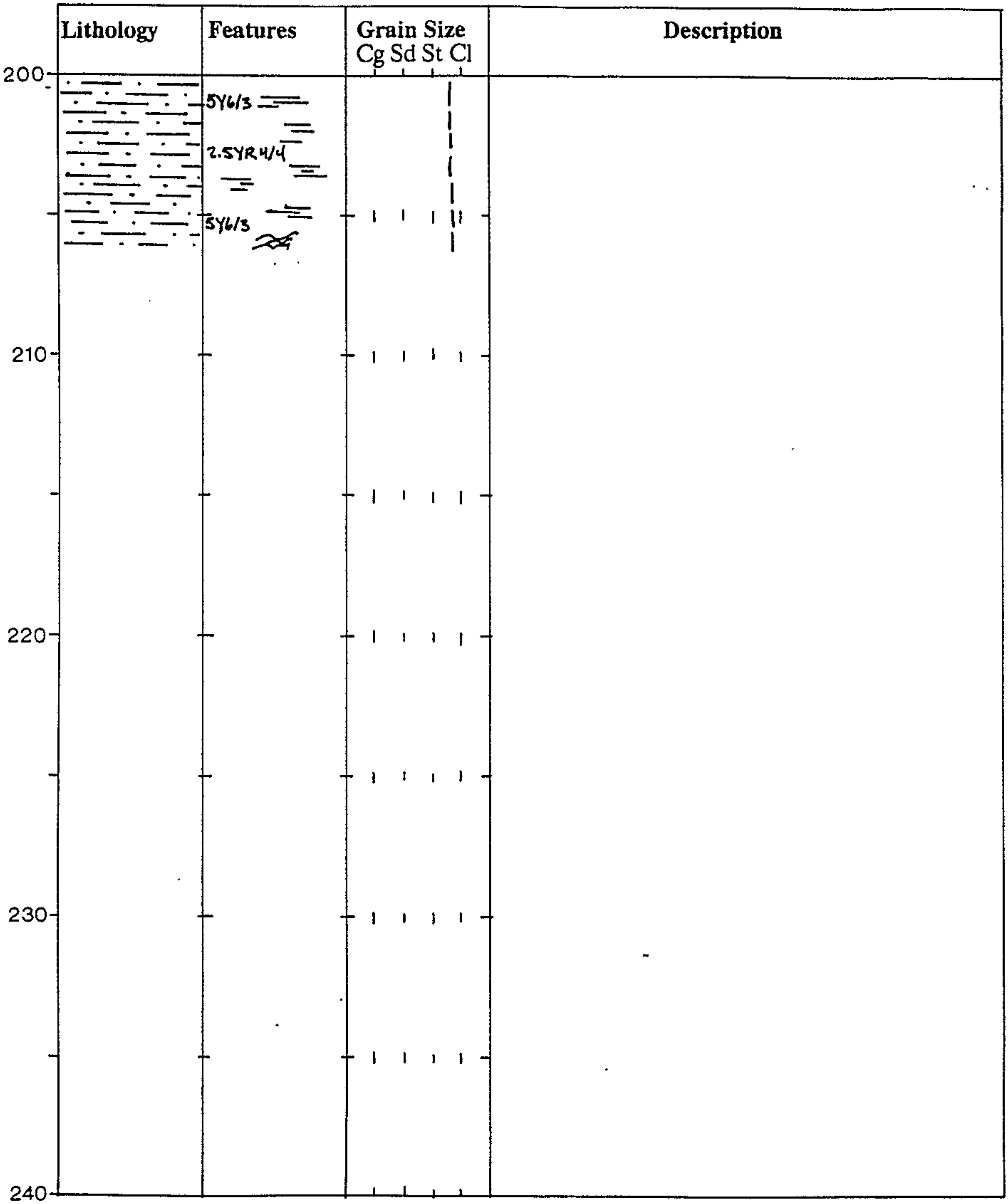
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-2   *Location: ~ 50fwl, 1300fnl*   *Drilling Date: 06/02-03/92*



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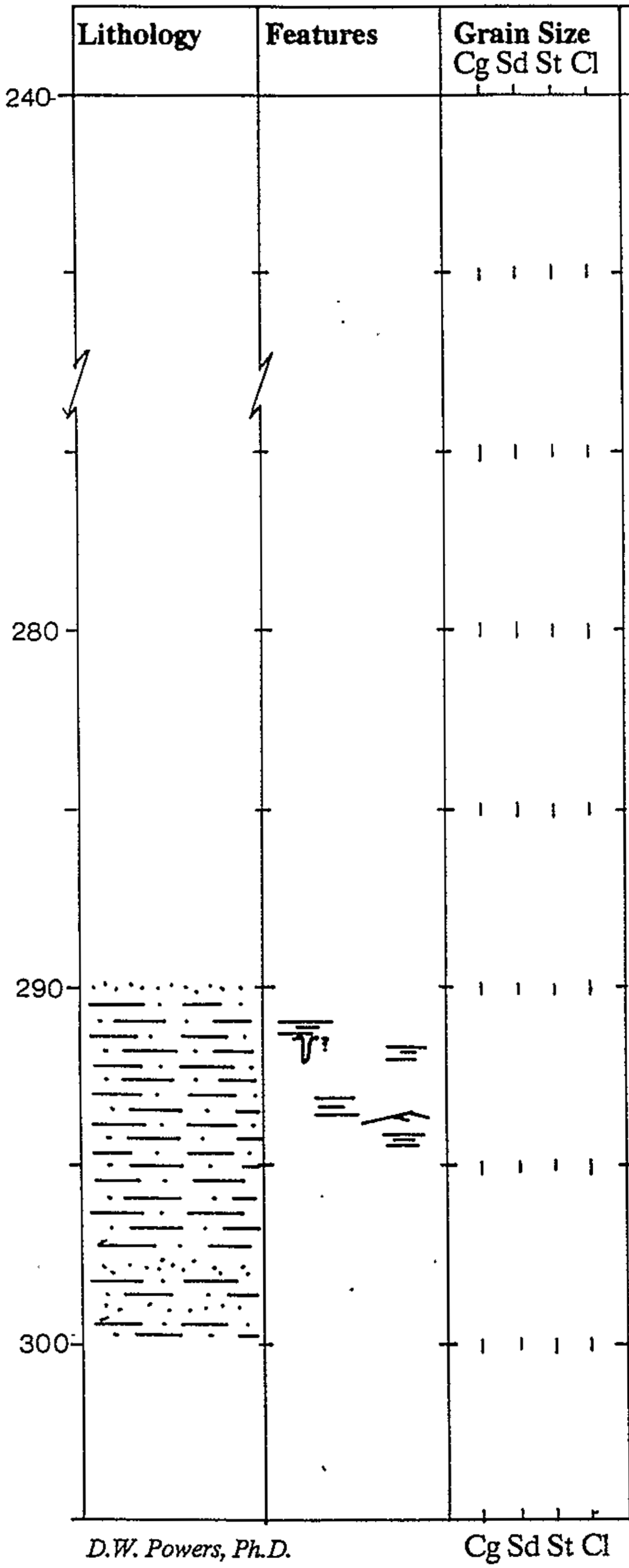
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-2 *Location: ~ 50fwl, 1300fnl* *Drilling Date: 06/04&09/92*



Description

top Dewey Lake Formation

Siltstone, argillaceous, slightly sandy, red with greenish (5Y 7/3: pale yellow) reduction spots and zones. Thin bedding to thin laminae, slight cross-cutting relationships. Possible desiccation cracks at 291'. Bedding included 15-20°. Thin calcareous sandstone at top (290').

T.D. 300 ft.

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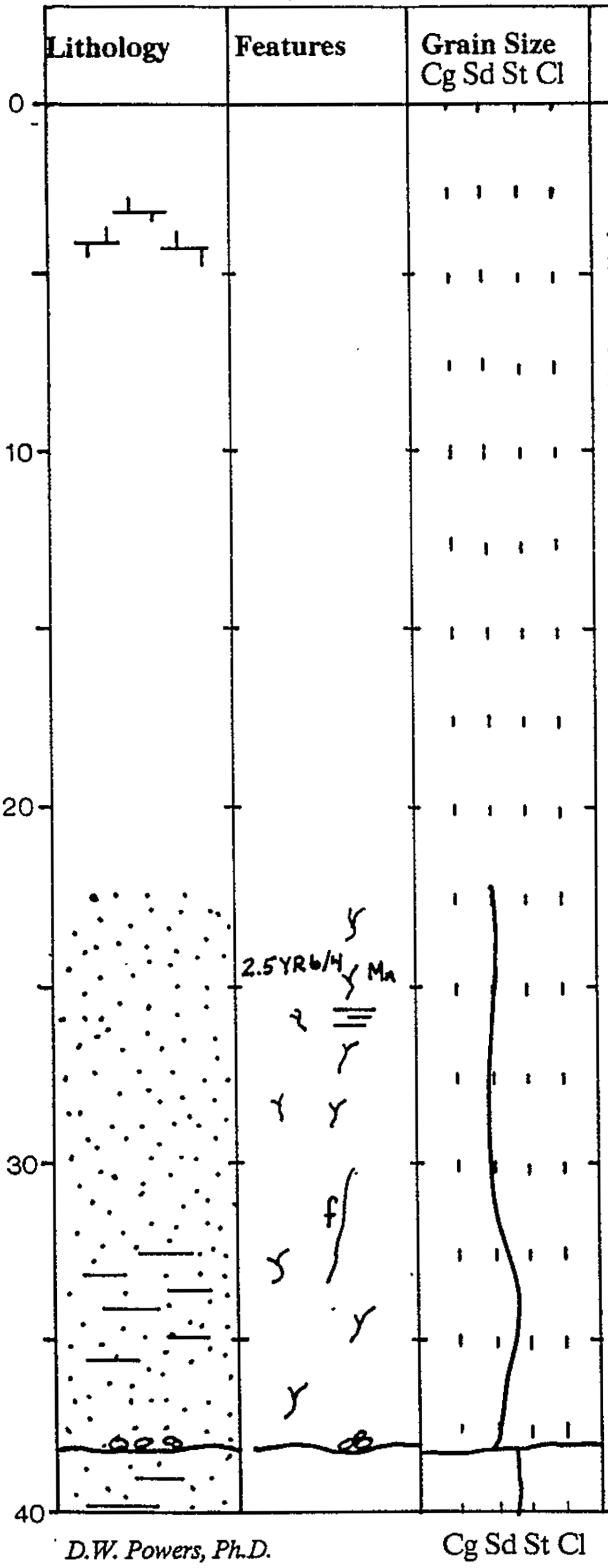
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-3 *Location: ~1300fwl, 50fnl* *Drilling Date: 06/11/92*



Description

4-5: Limestone. Mescalero caliche. Very poor recovery.

Cuttings: brown siltstone and sandstone, with carbonate cement and some granules. "McDonald Ranch member" of Gatuña Fm.

23-28: Sandstone, light reddish brown. Basal coarser unit with granules and pebbles over sharp basal contact. Unit is very porous, with intense bioturbation from rootlets ranging from very fine to about 1/8 inch diameter. Some evidence of horizontal bedding @ 26', but bioturbation has destroyed most. White carbonate lightly coats bioturbation. Slight fining upward in lower part.

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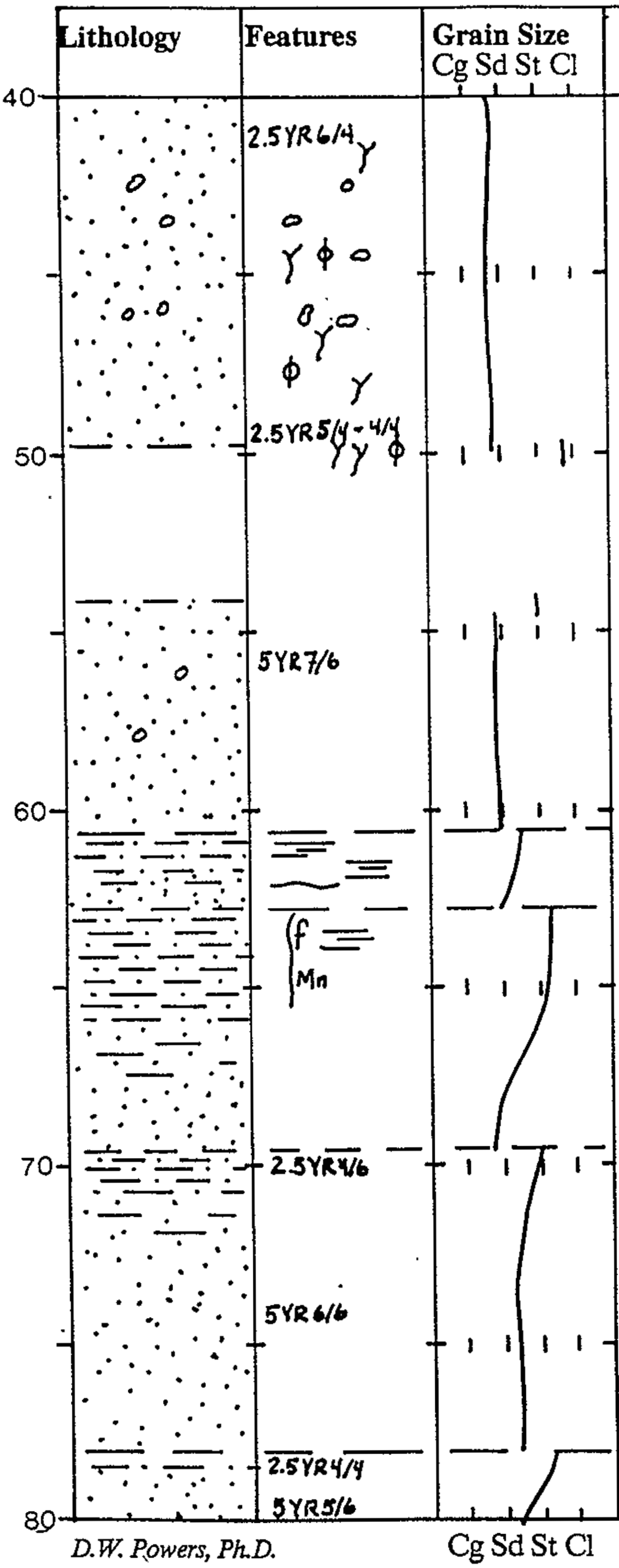
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-3 *Location: ~1300fwl, 50fnl* *Drilling Date: 06/11/92*



Description

38-50: Sandstone, light reddish brown. Mainly fine to coarse sand, subround to well rounded, < 1% dark grains; isolated white calcareous sandstone intraclasts to about ½ inch diameter. Some possible calcarous nodules in lower half. Narrow (< 1/16 inch) porosity due to rootcasts throughout. Poorly to moderately well indurated, some noncalcareous zones.

54-61: Sandstone, reddish yellow. Mainly fine to coarse, with a few granules; subrounded to rounded, < 1% dark grains. Small (< 1/16 inch) white calcareous spots. Poorly indurated, very porous, generally noncalcareous. Sandstone appears unbedded.

61-69: Sandstone to argillaceous siltstone or silty claystone in two fining upward cycles. Sand is generally fine to coarse, subround to rounded, about 1-2% dark grains. Sandstone is poor to moderately well indurated. No sedimentary structures in sand. Siltstone and claystones show laminae to thin bedding. Mn stain on subvertical fracture surface at 63-65 at top of lower fining upward cycle.

69-78: Sandstone, reddish yellow, with minor argillaceous and silty zone at top of fining upward unit. Sandstone is structureless, porous, fair to moderately indurated. Sand is fine to medium grain, subrounded to well rounded, about 1% dark grains.

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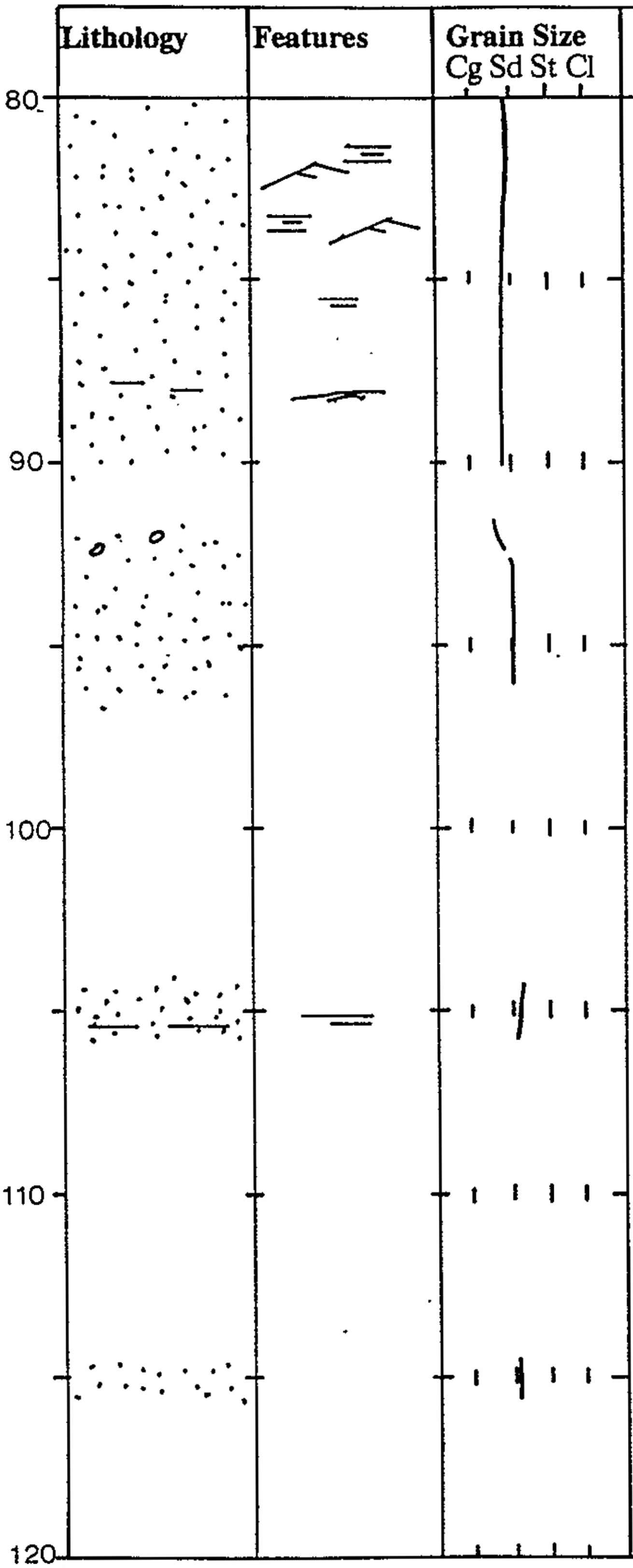
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-3 *Location: ~1300fwl, 50fnl* *Drilling Date: 06/11-12/92*



Description

78-90: Sandstone, similar to above. Some ripple crossbeds and horizontal laminar bedding.

92-96: Sandstone and sand, "orange", with some chert and carbonate granules @ top of recovered core. No bedding or other structures apparent. Mildly calcareous, poor to fair induration. Sand is very fine to medium, subrounded to well rounded, <1% dark grains. Moisture in core barrel from condensation of humidity from air flow.

104-106: As above; thin (1 inch) silty claystone near base of recovered section, flat contact with overlying sandstone.

114-116: Similar to 92-96, some coarse sand to granules.

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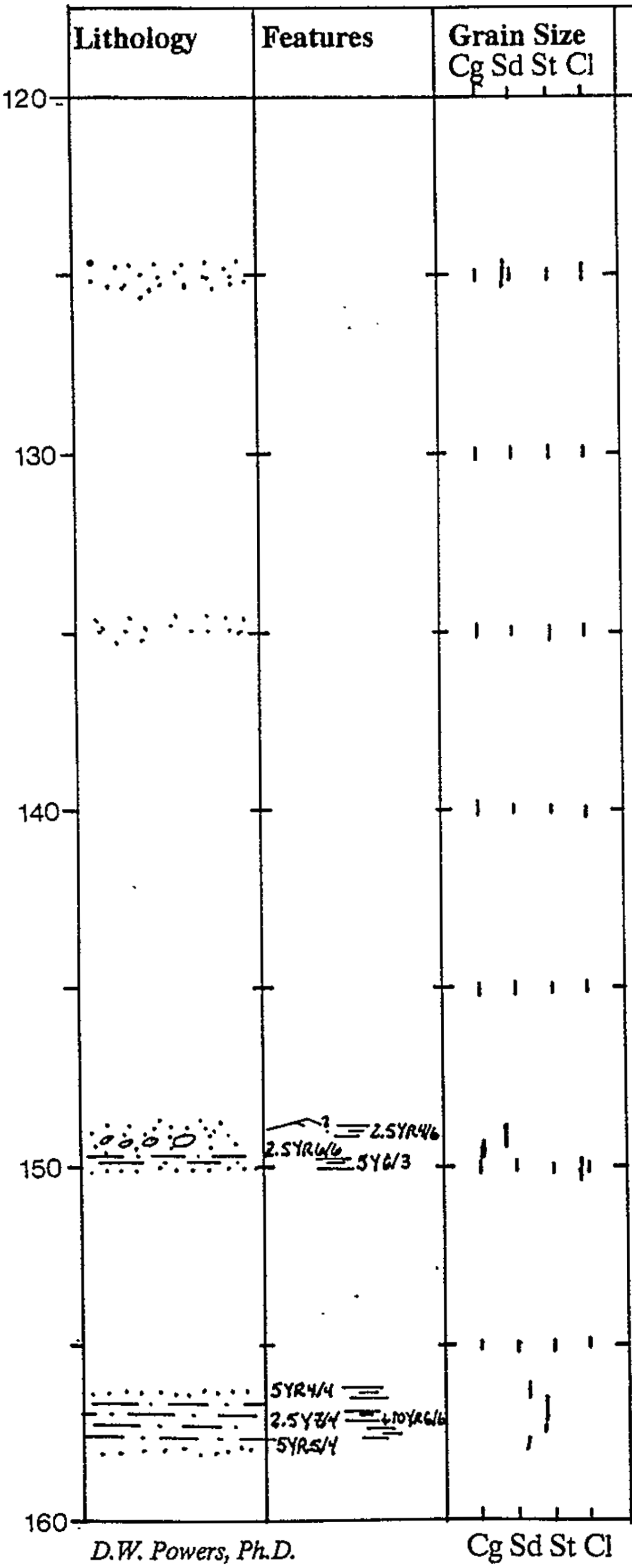
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-3 *Location: ~1300fwl, 50fnl* *Drilling Date: 06/12/92*



Description

125-126: Similar to 92-96; core moist from condensation.

135-136: Similar to 92-96.

149-150: Sandstone and sand (3 inches), red. Sand very fine to medium, about 1% dark grains. Thin laminar bedding and possible crosscutting relationships. Conglomerate, gravel (2 inches) with clasts to diameter of core barrel, includes chert, sandstone, Ogallala caliche clasts. Interbedded sandstone, siltstone, and silty claystone, pale olive, at base of recovered section. Similar to basal type Gatuña.

156-158: Thin laminae of fine sandstone, siltstone, and silty claystone, reddish brown, red, and pale yellow. Fair to poor induration. Similar to basal type Gatuña.

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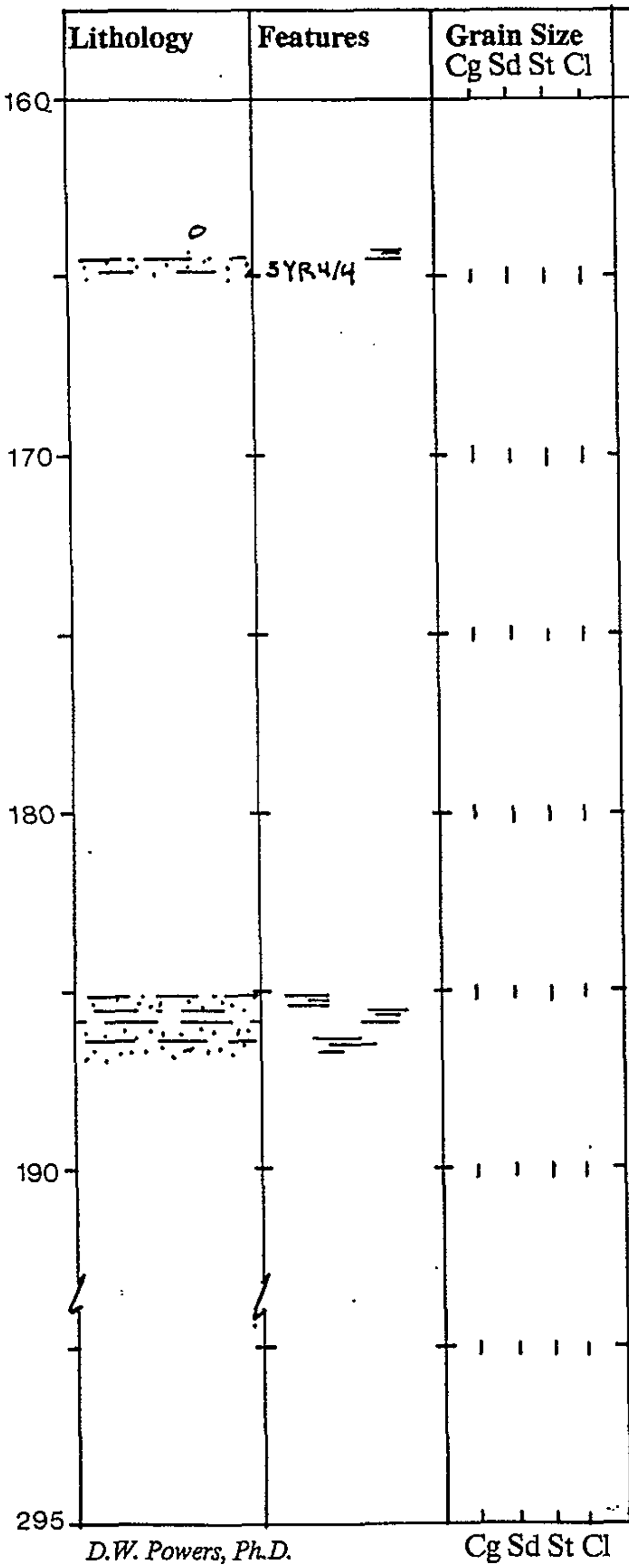
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-3 *Location: ~1300fwl, 50fnl* *Drilling Date: 06/12-13/92*



Description

163?: Recovered chert pebble from zone of hard drilling.

164-165: Thin laminae of sand, sandstone, siltstone, and silty claystone. Similar to 156-158, but without pale yellow colors. Sand very fine to fine, minor medium and rare granules; subround to rounded, about 1% dark grains.

185-187: Interbedded sandstone and silty claystone beds to 1 inch thick. Sand generally fine grained; some opaques concentrated at base of laminae, 1% upward. Includes very thin sands about 2 or 3 grain diameters thick within claystone. A few may be about 1 grain thick. Slight dip (about 2-5°).

292 Cuttings: Dewey Lake Fm.

T.D. 295

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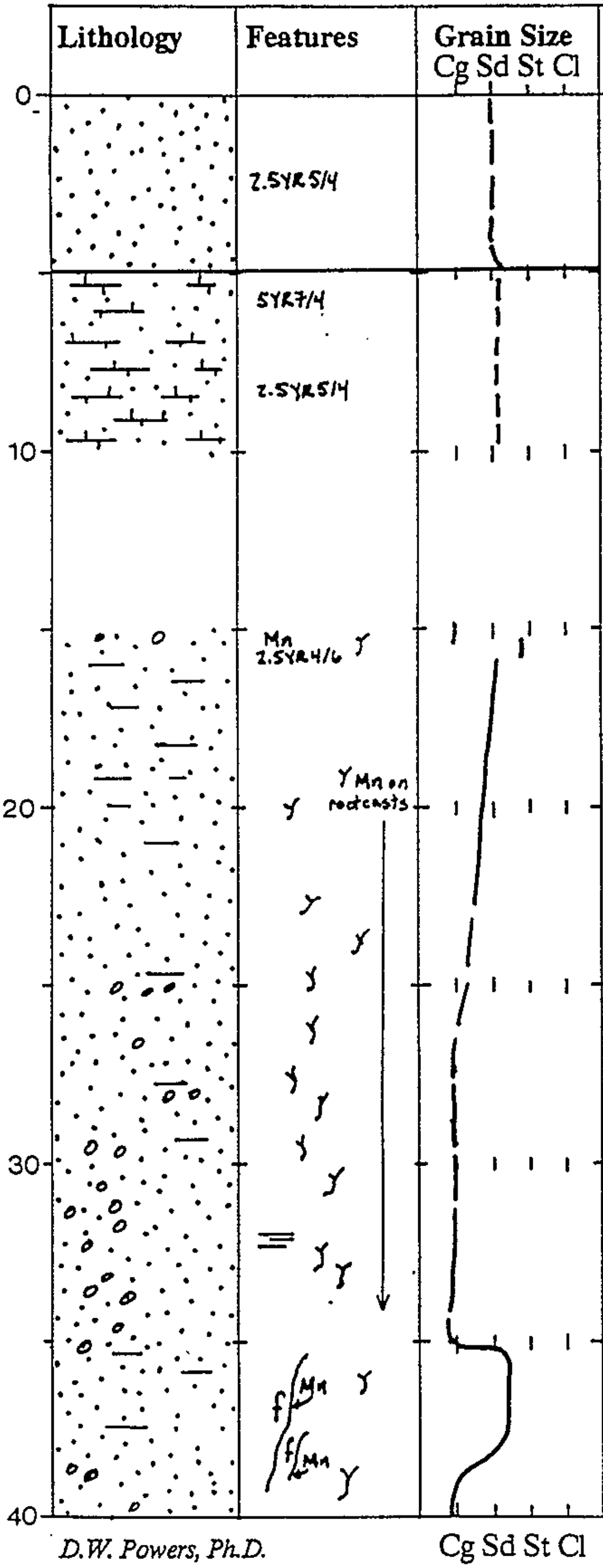
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-4 *Location: ~2600fwl, 1300fnl* *Drilling Date: 06/16/92*



Description

0-5: Sand, brown. No structure except for hint of laminar features in thin, dark brown (2.5YR 4/4: reddish brown) argillaceous zone just above caliche. Dune sand and pad fill.

top of Mescalero caliche.
Mescalero caliche. Moist, crumbly, with small (about ½ inch) pebbly caliche clasts showing modest recementing and vague laminar texture near top. Superimposed on Gatuña sediments from abuot 6' down.

Sand from cuttings.

Gatuña Formation

15: Chert pebbles, granules in loose sand.

16-17: Sandstone, silty, red. Sand is very fine to fine. MnO_2 stains; pores from root bioturbation.

17-34: Sandstone, conglomeratic in lower part, silty and argillaceous in upper part. Sand very fine to medium. Extensive bioturbation, MnO_2 stains, and zones of probable soil "brecciation". Calcareous material to 26' probably from Mescalero. Clasts from 25-35' include Gatuña, Permian ls, chert, Dewey Lake, and probably coarse grain sandstone from Santa Rosa. Some clasts are matrix supported.

34-37: Siltstone, sandy, argillaceous. Extensive fracturing, MnO_2 stains, bioturbation, clay illuviation along fractures.

38-41: Sandstone, siltstone, conglomeratic. Mainly framework supported; clasts from Dewey Lake and Gatuña.

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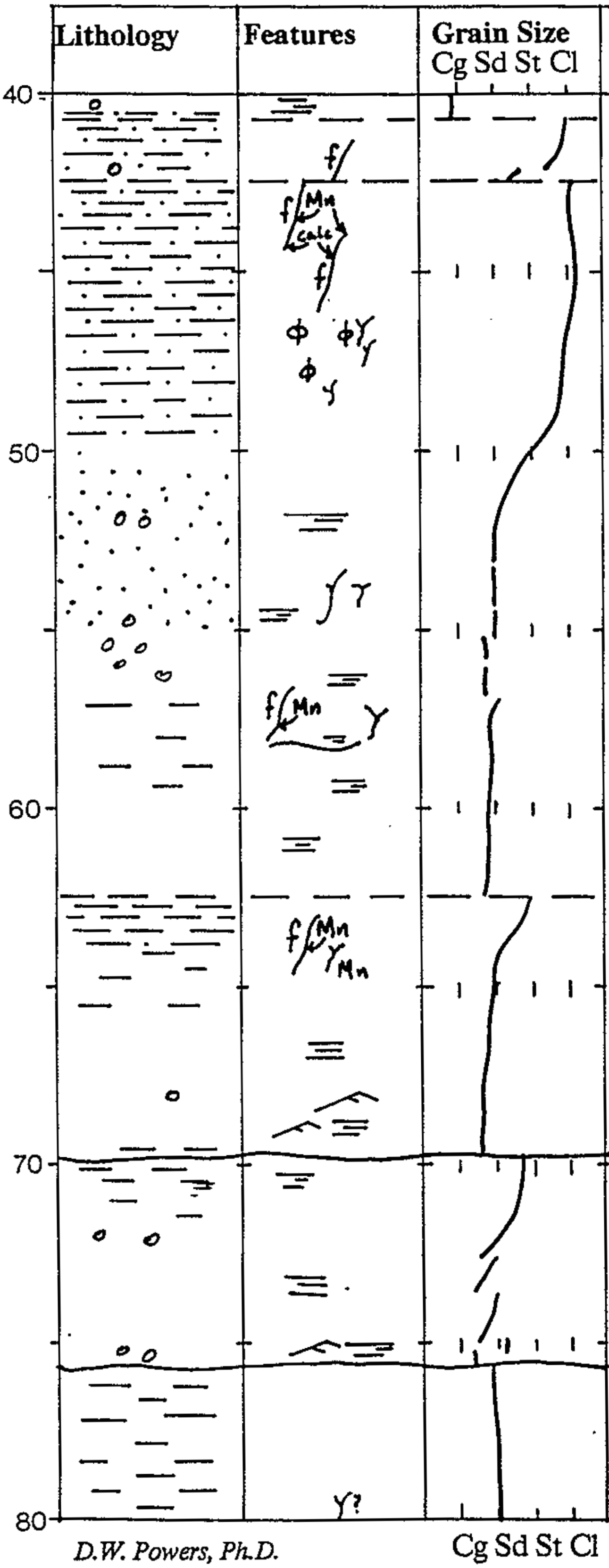
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-4 *Location: ~2600fwl, 1300fnl* *Drilling Date: 06/16/92*



Description

41-119': Series of mainly fining upward cycles of sandstone to siltstone or claystone. Sandstone is mainly very fine to medium grain with some coarse; granules and pebbles are scattered throughout this zone in coarser sandstone. Some sandstones are similar to "orange sands" at Sand Point and at Remuda Basin; are generally more poorly sorted in this borehole, with more siltstone and clay mixed. Bioturbation and fractures with MnO_2 stains are generally better developed in thicker claystone or argillaceous sections. Sandstones are noncalcareous to moderately calcareous, generally porous. Carbonate/calcareous nodules (e.g. 47-48') appear to have formed in root zones.
Laminar and ripple cross-bedding common within sandy to silty sections of zone.

Probable paleosol complex from 42-49'. Lesser paleosol at 62-65'.

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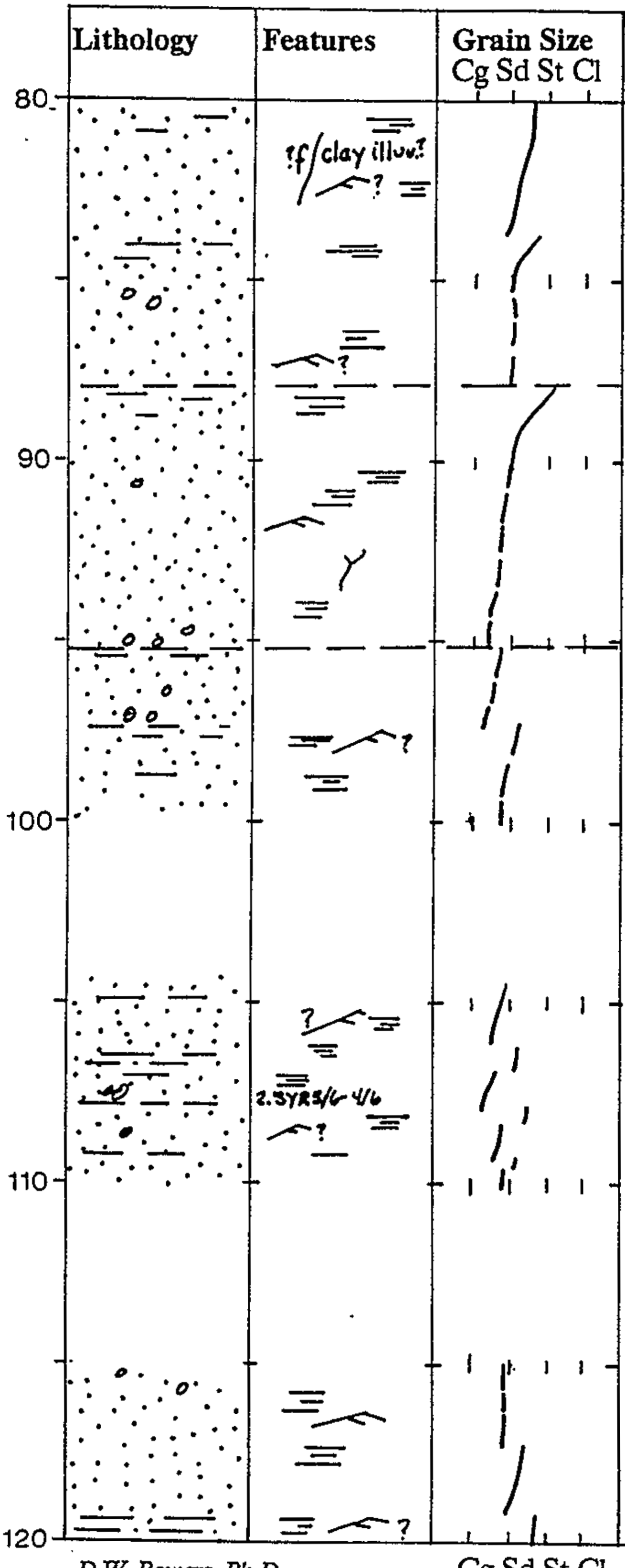
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-4 *Location: ~2600fwl, 1300fnl* *Drilling Date: 06/16/92*



Description

see above description.

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DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-4 *Location: ~2600fwl, 1300fnl* *Drilling Date: 06/16-17/92*

Depth	Lithology	Features	Grain Size (Cg Sd St Cl)	Description
120		2.5YR5/6: sand 2.5YR4/4: clay ?		119-128: Interbedded sandstone, siltstone, silty claystone, in generally fining upward sequence; red. Calcareous; poor to fair induration. Sand is very fine to medium, subrounded to well rounded, with about 1% dark grains. Silt and clay more abundant than in "orange sands". Thin laminae to possible ripples in some sandstones; others are featureless. Claystones and siltstones are generally finely laminar, with mild soft sediment deformation; slight bioturbation from root casts, slight color mottling. Calcareous. Contacts between sandstone and claystone or siltstone generally sharp and nearly flat.
130				
		2.5YR5/6 2.5YR4/4		135-140: Very similar to 119-128, dominated by sandstone in upper part, claystone lower. Claystone shows very fine laminae with some soft deformation and small sandstone pillowing. Minor MnO_2 along laminae from 138-139'. Laminae, wavy bedding, ripple cross-bedding.
140				
				148-150: Sand and sandstone, similar to "orange sands". Very moist in core barrel. Sand is fine to medium, well sorted and rounded, < 1% dark grains. Minor claystone similar to interval from 135-140.
150				
				160-161: Conglomerate, sandy. Dewey Lake and Gatuña clasts.
160				

Cg Sd St Cl

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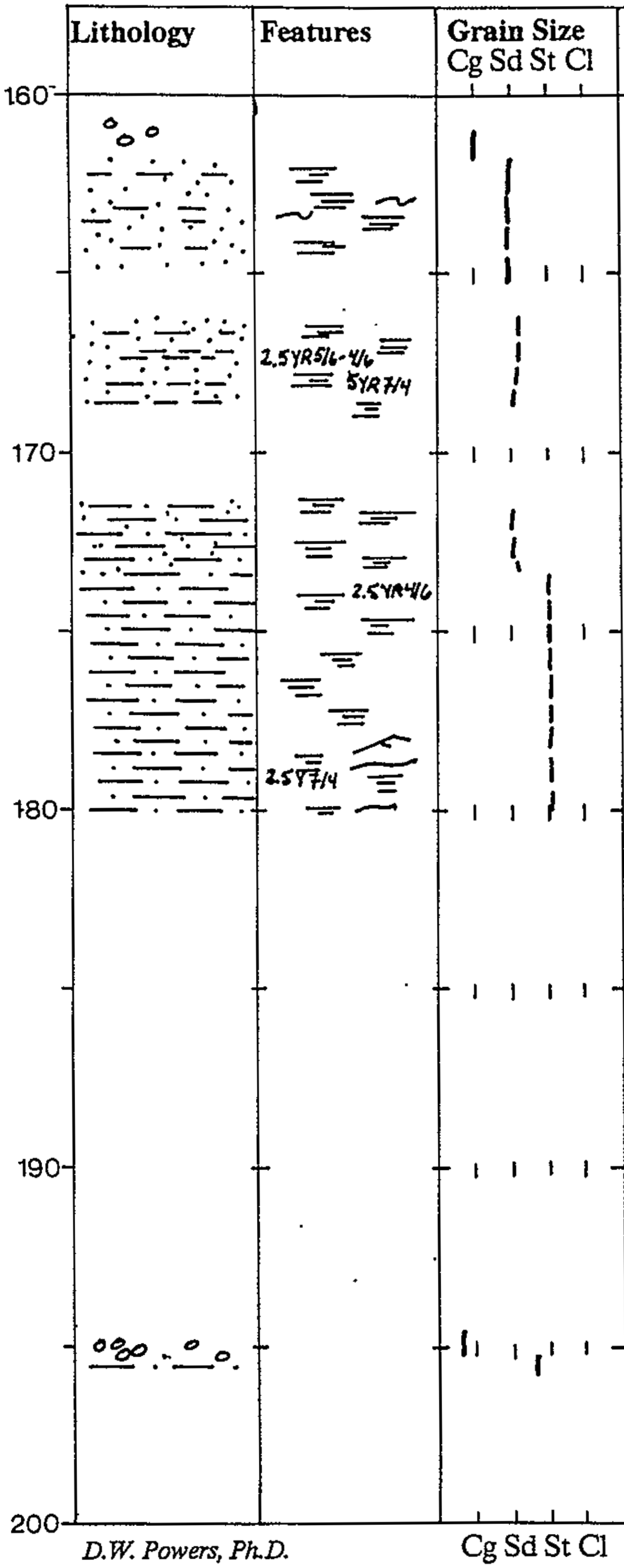
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-4 *Location: ~2600fwl, 1300fnl* *Drilling Date: 06/17/92*



Description

162-168: Sandstone and silty claystone, interlaminated to interbedded; red. Similar to intervals above to 119'. Some soft sediment deformation around sandstone. Some fine laminae in claystones are very flat and parallel. Sand is very fine to fine, some medium grain.

170-180: Sandstone, siltstone, and silty claystone interlaminated in multiple thin (about 1 inch thick) fining upwards units as well as multiple stacked sandstone and claystone interlaminae. Greenish gray mottling near 180'.

180-190: Some mud chunks and pebbles in cuttings and sticking to core barrel. Origin indeterminate.

195: Conglomerate clasts recovered. Some Dewey Lake and Gatuña clasts as large as the core barrel. Sand very poorly sorted. Some framework supported conglomerate. Recovered 8" of interlaminated sandstone and siltstone or claystone similar to interval from 170-180'.

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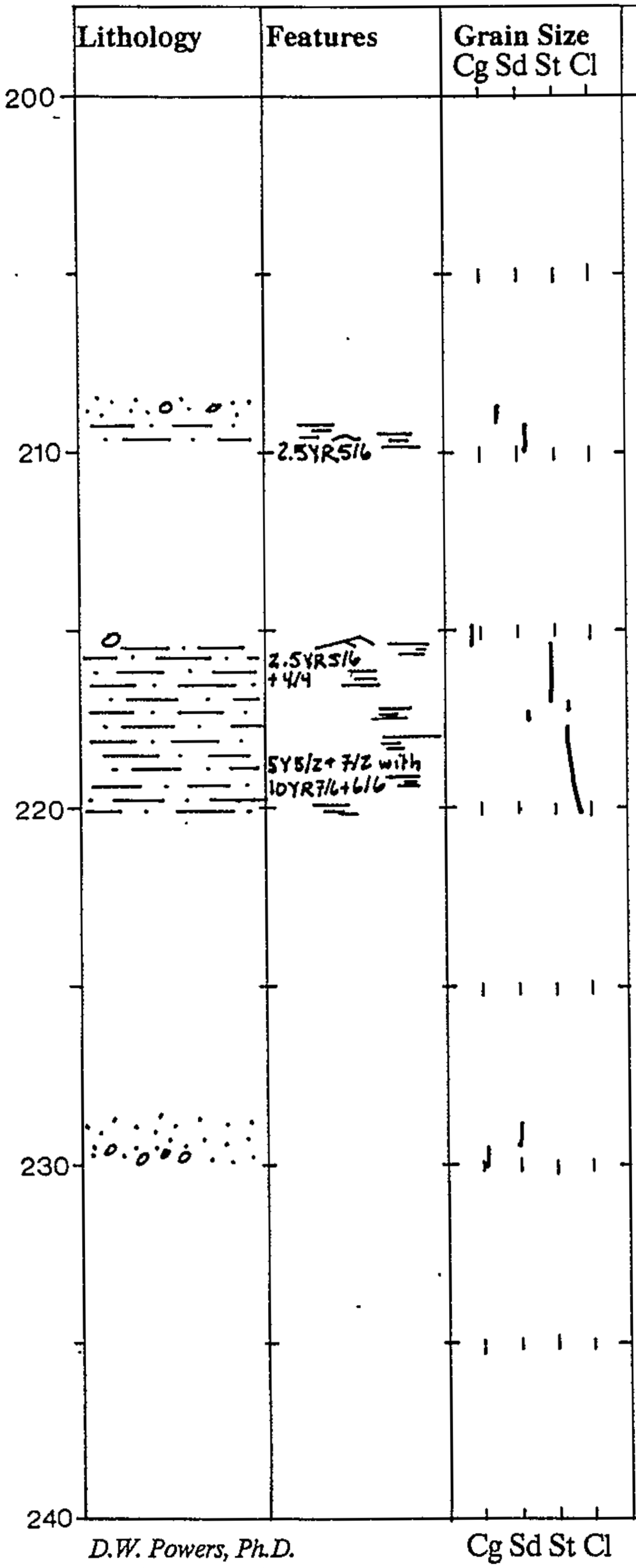
DRILLHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP G/H-4 *Location: ~2600fwl, 1300fnl* *Drilling Date: 06/17/92*



Description

208-210: Sandstone, granular, with possible Dewey Lake clasts; red. Sand is fine to coarse, subround to well rounded; < 1% dark grains. Siltstone and silty claystone interbedded with fine sandstone. Fine laminae < ½ inch. Some fining upward sequences, mostly sharp contacts and no grading. Samples very moist.

215: Clast of Dewey Lake as large as core barrel.
215-217: Siltstone, interlaminated with very fine grained sandstone and argillaceous zones at scales from < ½ inch to about 1/8 inch. Some fining upwards, mostly interlaminated with sharp contacts. Bedding dips about 5°.

217-220: Similar to above, increased clay content. Color change to gray is most obvious change. Clay at 220 is very sticky and slightly expandable. Laminae show slight deformation, are inclined about 5°. Some possible tiny ripples.

229-230: Conglomeratic sandstone.

T.D. 230 ft.

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APPENDIX 5

Borehole Drilling Plan,

Alternate to State Regulations for

Sand Point Characterization

The attached plan, dated August 18, 1992, was forwarded to the Environment Department on August 21, 1992, by JOAB, Inc.

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Environmental Geology
Evaporite Geology
Frontier Sulfur

08/18/92

Borehole Drilling Plan for Sand Point Site Characterization

Section 202 of the New Mexico Solid Waste Management Regulations (1991) describes additional requirements for permits for landfills, including a plan for boreholes to characterize the geology under the site to depths at least 100 ft below the deepest proposed fill area. Guidelines within the regulations suggest the number of boreholes to be drilled depending on the size of the landfill site. Section 202 also provides for alternate plans to be submitted to the Environment Department for approval. This alternate plan is based on current knowledge of the Sand Point site obtained during preliminary site investigations and is submitted for approval by the Environment Department.

General Site Description

The Sand Point site under investigation consists of the northwest quarter of section 11, T.21S., R.28E., in Eddy County, New Mexico. The site is approximately 160 acres in size. Buffer zones are planned around the margin of the site, enabling development of approximately 90 to 100 acres for use as a landfill.

General Background Geology and Hydrology

From basic background information and preliminary site characterization, including drilling (Figure 1), the geology and hydrology basics are established and have been summarized here. Recent drilling at the site involved four drillholes at separate locations and a supplementary drillhole at one of the original locations to establish a piezometer.

Four drillholes at the site established as piezometers show ground water more than 100 ft below the maximum excavation depth for a landfill. The shallowest ground water is along the southern part of the site, where piezometer G/H-1A shows a water level about 170 ft below the ground surface. As of August 6, relative elevations of groundwater in the four piezometers (Figure 2) could be interpreted as indicating a general northeastward groundwater flow. *These interpretations should be treated with some caution, though the evidence indicates that these ground water levels have reached near equilibrium.* The same figure shows ground water elevations measured July 2, July 21, and August 6, indicating relatively small changes over a period of nearly three weeks. Further changes are also expected to be small (generally < 1 ft).

More accurate ground water gradients may be established when sampling and testing of ground water chemistry of the piezometer boreholes provides possible density corrections. The ground water chemistry may also provide evidence of possible flow paths and of areas which may have longer rock/water interactions (residence time).

Drilling at these four locations (G/H-1 and 1A, -2, -3, and -4) shows similar geology: eolian sand (and pad fill) at the surface, a few feet of Mescalero caliche, and at least 200 ft of the Tertiary age Gatuña Formation. The first three drillholes (G/H-1, -2, and -3) were continued to the Permian Dewey Lake Formation, and G/H-1 was drilled an additional 155 ft in Dewey Lake before being abandoned and plugged. These units are commonly known in southeastern New Mexico; they vary in thickness depending on the degree of erosion, local depositional environments, and earlier subsidence due to regional processes of salt dissolution.

The site is acceptable for several other geological criteria. There is no evidence of faulting at the site based on surface geology, drilling, or broader regional geology (e.g., Powers and others, 1978). The surface of the site and immediate surroundings does not indicate karst is active or has existed, though regional dissolution of the upper Salado Formation does occur (e.g., Bachman, 1980) and likely caused some local subsidence prior to the deposition of the Gatuña Formation. Minor topographic closures around the northwest corner of the site are due to sand dune configurations and adjacent blowouts. There is no known evidence of active dissolution at the site. There is also no evidence of an alluvial fan at the site. The location is outside the Known Potash Leasing Area and is several miles from the nearest underground mine workings. None of these geologically related criteria exclude the Sand Point site.

Boreholes to develop geological data within the site area will generally be approximately 140 ft in depth and are expected to encounter eolian sand, Mescalero caliche, and Gatuña Formation in that interval. There is a slight possibility that boreholes could encounter the Dewey Lake in the southeastern part of the quarter section, but the Gatuña has been at least 200 ft thick in four holes drilled to date.

The Gatuña Formation is predominantly a fluvial unit with channel sandstones and conglomerates, floodplain siltstones and claystones, paleosols and other evidence of exposure, well sorted unconsolidated sand interpreted as probable eolian deposits, and less common subaqueous gypsum and laminar claystone/siltstone which may indicate shallow flooded areas or playas. These subaqueous units are not known to be continuous enough to justify interpreting them as lacustrine deposits. They are highly likely, however, to impede or prevent local vertical fluid flow and recharge. The upper part of the Gatuña Formation commonly consists of sedimentation units with clasts in a mud matrix indicating probable mud flow or debris flow; these units are also commonly overprinted by soil features including rootcasts and illuviated clays and/ or manganese deposits along soil fractures. I have described the Gatuña Formation in outcrops from the type area in Clayton Basin to Pierce Canyon for work in progress for the WIPP project. The deposits at Sand Point do not differ lithologically with the exception that gypsum has not been found. Gypsum does not occur in most other outcrops of the Gatuña either. The proportions and positions of specific lithologies at Sand Point show ordinary heterogeneity of the Gatuña because the fluvial depositional environment is highly variable, and sediment was deposited in an area of variable topography. Boreholes located even 100 or 200 ft apart may well show considerable differences in lithology at a specific depth, in contrast to units like the Rustler Formation which can be correlated in detail over thousands of square miles.

Because the Gatuña Formation is inherently variable over short distances but shows the same range in lithologies over a larger area, the drilling plan proposed here limits the number of boreholes in the quarter section. Beyond a few boreholes, our knowledge of the geology will not be improved except as an academic exercise.

Basic Drilling Plan

The drilling plan proposed consists of five drillholes located near the corners and center of the landfill area within the quarter section (Figure 3). The drillholes may be drilled in any order.

Each borehole is expected to encounter a variable thickness of sand and soil, up to 10 to 20 ft of Mescalero caliche and underlying calichified Gatuña Formation, and Gatuña to the remaining depth of the borehole. The saturated zone encountered during current drilling is well below the depth of about 140 ft for these proposed boreholes.

It is proposed that these boreholes be drilled with continuous flight augurs with continuous sampling and/or split spoon samples to obtain and preserve an objective record of the geology. No fluids will be used during drilling unless necessary. Each borehole will be plugged to the surface with cement and abandoned after drilling of the borehole is completed.

For each borehole, a geologic log and description will be prepared based on core or cuttings. Depths will be related to a surveyed elevation point. The descriptions will include the following elements where they can be determined: rock type, contacts and sedimentary structures, fractures and other secondary structures, color (GSA rock color chart or Munsell Soil Color Chart), general lithification or compaction, evidence of moisture, and any additional and appropriate information. Based on experience in drilling during preliminary site characterization, the boreholes are expected to reveal mostly (if not entirely) rock unis below surficial sand; few units will be classified based on the Unified Soils Classification System. A graphic log will be produced for each borehole.

Based on current site information, groundwater should be well below total depth of each of these boreholes. I do not anticipate establishing any piezometers to supplement the four already established. Any encounter with groundwater, however, will be noted, reported, and further evaluated.

The preliminary design for the landfill incorporates a lining of engineered materials. Samples will be taken for possible testing to obtain moisture content, plasticity index, liquid limit, and sieve analysis. Samples will also be reserved for possible hydraulic conductivity tests. These tests will provide evidence of natural capacity to retard or prevent significant vertical fluid flow and recharge. All samples will be marked by location.

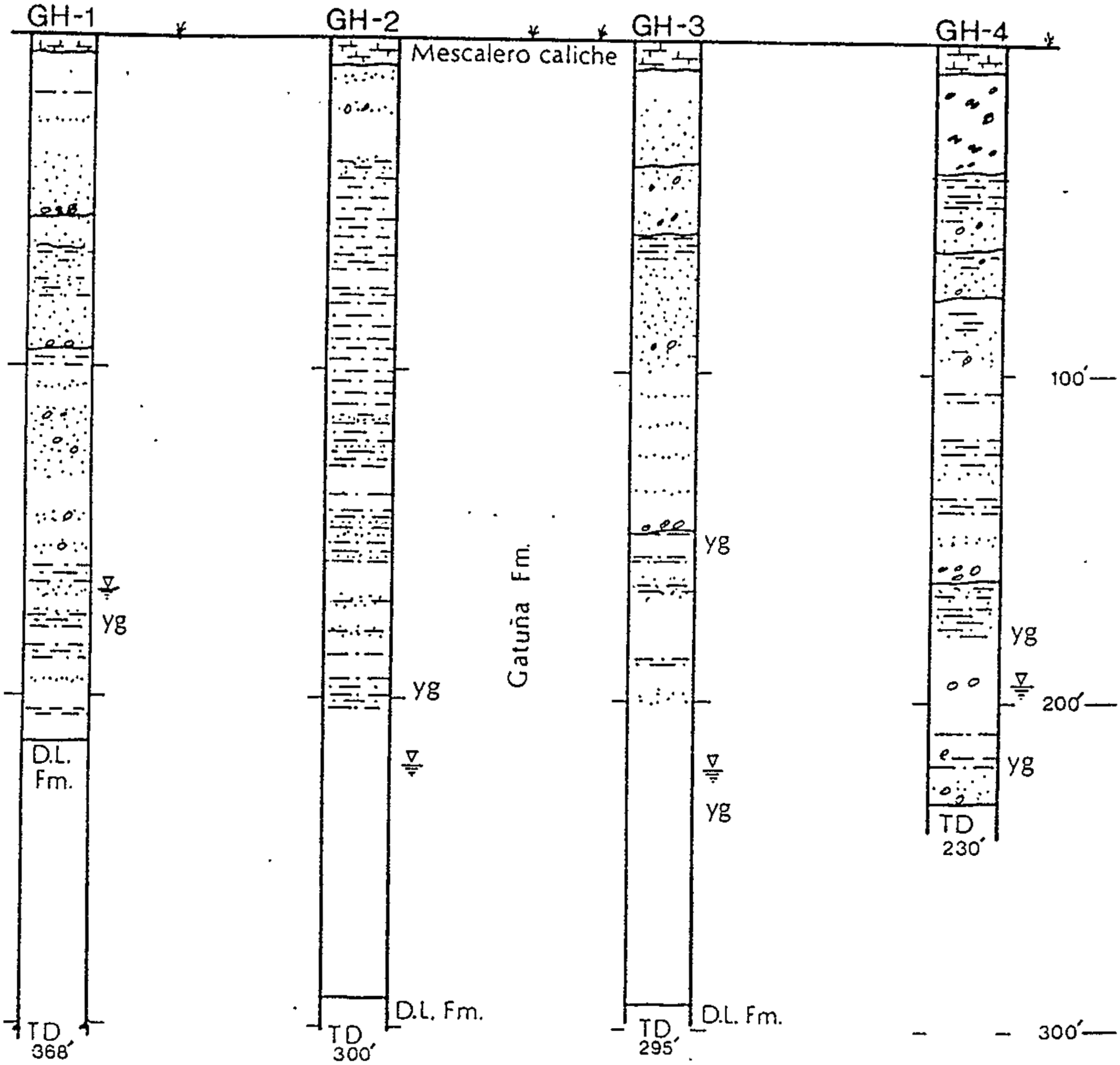
References Cited

Bachman, G.O., 1980, Regional geology and Cenozoic history of Pecos region, southeastern New Mexico: Open-File Report 80-1099, US Geological Survey, Denver, CO.

Powers, D.W., Lambert, S.J., Shaffer, S-E., Hill, L.R., and Weart, W.D., eds., 1978, Geological characterization report, Waste Isolation Pilot Plant (WIPP) site, southeastern New Mexico: SAND78-1596, v. I&II, Sandia National Laboratories, Albuquerque, NM.

Figure 1
General Geology and Stratigraphy
Drillholes for Preliminary Site Characterization
Sand Point Location

Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology drillhole. Graphic log is shown relative to depth. Symbols: yg = yellowish green siltstones, D.L. Fm. = Dewey Lake Fm., T.D. = total depth. Groundwater symbol (⊻) is at approximate depth. Lithologic symbols are standard; they are not shown where core not recovered.

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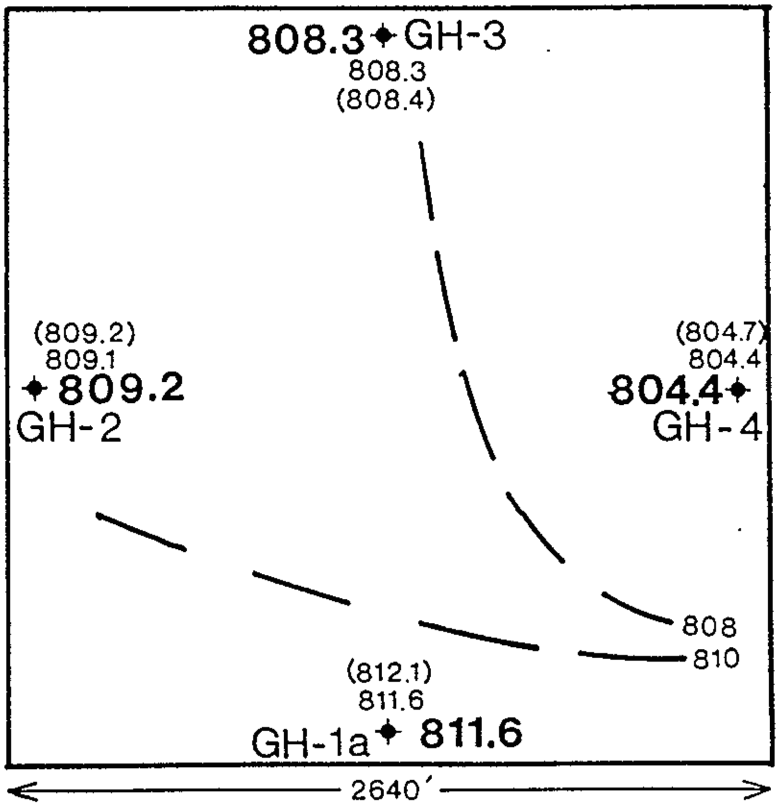
Consulting Geologist
08/18/92

Figure 2
Location Map of Drillholes for Preliminary Site Characterization and Preliminary Elevations (Arbitrary) of Groundwater Sand Point Location

Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology well completed. Elevation of groundwater is relative to point of turning (POT) established at center of section and assigned *an arbitrary elevation of 1000.00 ft.* Top of groundwater measured July 2 ( ), July 21, and August 6(bold), 1992, by Marvin Magee (JOAB, Inc.).

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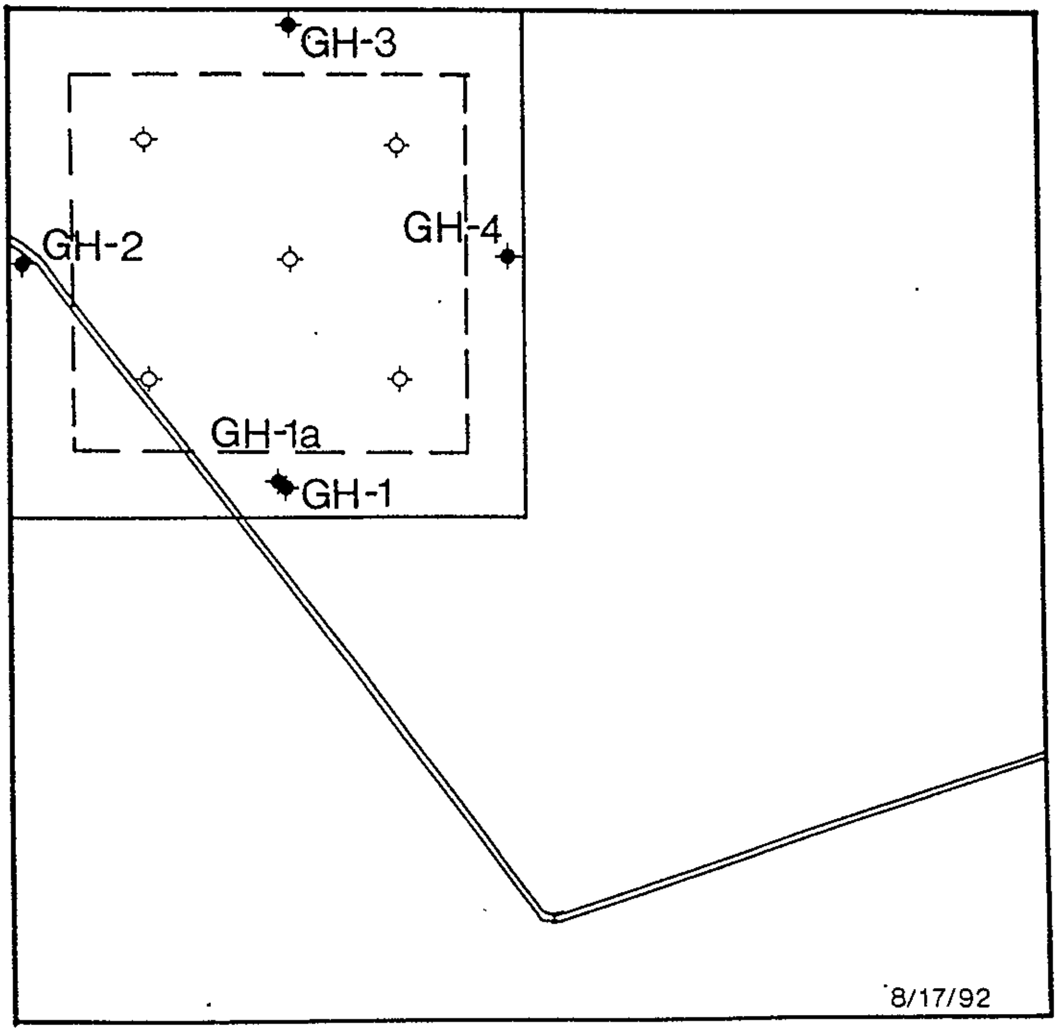
08/18/92

Figure 3
General Location Map of Drillholes for Preliminary Site Characterization and Borehole Drilling Plan Sand Point Location

Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology well completed or being drilled.

represents tentative location for boring within proposed landfill site.

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Summary
of
Borehole Drilling

for the
Sand Point Site, Eddy County, NM

Prepared for

JOAB, Inc.

P.O. Box 580

Sunland Park, NM 88063

by

Dennis W. Powers, Ph.D.

Consulting Geologist

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Anthony, TX 79821

11/12/92

revised 12/29/92

TABLE OF CONTENTS

ABSTRACT

Five boreholes were drilled in the northwest quarter of section 11, T.21S., R.28E., as part of the characterization of the Sand Point site for a possible landfill for Carlsbad and Eddy County. Borehole depths ranged from 140 to 150 ft. Drilling methods included auguring with "continuous" sampling, auguring with split spoon sampling at prescribed intervals, and "continuous" coring with a wireline retrieval system. Sample recovery within drilling intervals ranged from no recovery to 100 % recovery.

Each borehole penetrated surficial sediment/soil, Mescalero caliche, and part of the Gatuña Formation of probable Pleistocene age. The Mescalero ranges from very hard to somewhat soft; sampling indicates carbonate accumulation may be thicker in the southern boreholes. The Gatuña displays claystone, siltstone, and sandstone/sand units similar to those encountered during previous drilling. The rocks reflect fluvial and overbank environments and eolian sands in dune accumulations or reworked eolian sands. The upper part of the Gatuña also shows root bioturbation and MnO_2 staining on pores and fractures over intervals of about 40 ft; the interval is interpreted to have formed these features as a result of extended subaerial exposure and soil processes. The rocks in these boreholes are consistent with previous evidence developed from drilling the geology/hydrology (G/H) series boreholes.

As expected, no ground water was encountered during drilling of the B series boreholes. Ground water is expected to range from about 165 ft deep in the southern part of the site to about 220 ft deep in the northern part.

Evidence from the boreholes is consistent with the requirements for establishing a landfill. It is recommended that further minor geological site characterization be undertaken and completed and that final field evidence be obtained for planning and completing ground water monitoring wells at the site.

INTRODUCTION

Carlsbad and Eddy County, NM, are investigating a potential site at Sand Point in Eddy County for a new landfill. The site, located in the northwest quarter of section 11, T.21S., R.28E., was selected after three other sites and two other locations were examined (Powers, 1992). Five dillholes (SP G/H-1, 1A, 2, 3, and 4) were drilled at four perimeter locations around the Sand Point site to characterize the general site geology and hydrology (Powers, 1992). Based on the data obtained from the drilling and generally available data from various reports and sources, the Sand Point site appeared consistent with a landfill location. I recommended the Sand Point site be selected for further site characterization leading to a permit application (Powers, 1992).

A plan (Borehole Drilling Plan for Sand Point Site Characterization) (Appendix C; also Powers, 1992, Appendix 5) was prepared as an alternative to the basic requirements of State regulations for borehole drilling (see Section 202.A.8.c of the New Mexico Solid Waste Management Regulations of 1991). The plan called for five boreholes drilled to depths of about 140 feet to determine that the geology of the northwest quarter of section 11 is consistent with the geology found in the perimeter drillholes. After approval of the plan by the New Mexico Environment Department, the boreholes were drilled to obtain the basic geologic information.

The results of drilling the five boreholes under this alternate plan are reported in this document.

The five boreholes (SP B-1, -2, -3, -4, and -5) drilled during this program are all located in the northwest quarter of section 11 (Figure 1). Approximate locations were established in the Borehole Drilling Plan. Specific sites were located and marked during a site survey by Skyline Engineering (Table 1). Equipment was moved along lanes cleared for archeological sites, and each borehole was drilled in a practical location very near the surveyed point (Table 1).

Table 1

BOREHOLE LOCATIONS

Borehole	Survey pt location	Survey pt elevation	Drillhole location
SP B-1	*1319 fnl, 1322 fwl*	*3354 ft*	*about 22' NNE of pt*
SP B-2	*660 fnl, 1983 fwl*	*3343*	*about 15' W of pt*
SP B-3	*660 fnl, 661 fwl*	*3368*	*about 8' NE of pt*
SP B-4	*2063 fnl, 2067 fwl*	*3326*	*about 18 ' W of pt*
SP B-5	*1953 fnl, 688 fwl*	*3337*	*about 15' E of pt*

Survey point locations and elevations are derived from information provided to JOAB, Inc., by Skyline Engineering. Borehole elevations and locations are not precisely measured; ground elevations should be within 1 to 2 ft of the survey point elevation.

BACKGROUND GEOLOGY AND HYDROLOGY

The basic geology and hydrology have been presented in a separate document describing the preliminary characterization of the Sand Point site (Powers, 1992). The site geology anticipated for the borehole drilling included:

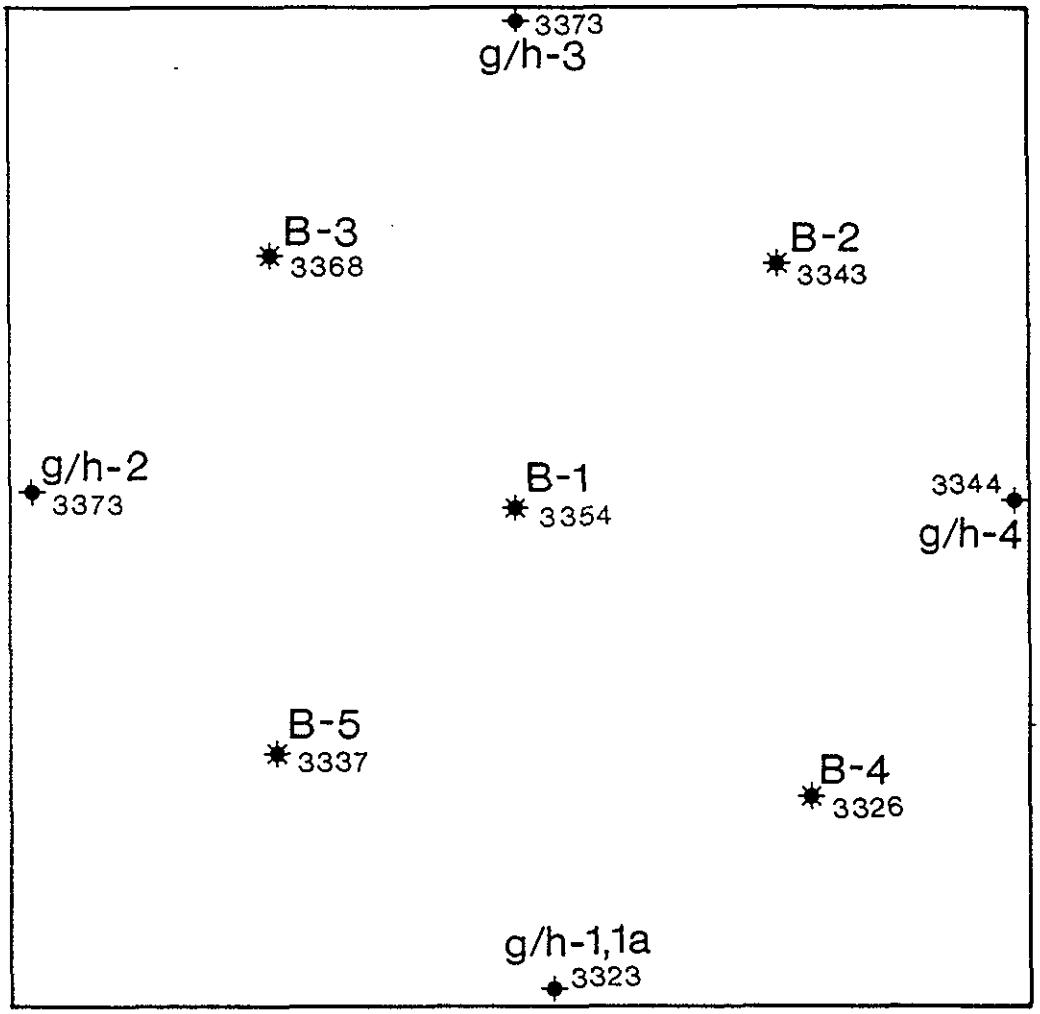
a thin cover of soil and/or eolian sand (a few inches to several ft in thickness),

Mescalero caliche (generally 3-6 ft thick),

Gatuña Formation.

Figure 1
Location of Drillholes and Boreholes
Site Characterization, Sand Point

Northwest ¼, Section 11, T.21S., R.28E.



B-# represents borehole drilled under this program. Smaller numbers represent ground surface elevation (in ft) near borehole location.

GH-# represents geology/hydrology drillhole. Smaller numbers represent the elevation of top of well shroud cap (in ft).

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11/12/92

The Gatuña consists of uncemented to well indurated sands, siltstones, and claystones deposited in a complex fluvial environment which developed soils on exposed surfaces and accumulated some wind-blown sands. Though the lithologic association for the Gatuña is similar for the drillholes at the site, the very detailed stacking of units is variable because of the complexity of the depositional environment.

Ground water levels in the original drilling at the site are at depths from about 165 to 220 ft below ground level, at elevations of about 3150 ft. These are broadly consistent with regional information (Powers, 1992), but the local apparent gradient, uncorrected for fluid density, is to the east or northeast. The broad regional gradient is suggested to be to the south. For these boreholes, drilling to anticipated total depths of 140 ft was not expected to encounter ground water.

METHODS

The basic methods employed during drilling included auguring with "continuous" sampling or with split spoon samples and coring with foam and liquid mud additives to water. (See Appendix A for borehole histories.) Though it was desirable to drill without fluids, if possible, the rocks did not permit auguring to total depth and coring was not possible without fluid. The decisions was made in the field, on each borehole, when auguring and sampling had reached effective limits and when coring was necessary. In boreholes B-2 and B-3, it was necessary to extend drilling slightly because sample recovery was negligible from the interval just above 140 ft depth.

Sergeant, Hauskins & Beckwith (SHB) drilled the boreholes with a CME 75, top head rotary drive rig. The upper part of each borehole was drilled with hollow stem flight augurs 6½ inches in diameter. For borehole B-1, clear plastic tubing inside a core barrel was used to acquire samples continuously. For the remaining boreholes, split spoon samples were acquired at the surface, 2.5 ft, 4.5 ft, and at intervals of 5 ft to "refusal." We generally persisted with split spoon samples until 50 to 100 hammer blows yielded very little progress (e.g., 1-3 inches). The depth for "refusal" ranged from 30 ft to 55 ft. The remainder of the borehole was drilled with a wireline core barrel (either 5 or 10 ft length) retrieving NQ size core. Both diamond and tungsten carbide tipped bits were used to determine the best drilling rate and recovery. Other details of drilling procedures and boring logs for boreholes B-1 through B-3 are presented in a report by SHB AGRA, Inc. (1992).

Sample recovery ranged from 0 to 100% in different intervals. Drilling rates were slowed because even foam and liquid mud additives did not always remove cuttings well. Both additives (QUIK-FOAM and EZ-MUD) are products of Baroid. The last two boreholes were drilled more rapidly, probably due in part to a different core bit designed by Longyear and acquired to complete this job.

Each borehole was grouted by SHB after the drilling program was completed.

Samples recovered in plastic tubes during auguring were measured and marked upon recovery. Split spoon samples were preserved in plastic bags marked for borehole number and interval. Core samples were measured and photographed after recovery. These samples were then placed in core boxes marked for drilling intervals and with markers separating coring intervals. Samples were moved temporarily to SHB offices in El Paso for checking of field determinations; the samples will be returned to storage in Eddy County through JOAB, Inc.

BOREHOLE GEOLOGIC INFORMATION

Each of the boreholes drilled during this project encountered similar geology (Figure 2; Appendix B). Each of the boreholes reached a total depth between 140 and

150 ft, most of which was within the Gatuña Formation. The surficial deposits included thin brownish gray soil or thicker eolian sand somewhat modified by modern soil processes.

Mescalero caliche

The Mescalero caliche, which underlies unlithified surficial deposits, ranges from a moderately soft unit to a very hard unit; the northern part of the site has harder caliche, nearer the surface. The caliche in the southern part of the site begins deeper, below sand of varying thickness, and it seems to be softer (less indurated). The thickness is commonly about 3 to 6 ft, though it is not well determined. The upper part of the Gatuña Formation is also calcareous from the same processes which resulted in the Mescalero caliche. It is possible the caliche in the southern part of the site did not undergo as lengthy a period of formation as on the northern part of the site or that it is more disseminated in the southern part by additional near-surface infiltration through the sand cover.

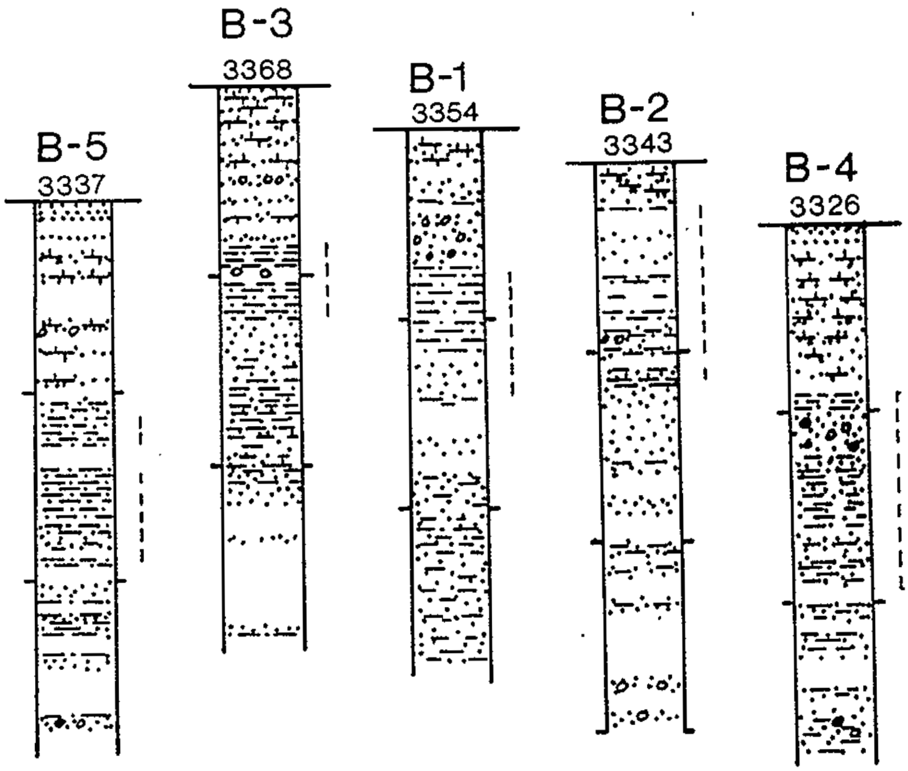
Gatuña Formation

Gatuña rocks encountered in the boreholes are similar to those described from the drillholes (G/H series) on the perimeter of the site. The lithologies ranged from conglomeratic or pebbly sandstones to claystones. Sandstone and siltstone predominate within the upper part of the Gatuña in these shallower boreholes.

Soft sands and sandstones were difficult to recover during coring of three of the boreholes, especially in the lower 40 to 50 ft. Many of the recovered sands and sandstones have been described as "orange sands" because of a characteristic light red (2.5YR 6/8) color when dry. The normal moist color of these sands and sandstones is red (2.5YR 5/8). These sands/sandstones have grains mostly fine to medium while

Figure 2
Generalized Geology of Boreholes for Site Characterization, Sand Point Location

Northwest ¼, Section 11, T.21S., R.28E.



Graphic log is shown relative to depth; side ticks represent 50 ft intervals. Lithologic symbols are standard; they are not shown where core was not recovered. Dashed lines represent interval of intensive bioturbation and MnO_2 staining indicating soil forming processes. Nearby ground surface elevation (in ft) from Skyline survey is below borehole identifier. Detailed logs are provided in Appendix B.

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ranging from very fine to medium or coarse. The grains are also generally subround to well rounded. About 1% of the grains are estimated to be opaque. Some units of "orange sand" show zones of probable accumulation of clay or carbonate. Sedimentary structures are rarely observed in recovered samples from "orange sands"; samples are commonly too soft to preserve structures, and bedding may be too subtle to recognize. Because of the grain sizes and rounding, the "orange sands" are interpreted as eolian and reworked eolian deposits. Clay or carbonate accumulated in basal zones of some of these sands by infiltration of meteoric water carrying clay minerals or solutes. The "orange sands" are quite similar to modern eolian sands on the surface of the Sand Point site.

Each of the boreholes encountered a zone of extensive bioturbation by roots and of MnO_2 accumulation along the root porosity and/or on surfaces of probable ped structures. This zone of bioturbation/Mn accumulation represents surfaces of weathering and soil formation; the zones are also interpreted here as representing a common period of exposure and weathering over the area of the site. The zone ranges from about 20 ft thick in B-3 to about 40 ft thick (B-2, -4, -5).

Within the bioturbation/Mn zone, small, near-vertical fracture surfaces are also common. These surfaces generally show Mn staining and some are also lightly coated with white carbonate. Slickensides have also been observed within this sequence. There is no observable displacement across either kind of feature. These fractures and slickensides are soil features, not due to tectonic processes.

Below the bioturbation/Mn zone, four of the boreholes encountered intervals of siltstone and sandstone with common thin bedding to laminae. The bedding is mostly flat and parallel; a few intervals display mild soft sediment deformation, probably from shear due to traction along the bed load of subsequent stream flow.

Discussion

The Gatuña encountered in the boreholes displays the same lithologies described from the perimeter drillholes (G/H series) (Powers, 1992). A review of the borehole basic data from the G/H series drillholes shows that the bioturbated/Mn zone is present in G/H-1, -2, and -4. Manganese oxide staining is less developed in G/H-3. This zone very probably represents a period during which the sediments across the site area were exposed for a sufficient time (or several times) to develop soil features. The zone may be useful over a larger area as possible means of correlation.

The sands/sandstones in the B series boreholes are also similar to those in the G/H series drillholes. The "orange sands" appear to have been deposited as eolian sands intermittently throughout deposition of the Gatuña at the site. Some of the sand was subaerially exposed long enough for clay to infiltrate and accumulate in the lower parts of the beds. Some bioturbation and some calcification also developed. Other sands/sandstones appear to be reworked; these show considerable components of fine to medium, well-rounded sand, but they also include some more angular and coarser grains. Still other sands are poorly sorted, have greater concentrations of opaque grains, and are subangular to subround. These latter sands/sandstones are interpreted to have been deposited by stream flow with little or no local eolian component.

The granule to pebble-sized grains are mainly from local sources, such as exposed Dewey Lake Formation. Some probable intraclasts of Gatuña were identified, indicating early consolidation before erosion. The most "exotic" clast is a coarser, grayish sandstone which was probably eroded from Triassic rocks to the northeast of the site.

Bedded to laminar deposits of the Gatuña appear to all be floodplain deposits. Bioturbation, manganese and carbonate accumulations, and fracturing are minor in these sections, indicating limited periods of subaerial exposure and soil development. There is some minor bedding and laminae in the bioturbation/Mn zone which may indicate these sediments were similar to the underlying bedded to laminar deposits. It is possible that the pedogenesis of the bioturbation/Mn zone was strong enough to obliterate most of the primary sedimentary structures.

The Gatuña Formation at the Sand Point site is dominated by low energy fluvial deposits and associated eolian deposits. Coarser clasts appear to be more common in the southeastern part of the site area and may reflect local higher relief to the southeast or east during deposition. The western part of the site seems to have somewhat more finer, bedded deposits from the floodplain.

There is no evidence observed from the drilling at the Sand Point site that vertical recharge is occurring over the site. The Gatuña includes zones which are relatively porous as well as zones which are relatively non-porous. The near-surface carbonate deposits of the Mescalero caliche, however, are a strong argument that surface infiltration is limited. Carbonate in samples taken at about 40 to 50 ft in B-4 and B-5 may indicate a somewhat greater depth of infiltration. These boreholes also have additional surface sand above the caliche, contributing to a greater apparent depth to carbonate. The argillaceous zones and the lack of continuous carbonate cementation of pores below the caliche are consistent with a lack of vertical recharge from site.

HYDROLOGICAL INFORMATION

There was no evidence during drilling that these boreholes encountered ground water. The G/H series drillholes indicate that ground water should be about 170 ft or more below the surface at each of the B series locations. The deepest drilling was 150 ft. No ground water was expected at these depths, and none was indicated.

During drilling of B-3 with foam and liquid mud, relatively clear water was returned to the surface at a depth of about 60 ft. The drilling pipe was removed from the hole after compressor air was used to blow foam/liquid from the borehole. An electric probe stuck to the walls of the hollow-stem augurs during attempts to check for fluid with the instrument. After a further wait of 15 minutes, the drill pipe was put back into the hole.. Compressed air was blown through the drill pipe with no return of water or foam to the surface. It was concluded that the foam and liquid mud had not been sufficiently mixed for a short period of time and that relatively pure water had been pumped into and out of the borehole. Samples from this interval were quite argillaceous to sticky, indicating little possibility of yielding water. There was no indication during further drilling of this borehole that it was yielding water.

The lack of ground water indications during this drilling is entirely consistent with the results from drilling of the G/H series and measurements of water levels in those boreholes.

RECOMMENDATIONS

It is recommended that smaller site investigations of the geology be carried out as further backup to the information now available. The first recommended program is to examine and describe the Mescalero caliche in shallow trenches and in an existing caliche borrow pit. This brief study should further confirm the existing data about the state of preservation of the Mescalero caliche through drilling at the site. The second recommended program is to map the surficial deposits over the site area utilizing field work, the recently obtained photography, and the new contour data obtained from the aerial photography. Modern and potential past drainage should be indicated by the mapping as well. A reconnaissance petrographic study of thin section (estimated 40) is appropriate to establish microscopic confirmation of soil forming features and processes, general porosity character, and sand size/composition as estimated from field examination. These recommendations are supplemental to the current studies to further establish the evidence regarding stability of the site.

It is recommended that a hydrologic sampling and testing plan be developed and implemented which will take into consideration special characteristics of many fluid-bearing zones in the area. When the water levels in the G/H series drillholes are judged to have reached equilibrium, it is recommended that the boreholes be carefully sampled to determine the specific gravity of the fluid now in the tubing. Some of the ground water systems are highly areally variable in specific gravity, affecting the potentiometric surface. Some systems also recover very slowly from sampling and pumping. Pumping, sampling, and other test methods may require considerable flexibility in the field to successfully determine hydraulic parameters, gradients, and general water quality before recommending monitor well locations. It is also recommended that careful consideration be given to utilizing current G/H locations for monitor wells if properly located.

CONCLUSIONS

The geological and hydrological data from the Sand Point borehole drilling is consistent with the background data from previous drilling and review of available data. No ground water was observed during drilling; drilling depths of 140 to 150 ft were less than was anticipated to reach ground water levels indicated in the G/H series drillholes. The Sand Point site remains suitable for further work in preparation for permit applications.

REFERENCES

Powers, D.W., 1992. *Summary of Site Selection and Preliminary Site Characterization for the Sand Point Site, Eddy County, NM.* Report for JOAB, Inc., Sunland Park, NM.

SHB AGRA, Inc., 1992. *Field Investigation Report, Drilling Services Proposed Landfill Site Carlsbad, New Mexico.* Report for NuMex, Inc., Sunland Park, NM.

State of New Mexico Environment Department, 1991. *New Mexico Solid Waste Management Regulations.* Santa Fe, NM.

Appendix A
Sand Point Borehole Histories
and Basic Data

General

The hole histories for Sand Point boreholes (SP B-1 through B-5) are compiled from the field notes by Dennis Powers as a chronological record of the daily events in the drilling of each hole. Some events have been recorded without noting the specific hours where Powers was not present.

The drilling contractor was Sergeant, Hauskins & Beckwith (SHB), with a two man drilling crew from the Phoenix, AZ, office. A field engineer (R. Murthy) or geologist (K. Miller) was assigned from the El Paso or Albuquerque offices, respectively. The drilling rig was a four-wheel drive CME 75, top head drive, rotary drilling rig. The crew was mobilized September 27, 1992, and field activities began September 28, 1992. Drilling was completed October 17, 1992, and the crew remained to grout each borehole.

The borehole drilling program at Sand Point was to establish the near-surface geological character from the central part of the potential landfill site; the geology is expected to be similar to that found in the G/H series holes, with local expectable variations in the thickness and sequence of fluvial rocks. Boreholes were augured with continuous or split spoon samples to "refusal" and then were cored as possible using foam and/or some liquid mud additives. No evidence of ground water was observed in the boreholes during or after drilling.

Borehole SP B-1

SP B-1 was located at nearly the center of the northwest quarter of section 11, T.21S., R28E., at a ground surface elevation of about 3354 feet. The borehole was located about 22 ft north-northeast of survey point 16 (Skyline Engineering), which was located about 1322 ft from the west line and 1319 ft from the north line of section 11.

September 27

Crew mobilized to Carlsbad.

September 28

0830-1100 Mobilized to Sand Point; rig stuck trying to reach B-1 location.

1100-1730 Arrange tracked equipment to improve access and extract drill rig.

1730-1900 Move drill rig to B-1 site and set up; improve access track to B-1, 2, and 3.

September 29

0700-0800 Set up; moved drilling materials to B-1 site.

0800-1145 Drilled with 6½ inch flight augurs with core barrel and clear plastic tubing for "continuous" sampling to about 45 ft. Drilled from 10-15 ft without tubing with poor recovery; resumed drilling with tubing.

1145-1530 Clutch problems with rig. Attempted repairs and ordered replacement parts. Shut down for day.

September 30

Completed clutch repairs.

0900-1430 Augured without tubing 40-45 ft. Augured with tubing 45-50 ft; auguring very difficult. Decided to begin coring and made equipment changes for coring inside hollow-stem flight augurs from 50 ft.

1430-1755 Cored from 50 to 75 ft with NQ size diamond core bit. Attempted air drilling to 51½ ft; decided to use foam assist because of difficulty in drilling. Used Quick-Foam sold by Baroid Drilling Fluids, Inc., as foaming agent.

1755-1815 Shut down operations and left site.

October 1

0720-0805 Moved water, set up for coring.

0805-0850 Began coring; cable frayed, removed part of cable to continue drilling until replacement available.

0850-1445 Coring from 75 to 110 ft with variable recovery.

1445-1805 Difficulty getting core barrel out of augurs. Removed drill pipe from inside augurs to get core barrel out of drill pipe. Ten ft core barrel requires replacement; ordered new barrel. Re-entered borehole with drill string and 5 ft barrel. Borehole plugged from 75 ft. Circulated foam while "drilling" to 110 ft. Pulled core barrel and discarded soft sand. Withdrew drilling string and turned augurs slightly. Decided to augur to about 85-90 ft on following day to try to secure hole through soft sands. Shut down for day.

October 2

0730-0910 Augured to 90 ft.

0910-1030 Circulated fluid while re-entering borehole with core barrel to 110 ft.

1030-1510 Cored from 110 to 140 ft using foam with variable recovery. End B-1 drilling.

1510-1800 Rigged down, moved rig to next site (B-2).

Borehole SP B-2

SP B-2 was located near the center of the northeast quarter of the northwest quarter of section 11, at a ground elevation of about 3343 feet. The borehole was located about 15 ft west of survey point 41 (Skyline Engineering), which was located about 1983 ft from the west line and about 660 ft from the north line of section 11.

October 2

1800-1810 Augur to 2 ft in sand. Shut down daily operations.

October 3

0730-1215 Augur with split spoon samples to refusal at 55 ft. Rig repairs from about 1030-1140.

1215-1445 Moved support equipment for coring and set up to core with fluid from 55 ft.

1445-1510 Cleaned hole by circulating fluid while entering with core barrel and drilling string to 55 ft.

1510-1900 Cored from 55 to 105 ft through flight augurs in place. Variable recovery using either tungsten carbide or diamond core bits. Shut down daily drilling operations.

October 4

0830-1000 Attempted to bring water to drilling site. Four wheel drive support vehicle with tire puncture; spare on improper rim. Shut down field operations to obtain spare.

1000-1500 Crew obtained spare (sources closed on Sunday), prepared vehicles for service. Ceased daily operations.

October 5

0700-0815 Moved drilling water; cleared hole to 105 ft while circulating fluid.

0815-1110	Cored, with difficulty, to 120 ft. Borehole partially plugged when drilling string lifted.
1110-1245	Compressor problems. Pulled drilling string from borehole to prevent sticking.
1245-1725	Obtained compressor parts and performed field repairs. Changed compressor oil.
1725-1845	Augured from 55 to 85 ft.
1845-1900	Shut down rig operations and prepared to leave site for day.

October 6

0730-1145	Augured from 85 to 120 ft to protect hole from soft areas. Added water with Quik-Foam inside hollow stem augurs through difficult zones.
1145-1330	To Carlsbad to make required telephone report to Phoenix and arrange water. Prepare for coring.
1330-1630	Coring from 120 to 150 ft. No recovery from 120-135 ft; about 0.25 ft recovered from 135-140 ft. Coring continued below 140 ft for additional sample. No recovery 140 to 145 ft. About 0.5 ft recovered from 145 to 150 ft clearly representing Gatuña Fm. Drilling ended.
1630-1900	Remove drilling string and augurs from borehole. Move materials to new drilling site (B-3). General rig demob and improvement of access track. Broken hydraulic connection on rig on right rear leveling leg requires repair before rig can move.

Borehole SP B-3

SP B-3 was located near the center of the northwest quarter of the northwest quarter of section 11, at a ground elevation of about 3368 feet. The borehole was located about 8 ft northeast of survey point 40 (Skyline Engineering), which was located about 661 ft from the west line and about 660 ft from the north line of section 11.

October 7

	Repair rig, demob, and set up on B-3 location.
1000-1235	Augur and split spoon samples from surface to 45 ft ("refusal").
1235-1315	Prepared for coring operations.
1315-1445	Crew to Carlsbad for report to Phoenix office.
1445-1510	Final set up for coring.
1510-1900	Cored from 45 to 60.5 ft with excellent recovery. Used fluid mud additive EZ-MUD from Baroid in addition to foaming agent. Began to return some water while drilling from about 55 to 60 ft. Recovered full core at end of run consisting mainly of claystone. Blew foam from borehole with air and removed drilling steel. Checked for water, but unable to get weighted probe through augurs because the probe tape stuck to the inside of the augurs. Placed drilling

string into borehole in preparation for additional coring. After interval of about 40 minutes with the hole standing open, blew air in hole with no return of fluid. Concluded that water at surface had been returned from inadequate mixing or separation of water and additives during pumping. Continued drilling to 60.5 ft. Shut down daily drilling operations.

October 8

0715-1000 Attempt coring. Pump required field repairs.

1000-1730 Coring very slow from 60.5 to 97.5 ft with excellent recovery. Foam and liquid mud additives in water. Shut down daily drilling operations.

October 9

Water pump field repairs.

0840-1000 Coring from 97.5 to 100 ft with good recovery, but very slow drilling. Shut down drilling operations for crew break and to obtain Longyear advice re bit design to increase drilling rates.

October 12

Crew mobilization to Carlsbad, basic field preparations for drilling.

October 13

Core from 100 to 112 ft with existing bits, using water with foam and liquid mud additives. Recovery excellent.

1100-1230 Crew to Carlsbad to obtain new core bit.

1230-1545 Change new core bit, ream hole slightly from about 70 ft to 112 ft. Attempt coring from 112 to 115 with no recovery. Field repairs of fluid pump.

1545-1840 Core using foam and mud additive. No recovery from 120 to 140 ft. Continued coring from 140 to 145 ft with about 3 ft recovery of representative Gatuña Formation. Ceased drilling.

1840-1900 Shut down operations for rig demob.

Borehole SP B-4

SP B-4 was located slightly southeast of the center of the southeast quarter of the northwest quarter of section 11, at a ground elevation of about 3326 feet. The borehole was located about 18 ft west of survey point 42 (Skyline Engineering), which was located about 2067 ft from the west line and about 2063 ft from the north line of section 11.

October 14

Demob rig from B-3 and set up on B-4 location.

1040-1250 Auguring with split spoon sampling from surface to "refusal" at 40 ft.

1250-1335 Prepare for coring with foam and liquid mud additive.

1335-1845 Core from 40 to 75 ft. Shut down daily drilling operations.

October 15

0730-1615 Coring from 75 ft to 140 ft with good, but variable, recovery. Complete drilling B-4.

1615-1730 Crew prepare rig for demob to B-5. Rig requires repair of hydraulic lift on rear right leveling leg. End of daily operations.

Borehole SP B-5

SP B-5 was located slightly east of the center of the southwest quarter of the northwest quarter of section 11, at a ground elevation of about 3337 feet. The borehole was located about 15 ft east of survey point 43 (Skyline Engineering), which was located about 688 ft from the west line and about 1953 ft from the north line of section 11.

October 16

Repair rig. Mobilize to B-5 location and set up for operations. Augur and split spoon sample to "refusal" at 30 ft.

Core with foam and liquid mud additive from 30 ft to 95 ft with variable recovery.

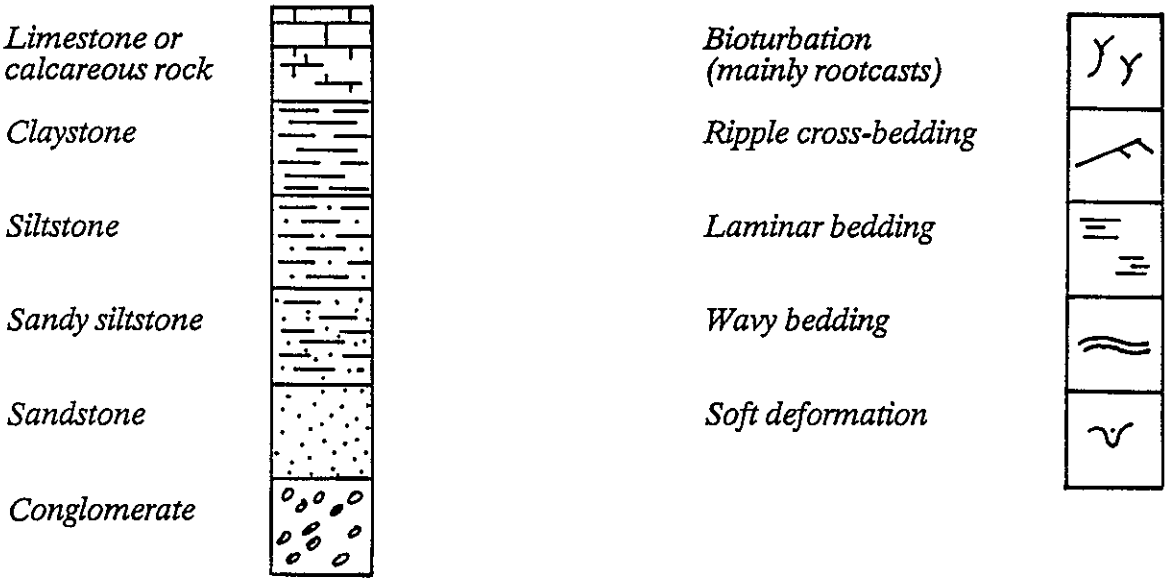
October 17

Core with foam and liquid mud additive from 95 ft to 140 ft with variable recovery. End B-5 drilling operations.

Appendix B
Borehole Graphic Logs and Descriptions, Sand Point Borehole Drilling

The borehole 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 11 are given; precise survey locations were provided by Skyline Engineering.

Explanation of Symbols



Abbreviations: f - fracture; MnO_2 - manganese oxide stain; sl - slickensides; calc - calcareous; 2.5YR 4/6 - numbers refer to colors based on Munsell Soil Color Chart.

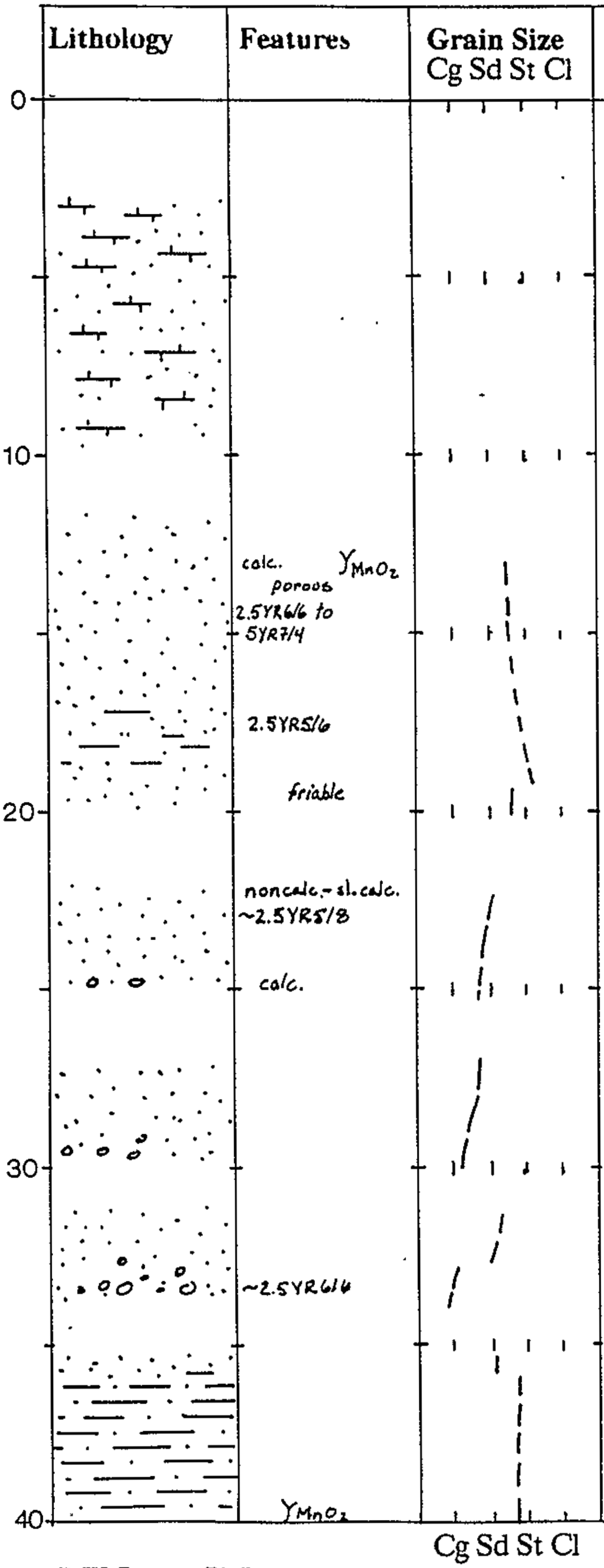
The descriptions are based only on field study; estimates of the average grain size are not precision analyses of the rocks and have been given to show trends and relative sizes. Poor or no recovery is indicated by placing no graphic symbols. Graphic symbols may be arbitrarily placed in a coring interval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

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.

Engineering properties and descriptions, reported separately by Sergeant, Hauskins, and Beckwith (SHB AGRA, Inc., 1992), differ somewhat from the geological descriptions here; data were developed in parallel to serve differing purposes.

BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: *SP B-1* *Location:* *center, NW¼, s11* *Date:* *09/29/92*



Description

0-2.5: No apparent recovery. Auguring with "continuous sampling.

2.5-10: "Limestone," (Mescalero caliche); white; moderately well indurated, though drilled without difficulty. Caliche is sandy and silty, with probable zones of calcareous silt. Lower part is very sandy, with zones of well-cemented sandstone and siltstone. Includes cemented "clasts" of Gatuña Fm, especially from 8-10 ft.

Gatuña Formation
10-20: Sandstone, silty, to sandstone and argillaceous siltstone (with sandstone zones) near base. May be "orange sand" near base. Calcareous, light red to pink. Sand generally fine to very fine, rare medium grains; about 1% dark grains. Root casts, some with MnO_2 stain. Friable to poorly indurated. Affected by infiltrating Mescalero carbonate.

20-25: Sandstone, light red, friable, to granular ss with silt and clay at base. Possible bedding at 24-25 ft. Sand generally fine to medium, rounded to well rounded, <1% dark grains, in upper part. Grains in basal part to 1/8 inch; about 1% dark grains; well rounded to subangular. Calcareous.

25-30: Sand and ss; sand generally very fine to medium, similar to "orange sand." Ss in basal part is fine to very coarse, with granules of quartz and ?Gatuña - possible Santa Rosa source. Well indurated.

30-35: Sand, fine to very coarse, poorly sorted, poorly indurated. Basal conglomeratic ss, Gatuña intraclasts and some Dewey Lake clasts, subrounded, to 1 inch diameter. Very calcareous.

35-36: Sand, fine to medium, friable.

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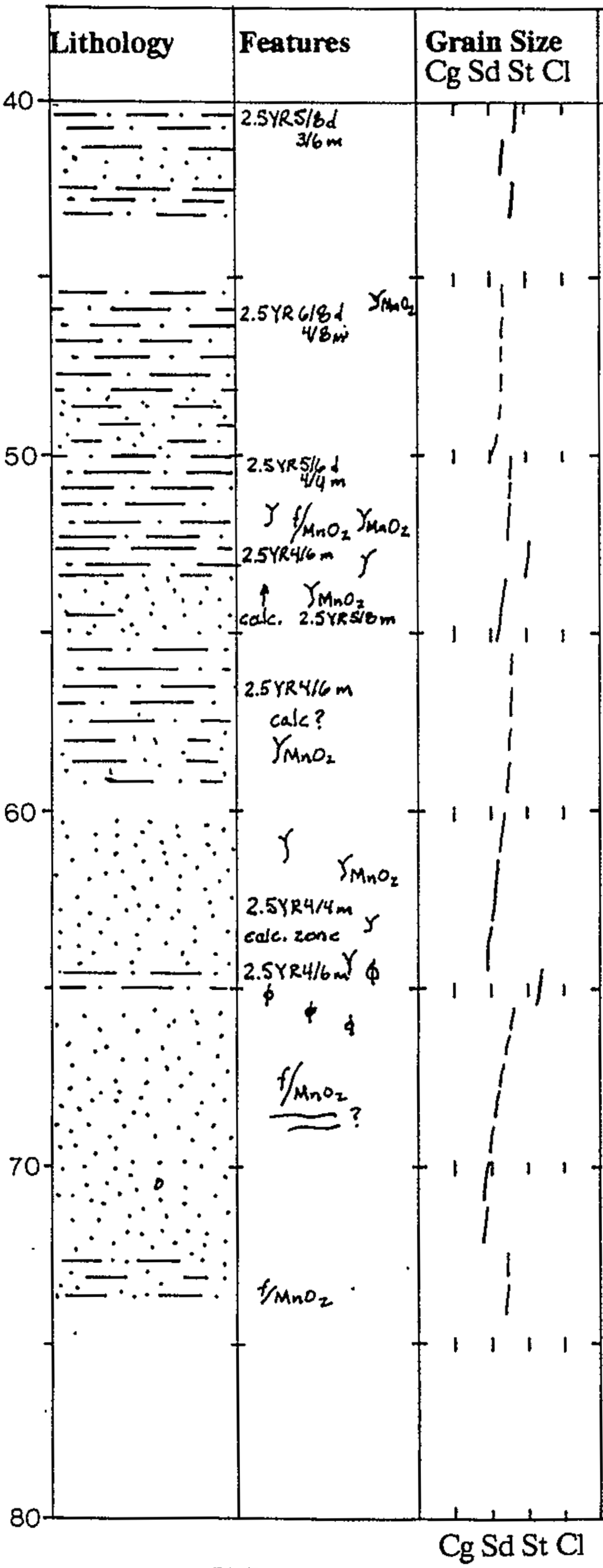
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP B-1 *Location:* center, NW¼, s11 *Date:* 09/29-10/01/92



Description

36-60: Siltstone, sandy to argillaceous, with zones of sandstone and an argillaceous zone at 52-53 ft. Zones of root casts with MnO_2 stain; some stained fractures on probable ped structures. Very small pores about 45 ft. Possible laminar bedding between 35 and 40 ft. Whitish mottled calcareous zone below argillaceous zone at about 53 ft.

Begin coring at 50 ft.

60-64: Claystone, sandy to argillaceous sandstone downward. Sand is fine to medium, subround to rounded, matrix increasing downward; <1% dark grains. Some bioturbation, mostly without Mn staining. Probable clay illuviation near base. No apparent bedding. Sharp basal change, no erosional plane. Some calcite in porosity near base and in very calcareous zone.
64-65: Claystone, sandy. Sand similar to above. Calcareous nodule about ½ inch. No apparent bedding.

65-75: Sandstone, silty, with rare calcareous clasts and calcareous nodules (about 66-67 ft). Sand is fine to medium, subround to round, < 1% dark grains. Possible laminar bedding at about 68 ft. Matrix increases near base; MnO_2 stain on small fractures.

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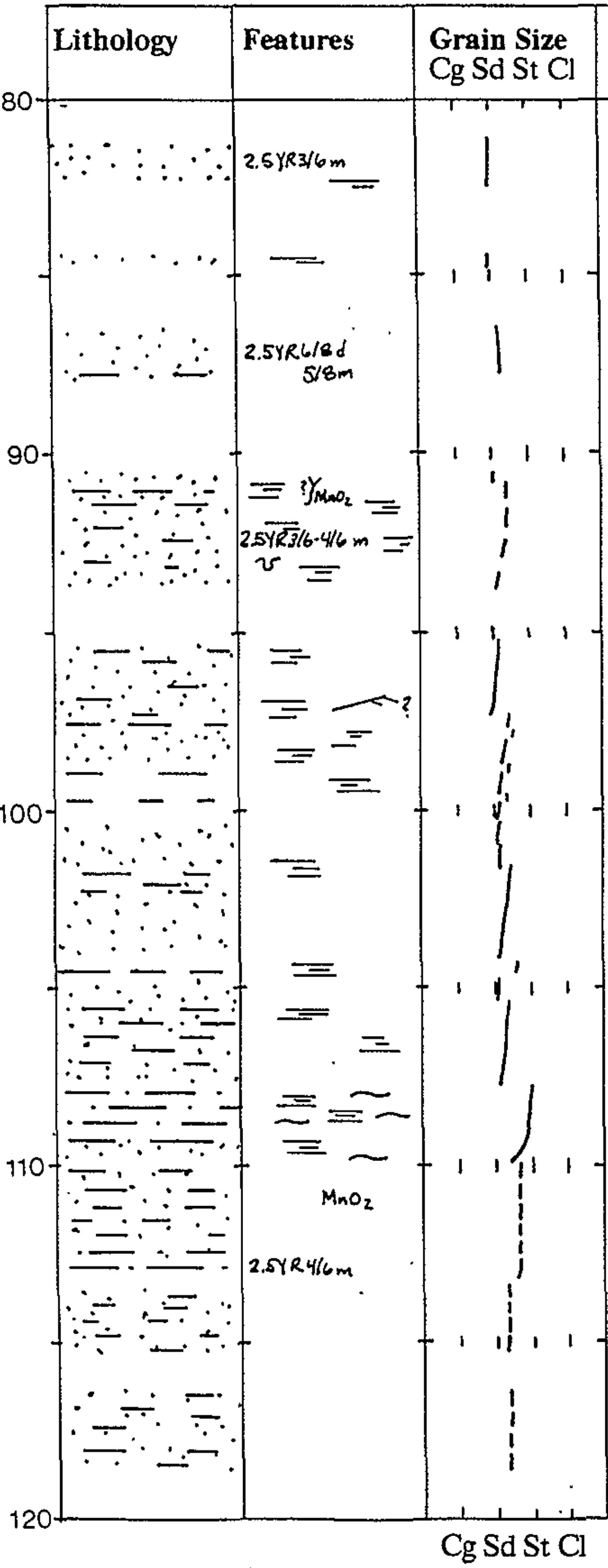
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: *SP B-1* *Location:* *center, NW¼, s11* *Date:* *10/01-02/92*



Description

80-85: Sandstone, silty, crumbly. Sand is fine to medium, subround to well rounded, about 1% dark grains. Some indications of possible planar bedding.

85-90: Sand; fine to medium, moderately well sorted, round to well rounded grains, < 1% dark grains. No lithification. Piece of argillaceous siltstone at base of recovered sample.

90-95: Sandstone, with some interbedded silty claystone. Sand is very fine to medium grain with silt and clay matrix; subangular to subround, < 1% dark grains. Generally subparallel and nearly horizontal bedding and thin (<½ inch) laminae. Some deformed bedding about 1 ft above base of sample. Poor to moderate induration. Variable calcite cement.

95-110: Mainly sandstone and sand, with some interbedded silty sandstone and argillaceous siltstone. Sand grains are generally fine to medium, subangular to subround, about 1 % dark grains, and some coarser sand near base of slightly fining upward cycles. Parallel laminar bedding is common, possible ripple cross-laminae at 97 ft and slight soft sedimentary deformation of bedding from 107-110 ft. Calcareous zone at 106 ft.

110-113: Siltstone, argillaceous and sandy, and silty sandy claystone. Poor to moderately well indurated. Thin (about 2 inches) very calcareous zone with Mn stain at 111 ft. No observed bedding.

113-120: Sand to sandstone, silty and argillaceous, slightly calcareous. Sand is very fine to medium, moderately well sorted; subround to well rounded, about 1% dark grains. Similar to "orange sand" at 85 ft, but with more clay matrix holding sand together.

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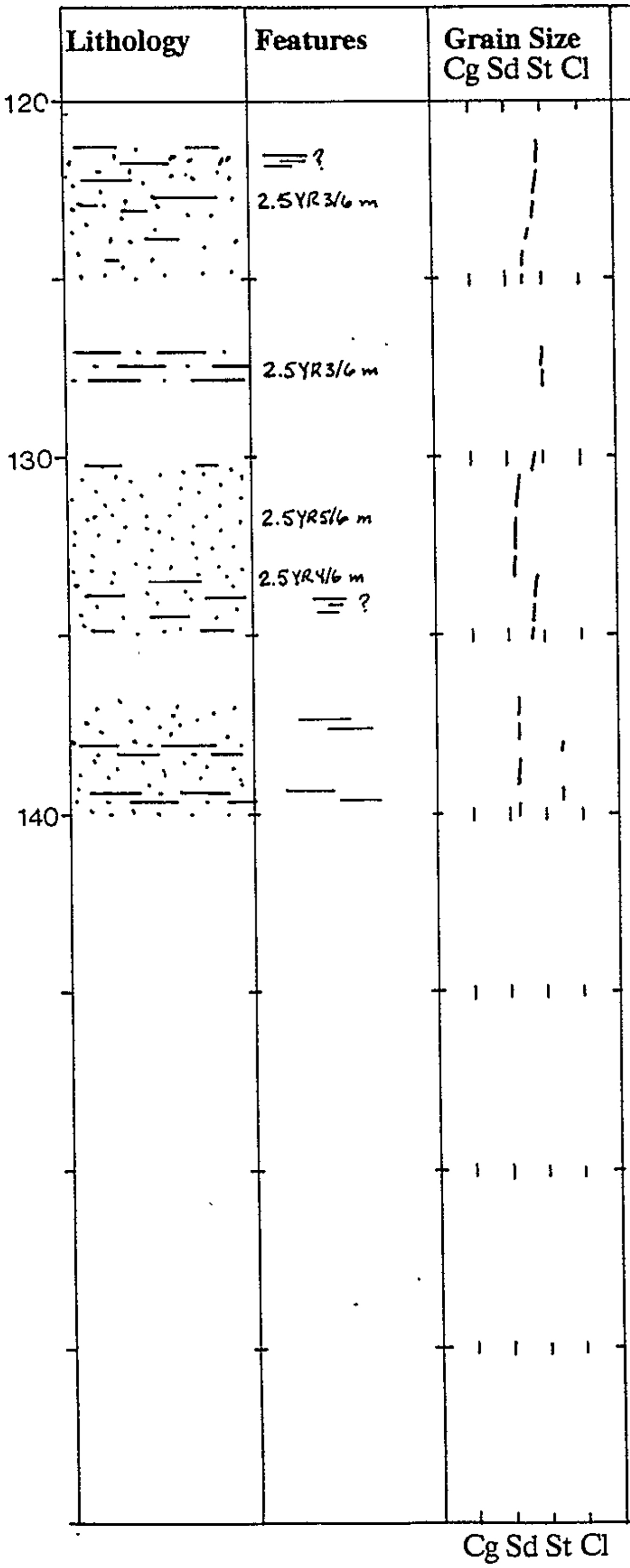
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: *SP B-1* *Location:* *center, NW¼, s11* *Date:* *10/02/92*



Description

121-123: Sandstone, silty, argillaceous, interbedded with silty sandy claystone. Probable laminar bedding. Poor to fair induration.
123-125: Sandstone, silty, argillaceous, similar to 115-120 ft. Sand is very fine to medium, subangular to well rounded, < 1% dark grains.

125-130: Siltstone, argillaceous, sandy. Poor to fair induration; recovered in chunks.

131-133: Sand, silty, very slightly argillaceous. Sand is very fine to medium, generally fine; subround to round; about 1% dark grains. Similar to "orange sand." Argillaceous sandstone at top of recovered section.
133-135: Siltstone, argillaceous, sandy. Possible laminar bedding. Sample recovered in chunks.

135-140: Interbedded to interlaminated sand, sandstone, and silty claystone. Sand grains are very fine to medium, subangular to rounded, <1% dark grains. Claystones are silty, slightly sandy, probably bedded to thinly laminated. Very sticky clay. Sample recovered in chunks.

End drilling. T. D. 140 ft.

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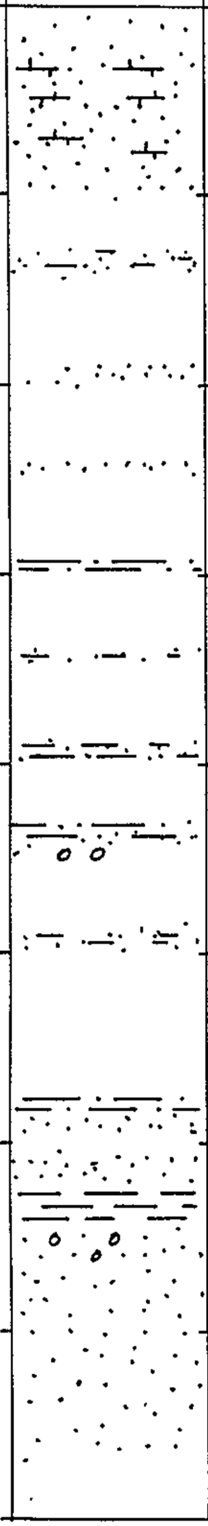
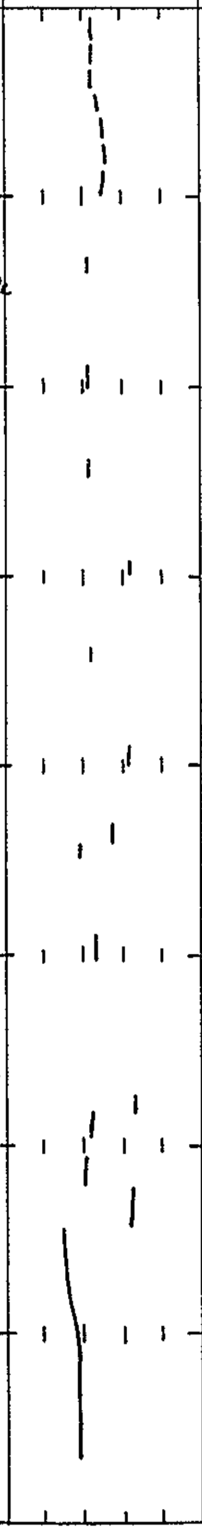
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: <u>*SP B-2*</u> *Location:* <u>*ctr, NE¼ NW¼, s11*</u>*Date:* <u>*10/02-03/92*</u>

Lithology



Grain Size (Cg Sd St Cl)



Depth (ft)	Features	Description
0		0-3.75: Dune sand. Augur with split-spoon sampling.
	7.5YR8/2 d	3.75: Mescalero caliche.
10	2.5YR5/4-4/6 with 7.5YR8/2	9.5: Upper Gatuña Formation and lower Mescalero caliche.
	2.5YR6/6-5/4 Y MnO_2	14.5: Sandstone, silty, calcareous, especially at top. Porous; MnO_2 stain on root casts.
20	2.5YR5/8 Y MnO_2	19.5: Sand; very fine to medium, subangular to subround. Friable sample, some small pieces with root cast porosity and MnO_2.
	2.5YR5/8	24.5: Sand, loose, similar to above.
30	2.5YR5/4 f/calc Y MnO_2	29.5: Siltstone, argillaceous, slightly sandy. Well indurated. Subvertical fracture with calcite stain. Pores with MnO_2.
	2.5YR5/4	34.5: Siltstone, argillaceous, sandy. Moderate induration. Sand grains to medium sand, subangular to subround. Calcareous.
40	2.5YR5/4 Y?	39.5: As above. Possible bioturbation.
	2.5YR5/4 f/MnO_2	44.5: As above. Definite MnO_2 on small fracture surfaces. Small (< ½ inch) clasts of Dewey Lake Formation. Calcareous.
50	2.5YR4/8 Y MnO_2	49.5: Siltstone, sandy and argillaceous. Sand is very fine to fine or medium; subangular to subround. Bioturbation, root casts, some MnO_2. Calcareous.
		Change scale. Begin coring at 54 ft.
	2.5YR3/6m Y MnO_2 Y	54-54.5: Siltstone, argillaceous, slightly sandy. Well indurated. Abundant fine bioturbation with some MnO_2. Calcareous.
55	2.5YR4/6m Y Y Y MnO_2	54.5-55: Sandstone, silty, slightly argillaceous, calcareous. Well indurated. Sand grains are very fine to medium, subangular to well rounded, < 1% dark grains. No apparent bedding.
	2.5YR5/6m	
	2.5YR6/6m	
60		55-65: Mainly sandstone, silty, with zone of rare granules at about 57.5 ft and silty sandy claystone at about 57 ft. Sand is generally fine to medium, some coarse; subangular to subround; about 1% dark grains. No observable bedding. Calcareous to very calcareous.
65		

Cg Sd St Cl

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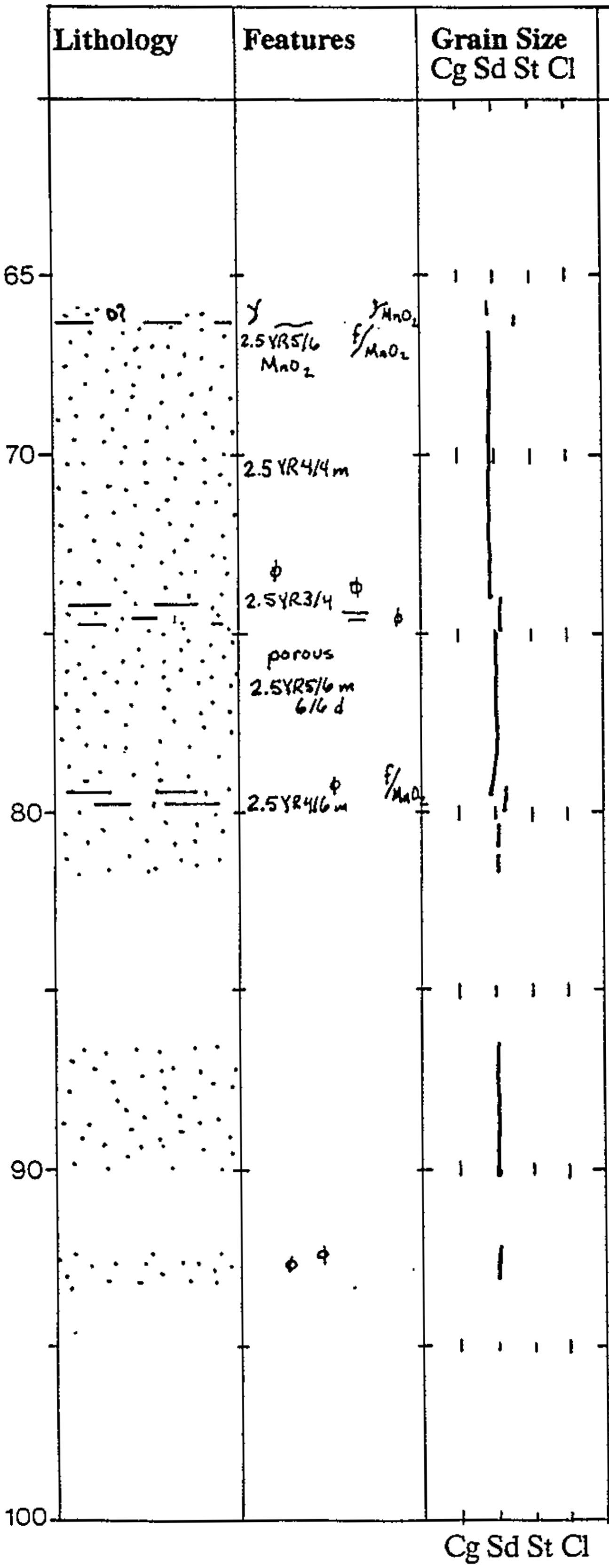
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.:SP B-2 *Location: ctr, NE¼ NW¼, s11* *Date: 10/03/92*



Description

65-95: Sandstone, silty, slightly argillaceous. Sand is very fine to rare coarse, fair sorting; generally subround; about 1% dark grains. Sand below 85 ft appears slightly better sorted and rounded. MnO_2 on pores and bioturbation. Fractures with MnO_2 at 67 and 79 ft. Small carbonate nodules at 73-74, 79, and 92 ft. Thin argillaceous zones at 74 and 79 ft, below carbonate nodules.

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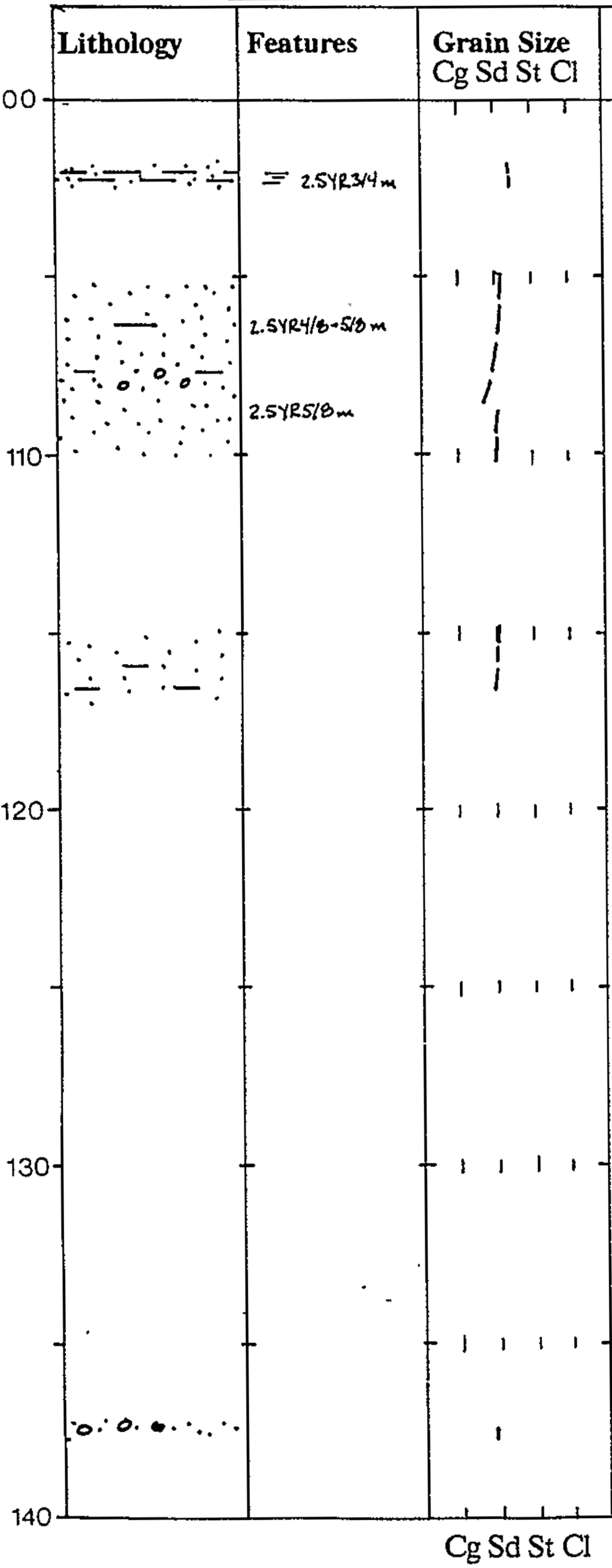
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: *SP B-2* *Location:* *ctr, NE¼ NW¼, s11* *Date:* *10/03-06/92*



Description

102: Siltstone, silty claystone, silty sandstone interlaminated at scales of about ¼ inch and thicker. Sand is very fine to medium, mainly fine; about 1% dark grains. Very calcareous, moderate induration. May also have drilled soft sand or sandstone with no recovery.

105-110: Sand and sandstone; sand ranging from very fine to medium to fine to coarse with some granules and very coarse grained, to very fine to medium downward. All sand grains generally subround to well rounded; very coarse to granule size are subround and are sand supported. Induration fair at upper ?3 ft, poorly lithified or unlithified lower 1-2 ft. "Orange sands."

115: Sand, with some sandstone. Not indurated to poorly indurated. Sand is very fine to medium, subround to round, < 1% dark grains.

120-135: No recovery.

137: Sandstone, with granules and pebbles of chert and limestone of probable Permian age sources. Also silty and argillaceous. Moderately well indurated. No structures observed.

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BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP B-2 *Location:* ctr, NE¼ NW¼, s11 *Date:* 10/06/92

Depth	Lithology	Features	Grain Size Cg Sd St Cl	Description
140				No recovery, 140-145.
				145-150: Sand and sandstone, with granules and pebble. Sandstone also with silt and minor clay. Very calcareous chunk of sandstone included. Sand grains range from very fine to coarse, generally fine to medium; subangular to subround; < 1% dark grains.
150				**End drilling. T.D. 150 ft.**

Cg Sd St Cl

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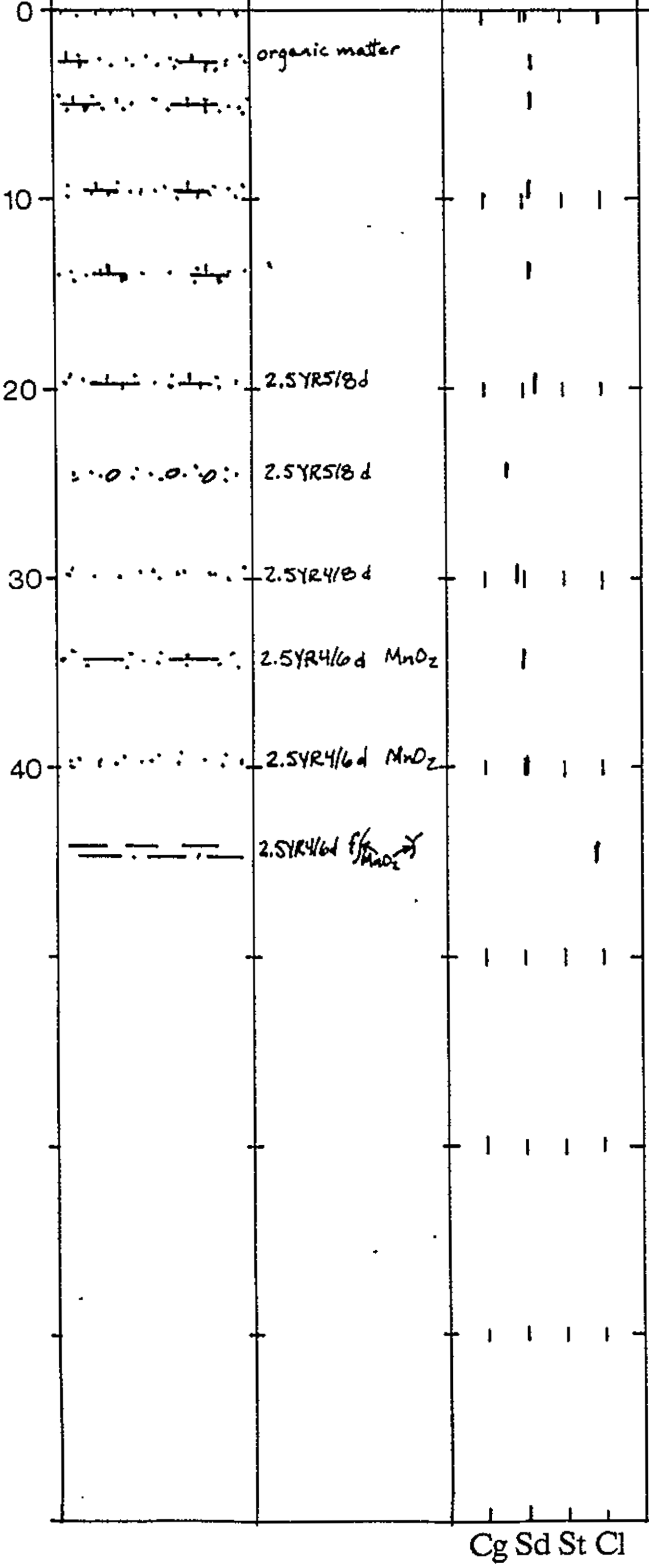
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP B-3 *Location:* ctr. NW¼ NW¼, s11 *Date:* 10/07/92

Lithology	Features	Grain Size Cg Sd St Cl	Description



0: Sand, very fine to medium; dune sand. Augur with split-spoon sampling. (Surface)

2.5: Sand, with organic matter and roots overlying Mescalero caliche: white calcareous ss to sandy "limestone."

5: White calcareous ss to sandy "limestone."

10: Sand to probable sandstone, reddish to white: Gatuña Formation overprinted by caliche.

15: Similar to above.

20: Sand and sandstone, very calcareous, silty and slightly argillaceous. Sand mainly very fine to medium, about 1% dark grains, subangular to subround.

25: Sand to possible sandstone. Sand is fine to very coarse, few granules, decomposing gray ss pebble. Also granules of Dewey Lake. Subangular grains to subround, a few rounded grains; 1-2 % dark grains.

30: Sand to possible sandstone. Sand is fine to very coarse, subangular to subround, about 2% dark grains. Calcium carbonate decreasing downward.

35: Sand and sandstone, silty, slightly to moderately argillaceous. Sand very fine to coarse, mainly medium to coarse, subangular to subround, about 1% dark grains. Some MnO_2 stains. May include sandy claystone near base of sample. Calcareous.

40: Similar to above, less argillaceous. Sample may not be from this zone; discarded.

45: Claystone, silty, slightly sandy. MnO_2 on vertical fracture (about 3 inches) and on bioturbation porosity. Clays expandable.

Begin coring at 45 ft.

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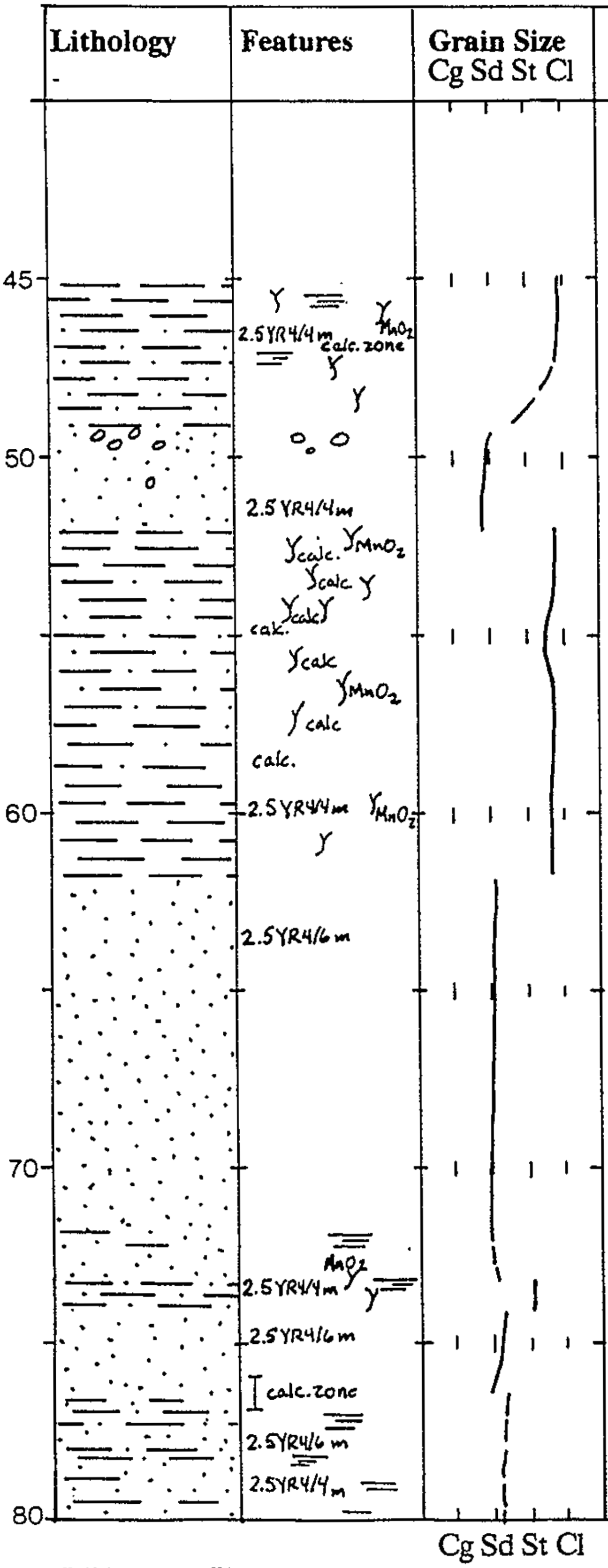
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: *SP B-3* *Location:* *ctr, NW1/4 NW1/4, s11* *Date:* *10/07-08/92*



Description

45-49: Claystone, slightly silty. Bioturbation coated by MnO_2. Flat bedding to laminae; grades from silty claystone and argillaceous siltstone with similar features and calcareous zone at about 47 ft.

49-52: Granular to pebbly sandstone. Sand ranges from very fine to very coarse, mainly fine to medium, with scattered pebbles to 3/4 inch diameter. Sand is subangular to rounded, more rounded near top; 1-2 % dark grains. Pebbles include quartz, Permian limestones, possible volcanic sources.

52-62: Claystone, similar to 45-47 ft. Includes abundant bioturbation marked by calcite, minor MnO_2. Calcareous, silty zone at 54.5 may be carbonate accumulation from above. Rootcasts decrease downward.

62-73: Sandstone. Sand generally fine to medium, ranges from very fine to coarse, coarsens slightly downward. Grains subround to well rounded, may be slightly more angular downward; about 1% dark grains. Slight amount of silt and clay in lower foot.

73-74: Claystone, silty and sandy. Laminar bedding 1 inch thick or less. Moderate bioturbation with MnO_2 stain.

74-76.5: Sandstone, very similar to 62-73 ft interval.

76.5-85: Interbedded sandstone, claystone, and siltstone, with sandstone predominant above 80 ft, siltstone and claystone predominant from 80 to 85 ft. Sand in upper part generally very fine to

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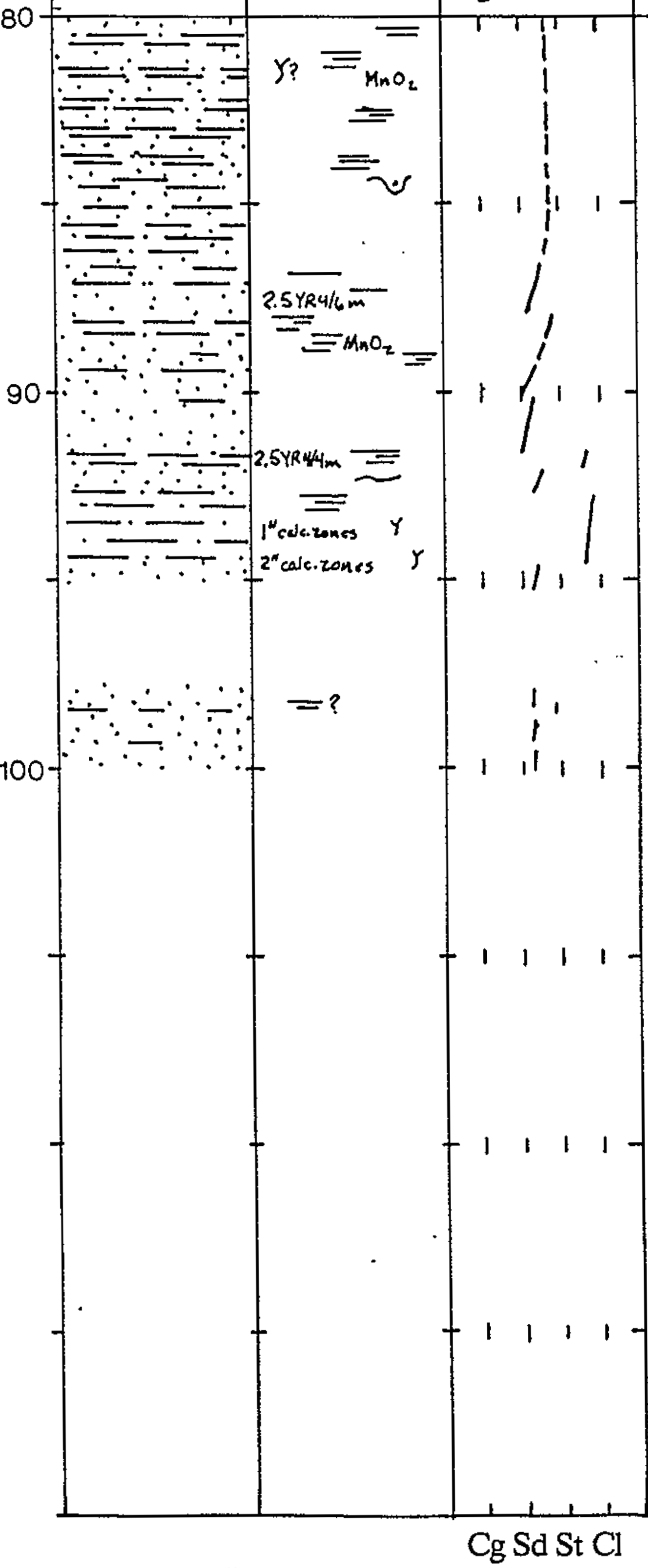
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: *SP B-3* *Location: ctr. NW¼ NW¼ s11* *Date: 10/08-09/92*

Lithology	Features	Grain Size Cg Sd St Cl	Description



medium, subangular to subround, about 1% dark grains. Sand is generally very fine to fine in lower part. Moderately well indurated. Laminae from about 1 to 1/8 inch thick. Some laminae are calcareous. Mild soft sediment deformation. Slightly greenish lamina about 84 ft.

85-95: Series of fining upward cycles from sandstone (average about medium sand) to claystone; some interbedded sandstone and claystone. Sandstone generally fine to medium or coarse, subangular to subrounded, < 1 % dark grains. No internal bedding in sandstone. Claystones may be silty to sand at transition; commonly laminated from 1/2 to 1/8 inch, alternating from claystone and silty/sandy claystone or siltstone. Some argillaceous units also have 1-2 inch zones mottled white by carbonate along probable root zones. Very slight deformation of some laminae.

97-100: Sand and sandstone, with minor claystone and argillaceous zones. Sand below upper ½ ft is "orange sand"; very fine to medium, rare coarse grains, subround to round, about 1 % dark grains; poor to no induration. Clay-rich intervals may show bedding, but sample is in chunks. Upper sand is less rounded, slightly more dark grains.

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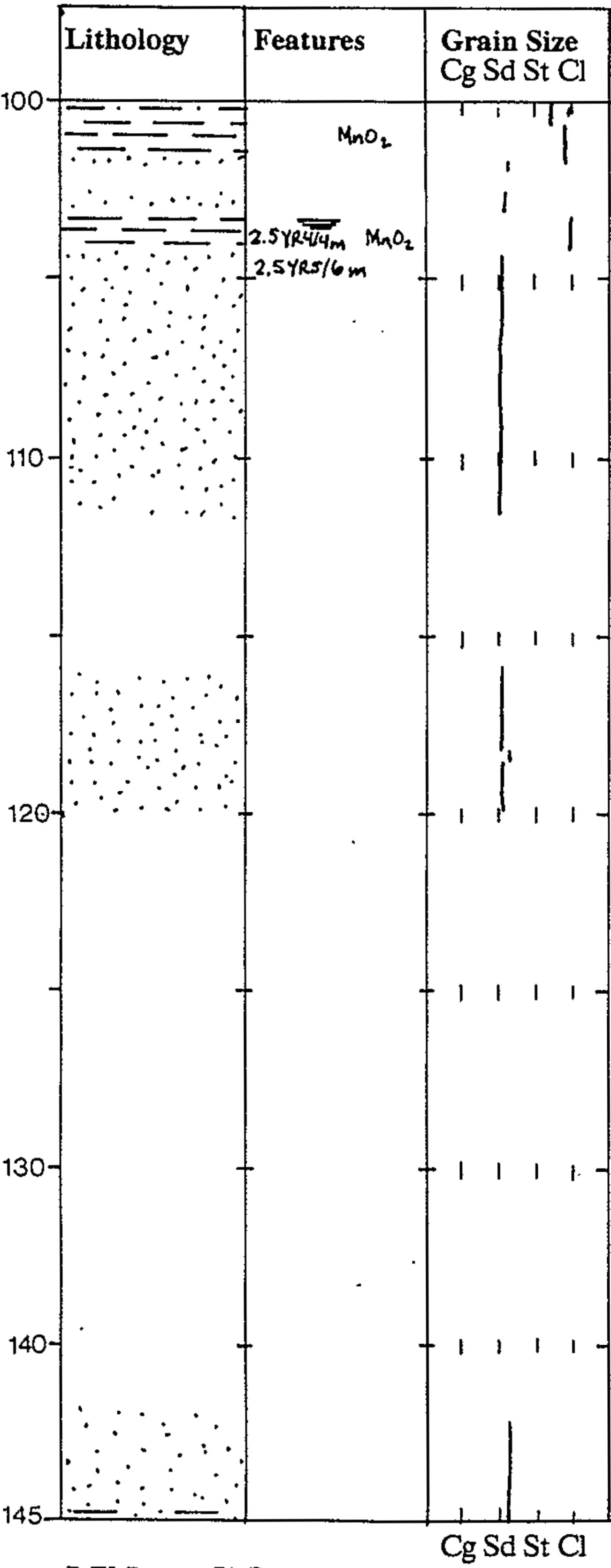
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP B-3 *Location:* ctr, NW¼ NW¼, s11 *Date:* 10/13/92



Description

100-101.5: Claystone, silty, with MnO_2. No apparent bedding.
101.5-103: Sandstone, with some silt and clay ("orange sand"). Sand is very fine to coarse, mainly fine to medium, subround to well rounded, < 1% dark grains.
103-104: Claystone, silty, slightly sandy in laminae. Laminated in upper part, MnO_2 zones, possible organic carbon in lower part.

104-112: "Orange sand," similar to 102 ft.

115-120: "Orange sand," similar to 102 ft. Two thin zones or samples with silt and clay causing improved induration.

No recovery, 125-140 ft.

140-145: "Orange sand," similar to 102 ft. Some argillaceous material near base of sample.

End drilling. T.D. 145 ft.

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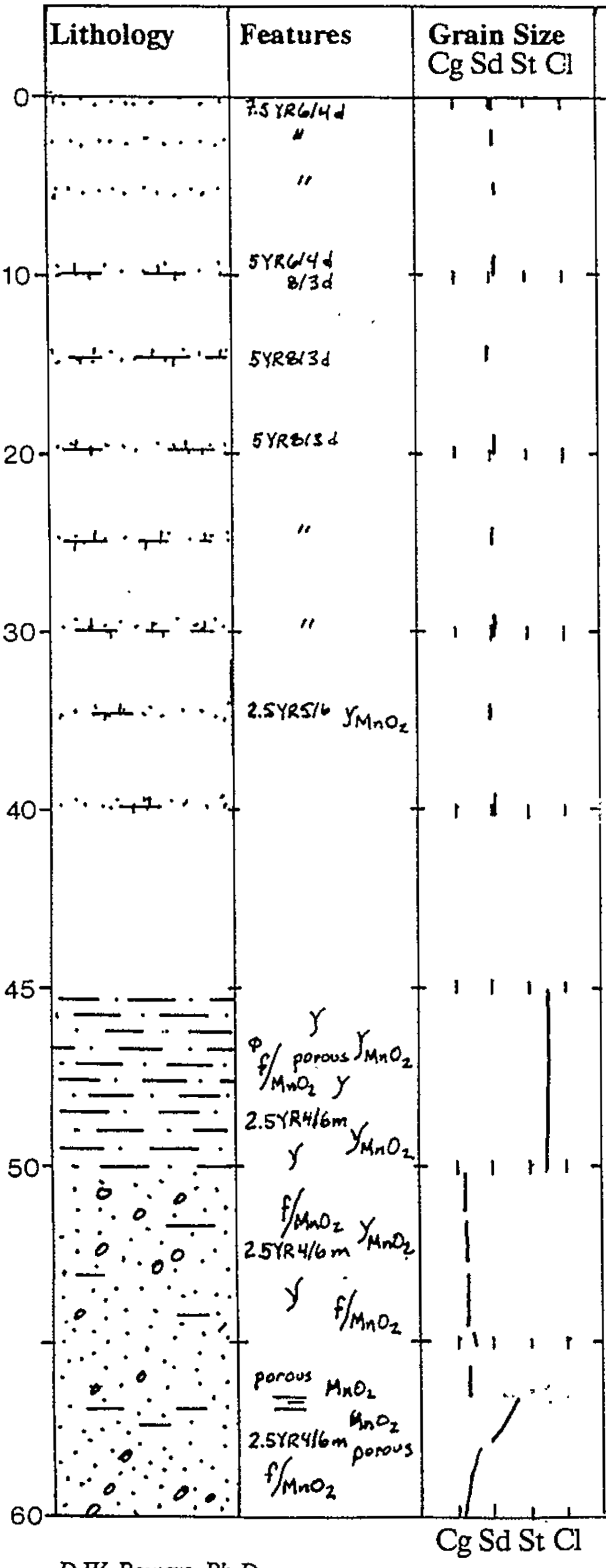
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.:SP B-4 *Location: ctr, SE¼ NW¼, s11* *Date: 10/14/92*



Description

Augur with split-spoon sampling.
0: Sand, very fine to medium, mainly subround to round, < 1% dark grains. Similar to "orange sands" at depth, except color is more brown. (surface)
2: as above.
5: as above, some additional silt and clay. Augur returns more calcareous from 8-9 ft.
10: Sand/sandstone, generally as above, becomes more calcareous with depth. Top Mescalero caliche at about 10 ft: soft, white, mainly calcareous ss.
15: Sand/sandstone. Sand generally fine to coarse, subangular to rounded, < 1 % dark grains. Very calcareous, probable transition to Gatuña.
20: Sand/sandstone, generally very fine to medium, subround to round, about 1% dark grains. Very calcareous; some silt and clay.
25: as above
30: as above, more cemented and indurated. Hard cutting about 31 ft; augur turned up pebble sized pieces of Mescalero including siliceous zones.
35: Sandstone, red. Sand is very fine to coarse, generally fine to medium, subangular to surbrounded, 1-2% dark grains. Possible root casts with MnO_2. Very calcareous.
40: as above.

Begin coring at 40 ft. No recovery 40-45 ft.

45-50: Siltstone, argillaceous, sandy. Moderately well indurated. Vague sense of bedding. Very porous throughout, highly bioturbated.

50-57: Sandstone, conglomeratic, silty, argillaceous. Includes numerous clasts of Dewey Lake Formation up to ½ inch diameter. Clasts mainly matrix supported. Sand are very fine to very coarse, mainly fine to coarse, subangular to rounded, about 1-2 % dark grains. MnO_2 on near-vertical fracture surfaces. Some bioturbation with MnO_2 as well.

57-61: Sandstone, similar to 57-50, grading upward to silty and argillaceous sandstone with minor bedding. Sand in upper part is very fine to medium, generally fine; subrounded; about 1 % dark grains. Porous. MnO_2 dispersed in upper part.

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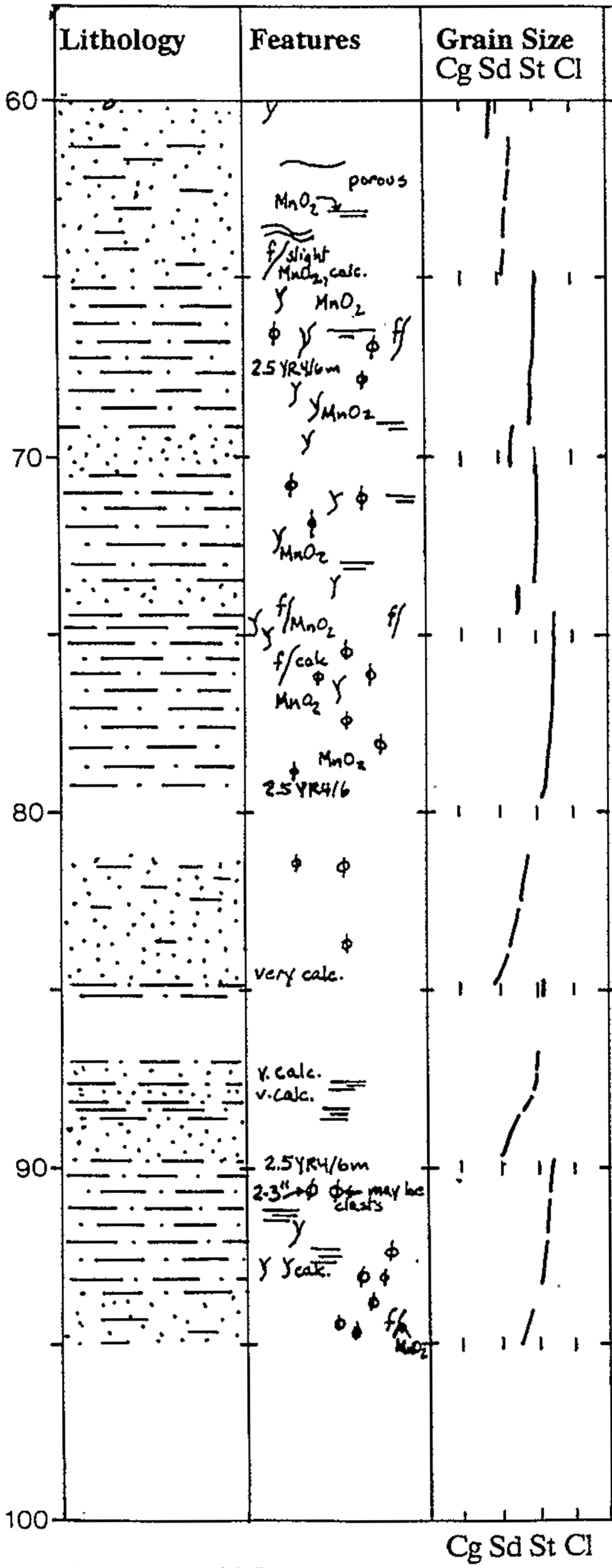
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP B-4 *Location:* ctr, SE¼ NW¼, s11 *Date:* 10/14/92



Description

61-65: Sandstone, silty, argillaceous, with some thin sandy claystone. Sand generally very fine to medium, few coarse grains; subround, some rounded. MnO_2 on horizontal partings and irregular small surfaces. Porous. Some bedding. Fracture near 65 ft about 30° from vertical shows slight Mn and calcareous deposit.

65-69: Siltstone, argillaceous, sandy. Some thin laminae. Zones of open pores generally about 1/16 to 1/8 inch diameter with some MnO_2 stain. Small (about 1/8 to 1/2 inch diameter) calcareous nodules in zones within siltstone. Fractures, near-columnar structures with and without manganese staining.

69-70: Sandstone. Sand is very fine to medium, subround to subangular. Some bioturbation near top.

70-74: Similar to 65-69 ft.

74-75: Similar to 69-70 ft.

75-80: Similar to 65-69 ft, with more carbonate nodules and cement and somewhat less bioturbation and manganese staining.

81-85: Sandstone similar to 74-75 ft, fining upward. Calcareous nodules, very calcareous at base.

85-88: Fining upward cycle with sandstone similar to 74-75 and siltstone similar to 75-80 ft.

90-95: Sandstone and siltstone, fining upward. Similar to units above.

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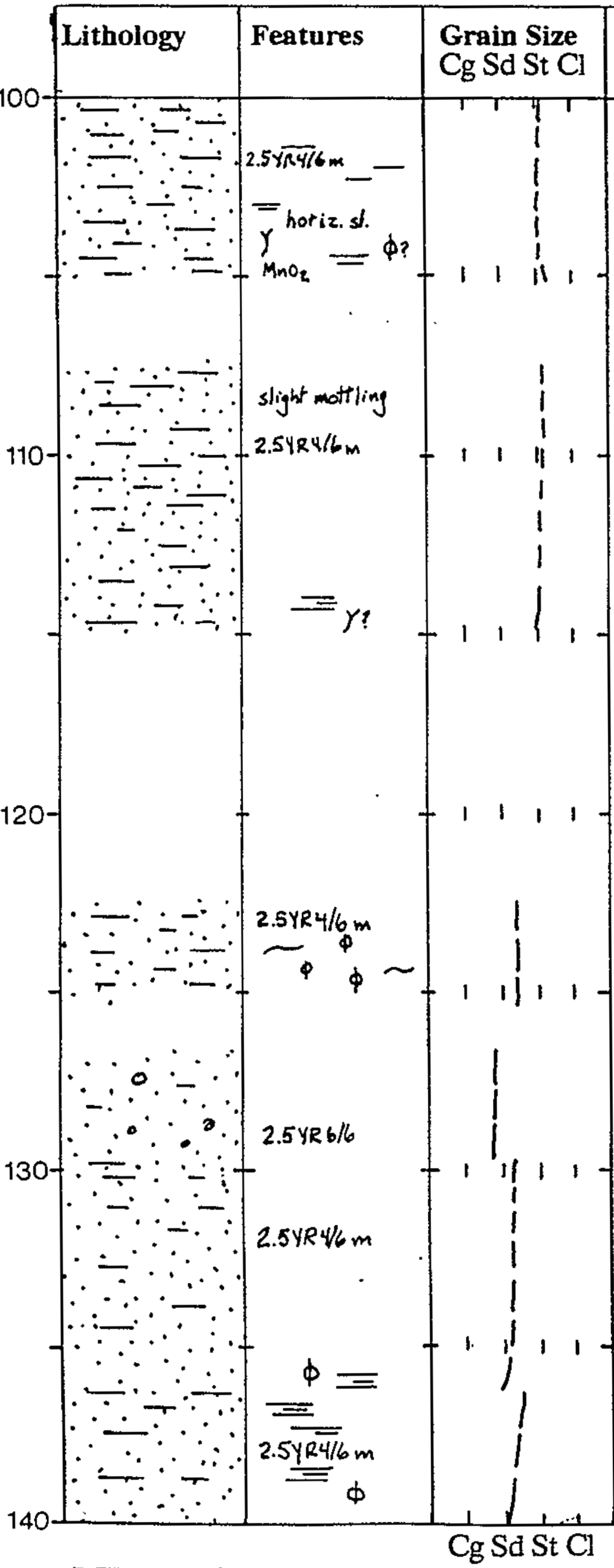
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP B-4 *Location:* ctr. SE¼ NW¼, s11 *Date:* 10/15/92



Description

100-125: Sand, argillaceous, silty, soft and spongy. Sand generally very fine to medium, mainly fine; slightly coarser at 125 ft; subrounded to rounded, < 1% dark grains. Some bedding slight color changes on 1 inch scale. Minor laminae at about 114 ft. Siltstone, soft and sandstone, silty and argillaceous at 105 ft. Horizontal slickensides, minor bioturbation. Some incipient(?) carbonate zones to nodules about 114 ft.

126.5-129: Sand/sandstone, with granules to small pebbles of Dewey Lake and possible Gatuña intraclasts. Sand is very fine to very coarse, mainly medium; subangular to rounded, about 1% dark grains. Some clay helps hold material together; fair to no induration.

129-136: Sand/sandstone, soft, very similar to 123-125 ft, fines upward. Generally fine to coarse in lower part; subangular to subround, < 1% dark grains. Sparse carbonate concretions near base.

136-140: Sand/sandstone, soft, and soft siltstone/sandy claystone; fines upward. Similar to 123-125 ft. Bedding more apparent near top. Small carbonate nodules.
End drilling. T.D. 140 ft.

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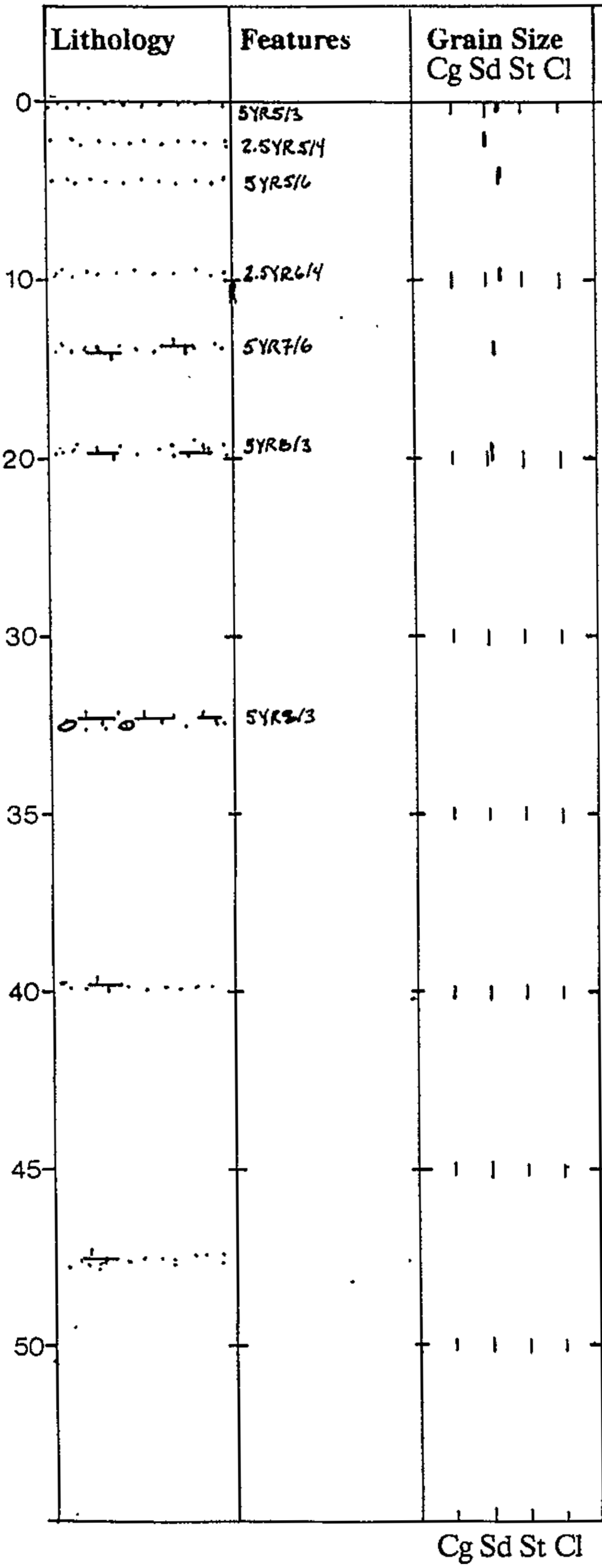
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: *SP B-5*   *Location:* *ctr, SW¼ NW¼, s11* *Date:* *10/16/92*



Description

0: Sand and silt, grayish brown. Auguring with split-spoon sampling.

2.5: Sand; generally very fine to medium, subround to well rounded, about 2% dark grains.

5: Similar to above, slightly more clay.

10: Sandstone and sand, silty, argillaceous. Similar to above. Probable root casts.

15: Sand and sandstone, very calcareous. Sand from fine to coarse, subround to round, 1-2% dark grains.

Top Mescalero caliche at about 18 ft.

20: Similar to 14.5 ft, more calcareous and better indurated.

no recovery at 25 or 30 ft.

Begin coring at 30 ft.

32: "Limestone," (Mescalero caliche), with isolated light reddish brown sandstone clasts from Gatuña Formation; laminar carbonate developed around clasts.

40: Mescalero caliche and Gatuña sandstone pieces.

47: as above.

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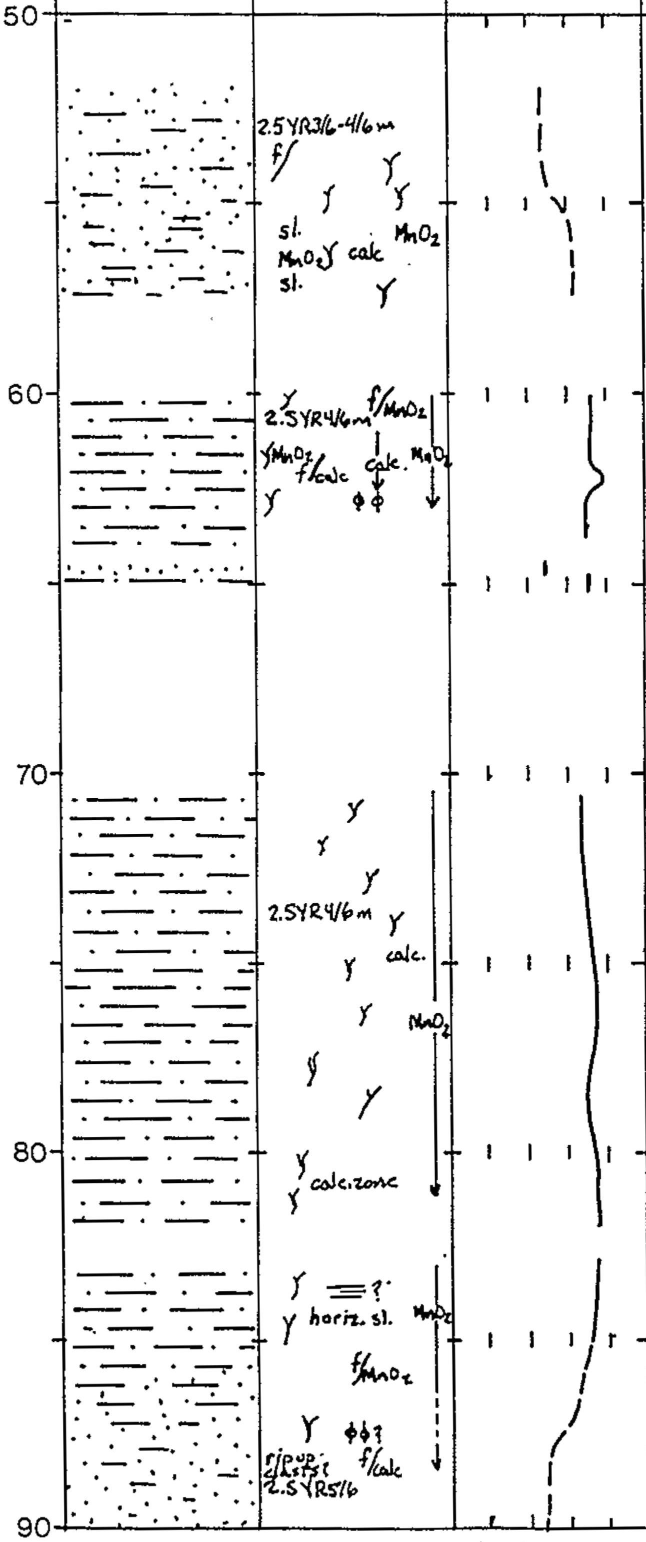
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.:SP B-5 *Location: ctr, SW¼ NW¼, s11Date: 10/16/92*

Lithology	Features	Grain Size Cg Sd St Cl	Description



50-55: Sandstone, light red. Sand very fine to coarse, generally fine to medium; subround to round; about 1% dark grains. Very porous, much root bioturbation. MnO_2 on some pores, generally seems to be on grains and matrix apart from open porosity but has pattern similar to open porosity. Calcareous, moderately well indurated.

55-87: Claystone with silty to sandy zones. Strong MnO_2 on porosity and on small surfaces (< ½ inch²) of possible ped structures. Light surface calcite on top of manganese at 57 ft. Small slickenside surfaces at 57 ft. Open porosity. Fractures.

Similar to above (64 ft).
Possible intraclasts (65 ft).

similar to above.

small (about 1/8 inch) incipient calcareous nodules.

87-93: Sandstone and sand ("orange sand"). Sand very fine to coarse, generally fine to medium; subrounded to well rounded, < 1% dark grains.

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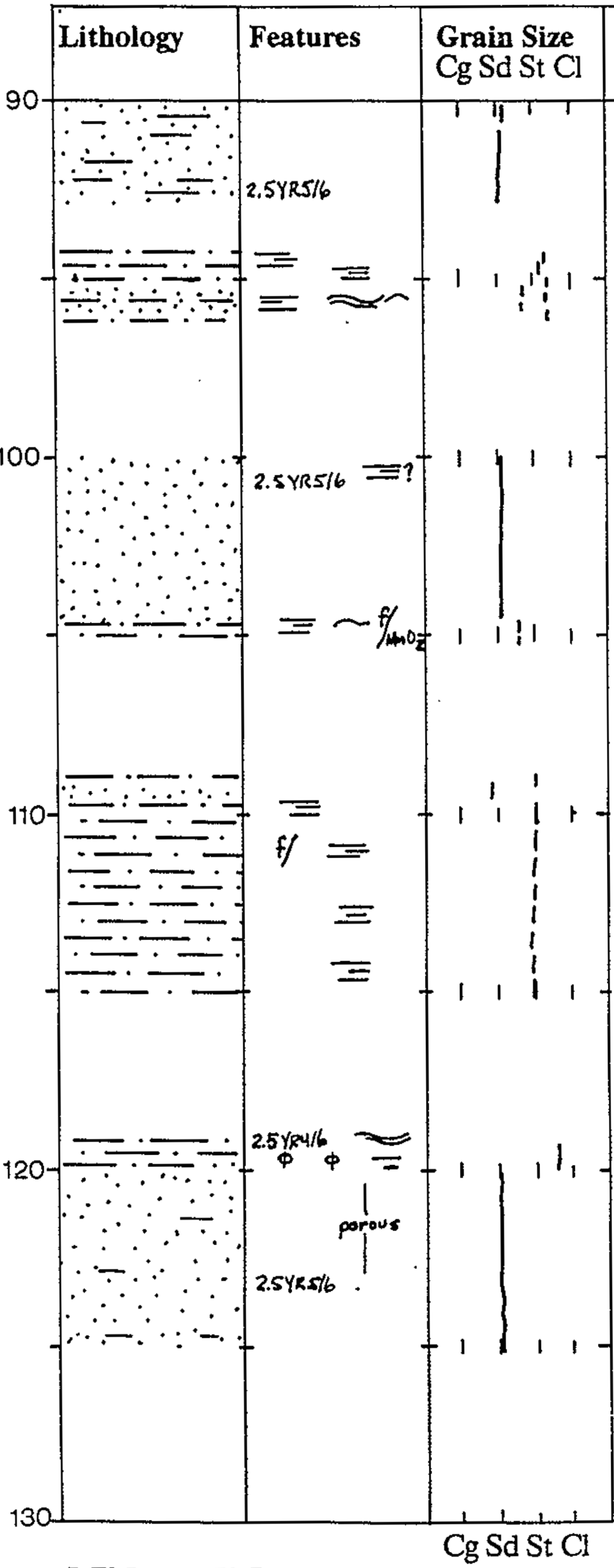
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: *SP B-5* *Location:* *ctr, SW¼ NW¼, s11* *Date:* *10/16-17/92*



Description

94-96: Interlaminated silty sandstone and sandy, silty claystone with some soft sediment deformation. Laminar bedding.

100-105: Sand and sandstone, similar to 90 ft.

105: Interlaminated silty sandstone and sandy, silty claystone, similar to 95 ft; with MnO_2 on near-vertical fracture. Mild soft sediment deformation.

108-115: Interlaminated silty claystone and sandstone. Some thin sand laminae are very light colored. Sand is very fine to coarse, subangular to well rounded, 1-2 % dark grains. Recovered in chunks.

119-120: Claystone, silty, sandy, laminar. Irregular calcification to incipient nodule formation. Calcareous sandstone laminae at basal transition.

120-125: Sand/sandstone ("orange sand"), with some silty and clay. Very porous. Similar to "orange sandstone" above at 90 ft.

No recovery, 125-135 ft.

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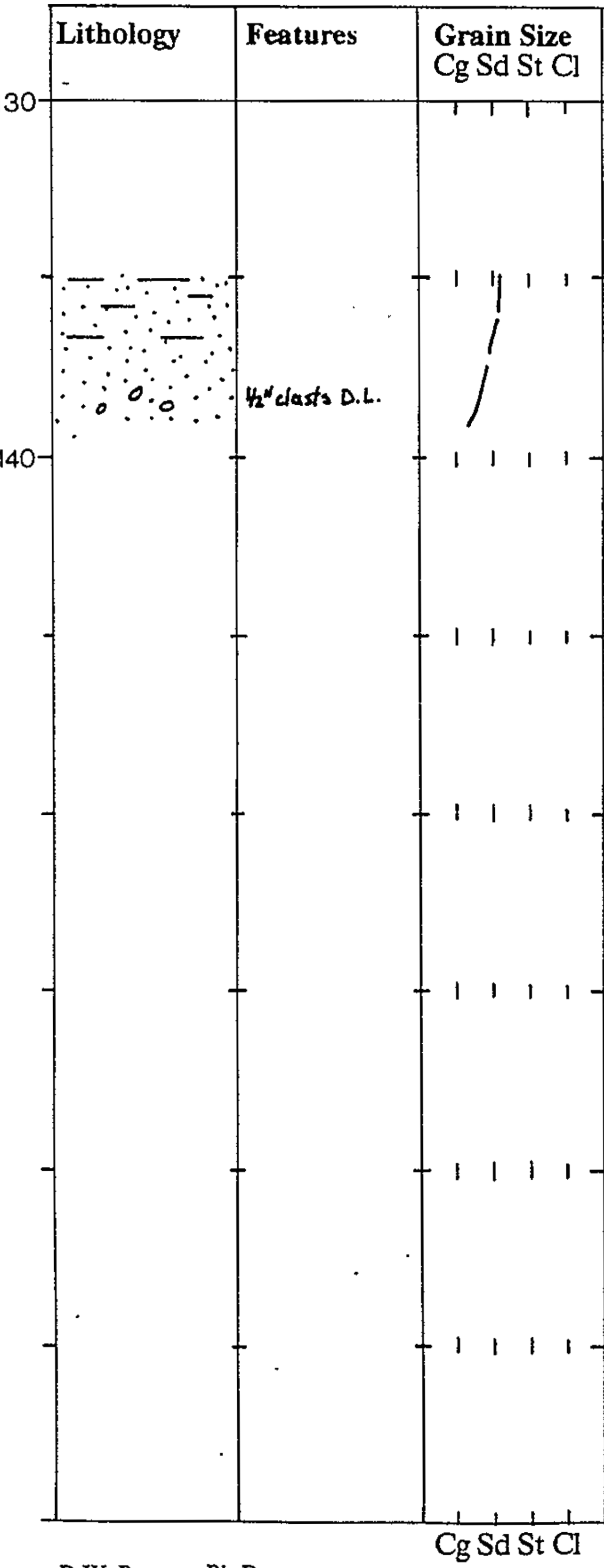
BOREHOLE GEOLOGICAL LOG
SAND POINT SITE CHARACTERIZATION

Drillhole No.: SP B-5 *Location:* ctr, SW¼ NW¼, s11 *Date:* 10/17/92



Description

135-140: Sandstone and sand, with ½ inch pebbles of Dewey Lake at 139 ft, silty and argillaceous at top. Sand is very fine to coarse, mainly fine to medium, subround to well rounded, about 1% dark grains.

End drilling. T.D. 140 ft.

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APPENDIX C
Borehole Drilling Plan, Alternate to State Regulations for Sand Point Characterization

The attached plan, dated August 18, 1992, was forwarded to the Environment Department on August 21, 1992, by JOAB, Inc.

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Environmental Geology
Evaporite Geology
Frontier Sulfur

08/18/92

Borehole Drilling Plan for Sand Point Site Characterization

Section 202 of the New Mexico Solid Waste Management Regulations (1991) describes additional requirements for permits for landfills, including a plan for boreholes to characterize the geology under the site to depths at least 100 ft below the deepest proposed fill area. Guidelines within the regulations suggest the number of boreholes to be drilled depending on the size of the landfill site. Section 202 also provides for alternate plans to be submitted to the Environment Department for approval. This alternate plan is based on current knowledge of the Sand Point site obtained during preliminary site investigations and is submitted for approval by the Environment Department.

General Site Description

The Sand Point site under investigation consists of the northwest quarter of section 11, T.21S., R.28E., in Eddy County, New Mexico. The site is approximately 160 acres in size. Buffer zones are planned around the margin of the site, enabling development of approximately 90 to 100 acres for use as a landfill.

General Background Geology and Hydrology

From basic background information and preliminary site characterization, including drilling (Figure 1), the geology and hydrology basics are established and have been summarized here. Recent drilling at the site involved four drillholes at separate locations and a supplementary drillhole at one of the original locations to establish a piezometer.

Four drillholes at the site established as piezometers show ground water more than 100 ft below the maximum excavation depth for a landfill. The shallowest ground water is along the southern part of the site, where piezometer G/H-1A shows a water level about 170 ft below the ground surface. As of August 6, relative elevations of groundwater in the four piezometers (Figure 2) could be interpreted as indicating a general northeastward groundwater flow. *These interpretations should be treated with some caution, though the evidence indicates that these ground water levels have reached near equilibrium.* The same figure shows ground water elevations measured July 2, July 21, and August 6, indicating relatively small changes over a period of nearly three weeks. Further changes are also expected to be small (generally < 1 ft).

More accurate ground water gradients may be established when sampling and testing of ground water chemistry of the piezometer boreholes provides possible density corrections. The ground water chemistry may also provide evidence of possible flow paths and of areas which may have longer rock/water interactions (residence time).

Drilling at these four locations (G/H-1 and 1A, -2, -3, and -4) shows similar geology: eolian sand (and pad fill) at the surface, a few feet of Mescalero caliche, and at least 200 ft of the Tertiary age Gatuña Formation. The first three drillholes (G/H-1, -2, and -3) were continued to the Permian Dewey Lake Formation, and G/H-1 was drilled an additional 155 ft in Dewey Lake before being abandoned and plugged. These units are commonly known in southeastern New Mexico; they vary in thickness depending on the degree of erosion, local depositional environments, and earlier subsidence due to regional processes of salt dissolution.

The site is acceptable for several other geological criteria. There is no evidence of faulting at the site based on surface geology, drilling, or broader regional geology (e.g., Powers and others, 1978). The surface of the site and immediate surroundings does not indicate karst is active or has existed, though regional dissolution of the upper Salado Formation does occur (e.g., Bachman, 1980) and likely caused some local subsidence prior to the deposition of the Gatuña Formation. Minor topographic closures around the northwest corner of the site are due to sand dune configurations and adjacent blowouts. There is no known evidence of active dissolution at the site. There is also no evidence of an alluvial fan at the site. The location is outside the Known Potash Leasing Area and is several miles from the nearest underground mine workings. None of these geologically related criteria exclude the Sand Point site.

Boreholes to develop geological data within the site area will generally be approximately 140 ft in depth and are expected to encounter eolian sand, Mescalero caliche, and Gatuña Formation in that interval. There is a slight possibility that boreholes could encounter the Dewey Lake in the southeastern part of the quarter section, but the Gatuña has been at least 200 ft thick in four holes drilled to date.

The Gatuña Formation is predominantly a fluvial unit with channel sandstones and conglomerates, floodplain siltstones and claystones, paleosols and other evidence of exposure, well sorted unconsolidated sand interpreted as probable eolian deposits, and less common subaqueous gypsum and laminar claystone/siltstone which may indicate shallow flooded areas or playas. These subaqueous units are not known to be continuous enough to justify interpreting them as lacustrine deposits. They are highly likely, however, to impede or prevent local vertical fluid flow and recharge. The upper part of the Gatuña Formation commonly consists of sedimentation units with clasts in a mud matrix indicating probable mud flow or debris flow; these units are also commonly overprinted by soil features including rootcasts and illuviated clays and/ or manganese deposits along soil fractures. I have described the Gatuña Formation in outcrops from the type area in Clayton Basin to Pierce Canyon for work in progress for the WIPP project. The deposits at Sand Point do not differ lithologically with the exception that gypsum has not been found. Gypsum does not occur in most other outcrops of the Gatuña either. The proportions and positions of specific lithologies at Sand Point show ordinary heterogeneity of the Gatuña because the fluvial depositional environment is highly variable, and sediment was deposited in an area of variable topography. Boreholes located even 100 or 200 ft apart may well show considerable differences in lithology at a specific depth, in contrast to units like the Rustler Formation which can be correlated in detail over thousands of square miles.

Because the Gatuña Formation is inherently variable over short distances but shows the same range in lithologies over a larger area, the drilling plan proposed here limits the number of boreholes in the quarter section. Beyond a few boreholes, our knowledge of the geology will not be improved except as an academic exercise.

Basic Drilling Plan

The drilling plan proposed consists of five drillholes located near the corners and center of the landfill area within the quarter section (Figure 3). The drillholes may be drilled in any order.

Each borehole is expected to encounter a variable thickness of sand and soil, up to 10 to 20 ft of Mescalero caliche and underlying calichified Gatuña Formation, and Gatuña to the remaining depth of the borehole. The saturated zone encountered during current drilling is well below the depth of about 140 ft for these proposed boreholes.

It is proposed that these boreholes be drilled with continuous flight augurs with continuous sampling and/or split spoon samples to obtain and preserve an objective record of the geology. No fluids will be used during drilling unless necessary. Each borehole will be plugged to the surface with cement and abandoned after drilling of the borehole is completed.

For each borehole, a geologic log and description will be prepared based on core or cuttings. Depths will be related to a surveyed elevation point. The descriptions will include the following elements where they can be determined: rock type, contacts and sedimentary structures, fractures and other secondary structures, color (GSA rock color chart or Munsell Soil Color Chart), general lithification or compaction, evidence of moisture, and any additional and appropriate information. Based on experience in drilling during preliminary site characterization, the boreholes are expected to reveal mostly (if not entirely) rock unis below surficial sand; few units will be classified based on the Unified Soils Classification System. A graphic log will be produced for each borehole.

Based on current site information, groundwater should be well below total depth of each of these boreholes. I do not anticipate establishing any piezometers to supplement the four already established. Any encounter with groundwater, however, will be noted, reported, and further evaluated.

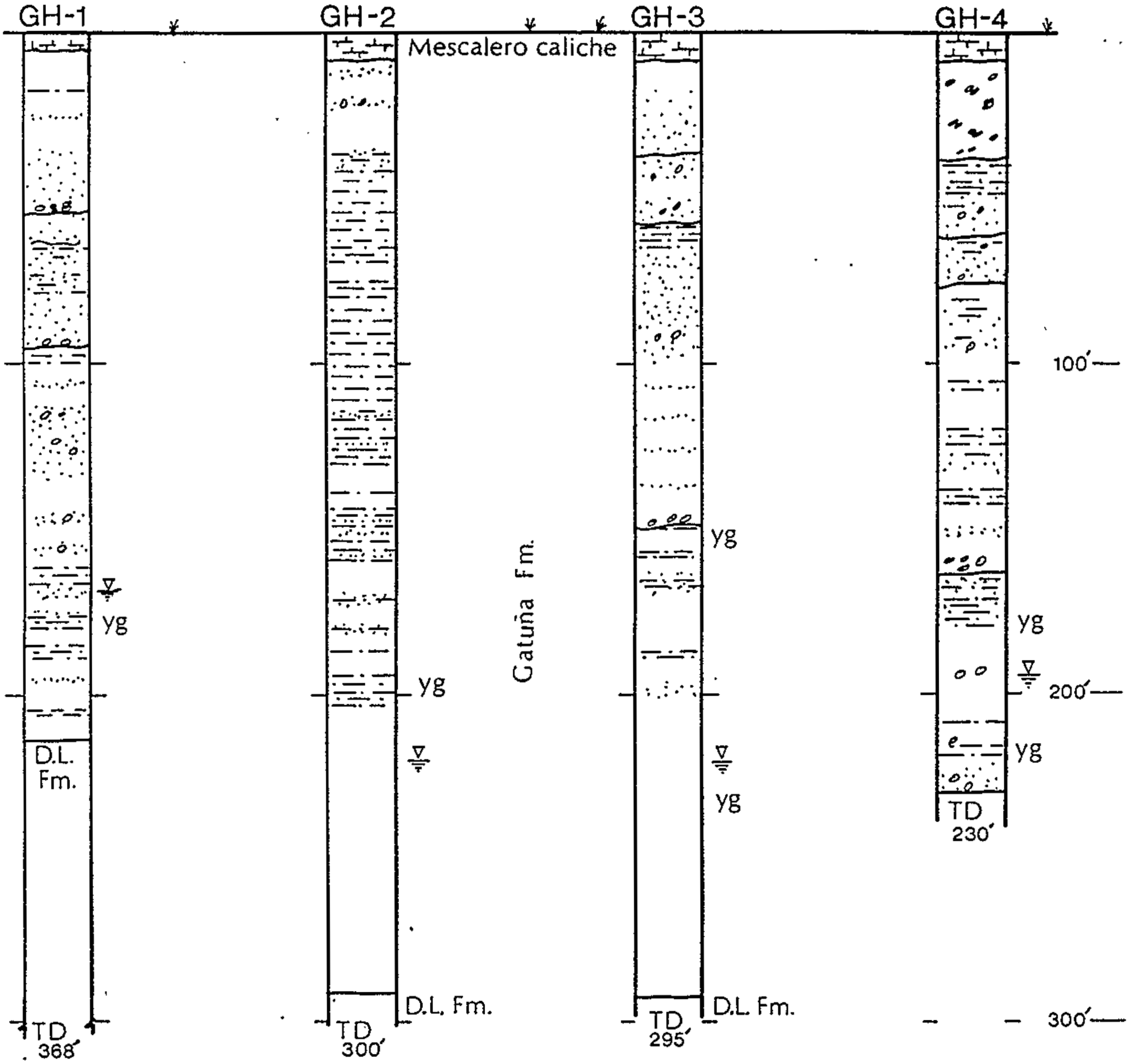
The preliminary design for the landfill incorporates a lining of engineered materials. Samples will be taken for possible testing to obtain moisture content, plasticity index, liquid limit, and sieve analysis. Samples will also be reserved for possible hydraulic conductivity tests. These tests will provide evidence of natural capacity to retard or prevent significant vertical fluid flow and recharge. All samples will be marked by location.

References Cited

Bachman, G.O., 1980, Regional geology and Cenozoic history of Pecos region, southeastern New Mexico: Open-File Report 80-1099, US Geological Survey, Denver, CO.

Powers, D.W., Lambert, S.J., Shaffer, S-E., Hill, L.R., and Weart, W.D., eds., 1978, Geological characterization report, Waste Isolation Pilot Plant (WIPP) site, southeastern New Mexico: SAND78-1596, v. I&II, Sandia National Laboratories, Albuquerque, NM.

Figure 1
General Geology and Stratigraphy
Drillholes for Preliminary Site Characterization
Sand Point Location



GH-# represents geology/hydrology drillhole. Graphic log is shown relative to depth. Symbols: yg = yellowish green siltstones, D.L. Fm. = Dewey Lake Fm., T.D. = total depth. Groundwater symbol ( ) is at approximate depth. Lithologic symbols are standard; they are not shown where core not recovered.

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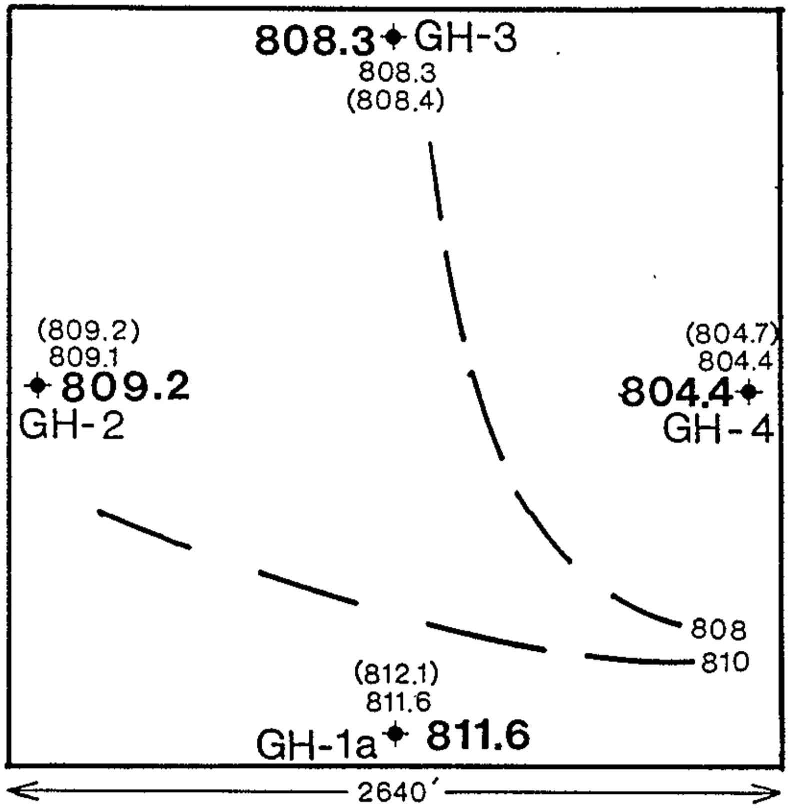
Consulting Geologist
08/18/92

Figure 2
Location Map of Drillholes for Preliminary Site Characterization and Preliminary Elevations (Arbitrary) of Groundwater Sand Point Location

Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology well completed. Elevation of groundwater is relative to point of turning (POT) established at center of section and assigned *an arbitrary elevation of 1000.00 ft.* Top of groundwater measured July 2 ( ), July 21, and August 6(bold), 1992, by Marvin Magee (JOAB, Inc.).

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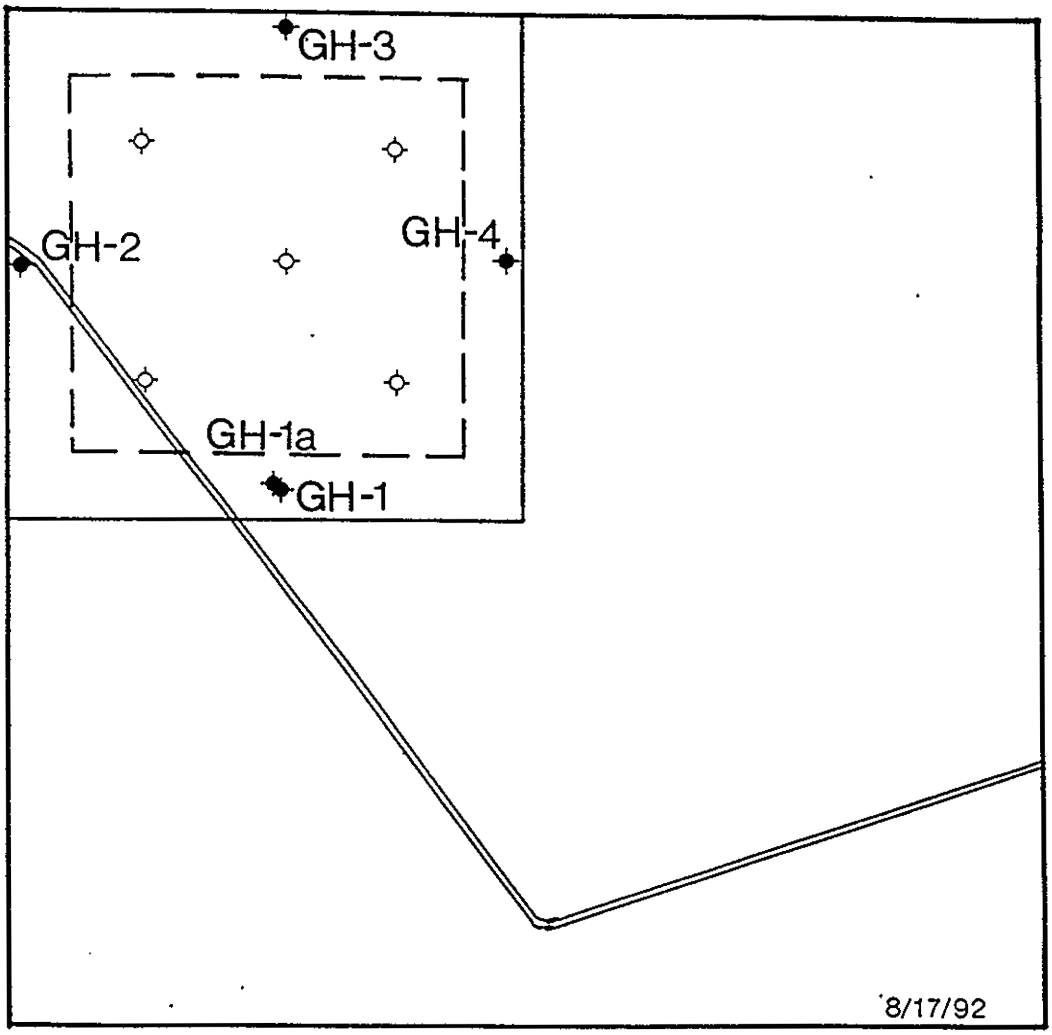
Figure 3
General Location Map of Drillholes for Preliminary Site Characterization and Borehole Drilling Plan Sand Point Location

Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology well completed or being drilled.

represents tentative location for boring within proposed landfill site.

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08/18/92

Preliminary Site Characterization for the Sand Point Site, Eddy County, NM

Prepared for

JOAB, Inc.

P.O. Box 580

Sunland Park, NM 88063

by

Dennis W. Powers, Ph.D.

Consulting Geologist

Star Route Box 87

Anthony, TX 79821

05/17/1993

TABLE OF CONTENTS

ABSTRACT

Dwindling capacity of Carlsbad landfills and new (1991) state regulations necessitate finding a new landfill site for Carlsbad and Eddy County, NM. Large areas of Eddy County are unsuitable because of rock outcrops and national park/forest land (western part), river and floodplain areas with shallow ground water (along the Pecos River), and areas with active karst/sinkholes (commonly along the eastern side of the Pecos River and south of the Black River). Three sites close to Carlsbad were examined and rejected as unsuitable during preliminary work leading to the selection of Sand Point. Three broader locations, including the **Sand Point location** (six square miles), were also examined during preliminary work for background data on hydrological and geological suitability. These data, and two auger holes drilled at the Sand Point location, showed no evidence of negative features at this location.

Additional background hydrological and geological data about Sand Point were obtained and analyzed, indicating the possibility of regional ground water and further structural changes of the Rustler Fm under the location. Based on the broader geological and hydrological data, areas along the northern part of the location are more suitable, while the southern part of the location may be unsuitable because of ground water depths and karst. The areas suitable in view of background geological and hydrological data were reviewed; engineering and location data were preferable for the NW¼ of section 11 (T.21S., R.28E), and this site was chosen for preliminary characterization.

Of eight drilling locations proposed and reviewed around the perimeter of the site, four were chosen for preliminary characterization and were drilled from late May to late June (1992). Each location was cored as possible as an objective record of the

geology. Ground water was intercepted at each location, ranging in depths from about 170 ft to about 220 ft below the surface. The boreholes were completed with screens and tubing as piezometer wells. The annulus of each well was filled with sand, bentonite, and grout, over appropriate intervals, to provide good inflow conditions and prevent surface inflow. The boreholes are completed with surface casing in cement and a secure cover.

The geology encountered by drilling at Sand Point shows near-surface Mescalero caliche of variable induration and thickness. The (?Plio-Pleistocene) Gatuña Formation ranges in thickness from a minimum of about 220 ft to about 290 ft. Three boreholes intercepted the Permian Dewey Lake Formation, and one drillhole was drilled an additional 155 ft in the Dewey Lake without reaching the underlying Rustler Formation. The Gatuña is thicker at Sand Point than it is in most nearby outcrops, but it does not exceed regional outcrops. The Dewey Lake is also somewhat thicker than expected. These conditions are interpreted as evidence of significant pre-Gatuña solution of salt from the upper Salado Formation. Salt solution is a regionally significant process, but there is no indication of surface sinks or karst suggesting enhanced vertical permeability or recent activity.

Ground water levels in the boreholes appear to have nearly stabilized by early August. The levels are more than 150 ft below the ground surface, exceeding the minimal requirements of new regulations. The ground water gradient appears to be toward the east or northeast, based on present water levels. No water quality samples have been taken from the boreholes to determine density differences in the fluids.

Based on the existing geological and hydrological evidence from the **Sand Point site**, it is recommended that the site be selected for further characterization leading to a permit application.

1.0 INTRODUCTION

New regulations by the State of New Mexico and the capacity of existing landfills utilized by the city of Carlsbad and Eddy County, NM, require closure of landfills in the near future and development of new landfills. This report documents the geological studies, mostly by Dennis Powers, by which activities reached the stage of recommending further geological and hydrological characterization of the Sand Point site east of Carlsbad. Plans for further characterization leading to applying for a landfill permit, as well as closure plans and data for existing landfills, are covered in separate documents included in the permit application.

1.1 Objective of Report

This report summarizes the initial geological and hydrological activities during which the Sand Point site was selected and four holes were drilled as part of preliminary characterization. Draft reports were provided to JOAB earlier as evidence of progress, and a comprehensive summary report (Powers, 1992) recommended a course of action to Carlsbad and Eddy County to continue to characterize the site for permitting.

This report is derived and modified from the comprehensive summary report (Powers, 1992) and retains principally the information regarding Sand Point.

Other reports of a later phase of borehole drilling for site characterization and of the surface geology of the site are included as separate exhibits in the application.

1.2 Topics Covered

The main topics for Sand Point include general data acquisition for the "Sand Point location" and preliminary selection/characterization of the Sand Point site. Activities leading to identification of Sand Point as a potential site are covered in a summary report not included here (Powers, 1992).

1.3 General Flow of Activities

Some activities developed in response to specific requests by Carlsbad and Eddy County. Three sites were rejected before broader screening was considered (Powers, 1992). After these specific sites were rejected, the activities assumed a pattern for developing a site from a more general search to specific site investigation. Three general locations, including Sand Point, were considered based on broad siting characteristics, personal knowledge of the regional geology, and readily available information (Powers, 1992). For the Sand Point site, the activities followed more nearly a conceptual outline from initial screening through preliminary characterization (Table 1).

Preliminary location/site screening and site location to identify the Sand Point area were based on generally available geological and hydrological information as well as personal knowledge of the regional geology. From this information and modest site examination, no factors were apparent that would cause rejection of the location without more specific information. From a more general 6 square mile location, we (JOAB employees and I) located a potential site (¼ section or ¼ square mile), combining good geological and hydrological characteristics with positive engineering factors, for further investigation. We completed field investigations as part of the *Preliminary Location/Site Characterization* phase. The preliminary site characterization reported in this document indicated that the site was still acceptable. Based on the preliminary site characterization, the Sand Point site was selected and further investigated (see later Exhibit) during a borehole drilling phase leading to a permit application.

Table 1
General Phases of Landfill Site Investigations,
Carlsbad & Eddy County Landfill

Preliminary Location/Site Screening
- based on broad siting criteria and regulations - avoid areas obviously in conflict with regulations
- examined broader area around Carlsbad for potential locations/sites
- included reconnaissance of area and exam of proposed sites
- this phase may continue if region-wide work is necessary

Preliminary Location/Site Selection
- obtain and summarize available information
- consider relative merits of locations or sites from screening
- include basic engineering and other qualifications:
  - haulage distance
  - "culture", i.e. pipelines, oil wells, etc
- select principal and backup locations/sites for initial characterization

Preliminary Location/Site Characterization
- conduct initial detailed field investigations of site or location
- concentrate on most likely flaws or anomalies at site/location
- conduct mapping, drilling, initial hydrology studies
  - establish basic geology conditions in the near-surface (<1000 ft)
  - establish initial hydrology conditions for site
    - depth to groundwater (gradient, flow velocity)
    - groundwater quality

Site Selection
- mainly confirms that information from preliminary characterization is still consistent with locating a site
- constitutes a formal decision to proceed with more detailed investigations which are expected to lead to permitting process
- if questions at this stage are significant, alternate or backup site might be chosen for preliminary characterization

Site Characterization
- investigated in detail all necessary aspects of geology and hydrology, as well as engineering and construction, to prepare for the permit application
- more detailed geology of the upper 140-150 ft
- more detailed hydrology
  - monitoring wells are established
  - more sophisticated testing and observation of wells
  - may include slug, pumping, or other tests

Permit Application

Construction

Operation

Closure and Monitoring

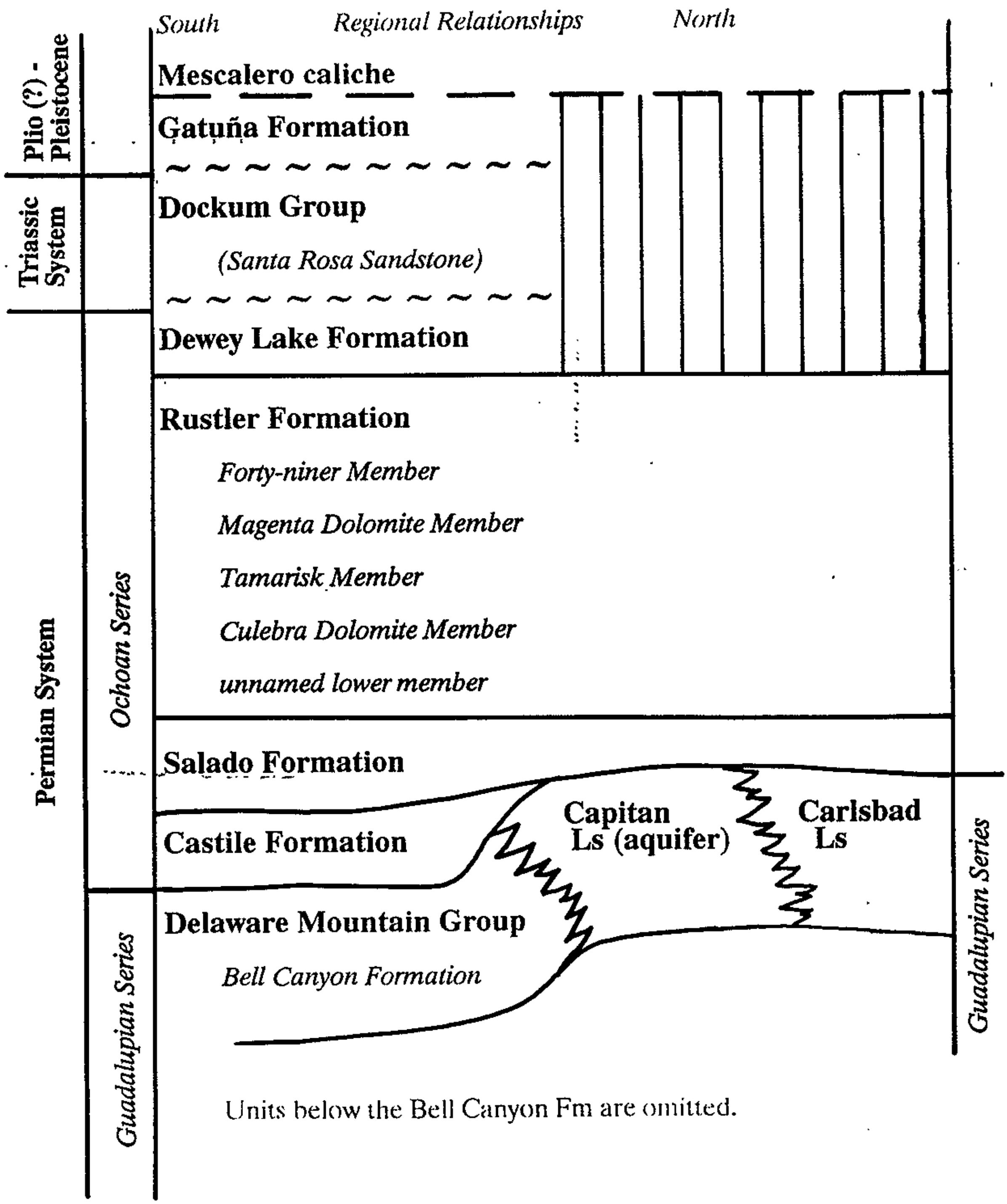
1.4 Brief Overview of Relevant Geology

Much of the geology of surficial and near-surface rocks in Eddy County and the area around Carlsbad is dominated by a general series of events: 1) the geological setting for deposits of Permian age (about 250 million years old) evaporites, 2) subsequent mild tectonic events and erosion, 3) solution of carbonates and soluble evaporites, and 4) late Tertiary to Holocene age deposits on the irregular surfaces formed by dissolution and erosion. Major units of the area examined during this study are shown in their stratigraphic relationships in Figure 1.

From south to north, through a line passing through Carlsbad, Eddy County is underlain by a major basin (south), a transition from basin to major reef rocks (Carlsbad), and shallower shelf carbonate rocks (north). The basin was first filled with evaporite rocks (Castile Formation), followed by more evaporites that lap onto (were deposited over) much of the shelf to the north (Salado and Rustler Formations). By the end of the Permian, the basin and shelf areas were covered with fine-grained sediment brought in by intermittent or slow-flowing rivers or streams (Dewey Lake Formation). The Dewey Lake and Rustler Formations crop out or are near the surface in the eastern part of the county where the search for a new landfill is concentrated.

During the early Triassic, much of this area was subject to erosion. Coarser sandstones and conglomerates were deposited over the eastern part of Eddy County and are thicker to the east. Following these events, most of this area was subject to erosion through much of Mesozoic and Cenozoic time. In one or more events following the deposition of Permian evaporites, the basin and much of the shelf was gently tilted to the east, with the latest tilting in late Miocene time. The Ogallala Formation was deposited on the high plains following this tilting. It is uncertain how much of the Eddy County area was covered by Ogallala sediments.

Figure 1
Important Stratigraphic Relationships Among Units in the Area Covered by this Report



During the Pleistocene, at least, erosion by the Pecos system progressed, developing the major drainage of the area. Solution of the underlying evaporites caused subsidence, affecting the Pecos drainage. Features such as Nash Draw also developed by combined erosion/solution processes. The Gatuña Formation was deposited during the early development of these drainage and solution features. It shows mainly fluvial deposits incorporating clasts from Ogallala and older local formations as well as clasts of igneous rocks from the Sierra Blanca (New Mexico) area (Bachman, 1974). The Gatuña includes gypsiferous deposits to the south and locally in Nash Draw, demonstrating local intermittent ponding and probable saturated soil conditions. The Gatuña displays tilted and cross-cutting relationships in some areas (e.g., Pierce Canyon) that indicate the underlying rocks were also being dissolved while the Gatuña was being deposited. Highly variable Gatuña thicknesses accumulated depending on both local relief and differential subsidence from dissolution.

The Mescalero caliche (about ½ million years old; Szabo and others, 1980) overlies the Gatuña and other formations over large areas in eastern Eddy County, indicating the degree of stability over that period. The caliche forms over a period of time and will be affected by tilting/subsidence associated with dissolution.

The rocks over most of Eddy County broadly tilt to the east; erosion of higher areas to the west exposed large areas of carbonate which are unsuitable for landfill purposes and which have been set aside in national forest and park lands. Along the Pecos and general longitude of Carlsbad, evaporites and their residues crop out and are subject to both erosion and solution. Further east, outcrops are dominated by clastic rocks which are insoluble, though affected when underlying evaporites are dissolved.

The Pecos River and floodplain have deposits of alluvium with shallow ground water underneath. Reef and shelf carbonates yield ground water at varying depths from very shallow around Carlsbad to much deeper to the east. Clastic rocks have variable water resources at moderately predictable depths and stratigraphic positions.

2.0 PRELIMINARY SITE SELECTION ACTIVITIES - SAND POINT

2.1 Preliminary Site Investigations for the Sand Point Location (Quahada Ridge)

As indicated in Section 1.0, other sites and locations were considered before selecting Sand Point as a potential site. One location was considered a possible alternative if Sand Point proved unacceptable. These investigations are reported in a summary (Powers, 1992) as evidence of the activities leading to the selection of the Sand Point site, but they are not repeated here.

Broad screening criteria (Table 2) were applied to areas within Eddy County; these are partially based on recent regulations established by the state (State of New Mexico Environment Department, 1991). These screening criteria consider various specific geological, hydrological, and socioeconomic factors (e.g., presence of pipelines and other "cultural" features). To find a potential site, priority factors included distance from Carlsbad and suitable geological and hydrological conditions.

There is no known tectonic fault with displacement during the last 11,000 years near Sand Point. Kelley (1971) observed lineaments, which he designated as the Carlsbad and Barrera faults, along the eastern escarpment of the Guadalupe Mountains. Hayes and Bachman (1979) re-examined these outcrops and concluded there was no faulting. The nearest known probable Quaternary faulting due to tectonic forces is along the western escarpment of the Guadalupe Mountains (e.g. King, 1948; Muehlberger and others, 1978) more than 40 miles from Sand Point.

The archeological and historical site criteria are not addressed here. Preliminary information can be obtained through Federal agencies; the Bureau of Land Management has been consulted and has located potential archeological sites for Sand Point.

The Sand Point site is not located on an alluvial fan.

Principal geological and hydrological factors for Sand Point include the lack of sinkholes/karst and depth to ground water greater than 150 ft.

Table 2

SCREENING CRITERIA

Several criteria of general use help focus on the relative merits of these sites:

depth to groundwater:	more than 100 ft below landfill excavation depth
quality of groundwater:	preferred to exceed 10,000 mg/liter (ppm)
construction quality:	minimal or no bedrock in upper 30 ft.
	prefer higher clay content as infiltration barrier
topographic features:	no active sinkholes or probable karst
	moderate slopes
land ownership:	no state land
	private or BLM ownership preferred
"cultural features":	minimize oil/gas wells, pipelines
	minimize power lines, but nearby source desirable
	nearby good road desirable
distance for haulage:	minimize haulage distance for appropriate sources.

Of the above criteria, the most stringent are groundwater, bedrock, sinkholes, and land ownership. Other factors, such as pipe lines and power lines, might be overcome by rerouting if necessary, but the costs of overcoming such obstacles would have to be weighed relative to other costs.

Additional exclusions in proposed state regulations were partially considered during reconnaissance of sites and locations and were applied more stringently if potential site survived initial screening:

no floodplain locations, not within 500 ft of wetlands or within 200 ft of watercourses;

not within 200 ft of a fault that has had displacement within the last 11,000 yrs;

not within historically or archeaeologically significant sites, unless in compliance with various legislation (the Cultural Properties Act, Section 18-6-1 to 18-6-23 NMSA 1978; the Prehistoric and Historic Sites Preservation Act, Sections 18-8-1 to 180808 NMSA 1978); or

not in an active alluvial fan.

2.1.1 Location

Quahada Ridge is a topographic high that bounds the western side of Nash Draw and bends back to the west at its north end (Figure 2). The ridge is covered in many areas by the Mescalero caliche, which is as much as 6 ft thick in some parts. The remainder of the ridge consists of either the Plio-Pleistocene Gatuña Formation, commonly a few feet to a several tens of feet of brownish to slightly reddish brown sandstone and siltstone, or the Permian Dewey Lake Formation, a reddish brown siltstone ranging in thickness to about 600 ft to the east of Nash Draw. A broader location (sections 10-15, T.21S., R.28E.) was examined on the northwestern end of Quahada Ridge at and around Sand Point (section 10) to determine if general conditions were suitable for a landfill.

This location was chosen for further investigation because of relative proximity to Carlsbad, apparent regional depth to ground water, and favorable nearsurface lithologies for construction. An area of 6 sections (square miles) was designated for investigation to include possible favorable and adjacent areas.

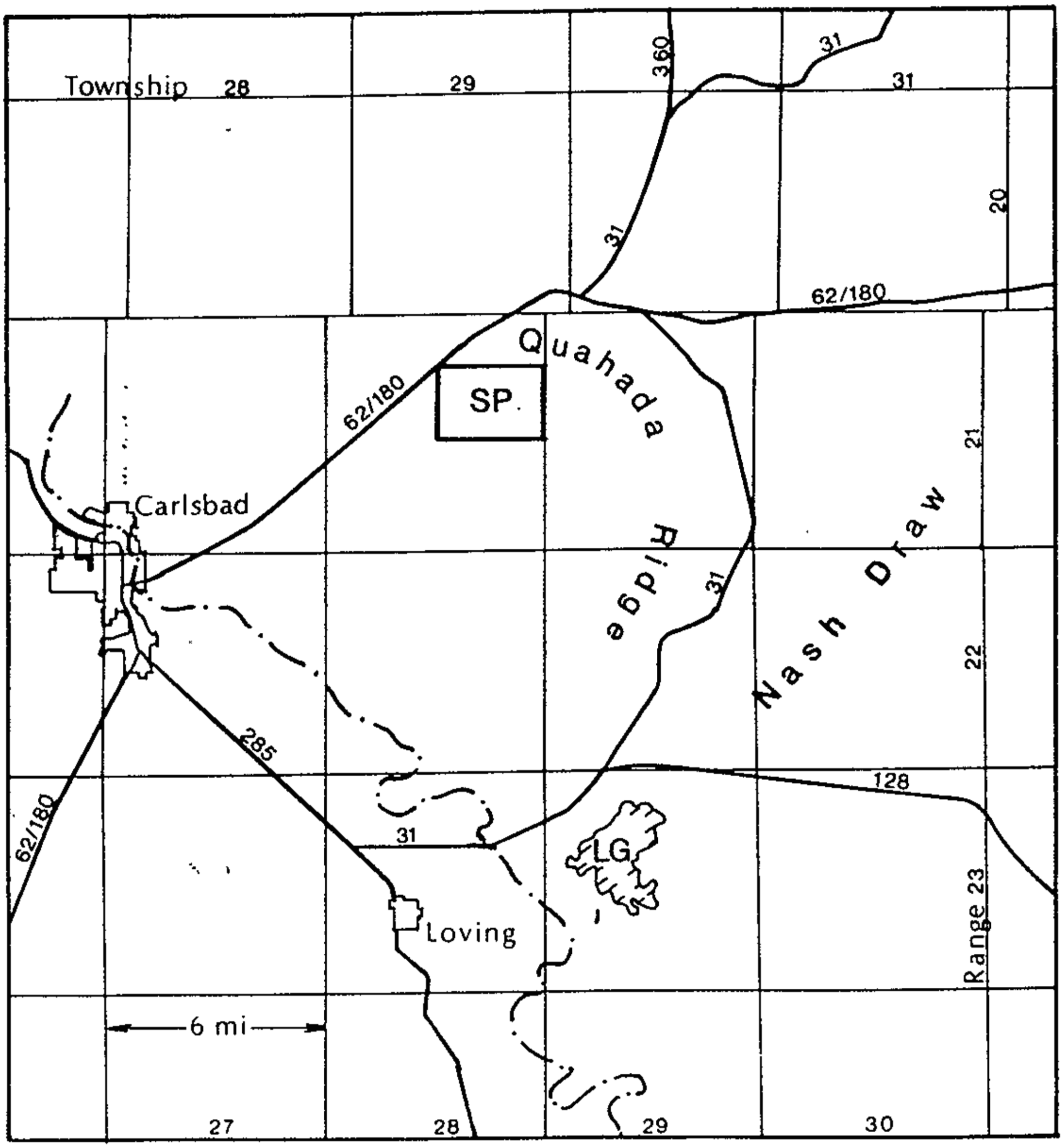
2.1.2 Background Geological and Hydrological Data

There are no observed shallow hydrologic wells in use in the six sections examined as a possible location for a landfill site. During the preliminary studies (Powers, 1992), data were examined from a broader area around the location (Hendrickson and Jones, 1952; Geohydrology Associates, Inc., 1978, 1979; Richey, 1989). Three wells located are most relevant to the hydrology: 1) a livestock well ("Lusk east well") in section 18 (T.21S., R.29E.) just east of the Sand Point location, 2) an "industrial" well in the southeastern ¼ of section 12 drilled as a supply well for Bass Big Eddy Unit #36, and 3) a stock well near the center of section 2, less than 1 mile north of the prime section (11) for the Sand Point location. Calculated elevations on the water in these three wells are nearly the same, from 3153 to 3157 ft (Powers, 1992).

General ground water elevations in the area of 3150 ft would indicate suitable depths (> 150 ft) below the higher, northern sections, but southern sections may have shallower ground water.

No sinkholes or evidence of probable karst were observed in these sections during reconnaissance. Further west and south, the Rustler Formation crops out or is

Figure 2
Regional Setting
Sand Point Location



SP identifies Sand Point location (six square miles). LG is the location of Laguna Grande de la Sal. Highway numbers are shown along the highway line.

weathering in the near surface. Closed depressions and swallowholes have been observed north, west, and south of the location, but are not known to be a problem within sections 10-15. A closed depression occurs adjacent to the Sand Point location in section 9. The depression may indicate solution of salt or of sulfate beds. At the location, salt is still present in the Salado Formation underlying the Rustler.

The relief and slopes in this area are not great. Local drainages connect to Indian Draw and Flats to the southwest, but it should be possible to locate a large site without including any significant drainage system.

It is believed Bureau of Land Management controls all sections (10 through 15) in the general Sand Point location.

Two subparallel pipelines running northeast-southwest cross parts of this location. One pipeline affects sections 13 and the southeastern part of section 14. The other pipeline cuts through section 12 and the southeastern part of section 11 (Fig. 3). Section 10 is not affected. Drilling has been minor. There are no nearby power lines. Potential sites range from about 1 to 2 1/2 miles from Hwy 62/180.

The haul distance from the center of Carlsbad would be about 11-12 miles, depending on location of a site.

Based on background data, the northern part of the Sand Point location appeared to be favorable and some initial augering was completed.

2.1.3 Sand Point Auger Results

Two holes were augered and partially sampled in this general location (Fig. 3). SP-1 was drilled about 20 ft from the road in the SW¼, NW¼, section 11, T.21S., R.28E. The location is at the lower end of a borrow pit for sand. The elevation of the surface at SP-1 is about 3320 ft, based on the topographic map. Borehole SP-2 was augered in the SW¼, SE¼, section 12, T.21S., R.28E., adjacent to the road. The elevation of SP-2 is about 3350 ft, based on the topographic map.

SP-1 was augered to refusal at a depth of 81 ft. The lithology can be described as three basic units, with detail provided in Appendix 1:

0-6 ft	Reddish brown argillaceous sand of eolian origin.
6-16 ft	White caliche clasts in light brown sandy to granular matrix (Mescalero caliche) overlying sandy silt and silty sand with pedogenic carbonate from the Mescalero.
16-81 ft	Reddish brown calcareous silty sand and sandstone with zones of thin bedding and zones with extensive open porosity and MnO_2 stains from rootlets in weak paleosols (Gatuña Formation).

No moisture was detected in this borehole. Cuttings returned to the surface from a drilling depth of about 8 ft were moist enough to hold together when pressed. Sampling from 11 to 16 feet returned material which was slightly moist as well. No moisture collected overnight in the hole to a depth of 60 ft.

SP-2 was augered to a total depth of 56 ft to refusal. The lithology consists of four units, with detail provided in Appendix 1:

0-2 ft	Loose dark brown sand with pebbles (surface wash and soil).
2-5 ft	Light brown to white calcareous matrix and caliche pebbles (Mescalero caliche).
5-53 ft	Reddish brown siltstone and fine sandstone with greenish reduction spots (Dewey Lake Formation). Drilling and recovery became variable from about 38 ft, and the auger assembly was not in solid rock through some zones. Drilling became difficult at 53 ft. No coring from 45-55 ft.
53-56 ft	TD in hard, slightly pinkish, white gypsum (Rustler Formation). Sample included some porous sandy carbonate chunks. Based on drilling difficulty, the top of Rustler is estimated to be at 53 ft.

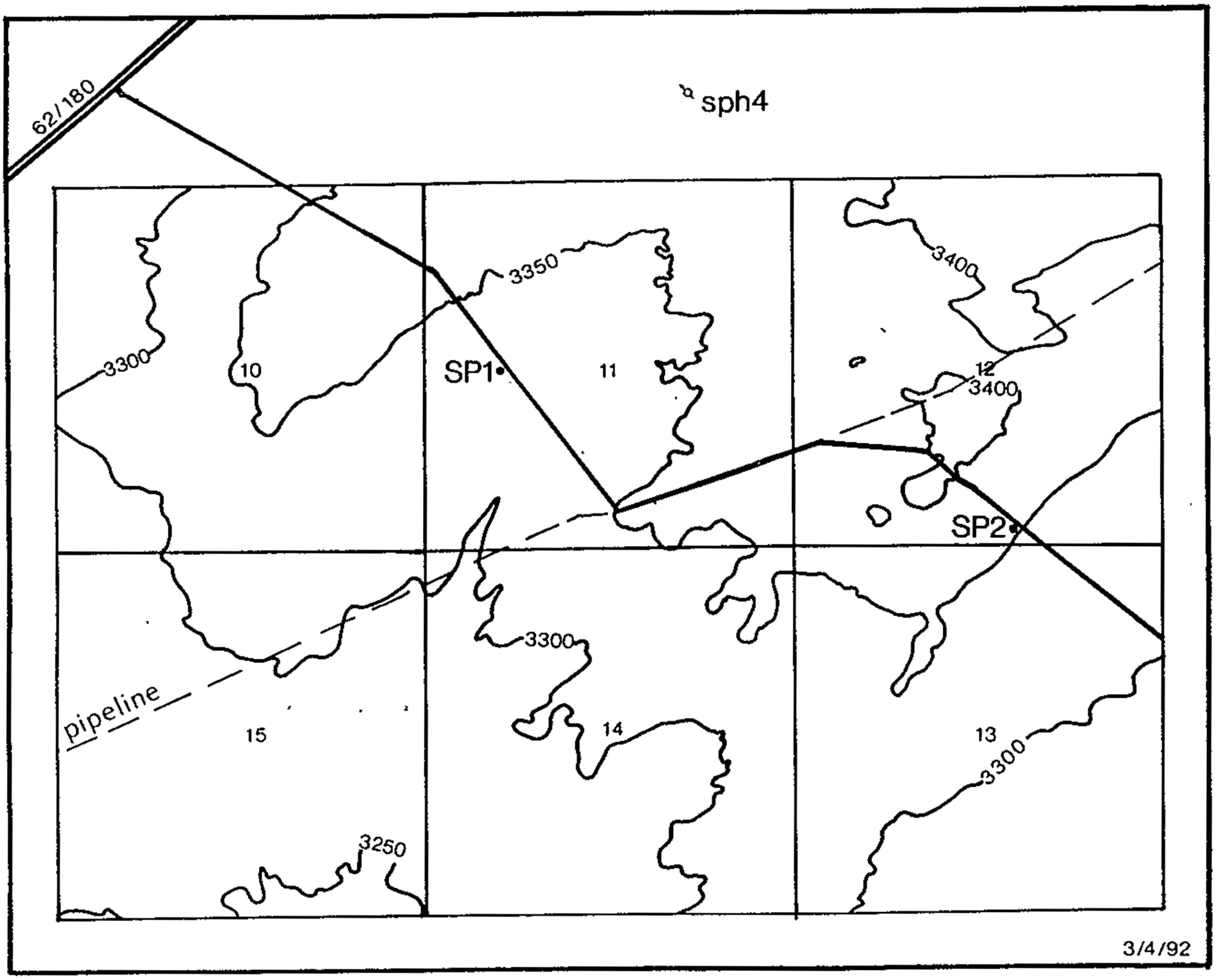
No moisture was detected in this borehole using a water depth gauge. There were neither cuttings nor core indicating any moist zones.

Based on the preliminary data and auger results, it was concluded that available records should be further researched as a basis for preliminary site characterization.

2.1.4 Additional Background Data, Sand Point Location

The Bureau of Land Management in Roswell made available information from potash or other drilling for the Sand Point location and surroundings where that information is releasable to the public. The requested information included stratigraphic information

Figure 3
Sand Point Location,
Auger Holes and Potential Exploratory Drillhole Locations



Topographic contours in feet. **SP#** refers to auger hole number.

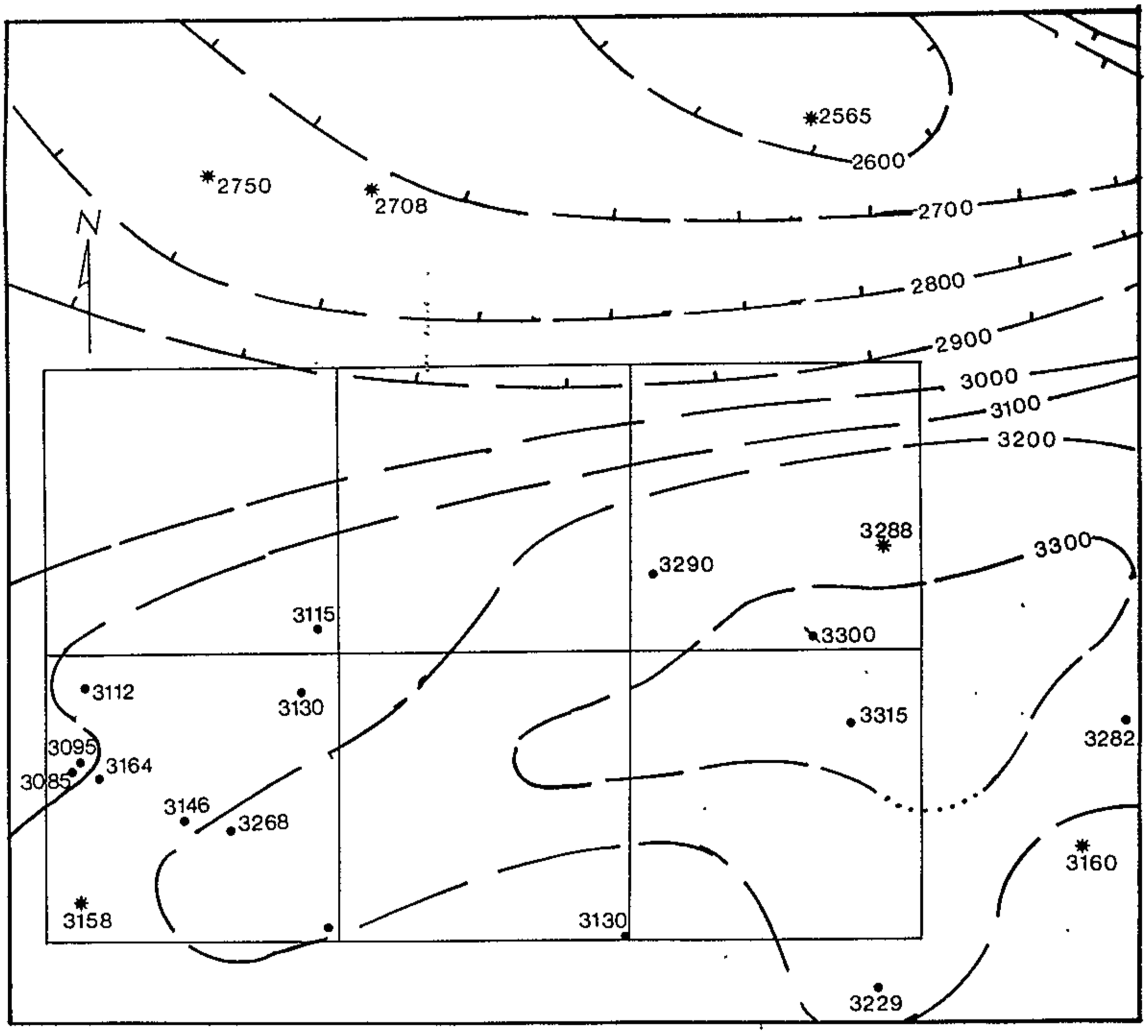
on units to the top of Salado or Salado salt and any hydrologic data which may have been recorded (lost circulation zones, moist zones, water level, water quality). Appendix 2 summarizes data from various boreholes.

The additional potash and hydrocarbon drillhole data within and around the 6 square mile Sand Point location were used to prepare a structure contour map of the top of the Rustler Fm (Fig. 4), demonstrating some possible anticlinal structure oriented generally east-west. The elevation of the top of Salado halite (Fig. 5) was estimated throughout the location using data along the south and by extrapolating along general structure contours of the overlying Rustler Fm.

Some hydrological data were obtained from potash and hydrocarbon exploration in the area to add to regional data reported by Geohydrology Associates, Inc. (1978). In section 12 (T.21S., R.28E.), a potash hole log reported water encountered at a depth of 280 ft, within the upper Culebra Dolomite Member of the Rustler Fm or in basal gypsum of the Tamarisk Member. In the southwestern part of the six square mile location, potash drillholes were reported to have encountered water at varying depths, even in adjacent boreholes. The depths and geologic information reported suggest that these intervals may correspond to Culebra Dolomite or unnamed lower member of the Rustler and the interval above Salado halite. It cannot be determined if water-bearing units were undetected during some drilling or if there exists highly variable and isolated fluid-bearing zones in this area. These data have been conservatively (i.e., assuming less favorable conditions) estimated to indicate an unconfined water-bearing unit at an elevation of about 3150 ft through much of the northern part of the location.

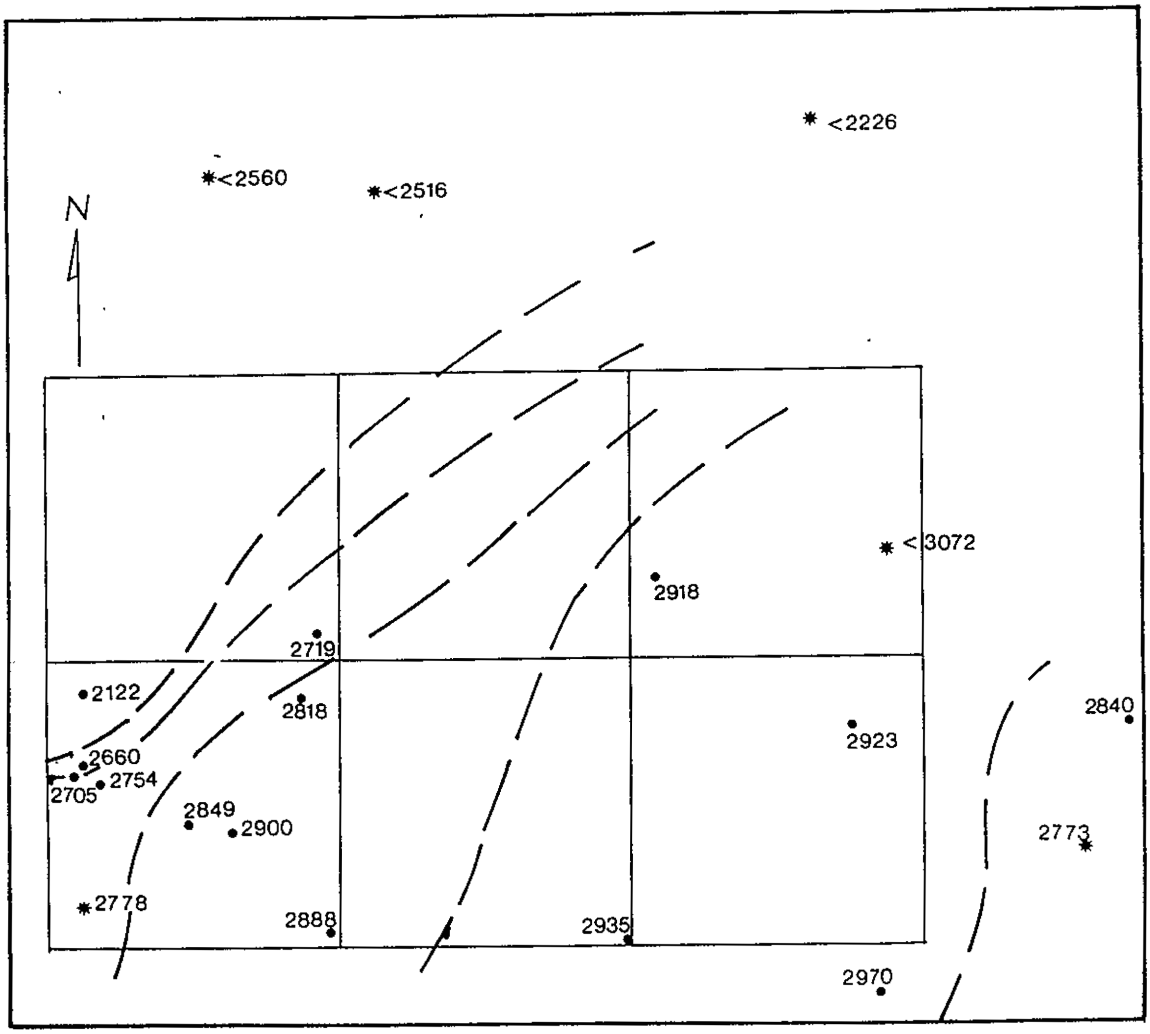
The data base gathered from various sources, as well as field investigations, shows that the northern three sections (10-12) have little direct information from drilling. This is an area where changes in the underlying structure are significant, as interpolated between boreholes in the southern three sections (13-15) and those north

Figure 4
Revised Structure Contours on Top of Rustler Formation, Sand Point Location



Data from Richey (1987) indicated by ✷. Data from Bureau of Land Management (Roswell office) files indicated by • and are reported in Appendix 2. SP-2 auger hole is indicated by ↘•. Contours prepared prior to Sand Point drilling.

Figure 5
Estimated Elevation Contours, Top of Salado Formation Halite Sand Point Location



Data from Richey (1987) indicated by ✱. Data from Bureau of Land Management (Roswell office) files indicated by ● and are reported in Appendix 2.

of the location. The lack of drilling and apparent lack of underlying resources is advantageous for a landfill, but it also signifies less confidence about the underlying geology.

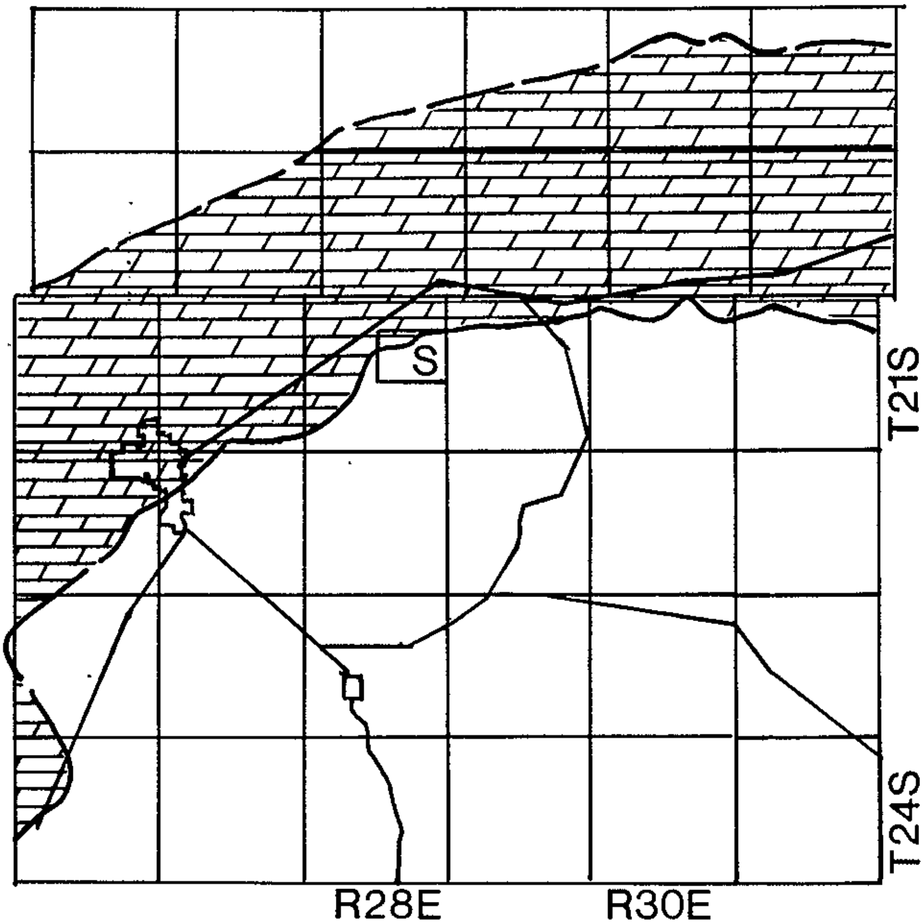
According to Hiss's map (1976) the Capitan aquifer could underlie much of section 10 and northern halves of sections 11 and 12 (Fig. 6). The map conservatively moves the boundary toward the basin. Given the locations of boreholes with and without Capitan, the Capitan could also be north of all of these sections. Until further information is obtained, the more conservative, more southerly position underlying part of the Sand Point location is assumed correct.

The Capitan is not a factor in site selection, as the depth to the Capitan is much greater than other fluid-bearing zones at the location. The nearest wells to the west and north show elevations of 2222 ft, 1944 ft, and 1884 ft on top of the Capitan. Even assuming the 2222 ft elevation continued under the Sand Point location would indicate minimum depths to Capitan in excess of 900 ft throughout the location. The eastward dip of the Capitan in the area also is of the order of 100+ ft/mi, indicating the Capitan should be even deeper, if present at all.

2.1.5 Preliminary Site Characterization Plan, Sand Point

A general plan for preliminary site characterization of the Sand Point location was prepared and discussed with New Mexico Environment Department. The plan is presented in another section of the Permit (Exhibit IIc). As implemented, the drilling plan and methods were revised, especially the order of drilling holes. The numbers and figures originally used have been revised to match identifiers for each borehole as constructed. Section 2.1.6 describes significant alterations to the plan and to field operations as actually carried out.

Figure 6
Location of Capitan aquifer Relative to Sand Point and Laguna Grande Locations



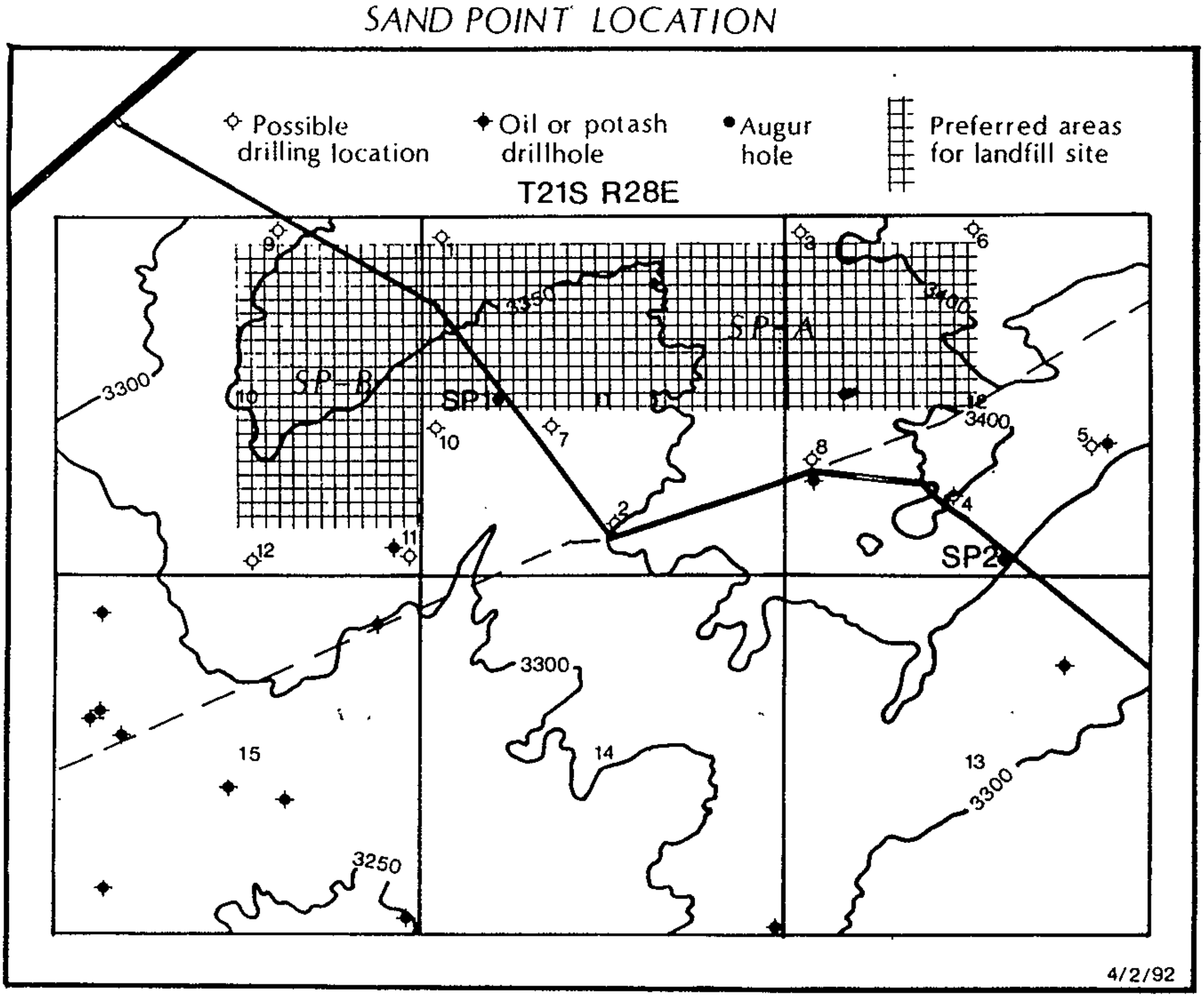
The Sand Point location is designated by S. Representative townships and ranges are given for orientation. Modified from Hiss (1976).

The Sand Point location of 6 square miles included areas not likely to be suitable. The southern row of 3 sections (13-15) were eliminated for further characterization based on probable depth to groundwater and outcrops or nearsurface beds of the Rustler Fm, which may be difficult construction material. Of the remaining 3 sections, the southeastern ¼ to ½ of section 12 and some of the southern areas of section 11 appeared less favorable, though possibly suitable for a landfill. From a geological and hydrological viewpoint, the NW¼ of section 12, north ½ of section 11, and eastern ½ of section 10 appear to be the most favorable areas (Fig. 7). The northern parts of sections 11 and 12 was termed SP-A, while the eastern half of section 10 was termed SP-B. SP-A would appear to have modest geological and hydrological advantages over SP-B. Based only on the existing geological and hydrological data, a sequence of 12 potential drillhole locations was proposed (Fig. 7) which would develop data to permit a smaller site to be selected from among the possibilities.

The NW¼ of section 11 was chosen from among the possibilities within SP-A and SP-B for preliminary site characterization based on factors of site visibility, road access and distance, and preliminary concepts of design and construction.

Eight general drilling locations (Fig. 8) around the NW¼ of section 11 were considered for maximum flexibility during *preliminary site characterization.* Only a few of the locations (probably 4 or 5) were expected to be drilled, and the principal targets were expected to be the uppermost saturated zone and the upper Rustler units. In the unlikely event a drillhole showed no significant evidence of any saturated zones, drilling was to be continued to the top of halite in the Salado. I estimated probable drilling depths for coreholes and hydrological monitoring for drilling locations based on preliminary selection of the NW¼, section 11, T.21S., R.28E., Eddy County, NM (see Exhibit IIc). These more specific locations and data modified earlier broader plans and locations (see above) which were based on the fact that the northern

Figure 7
Preferred Site Areas,
Sand Point Location



SP-A and SP-B preferred site areas are based on background geological and hydrological data available prior to preliminary site characterization. Potential drilling locations were proposed (numbered in probable order) as a means of identifying a preferred site within the location on geological and hydrological data. Engineering and access factors resulted in selecting the NW¼, section 11.

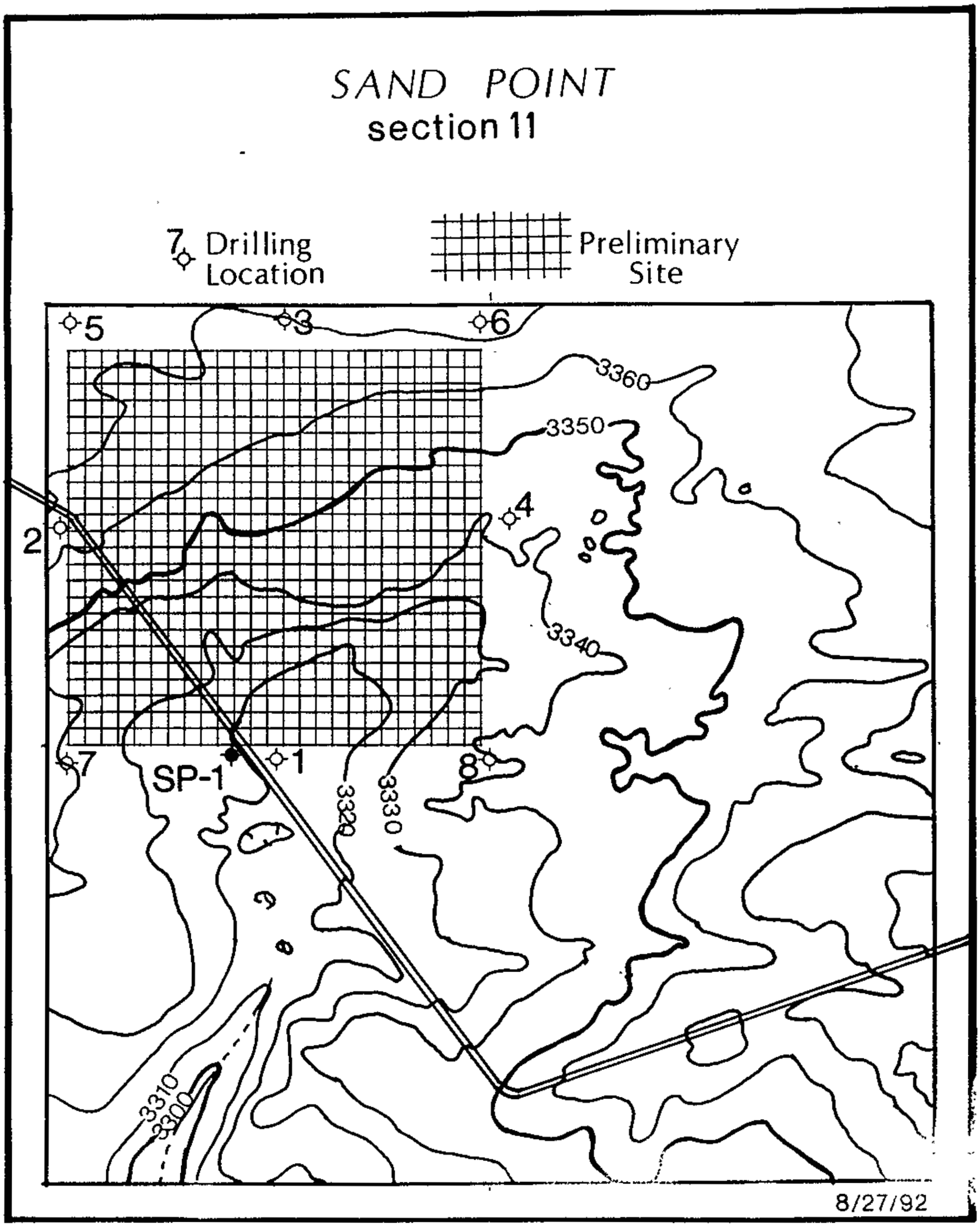
half of sections 11 and 12, as well as the eastern half of section 10, were of generally equal quality from the existing geological and hydrological data. Engineering factors and archeological potential of the area made the NW¼ of section 11 the preferred initial site for characterization. Other alternatives within sections 10, 11, or 12 were available if the NW¼ of 11 proved undesirable.

2.1.6 Modifications to Preliminary Site Characterization Plan

As preliminary site characterization was conducted, some planned activities were modified to reflect the on-site and drilling conditions. The major modifications are described here.

Drilling proved difficult through some zones. Some units did not core well or were not very stable in the borehole. Foaming agents and water were necessary for drilling in these zones, though their use was minimized as possible. Core recovery was somewhat irregular, reducing the sampling for possible laboratory tests. Core commonly could not be marked with marking pens with arrows as planned. Small wooden blocks were marked and placed at the top and bottom of core intervals and where samples were removed.

Figure 8
Location Map of Potential Drillholes, Preliminary Site Characterization NW ¼, Section 11, Sand Point



SP-1 shows location of augur hole. Numbered locations are described in Exhibit IIc.

2.2 Preliminary Site Characterization of Sand Point

The preliminary site characterization consisted principally of drilling five holes at four locations around the perimeter of the NW¼ of section 11. The holes were drilled to obtain geological data and to determine the presence and level of ground water at the site. The holes were drilled in general accordance with the plan (Exhibit IIc; Powers, 1992), with program modifications noted in Section 2.1.6. Borehole drilling and completion histories, and details of the geology and hydrology, are presented in several appendices while the broader information and interpretation is presented in this section.

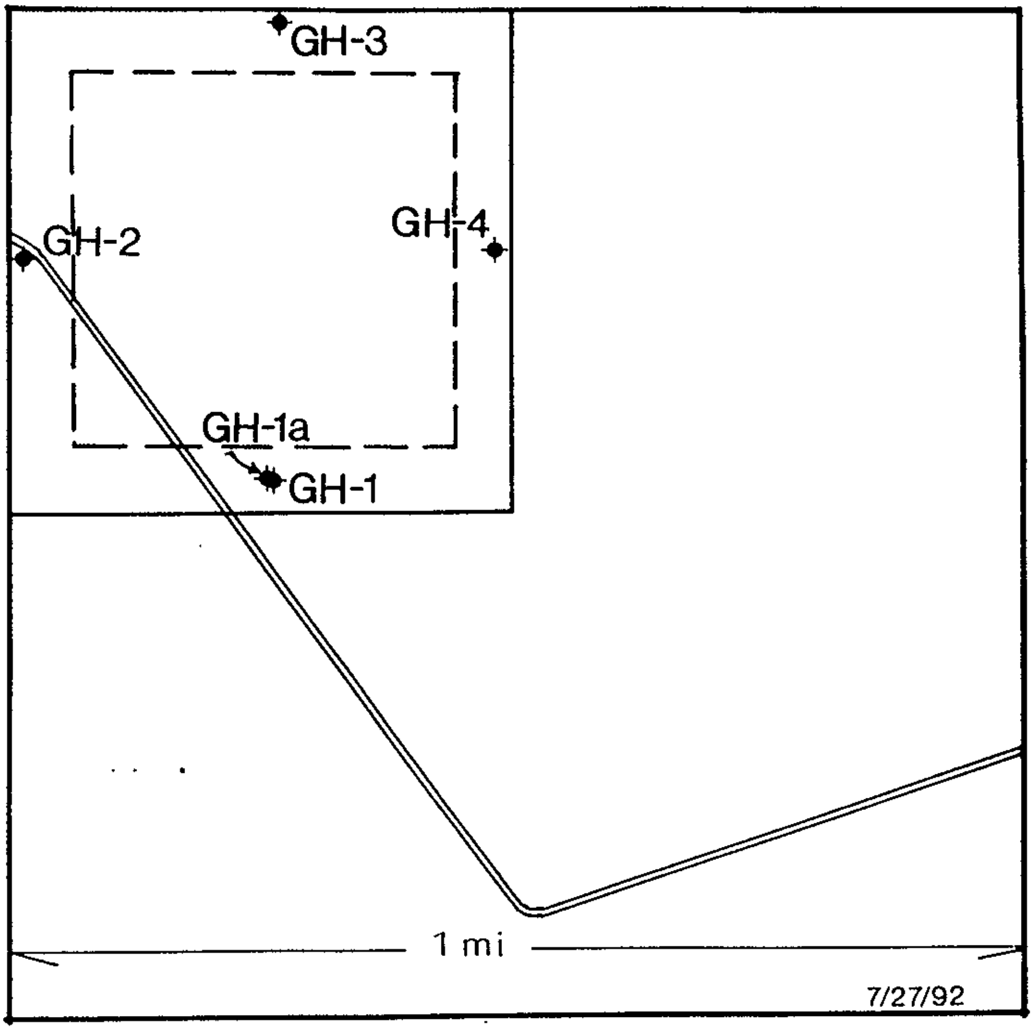
2.2.1 Sand Point Drilling

Four locations (Fig. 9) were chosen for initial drilling from among eight proposed locations around the NW¼ of section 11. These locations, near the midpoints along the side boundaries of the quarter section, were selected to provide probable upgradient and downgradient testing of the ground water level as well as to test general concepts of stratigraphy and structure at the proposed site. Details of borehole histories and basic drilling data are presented in Appendix 3.

The four locations (SP G/H-1 through 4) were drilled in order: G/H-1 along the center of the south line, G/H-2 along the center of the west line, G/H-3 along the center of the north line, and G/H-4 along the center of the east line. Initial drilling of G/H-1 did not clearly establish the presence of ground water due to difficult drilling conditions through the interval which later proved to yield water. G/H-1A was drilled about 12 ft from the G/H-1 location after G/H-4 was completed. G/H-1A was rotary drilled to the zone predicted based on ground water levels in G/H-2, -3, and -4.

Figure 9
General Location Map of Drillholes for Preliminary Site Characterization Sand Point Location

Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology well completed.

Most of the drilling used a coring bit about 5 inches in diameter with a wireline core barrel inside. For intervals with poor stability, some rotary drilling with a tricone bit about 5 inches in diameter was necessary. For further stability, some of the holes were reamed with a 7 7/8 inch tricone bit; temporary casing 5½ inches in diameter was used as well in some holes. The casing permitted coring and drilling inside it while maintaining stability. Some water and foaming agent were necessary for lubrication while drilling some intervals.

Core recovery ranged from excellent to no recovery for some drilling intervals. For drillholes G/H-1 through G/H-4, respectively, the recovery was 59%, 57%, 40%, and 60% (see Appendix 3). G/H-1A was not cored. For the first four holes, the total drilled interval was 1193 ft. Coring was attempted through 860 ft, about 72% of the total drilling for these four holes. About 487 ft of core were recovered, representing about 54.5% recovery over the 860 ft through which coring was attempted. Some intervals of sand, as well as deeper intervals, proved impractical to attempt to core.

The core was photographed, sampled as necessary, and stored in core boxes after being described.

2.2.2 Sand Point Geology

2.2.2.1 General Information

Drilling at Sand Point encountered three geologic units known from this area (Table 3). Each of the four locations showed the informal unit called the Mescalero caliche at the surface or immediately underlying surficial soil and/or eolian sand. Each of the drillholes showed a considerable thickness of the Plio(?)-Pleistocene Gatuña Formation below the Mescalero. The Gatuña ranged in thickness from a minimum of about 208 ft in G/H-1 to about 280 ft each in G/H-2 and G/H-3. The Gatuña is at least 220 ft thick in G/H-4, but the basal contact was apparently not encountered at total depth of

Table 3
Stratigraphic Units and Thickness*
Sand Point Drillholes

Stratigraphic Unit	*SP G/H-1A*	*SP G/H-2*	*SP G/H-3*	*SP G/H-4*
Mescalero caliche	1' +	4'	9'	5'
Gatuña Formation	196' +	281'	283'	220' +
Dewey Lake Formation	155' +	10' +	3' +	not intercepted

* Thicknesses are minimum demonstrated by coring and cuttings. Some surfical intervals did not return sufficient sample to determine Mescalero caliche thicknesses. Drilling did not completely penetrate Dewey Lake or Gatuña in some boreholes.

230 ft. The first three boreholes showed Permian Dewey Lake Formation below the Gatuña. The thickness of Dewey lake drilled was about 155 ft, 10 ft, and 5 ft, respectively, in G/H-1, G/H-2, and G/H-3. The deepest drilling, at 368 ft in G/H-1, was still in the Dewey Lake Formation.

2.2.2.2 Surficial Deposits

Surficial sand of eolian origin overlies the caliche at locations for G/H-1, -2, and -4. A very thin veneer of dark brown soil overlies caliche at G/H-3. Because of pad construction and poor sampling, these suficial soils were not described. The middle of the quarter section clearly displays stabilized to unvegetated eolian dune sand which is apparently quite thick, perhaps more than 10 ft.

2.2.2.3 Mescalero caliche

The Mescalero caliche is best developed on the higher, flatter surface along the northern and northwestern parts of the quarter section. G/H-3, located on this surface, proved hardest to drill through the caliche. Sampling was poor, at best, through this unit in all holes. Surface exposures at G/H-3 showed a compact petrocalcic or K horizon in Stage III to IV (in the sense of Gile and others, 1981) or in Stage VI (in the sense of Machette, 1985). Here the fabrics were very dense, well indurated, and showed brecciation and recementation of cobble-sized fragments.

It was not clear from modest examination whether the caliche is currently being recemented or is still in the process of brecciation. At the other three locations, the caliche clearly has been degraded and ranges from clasts and moderate cementing to softer calcareous matrix with harder nodules or clasts. These were poorly sampled during drilling. The Mescalero more nearly corresponds in samples from these three locations to stages II and III (Machette, 1985), as no calcareous laminae were detected to cap the K horizon.

2.2.2.4 Gatuña Formation (Plio?-Pleistocene)

Detailed lithological sequences and sedimentary structures of the Gatuña Fm. are presented in Appendix 4. An overview of the unit is presented here with discussion of some particulars.

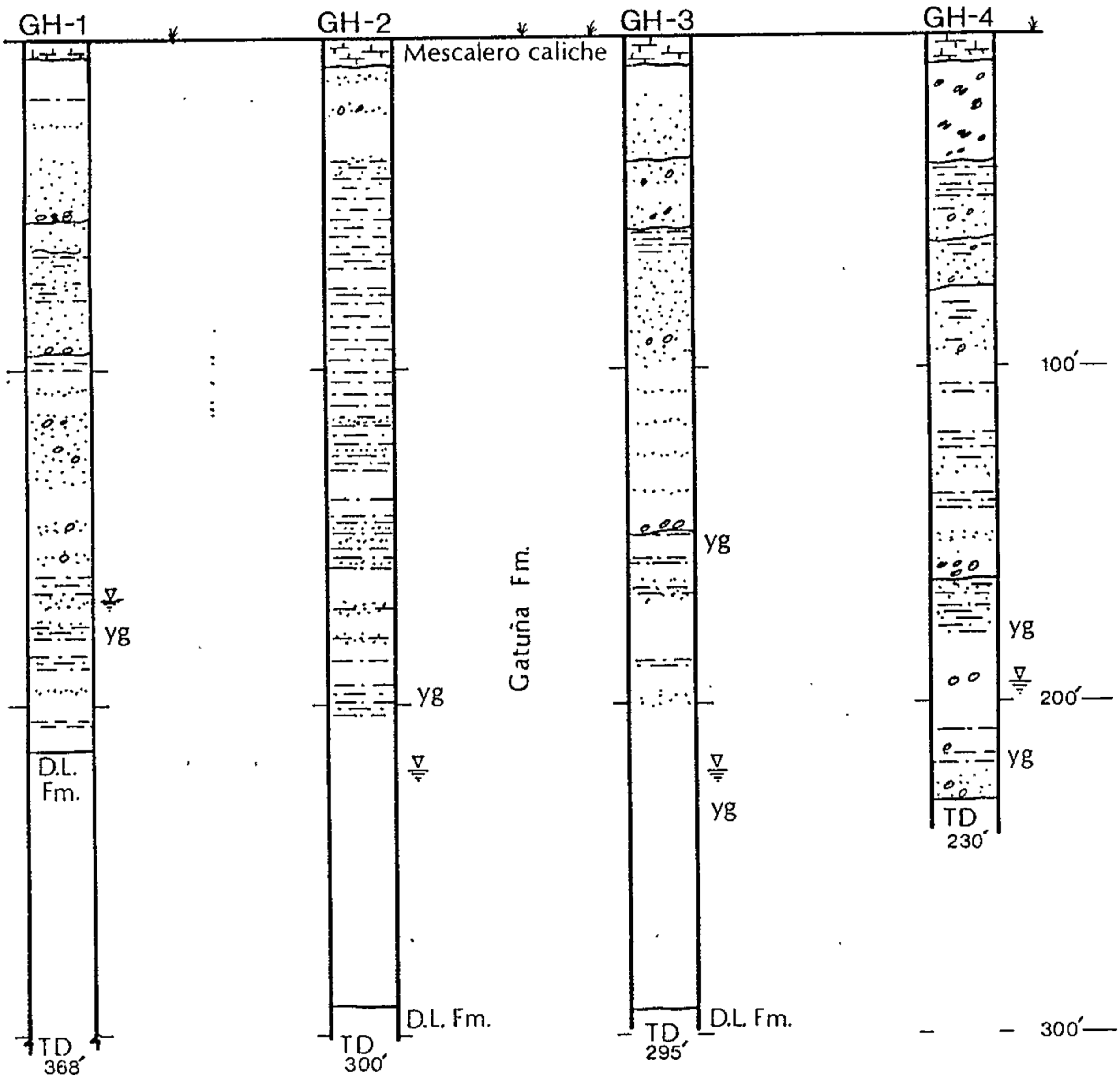
The Gatuña Fm (Figure 10) at Sand Point, as found in the cores from the four drillholes, is similar in lithology and depositional environments to most of the Gatuña outcrops from Clayton Basin (T.20S., R.30E.) to Pierce Canyon (T.24S., R.29 and 30E.) in southeastern New Mexico. The cored thickness is greater than that exposed in individual outcrops except at the head (eastern) of Pierce Canyon. Further south, and somewhat to the west as well, the Gatuña is thicker and commonly includes gypsum and gypsiferous beds which are not represented at Sand Point. I have intensively studied the Gatuña outcrops over much of this area for a project in progress on the hydrogeology of the Rustler Formation for the Waste Isolation Pilot Plant; Gatuña descriptions and interpretations from that report being drafted are considered in the comments about the Gatuña.

A common sedimentary sequence in the Gatuña is a fining upward cycle. The base of the cycle is coarser sediment (may include pebbles) and overlies a sharp contact that may have some relief in outcrop. The coarser sand may be one or more ft in thickness with some evidence of bedding. It is overlain by finer-grained siltstones, sandy siltstones, and/or silty claystones that commonly are thinly bedded to laminar. Clay content and finer-grained beds can increase upward. Some of these fining upward cycles are topped by siltstone/claystone with few or no sedimentary structures but having evidence of bioturbation (especially root casts), black staining (MnO_2), and possible ped structures and clay illuviation. These fining upward cycles were deposited in fluvial environments and floodplains with some soil development on the floodplain.

The basic fining upward cycle has variations depending on the environmental circumstances. Channel areas may develop thicker coarse deposits, while areas more distal from the channel may develop thicker fine-grained interbedded deposits. Soil development will depend on the length of exposure time before additional sediment is added.

In different locations, the Gatuña displays thick (up to 6 or 8 ft thick) conglomerates of pebble to cobble size. In the type area in Clayton Basin, the upper Gatuña shows beds with foresets at acute angles to the basal contact implying braided stream deposits. To the south, in eastern Pierce Canyon, conglomerates are more tabular and appear to have been deposited on a wider, flatter plain. A deeper

Figure 10
General Geology and Stratigraphy
Drillholes for Preliminary Site Characterization
Sand Point Location
Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology drillhole. Graphic log is shown relative to depth. Symbols: yg = yellowish green siltstones, D.L. Fm. = Dewey Lake Fm., T.D. = total depth. Groundwater symbol (⊽) is at approximate depth. Lithologic symbols are standard; they are not shown where core not recovered.

channel-filling conglomerate also crops out in the western part of Pierce Canyon. Gravelly to pebbly beds at Sand Point are dominated by sand with a small portion of coarser clasts. These deposits do not apparently form framework-supported thick units at Sand Point. High-energy environments were apparently limited at Sand Point.

The upper part of the Gatuña in the type section and elsewhere commonly is formed by deposits of mainly sandstone with the following features: disseminated (matrix-supported) clasts of coarser grains (mainly granule to pebble) in some beds, few or no sedimentary structures, bioturbation (mainly root casts), general calcareous cement, black staining (MnO_2) on bioturbation and fractures, probable ped structures at the top of some beds, and color that tends to be brown with lesser reddish hues than the rest of the Gatuña. This unit shows definite signs of pedogenic development, and the matrix-supported clasts suggest these deposits may also have partly originated as small mud flow or debris flow deposits on local slopes.

The first three drillholes (G/H-1, -2, and -3) included zones of poorly indurated or unindurated sand, especially in the interval above the Dewey Lake. Cuttings returned to the surface, as well as limited material in the core barrel, commonly showed moderately well sorted and well rounded sand. The sand from G/H-1 was slightly coarse and more "orange" in color than was most of the sand from G/H-2 and G/H-3. These "orange sands" are quite similar to sands which crop out in some exposures of the Gatuña, especially at Remuda Basin, to the southeast of Sand Point several miles. In those outcrops, and here at Sand Point, these sands are interpreted to have formed as probable eolian sand or eolian sand reworked by fluvial environments.

The Sand Point cores each include sections of distinctive yellowish to greenish-gray laminar to thin-bedded claystone or silty claystone interbedded with very thin beds or laminae of siltstone to fine-grained sandstone. These distinctively colored sections are in the lower part of each core but occur at different depths and positions above the base of the unit. G/H-3 appears to have two such sections based on cores and deeper cuttings returned. G/H-4 shows two zones more closely spaced near the bottom of the drillhole. These deposits are interpreted to have formed on the floodplain, probably in somewhat lower locations which may have remained flooded longer and were somewhat reducing environments rather than oxidizing, as in the reddish-brown deposits and paleosol sections. A similar interval occurs in the type section in Gatuña Canyon near the base of exposures. These distinctive rocks are not interpreted as lacustrine deposits because: 1) they do not appear to show continuity or even close stratigraphic equivalence and 2) the interbedding and rare hints of rippling and crosscutting suggest more common floodplain environments.

Each of the four drillholes cored through Gatuña has a generally distinct overall sequence reflecting the fact that the Gatuña was deposited in a fluvial-dominated environment with considerable lateral as well as vertical changes. The westernmost drillhole (G/H-2) includes a thick section of interbedded siltstones in the upper 200 ft. G/H-3 included more sand and a few thin pebbly units. Both G/H-1 and G/H-4 show several zones of pebbly sandstones, but G/H-4 shows a thicker unit of coarser sediments near the top of the core. There is no evident correlation from one location to another of specific units of pebbles. The most consistent lithologies or parts of the Gatuña are: 1) poorly indurated to unlithified sand in G/H-1, -2, and -3 in the section just above the Dewey Lake Fm and 2) the upper brownish units showing pedogenic features just below the Mescalero caliche in G/H-2 and -3. It isn't known if G/H-4 reached the broadly equivalent section of loose sand just above the Dewey Lake.

The Gatuña is thicker at Sand Point than at most outcrops and drillholes in the area, though the Gatuña is even thicker further south. The Gatuña lithologies at Sand Point are like the Gatuña elsewhere, though sequences differ from each other as a consequence of variable depositional environments.

2.2.2.5 Dewey Lake Formation (Permian)

The Dewey Lake Formation was partially drilled in each of the first three boreholes (G/H-1, -2, and -3). The Dewey Lake was observed only through cuttings in G/H-1 and -3; about 9.7 ft of core from the top of the Dewey Lake were recovered from G/H-2. Cuttings and core are typical lithologies for the Dewey Lake as observed elsewhere in outcrops and underground (e.g., description of lithology on air intake shaft walls at Waste Isolation Pilot Plant; Holt and Powers, 1991). The Dewey lake is dominated by fine grained sandstone and siltstone in thinly bedded units with thin bedding and cross-bedding. The Dewey Lake is a rather uniform reddish brown (2.5YR4/4; Munsell Soil Color Chart, 1971 ed.) with hues and color value somewhat more intense than the Gatuña. Another distinctive character of the Dewey Lake is the common grayish (5Y7/3, pale yellow; Munsell Soil Color Chart, 1971 ed.) "reduction spots" of varying size; even cuttings commonly are distinctive reddish brown siltstone/sandstone with grayish spots.

The Dewey Lake generally decreases thickness from east to west across the northern Delaware Basin. Different episodes of erosion, beginning during the early Triassic, have affected the Dewey Lake. Sand Point and Quahada Ridge provide some of the more westerly outcrops of the Dewey Lake. Based on preliminary field augering, background data available, and regional trends, the thickness of Dewey Lake (as well as Gatuña) was anticipated to be somewhat less than has been found through drilling. The Dewey Lake is at least 155 ft thick at G/H-1; drilling at G/H-2 and -3 was discontinued after reaching depths of less than about 10 ft in the uppermost Dewey Lake. The known thickness of Dewey Lake here is still only a fraction of the full section (> 600 ft) known to exist in the eastern Delaware Basin.

Core from G/H-2 shows Dewey Lake bedding inclined about 15 to 20° from the axis of the drillhole. Some portions of Gatuña core showed modest inclination, but most is near horizontal.

2.2.2.6 Discussion of Geological Features

The thicknesses of Gatuña and Dewey Lake encountered in the drillholes are significant features of the Sand Point location and require further inferences about structure and geological history of the site area.

The thicknesses differ from those estimated from background data as a guide to drilling. To the south and southeast, the Dewey Lake and Gatuña are much thinner, and the Rustler is closer to the surface. In section 12, the supra-Rustler deposits are about 100 ft thick. To the north, the Rustler has been affected by solution of Salado halite as well as by solution of sulfates within the Rustler. The site area was a relatively unknown location between these areas.

The thickness of Gatuña and Dewey Lake under the site area indicates the Rustler Fm is structurally displaced downward more than was expected before drilling. The estimated drilling depths to Rustler (Exhibit IIc) was extrapolated based on thinner overlying units and a more gradual estimated change in the structure than apparently exists. It appears that the inclination of the Rustler in the southern half of section 11 (south of the site) and to the southeast and east is more abrupt than expected. The topography of the southeastern quarter of section 11 may partly reflect the deeper structure. The dipping Dewey Lake bedding in G/H-2 is generally consistent with the structural changes in the site area but is unlikely to be representative of the entire area. Some areas may show less and others greater dip.

Thicker Dewey Lake preserved under the site area indicates that the Dewey Lake was lowered prior to some stages of erosion in the area. It was apparently lowered mostly prior to deposition of the Gatuña, in view of the Gatuña, because the Gatuña displays basically flat-lying bedding. Thicker Gatuña also implies that the locale was either lower throughout the period of deposition or was being lowered some during deposition. Even the easternmost borehole (G/H-4) shows few, if any, lithologies or structures likely to indicate the site or location was being lowered during deposition. The lowermost pebbly zone and uppermost coarse clastics might indicate some syndepositional changes or normal depositional environment variations. In contrast, Gatuña lithologies at the eastern end of Pierce Canyon (WIPP study in progress) clearly show thick units of cross-cutting and matrix-supported clasts in dipping units deposited during a time when some of the area was also subsiding, most probably in response to dissolution of underlying salt beds. The Sand Point lithologies do not show features similar in scale and lithology.

The Mescalero caliche differs in thickness and induration over the site. It is well preserved in the northwestern and northern part of the site. The rest of the site shows caliche with less development of diagnostic horizons or with diagnostic horizons being destroyed by slope and climate changes. A narrow channel cuts through a ridge to the south of the site. This channel drains runoff from the site area, though drainage is very poorly developed over the site. This small channel appears to have cut down through the ridge. Caliche also drapes some of the slopes south and east of the site, indicating it developed relatively well over a broader area. The southern part of the site, then, is being eroded somewhat, and this is disturbing the caliche and preventing further formation.

There are two somewhat different explanations of the present condition of the caliche and geomorphic expression in the southern part of section 11 and part of the site. Simple erosion by the drainage system could explain the general geomorphology of the southern part of the site. Caliche draping the slopes along the south and southeastern part of section 11, however, suggests that that area may have subsided modestly during the last 500,000 years. The drainage channel cut down through the small southern ridge as the area just to the north was let down slightly. This preserved elements of the caliche over most of the site but may have subjected it to erosion/solution in the southeastern corner during part of the period it would normally have formed.

The changes at the site are mainly attributed to pre-Gatuña subsidence due to dissolution of some of the salt in the upper Salado Formation. A thicker Dewey Lake was preserved, and space was provided for a thicker Gatuña deposit. Some post-Gatuña, and possibly post-Mescalero caliche, further subsidence may have contributed to the present geomorphology. Erosion processes in recent geologic time does not appear to be very effective in the site area, as dune sand, both unstabilized and vegetated, has accumulated and is not being carried out of the site area. Good near-surface infiltration in unconsolidated sand over caliche and evapotranspiration, as well as limited rainfall and runoff area, limit immediate potential for erosion of the site area. The prospect of further subsidence due to dissolution of salt like that which has apparently occurred at the site area, and which is widespread in eastern Eddy County, is slight over the near-geological future. If subsidence occurred, it would further lower the landfill topography and decrease the potential for erosion.

2.2.3 Sand Point Hydrology

2.2.3.1 Summary of Background Hydrology

From regional hydrologeological surveys and from more local information from potash and hydrocarbon exploration, the Culebra Dolomite Member of the Rustler Formation bears water to the south and southeast. The "Lusk east well" is most likely producing from the Culebra. It is possible that the Culebra is confined within a mile of the site. To the north and west, water-bearing units may include the Gatuña or karst in the Rustler Fm and they are more likely to be unconfined. It was estimated that, if a regionally connected water-bearing unit occurs at the site, it would show a ground water surface at an elevation of about 3150 ft. Under this assumption, borehole locations around the site were estimated to have ground water at depths of 165 to about 225 ft below the ground surface. Drilling was proposed to at least 215 to 275 in corresponding wells to test for this hydrologic unit (Exhibit IIc).

2.2.3.2 Summary of Initial Sand Point Hydrology

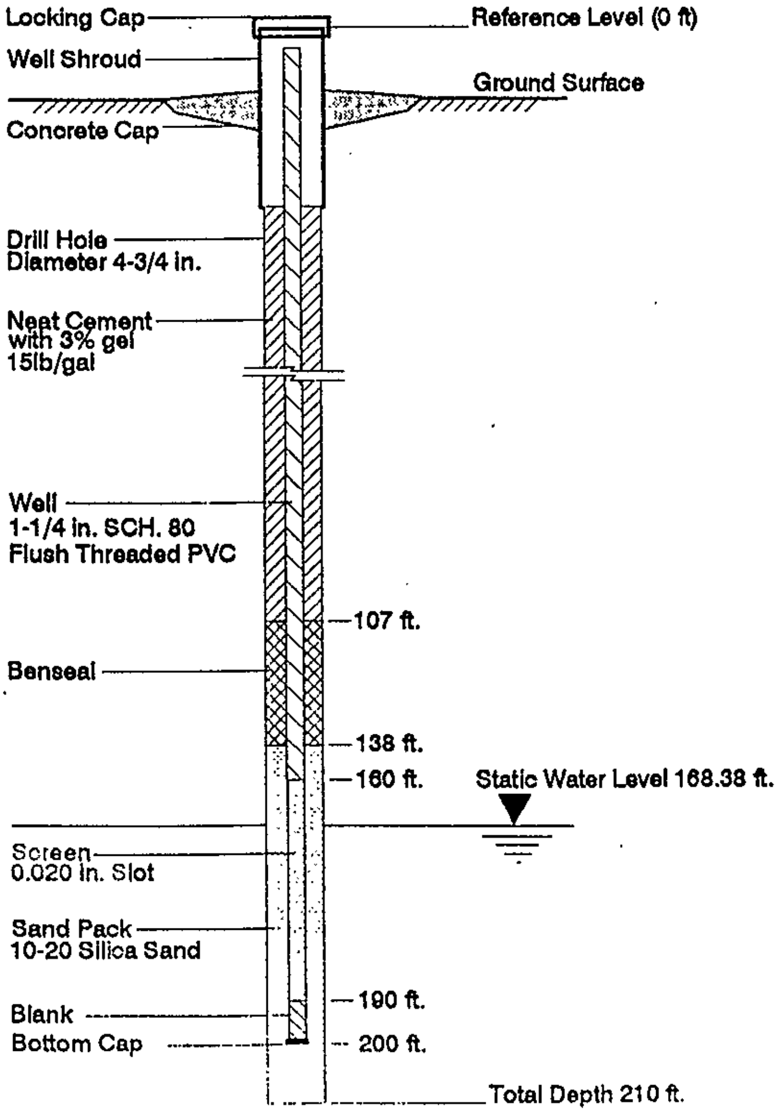
The first drillhole (G/H-1) was not obviously yielding water during drilling because borehole conditions required that some water and foam be used from about 49 ft depth. It was noted that fluid was present at 170 ft, but it could not be determined at the time if the borehole had intercepted a water-bearing zone or if the water/foam used in drilling was returning to the borehole. Later redrilling (G/H-1A) a few ft away demonstrated this was a producing zone. Cautious testing and observation on G/H-2 was necessary to determine the water-producing zone; G/H-3 and -4 were more easily interpreted as producing water because of experience in earlier drilling.

Each of the four locations drilled around the sides of the site was completed as a piezometer (Figures 11-14) (completion details in Appendix 3) to be used for observation or ground water levels and future sampling. In general, the wells were completed with a short blank tubing to collect sediment below 30 ft of screen placed across the estimated general water level in the borehole. Riser pipe to the surface was capped for protection. A sand pack was placed around the lower pipe and screen to about 10 ft above the top of the screen. Granulated and powdered Wyoming bentonite was put above the sand pack with a thickness of about 20 ft. The borehole was then cemented back to the surface with approximately 14 lb/gal cement with a small amount of bentonite added. The surface was completed with a protective casing cemented in place with a small cement pad to protect the top of the borehole from surface inflow. The protective casing has a cap and padlock for further security. Each borehole protective casing was surveyed as a reference point for measuring water depth.

Figure 11
As-Built Configuration SP G/H-1A

Well I.D.: *SP G/H-1a*	Type: *Piezometer*
Location: *Sand Point Landfill*	Elevation*:

* Elevation of the top of well shroud without locking cap.

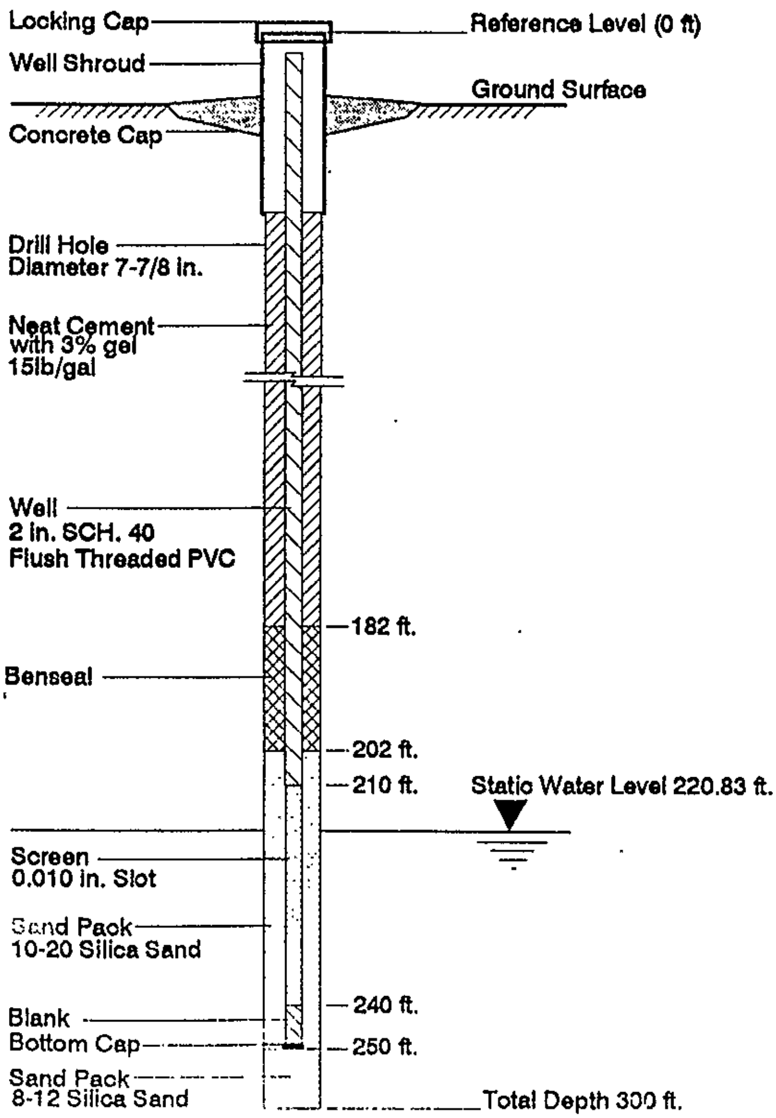


JOAB, Inc.	Drawn By:	Approved By:	Date:

Figure 12
As-Built Configuration SP G/H-2

Well I.D.: *SP G/H-2*	Type: *Piezometer*
Location: *Sand Point Landfill*	Elevation*:

* Elevation of the top of well shroud without locking cap.



JOAB, Inc.	Drawn By:	Approved By:	Date:

Figure 13
As-Built Configuration SP G/H-3

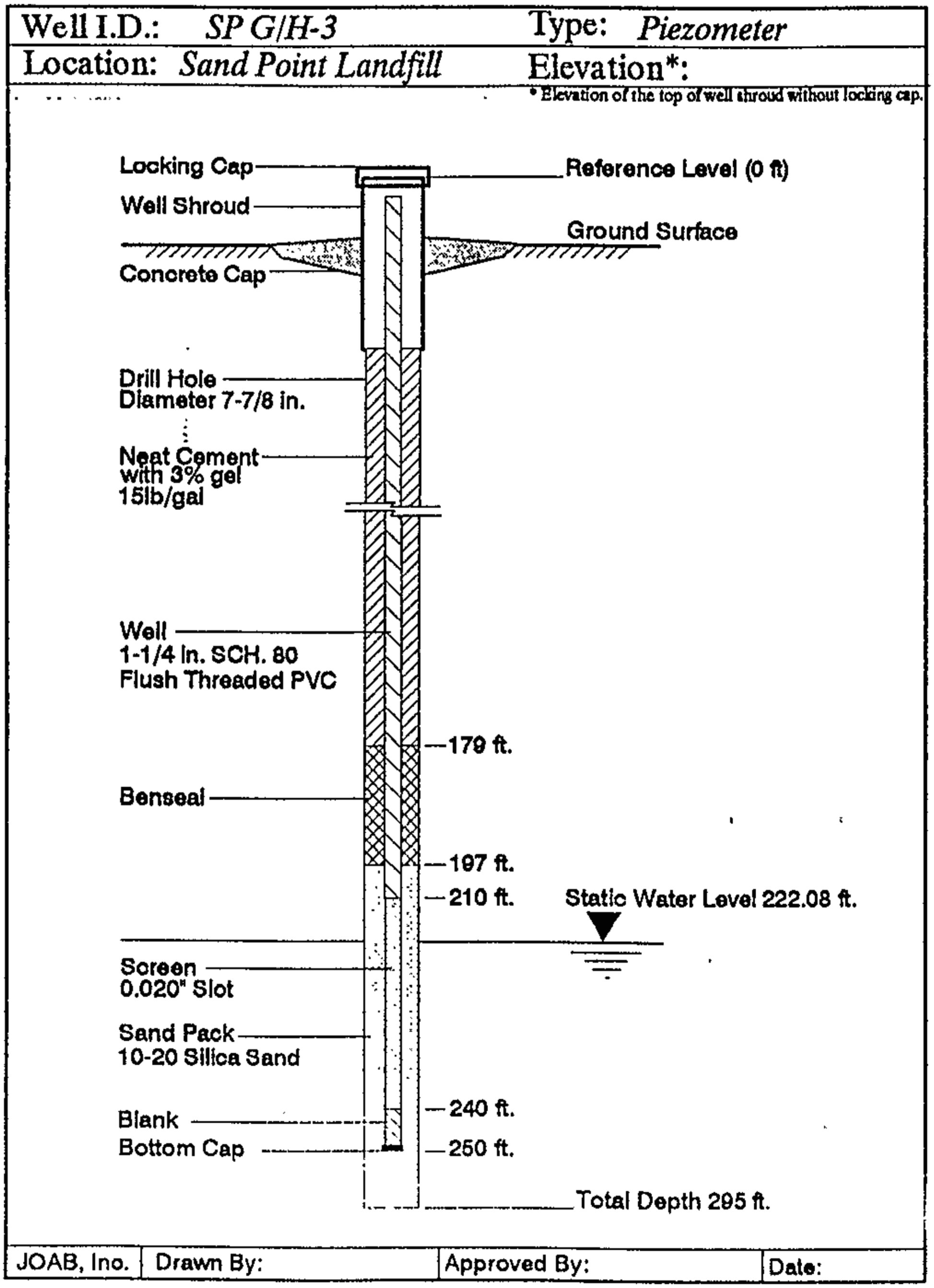
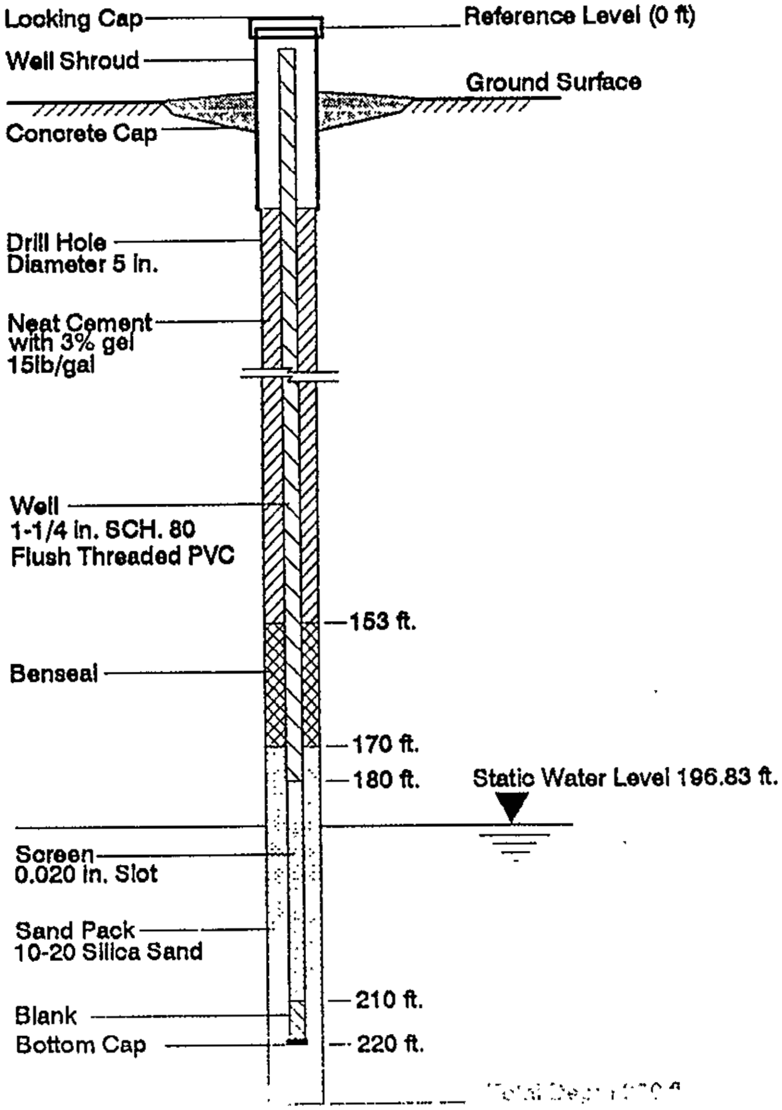


Figure 14
As-Built Configuration SP G/H-4

Well I.D.: *SP G/H-4*	Type: *Piezometer*
Location: *Sand Point Landfill*	Elevation*:

* Elevation of the top of well shroud without locking cap.



JOAB, Inc.	Drawn By:	Approved By:	Date:

During drilling, modest amounts of water and sediment were bailed from the boreholes. An estimated 50 gal was bailed from G/H-3, more than from other drillholes. Both fluid used for drilling and bailing/production were minimized as possible to provide the minimum disturbance to ground water level.

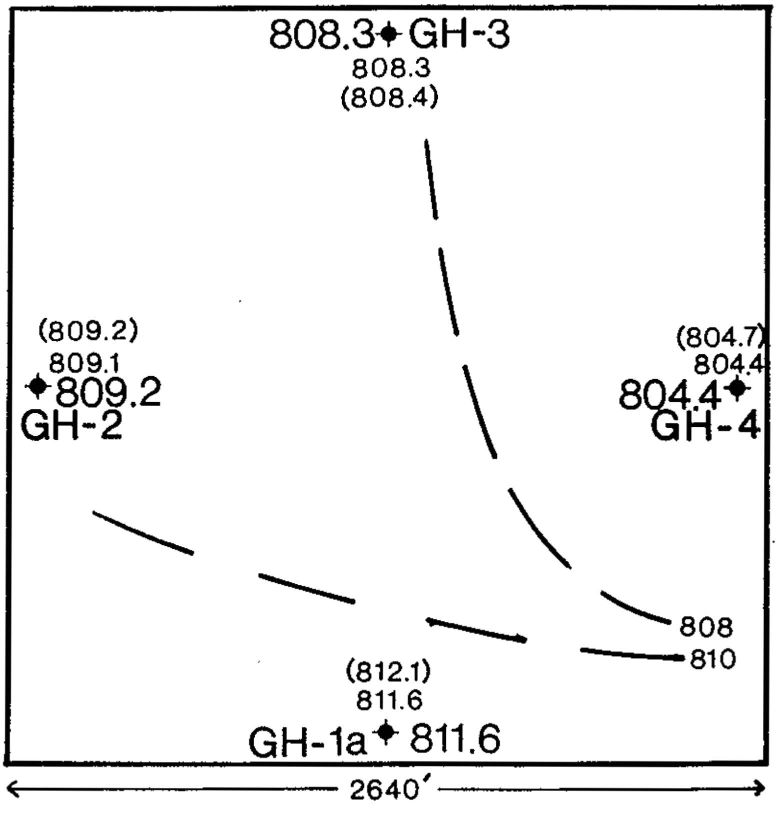
After each drillhole was completed, water levels were checked irregularly while drilling continued at other locations (Table 4). Each water level was measured July 2, July 22, and August 6, 1992, as a further preliminary baseline because most levels appeared to be changing relatively little (Table 5) (Figure 15). These early measurements were referenced to a temporary arbitrary basine point.

Each drillhole was surveyed and tied into surface elevation markers after the protective casing and cap were installed. Water levels were measured again from September 9 through October 14, 1992, demonstrating modest changes, and these modest changes are consistent with measurements in early 1993 (Table 6) (Figure 16,17).

2.2.3.3 Discussion of Preliminary Hydrological Data

The data on ground water elevations available at this time indicates that ground water movement would be towards the east and northeast. It is assumed that the ground water in each borehole is interconnected. There is no clear evidence indicating that the ground water in any borehole is confined, though the water level has generally risen modestly above the drilling depth at the time water in the borehole became evident. This effect is attributed to delay in circulation and delay in water entering the drillhole from borehole surface effects. If there is confined ground water, it is most likely to exist in G/H-4, where drilling encountered laminated claystone to siltstone in the lower part of the drillhole, and where water apparently delayed entering the borehole. Higher ground water levels to the south, shown by G/H-1A, may be related to more effective recharge at some time along the drainage area in the

Figure 15
Location Map of Drillholes for Preliminary Site Characterization and Preliminary Elevations (Arbitrary) of Ground Water, Sand Point Location
Northwest ¼, Section 11, T.21S., R.28E.



GH-# represents geology/hydrology well completed. Elevation of groundwater is relative to point of turning (POT) established at center of section and assigned *an arbitrary elevation of 1000.00 ft.* Top of ground water measured July 2 ( ), July 21, and August 6 (bold), 1992, by Marvin Magee (JOAB, Inc.).

Table 4
Sand Point Hydrological Data
Obtained During Drilling Program

Date	Time	Depth (fluid or hole)	Reference Point	Comment
SP G/H-1				
May 29	0700	180'	drill pipe	Foam/water in bailer
May 30	0700	170'	drill pipe	Possible water
SP G/H-1				
June 1	1345	120'	drill pipe	No fluid detected over 20 minutes
June 1	1545	125'	drill pipe	No fluid detected
June 2	0715	170'	drill pipe	No fluid detected
June 3	1905	245'	drill pipe	Top of fluid level
June 4	0730	224.9'	drilling floor	Sand at 253'. Removed 4 bailers of fluid (about 1 to 2 gallons total)
June 4	after 1330	235'	top of casing	
June 9	0830	222'	top of casing	Sand at 245-250'. Bailed about 1 gallon.
June 10	0715	232.15		Water level
June 11	1000	220.5	top tubing	Measured inside tubing
June 13	0703	220.3	top tubing	Measured inside tubing
June 23	1235	220.5	top tubing	Measured inside tubing
SP G/H-3				
June 12	0705	92'	top drill string	No fluid detected at TD
June 12	0835	97'	top drill string	No fluid detected at TD
June 12	1115	130'	top drill string	No fluid detected at TD
June 13	0705	200'	top drill string	No fluid detected at TD
June 13	1830	230'	top drill string	No fluid detected at TD
June 14	0715	221'	top drill string	Erratic indications of fluid
June 14	1245	292?'	top drill string	Uncertain indications of fluid
June 14	1340	230	top drill string	Possible water level
June 14	1502	234.0	top drill string	Measured water level
	1519	232	top drill string	Measured water level
	1541	230	top drill string	Measured water level
	1600	229.25	top drill string	Measured water level
June 15	0710	222	drilling floor (14.25" below string)	Measured water level
	0820	223	top tubing	Measured water level
June 23	1210	222.25	top well shroud	Measured water level

Table 4, cont.
Sand Point Hydrological Data
Obtained During Drilling Program

Date	Time	Depth (fluid or hole)	Reference Point	Comment
SP G/H-4				
June 17	0700	130'	top drill pipe	No fluid detected
	1145	160	top drill pipe	No fluid detected
	1645	199.7	drilling floor	Final fluid level
June 18	0705	195	drilling floor	Fluid level
	0845	203	top drill pipe	No fluid detected
	1025	228.1	top drill pipe	Measured fluid level
	1240	216.3	top drill pipe	Measured fluid level
	1320	214.5	top drill pipe	Measured fluid level
June 23	0800	193	drilling floor	Measured fluid level
June 24	0800	196.3	top of tubing	Measured fluid level
	1755	196.2	top of tubing	Measured fluid level
SP G/H-1A				
June 24	0700	172		Uncertain signal
	1345	178	top drill pipe	Measured fluid level
June 25	0800	168.7	top of tubing	Measured fluid level

Notes: These measurements are reported as part of the history of drilling. Bailing, drilling, or other activities may have occurred between successive measurements. The borehole histories in Appendix 3 show the range of activities and the measurements of fluid levels during drilling.

southern half of section 11. Discharge to the east or northeast, indicated by lower ground water levels at G/H-4, does not clearly relate to ground water elevations further to the southeast. Apparent ground water surfaces in existing wells and a potash drillhole around the site area (Section 2.1.2) range from about 7 to 10 ft above the level in G/H-4. As a consequence, the eastward flow direction may not be accurate far beyond the site. In addition, the boreholes need to be observed long enough to confirm stability for the ground water levels in each borehole, though data through early March, 1993, indicate the levels may have nearly reached a stable level.

From regional information, the ground water surface appears to slope generally southward. This may still be the overall direction of flow, though the site appears more complex. Neither hydraulic properties nor chemical quality have been determined for these observation wells, and gradient and velocity calculations will require knowledge of these properties.

2.2.4 Other Sand Point Characteristics

Several other relevant geological conditions or factors for site selection remain as found during checking of background data for the site. There is no evidence of faulting underlying the site or of any alluvial fan. Though salt under the site has evidently been partially dissolved by regional processes, the site shows no karst features. Dissolution does not appear to be a significant concern at the Sand Point site in the foreseeable future.

Table 5
Measured Water Levels* 7/2 - 8/6
Sand Point

Date	*SP G/H-1A*	*SP G/H-2*	*SP G/H-3*	*SP G/H-4*
July 2	812.1	809.2	808.4	804.7
July 21	811.6	809.1	808.3	804.4
August 6	811.6	809.2	808.3	804.4
August 28	811.4	809.1	808.3	804.2

* Measured water levels are given a reference elevation which is relative to a point of turning (POT) established at the center of section 11. The POT has been given an arbitrary elevation 1000.00 ft until it is surveyed relative to another established benchmark. Gradients should remain unchanged pending confirmation of surveys of the reference point on each well shroud. Measurements provided by Marvin Magee, JOAB, Inc.

Table 6
Summary of Recent Measurements
Ground Water Levels
Sand Point

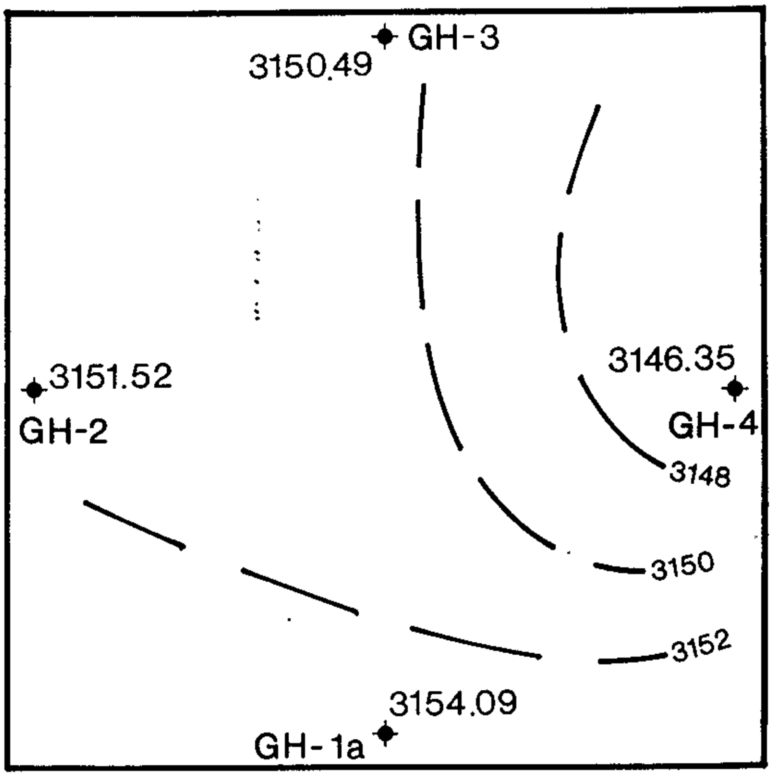
Borehole	Shroud Cap Elevation (ft) (Skyline Eng.)	Ground Water Elevations (ft) / Ground Water Depths (time) 09/29/92	10/05/92	10/14/92	01/07/93	03/12/93
SP G/H-1A	3322.68	**3153.73** 168.95 (1300)	**3154.08** 168.60 (1629)	**3154.24** 168.44 (1700)	**3154.30** 168.38 (1301)	**3154.09** 168.59 (0729)
*SP G/H-2**	3372.72	**3151.35** 221.37 (1245)	**3151.74** 220.98 (1619)	**3151.80** 220.92 (1710)	**3151.93** 220.79 (1253)	**3151.52** 221.20 (0746)
SP G/H-3	3372.99	**3150.47** 222.52 (1334)	**3150.61** 222.38 (1653)	**3150.65** 222.34 (1720)	**3150.64** 222.35 (1346)	**3150.49** 222.50 (0755)
SP G/H-4	3343.56	**3146.16** 197.40 (1315)	**3146.54** 197.02 (1639)	**3146.65** 196.91 (1637)	**3146.75** 196.81 (1312)	**3146.35** 197.21 (0715)

* G/H-2 was sucking air when opened on 9/29/92 and 01/07/93.

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.

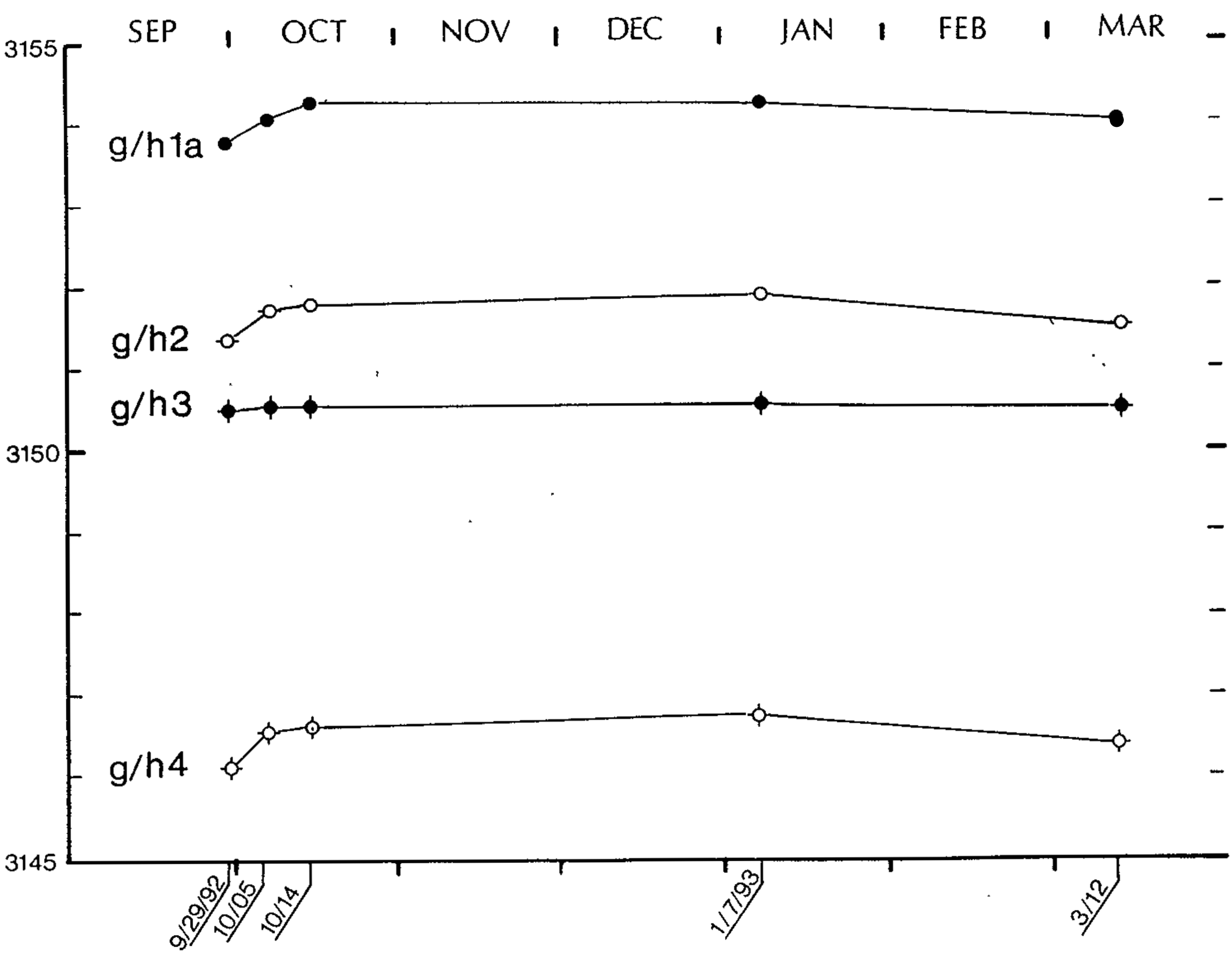
The shroud cap elevation was measured by Skyline Engineering, Inc., and reported to JOAB, Inc. The measurement in each case is on the top of the shroud cap. This measured elevation *on the top of the cap* will be slightly above the top of the well shroud used as a depth reference. The slight difference in elevation (<.05 ft) will not change gradient calculations as the shroud caps are of the same design and dimensions for each well.

Figure 16
Latest (3/12/93) Water Levels and Approximate Contours, Sand Point



GH-# represents geology/hydrology well completed. Elevation of ground water is for latest measurements (March 12, 1993) (Table 6) and is relative to surface markers established by Skyline Engineering. Contours are approximate. All measurements in feet.

Figure 17
Changes in Water Level Elevations
at Sand Point Site
September, 1992 to March, 1993



Elevations are in ft. g/h# is the drillhole number as in previous figures.

3.0 Conclusions and Selection of Sand Point as Potential Landfill Site

3.1 Summary of Sand Point Characteristics

Critical factors for preliminary site selection include exclusionary geohydrological factors based on new state regulations (State of New Mexico Environment Department, 1991). The site is not located on a floodplain, nor is it located within 200 ft of watercourses. The site is not within 200 ft of a fault with displacement within the last 11,000 years. The depth to groundwater exceeds 100 ft below designed (preliminary) landfill excavation. Groundwater quality is not determined; it is probably better quality than 10,000 mg/l, but this does not disqualify the site. Caliche near the surface can be moderately well lithified but should not present significant construction difficulties; there is no hard bedrock within the excavation depth. Clay content in the construction zone is variable, but may not meet qualifications for a natural liner. There are no known sinkholes or karst within the site. Slopes are moderate and suited to construction.

The Sand Point site meets known geohydrologic criteria based on background data and preliminary site characterization.

3.2 Recommendation to Pursue Permitting Activities

Based on preliminary site characterization, I recommended that the Sand Point site be selected for complete site characterization necessary to apply for a permit to operate a landfill. A borehole drilling program was developed for site characterization and was submitted to New Mexico Environment Department for approval (see later Exhibit). The drilling program was an alternative plan submitted according to state regulation.

4.0 REFERENCES CITED

Bachman, G.O., 1974, *Geological processes and Cenozoic history related to salt dissolutino in southeastern New Mexico:* Open-file Report 74-194, U.S. Geological Survey, Denver, CO.

Geohydrology Associates, Inc., 1978, *Collection of hydrologic data eastside Roswell range EIS area New Mexico:* report to Bureau of Land Management, Denver, Co.

Geohydrology Associates, Inc., 1979, *Water-resources study of the Carlsbad potash area, New Mexico:* report to Bureau of Land Management, Denver, Co.

Gile, L.H., Hawley, J.W., and Grossman, R.B., 1981, *Soils and geomorphology in the Basin and Range area of southern New Mexico - Guidebook to the Desert Project:* Memoir 39, New Mexico Bureau of Mines & Mineral Resources, Socorro, NM, 222 p.

Hayes, P.T., and Bachman, G.O., 1979, *Examination and reevaluation of evidence for the Barrera Fault, Guadalup Mountains, New Mexico:* Open-file report 79-1520, US Geological Survey, Denver, CO.

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 and Mineral Resources, Socorro, NM, 169 p.

Hiss, W.L., 1976, *Structure of the Permian Guadalupian Capitan aquifer, southeast New Mexico and west Texas:* Resource Map 7, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM, 1 sheet.

Holt, R.M., and Powers, D.W., 1991, *Geologic mapping of the air intake shaft at the Waste Isolation Pilot Plant:* DOE/WIPP 90-051, U.S. Department of Energy, Carlsbad, NM.

Kelley, V.C., 1971, *Geology of the Pecos country, southeastern New Mexico:* New Mexico Bureau of Mines and Mineral Resources, Mem. 24, 75 p.

King, P.B., 1948, *Geology of the southern Guadalupe Mountains, Texas:* U.S. Geological Survey Prof. Paper 480.

Machette, M.N., 1985, *Calcic soils of the southewestern United States in Soils and Quaternary Geology of the southwestern United States, Weide, D.L., ed.:* Special Paper 203, Geological Society of America, pp. 1-21.

Muehlberger, W.R., Belcher, R.C., and Geotz, L.K., 1978, *Quaternary faulting in Trans-Pecos Texas:* Geology, v. 6, no. 6, p. 337-340.

Powers, D.W., 1992, *Summary of site selection and preliminary site characterization for the Sand Point site, Eddy County, NM:* report to JOAB, Inc., prepared 09/02/1992, revised 12/28.92.

Richey, S.F., 1989, *Geologc and hydrologic data for the Rustler Formation near the Waste Isolation Pilot Plant, southeastern New Mexico:* Open-file report 89-32, U.S. Geological Survey, Albuquerque, NM, 72 p.

State of New Mexico Environment Department, 1991, *New Mexico Solid Waste Management Regulations.*

Szabo, B.J., Gottschall, W.C., Rosholt, J.N., and McKinney, C.R., 1980, *Uranium Series Disequilibrium Investigations related to the WIPP site, New Mexico, Part II: Uranium trend dating of surficial deposits and gypsum spring deposit near WIPP site, New Mexico:* Open-file report 80-879, U.S. Geological Survey, Denver, CO.

APPENDIX 1

Sand Point Auger Drilling Data

Prior to Sand Point Characterization

Descriptions of the following auger holes are based on cuttings returned to surface and, where available, cores taken through the auger with a split barrel corer. Samples were examined visually, were tested with 10% HCl, and were described for basic color using the Munsell Soil Color Chart (1971 Ed.). The descriptions here more nearly reflect a geological than an engineering approach, so that a rock name including the word "stone", as in sandstone, reflects enough lithification to hold a sample together for examination; this is not a reference to engineering properties. The descriptions begin with basic lithology, followed by modifiers of decreasing significance and color. Color chart names which differ from a perceived color are included with the hue and associated numbers while the perceived color is used as a general description. As an example, an apparent light brown or reddish brown color may have an official color somewhat different, for example (pink: 5YR 8/4). Other features are then described.

This appendix is modified from Appendix I of Powers (1992) by removing material not pertaining to Sand Point.

Basic Descriptions of Auger Holes at Sand Point

SP-1
NW1/4, SW1/4, Section 11, T.21S., R.28E.
Augered 2/26 and 2/27/92

Depth (ft)	**Description**
0-6	Argillaceous sand, reddish brown (5YR 4/4).
6-8	"Caliche" -pebble and smaller size, somewhat rounded white (5YR 8/1) clasts in light brown (pink: 5YR 8/4) sandy to granular matrix. Very calcareous.
8-11	Sandy silt, argillaceous, reddish yellow (5YR 6/6). Very calcareous, includes granules of white caliche. Moist, forms weak ball.
begin coring	**probable Gatuña Formation**
11-15	Silty sand, fine to medium grain, light brown (pink: 7.5YR 7/4), with minor granule-sized caliche and very minor clay illuviation. Very calcareous. Slightly moist, forms very weak ball.
15-16	as 11-15'.
	top of unalterred Gatuña Formation
16-19.5	Claystone with minor sand and silt, reddish brown (2.5YR 5/4). Shows dark stains (manganese oxide) on fractures and white material around root casts.
19.5-28	as 11-15' in general, light red (2.5YR 6/8).
28-29	Sand and sandstone, fine to medium grain, silty, with more argillaceous and calcareous zone at 28'; moderately well indurated.
29-30	Sand, fine to medium, with subvertical fracture about 1/8 inch wide filled with reddish brown clay stained black (manganese oxide) on surfaces.
30-30.7	Sandstone, thinly bedded, light brown (pink: 5YR 7/4), calcareous.
30.7-35	as 29-30.
35-40	Sandstone, silty, argillaceous, calcareous, yellowish red (5YR 5/8). Thin beds or partings from 36-29'. Also shows extensive small (< 1/16 inch) open bioturbation from probable root zone stained black. Unbedded, less calcareous in lower foot.
40-40.5	Sandstone, calcareous, bedded, similar to 36-39'.
40.5-45	Sand, silty, argillaceous, calcareous, similar to above, not indurated except for thin zones. Includes possible intraclasts of Gatuña.
45-50	similar to 36-39 and 40-40.5.

50-55	lithology similar to above, with less clay, no evidence of bedding, poorly lithified to friable. Lower 1' is loose sand with rare granule-sized clay clasts. Granule to pebble-sized, rounded clasts of Dewey Lake. Thin zones (< 6") are more calcareous and lithified.
55-56	Sand, with some evidence of crossbedding.
56-60	Sandstone, silty and slightly argillaceous, very calcareous, red (10R 5/8). Includes root casts and black staining. Beds are thin (about 1/4 inch).
60-61	Sand, fine, silty, slightly calcareous, red (2.5YR 5/8). May include slight amount of clay.
61-64.5	Claystone, very silty and slightly sandy, to argillaceous, sandy siltstone, light reddish brown (2.5YR 6/4). Abundant fine interconnected porosity from rootlets, modest dark stains on some rootcasts. Very calcareous. Platy to thinly bedded.
64.5-68	Sand, similar to 60-61' with slightly more silt and clay, reddish brown (2.5YR 5/4). Includes tan pebble or nodule of sandy crystalline limestone at 68' with porosity and rootcasts. May be secondary caliche or clast penetrated by bioturbation.
68-69	Claystone, silty, similar to 61-64.5 in lithology and structure. Light reddish brown (2.5YR 6/4).
69-72	Sand, silty, similar to 60-61'. Becomes sandier downward (fines upward) to medium sand at 72' with 5-10% opaques, some mica. Subangular to subrounded grains. Calcareous. Becomes lighter in color downward to red (2.5YR 5/6).
72-76	Argillaceous siltstone to sandy siltstone at base (fining upward), very calcareous, red (2.5YR 4/6). Shows block to slightly platy structure, open porosity due to rootlets, some dark staining on fractures and pores.
76-81 (TD)	similar unit to 72-76', slightly more argillaceous at base. Red (2.5YR 4/6).

SP-2
SW1/4, SE1/4, Section 12, T.21S., R.28E.
Augered 2/27/92

Depth (ft)	Description
0-2	Loose dark brown sand with pebbles.
2-5	Light brown to whitish carbonate matrix and pebble-sized caliche clasts (Mescalero caliche).
begin coring	**top of Dewey Lake Formation**
5-10	Sandstone, very fine to fine grained, silty, slightly argillaceous, dark reddish brown to reddish brown (2.5YR 3/4 to 4/4) with small greenish gray spots. Very calcareous, especially along fractures. Upper 1' more calcareous from overlying caliche. Blocky to somewhat play, well indurated. No observable finer bedding.

10-15	as above, with zones (< 1 ft) with more clay. Subvertical fractures show slight carbonate film. Some subhorizontal fractures show both carbonate films and black stains.
15-20	as above, with carbonate decreasing downward.
20-25	as above. 2 inch "purplish" argillaceous unit at 23'. Drilling harder through part of interval.
25-30	as above.
30-35	as above. Variable carbonate content from none to mildly effervescent. Zone from 33-35' slightly more argillaceous. Greenish reduction spots somewhat larger.
35-40	as above. Drilling became easier from about 38'. 80% core recovery.
40-45	as above. Drilling very easy last 3', auger not solid on bottom. About 25% core recovery, sample very loose.
begin augering only	
45-55	No sample, auger only. Drilling became hard at 53'.
begin coring	
55-56 (TD)	Core returned small sample of white to slightly pinkish gypsum and irregular porous sandy carbonate chunks alterred by solution. **Top of Rustler Formation** (probably at 53'); most likely Forty-niner Member gypsum; possibly Magenta Dolomite Member represented by carbonate with gypsum from top of Tamarisk Member.

Rock Sample List

Sample #	Depth Interval
SP2-1	5-10
SP2-2	10-15
SP2-3	15-20
SP2-4	20-25
SP2-5	25-30
SP2-6	30-35
SP2-7	35-40
SP2-8	40-45

NOTES re APPENDICES

Appendices 2, 3, and **4** are reproduced here as originally prepared for Powers (1992). **Appendix 5** from Powers (1992) has not been included here, as the appendix material also is included in the document reproduced in Exhibit IIId.

Surficial Units and Inferences of Stability, Sand Point Site, Eddy County, NM

prepared for

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02/17/93

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ABSTRACT

Surficial deposits have been mapped to supplement data from a pipeline trench and site drilling. The Mescalero caliche has been identified and is persistent over the site and surrounding areas. It overlies the Gatuña Fm at the site and is developed on the Permian Dewey Lake Fm. This pedogenic calcrete is a hard unit, overlain by the Berino soil, on upland areas of slight slope; is a bare, rocky outcrop or covered by dune sand on higher slopes in the transition area from the uplands; and is a calcareous soil to calcrete under the low areas occupied by drainage. The Mescalero is believed to have formed about 500,000 years ago based on geological inferences and radiometric ages. The younger Berino soil is best developed on the upland areas. More recent dune sand is common along slope breaks due to changes in wind flow. Mixed resedimented eolian sand and alluvium has collected in the drainage areas.

Drainage at and around the site is poorly developed due to limited rainfall, high evapotranspiration, small drainage area, and easily eroded sand that can choke the channels. Areas underlain by Mescalero caliche at shallow depths have maintained a channel, while sandy areas without shallow calcrete are obstacles to channel development and maintenance. Surface evidence indicates runoff is rare, probably occurring only during larger storms. Calcrete at the surface or at shallow depths indicates limited shallow infiltration and that vertical recharge to deeper saturated zones probably does not occur at the site.

The Mescalero likely developed on topography close to that observed today, indicating considerable stability at the site. There is little likelihood the site, especially the upland area, will naturally develop channels in the next few hundred to thousands of years and be subject to erosion without significant increases in rainfall and runoff. The southeastern part of the site will continue to serve as an outlet for the limited drainage northeast of the site; it should be developed carefully or be removed from the landfill development plan.

INTRODUCTION

Purpose

This report is designed to communicate basic surface and near-surface geological field data for the proposed Sand Point landfill site (Figure 1) and to use these data to further assess the stability of the site over the next few hundred to thousands of years.

Within the body of the report, field data/observations are reported on some of the soils, drainage, and sand dunes within the landfill site and adjacent areas. Pedogenic calcretes (in the sense of Machette, 1985), which are also known as caliche, are particularly important. The data and observations are also interpreted, with conclusions regarding stability of the site.

As part of the reporting, some map data has been included showing estimates of thickness of material overlying the calcrete and quality of the calcrete. These will be helpful in early design estimates for the site.

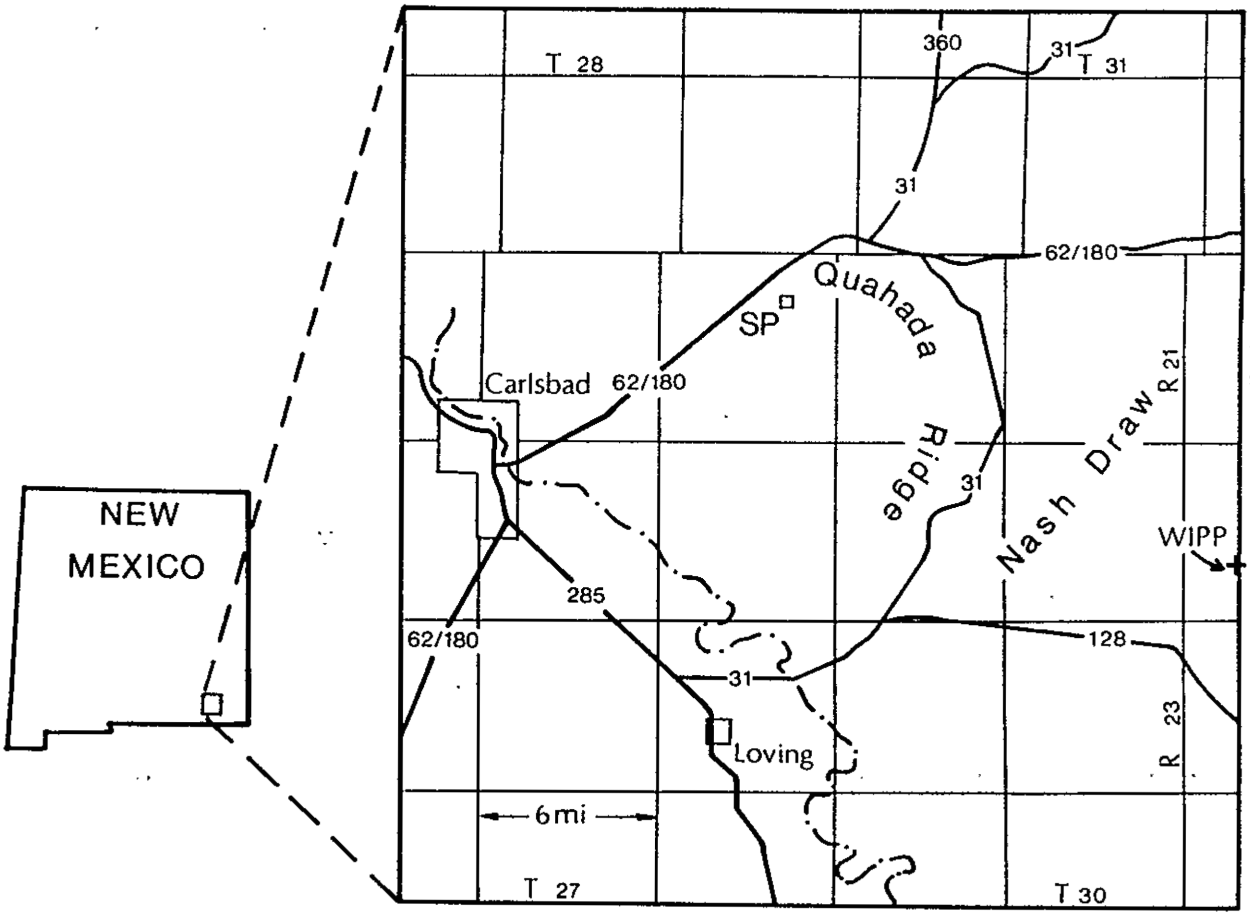
The field work for this report was mainly conducted January 8 and January 13-15, 1993. Other field observations from site characterization drilling are incorporated; some observations and interpretations from field work for other projects (especially the Waste Isolation Pilot Plant [WIPP] project) provide helpful background to the discussion.

Background Information on Sand Point

The site selection and characterization reports (Powers, 1992a,b) for the Sand Point landfill document the underlying geology and hydrology.

Drillholes around the perimeter of the landfill site penetrated variable thicknesses of the Gatuña Formation of probable Pliocene to Pleistocene age.

Figure 1



Site location map. SP refers to Sand Point location proposed as a landfill site. T and R indicate township and range numbers. Highway numbers (e.g., 62/180 or 31) are placed on the line of the highway.

Drillholes on the south, west, and north sides of the site intercepted the Permian Dewey Lake Formation at depths of 213 ft, 290 ft, and 292 ft, respectively. The drillhole along the east side of the site was still in Gatuña at a total depth of 230 ft. The Gatuña most likely overlies the Dewey Lake on an angular unconformity, though the detail is not available to demonstrate the relationship.

The Gatuña Formation is variable or heterogeneous over a scale of ft to tens of ft, consisting of units ranging from coarse clasts of gravel size to claystones. There are many fining upward cycles of varying thickness, and bedding and other structures are found with varying abundance. Many units were deposited by fluvial environments. Bioturbation is common, and the upper part of the Gatuña displays considerable staining of manganese oxide; both features are part of paleosol (fossil soil) complexes distributed throughout much of the formation. Sands and sandstones with moderate to good sorting and rounded grains within the sequence indicate probable eolian deposits.

The Gatuña is a relatively heterogeneous unit at the scale of beds, which are several feet thick, because of the complexity of fluvial depositional systems. The Gatuña as a whole is relatively homogeneous.

Units overlying the Gatuña at the surface include the Mescalero caliche (of Pleistocene age), Berino soil, eolian sand, and mixed alluvial and eolian sediment. These units are the focus of this report and are emphasized below.

NEAR-SURFACE AND SURFICIAL UNITS

Pedogenic Calcrete

Terminology

The term "caliche" is commonly understood in the southwestern U.S. as a carbonate or strongly calcareous unit formed originally near the surface due to soil-forming processes. The informal stratigraphic unit from southeastern New Mexico called the

Mescalero caliche is interpreted to have the same origin; I will continue to use the same informal name for the Mescalero caliche. Others have used the term "caliche" to describe units which are quite different in composition and origin, leading to some confusion.

Within the broader community of geologists and geomorphologists, the term calcrete (e.g., Goudie, 1973) has become useful to describe surficial or shallow carbonate or calcareous deposits. Calcrete includes deposits of various origins. Machette (1985) reviews some of the problems of terminology, and he uses "pedogenic calcrete" or "calcic soil" to describe these near-surface to surficial carbonate deposits formed by pedogenic (soil-forming) processes. I have described these deposits under the heading "pedogenic calcrete" to try to avoid confusion and because the deposits are near-surface carbonates/calcareous deposits formed as soils.

The K horizon and nomenclature was introduced by Gile and others (1965) to better describe calcic soils or calcretes and their features.

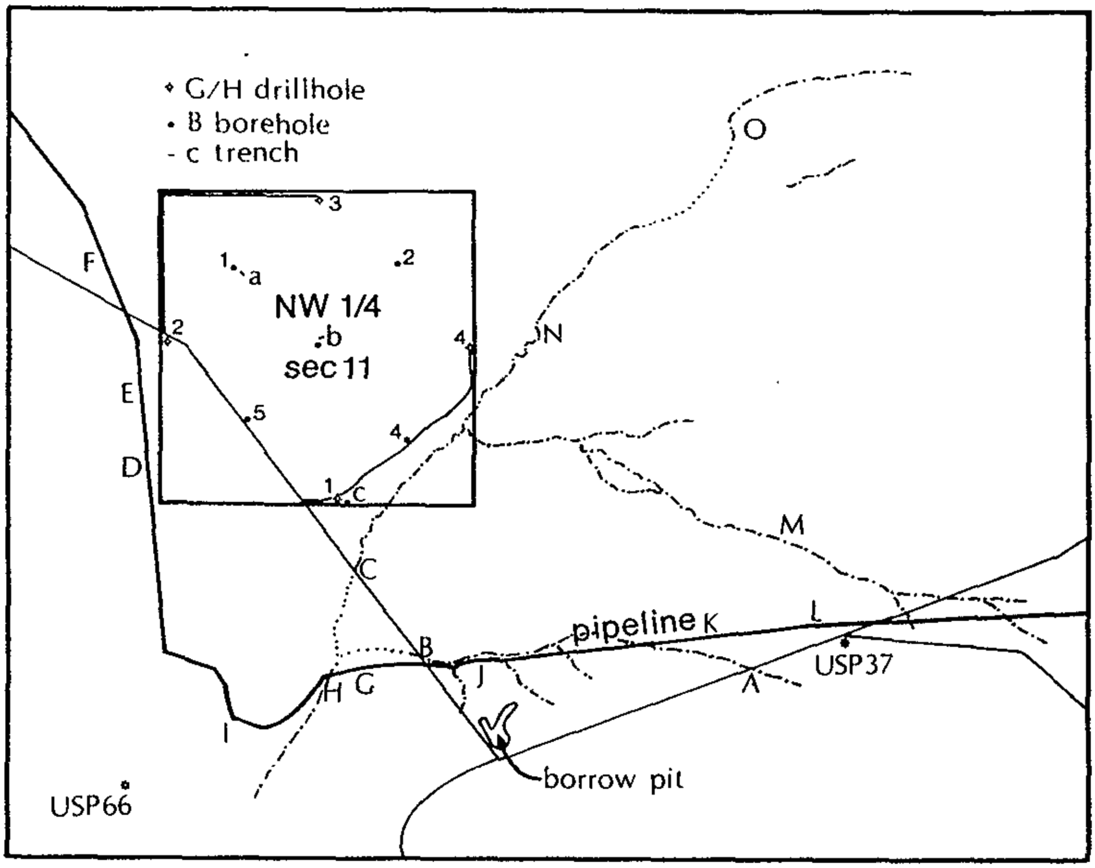
Basic Description

Information about the Mescalero caliche at the Sand Point site is available from surface outcrops, inspection of trench exposures, and from recovered samples during site characterization (Figure 2). Each of these sources will be used to compile the description of the Mescalero caliche at the site. The Mescalero caliche also has been identified in regional studies. Bachman (1974) is apparently the first to use this informal stratigraphic term. He described the unit as consisting of two parts:

> *an upper dense laminar caprock,* and,
>
> *a basal earthy to firm nodular calcareous deposit.*

Bachman (1974) further differentiated the Mescalero caliche from the older Ogallala caprock or caliche by noting that breccia and pisolitic textures are much more common within the Ogallala caliche.

Figure 2



Reference features and points around Sand Point site. Dotted portions of drainage are areas without identifiable channels and are based on heavier vegetation. Small numbers adjacent to G/H and B symbols refer to drillhole/borehole numbers. Capital letters designate field reference points for photos and descriptions; many are used as reference points in text. Site boundaries are 0.5 mile long.

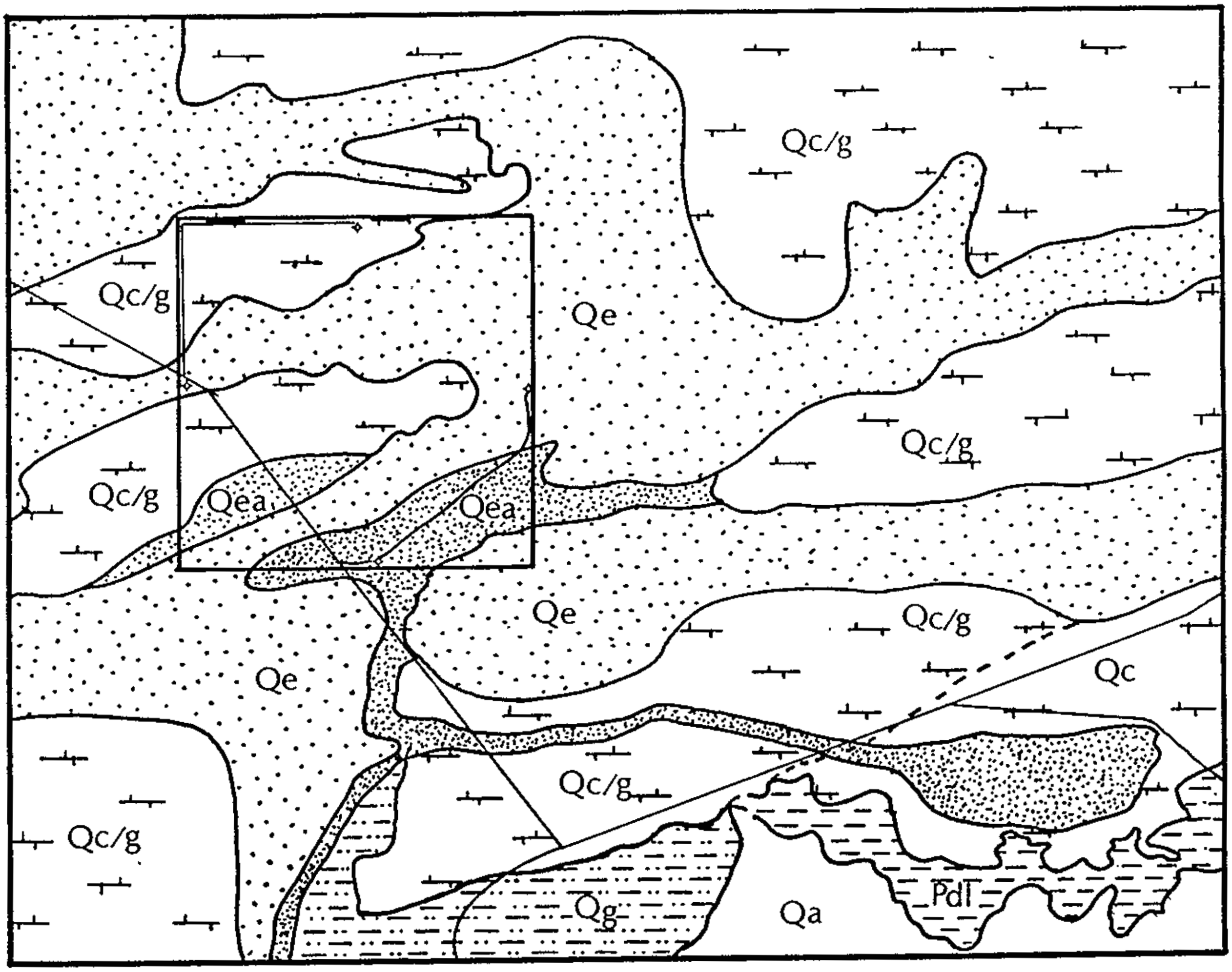
Within the Sand Point site, the Mescalero always overlies the Gatuña Formation and engulfs the uppermost beds of the formation. Sands and sandstones are the most common lithologies affected by the pedogenic calcrete. Further east, in western section 12, outcrops and trench exposures show that the Mescalero overlies and is engulfing the upper part of the Dewey Lake Formation. The change from Dewey Lake to Gatuña occurs along a general east-northeast to west-southwest line (Figure 3) that parallels both the topographic contours and the approximate strike of the Mescalero surface. A general northwest to southeast cross-section (Figure 4) illustrates the Dewey Lake-Gatuña relationship under the site, and it shows the relationship of the Mescalero to topography. Projecting the Mescalero and Gatuña to the southeast in this diagram shows the Mescalero would overlie the Dewey Lake, as is found in the pipeline trench in section 12.

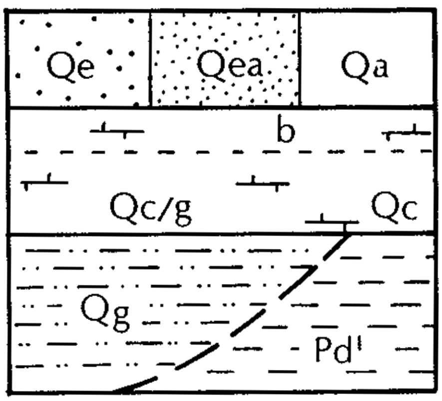
Borrow Pit Description. A *borrow pit* in the SW 1/4, SE 1/4, sec. 11 (Figure 2) displays a very accessible section of the Mescalero caliche. The Mescalero overlies and engulfs Gatuña sandstones at that locality. The exposed pedogenic calcrete section is about 6 ft thick; there appears to be additional but minor carbonate accumulation to slightly greater depth.

The calcrete section examined in the field is divided into three basic zones (Figure 5) reflecting different structure development and lithology.

The basal zone shows vertical nodular or pipe-like carbonate accumulating within the uppermost distinguishable Gatuña. The Gatuña itself is also being calcified, resulting in higher color values (increased "white") and more induration. Remnants of Gatuña appear more spherical upward with increasing calcification. The nodules are vertical, indicating no identifiable tilting since formation. The caliche has either been formed on the slope now existing, or the tilt is not distinguishable in outcrop on the basis of these nodules.

Figure 3





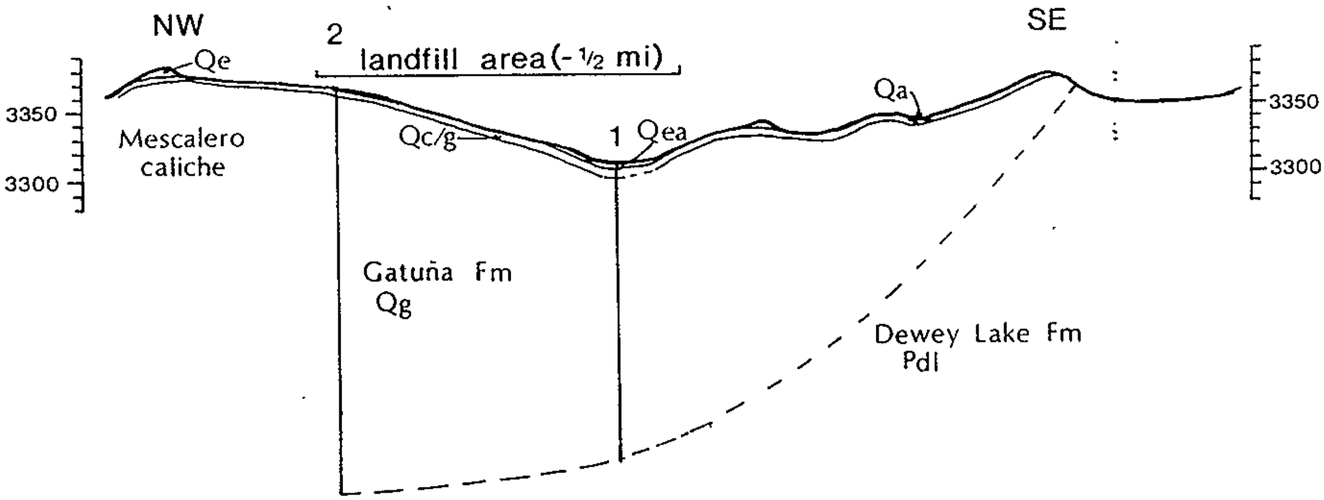
Map Explanation

Qe, ea, a - Quaternary eolian deposits (e), mainly dune sand; mixed eolian and alluvial deposits (ea); alluvial (or colluvial) deposits (a).
Qc - Pleistocene Mescalero caliche. Map area includes Berino soil (b) over much of site. Overlies Pdl (Qc) or Qg (Qc/g). Unit is within about 2 ft of surface.
Qg - Plio(?)-Pleistocene Gatuña Formation.

Pdl - Permian Dewey Lake Formation.

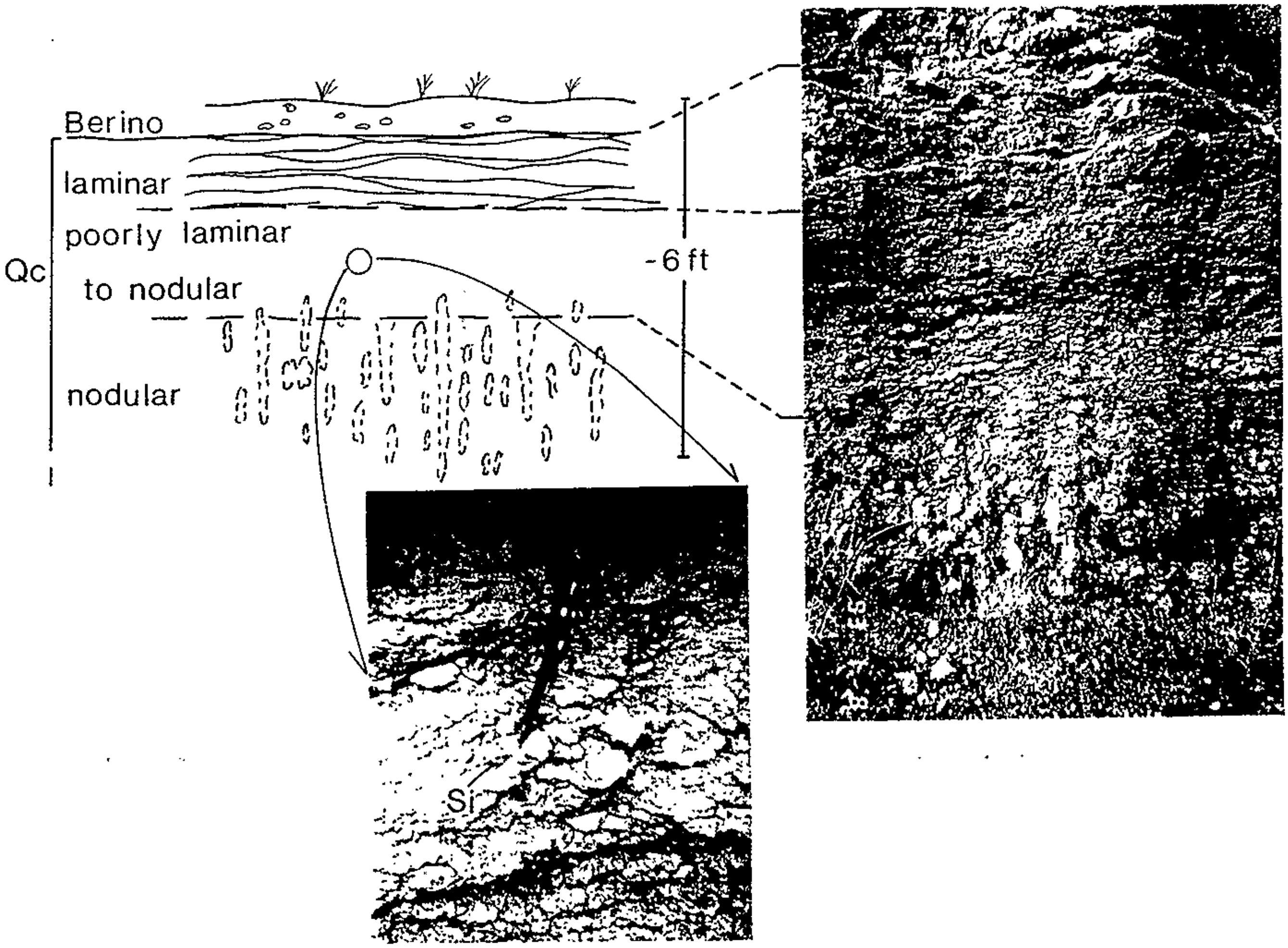
Surface and near-surface deposits mapped at and in vicinity of Sand Point site. Dashed boundary between Qc/g and Qc in southeast area is the subcrop boundary between Dewey Lake under the Mescalero caliche (Qc) and Gatuña under Mescalero (Qc/g). Site boundaries are 0.5 mi on each side.

Figure 4



Northwest to southeast cross-section (A-B, Fig. 12) through the site area. Elevations are in ft. See Fig. 3 for unit designations. Numbers 1 and 2 refer to drillholes SP G/H-1 and -2; they are near the line of the cross-section.

Figure 5



Mescalero caliche (Qc) exposed in borrow pit (Figure 2). Photo illustrates the descriptive zones. Inset photo shows silica cement/nodules within Mescalero.

The middle zone is relatively dense calcrete with some pisolite development and vague subhorizontal planar fabric. This zone displays considerable porosity along this planar fabric. Irregular masses of opal or chalcedony are most abundant in this zone. These masses are generally ½ to about 1 inch across with slightly irregular and transitional boundaries with carbonate. Some of the silica masses are elongate vertically, but they are much smaller than the carbonate pipe-like nodules. None of the siliceous masses showed interconnections or other features expected of root zones or other bioturbation.

The upper zone of the calcrete is dominated by laminar carbonate fabric with some slight evidence of brecciation and recementation. The bulk of the carbonate is very light brown. The laminar carbonate generally is whiter and surrounds irregular to platy masses of the browner carbonate along subhorizontal separation planes.

The Mescalero, as displayed in the borrow pit in section 11, is consistent with Stage V development (Table 1) of pedogenic calcretes. Machette (1985) also classified the Mescalero as Stage V, based on work by Bachman and Machette (1977).

Pipeline Trench Description. Recent (January, 1993) pipeline construction in the vicinity of the Sand Point site provided *trench exposures* across the southern parts of sections 11 and 12 and near the eastern boundary of section 10 (Figure 2). The trench was about 4 to 4½ ft deep and about 18 inches wide. The trench was widened, and less commonly deepened, at points to provide additional access for welding. I inspected the entire length of the pipeline trench from the ground surface in the area around the Sand Point site and entered the trench where it had been widened. By agreement with the pipeline crew, I did not enter the regular trench areas. The caliche depth (below surface) and general features were noted and extensively photographed.

Table 1

Stage of Calcium Carbonate Morphologies in Pedogenic Calcretes[1]

Stage	Gravel Content[2]	Diagnostic morphologic characteristics	$CaCO_3$ distribution	$CaCO_3$ content[3]
		Calcic Soils		
I	High	Thin, discontinuous coatings on pebbles, usually on undersides.	Coatings sparse to common	Tr-2
	Low	A few filaments in soil or faint coatings on ped faces.	Filaments sparse to common	Tr-4
II	High	Continuous, thin to thick coatings on tops and undersides of pebbles	Coatings common, some carbonate in matrix, but matrix still loose.	2-10
	Low	Nodules, soft, 0.5 cm to 4 cm in diameter.	Nodules common, matrix generally noncalcareous to slightly calcareous.	4-20
III	High	Massive accumulations between clasts, becomes cemented in advanced form.	Essentially continuous dispersion in matrix (K fabric).	10-25
	Low	Many coalesced nodules, matrix is firmly to moderately cemented.	---ditto---	20-60
		Pedogenic Calcretes (Indurated Calcic Soils)		
IV	Any	Thin (<0.2 cm) to moderately thick (1 cm) laminae in upper part of Km horizon. Thin laminae may drape over fractured surfaces.	Cemented platy to weak tabular structure and indurated laminae. Km horizon is 0.5-1 m thick.	> 25 in high gravel content. > 60 in low gravel content.
V	Any	Thick laminae (> 1 cm) and thin to thick pisolites. Vertical faces and fractures are coated with laminated carbonate (case-hardened surface).	Indurated dense, strong platy to tabular structure Km horizon is 1-2 m thick.	> 50 in high gravel content. > 75 in low gravel content.
VI	Any	Multiple generations of laminae, breccia, and posilites; recemented. Many case-hardened surfaces.	Indurated and dense, thick strong tabular structure. Km horizon is commonly > 2 m thick.	>75 in all gravel contents

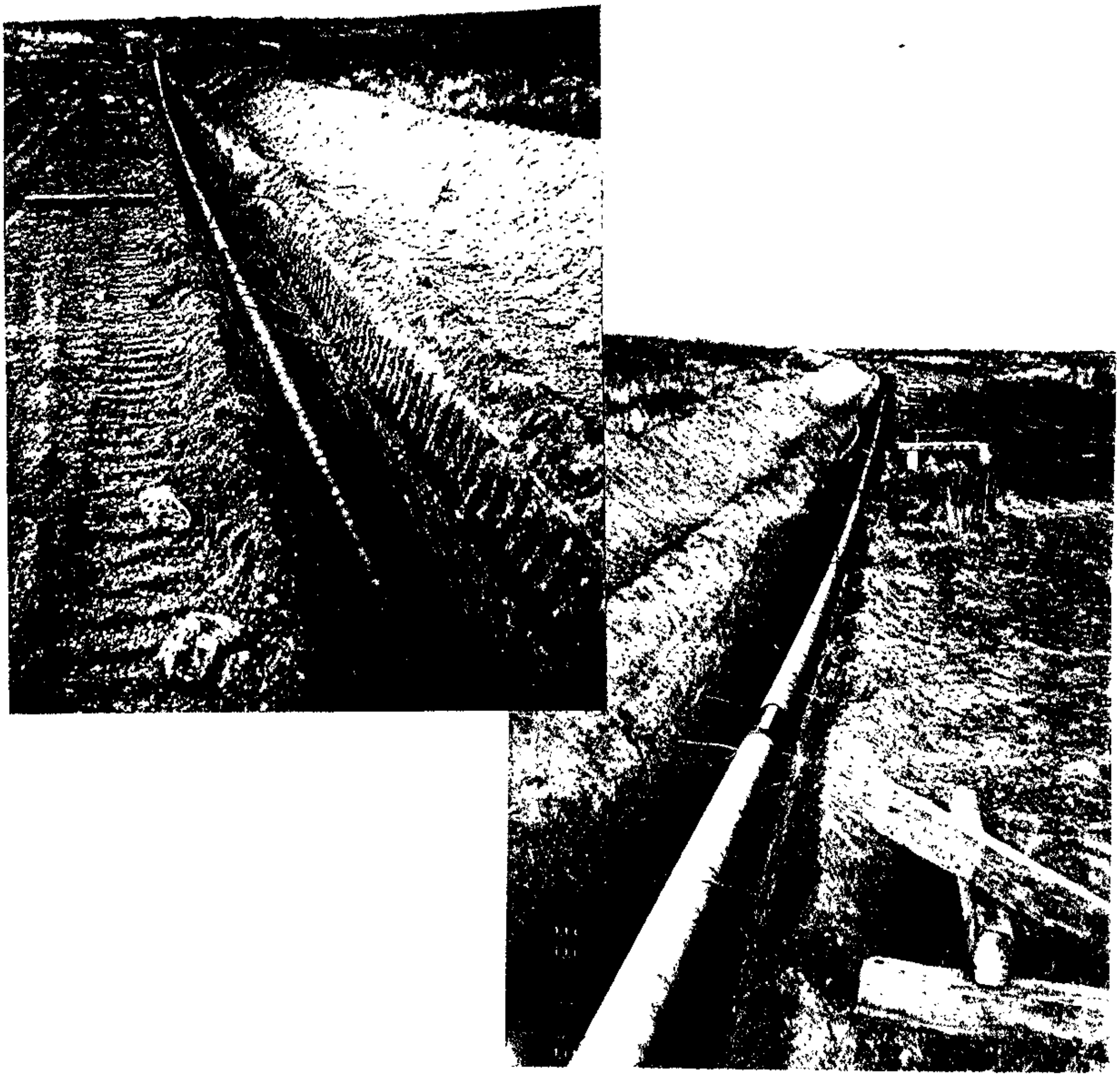
[1] Table is modified slightly from Machette (1985).
[2] High is > 50% gravel; low is < 20%.
[3] Percent carbonate in < 2mm fraction of soil; Tr is trace.

Based on the trench exposures, it is clear that caliche underlies most of the landfill site. An arroyo along the southern leg of the pipeline appears to have destroyed the Mescalero in a narrow zone through erosion and solution. Low points along the southern parts of sections 11 and 12 show the calcrete attacked by erosion and solution, creating an irregular surface and distributions (Figure 6). The calcrete has probably been destroyed or partially destroyed by erosion and solution below the main arroyo in the southwest ¼ of section 11, given the nearby outcrop evidence as well as the trench evidence. Four segments, mainly along the western leg of the pipeline, show eolian sand cover greater than 4 to 4½ ft thick over the calcrete. The calcrete is believed to be continuous under these thicker eolian sands for the following reasons:

- *there is no apparent disruption of the caliche as the sand becomes thicker to the point where the trench no longer exposes the calcrete,*
- *the county sand pit has exposed calcrete under 10 to 12 ft of eolian sand,* and
- *a few hand augur holes also drilled through modest sand thickness (< 5 ft) encountered hard calcrete.*

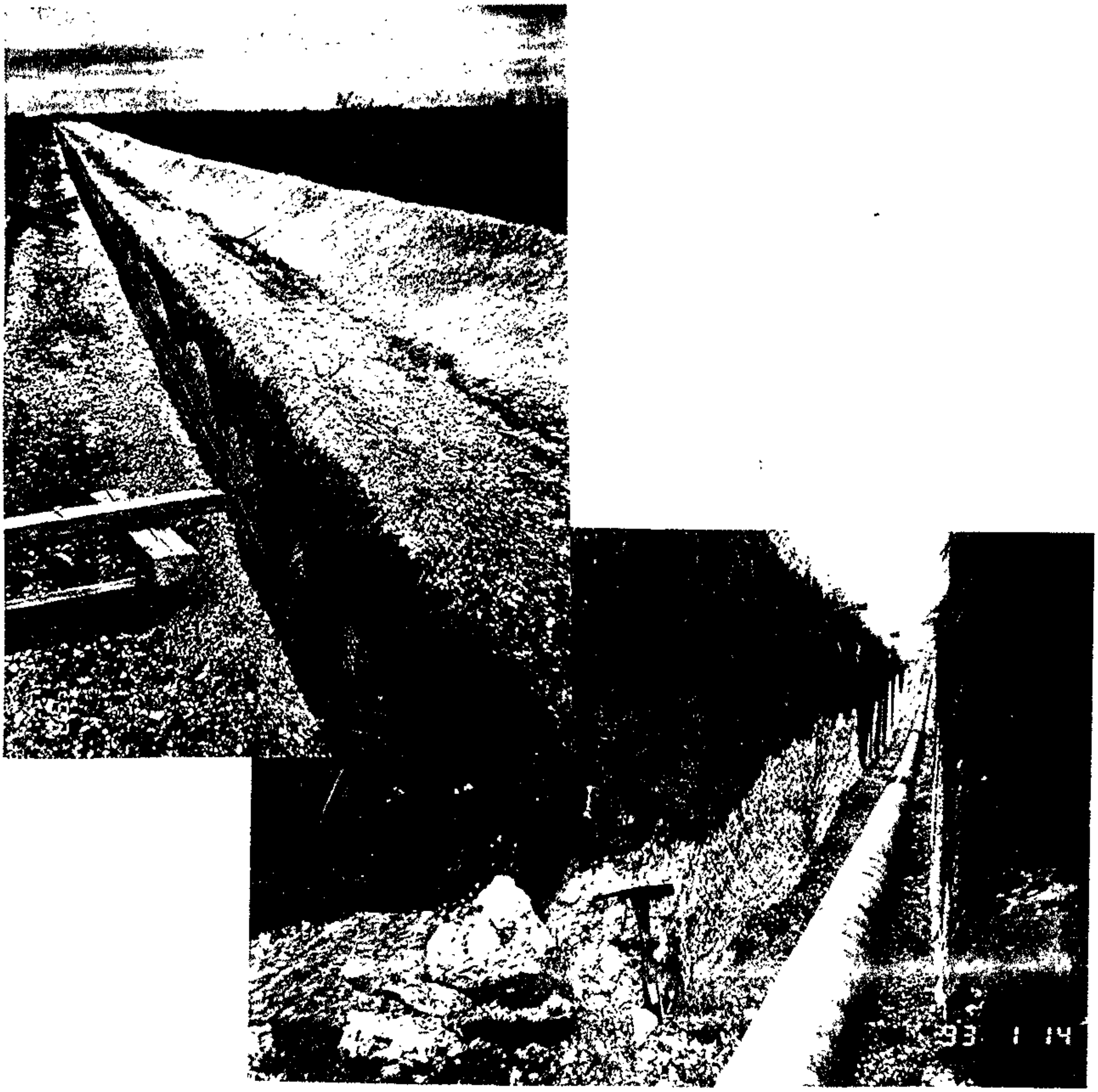
The pipeline trench through a low area (near D, Figure 2) in the southwest ¼ of section 11 reveals disruption of the calcrete (Figure 7) as it is covered by sediment of mixed eolian and alluvial origin and partly by later eolian [illegible] area is downslope of an area where the calcrete is exposed at the surface. The overlying soil has been stripped along this zone of greater slope (about 4+ %). The upper surface of the calcrete is undulatory to irregular under the thicker mixed alluvium/eolian sediment. The remaining calcrete section is hard to moderately hard, platy or laminar in upper part. Some pebbles of well-rounded chert, some silica, and some Gatuña

Figure 6



Irregular surface on Mescalero caliche near point J (Figure 2) toward the west (left) and east (right).

Figure 7



Irregular surface on Mescalero caliche near point D (Figure 2) where Berino soil or remains are also covered by mixed eolian and alluvial material. SP G/H-2 is just right of pipeline trench through dunes at horizon on upper photo.

clasts are included within the calcrete. The unit is more laminar upward and to the north away from the disrupted area.

The pipeline trench cuts through an area (see F, Figure 2) of slight southeastward slope (< 0.5%) where the calcrete is rather uniform and is covered by about ½ to 2 ft of stabilized soil (called the Berino soil; see below). The calcrete is as much as 4 ft thick in pits. Catclaw is a common plant in this area. The upper laminar to platy zone locally shows laminae that dip southeast at slightly greater angles than the underlying bed (Figure 8). Through this area, the calcrete is continuous.

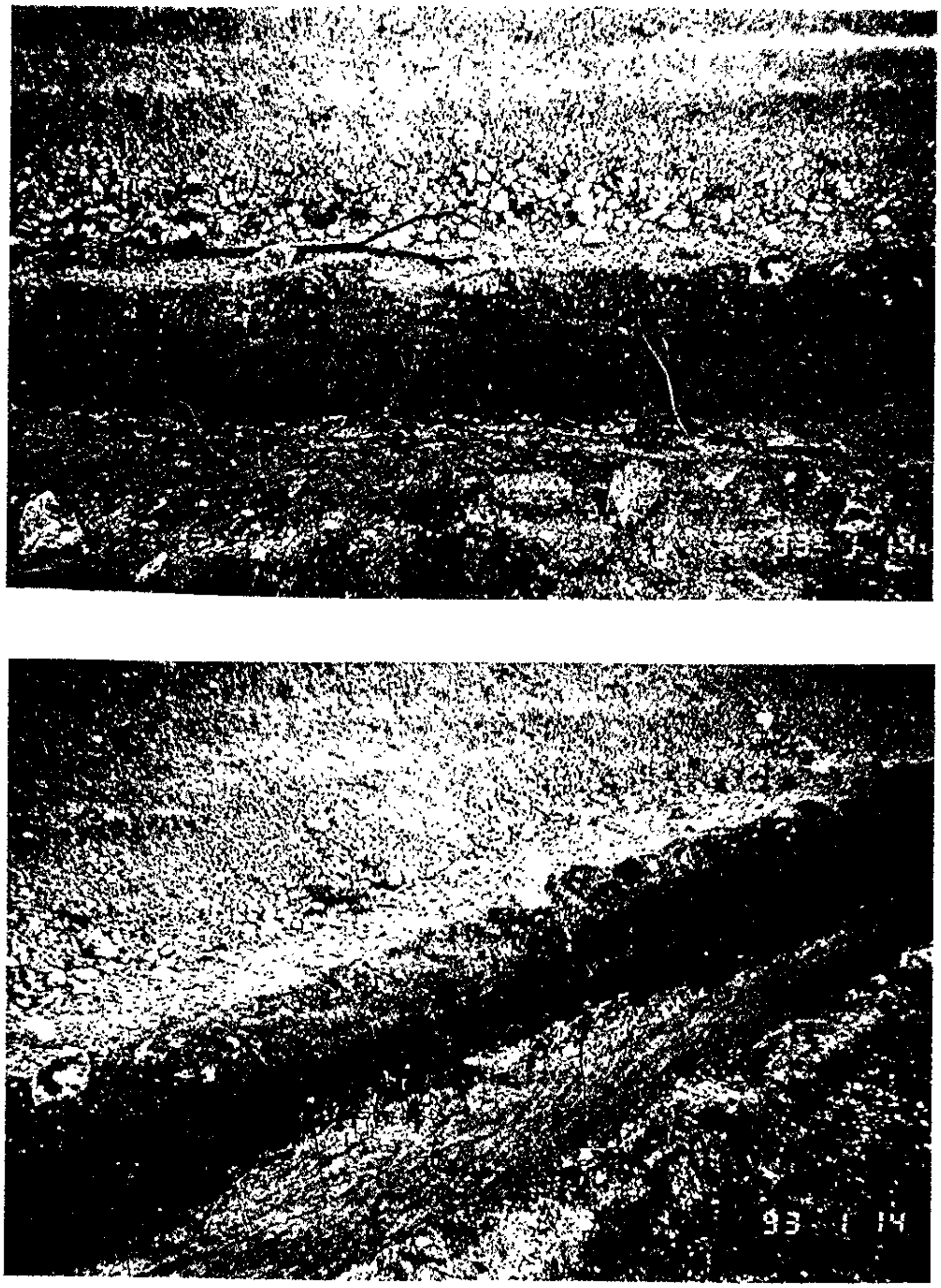
The pipeline trench also cuts through the zone (near K, Figure 2) where the Mescalero steps onto the Dewey Lake (to the east) from the Gatuña (to the west). There is no noticeable change in calcrete character attributed to the change in subcrop.

On-Site Borehole and Trench Descriptions. Four locations for preliminary characterization/hydrological testing and five boreholes for subsequent site study all showed that calcrete was present. The quality of information varied with drilling circumstances and technique as well as with location.

Drillholes SP G/H-2 and -3 and boreholes B-1, -2, and -3 are all in the northern half of the NW ¼ of section 11. Each of them indicated relatively hard caliche at shallow depths below soil and/or eolian sand (Powers, 1992a,b). The calcrete is similar to well-preserved calcrete found in the pipeline trench along the western boundary of the proposed site.

Drillholes SP G/H-1 and -4 and boreholes B-4 and -5 were drilled in the southern and eastern parts of the site, in areas of lower elevation along or adjacent to the main drainage through the southeastern part of the site. Each of these drillholes or boreholes encountered softer calcrete or calcareous sands instead of much harder calcretes in the northern part of the site. The calcrete or calcareous zones are also deeper, below eolian or mixed alluvial/eolian sequences. All of the drilling

Figure 8



Mescalero caliche overlain by Berino soil near point F (Figure 2). Laminae in upper calcrete slope to right (south). Berino thickness (Bt horizon) also corresponds to undulations on the calcrete surface.

demonstrates some form of calcrete present, though it may be partially degraded by erosion and/or infiltration and solution.

Three trenches were dug by bulldozer adjacent to drillholes or boreholes to expose the calcrete for better examination (Figure 2). Trench A is near B-3, in the center of the NW ¼ of the NW ¼. Trench B is near B-3, in the center of the NW ¼ of section 11. Trench C was near SP G/H-1, at the center of the south line of the NW ¼ of section 11. Trenches A and B exposed about 3 ft of hard, well preserved calcrete of Stage V on the upland slope of the northern half of the site. Features are similar to those in the borrow pit and in the pipeline trench just west of the proposed site. Trench C was dug to a depth of about 9 ft below the drillpad surface. Additional digging with a hand shovel revealed the top of the Mescalero at a depth of 10 ft. The calcrete at 10 ft was medium hard, but no laminae were observed. The calcrete was not further excavated. The sediment above the calcrete shows a series of soil horizons in mixed alluvial and eolian deposits (see below).

Mescalero Caliche "Facies" and Distribution

The Mescalero caliche exists in each drillhole, borehole, or trench within the proposed Sand Point site. The calcrete is relatively dense, hard, and laminar to platy over most of the northwestern or northern 2/3 of the site. In the southeastern part of the site, at lower elevations, the calcrete is under a greater thickness of eolian sand, mixed eolian sand and alluvium, and soil material. It is not as hard or dense as in the northern part of the site. It is likely that the laminar to platy zone is very poor or does not exist over much of this southeastern part of the site, though direct evidence is meager.

Lateral changes in equivalent rock units are commonly called facies changes, and the changes in facies usually reflect changes in environment of deposition. This informal usage of the term "facies" here is preferred to some pedologic terms, such as catena.

Three general "facies" of the Mescalero can be differentiated within the site (Figure 9):

1 *slight slope (generally < 1 %), generally 1-2 ft of covering soil; hard, continuous, laminar to platy calcrete in the northern area of the site; includes areas with thicker dune sand.*

2 *gentle slope (may be 4+ %), surface exposure of calcrete, also areas covered by dune sand; hard, continuous, laminar to platy calcrete, undulatory or irregular upper surface.*

3 *slight or no slope, burial under 2+ ft of mixed alluvial/eolian sediment and/or soils; soft to moderately hard, may lack laminar or platy character, may have irregular surface.*

These "facies" of the Mescalero are interpreted as consequences mainly of the late-stage or post-formational changes affecting the calcrete. This will be discussed later under a review of the significance of different near-surface to surficial deposits of the Sand Point site.

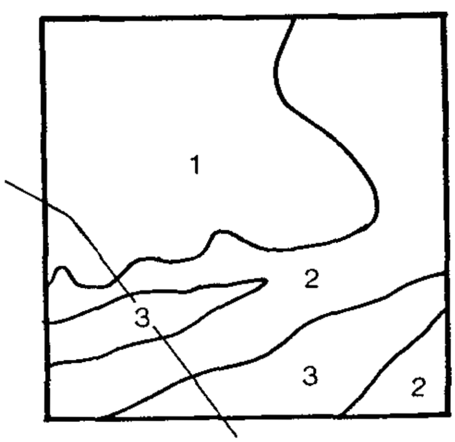


Figure 9

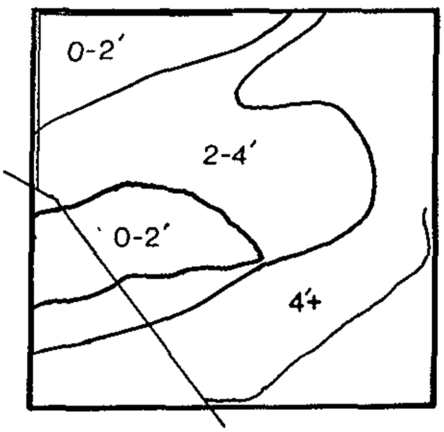
Approximate distribution of "facies" of Mescalero caliche at site.

1 - hard, continuous, laminar calcrete; slight slope; 1-2 ft cover
2 - hard, continuous, laminar calcrete; slope 4+%; bare to covered by dune sand
3 - soft to hard calcrete or calcic soil; slight or no slope; buried by 2+ ft of alluvial/eolian sediment

Thickness of Soil and Sand Cover over the Mescalero Caliche

A simple map of the thickness of cover over the Mescalero is based on field evidence from pipeline trenches, presence of dune sand, depths in drillholes, and trenches in the site area. A few areas were augered with a soil sampler. The contour lines (Figure 10) are broad estimates based on these data and field experience at the site; they are not based on systematic sampling.

Figure 10



Estimated Thickness of Cover over Mescalero Caliche (in ft)

Age of the Mescalero Caliche

Earlier arguments about the age of the Mescalero caliche, based on stratigraphic and climatic interpretations rather than radiometric data, were presented well by Bachman (e.g., 1973, 1974, 1976) in several reports. The Mescalero was generally considered to have accumulated during the early to middle Pleistocene. Bachman (1973) suggested the Mescalero was equivalent to the Jornada-La Mesa surface in the Las Cruces, NM area. The calcrete was interpreted to have formed during a period of stability with semi-arid climate; Bachman (1974, 1980) tentatively correlated the

Mescalero with the Yarmouthian interglacial stage. In early papers, the stage of development of the Mescalero was considered less mature, and therefore younger, than that of the calcretes within the Pliocene Ogallala Formation of the High Plains. The Mescalero is developed on Gatuña Formation over large areas, and Bachman (1974) noted that the Gatuña in some areas includes a high proportion of large clasts that are interpreted as derived from erosion of the Ogallala calcrete. The Mescalero would therefore be younger than the Ogallala.

Three lines of radiometric data became available that firmed up the age of the Mescalero caliche. Bachman (1980) reported finding a volcanic ash in the upper Gatuña Formation along Livingston Ridge about 13 miles east-southeast of the Sand Point site. His original report of this as the Pearlette "O" ash about 600,000 yrs was superseded; Izett and Wilcox (1982) reported that the ash was identified as the Lava Creek B ash of 600,000 yrs age. The Mescalero is developed on top of the Gatuña a few feet higher and must be younger.

Mescalero samples from east of Sand Point, in the vicinity of the WIPP site, were studied using uranium-trend methods (Rosholt and McKinney, 1980). Bachman (1985) reports the basal part of the Mescalero began to form about 510,000 years ago and the upper part began to form about 410,000 years ago based on written communication from Rosholt in 1979. The samples are interpreted by Rosholt and McKinney (1980) as indicating an age of 570,000 ± 110,000 years for the lower part of the Mescalero and 420,000 ± 60,000 years for the upper part.

All of the stratigraphic and radiometric data are consistent with an age of formation of the Mescalero in the range of 500,000 years, though the calcrete features and radiometric ages also indicate the unit formed over a period of time. I will use the approximate age of 500,000 years for simplicity in later arguments about the significance of features at the Sand Point site.

Berino Series and Related Soils

At the Sand Point site and surrounding areas, a paleosol commonly overlies the Mescalero caliche, and it has been attributed to the "Berino soil" (e.g., Bachman, 1980). Bachman also interpreted the "Berino soil" as a paleosol that is the remnant B horizon of the underlying Mescalero.

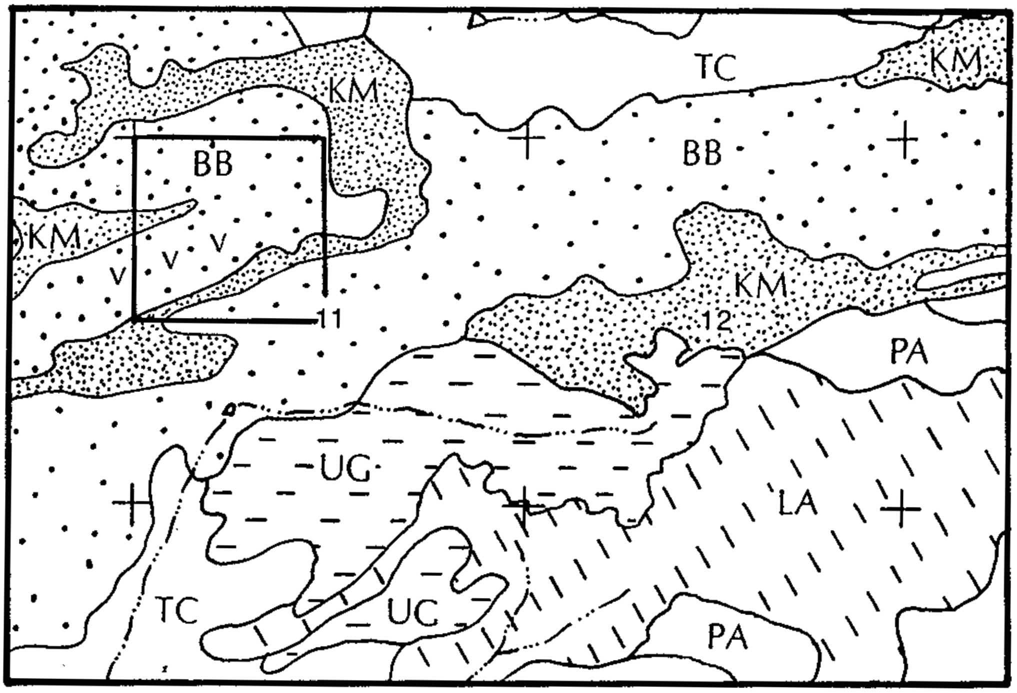
The soil survey of Eddy County (Chugg and others, 1971) assign soils for the site and immediate surroundings (Figure 11) mainly to the Berino complex (without dune sands) and the Kermit-Berino sands (in the sandy areas). The descriptions of the Berino Series and related soils in Chugg and others (1971) indicates that much of the area mapped by me as Qc or Qc/g (Figure 3) can alternatively be assigned to the Berino Series or two other similar soils, the Cacique Series or Tonuco Series. The map criteria for Mescalero caliche (Qc or Qc/g) is that the discernible dune sand be minor and the depth to caliche generally < 2 ft below the surface. From the field inspection, thinner soil profiles, moderate or poorer cutans, and weak ped structure indicate the soil might also be classified as part of the Cacique Series, but the difference is not significant here. More brown to reddish hues in the A horizon are more consistent with Berino Series. The thin reddish brown paleosol overlying the Mescalero is considered here as part of the Berino Series and referred to as the Berino soil.

The Berino soil in the site area was not described according to strict pedologic criteria. By inspection, the Berino in the northwest part of the site consists of three main horizons:

- *a thin (a few inches thick), brown, undifferentiated A horizon;*
- *a probable B2t horizon or horizons (also a few inches to about 1 foot thick) that are slightly reddish brown (about 5YR 5/4);* and
- *a reddish brown (about 2.5YR 4/6) B3t horizon up to 1 ft thick overlying the Mescalero.*

The basal B3t horizon is the most prominent, both by color and induration created by illuviated clay. Along the pipeline trench west of the northwest part of the proposed site (F, Figure 2; Figure 8), the B3t horizon thins and thickens over minor highs and lows on a slightly undulatory surface of the Mescalero.

Figure 11



Map Explanation

BB Berino complex, 0 to 3 % slopes, eroded.
KM Kermit-Berino fine sands, 0 to 3 % slopes.
LA Largo loam, 1 to 5 % slopes.
PA Pajarito loamy fine sand, 0 to 3 % slopes, eroded.
TC Tonuco loamy sand, 0 to 3 % slopes, eroded.
UG Upton gravelly loam, 0 to 9 % slopes.
vv rock outcrops (Mescalero caliche).

Map of soils in vicinity of site, modified from Chugg and others (1971). + marks section corners.

Along the pipeline trench north of point F (Figure 2), the B3t horizon is exposed to a point where the eolian sand exceeds 4-5 ft. The B3t horizon changes character and color; lithification due to clay illuviation decreases somewhat under the dune sand, and the color is more brownish (about 5YR 5/4 to 4/4) than red.

There is a general impression from the outcrops that the dune sand is probably later than the Berino soil. That is, the Berino soil developed over the area for some period of time, and the dune sand accumulated much later. The difference between the soil B3t horizon under the dune sand and without dune sand is not great. It seems less likely that the closely related horizon would develop under both areas to this degree of similarity. The observable differences between the horizon under dune sand and areas of thinner soil can be attributed to the change in soil environment after the more recent sand dunes accumulated.

Samples of the Berino soil were also studied using uranium-trend methods. Rosholt and McKinney (1980) interpreted the age of formation of the Berino as 330,000 ± 75,000 years. The Sand Point site is similar to the areas investigated by Bachman, and I also believe the "Berino soil" probably represents a remnant B horizon for the Mescalero.

Eolian Sand

Eolian sand at and around the Sand Point site occurs mainly in stabilized to semi-stabilized dune fields (Qe in Figure 3), but pipeline and bulldozer trenchs also show modest to slight accumulation of sand on much of the area (mapped as Qc/g, Qc) with near-surface (< 2 ft) Berino soil over Mescalero caliche. Mixed alluvial and eolian units (Qea) show reworking of eolian sand that has been transported as well as that deposited in the alluvial system. The eolian sand deposits are described on the basis of field work and literature review.

Basic Description

The eolian sand is distributed mainly in coppice dunes stabilized or anchored by vegetation that commonly includes shinnery oak and some mesquite. Blowouts have been excavated by the wind in areas of the dune field; these often begin to expose root systems of the stabilizing vegetation on the upwind (west) side of dune sand. Blowouts can be swept clean of sand to the depth of the Berino soil or to a basal zone of accumulated finer grains. Caliche clasts and "manuports", rock brought in by man, are exposed on some of these swept areas. These locations are more common sites of archeological materials. There is little identifiable about the dune form or shape in the field. Crescentic light colored areas on aerial photos resemble both barchan and parabolic dunes, but they are instead the exposed "blowouts" both upwind and downwind around central vegetated, stabilized areas.

Dune sand at Sand Point is mainly fine-grained and is dominated by rounded to well-rounded quartz. Opaque grains are not common, estimated at less than 1%. The dune sand is bioturbated extensively by root systems of woody plants, shrubs, and some grasses. No bedding has been observed in exposed dune faces, though most exposures are not favorably oriented (i.e., they are not usually north or south facing sides, parallel to the main wind direction). There was no visible grading of grain sizes in the main body of the dune material. At the base of dunes bulldozed for access, a slightly more brown to reddish-brown zone, several inches thick at least, is common. These zones have also been reported by Bachman (1974) to be as much as about 1.5 ft (0.5 m) thick within the region. They are generally more argillaceous and may also be slightly calcareous. This zone is observably equivalent to the Berino soil in some parts of the site, where the eolian sand has covered the paleosol (see above). Its relationship to the "Berino" is undetermined in other areas. In some areas, the zone of accumulation may entirely postdate the accumulation of the sand and be developed by clay eluviation from the overlying sand to the depth of percolation. Widdicombe (1979) reported similar basal accumulations below gypsum dunes in the region.

Despite vegetation on the stabilized dune areas, there is very weak or no development of soils on the dune sand.

Distribution

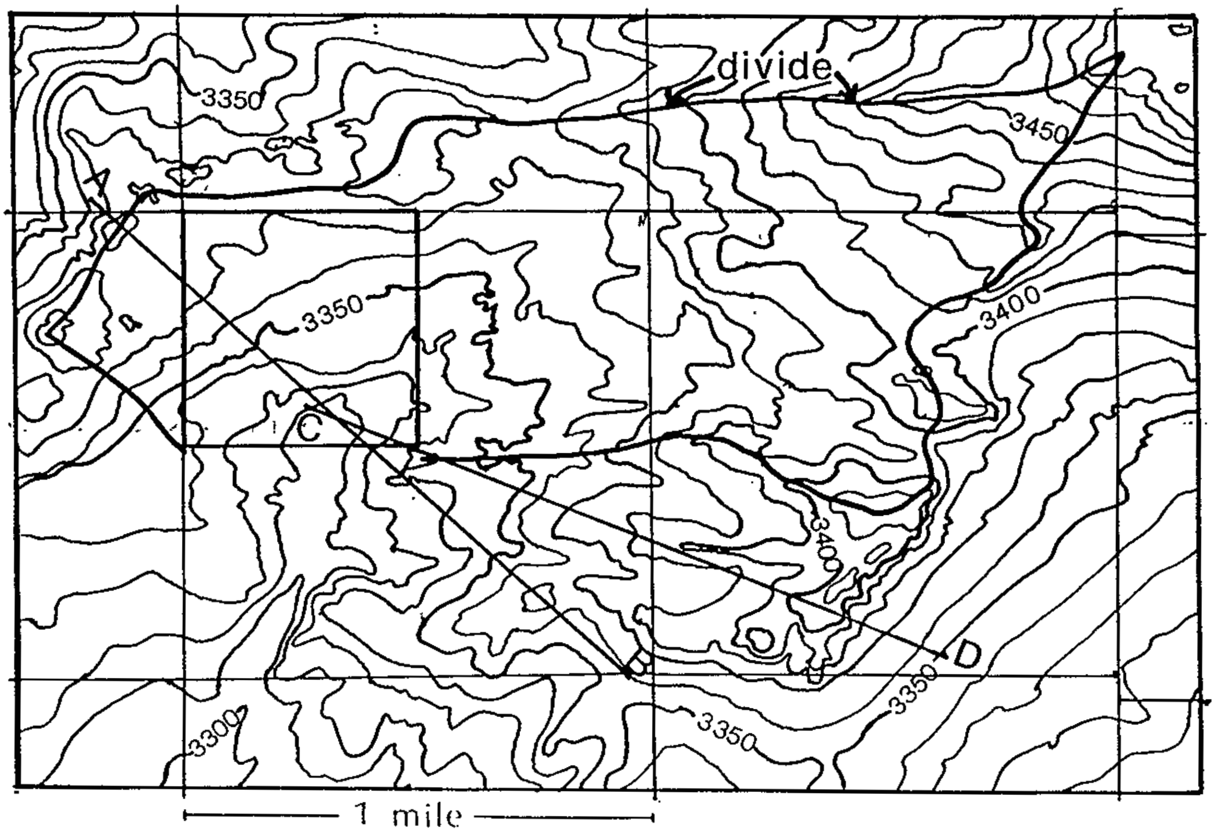
The dune sand areas (Qe, Figure 3) are broadly mapped as those areas where the eolian material is clearly identifiable as a separate deposit. The Mescalero caliche is generally > 2 ft below the surface within the mapped deposit. The sand dune deposits are demonstrated to be at least 10-12 ft thick in some areas, but the thickness is undetermined over much of the site.

Map trends and aerial photos of the site and surrounding area show more or less east-northeast to west-southwest elongate zones of dune sand and a north-south patch of sand just northeast of the site.

The two east-northeast elongate zones across the southern half of section 11 and the southeastern part of the landfill site parallel low areas and drainage. A poorly defined elongate zone across the location of SP G/H-2 and the middle of the landfill site does not occur along a drainage, but it is along a change in slope of the topography and underlying Mescalero caliche. An elongate zone of dunes just north of the landfill site occurs along the topographic divide which runs slightly north of east (Figures 3, 12). It is not certain if transport is being funneled by wind along these drainages or if sand is being dumped on the lea side of slope changes trending along the drainage. All of the elongate dune fields parallel slope breaks and could be associated with loss or change of carrying power by the wind; two of the elongate fields occur along low areas and drainage. The elongated dunes are therefore attributed to changes in slopes and loss or change of carrying power of the wind.

A large, more or less north-south oriented patch of dune sand in the northeast quarter of section 11 collected in a modest topographic basin downwind along the trend of three of the elongate zones. The change in slope broadened the lea-side area and dune sand collected over a larger area, coalescing the elongate trends and smearing the boundaries of each into a larger patch of dune sand. This patch of dune sand has also obscured the drainage through the area toward the southeastern part of the Sand Point site.

Figure 12



Topography near Sand Point. The drainage area upgradient of the site is enclosed with a broad line (marked "divide"). Profile locations are for Figures 4 (A-B) and 16 (C-D). Sources are 1985 editions of Indian Flats and Illinois Camp SE maps.

Alluvial Units

The low areas and areas of drainage at and around the site include sediment that has been transported by runoff (Qa, Qea). The sediments display few sedimentary features of fluvial environments. Channels are poorly developed, and some segments of the drainage lack a readily identifiable channel (see Geomorphology, below). No runoff was observed on site during rains while site drilling was underway. The deposits are marginally alluvial in nature, and they could also be called colluvial.

The alluvial sediments at and around the site include substantial amounts of eolian sand and reworked eolian sand (Qea). The low areas are often choked by sediment derived from eolian and alluvial transport; channels are poorly developed or non-existent in these areas. A trench (C) near drillhole SP G/H-1 (Figure 13) exposed 10 ft of these mixed sediments, modified by soil-forming processes, overlying the Mescalero caliche. No clear sedimentary features were observed. Some pebbles were distributed in a unit from 6-7 ft deep and in a unit of "orangish" sand from 4-6 ft. The pebbles are distributed and indicate more nearly sheet flow than normal fluvial transport. The orangish sand is well-sorted and rounded; it is interpreted as mainly eolian. The orangish sand also displays a basal calcareous zone and probable rhizoliths. The entire 10 ft thick sequence shows evidence of bioturbation from root growth.

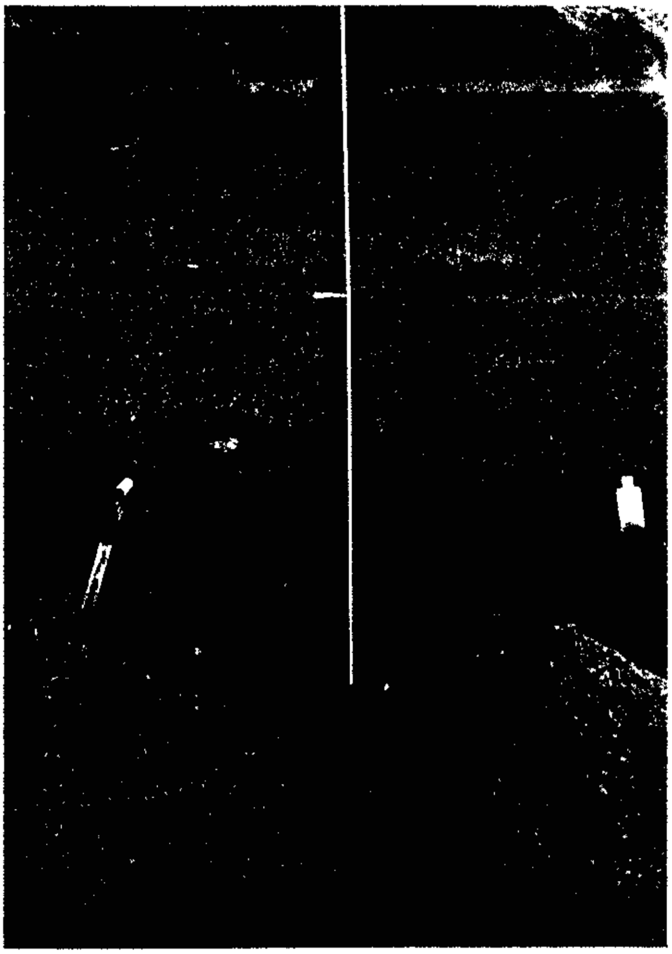
Relationships of Units

The stratigraphy of the described near-surface and surficial units is straightforward (Figure 3). The oldest near-surface unit in the immediate area is the Permian Dewey Lake Formation. Overlying the Dewey Lake is the Plio(?)-Pleistocene Gatuña Formation; it is the first rock unit under the Mescalero caliche throughout the

Figure 13

Trench near SP G/H-1 near center of south site boundary line. Marked divisions are at soil boundaries and are depths in ft from surface. Mescalero caliche is in pit at depth of 10 ft.

Figure 13



Trench near SP G/H-1 near center of south site boundary line. Marked divisions are at soil boundaries and are depths in ft from surface. Mescalero caliche is in pit at depth of 10 ft.

Sand Point site. The Pleistocene Mescalero caliche (Qc and Qc/g) persists over the site; the caliche is absent under the arroyo in the southeastern quarter of section 11. A Pleistocene paleosol called the Berino soil overlies the Mescalero caliche over much of the Sand Point site. It is absent where the Mescalero crops out, and it was not observed at the base of mixed alluvial/eolian sediments in trench C in the drainage area across the southeastern part of the site. The Berino soil has been included in the Mescalero as a map unit. The latest deposits at the site are the eolian sands (Qe) and mixed alluvial/eolian (Qea) sediments. Alluvial or colluvial deposits (Qa) in the map area are indistinguishable in age from the eolian or mixed alluvial/eolian sediments.

GEOMORPHOLOGY

Different geomorphic elements and the age relationships of surficial deposits can be used to infer the recent geological history of the site and area. A critical set of arguments is based also on the concept expressed by Bachman (e.g., 1974, 1976, 1985) that pedogenic calcrete is a useful indicator for interpreting the history of the area over a period of time. "Thick and well-developed accumulations of pedogenic caliche appear to indicate regional tectonic stability as well as relative climatic stability" (Bachman, 1974). It is expected that pedogenic calcrete will not develop or will be poorly developed on surfaces that are unstable over the period of accumulation. In addition, steeper slopes are expected not to develop calcrete. This latter point is not well established. Gile and others (1981) reported more mature calcretes mainly from areas ranging from level to 4% slopes; one study site showed a mature calcrete from a slope of about 15%. Thus the limit of slopes on which mature calcrete can develop and be preserved is not a settled issue, though low slopes would appear both empirically and conceptually to be much more favorable.

Land Forms

The dominant features of the landfill site and immediate surroundings are the topographic divide (Quahada Ridge) and the drainage being developed. The slopes from the divide across the site can be classified as: 1) an "upland" area in the northern to northwestern part of the site, where the surface slope is generally < 1%; 2) "lowland" drainage area, with broad slopes (disregarding local dunes) of 1-2%; and 3) transitional slope areas between the "upland" and "lowland" with slopes on exposed Mescalero caliche in the 4-8% range. Heavy dune cover in some transitional areas of the site accentuate slopes to about 25% locally. Irregular land forms from dune morphologies have been superimposed on each of these areas. The total relief within the Sand Point site is about 60 ft. The high point, based on aerial photography and a topographic map supplied to JOAB by Skyline Engineering, is near the northwest corner and has an elevation of 3379.4 ft. The low point is near the center of the south line of the site and has an elevation of about 3319 ft.

The land forms and the drainage are inter-related with the slopes and surficial to near-surface deposits at the site. The slightly sloping northwestern "upland" area at the site coincides with well-developed Mescalero caliche and a persistent covering of Berino soil. Mescalero caliche crops out in the southwestern quarter of the site along transitional areas where erosion has removed the Berino as well as any eolian sand. The "lowlands" drainage areas are complicated by an oversupply of sediment from the dune sand, resulting in little development of channels. And the break points in slope have been the locus of eolian sand dune accumulations. Slope elements are clearly important in preserving, accumulating, or displaying various units at the surface.

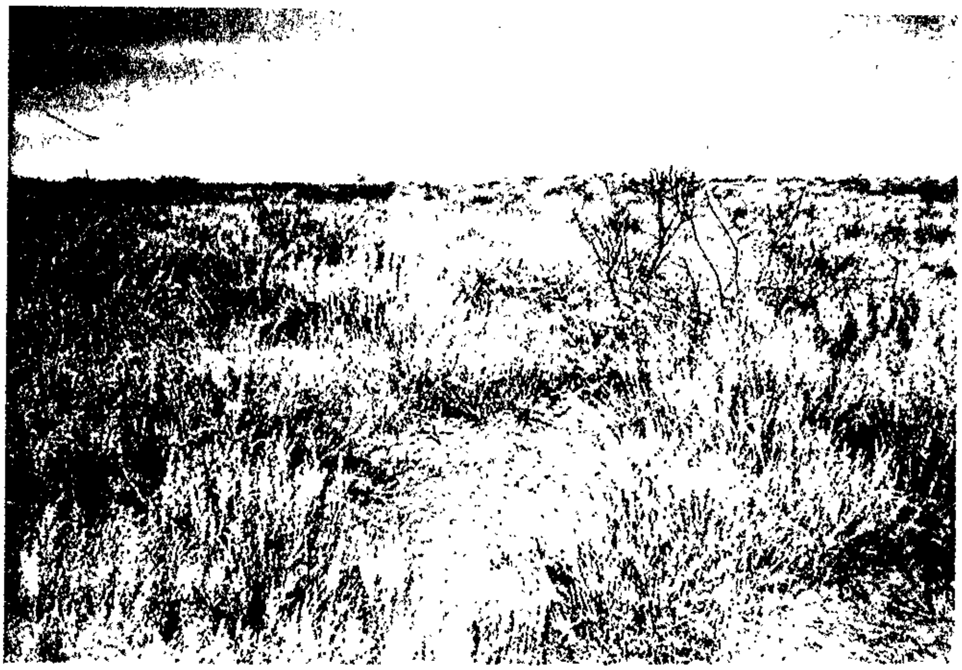
Drainage

Most of the site is not directly drained by an identifiable drainage channel. In the southwest quarter of the site, a former track paralleling and north of the present northwest-southeast road segment has probably served as a rare and very minor drainage. Aerial photography shows darker vegetation paralleling and south of the same road segment. This feature probably also served at some time as a very minor drainage across the transitional slope to the "lowland" area, but there is no observable evidence of it having been part of an integrated drainage.

The main drainage through the site runs from northeast to southwest across the southeast corner of the site (Figure 2). Some segments of this drainage show an identifiable channel (Figure 14), while a channel is indistinguishable in other segments. Upgradient from the site, the drainage traverses the large patch of dunes in the northeast quarter of section 11 (N, Figure 2; Figure 15). The drainage through this segment likely maintains a channel because the floor of the channel is on the Mescalero caliche (Figure 16). Without a relatively impermeable and hard base, accumulated runoff might be incapable of maintaining a channel. The potential bedload from the dune sand would choke off transport. The definable channel for several hundred feet upgradient from this point commonly shows bare Mescalero caliche.

At the northeast corner of section 11, and to the north in section 2, an area of 30 to 40 acres (between N and O, Figure 2) shows slopes of about 1 %, modest cover over the Mescalero, and little ground level evidence of drainage or channeling. Aerial photography reveals some heavier vegetation along two or three lines, undoubtedly indicating main pathways of water from more upland areas (with channels) to the defined channel downgradient. This 30 to 40 acre area obviously serves as a kind of funnel from the upgradient area into the drainage running through the SE corner of the site.

Figure 14



Upper photo - small channel developed in dune sand east of SP G/H-4.
Lower Photo - area near point O (Figure 2) without discernible channel.

Figure 15

Drainage through dune area east of SP G/H-4.

Figure 16

Mesalero caliche under dune sand forming channel baselevel.

The drainage in the vicinity of point N could be considered either first order or second order. No surficial connections of two first order streams were observed. The aerial photos, however, show vegetative evidence of the interconnection of two or three first order gullies or small arroyos in the area downgradient of point O (Figure 2), even if there is no evidence of surficial flow. Thus the channel at point N could be classified as second order.

Another poorly developed drainage leads from section 12 and the east central part of section 11 (M, Figure 2) toward the NW quarter of section 11 and the site. It connects with the main drainage just inside the site boundary and downgradient from point N (Figure 2). Upgradient from point M, short first-order segments join, and this drainage is therefore classified as second order from near point M downstream.

If both of the segments upstream of the site are considered second-order, the drainage segment through the corner of the site should be classified as third-order. Despite this, the drainage rarely appears to actually contain surface flow, even in the segments with an identifiable channel. Grasses and other vegetation grow in and around segments of the drainage. Other segments must be dominated by lateral percolation through surface and near-surface sands. No surface flow was observed during field work, even during rainy periods in 1992. Trench C (Figure 2) was excavated in the lowland area to 10 ft, the depth of the Mescalero caliche, in October 1992. The trench was open for about 24 hours and showed no moisture or moist zones.

Drilling and trenches through sediments along the drainage in the southeastern part of the site revealed caliche or strongly calcareous zones. Infiltration is either limited or has not had time to remove the carbonate from near-surface sediments.

A preliminary estimate of potential area draining across the site can be based on existing topography (Figure 12). Much of the surface shows no developed drainage channels or watercourses, indicating that evapotranspiration is important. Seepage probably doesn't occur on most of the site, as there is no evidence of any spring or seep activity. Runoff may occur along the south side of the site where some bare Mescalero crops out, and modest infiltration is expected at the drainage on the southeastern corner of the site. The drainage through the southeastern corner of the site has a general upgradient basin area to the northeast of less than one square mile (Figure 12); the site and upgradient area to the north and northwest does not appear to contribute significant runoff, as no channels have developed.

At Carlsbad airport, the mean annual precipitation (1931-1983) was about 12.6 in./yr (Swift, 1992). For the WIPP site, the mean annual precipitation is estimated to be between 11 and 13.4 in./yr, and the preshwater pan evaporation is estimated to exceed 108 in./yr (Hunter, 1985). Hunter (1985) also concluded that an average of 96% of precipitation is lost to evapotranspiration in this area. The drainage through the southeastern corner of the site appears to carry surface flow rarely, and the climatic conditions for the area are consistent with this observation. Calcareous to calcrete zones at depths of 10 ft or less in drillholes and boreholes along the drainage also suggest that infiltration is limited. Deeper paleosol carbonates also suggest that recharge along this drainage is limited or nil, or the carbonates would be removed from the system. Runoff, when it occurs, is probably due to unusually heavy storms; runoff is likely to occur within a short time and rapidly diminish or cease. Because of the upgradient drainage area, provision will have to be made to accommodate runoff. An alternative, recommended here, is that landfill development be limited in the southeastern corner of the site area, leaving the natural drainage largely in place.

IMPLICATIONS FOR STABILITY

Discussion

The Gatuña Formation at the proposed landfill site has been shown by drilling (Powers, 1992a) to be nearly 300 ft thick in drillholes on the west and north sides, and about 200 ft thick, at least, on the south and east sides of the site. These thicknesses are among the greatest clearly demonstrated in the region for the Gatuña by either drilling or outcrop reporting. The Gatuña thins rapidly to the east, feathering out in less than one mile at the erosional plane on which the Mescalero accumulated. Major outcrops two miles north indicate significant, though unmeasured, thicknesses. Thus, the Gatuña at the site is a significant representation of the unit in the region.

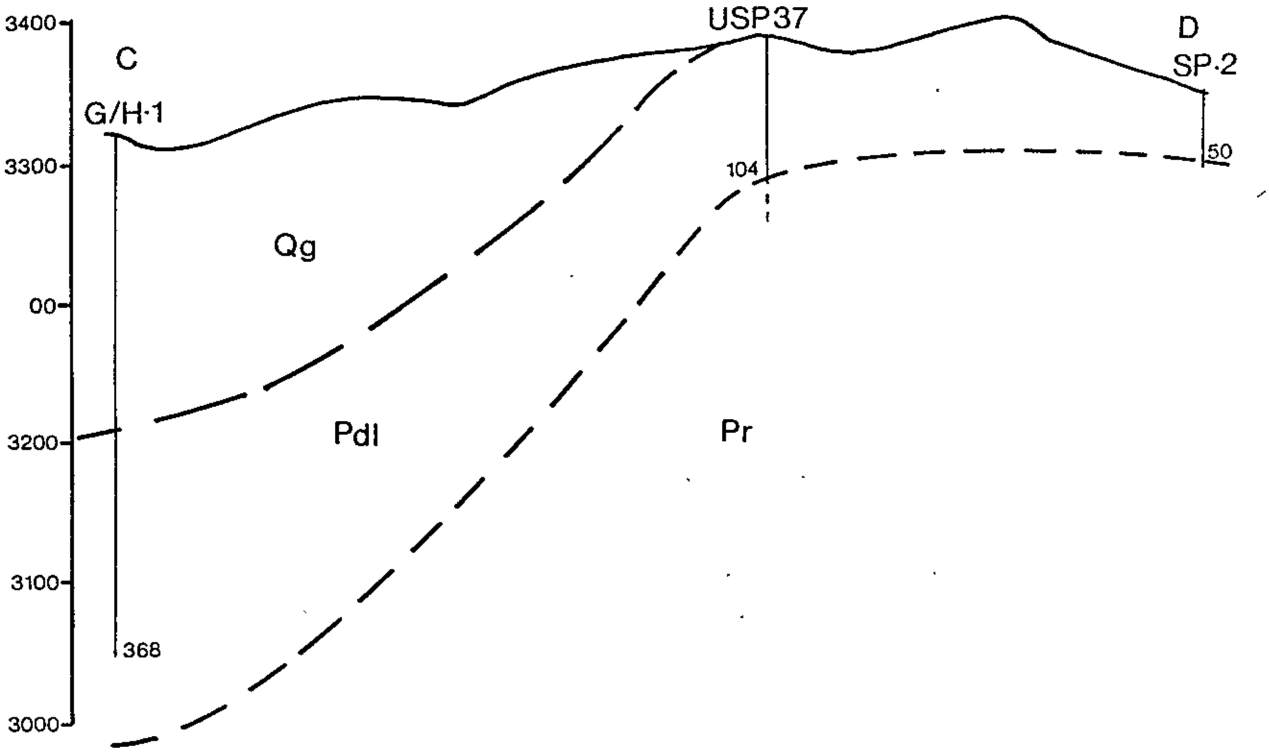
Within the Gatuña at the site, drillholes G/H-1 and -4 (Figure 2) encountered significant coarser sediment, including clasts from the Dewey Lake. G/H-3, on the north side of the site, showed fewer coarse sediments and little or no evidence of Dewey Lake sources. G/H-2, to the west, showed much more fine-grained sediment. Each of the drillhole cores also displayed more laminar structures and yellowish-green colors (possibly from reducing chemical conditions) in their lower parts. The sedimentary facies within the site area indicate coarser Dewey Lake clasts are concentrated on the southeast and finer sediments to the northwest. These show some sources of Dewey Lake clasts to the southeast, where the Dewey Lake is adjacent to the Gatuña (see below). Laminar bedding and possible reducing conditions are consistent with lower energy environments and may show the area being somewhat lowered during deposition.

Evidence from drilling (Powers, 1992a,b) and mapping also shows the broad relationships of the older stratigraphic units at the site. The Gatuña unconformably overlies the Dewey Lake. Both broad relationships and large change in Dewey Lake thickness demonstrate the unconformity. The boundary between these units east of the site parallels the slope and the outcrops of Dewey Lake in section 12. Under the site, a generalized interpretation of the boundary (Figure 17) includes a steeper boundary along the southeast and a flatter boundary to the northwest. The boundary under SP G/H-2 is structurally the same as under SP G/H-3, on the north side of the site. The Gatuña-Dewey Lake contact is at an elevation of about 3080 ft in these boreholes. The Gatuña/Dewey Lake relationship greatly resembles a valley and fill. Another data point (USP 66, a potash hole in the SE¼, SE¼, section 10; Figure 2) southwest of landfill site can be interpreted to have Dewey Lake at about 120 ft below the surface elevation of 3313 ft. The Gatuña-Dewey Lake contact would be about 3190 ft in this borehole. This would considerably restrict the valley fill geometry; it can also indicate the valley fill relationship may have been structurally lowered in the immediate site area during or subsequent to deposition. The details of this relationship are not available, however.

At Gatuña Canyon and Nimenim Ridge, six to 10 miles northeast of the site, the Gatuña occurs at elevations of about 3450 to 3500 ft. At the site, the uppermost Gatuña is at about 3360 ft, and nearby deposits are at slightly higher elevations. These elevations are consistent with the northeastern deposits, and they provide some additional support that the Gatuña here has apparently subsided little, if at all, since deposition ended and the Mescalero formed.

The upper Dewey Lake surface at the site could have been largely formed by erosion prior to or partly during deposition of the Gatuña. The Dewey Lake may also have been lowered significantly by dissolution of soluble minerals in units below the Dewey Lake. In either variation of this scenario, the unit would have formed mainly as valley fill. An alternate hypothesis is that the Dewey Lake surface was nearly flat when the Gatuña was deposited. There is no evidence, however, of any uplift in the

Figure 17



Cross-section (C-D, Figure 2 for location) showing well and surface data and possible subsurface relationships. USP 37 is a potash borehole; SP-2 is an early auger hole (Powers, 1992a).

area, meaning that the Dewey Lake nearby at elevations of 3400 ft would be a minimum elevation surface. Adding Gatuña 300 ft thick on top of this would indicate Gatuña was at an elevation of 3700 ft, which is well above any other nearby deposit of Gatuña. This is highly unlikely, and the interpretation here is that the Dewey Lake-Gatuña surface is in, or near, its configuration at the time the Gatuña was deposited. Some modifications may have occurred, as discussed further.

Erosion planed some of the area after Gatuña deposition and prior to accumulation of the Mescalero caliche. This relationship is clear from field relationships in the pipeline trench in eastern section 11 and western section 12. It is less clear whether the Mescalero was deposited over the site area on a broader and flatter plain, which was subsequently moderately deformed, or whether the Mescalero was deposited on a more complex surface, essentially the same as exists today. Erosion, after Gatuña deposition and before Mescalero formation, may have formed some or all of the topography that now exists at the site. The unsettled question of forming/preserving calcrete on sloping surfaces is the key element in inferring that the Mescalero is accumulated on a pre-existing surface or, alternatively, may have been modestly deformed in the south-southeastern part of the site since formation about 500,000 years ago.

The slopes within the site and adjacent areas are within the bounds on which other mature calcretes have been found (Giles and others, 1981), but some slopes are higher than those *commonly* associated with mature calcretes. With the assumption that the Mescalero could have formed on these slopes, it is reasonable to infer a pre-Mescalero drainage system through the arroyo to the south. Following this reasoning, the site area has undergone some minor modification by local erosion and deposition postdating the Mescalero.

It could also be assumed that the lesser slopes (e.g., < 1-2 %) on which the Mescalero is preserved are consistent with original slopes and that higher slopes (e.g., > 4%) are greater than the Mescalero would have formed on. By these assumptions, it could be inferred that the Mescalero surface subsided (since about 400,000 years ago) between about 20 and about 40 ft along the main drainage at the south side of the site.

Restatement of Later Geological History

Based on thick outcrops of the Gatuña to the north, the consistency of thickness between drillholes, and apparent lack of consistent structural complications in the lower Gatuña toward the east (SP G/H-4), pre-Gatuña erosion and valley fill is believed to be the dominant process contributing to the thick Gatuña at the site and affecting the Gatuña-Dewey Lake relationship at the Sand Point site.

The Mescalero is assumed here to have formed in a continuous deposit from the same beginning time, for all practical purposes, across the site. Except for the main drainage across the southeastern corner of the site, the calcrete has fundamentally the same character across the site. Most of the character changes are interpreted as later modifications of a relatively mature calcrete (as discussed below).

The general topography underlying the Mescalero would appear to be due to modest pre-Mescalero erosion that created a valley with about 60 ft relief. The Mescalero developed to a stage V maturity over the slopes of the site area over the period of about 100,000 years or more, and the Berino soil probably mantled the area, except possibly under the draw area.

The data also permit an interpretation that pre-Mescalero [illegible] valley on which the Mescalero formed, followed by minor subsidence (20 - 40 ft) al[illegible] the modern drainage across the southeastern corner of the site. Such subsidence could be attributed to solution of minerals well below the depth of drilling. This would be a low rate and degree of subsidence in this region. Furthermore, slight subsidence of this part of the area in the future should mainly decrease the potential for erosion of surface cover for a landfill.

Drier and wetter periods following the development of the Mescalero and Berino, perhaps in the last 250,000 years, resulted in eroding the Berino from some higher slope areas. This may post-date the eolian deposits as well. During this same period, calcrete on transitional slopes, and probably in low areas, was undergoing modifications. The upper surface was locally attacked by solution aided by plant growth and some erosion. These areas were also points of sediment accumulation, and the erosion and solution only partially destroyed the calcrete before burial was effective in preserving the remaining calcrete.

CONCLUSIONS

Site investigations at the proposed Sand Point landfill site show that the Gatuña Formation formed on an unconformable surface over the Dewey Lake Formation, principally as valley fill. Relief on the Dewey Lake to the southeast provided coarse clasts that were encountered in cores of the Gatuña from the southeast part of the site. Finer-grained rocks to the west, laminar bedding, and greenish-grayish colors are consistent with lower energy environments during part of the Gatuña depostional history. Following the end of Gatuña deposition, erosion planed part of the sediment and created part or most of the present topography of the site and surrounding area. Surface mapping, drilling, and pipeline trenches reveal the Mescalero caliche is a nearly continuous pedogenic calcrete developed on this erosional surface. A related paleosol, the Berino soil, is preserved on upland areas of lower slopes while small areas of greater slopes have been stripped to bare calcrete. During drier climate intervals since the formation of the Berino soil, dune sand accumulated on top of the Berino. Elongate dune zones occur at changes in slope that create changes in turbulent wind flow and provided more protected lea areas. Poorly integrated drainage has mixed some eolian with alluvial (or colluvial) sediment along the topographic lows. The modest drainage basin area and climatic factors result in irregular and infrequent surface flow that is likely short in duration and modest in intensity. Areas along the drainage lacking detectable channels show evidence of calcretes or calcareous soils at shallow depths, suggesting limited or no infiltration.

The proposed landfill site area is geomorphically rather stable. Erosion is minimal to non-existent now and will generally not be a factor without significant climatic change. Rainfall and runoff in recent geological history has been insufficient to develop channels through parts of the area or handle the easily erodible bedload of dune sand. The erosion has been insufficient over more than half the site to wash even the Berino soil from over a rather impermeable calcrete. The southeastern corner of the proposed site can be left undeveloped or must be developed to provide continued drainage from the modest basin in the NE¼ of section 11 and adjacent runoff areas.

REFERENCES CITED

Bachman, G.O., 1973, Surficial features and late Cenozoic history in southeastern New Mexico: U.S. Geological Survey, Open-file Report 4339-8.

Bachman, G.O., 1974, Geologic processes and Cenozoic history related to salt dissolution in southeastern New Mexico: U.S. Geological Survey, Open-file report 74-194.

Bachman, G.O., 1976, Cenozoic deposits of southeastern New Mexico and an outline of the history of evaporite dissolution: J. of Research, U.S. Geological Survey, v. 4, no. 2, p. 135-149.

Bachman, G.O., 1980, Regional geology and Cenozoic history of Pecos Region, southeastern New Mexico: U.S. Geological Survey, Open-file Report 80-1099.

Bachman, G.O., 1981, Geology of Nash Draw, Eddy County, New Mexico: U.S. Geological Survey, Open-file Report 81-31.

Bachman, G.O., 1985, Assessment of near-surface dissolution at and near the Waste Isolation Pilot Plant (WIPP), southeastern New Mexico: SAND84-7178, Sandia National Laboratories, Albuquerque, NM.

Bachman, G.O., and Machette, M.N., 1977, Calcic soils and calcretes in the southwestern United States: U.S. Geological Survey, Open-file Report 77-794, 163 p.

Chugg, J.C., Anderson, G.W., Kink, D.L., and Jones, L.H., 1952, Soil survey of Eddy area, New Mexico: U.S. Department of Agriculture, 82 p. plus figures.

Gile, L.H., Hawley, J.W., and Grossman, R.B., 1981, Soils and geomorphology in the Basin and Range area of southern New Mexico - guidebook to the Desert Project: Memoir 39, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM, 222 p.

Gile, L.H., Peterson, F.F., and Grossman, R.B., 1965, The K horizon - master soil horizon of carbonate accumulation: Soil Science, v. 99, no. 2, p. 74-82.

Goudie, A., 1973, Duricrusts in tropical and subtropical landscapes: Oxford, Clarendon Press, 174 p.

Hunter, R.L., 1985, A regional water balance for the Waste Isolation Pilot Plant (WIPP) site and surrounding area: SAND84-2233, Sandia National Laboratories, Albuquerque, NM.

Izett, G.A., and Wilcox, R.E., 1982, Map showing localities and inferred distribution of the Huckleberry Ridge, Mesa Falls, and Lava Creek ash beds in the western United States and southern Canada: U.S. Geological Survey, Misc. Investigations Map I-1325, scale 1:4,000,000.

Machette, M.N., 1985, Calcic soils of the southwestern United States, *in* Soils and Quaternary Geology of the Southwestern United States, Weide, D.L., ed., Special Paper 203, Geological Society of America, p. 1-21.

Powers, D.W., 1992a, Summary of site selection and preliminary site characterization for the Sand Point site, Eddy County, NM: report to JOAB, Inc., Sunland Park, NM.

Powers, D.W., 1992b, Summary of borehole drilling for the Sand Point site, Eddy County, NM: report to JOAB, Inc., Sunland Park, NM.

Rosholt, J.N., and McKinney, C.R., 1980, Uranium series disequilibrium investigations related to the WIPP site, New Mexico, Part II Uranium trend dating of surficial deposits and gypsum spring deposit near WIPP site; New Mexico: Open-file report 80-879, U.S. Geological Survey, Denver, CO.

Swift, P.N., 1992, Long-term climate variability at the Waste Isolation Pilot Plant, southeastern New Mexico, USA: SAND91-7055, Sandia National Laboratories, Albuquerque, NM.

Vine, J.D., 1963, Surface geology of the Nash Draw Quadrangle[,] Eddy County[,] New Mexico: U.S. Geological Survey Bulletin 1141-B, 46 p.

Widdicombe, R.E., 1979, Quaternary surficial features in the Delaware Basin, Eddy and Lea Counties, New Mexico: M.S. Thesis, University of New Mexico, Albuquerque, NM.