GW - 32

PERMITS, RENEWALS, & MODS

Application

NOVEMBER 1985

DISCHARGE PLAN APPLICATION FOR GIANT REFINING COMPANY CINIZA REFINERY GALLUP, NEW MEXICO

November 21, 1985

Prepared for:

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1.0 EXECUTIVE SUMMARY

Giant Refining Company (Giant) operates an 18,000 BBL/day petroleum refinery at Ciniza, New Mexico, approximately 17 miles east of the city of Gallup in McKinley County, New Mexico in Sections 28 and 33 of Township 15N, Range 15W. This refinery has been in operation under various owners since 1957, and has been owned and operated by Giant since 1982. The refinery discharges approximately 160,000 gallons per day of process and non-process wastewater, with an average total dissolved solids content ranging from 2000 to 3000 mg/l.

Wastewater from process units which contacts feedstocks or products is routed to an twin-cell API separator, from which it flows to a series of evaporation ponds with natural clay liners. Other wastewater which does not contact hydrocarbons (boiler blowdown, water-softener backwash) flows through a neutralization tank prior to discharge directly to the evaporation ponds.

The uppermost aquifer beneath the Refinery is the Sonsela Sandstone Bed, which lies at a depth of 70 to 140 feet and contains ground water with an average total dissolved solids (TDS) content of 950 mg/l. Ground water in the Sonsela is under considerable artesian pressure. An additional zone of ground water exists in a thin, discontinuous lens of sand (Ciniza sand) which is interbedded with the shales of the Chinle Formation, 40 feet above the Sonsela. This ground water is also under artesian conditions and has an average TDS of 2240 mg/l. Neither the Sonsela nor the Ciniza sand ground-water zones are likely to be affected by refinery discharges, because:

- The shales and clays of the Chinle Formation have permeabilities (10^{-8} to 10^{-9} ft/sec) which are <u>less</u> than those specified for engineered clay liners under RCRA interim standards (10^{-7} ft/sec)

- Boreholes drilled within 20 feet of the perimeters of evaporation ponds, which have been in use for 13 years, show no evidence of pond leakage

- Artesian pressure prevents downward movement of contaminants by advection

Giant currently maintains a network of 10 ground-water monitoring wells at Ciniza, and regularly samples these wells according to a schedule required by RCRA and NMHWM regulations. Previous sampling has shown no evidence of ground water contamination due to refinery activities, and subsequent sampling and analysis will serve to immediately detect any migration of contaminants into the Ciniza sand or the Sonsela.

In order to further reduce the waste burden of its effluents, Giant is planning to install an aerated, biological-treatment lagoon to treat the discharge from the API separator. This treatment lagoon is anticipated to reduce the biological oxygen demand of the final effluent by 60%, and also to reduce the levels of organic constituents.

2.0 LOCATION, PHYSIOGRAPHY AND CLIMATE

2.1 LOCATION AND MAILING ADDRESS

The Giant Refining Company's Ciniza Refinery facilities and wastewater-management system are located approximately 17 miles east of the city of Gallup, in McKinley County, New Mexico. The refinery location and local topography are shown in Figure 2-1. The refinery plant is sited in Sections 28 and 33 of T. 15 N., R 15 W. (New Mexico Prime Meridian). Access to the site is provided by Interstate 40 (Ciniza exit) and old Route 66 (Figure 2-1). All correspondence regarding this Discharge Plan should be sent to:

o Mr. Carl D. Shook
Refinery Manager
Ciniza Refinery
Route 3, Box 7
Gallup, New Mexico 87301

Copies of all correspondence should be forwarded to:

o Mr. Carlos Guerra, Esq.
General Counsel
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2.2 PHYSIOGRAPHY

The Ciniza site lies on the southeastern margin of the San Juan Basin on the northern flank of the Zuni Mountains. The site slopes gently (approximately 100 feet per mile) to the northeast and the area is drained by the intermittent South Fork of the Puerco River. The Ciniza refinery is located on the southern margin of the topographic valley of the Puerco River, which joins the Little Colorado River near Holbrook, Arizona.

2.3 CLIMATE

The region is semiarid, with an average rainfall of about 10 to 12 inches per year. Yearly (lake) evaporation is on the order of 50 to 55 inches per year (United States Soil Conservation Service, 1972). Temperatures range from maximum of over 100^{0}F in the summer months to minimum of 0^{0}F or less in the winter. The mean annual temperature is 48^{0}F. Precipitation is highly seasonal, with most of the volume occurring as rainfall during the months of July


Flowing Well
PIPELINE
6900
ATCHISON
TOPEKA
AND
SANTA FE
6930
6929
South
Fork
Puerco
River
29
28
27
6917
6940
6860
6862
SANTA FE
River
Ciniza
6920
CINIZA LANDING STRIP
6867
6869
Sludge Pits
Ciniza Refinery
6948
WT
32
33
34
6880
7000
7076
6938
Sewage Disposal
6907
66
40
T 15 N
T 14 N
Picnic Area
Gravel Pit
Canyon
7100
5
4
3
21

G
Cor

through September. Rainfall is typically in the form of brief, intense thundershowers which are fed by moist air derived from the Gulf of Mexico. Precipitation is initiated by orographic cooling of moist air-masses as they rise on the slopes of the Zuni Mountains to the south, or Mount Taylor to the east.

3.0 BRIEF HISTORY OF OPERATION

The Ciniza Refinery was constructed by El Paso Natural Gas Company, at essentially its present capacity of 18,000 BBLS per day, in 1957. El Paso operated the refinery until 1964, when it was sold to Shell Oil Company.

Shell operated the Ciniza Refinery from 1964 through 1982, with no major changes in capacity or process. In 1982, the refinery was purchased by its present owner, Giant Industries, Inc. and operated by Giant Refining Company a division of Giant Industries, Inc.

The refinery currently produces regular, unleaded and unleaded premium gasoline, JP4 and JetA aircraft fuels, diesel, kerosine, naptha and minor amounts of other petroleum products.

The majority of feedstock crude arrives by pipeline from the San Juan Basin oil and gas fields. Products are primarily shipped by tank trucks, which are either common carriers, trucks owned or leased by Giant, or trucks operated by the product customers. Some diesel product is shipped via rail.

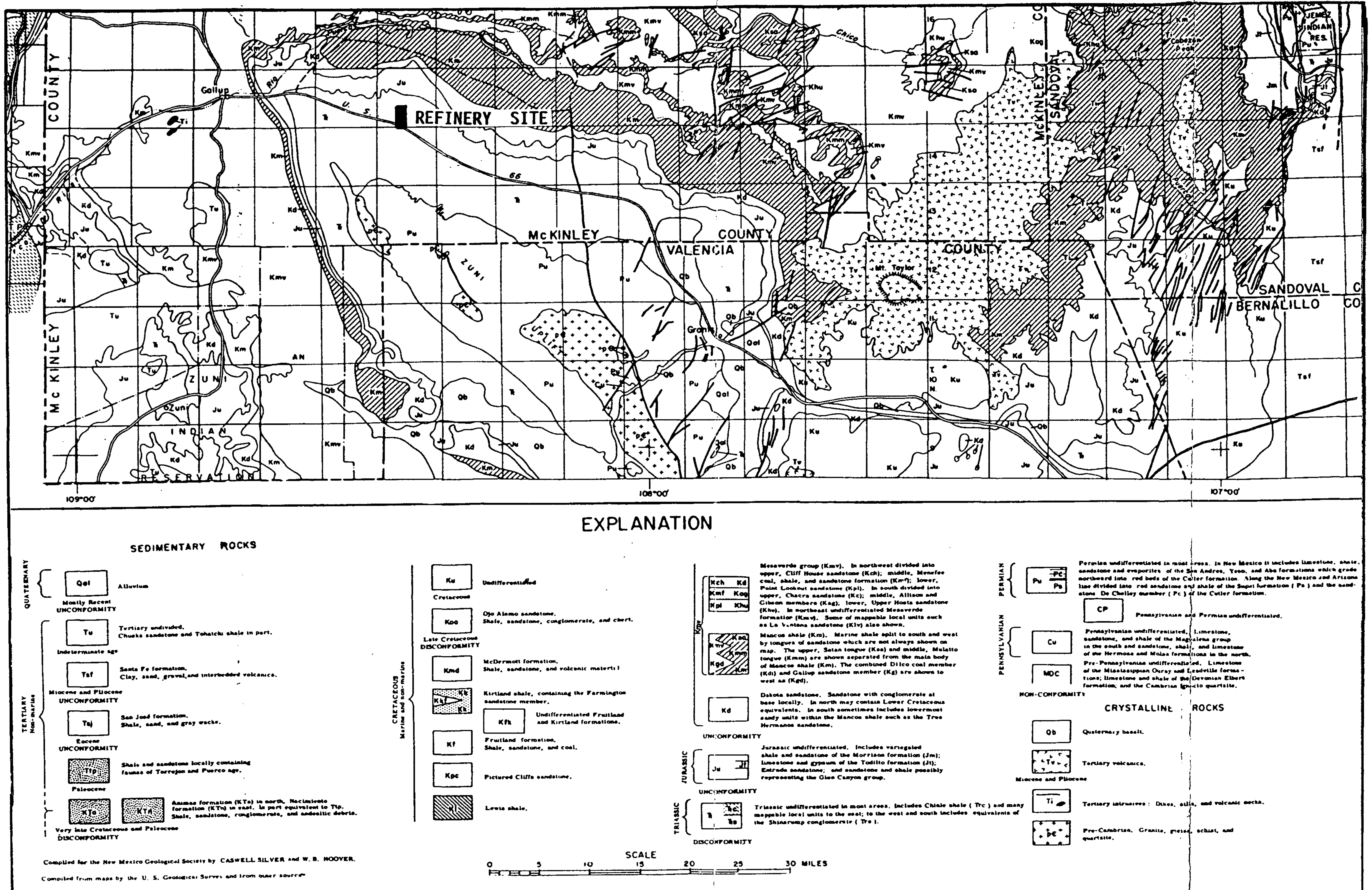
4.0 DESCRIPTION OF PHYSICAL ENVIRONMENT AT SITE

4.1 LOCAL GEOLOGY

The Ciniza Refinery site lies on the southeastern margin of the San Juan Basin, on the northern flank of Zuni Uplift (Figure 4-1). Bedrock (Chinle Formation) strikes approximately N. 40 E., and structure is expressed as a gentle, homoclinal northwesterly dip of 1.5 to 2.5 degrees. No significant faults are observed or inferred on or near the refinery site. Figure 4-2 is a cross-section showing the structure and stratigraphy of the bedrock deposits beneath the refinery area. Figure 4-3 is a generalized stratigraphic column for the Ciniza area. Logs of boreholes from monitor wells and exploratory holes are includes in Appendix A.

The refinery is underlain by outcrops of the upper part of the Petrified Forest Member of the Chinle Formation. The Petrified Forest is composed of volcanigenic siltstones, claystones and shales with localized and discontinuous sand bodies, deposited in a low-energy fluvial and flood-plain environment. Shales and claystones of the Petrified Forest comprise the overlying confining bed (aquitard) for the artesian Sonsela aquifer and for the confined ground water in the "Ciniza sand". These variegated blue, gray, brown, red and purple mudrocks weather into very fine clays, which swell slightly and become extremely plastic and slippery when water-saturated. Figure 4-4 includes photographs of drill cores from the Refinery site, illustrating the lithologies typically present in this area.

The upper and lower parts of the Petrified Forest Member are separated by the Sonsela Sandstone Bed. This sandstone is typically light yellow to greenish, fine to medium grained, cross-bedded and contains local interbeds of conglomerate and shale (Figure 4-5). Regionally, this unit varies in thickness from 40 to nearly 300 feet, but is about 60 to 100 feet thick in the Ciniza area. The Sonsela is recognized as the uppermost aquifer in this area.



Geoscience Consultants, Ltd.

FIGURE 4-1
GEOLOGIC MAP OF REFINERY AREA

CLIENT: GIANT
DATE: OCTOBER, 1985
DRAWN BY: JCH
CHECKED BY:
REVISED:
SCALE:

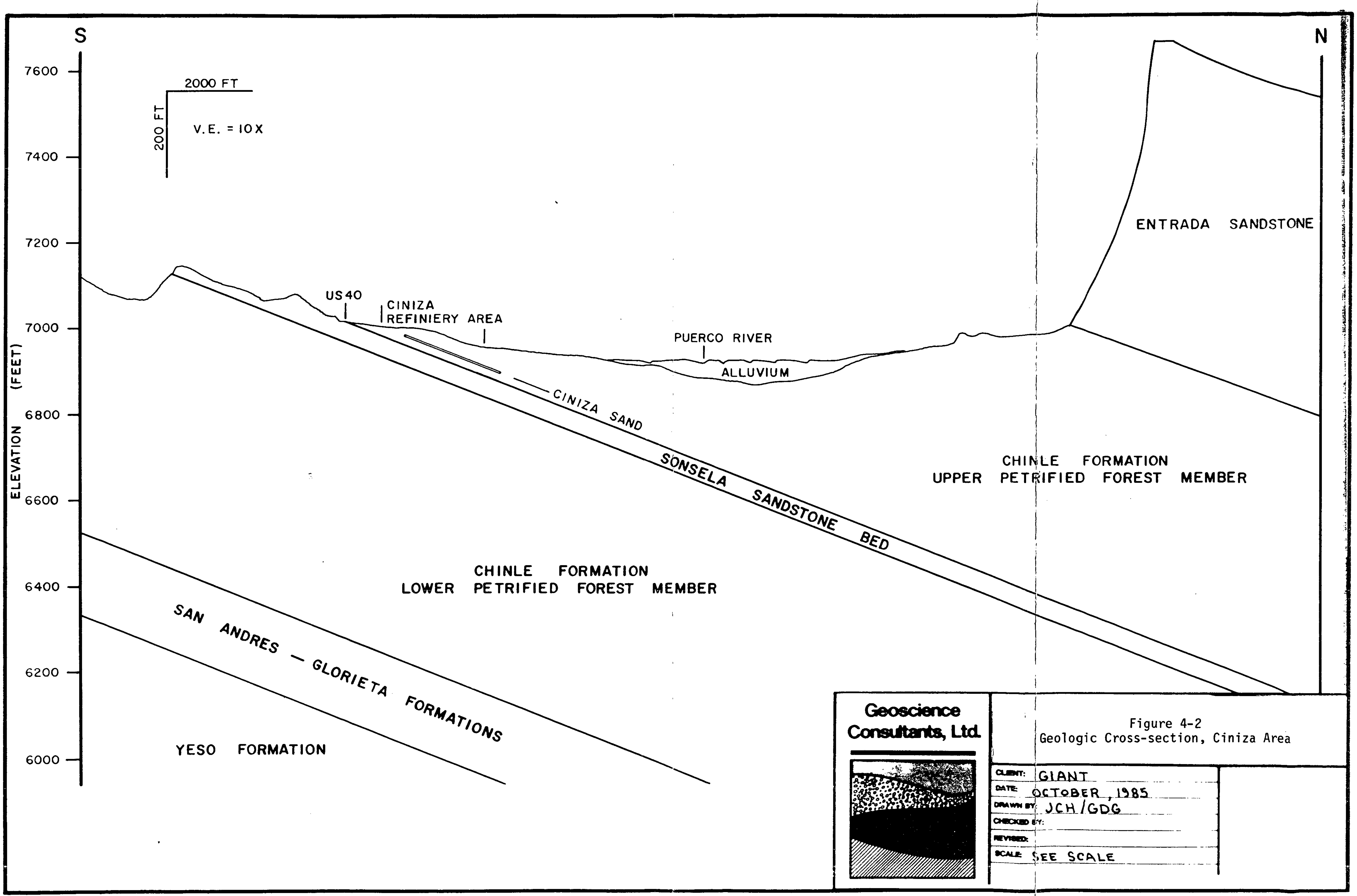


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Figure 4-2
Geologic Cross-section, Ciniza Area

CLIENT: GIANT
DATE: OCTOBER, 1985
DRAWN BY: JCH/GDG
CHECKED BY:
REVISED:
SCALE: SEE SCALE

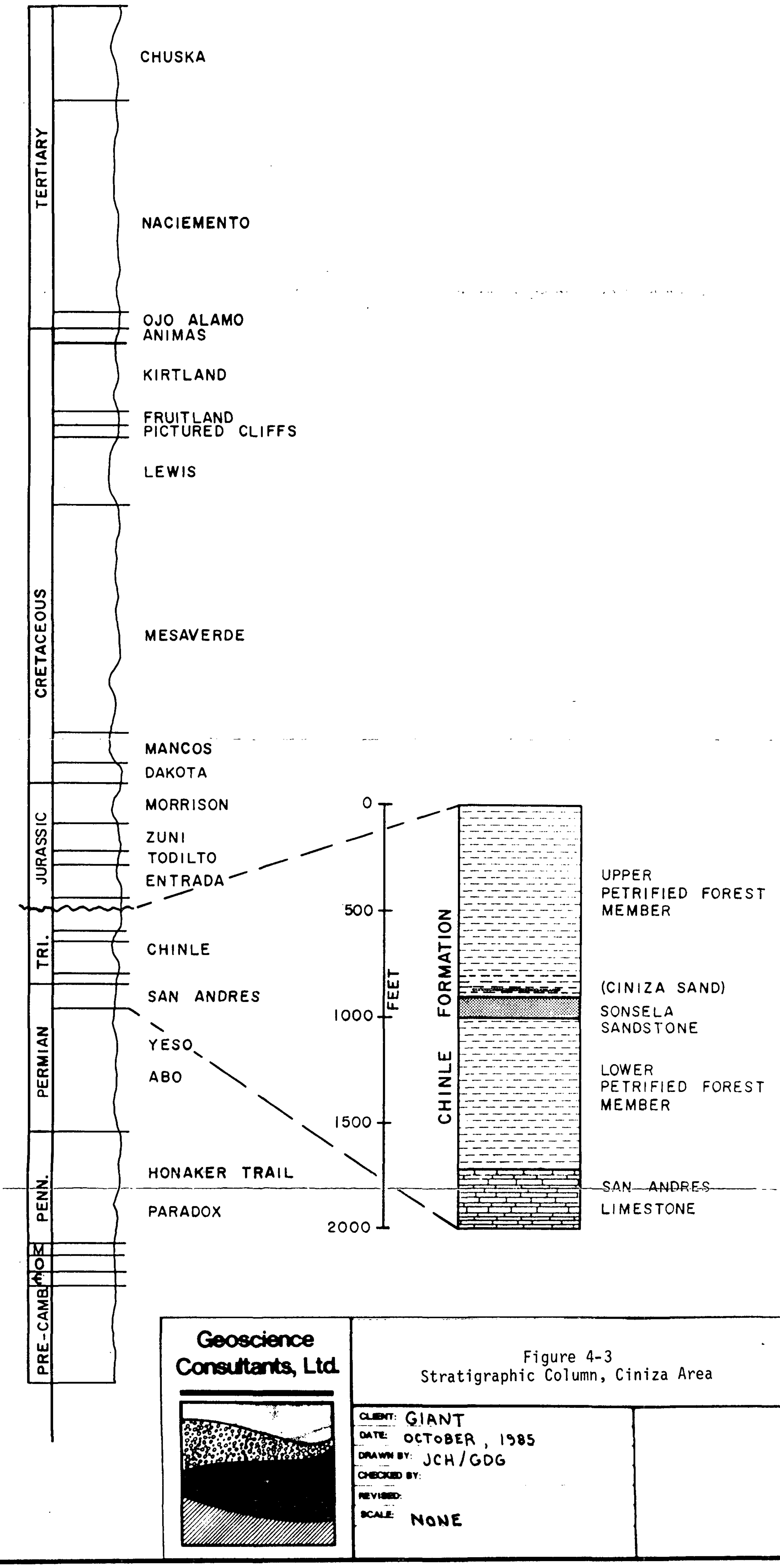

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Figure 4-3
Stratigraphic Column, Ciniza Area

CLIENT: GIANT
DATE: OCTOBER, 1985
DRAWN BY: JCH/GDG
CHECKED BY:
REVISED:
SCALE: NONE

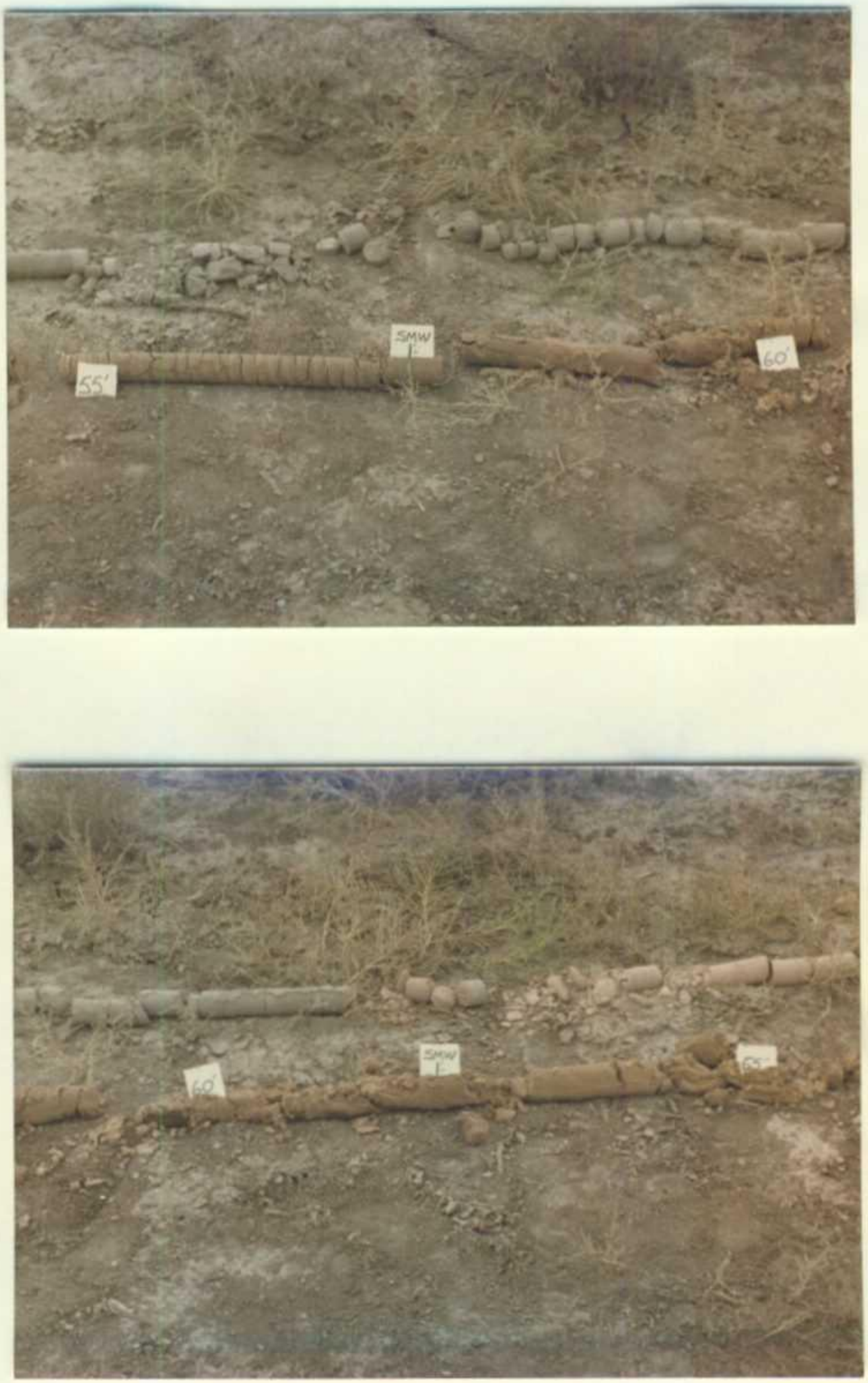


Figure 4-4
PHOTOGRAPHS OF CORES FROM BOREHOLE SMW-1
SHOWING CINIZA SAND (60'-65')

Figure 4-5

PHOTOGRAPH OF SONSELA OUTCROPS ON RIDGE SOUTH OF REFINERY (US 40 IN FOREGROUND)

Exploratory drilling and field investigations have revealed the presence of a thin (0-10 feet), lenticular sandstone body (the "Ciniza sand") in the upper Petrified Forest Member, approximately 40 feet above the Sonsela. This sand body is further described in Section 4.3.2

The lower part of the Petrified Forest Member is lithologically very similar to the upper part, and is also composed of siltstones and mudrocks with some local sandstone lenses (O'Sullivan, 1977).

Underlying the Chinle Formation are the San Andres and Glorieta formations (Permian), which contain the drinking water aquifer in this region. Approximately 600 feet of Chinle shales separate the San Andres from the Sonsela. The San Andres is composed of carbonates with interbedded clastic rocks, and the Glorieta is primarily a sandstone.

4.2 GEOMORPHOLOGY AND SOILS

The Ciniza Refinery is sited on soil-mantled (Montoya Series) bedrock outcrops of the upper Petrified Forest Member. Logs of numerous borings (Appendix A) indicate that <u>none</u> of the site is underlain by the alluvial deposits of the nearby Puerco River. No significant natural drainages cross the Refinery plant site, which is located on a slight (30 to 50 foot) topographic rise. The area's geomorphology is dominated by the 1 to 2 degree northwesterly dip-slopes of the Chinle outcrops and the effects of arid weathering on montmorillonite-rich shales and other mudrocks. Topographic relief is primarily the result of differential weathering and erosion of soft shales and resistant sandstones and conglomerates. Hills, buttes and mesas are capped by the resistant sandstones and conglomerates, whereas slopes and valleys develope in areas of shale and mudstone outcrops. Valleys formed in the Chinle are generally filled with very-fine-grained alluvial detritus from the weathering of mudstones and shales.

Soils derived from deep weathering of the shales and siltstones of the Chinle Formation are typically classified as Ustolic Camborthids

(USSCS, 1972). Soil types and physical properties are summarized in Table 4-1 and detailed in Appendix B. Soils are predominantly of the Montoya series. These clay-rich soils have very low permeabilities and high moisture retention capacities.

4.3 HYDROLOGY

4.3.1 Regional Geohydrology

The geohydrology of the southern San Juan Basin is controlled by geologic structure and by the vertical hetrogeneity of the hydraulic properties of the layered sedimentary bedrock. Beds dip into the basin at 1 to 5 degrees from the northern flanks of the Zuni Mountains. Interbedded permeable (sandstone and carbonate) and impermeable (shale and siltstone) units form numerous local and regional artesian aquifers in the Permian, Triassic, Jurassic and Cretaceous systems (see Figures 4-1, 4-2). The major aquifer in this region is the San Andres/Glorieta formation.

The San Andres/Glorieta aquifers are the most prolific and commonly-used local sources of ground water. These confined, artesian aquifer systems support wells (many of which are freely flowing) with capacities of over 300 gallons per minute (GPM). Although the Sonsela is an aquifer, its productivity is approximately one order of magnitude less than an equivalent-diameter San Andres well. Sonsela wells produce up to 30 GPM, but 5 to 20 GPM is more typical (Cooper and John, 1968). Wells in some areas can be completed in isolated sandstone lenses in the Petrified Forest Member, but these wells are of low capacity (≤ 1 GPM), have not been developed and are not considered reliable sources of ground water.

Recharge of the San Andres/Glorieta aquifers occurs primarily in the areas of the upper Zuni Mountains, where permeable beds crop out. Ground water moves down dip through the permeable beds of porous limestone and sandstone (aquifers) and is restricted in its vertical movement by relatively impermeable beds of shales and mudrocks (aquitards). Discharge is through wells and springs, and by leakage in the deeper, central parts of the basin.

Table 4-1

Hydrologic factors, erodibility classification, and erosion hazard

[Dashed lines indicate that no rating was assigned]

Map symbol	Soil	Infiltration [1]	Permeability [1] of least pervious layer	Space for water storage [2]	Runoff potential (water yield) [3]	Hydrologic group [4]	Erodibility [5]	Erosion hazard [6]
Ag	Andrews gravelly loam, 5 to 20 percent slopes	Moderate	Slow	Low	Medium	C	Moderate	Moderate.
Ba	Badland	---	---	---	---	---	---	---
Bd	Bandera gravelly loam, 5 to 15 percent slopes	Rapid	Moderate	Low	Low	A	Moderate	Low.
Bg	Bandera gravelly loam, 15 to 35 percent slopes	Rapid	Moderate	Low	Low	A	Moderate	High.
Bo	Bond sandy loam, 5 to 15 percent slopes	Rapid	Slow	Medium	High	C	Moderate	High.
Ca	Cabezon rocky complex, 2 to 10 percent slopes	Moderate	Slow	Low	Medium	D	Moderate	Low.
Cb	Clayey alluvial land (0 to 2 percent slopes)	Moderate	Slow	Medium	Low	C	Moderate	Moderate.
Cc	Concho clay loam, 1 to 3 percent slopes	Moderate	Slow	High	Low	D	Moderate	Moderate.
Co	Concho clay loam, 3 to 10 percent slopes	Moderate	Slow	High	Low	D	Moderate	Moderate.
Fo	Fortwingate loam, 2 to 8 percent slopes	Rapid	Slow	High	Low	C	High	Moderate.
Fr	Friana silt loam (1 to 3 percent slopes)	Moderate	Slow	High	Medium	C	High	Moderate.
Gm	Gem stony loam, 2 to 7 percent slopes	Moderate	Slow to very slow.	Medium	Medium	C	Moderate	Low.
Je	Jekley silt loam, 3 to 7 percent slopes	Rapid	Slow	Low to medium.	Low	C	High	Low.
Jk	Jekley stony loam, 10 to 30 percent slopes	Rapid	Slow	Low	Medium	C	High	High.
Jr	Jekley rocky complex, 30 to 40 percent slopes	Moderate	Slow	Low	High	C	High	High.
Ke	Kettner loam, 3 to 10 percent slopes	Moderately rapid.	Moderate	Medium to low.	Low	B	High	Moderate.
Kn	Kettner stony loam, 10 to 20 percent slopes	Moderate	Moderate	Low	High	D	High	High.
Kr	Kiln rocky complex, 3 to 20 percent slopes	Moderate	Moderate	Low	Medium	D	Moderate	Moderate.
Kx	Kiln rocky complex, 20 to 40 percent slopes	Moderate	Moderate	Low	High	D	Moderate	High.
La	Laporte stony loam, 3 to 10 percent slopes	Moderate	Moderate	Low	Medium	B	Moderate	High.
Lp	Laporte stony loam, 20 to 40 percent slopes	Moderate	Moderate	Low	Medium	B	Moderate	High.
Lr	Larry silty clay loam (2 to 5 percent slopes)	Moderate	Slow	High	Medium	D	Low	Low.
Ls	Lava flows	---	---	---	---	---	---	---
Lv	Lava rock land	---	---	---	---	---	---	---
Ma	McGaffey loam (1 to 3 percent slopes)	Rapid	Moderate	High	Medium	B	Moderate	Moderate.
Mb	Mirabal stony loam, 5 to 15 percent slopes	Rapid	Moderate to rapid.	Low	Medium	A	High	Moderate.
Mm	Mirabal stony loam, 15 to 45 percent slopes	Rapid	Moderate to rapid.	Medium	Low	B	High	High.
Mn	Mirabal stony loam, low rainfall, 5 to 20 percent slopes.	Rapid	Moderate to rapid.	Low	High	D	High	High.
Mo	Montoya clay (0 to 3 percent slopes)	Moderate	Slow to very slow.	Medium	Low	D	High	High.
Na	Nathrop loam, 0 to 5 percent slopes	Moderate	Moderate	Low to medium.	Low	C	Moderate	Moderate.
Od	Ordnance loam (5 to 15 percent slopes)	Slow	Slow	Low	Medium	D	High	High.
Or	Osoridge rocky complex, 5 to 20 percent slopes	Rapid	Slow	Low	High	D	High	High.
Ox	Osoridge rocky complex, 20 to 40 percent slopes	Rapid	Slow	Low	High	D	High	High.
Po	Polich loam (0 to 2 percent slopes)	Moderate	Slow	High	Medium	C	High	Moderate.
Pr	Prewitt clay loam (0 to 5 percent slopes)	Moderate	Slow to very slow.	Medium	Medium	D	High	High.
Rk	Rock land (5 to 50 percent slopes)			---	---	---	---	---
Ro	Rock outcrop, gently sloping			---	---	---	---	---
Rp	Rock outcrop, cliffs			---	---	---	---	---
Sa	Sanchez stony complex, 10 to 20 percent slopes	Moderate	Moderate to slow.	Low	Medium	D	High	High.

Sonsela outcrops are observed at lower elevations on the northern side of the Zuni Mountains, and in the area immediately to the south of Interstate 40 near the Refinery. All observed Sonsela outcrops are above the Refinery facilities topographically, and are also hydraulically upgradient from the site.

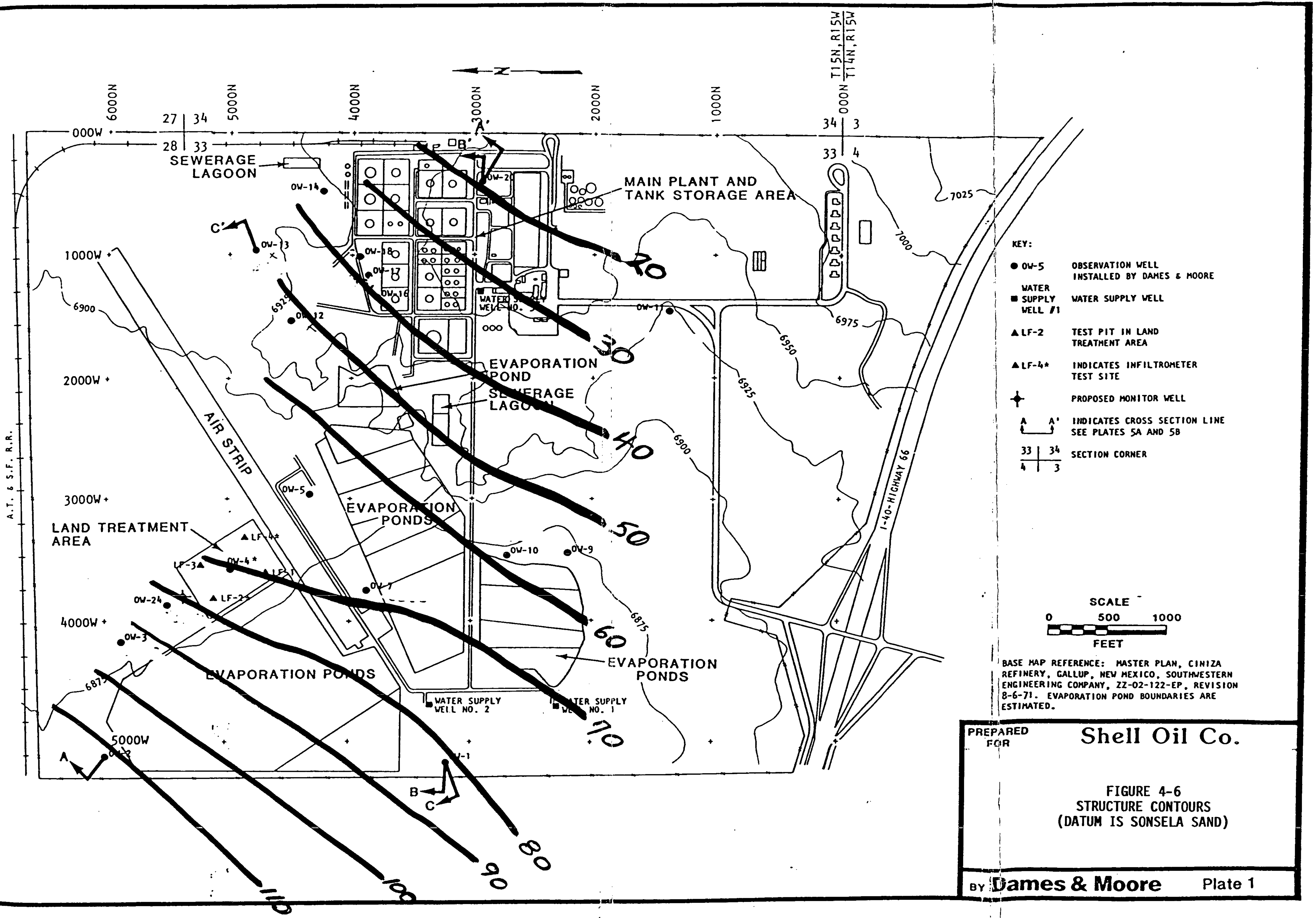
4.3.2 Local Geohydrology

Three water-bearing units are present beneath the Ciniza Refinery site (see Figure 4-2):

- The San Andres and Glorieta Formations (Uppermost Drinking Water Aquifer)
- The Sonsela Sandstone Bed of the Chinle Formation (Uppermost Aquifer)
- A local sand lens (Ciniza sand) in the Chinle Formation (Uppermost Water-Bearing Zone)

The San Andres and Glorieta Formations (Permian) are principally composed of limestone with local clastic interbeds. The San Andres lies approximately 800 feet beneath the refinery, and produces ground water from 3 on-site wells for refinery process and local domestic uses. The San Andres-Glorieta aquifer contains water under considerable artesian pressure, and is recognized as the principal deep aquifer in the Grants/ Bluewater basin (Stone, et.al., 1983). The depth of this aquifer, its artesian pressure, and the extremely low permeability of the units between it and the surface act together to prevent downward movement of any refinery products or effluents into the San Andres aquifer.

The Sonsela Sandstone Bed, the uppermost geohydrologic unit which is recognized as a aquifer, is also a confined, artesian unit. This sandstone bed lies 70 to 140 feet beneath the refinery site (Figure 4-6). Ground water in the Sonsela is under 20 to 100 feet of artesian head



BASE MAP REFERENCE: MASTER PLAN, CINIZA REFINERY, GALLUP, NEW MEXICO, SOUTHWESTERN ENGINEERING COMPANY, ZZ-02-122-EP, REVISION 8-6-71. EVAPORATION POND BOUNDARIES ARE ESTIMATED.

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FIGURE 4-6
STRUCTURE CONTOURS
(DATUM IS SONSELA SAND)

BY **Dames & Moore** Plate 1

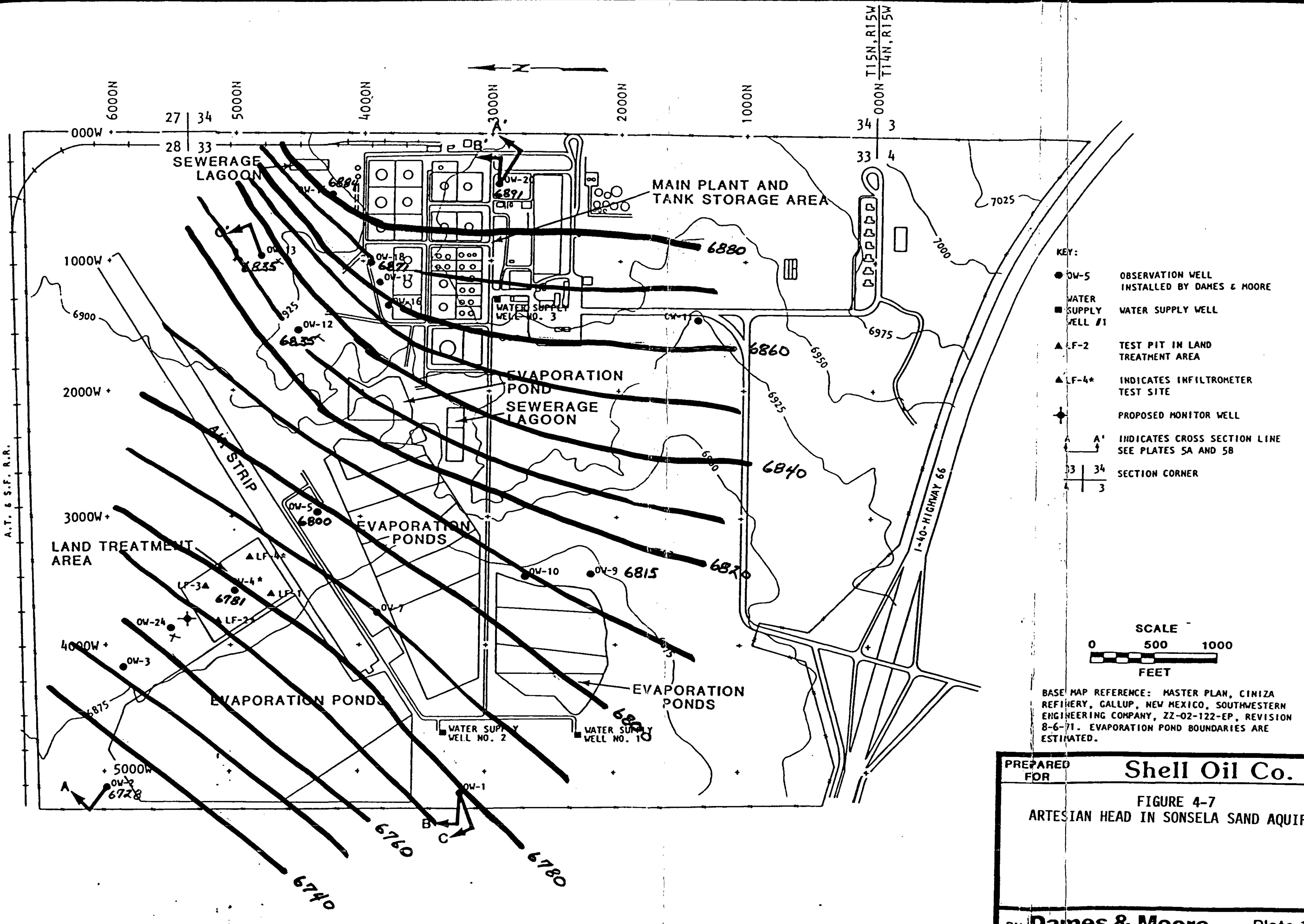
(Figure 4-7). The potentiometric surface of this aquifer slopes northwest at about 0.01. Like the San Andres, artesian conditions insure that the Sonsela will be protected from contamination by any refinery products or effluents discharged at the surface. Ground water in the Sonsela is confined by the essentially impermeable shales of the Petrified Forest Member of the Chinle Formation (Triassic), of which the Sonsela is a part. Appendix D contains analyses from Sonsela Wells.

4.3.3 Uppermost Water-Bearing Zone

The uppermost water-bearing unit at the Refinery site is a local, lenticular sand body contained in the shales and clays of the Petrified Forest Member overlying the Sonsela. This sand unit has been given the informal field name "Ciniza sand". The lateral extent of this sand is shown on a map based on continous coring on a portion of the refinery site (Plate 1). Ground water in the Ciniza sand is confined by the surrounding clays and shales and is under 10 to 30 feet of artesian head. The potentiometric surface of this ground water zone slopes northwest at a gradient of .008.

The Ciniza sand is approximately 5 feet in thickness (ranging from 0 to 10 feet), and is only observed in the area north and west of the Refinery site (Plate 1). Approximately 40 feet of Petrified Forest shales and siltstones separate the Ciniza sand from the Sonsela. <u>Difficult or impossible to recognize in outcrop, this sand body was discovered by continuous-core drilling while installing additional RCRA monitoring wells for the refinery's land treatment area.</u> The Ciniza sand lies from 0 to 65 feet below the land surface in the area north and west of the refinery site, and strikes N.35 E. with a northwesterly dip of 2.4 degrees (Plate 2). The sand is a relatively continous unit under the land treatment area, but pinches out near the eastern, western and southern boundaries of that area.

The Ciniza sand is typically a fine to very-fine-grained, moderately-to-poorly-sorted quartzose sand with a clay and silt content which varies from 5% to over 35% . Sharp contacts are observed with the overlying



BASE MAP REFERENCE: MASTER PLAN, CINIZA REFINERY, GALLUP, NEW MEXICO, SOUTHWESTERN ENGINEERING COMPANY, ZZ-02-122-EP, REVISION 8-6-71. EVAPORATION POND BOUNDARIES ARE ESTIMATED.

PREPARED FOR **Shell Oil Co.**

FIGURE 4-7
ARTESIAN HEAD IN SONSELA SAND AQUIFER

BY **Dames & Moore** Plate 1

and underlying clays, and preserved sedimentary structures indicate a fluvial origin.

Giant has recently installed a total of 6 RCRA monitoring wells in the Ciniza sand in the vicinity of the land treatment area; all of these wells are hydrologically downgradient from the NMOCD regulated waste management units. As further discussed in Section 7.1, regular analyses of water samples from these wells will indicate the presence and movement of any potential contaminants in the ground water in the Ciniza sand. Samples have been collected from all 6 wells in the Ciniza sand, and complete RCRA analyses are pending.

The ground water in the Ciniza sand is typically under 10 to 30 feet of artesian head (Plate 3), and is confined by the highly impermeable clays and shales of the Petrified Forest Member. The potentiometric surface dips N.85 W. at a gradient of 0.008. Examination of numerous cores shows that these clays and shales are essentially unsaturated, and commonly dry, within less than 2 feet of their contact with the saturated sand. This observation is confirmed by moisture-content analyses from boreholes (Appendix A) which show that the clays are unsaturated within a few feet of the water-bearing sand (Figure 4-8). Thin beds of sand (0.5 to 2.0 feet) were commonly observed to lie within 5 to 15 feet of the Ciniza sand; these other sands were invariably dry in all borings.

Several of the exploratory boreholes (e.g., SMX-7, 8; see Plate 1) did not encounter the Ciniza sand at its expected depth, but were advanced to depths of 10 to 20 feet below the expected target-depth. These boreholes were allowed to remain open for up to 6 weeks; during that period <u>no</u> water was observed to accumulate in these boreholes. This shows that there is little or no ground water in the strata above the Ciniza sand, and no ground water in the shales and clays adjacent to the stratigraphic "zero edge" of that sand. Other exploratory piezometers, completed in the Petrified Forest shales above the Ciniza sand have remained totally dry for a period of several months. This demonstrates

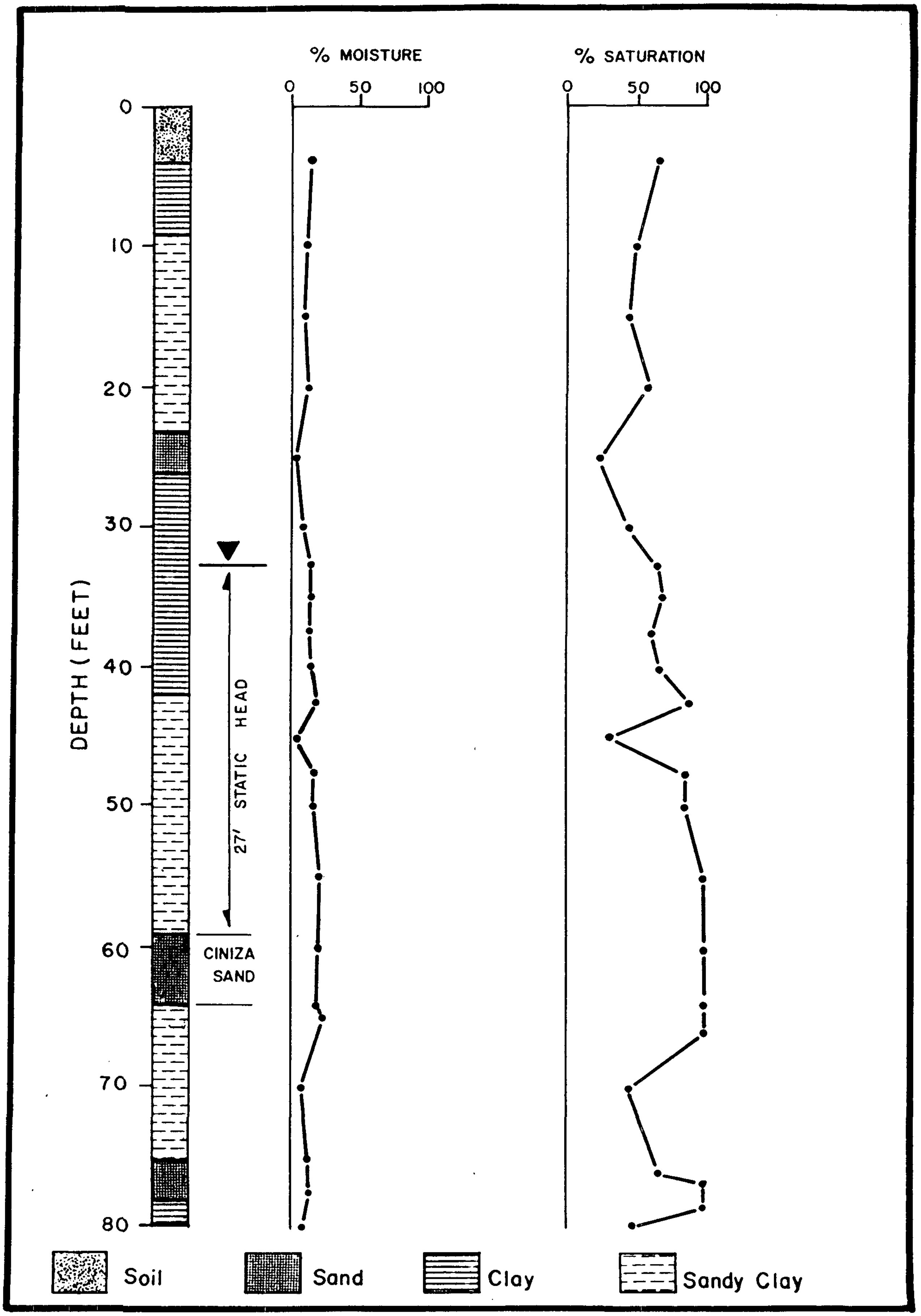


Figure 4-8: Soil Moisture Profiles From Borehole SMX-1

that there is effectively no consistent zone of saturation in the Chinle shales.

No known water wells (other than Giant's SMW-series monitor wells) are completed in the Ciniza sand. The discontinuous nature, small saturated thickness, extremely low transmissivity, and highly variable water-quality of this unit indicate that it has no potential as a present or future source of ground water.

4.3.4 Hydrogeologic Properties Of Uppermost Ground Water Zones

In conjunction with its RCRA Part B Application, Giant Refining Company has performed several tests to determine the hydrologic properties of the Sonsela aquifer and the Chinle shale aquitard which overlies the Sonsela and contains the Ciniza Sand. The results of these tests are summarized in Table 4-2. Further information on these tests is contained in Appendix C.

In addition to planned tests, field observations of hydrogeologic properties of the Chinle Formation were made during the installation of numerous boreholes and wells on the Refinery site. Several of these borings were located within a few tens of feet from the edges of evaporation ponds, but in no case was free water or saturation of soils observed in any zones above the Ciniza sand. This observation, coupled with the presence of unsaturated clay in beds located within a few feet above or below the pressurized, confined-water Ciniza sand, indicates that the hydraulic conductivity of the Pertified Forest shales is at least several orders of magnitude less than the values indicated by the pump tests.

The pump test of the Chinle Shale zone was conducted before the discovery of the Ciniza sand, and was performed in a well which may be interconnected with that sand. Therefore, the hydraulic conductivity calculated from that pump-test represents a maximum possible value for the shales and a minimum value for the Ciniza sand.

TEST	UNIT	T	K
Slug	Sonsela	1.3×10^{-4}	3.9×10^{-6}
Slug	Chinle Shale	5.2×10^{-7}	1.3×10^{-8}
Pump	Chinle Shale	1.7×10^{-7}	8.3×10^{-9}

T in ft^2/sec
K in ft/sec

Table 4-2
SUMMARY OF AQUIFER-TEST RESULTS
SONSELA AND OVERLYING CHINLE FORMATION

The Sonsela aquifer has a maximum hydraulic conductivity of 3.94 X 10^{-6} ft/sec (0.35 ft/day). Tests of the shale aquitard show conductivities of 1.3 X 10^{-8} to 8.3 X 10 $^{-9}$ ft/sec (.001 to .0007 ft/day). These values are for <u>horizontal</u> conductivity, and vertical conductivities for shales are typically <u>one or more orders of magnitude less</u>. The measured conductivities (.001 to .0007 ft/day) are equal to or exceed the New Mexico Water Quality Control Commission standards for clay-pond liners, which are 0.0013 ft/day.

4.4 GROUND WATER USERS IN THE CINIZA AREA

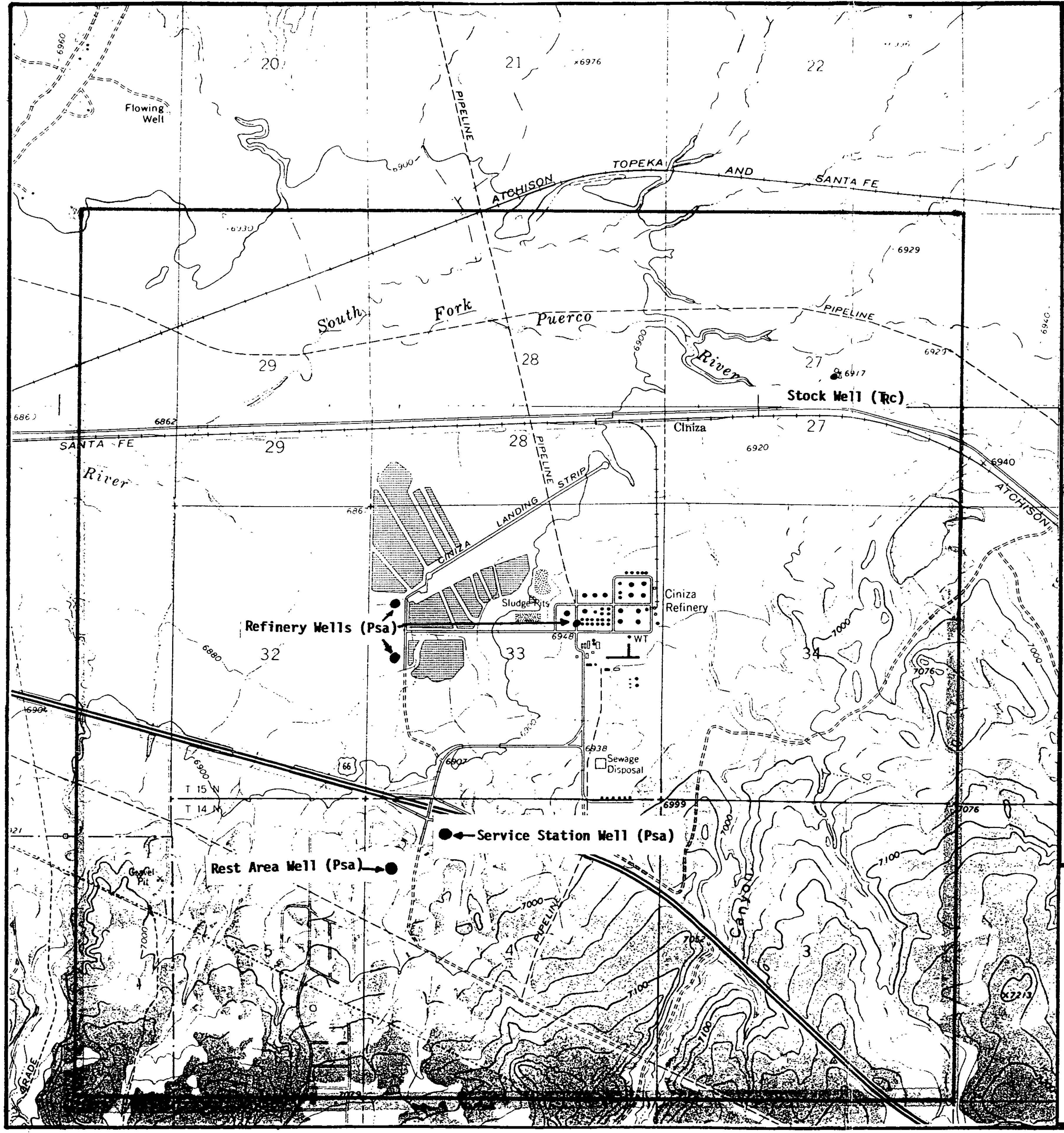
The Ciniza Refinery, and all known users of ground water within a 1 mile radius of the Refinery are shown in Figure 4-9. The Ciniza Refinery withdrew an average of 175,000 gallons per day of ground water from the San Andres aquifer during the period of review, making it the largest user of ground water in the area. The only other adjacent users of drinking water from the San Andres are the rest area and the service station. These wells are upgradient of the Refinery. The "Stock Well" is completed in the Sonsela, and is not used for human consumption.

4.5 FLOODING POTENTIAL

Figure 4-10, from Giant's Part B Application, shows the anticipated pathways of a 100 year flood. Table 4-3 presents the results of the calculations used to determine these flood paths. With the exception of evaporation pond #9, no plant or waste-management units are likely to be affected by a 100-year flood event.

Giant is aware of this potential threat to pond #9, and is currently taking several steps to mitigate this problem:

- The area in question has been surveyed, and options for additional flood-control measures such as dikes, ditches and channel re-direction are being evaluated
- Giant is proceeding with plans to construct a truck stop at the Ciniza exit; flood and drainage control plans for this construction may be modified to divert runoff (from south of I-40) to pathways which do not endanger any of the evaporation ponds

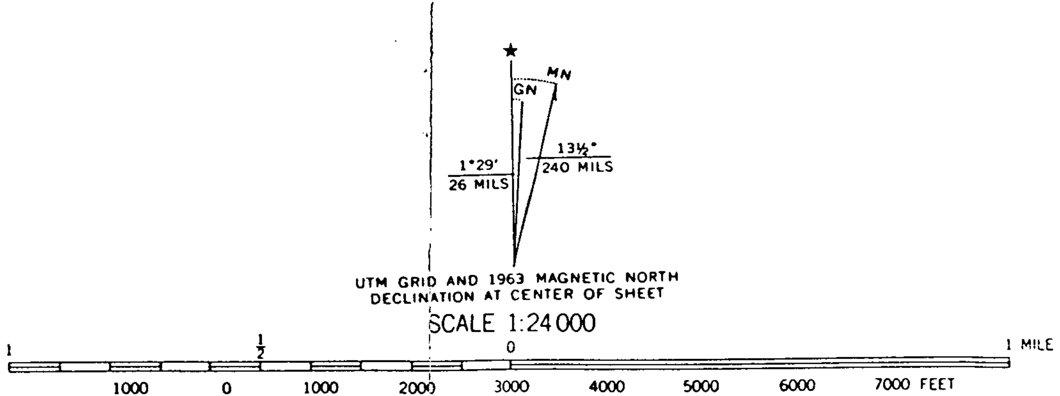


EXPLANATION

(Psa) Well Completed in San Andres Formation

(Trc) Well Completed In Chinle Formation

Edge of 1-Mile Radius From Refinery

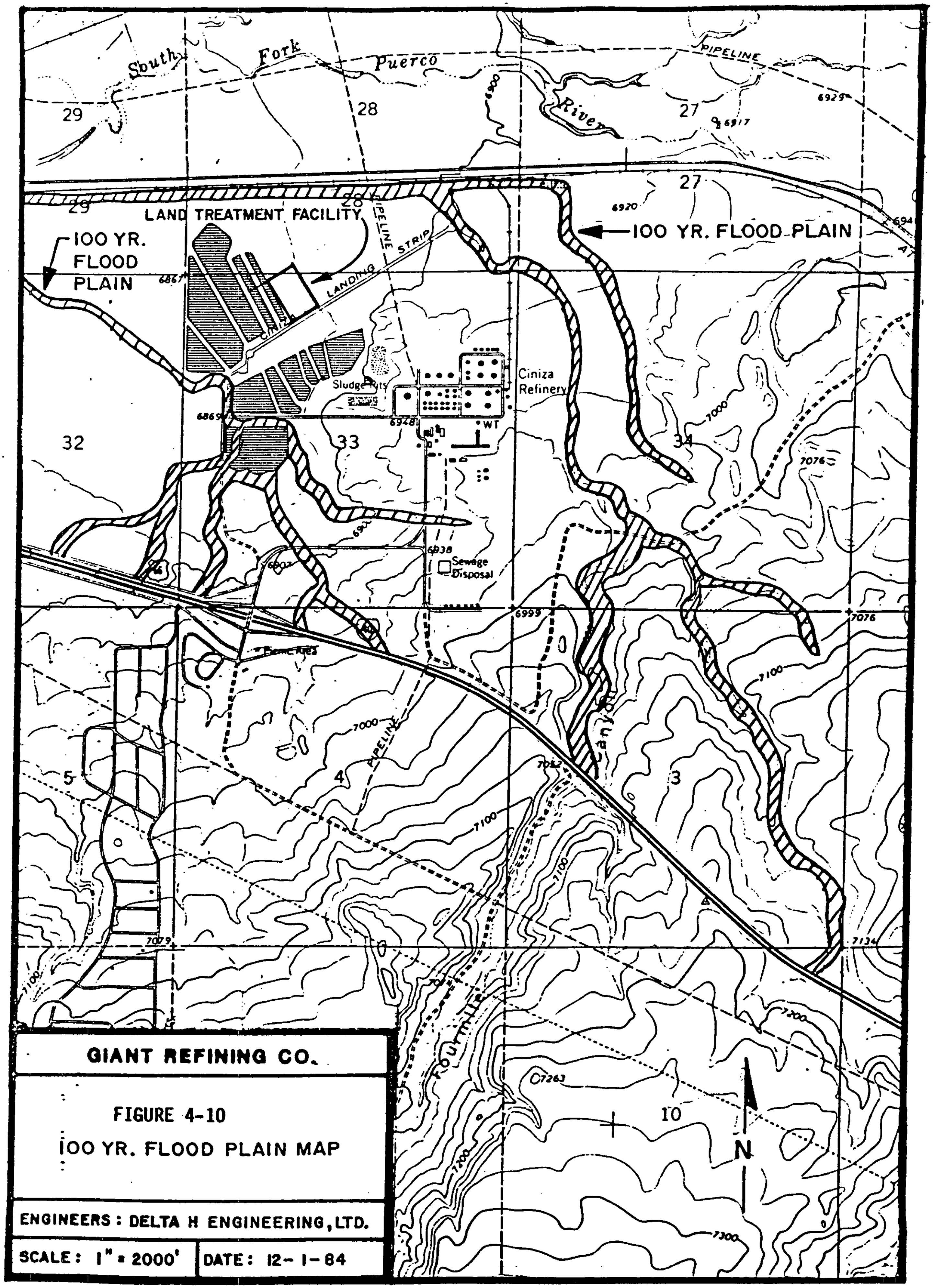


CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Geoscience Consultants, Ltd.

FIGURE 4-9
LOCATIONS OF WELLS WITHIN 1 MILE
OF REFINERY SITE

CLIENT: GIANT
DATE: OCTOBER, 1985
DRAWN BY: JCH
CHECKED BY:
REVISED:
SCALE: 1:24,000



GIANT REFINING CO.

FIGURE 4-10

100 YR. FLOOD PLAIN MAP

ENGINEERS : DELTA H ENGINEERING, LTD.

SCALE : 1" = 2000'

DATE : 12-1-84

TABLE 4-3

PEAK DISCHARGE AND RUNOFF CALCULATION SHEET #1

Referrence: Chapter 2 - Engineering Field Manual for Conservation Practices; U.S.D.A., Soil Conservation Service

Location: Area NW, Fourmile Canyon, Ciniza, New Mexico

Soil and Cover: Subarea I, B/C soil, 75 percent cover, good condition, ponderosa pine

Date: December 15, 1983

Purpose: 100-year floodplain at Ciniza Refinery

Drainage Area: A = 5,071 ac

Length: L = 20,000 ft

Elevation Differences: H = 900 ft

Runoff Curve Number: CN = 58

Time of Concentration T_c = 8.84 hr

Rainfall, 24-hr at 100 year: P_{24} = 2.8 in

Direct Runoff: Q = 0.3 in

Distribution Curve No: DC = 70

Runoff Rate: R = 0.84 cfs/ac-in

Peak Discharge, $q = A \times Q \times R$ = 1,280 cfs

Runoff Volume, $v = A \times Q/12$ = 127 ac-ft

Delta H Engineering, Ltd., P.O. Box 2023, Santa Fe, NM 87501

TABLE 4-3 (Con't.)

PEAK DISCHARGE AND RUNOFF CALCULATION SHEET #2

Reference: Chapter 2 - Engineer Field Manual for Conservation Practices; U.S.D.A., Soil Conservation Service

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Location: Area NW, Fourmile Canyon, Ciniza, New Mexico

Soil and Cover: Subarea II, B/C soil, mountain brush and juniper grass, 50 percent cover

Date: December 15, 1983

Purpose: 100-year floodplain at Ciniza Refinery

Drainage Area:	A	=	1,894	ac
Length:	L	=	17,000	ft
Elevation Difference:	H	=	200	ft
Runoff Curve Number:	CN	=	65	
Time of Concentration:	T_c	=	1.3	hr
Rainfall, 24-hr at 100 yr:	P_{24}	=	2.8	in
Direct Runoff:	Q	=	0.4	in
Distribution Curve No.	DC	=	70	
Runoff Rate:	R	=	0.55	cfs/ac-in
Peak Discharge, $q = A \times Q \times R$		=	1,895	cfs
Runoff Volume, $v = A \times Q/12$		=	3,175	ac-ft

Delta H Engineering, Ltd., P.O. Box 2023, Santa Fe, NM 87501

TABLE 4-3 (Con't.)

PEAK DISCHARGE AND RUNOFF CALCULATION SHEET #3

Reference: Chapter 2 - Engineering Field Manual for Conservation Practices; U.S.D.A., Soil Conservation Service

Location: Area NW, Fourmile Canyon, Ciniza, New Mexico

Soil and Cover: Subarea III; B/C soil, 50 percent cover, herbaceous and mountain brush

Date: December 15, 1983

Purpose: 100-year floodplain at Ciniza Refinery

Drainage Area: A = 1,028 ac

Length: L = 14,000 ft

Elevation Difference: H = 2,500 ft

Runoff Curve Number: CN = 70

Time of Concentration: T_c = 0.95 hr

Rainfall, 24-hr at 100 yr: P_{24} = 2.8 in

Direct Runoff (Figure 2-4): Q = 0.60 in

Distribution Curve No: DC = 70

Runoff Rate (Figure 2-5): R = 0.70 cfs/ac-in

Peak Discharge, q = A x Q x R = 432 cfs

Runoff Volume, v = A x Q/12 = 51.4 ac-ft

Delta H Engineering, Ltd., P.O. Box 2023, Santa Fe, NM 87501

TABLE 4-3 (Con't.)

PEAK DISCHARGE AND RUNOFF CALCULATION SHEET #4

Reference: Chapter 2 - Engineering Field Manual for Conservation Practices; U.S.D.A., Soil Conservation Service

Location: Area SW, immediately west of Fourmile Canyon, Ciniza, New Mexico

Soil and Cover: B/C soil, 60 percent ponderosa pine, 40 percent mountain brush

Date: December 15, 1983

Purpose: 100-year floodplain at Ciniza Refinery

Drainage Area: A = 2,572 ac

Length: L = 22,000 ft

Elevation Difference: H = 690 ft

Runoff Curve Number: CN = 64

Time of Concentration: T_c = 1.0 hr

Rainfall, 24-hr at 100 yr: P_{24} = 2.8 in

Direct Runoff: Q 0.4 in

Distribution Curve No: DC 70

Runoff Rate: R = 0.68 cfs/ac-in

Peak Discharge, q = A x Q x R = 700 cfs

Runoff Volume, v = A x Q/12 = 86 ac-ft

Delta H Engineering, Ltd., P.O. Box 2023, Santa Fe, NM 87501

Following the completion of surveys and engineering analysis, Giant will select options for dealing with the potential threat to Pond #9. These may include:

- Diversion of natural channels, at US 40 and/or between the highway and the pond
- Construction of a berm, or increasing the height of the berms around Pond #9

Giant will notify NMOCD when an option is selected, and will provide design and as-built specifications in a timely manner.

5.0 PROCESS DESCRIPTION AND WASTEWATER CHARACTERISTICS

5.1 OVERVIEW

A petroleum refinery is a complex combination of interdependent operations engaged in crude separating, molecular cracking, molecular rebuilding and finishing to produce petroleum-derived products. There are a number of distinct processes utilized by the industry for refining crude petroleum and its fractionation products. An EPA survey of the petroleum refining industry, conducted during 1977, identified over 150 separate processes being used and specified many more process combinations that may be employed at any individual refinery. The specific processes currently in use at the Ciniza Refinery are described and discussed in the following sections. The origin, paths and fate of the individual waste streams are shown in Plate 4.

A significant distinction is made between contact (containing or likely to contain hydrocarbons due to direct contact during process operations) and non-contact (unlikely to contain hydrocarbons) waste streams. In the following sections, contact waste streams are identified by (C) and non-contact streams are labeled (NC).

Each process is itself a series of unit operations which cause chemical and/or physical changes in the feedstock or product. In the commercial synthesis of a single product from a single feedstock there are sections of the process associated with the preparation of the feedstock, the chemical reaction, the separation of reaction products, and the final purification of the desired product.

Major sources of process wastewater and the subsections in which these are discussed are:

WASTEWATER SOURCE	SUBSECTION
o Crude Oil Fractionation	5.2.1
o Fluidized Catalytic cracking	5.2.2
o Alkylation	5.2.3

o Platforming	5.2.4
o Merox Treating	5.2.5
o Naphtha Hydrotreating	5.2.6

The following processes are associated with several auxiliary activities which do not directly result in conversion of crude oil to product nor result in complex chemical changes in the product. Instead these auxiliary processes separate impurities from the feedstocks and products, or are required for other aspects of the operation and maintenance of a refinery. These auxiliary units are:

WASTEWATER SOURCE	SUBSECTION
o Boilers	5.3.1
o Cooling Towers	5.3.2
o Storage Tanks	5.3.3
o Water Softening Units	5.3.4
o Desalting Units	5.3.5
o Additive-Mixing Facility	5.3.6
o Oil/Water Separation System	5.3.7
o Blowdown/Relief Flare System	5.3.8
o Air Compressors	5.3.9

Plates 4 and 5 show the location of these process and auxiliary units at the refinery. Each process or auxiliary unit operation has different water usages associated with it. The nature and quantity of wastewater produced by the units varies according to the process involved. The final aqueous waste effluent of the Ciniza Refinery is a blend of eight major process and auxiliary waste streams (Table 5-1) and several intermittent flows from such minor sources as seal leakage from water-cooled pumps. During the period of review, the relative flow volumes from the different units were:

TABLE 5-1
PROCESS UNITS AND WASTEWATER TREATMENT/DISPOSAL UNITS

Process Unit	Treatment/ Disposal System	Flow (gpm)
Crude Receiver Primary Separation	To API Separator	4
Crude Receiver Secondary Separation	To API Separator	1
Desalter	To API Separator	26*
Fluidized Catalytic Cracking (FCC) Unit	To API Separator	10
Alkylation Unit Regenerator	To API Separator	0.02
Kerosine Water Wash	To API Separator	1 gpm*
NHT Separator Drum	To API Separator	5
NHT Stripper	To API Separator	1
Boilers **	To Limestone Contact Chamber for pH Adjustment	30*
Cooling Tower ***	To API Separator	45*
	[illegible]	123 gpm

* Maximum flow, based on water input

** Blowdown and backwash [illegible]

*** Blowdown

Cooling Towers	37%
Boiler Blowdown	24%
Process and Remaining Auxiliary Units	39%

Based upon weir measurements taken over the course of several days, the maximum effluent discharge is approximately 0.25 cfs or about 161,000 gallons per day at a maximum production of 18,000 BBLS/calendar day.

The total flow from Table 5-1 is 123 GPM, or 177,000 GPD. This figure represents a <u>maximum</u> value based on <u>input</u> to the boilers and cooling towers. Evaporative and other minor losses account for the 16,000 GPD difference.

Additional wastewater is produced by stormwater runoff, drainage from wash pads and cleanup areas, drainage from truck and railroad loading racks and from domestic sewage. The nature and fate of these discharges are discussed in Section 5.4.

5.2 MAIN PROCESS UNIT DESCRIPTIONS AND WASTEWATER CHARACTERISTICS

5.2.1 Crude Oil Fractionation (C)

Fractionation serves as the basic refining process for the separation of petroleum crude into intermediate fractions of specific boiling-point ranges. Increasing temperatures and decreasing pressure evaporate progressively heavier constituents yielding straight run gasoline, naptha, kerosene, diesel, atmospheric gas oil and reduced crude. Naphtha is further fractionated and fed into the NHT platformer for reforming.

Waste streams are generated from two areas: condensation on overhead piping or accumulators and water sinking to the bottom of process units and being drawn off as an emulsion. Wastewater produced from these units contains ammonia, sulfides, chlorides, oil, and phenols. The process flow sheet (Plate 4) shows the location of all wastewater collection pipes for this and other units. Table 5-1 summarizes the type and volume of effluent produced and the treatment units to which the streams are discharged.

5.2.2 Catalytic Cracking (C)

Fluidized catalytic cracking is employed at Ciniza. Catalytic cracking involves four major types of reactions:

- Thermal decomposition
- Primary catalytic reactions at the catalyst surface
- Secondary catalytic reactions between the primary products
- Removal of products which may be polymerized from further reactions by adsorption onto the surface of a fluidized bed of catalyst such as coke

This last reaction is the key to catalytic cracking because it permits decomposition reactions to move closer to completion than is possible in simple thermal cracking. The catalysts are in the form of beads or pellets in the thermal unit and powder for the fluidized unit. The catalyst is usually heated and lifted into the reactor area by the incoming oil feed which, in turn, is vaporized upon contact. Vapors from the reactors pass upward through a cyclone separator which removes most of the entrained catalyst. These vapors then enter the fractionator, where the desired products are removed and heavier fractions recycled to the reactor.

The major wastewater constituents resulting from catalytic cracking operations are oil, sulfides, phenols, cyanides and ammonia. High BOD_5 (5-day culture) and COD levels are also found in the alkaline wastewater. The wastestreams from the catalytic cracking process are routed through the API separator to the evaporation ponds.

5.2.3 Alkylation (C)

Alkylation is the reaction of an isoparaffin (usually isobutane) and an olefin (propylene butylenes, amylenes) in the presence of an acid catalyst at carefully controlled temperatures and pressures. Hydrofluoric acid is currently used as the catalyst at the Ciniza Refinery. These reactions produce propane, butane and a high-octane alkylate used in gasoline blending. The reaction products are separated in a catalyst recovery unit, from which the catalyst is recycled. The hydrocarbon stream is passed through a caustic-soda and water wash after passing through the fractionation section.

The wastewater from the alkylation unit is an acidic solution containing some suspended solids, oils, dissolved solids, fluoride and phenols. The waste stream is discharged to the API separator.

5.2.4 Platforming

Platforming converts low octane naphtha, heavy gasoline and naphthene-rich stocks to high-octane gasoline blending stock, aromatics for petrochemical use, and isobutane. Feed stocks are usually hydrotreated for the removal of sulfur and nitrogen compounds prior to charging to the platformer (see Section 5.2.6), because the extremely expensive platinum catalysts used in the units are readily contaminated and ruined by sulfur and nitrogen species. The predominant reaction during platforming is the dehydrogenation of naphthenes. Important secondary reactions are the isomerization and dehydrocyclization of parafins. All reactions result in high octane products. At Ciniza the platformers do not produce a waste stream.

5.2.5 Merox Treating (C)

A proprietary procedure, Merox treating, converts mercaptans to alkyl disulfides in a catalytic process known commonly as sweetening. This is a single-stage process which reduces odors in the final product. There are two Merox treating units utilized at the Ciniza Refinery, one for straight-run gasoline and the other for kerosine. The straight-run gasoline process uses caustic soda to reduce the mercaptan levels to an acceptable level prior to contact with the catalyst. Following catalytic contact, a waste stream containing caustic soda and Merox catalyst is produced. The kerosine Merox treating unit requires no caustic pretreatment and therefore generates no aqueous wastes. Alkaline wastewater containing small amounts of commercial Merox catalysts is discharged to the API separator. An analysis of the wastewater stream is presented in Table 5-2.

5.2.6 Naphtha Hydrotreating (C)

Hydrotreating is used to saturate olefins and control such parameters as sulfur compounds, nitrogen compounds, odor, color and gum-forming elements. This process mixes the feedstock with hydrogen, raises the temperature and then sends it to the catalytic reactor. The catalytic reactor is used to remove sulfur and saturate naphtha for the reforming unit. The reactor products are cooled and three constituents are separated out: high grade products, hydrogen and impurities. Increasing the hydrogen content or decreasing the temperature decreases the level of impurities in the product.

Hydrotreating typically reduces the sulfur and nitrogen content of the treated material by 90 percent and 85 percent, respectively. The primary constituents of the wastestream are ammonia, sulfides and phenols if the temperature is at the high end of the range. Table 5-2 contains a representative analysis of the waste stream. Wastes are routed to the API separator.

5.3 AUXILIARY PROCESS UNIT DESCRIPTIONS AND WASTEWATER CHARACTERISTICS

5.3.1 Boilers (NC)

Steam is consumed throughout the refining process and is generated in boilers located on the facility. To assure proper operation of the boilers, a certain amount of condensate must be discharged (blowdown) and well water added as make-up. Boiler feed water is made of softened well water with an oxygen scavenger additive (hydrazine derivitive) and a patented boiler-treatment additive, purchased from Nalco Chemical Company located at 4435 Civic Center Plaza, Suite # 11, Scottsdale, Arizona. Boiler blowdown is routed to the evaporation ponds. Analyses are given in Table 5-2. Wastes are routed to the neutralization tank.

TABLE 5-2
CHEMICAL ANALYSES OF SELECTED WASTE STREAMS AT GIANT CINIZA REFINERY
(VALUES IN MG/L)

WQCC 3-103 PARAMETERS	CRUDE UNIT PROCESS (#2.1)	NHT STRIPPER (#2.6b)	HYDROTREATOR SEPARATOR DRUM (#2.6A)	KEROSINE WATER WASH (#2.5)	FCC UNIT (#2.2)	COOLING UNIT BLOWDOWN (#2)
As	<0.05	<0.05	<0.05	<0.05	<0.05	---
Ba	<1.0	<1.0	<1.0	<1.0	<1.0	---
Be	<0.001	<0.001	<0.001	<0.001	0.2	---
Ca	---	---	---	---	---	<1200.0
Cd	<0.01	<0.01	<0.01	<0.01	<0.01	---
Cr	<0.05	<0.05	<0.05	<0.05	<0.05	17.81
CN	---	---	---	---	---	---
F	---	---	---	---	---	1.98
K	---	---	---	---	---	17.0
Pb	<0.001	<0.001	<0.001	<0.001	<0.001	---
Hg	<0.0002	<0.0002	<0.0002	<0.0002	<0.0002	---
NO_3	---	---	---	---	---	300
Se	<0.01	<0.01	<0.01	<0.01	<0.25	---
Ag	<0.05	<0.05	<0.05	<0.05	0.05	---
U	---	---	---	---	---	---
Cl	---	---	---	---	---	384.0
Cu	<0.002	<0.002	<0.002	<0.002	<0.002	---
Fe	---	---	---	---	---	0.79
Mg	---	---	---	---	---	85.0
Mn	---	---	---	---	---	---
SO^4	---	---	---	---	---	2500.0
TDS	---	---	---	---	---	6580.0
Zn	<0.004	<0.004	<0.004	<0.004	0.070	---

pH	9.0	7.4	6.4	6.0	---	6.1
Silica	---	---	---	---	---	37.51
Mo	---	---	---	---	---	---
Na	---	---	---	---	---	1948.0
Ni	<0.01	<0.01	<0.01	<0.01	0.4	---
Phenols	15.8	0.06	9.0	10.6	986.0	---
Phosphate	---	---	---	---	---	0.20
TSS	---	---	---	---	---	<4.0
Cond.	---	---	---	---	---	8070
COD	454.0	198.0	191.0	127.0	599.0	277.0
NH_4	---	---	---	---	---	0.1
Sb	<0.002	<0.002	<0.002	<0.002	1.8	---
COD	149.3	89.8	89.8	120.0	500.0	9
Oil & Grease	8.1	8.5	5.3	20.0	50.0	25.0
TOC	---	---	---	---	---	767.1
Hardness	---	---	---	---	---	3346.4

5.3.2 Cooling Towers (NC)

Water used for cooling process-streams is produced by cooling towers and comprises most of the water usage at the facility. A significant amount of water is lost by evaporation in the cooling towers resulting in an increased concentration of dissolved solids in the cooling water over time. To prevent excessive concentrations of dissolved solids, a certain portion is discharged and an equal amount of well water is added. To prevent scaling, corrosion and biological growth in the towers, chromate is added to the cooling water. Analyses of cooling tower blowdown is given in Table 5-2. Cooling tower wastewater, containing small amounts of chromate, is routed to the API separator. In the reducing and organic-rich environment of the separator, chromate forms insoluble complexes with organic constituents. These complexes precipitate and settle to the bottom of the API separator. The chromate-bearing sludges are periodically removed by a vacuum truck and transported to the Land Treatment Area, which is regulated under RCRA and the NMHWMA.

5.3.3 Storage Tanks (C)

Storage of crude typically allows some gravity-separation of any water or suspended solids entrained in the fluid. These wastes, removed from the tank bottoms, contain emulsified oil, phenols, iron, sulfide and other constituents which depend upon the nature of the material stored in a particular tank. This liquid is either decanted off or removed by vacuum trucks to the API separator. The volume of effluent from this unnumbered source is relatively small. Solid wastes (tank-bottom sludges) are regulated under RCRA and NMHWM regulations. These wastes are transported to the Refinery's Land Treatment Area. A full description of these wastes and the waste management and monitoring system is contained in the Ciniza Refinery's Part B application on file with NMEID's hazardous waste bureau.

5.3.4 Water Softening Units (NC)

To prevent scaling, softened water must be supplied to the boiler units as well as several of the process systems. The softening process basically contacts the water with a zeolite ion-exchange medium, at a controlled pH, to precipitate out the calcium and magnesium salts which would produce scale in the boiler. With use, the softening units build up high concentrations of calcium and magnesium-rich solids which hinder further operation. Waste water from backwashing operations is sent to the neutralization tank and then to the evaporation ponds.

5.3.5 Desalters (C)

All produced crude contains some formation (connate) water. Although northwestern New Mexico crude is generally found in marine formations, this connate water is not highly saline. Desalters remove the existing saline fluid from the crude by passing crude (with some added water) through an electrostatic field which acts to agglomerate dispersed brine droplets. Desalters are considered an integral part of the crude oil fractionation unit at the Ciniza Refinery.

The wastewater can contain high levels of dissolved solids, some phenols and (depending upon crude type) ammonia and sulfides. This contact wastewater is discharged to the API separator. A characterization of desalter effluent is shown in Table 5-2.

5.3.6 Additive Mixing Facility

The additive facility simply provides a containment area for mixing and addition of lead or other additives. There is no waste stream produced.

5.3.7 Oil/Water Separation System (C)

All waste streams which contain or may contain free feedstocks or products are directed to an twin-celled oil-water separation system (API separator) before discharge to the evaporation ponds. This separator is a series of settling tanks which physically separates and collects lighter fractions (crude oil and products) at the top as the wastewater flows from the bottom. Heating of the inflow by steam improves the separation by reducing viscosity. An analysis of the API separator wastestream is presented in Table 5-3.

	EFFLUENT SOURCE				
	API SEPARATOR	NEUTRALIZATION TANK	SEWAGE	ASPHALT PIT	RAILROAD LAGOON
TSS	52.0	<1.0	28.0		
TDS	2490.0	2324.0	1124.0	184	620
Oil & Grease	75.4	<0.1	48.2		
Phenols	52.6	<0.01	<0.01	<0.01	0.07
Benzene	9.9	<0.001	<0.001		
BOD	567.4	2.8	9.6		
COD	1206.4	64.9	245.9		
Na	1275.0	1296.0	636.0		
K	9.0	4.0	7.0		
Ca	89.0	90.0	19.0		
Cr	1.44	<0.050	<0.050	<.050	<0.050
Mg	10.0	14.0	8.0		
P Total	<0.01	0.03	0.35		
CI	588.0	710.0	61.0	30	10
SO_4	1812.0	600.0	489.0	<0.01	138
S Total	7045.0	278.0	241.0		
HCO_3	512.0	232.0	308.0		
Fe	0.5	0.10	0.12	0.34	0.35
Cu	<0.03	<0.03	<0.03		
Mn	0.2	0.03	0.2		
Zn	<0.01	<0.01	<0.01		
Mo	<0.01	<0.01	<0.01		
AI	<0.01	<0.01	<0.01		
B	<0.01	<0.01	<0.01		
NO_3 as N	<0.01	<0.01	<0.01	0.1	<0.01
NH_4	477.0	<0.01	0.2		
TKN	479.0	1.8	2.8	3.9	4.9
CN	6.0	<0.01	<0.01		

TABLE 5-3
ANALYSES OF COMINGLED WASTES, SEWAGE AND MISCELLANEOUS WASTES
(all values in mg/l)

5.3.8 Blowdown/Relief Flare System

Liquid or gaseous hydrocarbons discharged from pressure-relief valves are directed to a blowdown system. The blowdown system is a series of condensers intended to recover as much product as possible for recycling. Those gaseous cuts which cannot be condensed and recycled are fed to the relief flare system. The Ciniza Refinery utilizes a flare system fueled by refinery gas or purchased gas. Live steam is continuously passed through the flare-stack chimney to reduce particulates and to prevent clogging. No aqueous or solid-waste streams are produced from this auxiliary unit process.

5.3.9 Air Compressors (NC)

The air compressors provide pneumatic-instrument air for flow and termperature control devices and utility air for cleaning purposes and equipment (i.e., impact wrenches). The only waste produced by these units is a small quantity of condensed water, which is periodically drained from the compressor tanks. This water is routed to the shop drains (see Section 5.4.5), from which it flows through the API separator to the evaporation ponds.

5.4 NON-PROCESS WASTE STREAMS

In addition to the waste streams generated by Refinery processes and associated operations, several other wastewater streams are produced by:

- Storm-water runoff from the refinery area
- Runoff from an equipment and vehicle-cleaning wash pad
- Runoff from the tank-truck loading rack
- Runoff from the railroad-car loading rack
- Drains from shops and warehouses on the Refinery site
- Condensed steam from heating jackets on pipes and tanks
- Condensed steam from the asphalt plant
- Domestic sewage from the refinery and from employee housing

With the exception of storm water, these waste streams comprise only a small fraction of the total aqueous wastes produced by the Refinery. The origin, paths and disposition of these non-process waste streams are shown in Plate 5. Available analyses of these waste streams are given in Table 5-3.

5.4.1 Storm Water Runoff (NC)

Storm water which falls onto or flows into the Refinery area is collected by a system of storm sewers and surface ditches. The effluent is transported by underground pipes and/or open ditches to either the main API separator, or to a secondary separator ("Oil Skimmer" in Plate 5), before being discharged to the evaporation. Due to the intermittent and unpredictable nature of precipitation at Ciniza, no samples of this waste stream are currently available for analysis.

5.4.2 Wash-Pad Runoff (NC)

Refinery tools, equipment and vehicles are cleaned with high-pressure water, detergents and by steam. Clean-up operations are performed on a concrete wash-pad. Waste water is collected by drains, and flows through the storm-sewer system to the API separator, from which it is discharged to the evaporation ponds.

5.4.3 Truck Loading-Rack Drains (NC)

Giant ships the majority of its refinery products by tank truck. These trucks are loaded at an overhead-filling rack. The rack area is paved with concrete, and runoff is controlled by steel grates over a drain. The fluids which drain from this area include stormwater, water from truck washdown (in the event of minor loading spills) and small quantities of product due to minor spills. From the drains, these fluids are directed by a storm sewer to the API separator. The aqueous fraction is then discharged to the evaporation ponds. No analyses of this intermittent waste stream are available.

5.4.4 Railroad Loading Rack (NC)

Giant ships some of its refinery products by rail, and tank cars are loaded by an overhead rack located on a spur of the Santa Fe Railroad's tracks which enters the east side of the Refinery plant (Figure 5-2). Like the truck-loading area, the railroad rack is paved with concrete and drained by underground sewers. Effluents consist of stormwater, washdown from tank cars and minor amounts of product due to occasional, small spills. Fluids are directed through an underground pipe to an evaporation pond (Plate 5). The evaporation pond is currently equipped with an underdrain which allows pond water to discharge to grade before the fluid level exceeds the 2-foot minimum freeboard. Analyses of the railroad evaporation-pond fluids are given in Table 5-3.

5.4.5 Shop Drains (NC)

The Ciniza Refinery operates in-house facilities for pipefitting, welding, carpentry and general machine work. Shops housing these service facilities are equipped with floor drains which connect with the API sewer network (Plate 5). Effluents contain water, detergents, minor amounts of oil and grease, and miscellaneous particulates. These wastestreams flow to the API separator, where the insoluble organic fractions are removed. The remaining wastewater is the discharged to the evaporation ponds.

5.4.6 Condensed Steam (NC)

In order to maintain the correct product viscosity for flow, pipelines and tanks are heated by steam jackets or parallel steam pipes. As the steam heats the lines or tanks it condenses, and this condensed water is then drained or blown down from the lines. Small volumes of this water are discharged at numerous locations throughout the Refinery. The condensed water is similar in chemistry to the boiler blowdown, but may also contain small amounts of hydrocarbons. Following discharge, these small quantities of water flow into the storm sewer system, through the API separator and into the evaporation ponds.

5.4.7 Asphalt Plant (C)

The fractionation and refining of petroleum results in the accumulation of heavy, non-volatile liquids and semi-solids which are collectively known as asphalt. This material has many uses as a paving, roofing and sealing material, and as a raw material for the manufacture of paints and floor coverings. The Ciniza asphalt plant has been inactive since 1979. The old asphalt plant is now retained as a steam-heated tank farm (Plate 5). Wastewater is produced from steam condensation. This wastewater is directed to a small evaporation pond ("Asphalt Pit" in Plate 5). The pond has a thick natural liner of asphalt. Occasional overflows from this pond are discharged to grade.? Analyses of this wastewater are given in Table 5-3.

5.4.8 Domestic Sewage (NC)

Sewage is produced from the Refinery plant and offices, and from a small (7 dwellings housing 28-30 persons) employee-housing area. As shown in Plate 5, the sewage follows several paths. Refinery work-area sewage flows to an aerobic treatment/evaporation lagoon, labeled "Plant Sewage" on Plate 5. Sewage from the office building flows into the "Office Sewage" lagoon, and one remote building is served by the "Railroad Office" lagoon. Sewage from the residential area flows into an underground septic tank, from which it is discharged to an aerobic treatment/ evaporation pond. At this time, no domestic sewage is comingled with any refinery process effluent or stormwater.

It is anticipated that, as part of a pilot-scale study of biological treatment, some domestic sewage may be diverted to the API pond (Pond 1). Aerators will be installed, and nutrients in the sewage will allow bacteria to degrade organic wastes in the API effluent. This system is discussed in further detail in sections 6.2 and 6.3.9.

6.0 WASTE MANAGEMENT SYSTEM

As discussed in the preceeding sections, Giant maintains a comprehensive system of waste management for:

- Refinery process wastes
- Non-process refinery wastes and stormwater
- Domestic sewage
- Wastes classified as hazardous under RCRA and NMHWMA

The aqueous process and non-process wastes are ultimately discharged, following oil-water separation (API separator) and/or neutralization (neutralization tank), to the evaporation ponds located to the west and north of the refinery plant. Minor occasional waste streams from the railroad rack and the disused asphalt plant area are diverted to small, individual evaporation ponds. Domestic sewage is treated in septic tanks and aerobic lagoons; these lagoons also serve as evaporation ponds for the sewage.

Under the provisions of the Federal Resource Conservation and Recovery Act (RCRA) and the New Mexico Hazardous Waste Management Act, Giant has segregated the wastes characterized as hazardous from the general refinery waste streams. These wastes include:

- API separator sludges
- Heat-exchanger bundle cleaning sludges
- Leaded and unleaded tank bottoms
- Spent solvents

With the exception of spent solvents, which are commercially recycled, Giant disposes of these wastes in a Land Treatment Area, located to the north of the plant site. This Land Treatment Area is regulated and monitored by the New Mexico Environmental Improvement Division (NMEID) and the United States Environmental Protection Agency (USEPA). Giant has filed a Part B application, and is currently managing their hazardous wastes under interim status. Complete information concerning the nature, treatment, storage and disposal of these wastes is contained in the Part B documents, which are on file with NMEID and USEPA Region VI.

6.1 WASTEWATER PATHS AND DISPOSITION

Giant diverts its wastewater into different evaporation ponds, depending on the waste source. Figure 6-1 shows the locations and configurations of these ponds. Figure 6-1 also includes the flow paths connecting the ponds, by which wastewater is moved to and among the ponds. Table 6-1 is a water balance for the ponds.

As described in Section 5.0, there are many discrete and chemically distinct waste streams generated by the refinery. Some of these streams are comingled, either in the drains, sewers and ditches, in the API separator, and in the ponds. Tables 5-2 and 5-3 present analyses of the effluents, sewage-lagoon waters and samples of pond waters.

The main division of waste streams is based on the distinction between contact and non-contact waste streams. Contact waste streams are those which involve water contact with product, wastes and/or feedstocks. These waste streams typically contain some hydrocarbons as a free phase. Streams containing (or likely to contain) free hydrocarbons are routed through the API separator. Following oil-water separation these wastes flow into Pond 1, where some additional separation of oil and water may occur. An underdrain allows the aqueous phase to flow into Pond 2. Pond 2 discharges through a weir, from which the flow is normally diverted to Ponds 12, 11, 7 and 8 (Figure 6-1).

Non-contact wastewater normally passes through the neutralization tank, where contact with limestone chips neutralizes any residual acids. From the tank the wastewater flows into Pond 3 via a short conveyence ditch which feeds a buried pipeline. Wastewater then may pass into Ponds 4, 5, 6A and 6B. If these ponds approach their capacity (defined by the minimum of 2 feet of freeboard) the wastewater may be diverted by underground pipes to Pond 9, or to Ponds 7 and 8.

FIGURE 6-1
WASTEWATER DISPOSITION IN EVAPORATION PONDS

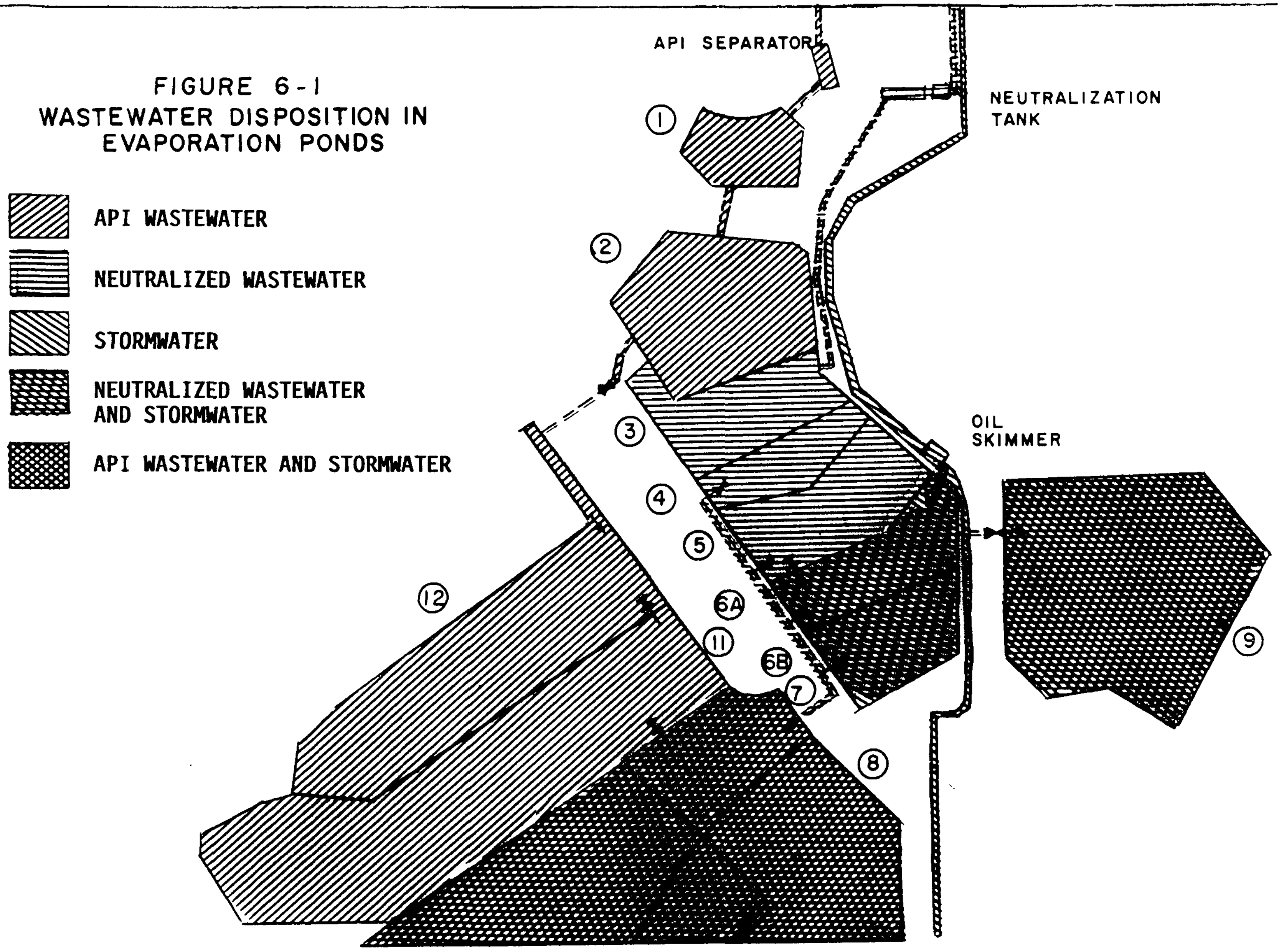

TABLE 6-1

WATER BALANCE FOR EVAPORATION PONDS

MONTH	PRECIP. (IN.)	PAN EVAP. (IN.)	DIFFERENCE (IN.)
Jan	.56	.38	+.18
Feb	.50	.50	0.00
Mar	.61	.84	-.23
Apr	.43	2.05	-1.62
May	.43	3.82	-3.39
June	.52	5.81	-5.29
July	1.83	7.11	-5.28
Aug	1.65	5.92	-4.27
Sep	.99	3.89	-2.90
Oct	1.17	2.03	-.86
Nov	.62	.70	-.08
Dec	.68	.39	+.29
	9.99	33.44	-23.45

Average discharge = 161,000 gallons/day

Yearly Discharge = 365 days x 161,000 gallons/day = 58,765,000 gallons/year

58,765,000 gallons/year x 1 Acre-Foot/325,742 gallons = 180.4 AF/year

Net Pond Evaporation = 23.45 in/year = 1.954 ft/year

Pond Evaporative Capacity = 117 Acres x 1.954 ft/year = 228.6 AF/year

$$\text{Relative Capacity} = \frac{228.6\ \text{AF/year}}{180.4\ \text{AF/year}} = 127\%$$

Stormwater which is not captured by the storm sewer system (which passes through the API separator) is collected into a ditch (Figure 6-1) which flows into the oil skimmer. This skimmer is a smaller, unheated version of the API separator which serves to remove any oily phases from stormwater. From the oil skimmer, the wastewater the flows by conveyence channel to Pond 6A. To prevent overtopping of either the ponds or the skimmer, some of the skimmer effluent can be diverted to grade, adjacent to Pond 8.

6.1.1 Evaporation Ponds

The Ciniza Refinery currently maintains 16 evaporation ponds, with a total available area of approximately 117 acres. These ponds were constructed at various times in the history of the refinery, but the last ponds were built in 1972. These ponds are constructed with natural liners and berms made from the clays and shales of the Chinle Formation, which have an extremely low natural permeability (10^{-7} to 10^{-9} ft/sec).

A minimum of 2 feet of freeboard is maintained at all times by daily inspection, which also serves to immediately identify any erosion or structural problems. As discussed in Section 6.1, Giant maintains a comprehensive system of flow control, which allows plant personnel to divert the wastewater from pond to pond in order to maximize the area available for evaporation and to prevent overfilling of any pond.

As described in Section 4.3.4, boreholes advanced to depths of over 50 feet, and located within 20 feet of the pond berms, were observed to be completely devoid of free water. Soil-moisture analyses (Appendix A) show that there is no soil saturation at any level above the Ciniza sand. This demonstrates that even after over 13 years of service, these ponds retain an excellent degree of hydraulic integrity.

6.1.2 Water Balance For Evaporation Ponds

Giant's evaporation pond system has a total area of approximately 117 acres, and recieves a water input of approximately 160,000 gallons of water per day. As outlined in Table 6-1, the local evaporation rates indicate that the Refinery's ponds have an evaporative capacity of 130% in excess of the present wastewater load. Giant has considerable area available on site for the construction of additional ponds if necessary. This calculation is based on pan evaporation, and as such is quite conservative. Using a lake evaporation of 50 in/year, the ponds have a capacity of 216% of load.

In the unlikely event that 2.0 feet of freeboard cannot be maintained in the ponds for 2 consecutive quarters, or if overtopping was likely, Giant would take the steps (Contingency Plans) that are further discussed in Section 8.0.

6.1.3 Proposed Aerated Lagoon

In order to reduce the levels of certain waste parameters in the wastewater from the API separator, Giant is currently examining the feasibility of constructing an aerated lagoon for secondary biological treatment of the API separator effluent. This secondary treatment is based on the principal of biological degradation of hydrocarbon and other waste constituents by coliform and other natural bacteria. Both the bacteria and their necessary nutrients will either be supplied or supplemented by domestic sewage. The sewage will be diverted to the existing API-separator lagoon, which is located adjacent to the API separator. Aerators will be installed to facilitate aerobic degradation of wastes. The aerated lagoon design is based upon a minimum 60% BOD reduction. Further information on this proposed lagoon will be provided with the Plans and Specifications.

7.0 MONITORING AND REPORTING PLAN

7.1 MONITORING

In conjunction with NMEID and RCRA regulations, the Ciniza Refinery has developed and maintained comprehensive plans for sampling and analysis of wastes and wastewater. A ground water monitoring network consisting of 10 monitoring wells is in place, and 4 of these wells (1 up-gradient, 3 down-gradient) in the uppermost aquifer (Sonsela) have been regularly sampled since 1982 (See Plates 3,4). The original 4 monitoring wells (MW Series) are completed in the Sonsela. Six new RCRA wells, completed in the Ciniza sand (SMW Series), were installed in October, 1985. These wells have been sampled, and analysis for all first-quarter RCRA parameters is in progress. Based on a review of the 4 years of RCRA analysis of samples from the monitoring wells in the Sonsela (MW Series), there is no evidence for any ground-water contamination due to refinery activities. Giant will continue to perform sampling and analysis of ground water from these wells, according to the schedule and parameters described in the Part B application.

Giant will monitor the quantities and quality of their discharges on a regular basis. This monitoring will include:

- Weir measurements on a quarterly basis to determine the quantity of wastewater discharged to the evaporation ponds
- Sampling and analysis of input to the proposed aerated lagoon on a quarterly basis, analysing for TDS, TOC, BOD, COD
- Sampling and analysis (for the parameters above) of the final effluent to the ponds, on an quarterly basis
- Inspection of all evaporation ponds for fluid levels and freeboard on a monthly basis, and following any major storms
- Sampling and analysis of ground water samples from the monitoring wells, according to the schedule outlined in Giant's Part B application, and transmittal of the results of these analyses to NMOCD annually

Giant has installed and attempted to sample several pressure-vacuum lysimeters near the Land Treatment Area. To date, these devices have produced no useful quantities of soil-pore water. Due to the extremely high soil-suction of the Chinle shales, it does not appear that any lysimeters will function in these soils. No further vadose-zone monitoring is planned at this time.

7.2 REPORTING AND RECORD KEEPING

Giant will report the results of its monitoring program to the Director on a yearly basis. If Giant elects to modify its facilities and/or processes in a manner which would result in a significant change in the quantity or chemical quality of the wastes discharged, the Director will be notified of these changes within 90 days.

Unplanned discharges, such as spills, leaks or process upsets, will be reported to the Director within 15 days. As outlined in the Contingency Plan (Section 8.0 of this document), Giant will take immediate steps to contain, control and mitigate the effects of any unplanned release of products or wastes.

Records of all monitoring and emergency-response activities will be retained at the refinery for 5 years. These records will be made available to the Director or his authorized representative upon request. Authorized representatives of the Director may, upon request, inspect and copy discharge plan records, inspect the plant's waste management and monitoring systems, sample effluents and collect samples from monitoring devices installed pursuant to NMOCD discharge plan requirements.

Under RCRA and NMHWMR, Giant will continue ground-water monitoring for a period of 30 years after closure of the Land Treatment Area. NMOCD will be provided with yearly reports of the results of this monitoring.

8.0 CONTINGENCY PLANS

Giant has developed a comprehensive Contingency Plan (included in the Part B Application filed with USEPA and NMEID) for dealing with any unplanned release of any substances which might pose a threat to human health or the environment. This contingency plan does not, however, address the evaporation ponds with respect to inspection, structural integrity, fluid levels or flooding potential.

Giant will inspect all active evaporation ponds on a monthly basis, or following any major storm. Erosion or other damage will be repaired in a timely manner, so that the structural integrity of the dikes is maintained. During monthly inspection, freeboard levels will be observed. If the 2-foot freeboard requirement is not met for 2 consecutive quarters, Giant will report this finding to NMOCD, and take one or more of the following steps:

- Construct additional ponds to contain and evaporate the additional wastewater
- Take steps to reduce the quantity of wastewater discharged
- Install devices (e.g., sprinklers) to enhance evaporation
- Evaluate other methods to restore the water balance

The hydrology of the site (confined ground water overlain by highly impermeable shales and clays) indicates that there is little or no chance that ground water would be affected by any spills of products, feedstocks or wastes. Spills will be handled under the Part B contingency plan, and all spills and the response to them are reported to NMEID within 15 days.

9.0 SUMMARY OF DISCHARGE PLAN REQUIREMENTS

This Discharge Plan Application summarizes the location, site characteristics, hydrogeology, processes, waste management systems, monitoring systems and reporting and contingency plans for the Ciniza Refinery. Under the New Mexico Water Quality Control Commission regulations as administered by the New Mexico Oil Conservation Division (NMOCD), Giant will:

- Submit plans and specifications of the present process and wastewater systems and any subsequent modifications to NMOCD
- Sample and analyze ground water from the existing network of monitoring wells, according to the schedules and parameters specified by the RCRA and NMHWMR regulations
- Inspect all evaporation ponds on a monthly basis
- Analyse all effluents on a quarterly basis
- Notify NMOCD within 15 days of any significant spill or release
- Take steps to modify pond volume and/or wastewater volumes if minimum freeboard requirements are not met for 2 consecutive quarters
- Notify NMOCD when an option for dealing with the flooding potential of pond #9 is selected, and provide NMOCD with as-built plans and specifications for the option selected

10.0 BASIS FOR APPROVAL

The hydrogeologic conditions at the Ciniza site, and Giant's comprehensive system of waste management and control act together to insure that there is no feasible danger of ground water contamination due to discharges to the present waste-management units. No present or foreseeable future users of ground water in the Ciniza area can be affected for the following reasons:

- Pump and slug tests indicate that the clay shales underlying the evaporation ponds have permeabilities of 10^{-8} to 10^{-9} ft/sec; this is <u>less</u> than the 10^{-7} ft/sec requirement for engineered clay liners specified by RCRA interim standards
- The clays and shales which overlie the Sonsela are highly impermeable, as evidenced by dry boreholes located within 20 feet of the pond perimeters
- The Ciniza sand (uppermost ground-water zone) is a thin, localized unit which does not appear to extend beyond the refinery boundary
- The uppermost aquifer, the Sonsela Sandstone Bed, is under considerable artesian pressure which prevents any downward migration of contaminants by advection
- Giant maintains an extensive network of ground-water monitor wells in the Sonsela and overlying Ciniza sand; regular sampling and analysis of ground water would immediately identify any migration of wastes to ground water
- The evaporative capacity of the evaporation ponds is 130% of the present waste input, and space exists to construct additional ponds if necessary
- Giant is planning to construct an aerated lagoon for wastewater treatment, which will further reduce the levels of many parameters of concern in the final effluent to pond
- There is no significant potential for wastewater release due to flooding by the 100 yr storm; Giant is currently evaluating options to eliminate the potential of flood damage to pond #9 from the 100 year storm

11.0 REFERENCES CITED

Stone, W.P., Lyford, F.P., Frenzel, P.F., Migell, N.H. and Padgett, E.T., 1983: Hydrology and Water Resources of San Juan Basin, New Mexico. New Mexico Bureau of Mines and Mineral Resources Hydrologic Report 6, Socorro New Mexico

United States Soil Conservation Service, 1972: Soil Survey of Zuni Mountain Area; United States Department of Agriculture, Washington, D.C.

App. A

APPENDIX A

LOGS OF BORINGS AND SOIL-MOISTURE ANALYSES

Geoscience Consultants, Ltd.

Now Numbered ~~MW-1~~ SMW-1

WELL LOGGING FORM

Page_____of_____

Client GIANT REFINERY Well Number SMW-6

____ ¼ ____ ¼ ____ ¼ ____ ¼ S____ T____ R____ State_____

County__________ Contractor Fox Drilling Company

Spud Date 10-4-85 Completion Date__________

Logs Run__________ Logged By SELKE

Elevation 6901.83 TOC Spud In (Fm.)__________

Remarks

Depth	Litho	recov	Run	From	To	sample #	
0			1	0	5	851004 1000/0.0' 1001/0.5' 1002/5.0'	0-0.5'- SOIL
5			2	5	10	1005/7.5 1006/10.0	0.5-9.0 CLAY
10			3	10	15	1016/12.5 1017/15.0	9.0-10.0 SAND; buff coloured, fn-med gr
15			4	15	20	1026/17.5 1027/20.0	10.0-15.0 SILTY ~~[illegible]~~ SANDY CLAY
20			5	20	25	1038/22.5 1039/25.0	15.0-18.0 CLAY
25			6	25	30	1051/27.5 1052/30.0	(wet) ↓ 18.0-19.0 SILTY CLAY
30			7	30	35	1110/32.5 1111/35.0	↓ 19.0-21.0 CLAYEY SAND (DRY)
35			8	35	40	1124/37.5 1125/40.0	↓ 21.0-24.5 SANDY CLAY (DAMP) } capillary fringe
40			9	40	45	1144/42.5 1145/45.0	TD 24.5-27.0 SAND (~~[illegible]~~)(DAMP)
45							27.0-28.0 SANDY CLAY (~~WET~~) DAMP
50						10'	28.0-38.0 SAND; BRN, FN-MED GR.
							38.0-45.0 CLAY

Geoscience Consultants, Ltd.

WELL LOGGING FORM

Page____of____ = SMW - 1

Client GIANT REFINING COMPANY Well Number ~~SMW-3~~

____¼____¼____¼____¼ S____ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9/26/85 Completion Date ____

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation 6882.83 Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth	Litho	Recov	RUN	From	To	Sample#/Ft	Lith/Remarks
							SE corner of LTA Times should be
						850925	15 xx, not 14 xx etc
TTR 1410 0			∅	0	5	1415/4.0 SDY CLY	0-1.5 SOIL
5			2	5	10	1420/10.0 CLY SD	
10			3	10	15	1426/15' CLY,	1.5 - 4.0 CLAY
15			4	15	20	1432/20' SD	
20			5	20	25	1438/25' CLY	4.0 - 19.0 SANDY CLAY
25			6	25	30	1445/27.5 SD 1446/30.0 CLY SD	
30			7	30	35	1452/32.5 CLY 1453 35.0 SD	19.0 - 24 SAND; gr rd (5R4/2); med gr,
35			8	35	40	1458/37.5 1459/40.0	poor srt, qtz + blk rx frag
40							24 - 25 CLAY
							25 - 28 SAND, as above
							28 - 33 CLAYEY SAND & CLAY
						5'	33 - 38 SAND (WET) mod rd brn (10R4/6)
							med grn, mod srt, qtz, rnd
							38-40 CLAY
							9/26/85 H_2O level 29'2" 9:40
							N 120° to SMW2
							pH 7.1 #850926 1445

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WELL LOGGING FORM

Page 1 of 1

Client GIANT REFINING COMPANY

Well Number ~~SMW-4~~ SMW-3

___ ¼ ___ ¼ ___ ¼ ___ ¼ S ___ T 15 N R 15 W State New Mexico

County McKinley

Contractor Fox

Spud Date 10/1/85

Completion Date 10/1/85

Logs Run Lith from Cores

Logged By J.C. Hunter

Elevation 6883.25

Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth	Litho	Recov	RUN	From	To	Sample#/Ft	Lith/Remarks
							Upgradient well SS side of TA
0						851001	Meas from top of pipe (2.7)
5			1	0	5	0835/4.0'	0-3 SOIL gry rd (10R 4/2) cly loam, roots
10			2	5	10	0845/10.0	
15			3	10	15	0852/15.0	3-11 CLAY dk rd brn (10R 3/4) plastic,
20			4	15	20	0859/20.0	≤5% silt
25			5	20	25	0906/25.0	11-17 SANDY CLAY gry rd (5R 4/2), 10-20%
30			6	25	30	0914/30.0	vfg sand & silt
35			7	30	35	0921/35.0 SD	wet sd @ 33 B.A.TOP
40			8	35	40	0935/40.0	17-25 SAND: gry rd (5R 4/2); vc-vfg
45			9				poor sort, subang, Q+F±Lv
50			10				25-27 CLAY; dk rd brn (10R 3/4); ≤2% silt
							27-30 SAND; pale rd brn; vfg, subrd, mod sort
							Q+F±Lv
							35' [illegible] – 41 pipe = 44'
							[illegible] 45' [illegible]
							TD @ 42'
							Pipe in hole = 43½' below top of
							casing (2.5' stick up)
							Bottom screen @ 41'
							30-33 CLAY, pale rd brn (10R 5/4), ±10% silt
						4'	31.5 33-37 SAND (wet); pale rd brn

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WELL LOGGING FORM

SMW-4

Page_____of_____

Client GIANT REFINING COMPANY Well Number ~~SMW-1~~

___¼___¼___¼___¼ S___ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9/25/85 Completion Date 9/25/85

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation 6878.84 Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth	Litho	recov	RUN	From	To	Sample#/Ft	Lith/Remarks
							Between MW1- & MW-2 Depths from top
0							of auger, ~1.5' AGL (typical)
TTR 0830 5			1	0	5	850925:a 0840/4.0	0-1.5' (1.5') SOIL; gry rd (10R 4/2); silty cly
10			2	5	10	0847 /10.0 cl	w/ minor sd; roots & org matter
15			3	10	15	0852 /15' cl,	1.5-9.0 (7.5') CLAY; gry rd (5R4/2) - dk rd
20			4	15	20	0859 /20' cl,	brn (10R 3/4); dense, plastic, 1-5% silt
25			5	20	25	0906 /25' sd	9.0-16.0 (6.0') SANDY CLAY; gry rd (10R 4/2)
30			6	25	30	0913/27.5 cl 0914/30.0 snt	- dsky rd (5R 3/4); cly w/ 15-20% mod
35			7	30	35	0919/32.5 cl 0920/35.0 cl	cly Balls @ 35') gr - cr gr sd, local f grvl, poor sort
40			8	35	40	0927/37.5 cl 0928/40.0 cl	
45			9	40	45	0936/42.5 cl 0937/45.0 cl	2410 cutting @ 45')
50			10	45	50	0950/47.5 sdy cly 0951/50.0 cly	15.0-23.0 (7.0) CLAY; gry rd (5R 4/2),
TD 1000 55			11	50	55	0954/52.5 sdy cly 1000/55.0 cly	loc. sandy, 5-10% sd
			13	55	60	850925:1215/57.5' cly 1216/60.0 sd	23.0-24.0 (1.0) SAND; pale rd brn (10R 5/4) - mod
Move 1020			14	60	65	1241/62.5 1242/65.0	rd brn (10R 4/6); f g, mod srt, loose,
Restarted 9/25/85 1100			15	65	69	1258/67.5 1259/69.0	qtz ± K-spar
							24.0-33.0 (9.0) SILTY CLAY; mod rd (5R 5/4)
							cly w/ 10-20% slt, loc f g sand
							33.0-~~55.0~~ 59 (~~22~~ 26) CLAY; mod rd brn (10R 4/6)
							loc slty - sandy
							57.5 - 59.5 59 - 61 (2') Sand (wet) mod rd brn
							~~61~~ (10R 4/6); f g, mod sort
							61-69 Silty Sandstone (dry) pale red (10R 6/2)

SMW-4

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WELL LOGGING FORM

Page____of____

Client GIANT REFINING COMPANY Well Number ~~SMW-1~~

____¼____¼____¼____¼ S____ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9/25/85 Completion Date 9/25/85

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation 6878.84 Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for $\%H_2O$. Comp. as SS monitor Well

Depth	Litho	Recov	RUN	From	To	Sample#/Ft
0						
TTR 0830 5			1	0	5	850925:a 0840/40
10			2	5	10	0847 cl /10.0
15			3	10	15	0852 cl /15'
20			4	15	20	0859 cl /20'
25			5	20	25	0906 SD /25'
30			6	25	30	0913/27.5 cl 0914/30.0 SLT
35			7	30	35	0919/32.5 cl 0920/35.0 cl
40			8	35	40	0927/37.5 cl 0928/40.0 cl
45			9	40	45	0936/42.5 cl 0937/45.0 cl
50			10	45	50	0950/47.5 SD/CLY 0951/50.0 CLY
TD 1000 55			11	50	55	0959/52.5 SD/CLY 1000/55.0 CLY
Move 1020			13	55	60	850925:1215/57.5 CLY 1216/60.0
			14	60	65	1241/62.5 1242/65.0
Pertined 9/30/85 1100			15	65	69	1258/67.5 1259/69.0

Lith/Remarks

Between MW1- & MW-2 Depths from top of auger, ~1.5' AGL (typical)

0-1.5' (1.5') SOIL; gry rd (10R 4/2); silty cly w/ minor sd; roots & org matter

1.5-9.0 (7.5') CLAY; gry rd (5R4/2) - dk rd brn (10R 3/4); dense, plastic, 1-5% silt

9.0-15.0 (6.0') SANDY CLAY; gry rd (10R 4/2) - dsky rd (5R 3/4); cly w/ 15-20% med gr - cr gr sd, local f grvl, poor sort

cly balls @ 35')

also cutting @ 45')

15.0-23.0 (7.0) CLAY; gry rd (5R 4/2), loc. sandy, 5-10% sd

23.0-24.0 (1.0) SAND; pale rd brn (10R 5/4) - mod rd brn (10R 4/6); f g, mod srt, loose, qtz ± K-spar

24.0-33.0 (9.0) SILTY CLAY; mod rd (5R 5/4) cly w/ 10-20% slt, loc f g sand

33.0-~~55.0~~ 59 (~~22~~ 26) CLAY; mod rd brn (10R 4/6) loc slty-sandy

57.5 - 59.5

59 - 61 (2') Sand (wet) mod rd brn (10R 4/6); f g, mod sort

61 - 69 Silty Sandstone (dry) pk rd (10R 6/2)

Geoscience Consultants, Ltd.

WELL LOGGING FORM

SMW-5

Page ____ of ____

Client GIANT REFINING COMPANY Well Number SMW-2

____ ¼ ____ ¼ ____ ¼ ____ ¼ S ____ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9/25/85 Completion Date 9/25/85

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation 6876.78 Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth | Litho | Recov

RUN	From	To	Sample#/Ft	Lith/Remarks
			850925:	
1	0	5	1050/4.0	0-3.0 SOIL
2	5	10	1056/10.0	
3	10	15	1102/15	3.0-10.0 SILTY CLAY
4	15	20	1106/20	
5	20	25	1114/25	10.0-12.5 SAND
6	25	30	1126/30	
7	30	35	1141/32.5 1142/35.0	12.5-14 CLAY
8	35	40	1235/37.5 1236/40	
9	40	45	1254/42.5 1255/45.0	14-15 SAND
10	45	50	1310/47.5 1311/50.0	
11	50	55	1320/52.5 1321/55.0	15-24 SANDY CLAY
				24-25 SAND
				25-32 SANDY CLAY
				32-45 CLAY
				45-55 SANDY CLAY

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WELL LOGGING FORM

Page 1 of ____

Client GIANT REFINING COMPANY Well Number ~~SMW-8~~ = SMW-

___ ¼ ___ ¼ ___ ¼ ___ ¼ S ___ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 10/3/85 Completion Date ____

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation 6879.45 Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

COMPLETED AS SMW-6

Depth	Litho	Recov	RUN	From	To	Sample#/Ft	Lith/Remarks
			1	0	5.	0815/4'	0-3' SOIL; gry rd (5R 4/2) cly loam, Roots
			2	5	10	0820/10'	3-10' CLAY; dk rd brn (10R 3/4), ≤5% silt
			3	10	15	0825/15'	10-14 SANDY CLAY; gry rd (10R 4/2), cly w/ 10-20%
			4	15	20	0830/20'	vfg sd & silt
			5	20	25	0835/25'	14-15 SAND; pale rd (10R 6/2) - gry rd (10R 4/2);
			6	25	30	0840/30'	fg-mg, mod sort, subrnd, Q+F±Lv
			7	30	35	0845/35'	15-28 SANDY CLAY; gry rd (10R 4/2), cly w/10-15%
			8	35	40	1015/40	vfg sd & silt; irreg lam bdg 0-2°/core
			9	40	45	1025/45	28-36 SAND; gry rd (10R 4/2) - mod rd brn (10R 4/6)
			10	45	50	1030/50	vfg-fg, mod sort, subrnd, Q+F+Lv, local
			11	50	55	1035/55	thin cly interbeds
			12	55	60	1045/60	
			13	60	65	1101/62.5	Wet sand @62.5
			14	65	70	No Sample	36-61 CLAY; dk rd brn (10R 3/4); ≤5% vfg
							sd & silt.
							61-63 SAND, WET; mod rd brn (10R 4/6) fg-vfg, poor sort, ≥15% clay
							matrix, some lost recovery, free H_2O, clayey
							@ base
							63-70 clayey SANDSTONE; grn gry (5GY 6/1)-
							gry rd (10R 4/2), vfg sd & silt, clay
							interbeds (laminae), dry, reduction
							spots
							Completed w/ 23' screen & tras @ bottom of

Geoscience Consultants, Ltd.

WELL LOGGING FORM

Page ____ of ____

Client GIANT REFINING COMPANY Well Number SMW-1

___ ¼ ___ ¼ ___ ¼ ___ ¼ S ___ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9/24/85 Completion Date 9/24/85

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation ________ Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth	Litho	Recov	RUN	From	To	Sample#/Ft	Lith/Remarks
0			1	0	5	850924: 1125/4.0'	0.0-4.0 (4.0') SOIL; gry rd (5R 4/2) cly & slt 15.4 + organic matter, loose & dry
5			2	5	10	1130/10.0	4.0 - 9.0 (5.0') ~~Silty~~ CLAY; dk rd brn (10R 3/4) 10.5
10			3	10	15	1135/15.0'	9.4 <5% silt, plastic cly w/ minor roots 9.0 - 23.0 (14.0) SANDY CLAY; gry rd (10R 4/2),
15			4	15	20	1142/20.0'	12.0 clay + 10-25% mg ws sd
20			5	20	25	1147/25.0'	23.0 - 26 (3.0) SAND Med rd brn (10R 4/6); fg 4.0 SANDY ws qtz sd, loose, dry
25			6	25	30	1155/30'	26.0 - 32.0 CLAY, As Above 9.4 32.0 - 42.0 CLAY, As Above
30			7	30	35	1203/32.5', 1204/35.0'	16.5 "clay balls" in cuttings @ 34'
35			8	35	40	1210/37.5' 1211/40.0'	13.8 14.3 16.3 42.0 - 59.0 Sandy CLAY, As Above
40			9	40	45	1222/42.5' 1223/45.0'	12.9 57.5 BGL ≈ 6819 6.2 59.0 - 64.0 SAND; med rd brn (10R 4/6); mg
45			10	45	50	1235/47.5' 1236/50.0'	17.9 ws qtz sd; water sat, sharp up & lower 18.0 contact
50			11			1248/52.5' 1249/55.0'	18.9 20.9 64.0 - 75.0 SANDY CLAY, As Above, wht & green red
55			12			1259/60'	spots NA Free H_2O in sand@ 60'
60			13			1312/64'	18.9 Sat Sand Base H_2O Sand @ 64' on clay
65			14			1315/65' 1328/70'	Sat cly @ 65' 23.4 Sat Clay & 9.6
70			15			1347/75'	soupy cly @ 75, H_2O in cuttings 75': unsat cly & sh 14.2 unsat clay
75			16			1400/80'	11.8
@1400 80							
							75.0 - 78.0 SAND; med rd brn (10R 4/6); m-cg, ws qtz sd, wat sat; sharp upr lower contact w/ cly
							78.0 - 80.0 (TD) clay; As Above, green red spots. dry
							NW Corner, LTA

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WELL LOGGING FORM

Page____of____

Client GIANT REFINING COMPANY Well Number SMX-2

___¼___¼___¼___¼ S___ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9-26-85 Completion Date ____

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation 6883 Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth | Litho | Recov

0
5
10
15
17
20
23
25
30

Sand ~17' [illegible]
~1 - 23'

RUN	From	To	Sample#/Ft	Lith/Remarks
				~ 81' N62E FROM MW-4
			850926	
1	0	5	1015/2.5 1016/5.0	0-2.5' soil light-buff some
2	5	10	1018/7.5 1019/10.0	calcification root" casts silty clay
3	10	15	1023/12.5 1024/15.0	2.5'-9.0' clay red slightly moist very cohesive
4	15	20	1050/17.5 1051/20.0	9.0'-9.1 sand buff fine-med gr crumbly
5	20	25	1059/22.5 1100/25.0	dry 9.1'-~17.0' CLAY; Red, slightly moist, plastic
6	25	30	1112/27.5 1113/30.0	~17.0'-~23.0' SAND (WET) fn-med gr
				23'-30' CLAY: red, slightly moist, plastic
				WATER LEVEL 15'-7" . 1150

Geoscience Consultants, Ltd.

WELL LOGGING FORM

Page______of______

Client GIANT REFINING COMPANY Well Number SMY-3

____¼____¼____¼____¼ S____ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9-26-85 Completion Date______

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation______ Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for $\%H_2O$. Comp. as SS monitor Well

Depth | Litho | recov

0
5
10
15
20
25
30

RUN	From	To	Sample#/Ft	Lith/Remarks
			850926 1214 0.0	
1	0	5	1215/ 2.5 1216/ 5.0	0 - 4.5' SOIL; brn, clayey, sandy soil
2	5	10	1218/ 7.5 1219/ 10.0	4.5 - 28.0 RED CLAY; s dry to slightly
3	10	15	1221/ 12.5 1222/15.0	moist, local reduction nodules
4	15	20	17.5 20.0	28.0-30+ RED SILTY CLAY, as above but more dry
5	20	25	1234/22.5 1235/25.0	
6	25	30	27.5 30.0	

Geoscience Consultants, Ltd.

WELL LOGGING FORM

Page ______ of ______

Client GIANT REFINING COMPANY Well Number SMX-4

____ ¼ ____ ¼ ____ ¼ ____ ¼ S ____ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9-26-85 Completion Date ____________

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation ____________ Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth	Litho	Recov	RUN	From	To	Sample#/Ft	Lith/Remarks
						850926	
0			1	0	5	1325/0.0 1326/2.5 1327/5.0	0-10 shale/clay red slightly moist cohesive
5			2	5	10	1330/7.5 1331/10.0	
10	∇		3	10	15	1335/12.5 1336/15.0	10-15 sand encountered at 10' dry coarse-fn gr low recovery
15			4	15	20	1345/17.5 1346/20.0	water level 15'5"
20			5	20	25	1354/22.5 1355/25.0	18-20 clayey sand (saturated) brn, fn-med gr w/ abundant clay
25	∇		6	25	30	1402/27.5 1403/30.0	W.L. 26'-10 #8509261410
30							22-24 sand; brn, fngr (saturated) w/v. minor clay
							24-25 sandy clay; brn (saturated) w/ silt & fn sand
							25-27.5 sand; fn-med gr (saturated) v. minor clay
							27.5-29 sandy clay (moist) silt & fn sand
							29-30+ silty clay; (dry) reddish brn w/ ~~ss~~ greenish reduction nodules

pH 7.4

Conductance 4850

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WELL LOGGING FORM

Page ____ of ____

Client GIANT REFINING COMPANY Well Number SMX- 5

____ ¼ ____ ¼ ____ ¼ ____ ¼ S ____ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 9-26-85 Completion Date ____

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation ____ Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth	Litho	Recov	RUN	From	To	Sample#/Ft	Lith/Remarks
0 5			1	0	5	1444/ 0.0 1445/ 2.5 1446/ 5.0	0-0.5 Sand; lt brn, fn-med gr w/ minor clay
10			2	5	10	1453/ 7.5 1454/10.0	0.5-20.0+ clay; reddish brn, slightly moist plastic clay w/ minor amounts of reduction nodules increasing w/ depth
15			3	10	15	1500/12.5 1601 15.0	
20			4	15	20	1610/17.5 1611/20.0	
25							
30							

Samples labeled SMW-5 → ~~SMW-5~~ = SMX-6

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WELL LOGGING FORM

Page____of____

Client GIANT REFINING COMPANY Well Number SMX-6

__¼__¼__¼__¼ S__ T 15 N R 15 W State New Mexico

County McKinley Contractor Fox

Spud Date 10/1/85 Completion Date 10/1/85

Logs Run Lith from Cores Logged By J.C. Hunter

Elevation____ Spud In (Fm.) Chinle

Remarks Drilled w/Hollow Stem Auger & Continuous Sampler. Collected samples @ 2.5 and 5.0' intervals for %H_2O. Comp. as SS monitor Well

Depth	Litho	Recov	RUN	From	To	Sample#/Ft	Lith/Remarks
							Renumbered SMX-6; open borehole, not
-7/5 1105 0						851001:	completed
5			1	0	5	1118/ 4.0	0-4.0' SOIL; gry rd (10R 4/2); clayey loam w/ roots
10			2	5	10	1114/ 10.0	4.0 - 12.5' CLAY; dk rd brn (10R/3/4); v soft
15			3	10	15	1120/ 15.0	& plastic; ≤ 5% silt
20			4	15	20	1124/ 20.0	12.5-20.0 SANDY CLAY; gry rd (5R 4/2); clay
25			5	20	25	1128/25.0	w/ 10-25% fg sand; faint wavy discont. lam bdd 0°-3°/core
30			6	25	30	1135/30.0	
35			7	30	35	1140/55.0	20-22.0 SAND; gry rd (10R 4/2), cg-fg, poor
40			8	35	40	1148/40.0	sort, qtz + volc R.F. + K-spar ± plag; subrnd
Lunch 1200 - 1250 45			9	40	45	1159/45.0	22-33 SANDY CLAY; pale rd brn (10R 5/4);
50			10	45	50	1255 /50.	cly w/ 15-25% f g sand; faint wavy
			11	50	55	1306/55.	to discont lam bdd 0°-3°/core
			12	55	60	1325/60.0	33-36 SAND; gry rd (10R 4/2) - pale rd brn
			13	60	65	1345/65.0	(10R 5/4) fg-vfg; poor sort, subang-
Ref Auger @ 68 1405			14	65	68	1359/68.0	subrnd; Qtz + feldspars
							36-57 CLAY; dk rd brn (10R 3/4); ≤ 2%
							silt; no reduction spots
							57-66 SANDY CLAY; gry rd (5R 4/2) - dsky rd
							(5R 3/4), locally mod brn (5YR 4/4); 10-
							20% vfg sd
							66-68 SANDSTONE; pale olive (10Y 6/2) - lt grn
							gry (5GY 8/1).

Geoscience Consultants, Ltd.

WELL LOGGING FORM

Page_____ of _____

Client Giant Well Number SMX-7

____ ¼ ____ ¼ ____ ¼ ____ ¼ S____ T____ R____ State_____

County_____ Contractor_____

Spud Date_____ Completion Date_____

Logs Run_____ Logged By_____

Elevation_____ Spud In (Fm.)_____

Remarks Samples labeled SMW-6; 30' W of SP-2

Depth Litho recov

0-4.0 Soil; gry rd (10R 4/2), cly loam

4.0-9.0 CLAY: dk rd brn (10R 3/4), plastic w/ ≤10% silt

9.0-13.0 SAND: gry rd (5R 4/2); mg-fg, mod-poor sort,
subang, Q ± F, Lo

13.0-20.0 CLAY; dk rd brn (10R 3/4), plastic, 10-15% silt

20.0-23.0 SAND: pale rd brn (10R 5/4); fg, subang, mod sort,
Q, ± Lo, F

23.0-26.0 CLAY: dk rd brn (10R 3/4), <5% silt

26.0-27.0 SAND: pale rd brn (10R 5/4) - gry rd (5R 4/2),
vfg-fg, mod sort, subang,

27-28 CLAY, dk rd brn (10R 3/4)

28-29 SAND; as above

29-31 CLAY; as above, moist

31-35 SAND: WET; pale rd brn (10R 5/4) fg-vfg
mod sort, Q + F + Lo

35-40 CLAY: dk rd brn (10R 3/4), ≤10% silt

40-45 CLAY: as above, dry

45-47 SAND:, pale rd brn (10R 5/4), vfg, dry

47-49 PEBBLE CONGLOMERATE: lt grn gry (5GY 8/1) in
clay matrix, pale rd brn (10R 5/4); chert and ss
pebbles 1/4"-1 1/2" in clay matrix, reduction spots

49-60 ~~Re~~ ~~Re~~ CLAY; as above

60-67 CLAYEY SILTSTONE: pale rd brn (10R 5/4)

67-70 SILTY SANDSTONE: gry rd (10R 4/2) & pale
yel grn (10GY 7/

Giant 950

ASSAIGAI
ANALYTICAL
LABORATORIES

TO: GeoScience Consultants
500 Copper N.W. Suite 325
Albuquerque,NM 87102

DATE: 9 October 1985
1402
Page 1 of 2

ANALYTE: % Moisture

SAMPLE ID	ANALYTICAL RESULTS
85-09-25 1415 SMW-3 4.0'	8.3
85-09-25 1320 SMW-2 52.5'	18.1
85-09-25 1426 SMW-3 15.0'	13.5
85-09-25 1321 SMW-1 55.0'	15.0
85-09-25 1458 SMW-3 37.5'	17.3
85-09-25 1445 SMW-3 27.5'	8.6
85-09-25 1438 SMW-3 25.0'	9.6
85-09-25 1446 SMW-3 30.0'	5.3
85-09-25 1459 SMW-3 40.0'	14.5
85-09-25 1311 SMW-3 50.0'	14.9
85-09-25 1452 SMW-3 32.5'	20.7
85-09-25 1453 SMW-3 35.0'	15.3
85-09-25 1056 SMW-2 10.0'	8.4
85-09-25 1235 SMW-2 37.5'	13.3
85-09-25 1236 SMW-2 40.0'	16.2
85-09-25 1420 SMW-3 10.0'	7.4
85-09-25 0927 SMW-1 37.5'	12.6
85-09-25 1050 SMW-2 4.0'	16.9
85-09-25 0928 SMW-1 40.0'	17.9
85-09-25 1141 SMW-2 32.5'	16.9
85-09-25 1126 SMW-2 30.0'	8.1
85-09-25 1310 SMW-2 47.5'	18.0
85-09-25 1142 SMW-2 35.0'	16.3
85-09-25 0913 SMW-1 27.5'	10.8
85-09-25 1432 SMW-3 20.0'	3.6
85-09-25 0920 SMW-1 35.0'	15.0
85-09-25 1114 SMW-2 25.0'	4.5
85-09-25 1254 SMW-2 42.5'	18.5
85-09-25 0914 SMW-1 30.0'	7.1
85-09-25 0919 SMW-1 32.5'	13.0
85-09-25 1255 SMW-2 45.0'	3.6
85-09-25 0959 SMW-1 52.5'	15.0
85-09-25 1102 SMW-2 15.0'	7.2
85-09-25 0859 SMW-1 20.0'	8.4
85-09-25 0847 SMW-1 10.0'	5.4
85-09-25 0906 SMX-1 25.0'	4.3
85-09-25 0936 SMW-1 42.5'	20.0
85-09-25 0937 SMW-1 45.0'	14.3
85-09-25 0951 SMW-1 50.0'	13.3
85-09-25 0840 SMW-1 4.0'	11.9

TO: GeoScience Consultants
500 Copper N.W. Suite 325
Albuquerque,NM 87102

DATE: 9 October 1985
1402
Page 2 of 3

ANALYTE: % Moisture

SAMPLE ID	ANALYTICAL RESULTS
85-09-25 0950 SMW-1 47.5'	5.8
85-09-25 0852 SMX-1 15.0'	11.0
85-09-25 1106 SMW-2 20.0'	7.0
85-09-25 1000 SMW-1 55.0'	20.0
85-09-26 1112 SMX-2 27.5'	24.1
85-09-26 1215 SMX-3 2.5'	5.6
85-09-26 1446 SMX-5 5.0'	15.5
85-09-26 1250 SMX-3 27.5'	14.8
85-09-26 1251 SMX-3 30.0'	11.5
85-09-26 1336 SMX-4 15.0'	2.7
85-09-26 1100 SMX-2 25.0'	21.4
85-09-26 1327 SMX-4 5.0'	20.5
85-09-26 1501 SMX-5 15.0'	17.8
85-09-26 1500 SMX-5 12.5'	13.0
85-09-26 1234 SMX-3 22.5'	14.2
85-09-26 1214 SMX-3 0.0	7.9
85-09-26 1445 SMX-5 2.5'	15.3
85-09-26 1216 SMX-3 5.0'	14.3
85-09-26 1403 SMX-4 30.0'	17.5
85-09-26 1444 SMX-5 0.0	6.8
85-09-26 1354 SMX-4 22.5'	20.8
85-09-26 1335 SMX-4 12.5'	4.2
85-09-26 1510 SMX-5 17.5'	16.8
85-09-26 1511 SMX-5 20.0'	16.3
85-09-26 1355 SMX-4 25.0'	11.0
85-09-26 1345 SMX-4 17.5'	20.8
85-09-26 1219 SMX-3 10.0'	14.7
85-09-25 1218 SMX-3 7.5'	14.8
85-09-26 1453 SMX-5 7.5'	15.4
85-09-26 1454 SMX-5 10.0'	19.4
85-09-26 1331 SMX-4 10.0'	16.2
85-09-26 1402 SMX-4 27.5'	20.8
85:09-26 1346 SMX-4 20.0'	24.4
85-09-26 1051 SMX-2 20.0'	17.5
85-09-26 1113 SMX-2 30.0'	18.4
85-09-26 1050 SMX-2 17.5'	18.1
85-09-26 1222 SMX-3 15.0'	17.3
85-09-26 1221 SMX-3 12.5'	16.0
85-09-26 1325 SMX-4 0.0'	26.8
85-09-26 1059 SMX-2 22.5'	23.1
85-09-26 1235 SMX-3 25.0'	13.8
85-09-26 1330 SMX-4 7.5'	20.7
85-09-26 1326 SMX-4 2.5'	18.6

TO: GeoScience Consultants

1402
Page 3 of 3

ANALYTE: % Moisture

SAMPLE ID	ANALYTICAL RESULTS
SMX-2 1015	14.6
SMX-2 1018	19.5
SMX-2 1019	11.3
SMX-2 1023	21.2
SMX-2 1024	21.5
SMX-3 20'	15.6
SMX-3 17.5'	18.3

REFERENCE: "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", USEPA, SW 846, EMSL-Cincinnati, 1982.

An invoice for services is enclosed. Thank you for contacting Assaigai Laboratories.

Sincerely,

Jennifer V. Smith

Jennifer V. Smith, Ph.D.
Laboratory Director

TO: GeoScience Consultants

ANALYTE: % Moisture

SAMPLE ID	ANALYTICAL RESULTS
SMX-2 1015 2.5'	14.6
SMX-2 1018 7.5'	19.5
SMX-2 1019 10.0'	11.3
SMX-2 1023 12.5'	21.2
SMX-2 1024 15.0'	21.5
SMX-3 20'	15.6
SMX-3 17.5'	18.3

REFERENCE: "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", USEPA, SW 846, EMSL-Cincinnati, 1982.

An invoice for services is enclosed. Thank you for contacting Assaigai Laboratories.

Sincerely,

Jennif V. Smith

Jennifer V. Smith, Ph.D.
Laboratory Director

ASSAIGAI
ANALYTICAL
LABORATORIES

TO: GeoScience Consultants
500 Copper N.W. Suite 325
Albuquerque,NM 87102

DATE: 9 October 1985
1463

ANALYTE: % Moisture

SAMPLE ID	ANALYTICAL RESULTS
SMW-6 85-10-04 1002 5'	11.5
SMW-6 85-10-04 1017 15'	15.3
SMW-6 85-10-04 1039 25'	17.6
SMW-6 85-10-04 1111 35'	16.5
SMW-6 85-10-04 1145 45'	13.9
SMW-2 1016 5'	17.7
SMW-1 85-09-27 1301 65'	19.5
SMW-3 85-09-27 0841 45'	14.5

REFERENCE: "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods", USEPA, SW 846, EMSL-Cincinnati, 1982.

An invoice for services is enclosed. Thank you for contacting Assaigai Laboratories.

Sincerely,

Jennifer V. Smith

Jennifer V. Smith, Ph.D.
Laboratory Director

7300 Jefferson, N.E. • Albuquerque, New Mexico 87109 • (505) 345-8964

App. B

APPENDIX B
SOIL PROPERTIES

Typical profile of Mirabal stony loam, in a steep, south-facing area under ponderosa pine, grass, and forbs; SW¼ sec. 21, T. 11 N., R. 12 W., Valencia County:

O1&O2—½ inch to 0, loose mat of pine needles and grass, in various stages of decomposition.

A1—0 to 5 inches, grayish-brown (10YR 5/2) stony loam, very dark grayish brown (10YR 3/2) when moist; weak to moderate, fine, granular structure; soft when dry, very friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 6.0; 25 to 30 percent stones; clear, smooth boundary.

AC—5 to 12 inches, pale-brown (10YR 6/3) stony sandy loam, brown (10YR 4/3) when moist; weak, fine, subangular blocky structure breaking to fine, granular structure; slightly hard when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 6.4; 45 to 55 percent gravel, cobblestones, and stones; clear, slightly wavy boundary.

C—12 to 18 inches, pale-brown (10YR 6/3) gravelly sandy loam, brown (10YR 4/3) when moist; weak, fine, subangular blocky structure, or massive; slightly hard when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 6.4; about 10 percent more gravel and cobblestones than in the AC horizon; gradual boundary.

R—18 inches +, hard, somewhat shattered and fractured granite; some soil material in fractures.

The depth to bedrock ranges from 15 to 22 inches. The texture of the surface layer may be stony loam, gravelly sandy loam, or stony sandy loam.

Supervisor Series

The Supervisor series consists of shallow to moderately deep, well-drained soils on steep, north-facing slopes. These soils occur at elevations of 8,600 to 9,200 feet, where the annual precipitation is 20 to 25 inches and the average annual temperature is about 42° F. The slope range is 20 to 45 percent, and slopes of more than 30 percent are common. The parent material weathered from granite and granitic gneiss. The vegetation is mainly Douglas-fir, limber pine, ponderosa pine, and grass.

Although Supervisor soils are classified as Lithosols, they have some characteristics of Brown Forest soils.

The Supervisor soils are associated with the Mirabal soils. Generally, they are darker colored, less stony, and deeper than those soils. They have a thicker layer of litter and more organic matter in their surface layer.

Typical profile of Supervisor stony loam, on a north-facing slope, under a cover of Douglas-fir, limber pine, and ponderosa pine; SW¼ sec. 21, T. 11 N., R. 12 W., Valencia County:

O1—2 inches to 0, loose mat of fir and pine needles, in various stages of decomposition; pH 6.2.

A11—0 to 0 inches, dark grayish-brown (10YR 4/2) stony loam, very dark brown (10YR 2/2) when moist; weak to moderate, fine, granular structure; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; noncalcareous; pH 6.3; 20 percent stones; clear, smooth boundary.

A12—4 to 10 inches, grayish-brown (10YR 5/2) stony gravelly loam, dark brown (10YR 3/3) when moist; moderate, fine, granular structure; soft when dry, very friable when moist, slightly sticky and slightly plastic when wet; noncalcareous; pH 6.4; 25 to 30 percent angular gravel and stones; clear, wavy boundary.

AC—10 to 16 inches, brown (10YR 5/3) gravelly loam, dark brown (10YR 4/3) when moist; weak, fine, granular structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; noncalcareous; pH 5.8; 30 to 40 percent gravel and stones; gradual boundary.

C—16 to 22 inches, yellowish-brown (10YR 5/4) stony and gravelly sandy loam, dark yellowish brown (10YR 4/4) when moist; massive; slightly hard when dry, friable when moist, nonsticky and nonplastic when wet; noncalcareous; pH 5.9; 45 to 55 percent gravel and stones; gradual boundary.

R—22 inches +, hard, somewhat shattered granitic rock; some soil material in fractures.

The texture of the surface layer may be sandy loam, gravelly sandy loam, stony loam, or gravelly loam. The depth to shattered and fissured granite is 18 to 22 inches in most places, but it may be as little as 12 or as much as 30 inches. The deeper soils occur in pockets on benches.

REGOSOLS

Regosols consist of deep, unconsolidated material in which few or no clearly expressed soil characteristics have developed. The Regosol great soil group is represented in the Zuni Mountain Area by the Montoya, Thurloni, and Valentine soils. The Montoya and Thurloni soils formed in material weathered from red, clayey shale. The Valentine soils developed in wind-deposited sandy material. The Montoya and Thurloni soils have better horizon expression than the Valentine soils.

Montoya Series

The Montoya series consists of deep, well-drained, level or nearly level soils on flood plains and alluvial fans and in swales. These soils occur at elevations of 6,800 to 7,200 feet, where the annual precipitation is 15 to 18 inches and the average annual temperature is about 47° F. They formed in alluvium washed from shale of the Chinle formation. Grass and shrubs make up most of the vegetation, but at the higher elevations Gambel oak and pinyon pine grow also.

These soils are characterized by a granular A horizon, a prismatic to blocky B2 horizon, and a thick C horizon.

The Montoya soils are associated with McGaffey, Trail, and Concho soils. They are finer textured than the McGaffey and Trail soils, and they have slower permeability. They are redder than the Concho soils.

Typical profile of Montoya clay, in a grassy area; SW¼NE¼ sec. 19, T. 12 N., R. 15 W., Valencia County:

A1—0 to 9 inches, weak-red (2.5YR 4/2) light clay, dusky red (2.5YR 3/2) when moist; strong, fine and medium, granular structure; uppermost 3 inches has strong, very fine, granular structure; hard when dry, firm when moist, sticky and plastic when wet; abundant fine roots; calcareous; pH 8.2; gradual boundary.

B2—9 to 27 inches, weak-red (2.5YR 4/2) clay, dusky red (2.5YR 3/2) when moist; weak, medium, prismatic structure breaking to strong, medium, angular blocky; very hard when dry, very firm when moist, very sticky and very plastic when wet; strongly calcareous; pH 8.2; gradual, wavy boundary.

C—27 to 52 inches +, weak-red (2.5YR 4/2) clay, dusky red (2.5YR 3/2) when moist; extremely hard when dry, very firm when moist, very sticky and very plastic when wet; some slickensides; strongly calcareous; pH 8.2.

The colors of these soils range from 5YR to 10R in hue. In most places the profile is calcareous throughout, but in some places the surface layer is noncalcareous. In places also, the B and C horizons contain fine gravel, and in some the texture of the B horizon is silty clay.

TABLE 11.—*Engineering interpretations*

Soil series and map symbol	Suitability for use as—		Suitability as a source of—			Suitability for—					
	Subgrade	Subbase	Topsoil	Sand and gravel for subgrade	Rock	Stock tanks and reservoirs		Terraces and diversions	Water spreading	Range pitting and chiseling	Waterways
						Embankment	Reservoir area				
Andrews (Ag)	Fair	Poor	Poor; gravelly	Unsuitable	Good for limestone	Fair to poor	Poor; too shallow	Poor; too shallow	Unsuitable	Unsuitable	Poor.
Badland (Ba)	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
Bandera (Bd, Bg)	Fair	Poor	Poor	Poor; good source of cinders.	Poor	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
Bond (Bo)	Fair	Fair to poor	Poor	Unsuitable	Good for sandstone	Fair	Poor; shallow and rocky.	Poor	Unsuitable	Unsuitable	Unsuitable.
Cabezon (Ca)	Fair	Poor	Good	Unsuitable	Good for basalt	Fair	Poor; too shallow	Fair, but soil is shallow.	Poor; too stony	Poor; too rocky for equipment to be used.	Poor.
Clayey alluvial land (Cb)	Poor	Poor	Good	Unsuitable	Unsuitable	Fair	Good	Good	Good	Good	Good, but should be vegetated.
Concho (Cc, Co)	Fair to poor	Poor	Good	Unsuitable	Unsuitable	Good	Good	Good	Good	Good	Good.
Fortwingate (Fo)	Fair	Fair to poor	Good	Unsuitable	Fair for sandstone	Good; compacts easily.	Good	Good	Good	Good	Good.
Friana (Fr)	Fair	Poor	Good	Unsuitable	Unsuitable	Fair	Good	Good	Good	Good	Good, but protection against erosion needed.
Gem (Gm)	Fair	Poor	Good	Unsuitable	Fair for basalt	Fair	Good	Good	Good; gentle slopes	Good	Good; erosion hazard low.
Jekley (Je, Jk, Jr)	Good to fair	Fair to poor	Good (Je); poor (Jk, Jr).	Unsuitable	Fair for fine-grained sandstone.	Fair to poor; not much soil material.	Fair to poor (Je, Jk); unsuitable (Jr); shallow.	Good, but poor on steep slopes.	Fair (Je, Jk); unsuitable (Jr); shallow.	Poor (Je, Jk); unsuitable (Jr); too shallow.	Fair to unsuitable.
Kettner (Ke, Kn)	Good	Fair	Poor	Unsuitable	Fair to good for schist.	Fair to good; compacts well.	Poor; too shallow; rapidly permeable.	Good	Fair	Fair	Fair; protection against erosion needed.
Kiln (Kr, Kx)	Poor to fair	Poor	Poor; too rocky	Unsuitable	Good for limestone	Poor; not much soil material.	Unsuitable; too shallow to limestone.	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
Laporte (La, Lp)	Good to fair	Fair to poor	Poor; too stony	Unsuitable	Good for limestone	Poor; not much soil material.	Poor; shallow; limestone is fissured.	Poor; too stony	Unsuitable	Unsuitable	Fair to unsuitable, depending on slope.
Larry (Lr)	Poor	Poor	Good	Unsuitable	Unsuitable	Poor; too clayey	Good	Good	Good, but subsoil is slowly permeable.	Good	Good.
Lava flows (Ls)	Poor	Unsuitable	Unsuitable	Unsuitable	Good for basalt	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
Lava rock land (Lv)	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Good for basalt	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
McGaffey (Ma)	Fair	Poor	Good	Unsuitable	Unsuitable	Good	Good, but stratified	Good	Good	Good	Good, but will headcut.
Mirabal (Mb, Mm, Mn, Zm)	Good	Fair to poor	Fair (Mb, Mm, Mn); poor (Zm).	Unsuitable	Good for granite	Fair (Zm); poor, must be compacted (Mb, Mm, Mn).	Poor because too shallow (Zm); unsuitable (Mb, Mm, Mn).	Fair to poor; shallow and steep.	Fair (Zm); unsuitable (Mb, Mm, Mn).	Fair (Zm); unsuitable (Mb, Mm, Mn).	Fair (Zm); unsuitable (Mb, Mm, Mn).
Montoya (Mo)	Poor	Poor	Poor	Unsuitable	Unsuitable	Poor; hard to compact.	Good; slow permeability.	Good	Good	Good, but slow permeability.	Good, but erodes easily.
Nathrop (Na)	Fair	Fair to poor	Fair	Unsuitable	Good for limestone	Fair to good	Poor; shallow	Fair to good	Fair to good	Fair to good	Fair, but erodes easily.
Ordnance (Od)	Fair to poor	Poor	Poor	Unsuitable	Poor	Poor; material dispersed.	Fair; shallow	Poor; unstable	Poor; dispersed	Fair, but unstable	Poor; erodes easily.
Osoridge (Or, Ox)	Fair	Poor	Poor	Unsuitable	Good for sandstone	Poor; too shallow and rocky.	Unsuitable; too shallow and rocky.	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
Polich (Po)	Fair	Poor	Good	Unsuitable	Unsuitable	Good	Good	Good	Good	Good	Good, but should be vegetated.
Prewitt (Pr)	Fair to poor	Poor	Fair to poor	Unsuitable	Unsuitable	Poor; hard to compact.	Good; slow permeability.	Good	Good	Good, but slow permeability.	Good, but erodes easily.
Rock land (Rk)	Poor	Unsuitable	Unsuitable	Unsuitable	Good for sandstone	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
Rock outcrop, gently sloping (Ro).	Poor	Unsuitable	Unsuitable	Unsuitable	Good for sandstone and granite.	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
Rock outcrop, cliffs (Rp)	Poor	Unsuitable	Unsuitable	Unsuitable	Good for sandstone and limestone.	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable.
Sanchez (Sa)	Good to fair	Fair to poor	Poor	Unsuitable	Fair	Poor	Poor; too shallow	Poor; too shallow	Unsuitable; erodes easily.	Unsuitable	Unsuitable.
Savoia (Sb, Sf)	Good to fair	Fair	Good	Fair	Unsuitable	Good	Good to fair	Good	Good	Good	Good, but should be vegetated.
Showlow (Sh, Sm)	Fair to poor	Poor	Fair	Unsuitable	Poor; shale	Poor; disperses; may pipe and slough.	Good to fair	Poor; unstable	Poor; erodes easily	Fair, but unstable	Poor; erodes easily.
Supervisor (Su)	Good	Fair	Good	Unsuitable	Good; granite	Good, but should be compacted.	Unsuitable	Fair; shallow; steep.	Unsuitable	Unsuitable	Unsuitable.
Tabiona (Ta)	Good to fair	Fair to poor	Fair	Unsuitable	Unsuitable	Good	Good	Good	Good	Good	Fair.

TABLE 10.—*Brief descriptions of the soils and their estimated physical and chemical properties*—Continued

Map symbol	Soil name	Description	Depth from surface	Classification			Permeability	Reaction	Dispersion	Shrink-swell potential
				USDA texture	Unified[1]	AASHO[2]				
			Inches				*Inches per hour*	*pH*		
Lr	Larry silty clay loam (2 to 5 percent slopes).	Silty clay loam over heavy clay that grades to silty clay underlain by gravelly clay loam; on meadow lands.	0 to 6 6 to 19 19 to 23 23 to 44+	Silty clay loam Clay Silty clay Gravelly clay loam	CL–ML CH CL–CH CL–ML	A–6 or A–7 A–7 A–7 A–6 or A–7	0.05 to 0.5 0.05 0.05 0.05 to 0.5	6.4 to 7.4 6.2 to 7.4 6.6 to 7.4 6.6 to 7.8	Low High High Moderate	Moderate. High. High. High.
Ls	Lava flows.	Recent lava flows; rough broken surface. No estimates of properties given, because nature of area precludes proper appraisal.								
Lv	Lava rock land.	Mixture of lava flows and pockets and basins of soil. No estimates of properties given, because nature of area precludes proper appraisal.								
Ma	McGaffey loam (1 to 3 percent slopes).	Loam over silt loam that grades to sandy clay loam to clay; bedrock at a depth of more than 10 feet; on alluvial fans and flood plains.	0 to 6 6 to 18 18 to 51 51 to 56	Loam Silt loam Sandy clay loam Clay	ML ML SC CL	A–4 A–4 or A–6 A–6 A–6	0.5 to 2.5 0.5 to 2.5 0.5 to 2.5 0.05 to 0.5	7.2 to 7.8 7.4 to 8.4 7.8 to 8.6 7.8 to 8.6	Low Moderate Moderate Moderate	Low. Moderate. Moderate. High.
Mb Mm	Mirabal stony loam, 5 to 15 percent slopes. Mirabal stony loam, 15 to 45 percent slopes.	Stony loam and stony sandy loam; underlain by granite and gneiss at a depth of 1 to 2 feet; Mb on ridgetops and very shallow.	0 to 5 5 to 18	Stony loam Stony loam and stony sandy loam	SM SM	A–4 A–4	2.5 to 7.5 2.5 to 7.5	5.8 to 6.4 6.0 to 6.8	Low Low	Low. Low.
Mn	Mirabal stony loam, low rainfall, 5 to 20 percent slopes.	Stony loam and stony sandy loam underlain by granite and gneiss at a depth of 1 to 2 feet.	0 to 5 5 to 18	Stony loam Stony loam and stony sandy loam	SM SM	A–4 A–4	2.5 to 7.5 2.5 to 7.5	5.8 to 6.4 6.0 to 6.8	Low Low	Low. Low.
Mo	Montoya clay (0 to 3 percent slopes).	Clay, silty clay, and gravelly clay on flood plains and in basins; bedrock at a depth of 5 feet or more.	0 to 3 3 to 40 40 to 62	Clay Clay Silty clay	CH CH CH	A–7 A–7 A–7	0.05 0.05 0.05	7.8 to 8.6 7.8 to 8.8 7.8 to 8.8	High High Moderate	High. High. High.
Na	Nathrop loam, 0 to 5 percent slopes.	Loam over clay loam; underlain by limestone at a depth of 16 inches or more.	0 to 5 5 to 16	Loam Clay loam	ML ML–CL	A–6 A–6 or A–7	0.5 to 2.5 0.05 to 0.5	7.4 to 8.2 7.4 to 8.6	Moderate Moderate	Low. Moderate.
Od	Ordnance loam (5 to 15 percent slopes).	Loam and gravelly loam over clay underlain by mixture of clay, sandstone, and shale; bedrock at a depth of 2 to 4 feet.	0 to 4 4 to 8 8 to 30 30 to 36	Loam and gravelly loam Sandy clay loam Clay Shaly clay	ML ML CL–CH CL–CH	A–6 A–6 A–6 or A–7 A–6 or A–7	0.5 to 2.5 0.05 to 0.5 0.05 0.05	6.2 to 6.6 6.2 to 6.8 6.2 to 8.2 7.8 to 8.6	High High High High	Moderate. High. High. High.
Or Ox	Osoridge rocky complex, 5 to 20 percent slopes. Osoridge rocky complex, 20 to 40 percent slopes.	Shallow stony sandy loam over clay; sandstone at a depth of 1 to 2 feet; much outcropping rock.	0 to 5 5 to 9 9 to 18	Stony sandy loam Stony light clay Heavy clay	SC ML CH	A–4 A–6 A–7	2.5 to 7.5 0.5 to 2.5 0.05	6.0 to 6.6 5.8 to 6.4 5.8 to 6.6	Low High High	Low. High. High.
Po	Polich loam (0 to 2 percent slopes).	Loam over silt loam to sandy clay loam underlain by clay; bedrock at a depth of more than 5 feet; on bottom lands; seasonal water table.	0 to 6 6 to 18 18 to 51 51 to 56+	Loam Silt loam Sandy clay loam Clay	ML ML SC CL	A–4 A–4 or A–6 A–6 A–7	0.5 to 2.5 0.5 to 2.5 0.05 to 0.5 0.05	7.2 to 7.8 7.6 to 8.4 7.6 to 8.6 7.6 to 8.6	Low Moderate Moderate Moderate	Moderate. Moderate. Moderate. High.
Pr	Prewitt clay loam (0 to 5 percent slopes).	Stratified clay loam over silty clay loam underlain by clay; bedrock at a depth of more than 5 feet; on alluvial fans and flats.	0 to 4 4 to 9 9 to 13 13 to 33 33 to 50+	Clay loam Silty clay loam Heavy clay loam Silty clay Clay	CL–ML CL–ML CL–CH CH CH	A–6 or A–7 A–6 or A–7 A–7 A–7 A–7	0.05 to 0.5 0.05 to 0.5 0.05 to 0.5 0.05 0.05	7.6 to 8.6 7.6 to 8.6 7.6 to 8.6 7.4 to 8.8 7.4 to 8.8	High High High High High	High. High. High. High. High.
Rk	Rock land.	Mixture of rock outcrop and shallow to deep soils; bedrock generally at a depth of less than 1 foot. No estimates of properties given, because nature of area precludes proper appraisal.								
Ro	Rock outcrop, gently sloping.	Bare rock. No estimates of properties given, because nature of area precludes proper appraisal.								
Rp	Rock outcrop, cliffs.	Rock outcrop on escarpments and steep walls of canyons. No estimates of properties given, because nature of area precludes proper appraisal.								
Sa	Sanchez stony complex, 10 to 20 percent slopes.	Mixture of shallow stony sandy loams, stony clay loams, and sandstone outcrop; bedrock at a depth of 1 to 2 feet.	0 to 2 2 to 17	Stony sandy loam Sandy clay loam or clay loam	SM SC–CL	A–4 A–6 or A–7	2.5 to 7.5 0.5 to 2.5	6.2 to 7.0 6.6 to 7.4	High Moderate	Low. Moderate.

See footnotes at end of table.

TABLE 9.—*Hydrologic factors, erodibility classification, and erosion hazard*

[Dashed lines indicate that no rating was assigned]

Map symbol	Soil	Infiltration [1]	Permeability [1] of least pervious layer	Space for water storage [2]	Runoff potential (water yield) [3]	Hydrologic group [4]	Erodibility [5]	Erosion hazard [6]
Ag	Andrews gravelly loam, 5 to 20 percent slopes	Moderate	Slow	Low	Medium	C	Moderate	Moderate.
Ba	Badland	---	---	---	---	---	---	---
Bd	Bandera gravelly loam, 5 to 15 percent slopes	Rapid	Moderate	Low	Low	A	Moderate	Low.
Bg	Bandera gravelly loam, 15 to 35 percent slopes	Rapid	Moderate	Low	Low	A	Moderate	High.
Bo	Bond sandy loam, 5 to 15 percent slopes	Rapid	Slow	Medium	High	C	Moderate	High.
Ca	Cabezon rocky complex, 2 to 10 percent slopes	Moderate	Slow	Low	Medium	D	Moderate	Low.
Cb	Clayey alluvial land (0 to 2 percent slopes)	Moderate	Slow	Medium	Low	C	Moderate	Moderate.
Cc	Concho clay loam, 1 to 3 percent slopes	Moderate	Slow	High	Low	D	Moderate	Moderate.
Co	Concho clay loam, 3 to 10 percent slopes	Moderate	Slow	High	Low	D	Moderate	Moderate.
Fo	Fortwingate loam, 2 to 8 percent slopes	Rapid	Slow	High	Low	C	High	Moderate.
Fr	Friana silt loam (1 to 3 percent slopes)	Moderate	Slow	High	Medium	C	High	Moderate.
Gm	Gem stony loam, 2 to 7 percent slopes	Moderate	Slow to very slow.	Medium	Medium	C	Moderate	Low.
Je	Jekley silt loam, 3 to 7 percent slopes	Rapid	Slow	Low to medium.	Low	C	High	Low.
Jk	Jekley stony loam, 10 to 30 percent slopes	Rapid	Slow	Low	Medium	C	High	High.
Jr	Jekley rocky complex, 30 to 40 percent slopes	Moderate	Slow	Low	High	C	High	High.
Ke	Kettner loam, 3 to 10 percent slopes	Moderately rapid.	Moderate	Medium to low.	Low	B	High	Moderate.
Kn	Kettner stony loam, 10 to 20 percent slopes	Moderate	Moderate	Low	High	D	High	High.
Kr	Kiln rocky complex, 3 to 20 percent slopes	Moderate	Moderate	Low	Medium	D	Moderate	Moderate.
Kx	Kiln rocky complex, 20 to 40 percent slopes	Moderate	Moderate	Low	High	D	Moderate	High.
La	Laporte stony loam, 3 to 10 percent slopes	Moderate	Moderate	Low	Medium	B	Moderate	High.
Lp	Laporte stony loam, 20 to 40 percent slopes	Moderate	Moderate	Low	Medium	B	Moderate	High.
Lr	Larry silty clay loam (2 to 5 percent slopes)	Moderate	Slow	High	Medium	D	Low	Low.
Ls	Lava flows	---	---	---	---	---	---	---
Lv	Lava rock land	---	---	---	---	---	---	---
Ma	McGaffey loam (1 to 3 percent slopes)	Rapid	Moderate	High	Medium	B	Moderate	Moderate.
Mb	Mirabal stony loam, 5 to 15 percent slopes	Rapid	Moderate to rapid.	Low	Medium	A	High	Moderate.
Mm	Mirabal stony loam, 15 to 45 percent slopes	Rapid	Moderate to rapid.	Medium	Low	B	High	High.
Mn	Mirabal stony loam, low rainfall, 5 to 20 percent slopes.	Rapid	Moderate to rapid.	Low	High	D	High	High.
Mo	Montoya clay (0 to 3 percent slopes)	Moderate	Slow to very slow.	Medium	Low	D	High	High.
Na	Nathrop loam, 0 to 5 percent slopes	Moderate	Moderate	Low to medium.	Low	C	Moderate	Moderate.
Od	Ordnance loam (5 to 15 percent slopes)	Slow	Slow	Low	Medium	D	High	High.
Or	Osoridge rocky complex, 5 to 20 percent slopes	Rapid	Slow	Low	High	D	High	High.
Ox	Osoridge rocky complex, 20 to 40 percent slopes	Rapid	Slow	Low	High	D	High	High.
Po	Polich loam (0 to 2 percent slopes)	Moderate	Slow	High	Medium	C	High	Moderate.
Pr	Prewitt clay loam (0 to 5 percent slopes)	Moderate	Slow to very slow.	Medium	Medium	D	High	High.
Rk	Rock land (5 to 50 percent slopes)	---	---	---	---	---	---	---
Ro	Rock outcrop, gently sloping	---	---	---	---	---	---	---
Rp	Rock outcrop, cliffs	---	---	---	---	---	---	---
Sa	Sanchez stony complex, 10 to 20 percent slopes	Moderate	Moderate to slow.	Low	Medium	D	High	High.

APP. C

APPENDIX C

AQUIFER-TEST DATA AND ANALYSES

[illegible]

TEST PUMPING OF CHINLE SHALE

METHODOLOGY AND DESCRIPTION OF THE TEST

The test consisted of a 5 hour pumping period and a 2 hour recovery period. An air-driven piston pump capable of sustaining pumping rates as low as 10 gallons/hour (0.167 gpm) was used for the test. Water level measurments were taken with an electronic sounder. The well (OW-24) is located approximately 250 feet northwest of the land treatment facility and is completed within the Chinle shale. The lithologic and completion log of the well is attached (Figure F-2).

Pumping began at 1515 hours on February 20, 1985 at a rate of 10 gallons/hour. The produced water was very turbid. Clogging of the pump and pump lines necessitated continuous monitoring and adjustment of the discharge.

After 4 hours of pumping at 10 gallons/hour, the drawdown of the well appeared to stabilize at about 7 feet. The discharge rate was increased to 20 gallons/hour in order to more effectively stress the aquitard. After one hour of additional pumping a total drawdown of 12 feet was observed. However, this higher pumping rate increased the turbidity of the discharge and caused instability of the pumping rate. The lack of control of the discharge rate and the potential of diamage to the pump forced the termination of the test after a total of 5 hours of pumping.

Water level recovery was observed for 100 minutes. At this time the water level had recovered to within 90% of the pre-pumping level.

TABLE F-1

Pump Test Data, OW-24

PUMP TEST ANALYSIS

Field measurements are summarized in Table F-1. Due to the short pumping time and potential well-bore and gravel-pack effects, the final analysis was based on methods developed by Shafer, for low-conductivity materials.

Partial penetration effects were neglected in the analysis because the low pumping rates and the expected anisotropy of the aquitard would prevent significant vertical flow to the well bore. The low pumping rate was also designed to completely drain the gravel pack in the well to insure accurate recovery data.

A copy of Shafer's methodology is attached, and the data for his analysis is given in Table F-2. Figure F-1 is a plot of the recovery data, according to Shafer's methods. This Figure includes calculation of T and K for the Chinle shales.

TD = 58'-4" = 58.33'
DW = 31.96
Pump @ 55
26.37' of water
≈ 18 gal

PUMPING DATA

Page 1 of 2

DATA SHEET FOR RECORDING PUMP TEST DATA

County: McKinley Co.
Location: Ciniza Refinery 2/20/85
Observation well no. ....
Pumped well no. CW-24

Average Q ________ gpm r = ________ ft. r^2 = ________

	Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	gph Q (~~gpm~~)	Remarks
	2-20	1515	0			31'-11.5"	0 in	Feet		10 gph	STATIC LEVEL w/ PUMP
		1516	1			33-0	12.5	1.04			LARGE INITIAL DRAW FROM HOSE FILL UP
		1517	2			33-1	13.5	1.13			Setting pump rate
		1518	3			33-4	16.5	1.38			
		1519	4			33-8¾	20.75	1.73			
		1520	5			33-11½	24.0	2.0'			
		1521	6			34-2	26.5	2.22			
		1522	7			34-2½	27.0	2.25			
1 min		1523	8			34-3	27.5	2.27			
		1524	9			34-4	28.5	2.37			
		1525	10			34-5	29.5	2.46			
		1527	12			34-6¾	30.75	2.56			
		1529	14			34-9	33.5	2.79			
		1531	16			35-0	36.5"	3.04			
2 min		1533	18			35-2¾	38.75	3.23			
		1535	20			35-4½	41.0	3.42			
		1540	25			35-10½	47.0	3.92			
		1545	30			36-3	51.5	4.28			
		1550	35			36-2½	51.0	4.25			
		1555	40			36-8	56.5	4.71		10 gph	CLEARED PUMP value
5 min		1600	45			37-2¾	62.75	5.23			
		1605	50			36-10½	61.0	5.08			clear pump value
		1610	55			NR					
		1615	60			37-10¾	70.75 ~~82.75~~ ~~NR~~	5.90			Pumped 10 gal
10 min		1625	70			38-1½	85.0 73.0	6.08			

PUMPING DATA

Page 2 of 2

DATA SHEET FOR RECORDING PUMP TEST DATA

County : ____________
Observation well no. MW-24
Location: Ciniza Refinery
Pumped well no. MW-24
Average Q 10 gph ~~gpm~~ r = — ft. r^2 = —

Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	gph ~~(gpm)~~	Remarks
5-20	1635	80			39-3½	76 ~~88.0~~	6.33		10	
	1645	90			38-7-	79.5 ~~91.5~~	6.79			Lift pump to 50'
	1655	100			37-6½	69.0	5.75			clear pump, ready pressure
	1705	110			38-11½	84.0 ~~94.0~~	7.00			
2 hour	1715	120			39-2½		7.27			Pumped 20 gal
	1730	1.35 ^{5}			38-11		6.97			
15 min	1745	150			39-2½		7.25			
	1800	165 ^{5}			39-0½		7.08			
3 h	1815	180 ^{60}			39-2		7.21			Pumped 30 gal
	1830	195 ^{5}			39-5		7.46			
	1845	210 ^{30}			39-5		7.46			
	1900	225 ^{45}			39-2		7.21			
4 h	1915	240 ^{60}			38-11½		7.00			Pumped 40 gal
	1930	255 ^{15}			39-0		7.04		10	
	1932	257 ^{17}			39-4		7.38	←	20	INCREASE PUMP RATE TO 20 GPH
	1934	259 ^{19}			39-10		7.87			PUMP SLIPPED APPROX 1 FOOT - REPLACED TO APPROX SAME LEVEL
2 min	1936	261 ^{21}			40-3½		8.33			
	1938	263 ^{23}			40-3½		8.33			
	1990	265 ^{25}			40-1½		8.17			PUMPING RATE FELL-OFF SLIGHTLY
	1995	270 ^{30}			40-9		8.79			
	1950	275 ^{35}			41-9½		9.83			
5 min	1955	280 ^{40}			42-0		10.04			
	2000	285 ^{45}			41-8		9.72			
	2005	290 ^{50}			42-8¼		9.75			
	2010	295 ^{55}			43-4		11.27			Silt in Pump
	2015	300 ^{05}			43-2½		11.25			Adj pump valve
15 min 5 h	2030	315 ^{15}			43-10½		11.92			pumped 100 gal

RECOVERY DATA

Page 1 of 1

DATA SHEET FOR RECORDING PUMP TEST DATA

County: ________________ Observation well no. ______

Location: Ciniza Refinery Pumped well no. RW-24

Average Q ______ gpm r = ______ ft. r^2 = ______

Date	Hour	t (min)	t' (min)	t/t'	Depth to water	s (unadjusted)	Adjustment Δs	s' (adjusted)	Q (gpm)	Remarks
1/23	20:32		0		43-10½	144"	12.0'	0	20gph	
	2034		2		42-7-		10.63'	1.37		
	2036		4		41-8¾		9.69	2.31		
2 min	2038		6		40-10¼		8.86	3.14		
	2040		8		40-2		8.21	3.79		
	2042		10		39-6¼		7.56	4.44		
	2047		15		38-0¾		6.11	5.89		
	2052		20		37-1½		5.17	6.83		
	2057		25		36'4-		4.38	7.62		
	2102		30		35-8½		3.75	8.25		
	2107		35		35-2¼		3.27	8.73		
	2112		40		34-9¾		2.86	9.14		
5 min	2117		45		34-5¾		2.52	9.48		
	2122		50		34-2¾		2.27	9.73		
	2127		55		34-0½		2.07	9.93		
	2132		60		33-10½		1.92	10.08		
	2142		70		33-7½		1.66	10.34		
10 min	2152		80		33-5¾		1.51	10.49		
	2202		90		33-4½		1.42	10.58		
	2212		100		33-3¼		1.32	10.68		
	2222		110							
	2232		120							
15 min	2247		135							
	2302		150							
	2317		165							

TABLE F-2

DATA FOR SHAFER'S METHOD

Time Since Pumping Started (min)	Drawdown (feet) (s)	Feet of Casing Filled (ft)	Time To Fill (min)	Q (gpm)	S/Q (ft/gpm)
317	12.0	0	0	---	----
319	10.63	1.37	2	.45	23.8
321	9.69	.94	2	.31	31.6
323	8.86	.83	2	.27	32.7
325	8.21	.65	2	.21	38.7
327	7.56	.65	2	.21	35.6
332	6.11	1.45	5	.19	32.3
337	5.17	.94	5	.13	42.1
342	4.38	.79	5	.10	42.5
347	3.75	.63	5	.08	45.6
352	3.27	.48	5	.06	52.2
357	2.86	.41	5	.05	53.4
362	2.52	.34	5	.04	56.8
367	2.27	.25	5	.03	69.5
372	2.07	.20	5	.026	79.3
377	1.92	.15	5	.019	98.0
387	1.66	.26	10	.017	97.8
397	1.51	.15	10	.009	154
407	1.42	.15	10	.009	145
417	1.32	.10	10	.006	202

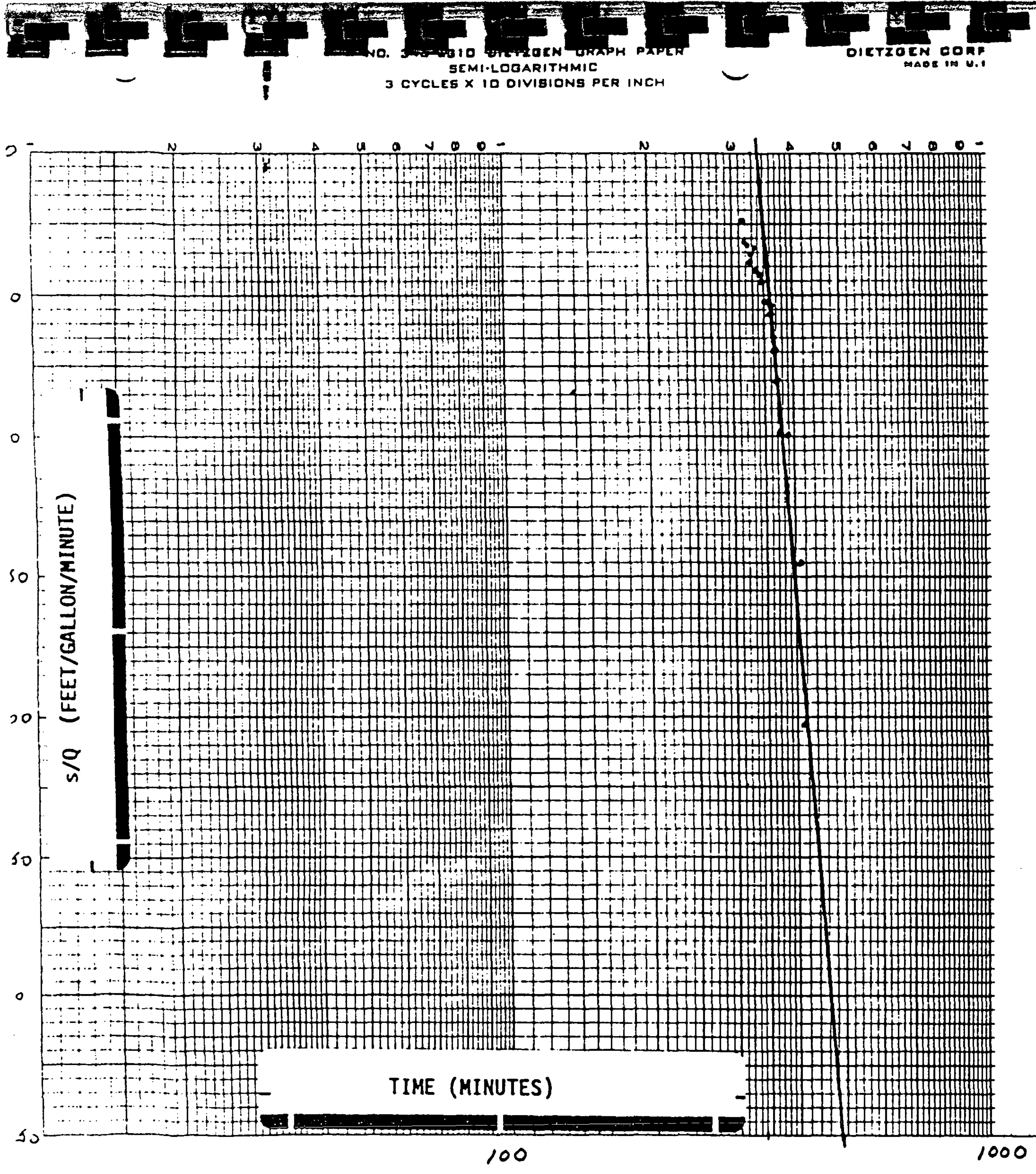


FIGURE F-1

SHAFER PLOT OF DATA FROM OW-24

Calculation of T & K

1) Over the total vertical scale of 350 feet/GPM, time varies by 0.1567 log cycles

2) For 1 full log cycle, s/Q equals 350/.1567 = 2233

3) T = 264/(s/Q) = 264/2233
or T = 0.110 gallons/day/foot

4) For a 20 foot screened interval
K = T/b = 0.0055 gallons/day/square foot.

5) .0055 g/d/ft x 1.55 x 10^{-6} (ft/sec)/(g/d/ft)

= 8.3 x 10^{-9} ft/sec

BORING OW-24

SURFACE ELEVATION: 6878 FEET

DEPTH IN FEET	LABORATORY TEST DATA								
	TESTS REPORTED ELSEWHERE	ATTERBERG LIMITS		STRENGTH TEST DATA				MOISTURE CONTENT (%)	DRY DENSITY (PCF)
		LIQUID LIMIT (%)	PLASTICITY INDEX (%)	TYPE OF TEST	NORMAL OR CONFINING PRESSURE (PSF)	SHEAR STRENGTH (PSF)	DEVIATOR STRESS (PSF)		
0									
10									
20									
30									
40									
50									
60									
70									
80									
90									
100									
110									
120									
130									
140									
150									
160									

PENETRATION RATE MINUTES/FOOT	SYMBOLS		DESCRIPTION
2.4	▨	CL	TRIASSIC PERIOD CHINLE FORMATION REDDISH BROWN, VERY FINE SANDY CLAY, SOFT, HIGHLY WEATHERED
2.0	▨		
2.0	▨		
1.6	▨		
2.0	▨		
1.8	▨		
2.3	▤	SHALE	30 FEET: SHALE, REDDISH BROWN, SANDY, SOFT, FRESH
1.8	▤		
2.3	▤		
3.5	▤		
3.3	▤		
4.0	▤		
3.7	▤		
4.0	▤		
2.0	▤		
3.0	▤		
2.3	▤		
2.4	▤		

BORING COMPLETED AT 65.0 FEET ON 1/2/81.
4-INCH PVC PIEZOMETER INSTALLED WITH PERFORATIONS FROM 41.0 TO 61.0 FEET.
GRAVEL PLACED FROM 28.0 TO 61.0 FEET AND BORING SEALED WITH BENTONITE AND CEMENT TO SURFACE.
GROUND WATER LEVEL MEASURED AT 32.5 FEET BELOW GROUND ON 1/5/81.

FIGURE F-2
LOG OF WELL OW-24

LOG OF BORINGS

DAMES & MOORE

Pumping Test Analyses for Low Yield Formations

by David C. Shafer

William F. Achuff
Director

Occasionally it is necessary to determine aquifer characteristics of very low yielding formations—those with transmissivities less than 500 gallons per day per foot. Though interest in these aquifers is certainly not because of their productive capability, it may be desirable to determine groundwater flow characteristics even in these low yield formations in order to determine such things as regional groundwater flow patterns, effect of dewatering or migration of pollution plumes near point sources of contamination.

Different Approach

Conventional pumping test analysis using the standard time drawdown graph often does not work effectively in low T (transmissivity) formations for two reasons. First, the pumped well's low specific capacity (gallons per minute per foot of drawdown) may cause the pump to break suction during the test and it may be impractical to throttle back the pumping rate sufficiently to prevent this. Second, even if a constant pumping rate can be maintained without breaking suction, most of the data obtained will probably reflect casing storage effects rather than true aquifer parameters (see "Casing Storage Can Affect Pumping Test Data," Jan-Feb. 1978, Johnson Drillers Journal). Thus a different approach is required.

The best method for analyzing these formations is to pump a substantial portion of the casing empty, then shut the pump off and measure water levels as they recover. In ordinary pumping tests these measurements correspond to the nonpumping portion of the test. However, in the low T formations this "recovery period" is actually the "pumping period!"

After pump shut-off, the casing slowly begins filling with water. This water comes from the aquifer and actually represents the water pumped during this so called "pumping period." The pumping rate is determined by measuring the volume of

Pumping rate = 10 gpm
Pumping period = 15 minutes
Drawdown at pump shut off = 90 ft
Casing — 6" I.D.
Drop pipe — 1¼" I.D.

Time in minutes since pumping started (t)	Drawdown in feet (s)	Number of feet of casing filled	Time in minutes required to fill	Volume filled divided by time required in gallons per minute (Q)	s/Q in feet per gallon per minute
15 (pump shut off)	90				
17	85.66	4.34	2	3.04	28.2
20	79.7	5.96	3	2.78	28.6
30	64.2	15.5	10	2.17	29.5
40	51.9	12.3	10	1.72	30.2
60	35.6	13.3	20	1.14	31.1
80	24.6	11.0	20	.77	31.8

Table 1

casing filled in a given length of time.

During the test, careful measurements are made of time since pumping began (t) along with drawdown (s) at each of these times. Then a calculation is made to determine Q for each time t and finally the ratio s/Q is computed for each measured drawdown value. The ratio is simply the reciprocal of the specific capacity.

A graph is then constructed showing t versus the ratio s/Q plotted as usual on semi-logarithmic graph paper with t on the log scale. A straight line of best fit is drawn through the data points and T is calculated as follows:

$$T = \frac{264}{\Delta(s/Q)}$$

where Δ(s/Q) is the change in s/Q over one log cycle of graph paper.

This graph has the unique advantage that it will accurately reflect aquifer transmissivity independent of casing storage effects. In addition it will be sensitive to nearby recharge and/or negative boundaries and will reveal these conditions like any ordinary time drawdown graph.

To see how this technique works it is best to work an example. Table 1 shows data obtained from a 6-inch well pumped at 10 gpm for 15 minutes. Drawdown after 15 minutes of pumping measured 90 feet.

The next data point was recorded two minutes following pump shutoff or 17 minutes since pumping started. At this time the pumping water level was 85.66 feet, indicating that 4.34 feet of casing had filled during the two minute interval.

The annulus between the 6-inch casing and 1¼" drop pipe holds 1.4 gallons per foot so that the volume of casing filled is 1.4 times 4.34, or 6.08 gallons in two minutes. Thus,

$$Q = 6.08 \text{ gallons/2 minutes}$$
$$= 3.04 \text{ gpm}$$

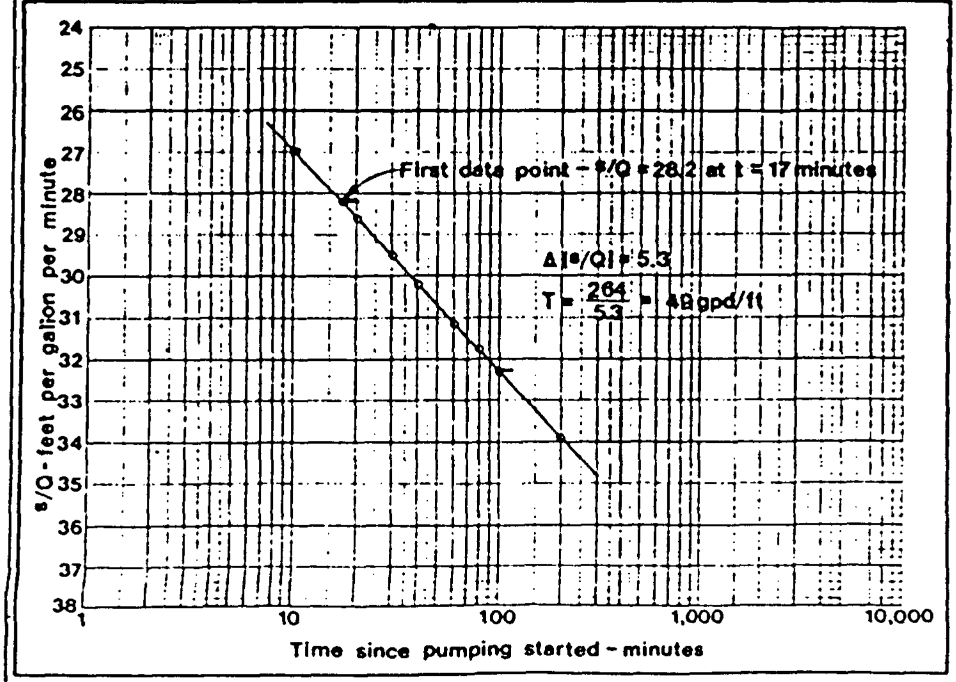
finally,

$$s/Q = 85.66 \text{ ft/3.04 gpm}$$
$$= 28.2 \text{ ft/gpm}$$

which is plotted at a time of 17 minutes on the graph shown here.

This analysis is repeated for each drawdown measurement. The resultant calculated s/Q values are shown in the table and plotted in the figure. The formation T value from the graph is

$$T = \frac{264}{\Delta(s/Q)}$$
$$= 264/5.3$$
$$= 49 \text{ gpd/ft}$$



In low transmissivity situations, readings are taken after pump shut-off. In this method, s/Q is the reciprocal of the specific capacity and t is time, measured after shut-off as water begins to enter the casing.

Conventional Analysis

~~Examination of the hydraulic characteristics of this well (not included here) shows that if a conventional time drawdown graph had been used, casing storage effects would have lasted for approximately twelve hours.~~ This means that data recorded in the first twelve hours of pumping would have been useless and longer pumping than this would have been required to obtain any usable data at all. However, data collected after twelve hours of pumping probably would be more influenced by boundary conditions than by aquifer transmissivity. ~~Thus, in practice it actually might have been impossible to determine the T value using conventional analysis techniques regardless of the length of the test.~~ The value of the method described above becomes very clear; it may be the only way to determine T values in certain low yielding aquifers.

In order to maximize the accuracy of this method, it is best to unload (empty) the casing as rapidly as possible. Thus it is actually better to use a high capacity pump than a low capacity pump in analyzing extremely low-yielding wells!

Another good idea is to unload the casing with compressed air since this can typically be done in one minute or less.

Recorded Data Must Be Accurate

An additional important consideration is that all data recorded for this type of analysis must be absolutely accurate. Small errors in the recorded values of time and/or drawdown can result in large errors in the calculated values of s/Q. For best results, drawdown should be recorded to the nearest hundredth of a foot and timed to the nearest second or two.

JOHN W. SHOMAKER
CONSULTING GEOLOGIST
3236 CANDELARIA, N.E.
ALBUQUERQUE, NEW MEXICO 87107

(505) 884-2897

RECEIVED SEP 24 1984

September 20, 1984

Carl D. Shook, Plant Manager
Giant Refining Company, Ciniza Refinery
Route 3, Box 7
Gallup, New Mexico 87301

Re: results of permeability tests, July 2 and 3, 1984

Dear Carl:

Copies of the field notes, calculations, and data plots for the two permeability tests are attached. The tests are summarized as follows:

Well OW-4 The well is completed principally in the clay and shale sequence which overlies the uppermost aquifer; a small thickness of sandstone which may be part of the uppermost aquifer was also penetrated. Total depth when drilled was 102.0 ft. Perforations are from 62.0 ft to 102 ft. The well is located near the center of the land-treatment area. A slug test was performed on July 3, 1984, following the method described by S. W. Lohman (1972, Ground-Water Hydraulics, U. S. Geol. Survey Prof. Paper 708, p. 27-29), which indicates the permeability of the section open to the well to be about 4×10^{-7} cm/sec.

Well MW-1 This well is one of the monitoring wells on the boundary of the land-treatment area, and is completed in the uppermost aquifer. It was drilled to 120 ft, and is screened in the interval 87 to 120 ft; the casing is sealed above 89 ft so as to isolate the uppermost aquifer. The slug test performed on July 3, 1984 indicated a permeability of about 1.2×10^{-4} cm/sec.

Information as to the construction of the wells is taken from Dames and Moore (March, 1981; Ground water and soils investigation, Ciniza Refinery near Gallup, New Mexico, and November, 1981, Groundwater monitoring plan, Ciniza Refinery near Gallup, New Mexico).

Please let me know if there are questions.

Sincerely,

John W. Shomaker
Consulting Geologist

cc: ✓Tom Andrews, Delta H Engineering, w/encl date: 7-3-84

casing size: nominal 4½" ID 4.0 csg. mat'l. PVC
water levels measured from top 4½ OD PVC casing, S side →
which is 1.7 ± above ground level.
volume of slug:

$$\text{OD, ft}\left(\frac{0.27}{}\times\frac{1}{2}\right)^2\times\pi\times\text{length, ft}\ 0.10 = 0.006\ ft^3$$

OD, ft	length, ft	ft³
0.27	0.10	0.006
0.30	0.04	0.003
0.243	4.84	0.224
0.27	0.26	0.015
0.243	4.81	0.223
0.27	0.26	0.015
0.18	0.03	0.001
0.11	0.25	0.002

Note- obstruction in casing at 33. won't pass 0.27 OD.

sum 0.489 = V, ft³ = 3.66 gal.

r_c = internal radius of casing above perfs: 0.165 ft

r_S : radius of screen or open hole: ______ ft

initial water level 26.15 ft below MP, time 07:51

$$H_0 = \frac{V}{\pi r_c^2} = \frac{0.489}{\pi(0.165)^2} = 5.72\ ft$$

clock time	t, sec.	water level	H	H/H₀	remarks
08:20:54	0				slug released top slug: 23.2' MP
21:25 ?	31 ?	20.75	5.40	0.944	
22:28	94	20.76	5.39	0.942	
23:14	140	20.80	5.35	0.935	
23:51	177	20.81	5.34	0.934	
24:42	228	20.83	5.32	0.930	
25:42	288	20.87	5.28	0.923	
27:06	372	20.90	5.25	0.918	
28:14	440	20.92	5.23	0.914	
29:43	529	20.95	5.20	0.909	
30:55	601	20.97	5.18	0.906	
32:46	712	21.00	5.15	0.900	
35:16	862	21.04	5.11	0.893	
38:38	1064	21.10	5.05	0.883	
43:30	1356	21.19	4.96	0.867	
46:52	1558	21.21	4.94	0.864	raised slug 0.4ft.
49:26	1712	21.25	4.90	0.857	
52:54	1920	21.30	4.85	0.848	

t_0 = 08:20:54

0:00 = 23:46

clock times	t, sec.	level	H	H/H_0	remarks
~~08:54:13~~		~~21.34~~			
08:56:50	2096	21.35	4.80	0.839	
09:00:16	2362	21.39	4.76	0.832	
:05:00	2646	21.45	4.70	0.822	
09:55	2941	21.50	4.65	0.813	
17:46	3412	21.60	4.55	0.795	
28:25	4051	21.71	4.44	0.776	m-scope trouble
46:00	5106	21.89	4.26	0.745	
10:02:23	6089	22.05	4.10	0.717	
14:00	6786	22.15	4.00	0.699	
10:24:26	7412	22.25	3.90	0.682	stopped test; slug almost uncovered

late data matches: $\alpha = 10^{-1}$ curve, $Tt/r_c^2 = 1$ at $t = 50{,}000$ sec.

$$T = \frac{1.0\, r_c^2}{t} = \frac{(1.0)(0.165)^2}{50{,}000} = 5.4 \times 10^{-7} \text{ ft}^2/\text{sec}$$

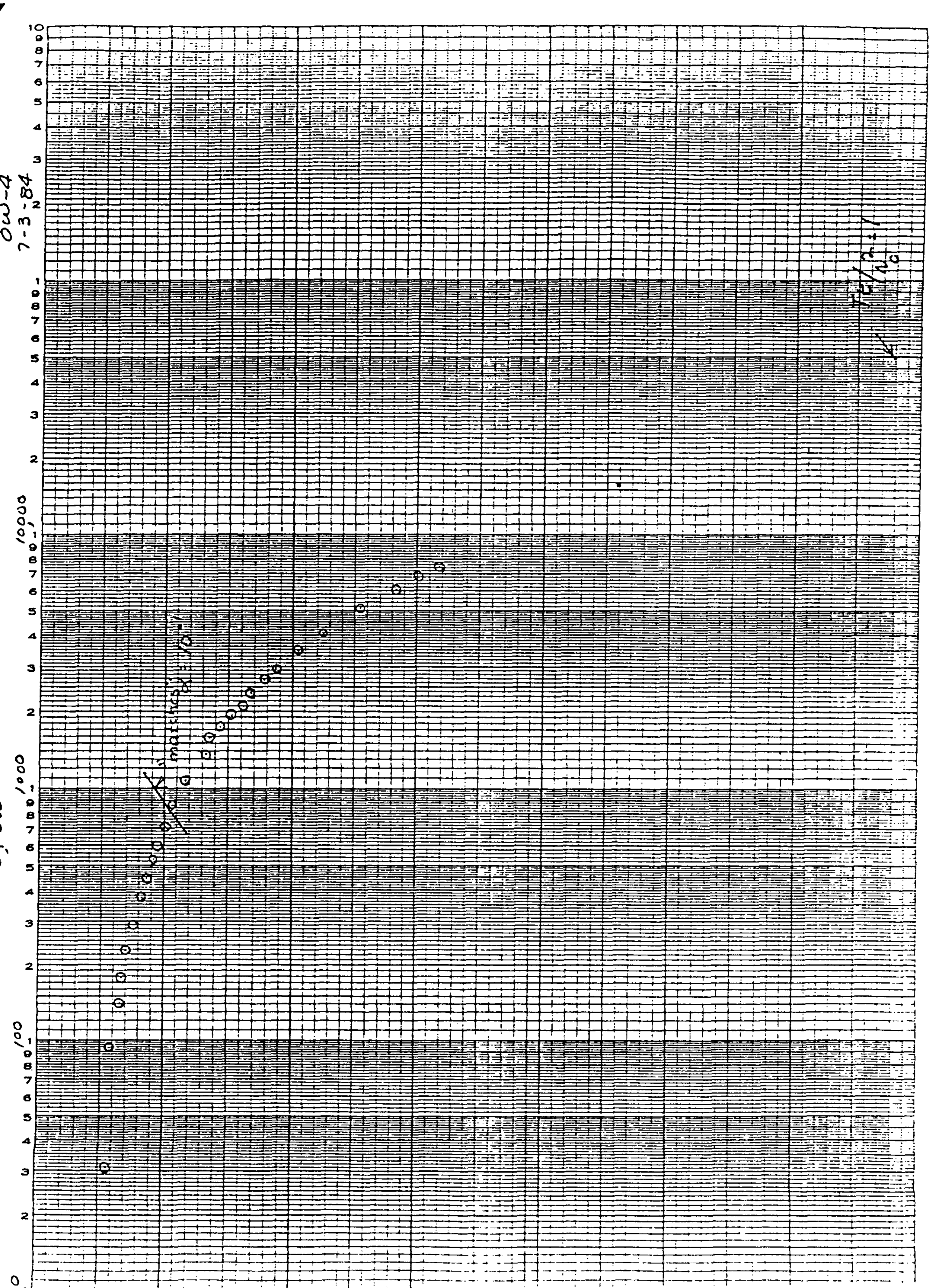
$= 0.05$ ft²/day $= 0.35$ gpd/ft

$$K_h = \frac{0.05 \text{ ft}^2/\text{day}}{40 \text{ ft screen}} = 0.001 \text{ ft/day}$$

$$0.001 \text{ ft/day} \times 30.5 \text{ cm/ft} \times \frac{1}{60 \times 1440 \text{ sec/day}} = 4 \times 10^{-7} \text{ cm/sec}$$

$S = \frac{r_c^2}{r_s^2} \alpha \frac{0.027}{\approx 0.080}\, 10^{-1} = 0.03$ ∴ water-table storage

$6\frac{3}{4}$" hole?


OW-4
7-3-84
t, sec
100
1000
10000
K₁ matches t_d: 10⁻¹
$Tt/r_a^2 = 1$
10
9
8
7
6
5
4
3
2
1
0
NO. 340-L310 DIETZGEN GRAPH PAPER
SEMI-LOGARITHM
5 CYCLES X 10 DIVISIONS PER INCH
DIETZGEN CORPORATION
MADE IN U.S.A.

date: 7-2-84

casing size: nominal 5½" OD, ID 5.1" csg. matl. PVC
water levels measured from top PVC casing, SW side →
which is 1.37 ft above ground level, (concrete slab)
volume of slug:

$$2.05 - .68 = 1.37$$

cap OD, ft $\left(0.37 \times \frac{1}{2}\right)^2 \times \pi \times$ length, ft 0.10 = 0.011 ft^3

0.37	0.10	0.011
0.39	0.05	0.006
0.33	4.81	0.411
0.38	0.28	0.032
0.33	0.04	0.003
0.42	0.04	0.006
0.29	0.03	0.002
0.16	0.03	0.001
0.11	0.25	0.002

sum 0.474 = V, ft^3 = 3.55 gal

r_c = internal radius of casing above perfs.: 0.211 ft

r_s: radius of screen or open hole: ______ ft

initial water level 5.72 ft below MP, time 13:32

$$H_0 = \frac{V}{\pi r_c^2} = \frac{0.474}{\pi (0.211)^2} = 3.389 \text{ ft}$$

clock time	t, sec.	water level	H	H/H₀	remarks
13:48:00	0				slug released
13:48:20	20	2.30 ft ?	3.42	1.009	??
49:00	60	2.36	3.36	0.991	
49:26	86	2.42	3.30	0.974	
49:52	112	2.44	3.28	0.968	
50:32	152	2.50	3.22	0.950	
51:05	185	2.56	3.16	0.932	
51:42	222	2.60	3.12	0.921	
52:19	259	2.65	3.07	0.906	
52:55	295	2.70	3.02	0.891	
53:33	333	2.74	2.98	0.879	
54:26	386	2.80	2.92	0.862	
55:30	450	2.86	2.86	0.844	
57:05	545	2.97	2.75	0.811	
59:12	672	3.10	2.62	0.773	
14:01:05	785	3.20	2.52	0.744	
02:28	868	3.28	2.44	0.720	
03:52	952	3.36	2.36	0.696	

clock time	t, sec.	level	H	H/H_o	remarks
14:05:38	1058	3.45	2.27	0.670	
07:22	1162	3.54	2.18	0.643	
09:16	1276	3.62	2.10	0.620	
11:01	1381	3.69	2.03	0.599	
13:17	1517	3.79	1.93	0.569	
15:59	1679	3.89	1.83	0.540	
18:14	1814	3.97	1.75	0.516	
20:40	1960	4.07	1.65	0.487	
23:15	2115	4.15	1.57	0.463	
25:44	2264	4.22	1.50	0.443	
28:45	2445	4.31	1.41	0.416	
33:09	2709	4.43	1.29	0.381	
36:51	2931	4.52	1.20	0.354	
41:56	3236	4.64	1.08	0.319	
46:19	3499	4.71	1.01	0.298	
50:03	3723	4.78	0.94	0.277	
57:39	4179	4.90	0.82	0.242	
15:05:36	4356	5.01	0.71	0.210	
14:12	5172	5.12	0.60	0.177	
21:12	5592	5.18	0.54	0.159	
33:01	6301	5.28	0.44	0.130	
44:35	6995	5.36	0.36	0.106	
53:43	7543	5.40	0.32	0.094	
16:08:22	8422	5.46	0.26	0.077	
26:59	9539	5.52	0.20	0.059	
47:10	10,750.	5.56	0.16	0.047	
17:00:20	11,540	5.58	0.14	0.041	

late data matches: $\alpha = 10^{-5}$ curve, $Tt/r_c^2 = 1$ at $t = 830$ sec.

$$T = \frac{1.0\, r_c^2}{t} = \frac{(1.0)(0.21)^2}{830} = 5.36 \times 10^{-5}\ \mathrm{ft^2/sec}$$

$$= 4.63\ \mathrm{ft^2/day} = 35\ \mathrm{gpd/ft}$$

$$K_h = \frac{4.63\ \mathrm{ft^2/day}}{13.3\ \mathrm{ft\ screened}} = 0.35\ \mathrm{ft/day}$$

$$0.35\ \mathrm{ft/day} \times 30.5\ \mathrm{cm/ft} \times \frac{1}{60 \times 1440\ \mathrm{sec/day}} = 1.2 \times 10^{-4}\ \mathrm{cm/sec}$$

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5 CYCLES X 10 DIVISIONS PER INCH

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MW-1
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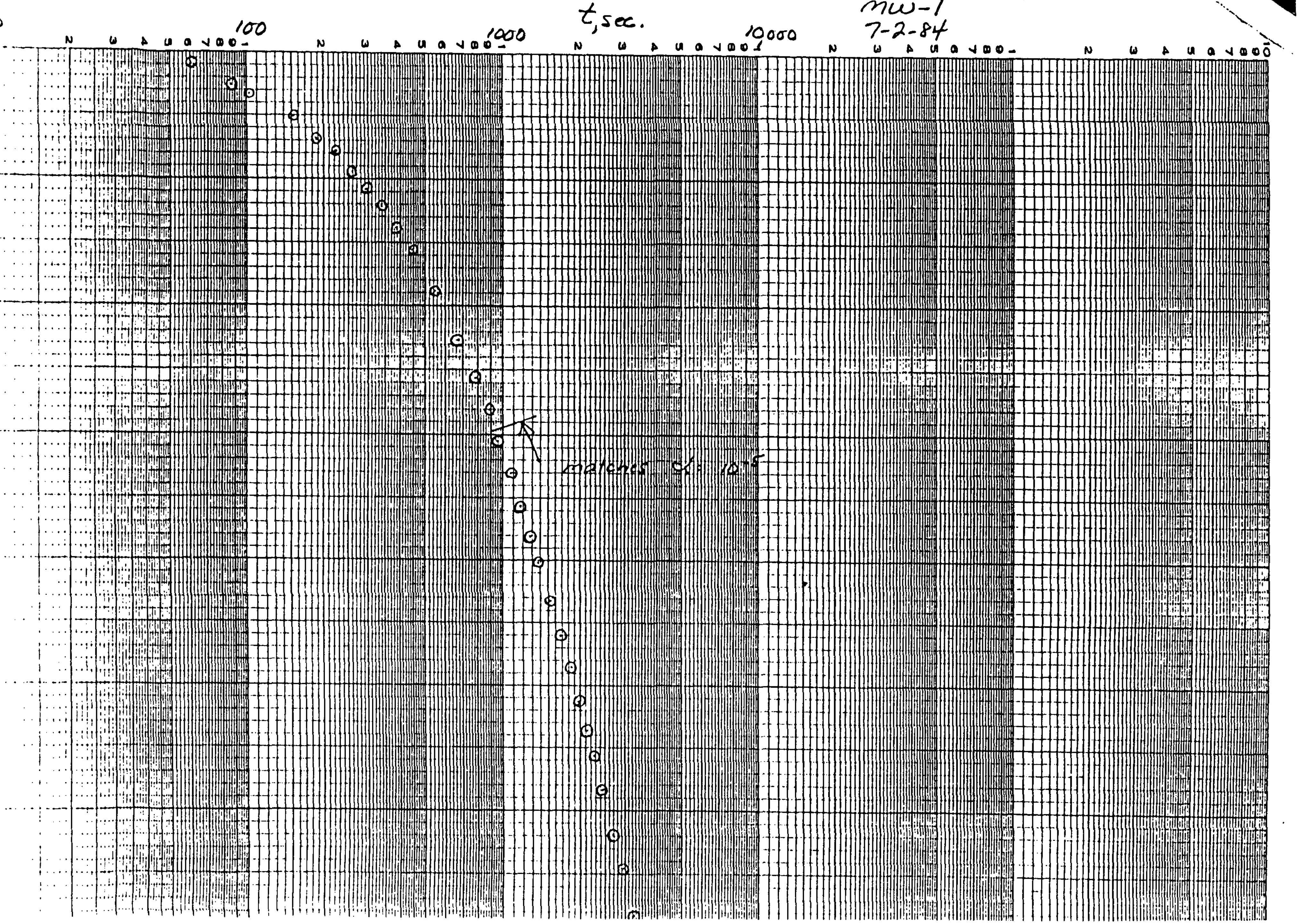
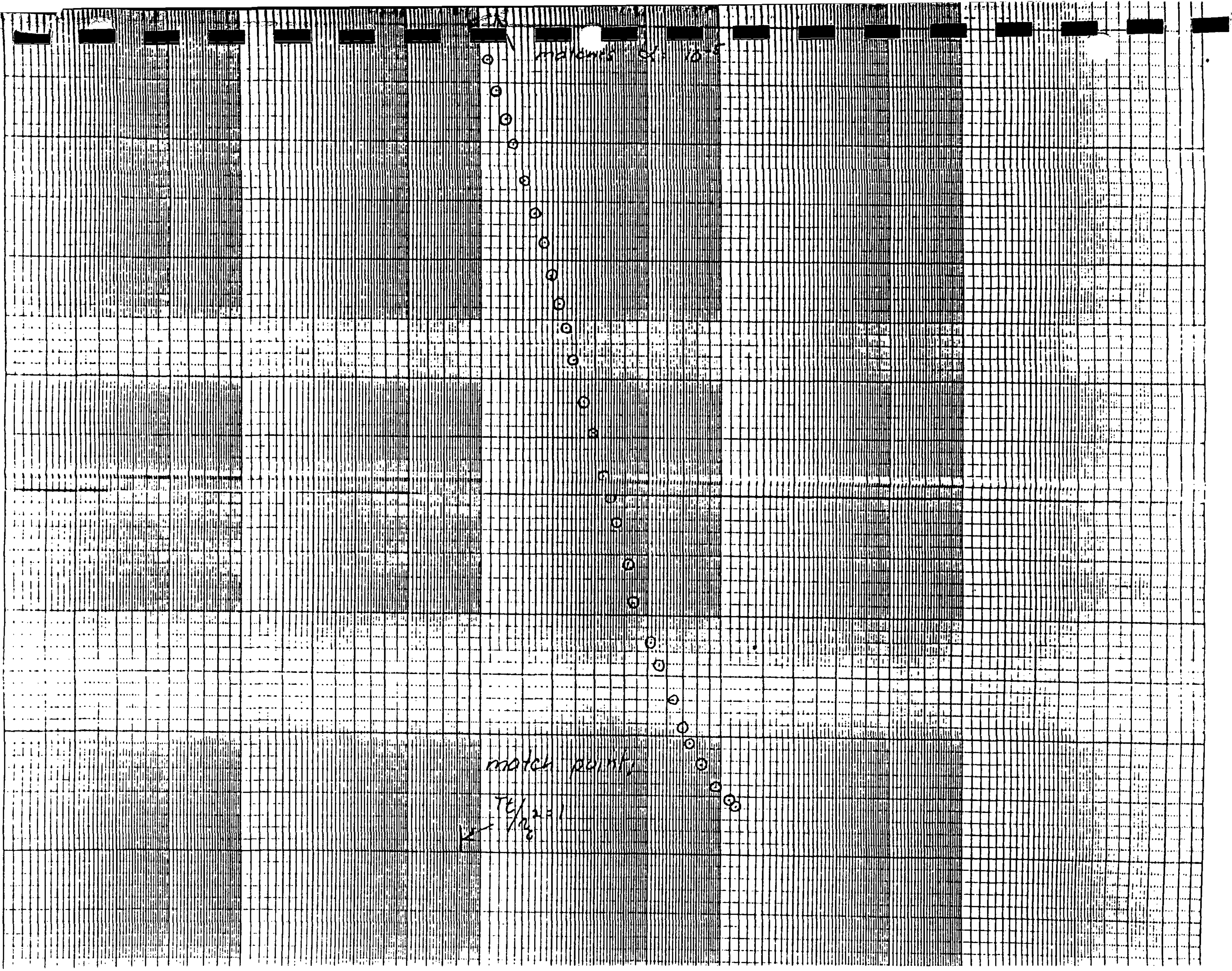
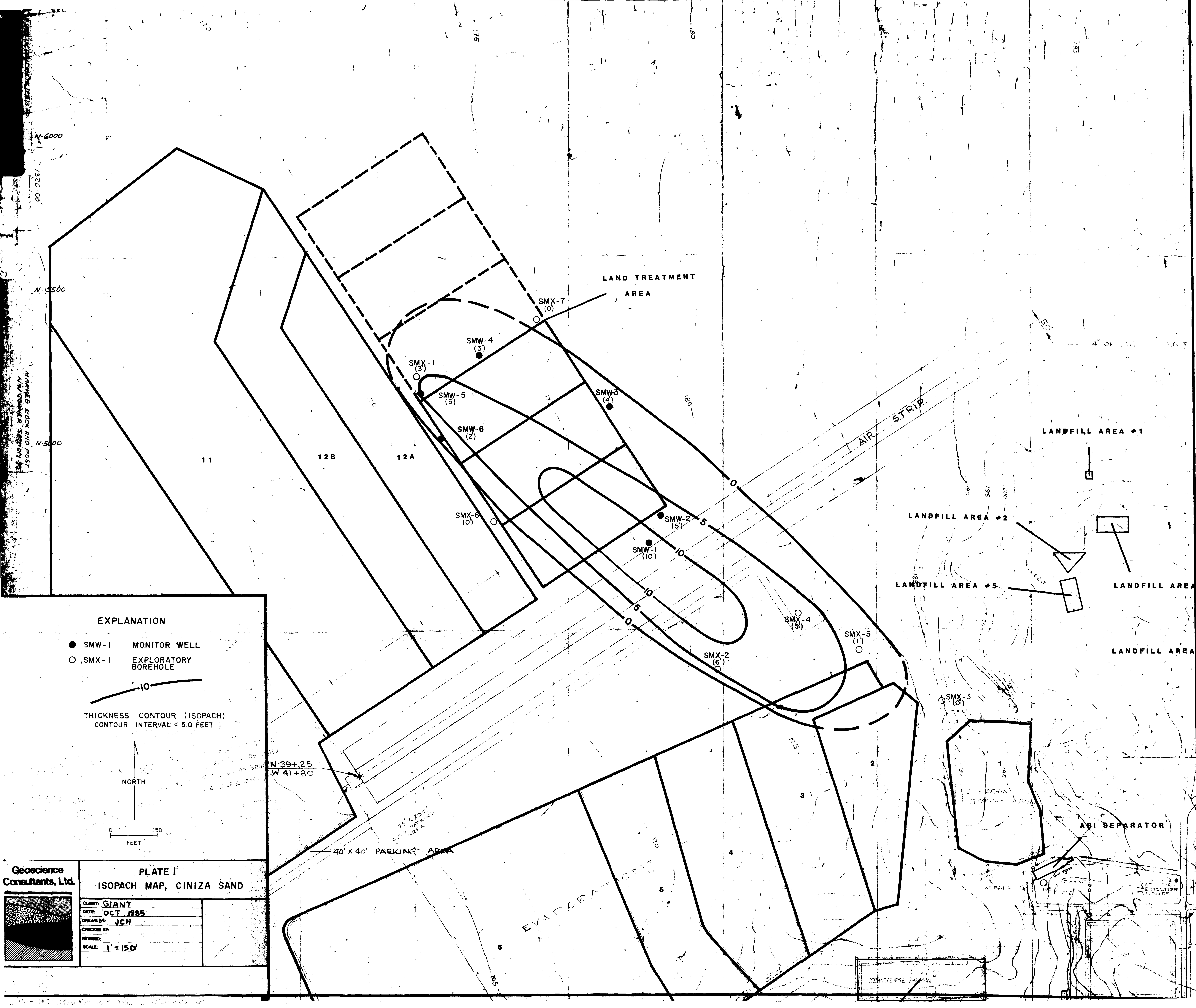



malones α 10^{-5}
match point,
$Tt/r_c^2=1$



EXPLANATION

● SMW-1 MONITOR WELL

○ SMX-1 EXPLORATORY BOREHOLE

THICKNESS CONTOUR (ISOPACH)
CONTOUR INTERVAL = 5.0 FEET

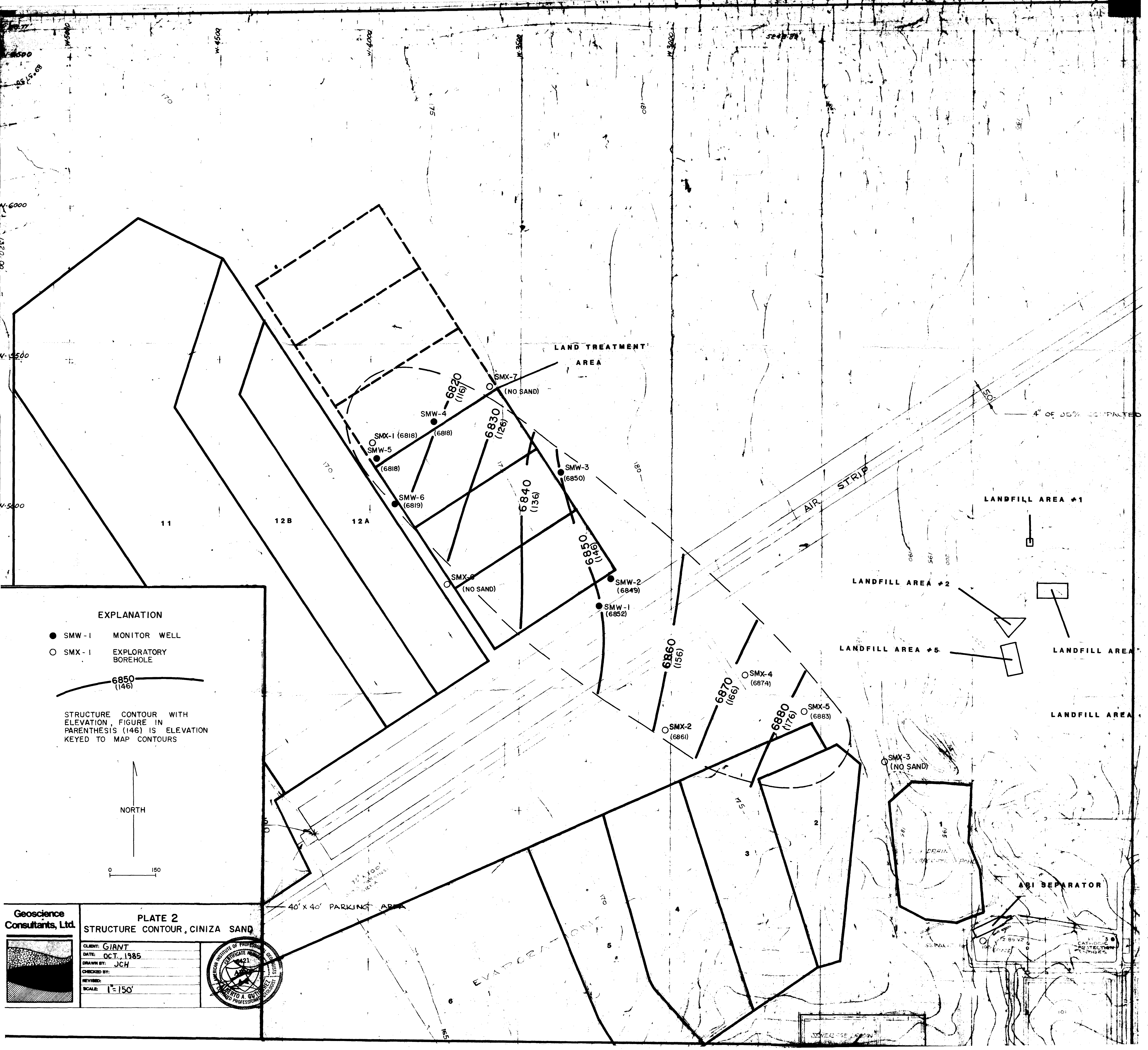
NORTH

0 150
FEET

Geoscience Consultants, Ltd.

PLATE I
ISOPACH MAP, CINIZA SAND

CLIENT:	GIANT
DATE:	OCT. 1985
DRAWN BY:	JCH
CHECKED BY:	
REVISED:	
SCALE:	1" = 150'

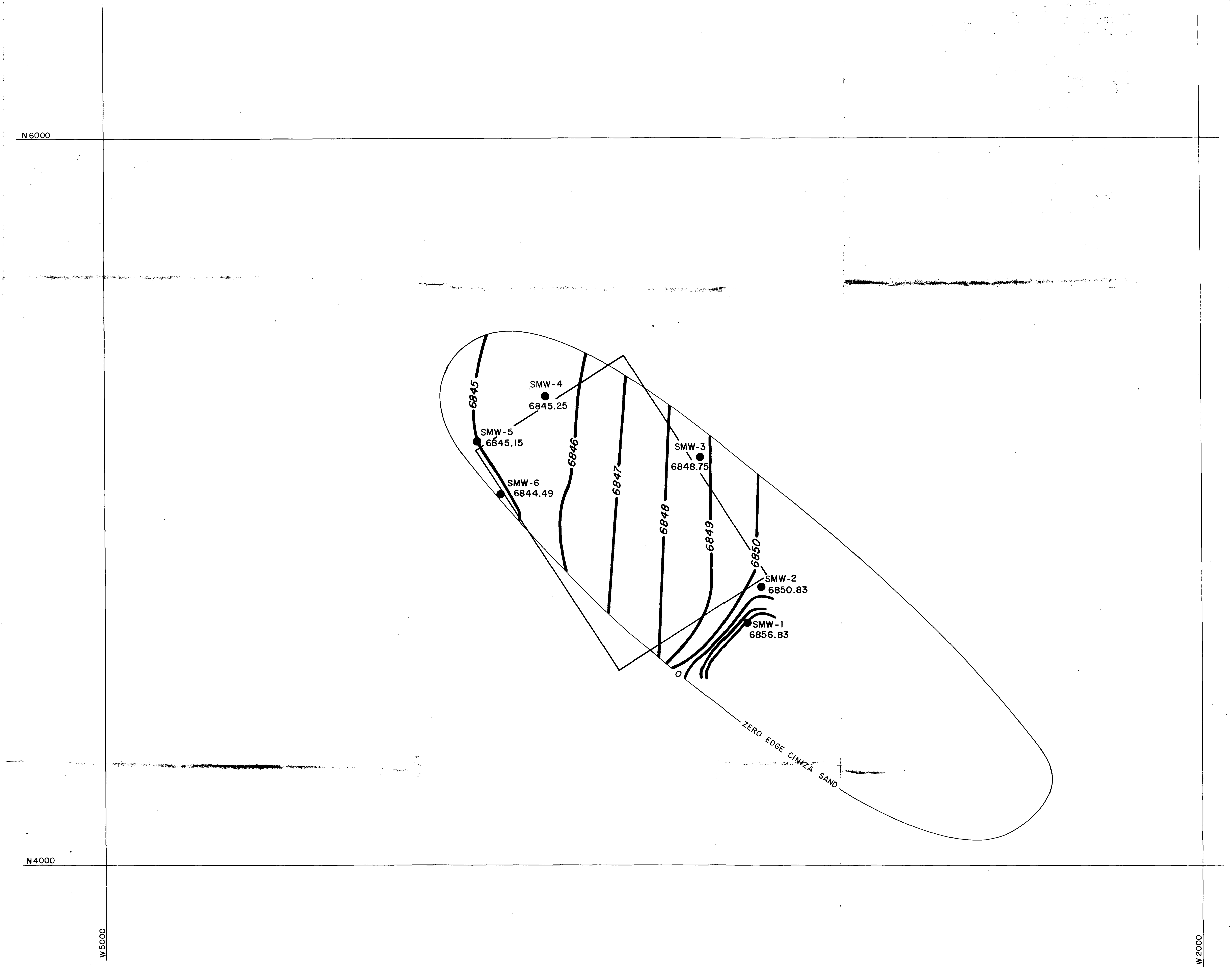


Geoscience Consultants, Ltd.

PLATE 2
STRUCTURE CONTOUR, CINIZA SAND

CLIENT: GIANT
DATE: OCT., 1985
DRAWN BY: JCH
CHECKED BY:
REVISED:
SCALE: 1" = 150'

ALBERTO A. GUTIERREZ



EXPLANATION

● SMW-1	MONITOR WELL
6856 83	WATER LEVEL ELEVATIONS
6850	WATERLEVEL CONTOUR

CONTOUR INTERVAL = 1.0 FEET
GRID LINES MATCH PLATES 1, 2

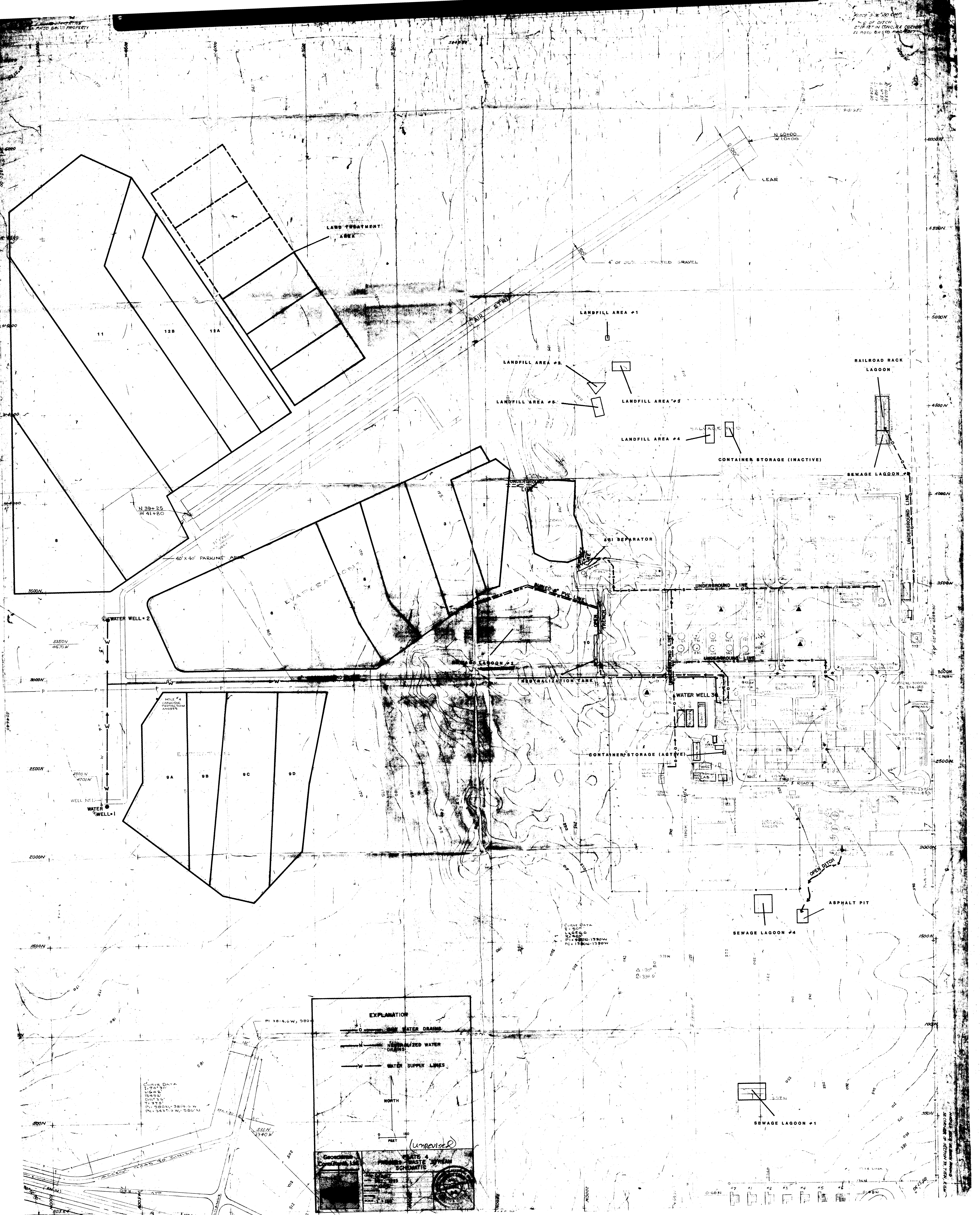
NORTH

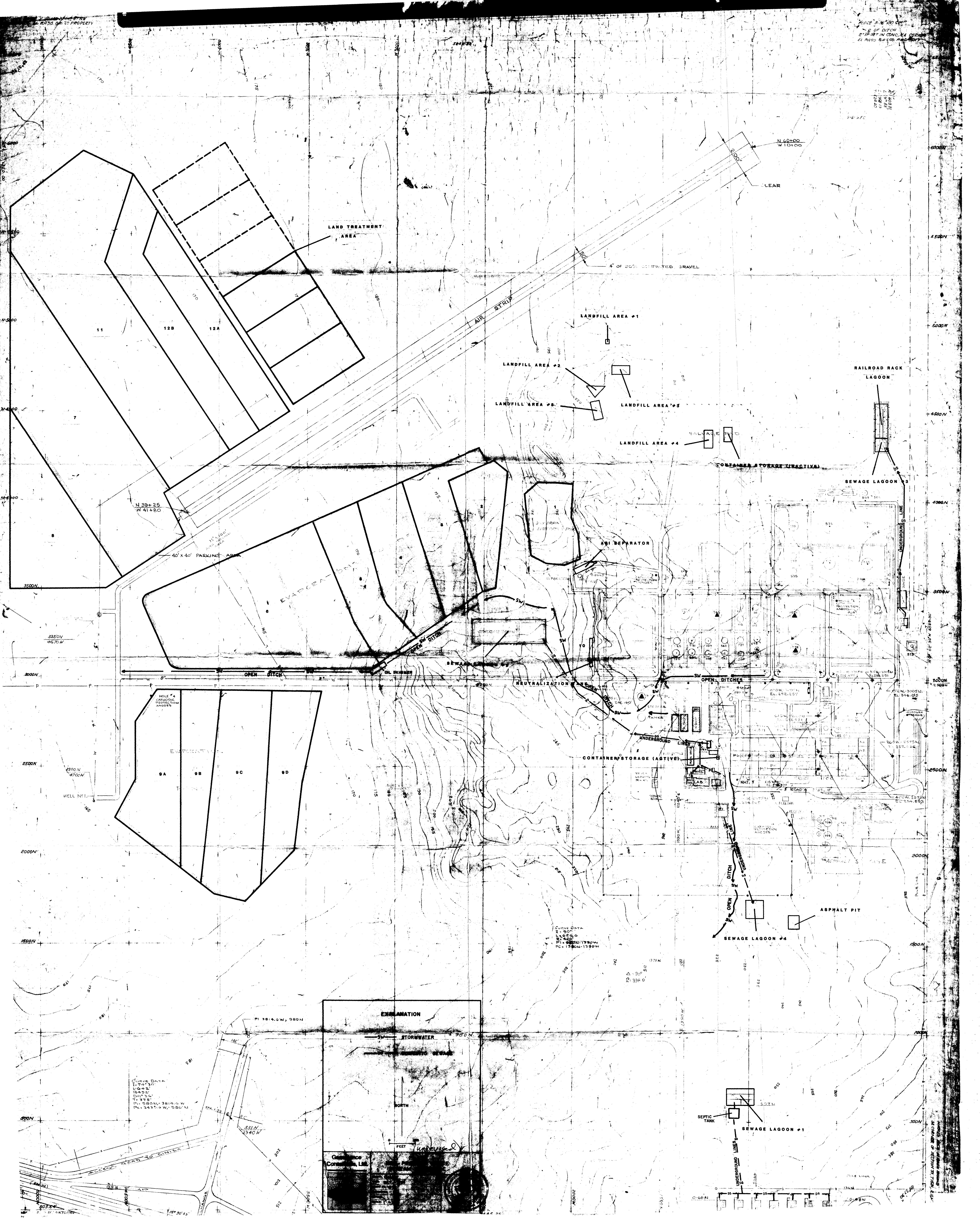
0 150
FEET

Geoscience Consultants, Ltd.

PLATE 3
WATER-LEVEL ELEVATIONS CINIZA SAND

CLIENT:
DATE:
DRAWN BY:
CHECKED BY:
REVISED:
SCALE:


LAND TREATMENT AREA
11
12B
12A
7
8
AIR STRIP
N 60+00
W 10+00
200'
LEAR
50'
4" OF COMPACTED GRAVEL
N 39+25
W 41+80
40' x 40' PARKING AREA
EVAPORATION
6
5
4
3
2
1
UNDERGROUND LINE
API SEPARATOR
BURIED 6" PVC LINE
OPEN TRENCH
10
SEWAGE LAGOON #2
NEUTRALIZATION TANK
WATER WELL 3
WATER WELL 2
3350'N
4670'W
HOLE #4 CATHODIC PROTECTION ANODES
9A
9B
9C
9D
2300'N
4700'W
WELL No 1
WATER WELL 1
LANDFILL AREA #1
LANDFILL AREA #2
LANDFILL AREA #3
LANDFILL AREA #5
LANDFILL AREA #4
SALVAGE YARD
CONTAINER STORAGE (INACTIVE)
RAILROAD RACK LAGOON
SEWAGE LAGOON #3
UNDERGROUND LINE
CONTAINER STORAGE (ACTIVE)
OPEN DITCH
ASPHALT PIT
SEWAGE LAGOON #4
SEWAGE LAGOON #1
6000'N
5500'N
5000'N
4500'N
4000'N
3500'N
3000'N
2500'N
2000'N
1500'N
1000'N
500'N
EXPLANATION
O — OILY WATER DRAINS
N — NEUTRALIZED WATER DRAINS
W — WATER SUPPLY LINES
NORTH
0
150
FEET
(unrevised)
Geoscience Consultants, Ltd.
PLATE 4
PROCESS WASTE STREAM SCHEMATIC
DATE OCT. 1985
SCALE 1" = 150'


LAND TREATMENT AREA
AIR STRIP
4" OF 2" COMPACTED GRAVEL
11
12B
12A
7
8
N 40+00
W 10+00
200'
N 39+25
W 41+80
40' X 40' PARKING AREA
EVAPORATION
LANDFILL AREA #1
LANDFILL AREA #2
LANDFILL AREA #5
LANDFILL AREA #3
LANDFILL AREA #4
SALVAGE YARD
CONTAINER STORAGE (INACTIVE)
RAILROAD RACK LAGOON
SEWAGE LAGOON #3
UNDERGROUND LINE
API SEPARATOR
SW
OPEN DITCH
OIL SKIMMER
SEWAGE
NEUTRALIZATION TANK
OPEN DITCHES
UNDERGROUND LINES
CONTAINER STORAGE (ACTIVE)
HOLE 4 CATHODIC PROTECTION ANODES
EVAPORATION
9A
9B
9C
9D
WELL Nº1
3350N
4670W
2300N
4700W
3500N
3000N
2500N
2000N
1500N
1000N
500N
4500N
4000N
5000N
5500N
6000N
OPEN DITCH
UNDERGROUND LINES
ASPHALT PIT
SEWAGE LAGOON #4
SEPTIC TANK
SEWAGE LAGOON #1
CURVE DATA
PI 3814.6W, 980N
ACCESS ROAD TO CIELA
EXPLANATION
SW STORMWATER
DOMESTIC SEWAGE
NORTH
0
FEET
unrevised
Geoscience Consultants, Ltd.