N00213.AR.000042
NAS KEY WEST
5090.3a

HYDROGEOLOGIC INVESTIGATION AT THE KEY WEST TERMINAL OF CHEVRON U S A

NAS KEY WEST FL

3/1/1982

GERAGHTY AND MILLER INC

HYDROGEOLOGIC INVESTIGATION AT THE KEY WEST, FLORIDA, TERMINAL

PREPARED FOR:

SMATHERS AND THOMPSON
ATTORNEYS FOR CHEVRON U.S.A., INC.
MIAMI, FLORIDA

PREPARED BY:

GERAGHTY & MILLER, INC.
GROUND-WATER CONSULTANTS
WEST PALM BEACH, FLORIDA

MARCH 1982

HYDROGEOLOGIC INVESTIGATION AT THE KEY WEST, FLORIDA, TERMINAL

March 1982

Prepared for:
Smathers & Thompson
Attorneys for
Chevron U.S.A., Incorporated
169 East Flagler Street
Miami, Florida
33131

Prepared by:
Geraghty & Miller, Incorporated
Ground-Water Consultants
1665 Palm Beach Lakes Blvd., Suite 604
West Palm Beach, Florida
33401

TABLE OF CONTENTS

LIST OF FIGURES

HYDROGEOLOGIC INVESTIGATION AT THE KEY WEST, FLORIDA, TERMINAL

Confidential; Privileged attorney-client communication and attorney work product prepared in anticipation of litigation; restricted distribution.

INTRODUCTION

During the latter part of 1981, Geraghty & Miller, Inc., conducted a hydrogeologic investigation at the Key West Terminal of Chevron, U.S.A., located at 909 Caroline Street, Key West, Florida. The prime purpose of the study was to determine the nature of the ground-water flow system — in particular the direction of hydraulic gradient of the water-table aquifer; the nature of the materials comprising the aquifer; relationships (if any) with saline water of Key West Bight; and the influence of the ground-water system on the occurrence and movement of product present in the subsurface.

Prior to Geraghty & Miller's involvement, Chevron had been working for several months on the recovery of a documented product spill. These efforts consisted of the installation of a number of shallow, small-diameter exploratory holes, (referred to as wells) and several large-diameter wells (referred to as culverts) for the recovery of product. The former were used to aid in locating optimum sites for the culverts. A second purpose of the Geraghty & Miller investigation was to evaluate the effectiveness of the recovery operations.

The program goals were accomplished by installing additional monitor wells both on and off site to explore areas where no work had been done previously, to collect information on the nature of the materials forming the water-table aquifer, and to aid in mapping the water table. Selected wells were equipped with automatic water-level recorders; the remainder were monitored manually. The wells were surveyed to determine well-head elevations to permit mapping of the water table to a common datum. The various water-level and geologic data were then interpreted to determine the direction of movement, the effect of tidal fluctuations, and their influence on the occurrence of product floating on the water table.

This report documents the results of the investigation. It contains sections dealing with the methodology employed, the geologic setting, data interpretation, and findings. Supporting data in the form of figures, tables, and logs are presented in the text and appendix to the report.

FINDINGS

(1) Saline ground water occurs at shallow depths in artificial fill consisting of fine- to medium-grained silty sand and construction debris. The fill overlies limestone (Miami Oolite), a rock having varying permeability owing to the effects of solution. There is little opportunity for a fresh ground-water lens to develop because of limited rainfall recharge and tidal fluctuations which tend to disperse any fresh water entering the system. Because of limited recharge, tidal fluctuations are the principal mechanism controlling ground-water movement.

(2) Mapping of the water table reveals the existence of two distinct depressions in the water-table surface. One is located near the east-central portion of the property in the vicinity of Culverts 4 and 8 and Well 8; the other is located on the north part of the property near Well 1B and adjacent to the concrete sea wall. The sea wall acts as an effective barrier to the movement of water and product. The depressions are persistent features. Because they are consistently lower in elevation than the surrounding water table, water and product will migrate laterally into them from off the property. Because the product is less dense than the underlying salt water, it would tend to accumulate in the depressions and remain there. ~ over a period of time product components will tend to molecularly diffuse.

(3) The data show that product has accumulated in the two depressions. Product present in the depression adjacent to the sea wall probably is the result of the documented leaks in nearby lines and from the (now) discontinued practice of preserving lobster pots with oil. The accumulation of product in the depression near Culverts 4 and 8 is the result of documented spills and leaks and the lateral movement of product onto the property from outside areas.

(4) Judging from the recorded increase in product thickness observed in Wells 10 and 12 following the resumption of recovery operations, product is moving onto the property from the south. The source of the product is unknown and may be from the pipeline in Caroline Street or from past documented spills at the City electric plant. Additional exploratory work would have to be done (not by Chevron) to locate the source. why not?

(5) No product appears to be entering the property from the west, judging from its continued absence in the samples from Well 16.

(6) Wells 18 and 19, located east of the property, have remained free of product since they were completed in early December 1981. The

water-level data indicate that product would not move off site (upgradient) to the east.

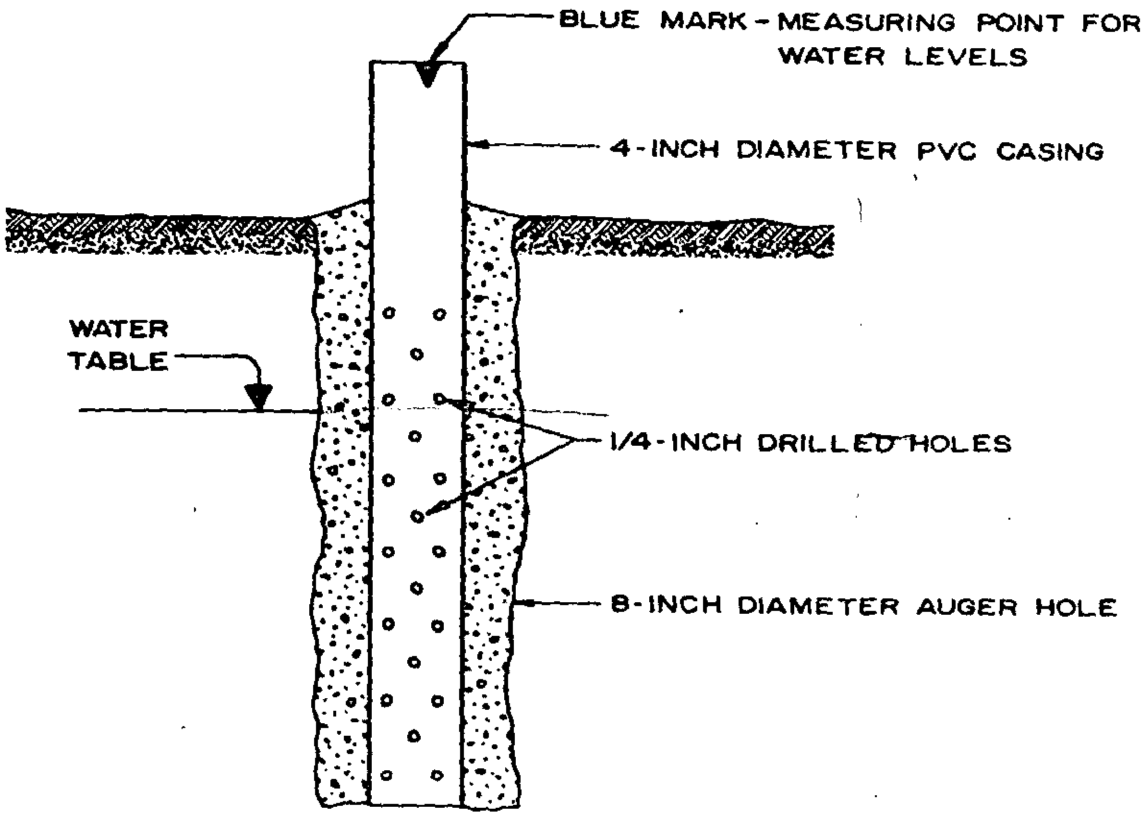
METHODOLOGY

Monitor Wells

A key element of the investigation was to map the water table and determine its fluctuations and their influence on the behavior of any hydrocarbons floating (because of their lower density) on the water table. At the outset of the program, it was believed that the ground-water flow system was the result of the development of a lens of fresh water floating on more dense saline ground water — a regime found in a setting such as Key West. The investigation revealed that this setting exists to a limited extent. However, it also was found that tidally-induced water-table fluctuations play an extremely important role and are the dominant influence on the behavior of water and product movement in the subsurface.

Prior to the Geraghty & Miller investigation, a series of wells and culverts had been installed by Quality Maintenance of Key West, Florida, for Chevron to identify areas where product was present on the subsurface and for the recovery of product. The wells were constructed by digging a hole to expose the water table, installing 12-inch-diameter PVC casing and filling the annulus with clean, crushed limestone as a gravel pack. The casings were perforated with drilled one-quarter-inch-diameter holes to achieve communication with the water table. No logs or well-construction data are available. Inspection of the wells revealed that they were adequately constructed to serve their intended purpose. Eight wells were installed numbered 1A, 1B, 2, and 5 through 9; one was constructed with 12-inch-diameter concrete pipe. The culverts are 36-inch-diameter steel pipe (one is 12-inch-diameter pipe) and were installed in the same manner as the wells; a total of five were constructed.

A total of 10 shallow holes were drilled as part of the Geraghty & Miller study. Of these, three (wells 13, 15, and 17) could not be completed due to the presence of concrete and construction debris. Wells 10, 11, 12, 14, and 16 were completed as monitor wells equipped with perforated 4-inch-diameter PVC casings; the off-site wells, Wells 18 and 19, were completed with two-inch diameter PVC casings . Each one is gravel packed and was constructed by centering the PVC casing within an 8-inch-diameter auger drilled hole and filling the annulus with clean, washed, and crushed limestone gravel. The off-site wells were installed by hand. Details of the construction of these wells are listed in Table 1 in Appendix A. Typical construction details are shown on Figure 1.



NOT TO SCALE

PREPARED FOR CHEVRON, U.S.A.		
TITLE MONITOR WELL CONSTRUCTION DETAILS Key West Terminal		
COMPILED BY V.P. Amy DRAWN BY P.Q. Smith	Geraghty & Miller, Inc. West Palm Beach, Florida	DATE March 1982 REVISED
CHECKED BY V.P. Amy	SCALE None	FIGURE 1

Monitoring and Data Collection

Prior to the implementation of the Geraghty & Miller monitoring program, Quality Maintenance was operating a product recovery system consisting of depression and skimmer pumps. Both product and water were removed from the ground. The product was separated from the water and removed from the site by a contractor. Water was returned to the ground through Culvert 1. The elevation of the water table was influenced by these activities. Because knowledge of the behavior of the water table under static conditions is essential to determining the factors controlling the subsurface movement of product, the recovery system pumps were turned off on November 7, 1981, to eliminate this influence. On November 6th, Quality Maintenance began measuring the depths to the top of the fluid surface in each well. Samples of the fluid also were taken from each well; in those wells where product was found, its thickness was measured. The Geraghty & Miller hydrogeologist instructed personnel of Quality Maintenance in the measurement of water levels and the recording of the data. — data appears relevant to product only; we should address components in the ug/l–mg/l range and their potential also.

The Geraghty & Miller monitoring wells were installed during the period December 2 through 8, 1981. Leupold & Stevens Type F automatic water level recording devices were installed on three of the wells. Continuous records of the static levels were taken until January 4, 1982. Recovery operations were resumed on January 20, 1982; the recorders were operated for about one week and were removed. During these periods, personnel of Quality Maintenance continued to collect daily measurements of the depth to fluid level in the wells and information on the presence and thickness of product.

The firm of Keith & Schnars, P.A., Licensed Surveyors, of Deerfield Beach, Florida was retained by Geraghty & Miller to survey the elevations of the various wells and culverts. This work was performed on December 8, 1981. The results of the survey and a location map are shown on Plate 1 in the pocket at the back of the report. The elevations of the wells were referenced to NGVD (National Geodetic Vertical Datum). In addition, the surveyor set a pin in the sea wall at the north end of the property. The pin was used as a reference point for measuring the tide level in Key West Bight in order to relate the water-table measurements to water levels in the Bight. The various routine field and office operations performed by Geraghty & Miller were conducted by an experienced staff geologist. Work tasks included installing and maintaining recording devices, collecting and analyzing formation samples; and preparing water-table and product thickness maps, hydrographs, and geologic logs.

Wells or culverts bearing numbers 1 through 9 were installed by Quality Maintenance for the recovery program. Wells 10 through 19 were drilled as part of the Geraghty & Miller program. Wells 13, 15, and 17 were never completed due to the presence of construction debris. Wells 10, 11, 12, 14, and 16 are on the terminal property; Wells 18 and 19 are off the property to the east on the east side of Grinnel Street on property owned by Singleton Sea Foods (Conagra). These latter wells were drilled to aid in mapping the water table and in determining the effectiveness of the recovery operation.

TERMINAL SETTING

The Key West terminal property is located on artificial fill overlying bedrock. The fill was emplaced a number of years ago. Based on the logs of the Geraghty & Miller wells, the fill consists of poorly sorted, fine- to medium-grained, silty, calcareous sand. Sand usually constitutes from 60 to 70 percent of a sample. Silt and clay form 10 to 20 percent of a sample, and gravel-sized fragments can make up as much as 20 percent. The color ranges from medium-grey to grey-brown. Considerable construction debris (concrete, block, foundations, etc.) is present; this prohibited the construction of three of the Geraghty & Miller wells. The logs of the various auger holes are included in Appendix A. Basically, the fill material is heterogeneous in nature and has a permeability estimated to range between 0.001 and 0.0001 cm/sec (centimeters per second).

The bedrock is assumed to be formed by the Miami Oolite. This formation can be a soft, white to yellowish limestone. It can be massive, cross-bedded, and stratified. Often it contains numerous sand-filled solution holes and channels, giving the rock an extremely high porosity. However, the degree of interconnection between pores and open spaces in the rock is low. Also, many of the solution features are vertically oriented, so that the vertical permeability of the rock is much higher than the horizontal (Parker, et al, 1955). Three continuous layers of hard, dense limestone have been reported being present in the formation. The depth to the top of the Miami Oolite beneath the fill is unknown, however, as none of the wells or auger borings penetrated this unit. The greatest depth reached by the Geraghty & Miller wells was about seven feet.

how is this known?

The water table occurs in the unconsolidated fill deposits. Water was encountered at depths of three feet or so below grade in the borings. Static water levels correspond to elevations of approximately sea level (0 feet NGVD). The northern portion of the terminal property is bounded by a concrete sea wall which extends for some distance back to the east and west. Reportedly, the sea wall was founded on bedrock and, therefore, would serve as a barrier to the movement of fluids contained in the water table. Evidence of its effectiveness as a barrier is presented in a subsequent section of the report.

Most of the land surface over the bulk of the property is covered with material of low permeability. The north end of the terminal is paved and most of the southern portion of the property is covered with compacted crushed limestone fill in addition to paved surfaces. The site is in a developed area and is surrounded by buildings, roads, parking lots, and sidewalks all of which are either paved or compacted to a high degree. These conditions would limit the amount of recharge by rainfall to the water table.

Annual rainfall in the Key West area averages 39.99 inches (Water Information Center, 1974), with the bulk falling during the rainy season occurring from June through October. Potential evapotranspiration in the Key West area is greater than the rainfall and is in excess of 50 inches per year (Dohrenwend, 1977).

In this type of setting very little recharge occurs. Paved and other relatively impermeable surfaces limit the amount of precipitation that can infiltrate into the ground and migrate to the water table. The little recharge that does occur may be reflected as an increase in the elevation of the water table, but soon dissipates due to evapotranspiration. Furthermore, cyclic water-level fluctuations of the water table results in the dispersion and tidal mixing of any fresh-water recharge with native salty ground water. Consequently, there is little opportunity for a significant lens of fresh water to develop. The recharge that does occur may result in the development of thin, isolated lenses of brackish water floating on saline water. These would be temporary because of the cyclic nature of the rainfall. During the rainy season, the water table may rise to above sea level; however, during the dry period it will decline. Evidence of this can be seen from the water-table elevations, which are normally at or close to sea level. Analysis of water samples collected from four of the monitor wells (Wells 8, 12, 14, and 18) attests to the salinity of the ground water. Copies of the laboratory reports are included in Appendix A, and the results are tabulated below.

Total Dissolved Solids Content of Water
from Selected Monitor Wells
at the Key West Terminal

Well No.	Total Dissolved Solids (milligrams per liter)
8	3,516
12	38,396
14	11,680
18	50,274

It would be more meaningful to have salinity (‰) data supplied for this situation

The range in salinities is considerable and is believed to be a result of the combined effects of limited recharge and evaporation from the water table. The lower values (from Wells 8 and 14) reflect the inputs of small amounts of fresh rain water and the development of very thin and minor lenses of brackish water due to tidal mixing of rain and saline ground water. There also may be some influence from the washing of vehicles with fresh water.

The higher salinity values were found in water from Wells 12 and 18 which are located in open grassy areas. The observed values are in excess of normal concentrations of total dissolved solids in (36,000 mg/l) sea water. They are the result of evaporation from the water table, which is normally as salty as sea water. In areas where potential evapotranspiration (evaporation from water and transpiration by plants) exceeds the annual rainfall, losses from the water table to the atmosphere can result in an increase in salinity because only the water and not the salt is evaporated. This phenomenon has been documented in other areas in southwest Florida where the annual rainfall is less than evapotranspiration (Amy, 1980). Also, the concentration of total dissolved solids in excess of normal sea water values indicates that the rate of ground-water circulation or movement in the fill materials is slow. - maybe. It could also indicate that the fill is a source of TDS, or another contributor exists in the area.

...tuitive!

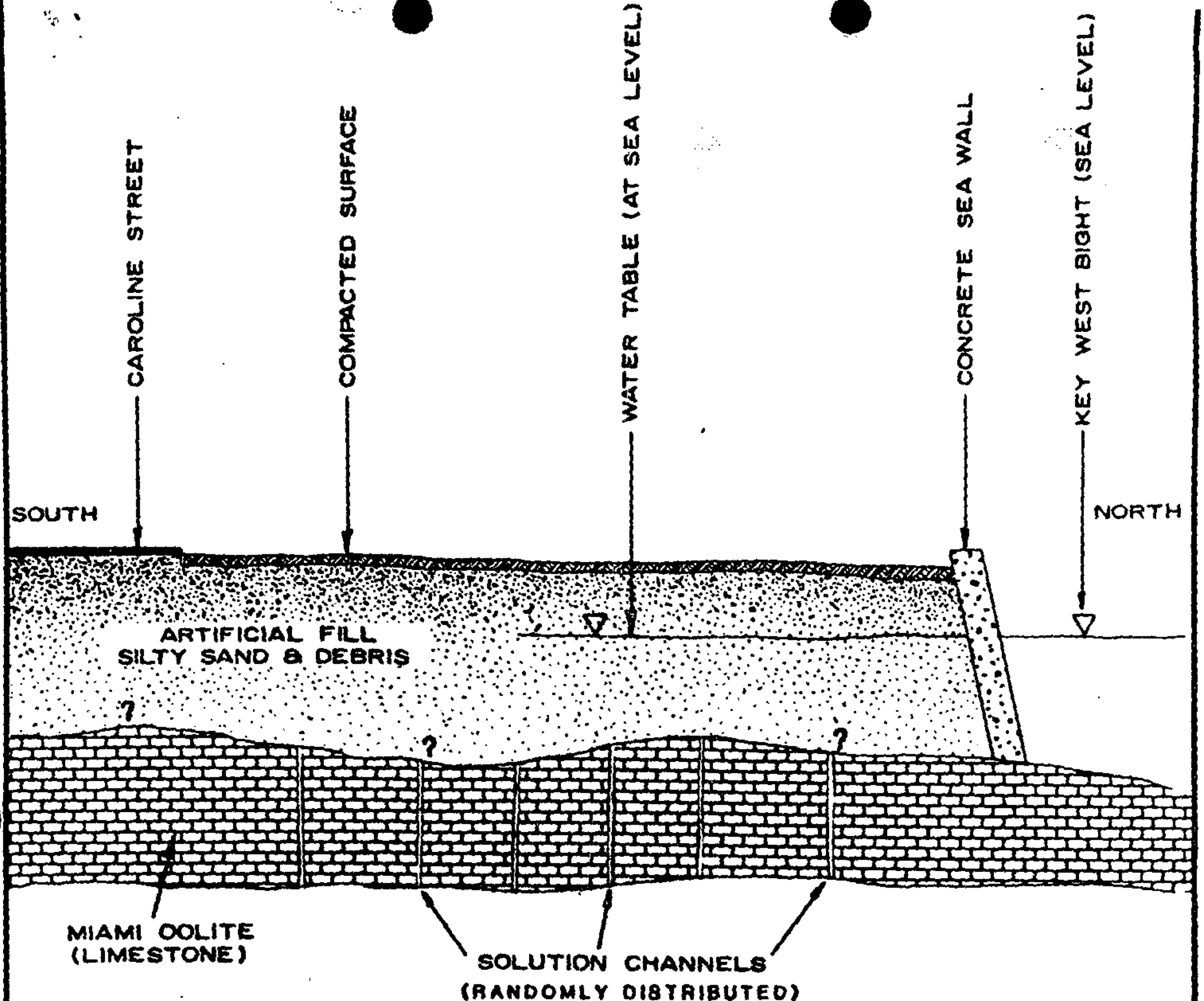
i.e. Amy couldn't take credit for his "discovery".

A schematic cross section of the terminal site showing the relationships between the various parts of the system is given on Figure 2.

MONITORING RESULTS AND INTERPRETATION

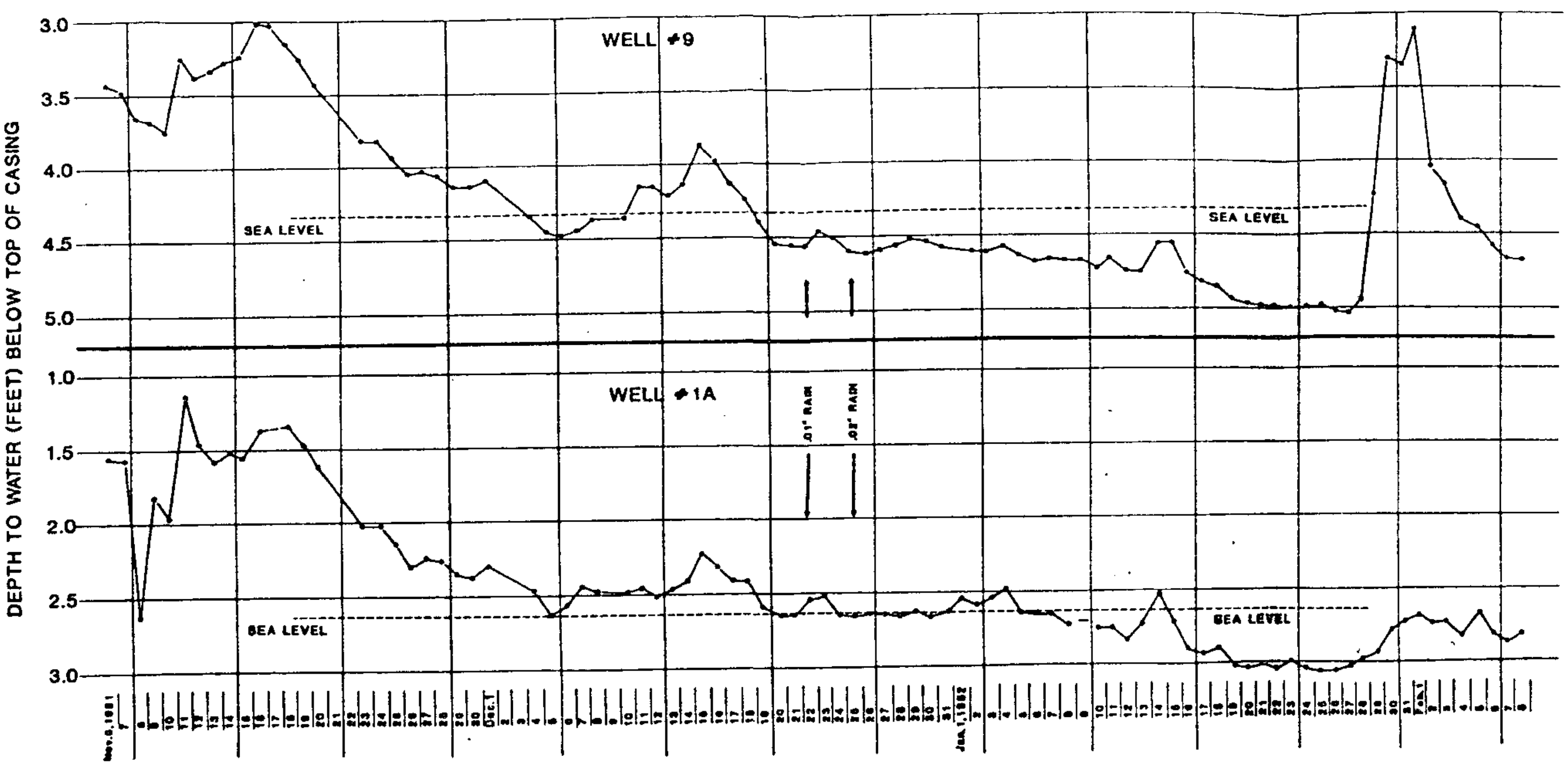
Recovery operations were stopped temporarily on November 7, 1981, to eliminate the effect of pumping and make it possible to investigate the behavior of the water table under static conditions. Hydrographs of the water levels in Wells 1A and 9 are shown on Figure 3. The period of record ends on February 8, 1982. Hydrographs of Wells 11 and 16 are given on Figure 4; these cover the period from December 5, 1981, through February 8, 1982. These wells were selected because of their widely-distributed locations on the property. Wells 1A and 9 are near Key West Bight, while Wells 11 and 16 are inland. Consequently, the data are respresentative of water-level behavior over the entire property. Evaluation of the water-level data from the other wells shows similar behavior.

Examination of Figure 3 shows that the water levels rose for about 10 days (until November 17th) or so after the shut down of recovery operations, and then began to decline slowly, reaching sea-level elevation in early December. Thereafter, the level continued to fluctuate at elevations close to sea level for the remainder of the period of record. The fluctuation of the water level in Wells 11 and 16 (shown on Figure 4) is essentially the same. Overall, the behavior of water levels in all four wells is essentially the same; highs and lows correlate well with each other.



NOT TO SCALE

PREPARED FOR CHEVRON, U.S.A.		
TITLE SCHEMATIC CROSS SECTION Key West Terminal		
COMPILED BY V.P. Amy DRAWN BY P.O. Smith	Geraghty & Miller, Inc. West Palm Beach, Florida	DATE March 1982 REVISED
CHECKED BY V.P. Amy	SCALE None	FIGURE 2



PREPARED FOR

CHEVRON, U.S.A.

TITLE

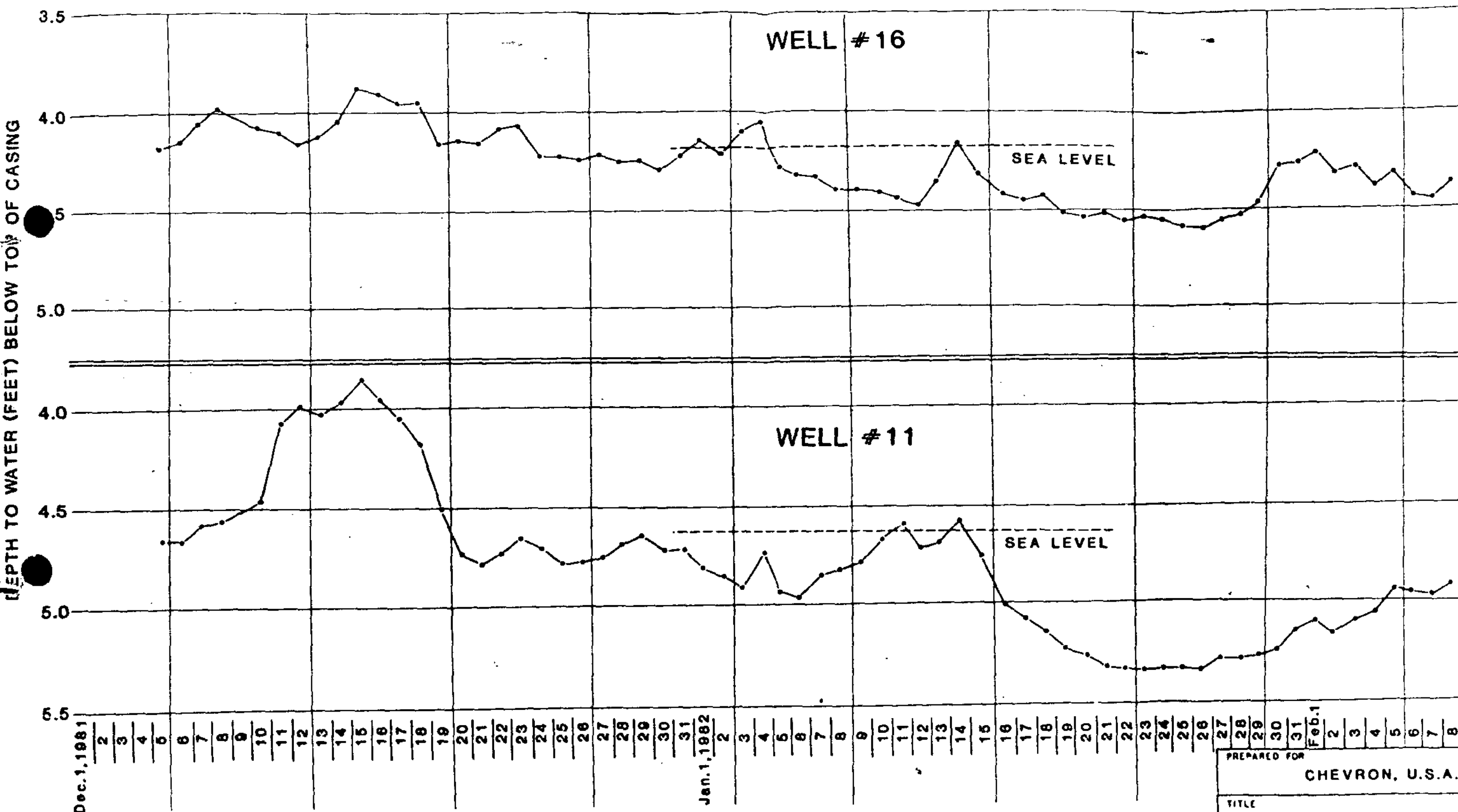
HYDROGRAPH OF WATER LEVELS IN WELL 9 AND WELL 1A

Key West Terminal

COMPILED BY V.P. Amy

Geraghty & Miller, Inc.

FIGURE 3



PREPARED FOR
CHEVRON, U.S.A.

TITLE
HYDROGRAPH OF WATER LEVELS
IN WELL 16 AND WELL 11
Key West Terminal

Geraghty & Miller, Inc.

FIGURE 4

The continuing decline of water levels shown on the hydrographs and observed in all of the wells is a reflection of the onset of the dry season and represents a normal water-level decline. During the period of record, very little rainfall occurred. Data furnished by Quality Maintenance indicate that it rained on December 22 and 25, 1981; 0.01 and 0.02, inches were recorded, respectively. On January 14, 1982, 0.05 inches were recorded.

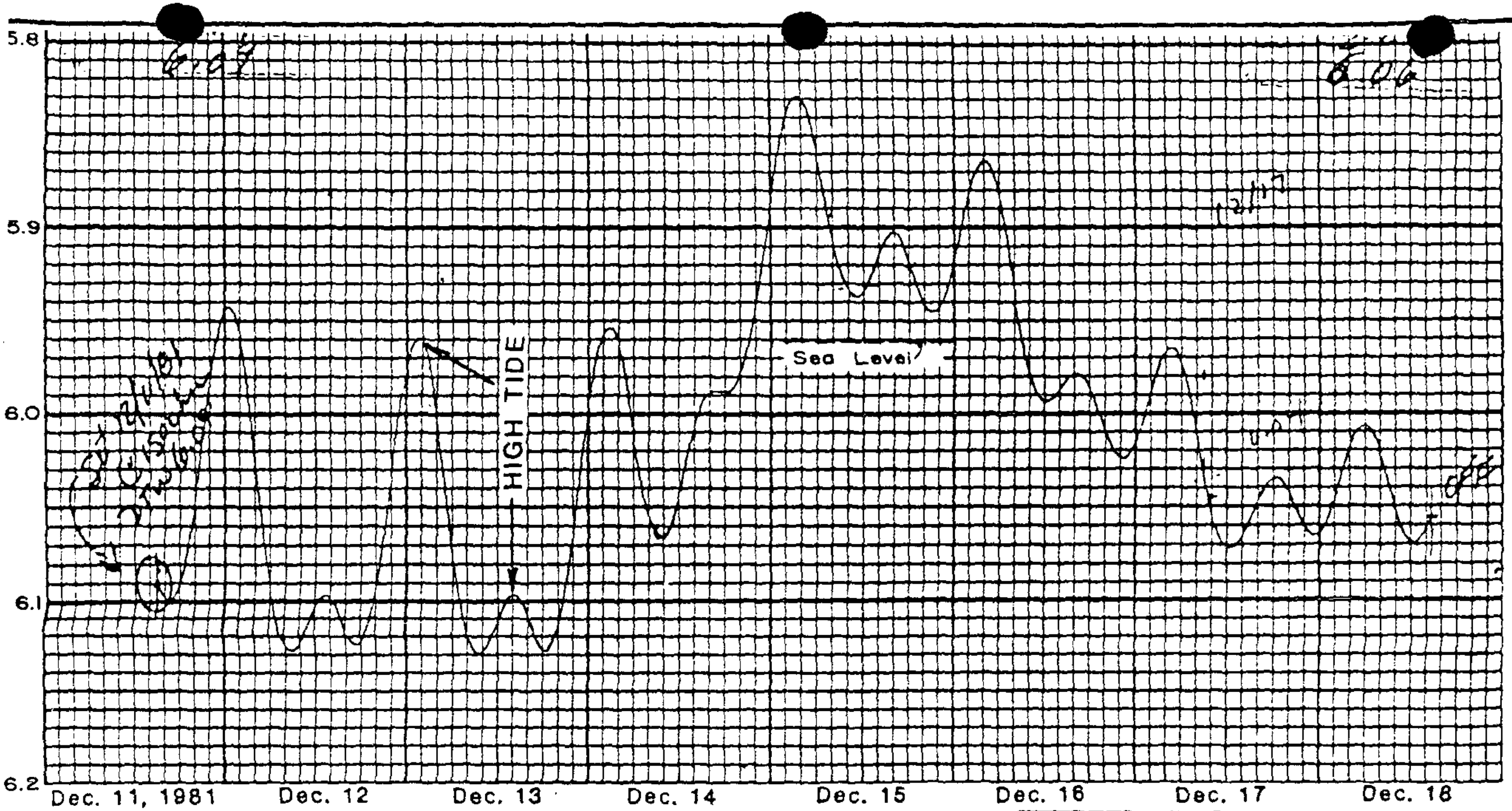
Examination of Figures 3 and 4 show no noticeable change of water levels that can be correlated with the rainfall occurring during the period of record.

The continuous water-level records show the influence of tidal fluctuations in Key West Bight on the water table. Tidal fluctuations in the Key West area are somewhat unusual; two highs and lows occur each day (actually slightly more than 24 hours). However, the amplitudes of the tidal highs differ. Each day there is one "very" high tide and one that is high, but lower in elevation. The "very" high tide will have an elevation of roughly +2 feet NGVD under normal conditions, while the other will be about +1 foot NGVD. Daily lows will range from as much as +.7 foot NGVD to -.7 foot NGVD. A typical example is shown on Figure 5, which is a record of water levels from Culvert 4 for the period December 11 through 18, 1981. The same type of fluctuations were noted on the records from the other wells.

In the absence of significant amounts of recharge, which precludes the development of a "significant" lens of fresh water and the formation of a "typical" ground-water flow system, tidal fluctuations assume an important role. Because water-table elevations generally remain at or close to sea level the movement of ground water is strongly influenced, even dominated, by the relationship between the elevation of the water table and the level to the sea (in this case Key West Bight) and not some arbitrary constant datum such as NGVD. This relationship is the dominant factor controlling the movement of fluids in the water-table aquifer at this Key West terminal. Its implications are discussed in a subsequent section.

Density (ρ) is the master variable

Comparison of the water-level records reveals that the tidal highs and lows occur later than predicted times for high and low tides at Key West. This is normal and may be due largely to the location of the station at which the "ocean" tides are measured relative to the wells on Key West Bight adjacent to the terminal. Comparison of the lag times between observed tidal highs and lows for two wells located at different distances from Key West Bight and the predicted highs and lows reveals a significant fact. The lag time for the tidal highs in the well closest to the Key West Bight is greater than for a well located further inland. This can be seen in Table 1, which lists the predicted high and low tides at Key West and the lag times for Culvert #1 and Well 10 for a three-day period in December 1981. The former is closer to Key West



NOTES:

(1) Culvert #4 record

(2) Water Level Measurements taken from the top of the well casing

(3) Elevation of the top of the casing: +ft.NGVD

PREPARED FOR

CHEVRON, U.S.A.

TITLE

TIDAL INFLUENCES ON WATER LEVELS

Key West Terminal

COMPILED BY V.P. Amy

DRAWN BY P.O. Smith

CHECKED BY V.P. Amy

Geraghty & Miller, Inc.
West Palm Beach, Florida

SCALE

DATE March 1982

REVISED

FIGURE 5

Bight while the latter is located in the southeastern corner of the terminal property.

Comparison Between Predicted Tidal Peaks
at Key West and
Observed Times in Well 10 and Culvert 1

Date	Predicted Time at Key West	Observed in Well 10	Observed in Culvert 1
12/11/81	Low 1457	1700	1730
	High 2123	0100	0130
12/12/81	Low 0435	0930	1000
	High 1053	1400	1530
	Low 1540	1800	1830
	High 2209	0200	0230
12/13/81	Low 0524	1000	1100
	High 1142	1450	1500
	Low 1628	1900	1930
	High 2258	0300	0330
12/14/81	Low 0613	1000	1100

Examination of the table shows that the times of both high and low tides occur consistently later in Culvert 1 than in Well 10. Normally the time lag between tidal highs and lows in a surface-water body and a nearby well is least in wells closest to the shore and increases with increasing distance from the coastline. This is analogous to a wave starting at the shoreline, influencing a nearby well, and traveling inland to influence a well at a later time. The observed lags at the Key West terminal are the reverse of what would be expected and are attributed to the presence of the sea wall which acts as a barrier to the movement of water. Because of the presence of the sea wall, Well 10 is closer hydraulically to the Bight than Culvert 1, and therefore, it responds sooner to tides than does the level in Culvert 1. In this case, the sea wall acts as a barrier to the movement of water and product and aids in preventing discharges of hydrocarbons floating on the water table at the terminal into Key West Bight. → perhaps, but has any monitoring been conducted to indicate contamination is not entering under this barrier?

It was concluded previously that the principal factor controlling ground-water movement is the hydraulic gradient that is developed between the elevation of the water table and the elevation of the water surface in Key West Bight. This is not a static relationship because of tidal fluctuations. Thus, any investigation of the flow system must examine the relationship between water levels in the aquifer and the

...ell again, ...sity and ...usion are not mentioned!

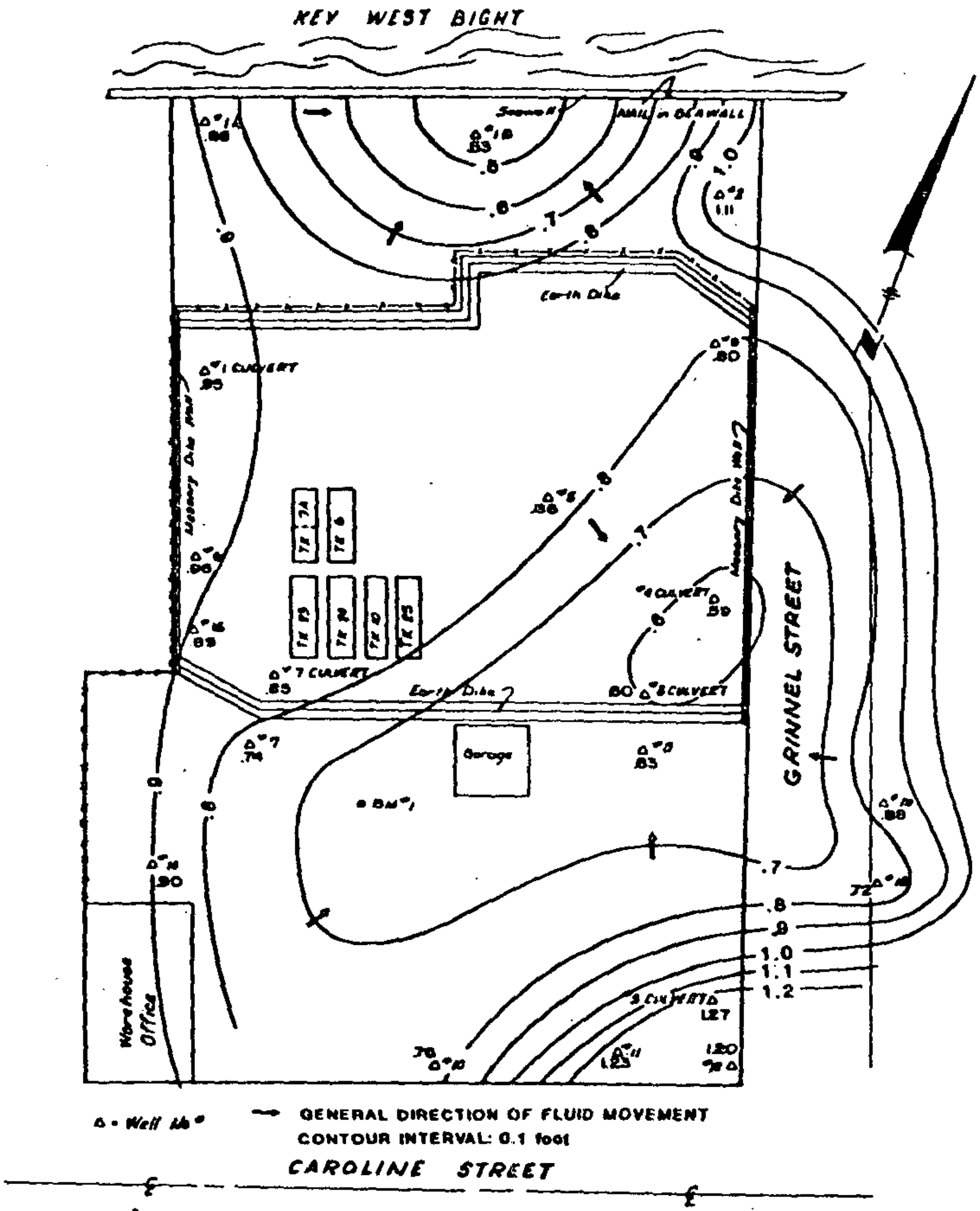
level of the Bight with respect to tidal fluctuations rather than relative to some arbitrary datum such as mean sea level (NGVD).

As part of the investigation, the surveyor set a pin in the sea well adjacent to the Bight and measured its elevation. Each day when the water levels in the wells were measured, the depth to the water level in the Bight was determined. Because the elevations of the pin and the wells were known, it was possible to determine the relationship of the water table to the tide level at the time the water-level measurements were taken. This made it possible to establish the relationships between the water table and the level in the Bight for high, low, and mean tides. Contour maps showing the water table referenced to high, low, and mean tides are shown on Figures 6, 7, and 8. Actually, the maps represent the surface of the fluids because the measurements were taken of the depth to the top of fluid in the well, which is water or product depending on the well. This does not affect the data and any conclusions because: (1) the product layer is thin where it is present; and (2) correcting for density would not change the shapes of the maps.

Examination of the maps reveals features that are significant insofar as the behavior of fluids in the subsurface is concerned. Figure 6 is the contour map of levels relative to low tide on December 17, 1981 (That date was selected because the time when the water levels were measured was close to the low tide in Key West Bight. Similarly, other dates were selected for preparing the other maps because the time of data collection coincided with high and mean tides in the Bight.). Figure 6 shows water levels that are positive with respect to the level in the Bight. In general, they appear to increase in elevation with increasing distance inland from the sea wall. The map also shows that two depressions exist in the water table; one is in the general vicinity of Well 1B, and the other in the area formed by the east-central and eastern portion of the property near the garage Culverts 4 and 8, and Well 8. These two depressions represent sinks towards which fluids would move. The general direction of movement is indicated by the arrows on the map.

Figure 7 shows the relationship at mean tide and represents an average condition. The water level is still positive with respect to tide, but not as great as at low tide. In general, elevations are still higher inland. The two closed depressions still exist and the general directions of movement remain the same.

Figure 8 shows water-level relationships at high tide. In this case, levels appear to be higher closer to the sea wall and lower inland, although they are higher at Wells 18 and 19 which are located on the east side of Grinnel Street. The water-table depression in the vicinity of Well 1B is not present. However, the larger depression in the vicinity of Well 8 and Culvert 8 still persists. The general direction of movement, particularly from the east towards the terminal property, remains the same.



PREPARED FOR

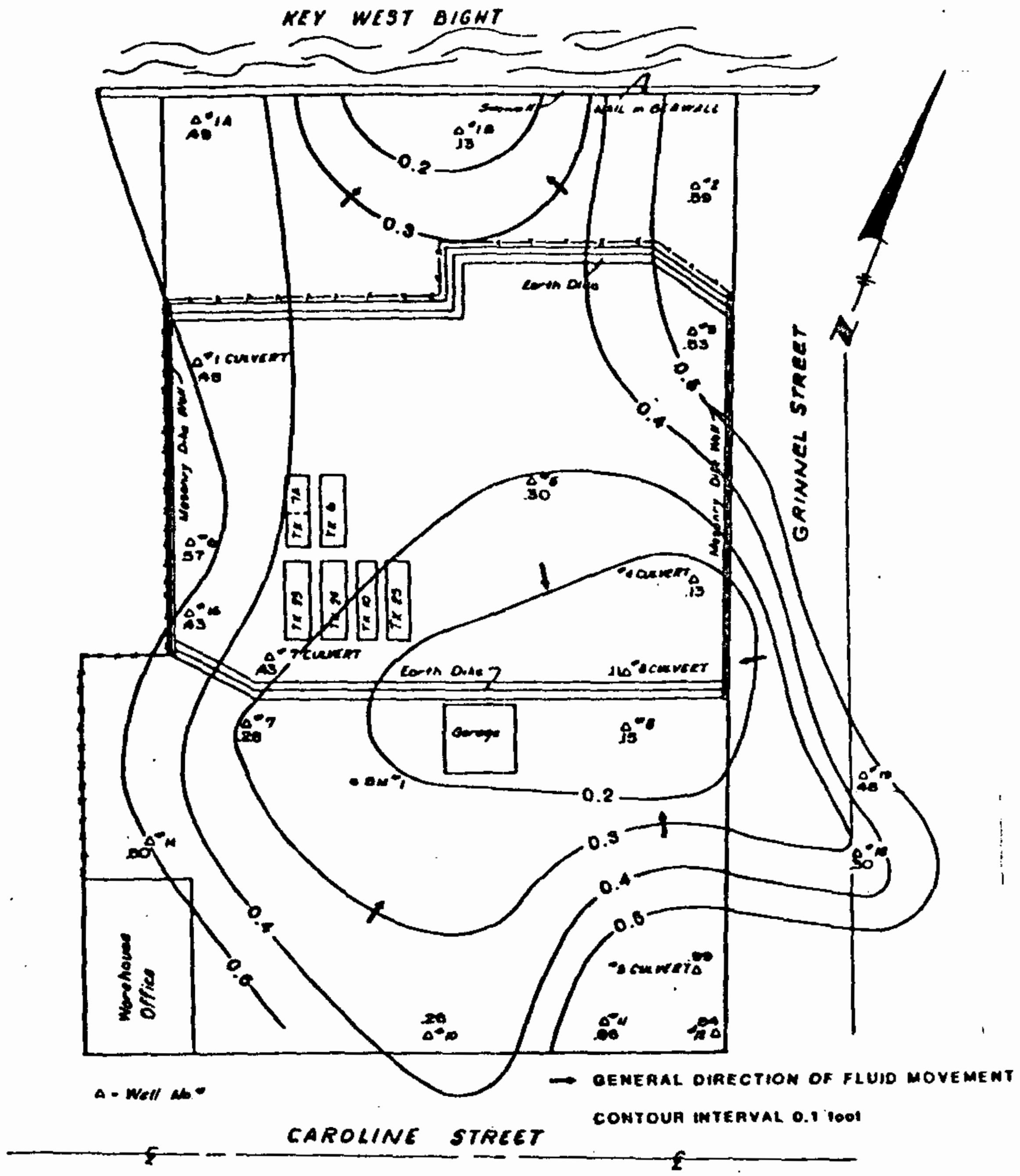
CHEVRON, U.S.A.

TITLE

FLUID LEVELS RELATIVE TO LOW TIDE IN KEY WEST BIGHT

December 17, 1981
Key West Terminal

COMPILED BY V.P. Amy	Geraghty & Miller, Inc.	DATE March 1982
DRAWN BY P.Q. Smith	West Palm Beach, Florida	REVISED
CHECKED BY V.P. Amy	SCALE None	FIGURE 6



PREPARED FOR

CHEVRON, U.S.A.

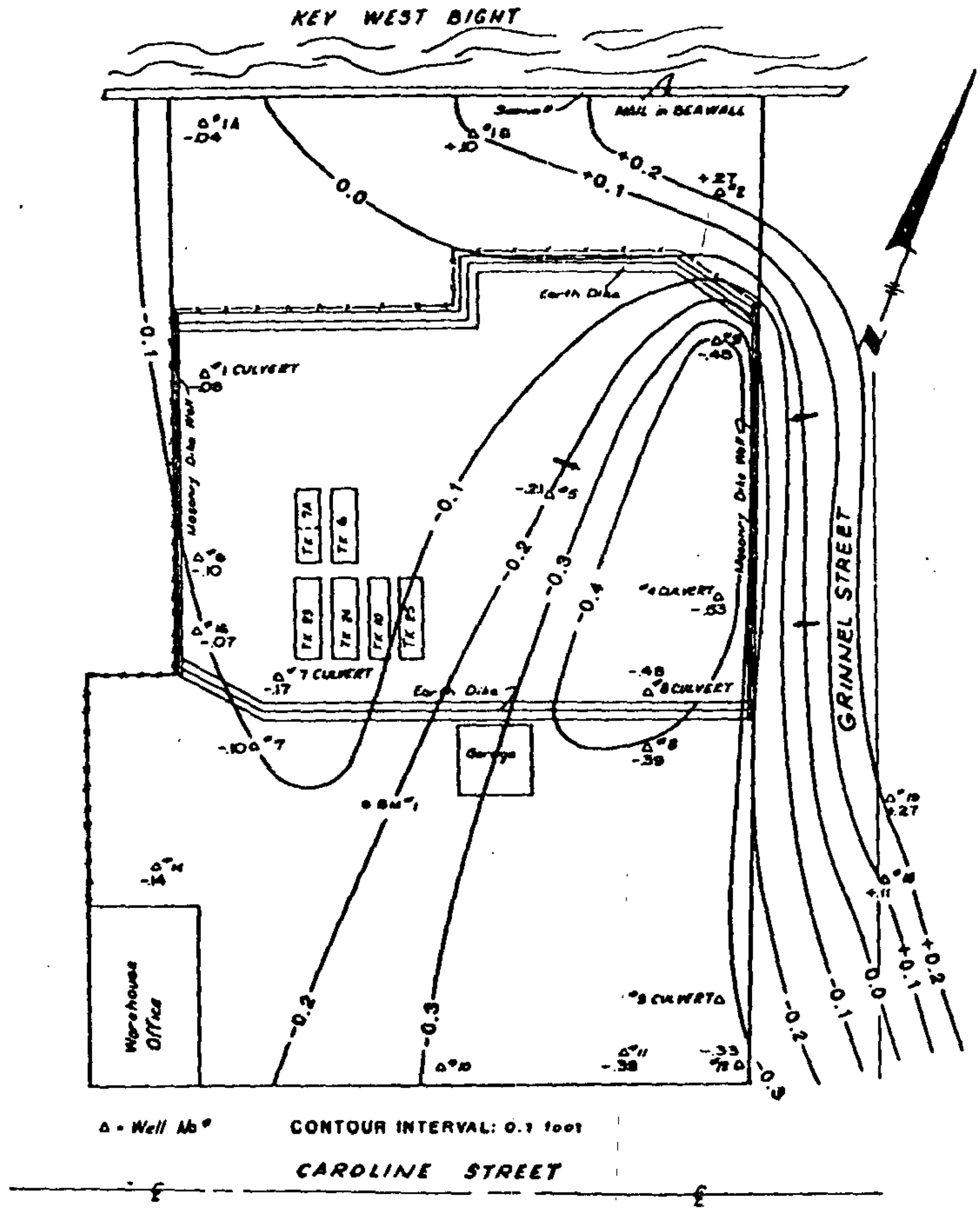
TITLE

FLUID LEVELS RELATIVE TO MEAN TIDE IN KEY WEST BIGHT

December 15, 1981

Key West Terminal

COMPILED BY V.P. Amy	Geraghty & Miller, Inc. West Palm Beach, Florida	DATE March 1982
DRAWN BY P.Q. Smith		REVISED
CHECKED BY V.P. Amy	SCALE None	FIGURE 7



PREPARED FOR

CHEVRON, U.S.A.

TITLE

FLUID LEVELS RELATIVE TO HIGH TIDE IN KEY WEST BIGHT

January 4, 1982

Key West Terminal

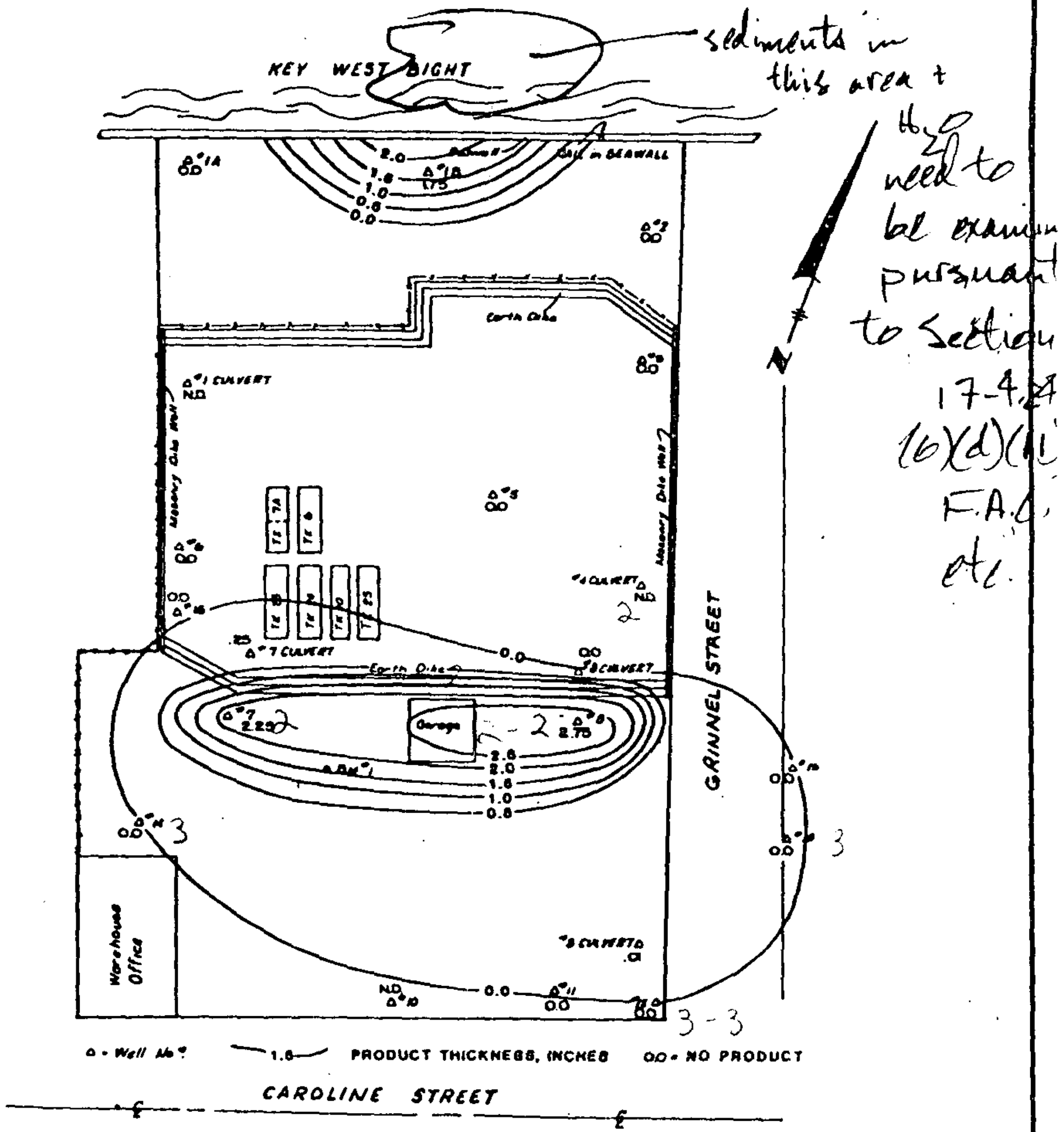
COMPILED BY V.P. Amy	Geraghty & Miller, Inc.	DATE March 1982
DRAWN BY P.O. Smith	West Palm Beach, Florida	REVISED
CHECKED BY V.P. Amy	SCALE None	FIGURE 8

The cause of the closed depressions is unknown. They could be caused by greater rates of evaporation in those areas from the water table or due to greater permeability of the fill and/or the underlying Miami Oolite. In any event, they are real and persistent features. As far as flow is concerned, they represent sinks towards which water and product will move from both on and off site. Spills of fluid on the terminal would tend to migrate toward them and accumulate in them rather than move off the property. (Because product is less dense than water, it would tend to float on saline or brackish water and remain in the water-table depressions.) — see previous comments with regard to such statements.

The high and low tide maps show an apparent reversal of the overall gradient. The depression centered on Well 1B disappears and the major one centered on Well 8 and Culvert 8 remains. This is a temporary situation occurring only at high tide. Long-term conditions with two depressions existing are best represented by the mean tide conditions depicted on Figure 7.

During the course of the investigation, personnel of Quality Maintenance collected samples of the fluid from each of the wells, and measured the thickness of any product floating on the surface. This information was plotted on a base map of the terminal and contoured to produce an isopach (thickness) map of the product. Data for December 14, 1981, are presented on Figure 9; Figure 10 shows data collected on November 6, 1981. This shows accumulation of product in areas that correlate with the known water-table depressions. Whether or not the contours represent the actual product thickness in the ground is speculative and the presentation may be in error. Consequently, it should not be used to determine an estimated quantity of product in the ground. The maps were prepared to demonstrate the relationship between the occurrence of product and the depressions in the water table. The fact that product is present or absent in a well cannot be denied. However, the presence or thickness of product in a well may not necessarily be a valid or reliable indicator of the thickness of product in the ground surrounding a well or in the area.

Comparison of product thickness in Well 8 between the two dates (November 6th and December 14th) shows that it was greater on November 6th than it was December 14th. The difference may be due to the fact that on December 14th the water level was at a depth of 68.75 inches, while on November 6th it was at 61.5 inches. The apparent reduction in thickness may be due to the fact that some of the product was not part of the lens because it was suspended above the water table and capillary zone. The product probably is less mobile than water and remained suspended when the water table declined. The December 14th data on product thickness were collected at a time of low tide. This relationship has no significant influence on the behavior of the product and does not alter any conclusions; it is presented simply to illustrate the difficulty associated with attempting to determine quantities of product in the ground based on the thickness observed in a well.



PREPARED FOR

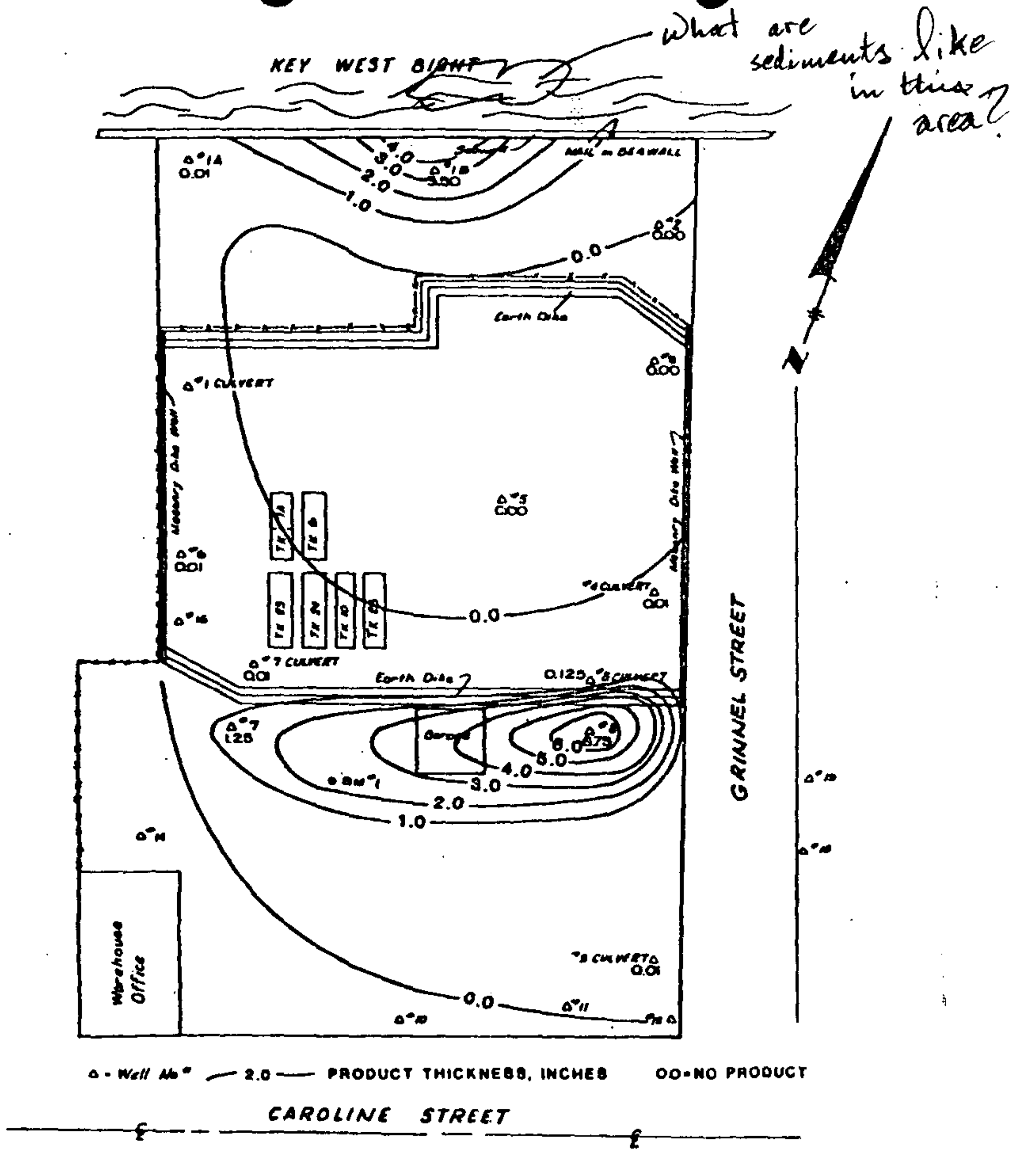
CHEVRON, U.S.A.

TITLE

PRODUCT ISOPACH MAP

December 14, 1981
Key West Terminal

COMPILED BY V.P. Amy	Geraghty & Miller, Inc.	DATE March 1982
DRAWN BY P.G. Smith	West Palm Beach, Florida	REVISED
CHECKED BY V.P. Amy	SCALE None	FIGURE 9



PREPARED FOR

CHEVRON, U.S.A.

TITLE

PRODUCT ISOPACH MAP

November 6, 1981
Key West Terminal

COMPILED BY V.P. Amy	Geraghty & Miller, Inc. West Palm Beach, Florida	DATE March 1982
DRAWN BY P.Q. Smith		REVISED
CHECKED BY V.P. Amy	SCALE None	FIGURE 10

Product Monitoring

The monitor wells installed for the Geraghty & Miller investigation were located along the periphery of the terminal property and off the property to the east. These latter wells, numbers 18 and 19, were installed on the east side of Grinnel Street. The first water-level measurements and samples (for product) from these wells were collected on December 7, 1981. Since then, a sample has been collected virtually every day. Data on product present in Wells 9, 10, 11, 12, 16, 18, and 19 are listed in Table 2 of Appendix A for the period of December 7, 1981 through February 26, 1982.

→ not sufficient!

Examination of the data reveal that the off-site wells, 18 and 19, have never shown any "product" to be present. The water-level data also show that these two wells are upgradient (heads or water levels are higher) from the water-table depression in the area of where product has accumulated. Consequently, it would be impossible for product to migrate upgradient from the terminal off the property to these two wells.

→ strong language in light of dispersion/diffusion, etc.

The data also indicate that product is present in Wells 10 and 12; none has been observed in Well 11. This fluid is a black substance and resembles old product. Samples of the fluid were collected and furnished to Chevron for analysis. The source of this product is off site and may be related to leaks in the fuel line located in Caroline Street. The water-level data show that the elevation of the water table is higher in this portion of the property and that the direction of fluid movement is toward the water-table depression (Figures 6, 7, and 8). Again, any fluid would have to be moving onto the terminal property, rather than off it, due to the direction of the gradient. Additional evidence of this can be seen by examining the product record for Wells 10 and 12, particularly for the period beginning on January 28, 1982, the day that the recovery operations were resumed. Records for Well 10 are partial because a water-level recorder was operating and it was impossible to collect a sample. The record for the well shows that a skim of product was present consistently. On February 18, 1982, one-quarter of an inch was recorded for the first time; as much as one inch was noted on February 22nd. In Well 12, product thickness ranging from one-eighth inch to one-half inch was recorded prior to January 28, 1982. On February 11th, 1.75 inches was noted, 3.75 inches was observed on the following day, and for the remainder of the period of record, the lowest reading was 1.75 inches.

Both increases in product thickness occurred after the resumption of recovery operations. This is a reflection of product moving onto the property as a result of the increase in gradient occurring due to the removal of water and product.

Well 1B has shown "product" to be present since the beginning of data collection in November 1981. The water level data from the wells reveal the presence of a persistent depression in the general area. Consequently, product would tend to accumulate and remain in the depression. The data also suggest that the product present in the vicinity of Well 1B has not originated from the storage tank area because the head or water-table elevation in the intervening area is higher. The "product" may be an accumulation of the reported line leaks in the area plus "product" used in preserving lobster traps in the past. In any event, the product would tend to stay in this general area because of the water-table depression and the presence of the sea wall barrier. → the "product" must be defined in terms of both organic & inorganic components!

The operation of the recovery system has been effective and has resulted in the removal of considerable "product" from the subsurface. The data indicate that more "product" has been removed than can be accounted for because laboratory reports of "product" analysis performed by Chevron indicate that some of the product does not resemble that stored at the terminal. Additional support to this conclusion is provided by the following: (1) The prevailing direction of ground water and product movement is toward the terminal property; and (2) there have been documented spills off-site by other parties in the area in the past.

The available product-thickness and water-level data indicate that under static conditions (no recovery), only small quantities migrate toward the depressions, and that there is an increase in the amount of "product" migrating onto the terminal property when the recovery system is operated (Table 2). Under static conditions there is little or no change in product thickness, whereas an increase occurred when recovery operations were resumed. The data also indicate that these small quantities of "product" accumulate in the natural water-table depressions and will remain there.

→ This is insufficient to insure that 17-3, 17-4, F.A.C. don't exist!

Based on the various data it is reasonable to assume that the recoverable amounts of "product" that have been spilled on the terminal property have been removed; in addition to that which has migrated onto the property under natural conditions, and as a result of the operation of the recovery system.

Consequently, it is recommended that the operation of the recovery system be stopped to minimize the amount of product moving onto the property, (assuming that it is determined the product does not have any dangerous characteristics.) ← cannot make this assumption without data!

Respectfully submitted,
GERAGHTY & MILLER, INC.

Vincent P. Amy

Vincent P. Amy

March 19, 1982

REFERENCES CITED

AMY, VINCENT P., 1980. The Ground Water Flow System in the vicinity of Marco Island, Florida. The National Symposium on Fresh Water Inflow to Estuaries, San Antonio, Texas.

BEAVEN, 1978. Record of Wells in the Floridan Aquifer in Dade and Monroe Counties, Florida. U. S. Geological Survey Report, Open File Report 78-881.

CHERRY, JOHN A., AND FREEZE, R. ALLAN, 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs, New Jersey 07632.

DOHRENWEND, ROBERT E., 1977. Evapotranspiration Patterns in Florida, Florida Scientist, Earth Science, Volume 40.

PARKER, G., ET AL, 1955. Water Resources of Southeastern Florida. U. S. Geological Survey Water-Supply Paper 1255, U. S. Department of the Interior.

U. S. DEPARTMENT OF COMMERCE, 1981. Tide Tables - High and Low Water Predictions. East Coast of North and South America, Including Greenland, by officials of the National Oceanic and Atmospheric Administration, National Ocean Survey.

WATER INFORMATION CENTER, 1974. Climates of the States, Volume I—Eastern States plus Puerto Rico and the U. S. Virgin Islands, by officials of the National Oceanic and Atmospheric Administration.

APPENDIX A

GEO TEC inc. 602 CLARE AVENUE.WEST

Geraghty & Miller, Inc.

3-3-82

CONFIDENTIAL

REPORT TO: GERAGHTY & MILLER
1675 PALM BEACH LAKES BLVD.
SUITE 404
WEST PALM BEACH, FL 33401

SUBJECT: FILTERABLE RESIDUE (TDS) ANALYSIS

#		NONFILTERABLE RESIDUE, mg/L
193	TEST WELL 8	3516
194	TEST WELL 12	38,400
195	TEST WELL 14	11,680
196	TEST WELL 18	50,270

THESE SAMPLES WERE RECEIVED 2-26-82

R. MARTIN Ph.D.

GEOLOGIC LOG OF WELL 10 KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 60%, quartzitic/limey, fine- to medium-grained, grey-brown, medium- to fine-grained unconsolidated, irregular texture; Gravel, 20%, lime, coarse to medium grains, well cemented, chalky to yellowish-white; Silt, 20%, very fine-grained, dusky-yellow, well sorted, no compaction	0 - 1	1
SAND - Sand, 70%, limey, medium- to fine-grained, poorly rounded, poorly sorted, unconsolidated, irregular texture; Gravel, 20%, lime, coarse- to medium-grained, well cemented in calcite matrix, chalky to yellowish-white; Silt, 10%, very fine-grained, medium gray, poorly sorted, no compaction	1 - 3	2
CLAYEY GRAVELLY SAND - Sand, 60%, lime; Gravel, 35%; Clay, 5%	3 - 4½	1½
SILTY LIMEY SAND - Sand, 50%; Silt, 40%; Diesel, 10%	4½- 5	½
SILTY LIMEY SAND - Sand, 50%, Silt, 40%; Diesel, 10%	5 - 7½	2½

GEOLOGIC LOG OF
WELL 11
KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 70%, clean, yellow-brown; Gravel, 20%; Silt, 10%; no odor; dry	0 - 2	2
SAND - Sand, 80%, dark brown; Gravel, 10%; Silt, 10%; no odor; moist; streak thin white chalk at 2½-3 feet	2 - 3	1
SAND - Sand, 70%, dark brown; Gravel, 10%; Silt, 20%; no odor; moist	3 - 4	1
SAND - Sand, 70%; Gravel, 10%; Silt, 20%; odor of petrol; wet	4 - 5	1
SILT - Silt, 70%; Gravel, 10%, Sand, 20%; odor of petrol; wet	5 - 7½	2½

Geraghty & Miller, Inc.

GEOLOGIC LOG OF
WELL 12
KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 70%, light brown; Gravel, 20%; Silt, 10%; no odor; dry	0 - 2	2
SAND - Sand, 80%, dark brown; Gravel, 10%; Silt, 10%; no odor; moist	2 - 3	1
SAND - Sand, 70%, dark brown; Gravel, 10%; Silt, 20%; no odor; wet	3 - 4	1
SAND - Sand, 60%, gray-brown; Gravel, 10%; Silt, 40%; slight petrol odor; wet	4 - 4½	1½
SILT - Silt, 50%, grey-brown; Gravel, 20%; Sand, 30%; strong petrol odor; wet	4½- 7½	2

Geraghty & Miller, Inc.

GEOLOGIC LOG OF
WELL 13
KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 70%, clean, buff brown; Gravel, 20%; Silt, 10%; no odor; dry	0 - 2	2
SAND - Sand, 60%, clean, buff brown; Gravel, 20%; Silt, 20%; no odor; moist	2 - 4	2
SAND - Sand, 60%, clean, buff brown; Gravel, 20%; Silt, 20%; no odor; wet	4 - 4½	½

Struck hard object; unable to deepen

GEOLOGIC LOG OF WELL 14 KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 70%, light buff brown; Gravel, 20%; Silt, 10%; no odor; dry	0 - 2	2
SAND - Sand, 60%, light brown; Gravel, 20%; Silt, 20%; no odor, moist	2 - 4	2
SAND - Sand, 60%, gray-brown; Gravel, 20%; Silt, 20%; strong petrol odor; wet	4 - 4½	½
SAND - Sand, 60%, dark grey-brown; Gravel, 20%; Silt, 20%; strong petrol odor; wet	4½- 6	1½
SAND - Sand, 50%; Gravel, 30%; Silt/Clay, 20%; strong petrol odor; wet and saturated	6 - 7	1

Geraghty & Miller, Inc.

GEOLOGIC LOG OF
WELL 15
KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 80%; Silt, 10%; Gravel, 10%; no odor; dry	0 - 2	2
Struck object at 2 feet; moved, struck object at 3 feet		

Geraghty & Miller, Inc.

GEOLOGIC LOG OF
WELL 16
KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 70%, dark grey-brown; Gravel, 30%; Silt; 20%; slight petrol odor; moist	0 - 2	2
SAND - Sand, 60%, dark brown; Gravel, 30%; Silt, 20%; strong petrol odor; wet	2 - 4	2
SILT - Silt, 50%; Sand, 30%; Gravel, 20%; strong odor; wet	4 - 6	2
SILT - Silt, 50%; Sand, 30%, Gravel, 20%; strong petrol odor; wet/saturated	6 - 7	1

GEOLOGIC LOG OF
WELL 17
KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
, 70%, clean, buff brown; Gravel, , 10%; no odor; dry	0 - 2	2
, 70%, dark grey-grown; Gravel, , 10%; strong petrol odor; moist	2 - 4	2

object at 5 feet; moved and
7A; wood and hard object struck

GEOLOGIC LOG OF WELL 18 KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 70%, clean, buff brown; Gravel, 20%; Silt, 10%; no odor; dry	0 - 2	2
SAND - Sand, 70%, medium grey-brown; Gravel, 20%; Silt, 10%; no odor; moist	2 - 5	3
CLAY - Clay, 60%; Silt, 20%; Sand, 20%; no odor; wet	6 - 7	1

GEOLOGIC LOG OF
WELL 19
KEY WEST TERMINAL

Sample Description	Depth Interval (Feet)	Thickness (Feet)
SAND - Sand, 70%, medium yellow-grey-brown; Gravel, 20%; Silt, 10%; no odor; dry	0 - 2	2
CLAY - Clay, 60%, grey; Silt, 20%; Sand, 20%; no odor; wet	5½- 7	1½

APPENDIX A

TABLE 1: CONSTRUCTION DETAILS OF MONITOR WELLS CONSTRUCTED DURING THE GERAGHTY & MILLER INVESTIGATION CHEVRON USA, KEY WEST TERMINAL

Well No.	Depth (feet)	Diameter (inches)	Casing Elevation (ft. NGVD)	Remarks
10	7.5'	4	4.18	
11	7.5'	4	4.62	
12	7.5'	4	4.78	
13	4.5'	-	-	Not Completed
14	7.0'	4	5.98	
15	2.0'	-	-	Not Completed
16	7.0'	4	4.20	
17	5.0'	-	-	Not Completed
18	7.0'	2	5.68	
19	7.0'	2	6.08	

Notes:

(1) All casings are PVC perforated with ¼-inch drilled holes covering the length of the casing.

(2) All completed wells are gravel packed with clean crushed limestone gravel.

(3) Well 13 required three attempts and could only be drilled to 4.5 feet.

(4) Well 15 required three attempts and could only be drilled to 2.0 feet.

(5) Well 17 required three attempts and could only be drilled to 5.0 feet.

(6) All wells drilled by the auger method.