98-08

DRAFT

PRELIMINARY GEOTECHNICAL ENGINEERING STUDIES
LONG RANGE PLANNING PROGRAM
WEST NEWPORT OIL COMPANY

Prepared For:

West Newport Oil Company
1080 West 17th Street
Costa Mesa, California 92627

Prepared By:

Woodward-Clyde Consultants
203 N. Golden Circle Drive
Santa Ana, California 92705

Project No. 41890A

2 April 1985

203 North Golden Circle Drive
Santa Ana, CA 92705
(714) 835-6886
(213) 581-7164
Telex 68-3420

Woodward-Clyde Consultants

2 April 1985

West Newport Oil Company
1080 West 17th Street
Costa Mesa, California 92627

Attention: Mr. Leonard W. Anderson

SUBJECT: DRAFT REPORT ON PRELIMINARY
GEOTECHNICAL ENGINEERING STUDIES
LONG RANGE PLANNING PROGRAM
WEST NEWPORT OIL COMPANY

Gentlemen:

Transmitted herewith is a draft copy of the report on "Preliminary Geotechnical Engineering Studies, Long Range Planning Program, West Newport Oil Company". This report is submitted at this time in draft form for your review and comments. It will be finalized at a later date.

It is a pleasure to be of assistance to you in the planning stage of this project, and we look forward to continued service to you as the plans progress.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

S. Thomas Freeman
Senior Project Geologist

I. M. Idriss
Vice President and
Managing Principal

STF:IMI/hab
Attachments

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

PRELIMINARY GEOTECHNICAL ENGINEERING STUDIES
LONG RANGE PLANNING PROGRAM
WEST NEWPORT OIL COMPANY

INTRODUCTION

This report presents the results of the Phase I preliminary geotechnical planning studies for the West Newport Oil Company's Long Range Planning Program. This site encompasses approximately 500 acres of land north of the Pacific Coast Highway and east of the Santa Ana River, in an area partly within the City of Newport Beach, as shown on Figure 1. Specific elements of work completed for this study include a review of the available geological and geotechnical information, a review of subsurface data regarding faulting contained in the files of the West Newport Oil Company, two days of field reconnaissance, and drilling of four boreholes and eight cone penetrometer tests in the lowlands area of the property.

This report describes our present understanding of the following geotechnical considerations:

- Surface Faulting
- Potential for Soil Liquefaction
- Slope Stability and Erosion
- Geotechnical Evaluation of the Lowland Area
- Potential for Tsunami Run-up

- Potential for Oil Field Subsidence
- Groundwater Characterization Beneath the Site

The following Executive Summary summarizes the general conclusions that may be drawn for each of the above considerations based on the presently available data.

EXECUTIVE SUMMARY

A branch of the ~~active~~ Newport-Inglewood fault zone crosses the southwestern portion of the property. This tectonic feature and the fact that the site is located in a seismically active region introduce concerns regarding the potential for future surface fault rupture and liquefaction along with other geotechnical considerations typically associated with developments in southern California. Our general conclusions are as follows:

- The North Branch of the Newport-Inglewood fault zone appears to cross the lowland portion of the property and trends out to sea southwest of the mesa. Based on evidence found elsewhere along the North Branch fault, it should be assumed that it is active although evidence of Holocene displacement has not been documented in the lowland portion of the property. Surface exposures of faulting do appear on the mesa portion of the property. These features are inferred to represent a splay fault off of the North Branch fault. The evidence presented by Guptill and Heath (1981) suggesting Holocene and possibly recent surface rupture along this splay fault was not

Why? SITE evidence if any but do not assume!

Where what portion of mesa

readily apparent during this study. ~~In order to provide documentation for the Coastal Commission and other regulatory review, additional effort is required to study the known fault exposures in~~ More detail ed ~~and to~~ investigat~~e~~ ion of known fault exposures ~~other locations~~ along the trend of this fault is required to resolve its activity and to better define the faults' width for planning purposes.

- Clayey soils at the site are not expected to experience high pore water pressure or significant loss of strength due to earthquake loading.

- For the planning purposes of this preliminary evaluation, a reasonable selection criterion for the proposed development would be a peak acceleration value of 0.25g and magnitude = 7 corresponding to an average return period of 200$\pm$ years.

- Above a depth of 10 to 12 feet the likelihood of liquefaction is high. Below a depth of 10 to 12 feet the likelihood of liquefaction is low (FS = 1.25) except in localized areas where layers of loose soil less than 2 to 3 feet thick may occur. Based on the preliminary data from CPT's these layers are not likely to be continuous over the entire site. It would be prudent to stabilize soils above a depth of 10 to 12 feet. This could be accomplished by removal and replacement with compacted soil in areas of important structures. It could also be accomplished by in-place densification using dynamic compaction or compaction piles.

- For planning purposes slopes on the site should be no steeper than 2:1 and adequate drainage and planting measures should be incorporated to control slope erosion.

- The top 4 to 10 feet where of in situ material may not be available for most structural fills because of the presence ~~of oil and~~ soft highly plastic soils. These soils could only be used as fill in selected locations or if special procedures are followed. Below 4 to 10 feet the soils would be suitable for use as structural fills provided they are properly compacted.

- The following construction costs may be used for feasibility-level planning purposes.

  -- One to two dollars per cubic yard to excavate and recompact existing soils.

  -- Nine to fifteen dollars per cubic yard to excavate and dispose of unsuitable materials and replace with suitable compacted engineered fills, assuming the unsuitable materials are not characterized as hazardous waste.

- Tsunami run-up is unlikely to be a major constraint to planning the proposed development.

- Based upon available information, oil field subsidence does not appear to be a major planning consideration. ~~although because of its occurrence in nearby oil fields it may also become a permitting issue for site development~~.

- The Talbert aquifer underlying the site has an estimated transmissivity of about 80,000 gallons per day per foot, and is estimated to be capable of supplying approximately 2,000 gallons per minute to a properly constructed well. These estimates can be used in planning to compare with needs for flushing a water element ~~lagoons~~. Concentrations of chloride are above the recommended U.S. Drinking Water Standard. Although the water may be unfit for human consumption, it does not appear that this water is unsuitable for human contact, based on the data reviewed.

The sections that follow describe the results of our studies in more detail.

SURFACE FAULTING

What is meant be active – is it active on our property?

General

The site is within the Newport-Inglewood Zone of Deformation, an active fault zone that extends across the southwestern portion of the Los Angeles Basin from the City of Beverly Hills on the northwest to the City of Newport Beach on the southeast, where it crosses the shoreline as shown on Figure 2a. The zone projects offshore farther toward the south.

Barrows (1974) presents a map showing several faults in the vicinity of the site associated with the Newport-Inglewood fault zone. Figure 2b is a modified version of Barrows (1974) map showing some of these traces, including those that cross the site.

what study?
WCC or Barrow
potential for surface rupture (during an earthquake) along the

This study considere~~d~~s the Newport-Inglewood fault zone ~~for its potential to be associated with surface rupture on~~ within the site of the proposed development ~~during an earthquake~~. In considering the potential for surface fault rupture, we reviewed previous literature regarding the location of the fault, data in the files of the West Newport Oil Company, and we conducted a ~~brief~~ field reconnaissance of the site with personnel of West Newport Oil Company. Based upon these data, we plotted zones for use in land use planning in which surface ~~faulting is most likely to be located if the fault~~ fault rupture may occur~~s~~ during the life of the project (Plate 1). The oil field data appear to be the best overall data presently available to map the locations of the faulting at depth beneath the site, and exposures in several areas shown on Plate 1 are useful to identify locations of faulting near the surface.

Field Reconnaissance and Data Review

Data in the files of the West Newport Oil Company confirmed that within the limits of the property the branch of the Newport-Inglewood fault zone with the largest stratigraphic separation is found in the lowland area and trends southward of the mesa, as shown in Figure 2b. This fault is referred to as the North Branch fault (Barrows, 1974; CDWR, 1966; OCWD, 1979-1981). Most of the stratigraphic separation due to faulting has taken place in pre-Pliocene time. Based upon current data, approximately 400 feet of vertical stratigraphic separation occurs across the North Branch fault at depths on the order of 1000 to 1500 feet below sea level, with the stratigraphic separation of progressively younger (and higher) units likely being no more than 40 to 50 feet.

The North Branch fault is identified within the West Newport oil field, to the northwest of the oil field, and offshore to the south of the oil field. The trace of the North Branch fault as mapped elsewhere along the Newport-Inglewood fault zone such as in Bolsa Chica shows evidence of Holocene displacements (CDWP, 1968; Woodward-Clyde Consultants, 1984a). The dip of the fault immediately south of the site in the subsurface, at depths of approximately 1500 to 2000 feet, is constrained to 82°W, based upon oil field data. However, as the fault nears the surface its dip may become steeper. The width of the planning zones shown for the North Branch fault on Plate 1 are based on these possible variations in the dip of the fault. The eastern side of the zone is based on projecting the fault to the surface with a dip of 82°W. The western limit of the zone assumes that the fault becomes vertical as it nears the surface. In all likelihood, the fault has an average dip that is intermediate between these two values. The width of the zone defined by these possible variations in the dip of the fault averages approximately 200 feet at the surface. The location was checked by comparing selected well logs along the eastern margin of the zone with well logs in and west of the zone.

Another fault was mapped across the mesa portion of the property by Hunter and Allen (1956), by Guptill and Heath (1981) and was found exposed in surface exposures during this study. A fault, which may correlate with the fault found on the mesa, was mapped in the subsurface by the West Newport Oil Company. At a depth of about 1000 to 1500 feet below sea level, the fault reportedly has approximately 100 feet of vertical stratigraphic separation. Due to the significantly less stratigraphic separation in relation to

smaller

that found at depth on the North branch fault, this fault which crosses the mesa is inferred ~~to be~~ a splay fault off of the North Branch fault. The preferred location of this splay fault, as shown in Figure 2b, was based upon subsurface data, but it also closely approximates the location of the fault as mapped at the surface by Guptill and Heath (1981). The width of the planning zone along the splay fault as shown on Plate 1 was based upon extending the dip of the splay fault to the surface with the assumption that the dip is approximately 80°W. ~~Although~~ However, at the surface, the fault might tend to have individual en echelon traces that are rotated clockwise from the subsurface trend, as is suggested by the locations where faulting was observed during reconnaissance ~~for this~~ study at the south end of the property. There, the fault traces exposed at the surface as reported by Guptill and Heath trend approximately N10°W to N15°W, whereas the fault at depth reportably trends approximately N40°W.
reportedly

The splay fault where exposed at the surface appears to be a very narrow zone of deformation. Near the south end of the property, Guptill and Heath identified three locations where the fault is exposed. At each, the fault is at most a few feet wide. Accordingly, if the individual fault traces were to be mapped in detail within the broad planning zone on the mesa, the width of the individual traces would likely be on the order of a few feet.

At location C (Plate 1), which is site 1 of Guptill and Heath (1981), the fault was excavated during this study by trenching into a narrow gully. The excavation showed possible landsliding or a landfill in part of the cut, but at least one planar rupture extended to greater depth than the apparent landsliding, and may indeed represent a fault trace. The excavation was not logged.

Excavations were 1 also made during this study along a steep slope near well 320, at the southern end of the property, Site B on Plate 2. This location is site 2 of Guptill and Heath (1981) where they reported displacement of a soil horizon by the fault. No fault could be identified in an excavation north of the well on a north-facing slope, because the area had been previously disturbed by an old drilling sump ~~was identified in part of that cut.~~ At the base of the slope south of well 320, an excavation was cut into bedrock along a projection of the fault trace. The excavation revealed bedded units that were stained orange to red along selected bedding planes. Within the excavation no faults were observed displacing the bedding planes although theexposure was not logged in detail.

An excavation was also placed at Site E on Plate 1, where a local thickening of the terrace deposits above bedrock was identified by geologists with the West Newport Oil Company. The excavation revealed that the rapid thickening is along a weathered slope on bedrock, with no evidence of faulting observed in the soil materials that were exposed. The most likely interpretation of this relationship is that the terrace deposits filled an old channel cut into the bedrock. Accordingly, no fault was plotted on Plate 1, however the location is shown for reference purposes. Disagree

The North Branch of the Newport-Inglewood fault zone appears to cross the lowland portion of the property and trends out to sea southwest of the mesa. Based on evidence found elsewhere along the North Branch fault, it should be assumed

why

that this is active although evidence of Holocene displacement has not been documented in the lowland portion of this property. Surface exposures of faulting do appear on the mesa portion of the property. These features are inferred to represent a splay fault off of the North Branch fault. The evidence presented by Guptill and Heath (1981) suggesting Holocene and possibly recent surface rupture along this splay fault was not readily apparent during this study. ~~In order to provide documentation for Coastal Commission and other regulatory review,~~ Additional field studies are required in other locations along the trend of this splay fault to resolve its activity and to better define the faults width for planning purposes.

POTENTIAL FOR SOIL LIQUEFACTION

General - This section discusses the potential for soil liquefaction in the lowland area of the site. Specifically the subsections that follow describe the field investigation and laboratory testing completed for this study to characterize the subsurface soils. Also described are the estimated earthquake ground motions, the liquefaction potential at the site, the general consequences of soil liquefaction and possible mitigation measures.

Field Investigation - The field investigation at the site was completed between 8 February 1985 and 20 February 1985. It included drilling 4 exploratory rotary wash borings and 8 cone penetrometer tests (CPT). The exploration was completed at each of four areas within the site, as approximately located on Figure 3a. Within each of the four areas, one boring and two CPT's were completed. The specific locations of the borings and CPT's are shown in

Figure 3b. Backhoe pits were excavated at selected boring and CPT locations to check the classification of near surface soils above the water table and check the depth to the water table. The specific data relating to drilling and CPT exploration are presented in Appendix A.

Laboratory Testing - Laboratory testing was completed on samples obtained from borings and test pits. The tests that were completed included moisture content determinations, Atterberg Limit tests, grain size analyses, and organic content determinations. Selected results of the tests are summarized in Table 1 and more details are provided in Appendix B.

Subsurface Characterization - The surface elevation at all boring locations varied between about +3 and +6 feet MSL. Based on the logs of borings and CPT's presented in Appendix A, the subsurface soils in the lowland area of the site generally consist of about 4 to 10 feet of soft to medium stiff silty clay with lenses of loose silty and clayey sand. This layer is generally underlain by loose silty to clean sand which generally grades to dense at depths of between 10 and 12 feet and extends to the maximum depth explored, 51.5 feet. Summary stick logs and CPT tip resistance logs are presented for each of the four areas investigated in Figures 4, 5, 6, and 7.

The CPT data indicate some localized low to medium dense sand layers less than two to three feet thick at locations B-2, D-1, and D-2 at depths of 22, 35, and 37 feet, respectively. Other isolated layers that might be in the medium dense range were noted at locations B-1 at depths of 17 and 23 feet, and in C-2, and D-2 at depths of 42, and 30 feet, respectively.

All standard penetration test results (corrected for effective overburden pressure) were plotted with depth in Figure 8. In addition, the CPT results representing the localized loose to medium dense and medium dense layers of sand were approximately converted to N_1 values and plotted on Figure 8. It is noted that except for the localized low CPT values, CPT data were in general agreement with N_1 data. As can be noted on Figure 8, some N_1 values have been corrected for grain size based on data summarized in Table 1. It is noted that based on the Atterberg Limits and moisture contents presented in Table 1, the clayey soils at the site are not expected to experience high pore water pressure or significant loss of strength due to earthquake loading.

Ground Motion - The proximity of faults to the site and their estimated maximum magnitudes are shown on Figure 2a and summarized in Table 2. No specific evaluation of earthquake ground motions was completed in this preliminary evaluation. However, based on available information from nearby sites with similar proximity to these faults, it appears that a reasonable selection criterion for the proposed development would be a level of shaking corresponding to an average return period of 200$\pm$ years. The possible range of peak horizontal acceleration (weighted with respect to magnitude, m = 7) is of the order of 0.2 to about 0.3 g. For the purpose of this preliminary evaluation, a value of peak acceleration of 0.25 g and m = 7 are considered in the liquefaction potential evaluation discussed below.

Liquefaction Potential - Based on the foregoing discussions regarding subsurface characterization and ground motions, a preliminary liquefaction analysis was made using the simplified procedure suggested by Seed and Idriss (1982). This evaluation assumes no major change in grade and a water table depth at 4 feet below grade. Curves of mean and minimum N_1 values plotted with depth are shown on Figure 9. Localized areas where CPT data indicate possible looser cohesionless soils are also plotted in terms of approximate N_1 values at their appropriate depths in Figure 9. In Figure 9, in addition to the curves summarizing measured data, a shaded curve is presented showing the critical N_1 (ie, N_{1c}) for which the factor of safety of 1.0 is calculated for liquefaction. It can be noted on Figure 9 that for values of N_1 to the left of or near the N_{1c} curve, the potential for liquefaction is high. Conversely, for values of N_1 to the right of the N_{1c} curve, the potential for liquefaction is low. Based on the results of the preliminary analyses summarized on Figure 9, we have developed the following preliminary conclusions:

1. Above a depth of 10 to 12 feet the likelihood of liquefaction is high.

2. Below a depth of 10 to 12 feet the likelihood of liquefaction is low (FS = 1.25) except in localized areas (layers of loose soil less than 2 to 3 feet thick). Based on the preliminary data from CPT's these layers are not likely to be continuous over the entire site but could be continuous locally as indicated for Site B and Site D on Figure 9.

Consequences and Potential Mitigation Measures - The potential consequences of liquefaction based on the foregoing analysis are summarized as follows:

1. For soils above a depth of 10 to 12 feet the potential consequences of soil liquefaction are settlement and possible lateral spreading (horizontal movement of soil of several feet). The lateral spreading would require a slope of a few degrees from horizontal or a change in grade caused by a wall or bulkhead.

2. For soils below 10 to 12 feet the likely consequences of soil liquefaction would be localized settlement of less than about 1-inch. The extent of the localized area of settlement will need to be evaluated in more detailed studies as discussed below.

Based on the above consequences it would be prudent to stabilize soils above a depth of 10 to 12 feet. This could be accomplished by removal and replacement with compacted soil in areas of important structures. It could also be accomplished by in-place densification using dynamic compaction or compaction piles.

It is noted that the above conclusions are based on very limited data. This analysis is for the purpose of a preliminary evaluation to identify potential problems related to liquefaction. Before development plans are finalized, we recommend that appropriate field data be acquired, and a more detailed analysis be made specifically to address the proposed development plan.

SLOPE STABILITY AND EROSION

The geology of the site consists of sedimentary bedrock units of Miocene and possibly Pliocene age covered by

Quaternary San Pedro Sands and terrace deposits in the mesa. In the lowland area, the Pleistocene sediments are covered by Holocene alluvial floodplain units derived from the Santa Ana River. As observed during the reconnaissance of the site, all of the units exposed in the mesa appear to be highly erodible; the deposits within the lowland are also likely to be very erodible. Steep slopes on the property underlain by the Pliocene sedimentary formations, the Quaternary San Pedro Formation, and the terrace deposits all have been extensively gullied. Accordingly, the planning for site development should consider mitigating measures to minimize soil erosion.

Slope stability of the geologic units on the property is generally good, although several small slumps and one small slide were observed on the slopes of the property. Bedding within the formations on the site is variable but generally with a northwest to westerly dip orientation. Locally, bedding dips steeper than 10 degrees and in some places may be out of slope. Because of the potential for some slope instability on steeper cuts, site planning should consider that slopes be no steeper than 2 to 1 (horizontal to vertical). If selected slopes are required that are steeper than this angle, they should be studied and, if appropriate, stabilized.

Plate 2 shows the area ~~along the bluff~~ where slopes are generally 2:1 or steeper. The plate shows one line along the base of the present ~~bluff~~ slope, with another corresponding line along the top of the ~~bluff~~ slope that would represent the top of a 2:1 slope from the base of the existing slope. Because the present slope angles are highly variable, the lines along the major breaks in slope are discontinuous. Lines generally are not shown where existing slopes, as observed on the topographic base map, are flatter than 2:1.

The slope area may be planned for development from the perspective of slope stability, provided the general guideline suggested here is followed. Engineering geologic studies will be required at a later time during the final design phases of the development; those studies will no doubt refine the criteria identified here for planning purposes.

EVALUATION OF EARTHWORK FOR THE LOWLAND AREA

Two subjects are addressed in this subsection. First, the suitability of near-surface and deeper soils for use as fill materials are discussed. Second, approximate construction cost estimates for earthwork and construction dewatering are presented.

Fill Suitability - Generally, the top 4 to 10 feet of in-situ material encountered in the borings and test pits may not be suitable for most structural fills because of the presence of ~~oil and soft highly plastic soils. In some areas tested (Borings B-1, C-1, and D-1) the in-situ surface soil contains oil or other petroleum products. Materials containing oil cannot be used in fills unless proper safety and health regulations are followed. In other areas where soil does not contain oil, the top 4 to 10 feet generally consist of~~ medium to highly plastic silty and sandy clays. Laboratory test results indicated that these materials have organic contents ranging between 1 and 4 percent. While the organic contents of these soils are relatively low these soils are generally difficult to compact and may yield relatively low strengths when compacted because of their high plasticity. Also, these materials may be highly expansive, based on plasticity tests, when subjected to changes in moisture content and as such, would not be advantageous for use below pavements, floor slabs, or other concrete flat work. In summary, these materials can be used as fill, but only in selected locations or if special procedures are followed.

Below a depth of 4 to 10 feet, the materials encountered in the borings would be suitable for use as structural fills, provided they are properly compacted. These materials, which include sands, clayey sands, and silty sands, generally make good fill materials. They are relatively easy to compact and yield relatively high strengths once compacted.

Construction Cost Estimates - It is difficult to estimate construction costs without an accurate development plan or scheme. However, the following costs may be used for feasibility-level planning purposes. These costs are based on our experience and discussions with several contractors familiar with the types of work for which cost estimates are presented.

Earthwork costs depend upon several variables, including material type (see Fill Suitability), treatment and compaction, location, and import/export quantities. To remove existing soils and replace them as compacted engineered fill, it generally costs between one and two dollars per cubic yard. This cost estimate assumes little or no haul distance and no unusual site conditions (rock outcrops, dewatering, very hilly terrain, etc.). The costs to excavate and dispose of unsuitable materials vary greatly depending upon the haul distance. For typical transport distances (approximately 10 miles), costs generally vary from \$5.00 to \$8.50 per cubic yard. To replace the unsuitable materials, it costs an additional \$4.00 to \$6.00 per cubic yard. For example, to remove unsuitable materials and replace them with suitable compacted engineered fills, costs generally vary between \$9.00 and \$14.50 per cubic yard. This assumes that unsuitable materials are not characterized as hazardous waste.

Costs for "special" materials such as crushed rock or filter rock, may average about \$12.00 per cubic yard. This cost includes transportation but not compaction (if required).

Dewatering costs are more difficult to accurately predict than earthwork costs. This is because of the unique situation for each dewatering project, the limited availability of experienced contractors and projects requiring dewatering, and difficulty in estimating dewatering flow rates, as well as several other factors.

The depth of excavation below the water level also greatly affects dewatering costs. Costs increase substantially as the depth of dewatering increases. Two approaches for estimating dewatering costs are presented below. To dewater an area about 200 by 500 feet in plan, 10 feet deep (assuming a water level at 5 feet) it costs about \$3.00 per cubic yard for the first month (about \$110,000). The second month, if required, would be less expensive because of the elimination of the initial set up costs. If the depth of dewatering increased to 15 feet (10 feet below the water level), the dewatering costs increase to about \$5.00 per cubic yard (\$275,000).

A second approach to help estimate the costs of dewatering is evaluate the number of wells needed. To dewater to a depth of 15 feet (for one month), each dewatering well costs about $3,000. These wells are typically spaced at 50-foot centers. Therefore, to dewater an area 50 feet by 2,000 feet (same plan area as before), approximately 40 wells are required for a total cost of about $120,000. Notice that this cost is significantly different from the cost in the previous paragraph because, in this case, the dewatering is for a narrow channel (aspect ratio of 40:1) and not for a rectangular area with an aspect ratio of 2-1/2:1.

POTENTIAL FOR TSUNAMI RUN-UP

A tsunami is a sea wave generated by a submarine earthquake, landslide or volcanic action. A major tsunami from either of the latter two events is considered to be remote for the site. Submarine earthquakes are common around the edges of the Pacific Ocean. Accordingly, all of the Pacific Coastal areas are subject to this potential hazard to a greater or lesser degree.

Tsunamis travel across the ocean as powerful, long wave length, low amplitude waves; perhaps 50 miles long and only 1 or 2 feet high. Travelling at almost 500 mph in the Pacific, such a wave in the open ocean causes no problems, and, in fact, the slope of the wavefront is likely to be imperceptible to a ship at sea. However, as the tsunami approaches the coastline, it is affected by the shallowing bottom and the configuration of the coastline, which may transform the waves into very high, potentially devastating waves. If large waves do not occur, strong currents, as rapid as 40 feet per second, can cause extensive damage.

The most damaging tsunamis are usually associated with vertical tectonic displacements. Furthermore, observable tsunamis are typically caused by large earthquakes of magnitude 7-1/2 or greater.

If faulting were to occur along the Newport-Inglewood fault, it likely would be primarily horizontal, based on present information. The 1933 Long Beach earthquake of magnitude 6.3 occurred on the Newport-Inglewood fault system, and apparently did not generate a noticeable tsunami. It is questionable that movement along the Newport-Inglewood fault system could cause a significant tsunami affecting the study area. Tsunamis can, however, be triggered by distant earthquakes, as in the case of the wave that hit Crescent City, California which was about 1,500 miles from the triggering earthquake in Alaska.

It is not possible to predict the likelihood or magnitude of a major tsunami. The Newport Beach area is afforded some natural protection by offshore islands and offshore banks. Tsunami damage from either the 1960 Chilean earthquake or the 1964 Alaska earthquake was not reported at Newport Beach. The chance of major damage from a tsunami is ~~not likely to be high~~ low for the coastal beaches and the mouth of the Santa Ana River, and is neglible for other inland areas upstream from this river mouth.

Based upon available information, tsunami run-up is unlikely to be a major constraint to planning the development. In the unlikely event that a major tsunami were to strike the beach adjacent to the site, significant run-up is unlikely to reach inland of Pacific Coast Highway, on the western margin of the site. Strong currents may develop in the channels that are open to the ocean, and might cause damage to a lagoon or marina. It is believed that tidal storm surge is far more likely to affect the beaches adjacent to the site, and possibly create high tides and strong currents in a lagoon or marina on the site, if either should be developed as part of the plan.

POTENTIAL FOR OIL FIELD SUBSIDENCE

The property covers the heart of the West Newport Oil Field. The oil field has been in operation since 1943 (Hunter and Allen, 1956), and will continue to be in operation for the foreseeable future. New exploration wells may also be drilled, in addition to reworking existing wells to enhance production. With production of oil taking place beneath the site, the potential for oil field subsidence has been raised as a potential concern.

Although the cause of subsidence in an area may be difficult to assess, land subsidence may be linked to one or more of the following:

- Oil reservoir compaction due to gas or fluid withdrawals.
- Lowering of hydraulic head due to groundwater withdrawals.
- Surface loading, such as by heavy structures.
- Lack of preconsolidation of sediments, which settle with time.

- Tectonic movements.

- Vibrations, due to land use or earthquakes.

- Chemical changes, such as oxidation of peat.

At this time the main potential concern for this property is the potential for subsidence due to hydrocarbon withdrawal, although there may be some potential for subsidence due to groundwater withdrawal in the lowland area of the Santa Ana River floodplain. Subsidence due to compaction of peat deposits is unlikely as peat has not been identified from borings completed in the lowland portion of the site.

Land subsidence due to withdrawal of hydrocarbons has been intensively studied at the Wilmington oil field in Long Beach. In that field, Mayuga and Allen (1969) reported that total subsidence from 1928 through 1965 was as much as 29 feet, and was centered in the Port of Long Beach where harbor facilities are dependent upon sea level remaining fairly constant relative to the facilities. The subsidence at the Port of Long Beach was reported to have cost approximately $100 million for repairs and maintenance. The major impacts of subsidence in Long Beach have been:

- Changes in ground elevation relative to sea level, which necessitated filling, construction of dikes or elevating structures, and modifying gravity flow systems.

- Horizontal changes, lateral shifting of the ground toward the center of the subsidence bowl, and breaking inflexible lines such as oil well casings (typically occurring during sudden shifts that produced minor earthquakes).

- Cracking of the ground surface and accompanying deformation of structures over the ground cracks.

Oil field subsidence has been documented in 27 California and Texas oil and gas fields as of 1969 (Yerkes and Castle, 1969). Of these, 20 are in California, with four in oil fields along the Newport-Inglewood Zone of Deformation (Dominquez, Huntington Beach, Inglewood, and Long Beach). In Orange County, only the Huntington Beach field is known to be associated with oil field subsidence (Morton and others, 1976); other land subsidence that has been documented in Orange County was due to ground water withdrawal in Santa Ana (that subsidence was mitigated by a groundwater recharge program that commenced in the Santa Ana River in 1949), and subsidence in areas of peat deposits in present and former tidal marshes near the coast (Morton and others, 1976).

Because of the known subsidence in the area of the Huntington Beach field, and the postulated subsidence elsewhere along the Orange County coastline, the Orange County Surveyor conducts an annual subsidence study along Pacific Coast Highway, from ~~the coastal bluffs at~~ Seal Beach to ~~the coastal bluffs at~~ Newport Beach. These studies have consisted of establishing vertical bench marks, in 1976, and measuring elevation changes annually. The changes in elevation are based upon the assumption that the two end points of the survey are relatively stable.

The coastal survey shows subsidence of the Huntington Beach oil field in excess of 0.1 feet from 1979 to 1983 for at least 15 benchmarks, with maximum subsidence in excess of 0.6 feet near the intersection of Golden West Boulevard and Pacific Coast Highway, which is considered the center of the subsidence bowl.

South of Beach Boulevard to the area of Newport Boulevard along Pacific Coast Highway, measurements of two bench marks show subsidence in excess of 0.2 feet from 1976 to 1983, but measurements of 9 other benchmarks show cumulative subsidence less than 0.1 feet. Of the two benchmarks showing subsidence in excess of 0.2 feet, benchmark NB2-7-77 is located out of the West Newport Oil field south of Superior Boulevard, in an area near a known closed landfill where methane gas is being vented at the surface. Accordingly, it is unlikely that subsidence there is related to oil field activities. Benchmark W-766 is located in the area of the West Newport Oil field north of the intersection of Superior and Coast Highway. That benchmark may be showing subsidence. If so, it is the only benchmark with such indication in proximity to the oil field, in contrast to the 15 benchmarks showing subsidence in the Huntington Beach oil field. Accordingly, the apparent subsidence at that benchmark may be due to oil field operations, or an unstable benchmark. In contrast, the adjacent bench marks to the north (on the Santa Ana River channel) are relatively stable, and the benchmark to the south (at Superior and Coast Highway) showed small elevation gains in 1981 and 1982 and an elevation loss in 1983.

Although subsidence has not been identified in the West Newport Oil field, the apparent lack of subsidence may be due to the following factors:

- Relatively thin oil-producing horizons, where recovery averages only 38% of the oil in the reservoir horizons, and the oil is quite viscous.

- A natural water drive in the field that appears to be replacing at least some portion of the hydrocarbons being removed.

- Partial replacement of hydrocarbon fluids by steam injection, used as a secondary recovery technique in some parts of the field.

In summary, based upon available information, ground subsidence due to oil field operations has not been identified in the West Newport Oil field, although minor subsidence may have occurred but gone unnoticed. One benchmark surveyed annually by the Orange County surveyor since 1976 may suggest subsidence, but data are not available for a thorough analysis of the entire oil field. If major subsidence were to occur, it would likely be centered in the areas where the greatest withdrawal of hydrocarbons is taking place and where those fluids are not being replaced. Based upon available information, oil field subsidence does not appear to be a major planning consideration. ~~It may, however, become a permitting issue for site development.~~

GROUNDWATER CHARACTERIZATION

The groundwater beneath the West Newport Oil Company site lies in the Santa Ana Gap portion of the Anaheim Groundwater Basin (Department of Water Resources, 1966).

The Anaheim Groundwater Basin is a coastal synclinal basin with a forebay and pressure area. The forebay is north of the Santa Ana Freeway and is where most of the recharge to the Anaheim Groundwater Basin occurs. The Santa Ana Gap region is in the Anaheim Groundwater Basin pressure area. The pressure area consists of confined aquifers underlying a semiperched water table.

The principal aquifer of interest underlying the West Newport Oil Company facility is the Talbert aquifer. Assessing the feasibility of using the Talbert aquifer involves: determining aquifer hydraulic characteristics; pumping lifts; potential well capacities; and determination of any water quality constraints.

Table 3 (Sinnott and Poland, 1959) shows specific capacity data for nearby wells perforated in the Talbert aquifer. Specific capacity values range from 37 to 82 gallons per minute/foot of drawdown. A rough estimate of the range of transmissivity (derived from the reported specific capacity) of the Talbert aquifer near the West Newport Oil Company facility is approximately 80,000 gallons per day per foot.

The Talbert aquifer extends from a depth of approximately 50 to 150 feet below sea level. Assuming a static water level of about mean sea level and assuming that the top of the Talbert aquifer is at about -50 elevation, the aquifer and specific capacity data indicate that a properly constructed well in the Talbert aquifer should be capable of producing about 2,000 gallons per minute.

Concentrations of chloride are elevated above the recommended U.S. Drinking Water Standard (250 mg/l). The elevated concentrations are due to seawater intrusion caused by overpumping of the Anaheim Groundwater Basin. However, following development of the Talbert Barrier, chloride concentrations have remained relatively stable due to control of seawater intrusion. Figures 10 and 11 show chlorine isochlors for the Talbert aquifer in 1963 and 1981. The location of the Talbert Barrier is shown in Figure 12.

The closest extraction well to the West Newport Oil Company facility is well number P-10 (Figure 12). To develop a water resources program at the West Newport Oil Field without causing adverse water quality impacts, the area around P-10 should be investigated as a possible site for future wells. Since there is already an extraction well in that area being used as part of a seawater intrusion barrier, this would be the most likely area for additional water resources development.

Water quality in the Santa Ana gap north of the sea water intrusion is very good. The water has a sodium/calcium bicarbonate character with a total dissolved solids range of 200 to 500 ppm (DWR Bulletin 147-1, 1966).
Where seawater intrusion has occurred, total dissolved solids concentration has been as high as 6,250 ppm (DWR Bulletin 147-1, 1966). Although the high total dissolved solids content make this water unfit for human consumption, seawater intrusion, alone, does not make the water unsuitable for human contact.

For purposes of flushing a water element ~~lagoon or marina eit~~her of the above waters appear to be suitable. Several options are available for flushing a water element ~~lagoon or marina~~ using existing sources of groundwater. These include: purchase of water from wells which have been abandoned due to salinity intrusion; and purchase of water from other water wells in Orange County.

Wells south of the Santa Ana gap salinity barrier have already been subject to saline intrusion. Numerous public and privately owned water wells exist within a two mile radius of the West Newport Oil Field. It may be possible to purchase water from the owners of these wells. If the owners are no longer able to use the well(s), permission to use the well may be easily obtained. Locations of wells and well owners can be obtained through the California Department of Water Resources or through the Orange County Water District.

REFERENCES

Aerial Photographs - early 1950's, 1972, and 1984.

Barrows, A. G., 1974, A Review of the Geology and Earthquake History of the Newport-Inglewood Structural Zone, Southern California; California Division of Mines and Geology Special Report 114, 115 p.

California Division of Oil and Gas, 1982, 67th Annual Report of the State Oil and Gas Supervisor: California Department of Conservation, Division of Oil and Gas Publication PR06, 137 p.

Department of Water Resources, 1966, Santa Ana Gap Salinity Barrier, Orange County: Bulletin No. 147-1, 178 p.

Fairchild, J. and Reilly, J., 1982, Talbert Barrier Status Report, Orange County Water District, p. 45.

Guptill, P. D., and Health, E. G., 1981, Surface faulting along the Newport-Inglewood zone of deformation: California Geology, July 1981, p. 142-148.

Hunter, A. L., and Allen, D. R., 1956, Recent developments in West Newport oil field: Summary of Operations, California Oil Fields: California Division of Oil and Gas, v. 42, no. 2, p. 11-18.

Mayuga, M. N., and Allen, D. R., 1969, Long Beach Subsidence, In Lung, R. and Proctor, R., eds., Engineering Geology in southern California, Association of Engineering Geologists Special Publication, p. 280-285.

Morton, P. K., Miller, R. V., and Evans, J. R., 1976, Environmental Geology of Orange County, California: California Division of Mines and Geology Open File Report 79-8.

Poland, J. R., and others, 1956, Groundwater geology of the coastal zone, Long Beach - Santa Ana, California: U.S. Geological Survey Water Supply Paper 1109, p. 162.

Sinnott and Poland, 1959, Yield Characteristics of eight wells withdrawing from the Talbert water bearing zone, U.S.G.S. Water Supply paper 1471, p. 257.

Yerkes, R. F., and Castle, R. O., 1969, Surface Deformation associated with Oil and Gas Field Operations in the United States: Association Internationale d'Hydrologic Scientific, Collogue de Tokyo, p. 55-66.

Woodward-Clyde Consultants, 1983, Preliminary Evaluation of Liquefaction Potential, Bolsa Chica Local Coastal Program, Bolsa Chica Planning Unit, Orange County, California; prepared for Signal Landmark, Inc.

Woodward-Clyde Consultants, 1984a, Preliminary Evaluation of Surface Faulting, Bolsa Chica Local Coastal Program, Bolsa Chica Planning Unit, Orange County, California; prepared for Signal Landmark, Inc.

Woodward-Clyde Consultants, 1984b, Preliminary Evaluation of Ground Subsidence, Bolsa Chica Local Coastal Program, Bolsa Chica Planning Unit, Orange County, California; prepared for Signal Landmark, Inc.

TABLE 1

SUMMARY OF LABORATORY TEST RESULTS

Location	Depth (feet)	USC	% Moisture	W_L %	W_P %	I_P %	D_{50} mm	% Passing #200 Mesh	% Finer than .005 mm
A-1	2.5	CL	33						
A-1	5	CL/CH	75	62	33	29	0.005	94	50
A-1	6.5	SP/SC	36	27	18	9	0.20	9	4
A-1	15	SP/SM					0.20	6	2
A-1	20	SP/SM					0.22	9	2.5
A-1	40	SP					0.30	5	2
A-2	3	ML	39				0.05	80	8
B-1	5	SM	39				0.16	13	4
B-1	10	SC	41	27	16	11	0.11	38	8
B-1	35	SM					0.12	18	5
B-1	2	CL/CH	38	62	31	31	0.004	98	53
C-1	5	SP/SM	47				0.18	9	3
C-1	5	CL		41	17	24			
C-1	10	SP/SM					0.17	11	3
C-1	15	SM					0.13	14	3
C-1	25	SP/SM					0.18	11	4
C-1	45	SP/SM					0.22	8	4
C-1	50	CL/CH	33	50	22	28	0.0035	82	55
TP-C-2	2.5	CL/CH	45	54	28	26	0.0008	98	38
D-1	2.5	ML/CL	39						

TABLE 1 (Continued)

Location	Depth (feet)	USC	% Moisture	W_L %	W_P %	I_P %	D_{50} mm	% Passing #200 Mesh	% Finer than .005 mm
D-1	5	CL	57						
D-1	6.5	CL/CH	52	75	31	44	0.0002	98	75
D-1	10	SM					0.12	34	6
D-1	20	SP/SM					0.21	11	2
D-1	30	SP/SM					0.19	10	2

Note:

USC = Unified Classification System

W_L = Liquid Limit

W_p = Plastic Limit

I_p = Plasticity Index

TABLE 2

CHARACTERISTICS AND ESTIMATED MAXIMUM EARTHQUAKES FOR REGIONAL FAULTS
WEST NEWPORT OIL FIELD

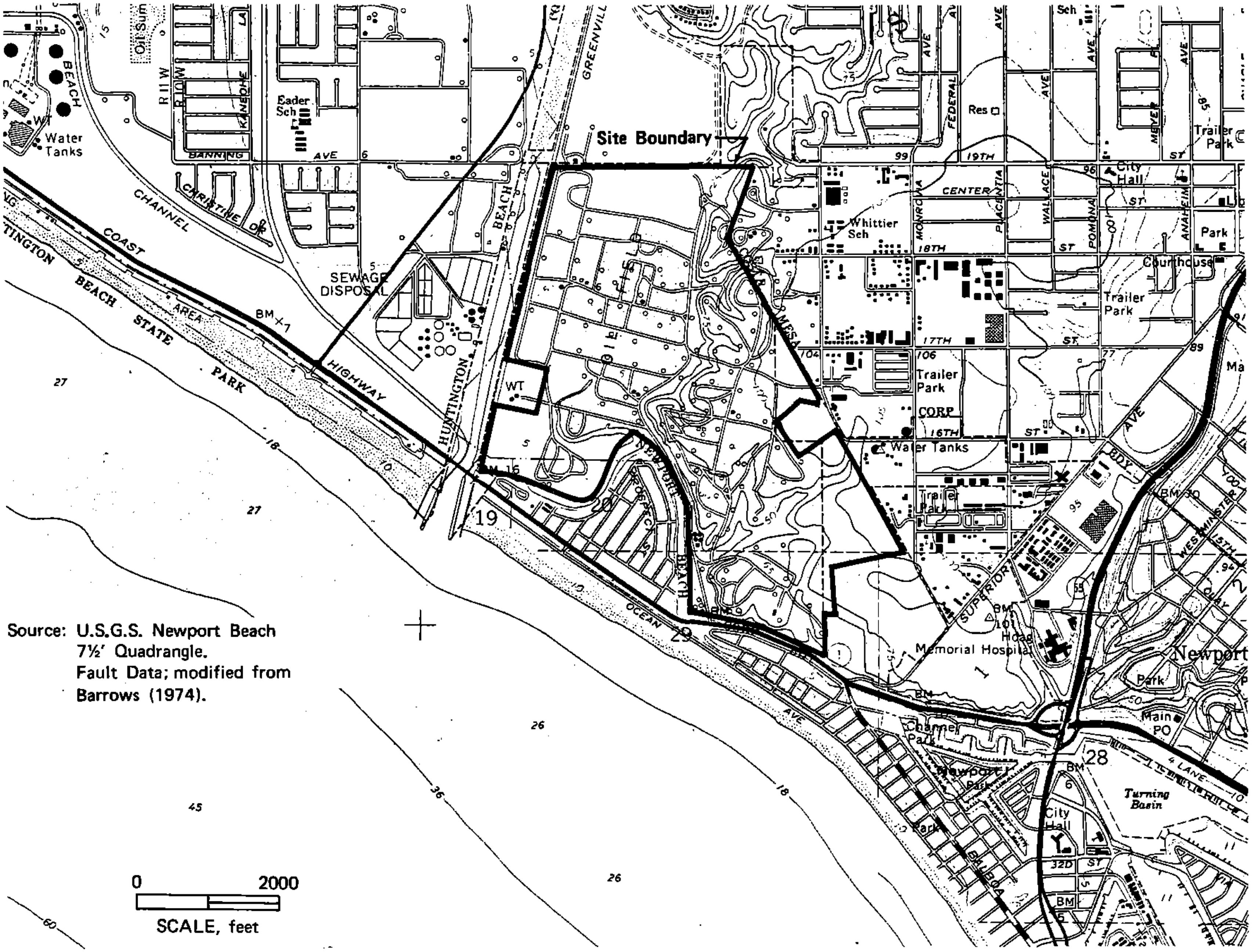
Fault Name	Fault Classification	Approximate Distance To Site miles	(km)	Approximate Fault Length miles	(km)	Estimated Slip Rate mm/yr	Maximum Historic Earthquake Magnitude	Estimated Maximum Earthquake
Newport-Ingelwood	Right Lateral	0	(0)	44	(70)	0.5	6.3 (1933)	7 (b)
Palos-Verdes	Right Reverse	12	(19)	50	(80)	0.8	3.9 (1972)	7 (b)
Whittier	Right Reverse	22.5	(36)	28	(45)	1.2	4.2 (1976)	7 (b)
Elsinore	Right Lateral	25	(40)	130	(208)	2.3	6.0 (1910)	7.5 (b)
Santa Monica	Left Reverse	40	(64)	60	(96)	0.4	5.7 (1973)	7-1/4 (b)
Sierra Madre	Left Reverse	37	(59)	36	(58)	1-4 (c)	6.4 (1972)	7 (c)
Catalina	Right Reverse	32	(51)	70	(112)	0.8 (d)	-	7 (b)
San Jacinto	Right Lateral	48	(77)	160	(256)	8	7.0 (1899)	7-1/2 (b)
San Andreas (South Central)	Right Lateral	54	(86)	204	(326)	37	8.3 (1857)	8-1/2 (a,b)

Notes:
(a) Based on historical events.
(b) Based on estimated rupture length and Slemmons (1977).
(c) Based on Crook and others (1978); and Mattl and others (1982).
(d) Unknown; assumed similar to Palos Verdes

TABLE 3

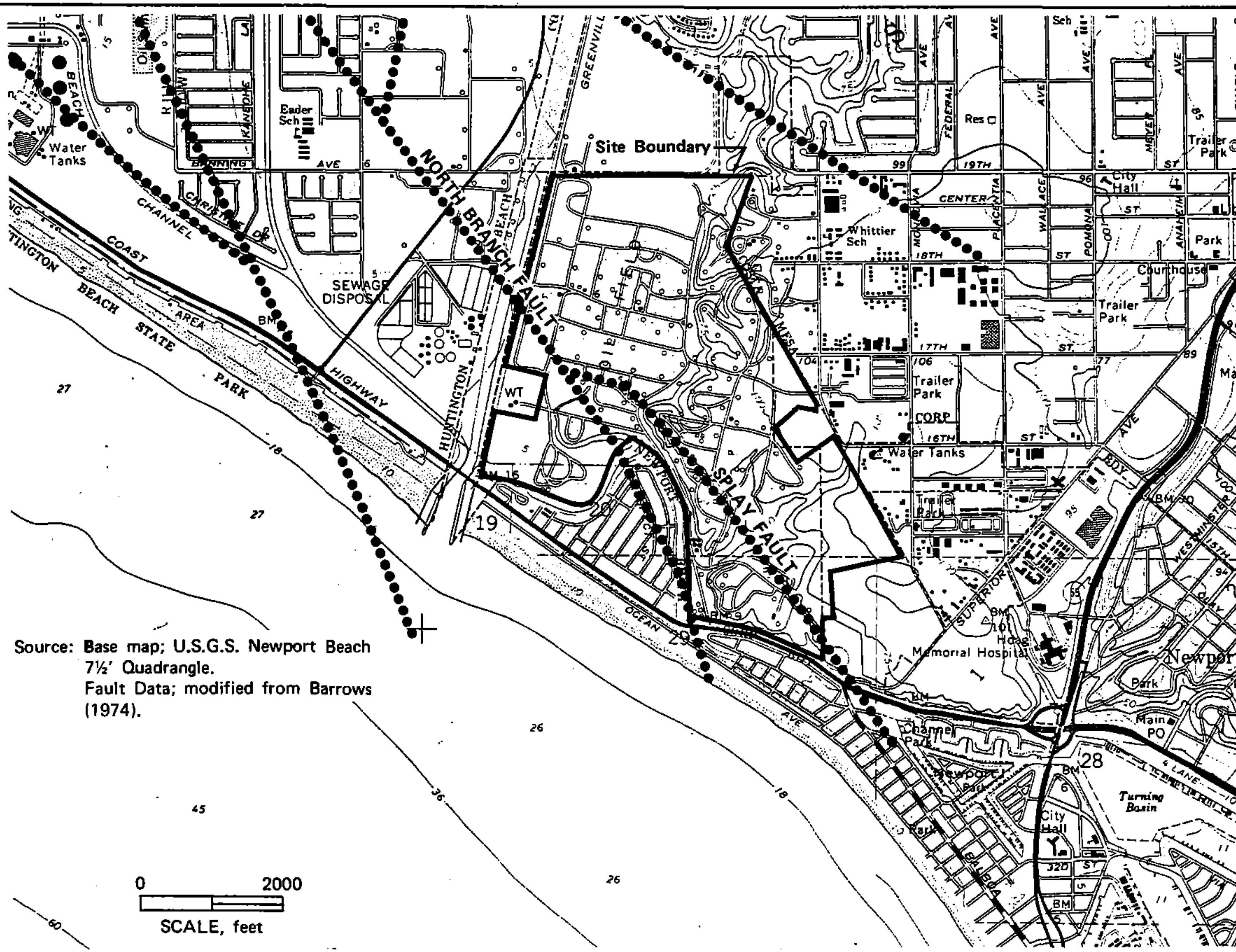
YIELD CHARACTERISTICS OF EIGHT WELLS WITHDRAWING
FROM THE TALBERT WATER-BEARING ZONE

Well	Depth (feet)	Water-yielding zone or zones					
		Depth range (feet)	Thick-ness (feet)	Yield (gpm)	Draw-down (feet)	Specific Capacity	Yield Factor
6/10- 8D5	279	218-212	42	1,060	13	82	194
18C1	196	95-136	41	820	18	46	112
18C2	190	95-140	45	970	15	65	144
6/11-13J1	150	....	....	480	13	37	....



Project: WEST NEWPORT OIL Project No. 41890A	SITE LOCATION MAP	Fig. 1

WOODWARD–CLYDE CONSULTANTS

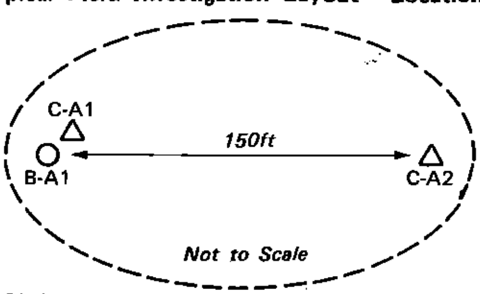


Source: Base map; U.S.G.S. Newport Beach 7½′ Quadrangle.
Fault Data; modified from Barrows (1974).

Project: WEST NEWPORT OIL Project No. 41890A	SITE LOCATION MAP ILLUSTRATING LOCAL FAULT TRACES	Fig. 2B

WOODWARD–CLYDE CONSULTANTS

Typical Field Investigation Layout - Location A



LEGEND

B-A1 ○ Boring location

C-A2 △ Cone penetration test (CPT) location

LEGEND

D — Approximate Investigation Location — See Figure 2 for specific locations

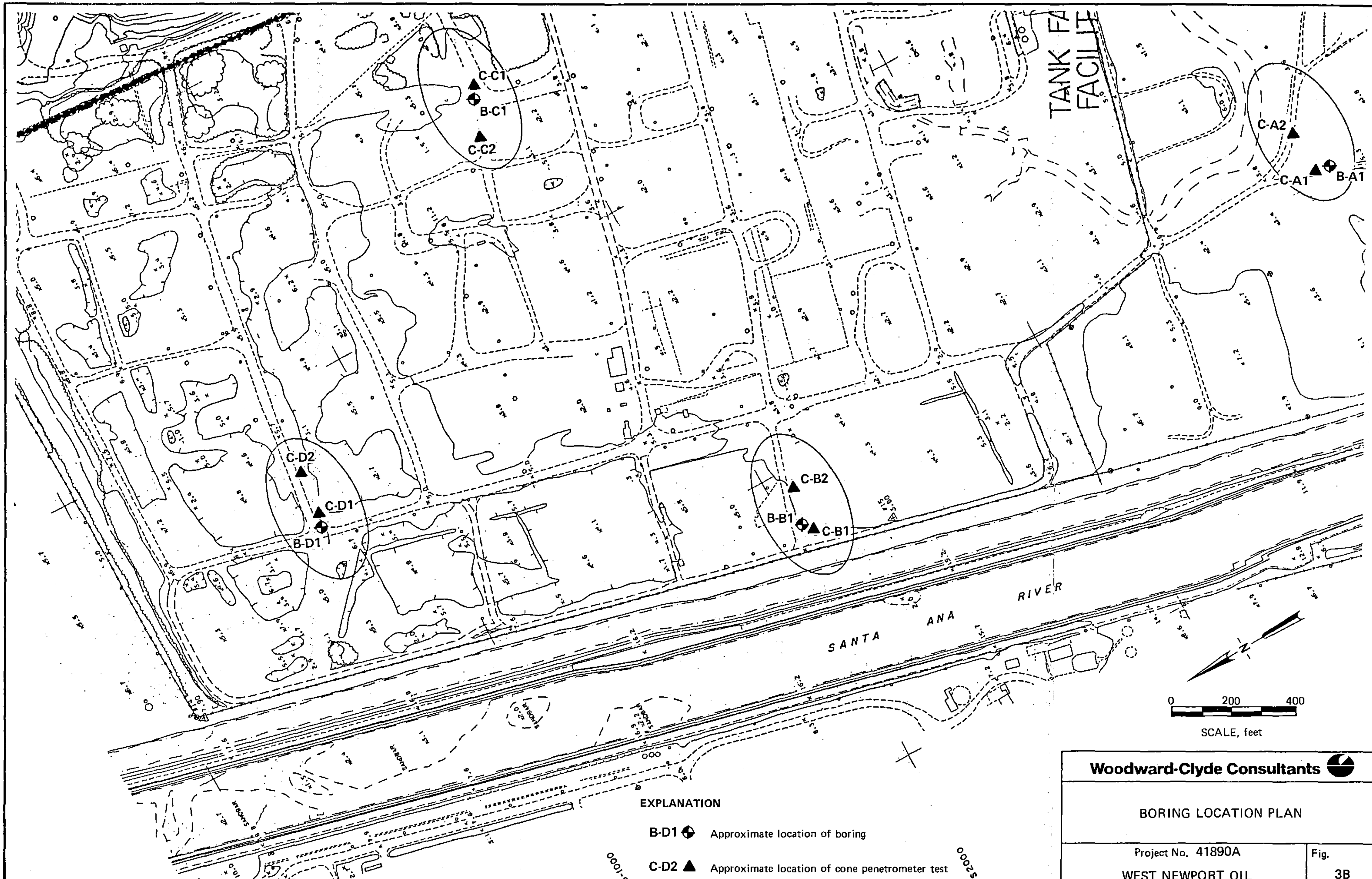
0 1,000 2,000

Approximate Scale, feet

-N-

Project: WEST NEWPORT OIL Project No. 41890A	SITE LOCATION AND EXPLORATION PLAN	Fig. 3A

WOODWARD–CLYDE CONSULTANTS



EXPLANATION

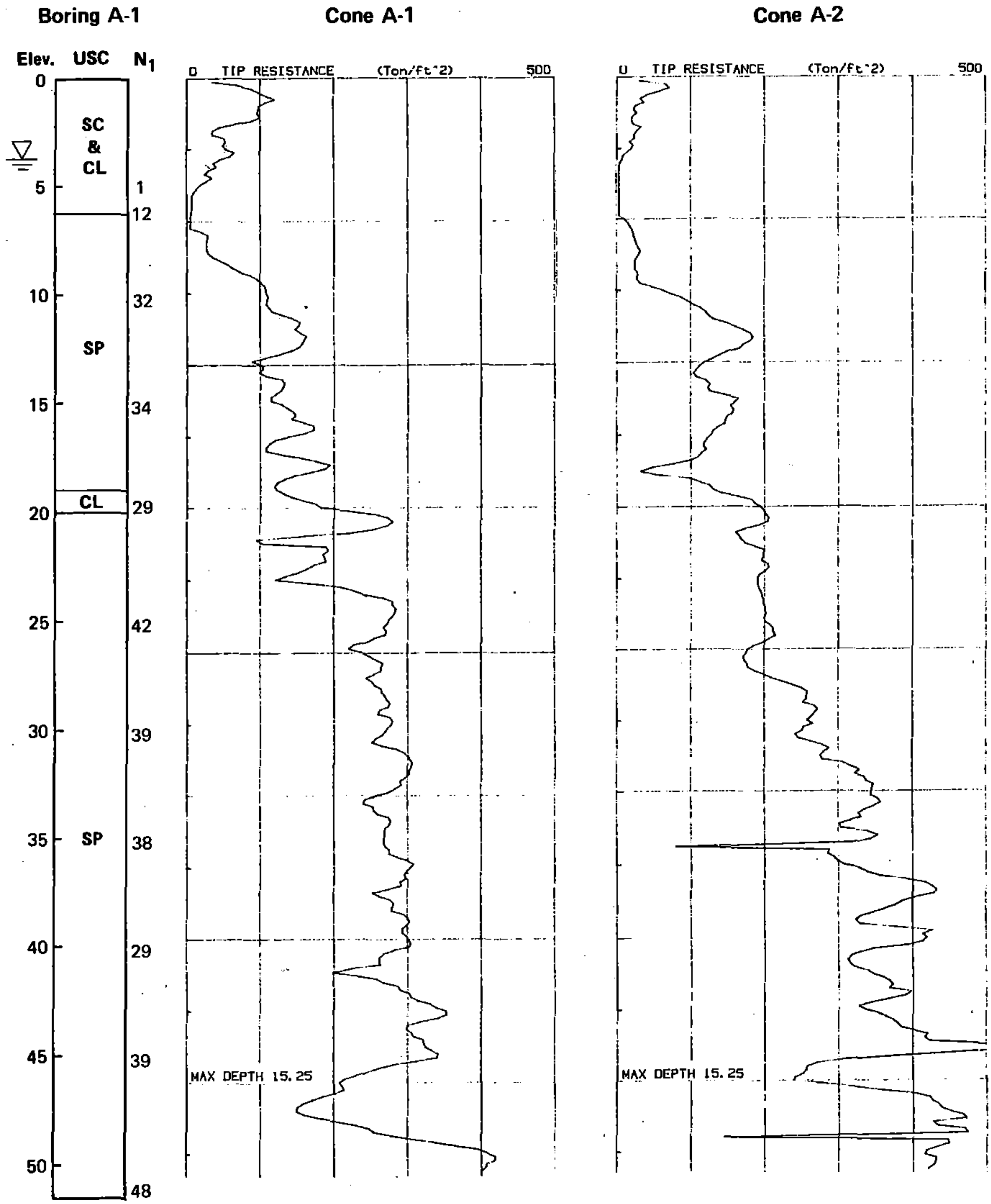
B-D1 ⊕ Approximate location of boring

C-D2 ▲ Approximate location of cone penetrometer test

Woodward-Clyde Consultants

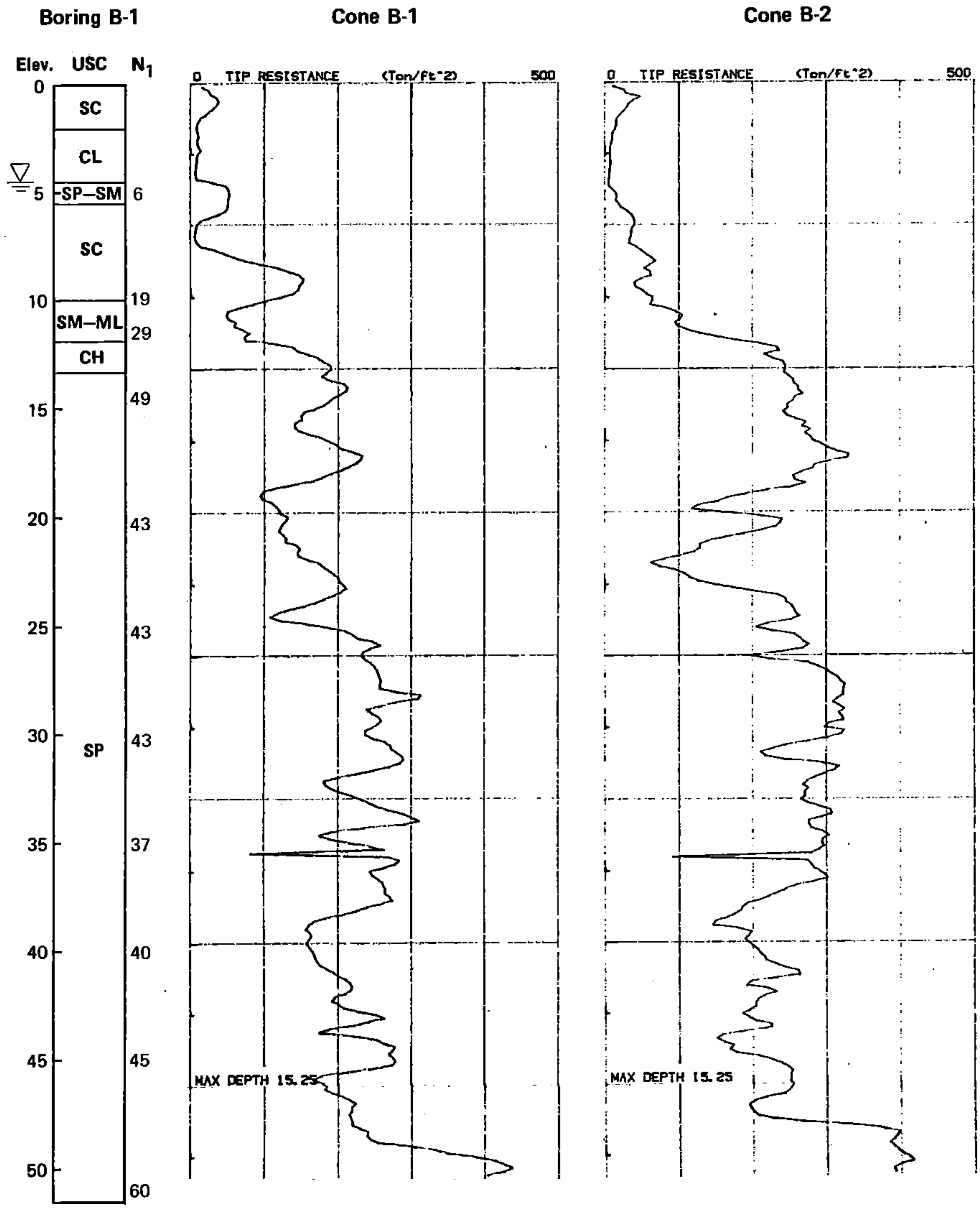
BORING LOCATION PLAN

Project No. 41890A	Fig.
WEST NEWPORT OIL	3B



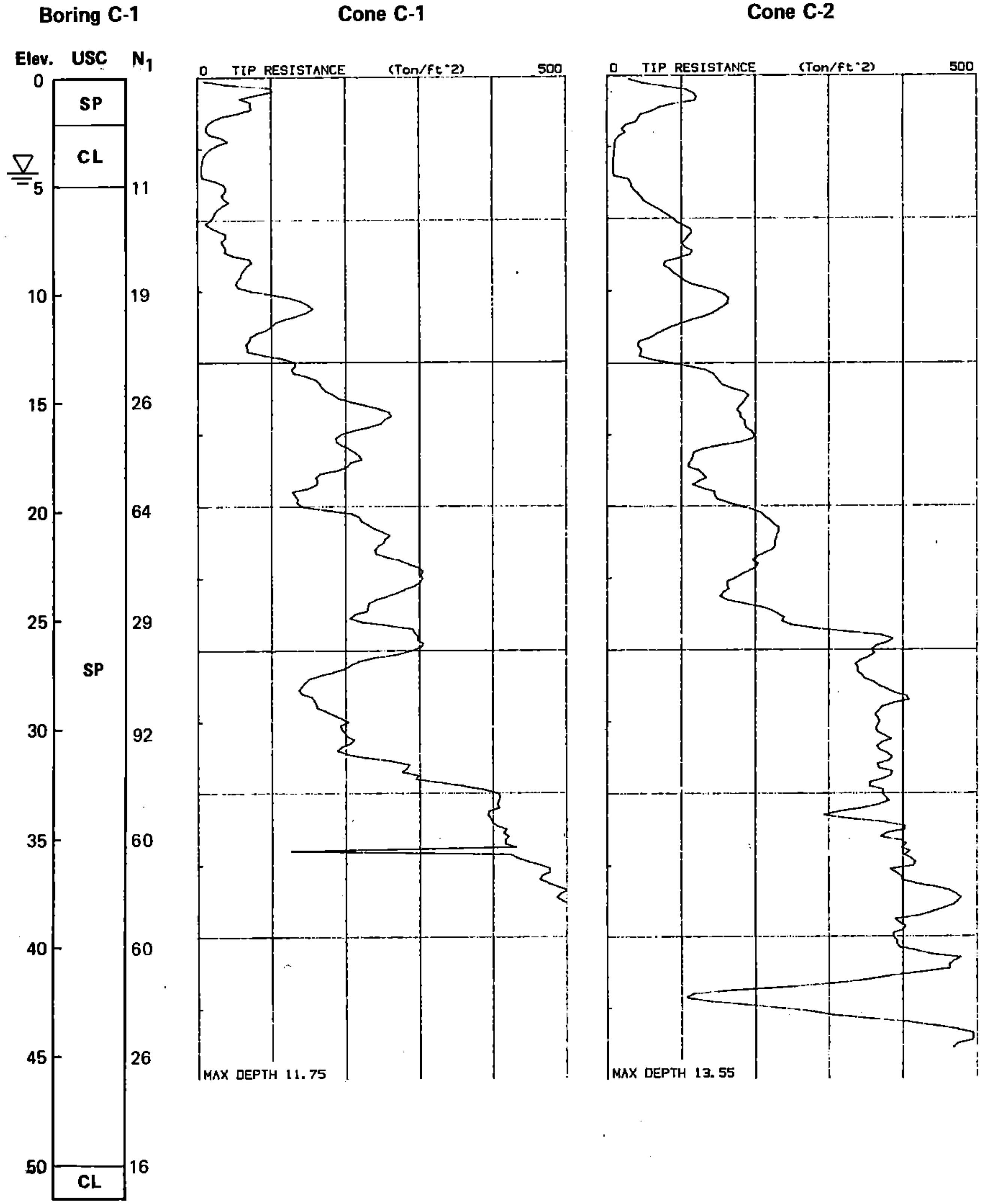
Project: WEST NEWPORT OIL Project No. 41890A	STICK AND CPT LOGS FOR AREA A	Fig. 4

WOODWARD–CLYDE CONSULTANTS



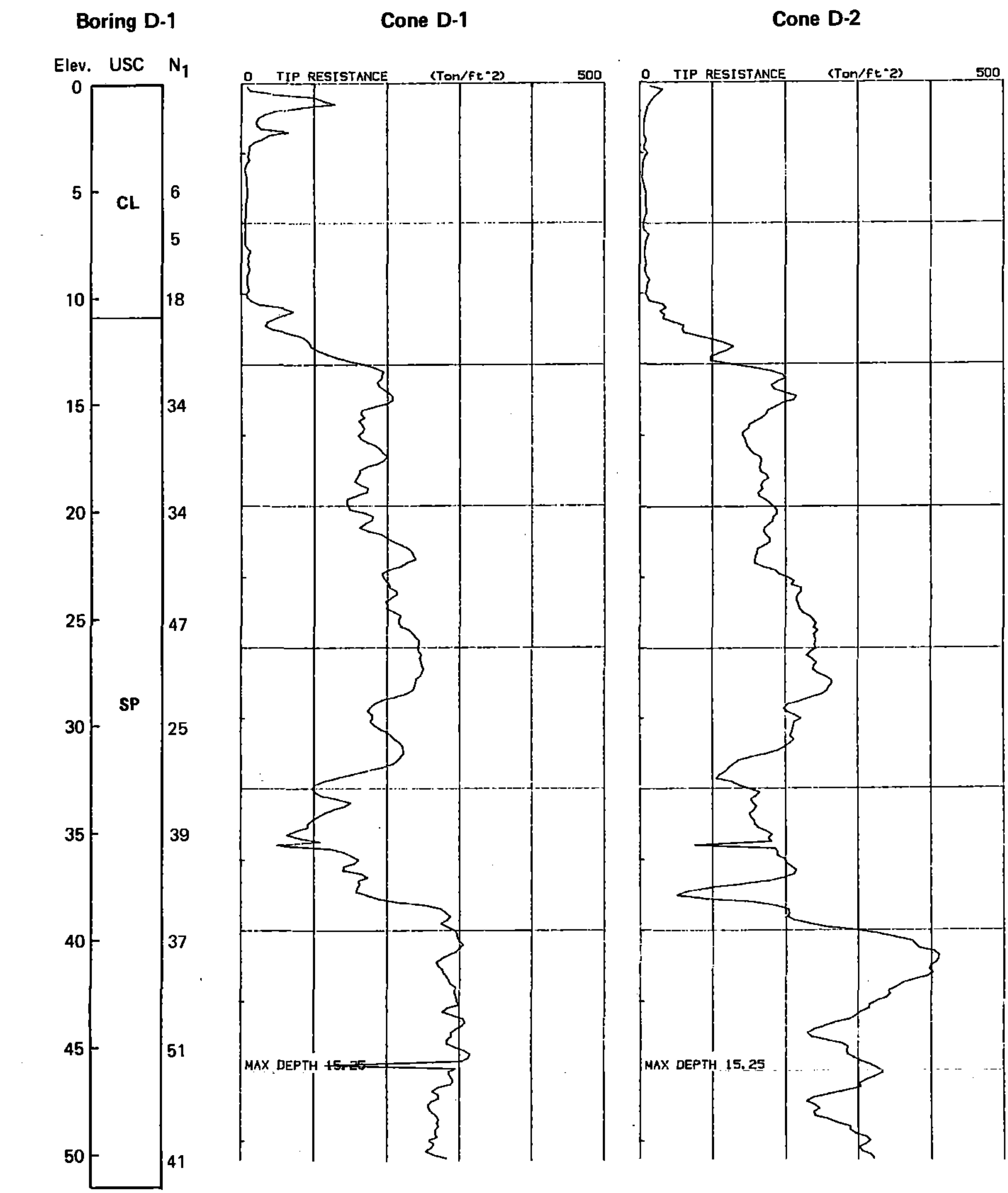
Project: WEST NEWPORT OIL **Project No.** 41890A	STICK AND CPT LOGS FOR AREA B	**Fig.** 5

WOODWARD–CLYDE CONSULTANTS



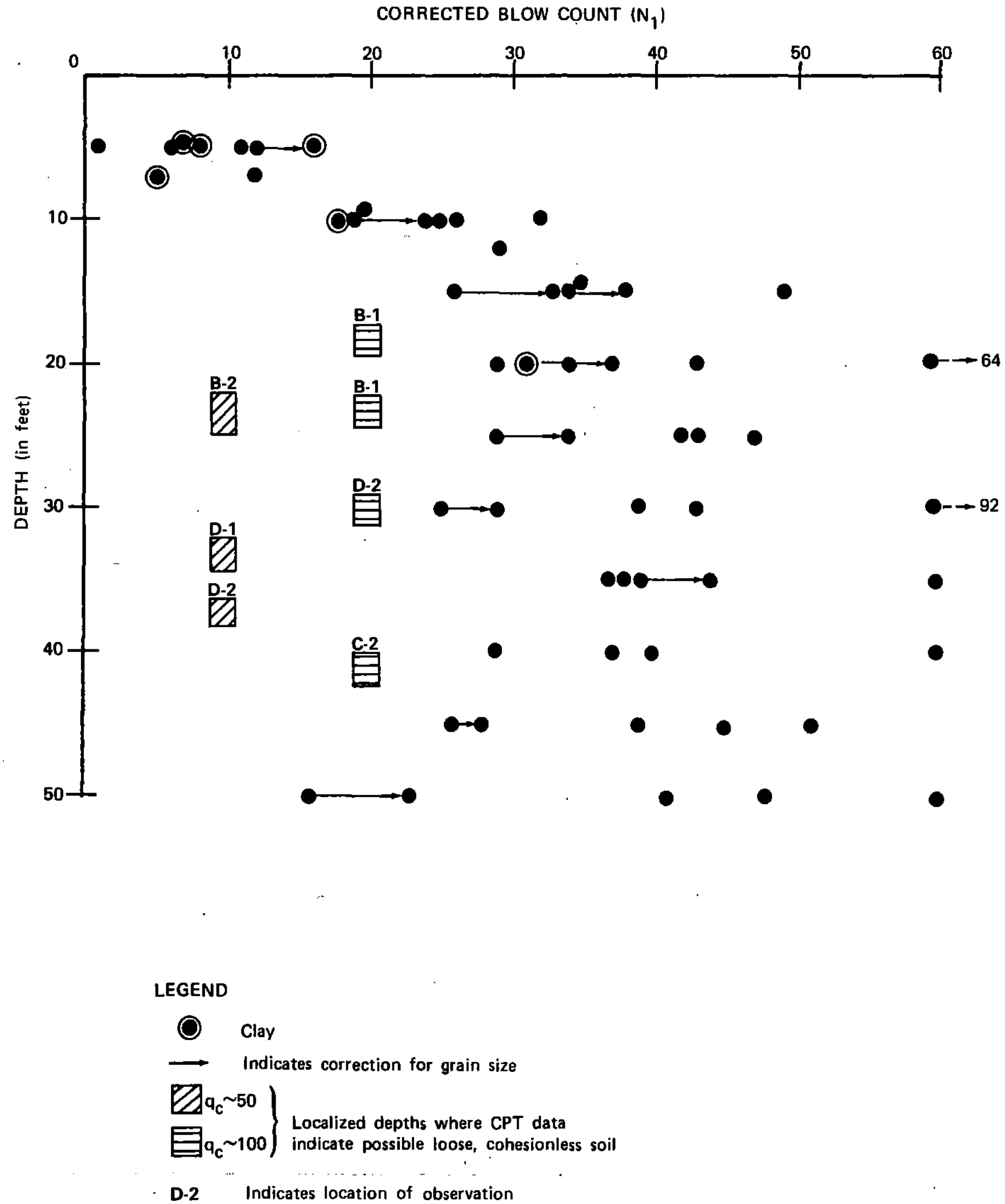
Project: WEST NEWPORT OIL Project No. 41890A	STICK AND CPT LOGS FOR AREA C	Fig. 6

WOODWARD–CLYDE CONSULTANTS



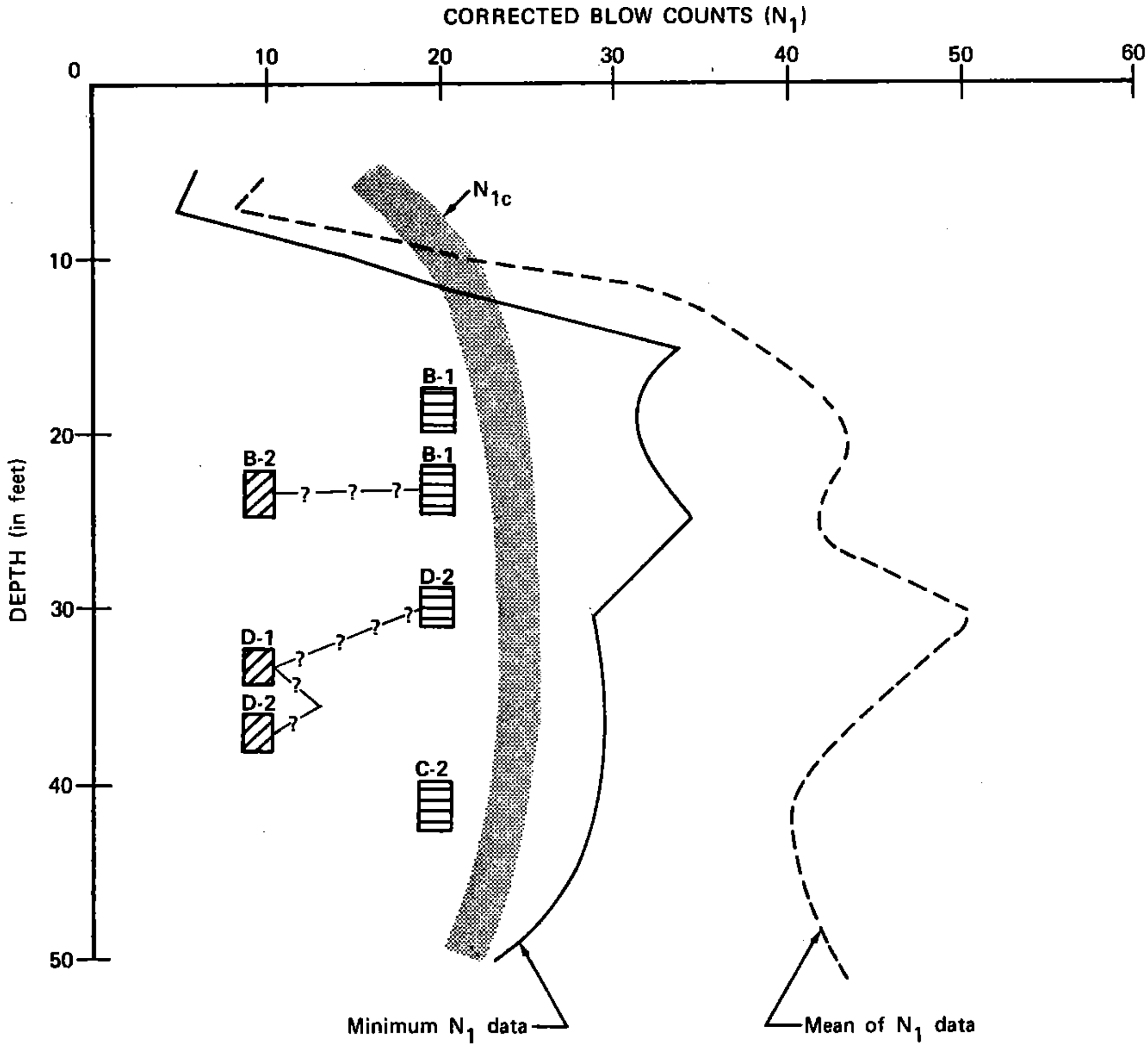
Project: WEST NEWPORT OIL **Project No.** 41890A	STICK AND CPT LOGS FOR AREA D	**Fig.** 7

WOODWARD–CLYDE CONSULTANTS



Project: WEST NEWPORT OIL Project No. 41890A	STANDARD PENETRATION BLOW COUNTS AND CPT DATA WITH DEPTH	Fig. 8

WOODWARD–CLYDE CONSULTANTS



LEGEND

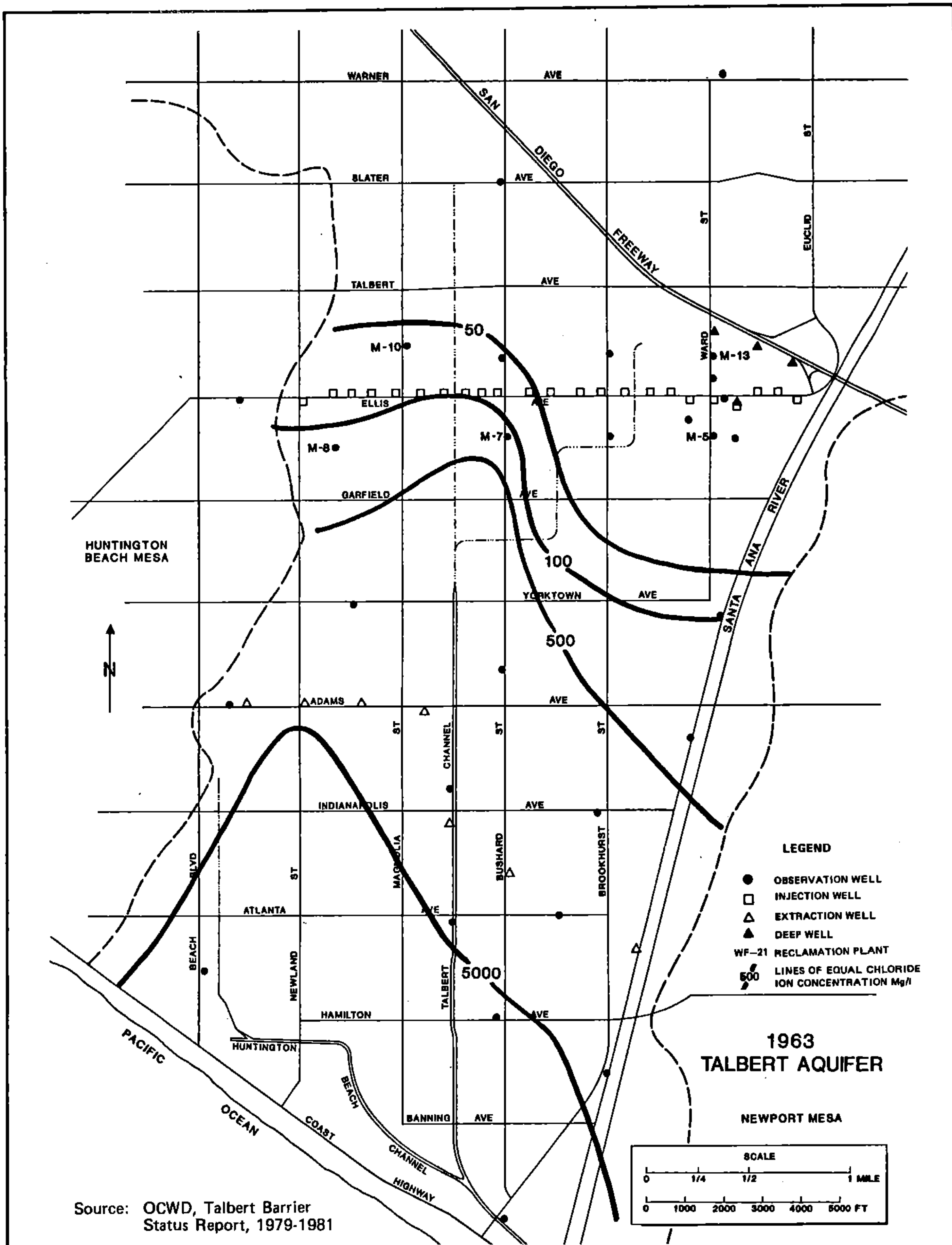
q_c~50 tsf
q_c~100 tsf
Localized depths where CPT data indicate possible loose, cohesionless soils

D-2 Indicates location of observation

—?—?— Indicates possible local continuity of layer

Project: WEST NEWPORT OIL	SUMMARY OF N_1 AND	Fig.
Project No. 41890A	CPT DATA COMPARED TO N_{1c}	9

WOODWARD–CLYDE CONSULTANTS



Project: WEST NEWPORT OIL Project No. 41890A	TALBERT BARRIER ISOCHLORS – SANTA ANA GAP	Fig. 10

WOODWARD–CLYDE CONSULTANTS

APPENDIX A

FIELD INVESTIGATION

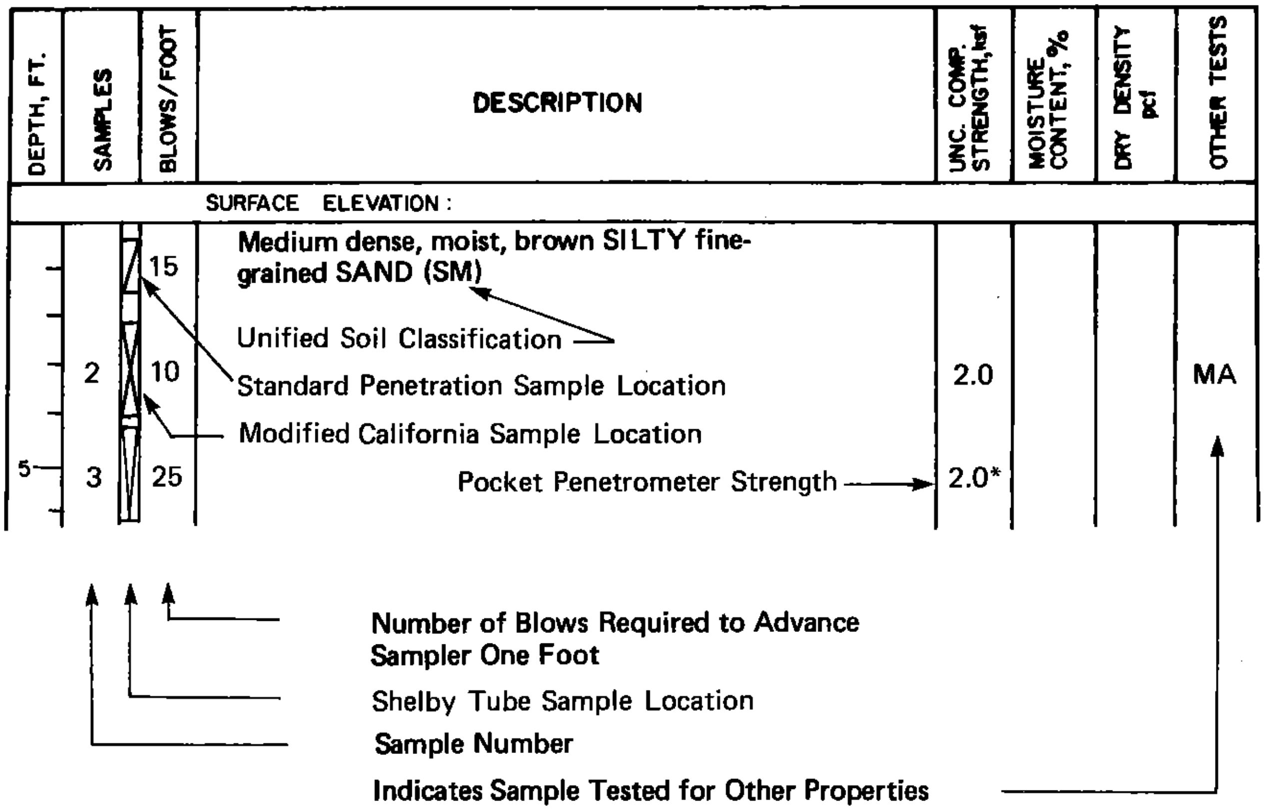
APPENDIX A
FIELD INVESTIGATION

The field investigation was conducted between 8 and 20 February 1985 and consisted of advancing four exploratory borings, three backhoe pits, and eight cone penetration tests. The approximate boring, backhoe test pit and cone penetration test locations are shown on the Boring Location Plan, Figure 2.

The borings were advanced by a Failing 1500 rotary wash drill rig to a depth of approximately 50 feet. Test pits were excavated with a tractor mounted backhoe.

The cone penetrometer tests were advanced generally in accordance with ASTM D3441-70 test procedure with a Hogendogler Electric Cone Penetrometer. Test information consisting of cone tip resistance, local friction resistance, friction ratio and pore pressure measurements were measured and recorded by a Mostek MDX computer. The friction ratio was calculated by comparing the measured valued of tip resistance and local friction.

A staff geologist prepared field logs of the subsurface materials based on visual inspection of the samples obtained, soil cuttings returned to the surface during the drilling operation, and the behavior of the drill rig. Further details of the drilling operations are presented in Key to Boring Logs, Figure A-1. The Logs of Borings, presented in Figures A-2 through A-9, are based on an observation of the samples obtained, on laboratory test results, and on field logs. Test pit logs are presented in Figures A-10 through A-12. The results of the cone penetration tests are presented in Figures A-13 through A-26.



LL – Liquid Limit, value as indicated

MA – Mechanical Analysis, percentage passing No. 200 sieve by weight indicated in parenthesis

PI – Plastic Index, value as indicated

ORG – Organic content in percent

NOTES OF FIELD INVESTIGATION

1. Borings were drilled with a truck mounted drill rig using a Failing 1500 rotary wash drill rig.
2. Samples with recorded blows/foot were obtained with a Standard Penetration or, Modified California sampler (2-inch inside diameter, 2½-inch outside diameter). The sampler was driven into the soil at the bottom of the hole with a 140 pound hammer falling 30 inches.
3. Samples labeled Sk were obtained by collecting cuttings in a cloth bag.
4. Classifications are based upon the Unified Soil Classification System and include color, moisture, and consistency. Field descriptions have been modified to reflect results of laboratory analyses where deemed appropriate.
5. Unconfined compression strengths noted by an asterisk(*) were obtained with a pocket penetrometer.
6. Descriptions on these boring logs apply only at the specific boring locations and at the time the borings were made. They are not warranted to be representative of subsurface conditions at other locations or times.

Project: WEST NEWPORT OIL Project No. 41890A	**KEY TO BORING LOGS**	Fig. A-1

WOODWARD-CLYDE CONSULTANTS

DATE OF BORING 11 February 1985 WATER DEPTH 4 feet DATE MEASURED 12 February 1985
TYPE OF DRILL RIG Failing 1500 Rotary Wash HOLE DIAMETER 9 inches
WEIGHT OF HAMMER 140 pounds FALLING 30 inches SAMPLES Standard Penetration Test

DEPTH, FT.	SAMPLES	BLOWS/FOOT	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
			SURFACE ELEVATION: Approximately 3 feet				
			Damp, loose, light brown SAND (SP) with roots				
			Soft, wet, gray SANDY CLAY (CH) with some organic debris		33		
		∇					ORG (3.1) LL=62 PI=33 MA (94)
5	1	1			75		
	2	10	Loose to medium dense, brownish gray, CLAYEY SAND (SP–SC)		36		LL=27 PI=9 MA (10) ORG (2.4)
10	3	27	Medium dense with some some shells				
			Becomes grayish brown, no shells				
15	4	28					MA (6)
			Lens of sandy clay				
20	5	24					MA (9)
25	6	30	Becomes dense with some shell fragments				
30							

Project: WEST NEWPORT OIL
Project No. 41890A

LOG OF BORING A-1

Fig. A-2

WOODWARD-CLYDE CONSULTANTS

DATE OF BORING 11 February 1985 WATER DEPTH 4 feet DATE MEASURED 12 Feb.1985

TYPE OF DRILL RIG Failing 1500 Rotary Wash HOLE DIAMETER 9 inches

WEIGHT OF HAMMER 140 pounds FALLING 30 inches SAMPLES Standard Penetration Test

DEPTH, FT.	SAMPLES	BLOWS/FOOT	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
			SURFACE ELEVATION: Approximately 3 feet				
	7	39	Dense, grayish brown CLAYEY SAND (SP–SC) (continued)				
35	8	40					
40	9	33	Becomes SAND (SP)				MA (5)
45	10	45					
50	11	57	Becomes very dense				
			Bottom of Boring at 51.5 feet				
55							
60							

Project: WEST NEWPORT OIL

Project No. 41890A

CONT. LOG OF BORING A-1

Fig. A-3

WOODWARD – CLYDE CONSULTANTS

DATE OF BORING 8 February 1985 WATER DEPTH 4.5 feet DATE MEASURED 20 Feb. 1985

TYPE OF DRILL RIG Failing 1500 Rotary Wash HOLE DIAMETER 9 inches

WEIGHT OF HAMMER 140 pounds FALLING 30 inches SAMPLES Standard Penetration Test and Modified California, Sack

SURFACE ELEVATION: Approximately 5 feet

DEPTH, FT.	SAMPLES	BLOWS/FOOT	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
			Loose, damp CLAYEY SAND (SC) (oil saturated)				
	SK-1		Wet, gray SILTY CLAY (CH)		38		MA (99) LL=62 PI=31
5	1	5	Loose, grayish brown SILTY fine SAND (SM)		39		MA (13)
			Loose, gray CLAYEY SAND (SC)				
10	2	16	Becomes medium dense		41		MA (37) LL=27 PI=11 ORG (1.8)
	3	24					
			Dense, gray SAND (SP) (sulfur odor)				
15	4	41					
20	5	36					
25	6	40					
30							

Project: WEST NEWPORT OIL

Project No. 41890A

LOG OF BORING B-1

Fig. A-4

WOODWARD-CLYDE CONSULTANTS

DATE OF BORING 8 February 1985 **WATER DEPTH** 4.5 feet DATE MEASURED 20 Feb. 1985
TYPE OF DRILL RIG Failing 1500 Rotary Wash HOLE DIAMETER 9 inches
WEIGHT OF HAMMER 140 pounds FALLING 30 inches SAMPLES Modified California, Standard Penetration Test and Sack

DEPTH, FT.	SAMPLES	BLOWS/FOOT	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
			SURFACE ELEVATION: Approximately 5 feet				
	7	43	Dense, gray SAND (SP) (sulfur odor) (continued)				
			Dense, gray SILTY fine SAND (SM)				
35	8	39					MA (18)
40	9	44					
45	10	51	Becomes very dense, no sulfur odor				
50	11	72					
			Bottom of Boring at 51.5 feet				
55							
60							

Project: WEST NEWPORT OIL
Project No. 41890A

CONT. LOG OF BORING B-1

Fig. A-5

WOODWARD – CLYDE CONSULTANTS

DATE OF BORING 11 February 1985 WATER DEPTH 4.5 feet DATE MEASURED 20 Feb. 1985
TYPE OF DRILL RIG Failing 1500 Rotary Wash HOLE DIAMETER 9 inches
WEIGHT OF HAMMER 140 pounds FALLING 30 inches SAMPLES Standard Penetration Test and Sack

SURFACE ELEVATION: Approximately 3.5 feet

DEPTH, FT.	SAMPLES	BLOWS/FOOT	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
			Loose, damp, brown CLAYEY SAND (SC) (FILL)				
	SK-1		Loose, damp, light brown SILTY SAND (SM) (FILL)				
			Medium stiff, wet, gray SANDY CLAY (CL)				
5	1	9	Loose, grayish brown CLAYEY fine SAND (SP–SC) with shell fragments		47		MA (9) LL=41 PI=24
10	2	16	Becomes dark gray, medium dense				MA (10)
15	3	22	Becomes CLAYEY fine SAND (SC)				MA (13)
20	4	54	(Blow count unreliable)				
			Becomes CLAYEY fine SAND (SP–SC)				
25	5	27					MA (11)
30							

Project: WEST NEWPORT OIL
Project No. 41890A

LOG OF BORING C-1

Fig. A-6

WOODWARD-CLYDE CONSULTANTS

DATE OF BORING 12 February 1985 WATER DEPTH 4.5 feet DATE MEASURED 20 Feb. 1985
TYPE OF DRILL RIG Failing 1500 Rotary Wash HOLE DIAMETER 9 inches
WEIGHT OF HAMMER 140 pounds FALLING 30 inches SAMPLES Standard Penetration Test and Sack

DEPTH, FT.	SAMPLES	BLOWS/FOOT	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
			SURFACE ELEVATION: Approximately 3.5 feet				
	6	92	Medium dense, gray CLAYEY fine SAND (SC) (continued)				
			Very dense				
35	7	63					
40	8	67					
45	9	30	25% shell fragments				MA (12)
50	10	19	Lens of very stiff, gray SANDY CLAY (CH)	4.3*	32		MA (82)
			Bottom of Boring at 51.5 feet				
55							
60							

Project: WEST NEWPORT OIL
Project No. 41890A

CONT. LOG OF BORING C-1

Fig. A-7

WOODWARD – CLYDE CONSULTANTS

DATE OF BORING 12 February 1985 WATER DEPTH 4 feet DATE MEASURED 20 Feb. 1985

TYPE OF DRILL RIG Failing 1500 Rotary Wash HOLE DIAMETER 9 inches

WEIGHT OF HAMMER 140 pounds FALLING 30 inches SAMPLES Standard Penetration Test and Modified California, Sack

DEPTH, FT.	SAMPLES	BLOWS/FOOT	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
			SURFACE ELEVATION: Approximately 6 feet				
			Loose, wet SANDY CLAY (CL) with roots, oil soaked				
			Medium stiff, wet, gray SILTY CLAY (CH)				
	SK-1				39		
5	1	5			57		
	2	4		2.5*	58		MA (99)
					51		LL=75 PI=44
10	3	15	Medium dense, gray SILTY SAND (SM) with shell fragments				MA (33)
15	4	28					ORG (1.6)
20	5	28	Becomes SILTY SAND (SP–SM)				MA (10)
25	6	43	Becomes medium dense to dense				
30							

Project: WEST NEWPORT OIL

Project No. 41890A

LOG OF BORING D-1

Fig. A-8

WOODWARD-CLYDE CONSULTANTS

DATE OF BORING 12 February 1985 WATER DEPTH 4 feet DATE MEASURED 20 Feb. 1985

TYPE OF DRILL RIG Failing 1500 Rotary Wash HOLE DIAMETER 9 inches

WEIGHT OF HAMMER 140 pounds FALLING 30 inches SAMPLES Modified California, Standard Penetration Test and Sack

DEPTH, FT.	SAMPLES	BLOWS/FOOT	DESCRIPTION	UNC. COMP. STRENGTH, ksf	MOISTURE CONTENT, %	DRY DENSITY pcf	OTHER TESTS
			SURFACE ELEVATION: Approximately 6 feet				
	7	25	Medium dense to dense, gray SILTY SAND (SP–SM) (continued)				MA (10)
35	8	41					
40	9	42					
45	10	58	Becomes dense to very dense				
50	11	49					
			Bottom of Boring at 51.5 feet				
55							
60							

Project: WEST NEWPORT OIL

Project No. 41890A

CONT. LOG OF BORING D-1

Fig. A-9

WOODWARD – CLYDE CONSULTANTS

DATE OF TEST PIT 20 February 1985 PIT DIMENSIONS —

EQUIPMENT Backhoe

DEPTH, FT.	SAMPLES	SYMBOL	DESCRIPTION	REMARKS
			SURFACE ELEVATION: Approximately 3 feet	
			Moist CLAYEY SAND (SC)	
	1		Wet, gray SANDY CLAY (CH)	Moisture Content – 39% Mechanical Analysis – (80)
5				
			Bottom of Test Pit at 6 feet	
10				
15				

Project: WEST NEWPORT OIL

Project No. 41890A

LOG OF TEST PIT TP-A-2

Fig. A-10

WOODWARD–CLYDE CONSULTANTS

DATE OF TEST PIT 20 February 1985 PIT DIMENSIONS —

EQUIPMENT Backhoe

DEPTH, FT.	SAMPLES	SYMBOL	DESCRIPTION	REMARKS
			SURFACE ELEVATION: Approximately 3 feet	
			Damp CLAYEY SAND (SC), oil soaked	
			Wet, gray SILTY CLAY (CL)	
	1			
5			Bottom of Test Pit at 5 feet	
10				
15				

Project: WEST NEWPORT OIL
Project No. 41890A

LOG OF TEST PIT TP-B-2

Fig. A-11

WOODWARD–CLYDE CONSULTANTS

DATE OF TEST PIT 20 February 1985 **PIT DIMENSIONS** —

EQUIPMENT Backhoe

DEPTH, FT.	SAMPLES	SYMBOL	DESCRIPTION	REMARKS
SURFACE ELEVATION: Approximately 3 feet				
			Damp, light brown SAND (SP)	Moisture Content — 45% Mechanical Analysis — (100)
	1		Soft, wet, gray SILTY CLAY (CH)	
5			Bottom of Test Pit at 5 feet	
10				
15				

Project: WEST NEWPORT OIL

Project No. 41890A

LOG OF TEST PIT TP-C-2

Fig. A-12

WOODWARD-CLYDE CONSULTANTS

CONE PENETRATION NUMBER A-1

APPROXIMATE SURFACE ELEVATION 3 feet

PREDRILLED DEPTH 0 feet

JOB # : 41890A
DATE : 2-11-85
LOCATION : C.P.T. A-1
FILE # : 86

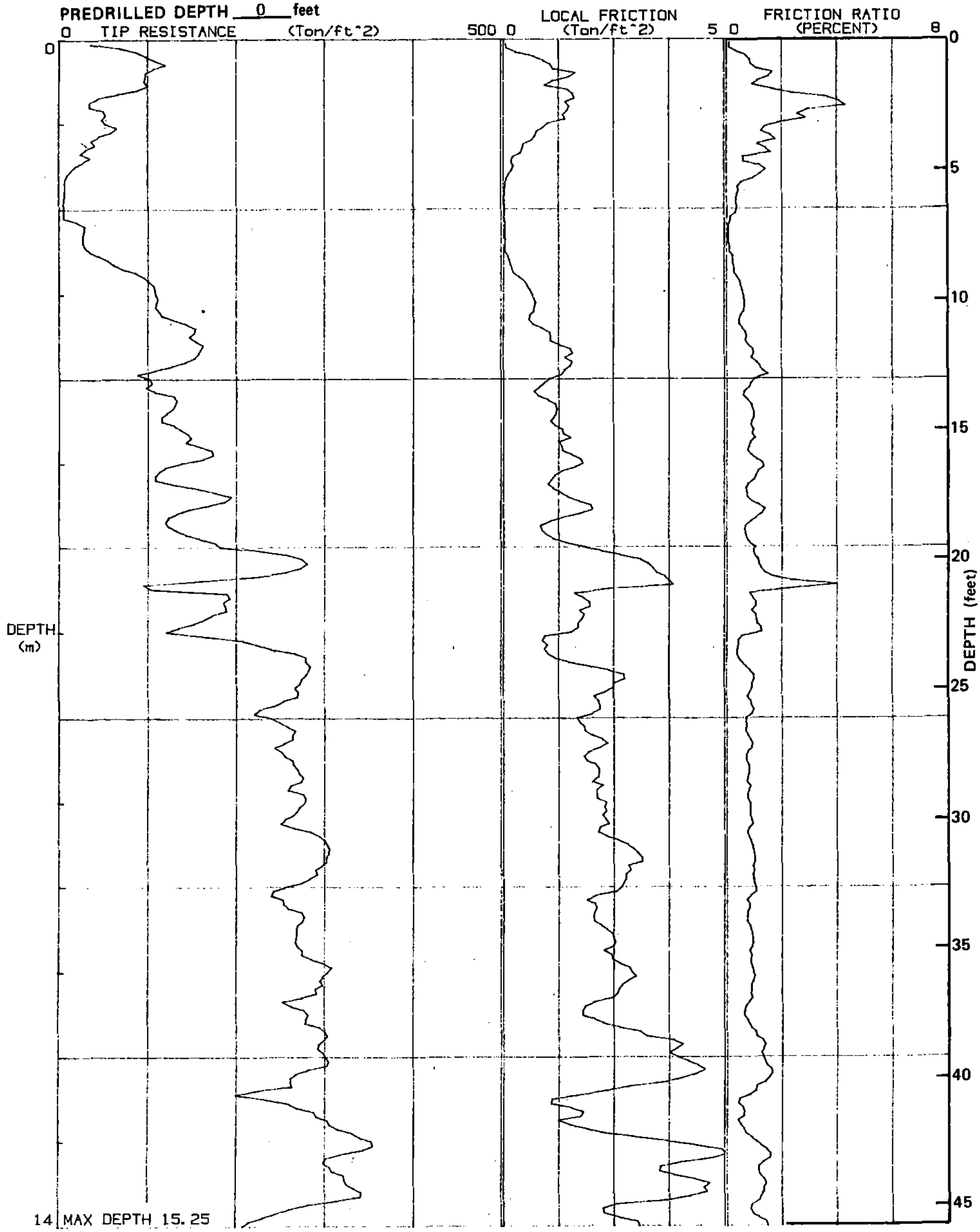


Figure A-13

CONTINUATION FROM PREVIOUS PAGE
CONE PENETRATION NUMBER A-1

JOB # . : 41890A
DATE : 2-11-85
LOCATION : C.P.T. A-1
FILE # : 86

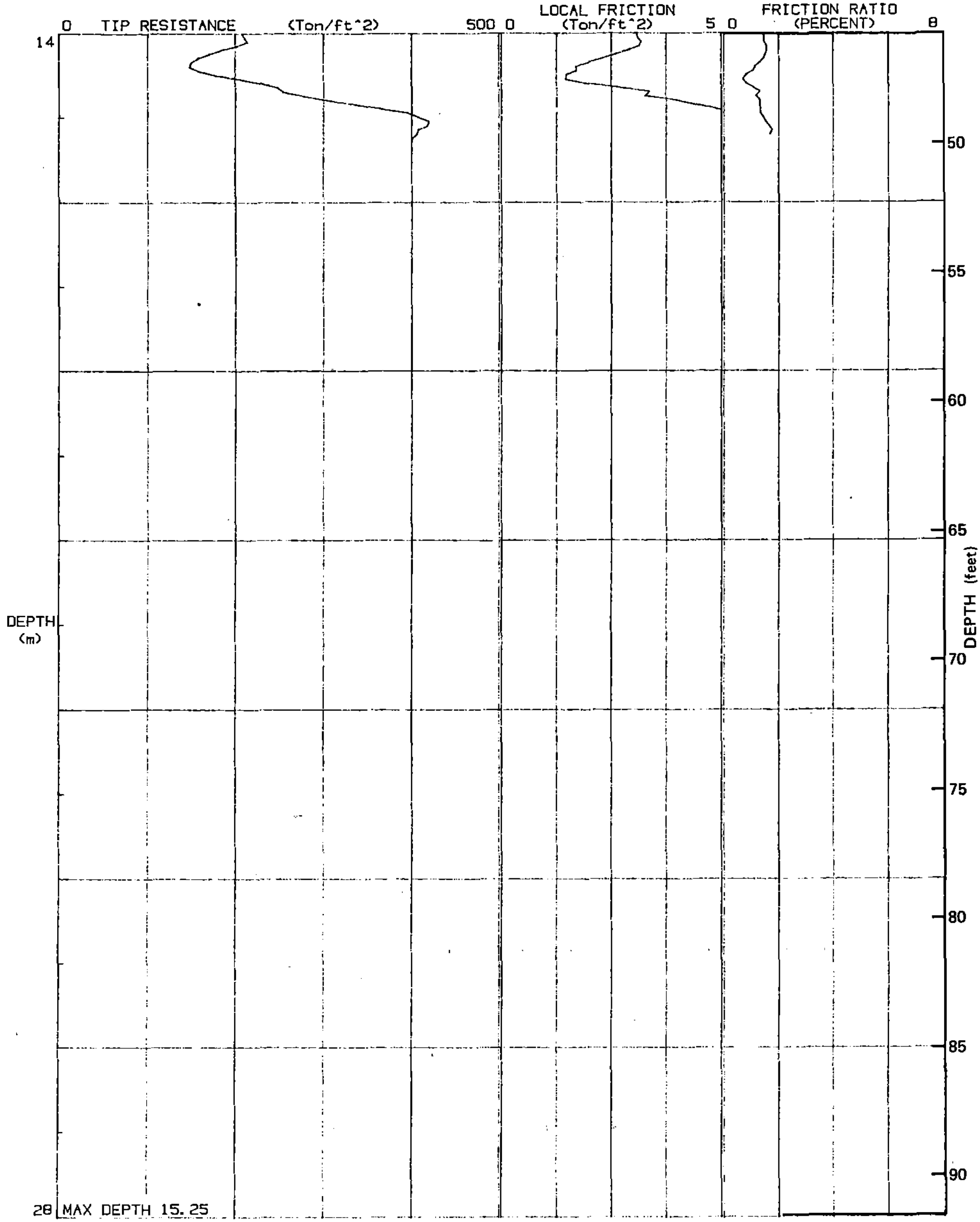


Figure A-14

CONE PENETRATION NUMBER A-2

APPROXIMATE SURFACE ELEVATION 3 feet

PREDRILLED DEPTH 0 feet

JOB # : 41890A
DATE : 2-11-85
LOCATION : C. P. T. A-2
FILE # : 85

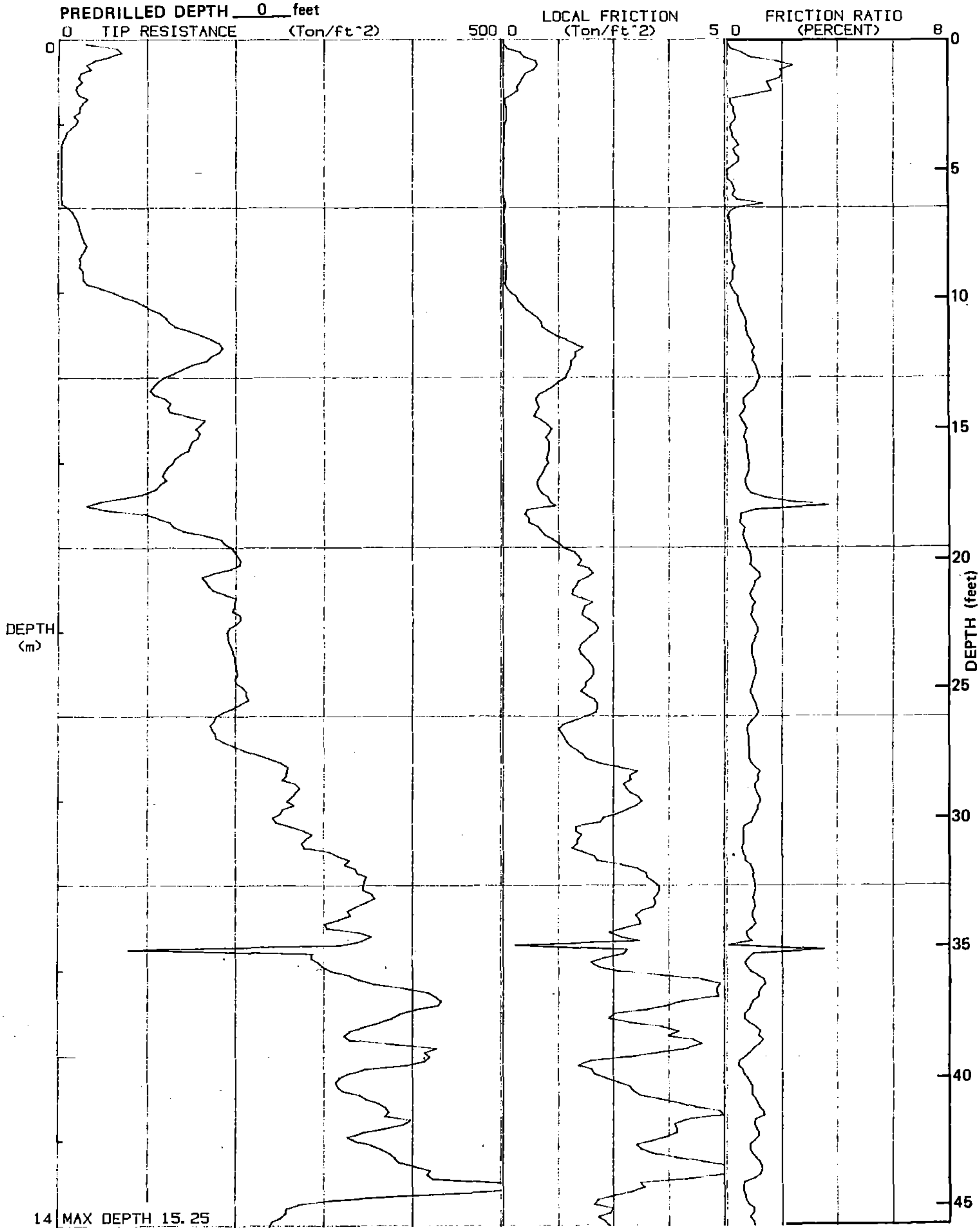


Figure A-15

CONTINUATION FROM PREVIOUS PAGE
CONE PENETRATION NUMBER A-2

JOB # : 41890A
DATE : 2-11-85
LOCATION : C.P.T. A-2
FILE # : 85

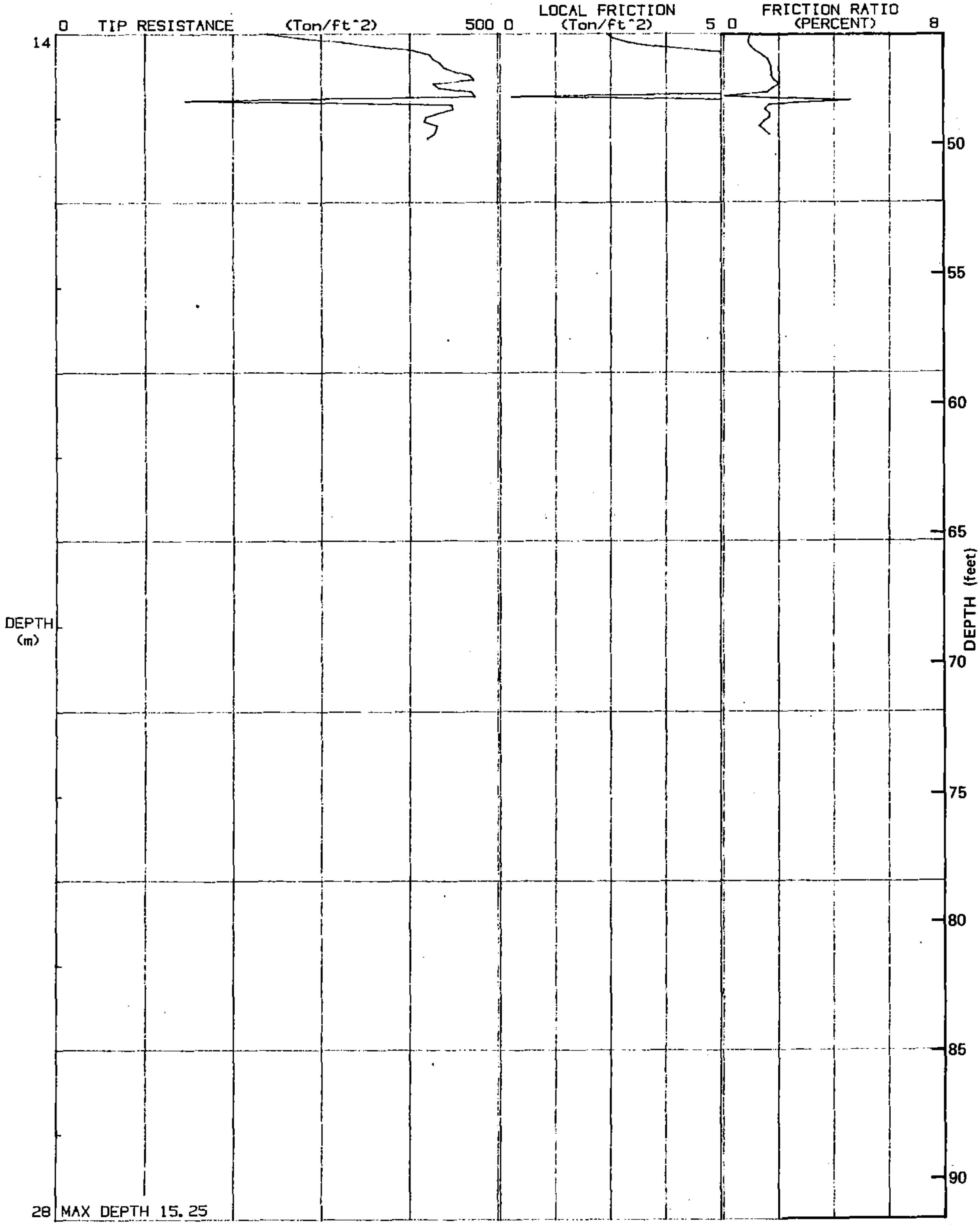


Figure A-16

CONE PENETRATION NUMBER B-1

APPROXIMATE SURFACE ELEVATION 5 feet

PREDRILLED DEPTH 0 feet

JOB # : 41890A
DATE : 2-11-85
LOCATION : C.P.T. B-1
FILE # : 83

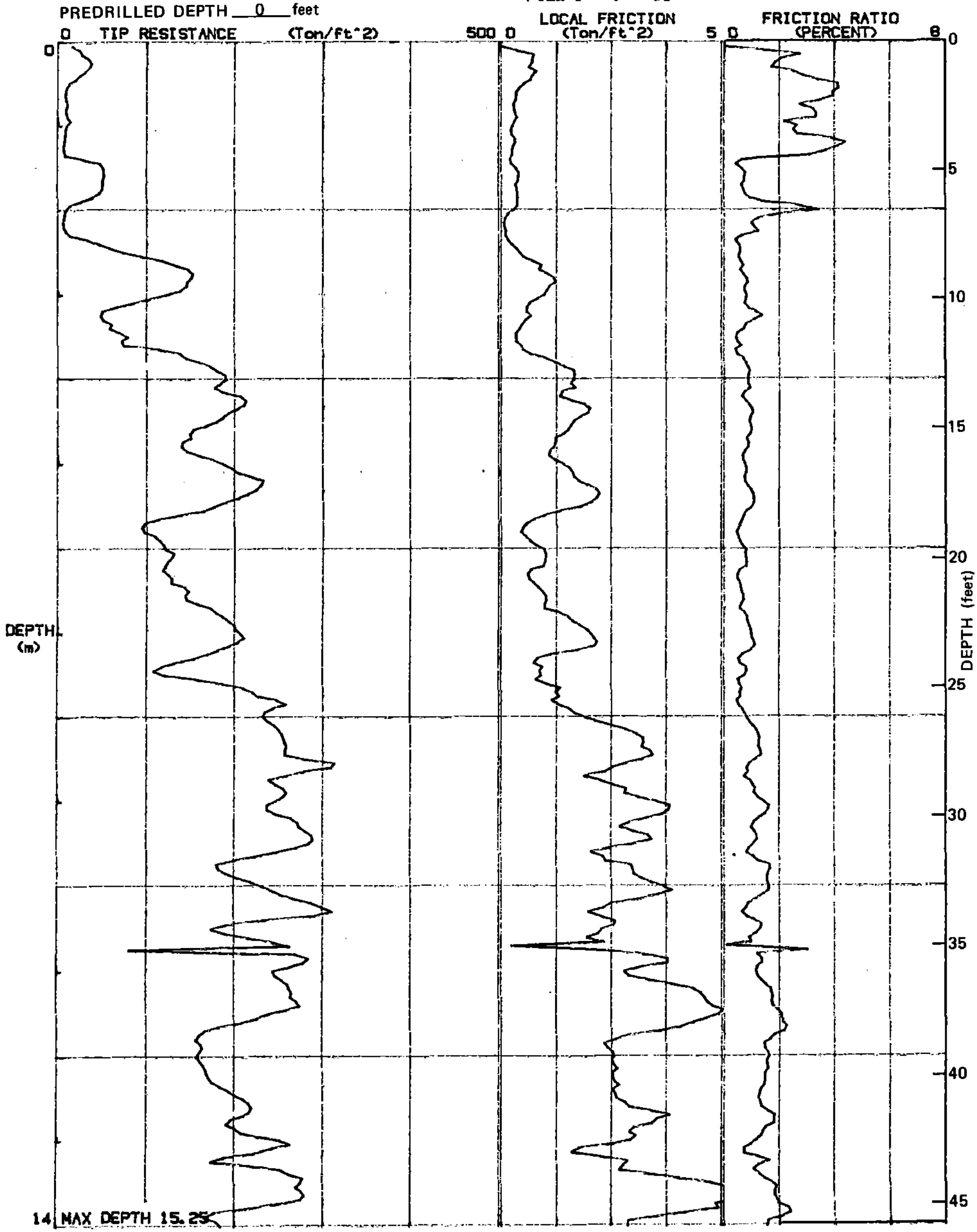


Figure A-17

CONTINUATION FROM PREVIOUS PAGE
CONE PENETRATION NUMBER B-1

JOB # : 41890A
DATE : 2-11-85
LOCATION : C.P.T. B-1
FILE # : 83

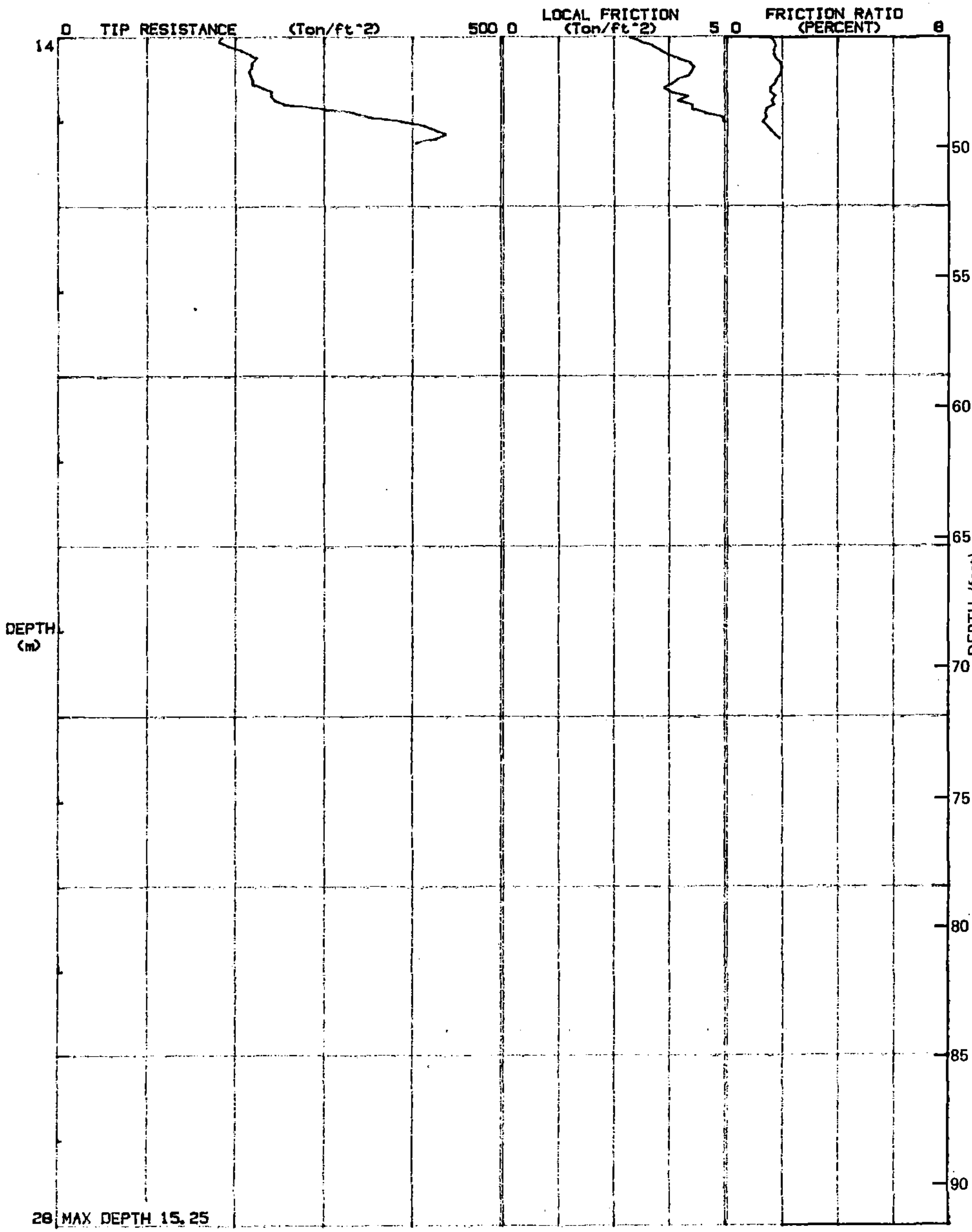


Figure A-18

CONE PENETRATION NUMBER B-2

APPROXIMATE SURFACE ELEVATION 5 feet

PREDRILLED DEPTH 0 feet

JOB # : 41890A
DATE : 2-11-85
LOCATION : C.P.T. B-2
FILE # : 84

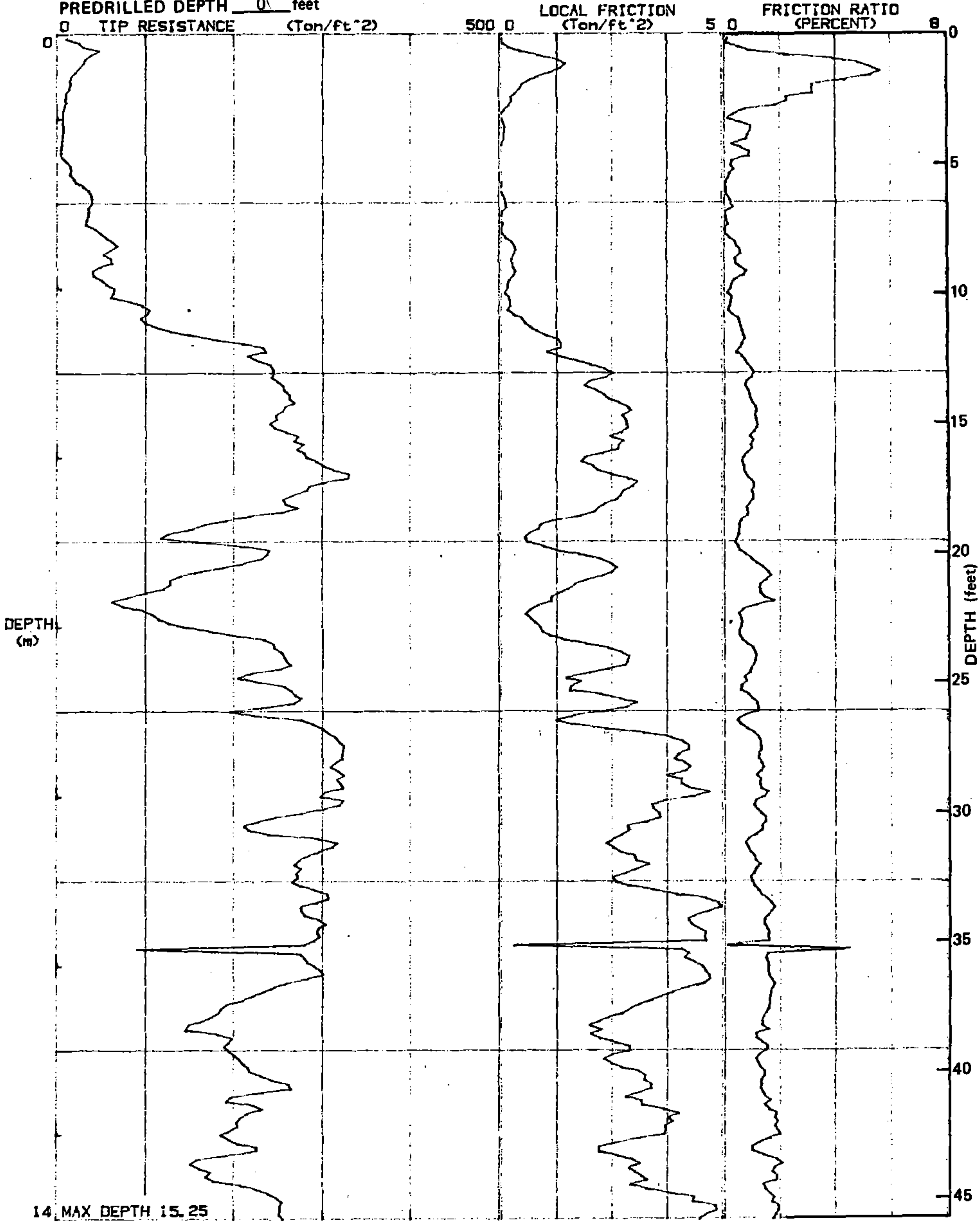


Figure A-19

CONTINUATION FROM PREVIOUS PAGE
CONE PENETRATION NUMBER B-2

JOB # : 41890A
DATE : 2-11-85
LOCATION : C.P.T. B-2
FILE # : 84

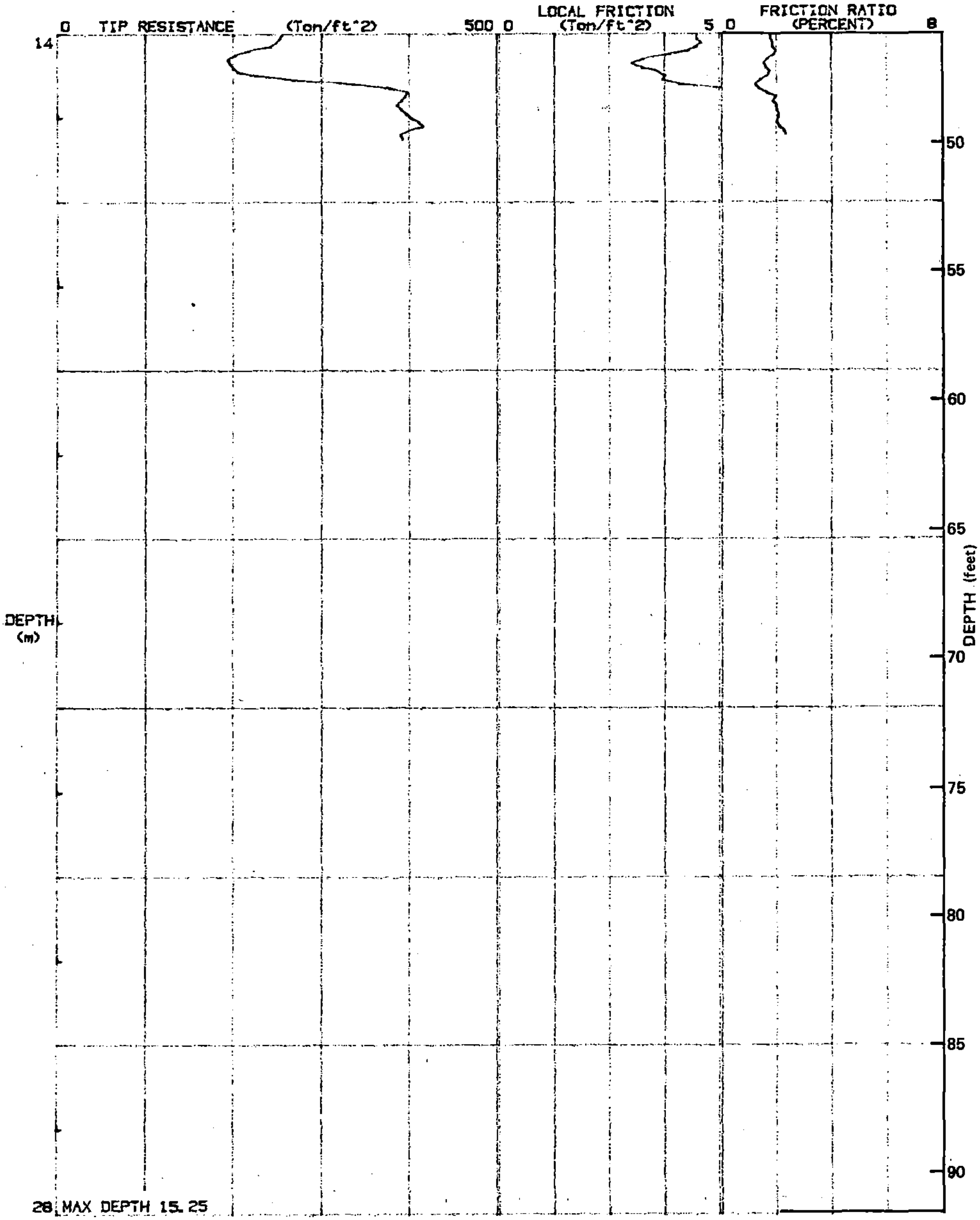


Figure A-20

CONE PENETRATION NUMBER C-1

APPROXIMATE SURFACE ELEVATION 3.5 feet

PREDRILLED DEPTH 0 feet

JOB # : 41890A
DATE : 2-13-85
LOCATION : C.P.T. C-1
FILE # : 87

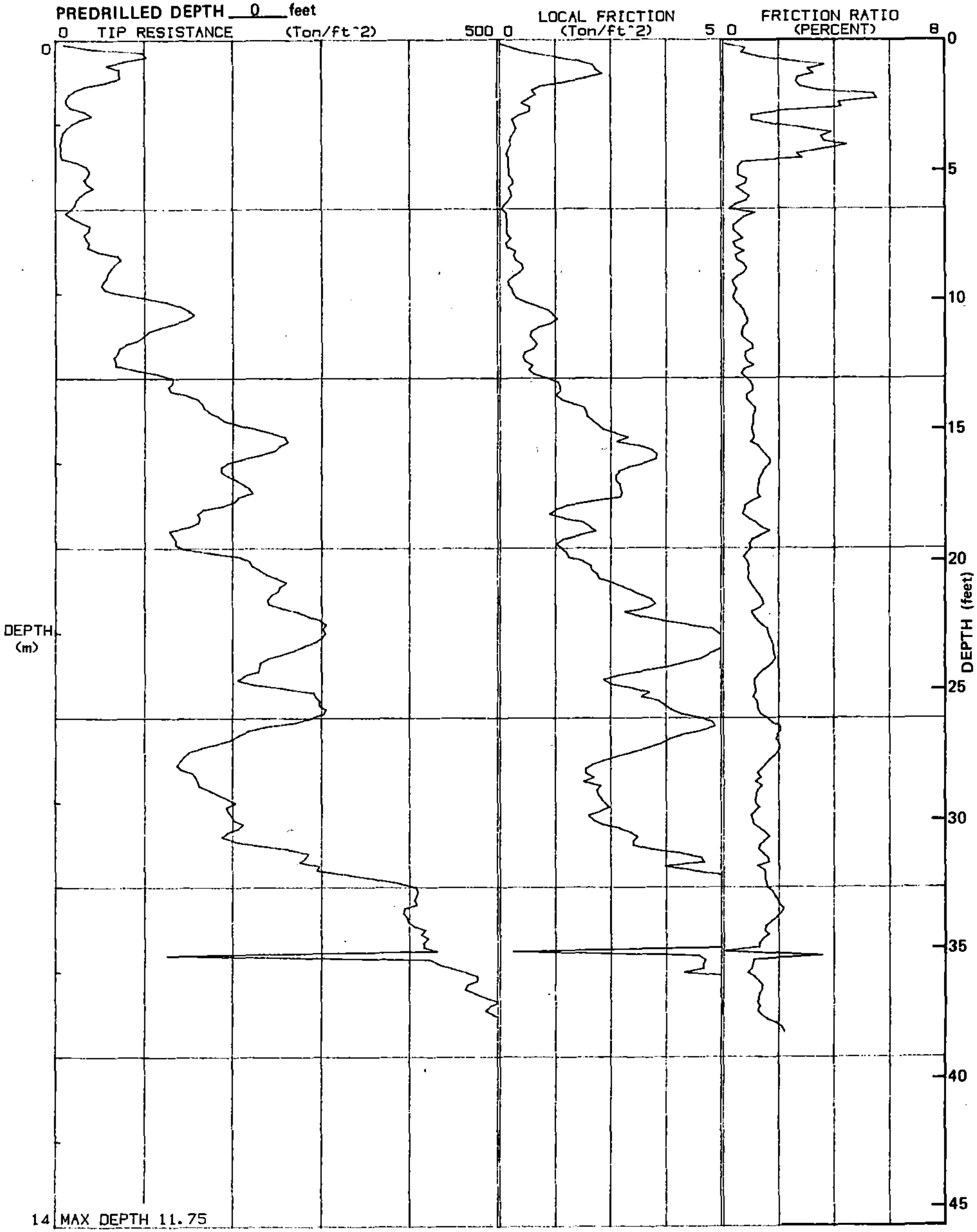


Figure A-21

JOB # : 41890A
DATE : 2-13-85
LOCATION : C.P.T. C-2
FILE # : 88

CONE PENETRATION NUMBER C-2

APPROXIMATE SURFACE ELEVATION 3.5 feet

PREDRILLED DEPTH 0 feet

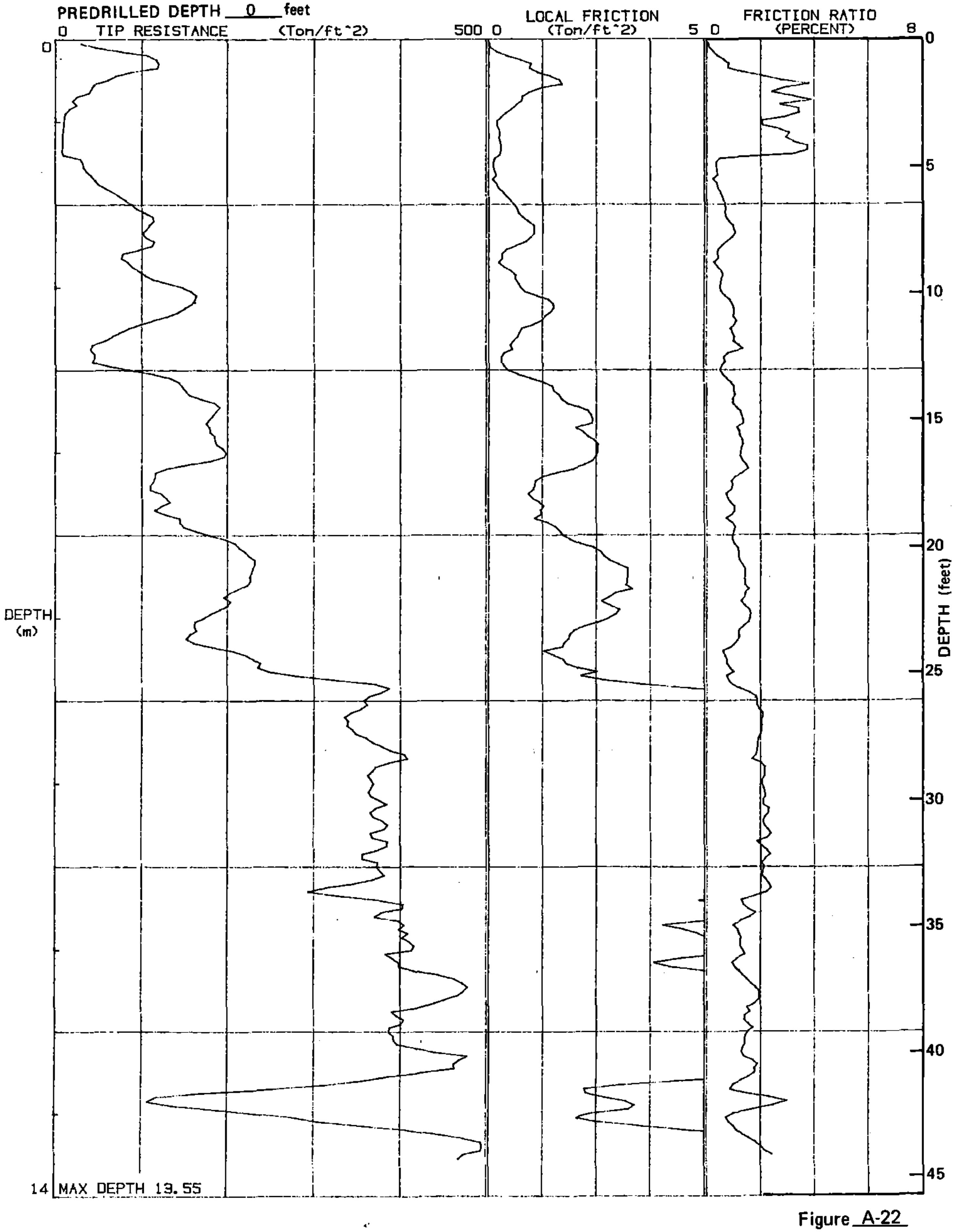


Figure A-22

CONE PENETRATION NUMBER D-1

APPROXIMATE SURFACE ELEVATION 6 feet

PREDRILLED DEPTH 0 feet

JOB # : 41890A
DATE : 2-13-85
LOCATION : C. P. T. D-1
FILE # : 89

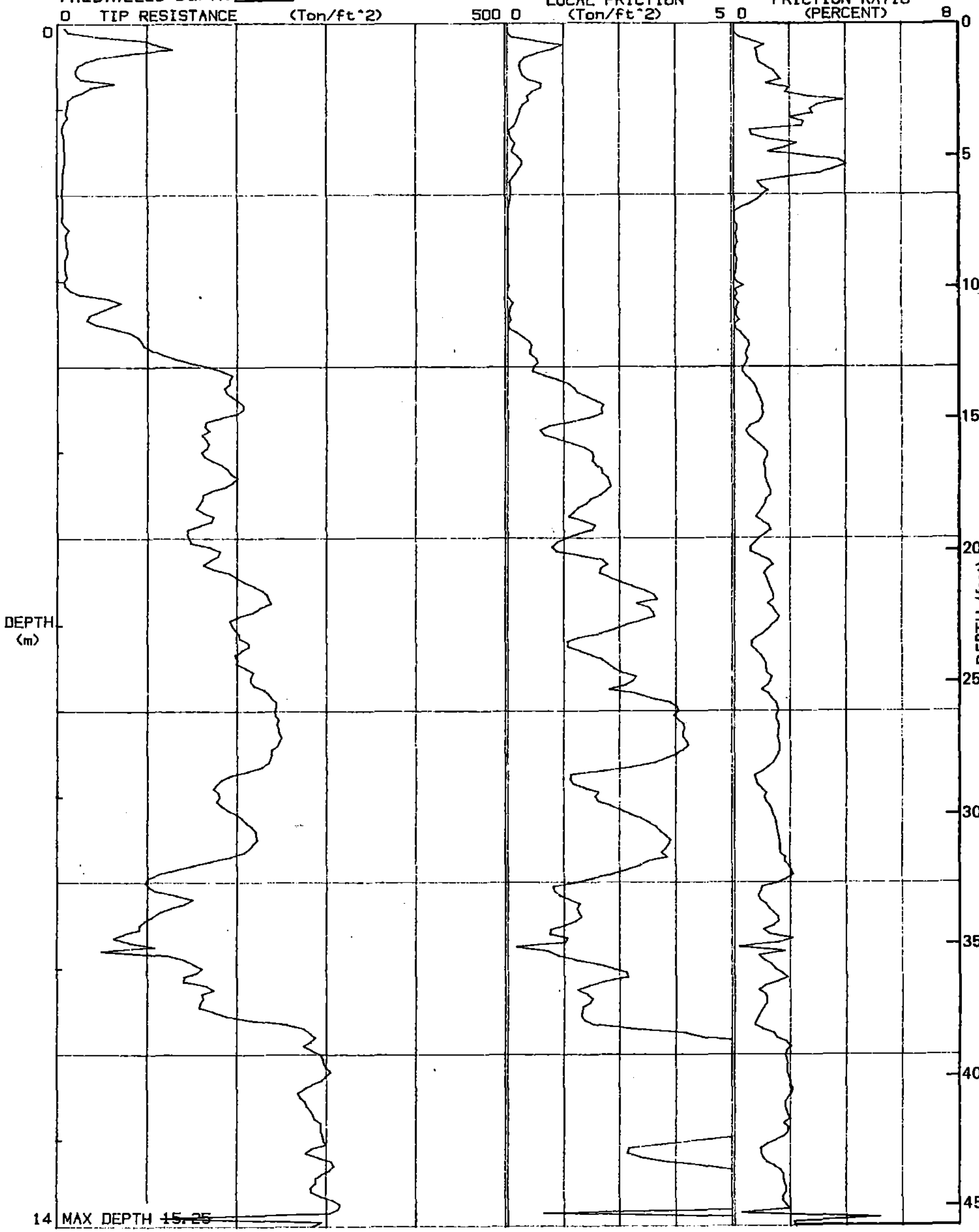


Figure A-23

CONTINUATION FROM PREVIOUS PAGE
CONE PENETRATION NUMBER D-1

JOB # : 41890A
DATE : 2-13-85
LOCATION : C.P.T. D-1
FILE # : 89

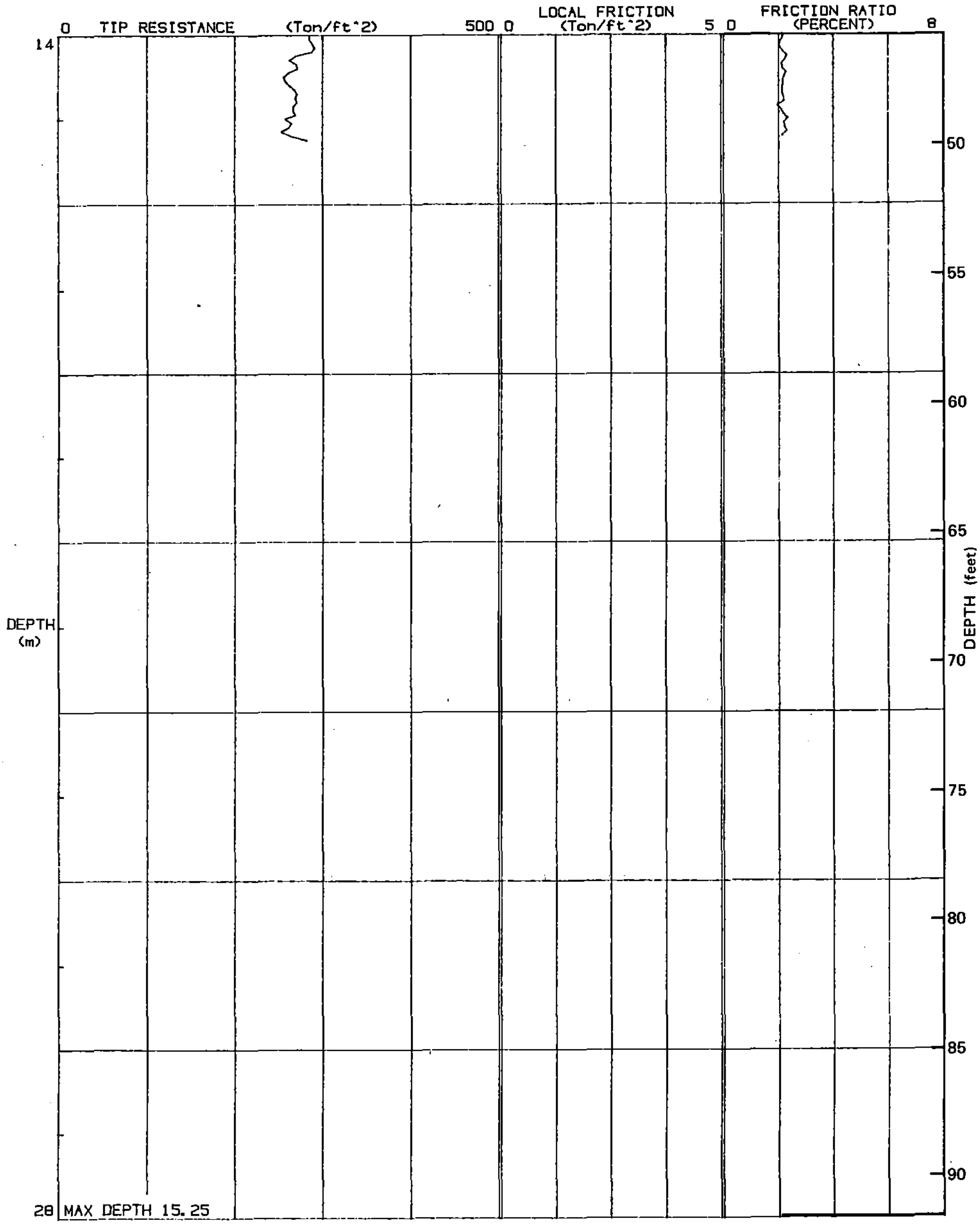


Figure A-24

CONE PENETRATION NUMBER D-2

APPROXIMATE SURFACE ELEVATION 6 feet

PREDRILLED DEPTH 0 feet

JOB # : 41890A
DATE : 2-13-85
LOCATION : C.P.T. D-2
FILE # : 90

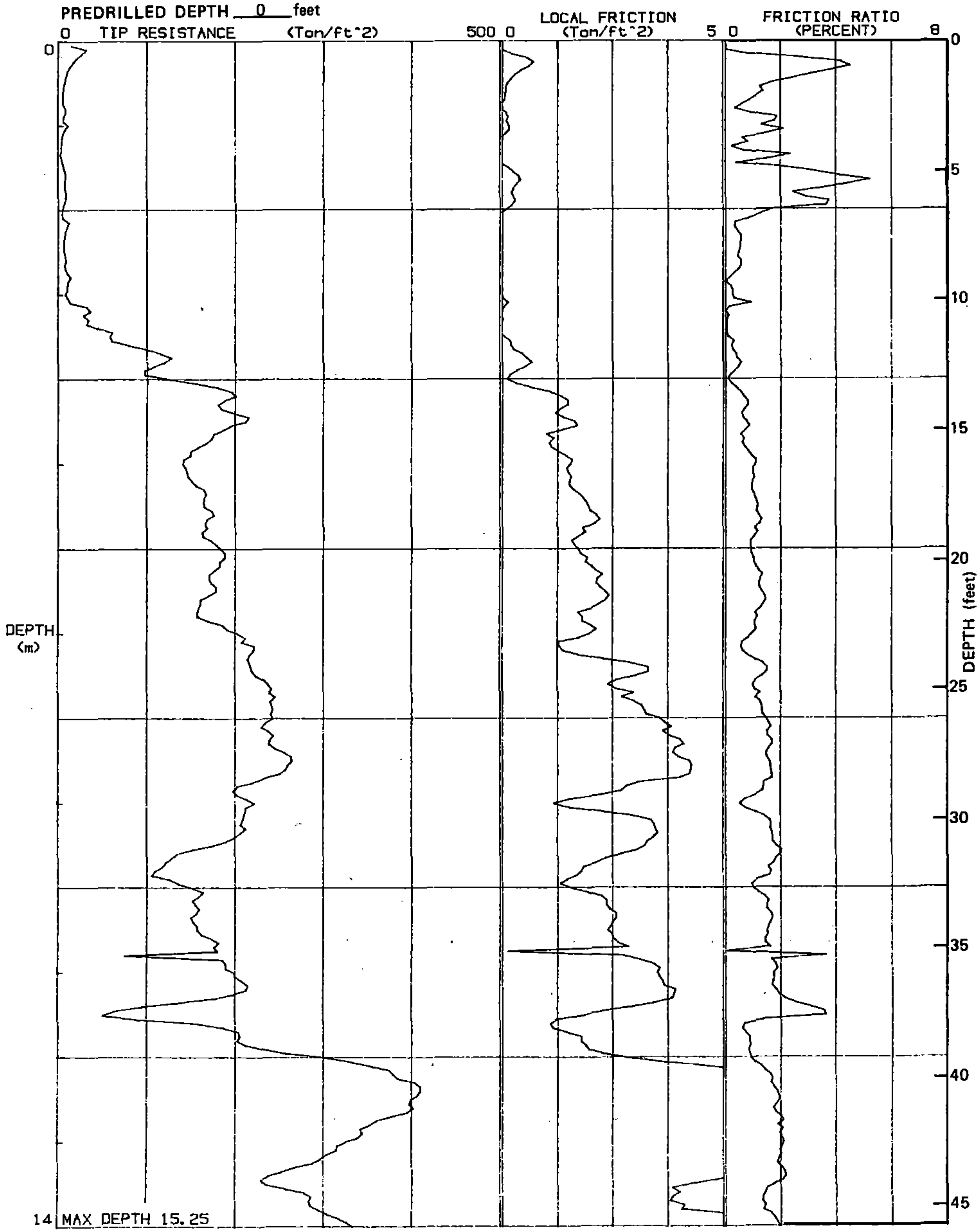


Figure A-25

CONTINUATION FROM PREVIOUS PAGE
CONE PENETRATION NUMBER D-2

JOB # : 41890A
DATE : 2-13-85
LOCATION : C.P.T. D-2
FILE # : 90

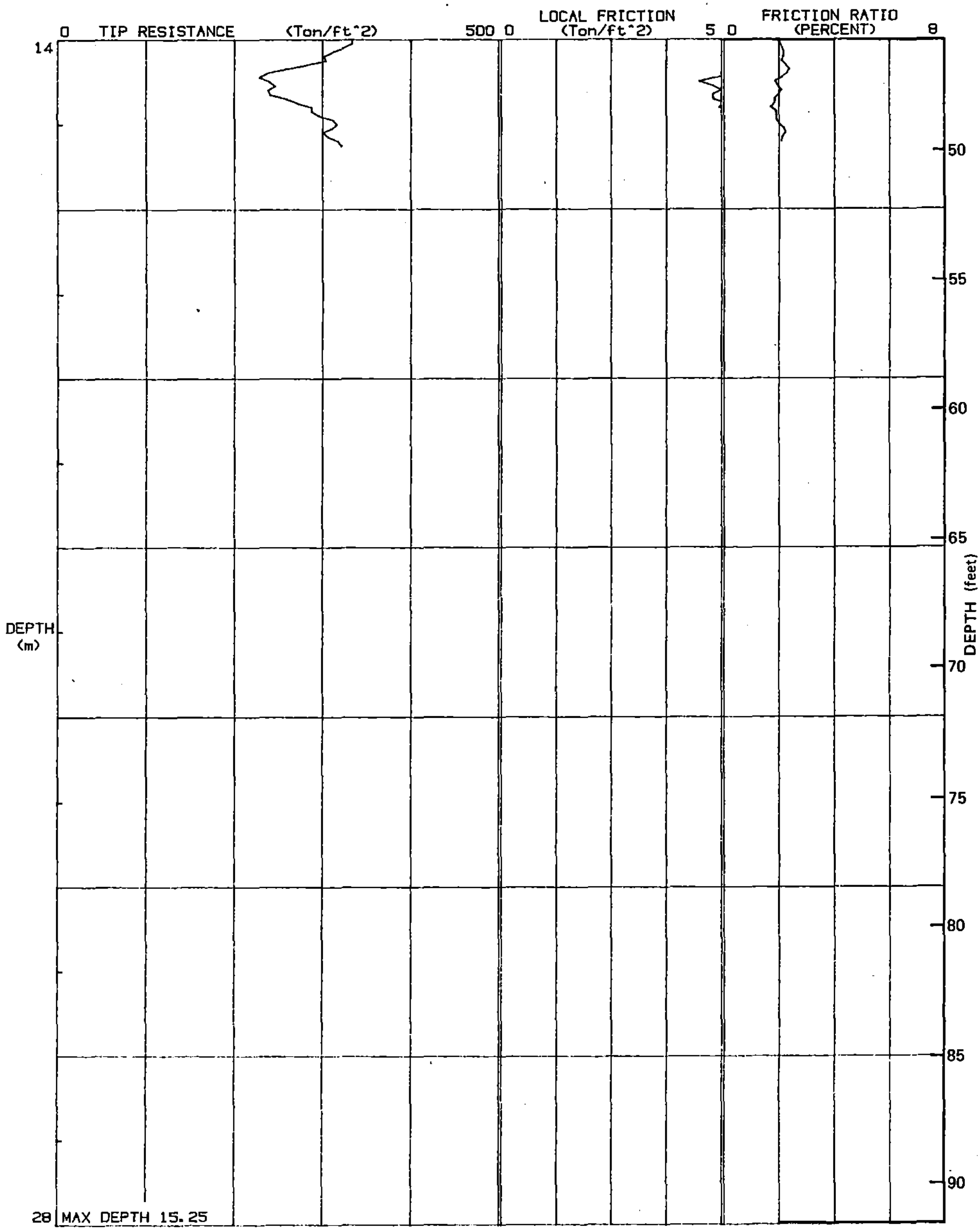


Figure A-26

APPENDIX B

LABORATORY TESTING

APPENDIX B
LABORATORY TESTING

The soil samples obtained from the borings were classified visually, and selected soil samples were tested in our laboratory to evaluate some of their properties. Moisture content test results are presented on the Logs of Borings for convenient correlation with the soil profile. Grain size distribution tests, made on selected samples to help characterize the soils, are summarized in Figures B-1 through B-6.

Atterberg limits were performed on selected samples to help substantiate the visual classification of the soils. Results of the Atterberg limits tests are given in Figure B-7.

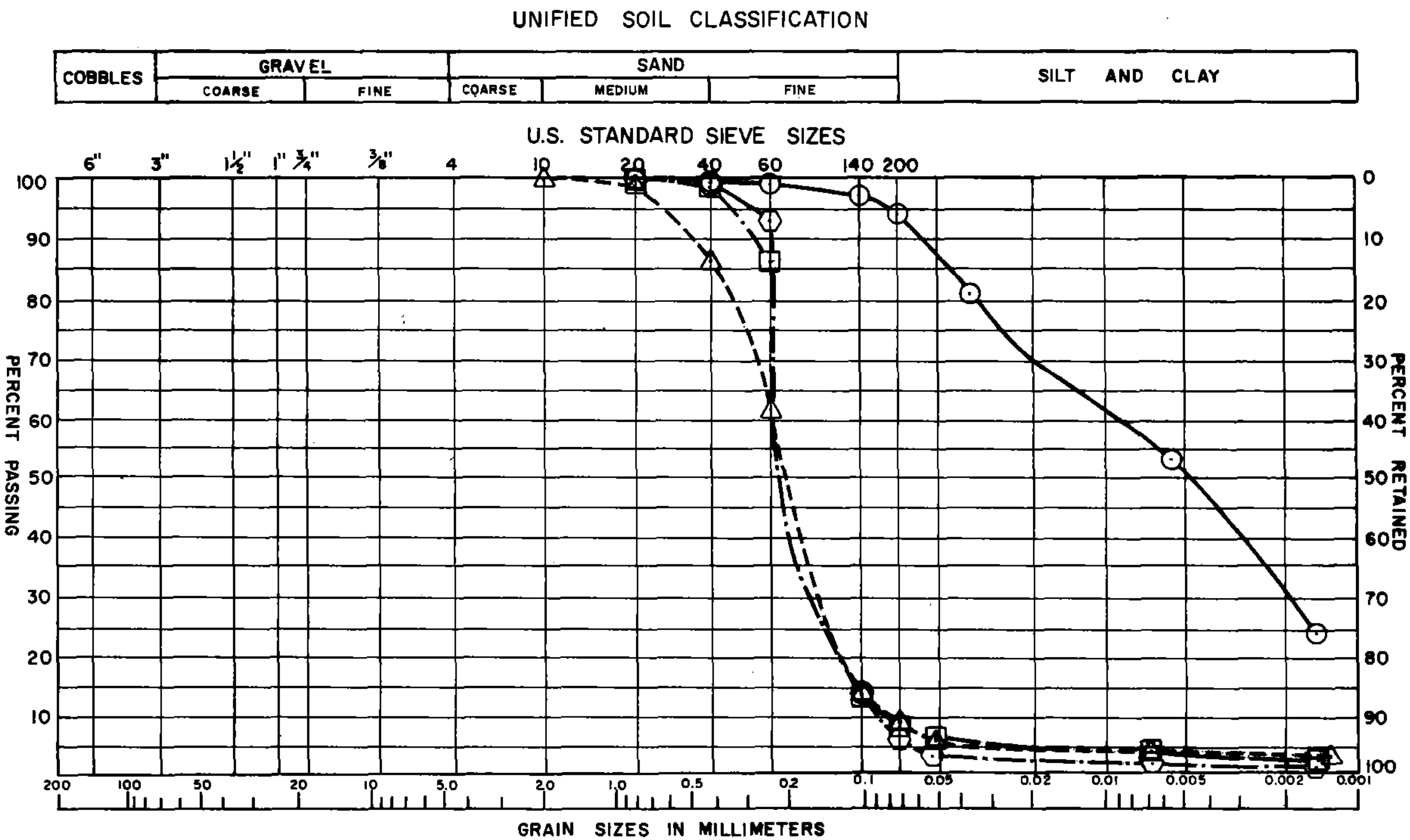
The strength characteristics of the fine grained soils were estimated by pocket penetrometer tests. Results of these tests are presented on the Logs of Borings at the corresponding sample location. These estimates supplement data on the moisture contents of the samples and the penetration resistance of the cone and the sampler during sampling (cone penetration tip resistance and blow count).

The results of organic content tests are presented in Figure B-8.

Project: WEST NEWPORT OIL

Project No. 41890A

GRAIN SIZE DISTRIBUTION CURVES



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
A-1	5′	⊙———⊙			Grayish SANDY CLAY (CH)
A-1	6.5′	△- - - - -△			Brownish gray, CLAYEY SAND (SP–SC)
A-1	15′	⬡—·—⬡			Grayish brown, CLAYEY SAND (SP–SC)
A-1	20′	⊡— —⊡			Grayish brown, CLAYEY SAND (SP–SC)

Fig. B-1

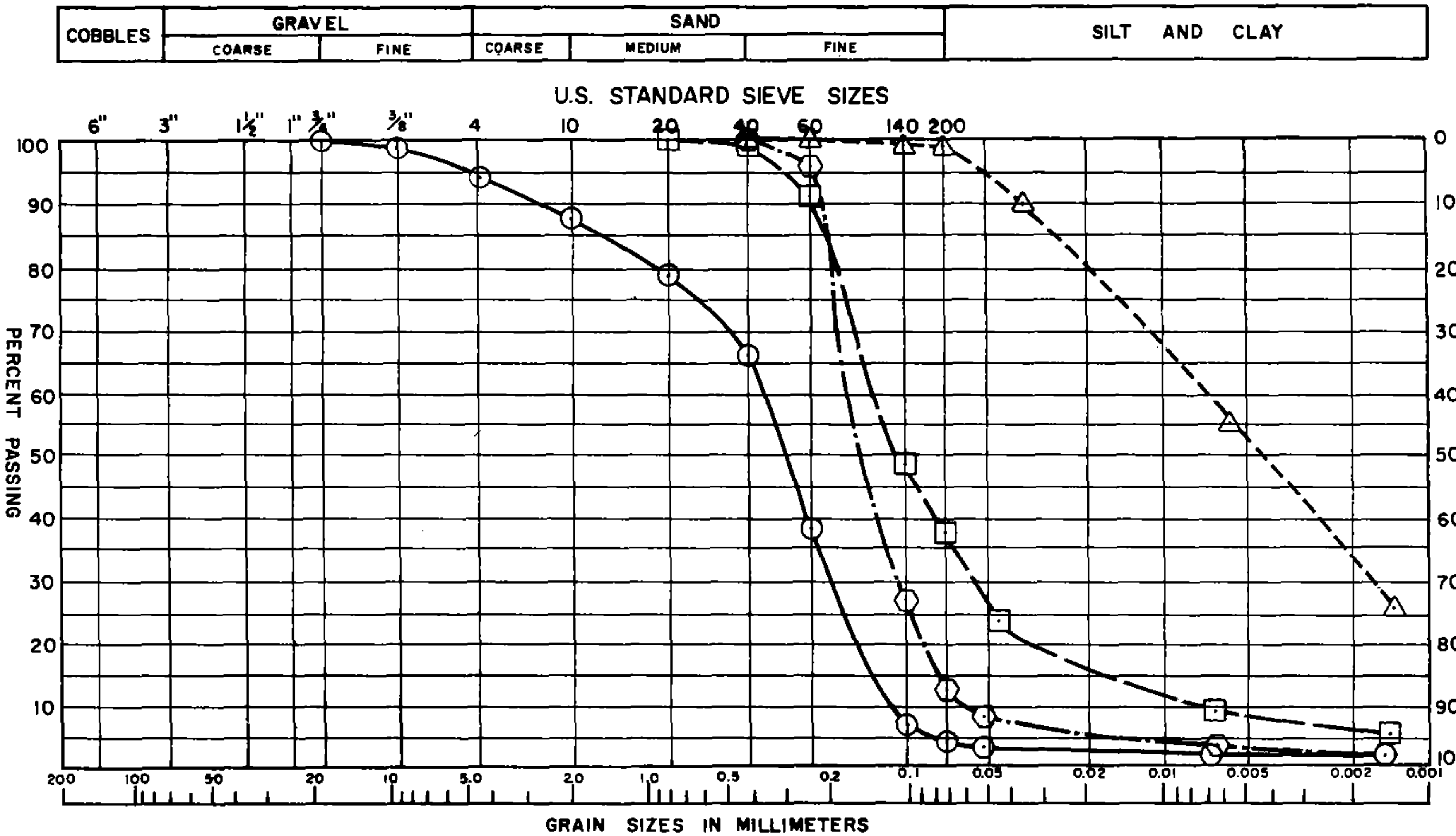
WOODWARD-CLYDE CONSULTANTS

Project: WEST NEWPORT OIL

Project No. 41890A

GRAIN SIZE DISTRIBUTION CURVES

UNIFIED SOIL CLASSIFICATION



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
A-1	40′	⊙———⊙			Olive brown SAND (SP) with shells
B-1	2′	△- - - -△			Gray silty CLAY (CH)
B-1	5′	⬡—·—⬡			Grayish brown, SILTY fine SAND (SM)
B-1	10′	⊡—— ——⊡			Dark gray, CLAYEY SAND (SC)

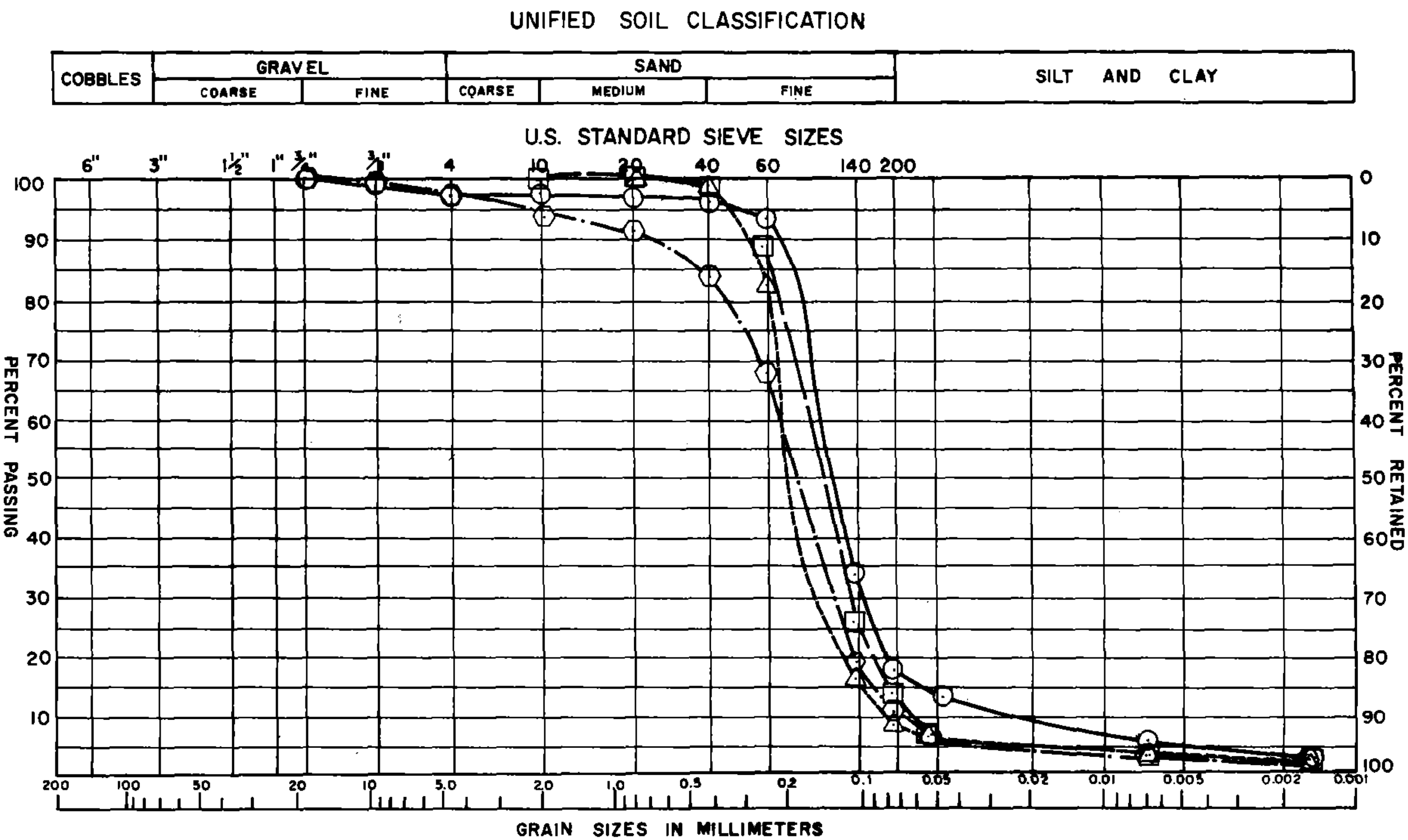
Fig. B-2

WOODWARD-CLYDE CONSULTANTS

Project: WEST NEWPORT OIL

Project No. 41890A

GRAIN SIZE DISTRIBUTION CURVES



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
B-1	35′	⊙———⊙			Dark gray SILTY fine SAND (SM)
C-1	5′	△- - - -△			Grayish brown CLAYEY SAND, little silt (SP–SM)
C-1	10′	⬡—·—⬡			Dark grayish brown CLAYEY fine SAND (SP–SC)
C-1	15′	⊡— —⊡			Dark gray CLAYEY fine SAND (SC)

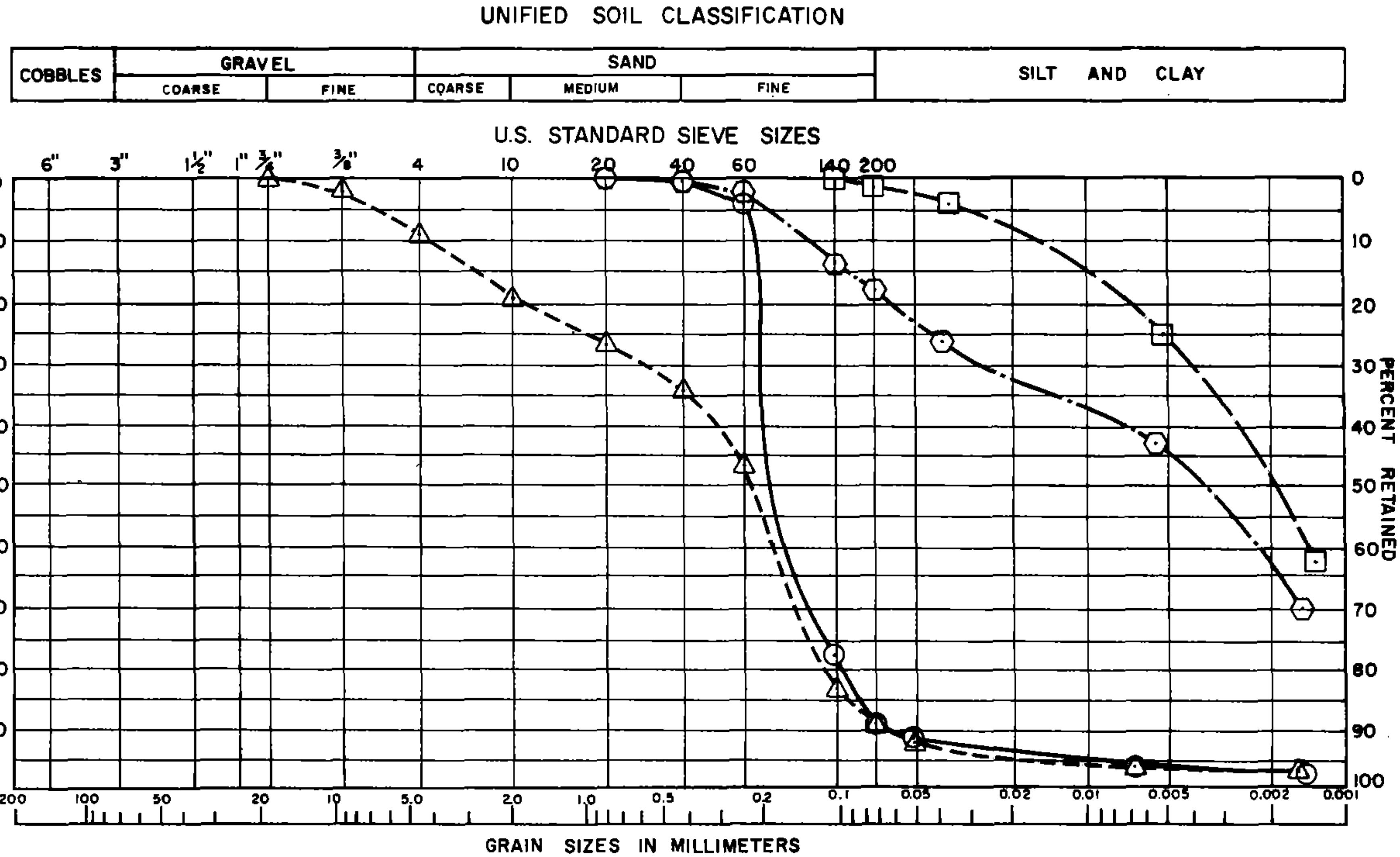
Fig. B-3

WOODWARD-CLYDE CONSULTANTS

Project: WEST NEWPORT OIL

Project No. 41890A

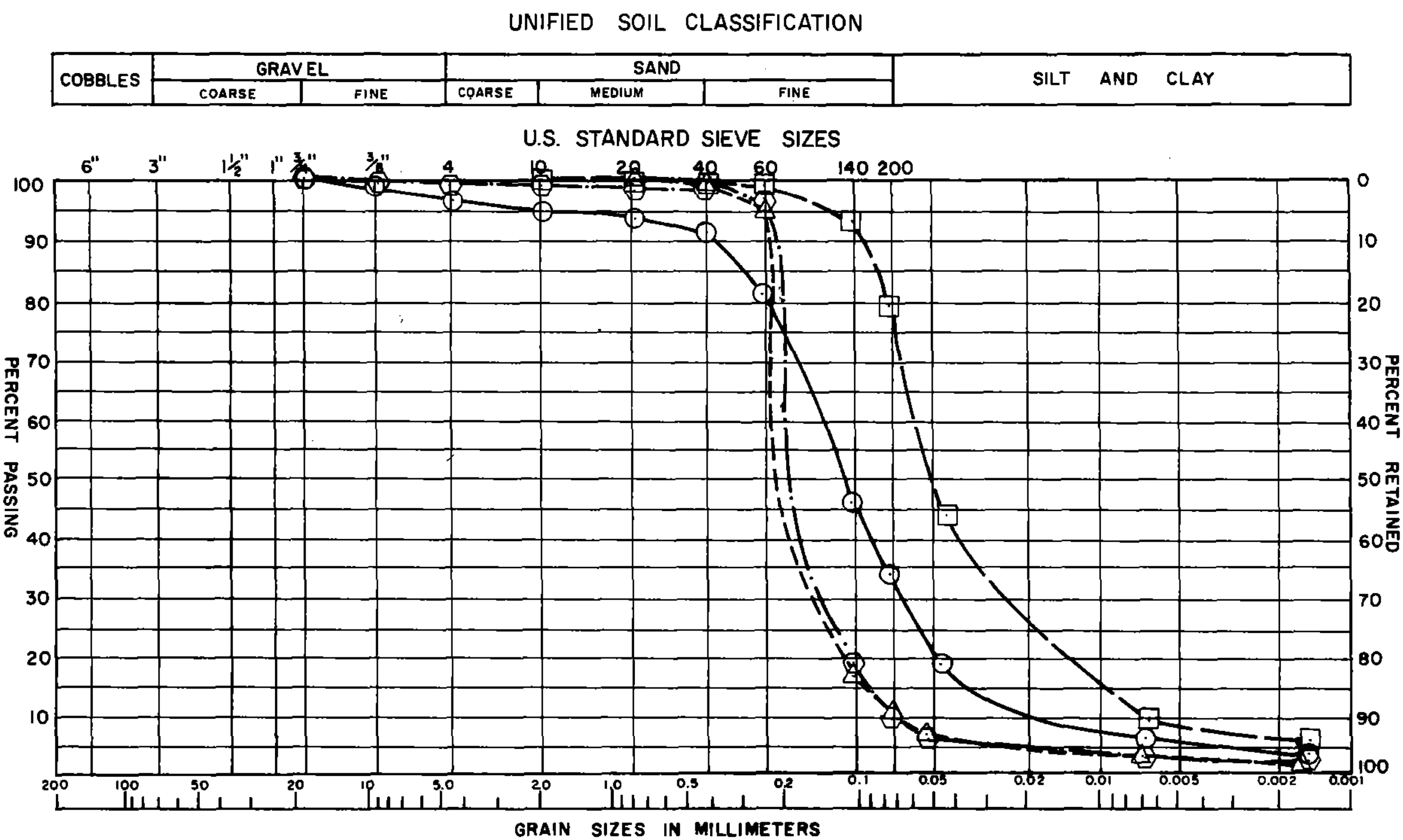
GRAIN SIZE DISTRIBUTION CURVES



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
C-1	25′	⊙———⊙			Dark gray CLAYEY SAND (SP–SC)
C-1	45′	△- - - -△			Dark gray SILTY SAND (SP–SM) with some shells
C-1	50′	⊙—·—⊙			Gray SANDY CLAY (CH)
D-1	6.5′	⊡—— ——⊡			Gray SILTY CLAY (CH)

Fig. B-4

WOODWARD-CLYDE CONSULTANTS



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
D-1	10′				Gray SILTY fine SAND (SM), with some shells
D-1	20′				Dark gray SILTY fine SAND (SP–SM)
D-1	30′				Gray SILTY fine SAND (SP–SM) with some shells
TP-A-2	3′				Grayish brown, fine SAND CLAY (CL)

Project: WEST NEWPORT OIL

Project No. 41890A

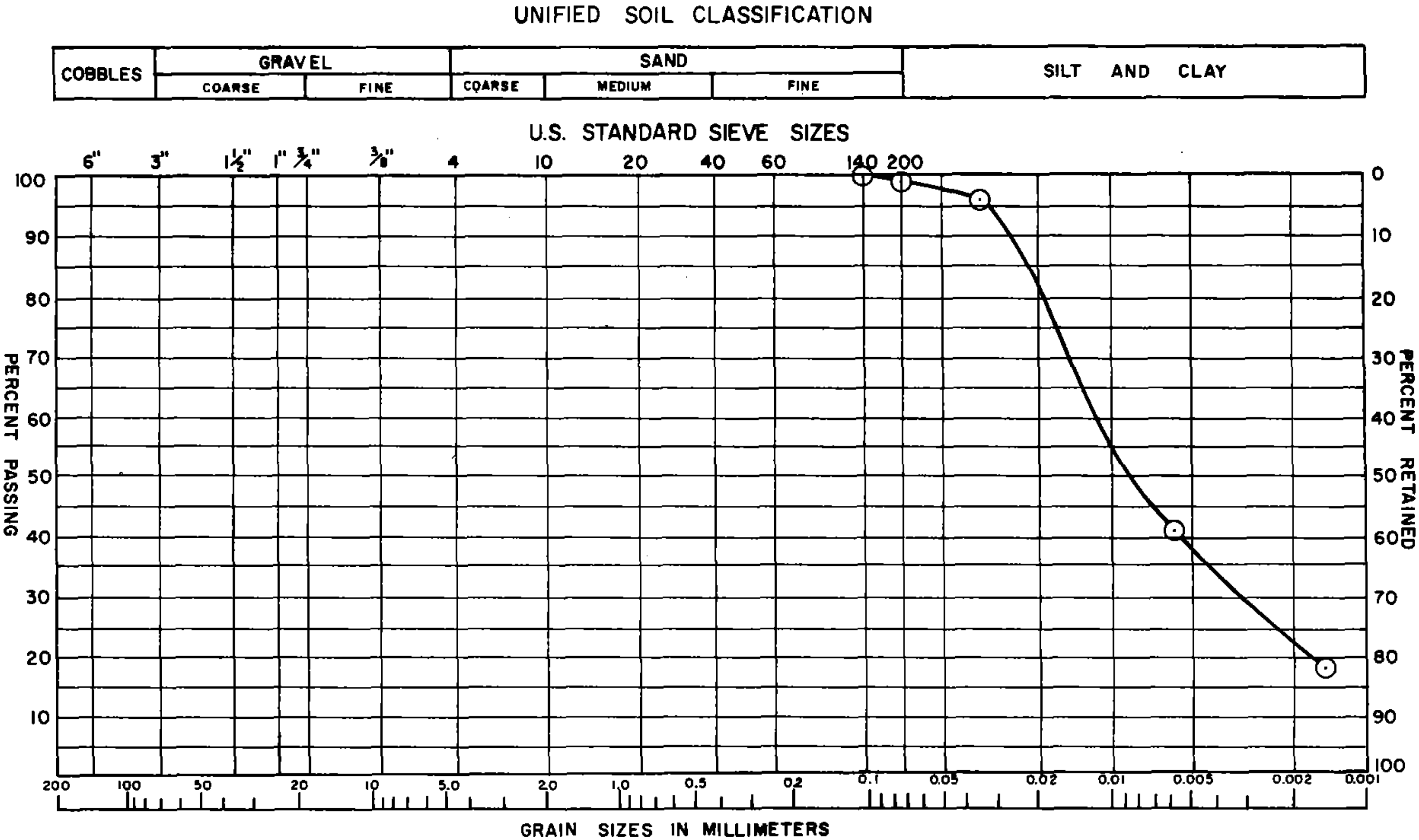
GRAIN SIZE DISTRIBUTION CURVES

Fig. B-5

WOODWARD-CLYDE CONSULTANTS

Project: WEST NEWPORT OIL
Project No. 41890A

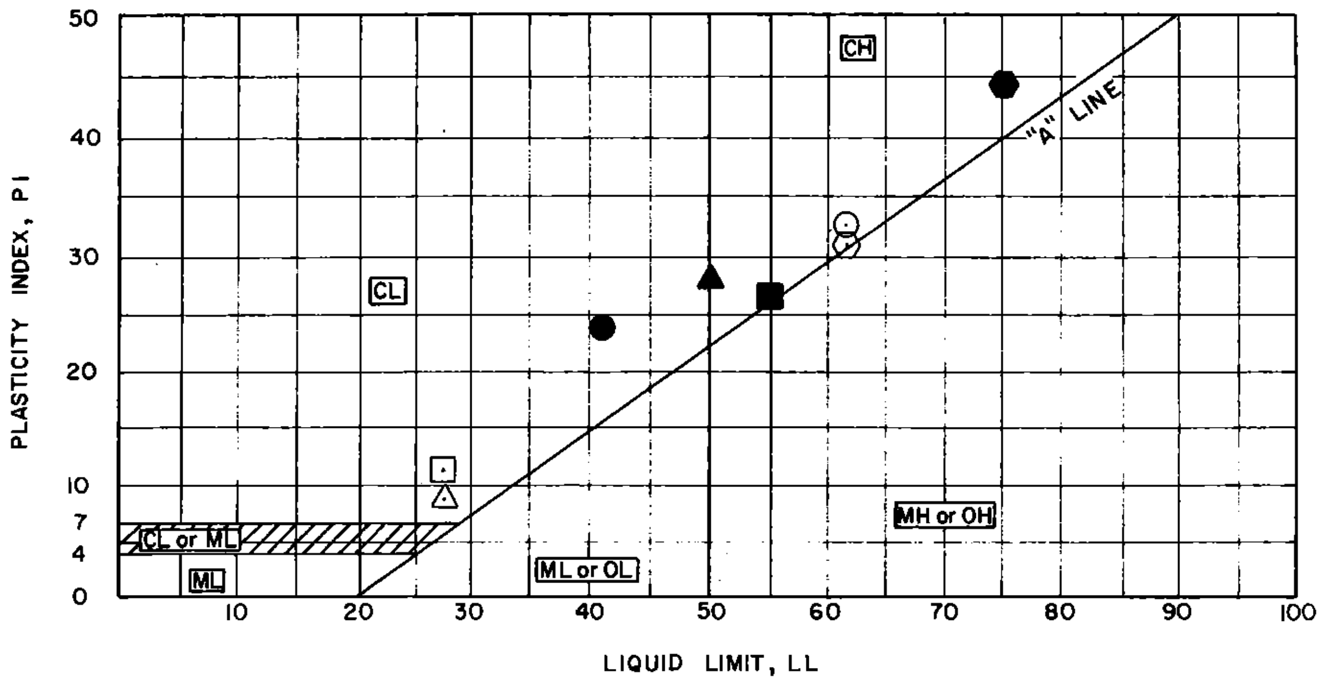
GRAIN SIZE DISTRIBUTION CURVES



BORING NO.	DEPTH	SYMBOL	LL	PI	CLASSIFICATION
TP-C-2	2.5′	⊙———⊙			Brown CLAY (CL)
		△- - - - -△			
		⬡—·—⬡			
		⊡—— ——⊡			

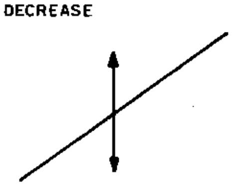
Fig. B-6

WOODWARD-CLYDE CONSULTANTS



GROUP SYM.	UNIFIED SOIL CLASSIFICATION FINE GRAINED SOIL GROUPS
OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY.
ML	INORGANIC CLAYEY SILTS TO VERY FINE SANDS OF SLIGHT PLASTICITY
CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY
OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
MH	INORGANIC SILTS AND CLAYEY SILTS.
CH	INORGANIC CLAYS OF HIGH PLASTICITY.

TOUGHNESS AND DRY STRENGTH INCREASE.
PERMEABILITY AND RATE OF VOLUME CHANGE DECREASE



TOUGHNESS AND DRY STRENGTH DECREASE
PERMEABILITY AND RATE OF VOLUME CHANGE INCREASE.

COMPARING SOILS AT EQUAL LL.

TEST SYMBOL	BORING NUMBER	SAMPLE DEPTH	DESCRIPTION
⊙	A-1	5	Gray SANDY CLAY (CH)
△	A-1	6.5	Brownish gray CLAYEY SAND (SP—SC)
⬡	B-1	2	Gray SILTY CLAY (CH)
⊡	B-1	10	Gray CLAYEY SAND (SC)
●	C-1	5	Gray SANDY CLAY (CL)
▲	C-1	50	Gray SANDY CLAY (CH)
⬢	D-1	6.5	Gray SILTY CLAY (CH)
■	TP-C-2	2.5	Gray SILTY CLAY (CH)

Project: WEST NEWPORT OIL Project No. 41890A	PLASTICITY CHART	Fig. B-7

WOODWARD-CLYDE CONSULTANTS

ASSOCIATED LABORATORIES
806 North Batavia - Orange, California 92668 - 714/771-6900

CLIENT

Woodward-Clyde Consultants
203 North Golden Circle Drive
Santa Ana, CA 92705

LAB NO. F02802

REPORTED 2/26/85

SAMPLE Soil

RECEIVED 2/25/85

IDENTIFICATION Project No. 41890A, Project Name: West Newport Oil Field - As Below

BASED ON SAMPLE As Submitted

	Organic Content*
Boring No. A-1, Sample No. PB-1, Depth 5'	3.08 %
Boring No. A-1, Sample No. PB-2, Depth 6.5'	2.42 %
Boring No. B-1, Sample No. PB-2, Depth 10'	1.81 %
Boring No. D-1, Sample No. PB-4, Depth 15'	1.65 %

*By Combustion.

ASSOCIATED LABORATORIES

Tito L. Parola

TLP/dsv

TESTING & CONSULTING
Chemical •
Microbiological •
Environmental •

C-1 10M

Project: WEST NEWPORT OIL Project No. 41890A	ORGANIC CONTENT TESTS	Fig. B-8