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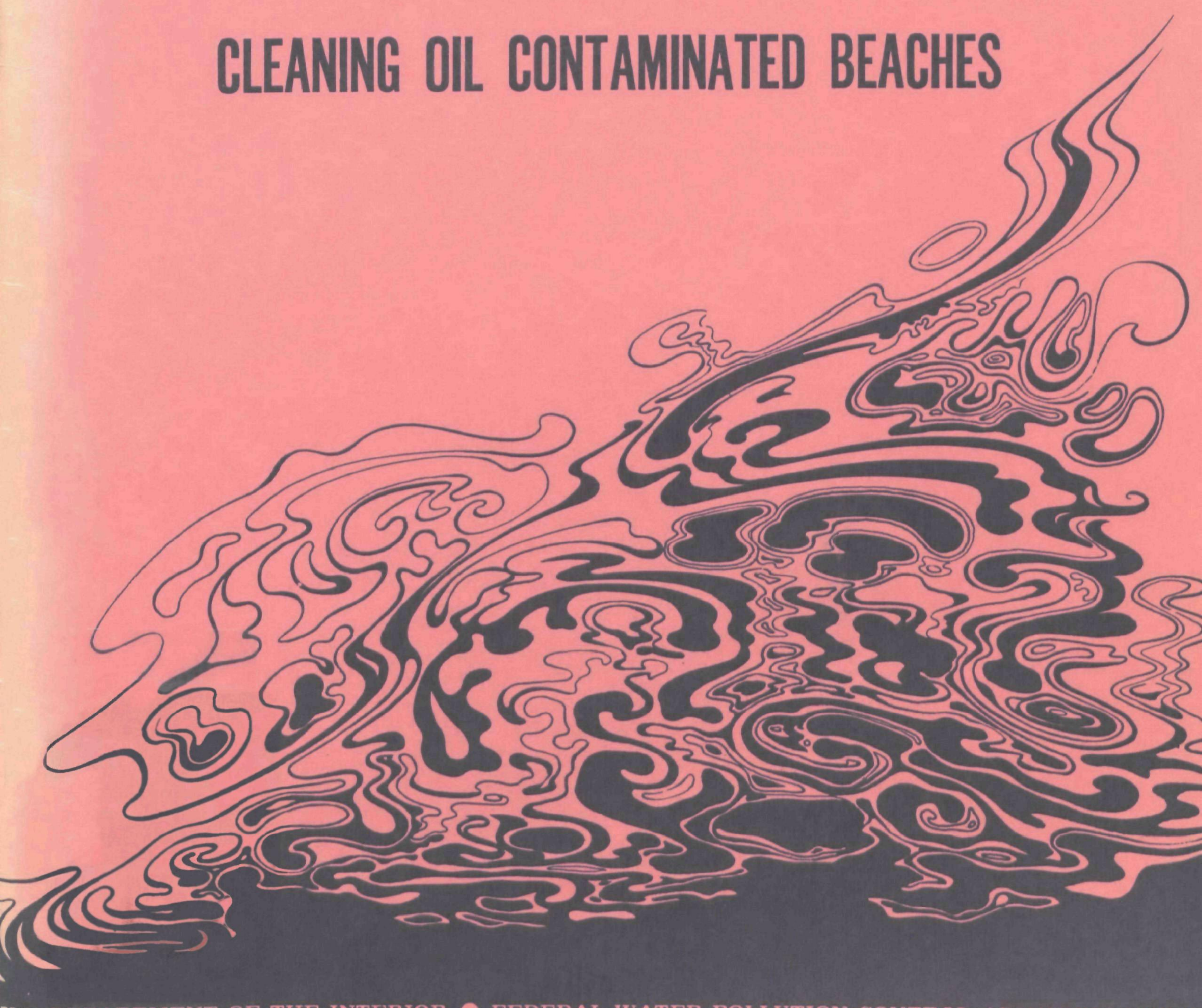
CLEANING OIL CONTAMINATED BEACHES



U.S. DEPARTMENT OF THE INTERIOR ● FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

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CLEANING OIL CONTAMINATED BEACHES WITH CHEMICALS

A Study of the Effects of Cleaning Oil Contaminated Beaches with Chemical Dispersants

by

Northeast Region Research and Development Program

Edison, New Jersey

for the

FEDERAL WATER POLLUTION CONTROL ADMINISTRATION

DEPARTMENT OF THE INTERIOR

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ABSTRACT

Oil-dispersing chemicals were treated for cleaning persistent-type crude oil from experimentally contaminated New Jersey coastal beaches and were found to be generally ineffective. Although they completely cleaned the surface of the oiled sand, they removed little of the total oil. Instead they caused the oil to penetrate more deeply into the underlying sand, thereby compounding the pollution problem by expanding the zone of pollution, complicating any subsequent mechanical removal and, possibly, causing the oil to persist longer.

Chemical treatment failed to induce "quicksand" or cause perceptible erosion of beach sand. A decrease in the "cohesiveness" of the sand was observed, but this also occurred in the presence of oil alone and could not be attributed to the presence of chemical.

KEY WORDS: Beach, cleaning, detergent, emulsifier, erosion, oil, pollution, quicksand, sand.

INTRODUCTION

During 1961 the Warren Spring Laboratory in England conducted studies which led to the recommendation of solvent-emulsifiers as the most effective means for cleaning beaches polluted by oil (1). This recommendation provided a basis for British action during the Torrey Canyon incident, when massive quantities of "detergents" were applied to contaminated shores (2). The devastating effects of these chemicals on coastal marine life, which have been extensively documented (e.g. 3, 4), led to widespread criticism of the British action and of the general use of "detergents" for the control of oil pollution.

Other significant limitations of solvent-emulsifiers for beach cleaning tended to be obscured by the spectacular nature of these biological effects. For instance, the official report of the Torrey Canyon affair (2) noted that these chemicals caused the oil to penetrate into the sand more deeply than untreated oil, thereby increasing the volume of contaminated sand, complicating any subsequent mechanical removal, and possibly causing the oil to persist longer. These field observations were confirmed by others (3, 5) and the basic phenomenon of increased penetration was demonstrated in bench tests at the Plymouth Laboratory (3).

Furthermore, many of the Cornish beaches polluted by the Torrey Canyon oil exhibited a "quick" condition which was generally attributed to the treatment with solvent-emulsifiers (2, 3). However, few beaches in Cornwall escaped heavy dousing with "detergents" and remained to demonstrate the effects of oil alone. Similar "quicksands" were reported from oiled beaches in Brittany, on which chemicals were not used (3).

Beach erosion due to "quicksand" caused by solvent-emulsifiers became a major issue during the Ocean Eagle spill in San Juan, Puerto Rico, even though documentation of this phenomenon was incomplete. In this case too, there had been previous reports of erosion of Puerto Rican beaches from oil alone (6).

Because of these controversial and poorly defined effects of solvent-emulsifiers upon beach sands, the Northeast Region Research and Development Program conducted a series of controlled experiments during the fall of 1968 on the use of oil-dispersing chemicals for cleaning sandy beaches at Sandy Hook, New Jersey.

CONCLUSIONS AND RECOMMENDATIONS

1. Penetration of oil into beach sand is a function of the nature of the oil and the type and granular texture of the sand.

2. Persistent-type crude oils contaminate only the surface of sandy beaches, penetrating to a maximum of two inches depth.

3. When overlaid by fresh sand, crude oils persist for long periods of time as narrow, discrete bands, gradually weathering into a tarry consistency.

4. Chemical dispersants clean only the surface of oil-contaminated beach sands and remove relatively little of the subsurface oil.

5. Chemical dispersants cause the oil to penetrate more deeply into beach sands.

6. Increased penetration increases the volume of contaminated sand, complicating any subsequent cleaning procedures and, possibly, causing the oil to persist longer in offensive form.

7. Chemical dispersants could not be shown to reduce the cohesion of oiled sand, nor to induce "quick sands".

8. Chemical dispersants or solvent-emulsifiers are not recommended as effective for cleaning oil-contaminated beaches.

EXPERIMENTAL

Location : All experiments were conducted on the shores of Ft. Hancock, New Jersey during October through December 1968. Two specific locations were selected:

1. Twin Gun Beach (Figure 7): located on the eastern, ocean side of Sandy Hook, and exposed to open surf. Grain size analyses of surface sand and sand at depths of 10 inches and 18 inches are shown in Figures 1, 2 and 3, respectively.

2. Spermaceti Cove (Figure 8): located on the western, bay side of Sandy Hook, in an area of no surf. Grain size analyses for surface sand and sand at a depth of 12 inches are shown in Figures 4 and 5, respectively.

Density : *in situ* sand density measurements were performed according to ASTM DI556-64; maximum and minimum density were performed according to Department of the Army Engineering Manual EM 1110-2-1906, dated 10 May 1965.

Sand cohesion: determined with a cone penetrometer according to Department of the Army Technical Bulletin TB ENG 37, dated 10 July 1959.

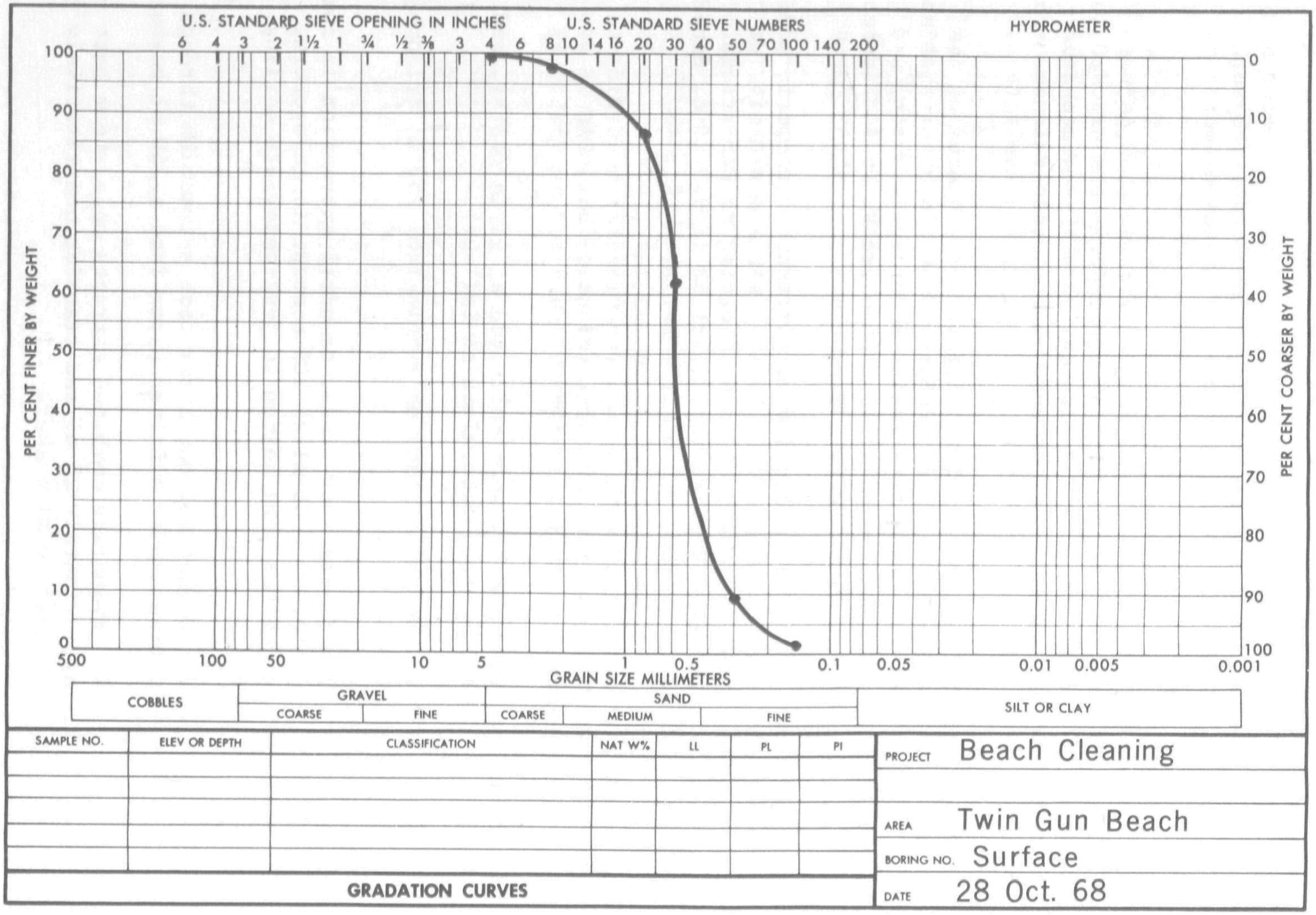
Oil content : sand samples were collected at given depths, and oil content determined as follows:

1. Weigh 50 grams of sample into 250 ml Erlenmeyer flask.

2. Slurry four times, or until extraction is complete, with 50 ml of 10% acetone in chloroform, which has been heated to just below its boiling point.

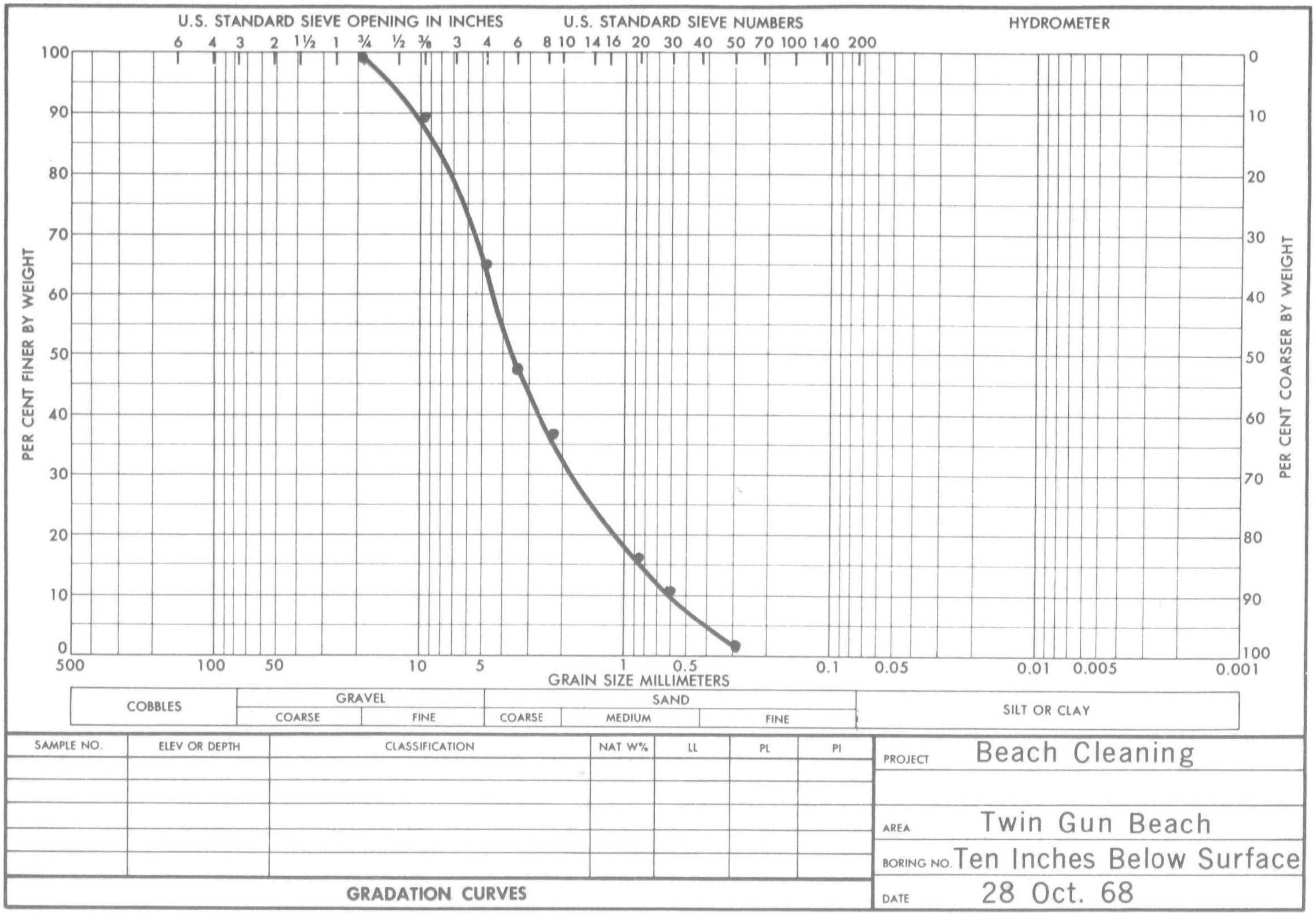
3. Decant solvent after each extraction through fluted number 4 filter paper into a 250 ml beaker.

4. Evaporate combined extracts on a steam bath to approximately 25 ml and transfer quantitatively to a tared 50 ml beaker.



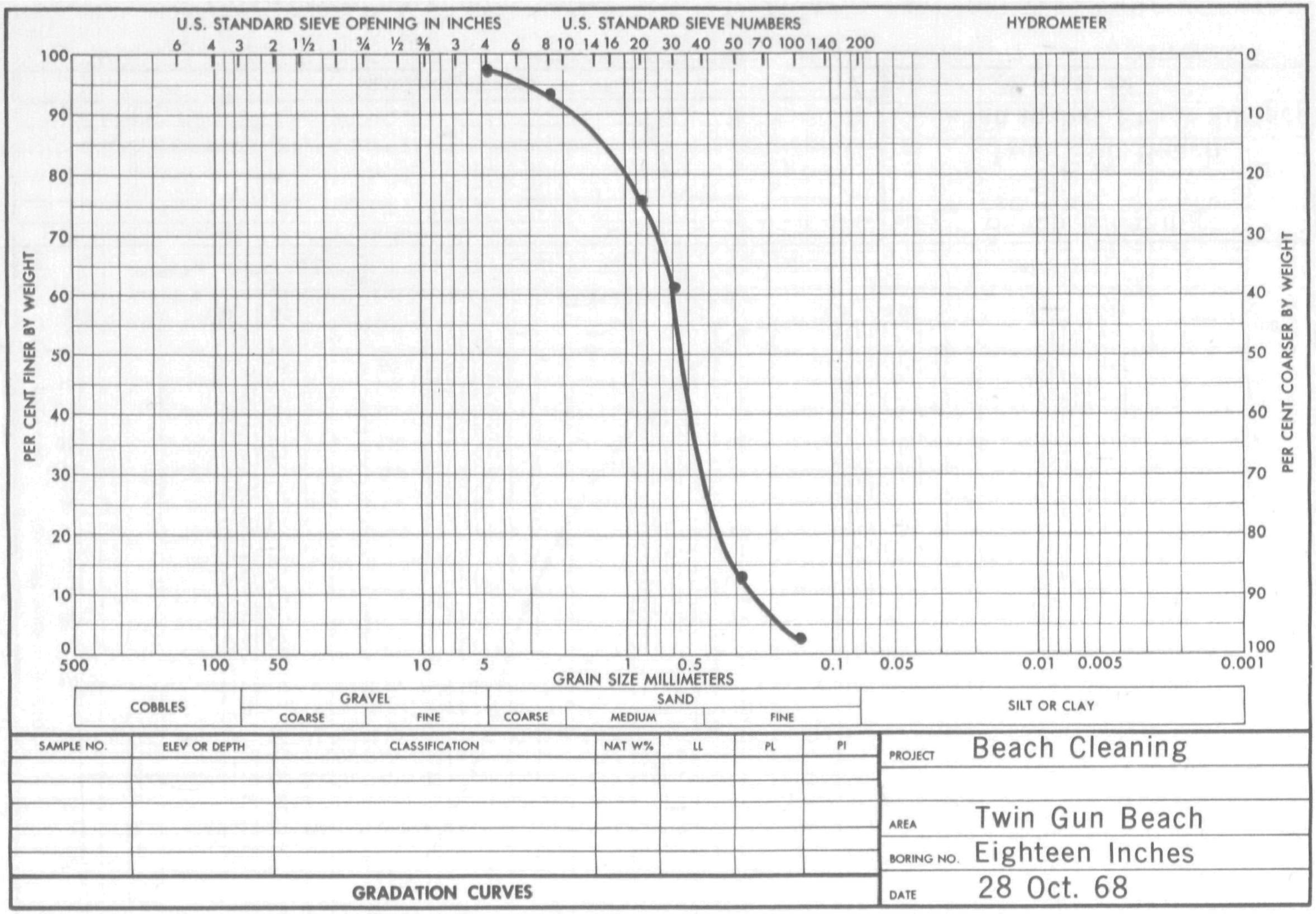
GRAIN SIZE ANALYSIS, TWIN GUN BEACH, SURFACE

Figure 1



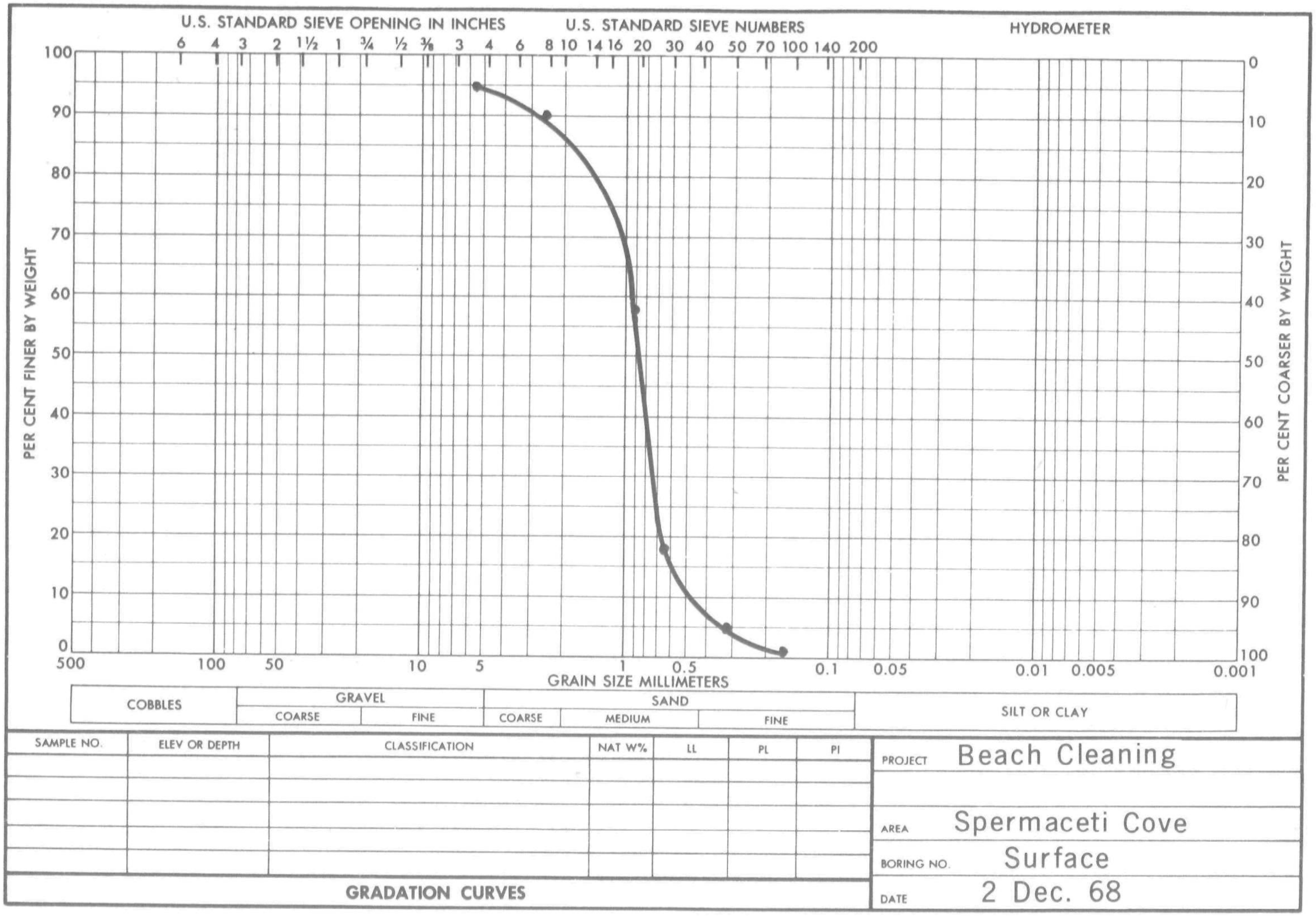
GRAIN SIZE ANALYSIS, TWIN GUN BEACH, TEN INCHES DEEP

Figure 2



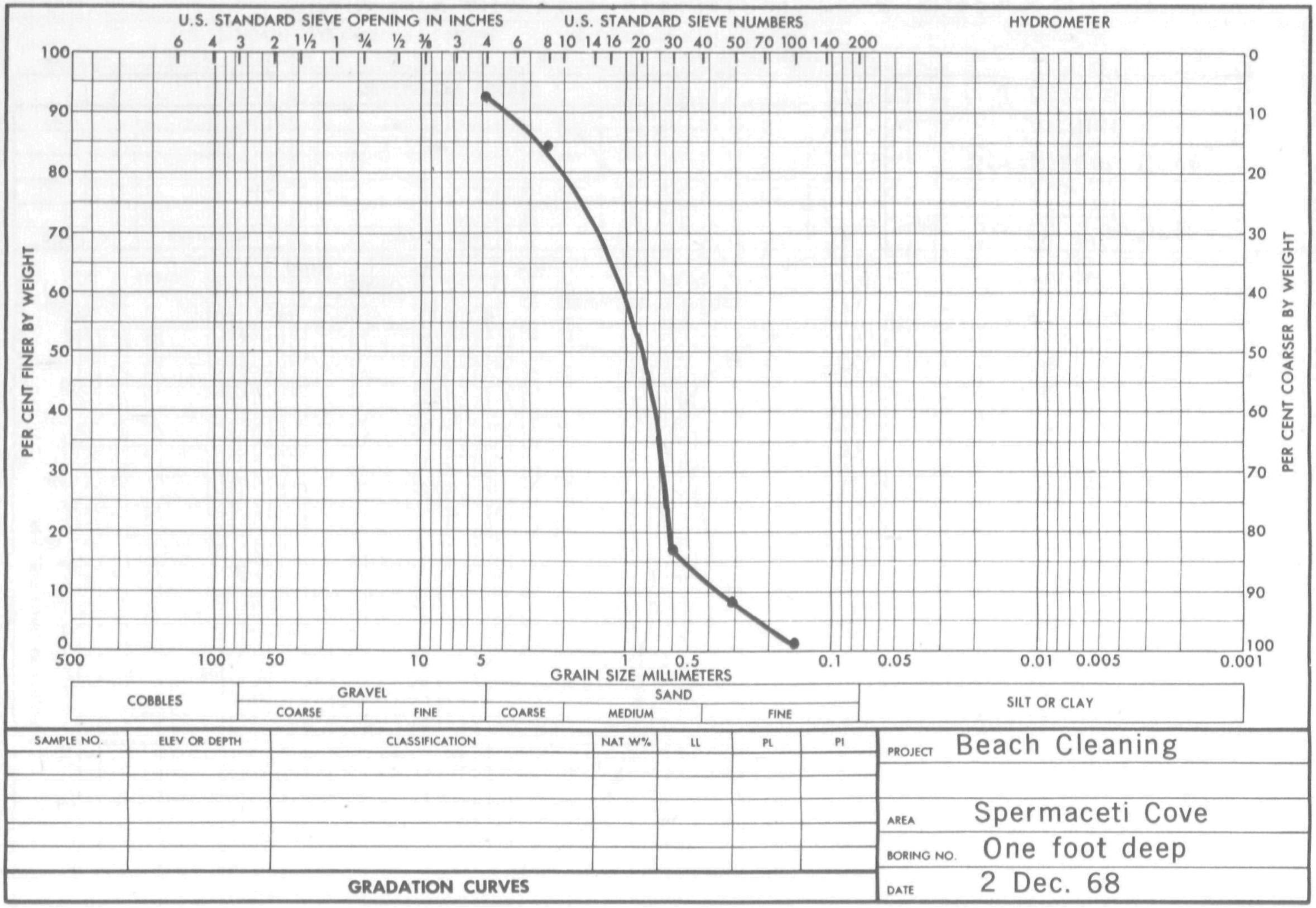
GRAIN SIZE ANALYSIS, TWIN GUN BEACH, EIGHTEEN INCHES DEEP

Figure 3



GRAIN SIZE ANALYSIS, SPERMACETI COVE, SURFACE

Figure 4



GRAIN SIZE ANALYSIS, SPERMACETI COVE, TWELVE INCHES DEEP

Figure 5

5. Evaporate extracts to dryness, then add 5 ml of acetone, and again evaporate to dryness.

6. Wipe off excess water from outside of beaker, then dry 10 minutes in an oven at 103 °C.

7. Cool in desiccator and weigh.

Oil content of the entire layer in the test section was calculated from the known 32 square foot area, the visually measured depth of the layer, the oil concentration per weight of sand (corrected for moisture content), and the measured in-place density of the sand.

Test sections: test sections were marked off just below average high tide level in units of 4 feet by 8 feet (Figures 8 and 9). Oil was spread evenly over the surface of the test sections, during low tide, in amount equivalent to a uniform 1/2 inch covering. Oil was allowed to penetrate into the sand for 10 minutes. Oil-dispersing chemical was applied in the amount specified, uniformly over the section, with a garden sprinkling can (Figure 11). Oil and chemical were allowed to interact for 10 minutes. The test section was then hosed for 5 minutes with salt water, pumped by a gasoline-driven portable fire pump; or the application of chemical timed to allow tidal wash within 30 minutes.

Chemicals: chemicals used are shown in Table I. Products A and D are of the typical solvent-emulsifier type. B and C are water soluble dispersants.

TABLE 1

APPARENT COMPOSITION OF CHEMICALS TESTED

Product Code	Surfactant Ionic Nature[1]	Basic Composition[2]	Solvent[3]
A	Nonionic	Ethylene oxide condensate of alkyl phenol	Aromatic, aliphatic hydrocarbon, boiling point range similar to that of #2 fuel oil.
B	Nonionic	Ethylene oxide condensate of alkyl phenol	Water, glycol
C	Nonionic	Polyhydric alcohol ester of fatty acid	Water, short-chained alcohol
D	Anionic	Alkyl aryl sulfonate	Aromatic, aliphatic hydrocarbon, boiling point range similar to that of #2 fuel oil.

1) According to Weatherburn test (7).

2) By infrared spectral analysis of dried (105°C) residue; test was not definitive, but results consistent with stated, presumed composition.

3) By distillation and infrared spectral analysis.

RESULTS AND DISCUSSION

The penetration of oil into beach sand is influenced by the nature of the oil and the type and granular texture of the sand. In these experiments, the lighter crude oils penetrated the sand to a maximum depth of two inches. If untreated, the oil tended to remain in a narrow, discrete band through successive tidal washings. This band usually moved to successively greater depth, but this was due to the overlaying with fresh sand rather than penetration. The oil appeared to remain with the originally contaminated sand grains.

Considerable quantities of oil disappeared during the first several tidal cycles (Figure 6A and B). Because of the formation of an obvious slick on the adjacent water and because of the low percentage of low-boiling point hydrocarbons in La Rosa and Lago crudes, this initial loss can be attributed to physical removal rather than "weathering". If untouched for several months the remaining oil gradually weathered to a tarry consistency.

When the oiled sand was treated with chemicals and subsequently flushed, the surface of the beach was rapidly washed free of all traces of contamination (Figures 13 and 14). Only Product C failed to produce this effect. All other chemicals effectively cleansed the surface at ratios of chemical to oil of 1 to 4. However, this observation was deceptive. Substantial quantities of oil still remained below the surface of the beach (Figure 15). Furthermore, the mixture of chemical and oil penetrated two to five times more deeply into the sand than oil alone (Figure 6).

At first glance the results from Experiment II appear to be anomalous. However, they can be explained by the type of beach involved. This experiment was performed when Twin Gun Beach was constituted of two inches of medium sand at the surface. Below this was eight inches of fine gravel underlaid by medium sand (see Figs. 1, 2, 3). These layers became deeper as more sand was deposited on this active beach. During successive tidal cycles the oil moved through the gravel layer until it reached the underlying sand (Figure 16). The results clearly indicate that this penetration was significantly accelerated by chemicals (also see Figs. 17 and 19). This penetration of oil alone was not observed in the finer sands.

The field conditions complicated the quantification of the total oil present and the amounts of oil reported in Figure 6 cannot be considered precise. Nonetheless, it is readily apparent that none of

PENETRATION AND PERSISTENCE OF OIL IN BEACH SAND, WITH AND WITHOUT CHEMICAL TREATMENT

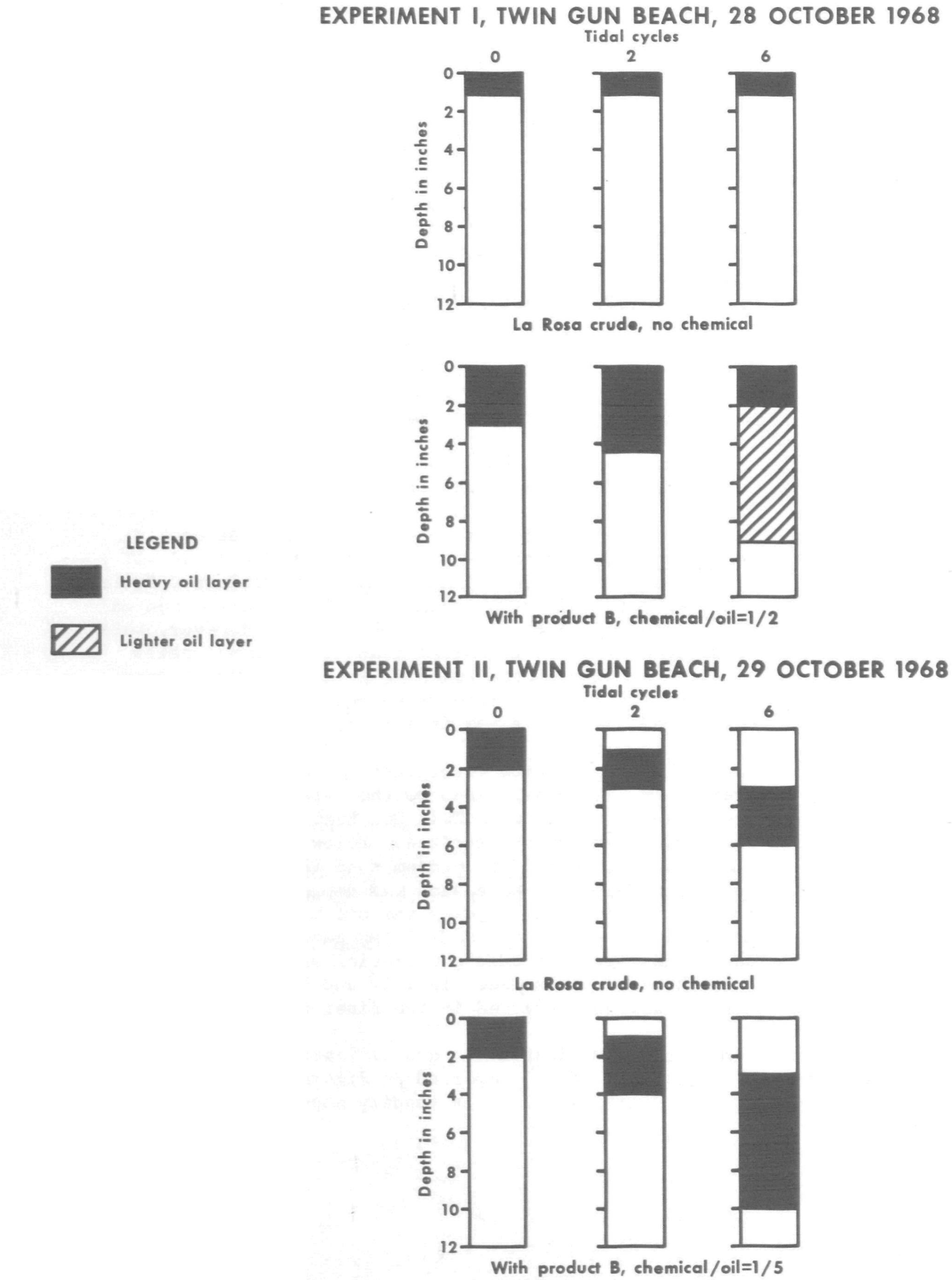


Figure 6-A

EXPERIMENT III ,TWIN GUN BEACH, 19 NOVEMBER 1968

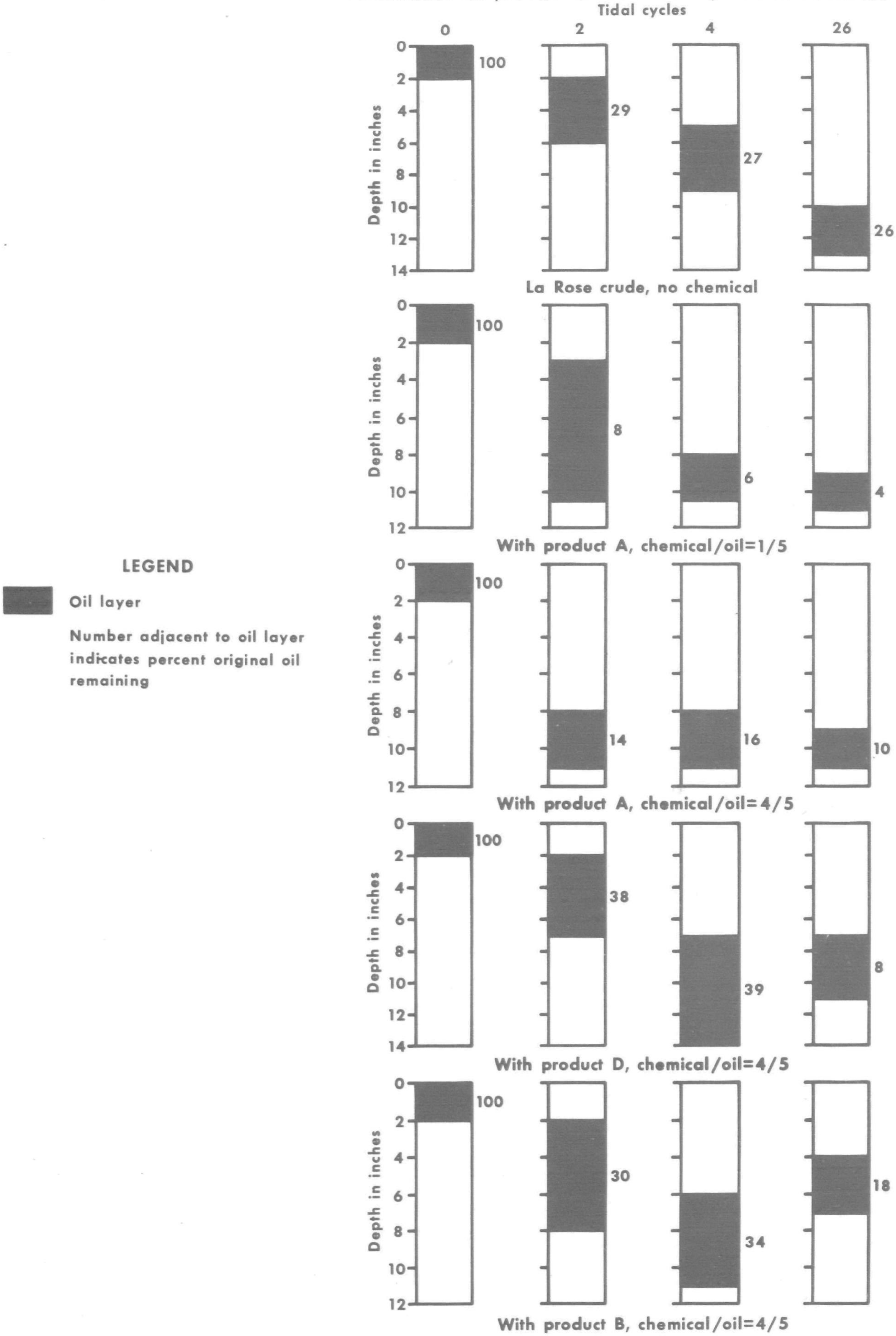


Figure 6-B

EXPERIMENT IV, SPERMACETI COVE, 2 DECEMBER 1968

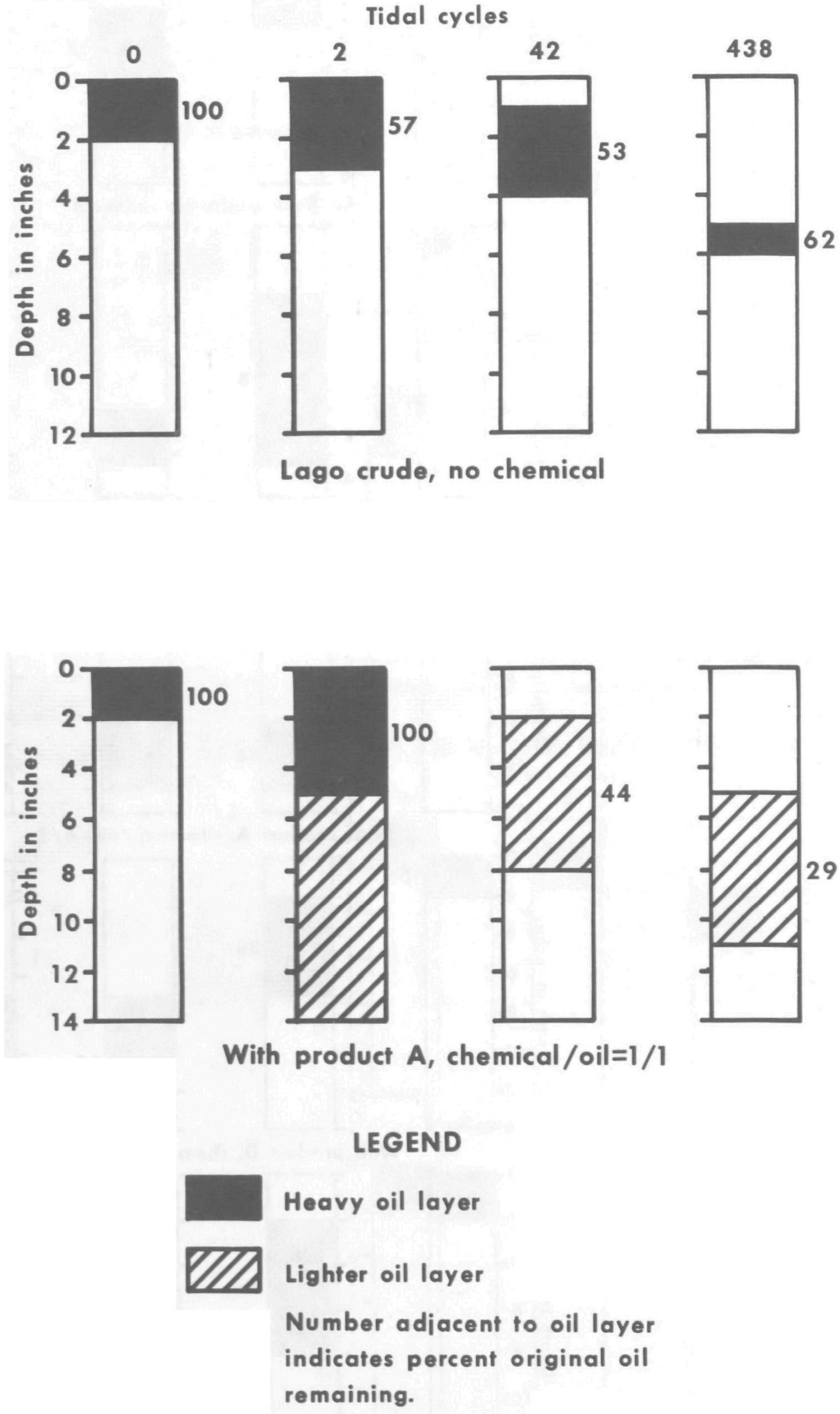


Figure 6-C

Fig. 7 Test Area: Twin Gun Beach, a typical New Jersey coastal beach on the eastern shore of Sandy Hook.

Fig. 8 Test Area: Spermaceti Cove, a sheltered beach on the western shore of Sandy Hook.

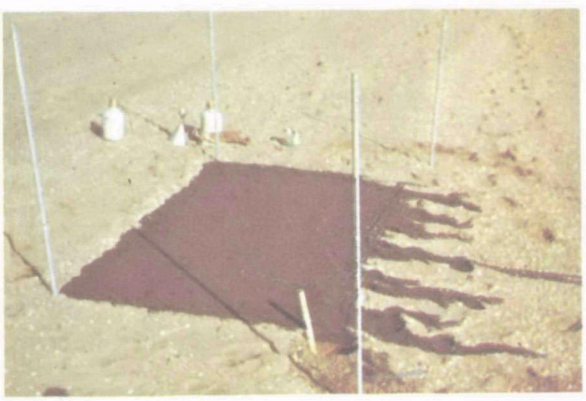


Fig. 9 Typical Test Section; immediately after application of crude oil.

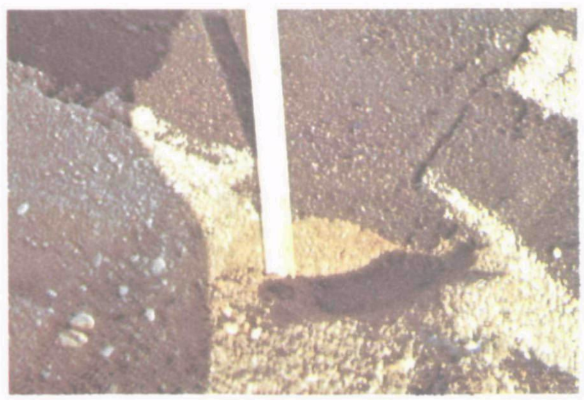


Fig. 10 Initial Penetration of Oil: Spermaceti Cove.

Fig. 11 Application of Chemical: Twin Gun Beach.

Fig. 12 Hosing of Oil Section: Oil is smeared around the beach surface; substantial quantities are washed into surf.

Fig. 13 Hosing of Chemically-treated Section: The surface of the sand rapidly washes clean.

Fig. 14 Chemically-treated Section: After Tidal Washing - no traces of oil remain on surface.

Fig. 15 Chemically-treated Section: After Hosing - the surface is clean, but much oil remains below.

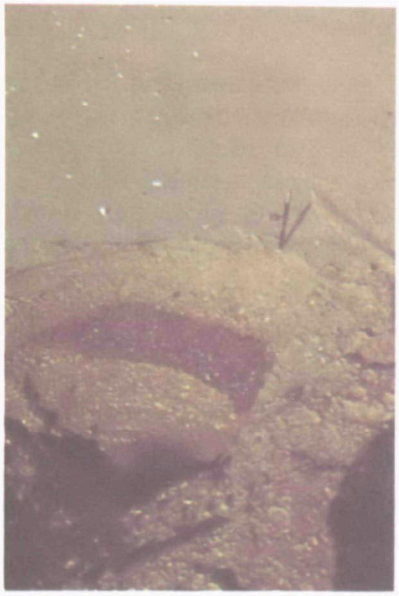


Fig. 16 Experiment III (Figure 6): Oil section, after four tidal cycles; oil in gravel layer.

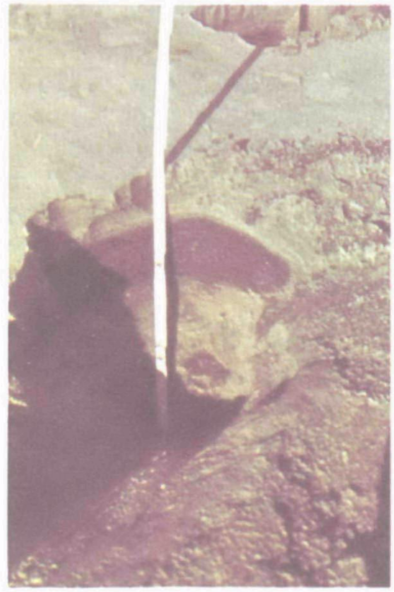


Fig. 17 Experiment III (Figure 6): Product A test section, after two tidal cycles; note irregular penetration to bottom of gravel layer at ten inches depth.

Fig. 18 Twelve feet below Figure 17: Note bands of oil extending towards water line.

Fig. 19 Experiment III (Figure 6): Product D test section, after four tidal cycles.

the chemicals tested were remarkably efficient in removing oil. The utility of even the most effective dispersant, Product A, can be questioned in view of the results from Experiment IV, in which one-third of the original oil remained seven months after treatment. This remaining oil was spread through a six-inch band whereas the untreated oil formed cohesive, tarry clumps which were less noxious and more easily handled for removal.

Thus, it may be concluded that oil-dispersing chemicals, used in this manner, are relatively ineffective for cleaning oil-contaminated beaches of the type found on the coast of New Jersey. Furthermore, they tend to compound the pollution problem. It may be assumed that they add polluting materials to the oil already present, in the form of surface active agents and, in some cases, solvents. They were demonstrated to increase the penetration of the oil/chemical mixture into the sand, thus increasing the volume of sand to be handled during mechanical or other manner of clean-up. The most effective chemical tested appeared to inhibit the natural weathering of oil into less offensive form.

At no time during these experiments was anything resembling "quicksand" observed, even when chemicals were applied in quantities equal to the amount of oil present. Chemically treated sand was somewhat less cohesive than uncontaminated sand, as indicated by the lesser weight required to force the cone penetrometer to a given depth (Table 2). However, approximately the same decrease in cohesiveness was observed in sand contaminated with oil alone. Oil alone also had a marked effect on the relative density of sand (but not the gravel on Twin Gun Beach), causing it to drop from 100% to 14% (Table 3). Thus, it is possible that heavy pollution by oil could disrupt the stability of certain types of beaches, but this would not likely be significantly affected by the presence of oil-dispersing chemicals. On the basis of these results and published reports, reported cases of "quicksand" and erosion cannot be attributed to the use of chemicals, but appear to be caused by oil alone.

TABLE 2

Cohesiveness of Oil-Contaminated and Chemically-treated Beach Sand

Determined with a Cone Penetrometer*. Each reported value represents the average of four measurements. Location: Spermaceti Cove. Oil was distributed in the sand as follows: 1) Oil Section - heavy oil layer from 0" to 3.5" depth; 2) Chemical Section - heavy oil layer from 0" to 4.5" depth, medium oil layer from 4.5" to 10" depth. Lago crude. Product A. Control areas were immediately adjacent to test sections.

Weight to Penetrate

Depth of Penetration	Control Area	Oil Section		Control Area	Chemically-treated Section	
inches	pounds	pounds	percent control	pounds	pounds	percent control
0	8	4	50	6	4	67
2	26	12	46	20	13	65
4	53	23	43	35	24	69
6	69	41	59	58	39	67
8	87	52	60	80	58	72
10	98	58	59	105	92	88
12	108	65	60	123	96	78
14	115	72	62	134	113	84
16	119	83	70	158	140	89
18	132	108	82	164	162	99

*This device measures the force (in pounds) required to cause an inverted cone of standard dimensions to penetrate a given depth of sand. The pounds of force applied to penetrate to a given depth are a function of the "cohesiveness" of the sand, reflecting its weight-bearing capacity.

TABLE 3

Relative Density of Oil-Contaminated Beach Sand

Experiment	Test Site	Location of Measurement	In Place Density Measured g/l	In Place Density Average g/l	Maximum Density g/l	Minimum Density g/l	Relative Density percent	Change Caused by Oil percent relative density
III	Twin Gun Beach 20 Nov. 68	beginning at gravel layer, 2 inches below beach surface						
		1. adjacent to oil test section	1934 2041	1987	-	-	-	-
		2. oil test section, La Rosa crude	2167 1995	2081	-	-	-	none
IV	Spermaceti Cove 2 Dec. 68	at beach surface	1823					
		1. adjacent to oil test section	1832	1828	1827	1536	100	-
		2. oil test section, Lago crude	1572 1570	1571	1827	1536	14	-86

Acknowledgments

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