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Report on environmental effects of the second Hampton Roads Bridge-Tunnel construction : sediment distributions and bottom characteristic

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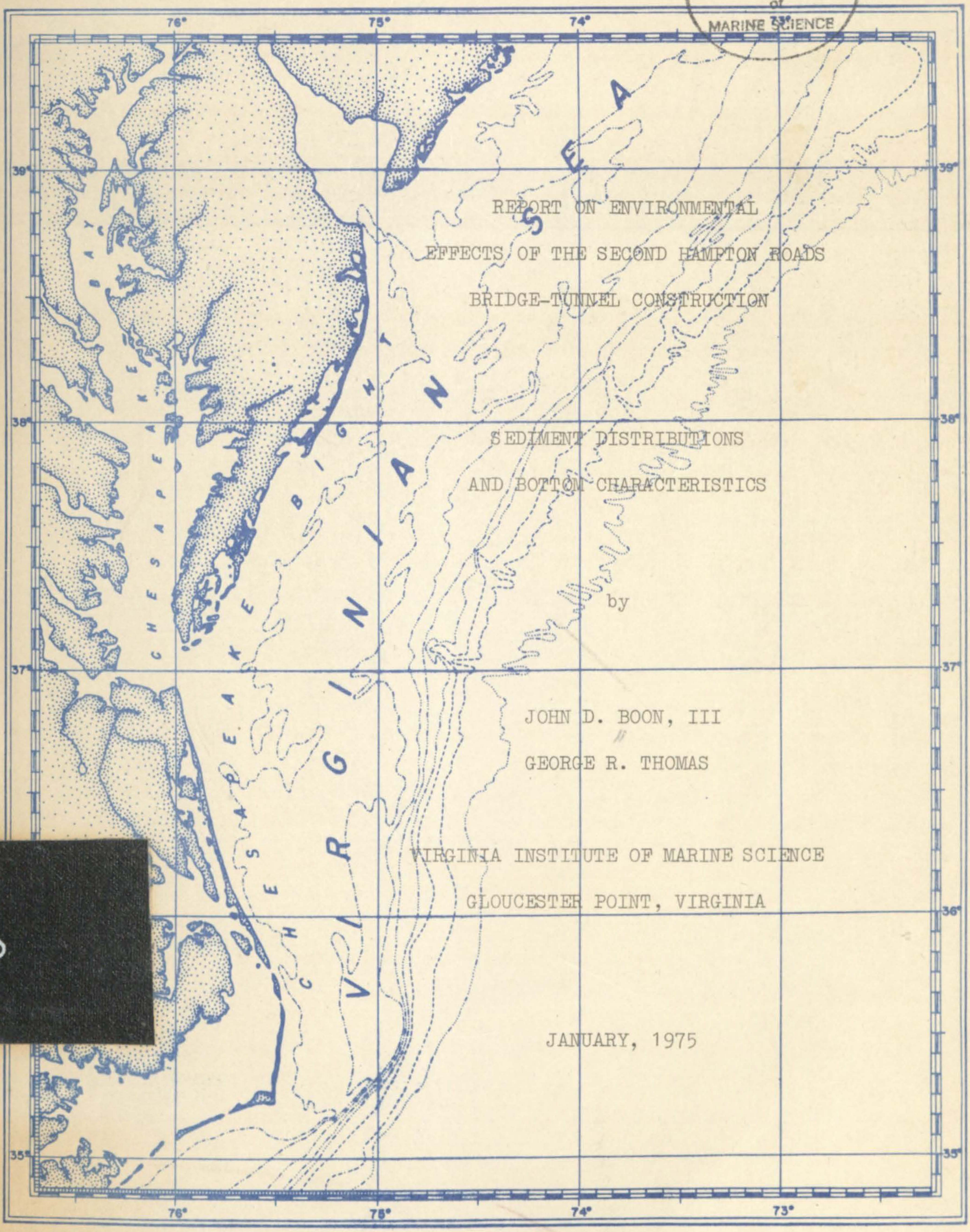

REPORT ON ENVIRONMENTAL EFFECTS OF THE SECOND HAMPTON ROADS BRIDGE-TUNNEL CONSTRUCTION

SEDIMENT DISTRIBUTIONS AND BOTTOM CHARACTERISTICS

by

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S U M M A R Y

The following is a summary of the principal findings and conclusions reached upon completion of the geological investigations described in this report:

1. Bottom sediments in the vicinity of the Second Hampton Roads Tunnel construction vary from near zero to almost 100% sand with varying admixtures of shell fragments and fine material having a clay-silt ratio of approximately 2:1.
2. Distributions of the percentages by weight of sand, silt, and clay as determined from recent sample analyses are very similar to those reported by Nichols (1972, p. 197) for samples collected in 1965 in the lower James.
3. In general, surface sediments containing more than 75% sand are found on the bottom in depths less than 60 feet. Below this depth, surface sediments are primarily composed of silts and clays.
4. Bottom cores show little evidence of bioturbation or disturbance by benthic organisms; angular bedding, mud gall inclusions, and thin mud-sand interlayering evidence the reworking of bottom sediments by currents amid active bedload transport.
5. Bottom profiles reveal sand waves having amplitudes of between 5 and 8 feet in the vicinity of the old and new tunnel transects. These features appear to be associated with flow turbulence caused by bottom roughness elements in the dredged areas.

6. Spatial distributions of suspended sediment show that a turbid layer exists close to the channel bottom; relief remnant from the first tunnel construction appears to modify boundary flow structure causing local admixing of the turbid water into higher, overlying flow layers.
7. Temporal distributions of the suspended sediment load varied considerably in the channel during spring current flows accompanied by moderate wind wave activity. At such times, surface concentrations may reach 10-15 mg/l through natural processes.
8. Samples collected during dredging operations yielded surface concentrations in the range of 3-9 mg/l outside the spoil plume and from 15-30 mg/l inside the plume at distances less than 1000 feet downstream from the dredge.
9. Photographs from overflights of the dredging operation indicate that the dispersal of escaped spoil was very rapid due to the high flow volumes and turbulent mixing within the Hampton Roads Channel. Surface concentrations above naturally-occurring ambient levels did not persist over any significant distance.
10. The dispersal factor, together with evidence for active reworking of bottom sediments near the tunnel construction site discount the possibility that significant amounts of escaped spoil have accumulated on the bottom at any one locality.
11. Certain shortcomings have been noted in the procedures that were followed in obtaining backfill material from the borrow areas:

a. Little information was made available in advance of this project on the nature of the deposits to be worked in approved borrow areas, including an estimate of useable sand quantities and the amount of nonuseable fines that would be disturbed.

b. Dredging that introduces severe bottom irregularities in borrow areas may lead to alteration of local wave and current patterns which in turn affect sediment transport. This may have been the case in one area east of Fort Wool.

c. The approved borrow areas were not adequately defined at the outset of this project in terms of both horizontal and vertical limits to dredging. Thus, extensive silt-clay deposits were occasionally penetrated which could have been avoided in this case by imposing a lower dredging limit of 25 feet below mean low water.

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PART I

FIRST YEAR OBSERVATIONS

JULY - DECEMBER 1973

INTRODUCTION

The following first year report presents the geological data thus far compiled under the environmental study program at the site of the second Hampton Roads Bridge-Tunnel in Virginia.

Briefly, this portion of the study will address two specific questions:

(1) What changes have been brought about as a result of dredging and filling operations in the Hampton Roads Channel, particularly changes in the bottom sediment composition, bedforms, and the suspended sediment load in the vicinity of the tunnel construction site?

(2) What will be the eventual bottom configuration, sediment composition, and sedimentary processes occurring in the subaqueous borrow areas from which back fill material is being transferred?

The latter question is of particular interest because substantial amounts of fill have already been removed from one borrow area with some of this material being replaced by sandy spoil dredged from the tunnel excavation site. Inasmuch as the final state of the borrow area at project's end may represent a disturbance which will persist for a long time, and considering that a recurring demand for backfill can be expected in this region, this portion of the study will receive special emphasis in future months.

Description of Location

The site of the present tunnel construction is found in the Hampton Roads channel just south of Old Point Comfort in Hampton, Virginia. This area marks the boundary between the James River Estuary and Lower Chesapeake Bay (Ref: NOS Chart 400). Here the channel is U-shaped in cross section, attaining depths of between 50 and 65 feet, and is bordered to the north and south by shallow shelves landward of the 18-foot depth contour. The shelves contain elongate sandy shoals near the channel edge (Hampton Bar, Sewell's Point Spit, and Willoughby Bank) whose outlines are primarily shaped by tidal currents. Along the shore, two large wave-built spits (Willoughby Spit and Old Point Comfort) protrude into Hampton Roads Harbor. The configuration of these spits indicate a pattern of wave-dominated sand transport from seaward which in turn contributes to tidally-controlled subaqueous sand bodies near the channel margins and perhaps to the main channel bottom as well.

Bottom Sediments

Only two publications exist that describe bottom sediments in the James River Estuary in the vicinity of Hampton Roads (Moncure and Nichols, 1968; Nichols, 1972). These studies describe the bottom sediments here as a marine facies characterized by sandy sediments rich in "light" minerals (chiefly quartz and feldspar) with minor amounts of mica, chlorite-rich clays, shell fragments, and a certain number of heavy minerals among which staurolite is common. The area seaward of the James River entrance has been given as the source of most of the sand-sized material whereas clays are locally derived through partial settling of the river-borne suspended load and from deposition of dredge spoil.

At the beginning of the present study, a number of bottom grabs were obtained at the locations shown in Figure 1. Analyses were performed to determine the percentage of sand, silt, and clay in each of these samples, shown on a triangular diagram in Figure 2[1]. Taken as a whole, the points indicate sand contents varying from near zero to almost 100% sand with varying admixtures of fine material having a clay-silt ratio of approximately 2:1. Essentially the same distributions were reported by Nichols (1972, p. 197) for samples collected in 1965 covering the lower James. With some exceptions, most of the Figure 1 samples having a high sand content occur on the north side of the channel and along and to the west of the new tunnel transect outside the areas of maximum depth.

A second suite of bottom grabs were collected at random locations along a line perpendicular to the tunnel transect near those tunnel sections designated 12, 13 and 14 in the engineering plans. These were the only sections as yet undredged at the time of the second sampling. The positions were determined by three-point sextant fixes plotted at a 1:10,000 scale. The grab used to collect these samples was a miniaturized van Veen device which collects only

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[1] Sand includes those grains larger than 1/16 mm in diameter; silt includes diameters between 1/16 and 1/256 mm and clays those diameters less than 1/256 mm as determined from equivalent diameter-particle settling methods.

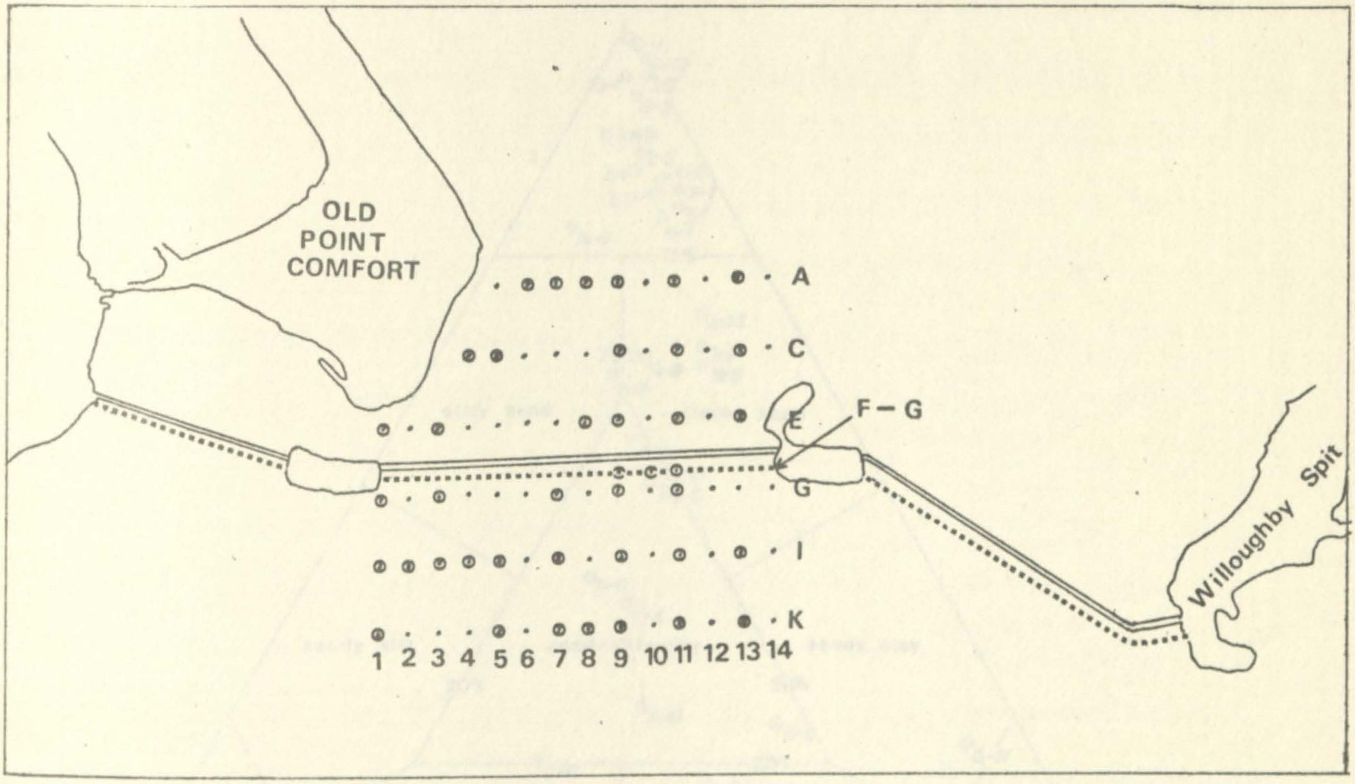

Figure 1. Location of bottom grab samples collected during initial sampling run, July, 1973 at entrance to Hampton Roads.

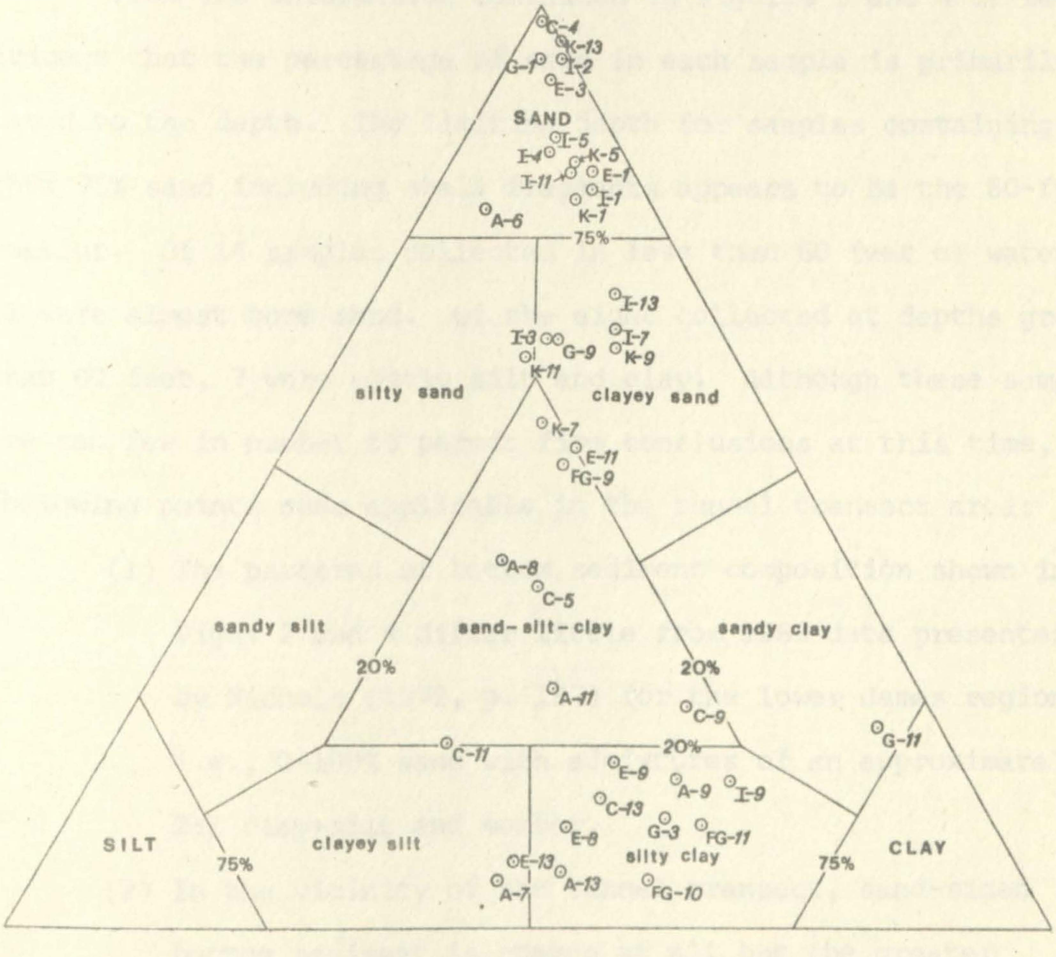

Figure 2. Percent sand-silt-clay in July, 1973 samples.

the upper two inches of surface sediment. The locations of these samples are shown in Figure 3. Sand-silt-clay percentages are shown in Figure 4.

From the information contained in Figures 3 and 4 it becomes evident that the percentage of sand in each sample is primarily related to the depth. The limiting depth for samples containing more than 75% sand including shell fragments appears to be the 60-foot contour. Of 14 samples collected in less than 60 feet of water, 11 were almost pure sand. Of the eight collected at depths greater than 60 feet, 7 were mostly silt and clay. Although these samples are too few in number to permit firm conclusions at this time, the following points seem applicable in the tunnel transect area:

(1) The patterns of bottom sediment composition shown in Figs. 2 and 4 differ little from 1965 data presented by Nichols (1972, p. 197) for the lower James region; i.e., 0-100% sand with admixtures of an approximately 2:1 clay-silt end member.

(2) In the vicinity of the tunnel transect, sand-sized bottom sediment is common at all but the greater depths in the main channel and is probably being supplied from the shoal areas at the channel edges where wave-transported sand is being continually redistributed by tidal currents.

(3) Significant accumulations of fine material do not occur near the shoals and in the shallower portions of the

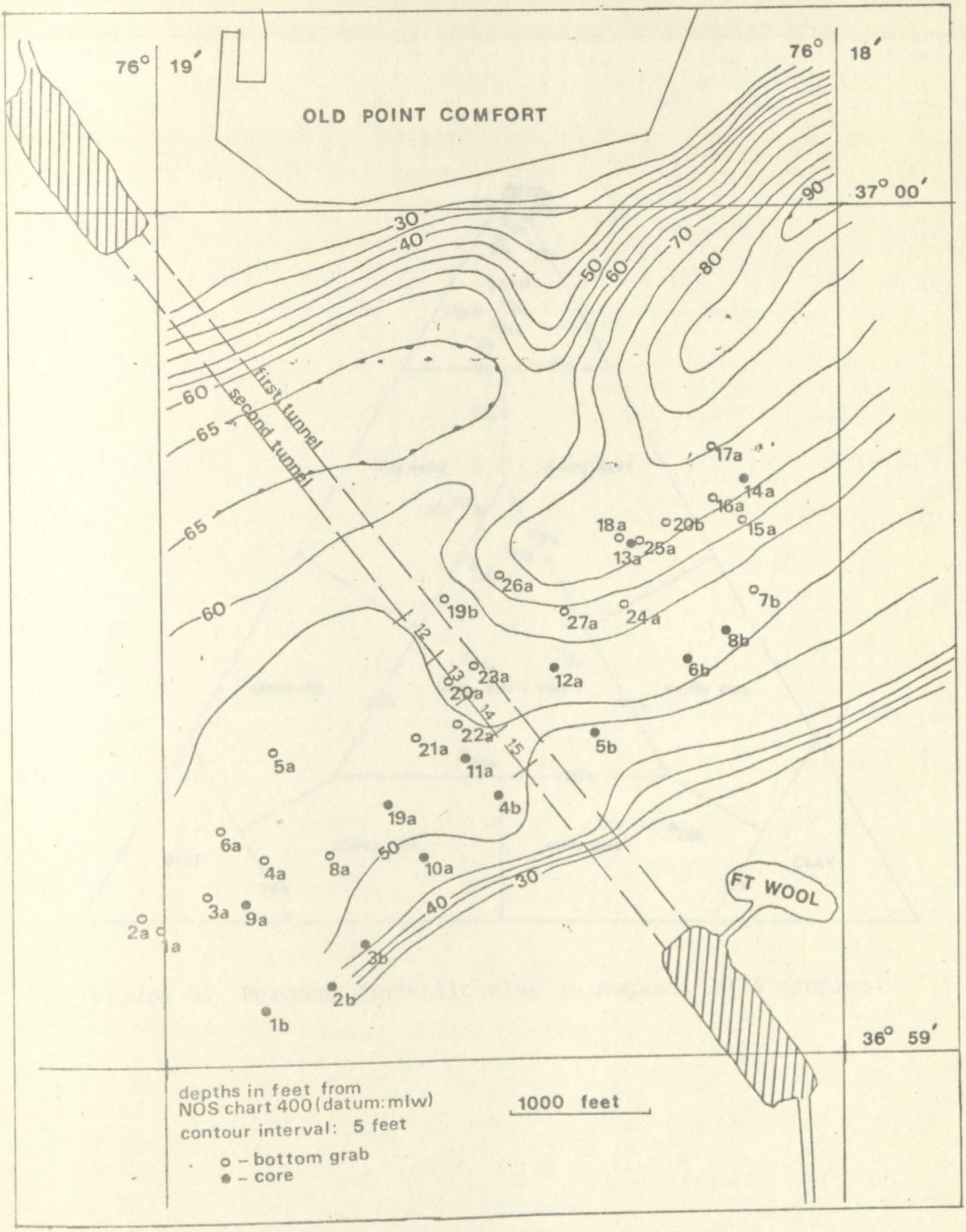

Figure 3. Location of bottom grab samples collected in undredged area on south side of Hampton Roads Channel, August, 1973.

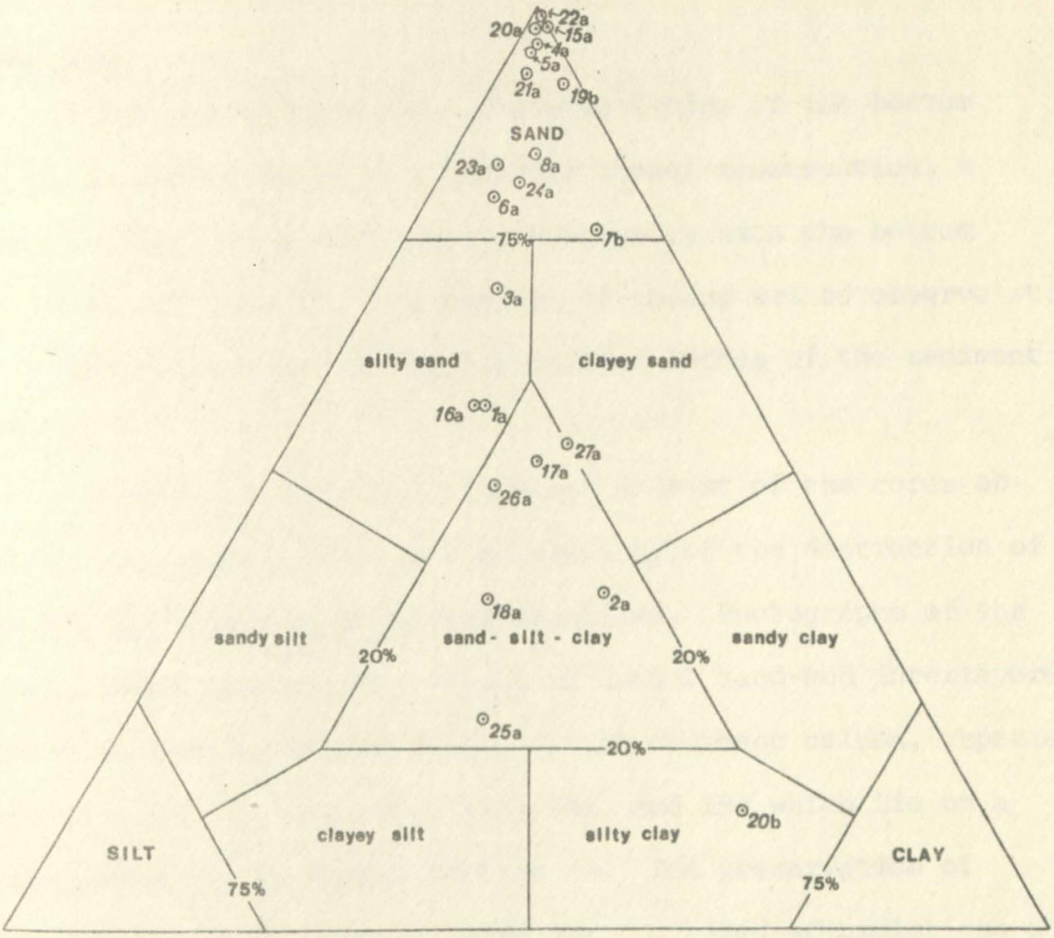

Figure 4. Percent sand-silt-clay in August, 1973 samples.

channel where bottom currents act to keep it in suspension. Fines do appear to be accumulating in the deeper parts of the channel.

Bottom Cores

To further elucidate the characteristics of the bottom deposits in the vicinity of the second tunnel construction, a series of short cores were taken concurrently with the bottom grabs shown in Figure 3. The purpose of coring was to observe structures which might exist in the top several inches of the sediment column.

A feature of particular interest in most of the cores obtained is the general lack of bioturbation, or the destruction of sedimentation layers by burrowing organisms. Photographs of the sectioned cores (Appendix A) reveal an intact sand-mud interlayered structure in the upper 6-10 inches of the sediment column, especially evident in cores 9a, 10a, 11a, 12a, 14a, and 19a which lie on a line perpendicular to tunnel section 14. The preservation of structures is probably due in large part to rapid accumulations and continual reworking of sediments by swift currents in the area, conditions which may also explain the paucity of living organisms here (see Boesch and Rackley, this report). Frequent abrupt transitions from depositional to erosional episodes are well-evidenced, particularly in cores 13a and 19a which contain angular bedding, mud gall inclusions, and thin sand and mud lenses intermixed. The latter features are brought out more clearly in two X-ray radiograph prints of cores 13a and 19a which are presented in Appendix B.

Sand Waves

A number of bottom profiles were taken running parallel to the channel axis using a Raytheon DE-719 fathometer. Three of these profiles have been selected to show the type of bedforms extant in the vicinity of the tunnel construction (Figure 6). Positions obtained by sextant fix are shown in Figure 5 to denote the location of the profile lines.

Sand waves with amplitudes of between 5 and 8 feet appear in Figure 6a on either side of a recently dredged tunnel trench (section 11 in the engineering plans). The waves are particularly noticeable proceeding to the west of the trench, the first three or four waves possessing a marked asymmetry. This type of bedform usually consists of loose sand in motion under the influence of strong bottom currents probably aided in this case by highly turbulent flow conditions in the lee of the trench.[2] In Figure 6b and 6c, the profiles pass over the as yet undredged sections 13 and 14, respectively, where the sand waves occur only to the west of the still visible outline of the first tunnel construction. Although they are of somewhat lesser amplitude (3-5 feet) than the waves in Figure 6a, these features also show a current-related asymmetry in their wave forms. Nichols (1972, p. 177) observed sand waves with 3-5 foot amplitudes in 1966 near Old Point Comfort, indicating that these bedforms are probably permanently existing features for this area even though they are not likely to be stationary but will migrate back and forth with the ebb and flood tides.

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[2] The fathometer runs were made shortly after the onset of ebb current on the afternoon of October 13, 1973.

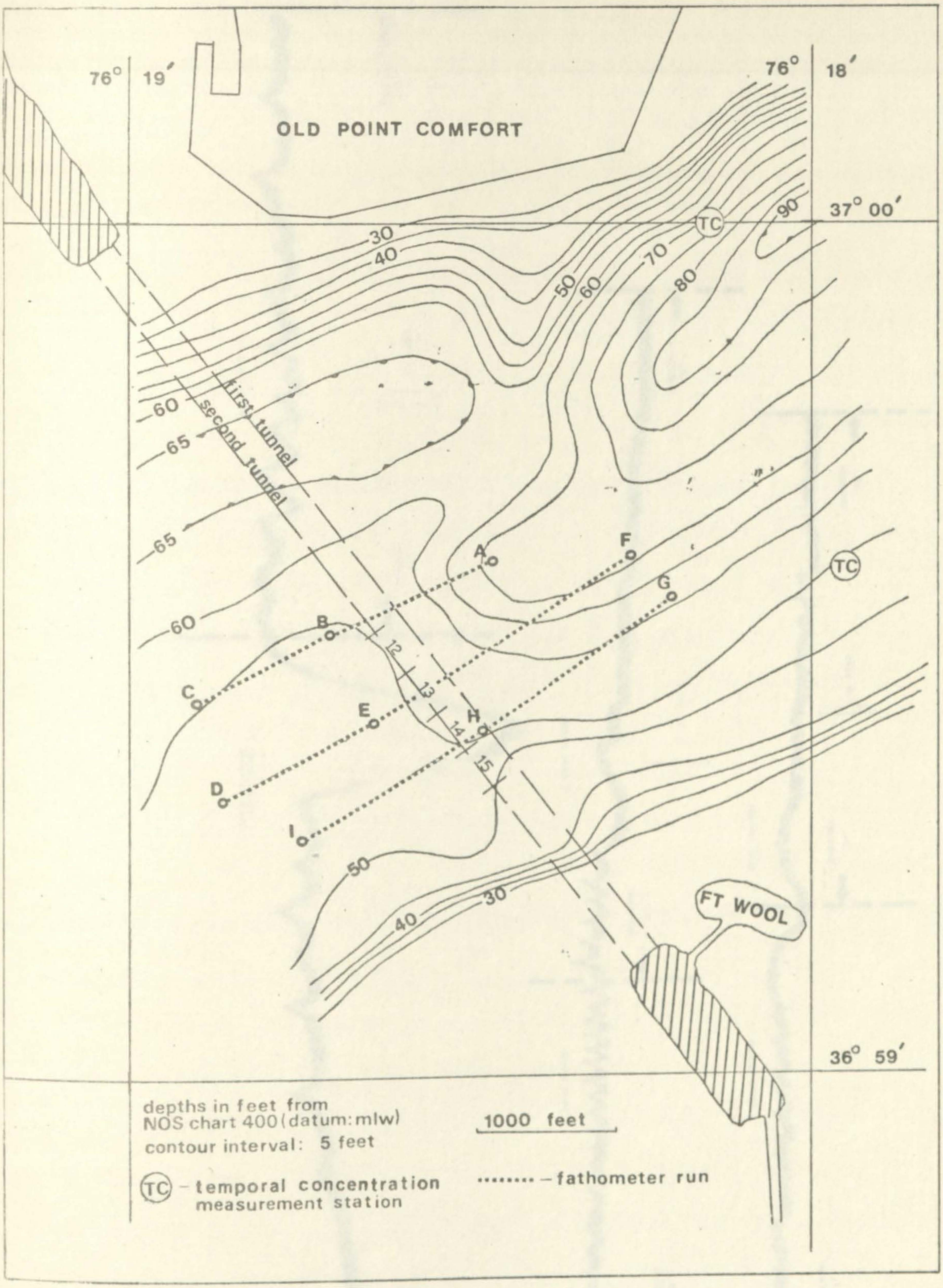


Figure 5. Positions of profile sounding lines, August 13, 1973.

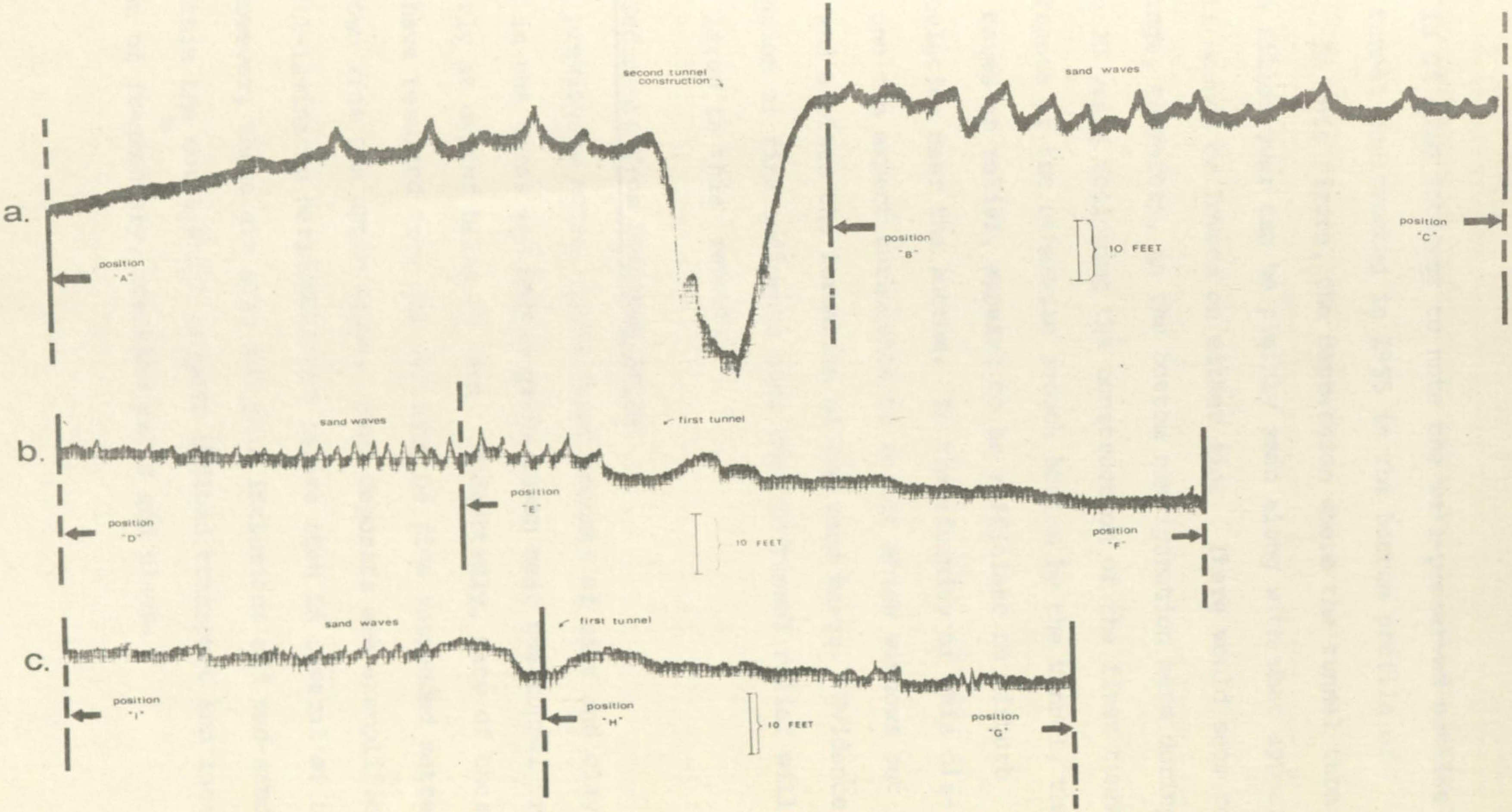


Figure 6. Bottom profiles, August 13, 1973
(positions shown in fig. 5)

It is of some interest to note the well-preserved outline of the first tunnel constructed in 1955 in the bottom profile of Figure 6c. In this figure, the depression where the tunnel tube was buried and filled over can be plainly seen along with what appear to be small mounds or levees on either side. There would seem to be little change, therefore, in the bottom configuration here during the nearly 20 years following the construction of the first tunnel. The disturbance of the otherwise smooth bottom by the tunnel, though slight in terms of relief, appears to be sufficient to disturb water circulation near the bottom. In the vicinity of this disturbance, one can expect turbulence to result which winnows out fine sediments and assists the formation of the sand waves. Evidence of the suspension of fine sediments near the old tunnel relief will be presented later in this report.

Reworked Sediments From Upstream Areas

As previously noted, significant amounts of silt and clay are found in the cores and bottom grabs taken near the tunnel transect, particularly at depths below 60 feet. Undoubtedly, many of these deposits have resulted from the settling of fine suspended matter carried down from the upper James. Such deposits are exemplified by the well-laminated horizontal mud layers seen in several of the cores. However, there are also mud gall inclusions and mud-sand lenses within the cores which suggest bedload transport and local deposition of fragmentary, reworked silts and clays.

A possible source of reworked sediment is found in an area less than a mile to the southwest of the coring stations in Fig. 3. This area was used as an emergency spoil dumping zone during and shortly after World War II. Data from the Nichols study indicate that these spoil deposits are up to 25 feet thick within the main channel and cover an area of nearly three-quarters of a square mile. Figure 7 shows the location of the spoil within a channel section off Sewell's Point in Norfolk and also illustrates that a significant amount of erosion has taken place along the north wall of the main channel. Much of the bedload in this area probably goes upstream in accordance with the usual net landward flow of saline bottom waters in an estuary such as the James. Nevertheless, reversing flows near the bottom should be capable of dispersing material in either direction from a given source area. These materials may subsequently enter the sediment column either through intermixing with sands transported from seaward or, in the case of the larger clay fragments (mud galls), may accumulate in the deeper regions of the bottom as lag deposits, particularly after periods of maximum river discharge.

Suspended Sediments

Water samples were collected at various positions within the water column and analyzed for suspended solids concentration using gravitimetric methods which derive the concentration as dry weight of solids per unit volume (milligrams per liter). The purpose of the sampling was to give some idea of the distribution of the suspended load, viewed both temporally and spatially, near tunnel sections 12 through 15 shortly before these sections were to be dredged.

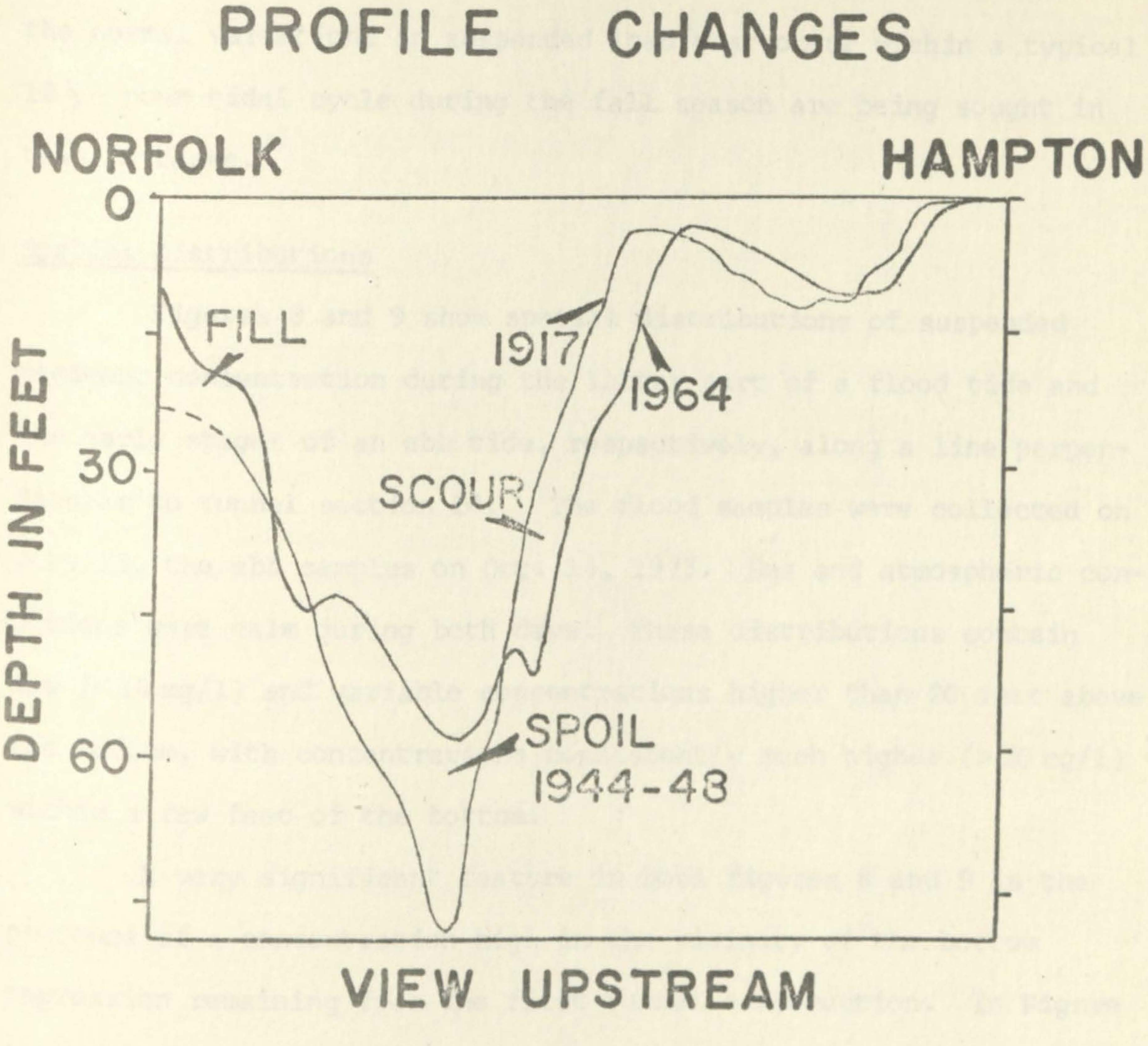


Figure 7. Profile changes, transect from Sewell's Point perpendicular to Hampton Roads Channel (after Nichols, 1972).

Although seasonal influences and various combinations of wind and tide may cause extremes in these distributions which we cannot hope to observe in a short-term series of measurements, examples of the normal variations in suspended load that occur within a typical $12\frac{1}{2}$- hour tidal cycle during the fall season are being sought in this instance.

Spatial Distributions

Figures 8 and 9 show spatial distributions of suspended sediment concentration during the latter part of a flood tide and the early stages of an ebb tide, respectively, along a line perpendicular to tunnel section 14. The flood samples were collected on Oct. 13, the ebb samples on Oct. 14, 1973. Sea and atmospheric conditions were calm during both days. These distributions contain low (< 10 mg/l) and variable concentrations higher than 20 feet above the bottom, with concentrations consistently much higher (> 20 mg/l) within a few feet of the bottom.

A very significant feature in both figures 8 and 9 is the presence of a concentration high in the vicinity of the bottom depression remaining from the first tunnel construction. In Figure 8, this high reaches a level of 60 mg/l which is indicative of highly turbid water such as one often sees in marsh creeks. The interpretation which we make of this data is that a turbid layer normally exists very close to the bottom and remains there within a fairly narrow shear zone along the smoother portions of the bottom. The depression of the original tunnel apparently interrupts smooth

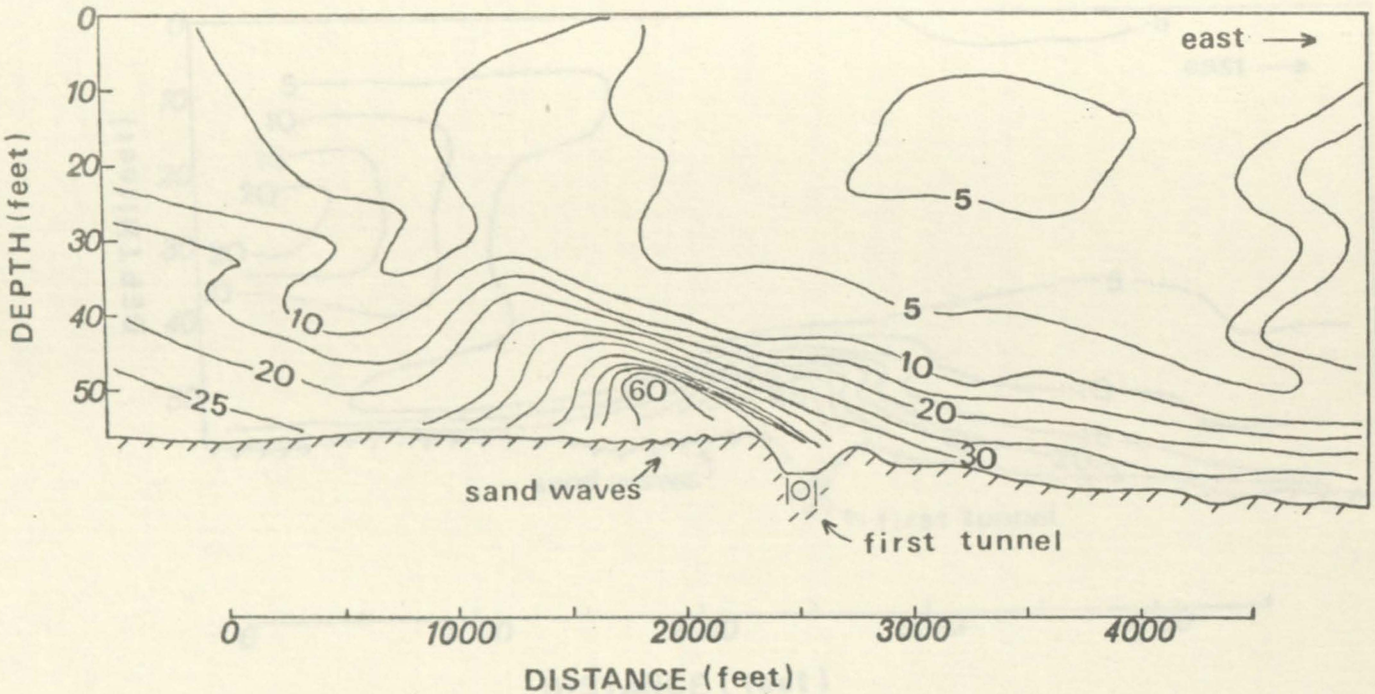


Figure 8. Spatial distribution of suspended sediment concentration along a line perpendicular to tunnel section 14, late flood stage, August 13, 1973.

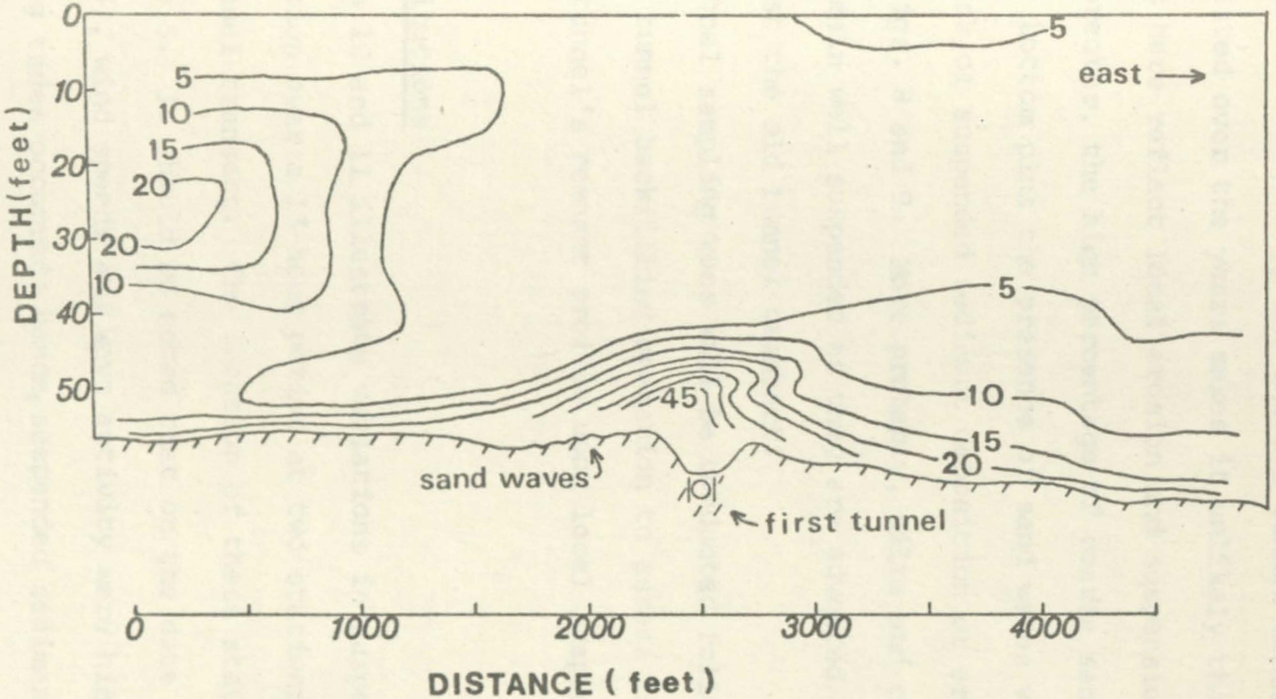


Figure 9. Spatial distribution of suspended sediment concentration along a line perpendicular to tunnel section 14, early ebb stage, August 14, 1973.

boundary flow and creates turbulence which disperses the turbid water upwards into the overlying flow layers. The fact that the bottom configuration caused by the initial tunnel construction in 1955 has persisted over the years makes it unlikely that the high concentrations here reflect local erosion and suspension of fine sediments. Moreover, the high percentage of coarse sand in the top portion of the bottom plus the presence of sand waves very definitely inidcates a lack of suspended sediment deposition or erosion below the highs in Figs. 8 and 9. More probably, silts and clays from other areas remain well suspended as they are advected by strong tidal flows past the old tunnel transect.

Additional sampling runs will be conducted following completion of the tunnel backfilling operation to assess the effect of the second tunnel's remnant profile upon local suspended sediment distributions.

Temporal Distributions

Figures 10 and 11 illustrate variations in suspended sediment concentration over a 13-hour period at two stations just seaward of the tunnel transect. The location of these stations is given in Figure 5. It should be noted that on the date of sampling (Sept. 13, 1973), wind speeds and wave activity were higher than usual and spring tides occurred; hence, suspended sediment concentrations should be above average levels.

In Figures 10 and 11, a variation in the level of concentration occurs throughout the water column which is closely related

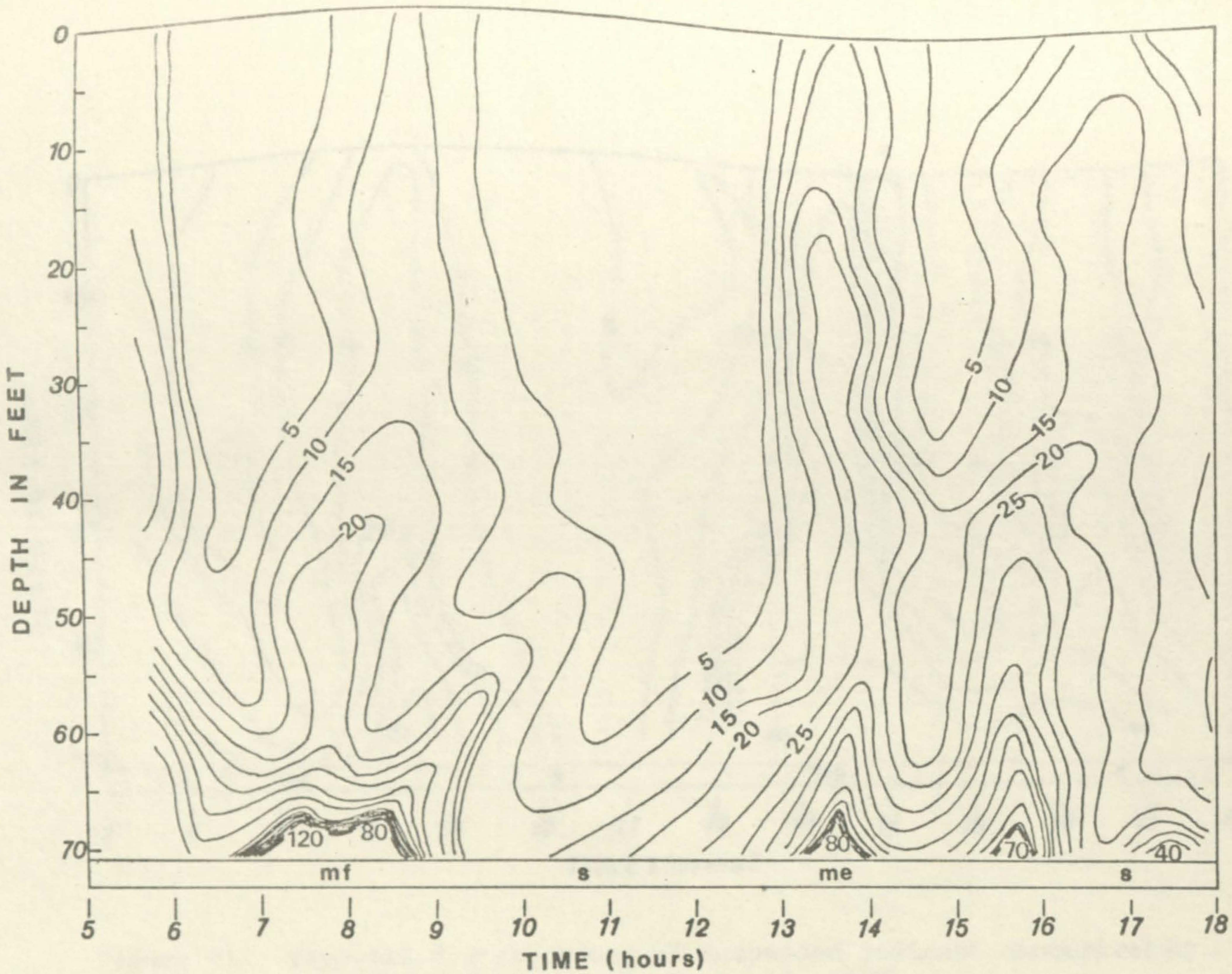


Figure 10. Temporal distributions of suspended sediment concentration, north station (Fig. 5), Sept. 13, 1973.

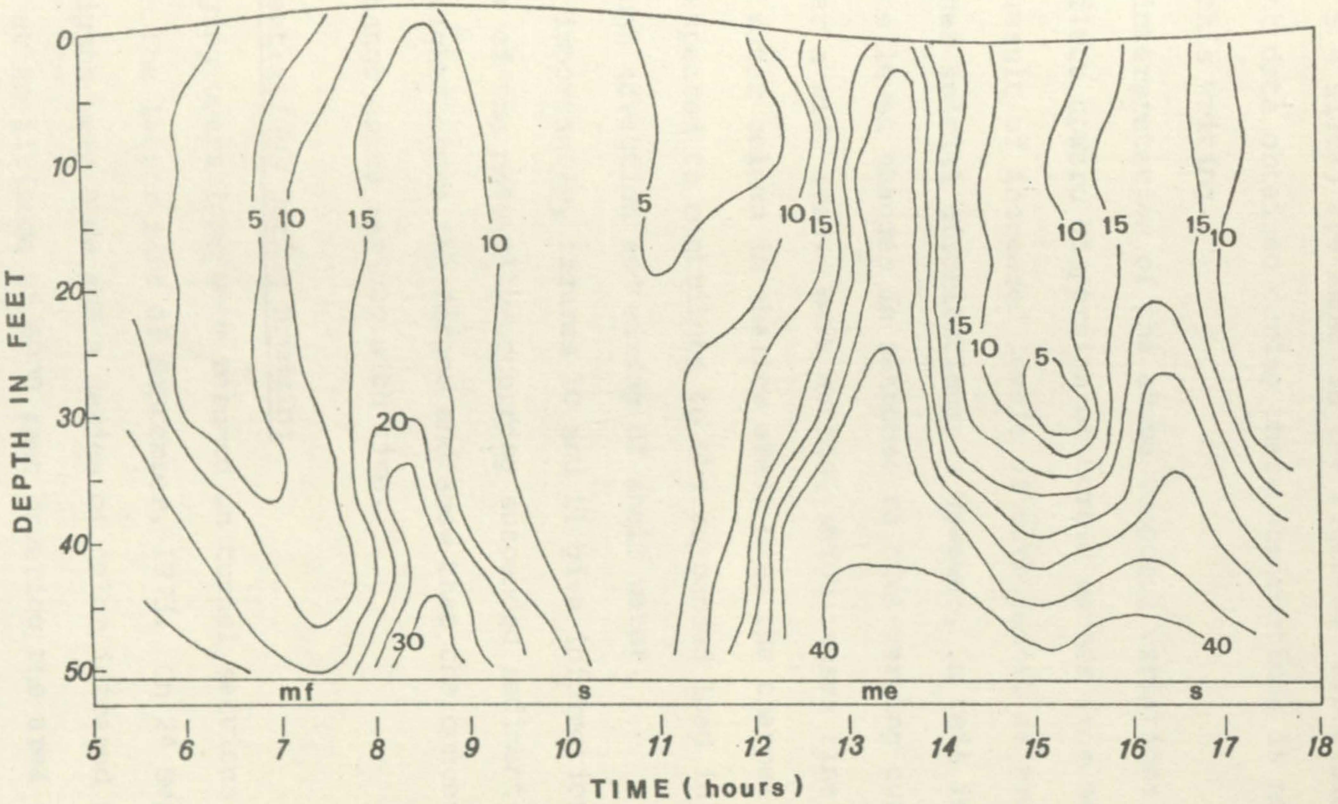


Figure 11. Temporal distributions of suspended sediment concentration, south station (Fig. 5), Sept. 13, 1973.

to variations in tidal current velocity. For convenience, the approximate times of the current extremes (MF = maximum flood, ME = maximum ebb, S = slack) are shown in the figures. Processing of actual current data obtained during these observations is not complete as of this writing.

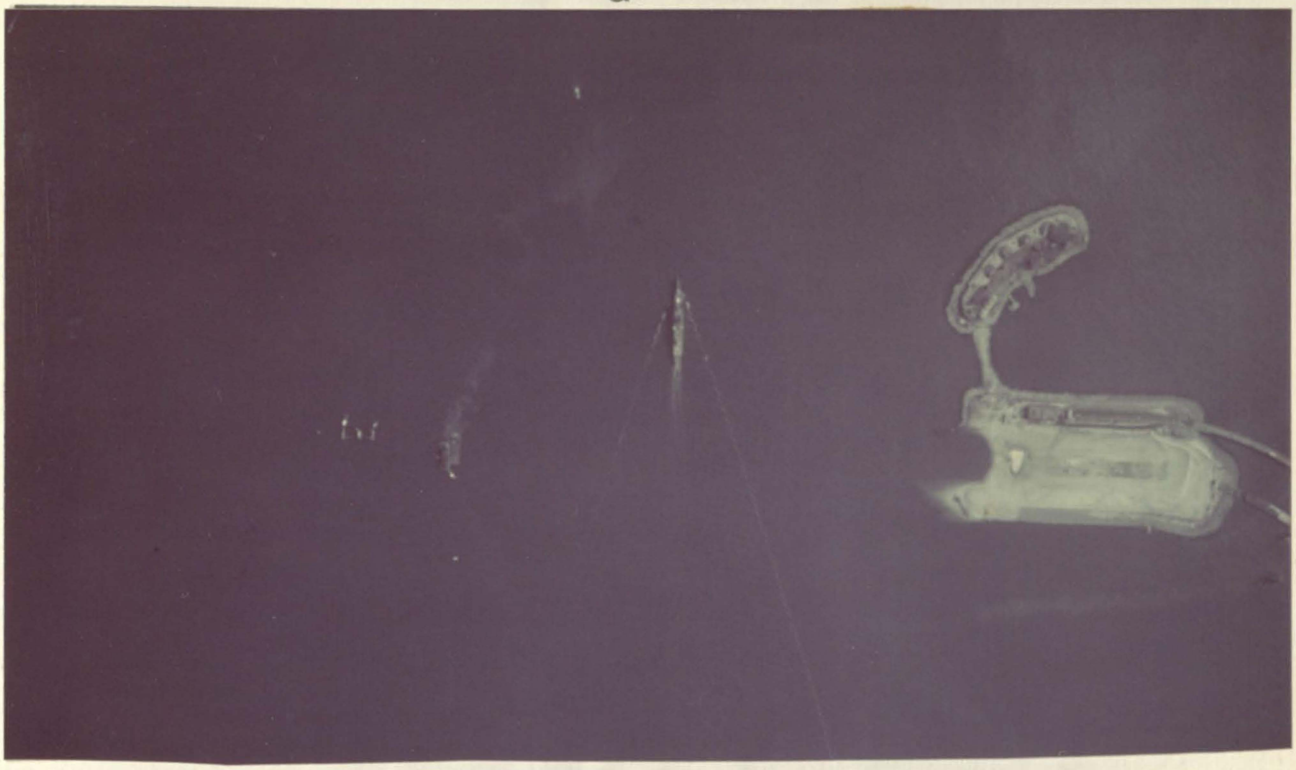
Our interpretation of the above temporal variations is that they also reflect upward dispersion of turbid waters from near the bottom as a result of increased levels of turbulence, as previously discussed under spatial distributions. However, in this instance the turbulence level changes in response to time-varying current strengths over a wide area. Wave action, which causes fine sediments to enter the water column in shallow areas near the channel margins, can also be expected to contribute to the suspended load in the main channel through advection and mixing of shelf water.

Most importantly, figures 10 and 11 give information as to the magnitude of the naturally-occurring suspended sediment load at various heights above the bottom and show that the concentration levels may change quite rapidly with time.

Surface Concentrations During Dredging

Dredging operations were resumed on tunnel sections 12, 13, 14, and 15 in the latter part of September, 1973. On 24 September, three overflights were made and a series of color infrared photographs taken at an altitude of 6000 feet covering the area affected by the dredging. Two color prints are presented in Figure 12 which show the dredge spoil plume shortly after the start of ebb (Fig. 12a) and near the time of maximum ebb (Fig. 12b).

a.



b.

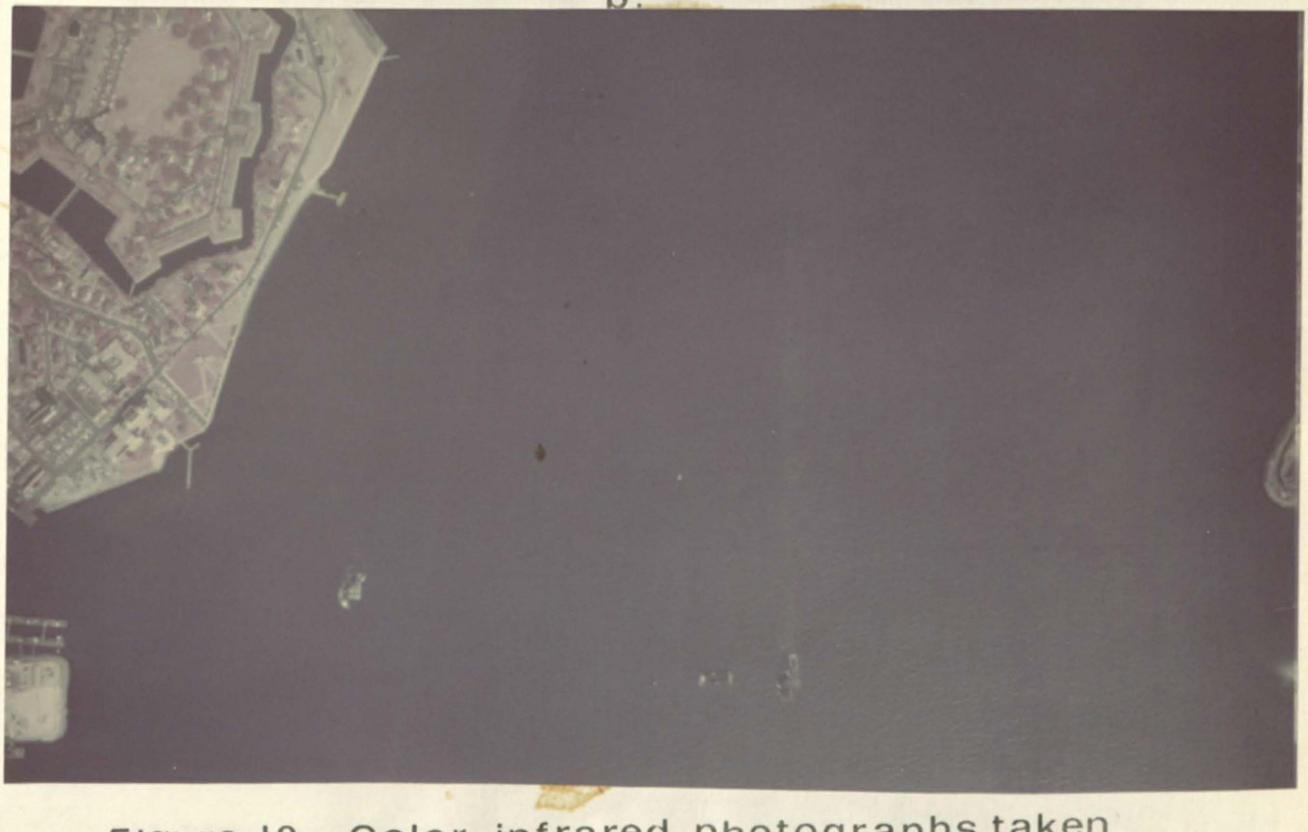


Figure 12. Color infrared photographs taken during dredging operations, Sept. 24, 1973. a.—Slack before ebb b.—Maximum ebb

Water samples were collected at various distances and on different bearings in relation to the dredge. Rather than attempt to follow a sampling pattern consisting of fixed positions or fixed intervals between sampling, we chose to do repeated sampling back and forth across the plume's major axis whatever its orientation might happen to be during the overflights. In addition, several samples were taken a short distance upstream from the dredge.

The first overflight was made between 9:29 and 9:40 am (standard time) shortly after the beginning of ebb flow. Fig. 12a shows the position of the plume at 9:35 am. In this photo, the plume has a somewhat broken and irregular form trending east-southeast. Our boat can be seen in the photo just below the dredge, sampling near a slightly clouded patch of water which may be remnant from the last of the flood stage, perhaps prolonged at depth. Surface concentrations within the faint upstream patch varied between 4.3 and 5.6 mg/l. To either side of the leeward plume, concentrations varied between 2.7 and 3.8 mg/l, reaching a maximum within the distal end of the plume of only 9.0 mg/l.

The second overflight took place between 12:41 and 12:52 pm near maximum ebb flow. Figure 12b is a photograph taken at 12:41 pm which shows the plume streaming in a narrow straight line towards the northeast. Obviously, mixing of the suspended spoil occurs rapidly under these conditions and the tail of the plume becomes indistinguishable about 3000 feet downstream. At a distance of about 1000 feet downstream from the dredge, surface concentrations within the plume varied between 15.2 and 19.6 mg/l. Outside of the plume, some 100 feet from the axis, concentrations varied between 6.1 and 8.9 mg/l.

The third overflight covered the period between 2:42 pm and 2:54 pm approaching the slack before flood. Photo coverage was compromised by cloud cover during most of this period; however, one or two glimpses of the dredge revealed a very ill-defined plume with little indication of a preferred direction of transport. Concentrations very close to the dredge reached a level of 33.1 mg/l but at distances of 100 feet or more, the levels fell to between 6.2 and 7.1 mg/l.

Compared to the temporal distributions of suspended sediment concentration in Figures 10 and 11, the surface concentrations observed during dredging do not appear unusual. Even within the spoil plume itself, concentration levels are not significantly higher than those normally occurring under moderate conditions of wind and tide, excepting concentrations immediately adjacent to the dredge. This situation can be attributed to the location of the tunnel transect at the point of a major constriction in tidal flow. Given the large volumes of water passing over the tunnel and the high levels of current speed and turbulence present, suspended sediments introduced into the water column in any part of the channel are undoubtedly dispersed very rapidly.

Remaining Work on Sediment Samples

Bottom cores and filtered suspended sediment samples have not as yet been analyzed for percent organic material. These and other analyses will be conducted in the near future.

R E F E R E N C E S

Nichols, M.N., 1972. Sediments of the James River Estuary, Virginia: Geol. Soc. Am. Memoir 133, pp. 169-212.

Moncure, R., and Nichols, M.N., 1968. Characteristics of Sediments in the James River Estuary, Virginia: Virginia Inst. Marine Sci., Spec. Sci. Rept. 53, 40 p.

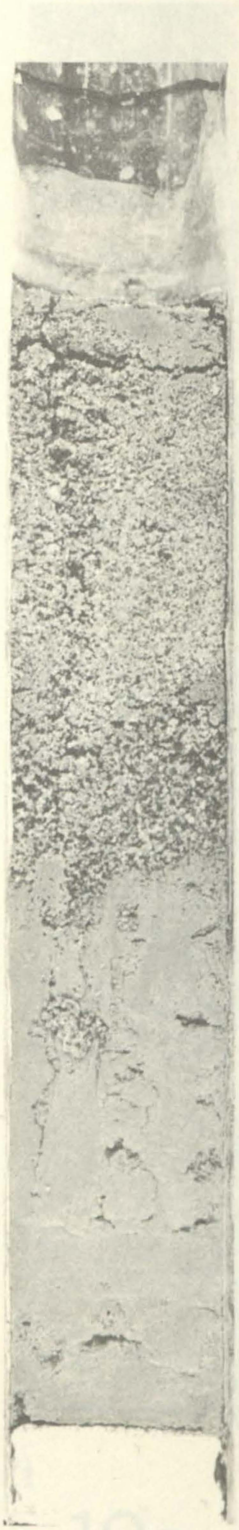
APPENDIX A

Photographs of Sectioned Cores
Collected August 13-14, 1973
(Positions given in Fig. 3)

9a

10a

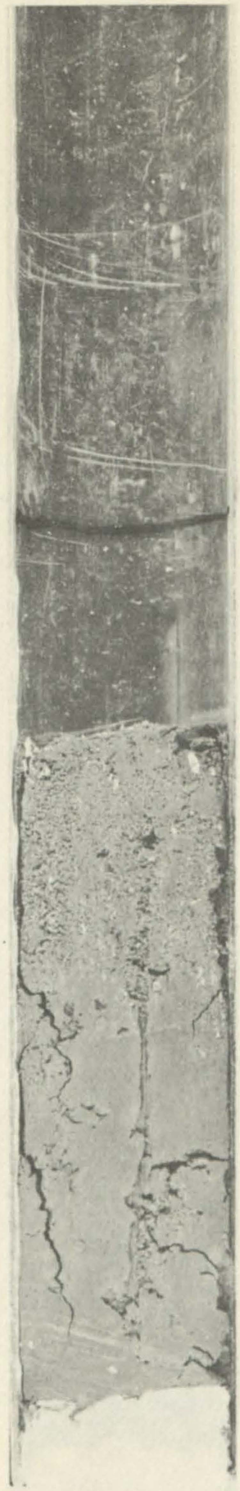
11a


12a


13a


14a

19a

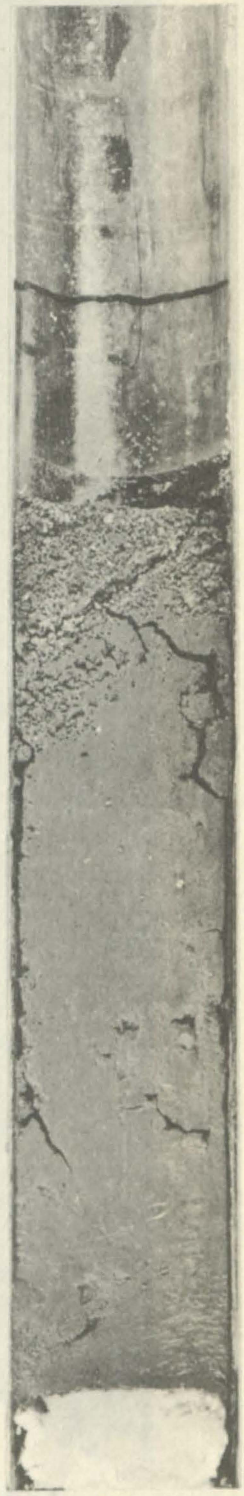


1b

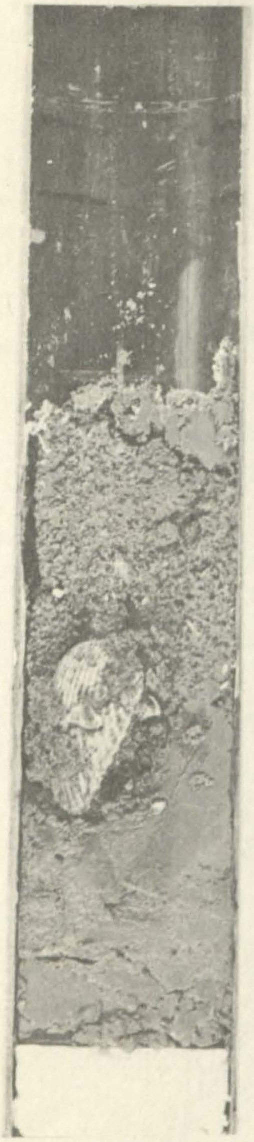
2b

3b

4b



5b

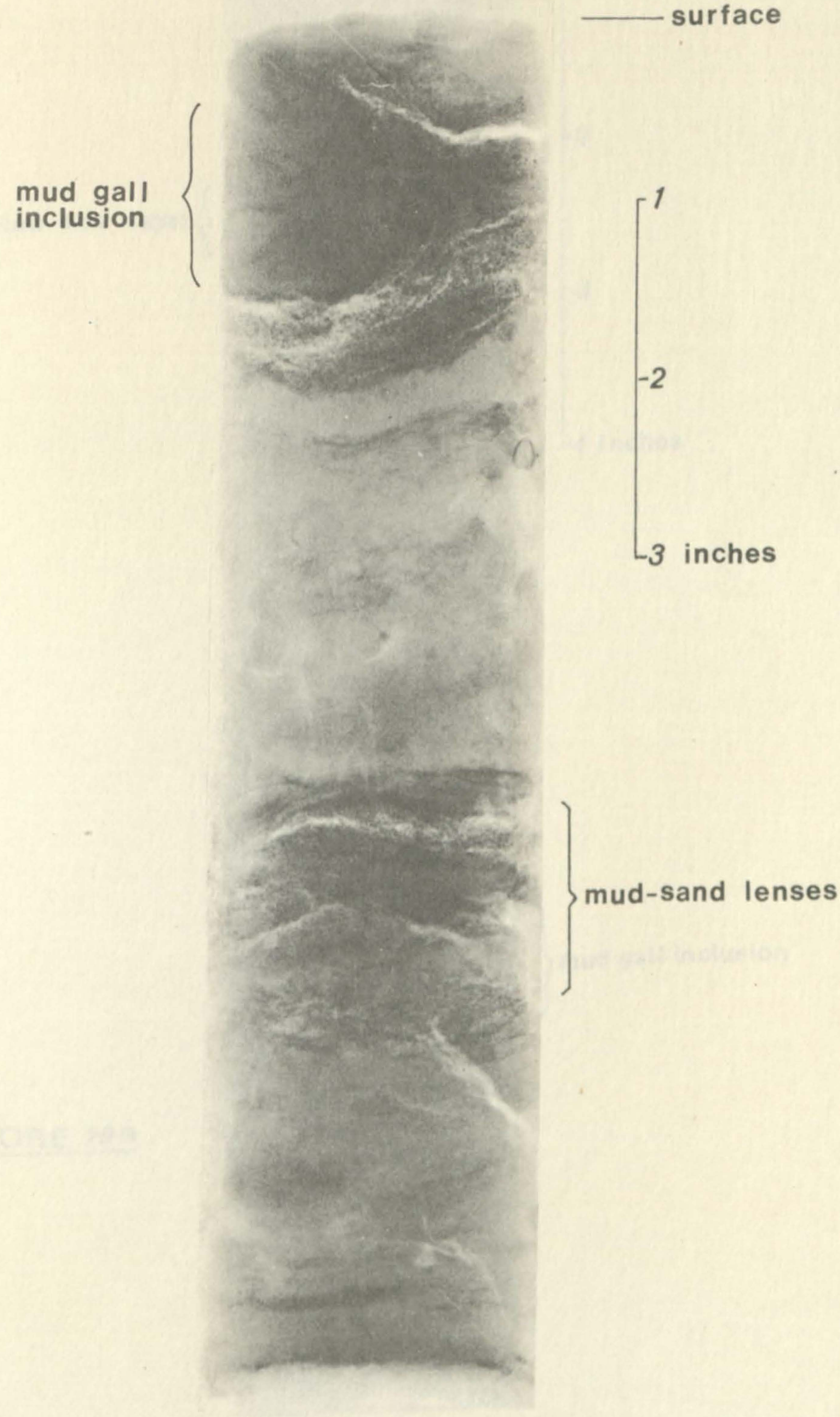


6b

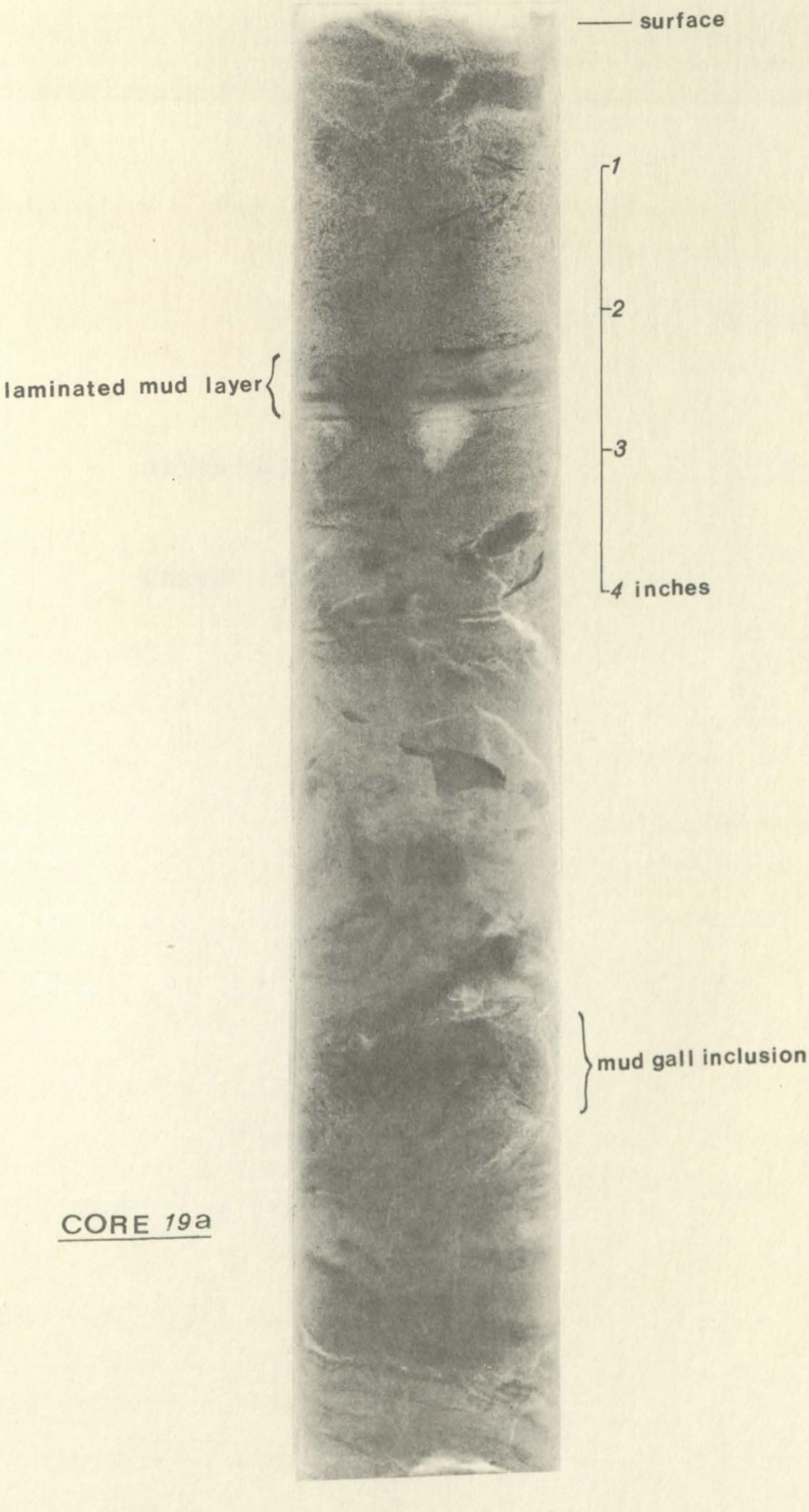
8b

A P P E N D I X   B

X-Ray Radiograph Prints
of Cores 13a and 19a



CORE 13a


surface
1
2
3
4 inches
laminated mud layer
mud gall inclusion

CORE 19a

PART II

SECOND YEAR OBSERVATIONS

JANUARY - NOVEMBER, 1974

INTRODUCTION

This report presents the final portion of the geological data obtained as part of the environmental impact study of the second Hampton Roads Bridge Tunnel construction project. An interim report submitted in January of 1974 reported findings of field investigations conducted up to that date, including an analysis of the effects of tunnel construction and dredging operations then in progress.

Underwater construction terminated on June 16, 1974 upon completion of the backfilling operation over tunnel section No. 14 near the south tunnel island. Two months were allowed to pass before repetitive sampling was conducted in September and October to examine the final bottom configuration and prevailing bottom sediment characteristics and to compare these with pre-existing conditions.

Special attention has been given to the shoal areas adjacent to the tunnel from which backfill material was removed during the construction. Two of these areas now show pronounced modification of the previous bottom contours including some isolated depressions reaching depths of about 30 feet in close proximity to surrounding depths of 12-18 feet below mean low water. These changes in the bottom topography are expected to persist for a considerable period pending further modifications in the future. Several criticisms of the dredging operations involved are presented along with a discussion of possible detrimental effects.

Description of Location

The second Hampton Roads Tunnel is located in the Hampton Roads Channel south of Old Point Comfort in Hampton, Virginia. This area falls at the seaward boundary of the James River Estuary at its engrance to Lower Chesapeake Bay (NOAA, National Ocean Survey Chart 400). The channel at the tunnel crossing is U-shaped in cross-section, attaining depths of between 50 and 65 feet; the tunnel causeways to the north and south extend across shallow shelves inside the 18-foot depth contour. The shelves contain elongate sandy shoals near the channel edge (Hampton Bar to the north, Sewell's Point Spit and Willoughby Bank to the south) whose outlines are predominantly shaped by tidal currents. Along the shore, two large wave-built spits (Willoughby Spit and Old Point Comfort) protrude into Hampton Roads Harbor. The configuration of these spits indicate a pattern of wave-dominated sand transport from seaward which in turn contributes to tidally-controlled subaqueous sand bodies. In the region immediately east of the tunnel transect, depths increase from 65 feet to approximately 95 feet along the channel axis off the eastern end of Old Point Comfort. The bottom sediments within this depression consist chiefly of soft silts and clays.

Bottom Sediments-Channel Area

Eleven short cores between 5 and 10 inches (12-25 cm) in length were obtained on October 11, 1974 at the positions shown in Figure 1. The sectioned cores are shown in Figure 2. In general, these cores show similar sediment types as compared to the cores previously obtained prior to tunnel excavation. Cores 1P through 6P, however, are capped by varying amounts of medium to coarse quartz sand at the surface which changes abruptly to fine sand, silt and clay lower in

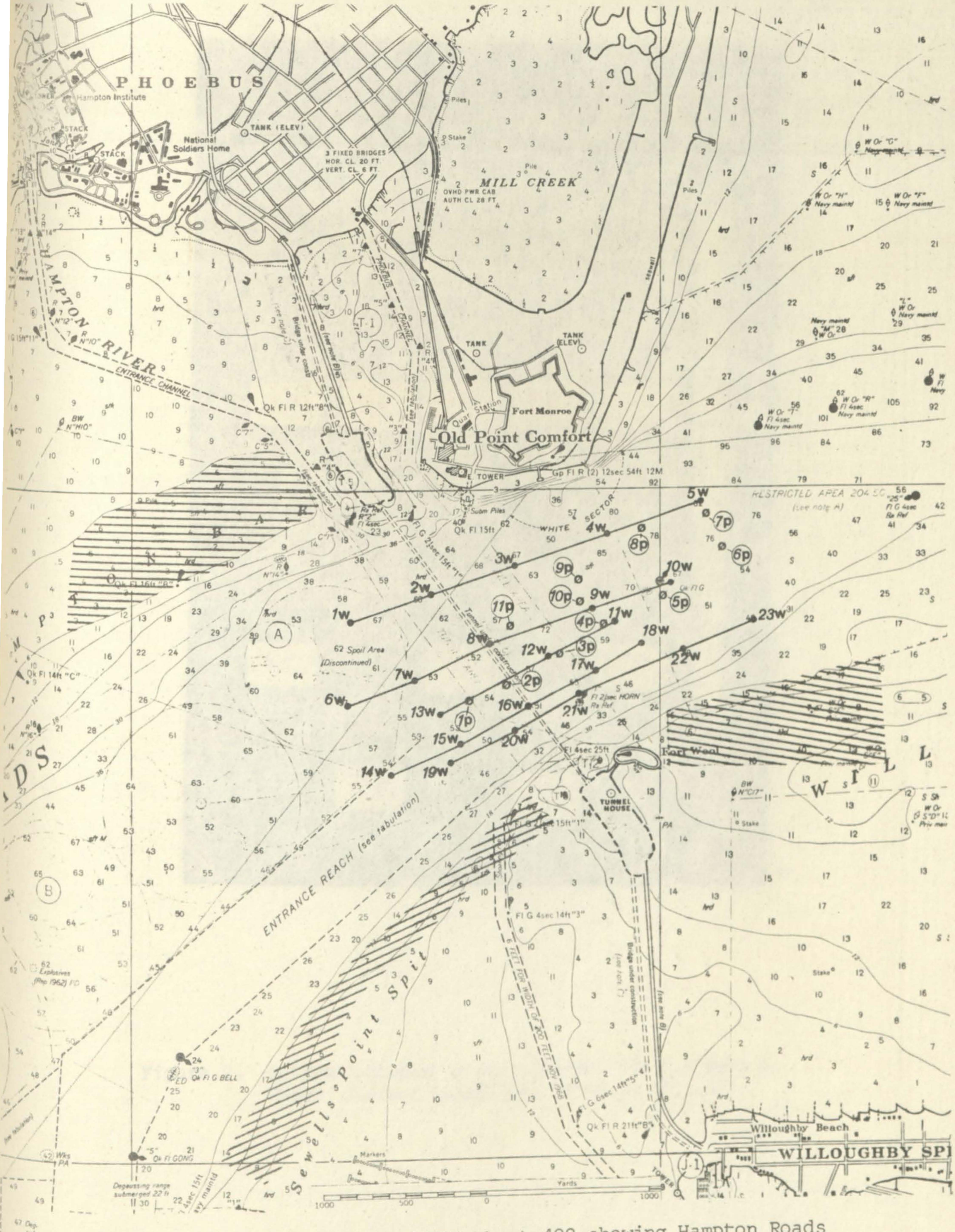


Figure 1. Reproduction of NOS chart 400 showing Hampton Roads bottom profile and core sample locations. Hatched zones are designated borrow areas.

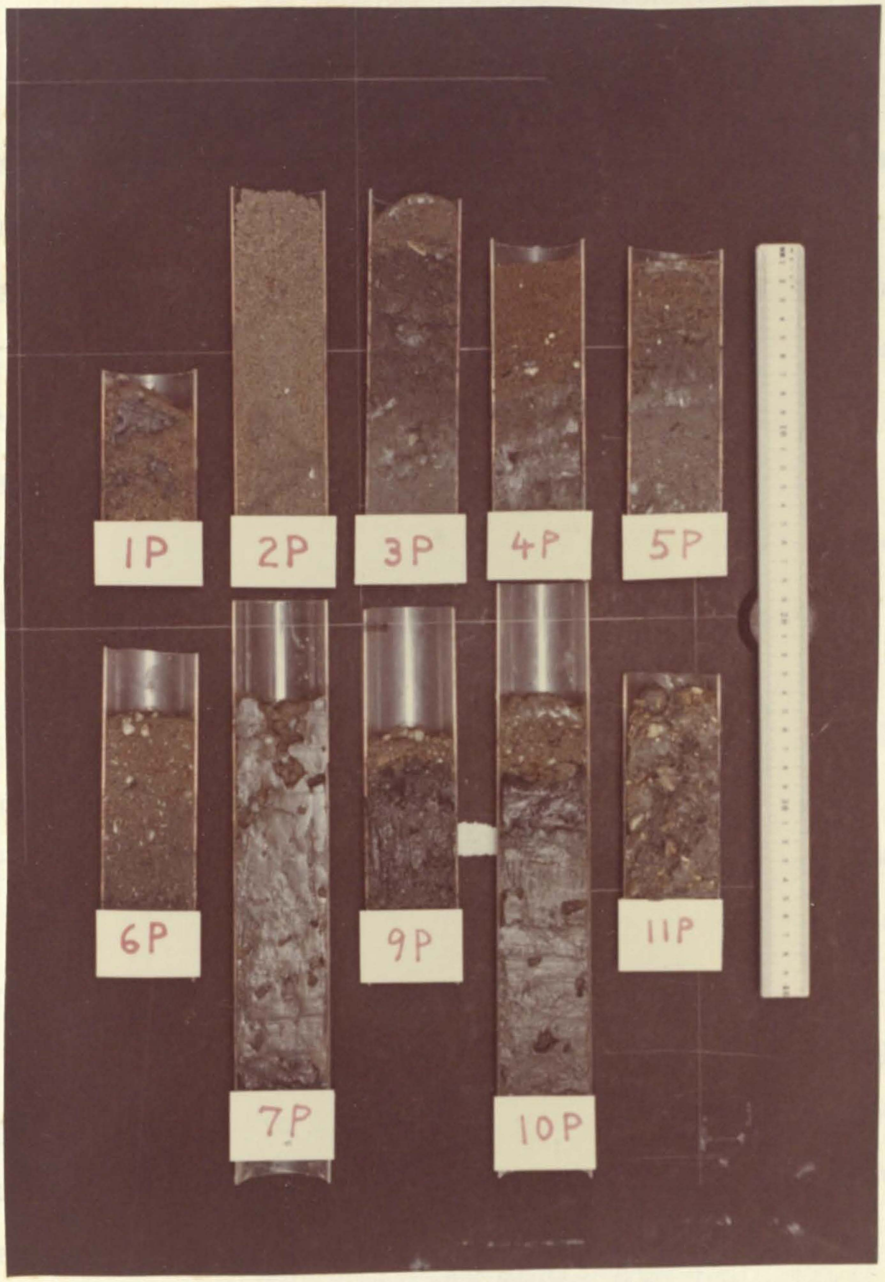


Figure 2. Bottom sediment cores obtained in the Hampton Roads channel (positions shown in Fig. 1).

the cores. This coarse surface sediment, well-sorted and containing little or no fines, is undoubtedly the tunnel backfill material which thus appears to have been widely distributed by bottom currents.

Core 1P was taken in a hard bottom with difficulty so that very little sediment was retrieved; it shows, however, some stiff clay inclusions embedded within coarse sand (Fig. 2). These clay inclusions or "mud galls" are indicative of reworked bottom deposits, apparently transported from an area southwest of the tunnel transect as noted in an earlier interim report. Their presence is a further indication of active bottom sediment movement in the vicinity of the tunnel transect.

Cores 7P through 11P are typical of the bottom sediments found in depths greater than 60 feet; i.e., mostly soft silts and clays. Cores 7P and 8P (not shown in Fig. 2) consisted entirely of silt and clay except for an abundance of the small clam *Mulinea lateralis* found living at the surface. Cores 9P and 10P contain soft organic mud capped by medium quartz sand and shell fragments with fewer numbers of *Mulinea* living at the surface. Core 11P consists of unconsolidated silt and clay mixed throughout with coarse sand and large shell fragments.

Bottom Profiles-Channel Area

Figures 3 and 4 contain five continuous bottom profiles run using a Raytheon Model DE-719 precision survey fathometer. The numbers marked on each profile correspond to the positions shown in Figure 1. Each numbered position was obtained by sextant angles using the three-point fix method at regular intervals with the boat moving at slow speed.

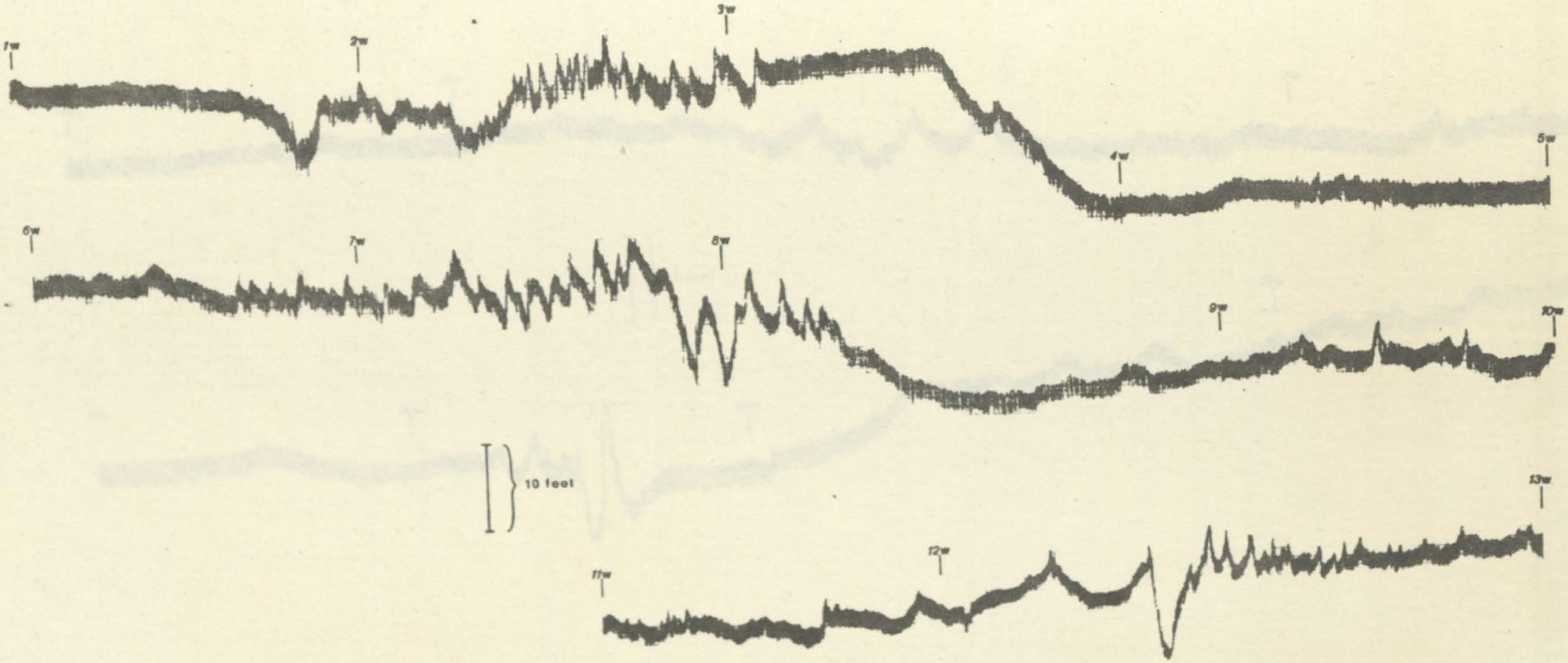


Figure 3. Bottom profiles, Hampton Roads channel (positions 1w-13w, fig. 1).

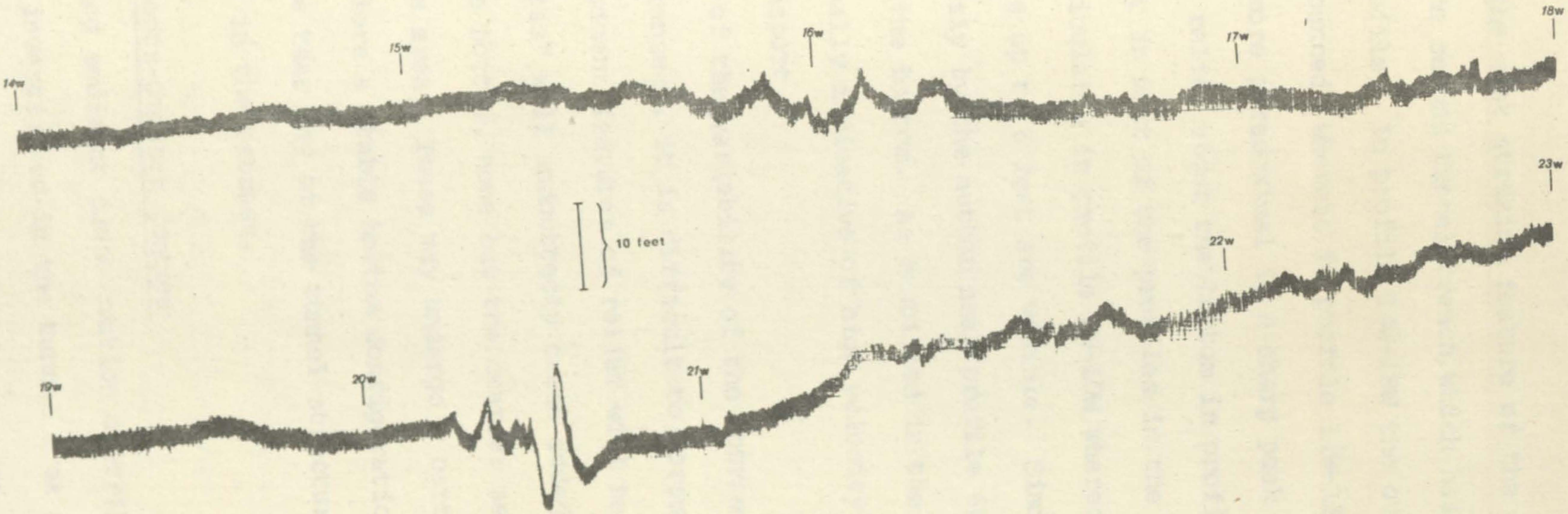


Figure 4. Bottom profiles, Hampton Roads channel (positions 14w-23w, fig. 1).

Perhaps the most striking feature of the five profiles is the outline of the second tunnel trench which has a different appearance in every profile. In profile 14W-18W the outline of the trench is not very pronounced whereas in profile 11W-13W a 10-foot hole can be seen. Still more paradoxical is a sharp peak having almost 15 feet of vertical relief about the bottom in profile 19W-23W. Additional relief is present in most of the profiles in the form of asymmetrical sand waves, particularly in profile 6W-10W wherein a number of waves having amplitudes up to 6 feet are visible. Similar bedforms were reported previously by the author near profile 6W-10W prior to dredging this portion of the bottom. As mentioned in the interim report, such features are usually indicative of high velocity bottom currents and active sand transport.

In view of the variability of the bottom profile in the vicinity of the tunnel transect, it is difficult to foresee how permanent any of the more prominent features of relief will be. Inasmuch as the present "roughness" will undoubtedly cause added turbulence in water flowing near the bottom, none but the coarser sediments are expected to remain in the area. These may undergo a certain amount of lateral displacement before a stable bottom configuration is reached, though it is improbable that any of the tunnel structures themselves would ever be exposed in the process.

Suspended Sediments-Organic Content

Suspended sediment concentration distributions in both time and space were investigated in the tunnel area prior to and during dredging operations. These distributions were discussed in detail in the interim report. Basically, the results showed that normal concentration levels at the surface vary between 1-5 mg/l and will reach about 5-10 mg/l during peak flood and ebb currents with moderate wind wave activity in the central channel area. While dredging was in progress, surface concentrations within the sediment plume reached only 15-20 mg/l at distances of between 100 and 1000 feet from the dredge, and a maximum of 33.1 mg/l was measured between 50 and 100 feet downstream. The generally low concentrations of suspended sediment observed were taken as evidence of rapid maxing and dispersion within the mainstream of the Hampton Roads channel.

Subsequent analyses have been performed on a number of the suspended sediment samples to determine the amount of particulate organic matter (POM) in each sample determined as the percent by weight of combustible material (loss on ignition). Although per cent POM determinations are not as precise and are inherently more variable than the concentration values themselves, there appears to be an inverse relationship between water depth and the per cent POM present in the water column. This can be seen in Figures 5 and 6 which show the relationship for a station some 1000 yards off Old Point Comfort in 75 feet of water. During both flood and ebb conditions, the POM level stood generally between 25 and 50% in the upper portions of the water column but fell to about 10-15% near the bottom where the total amount of suspended matter is normally highest. The resulting interpretation of this information is that the actual amount of POM remains small (1-8 mg/l) at any depth in comparison to the overall range in the inorganic fraction (1-80 mg/l or higher near the bottom).

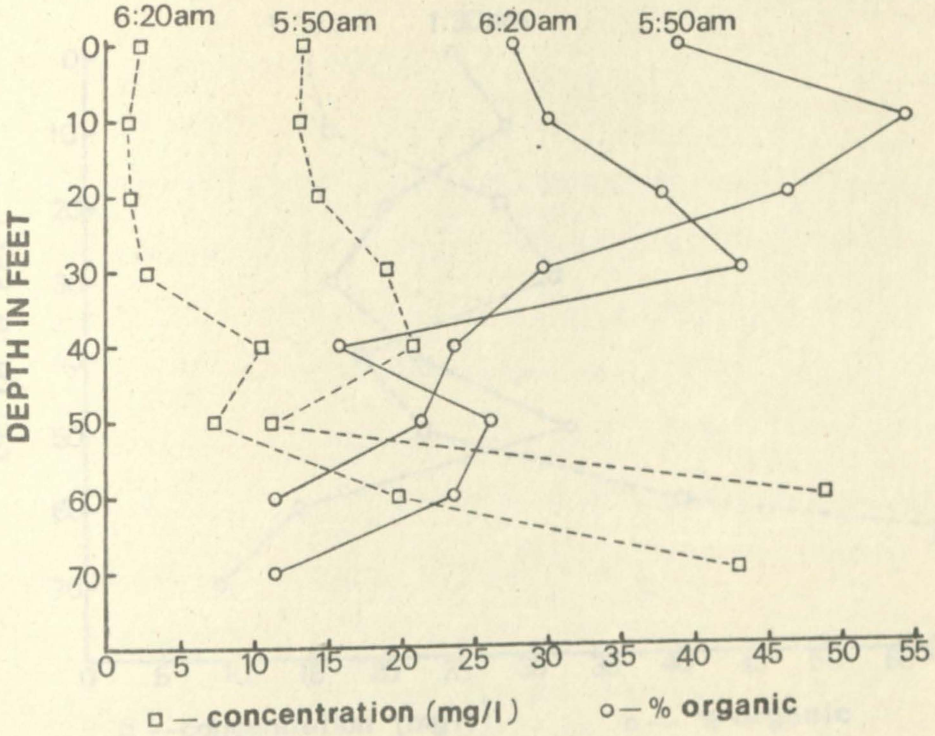


Figure 5. Suspended sediment concentration and % organic matter measured at North Buoy station (Old Point Comfort) during peak flood, 13 September, 1973.

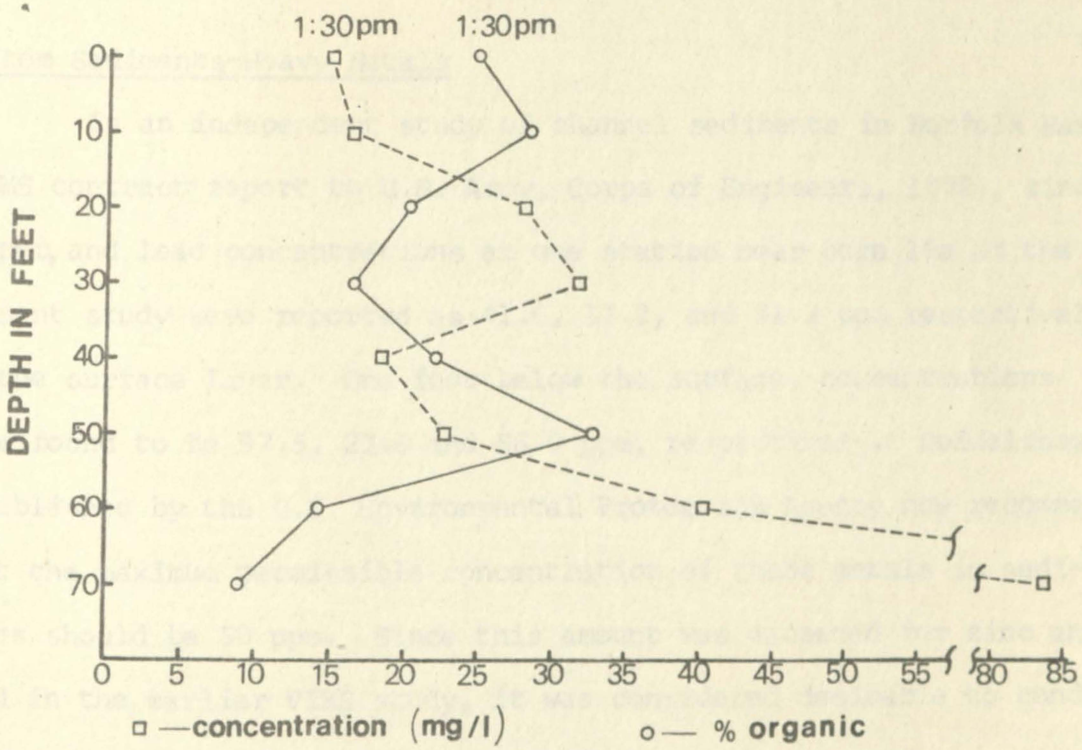


Figure 6. Suspended sediment concentration and % organic matter measured at North Buoy station (Old Point Comfort) during peak ebb, 13 September, 1973.

An important question at this point involves the amount of POM found in the plume generated by dredging. If the dredged material contained a disproportionately high level of organic matter, this could conceivably result in oxygen depletions in some areas. Samples collected during dredging, however, contained no more than 2 mg/l POM in any part of the surface plume, well within ambient levels.

Bottom Sediments-Heavy Metals

In an independent study of channel sediments in Norfolk Harbor (VIMS contract report to U.S. Army, Corps of Engineers, 1972), zinc, copper, and lead concentrations at one station near core 19a of the present study were reported as 41.6, 17.2, and 31.2 ppm respectively in the surface layer. One foot below the surface, concentrations were found to be 97.5, 23.6 and 56.9 ppm, respectively. Guidelines established by the U.S. Environmental Protection Agency now recommend that the maximum permissible concentration of these metals in sediments should be 50 ppm. Since this amount was exceeded for zinc and lead in the earlier VIMS study, it was considered desirable to conduct further analyses of the heavy metals in the area.

Five short cores taken in August, 1973, at the positions shown in Figure 7 were analyzed for zinc, copper, cadmium and lead concentrations in the sediment. These determinations were made by digesting one gram sediment samples in concentrated nitric acid for 24 hours and then analyzing them by atomic absorption spectrophotometry using a Varian Techtron instrument, Model AA-5. Results of the analyses are given in Table 1.

It is clear from the data in Table 1 that the finer the sediment, the higher the concentration of the metal in question. This is due to the large increase in particle surface area with decreasing grain size and the higher availability of sites for metal absorption per unit mass of material. However, it is also clear that copper and cadmium levels are nevertheless quite low, with zinc and lead showing the greatest amount of variation and also the highest maximum levels. Zinc in particular exceeds the EPA limit of 50 ppm at various positions in three of the five cores while lead exceeds 50 ppm only at the base of core 19a.

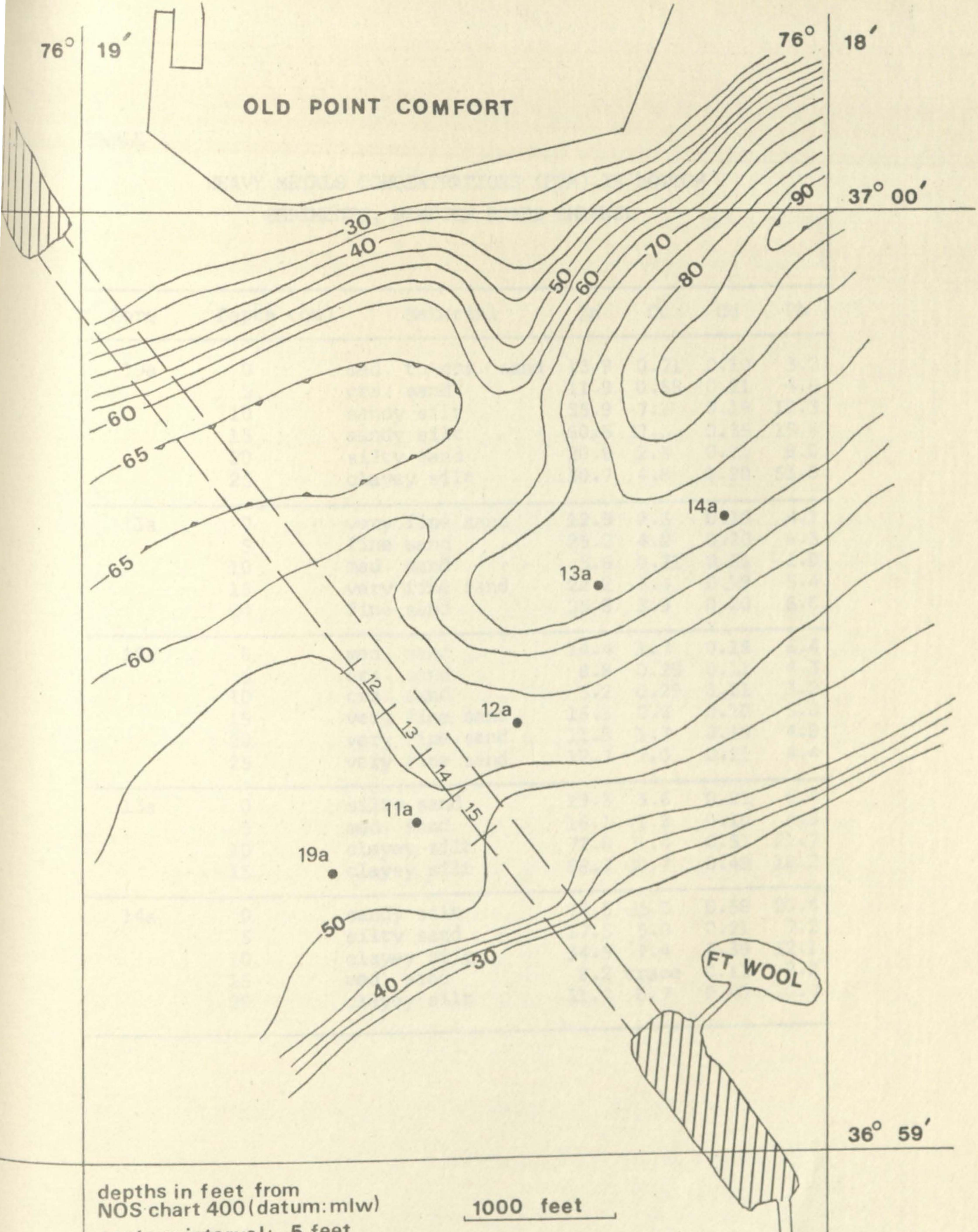


Figure 7. Positions of bottom cores collected in August, 1973, and analyzed for heavy metals concentrations.

TABLE 1

HEAVY METALS CONCENTRATIONS (PPM) IN BOTTOM SEDIMENTS, HAMPTON ROADS CHANNEL

Core	Depth (cm)	Material	Zn	Cu	Cd	Pb
19a	0	med. to crs. sand	13.9	0.71	0.10	3.2
	5	crs. sand	11.9	0.58	0.21	4.6
	10	sandy silt	35.9	7.1	0.19	12.3
	15	sandy silt	60.5	10.3	0.35	15.6
	20	silty sand	20.6	2.3	0.31	8.0
	25	clayey silt	30.7	4.8	0.20	53.0
11a	0	very fine sand	12.9	2.3	0.10	4.1
	5	fine sand	25.2	4.2	0.20	6.3
	10	med. sand	5.6	0.21	0.21	2.0
	15	very fine sand	22.2	3.4	0.19	5.4
	20	fine sand	25.8	3.9	0.20	6.6
12a	0	med. sand	14.4	1.7	0.18	6.4
	5	crs. sand	8.8	0.29	0.11	4.3
	10	crs. sand	3.2	0.29	0.21	3.2
	15	very fine sand	16.5	2.6	0.10	5.0
	20	very fine sand	11.8	1.7	0.19	4.0
	25	very fine sand	12.7	2.0	0.21	4.4
13a	0	silty sand	19.3	3.6	0.21	6.4
	5	med. sand	16.1	1.9	0.10	4.8
	10	clayey silt	72.8	11.4	0.51	21.7
	15	clayey silt	68.7	10.7	0.49	18.2
14a	0	sandy silt	76.5	15.3	0.58	20.4
	5	silty sand	17.5	5.0	0.21	7.2
	10	clayey silt	34.5	7.4	0.30	12.1
	15	med. sand	2.2	trace	0.11	2.2
	20	clayey silt	31.7	6.7	0.40	10.7

DREDGING IN BORROW AREAS

Background

Locally-dredged fine to medium sands were utilized in the construction as ordinary backfill. Ordinary backfill was used as surcharge material on the north and south tunnel islands and as part of the fill covering the tunnel tube sections lying in the Hampton Roads channel.

Three areas adjacent to the tunnel construction project were designated as borrow areas for the purpose of obtaining backfill material. These include 1) the Willoughby Bank borrow area east of Fort Wool, 2) the Sewell's Point Spit borrow area southwest of the south tunnel island, and 3) the Hampton Bar borrow area west of the north tunnel island. All three sites are shown in Figure 1 (hatched areas). The net amounts removed from each area are listed in Table 2 according to estimates received from the dredging contractor. Also, approximately 1,665,000 cubic yards of bottom material was removed during excavations of the tunnel trench. Of this amount, about 83% was useable as ordinary backfill; the remaining 17% was considered too fine and was transported by barge to the Craney Island spoil disposal facility. The greatest portion of the useable material from the trench excavation was temporarily stored in the Willoughby Bank borrow area.

TABLE 2. NET AMOUNTS REMOVED FROM DESIGNATED BORROW AREAS

Borrow Area	Quantity (cubic Yards)	Removal Period
Willoughby Bank	275,000	3/26/74 to 4/10/74
Sewell's Point Spit	400,000	5/11/74 to 6/14/74
Hampton Bar	325,000	1/11/73 to 1/28/74
Total	1,000,000	

Methods

The trench for the tunnel sections was excavated primarily by a clamshell-type dredge, with part of the trench near the islands being dug with a hydraulic dredge. The latter machine is normally more efficient in terms of its rate of removal of bottom material but could not be effectively used in the deep water, high velocity flows of the central channel. Following placement of each tunnel section in the trench, about half the tube was covered by special backfill consisting of coarse sand and gravel (this was introduced by a loading crane through a split hopper with twin downpipes). The remainder of the trench was filled with ordinary backfill removed directly from the borrow areas by hydraulic dredge, conveyed to the site by an outfall pipe, and introduced over the tunnel with a spreader barge (the spreader barge released the slurry through multiple outlets positioned 10-12 feet above the tunnel tube). A hydraulic dredge was also used to deliver the surcharge material to the tunnel islands through the open end of the outfall pipe. An aerial view of the hydraulic dredge and spreader barge in operation near the south tunnel island is presented in Figure 8.

Post-Dredging Bathymetry

A bathymetric survey of the Willoughby Bank and Sewell's Point Spit borrow areas was conducted in mid-October, some four months after dredging was completed in the latter area. Hampton Bar, however, was intermittantly worked and continues to be dredged as part of another construction project up to the present time. Hence, it is not possible to assess changes in this area due solely to the Second Hampton Roads Bridge Tunnel project.

Figure 8. Hydraulic dredge and spreader barge in operation off south tunnel island during a flood tide (note sharp boundary between wind-stirred turbid shelf water and clearer incoming bay water). Part of the outfall pipe is submerged.

Figure 9 is a map of the existing bathymetry in the vicinity of the south tunnel island. The depth contours in this figure are based on closely spaced sounding lines and cross lines positioned by visual fixes. Soundings were obtained using a recording fathometer and were reduced to mean low water values prior to plotting at a scale of 1:10,000.

The areas affected by dredging are clearly shown in Figure 9 by the irregularity of the contours and the greater depths found as compared to the previously existing bathymetry. For example, two 30-foot holes northeast of Fort Wool now appear where the depth previously was an even 6-8 feet (Ref: NOS chart 400, 37th ed., Sept. 15, 1973). Moreover, it can be seen that these holes are isolated depressions not connected to the deep water of the main channel. Selected profiles of the bottom are presented in Figures 10 and 11 showing the steep, almost vertical slopes that are typical of the dredged regions. The dredging of the Sewell's Point Spit Borrow Area, however, was conducted primarily on the slope at the channel margin and has created an irregular shelf between the 18 and 30-foot depth contours.

<u>Surface Sediments</u>

Sediments on the surface of the bottom were collected with a miniturized Van Veen grab sampler and are briefly described at selected locations on the map shown in Figure 9. East of Fort Wool the bottom consists primarily of fine sand (0.125-0.250 mm grain size) with greater amounts of silt (0.062-0.125 mm grain size) being included

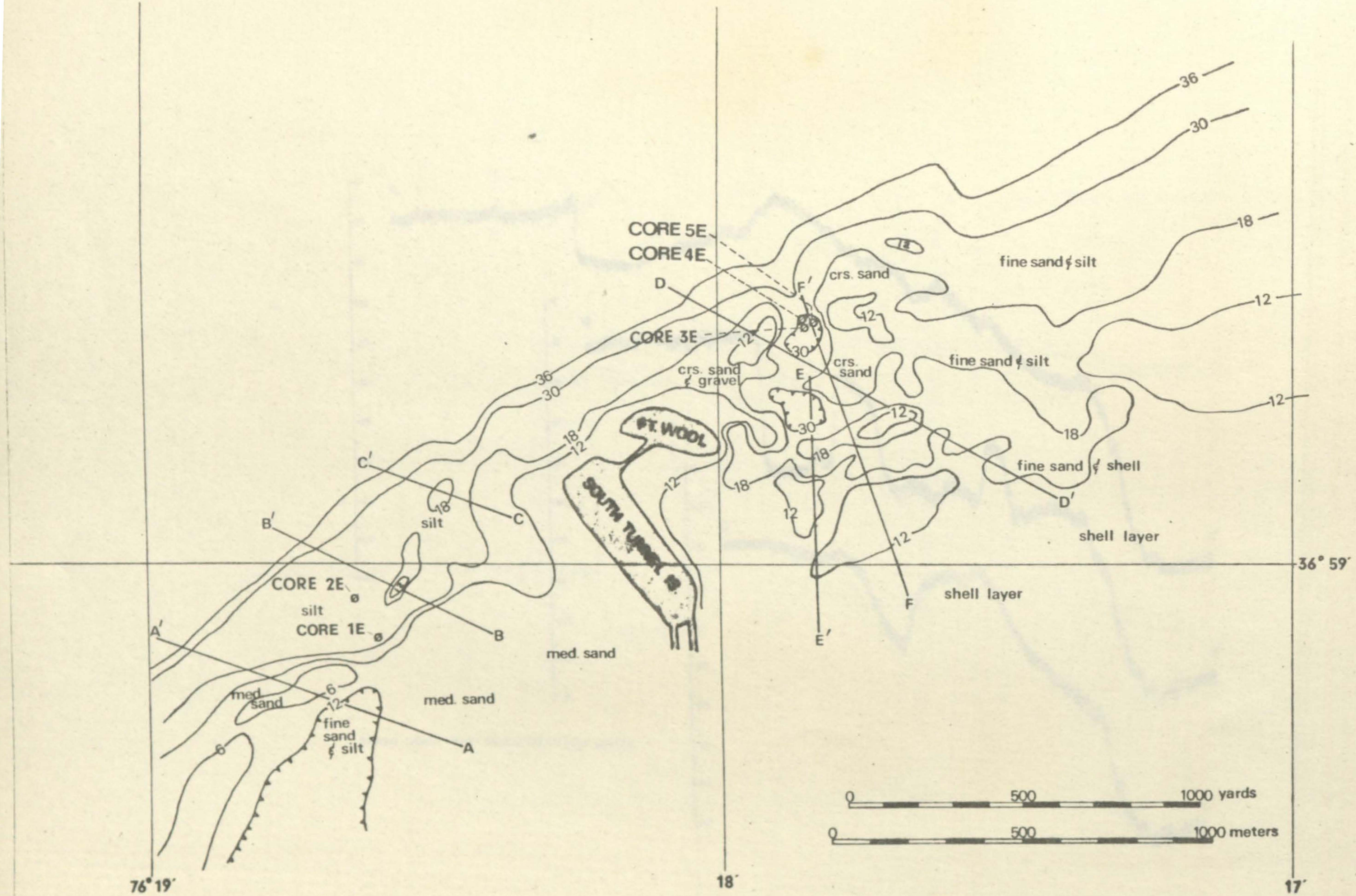


Figure 9. Map of post-dredgeing bathymetry in the south tunnel island borrow areas.

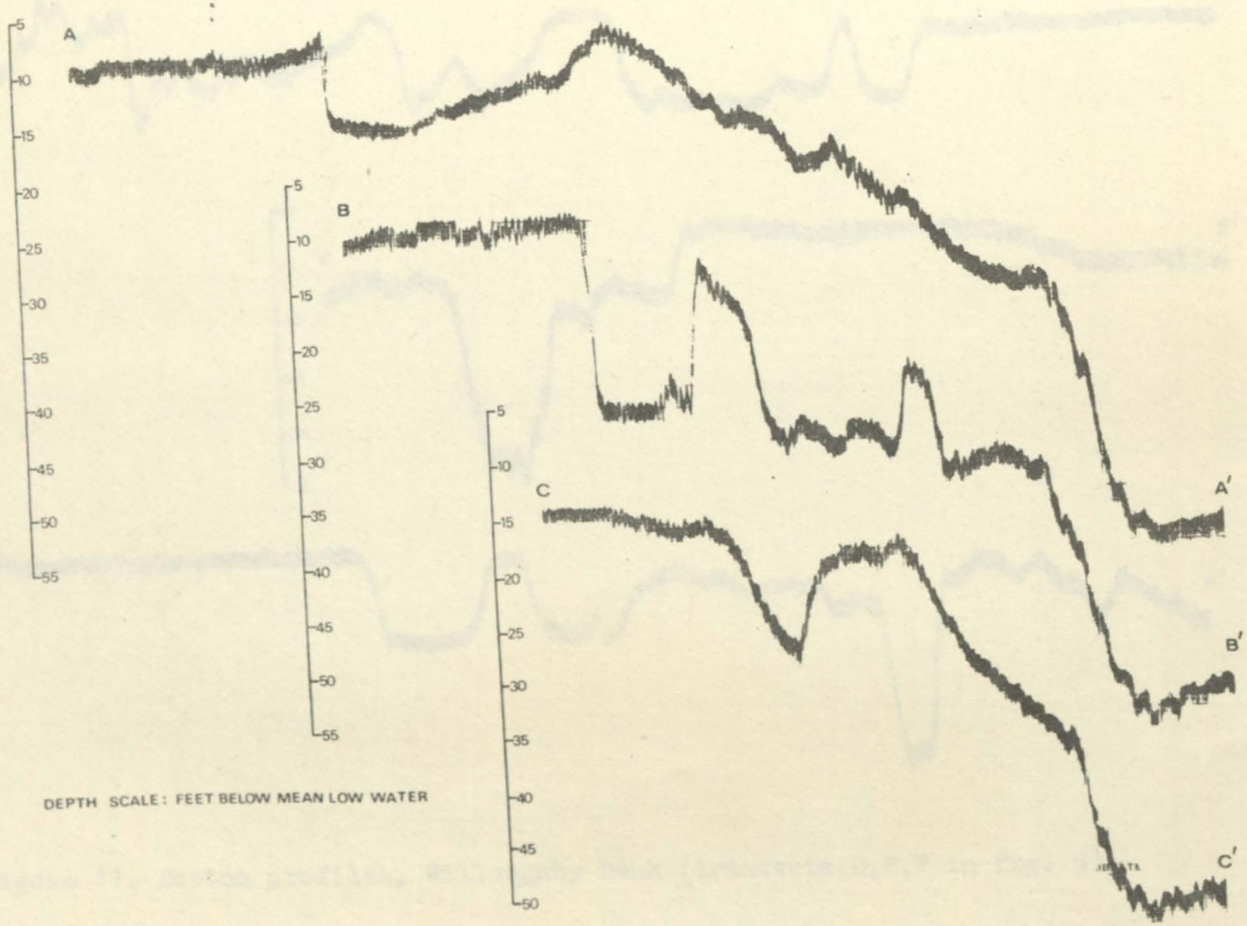


Figure 10. Bottom profiles, Sewell's Point Spit (transects A,B,C in fig. 9).

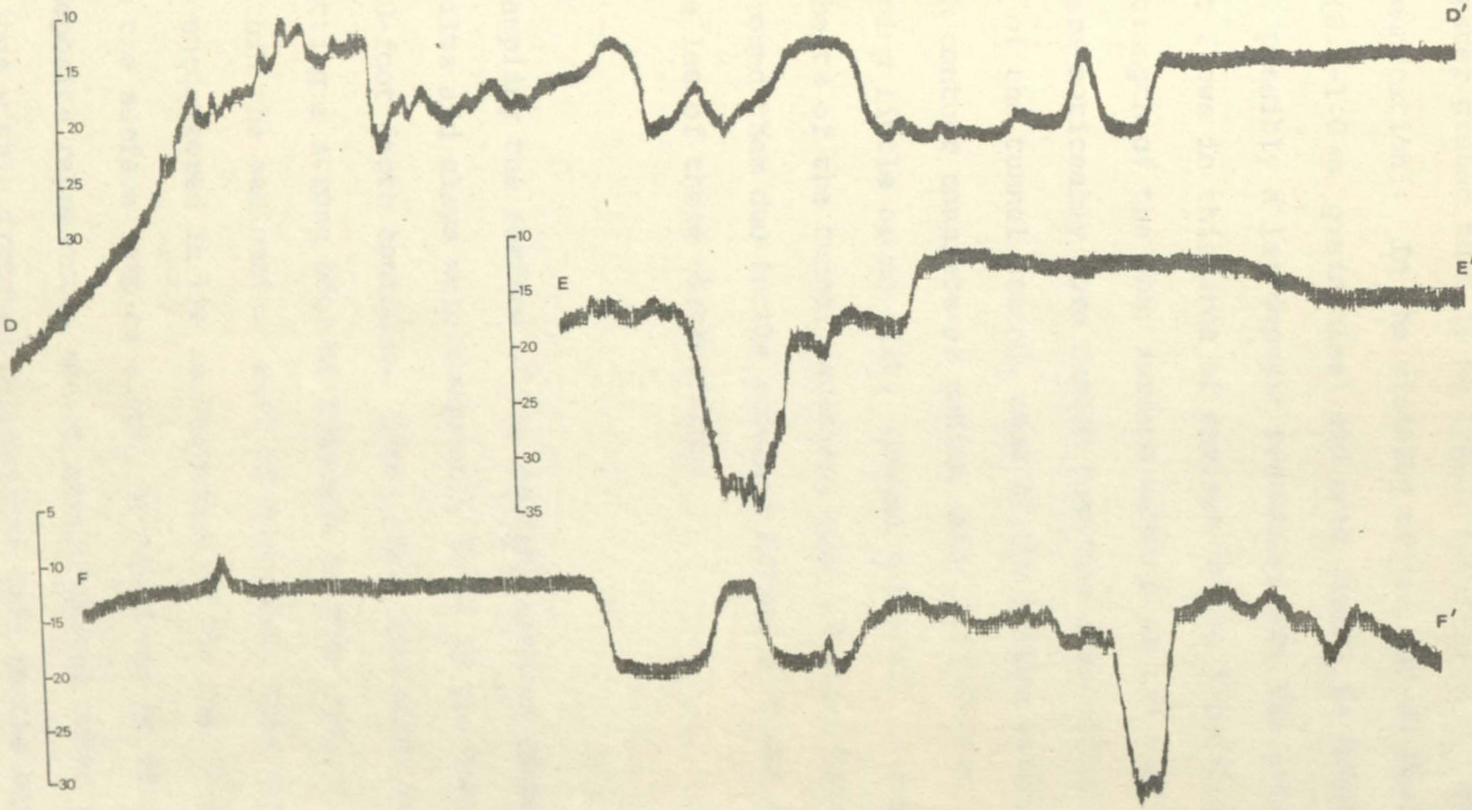


Figure 11. Bottom profiles, Willoughby Bank (transects D,E,F in fig. 9).

the channel margin. Just south of the Willoughby Bank borrow area there is an extensive layer of broken shell covering the bottom, part of an oyster ground that is no longer productive (D. Haven, personal communication). In the vicinity of the two 30-foot holes, coarse sand (0.5-1.0 mm grain size) and some gravel is found at shallower depths, possibly a lag deposit resulting from the strong currents and turbulent flows in this area of maximum bottom irregularity. During the strength of the ebb, surface water over the shoals and depressions are noticeably more turbid than the surrounding water.

West of the tunnel island, most of the bottom inside the 12-foot depth contour consists of medium sand (0.25-0.50 mm grain size) containing little or no silt. Gravel and shell is found close to the pile bents of the tunnel causeway, many of which have a slight depression around them due to the scouring action of tidal currents acting in the lee of these obstructions.

Bottom Cores

In sampling the surface of the dredged area on Sewell's Point Spit, soft silts and clays were frequently found in the regions between the 18 and 30-foot depth contours. Often these sediments were highly organic, emitting a strong odor of hydrogen sulfide indicative of oxygen depletion within the sediments. East of Fort Wool, this same type of sediment was encountered in the northernmost of the two 30-foot depressions. From the surface samples alone, it could not be determined whether these silt deposits represented recent accumulations under stagnant water conditions within isolated depressions (six months had elapsed since dredging was conducted in the Willoughby Bank area), or were part of an older, more extensive deposit overlain by other sediments. It was therefore considered necessary to examine them in greater depth. This was done using a heavily-weighted gravity corer with which five cores were retrieved measuring up to 4 feet in length. The positions of the cores are shown in Figure 9.

All five cores were carefully dewatered in the laboratory. Their plastic liners were first cut through with a table saw and the core material was then cut longitudinally with a cheese slicer. Color photographs of the numbered cores are presented in the appendix.

Core 1E - Taken from the Sewell's Point Spit area, this core consisted entirely of silt and clay, soft near the top but becoming fairly stiff near the bottom. No structures could be seen in this core and it contained no visible traces of organisms. A strong organic odor was present at the time of cutting. Total length of core 112 cm (44 in.).

Core 2E - Also from Sewell's Point Spit, this core contained fine sand at the top and in pockets lower down. A thin clay band appeared 6 cm (2.4 in.) below the surface with a sharp transition to predominantly silt-clay 18 cm (7.1 in.) below the surface. An enlarged color photograph of the partially cried core shows a heightened contrast between the sand and the silt-clay constituents. Total length of core - 130 cm (51 in.), the lower part of which consisted of stiff clay not shown in the photograph.

Cores 1E and 2E were both taken in about 28 feet of water.

Core 3E - This core was taken in the northernmost of the two 30-ft. depressions east of Fort Wool. Except for a 2 cm (3/4 in.)

cap of medium sand, it contained moderately stiff banded clay rich in organic matter. Total length of core - 25 cm (10 in.). The core was collected in 32 feet of water.

Cores 4E and 5E - These cores were quite similar to one another in their upper sections, having been collected in nearly the same location in about 30 feet of water. Core 4E was only 43 cm (17 in.) in length, however, compared to 99 cm (39 in.) for core 5E. The photograph of core 5E shows a very interesting progression from fine sand near the top to a transition zone containing first very thin clay laminations, then a mixed area of coarse sand and shell together with clay galls, below which an undifferentiated, stiff blue clay begins. Clay galls are also shown at the same level in core 4E, which, unfortunately, did not penetrate beyond this point. This sequence in 5E indicates that there were once strong currents eroding the clay near the present contact, removing all but the coarser sediments and eroded pieces of clay. These conditions were then followed at a later time by weaker currents and the deposition of finer materials (fine sand and clay laminations). Such features suggest that the underlying clay deposit predates the present configuration of the Hampton Roads Channel and shelf areas.

CONCLUSIONS

After examining the evidence amassed during this study, it is concluded that few of the changes in physical properties of the environment can be termed clearly detrimental insofar as the Second Hampton Roads Bridge Tunnel construction is concerned. Within the Hampton Roads Channel itself, the scale of the hydrodynamic forces present would seem to outweigh the effects brought about by tunnel dredging and filling operations. The impact on the environment which may eventually be felt, however, is that associated with the changes in bottom sediment properties and bathymetry within the three borrow areas. These areas are all the more deserving of attention inasmuch as they are likely to be subject to repeated demands as sources of fill in the future.

Briefly, three primary shortcomings are now evident from the point of view of physical changes caused by dredging in the borrow areas:

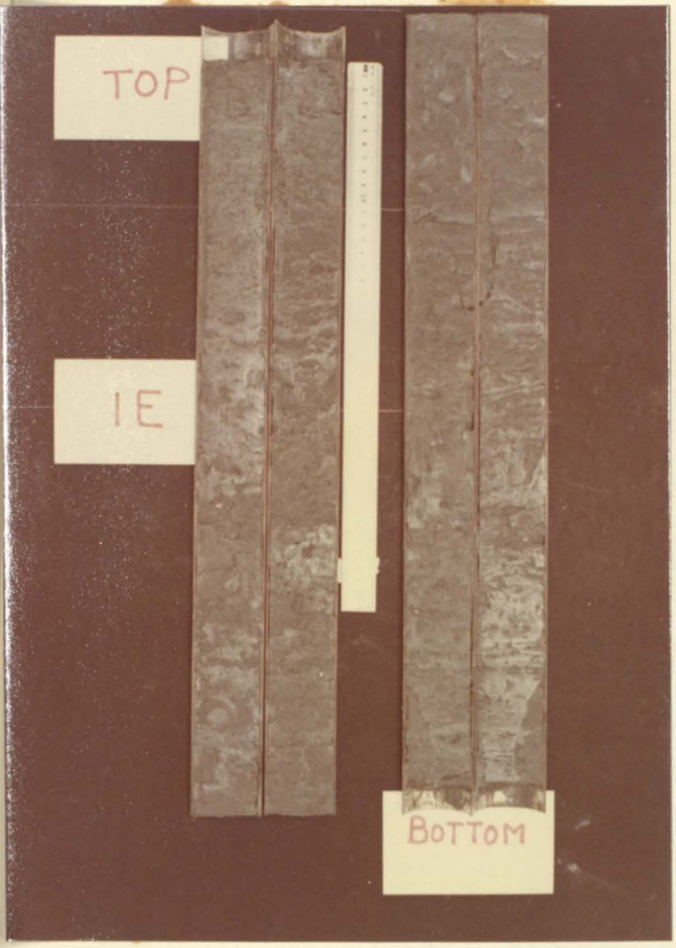
1) <u>Very little information has been made available in advance of dredging as to the nature of the deposit to be worked</u>. Without an "inventory" of the amount of suitable sand fill present and readily accessible in any defined area, controlling authorities cannot estimate the yardage that may reasonably be taken without drastically altering the configuration of the shoal or other body in question. Some knowledge of the expected percentage of silt and clay in the deposit to be worked is also needed since much of this material may be

separated and reintroduced into the environment in concentrated form under current dredging practices.

2) Bottom irregularities resulting from random removal and replacement of sediments in the borrow areas may alter local wave and current patterns which in turn affect sediment transport. East of Fort Wool the irregularity of the bottom appears to introduce additional flow turbulence and a higher level of sediment suspension near the surface, possibly contributing to the silt load moving eastward over Willoughby Bank with each ebb tide.

3) In addition to horizontal limits, vertical limits are needed as well in the area to be dredged. For example, in the Willoughby Bank and Sewell's Point Spit borrow areas, there is evidence of an extensive silt-clay formation at depths of between 25 and 30 feet below mean low water. In spite of the fact that such material is unsuitable as fill, the formation has been penetrated and left exposed in several places. The added exposure of fine, organic-rich, oxygen-poor sediments in the shelf region is undesirable in terms of water quality, growth of benthic organisms, and chemical properties, including the possible concentration of toxic metals.

A P P E N D I X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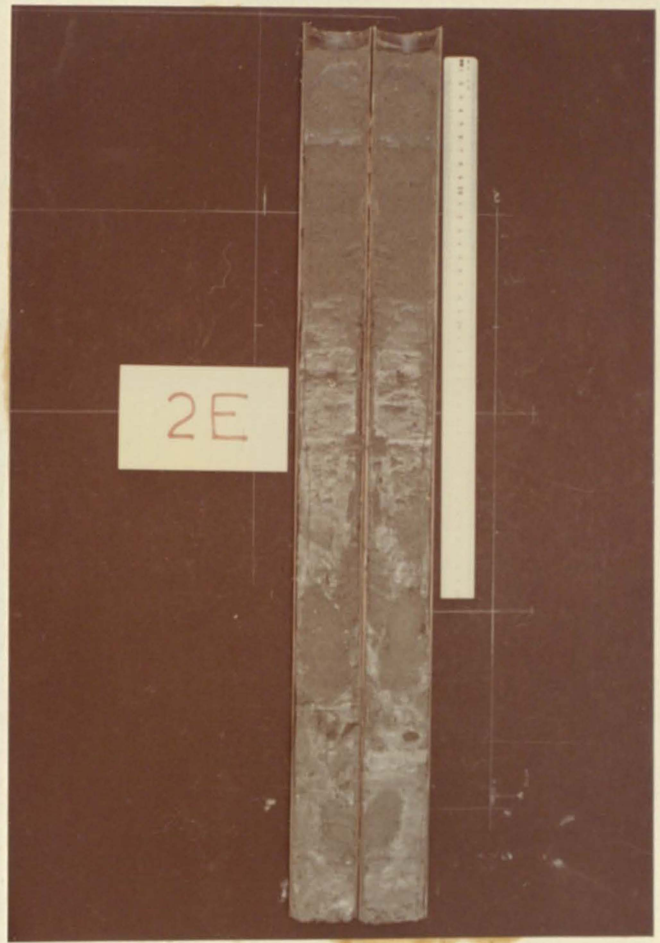
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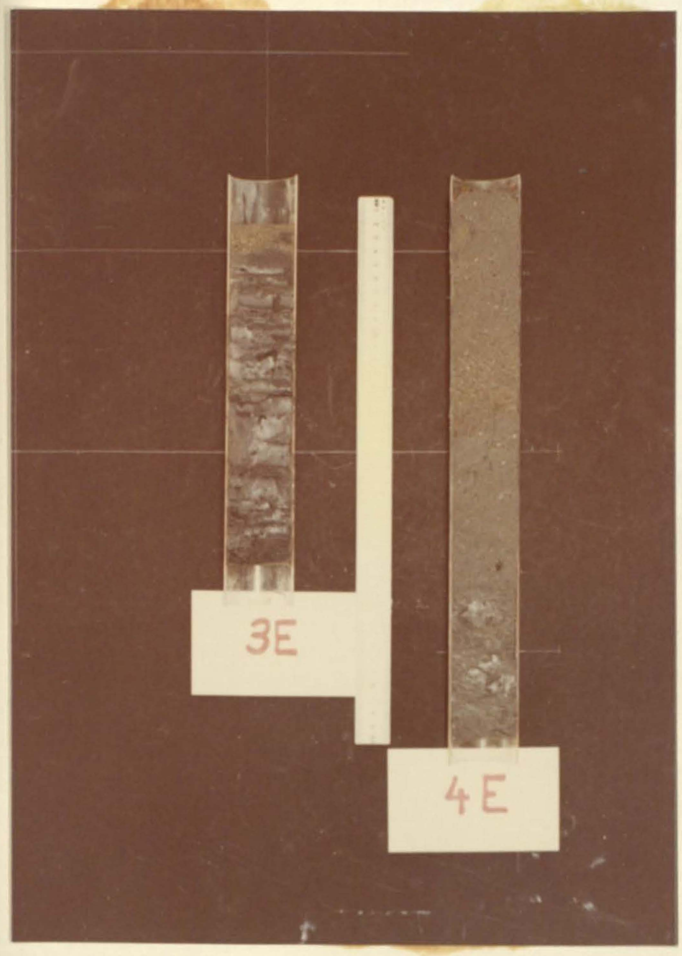
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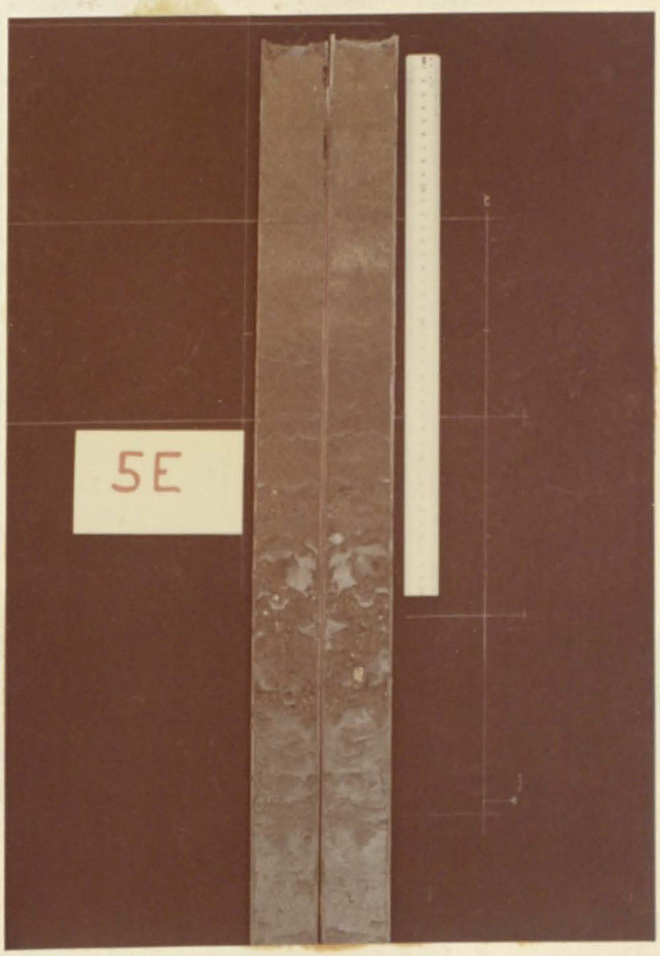
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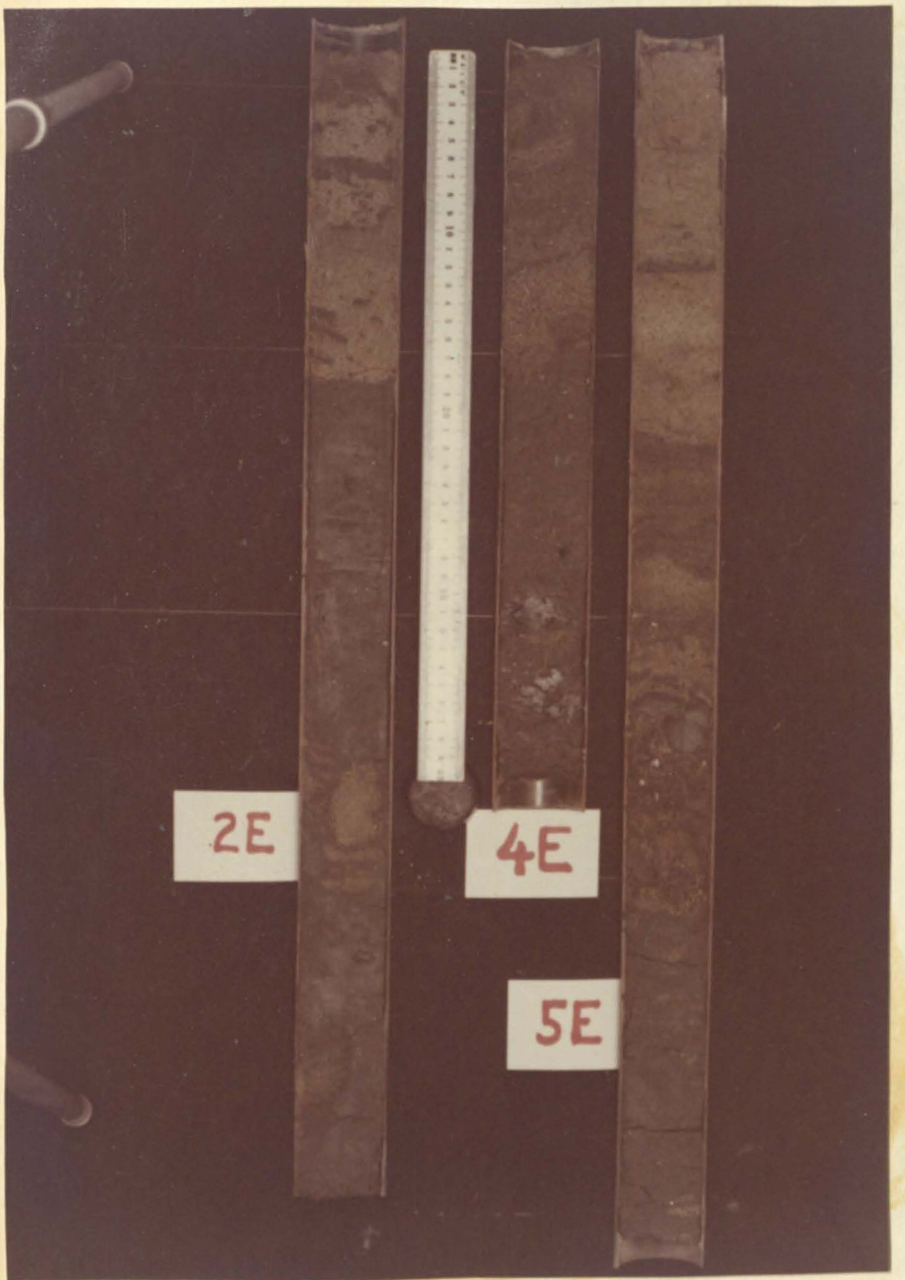
2E
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