SCIENCE APPLICATIONS, INC.

"CAPPING" PROCEDURES AS AN ALTERNATIVE TECHNIQUE TO ISOLATE CONTAMINATED DREDGE MATERIAL IN THE MARINE ENVIRONMENT

DAMOS CONTRIBUTION #11

Written Statement submitted to:

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Committee on Merchant Marine and Fisheries
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Submitted by:

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INTRODUCTION

Many of the major harbors on the northeast coast of the United States require extensive dredging of material that is contaminated with industrial waste products, principally heavy metals and PCBs. Because of the large quantities to be dredged, the lack of suitable upland or shore line disposal sites, and the prohibitive costs of transport beyond the continental shelf, placement of these sediments on the shelf is often the only viable method of disposal. During the past several years, attempts have been made to isolate small amounts of this material by covering it with cleaner material through specific management techniques such as dredging from the head to the mouth of an estuary, dredging docks and other "hot" spots during the initial phases of the operation, and combining clean material from nearby dredging operations at a common disposal point. The success of these procedures has led to the development of "capping" operations in which larger volumes of contaminated materials are dumped at a specific point and then covered with cleaner material as part of a carefully managed and monitored program of dredge spoil disposal.

One such capping operation has been conducted by the New England Division of the U.S. Army Corps of Engineers, and several other capping procedures have been proposed for ongoing and future disposal operations. The purpose of this testimony is to describe the results of the New England operation and to discuss the feasibility, costs and possible ecological effects to be expected in future capping operations.

STAMFORD-NEW HAVEN CAPPING OPERATION

The extreme shoaling conditions existing in Stamford and New Haven harbors required that dredging of these areas be conducted during 1979 to insure passage of commercial and particularly oil related traffic to terminals in those cities. Because bulk sediment analyses indicated that sediment originating from Stamford Harbor would be rich in heavy metals, management procedures were initiated to "cap" the Stamford material with silt and sand from New Haven Harbor. The objectives of these capping procedures were to isolate the enriched material from the benthic fauna and the overlying water column and to evaluate the relative merits of sand and silt as capping materials in terms of coverage, stability, effectiveness in isolating contaminants and recolonization potential.

Monitoring of the disposal operation was conducted as part of the Disposal Area Monitoring System (DAMOS) and consisted of precision bathymetric mapping of spoil distribution, visual observations of the spoil surface and margins, chemical comparisons of spoil and natural sediment and sampling of benthic populations for recolonization and bioaccumulation studies.

Baseline studies of all these parameters were made prior to disposal. Replicate precision bathymetric surveys, diver observations and chemical sampling were used during the disposal operation to monitor the volume and distribution of Stamford spoil at the disposal site, to manage the capping operation insuring coverage of the enriched spoils and to measure the thickness and distribution of capping material. Following disposal, additional replicate surveys were made and are continuing to monitor the stability of the spoil mounds created and to assess the long term effectiveness of the capping procedure.

The precision bathymetric survey monitoring procedures combined with the diver observation have resulted in data which represent a significant improvement over previous disposal monitoring efforts for several reasons including: 1) use of precision navigation control to survey at 25 meter lane spacing, 2) the nearly flat bottom available to provide a baseline datum, 3) the application of computer software to complete data sets to provide better calibration between surveys, 4) the careful management of the disposal operation to create topographic features for precision measurements of volume and 5) the ability to combine visual observations with physical measurements to more completely evaluate the environmental factors affecting the dredge material.

Whether or not these conditions can be duplicated in other areas will be seen in the future, however, this study provides a unique opportunity to accurately measure spoil volumes and evaluate the importance of such environmental parameters.

As described earlier there were two major objectives to be achieved through disposal of spoils at the Central Long Island Site. (Figure 1) These were: 1) containment and isolation of Stamford spoils by capping with New Haven material; and 2) an evaluation of the effectiveness of the procedure in general, with particular emphasis on the effectiveness of sand versus silt as a capping material. In order to compare the sand and silt caps, two disposal points were designated 1000 m north and south of the spoil mound created by the New Haven project in 1974 (Figure 1). The south site was designated for capping with silt from the inner harbor and the north site with sand from the outer breakwater area of New Haven Harbor. The North-South orientation was selected since tidal flow through the site is in an east-west direction, thus potential effects resulting from the older mound would be minimized.

Precision disposal of Stamford spoils was essential to minimize their areal distribution prior to capping. This was accomplished through installation of two, taut-wire moored buoys at the designated disposal points using a Trisponder system for navigation control. Towboat operators were then instructed to dispose of material close aboard the south side of each buoy. Even under adverse conditions, disposal generally took place within 25 meters of the designated point.

Initial disposal of Stamford material took place between March 25 and April 22, 1979 at the southern disposal point. After April 23, silt from New Haven was dumped at the south site to provide capping material, and disposal of Stamford spoils was restricted to the north site. Disposal of silt continued until June 15 when dredging was halted to prevent impact to oyster larvae by siltation caused by the dredging operation. Likewise, dredging of Stamford Harbor and associated disposal at the north site was halted on June 15. Between June 15 and June 21, the hopper dredge ESSAYONS removed sandy sediment from the mouth of the New Haven harbor and used this material to cap the north site.

Disposal of dredge spoil from Stamford Harbor at the southern site reached a total of 37,800 m^3 (based on scow load records) on April 22, 1979. A survey of the site was conducted on

CENTRAL LONG ISLAND SOUND DISPOSAL SITE

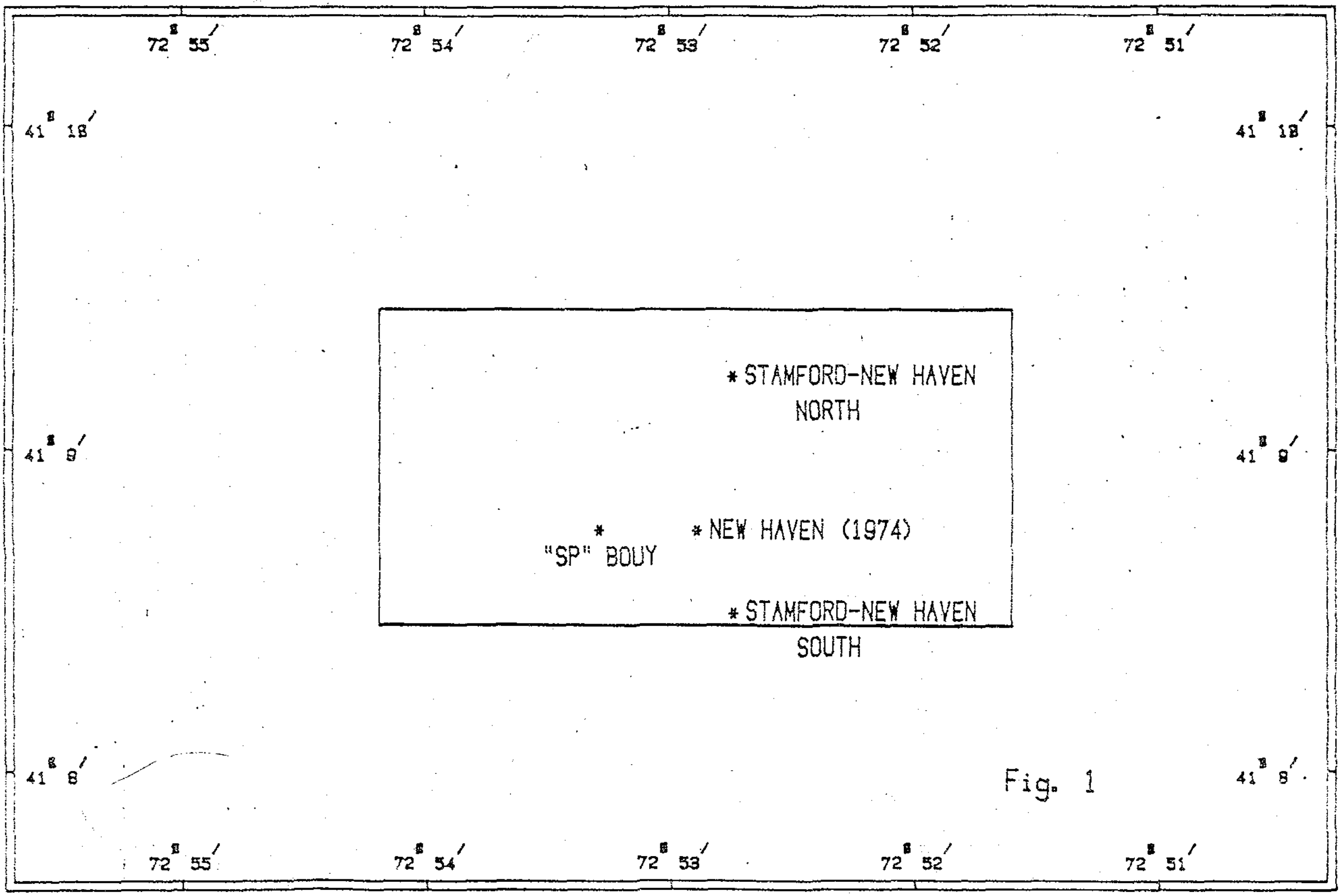


Fig. 1

April 24, to determine the distribution of spoil material prior to capping (Figure 2). This survey indicated that the disposal procedure was successful in developing a small mound approximately 100m in diameter and 1.25m thick.

Close examination of the vertical profiles for lanes 13-16 (Figure 3) indicates that the topography of this mound was quite variable, and thicknesses of two meters relative to the initial bottom were present. The rough topography exhibited in the vertical profiles was substantiated by diving observations and attributed to the cohesive nature of the spoils. Toward the margins of the spoil mound, specific barge loads could be identified as separate topographic features.

Calculations of total Stamford spoil detected relative to the baseline survey accounted for approximately 90% of the estimated volume deposited. The contour difference chart (Figure 4) indicated that there was additional material present beyond the immediate spoil mound, and it was possible that significant amounts of spoil might not be detected by acoustic measurements.

This problem was addressed through a combination of visual diver observations and precision (50m spacing) remote sampling of the fringes of the mound with a Smith-McIntyre grab. During the period of disposal an extensive population of the stalk hydroid, Corymorpha, was growing over the entire bottom. However, when dredge spoil was present to any significant degree, these hydroids were covered or destroyed. Consequently, divers could identify the boundary of the spoils by the presence of absence of these animals. Furthermore, the dark, organic spoils provided a sharp contrast to the natural, brown oxidized muds of the disposal site thus the thickness of spoils on the margins of the mound could be directly measured in the grab sampler.

The most striking result of these measurements was the rapid decrease in spoil thickness at the margins of the spoil mound. In the east and west directions the change from thickness greater than 50 cm to less than 5 cm occurred between 100 and 150 meters from the disposal point; while in the north-south direction, the change was between 50 and 100 m. In either case, it was apparent

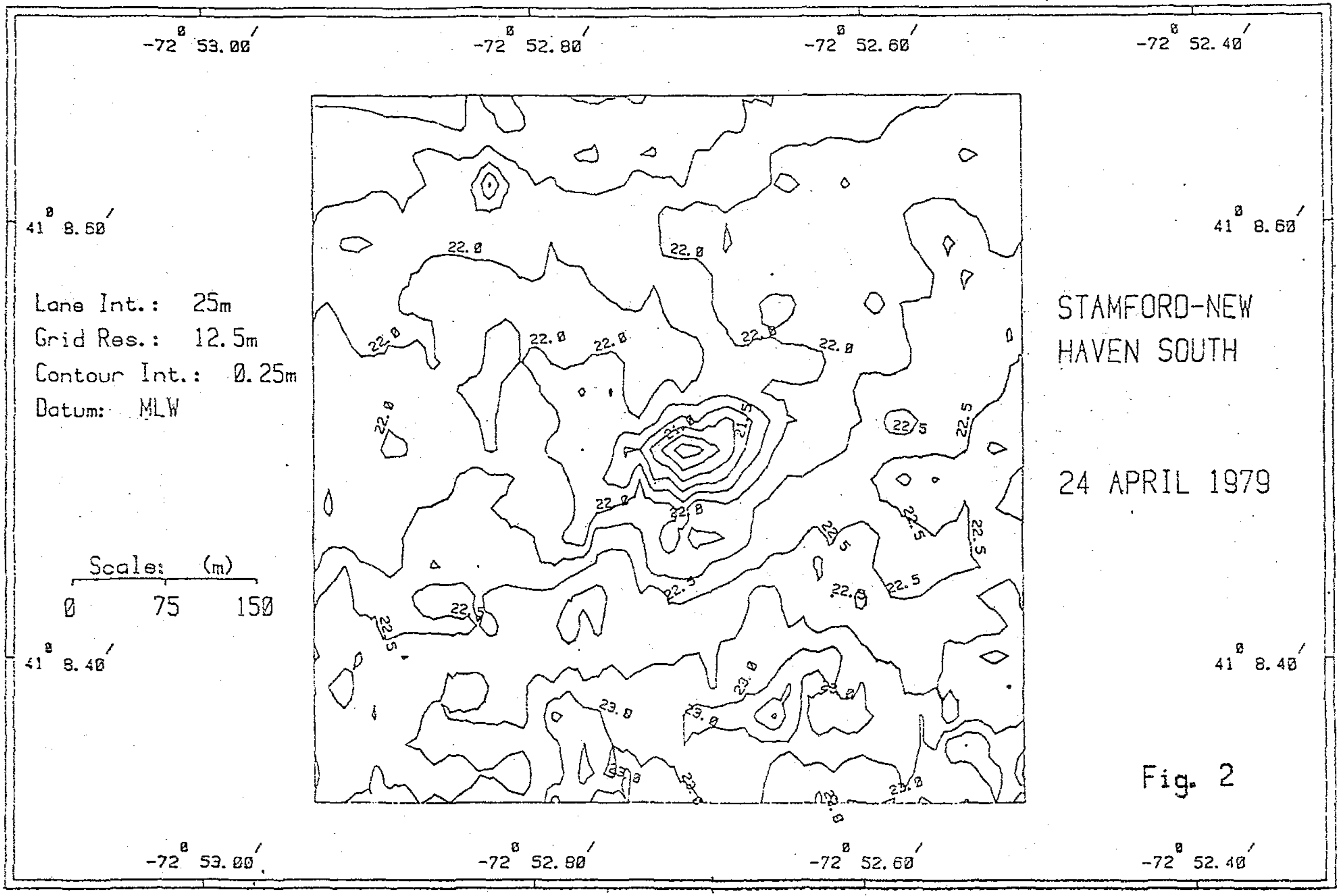

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
22.0
22.5
23.0
STAMFORD-NEW
HAVEN SOUTH
24 APRIL 1979

Fig. 2

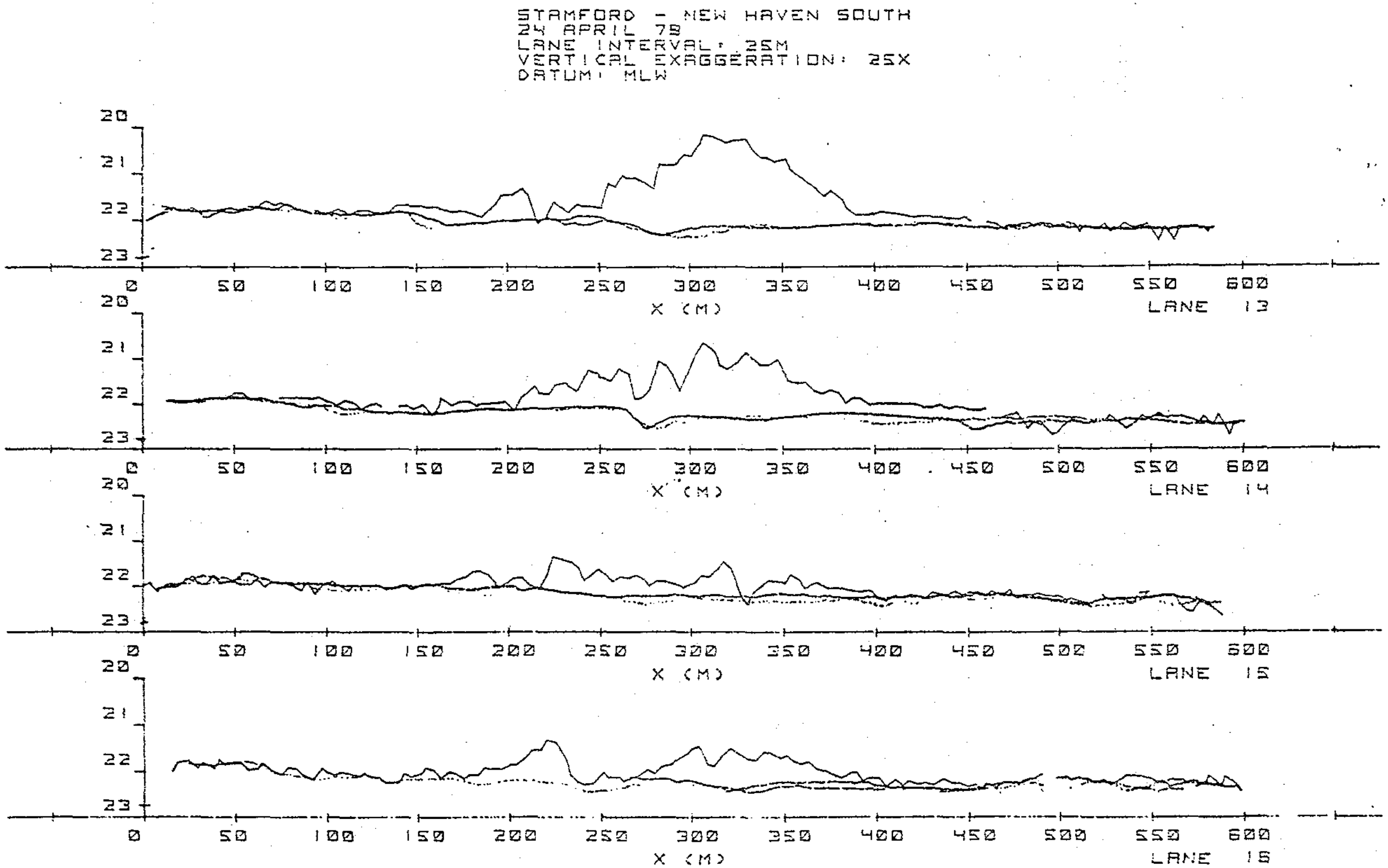

STAMFORD - NEW HAVEN SOUTH
24 APRIL 78
LANE INTERVAL: 25M
VERTICAL EXAGGERATION: 25X
DATUM: MLW
20
21
22
23
0 50 100 150 200 250 300 350 400 450 500 550 600
X (M)
LANE 13
LANE 14
LANE 15
LANE 16

Fig. 3

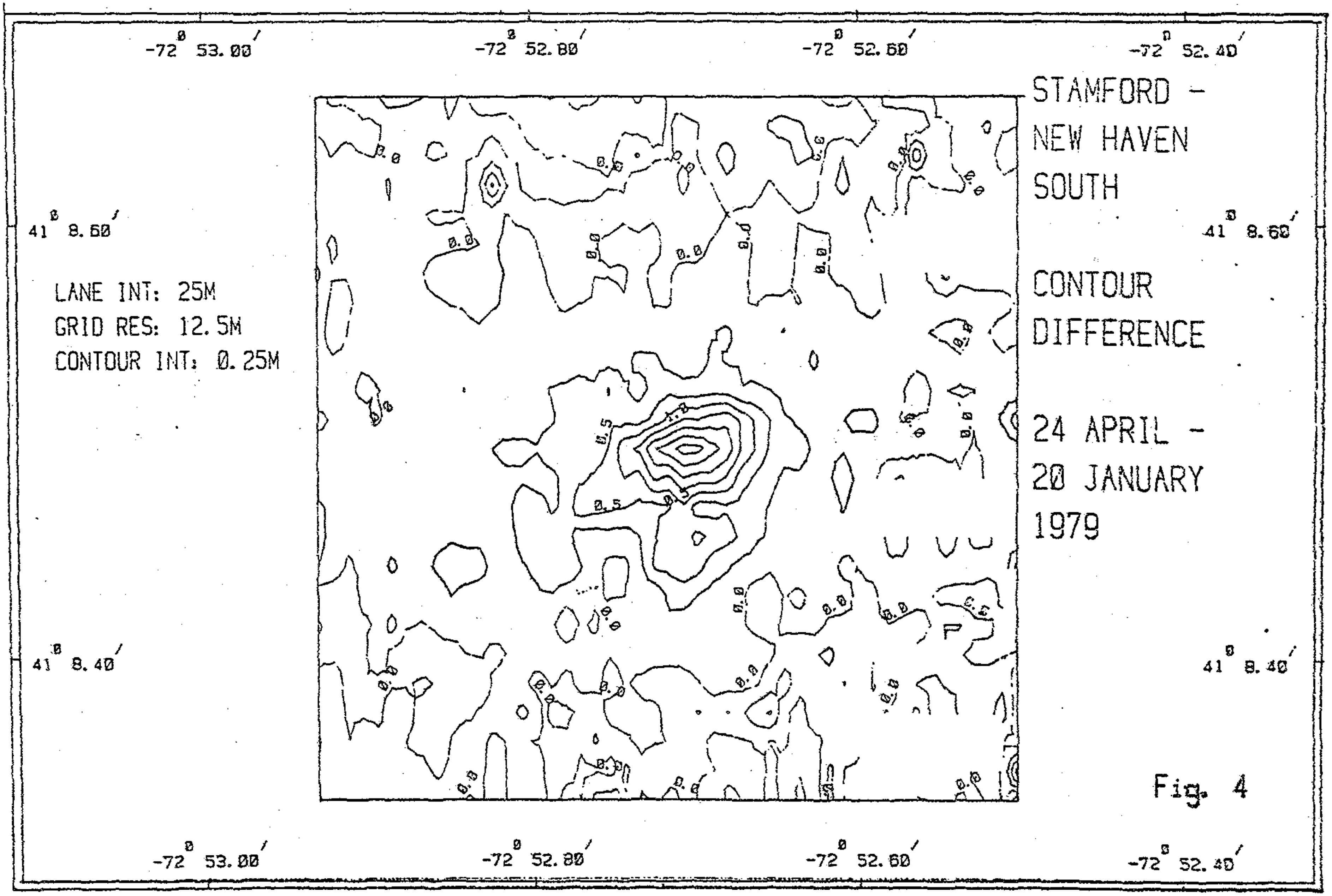

STAMFORD - NEW HAVEN SOUTH
CONTOUR DIFFERENCE
24 APRIL - 20 JANUARY 1979
LANE INT: 25M
GRID RES: 12.5M
CONTOUR INT: 0.25M
-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
0.0
0.5
1.0

Fig. 4

that the cohesive nature of the spoil material was creating a definite mound with discernable boundaries that could be detected acoustically to a spatial accuracy certainly better than 50 meters.

From these data, it is apparent that for cohesive spoils dredged with a clamshell bucket and transported by scow, most of the sediment (> 80%) is transferred to the bottom as a cohesive unit and forms a mound, while the remaining material forms a turbidite type deposit radially from the disposal point since the coarseness of the particles in the fringe areas have been observed to be inversely proportional to distance from the disposal point. Furthermore, these data indicated that the initial disposal of Stamford material was tightly controlled by the taut-wire buoy and subsequent capping with New Haven material should be successful. Disposal of additonal Stamford spoil at the north site was also accomplished successfully and a monitoring survey conducted on 21 May (Figure 5) indicated the development of a small mound similar to that observed at the south site. Twenty-six thousand cubic meters of Stamford material were deposited at this location prior to capping.

As described earlier, silt from New Haven Harbor was dumped on the Stamford material at the south site and sand from the breakwater area was used to cap the northern site. All capping procedures were completed by June 22, 1979. One June 20, a survey was made of the southern site (Figure 6) to determine the success of the silt capping operation. The contour chart and the vertical profiles (Figure 7) both indicated a distinct mound had developed at the disposal site with a minimum depth of 16 meters and a thickness of up to 4 meters over the Stamford spoils. Because the silt material from New Haven was cohesive, the resulting spoil mound did not have extensive spreading. Although the vertical profiles indicate all Stamford material was capped, future operations with silt should be designed to spread the capping sediment and reduce the thickness to some extent. The volume of New Haven spoil dumped at the south site was estimated at 76,000 m^3 from scow load measurements, of which 72,000 m^3, or 95% was accounted for by volume calculations.

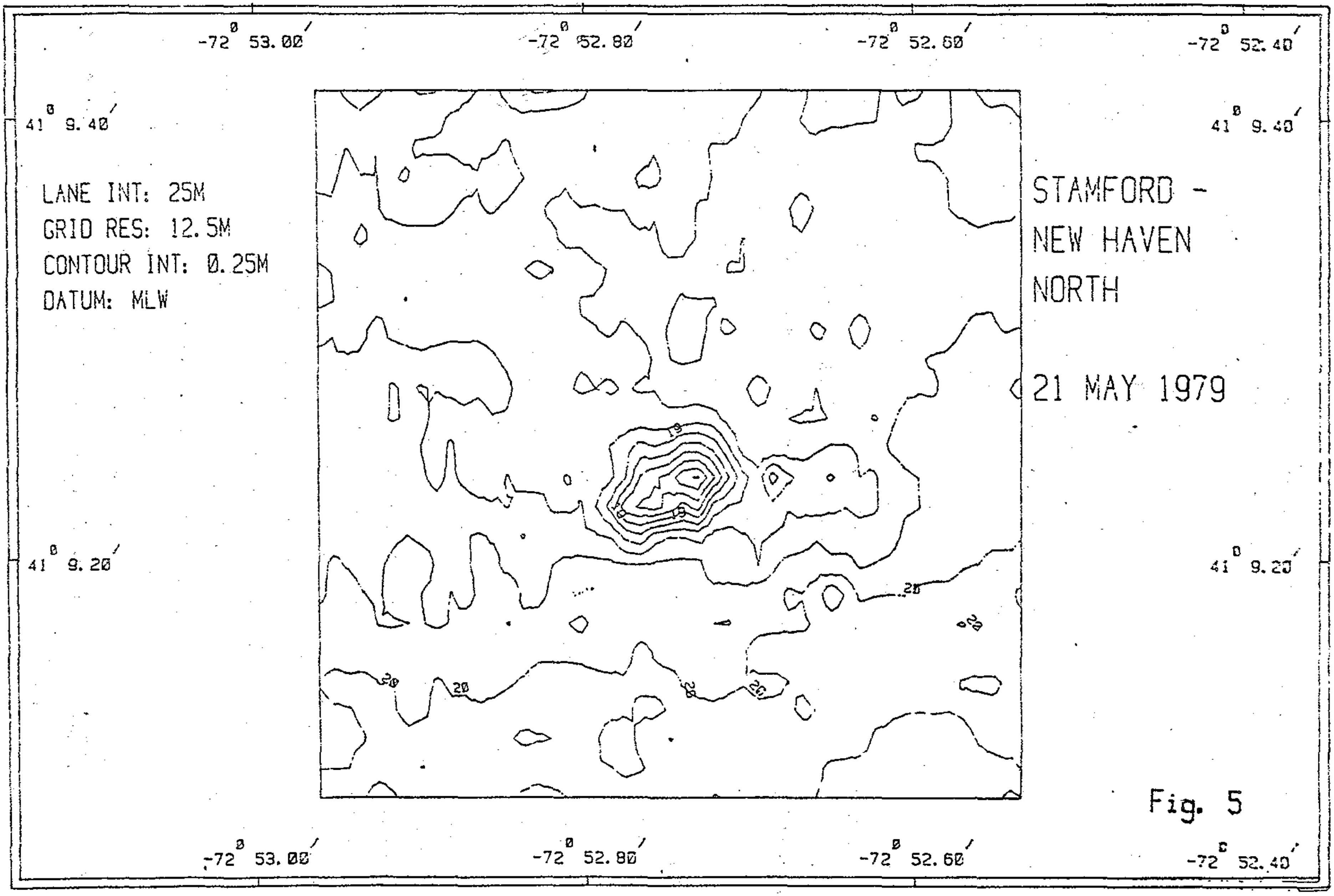
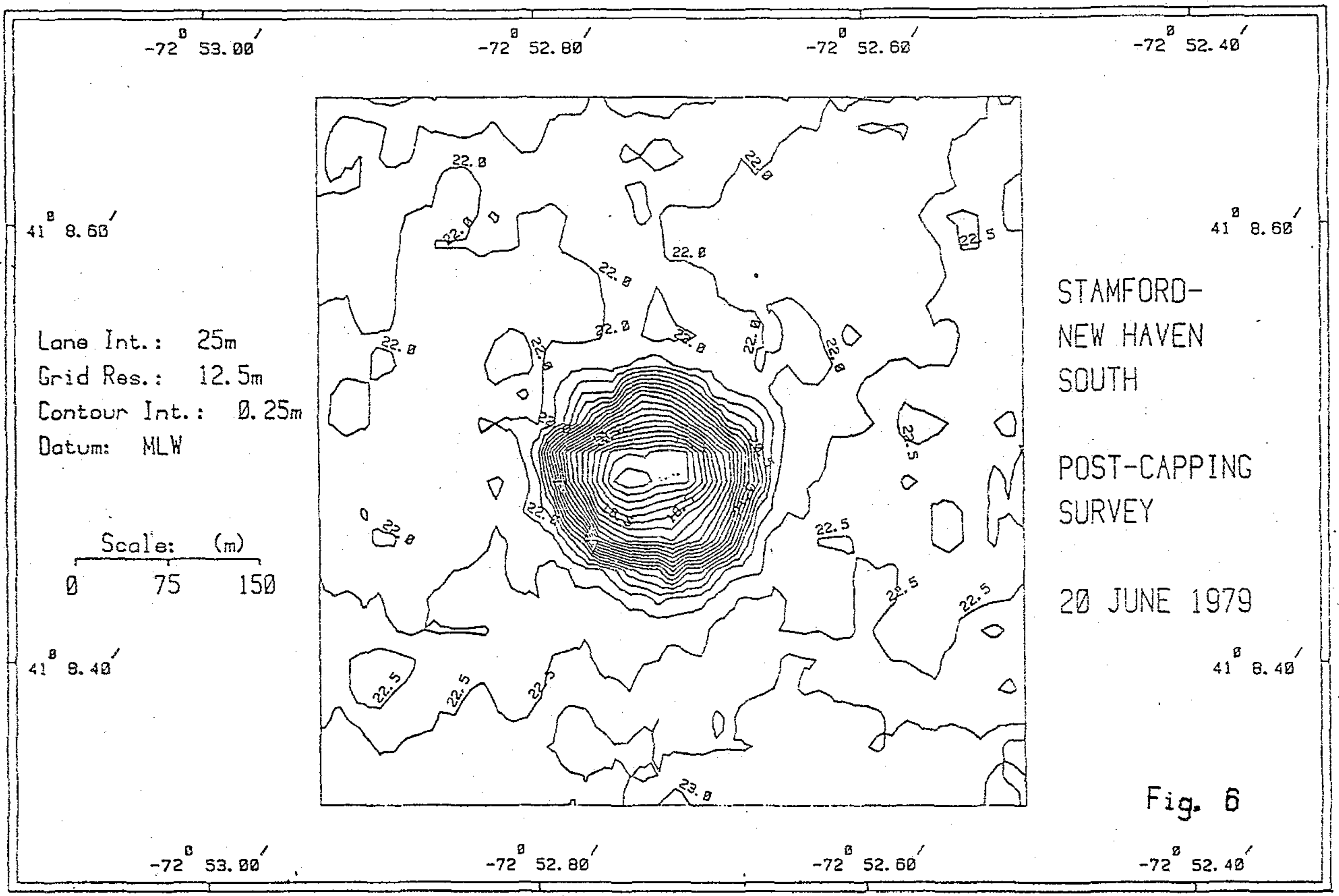

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 9.40'
41° 9.20'
LANE INT: 25M
GRID RES: 12.5M
CONTOUR INT: 0.25M
DATUM: MLW
STAMFORD -
NEW HAVEN
NORTH
21 MAY 1979
19
20

Fig. 5



-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
22.0
22.5
23.0
STAMFORD-
NEW HAVEN
SOUTH
POST-CAPPING
SURVEY
20 JUNE 1979

Fig. 6

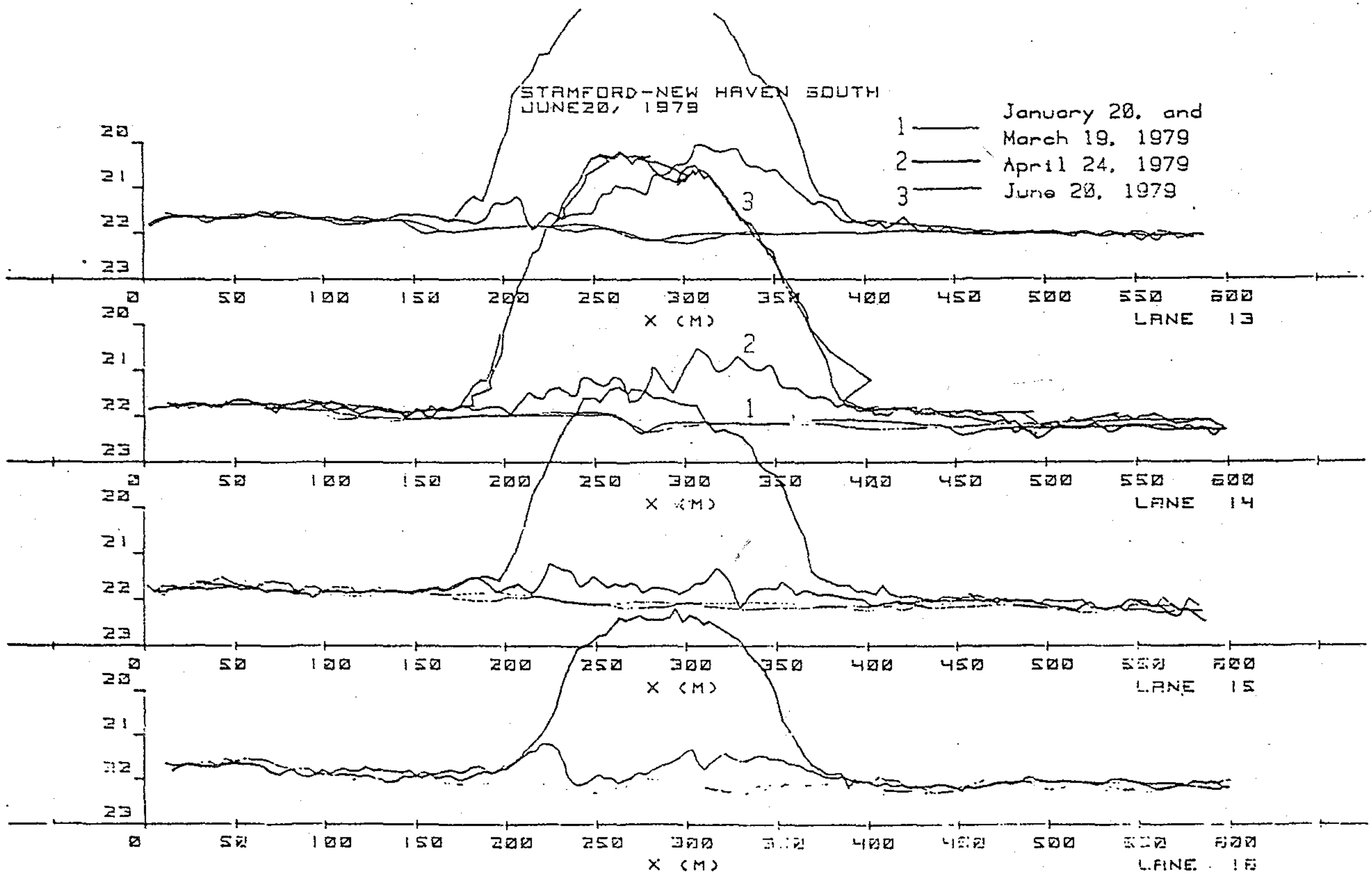

STAMFORD-NEW HAVEN SOUTH
JUNE20, 1979
1 January 20, and March 19, 1979
2 April 24, 1979
3 June 20, 1979
X (M)
LANE 13
LANE 14
LANE 15
LANE 16

Fig. 7

Capping of Stamford spoils at the northern disposal site was accomplished in six days using the hopper dredge ESSAYONS to create a sand layer. Management of this operation was aided by a bathymetric survey on June 19, to determine any areas that were not covered by sand, and the dredge was directed to dump additional material east of the disposal buoy to insure complete coverage. A final survey was conducted on June 22, after completion of the capping operation (Figure 8). This survey and the associated vertical profiles (Figure 9) indicate that all Stamford spoils were capped by the sand material. However, since the sand was less cohesive, it tended to flow during deposition thus creating a broader, flatter mound than that developed by silt at the southern site.

At the time of the June 22 survey the capping layer had a maximum thickness of 3.5m over the Stamford spoil mound. This cap was a smooth blanket of sand that divers were unable to penetrate more than 10-15 cm by digging with their hands. A calculation of the volume of spoil and sand deposited since the May 21 survey indicated an increase of 33,000 m^3. This volume compared favorably with dredge volumes specified by the ESSAYONS, however, large correction factors based on density and water content of the sand, made comparisons tenuous and calculations of volume and percentage lost to the water column meaningless.

The results of these surveys indicated that the capping procedures employed during the Stamford/New Haven disposal operation were extremely successful. The precision disposal of Stamford spoils resulted in a small compact mound that was readily covered with New Haven material. Apparently, there is little difference in the ability of sand or silt to accomplish the desired capping. In the case of sand, the capping layer is not as thick, but the smooth, dense nature of the deposit acts as a tough, impervious blanket over the capped sediment. Silt deposits on the other hand, derive their capping ability from the cohesive nature of the sediment, developing a thicker deposit with rougher micro-topography.

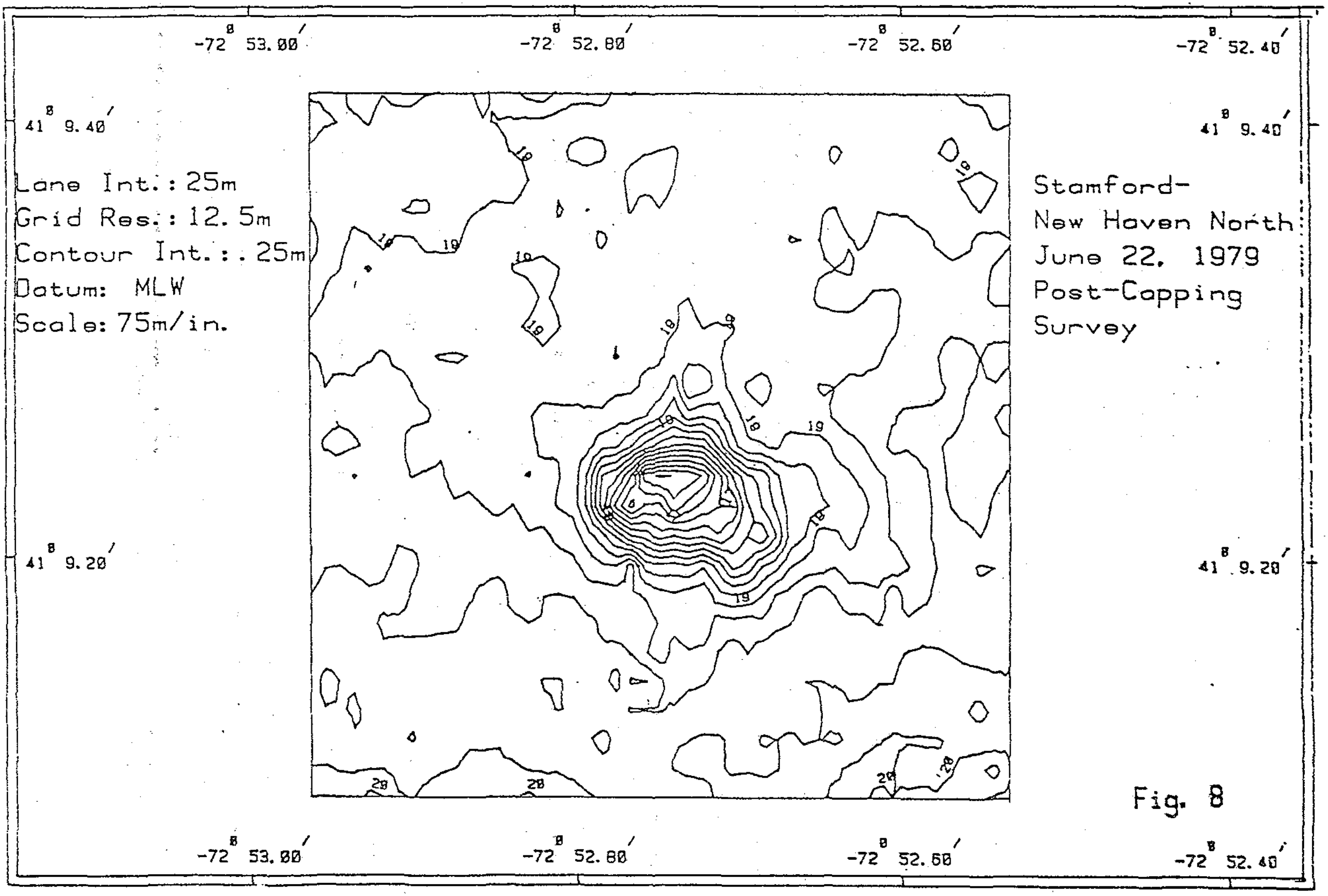

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 9.40'
41° 9.20'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: 75m/in.
Stamford-
New Haven North
June 22, 1979
Post-Capping
Survey

Fig. 8

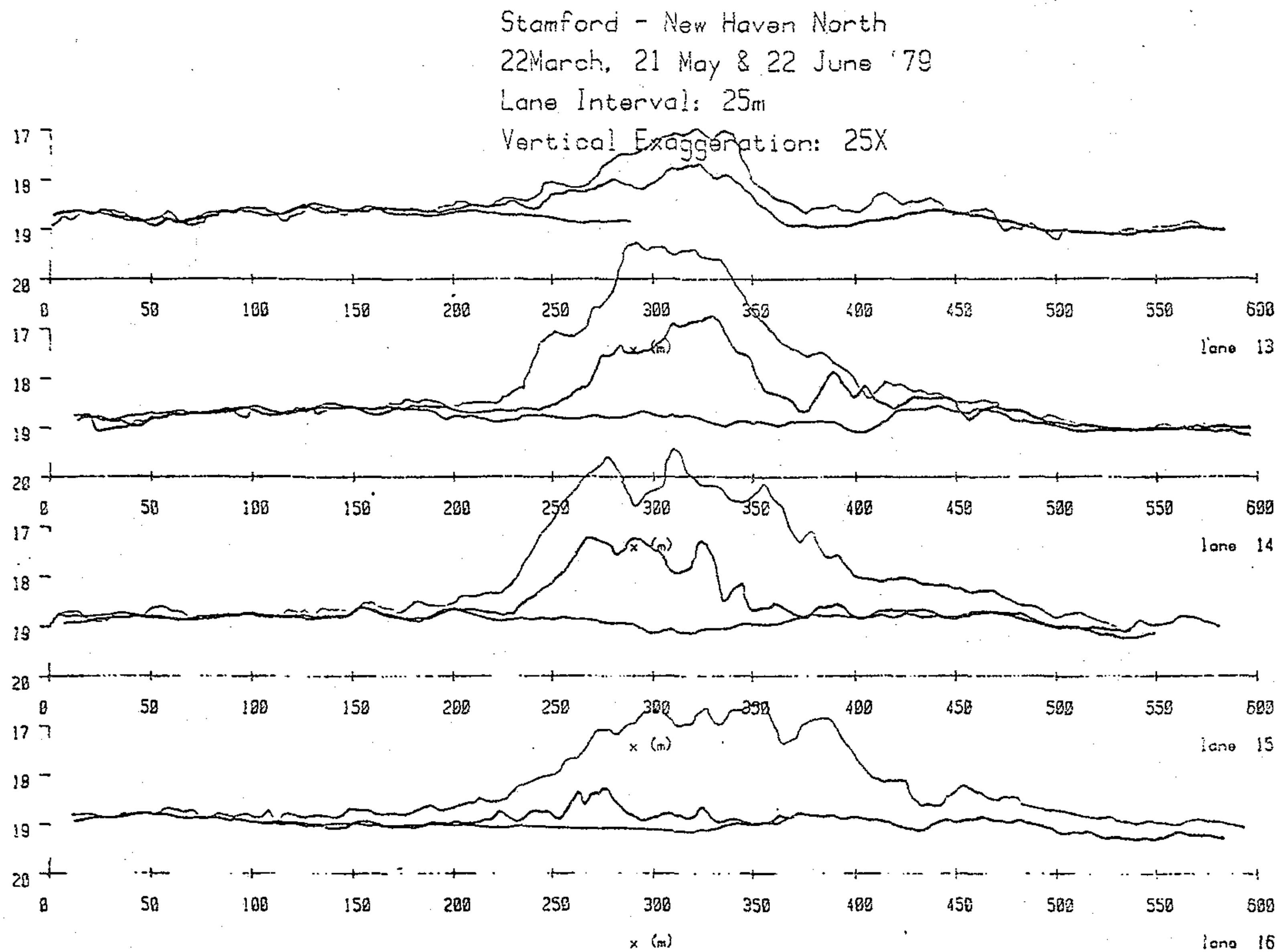

Stamford - New Haven North
22March, 21 May & 22 June '79
Lane Interval: 25m
Vertical Exaggeration: 25X
17
18
19
20
0
50
100
150
200
250
300
350
400
450
500
550
600
x (m)
lane 13
lane 14
lane 15
lane 16

Fig. 9

Several recommendations for future capping operations can be made based on the data obtained from this study.

- The spoils to be covered must be cohesive to reduce their spatial distribution. This would normally be the case since the forces that attract pollutants to the spoils also cause cohesion. However, dredging procedures should be conducted in a manner to preserve this cohesiveness.

- Point dumping of the material to be covered should be done as accurately as possible, preferably with a taut wire moored buoy as a disposal marker.

- Disposal of the capping material should be accomplished as soon as possible also using the buoy as a marker.

- After disposal of approximately 2/3 of the capping material at the disposal point, the remainder should be dumped in a circle with a radius equal to that of the initial spoil mound to insure capping of the flanks.

- Monitoring of the capping operation with bathymetric techniques should be done during disposal to allow for modifications in disposal operations required to insure coverage.

Prior to the disposal operation, chemical and biological samples were obtained from the proposed disposal site to provide baseline data for future monitoring. Bulk analyses of sediments from each harbor and the disposal site were made and used to develop statistical criteria for identifying sediment from each location. Using these criteria, it was then possible to confirm that the capping material was in fact New Haven spoil and that Stamford material was not displaced toward the surface of the mound during the capping operation.

Baseline benthic population parameters and infaunal body burden measurements were also made prior to disposal, however, post disposal data have not yet been analyzed.

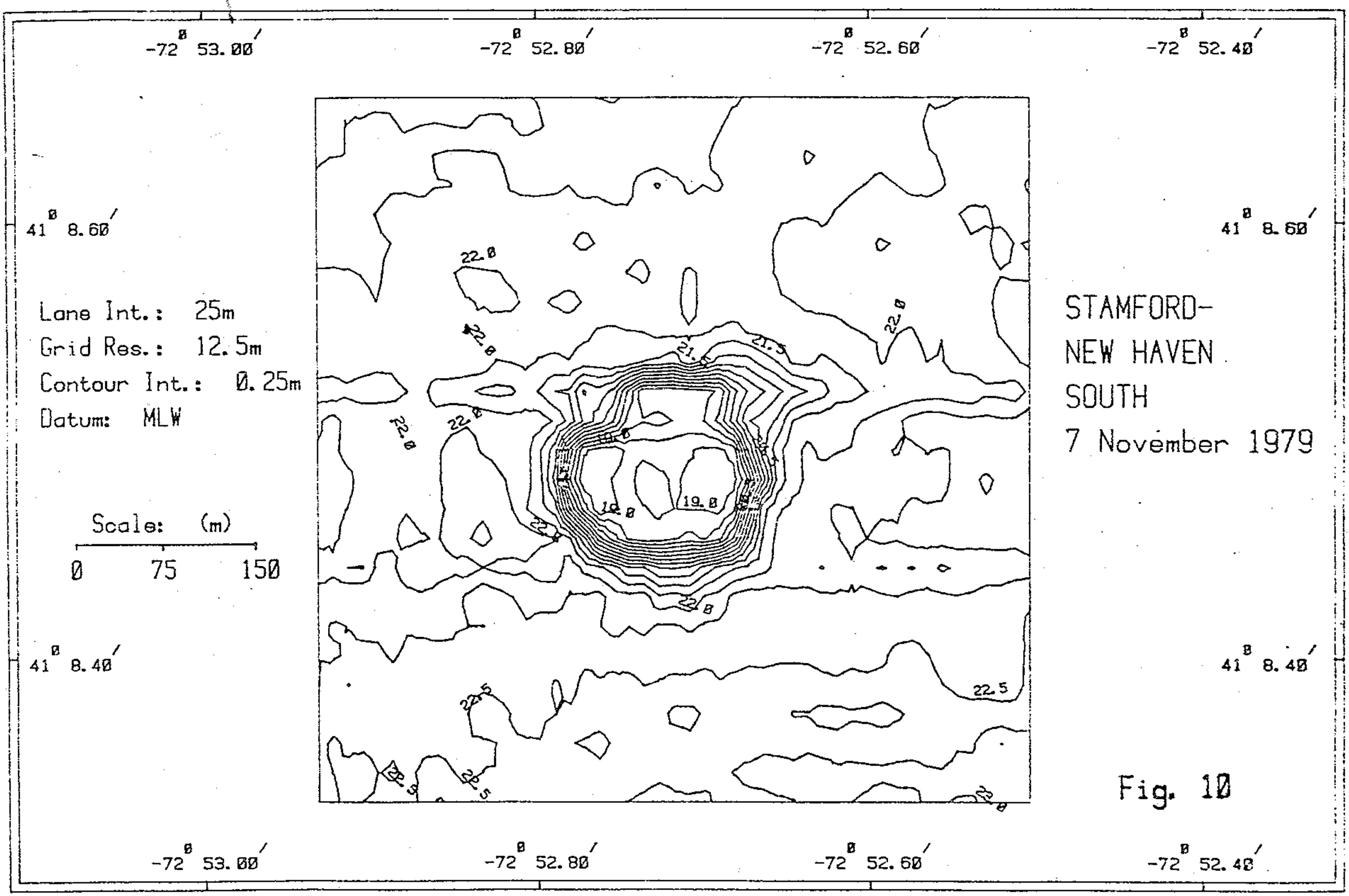
Although the operational techniques for capping Stamford material with silt and sand from New Haven Harbor were successful, the effectiveness of the procedure depends on the stability of the resulting cap and its ability to isolate the enriched spoils from the biota and the water column. Consequently, following deposition of the spoils the thrust of the monitoring effort changed to evaluation of the stability of the resulting mounds with time. Again, this was a multidisciplined effort involving physical, chemical and biological measurements.

On 7 August 1979, a bathymetric survey of the North disposal site was conducted that indicated there were no major changes in the topography of the spoil mound. Although the specific topographic features between surveys were consistant, the mound had settled or compressed slightly increasing the mean depth by approximately 20 cm. Calculation of volume differences between the June and August surveys indicated that the volume loss due to this compression was 1700 m^3.

A survey of the southern site was also run on August 7, 1979 which likewise indicated no major differences in the spoil mound. All transects across the mound had a slight increase of 20-40 cm that was similar to the settling or consolidation observed on the north mound. Calculation of the spoil volume difference indicated the total volume change for the entire survey was a decrease of 900 m^3 or approximately half the change on the north site. There was some indication of slumping on the north margin of the spoil mound where a broad decrease in depth of 20-40 cm occurred.

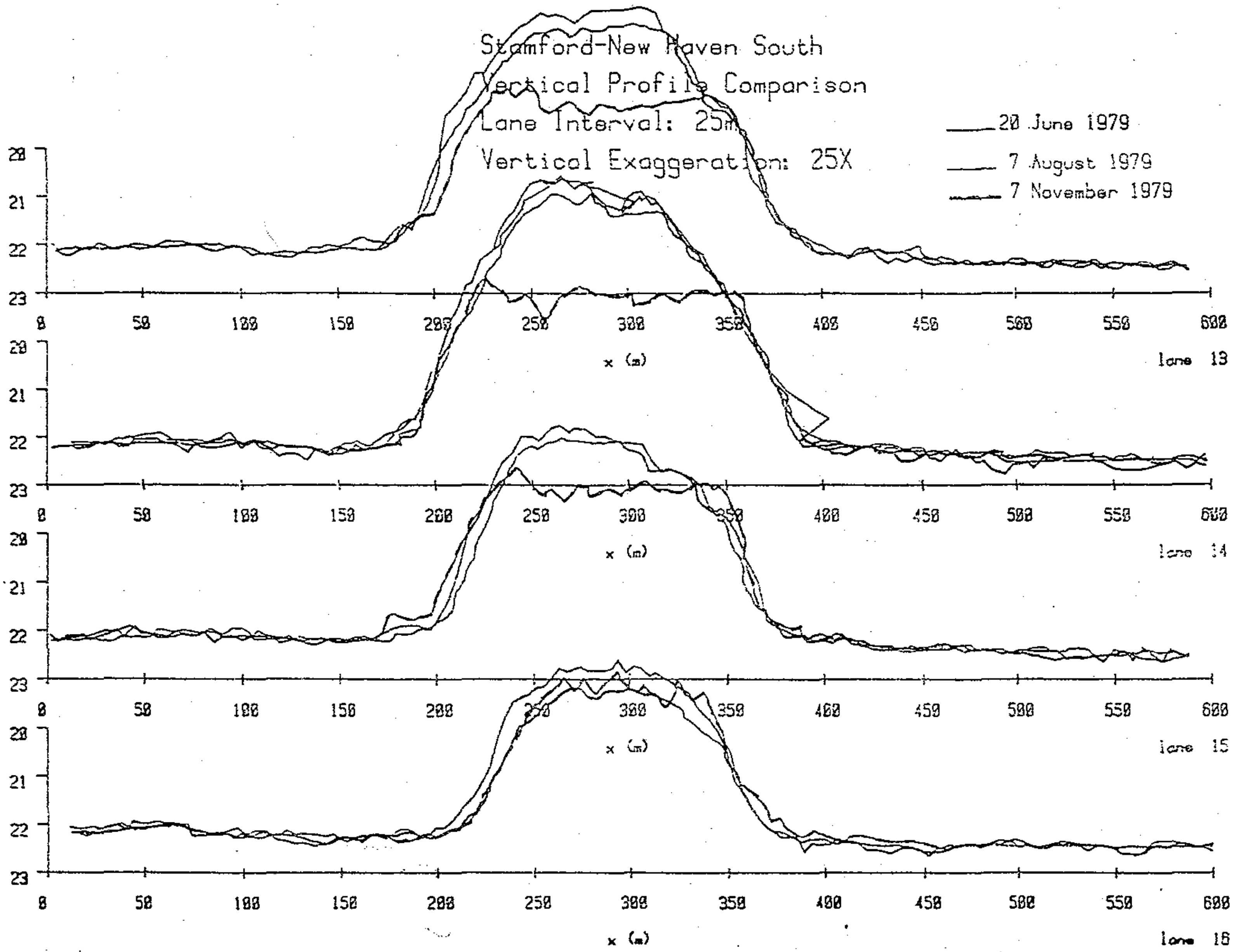
In summary, the results of the August surveys indicated no significant changes in the spoil mounds or the capping material could be detected. Slight settling or consolidation of both spoil mounds did occur, however, these results were expected since the spoil mound from the 1974 dredging operation has been stable for several years indicating the containment potential of the disposal site.

A second post-disposal survey was conducted on the southern site on November 7, 1979 (Figure 10). The results of that survey showed a major change in the topography of the spoil mound resulting from the loss of approximately 10,000 m^3 of spoil from the top of the mound. Vertical profiles across the center of the mound (Figure 11) revealed a flat surface at 19 meters which was also readily apparent on the contour chart.



-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
STAMFORD-
NEW HAVEN
SOUTH
7 November 1979
22.0
21.5
19.0
22.5

Fig. 10



Stamford-New Haven South
Vertical Profile Comparison
Lane Interval: 25m
Vertical Exaggeration: 25X
20 June 1979
7 August 1979
7 November 1979
lane 13
lane 14
lane 15
lane 16
x (m)

Fig. 11

Although this loss of material did not expose any Stamford spoil, further investigations were initiated to determine the causes of spoil movement and to evaluate conditions at the other sites.

The flat topography of the spoil surface at a constant depth suggested that wave action was most likely responsible for the movement of material and the passage of Hurricane David through the area on September 6 provided an energy source to create the wave motion required. Consequently, additional work was conducted to survey the other disposal sites and to determine the potential stress exerted on the spoil mounds as a result of the hurricane. Surveys were made of the north disposal site and the 1974 New Haven spoil mound on November 15, 1979. Both of these surveys were conducted using the same precision techniques, and both surveys indicated that no significant changes had occurred in either mound during the period in which the southern site was affected.

It is important to note that both the Stamford/New Haven North and the 1974 New Haven deposit have minimum depths that are less than the southern site, and thus should be more susceptible to wave motion. Since these three mounds are all within a mile of each other, on a comparatively flat bottom, it is highly unlikely that one site would experience markedly different environmental stress exerted by currents or wave action than would be expected at the other sites. Therefore, an explanation for the loss of material from the southern mound must account for the lack of movement at shallower depths through differences between the physical and lithological properties of the spoil mounds.

The Stamford/New Haven North and the 1974 New Haven spoil mounds can be distinguished from the southern site on the basis of a surface of fine sand material which is probably thicker on the newer spoil mound. This lithology is in sharp contrast to the cohesive silt surface of the southern mound which is characterized by clumps of cohesive clay interspersed within a fine silty matrix.

Movement of spoil material at the south mound could have been caused by stress induced by tidal currents, wave motion or a combination of both forces. There are several reasons to suggest that normal tidal currents are not responsible for the movement of material in this case. First, there has never been any previous indication of significant movement of spoils in this area, either on earlier disposal mounds or during this disposal operation. Second, although the motion of the tidal currents is in an east-west direction the only observed shift of material is in a north and south direction. Finally, a subsequent survey of the disposal site conducted on December 19, 1979 indicated that no further changes in the topography had occurred during the month following the original detection of spoil loss. Since tidal currents are not likely to initiate sediment motion, the most logical explanation would be the stress exerted on the spoils by wave action or a combination of waves and currents. Because Long Island Sound is a relatively protected area, the generation of long period waves that are capable of affecting sediment at depths greater than 18 meters must be a rare occurrence. However, the passage of Hurricane David may be just such a situtation and may have provided sufficient stress to initiate sediment motion.

To examine this possibility, calculations were made of theoretical shear shtress developed by hurricane waves over the rough surface of the south site and compared with stress developed over a smooth surface. These theoretical stresses were then compared with estimates of critical shear stress to determine the potential for sediment motion. The calculated shear stress for roughness heights similar to those present on the south site are near or exceed the critical value needed for erosion at wave heights and periods expected from Hurricane David. In contrast the shear stress developed over the smooth sand surface of the other sites never exceed the critical value. Consequently, we can conclude that the high roughness factor resulting from the clumps of cohesive sediment on the south site create a greater stress and may cause sediment motion under storm wave conditions, while the smoother surfaces of the other spoils mounds produce significantly smaller stress values thus insuring the stability of the spoils even at shallower depths.

Preliminary data from subsequent surveys of all sites in April 1980 show no additional changes to either site indicating that both mounds are stable under nominal tide and wave conditions.

In summary, the effectiveness of capping enriched spoils with cleaner material looks promising, but requires additional monitoring to evaluate long term stability and recolonization effects. The fact that both the sand and silt caps were effective in containing the contaminated spoils during the passage of a 10 year frequency storm such as Hurricane David is a strong indication of the potential of this procedure.

An explanation for the selective movement of silt material on the south site has been proposed based on the interaction of storm waves resulting from Hurricane David and the roughness parameters of the cohesive New Haven spoils. The implications of these conclusions are important to future disposal and/or capping operations. Consolidated, cohesive spoils are common in the New England area, and clamshell dredges which preserve the cohesive nature of the spoils must be used to reduce suspended load and spreading of spoils at both the dredging and disposal sites. Consequently, while these properties aid in reducing the area of coverage, most spoil mounds will have surface roughness comparable to the New Haven south site after disposal. These features have been observed at the New London site, but the cohesive clumps have broken down over a period of time primarily due to biological activity, but also as a result of fracturing and erosion (Stewart, 1979 personal communication).

From the results of this study, it is apparent that the stress created by the roughness factor associated with these clumps under storm wave conditions is more important than the depth of the spoil surface, the strength of currents or the cohesive nature of the sediment in determining the stability of spoils. The occurrence of a major storm such as Hurricane David, before the surface of the spoil mound has been smoothed by natural forces thus creates a potential for large scale erosion and transport of material.

Future capping operations with silt, might therefore, consider methods to produce a smooth spoil surface at the conslusion of the dumping procedure. Additional work is needed to determine if these smoothing procedures are in fact necessary and to more accurately evaluate and predict the recurrence of the effects observed at the New Haven south site. The problem of spoil stability is being addressed to some extent under the DAMOS program through a combination of bottom turbulence and spoil erosion studies, however, the phenomena observed at the Central Long Island Sound Site emphasize the importance of monitoring disposal areas and of understanding the interaction of the energy regime with spoil material.

OTHER CAPPING PROCEDURES

In addition to the capping operations recently completed in Central Long Island Sound, several proposals for capping of contaminated spoils are presently being considered or are currently underway. The dredging of Norwalk Harbor, Connecticut includes two specific capping procedures in the operation plan. Approximately, 1500 m^3 of sediment contaminated by a chemical spill of napthaleen and nitrobenzine will be placed in a pit dredged from the adjacent channel area and covered with cleaner material from other sections of the channel. This procedure, which will be closely monitored by EPA Region 1 representatives, should isolate the contaminated spoils without requiring transport of the material thereby reducing the exposure time of the material to the atmosphere and the chances of an accidental dump or spill.

Approximately 20,000 m^3 of Norwalk material which is considered Class III material under Connecticut's spoil classification program will be transported to the Central Long Island Sound disposal site, deposited at a new taut-wire buoy position and capped in a manner similar to that described earlier with additional clean dredge material from Norwalk Harbor.

Current disposal of PCB enriched material from the New York - New Jersey area which is taking place at the taut-wire buoy placed in the Mud Dump is slated for capping with cleaner material in the near future. Management and monitoring of this operation is under control of the New York District of the Corps of Engineers. Although this operation has many aspects in common with the capping procedure that took place in Long Island Sound, there are several differences that should be considered in developing this management and monitoring program:

- The volume of material to be covered is significantly larger, therefore, correspondingly larger volumes of suitable capping material must be identified and dredged.

- The disposal site is deeper, which combined with the larger volumes of material will expand the areal extent of the spoils to be capped. Therefore, some mechanism must be provided to monitor and control the capping operation to insure coverage.

- The disposal site is exposed to more severe wave action than the Long Island Sound Site and therefore, the spoil mound should be only as high as necessary to provide an adequate cap and should be as smooth as possible to reduce the stress exerted by wave action.

All of these considerations can be readily accomodated through implementation of a reasonable management plan centered around precision navigation control of the capping operation. Furthermore, a monitoring effort oriented toward evaluating the stability and containment characteristics of the deposit, and biological parameters beyond the margins of the mound should insure that overall environmental impacts are minimal.

Another approach to capping and containment of contaminated spoils has been proposed by Dr. Henry Bokuniewicz and others from the State University of New York at Stony Brook. This procedure would utilize existing submarine burrow pits resulting from sand mining in outer New York harbor as containment sites for contaminated sediments followed by isolation of the spoils through capping with sand of similar lithology to the surrounding area.

Several favorable aspects to the use of these burrow pits as defined by Dr. Bokuniewicz include:

- Many of these pits have demonstrated an ability to trap fine sediment, and therefore, should exhibit characteristics of containment sites.

- Filling of the pits and capping of the spoils would remove potential zones of anoxic conditions and would reduce the effect these deep holes might have on wave energy refraction.
- Filling of pits would most likely permit additional mining to be accomplished without drastically altering the ambient conditions in Lower New York Harbor.
- The location of the pits near the area to be dredged makes them economically attractive.

However, before such a procedure can be made operational several environmental parameters must be assessed; most important of these is the stability of the contaminated sediment deposit in the burrow pit prior to and after disposal of the capping material. This concern is warranted due to the shallow ambient bottom (approximately 4.5m) in the area and the average depth of the pit which is generally less than 15 meters. Therefore, any deposits in these pits would have surface depths on the order of 10 meters and be susceptible to extensive wave action. Data on existing sediment lithology indicate, however, that silty deposits do exist in these pits at depths of 9 meters, thus suggesting containment is possible. Obviously, contaminated spoils should be capped as soon as possible to reduce the potential for dispersion.

Once deposited, the sand cap should not be subject to erosion, since comparisions of bathymetric surveys over a period of years have shown only minor changes in the overall topography of the area. There will, however, always be an inherently unstable condition when dense sand is placed over less dense mud, and it is possible that deformation and sinking of the sand cap might occur. The conditions causing this deformation and the rate at which it might occur have not yet been fully evaluated.

COSTS ASSOCIATED WITH CAPPING

The additional expenses required to conduct a capping operation are directly related to the availability of suitable capping material. The operating costs associated with installation of taut-wire buoys or use of precision navigation systems to control the dumping operations are quite small in terms of the overall project costs. Therefore, if suitable capping material is available in an area that must be dredged as part of the project being considered or associated with other projects, then proper management of the dredging and disposal operation can produce a capped deposit at very little expense.

However, if additional dredging must be done to provide capping material the costs will increase substantially. On the Stamford/New Haven operation, approximately 30,000 m^3 of contaminated material were capped with sand, using the hopper dredge ESSAYONS for approximately $140,000. Since it was necessary to dredge this sand to open the outer channel of New Haven harbor these cost did not constitute an addition to the program. However, they do indicate the expenses involved for additional dredging. It should be remembered that it may be necessary for the volume of the cap to be substantially greater than that of the contaminated material, and therefore, costs for dredging this cap could be more than the initial operation.

SUMMARY

Under certain conditions, the use of uncontaminated dredge material to cap contaminated sediment appears to be an operationally feasible, cost-effective and environmentally sound method for disposal in the marine environment. Although additional management and operational controls are required to conduct these procedures, they are neither expensive nor complicated and are certainly within the capabilities of todays dredging and disposal technology.

The operational feasibility of the technique has been demonstrated at the Central Long Island Sound site, and its application to deeper waters on the shelf is currently being accomplished through the procedures at the Mud Dump Site in New York Bight. Although initial indications concerning the environmental considerations of capping are favorable, continued monitoring must be conducted to insure long term effects such as sand/silt instabilities, bioturbation, storm effects, etc. do not reduce the effectiveness of the cap in isolating contaminants from the environment.