THE MANAGEMENT AND MONITORING OF DREDGE SPOIL DISPOSAL AND CAPPING PROCEDURES IN CENTRAL LONG ISLAND SOUND

DAMOS CONTRIBUTION #8

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Presented by

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ABSTRACT

Dredge spoil disposal management procedures have been employed at the Central Long Island Sound Disposal Site to "cap" heavy metal enriched spoils from Stamford, CT with silt and sand from inner and outer New Haven harbor. The objectives of these capping procedures were to isolate the enriched material from 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. This paper is concerned primarily with the results and implications of the bathymetric monitoring procedures.

A computerized navigation and bathymetric data aquisition system was used to conduct baseline and replicate bathymetric surveys during the disposal operation to monitor changes in topography resulting from spoil accumulation.

Sequential profiles across two established spoil mounds indicated that Stamford spoil was concentrated as low mounds with rough topography and that both silt and sand provided adequate cover for the enriched material. However, the sand produced a thin (2m) dense blanket of material that spread over a larger area, while silt produced a thick (4m) cohesive cap with steeper sides and less spreading on the flanks.

Post disposal monitoring over a six month period has revealed no significant changes in the sand cap. However, although adequate cover still exists, the silt cap was substantially altered with extensive slumping of the flanks, flattening of the top of the mound and loss of material from the disposal site. This change has been attributed to the passage of Hurricane David combined with the relatively high bottom stress developed by the roughness factor created by the cohesive nature of the silt cap.

Capping of enriched spoils with cleaner materials has been a "qualified" success. The sand cap has been very stable and the silt cap has provided adequate coverage. Continued monitoring is required to insure the long term success of the operation.

ACKNOWLEDGEMENTS

This program was accomplished under the sponsorship of the New England Division of the U.S. Army Corps of Engineers with the cooperation of the U.S. Naval Underwater Systems Center, Newport, RI. Special thanks are due Mr. Carl Hard and Mr. Richard Semonian of the Corps for their efforts in managing this and the overall DAMOS program and to Dr. David Shonting of NUSC for his assistance.

All surveys in this program were made by the research vessel UCONN operated by the Marine Science Institute of the University of Connecticut. Capt Jack Blumie and his crew should be commended for their cooperation and excellent work.

INTRODUCTION

The disposal of dredge spoil in Long Island Sound waters has been a controversial and sensitive issue for several years. However, the extreme shoaling conditions that exist in some of the harbors bordering the Sound emphasize the need for a solution to this controversy that will allow dredging of these harbors in a safe and cost effective manner. Because of the large quantities to be dredged, the lack of suitable land sites and the prohibitive costs of diking or transport of spoils to the continental shelf, the New England Division of the Corps of Engineers has undertaken a carefully managed and monitored program of disposal at two sites within the Sound. Dredge spoils from the Thames River are being placed at the New London Disposal Site and spoils from Stamford and New Haven harbors are being placed at the Central Long Island Sound Disposal Site (Figure 1).

Because bulk sediment analyses indicated that spoils 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 contaminates and recolonization potential.

Monitoring of the disposal operation was conducted as part of the Disposal Area Monitoring System (DAMOS) and consisted of

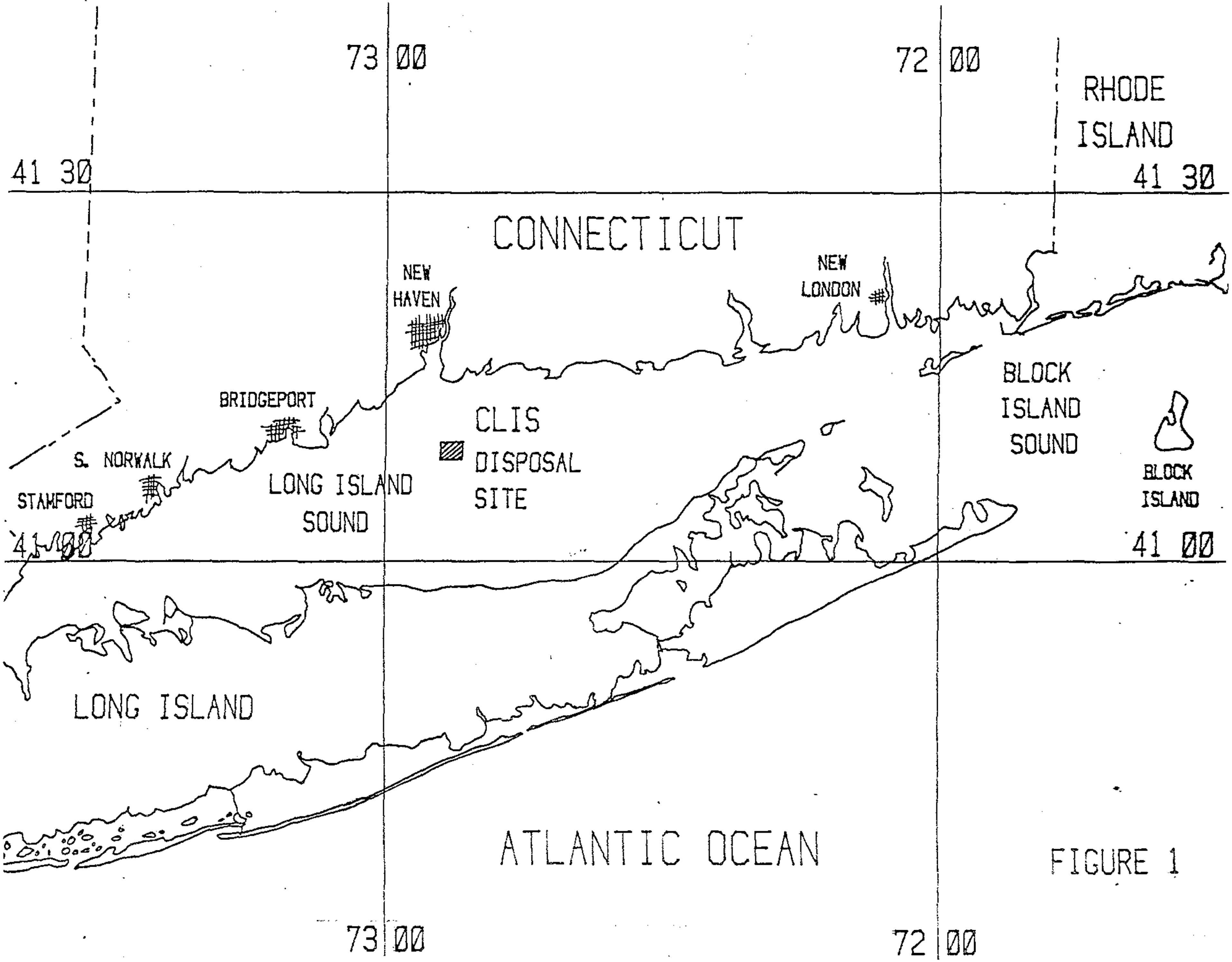

73 00
72 00
RHODE
ISLAND
41 30
41 30
CONNECTICUT
NEW
HAVEN
NEW
LONDON
BRIDGEPORT
CLIS
DISPOSAL
SITE
BLOCK
ISLAND
SOUND
S. NORWALK
STAMFORD
LONG ISLAND
SOUND
BLOCK
ISLAND
41 00
41 00
LONG ISLAND
ATLANTIC OCEAN
73 00
72 00

FIGURE 1

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. This paper is concerned primarily with the results and implications of the bathymetric monitoring procedures.

Replicate precision bathymetric surveys 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 to monitor the stability of the spoil mounds created.

INSTRUMENTATION AND PROCEDURES

Application of bathymetric data to monitoring small changes in topography resulting either from accumulation or loss of dredge spoil material requires that measurements be made with extreme precision. To accomplish this precision, a computerized navigation and data acquisiton system was used with carefully controlled range and depth measurement sensors.

A schematic of this data acquisition system is presented in Figure 2. A Hewlett Packard 9825A computer and 9872A plotter were interfaced with a Del Norte Trisponder system, an EDO 4034A fathometer and an EDO 261C Digitrak unit to provide the necessary capabilities. The computer and plotter could also be used to obtain report quality charts of bathymetric data within a short time after

BATHYMETRIC DATA ACQUISITION SYSTEM

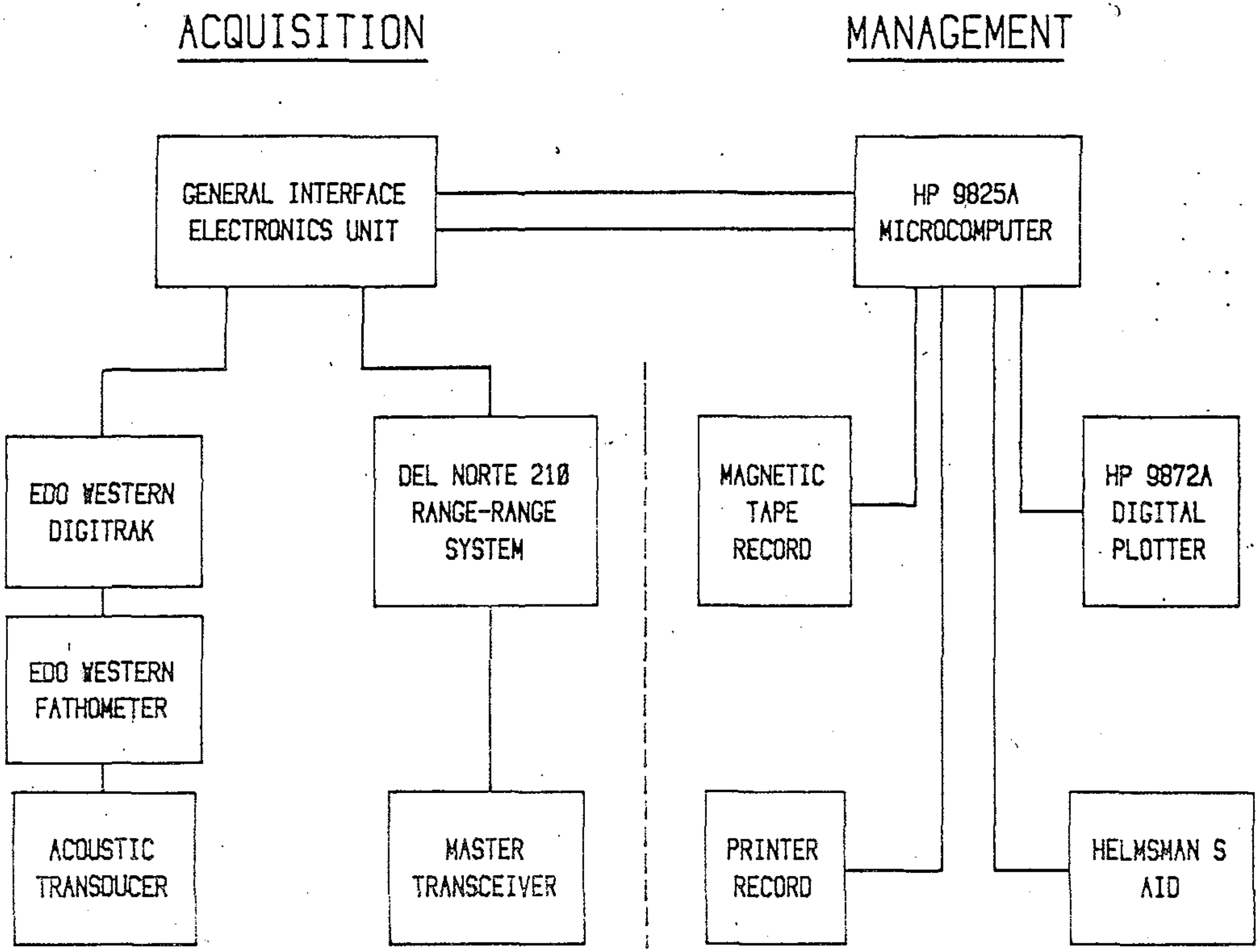


FIGURE 2

completion of a survey. Data quality were insured by a careful calibration program to insure accurate measurements of range and depth. All shore stations were surveyed to first order accuracy and the fathometer was calibrated with a bar check prior to each survey.

Since a computer was used for data acquisition, all corrections for ships draft, sound velocity and tidal height were made after completion of the survey and all adjustments on the fathometer were set to zero.

Earlier measurements of tidal height at the Central Long Island Sound Disposal Site have shown good agreement with predicted tidal heights under ambient weather conditions. Because this relationship was previously established and because additional corrections were applied that reduce tidal errors in the survey data, predicted tidal correction values were used for all surveys in this study.

Prior to disposal of dredge spoil at this site, a survey grid was established (Figure 3) consisting of 25 transects, 600 meters long oriented in the east-west direction and spaced 25 meters apart. While conducting the survey, range data were input to the computer which provided steering information to assist the helmsman in maintaining the ship's position relative to the survey grid. Since precision data were required for this work, surveys were only made on calm days and the errors in steering the ship were generally less than 5 meters either side of a given transect (Figure 4). This navigation precision was necessary for comparing replicate surveys because slight errors in position can cause large errors in depth over sloping bottoms.

Data acquisition was controlled by the sampling rate of

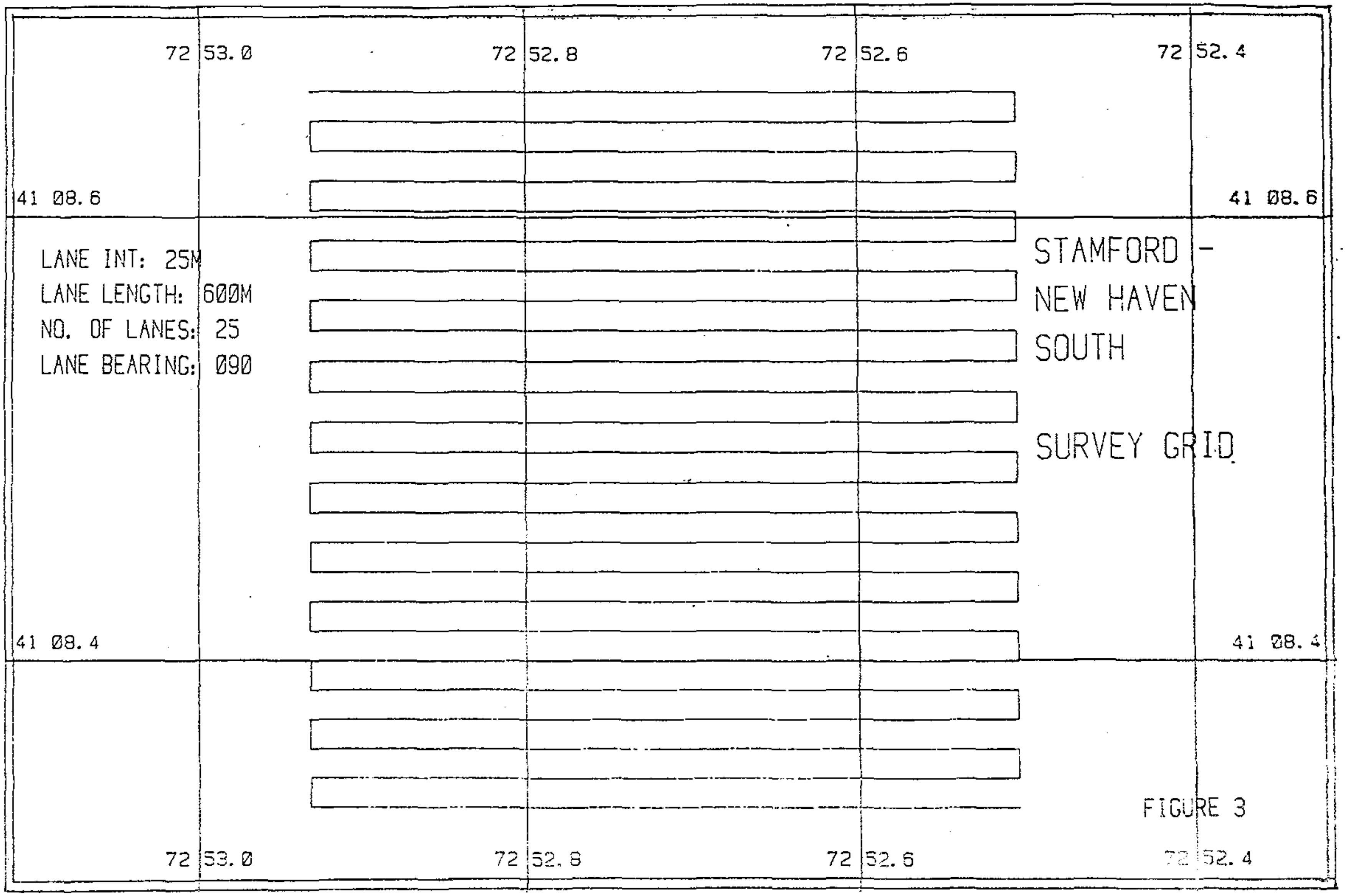

72 53.0
72 52.8
72 52.6
72 52.4
41 08.6
41 08.6
LANE INT: 25M
LANE LENGTH: 600M
NO. OF LANES: 25
LANE BEARING: 090
STAMFORD -
NEW HAVEN
SOUTH
SURVEY GRID
41 08.4
41 08.4
72 53.0
72 52.8
72 52.6
72 52.4

FIGURE 3

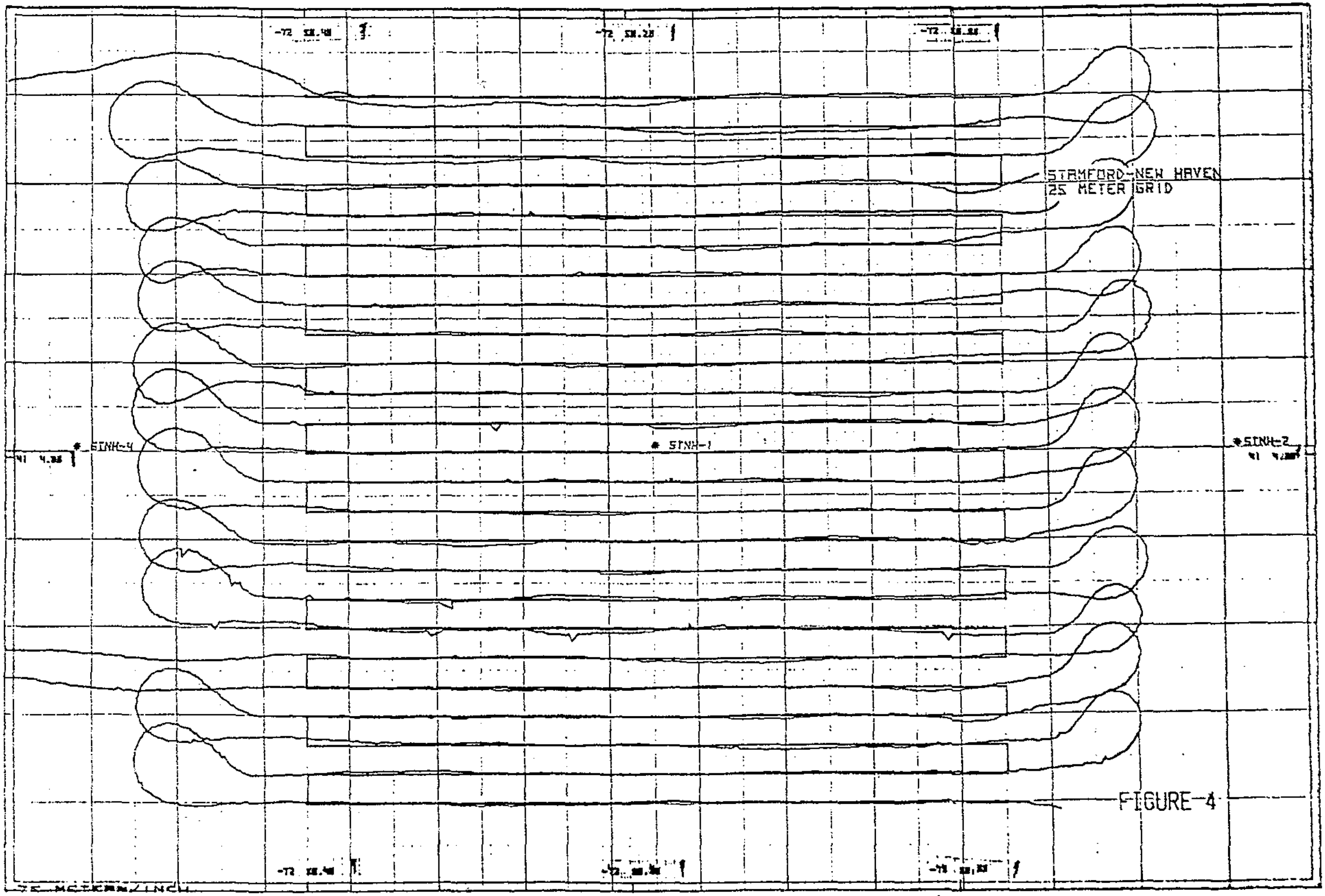

-72 58.40
-72 58.28
-72 58.88
STAMFORD-NEW HAVEN
25 METER GRID
SINH-4
41 4.88
SINH-1
SINH-2
-72 58.40

FIGURE 4

the Del Norte Trisponder unit which was nominally one range measurement per second. Depths were averaged over this one second interval and recorded on cassette tape along with time and position information.

Analysis of bathymetric data was first accomplished through development of vertical depth profiles along the transect lanes. Since each transect can be repeated with a positional accuracy of better than five meters, these profiles provide a means of evaluating small scale changes in the topography and the precision of the survey technique. All depths on these profiles have been corrected for sound velocity, draft and tidal height.

Figure 5 presents a sequence of these profiles for representative transects across the spoil mound at the southern New Haven disposal site. Assuming no significant change (i.e. deposition or erosion) in the depth of the ambient bottom at some distance from the spoil mound then the precision of the depth measurements between surveys can be evaluated by comparing these profiles at the extremeties of the transect. From an examination of Figure 5, it is apparent that no significant differences exist between sequential surveys at this site and ,therefore, adequate precision between surveys was attained.

After development of the vertical profiles, the data were inserted into an arbitrary grid pattern for further analysis. This grid pattern was established such that each grid block was centered on a transect lane, had a height equal to the lane spacing (25m) and a width equal to one half the spacing (12.5m). This convention has applied to all surveys even though

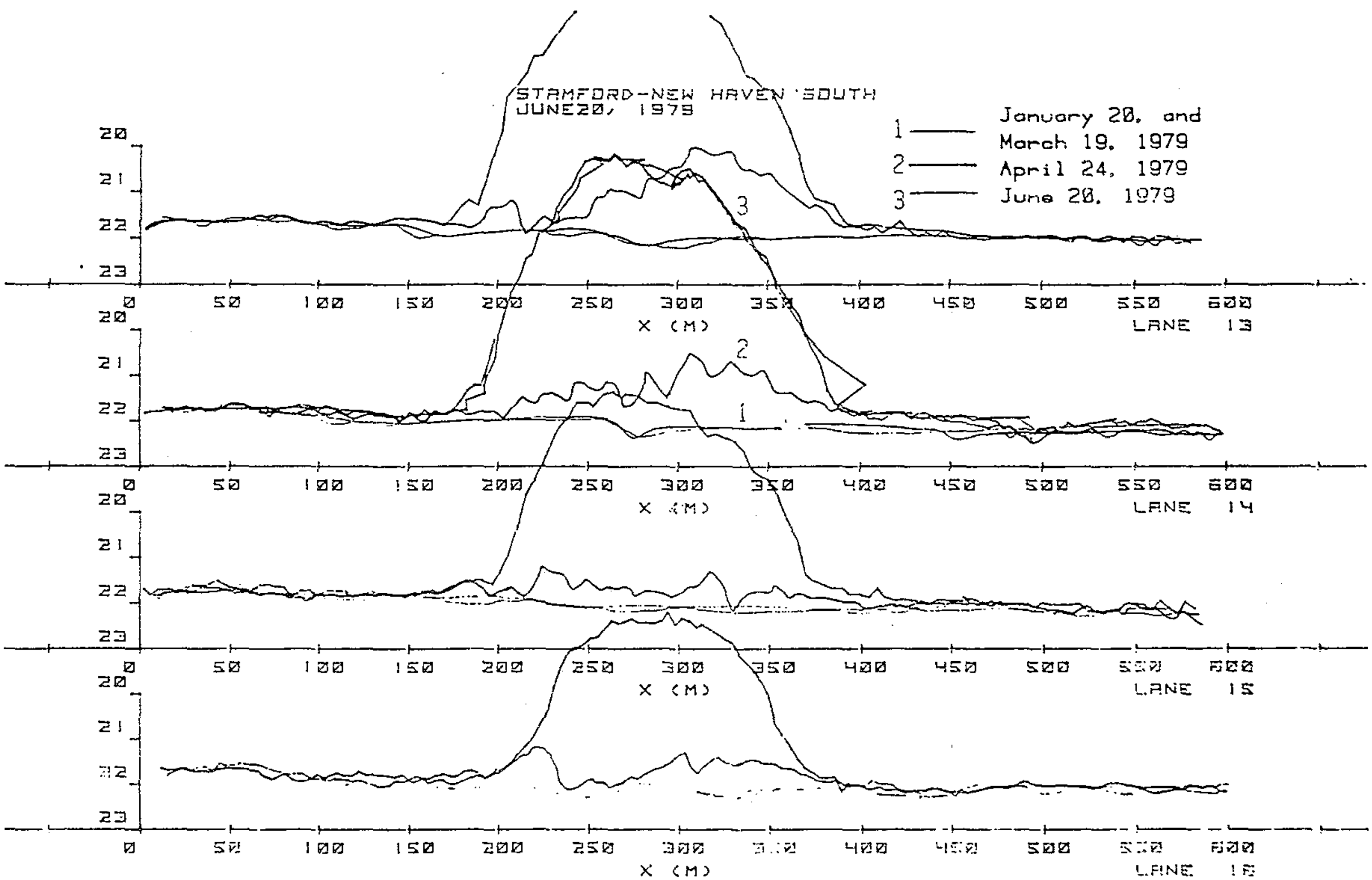

STAMFORD-NEW HAVEN SOUTH
JUNE20, 1979
1 January 20, and March 19, 1979
2 April 24, 1979
3 June 20, 1979
20
21
22
23
0
50
100
150
200
250
300
350
400
450
500
550
600
X (M)
LANE 13
LANE 14
LANE 15
LANE 16

FIGURE 5

it is possible to establish a finer grid pattern by sampling more frequently along the transect direction. The finer grid pattern would, however, introduce a bias into the data since the resolution between lanes cannot be improved.

All depth measurements falling within the area of each grid block were averaged and a mean depth assigned to each grid location. This matrix of depths was then used to develop a contour chart of the entire survey area. Contour intervals of .25 meter were drawn on all charts of the Central Long Island Sound Disposal Site.

Calculations of volume difference between successive surveys could also be accomplished by comparision of the gridded data.

The difference in depth (Δz_i) of each cell between successive surveys was determined by subtraction and then multiplied by the area of the cell to determine the net change in volume. The volume changes were summed along transects and over the entire grid to determine the total volume change.

The precision of the depth measurement must be extremely high to achieve an accurate volume because small changes in depth were multiplied by the area of the survey. In order to increase this precision additional corrections were made based on the assumption that no significant changes in depth occur on the natural bottom beyond the extremeties of the spoil mound. To make these corrections the average depth changes ($\Delta \overline{z_i}$) for all grid locations in first and last five lanes was determined. If this $(\Sigma \Delta \bar{z}_i)$ was different from zero a correction was applied to the third and twenty-third lanes to set those differences to zero. Correction factors for each transect were then determined by linear interpolation between these two lanes.

In this manner, small differences resulting from errors in tide, sound velocity or draft corrections were accounted for and the baselines of both surveys were accurately aligned with each other. Corrections of this type, while always less than 10cm were important for increasing the resolution of the volume difference technique.

The errors of the volume determination can be evaluated through a calculation of the standard error based on the standard deviation of the depth measurement. A conservative estimate of the precision in depth measurement resulting from an echo sounding, accounting for navigation, correction factors, topographic changes etc. anywhere within the disposal site is + or - 20cm.

Using this figure for the standard deviation of all depths measured within a grid cell, the standard error for a given cell is

$$\epsilon_i = \frac{\sigma_i}{\sqrt{n_i - 1}}$$

where n_i is the number of measurements in the cell.
For the entire survey, the average depth

$$\bar{z} = \frac{1}{M} \sum_{i=1}^{M} \bar{z}_i$$

where M is the number of cells. Therefore, the standard deviation of ($\bar{z}$) resulting from errors in the depth measurement can be expressed as

$$\sigma_{\bar{z}}^2 = \frac{1}{M^2} \sum_{i=1}^{M} \bar{\epsilon}_i^2$$

$$\sigma_{\bar{z}}^2 = \frac{1}{M} \bar{\epsilon}_i^2$$

$$\sigma_{\bar{z}} = \frac{\sqrt{\bar{\epsilon}_i^2}}{\sqrt{M}}$$

Since the volume difference approach is used for this calculation, the volume calculation is actually made on the amount of water over the site and the difference is expressed as

$$\Delta V = A \bar{z}_1 - A \bar{z}_2$$

Therefore, the standard error of the volume calculation for each survey is

$$\epsilon_v = A \sigma_{\bar{z}} = \frac{A \sqrt{\bar{\epsilon}_i^2}}{\sqrt{M}}$$

Assuming that the standard deviations of all cells are approximately equal, this equation reduces to

$$\epsilon_v = \frac{A\,\sigma_i}{\sqrt{M(n-1)}}$$

and for each New Haven survey

$$A = 600 \times 600 = 3.6 \times 10^5\ m^3$$

$$M = 48 \times 25 = 1200$$

$$\sigma_i = 0.2\ m$$

therefore,

$$\epsilon_v = 1200\ m^3$$

Since two surveys are required to accomplish a volume difference calculation, the total error could be as much as 2400 m^3.

Because a depth difference (Δz_i) was determined for each grid cell between successive surveys, the contour program was applied to the difference data and a contour difference plot can be generated. This chart provides information on the distribution of changes in depth resulting from accumulation of spoils or loss of material. Contour intervals of .2 meters were used on these charts with consistant results due to the correction procedures described above.

All of these procedures were applied to the monitoring of disposal operations at the Central Long Island Sound site during January to June, 1979, and to post disposal conditions through November, 1979. The data obtained during this study represent a significant improvement over previous disposal monitoring efforts for several reasons including: 1) use of precision navigation control to maintain 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, and 4) the careful management of the disposal operation to create topographic features for precision measurements of volume.

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 parameters as compaction, stability and capping.

MANAGEMENT OF DISPOSAL OPERATIONS

As described earlier there were two major objectives to be achieved through disposal of spoils at the Central Long Island Site. 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 6). 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 distributon prior to capping. To accomplish this, two taut-wire moored buoys were installed at the designated disposal points using the 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.

CENTRAL LONG ISLAND SOUND DISPOSAL SITE

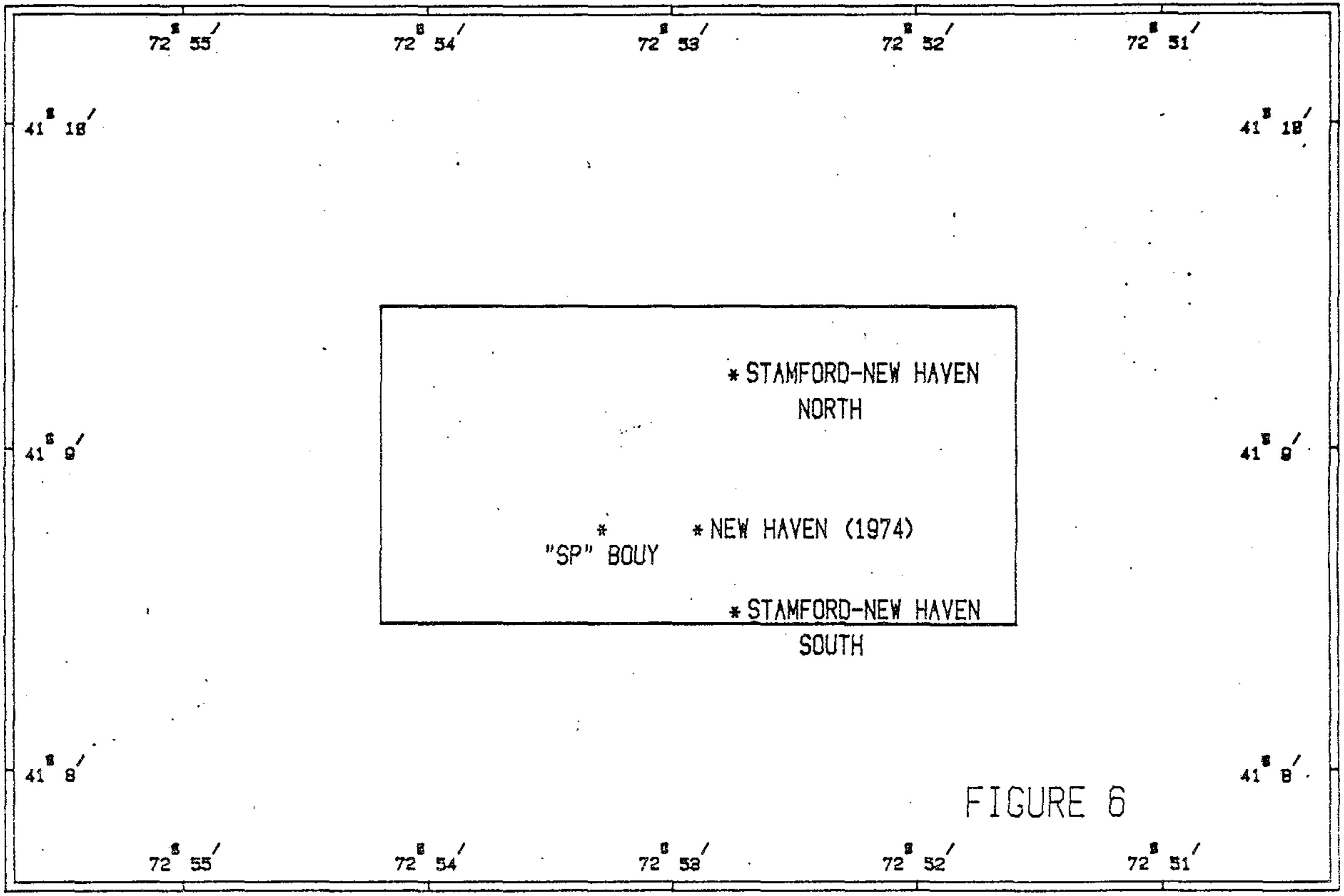


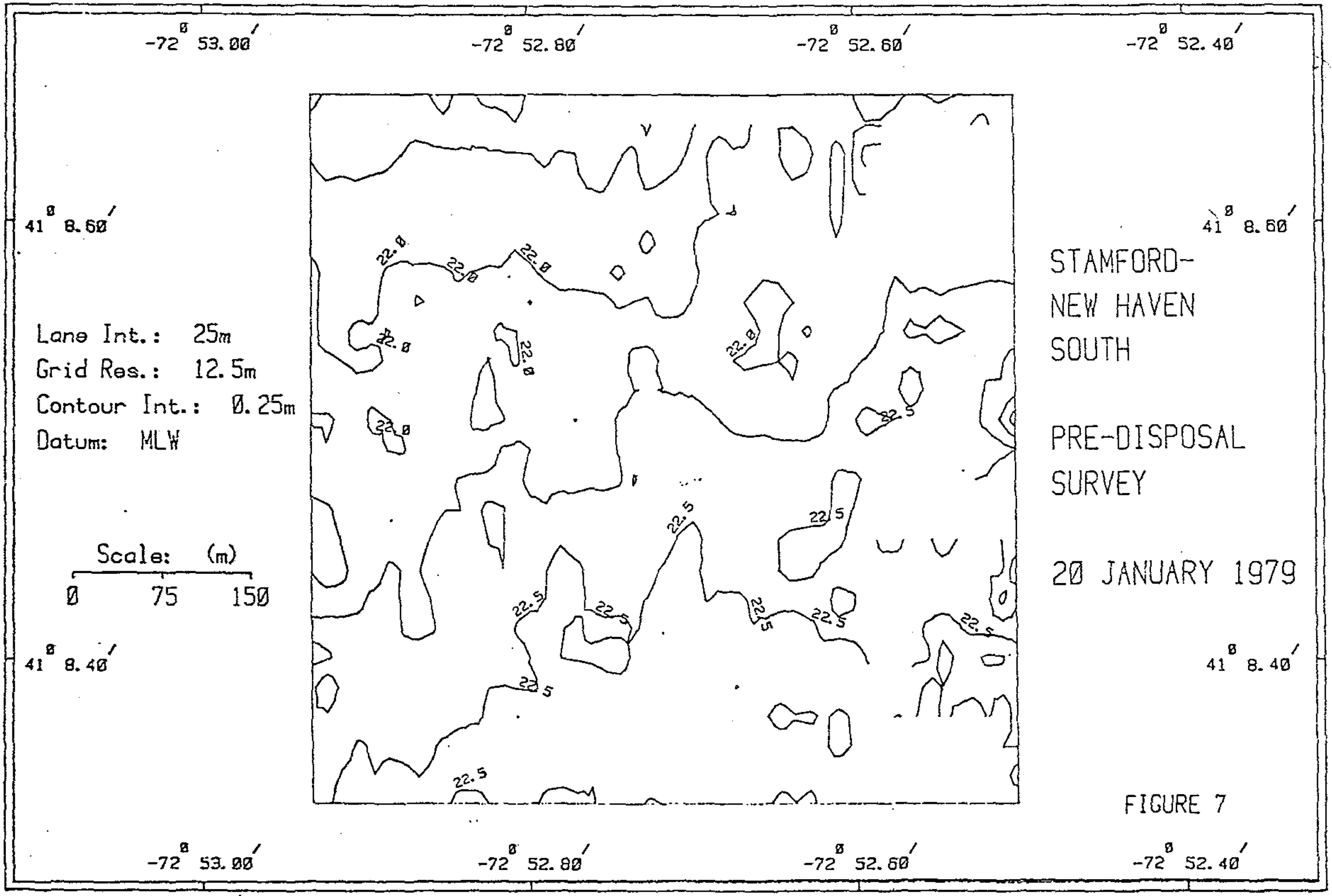
FIGURE 6

BATHYMETRIC MONITORING PROCEDURES

A survey grid similar to that shown in Figure 3 was established at both the north and south disposal sites with the disposal buoy centered in the 600 x 600 meter square survey area. Prior to disposal, background surveys were run on these tracks. Two baseline surveys were made at the south site on January 20 (Figure 7) and March 19 (Figure 8), and a single survey was made at the north site on March 22 (Figure 9). An estimate of the precision of the volume calculation technique was made by comparing the difference between the two southern surveys (Figure 10). This volume difference was approximately 2700 m^3 which is only marginally greater than the error expected from theoretical considerations. Furthermore, the contour difference chart (Figure 11) indicates the errors are random since all contours are + or - .2m or zero and show no consistant pattern over the survey area.

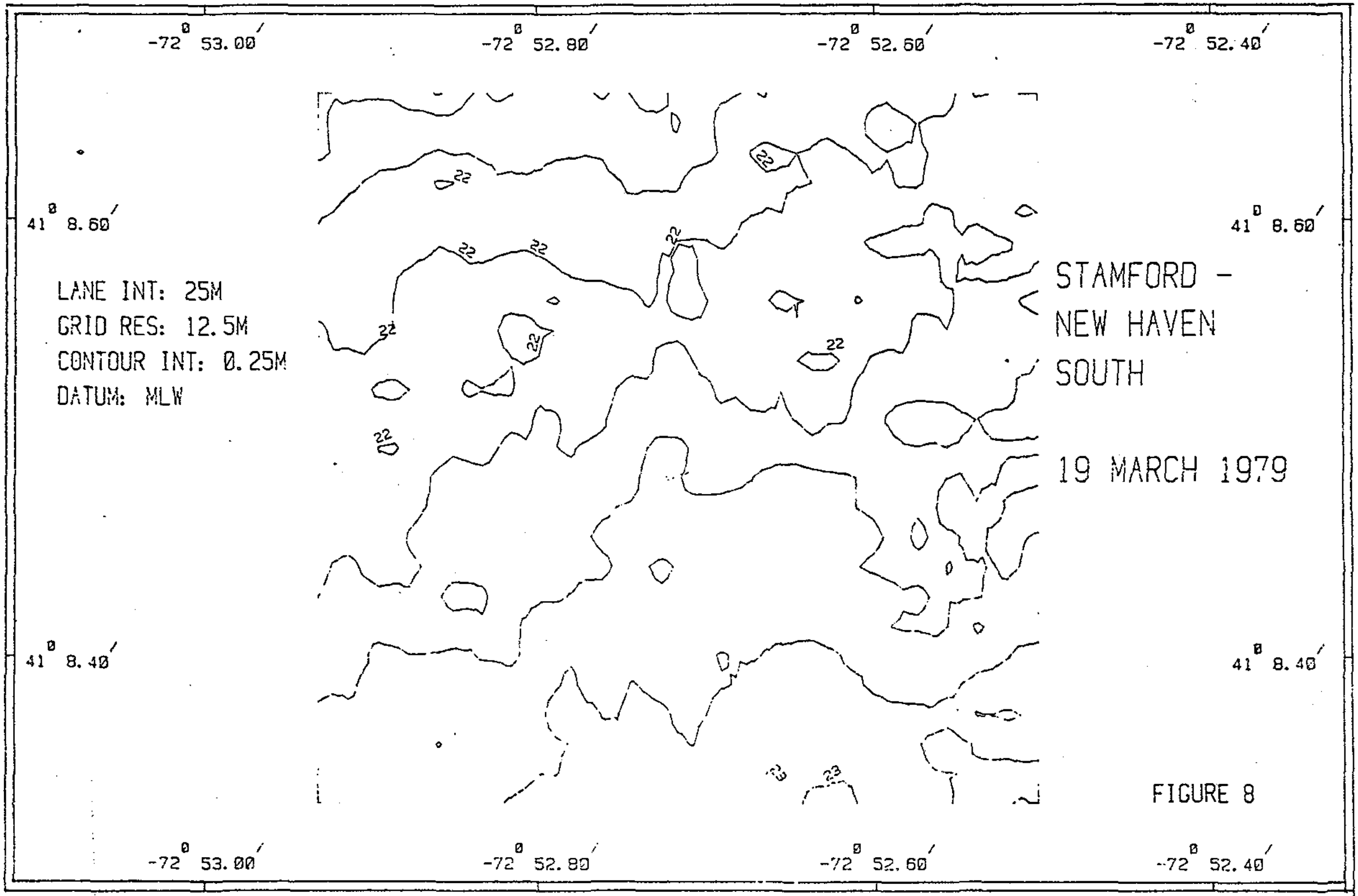
Disposal of dredge spoil from Stamford Harbor at the southern site reached a total of 37,800 m^3 (based on scow load records) on April 22, 1979. A survey of the site was conducted on April 24, to determine the distribution of spoil material prior to capping (Figure 12). This survey indicated that the 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 13) indicates that the topography of this mound is quite variable, and thicknesses of two meters relative to the initial bottom are present. It is important to note that contouring, by its



-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
STAMFORD-
NEW HAVEN
SOUTH
PRE-DISPOSAL
SURVEY
20 JANUARY 1979

FIGURE 7



-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
STAMFORD -
NEW HAVEN
SOUTH
19 MARCH 1979
22
23

FIGURE 8

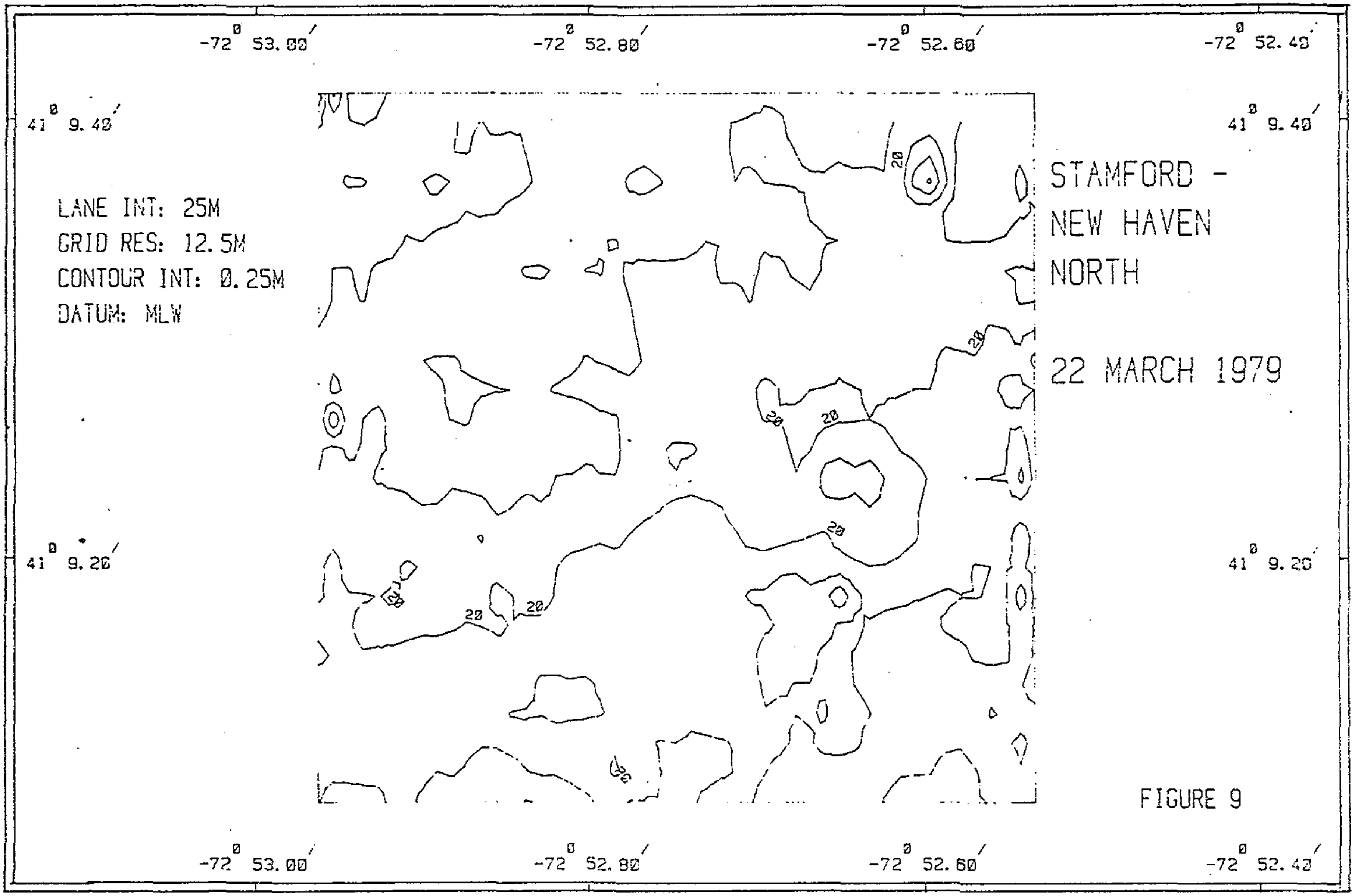

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 9.40'
41° 9.20'
LANE INT: 25M
GRID RES: 12.5M
CONTOUR INT: 0.25M
DATUM: MLW
STAMFORD -
NEW HAVEN
NORTH
22 MARCH 1979
20

FIGURE 9

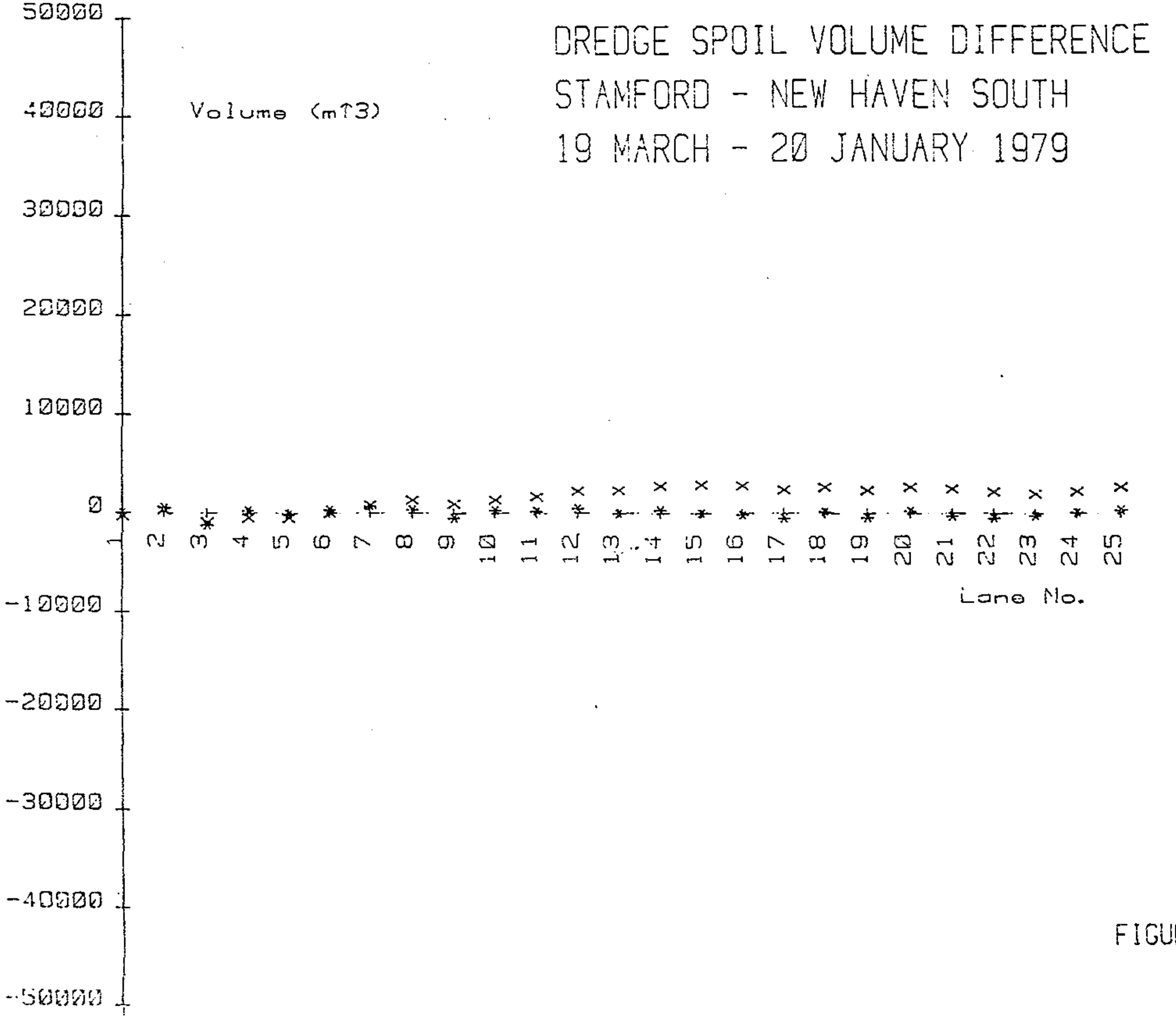

DREDGE SPOIL VOLUME DIFFERENCE
STAMFORD - NEW HAVEN SOUTH
19 MARCH - 20 JANUARY 1979
Volume (m↑3)
50000
40000
30000
20000
10000
0
-10000
-20000
-30000
-40000
-50000
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Lane No.

FIGURE 10

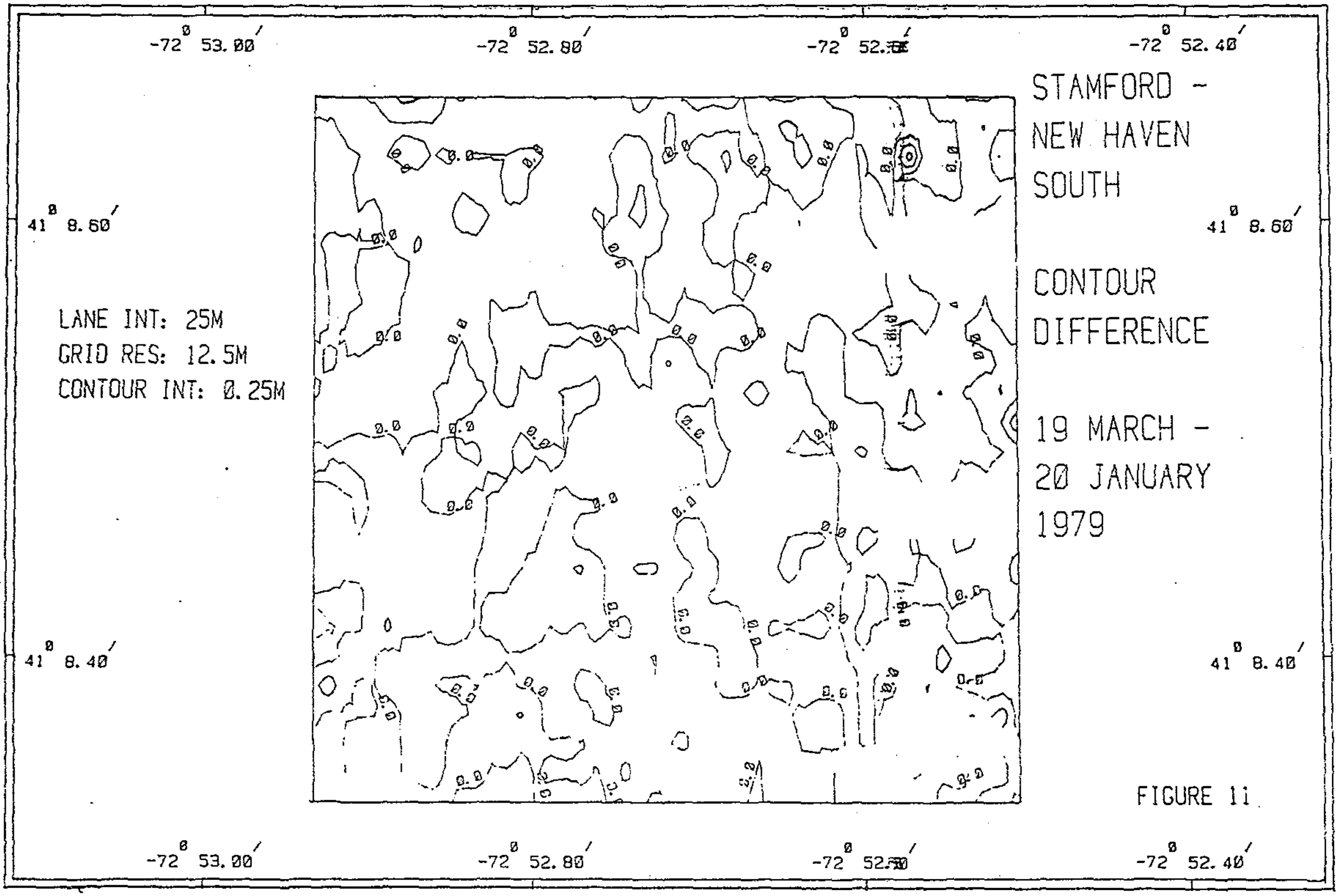

-72° 53.00'
-72° 52.80'
-72° 52.40'
41° 8.60'
41° 8.40'
LANE INT: 25M
GRID RES: 12.5M
CONTOUR INT: 0.25M
STAMFORD - NEW HAVEN SOUTH
CONTOUR DIFFERENCE
19 MARCH - 20 JANUARY 1979
0.0

FIGURE 11

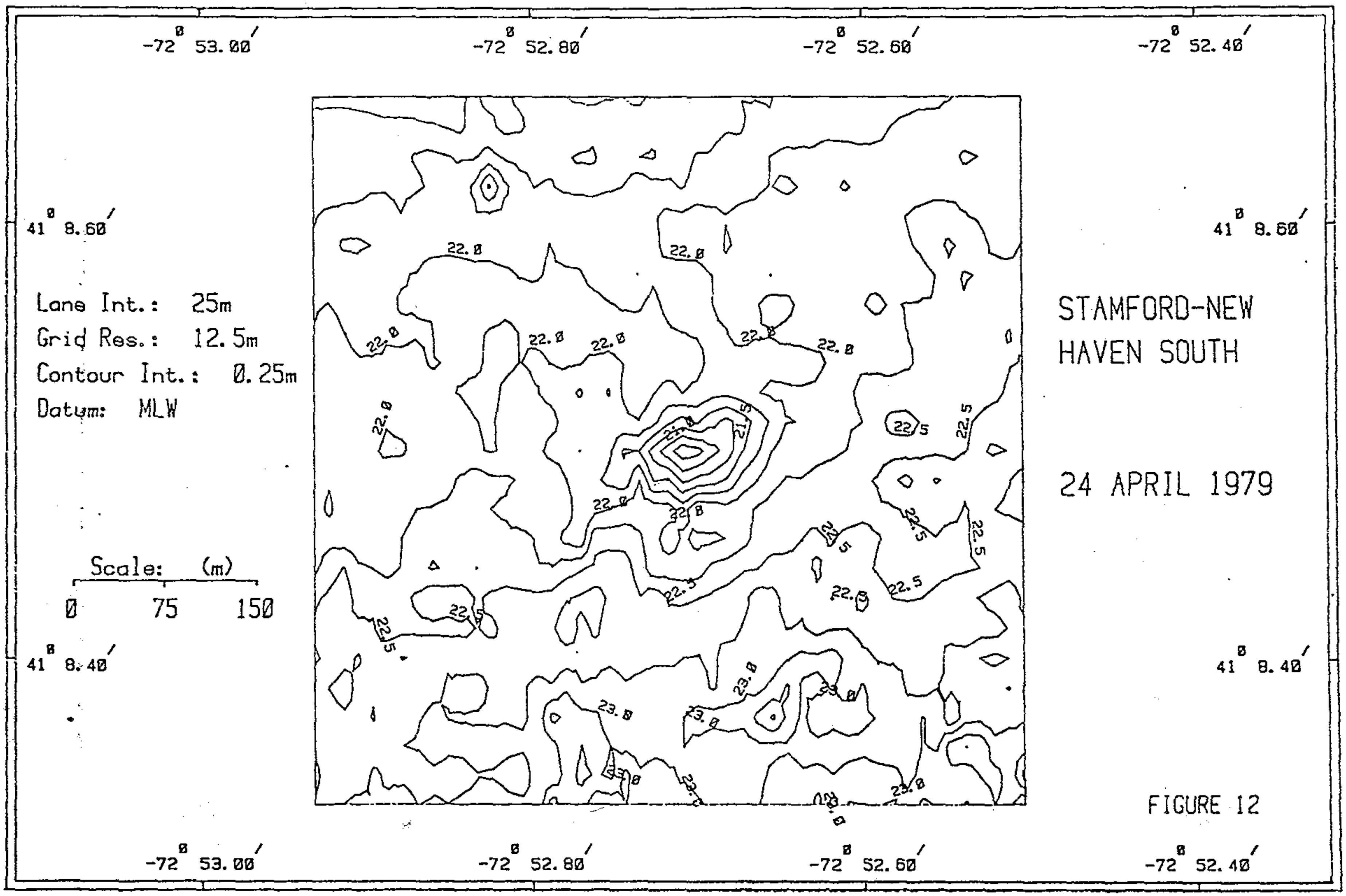
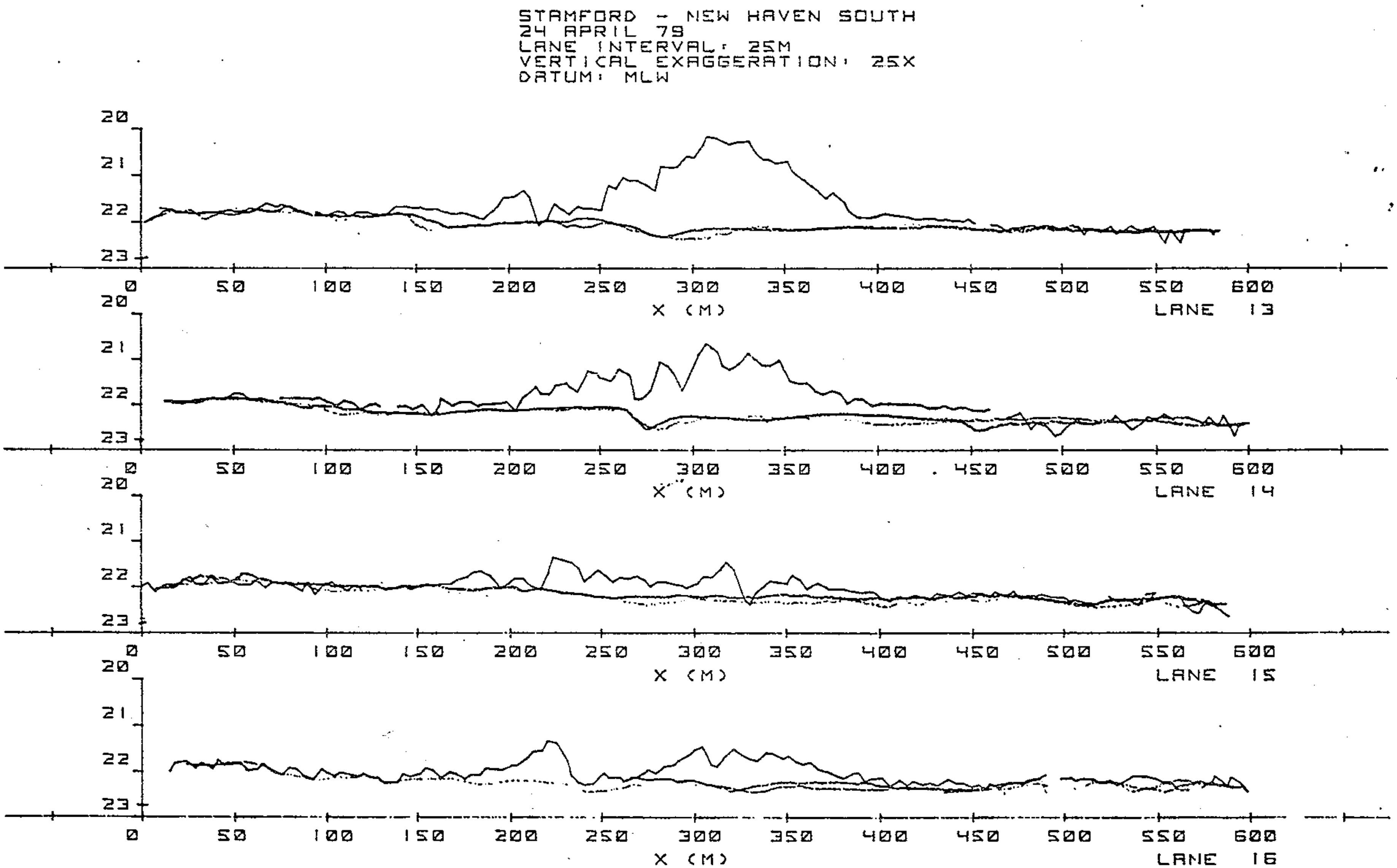

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
STAMFORD-NEW HAVEN SOUTH
24 APRIL 1979
22.0
22.5
23.0

FIGURE 12



STAMFORD - NEW HAVEN SOUTH
24 APRIL 79
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

FIGURE 13

nature will smooth and decrease the topographic expression of the spoils and while overall volumes are accurate due to averaging of all depths measured, specific features smaller than the grid size can not be accurately resolved. These features can be assessed in the vertical profiles, but only within the accuracy of navigation between successive surveys.

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 January baseline survey (Figure 14) resulted in a volume of 34,259 m3 or approximately 90% of the estimated volume deposited. The contour difference chart (Figure 15) 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, whenever dredge spoil was present to any significant degree, these hydroids were covered or destroyed. Consequently, the boundary of the spoils could be readily defined by the presense or absence of these animals. Furthermore, the dark, organic spoils provided a sharp

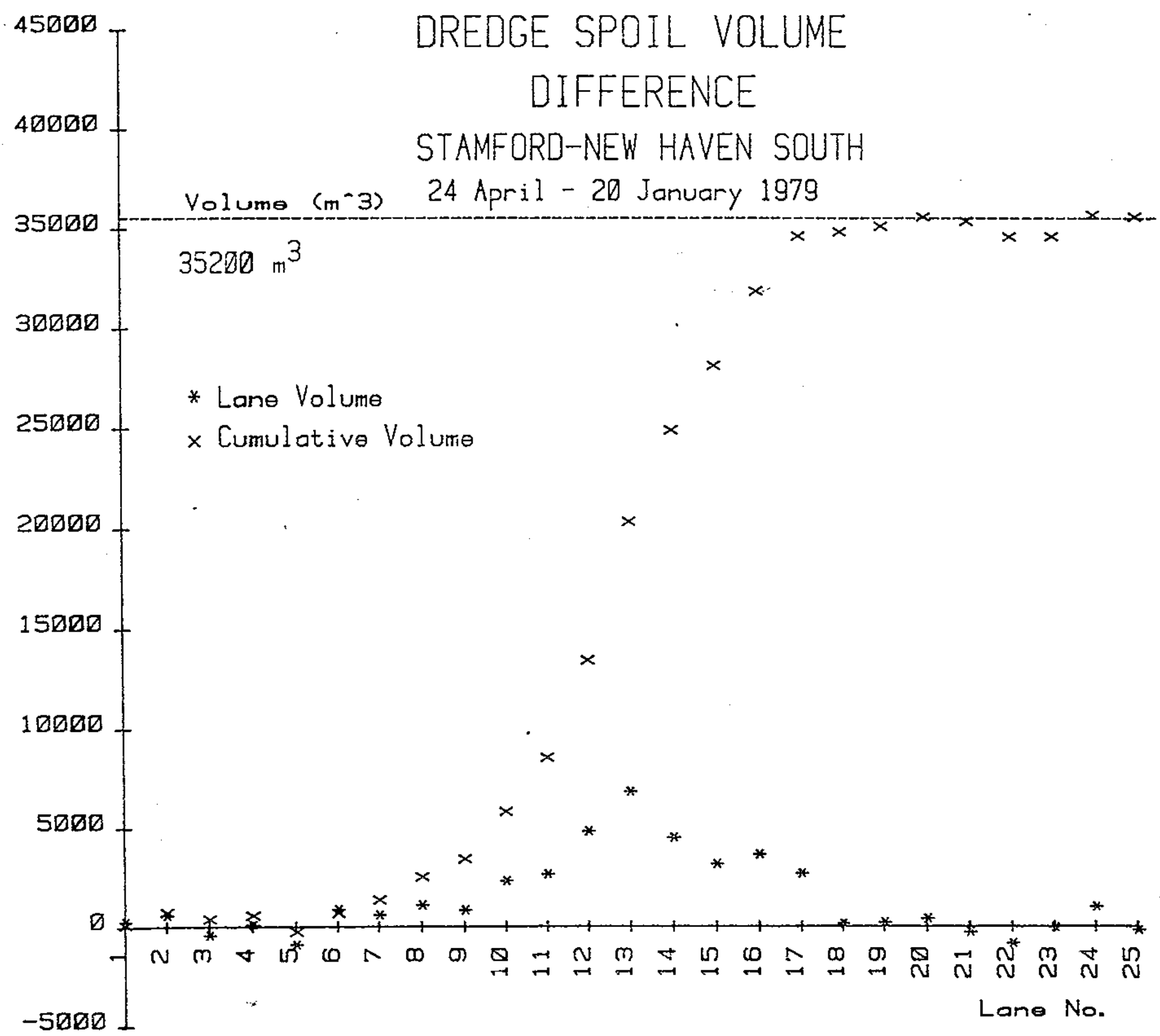
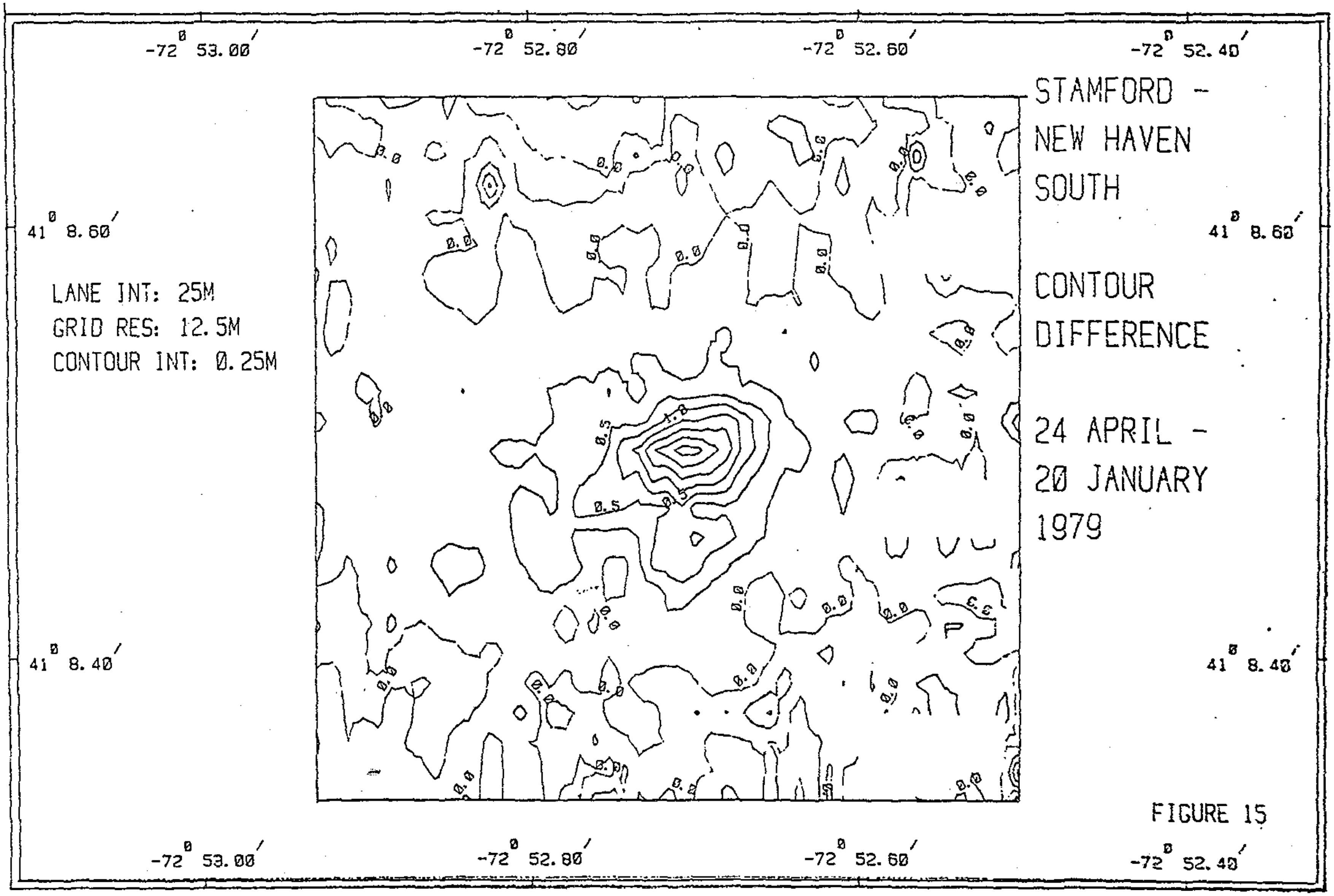

DREDGE SPOIL VOLUME
DIFFERENCE
STAMFORD-NEW HAVEN SOUTH
24 April - 20 January 1979
Volume (m^3)
35200 m3
* Lane Volume
x Cumulative Volume
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
-5000
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
Lane No.

FIGURE 14



-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
STAMFORD - NEW HAVEN SOUTH
CONTOUR DIFFERENCE
24 APRIL - 20 JANUARY 1979
0.0
0.5
1.0

FIGURE 15

contrast to the natural, brown oxidized muds of the disposal site and the thickness of spoils on the margins of the mound could be directly measured in the grab sampler.

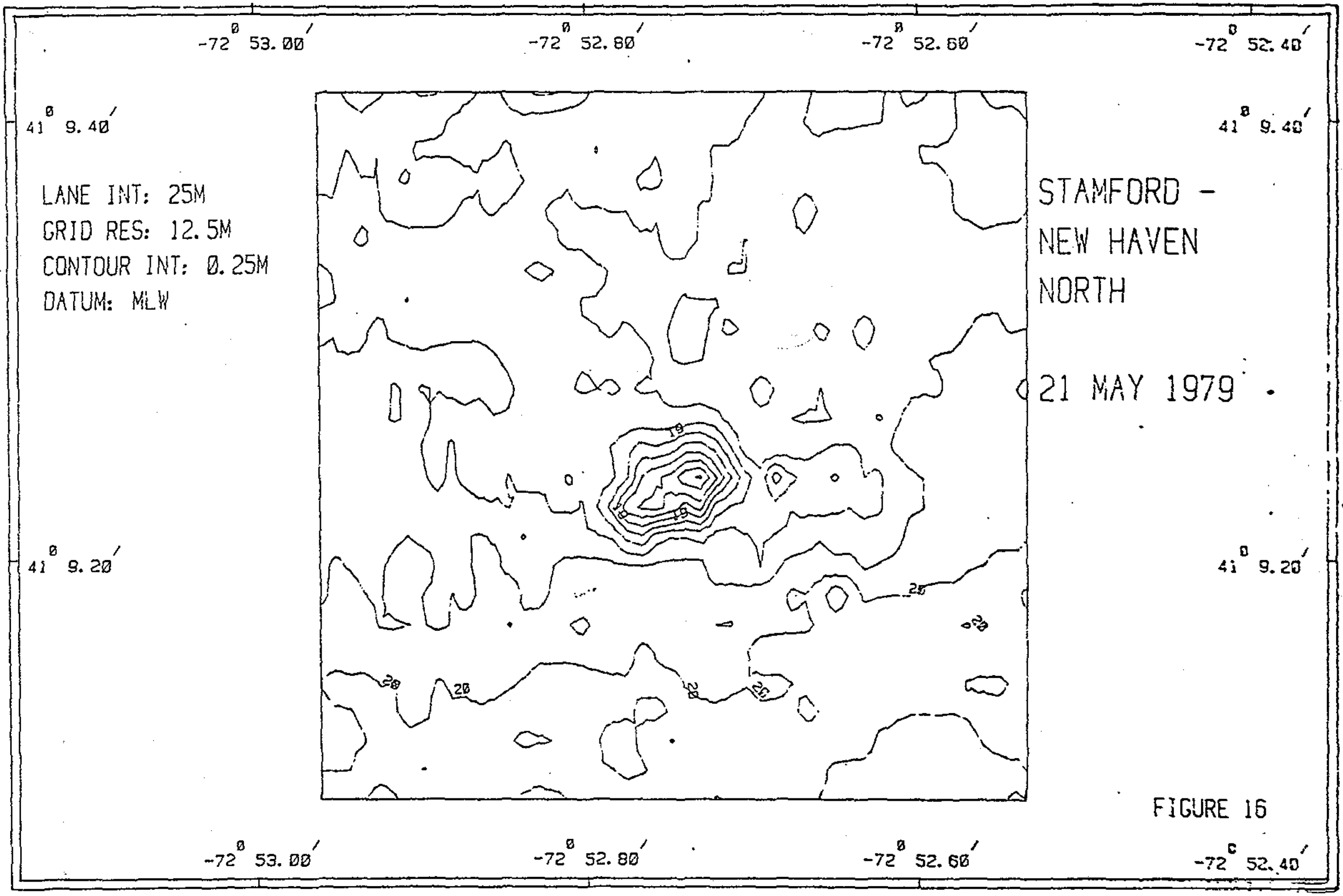
The most striking result of these measurements was the rapid decrease in spoil thickness at the margins of the spoil mound. In the east and west directions the change from thickness greater than 50 cm to less than 5 cm occurred between 100 and 150 meters from the disposal point; while in the north-south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

Volume calculations along the periphery of the spoil mound were made by assuming that the spoil material flowed uniformly outward and is, therefore, of uniform thickness at a given radius from the center of the mound. Observations tend to support this, particularly, since the coarseness of the particles in the fringe areas have been observed to be inversely proportional to distance from the disposal point. From these data and observations of the disposal operation, 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 most of the remaining material forms a turbidite type deposit radially from the disposal point.

The volume of spoil in the fringe area was estimated by contouring the measured thickness in the grab sample and measuring the major and minor axes of the resulting ellipse. The area of each ellipse was multiplied by the difference thickness and summed to calculate the total volume. This volume measured was 1980m^3 or approximately 5% of the estimated spoil volume.

Since the bathymetric and sampling procedures accounted for more than 95% of the estimated spoils dumped at the site and since the error of estimating volume in the scows must be relatively large, it was concluded that the bathymetric survey technique was adequate for monitoring disposal operations. 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 would be successful. Disposal of additional Stamford spoil at the north site was also accomplished successfully and a monitoring survey conducted on 21 May (Figure 16) 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. On June 20, a survey was made of the southern site (Figure 17) to determine the success of the silt capping operation. The contour chart and the vertical profiles (Figure 5) 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



-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

FIGURE 16

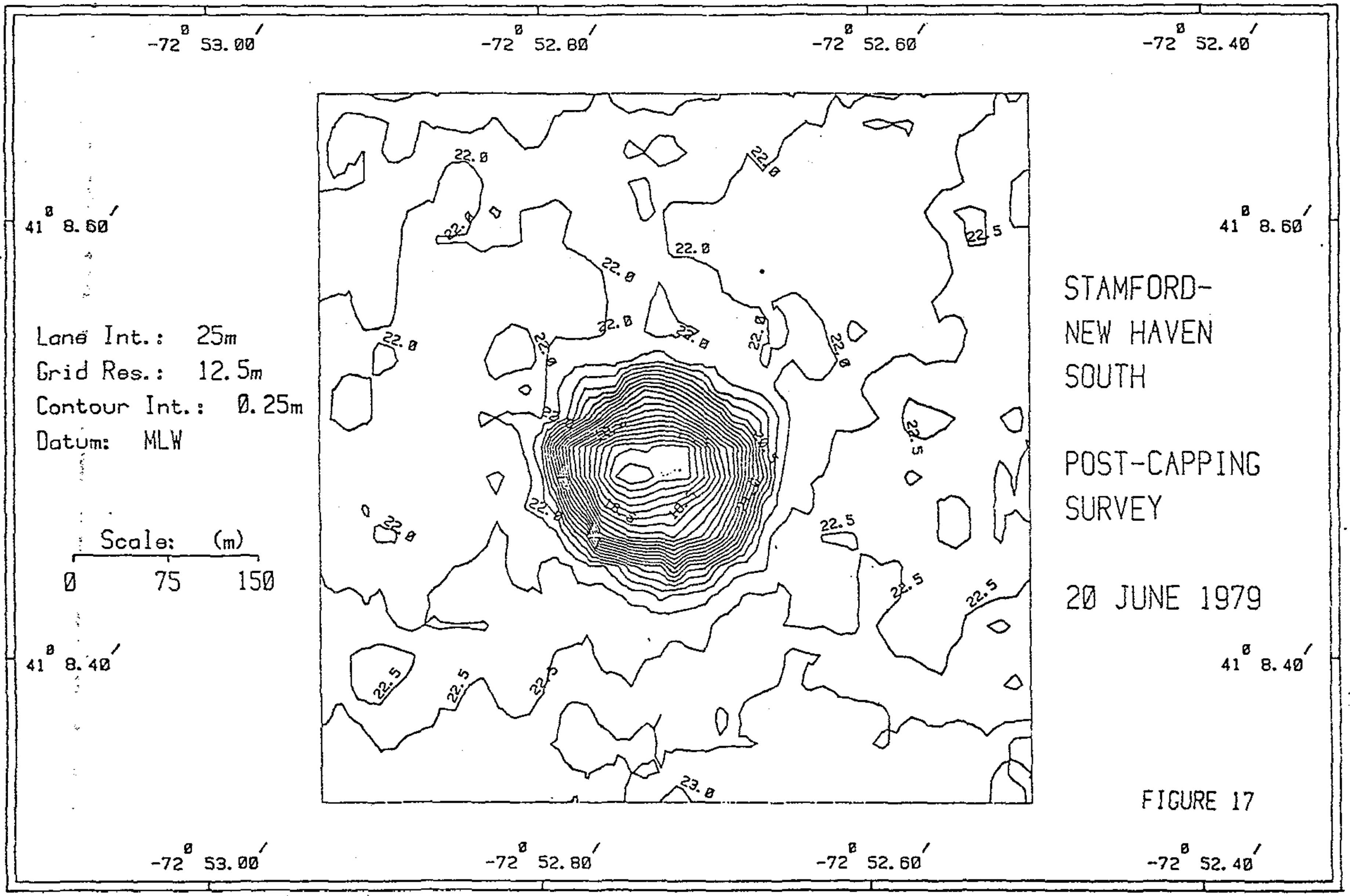

-72° 53.00′
-72° 52.80′
-72° 52.60′
-72° 52.40′
41° 8.60′
41° 8.40′
22.0
22.5
23.0
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
STAMFORD-
NEW HAVEN
SOUTH
POST-CAPPING
SURVEY
20 JUNE 1979

FIGURE 17

the thickness to some extent. The volume of New Haven spoil dumped at the south site was estimated at 76000m^3 from scow load measurements, of which 72000m^3, or 95%, was accounted for by volume calculations.

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 bathymetry 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 18). This survey and the associated vertical profiles (Figure 19) 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 10-15cm 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, make comparisons tenuous and calculations of volume and percentage lost to the water column meaningless.

The results of these surveys indicate that the capping

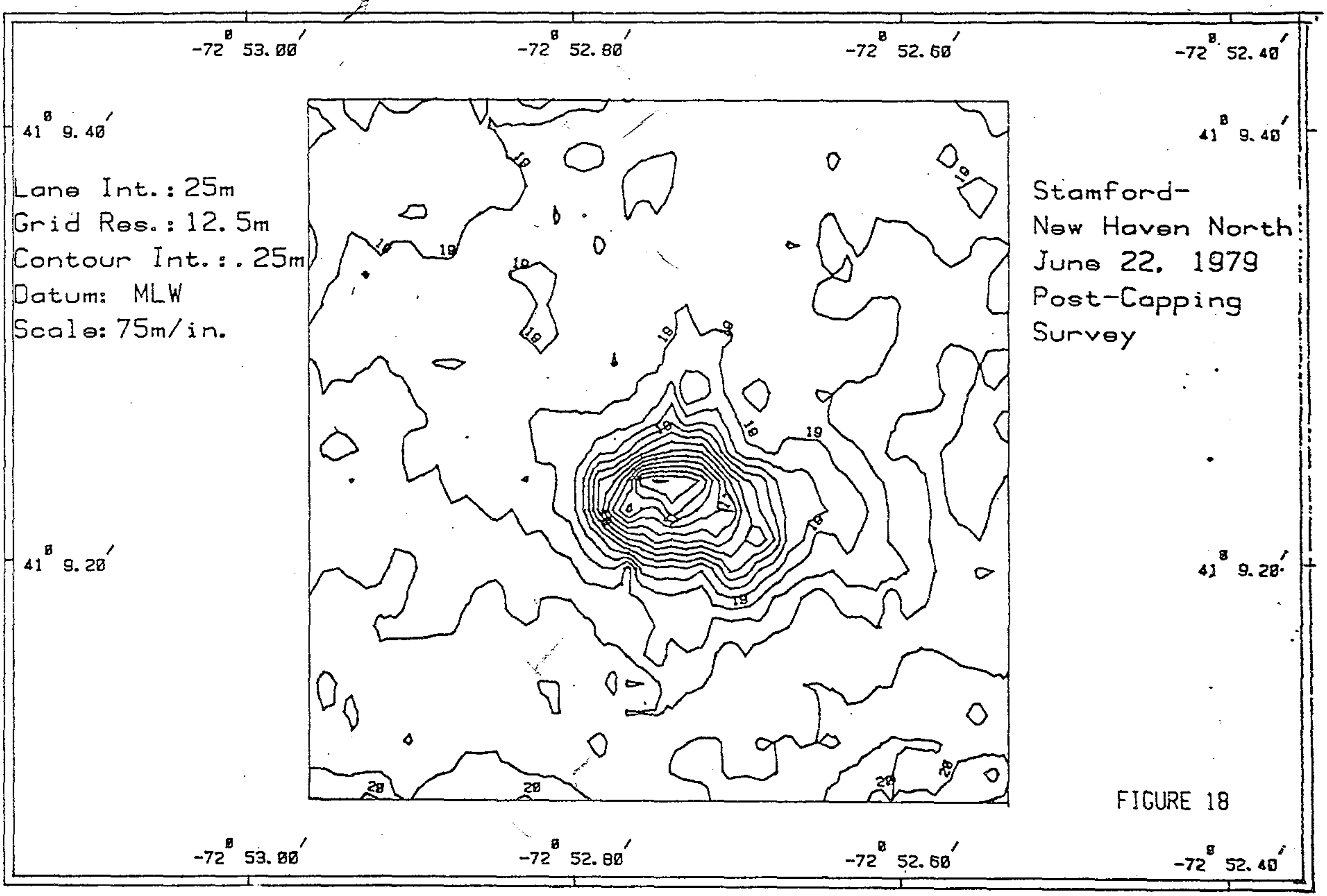
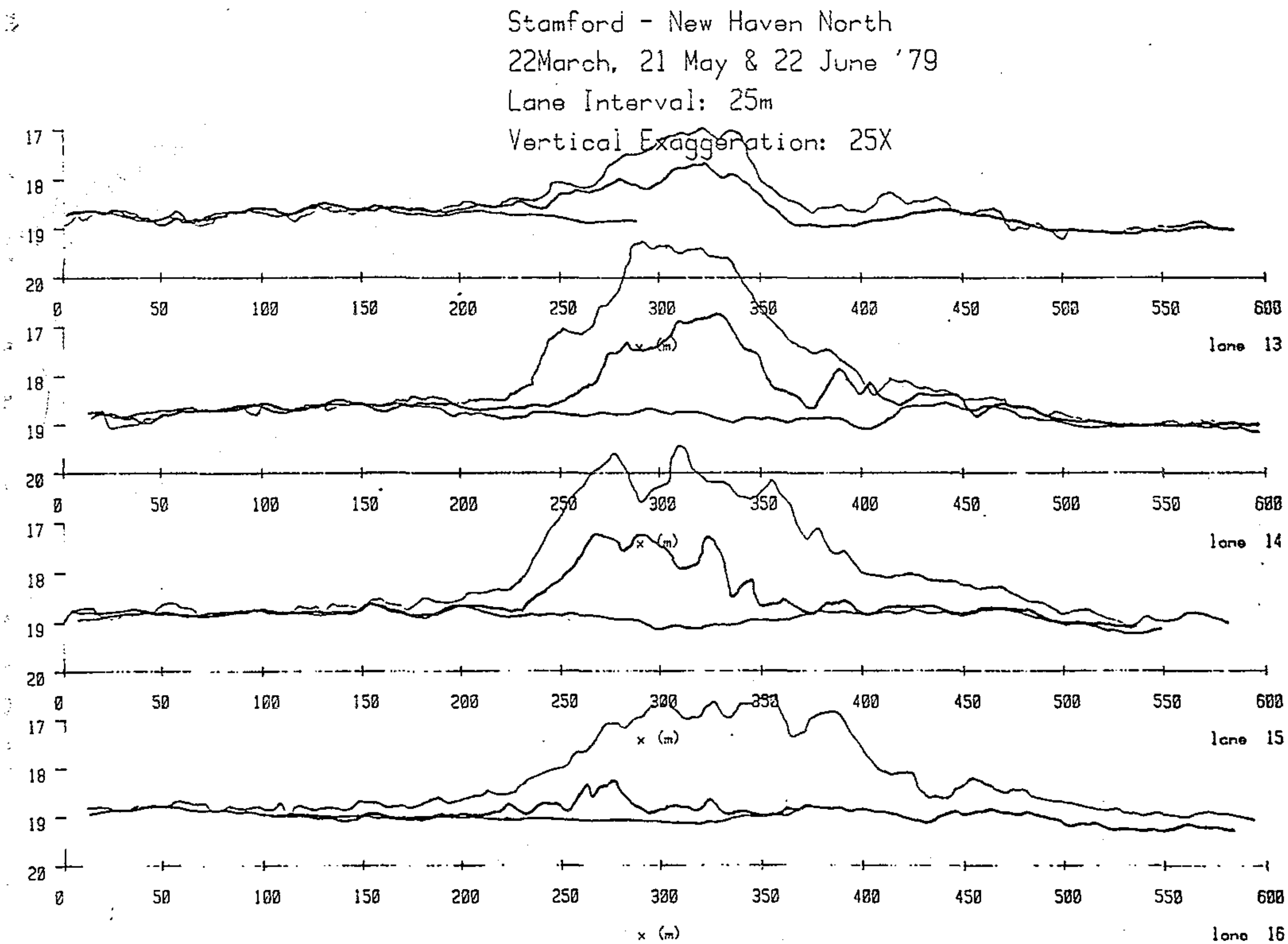

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 9.40'
41° 9.20'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: 75m/in.
Stamford-
New Haven North
June 22, 1979
Post-Capping
Survey
19
20

FIGURE 18



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

FIGURE 19

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. 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 acomplished 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.

POST-DISPOSAL MONITORING

Although the operational techniques for capping Stamford spoils 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, however, the emphasis in this paper is placed on the results of the bathymetric monitoring and its implication toward understanding physical processes acting on the spoils.

Evaluation of long term changes in the shape and volume of the spoil mounds requires an initial baseline for comparison similar to that used in the operational monitoring phase of the project. For post disposal studies the June 20 survey of the southern site (Figure 17) and the June 22 survey of the northern site (Figure 18) were used.

On 7 August 1979, a bathymetric survey (Figure 20) of the North disposal site was conducted that indicated there were no major changes in the topography of the spoil mound. Examination of the vertical profiles (Figure 21) supports this conclusion. In all cases, except Lane 13, the overall topographic features are consistant, however, the mound has settled or compressed slightly increasing the depth by approximately 20 cm. Calculation of volume differences between these surveys indicates that only Lane 13 has an

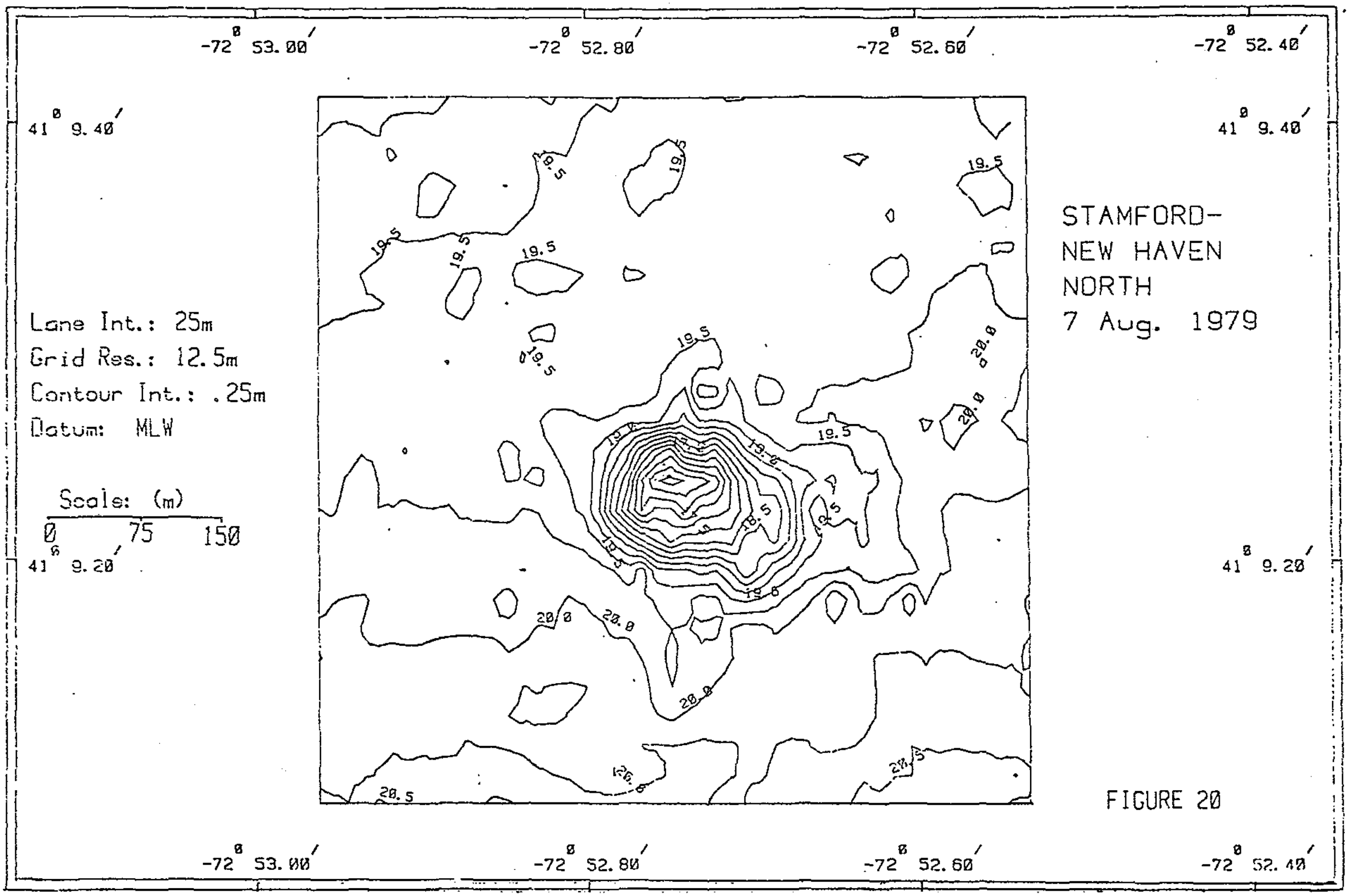
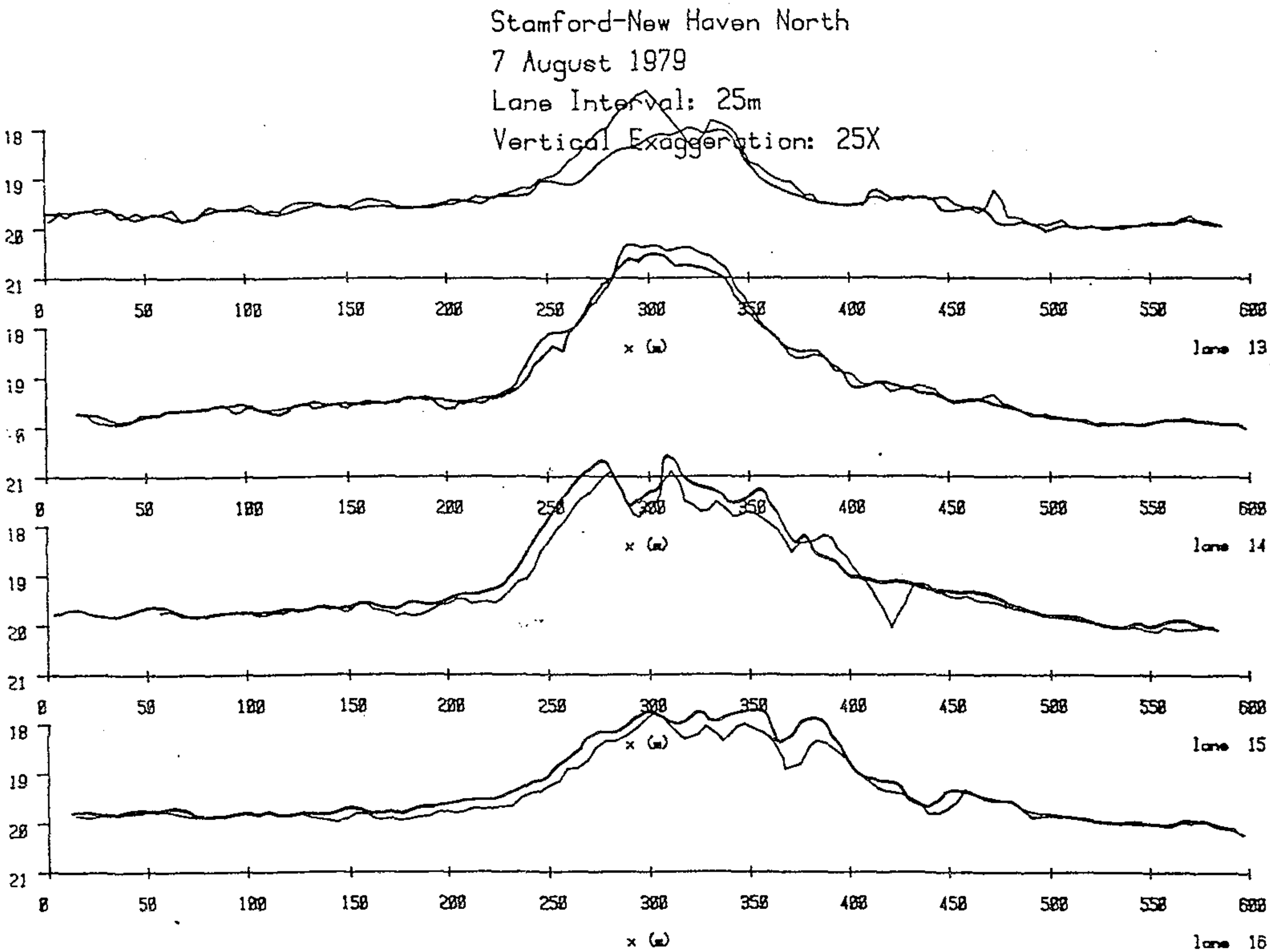

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 9.40'
41° 9.40'
STAMFORD-
NEW HAVEN
NORTH
7 Aug. 1979
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: .25m
Datum: MLW
Scale: (m)
0 75 150
41° 9.20'
41° 9.20'
19.5
20.0
20.5
-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'

FIGURE 20



Stamford-New Haven North
7 August 1979
Lane Interval: 25m
Vertical Exaggeration: 25X
18
19
20
21
0
50
100
150
200
250
300
350
400
450
500
550
600
x (m)
lane 13
lane 14
lane 15
lane 16

FIGURE 21

increase in volume while other lanes over he mound show a decrease. Total loss for the entire survey area was approximately 1700 m3 which was less than the 2400 m3 previously cited as the resolution of the survey procedure.

No explanation is readily available for the increase in volume for Lane 13. Examination of the survey track shows no deviation from the specified lane at this location negating the possibility of navigation error. However, the location of the increase in spoil is immediately west of the disposal buoy and it is possible that a permit contractor who should have been dumping west of the "SP" buoy could have mistakingly dumped at the North disposal buoy.

A survey of the southern site was also run on August 7, 1979 (Figure 22) which likewise indicated no major differences in the spoilmound. All ~~other~~ transects across the mound (Figure 23) have a slight increase of 20-40 cm that is 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 m3, 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 from 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 spoils mounds did occur resulting in a 20-40 cm increase in depth on the tops of the piles. These results were expected since the spoil

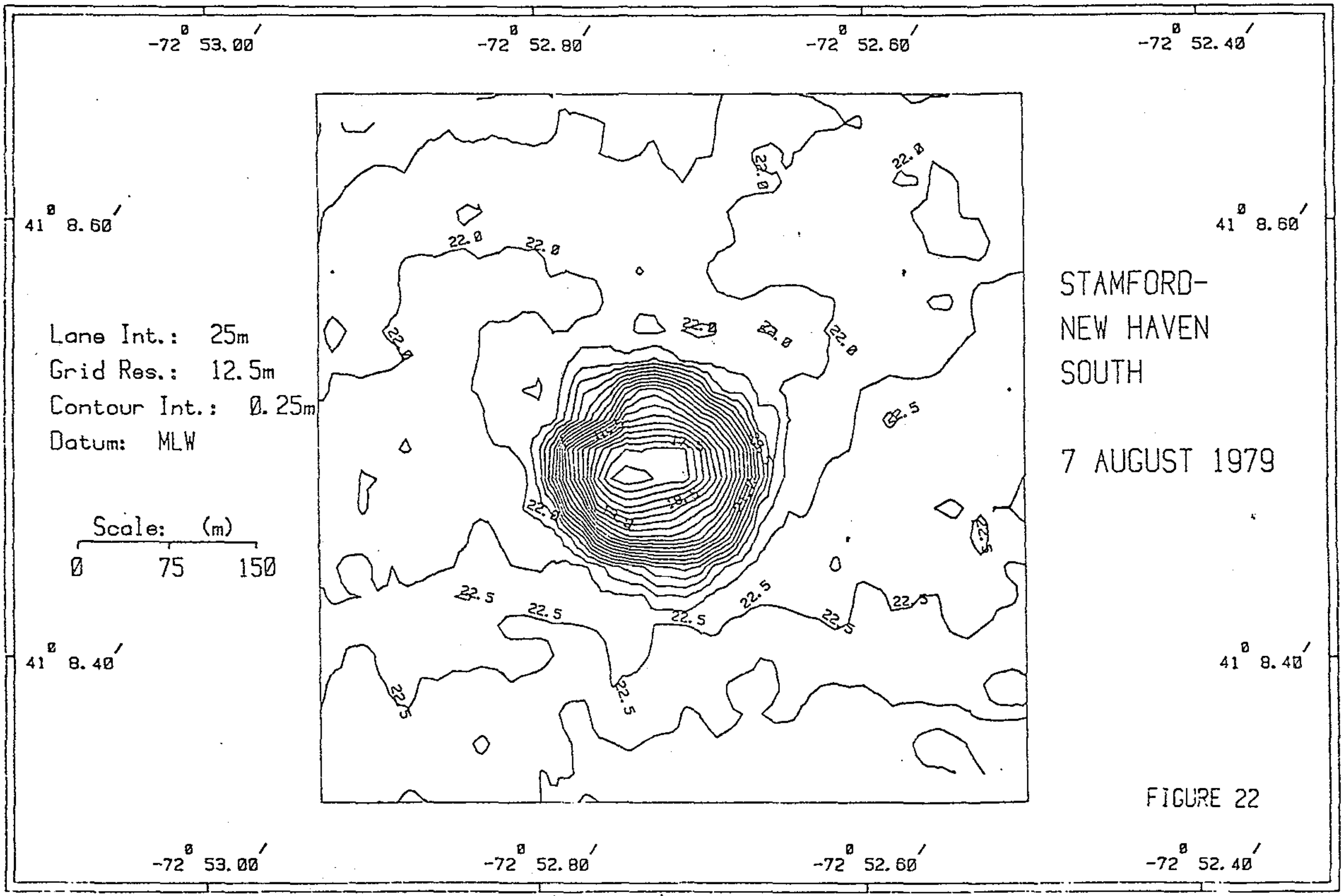

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
22.0
22.5
STAMFORD-
NEW HAVEN
SOUTH
7 AUGUST 1979

FIGURE 22

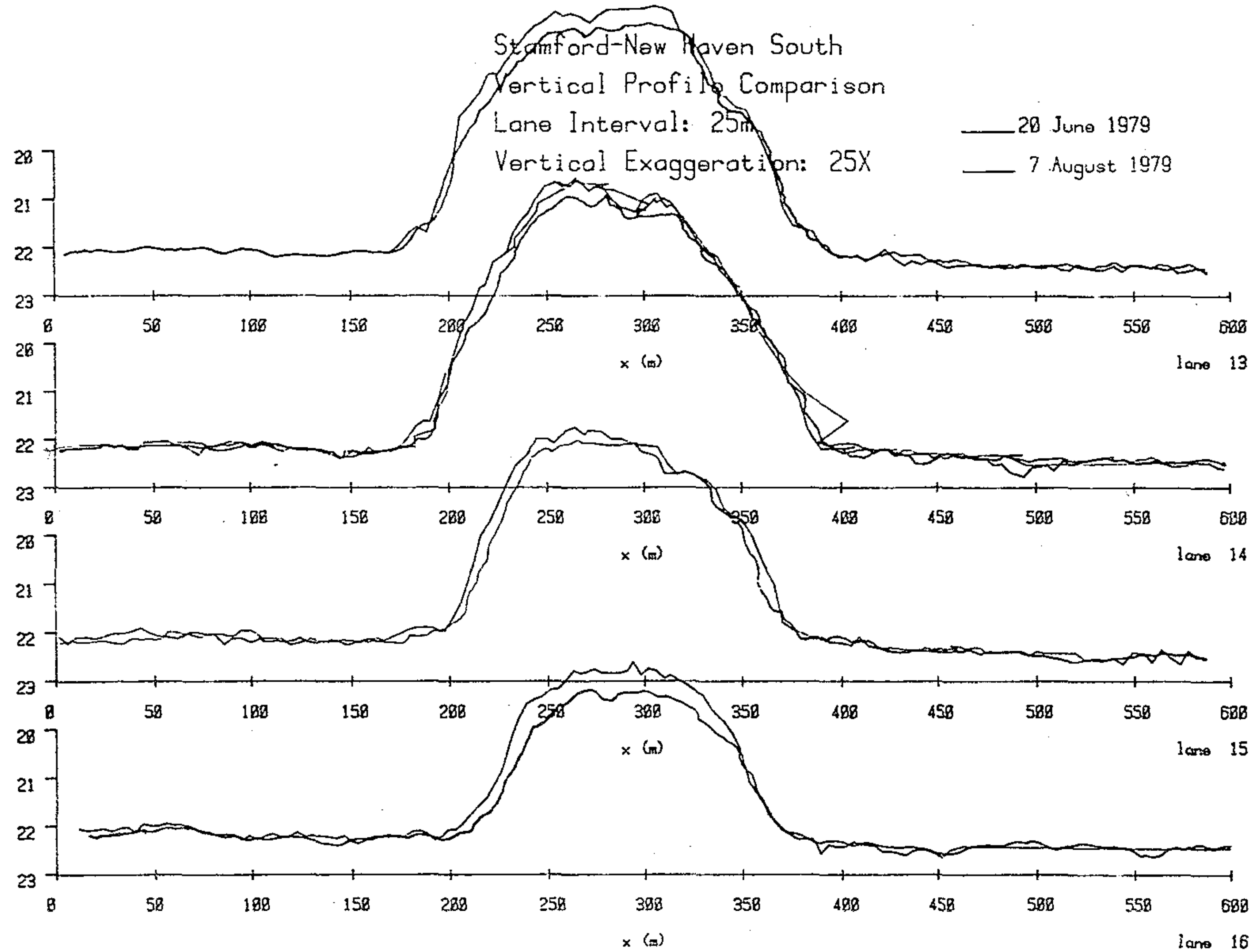

Stamford-New Haven South
Vertical Profile Comparison
Lane Interval: 25m
Vertical Exaggeration: 25X
20 June 1979
7 August 1979
x (m)
lane 13
lane 14
lane 15
lane 16

FIGURE 23

mound from the 1974 dredging operation has been stable for several years indicating the containment potential of the disposal site.

Following the August surveys an additional 6000 m^3 of clean-up material from Stamford harbor was deposited at the southern site and a survey was conducted on November 7, 1979, to evaluate changes resulting from the additon of these spoils (Figure 24). 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 25) revealed a flat surface at 19 meters which was also readily apparent on the contour chart (Figure 24) indicating that approximately 2 meters of spoil had been removed. Some of that material was present, particularly on the northeast margin of the mound where slumping of spoils had occurred, however, the build-up of material in that area cannot account for all the missing spoils. Although this loss of material did not expose any Stamford spoil, further investigations were initiated to determine the causes of spoil movements 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

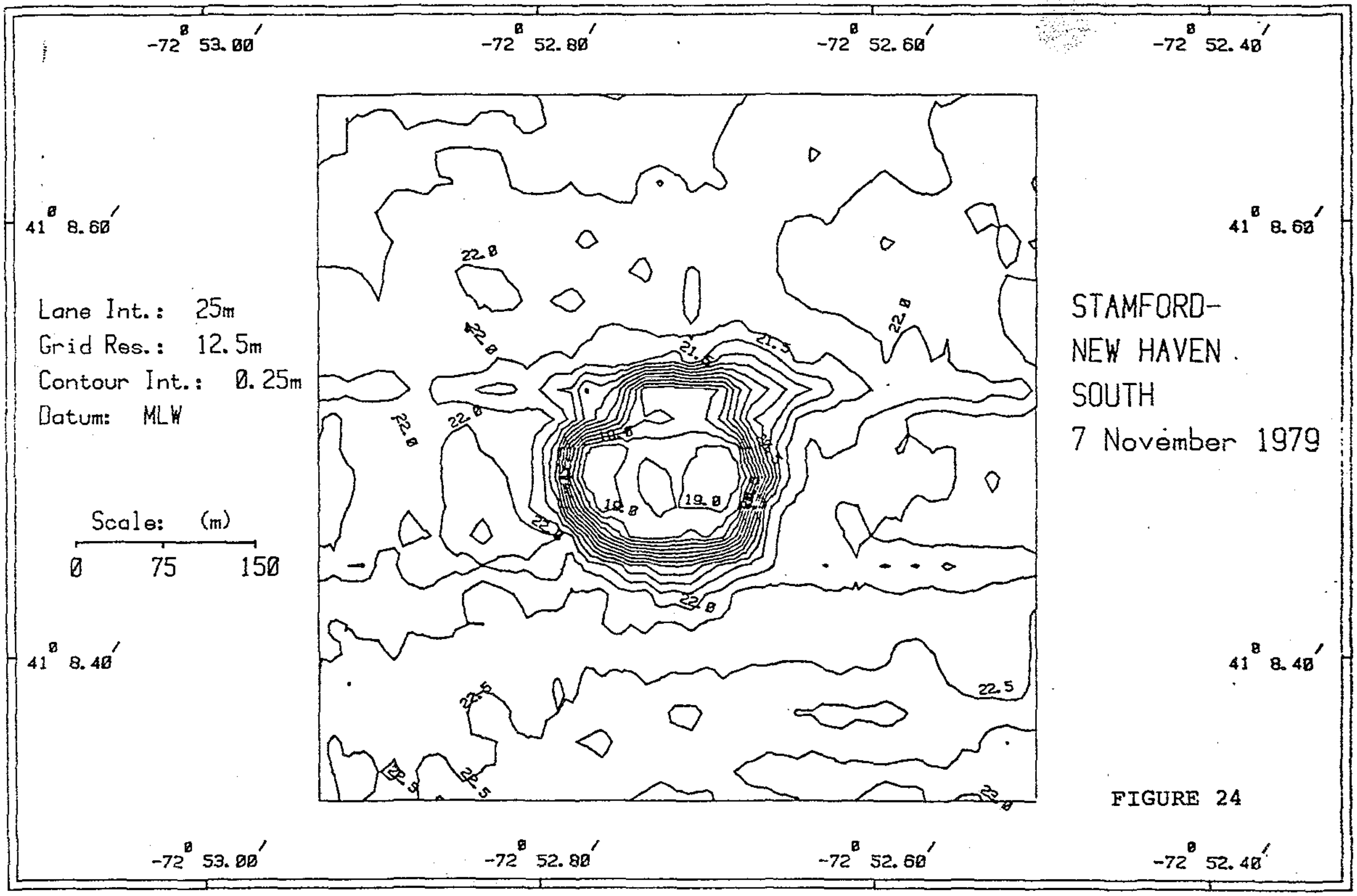

-72° 53.00'
-72° 52.80'
-72° 52.60'
-72° 52.40'
41° 8.60'
41° 8.40'
Lane Int.: 25m
Grid Res.: 12.5m
Contour Int.: 0.25m
Datum: MLW
Scale: (m)
0 75 150
22.0
21.5
19.0
22.5
STAMFORD-
NEW HAVEN
SOUTH
7 November 1979

FIGURE 24

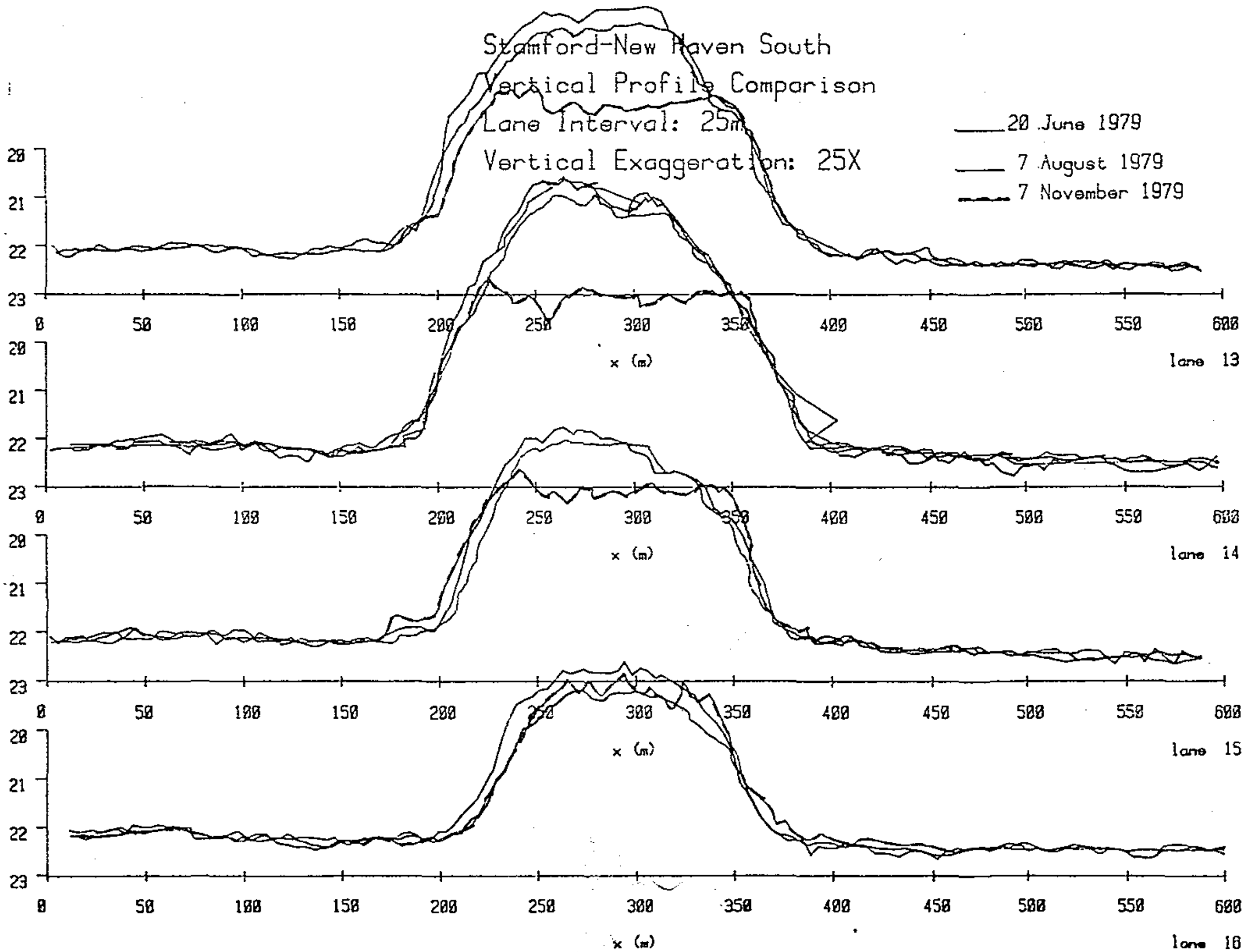

Stamford-New Haven South
Vertical Profile Comparison
Lane Interval: 25m
Vertical Exaggeration: 25X
20 June 1979
7 August 1979
7 November 1979
x (m)
lane 13
lane 14
lane 15
lane 16

FIGURE 25

conducted using the same precision techniques, replicating previous 25 meter lanes and both surveys indicated that no significant changes had occurred in either mound during the period in which the southern site was affected.

In 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. Furthermore, the slopes of the sand covered mounds are more gentle than those of the southern site, athough all three sites exhibit angles less than 5 degrees and should be within a stable angle of repose for the sediment.

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 spoils 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 situation and may have provided sufficient stress to initiate sediment motion.

To examine this possibility, calculations were made of theoretical shear stress 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. For unconsolidated fine sand similar to that present on the north spoil mound and the 1974 New Haven mound the critical threshold would be exceeded in water depths of 14 and 16 meters for 4.5 and 5.0 second waves of sufficient height ($<$ 1.5m).

The wave height in 18 meters depth (south pile) must ,however, exceed 2 meters with a period of 5 sec to meet the nominal threshold condition. To estimate stress, due to wave motion it was necessay to hindcast waves based on wind data and fetch distance. The wave hindcast data generated for Hurricane David indicated that development of such long period waves would be unlikely. However, since failure of the top of the 18 meter south pile was observed, estimates of the developed shear stress were made and compared.

The spoil mounds differ in depth of water, composition, shape and surface roughness. The south pile is composed of clumps of consolidated clay material surrounded by a fine silty clay matrix. These clumps protrude into the near bottom flow and will, therefore, develop shear stress due to form drag as well as skin friction. The size of these elements estimated from bottom photographs and relatively undisturbed grab samples, is approximately 20 cm. (Figure 26). The other spoil mounds have been covered with fine-medium sand and have a roughness estimated from the grain size to be about 0.025 cm.

The Shields Criterion (ψ) which expresses the threshold of sediment motion as a function of sediment properties was calculated for a grain diameter of D=.025 cm (S*=3.97) for waves of 4 and 4.5 second period. Shear stresses were then calculated as a function of wave height for both bottom roughness factors (20 cm, .025cm) (Table 1 & 2).

The calculated shear stress values for large roughness height are near or exceed the critical value for all tested wave heights at both periods (Figure 27 & 28). In contrast, the shear

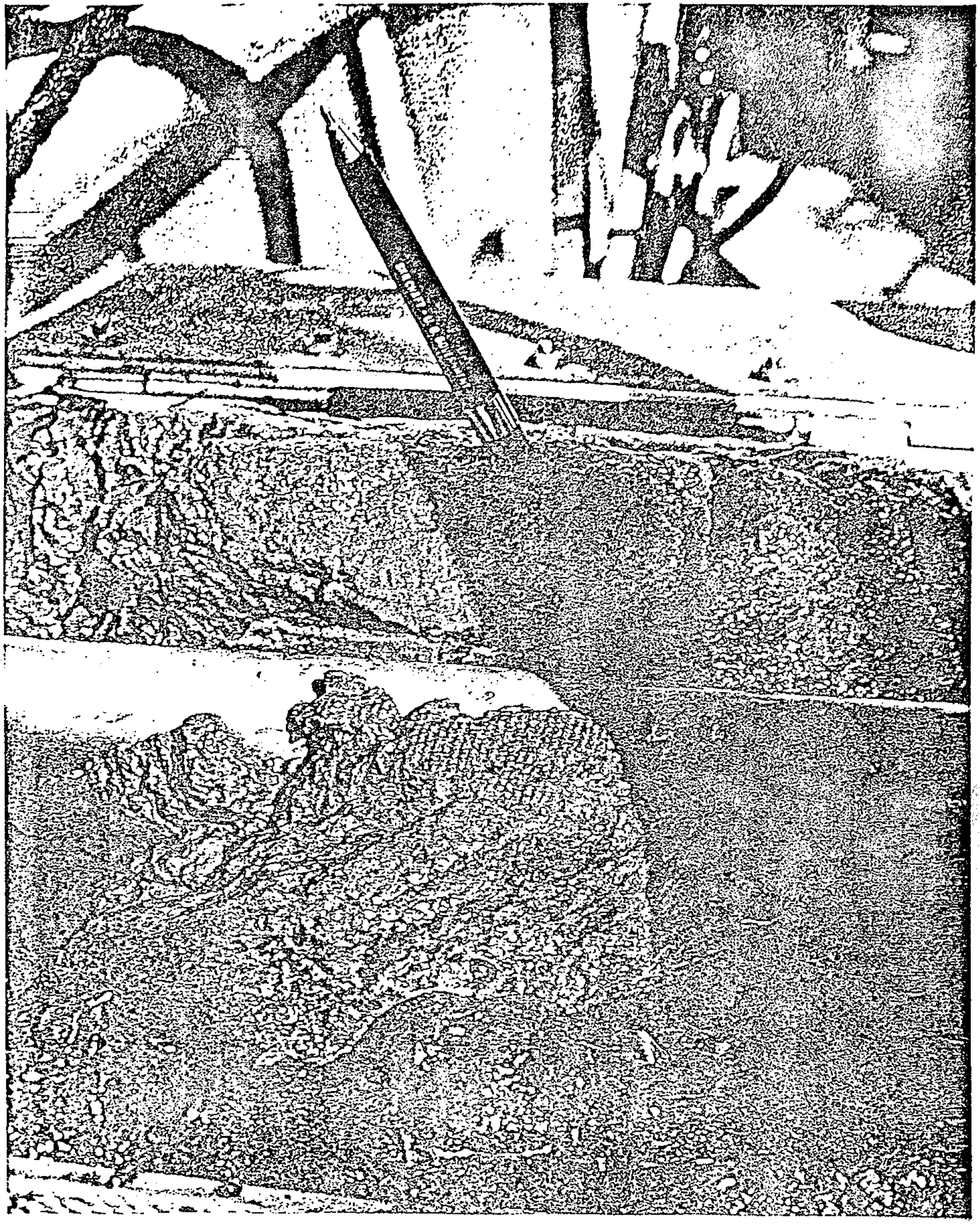


FIGURE 26

h = 1800 cm L_1 = 2500 cm   sinh kh = 46.14   h/L = .7202

T = 4 sec h/L_o = 0.72 k_1 = .025 k_2 = 20 cm

H (m)	d_o (cm)	U_m (cm/sec)	$\frac{U_m d_o/2}{\nu}$	$\frac{d_o/2}{k_1}$	f_1	$\frac{d_o/2}{k_2}$	f_2	τ_1	τ_2	ψ_1	ψ_2
	2.17	1.70	$1.84.10^2$	43.3	.1	.05	.60	.29	1.73	.007	.04
.5	3.25	2.55	$4.15.10^2$	65.0	.09	.08	.53	.30	1.77	.007	.04
	4.33	3.40	$7.39.10^2$	86.7	.07	.19	.5	.41	2.97	.01	.07
.5	5.42	4.26	$1.15.10^3$	108.	.059	.13	.5	.55	4.66	.031	.11
	6.50	5.11	$1.66.10^3$	130.	.048	.16	.5	.64	6.70	.16	.16
.5	7.59	5.96	$2.26.10^3$	152.	.040	.19	.5	.73	8.31	.018	.20

STRESS PARAMETERS AT 18 METER DEPTHS WITH A WAVE PERIOD OF 4 SECONDS AND ROUGHNESS ELEMENTS OF .025 and 20 CM.

TABLE 1

h = 1800 cm L_o = 3158.   sinh kh = 18.05   h/L = .5709

T = 4.5 h/L_o = 0.57 k_1 = 0.025 cm k_2 = 20 cm

m)	d_o (cm)	U_m (cm/sec)	$\frac{U_m d_o/2}{\nu}$	$\frac{d_o/2}{k_1}$	f_1	$\frac{d_o/2}{k_2}$	f_2	τ_1	τ_2	ψ_1	ψ_2
1	5.54	3.87	$1.07.10^3$	111.	.06	.14	.5	.46	3.85	.011	.09
1.5	8.31	5.80	$2.41.10^3$	166.	.04	.21	.5	.69	8.64	.017	.20
2	11.08	7.74	$4.29.10^3$	222.	.035	.28	.49	1.078	15.07	.026	.36
2.5	13.85	9.67	$6.70.10^3$	277.	.024	.35	.49	1.152	23.53	.028	.56
3	16.62	11.60	$9.64.10^3$	332.	.020	.42	.49	1.382	33.86	.033	.81
3.5	19.39	13.54	$1.31.10^4$	388.	.016	.48	.49	1.506	46.13	.436	1.11

STRESS PARAMETERS AT 18 METER DEPTHS WITH A WAVE PERIOD OF 4.5 SECONDS AND ROUGHNESS ELEMENTS OF .025 and 20 CM

TABLE 2

MODIFIED SHIELDS DIAGRAM (MADSEN & GRANT, 1970)
WAVE PERIOD T = 4.0 SEC.

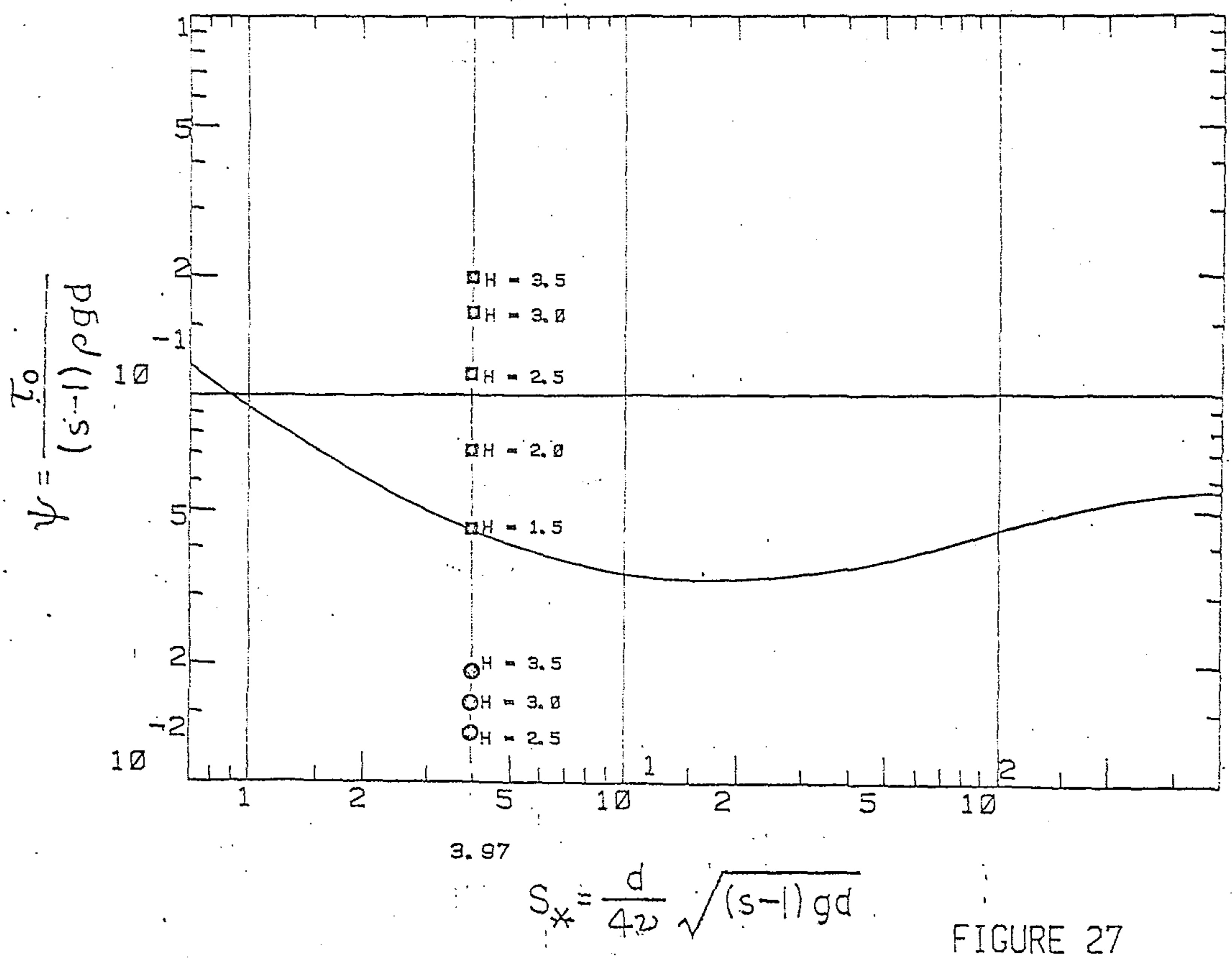


FIGURE 27

MODIFIED SHIELDS DIAGRAM (MADSEN & GRANT, 1970)
WAVE PERIOD T = 4.5 SEC.

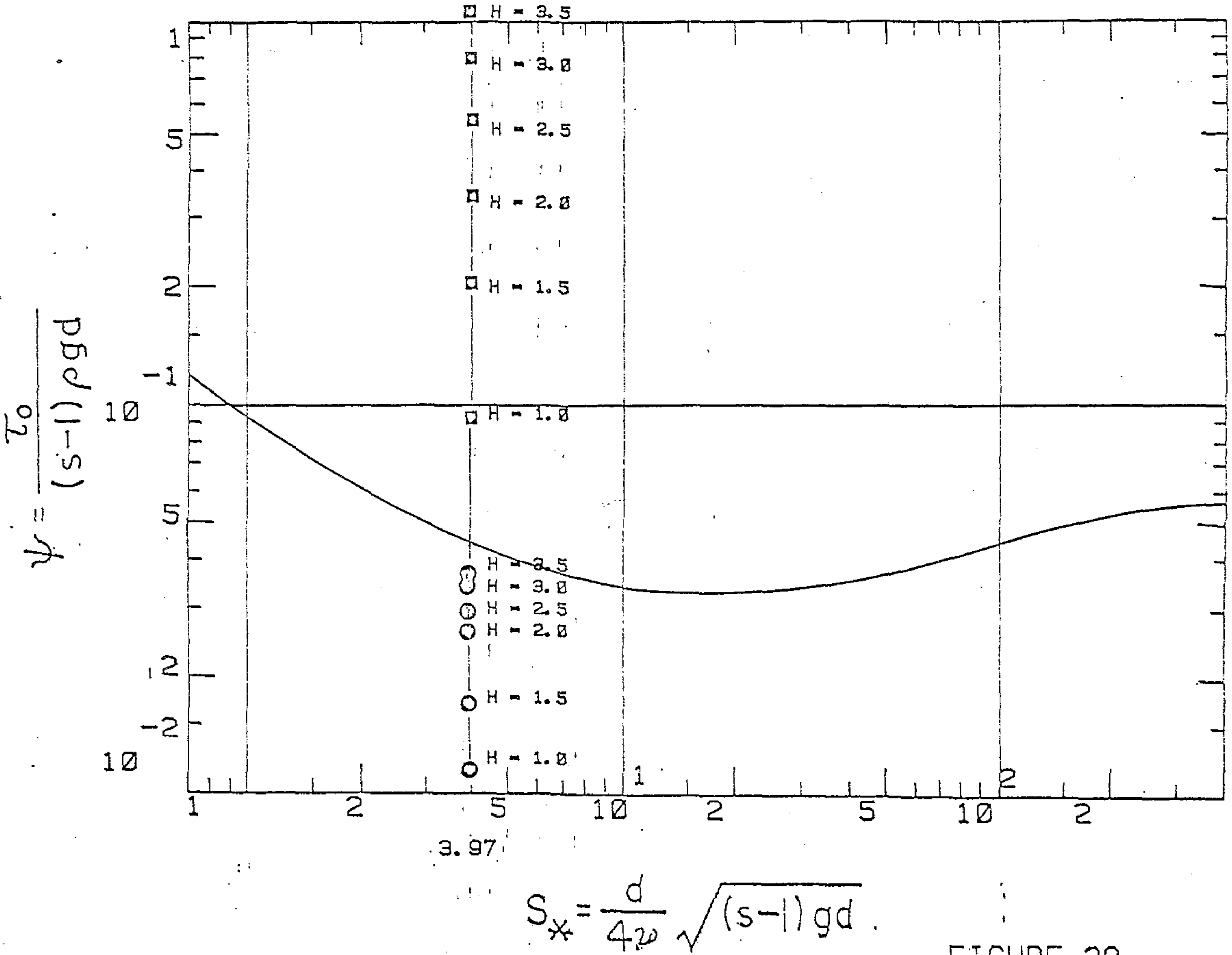


FIGURE 28

stress developed over the surface of smaller roughness 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.

Though the calculations show that this difference could have been the cause of the preferential erosion of the south pile, some factors affecting the accuracy of the results must also be considered. The calculation of shear shress due to waves over the relatively smooth surfaces may be done with some confidence since the relative roughness values are within the range of experimental observation. However, the determination of the stress over a surface of very great relative roughness must be considered more of an estimate. Without field observations under these conditions, we do not know how the stress is partitioned between skin friction, which may cause erosive failure of the block, and form drag, which may physically move the block or cause eddies which entrain interstitial material. Furthermore, actual Shields criteria for consolidated sediments are essentially unknown and can only be estimated as substantially greater than unconsolidated sediments.

Further investigation should be done in order to determine:

- the mode of failure of the blocky material under conditions of high shear stress.
- the degree of consolidation and cohesion of the bottom sediments (dredge pile, sand cover, block) and the effect of these parameters on erodability of spoils.

- the partitioning of shear stress over beds of large roughness under waves and currents.

SUMMARY

The precision bathymetric survey procedures enployed to monitor the Stamford-New Haven disposal operation have been successful in managing the capping operation and in monitoring changes that have occurred after disposal. With proper control of the disposal operation,these procedures can readily be applied at other locations.

The effectiveness of capping enriched spoils with cleaner materials has not yet been completely determined since the loss of silty clay spoils from the New Haven south site amounted to 10,000 m3 or approximately 12% of the total capping material. However, since all of this material was lost from the upper surface of the mound no exposure of Stamford spoils has occurred.

Observations of the other sand capped spoil mounds in the Central Long Island Sound Site have indicated sucessful capping since they have shown no measureable changes in spoil volume or distribution, even though these deposits have more shallow minimum depths than the southern site. An explanation for the selective movement of spoils 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, 1978

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 disposal operations might, therefore, consider methods to produce a smooth spoil surface at the conclusion of the dumping procedure. Such methods could include:

- capping with sand material, as was done at the north New Haven site

- dredging and disposal of less cohesive sediments near the end of the operation

- disposal of cleaner material from the mouth of the estuary after artificially increasing the water content of these spoils to break down cohesion

- artificially smoothing the surface through dragging.

Additional work is needed to determine if these procedures are in fact necessary and to more accurately evaluate and predict the reccurrence 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.