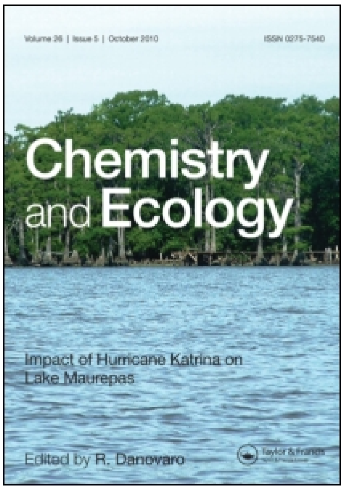

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

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To cite this Article Tsai, John J. , Proni, John R. , Dammann, Paul W. and Kraus, Nicholasc(1992) 'Dredged Material Disposal at the Edge of the Florida Current', Chemistry and Ecology, 6: 1, 169 — 187

To link to this Article: DOI: 10.1080/02757549208035270

URL: http://dx.doi.org/10.1080/02757549208035270

Chemistry and Ecology, 1992, Vol. 6, pp 169–187

DREDGED MATERIAL DISPOSAL AT THE EDGE OF THE FLORIDA CURRENT

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(Received 15 July, 1991; in final form 8 October, 1991)

A field data collection project was undertaken to investigate the short-term fate of dredged material discharged in the designated Miami Ocean Dredged Material Disposal Site (ODMDS) before dredging of the Miami River and the Miami Harbor Turning Basin begins. The designated ODMDS is located in relatively deep water for discharge sites with a typical bottom depth of 150 metres and is also located in the western boundary region of the Gulf Stream current off Miami. Acoustical backscattering, current, particulate, temperature and salinity data were gathered over a three day period from April 24, 1990 through April 26, 1990. The major generic features of shallow-water discharge plumes were observed to be present: (a) the presence of a rapid convective descending plume portion; (b) impact of that plume portion with the ocean bottom and concomitant generation of a bottom surge; (c) rapid horizontal width growth of the descending plume through entrainment; and (d) retention of a residual plume portion within the water column. A well-mixed upper water column layer extending to a depth of 40 to 60 metres below the surface of the ocean permitted measurements of the plume entrainment coefficient free from bottom boundary, water column density gradient, and vertical current shear effects which are usually present in relatively shallow, e.g. less than 40 metres bottom depth, coastal ocean discharge studies. Entrainment coefficient estimates obtained in this study were between 0.5 to 0.7. The residual water plume material was tracked over one-half hour during each of eight discharge events and was transported in a north-northeast direction.

KEY WORDS: Discharge plumes, bottom sediments, water column, entrainment

INTRODUCTION

There are only limited inland disposal sites for dredged material in the Miami, Florida area. The recently planned deepening of the Miami Harbor creates a need for designation by the US Environmental Protection Agency (EPA) of an environmentally acceptable, adequately sized and economically feasible offshore Ocean Dredged Material Disposal Site (ODMDS). Because the designated Miami ODMDS (Figure 1) lies near the western edge of the Florida Current and the mean current can be greater than 100 cm s^{-1} in the spring and summer, transport, dispersion and mixing of dredged material dumped in this area could be greatly affected by physical processes associated with the Florida Current.

Both natural and artificial reefs are located in the general vicinity of the discharge site. The seaward extent of the natural reef zone in the area lies approximately 2.4 km in-shore of the west side of the interim disposal site. Two concentrations of artificial reef sites are also located in the area, one group about 6.1 km north and slightly in-shore, and the other about 3.2 km south and in-shore of the proposed

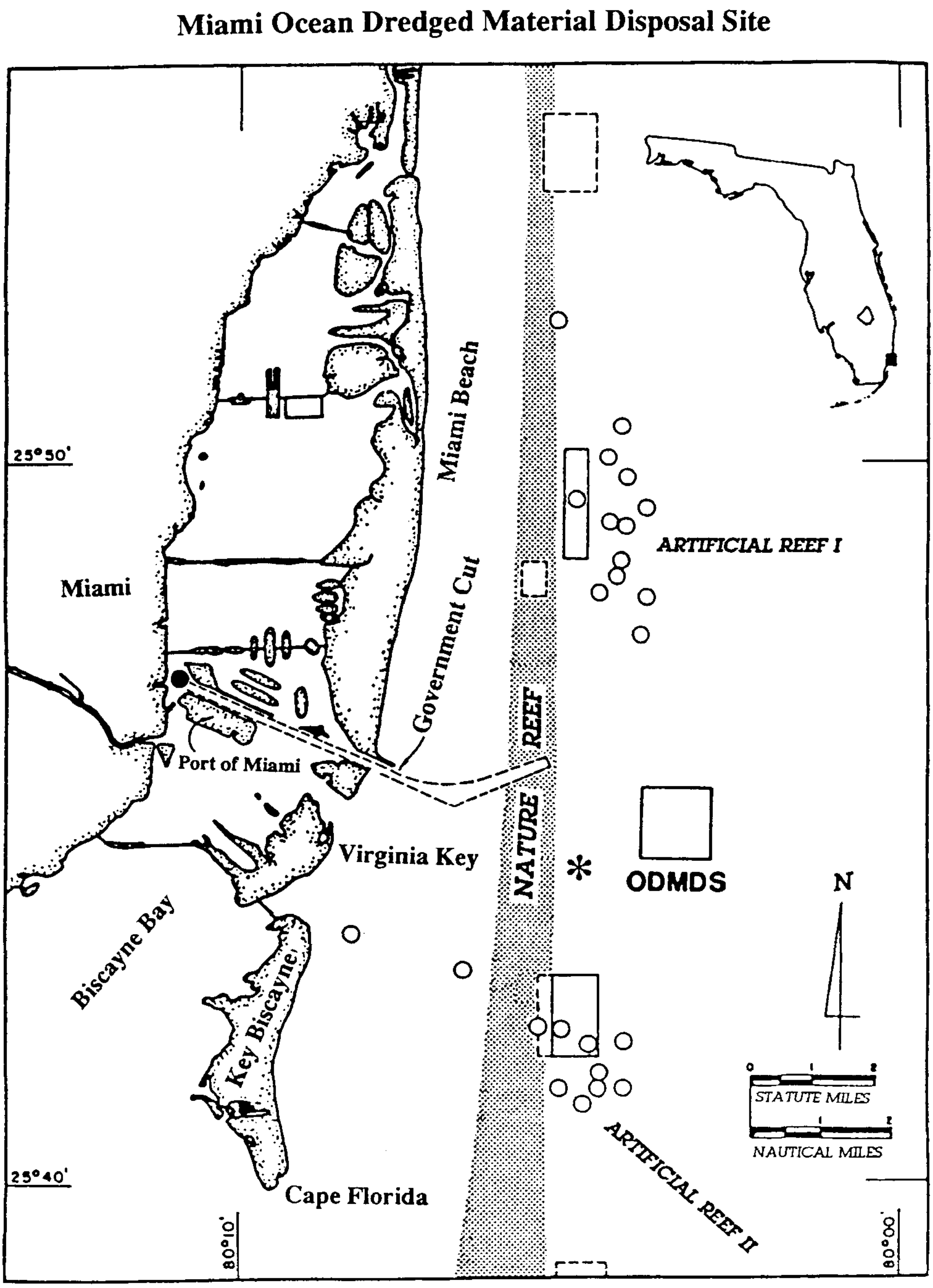


Figure 1 Location map of Miami ODMDS. Insert at the upper right corner indicates the location in Florida. Solid circles and squares represent active artificial reefs, and dotted squares are proposed artificial reefs. The large symbol * indicates location of an outfall. The black dot near the Port of Miami indicate the location of the turning basin where dredging took place.

disposal site. There are concerns of potential contamination of these reef areas due to the proposed disposal of up to 4.6 million cubic metres of material from the Miami Harbor deepening project. A monitoring study, partially in response to these concerns, was undertaken during the period of April 24 to April 26, 1990. The material was dredged from the turning basin area, Port of Miami, and was discharged at the designated Miami ODMDS. The study was a joint project of the US Army Engineer District, Jacksonville and the Coastal Engineering Research Center (CERC) of the US Army Engineer Waterways Experiment Station (WES), and was conducted by the Oceanic Acoustic Division, Atlantic Oceanographic and Meteorological Laboratory (OAD/AOML) of the National Oceanic and Atmospheric Administration (NOAA) near Miami. The procedures followed and results obtained from this study are expected to provide information on other ODMDS's managed by the Jacksonville District.

The present, relatively deep-water study, provides the opportunity to measure certain discharge plume characteristics free from the influence of bottom boundary effects and free from water column density and vertical shear current effects often encountered in relatively shallow-water studies. The presence of a well-mixed upper water column surface layer extending forty to sixty metres below the surface of the ocean provides an opportunity to measure entrainment coefficients without the distortion introduced by water column density gradients occurring over vertical scales of a few metres. The study further provides the opportunity to observe the presence and persistence of the rapid convective descent of the discharge central core and to determine whether said central core impacts the ocean bottom with the concomitant generation of a bottom surge. A key plume feature is the quantity of residual material remaining within the water column after the convective descent phase of the material discharge has been completed. The present study occurred in a large open area of water of low-background particulate concentration, ideally suited for tracking a low concentration water column plume residual. Where such material is transported by ambient currents is of major concern.

PROCEDURE

During the period of April 24 to 26, 1990, sediment plumes issuing from eight placement operations of dredged material from the Miami Harbor turning basin area were monitored continuously with an Acoustic Concentration Profiler (ACP) of OAD/AOML and an Acoustic Doppler Current Profiler (ADCP) manufactured by RDI (RD Instruments, Inc.). CTD (conductivity-temperature-depth) measurements were taken using a Seabird CTD profiler, and sediment samples were collected from the dredging vessel with a sediment grab sampler. Before each discharge and between successive discharges, the surveying vessel *Seaward Explorer* monitored the water column to obtain background concentrations of suspended material and ambient currents in the area using the ACP and ADCP on board the surveying vessel. Ambient density and salinity were measured by taking CTD casts at locations of previous discharge that were determined from ship track records. Sediment samples were collected directly from the dredging vessel *Atchafalaya* for each discharge. Discharge occurred when the *Atchafalaya* began to turn to return shoreward. Both the ADCP and ACP were set ready to operate upon the approach of *Atchafalaya*, and the *Seaward Explorer* proceeded to make the transects immediately after the dumping commenced. The *Seaward Explorer* tracked the sediment plume for several transects until the concentration of suspended material could no longer be detected by the ACP. This reduction in concentration usually took about 40 minutes after the release. Figure 2 shows a typical ship track as the *Seaward Explorer* surveyed a sediment plume. During each transect, water samples were collected by a towed V-fin with a pump that discharged water continuously *via* a hose to the deck of the *Seaward Explorer.* The water sampling took place at approximately constant depth by maintaining constant ship speed, and only during the periods when transects crossed the plume. Ship position was determined using LORAN and GPS and was automatically logged with a computer and displayed in real time to assist monitoring. Surface features of the sediment plume were visible up to 30 minutes after discharge and were helpful in tracking the plume.

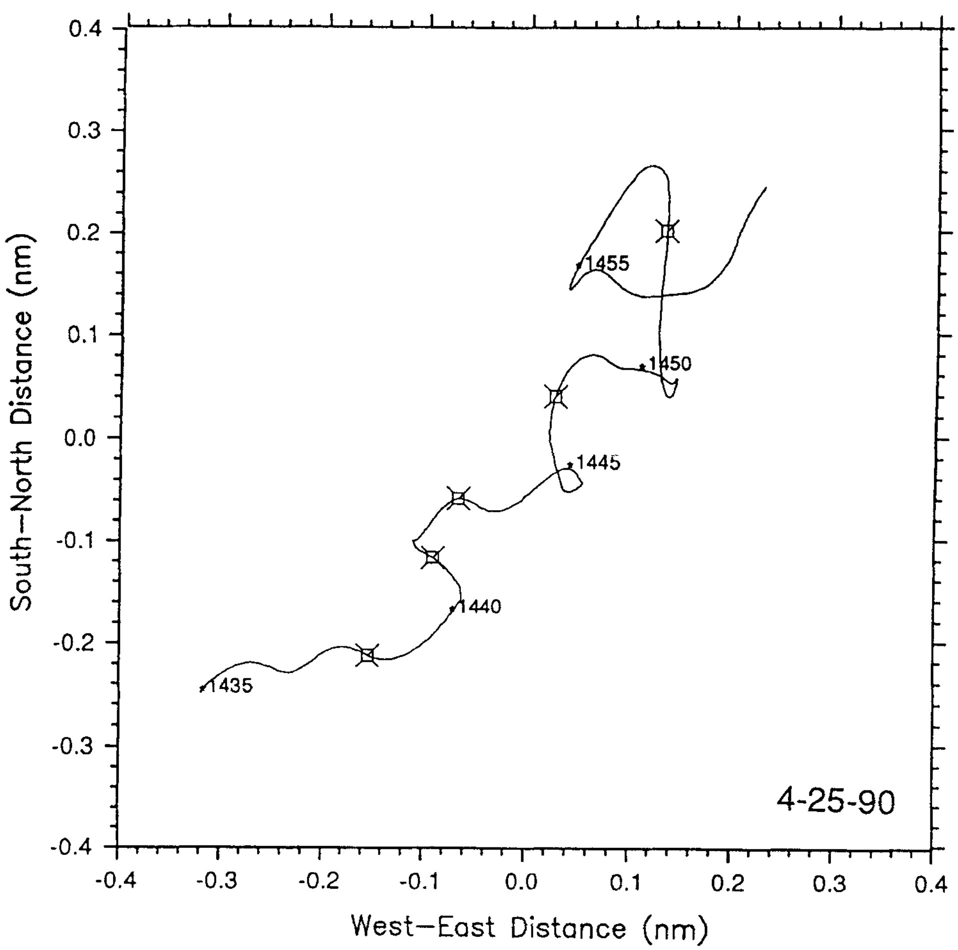


Figure 2 Ship track of monitoring of one discharge on April 25, 1990. The numbers along the track are times in hours and minutes at locations marked with a star. The square symbols indicate locations when sediment plumes were encountered.

The variable measured acoustically is the backstattering intensity of the discharged material cloud. A description of the system and procedure is presented in Dammann and Proni (1990) and Dammann, *et al.* (1991). The logarithm of this variable is called the volume scattering strength or level and is the physical quantity used in acoustical analysis. The scattering strengths are taken to represent the logarithm of the sediment concentrations observed in the water column and can be plotted in constant levels and contoured to show the detailed plume structure. These acoustically measured concentrations can be compared with the particulate concentrations derived from the bottle samples.

The echo amplitude from the ADCP as a by-product of the AGC (automatic gain control) circuit also provides an estimate of backscattering intensity and is comparable to the ACP acoustic intensity measurement. Both echo amplitudes from ADCP and acoustic scattering strengths from ACP can be used to locate the peak concentrations of discharged plume at different times after disposal.

RESULTS

Temperature and Salinity Measurements

The Miami ODMDS is situated on the continental slope with depths ranging from 130 to 240 m, and the depth at the centre of the site is approximately 191 m. The average declivity of the slope at the ODMDS is approximately 55 m km^{-1}. The eight monitored discharges took place at locations with depths varying from 120 m to 170 m. These are relatively deep water depths for an ODMDS. However, each discharged cloud of all eight dumps reached the ocean bottom in 1 to 2 minutes at these depths. The central core did not appear to achieve neutral buoyancy in the water column in any of the discharges.

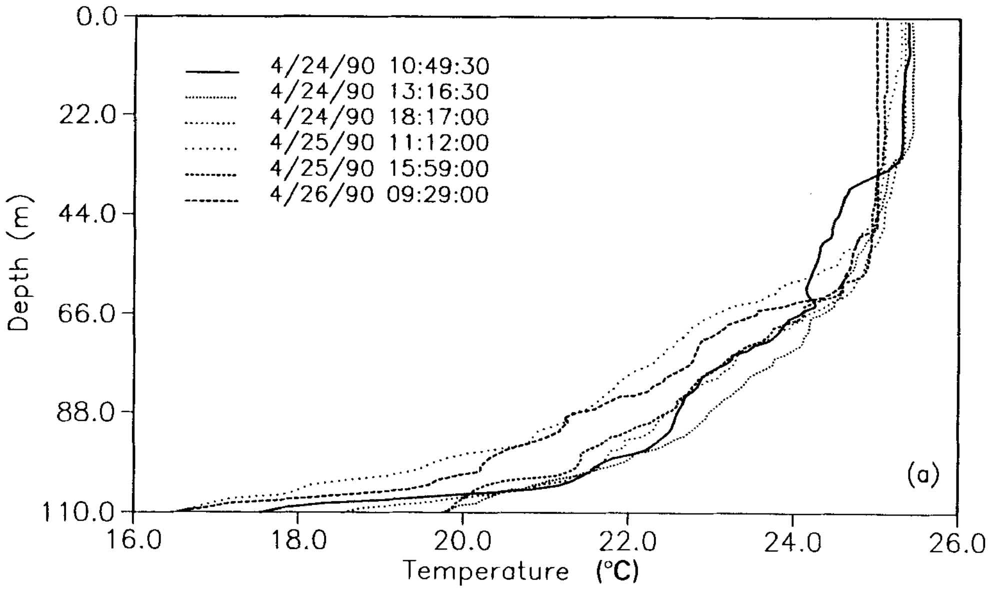
The temperature profiles indicated a well-mixed surface layer of 25 °C water for the 3-day period (Figure 3(a)). There were strong vertical gradients below 50 m depth that extended possibly to the ocean bottom. The surface temperature varied only about 0.5 °C daily. Temperature gradients differed significantly from time to time and day to day, however. This temperature difference created important variations in density stratification (Figure 3(b)) because the salinities did not change significantly (Figure 3(c)). The maximum overall gradient was about −0.138 °C per metre depth. In some cases, there existed more than two strong vertical gradients at different depths. The middle water temperature gradient was always greater than that of deeper water.

Density is primarily a function of water temperature. Observed density ranged from 1.024 g cm^{-3} to 1.027 g cm^{-3} with average density gradient of 0.027 mg cm^{-3} m^{-1}. These values agree fairly well with values given by US EPA (1990).

Salinity at the dump site was fairly constant through all depths except in deep water below 100 meters (Figure 3(c)). The surface salinity was about 36.3 ppt, and the salinity of near-bottom water was as low as 35.6 ppt. Average salinity gradient was about 0.018 ppt m^{-1}.

Ambient Current

The current profiles from the ADCP provide good information on the current structure at the Miami ODMDS. An initial sample averaging interval of two minutes



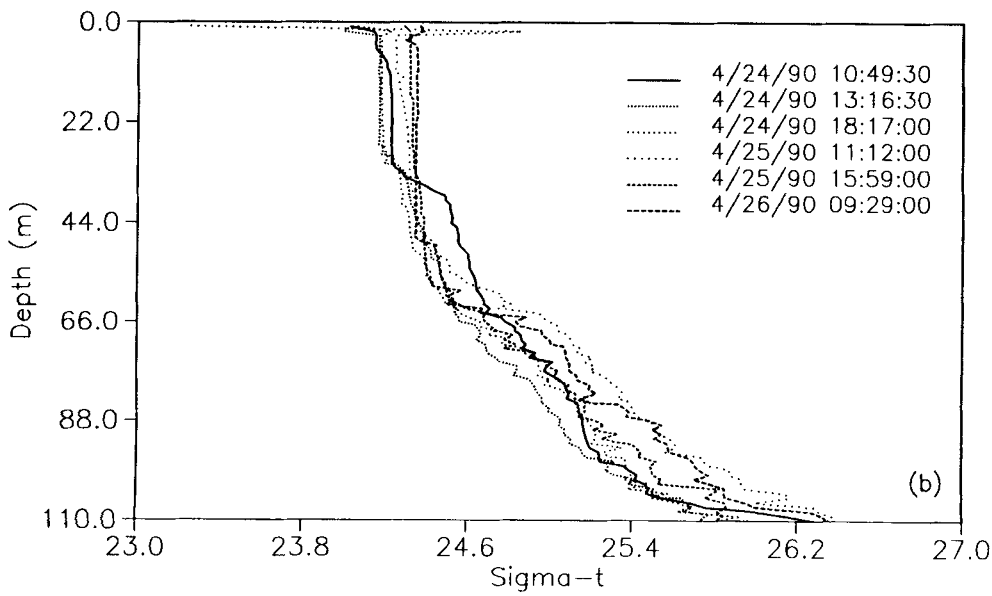


Figure 3(a) Profiles of temperature (°C), **(b)** density (σ) from six CTD stations during the three day period, April 24 to 26, 1990

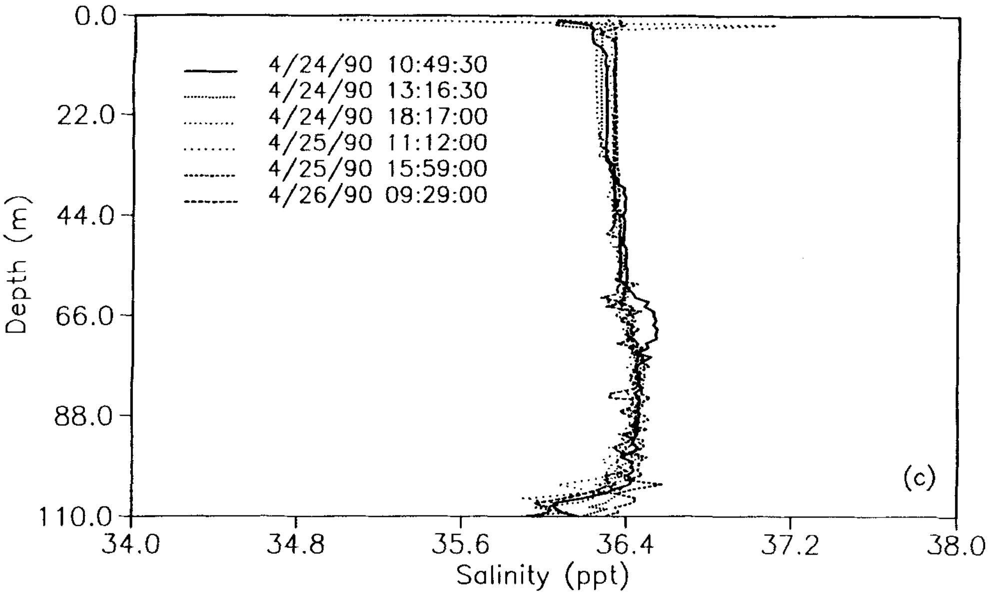


Figure 3(c) Salinity profiles from six CTD stations taken during the 3-day period from April 24 to 26, 1990.

was selected for the first day and was reduced to 30 seconds for the second and third days because the tracking ship took only 30 to 60 s to cross a plume. Only those ADCP data with 30 s average were used for analysis.

The transmitted pulse length and bin length were 4 metres for the 150-kHz frequency ADCP. The 30 second averaged data consisted of 9 individual pings. The standard deviations of north and east current were 19.7 cm s^{-1} and 18.5 cm s^{-1} respectively (Atle Lohrmann, RDI, personal communication, 1991). They included the variance introduced by ship motion (pitch and roll) and the variation in the current field over the survey area as well as the instrument noise. The standard deviation of the vertical current measurements was 9.5 cm s^{-1} which included the instrument noise and the variation introduced by the ship motion (Atle Lohrmann, personal communication).

Typical current profiles are shown in Figure 4. In most cases, the north component of ambient current remained constant to the thermocline depth and then decreased with depth, sometimes reversing direction in deep water. The maximum north component was as high as 150 cm s^{-1}. The east component mostly fluctuated between +30 cm s^{-1} to −10 cm s^{-1}, with the maximum value sometimes reaching 60 cm s^{-1}. The general direction of current was always to the northeast or north-northeast. This current flow direction was also seen from the monitoring ship track shown in Figure 2. The average current shear observed from ADCP was about 0.6 cm $s^{-1}m^{-1}$ and was not as strong as expected. The average water depth from the thermocline to the bottom was about 60 m. The total current difference between the thermocline depth and the ocean bottom was then 3.6 cm s^{-1}.

The ADCP also provided an echo amplitude signal that indicates the presence of suspended material in the water column. Figure 5 shows time-series of echo amplitudes that were observed at fixed depths and corrected for spherical spreading. The depth intervals were between 10 m and 110 m with a 20-m increment for each of the seven depths. From these peak echo amplitudes which indicated the maximum

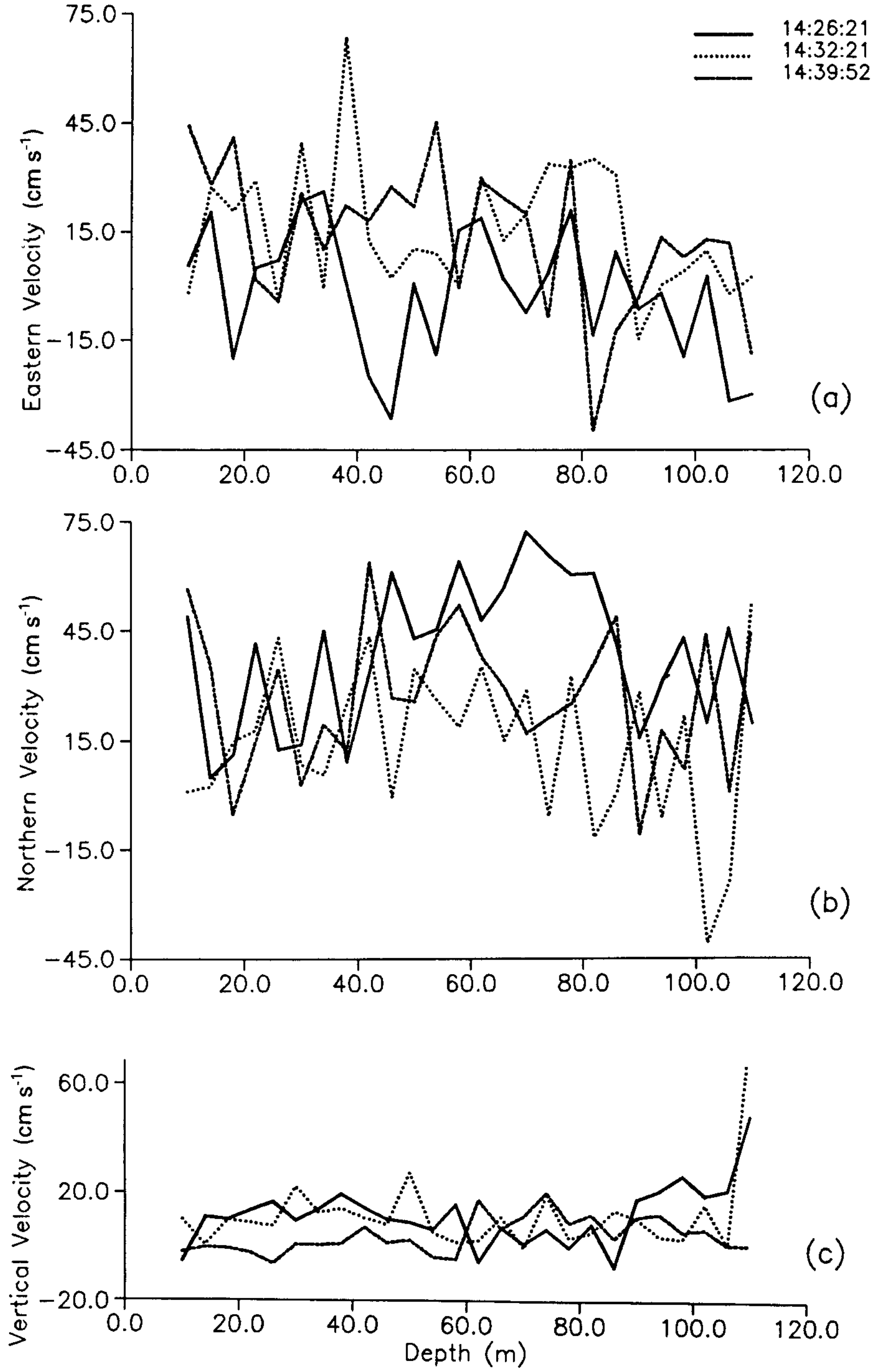


Figure 4 Current profiles from ADCP for three transects of one discharge on April 26, 1990. (**a**) eastern components, (**b**) northern components and (**c**) vertical components. The numbers shown in (a) are times of transects.

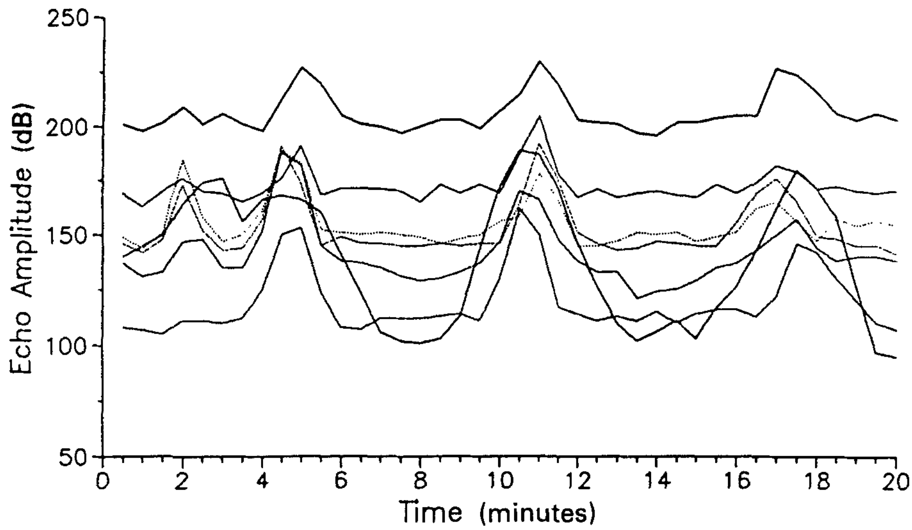


Figure 5 Time-series of echo amplitudes from ADCP for seven fixed depths. The top curve is for 10 m depth, and the bottom curve is for 110-m depth with interval of 20 m between consecutive depths. The four peaks indicate the locations where the sediment plumes were detected for this particular discharge on April 26, 1990.

sediment concentrations for each depth at each time instant, the difference in the horizontal current v_h (z) at two different depths in the water column z_1 and z_2 can be estimated directly. For depths z_1 and z_2, one can write

$$[v_h(z_2) - v_h(z_1)]t = r(z_2) - r(z_1)$$

where t is the time from initial discharge to the time of plume observation, and r(z) is the range from coordinate origin (cylindrical coordinates) at the time of plume observation.

From Figure 5, we see that the maximum time difference between peak concentrations encountered at any two depths in the water column is approximately 30 s. Thus for a ship speed of 1.5 ms^{-1},

$$r(z_2) - r(z_1) < 45 \text{ m} = 4500 \text{ cm}.$$

Then

$$v_h(z_2) - v_h(z_1) < 4500/t$$

Now t = 18 min = 1080 sec for the last transect in Figure 5, so

$$v_h(z_2) - v_h(z_1) < 4.2 \text{ cm.s}^{-1}$$

Plume Concentrations

The acoustic intensity or backscattering strength is an approximate measure of sediment concentrations in the water column (Tsai, 1984). The intensity can be displayed in real time on a Raytheon thermal paper recorder during the field study. Figure 6 shows four transects of the same sediment plume of one dump on April 26, 1990. The vertical coordinates are depth in metres, and the horizontal coordinate shows hours and minutes and represents a 21-minute time period, or a horizontal distance of 1890 m when the ship speed was taken to be constant at 3 knots.

Acoustic intensity was also recorded on DAT tapes. These data can provide more detailed plume structure when processed numerically to extract the acoustic backscattering intensity. The acoustic intensity is considered to be proportional to the particulate concentration, and contour plots of equal intensity levels provide the detected sediment plume field for each transect. Contour plots of two consecutive transects are shown in Figure 7 (a) and (b). The concentration levels are shown in dB and equivalent to backscattering strength which is proportional to the logarithm of acoustic intensity.

The horizontal axis of those contour plots is distance in metres calculated from time of transect with an estimated ship speed of 3 knots. One of the important observations is the presence of dredged materials near the ocean bottom during these two transects. This deep initial detection demonstrates that the dredged material did reach the bottom, and concomitantly generated bottom surges as shown clearly in Figure 7(a). During the first one or two transects of other discharges in present study, the acoustic backscatter signal was diminished by bubbles generated during the

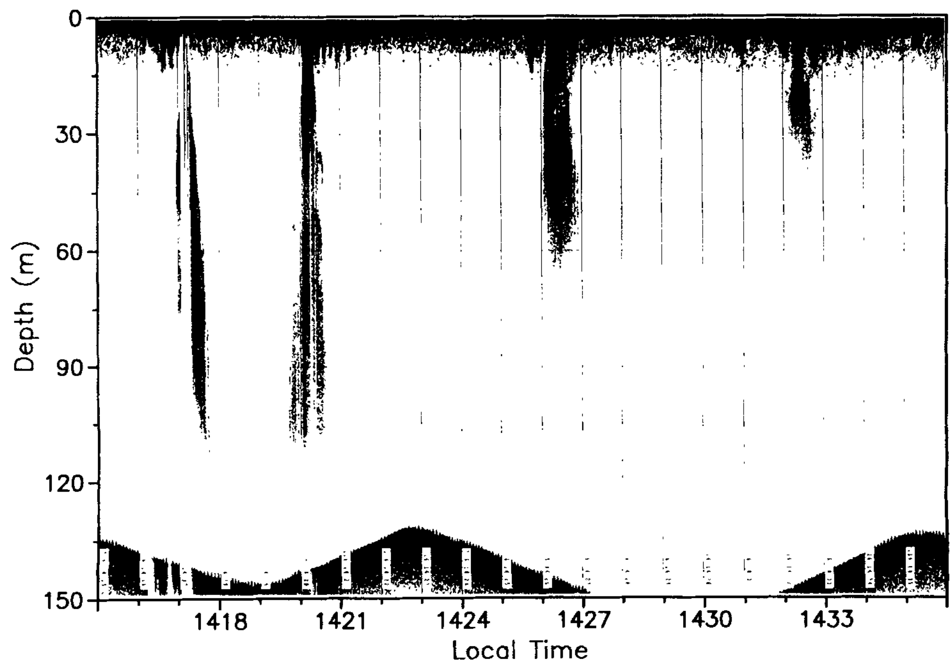


Figure 6 Acoustic echographs from ACP for one discharge on April 26, 1990 and shown in Figure 5.

dumping process. This phenomenon was observed in the shallow water dredged material disposal in Mobile Bay, Alabama (Dammann and Proni, 1990).

Contour plots of acoustic backscattering strength of the last two transects in Figure 6 are shown in Figure 7 (c) and (d). During the 20 minutes of tracking of the four transects shown in Figure 7, acoustic backscattering strength at constant depth indicates the peak values of plume concentration for each transect and are shown in Figure 8. Each plot shows time-series of acoustic backscattering strength at fixed depth and represents discharged material concentration at this depth for the particular dump. The distance obtained by multiplying time by tracking ship speed gives the plume width at that time. The change of peak values in time describe reduction of maximum concentration with time and represents the dilution curve of that particular discharge.

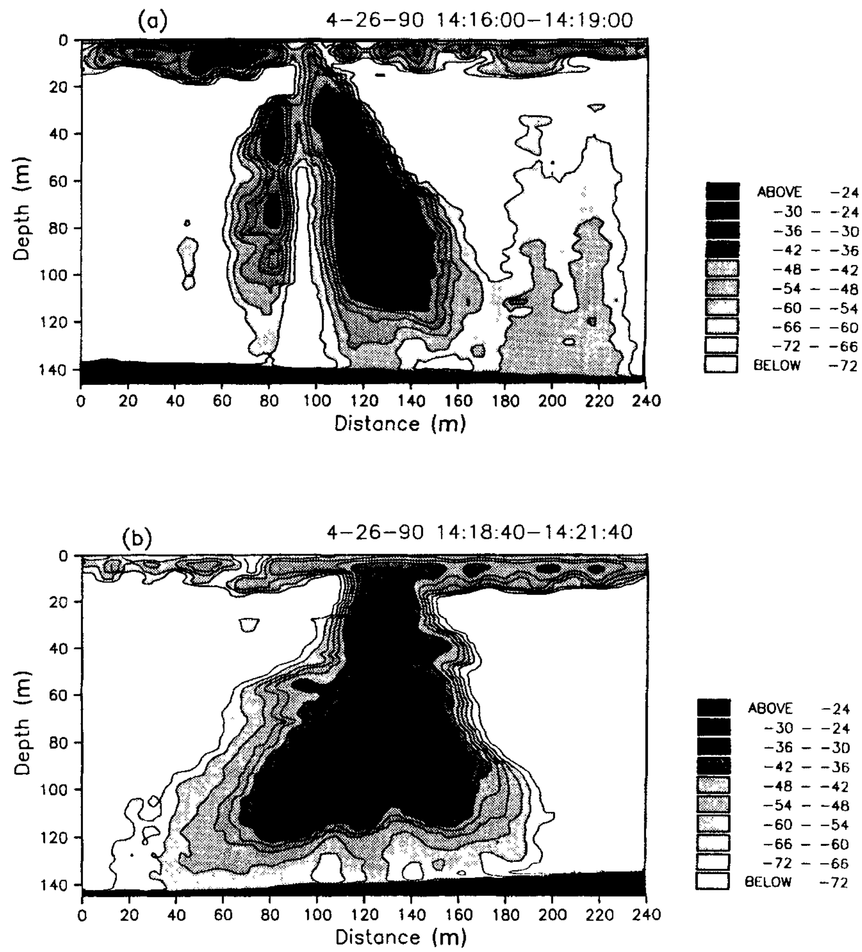
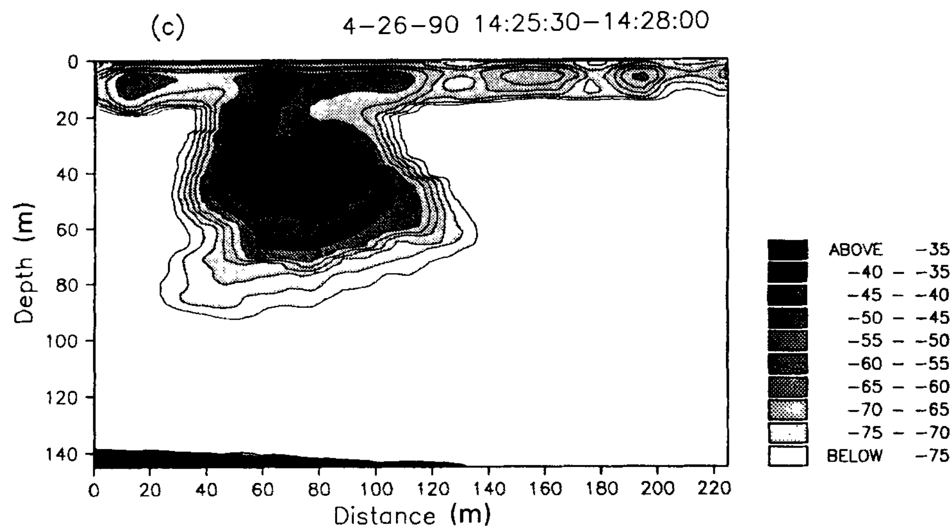


Figure 7 Acoustic iso-concentration contours of the four transects shown in Figure 6. The gap in concentration indicated in (a) at horizontal distance coordinate of 90 to 100 m is attributed to acoustic absorption at the frequency of 20 kHz by a cloud of bubbles in the water near the surface. Horizontal distances in (a) and (b) are greater than those of (c) and (d) in order to present the whole feature of the surge plume.



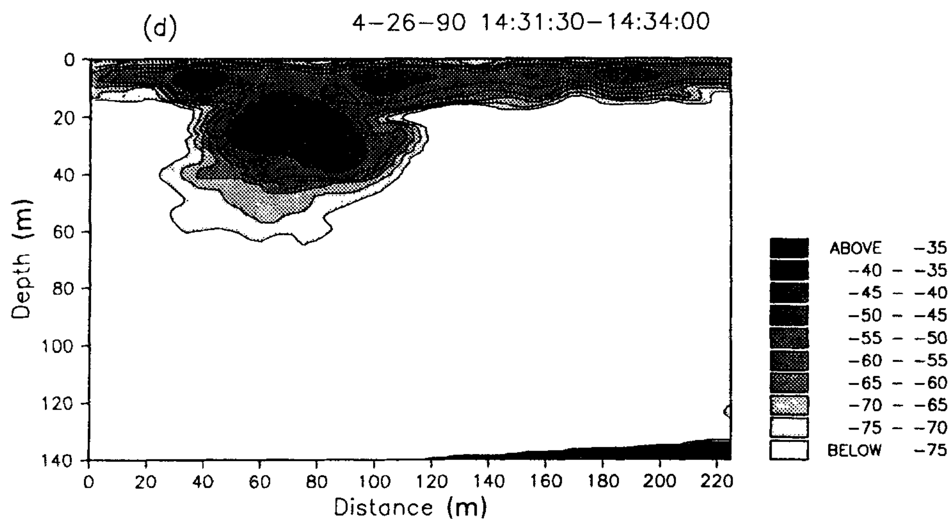


Figure 7 contd. (for caption, see p. 179)

Figure 9 shows dilution curves for discharge shown in Figure 8. A disparity in the rate of reduction of peak concentration is visible for those peaks below 40 metres in depth and those above 40 metres in depth. In particular, the rate of reduction appears to be greater at the lower depths and less at the shallower depths.

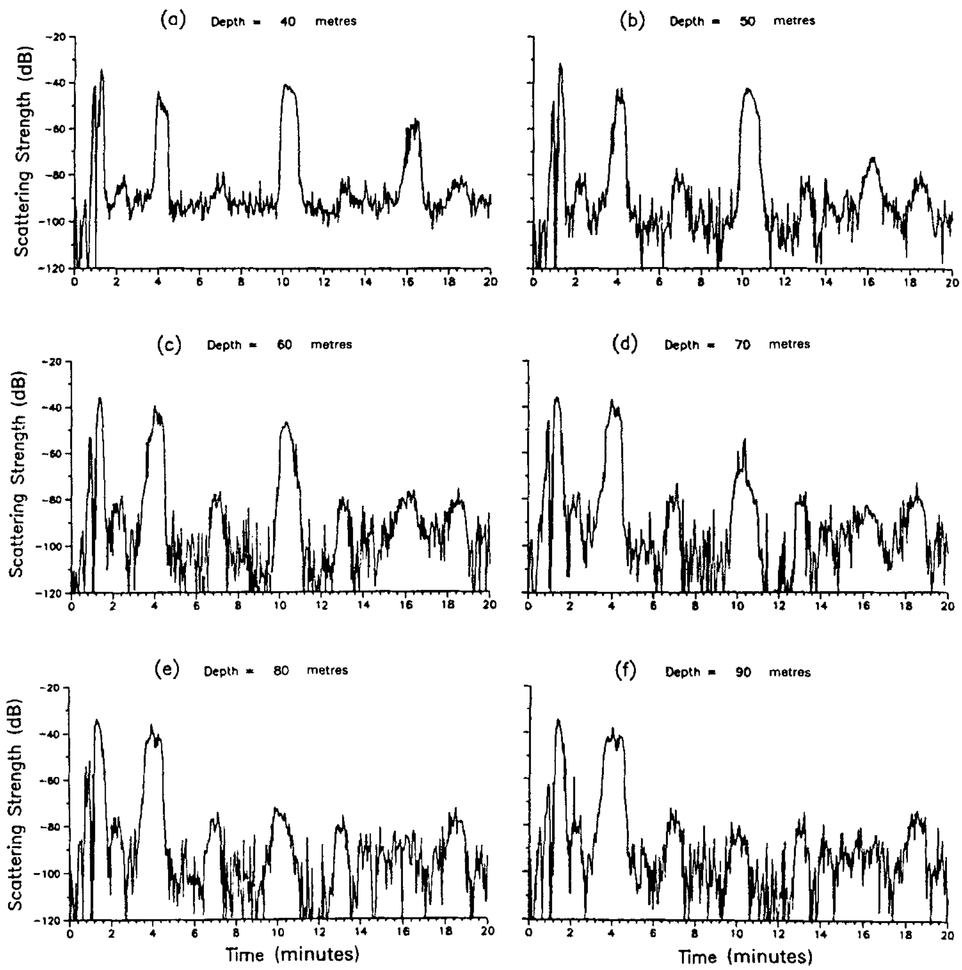


Figure 8 Time-series of acoustic scattering strength at fixed depth. The horizontal coordinate is time after discharge. The peaks of scattering strength indicate the locations of detected plume, and their values represent the maximum concentrations at different times after discharge.

DISCUSSION

Dilution Curves

The disposed dredged material from the turning basin of Miami Harbor was mostly coarse silt and fine to medium sand. A central question in the present study is whether the discharged material remained within the designated site boundaries. Numerical model results have indicated that the vast bulk of such discharged material should fall directly to the bottom and that a gradually diminishing quantity of material should remain within the water column. The material that remains within the water column for some period of time is expected to be "fine" material, i.e., of small size, and of low concentration. The acoustic observations of plume

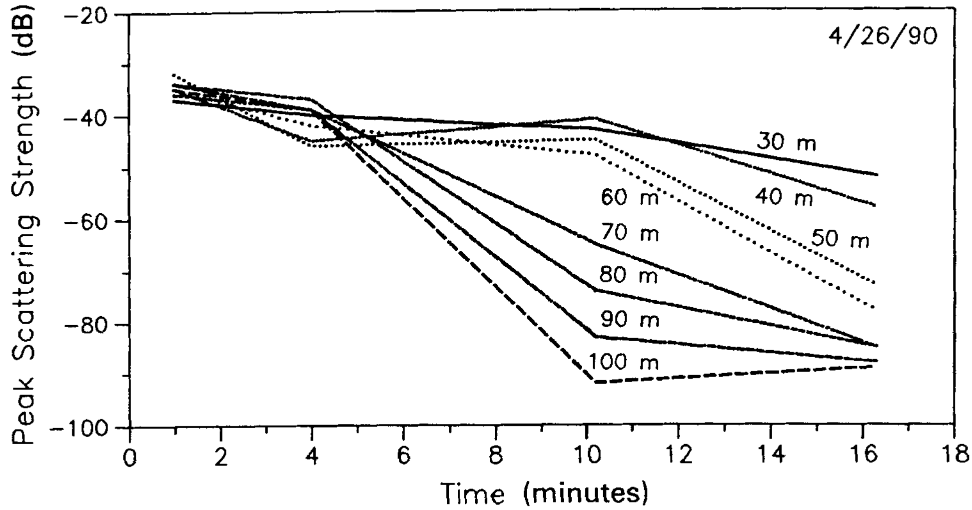


Figure 9 Peak scattering strengths as function of time at eight fixed depths for the discharge shown in Figure 8. The numbers represent depths in m at which the peak values were observed.

concentration shown in Figure 7 indicates that the discharged material reached the bottom (Figure 7(a)) and its central portion descended with a speed of 2 ms^{-1} or greater. This descending speed was estimated from the time of 1 minute or so it took to reach the bottom and the water depth of 140 m. The discharge plume grew laterally through entrainment and its centre descended rapidly to the bottom with great reduction in core concentration (Figure 7(b)). The residual fine material left in the water column above the pycnocline underwent approximately a two- to three-orders of magnitude reduction in concentration in 20 minutes (Figure 7(d)). The residual sediment concentration below the pycnocline was reduced by four- to five-orders of magnitude during the same period of time. These reductions in peak concentrations and their differences in magnitude below and above pycnocline were also evident in the dilution curves shown in Figure 8. The pycnocline apparently acts as a floor to slow the residual sediment continuously falling to the bottom (Tsai and Proni, 1985).

Although water bottle samples were gathered at the time of the cruise, these samples have not yet been analyzed for total particle content or load. It has been suggested that because of the lack of residual water column mass estimates occurring during dredge material discharge in the literature, that an attempt should be made to make such an estimate. The simplest way to make such an estimate would be to use the calibration curve derivable between acoustic backscattering intensity and total suspended mass as measured in the present study. As this calibration curve has not been derived for the present study, calibration values from the recent Mobil Bay Study will be used to provide a rough upper estimate of the total suspended mass corresponding to the backscattering intensity.

The approximate reduction in sediment concentration can be derived from the initial volume of disposed dredged material and the observed residual plume volume, asssuming an upper limit of concentration of 10 mgl^{-1} at lower concentration level (about 30 minutes after discharge) from previous Mobil Bay data (Dammann and Proni, 1990). From Figure 7(d), the cloud volume was $60\times(50\times50\pi)$ or $4.7\times10^5 m^3$ assuming a cylindrical water body of radius of 50 m (half of plume width) and height of 60 m (maximum depth of lower contour level). Therefore, an upper limit of residual concentration is estimated to be 4.7×10^6 g after 20 minutes from discharge. The total capacity of the dredging vessel was about 685 m^3. The mean specific gravity of disposed dredged material was 2.69 gcm^{-3} with 41% of mean total solids. The total initial material was then 7.6×10^8 g. The minimum dilution was 6.2×10^{-3}, an almost three- orders of magnitude in concentration reduction. The preceding calculation must be considered tentative until better calibration data is available.

Echo amplitudes from ADCP can be used to identify locations of peak concentration of residual material. One echo amplitude time series at 70 m depth from Figure 5 is shown with the scattering strength of Figure 8(d) for the same discharge and depth in Figure 10. The echo amplitude is the scattering strength without taking into account the source level. For the 20 kHz ACP, the source level was 213 dB. Source level for the ADCP was different from the ACP, but had the same magnitude in general. It is clear in Figure 10 that there is an excellent coincidence in locations of peak concentrations between ACP and ADCP.

Entrainment Coefficients

The first transect of each discharge event such as the one shown in Figure 7(a) displayed the convective descending phase of the discharge when it was detected in less than two minutes after the disposal. The descending cloud entrained the ambient water and increased its lateral width as it settled to the bottom. From these iso-concentration contours, the entrainment coefficients can be estimated by measuring the coordinates, i.e., depth and distance, of the outermost contour at two different depths.

From Brandsma and Divoky (1976), the entrainment, E, may be expressed as

$$E = Ae(\bar{v} - \bar{v}_a)$$

where A = area of hemispherical discharge volume,

e = entrainment coefficient,
$\bar{v}$ = vector velocity of discharged material,
$\bar{v}_a$ = vector velocity of ambient water.

For $\bar{v} >> \bar{v}_a$

$$dV/dt = eA(dz/dt)$$

where V = volume of hemispheric discharge.
Then,

$$e = (1/A)(dV/dz),$$

and for a hemispheric radius, r,

$$V = (2/3)\pi r^3,$$

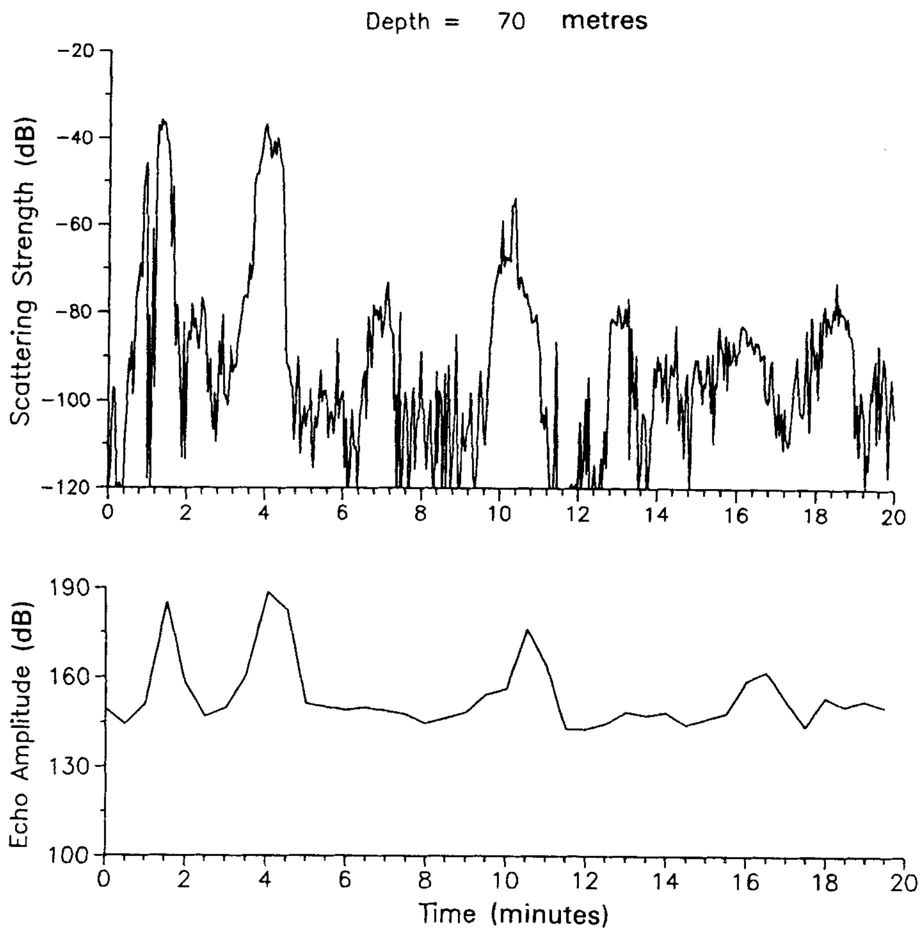


Figure 10 Comparison between acoustic scattering strengths from ACP an echo amplitudes from ADCP at 70 m. Top: from ACP taken from the same discharge shown in Figure 8(d); bottom: from ADCP and same as the echo amplitudes shown in Figure 5.

$$A = 2\pi r^2$$

so that

$$e = dr/dz.$$

The entrainment coefficient is then the slope of the lowest concentration line where the descending cloud interacted with the ambient water.

From Figure 7(a), for the iso-concentration line marking the outermost boundary of the plume, i.e., contour line of scattering strength above background equalling −70 decibels, the horizontal distance coordinate is 118 m at depth of 20 m, while at 50 m depth, a horizontal coordinate of 138 m is indicated. Thus

$$e = dr/dz = (138–118)/(50–20) = 0.67.$$

For a given discharge plume, two estimates for e may be made: an ingress estimate when the tracking vessel moves into the plume and an egress estimate when the vessel moves out of the plume. Depending on the circumstances of the discharge and time of transect, one, both or neither estimates may be made. For Figure 7(a), the egress estimate appears superior to the ingress estimate. Nevertheless, in the 25- to 50-m depth interval, an ingress estimate for a value of 0.57 was obtained.

Estimates of e have been made for various discharges in the present study and are summarized in Table 1. In selecting the depth interval for estimation of e, some care with regard to the water column vertical density structure and current structure must be taken. From the density profiles shown in Figure 3(b), it may be seen that the upper 50 m or so of the water column are well mixed with little structure in the density profile except one at about 40 m. At about 60 m depth, a density step occurs and structure appears within the water column. A change in the slope of the iso-concentration contour line occurs there, thus leading to a different estimate for e in that depth region.

The average of estimated e for both egress and ingress was 0.68. This value is greater than the turbulent thermal entrainment coefficient of 0.235 used in the numerical model (Davis and Bowers, 1980, Johnson, 1988) and originally derived from laboratory studies. In earlier studies, Newman *et al.* (1977) determined values between 0.45 and 0.80 for discharge in Lake Ontario, and Bokuniewick, *et al.* (1979) determined a value of 0.6 from their studies. A later paper is proposed in which beam width and other effects upon entrainment estimates will be discussed.

Veritcal Shear

The primary objective of the current measurements was to determine the water column ambient current profile and, in particular, the vertical shear, i.e., the change of horizontal current with depth at the time of discharge and during the subsequent tracking period. Because the tracking ship crossed a plume in about 30 to 60 s, it was not anticipated that the ADCP would provide data on plume-related currents. Furthermore, because the key assumption of spatial homogeneity of currents in different beam "look" directions for the JANUS geometry was clearly violated for a dredged material discharge plume, it was unrealistic to expect reliable horizontal current data for plume traverses. However, once the initial transient currents generated by the falling plume material were reduced or eliminated, and the "quasi-equilibrium" plume condition had been reached, then reliable current data could be gathered during (residual) plume traverses.

Because ambient current is one of several processes affecting the cloud of discharged material remaining within the water column, one of the key questions is the existence of vertical shear within the water column and its effect in displacing the upper portion of water column material vs. the deeper portion of water column material. Our concern is principally with the horizontal advection of the material because ambient vertical currents were in general quite small during the exercise (Figure 4(c)).

There are two different components of data which bear on this issue; the first is the acoustic Doppler measurements of the north and east directed components of the ambient current as a function of depth, and the second is the relative displacement of the centroid of cloud concentration as a function of depth as determined from backscattered echo amplitude measurements.

Table 1 Entrainment coefficients calculated from acoustic profiles

Dump	*Date*	*Time (LT) Interval*	*Ingress Estimate*	*Depth*	*Egress Estimate*	*Depth*
2	04/24/90	16:13:30–15:30	0.74	50 m	0.80	80 m
5	04/25/90	14:37:00–14:39:30	0.78	50 m	0.50	30 m
7	04/26/90	11:29:30–11:31:30	0.53	60 m	0.83	40 m
8	04/26/90	14:16:30–14:18:00	0.57	50 m	0.67	60 m
Mean			0.66		0.70	
Standard Deviation			0.11		0.13	

The average difference between current at the thermocline and current at the ocean bottom was about 3.6 cms^{-1} for an approximate depth difference of 60 m between the thermocline and the bottom because the average horizontal current shear was about 0.6 $cms^{-1}m^{-1}$. This is less than the maximum horizontal current of 4.3 cms^{-1} at any two depths estimated from echo amplitudes (see RESULTS Section).

The residual cloud had a general movement toward north-northeast direction as shown along the ship tracks where the discharge plume was tracked and detected (Figure 2). This general movement was expected and coincided with the general direction of ambient current in the area.

CONCLUSIONS

Acoustic detection and mapping of dredged material discharge plumes within the entire water column and impacting the ocean bottom have been made for the interim Miami ODMDS located at the western edge of the Florida Current. These detections and complete mappings have been achieved at the deepest dredged material site (typically 140 m depth) studied to date. However, the discharge plumes displayed the major generic features observed in shallow-water discharge plumes, namely lateral growth through entrainment, rapid descent of a central core, impact with the bottom and formation of an expanding bottom surge and rapid decrease of water column concentration residual with time. The central portion of discharged material descended quickly with a speed of 2 ms^{-1} and reached the bottom within the designated site boundaries. Of the residual material left in the water column, that material below about 50 m depth underwent approximately a four- to five-orders of magnitude reduction in concentration in 0.5 hour whereas that remaining in the upper portion of water column underwent approximately a two- to three-orders of magnitude reduction in concentration. For each of the eight discharge plumes detected and tracked for a period of about 0.5 hour average, the resulting plume was observed to be transported in a north to northeast direction. The vertical current shear did not separate the top and bottom portions of the plume in most cases of the observations.

The observation of the partitioning of the dredged material discharge into a rapidly descending discharge core and a water column residual suggests that the central core, because of its high density and apparently cohesive structure, is unlikely to be affected in its trajectory by ambient water column density and only to a minor degree by ambient water currents while the water column plume residual is indeed likely to be affected by ambient water column density and current structure. Therefore, so long as the physical structure and condition of the dredged material being discharged remains essentially the same, it may be expected that the central core will be deposited initially within the discharge site boundaries while the behaviour of the water column residual will depend on ambient water current and density.

Acknowledgements

The assistance in planning and execution of this project provided by Mr. Mark Skarbek of the Jacksonville District is gratefully acknowledged. The expert electronic assistance of Mr. Charles Lauter, the navigation help of Mr. Jules Craynock, and the shipboard assistance of Ms. Alejandra Lorenzo of OAD/AOML are also greatly appreciated.

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