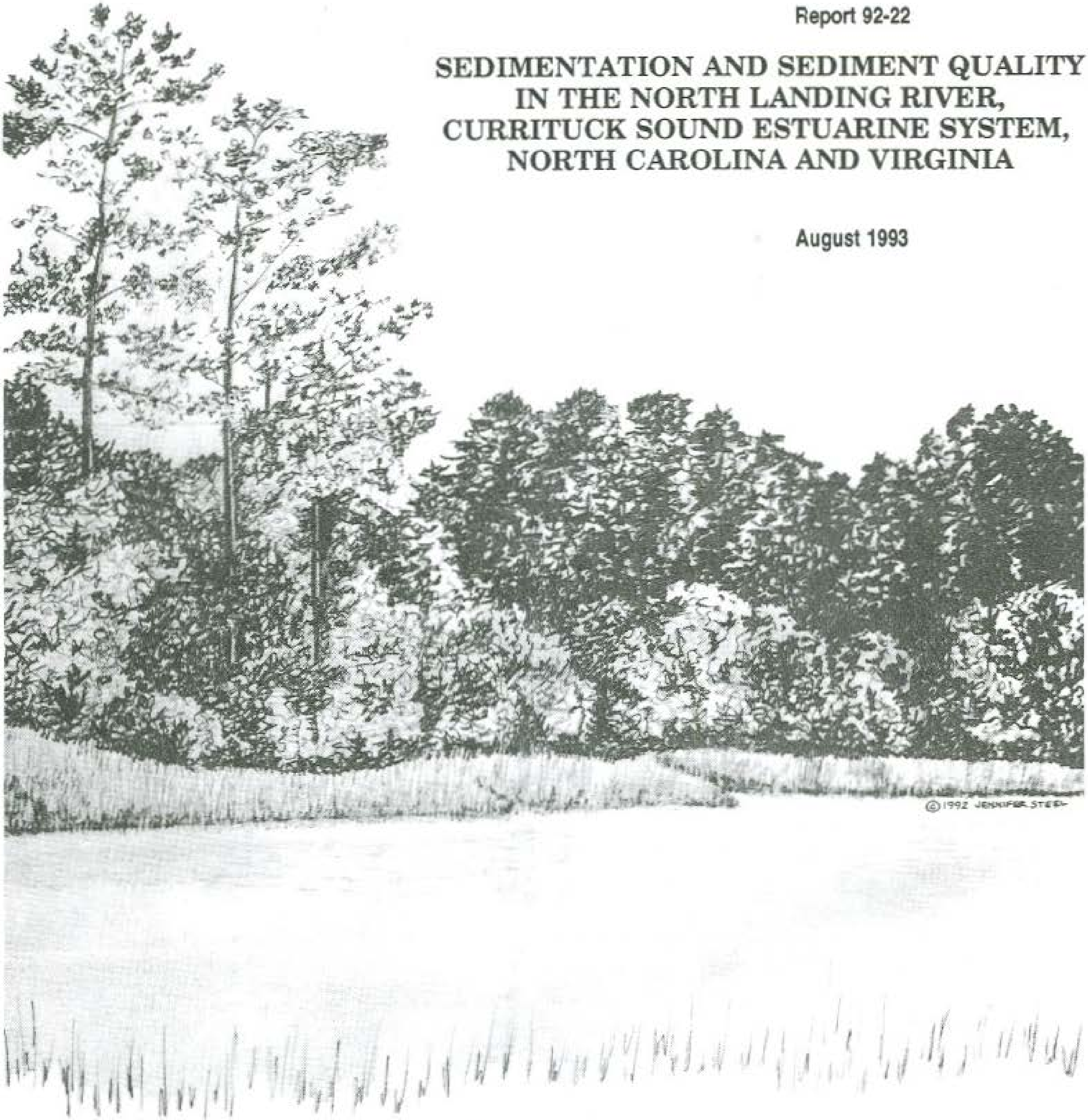
Report 92-22

SEDIMENTATION AND SEDIMENT QUALITY IN THE NORTH LANDING RIVER, CURRITUCK SOUND ESTUARINE SYSTEM, NORTH CAROLINA AND VIRGINIA

August 1993



ALBEMARLE-PAMLICO ESTUARINE STUDY

NC Department of Environment, Health, and Natural Resources

Environmental Protection Agency National Estuary Program

SEDIMENTATION AND SEDIMENT QUALITY IN THE NORTH LANDING RIVER, CURRITUCK SOUND ESTUARINE SYSTEM, NORTH CAROLINA AND VIRGINIA

by

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TO

CURRITUCK COUNTY
ALBEMARLE--PAMLICO ESTUARINE STUDY
US Environmental Protection Agency, National Estuary Program
NC Department of Environment, Health, and Natural Resources

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INTRODUCTION

In February and March of 1991, the U.S. Army Corps of Engineers carried out a maintenance dredging project for the Atlantic Intracoastal Waterway in the North Landing River of Virginia (Fig. 1). The project area extended from the mouth of Blackwater River southward to the Virginia--North Carolina line (Fig. 2). A letter dated April 9, 1991 from Cottrell Engineering Corp. stated that the project actually removed 361,677 yds^3 of dredged material from the North Landing River. U.S. Army Corps of Engineers dredging records demonstrate that the Virginia portion of the North Landing River had also been dredged in 1981 (422,740 yds^3) and in 1986 (343,140 yds^3).

This dredged material was disposed of in shallow, open-water estuarine sites on the west side of North Landing River navigation channel (Fig. 3). The dredged material was placed in four unconfined disposal areas between 200 and 500 meters from the channel. The U.S. Army Corps of Engineers concluded that these disposal sites were "very sparsely populated by benthic organisms and aquatic vegetation" and that there would be "no adverse impacts on wetlands and only minor and temporary impacts on fish, water quality and the terrestrial environment" (USACE, Environmental Assessment).

Dredging of the Intracoastal Waterway has also taken place within the North Carolina portion of the North Landing River. According to U.S. Army Corps of Engineers dredging records, this section was dredged in 1946 and again in 1965. The dredged materials were deposited in the shallow estuarine waters along the east side of the navigation channel and often behind bulkheads (Fig. 3).

The present study was undertaken at the request of Currituck County in North Carolina in an effort to obtain a preliminary understanding of the sedimentology of the North Landing River. The County was concerned about the maintenance dredging project of the Atlantic Intracoastal Waterway in the northern portion of the North Landing River. Consequently, a small contract was let to begin to evaluate the short-term and sedimentological response of the disposal of dredged materials and its potential effect upon the sediment quality within the immediate estuarine area.

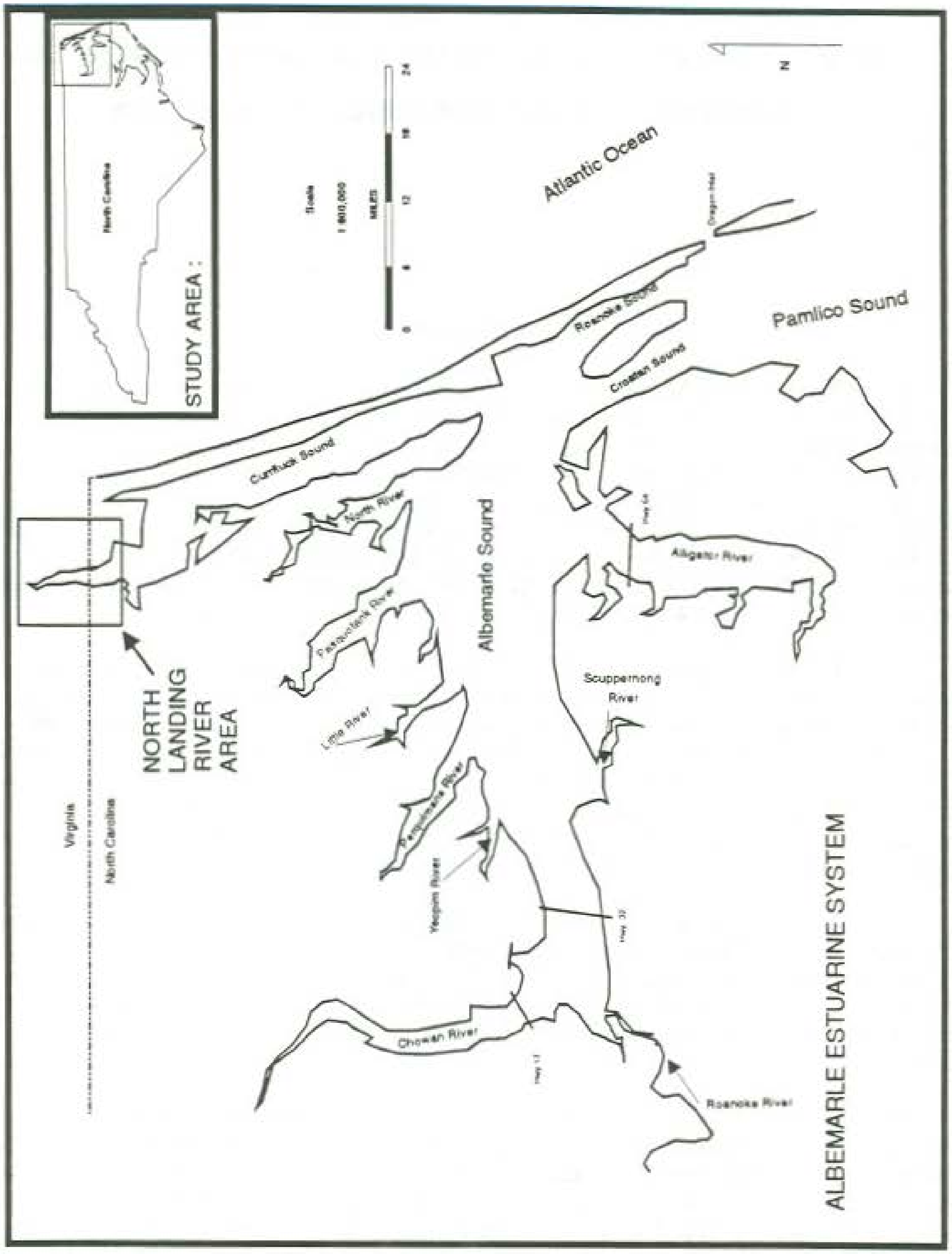


FIGURE 1. Regional map of the Albemarle Sound estuarine system showing the location of the North Landing River area.

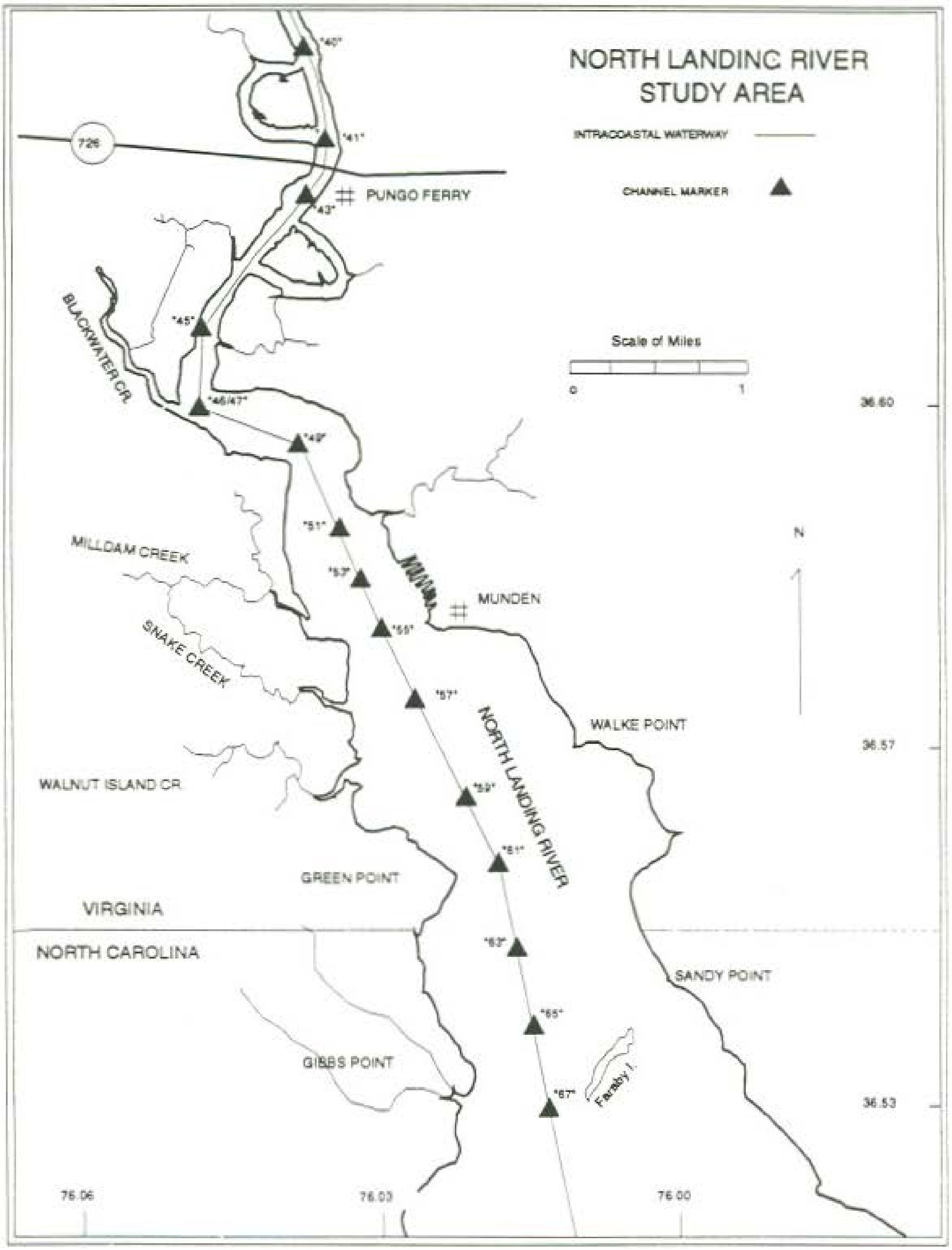


FIGURE 2. Location map of the North Landing River study area in North Carolina and Virginia.

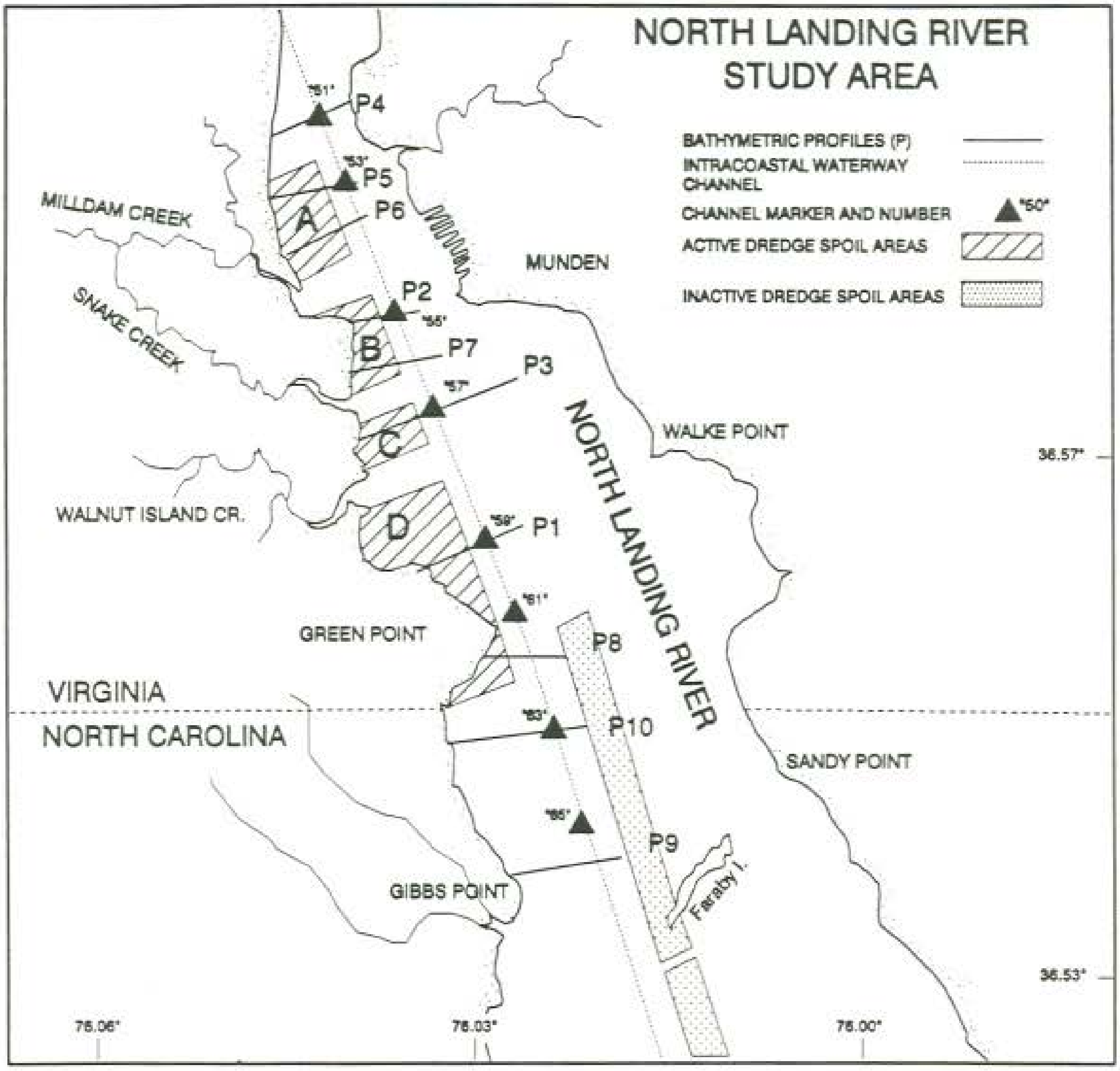


FIGURE 3. Location of the active and inactive disposal sites for dredged material in the North Landing River area of North Carolina and Virginia.

OBJECTIVES

The present study was undertaken to resolve the following questions concerning the shallow-water disposal of dredged materials in the northern portion of the North Landing River.

1. What are the sedimentological characteristics of surface and shallow subsurface sediments?

2. What are the concentrations and distributions of heavy metal contaminants within the bottom sediments?

3. Could trace element contaminants in the sediments be re-introduced into Currituck Sound through the processes of open-water disposal of dredged materials?

4. Are any toxic trace element contaminants being transported from the Norfolk harbor area, down the Waterway and into Currituck Sound?

5. Could shallow, open-water disposal of dredged materials from routine channel maintenance contribute to the long-term environmental degradation in Currituck Sound?

NORTH LANDING RIVER STUDY AREA

Only a small portion of Currituck Sound was included in this study (Fig. 1) due to the specific objectives of Currituck County and the very limited funds available. The study area is the northwestern end of Currituck Sound where it narrows down to form the North Landing River estuary. The study area (Figs. 2 and 3) extends from Gibbs Point, Faraby Island, and Sandy Point in North Carolina (Intracoastal Waterway marker "67"), northward into Virginia to 0.4 miles north of the Pungo Ferry bridge (midway between Intracoastal Waterway markers "40" and "41").

The North Landing River is an embayed estuary which narrows and grades into a riverine environment just north of the study area (Fig. 2). The eastern shore of the North Landing River is dominated by low sediment bank shorelines with scattered areas of low-density residential housing and agricultural operations. The western shore is dominated by many tributary creeks and an extensive zone of fresh water marshes that vary from 0.5 to 1.25 miles in width. The North Landing River estuarine system is characterized by fresh water, irregular wind tides, strong wind-tide currents, and by generally small wave energy due to the small fetch.

Circulation in Currituck Sound is primarily driven by direction and magnitude of winds with the SSW and NNE wind directions being the most important (Pietrafesa and Janowitz, 1991). Southerly winds push water into Currituck Sound from Albemarle Sound, whereas northerly winds blow the water out of Currituck Sound. The resulting tilt in the water surface sets up major pressure gradients and produces strong currents. Due to the shallow nature of much of the study area and the very narrow dimensions through specific portions of the waterway such as the North Landing River, Coinjock Bay, and the canal at Coinjock, these wind sets result in very strong current flows.

The dredged channel of the Atlantic Intracoastal Waterway runs through the middle of the North Landing River estuary and into the riverine portion where it is known as the Albemarle and Chesapeake Canal. The Waterway canal cuts across the interstream divide and connects with the Elizabeth River in the Chesapeake Bay drainage system. The Elizabeth River is the water body that constitutes much of the Norfolk harbor. This Waterway carries a heavy load of commercial and recreational traffic that generates frequent and fairly large boat wakes. The cumulative impact of the wave energy resulting from these wakes is a significant physical force that actively erodes the adjacent shorelines and effects the associated shallow water sediments.

The entire North Carolina portion of Currituck Sound is encompassed within Currituck County. The following numbers demonstrate a major growth in the population since the 1970's with an even greater projection for increased growth rates in the near future (Tschetter, 1989; Holman, 1993).

1960 = 6,601 people
1970 = 6,976
1980 = 11,089
1990 = 13,736
2000 = 18,516
2010 = 22,542

Most of the pre-1970's population was rural and scattered in small towns throughout the county with no major urban centers. The growth boom that began in the 1970's, and is projected to continue into the future, is largely associated with coastal ocean and estuarine development.

Holman (1993) classified the land use for the Currituck Sound watershed in 1990 as follows:

8.7% urban
33.0% agriculture
15.3% forests
40.6% wetlands
2.3% range and barren lands

The upland area consists of mixed pines and hardwood forests with extensive large-scale agricultural operations. Due to the generally low elevation and poor drainage system within the agricultural lands, most streams have been channelized with an extensive network of drainage ditches developed over the years (SCS, pers. comm.). Holman (1993) reported 17 point source dishargers, including 1 into Back Bay, 6 into North Landing River, 7 into Northwest River, and 3 into Currituck Sound. All of these NPDES discharges are small with less than 0.5 MGD and are not considered to be major contributors of trace metal pollutants.

Nonpoint discharges are the other important potential sources for pollutants within an estuarine system. Dodd et al. (1992) found that nonpoint sources were responsible for the highest loadings in the Currituck Sound watershed. They found high levels of loading for both total nitrogen and total phosphorus. Holman (1993) found that water column data for Currituck Sound in general was characterized by high values of pH, total N, total P, dissolved oxygen and fecal coliform. Also, "some of the highest values for suspended solids for the entire Albemarle-Pamlico estuarine system study area have been recorded in the Currituck Sound".

NORTH LANDING RIVER SEDIMENTS

Sediment Samples

Thirty six sites were sampled in the North Landing River (Fig. 4) producing 55 sediment samples for analysis. All samples were push cores obtained by free divers; the cores were obtained with 9 cm diameter clear polybuterate pipe that ranged from 0.5 to 1 meter in length. One 6 meter vibracore (CTK-V1) was obtained along profile P6 (Fig. 4) in order to characterize the undisturbed sediment column into which the Intracoastal Waterway has been dug. Figure 5 is a geologic log of vibracore CTK-V1. Sediment subsamples from all cores were analyzed according to standard sedimentological procedures. Sediment data were statistically analyzed and synthesized and represent the data base for the following discussion and conclusions. All samples and associated sedimentological data are presented in Appendix I. Detailed information on the analytical and statistical procedures are not included in this report; however, all procedures are identical to those utilized for both the Neuse River and Albemarle Sound studies and are described in detail in Riggs et al. (1991, 1993), respectively.

Table 1 summarizes the main sediment types and presents their locations within the estuarine environment. The North Landing River is subdivided into the following morphological components:

1. Two different shoreline types are each composed of several parts and very different sediments.
    a. The western shore is dominated by an eroding modern marsh peat with an adjacent eroded Holocene peat platform.

    b. The eastern shore is dominated by an eroding Pleistocene sediment bank with an adjacent Pleistocene clay and sandy clay platform.

2. The estuarine basin is a shallow, saucer-shaped depositional basin.
    a. The lip of the saucer is cut into and underlain by the eroded peat platform on the western side and eroded Pleistocene clay platform on the eastern side.

    b. The main portion of the saucer forms the central basin which is filled with a thick sequence of slightly sandy, organic-rich mud.

    c. Superimposed upon the slightly sloping eroded platforms and outer portion of the basin are the shallow shoal structures produced by the periodic disposal of dredged material.

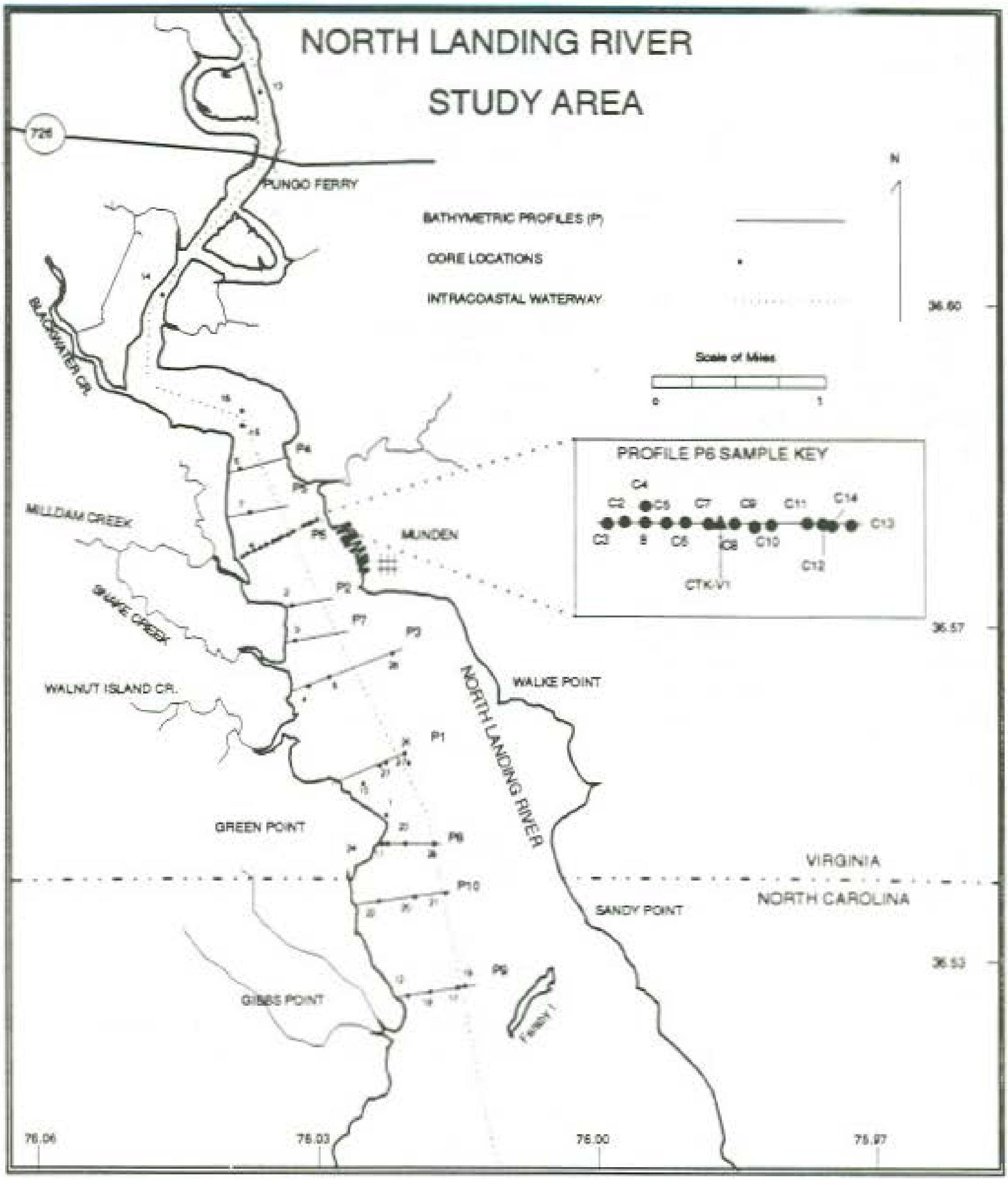


FIGURE 4. Location of sediment samples along bathymetric profiles in the North Landing River area. All sediment samples are 0.5 to 1 meter cores except CTK-V1, which is a 6 meter vibracore.

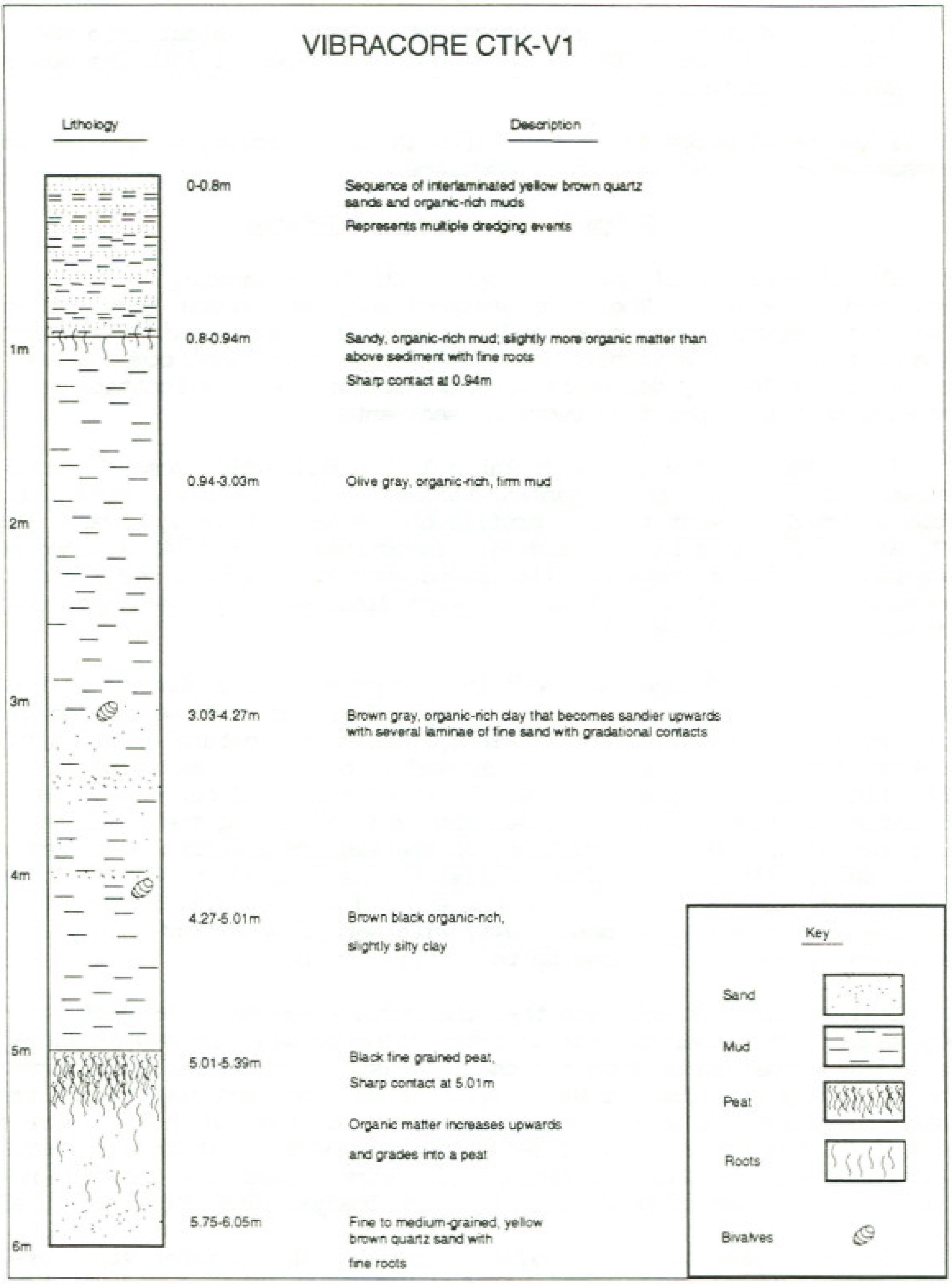


FIGURE 5. Geologic log of vibracore CTK-V1. Vibracore location is on profile P6 on Figure 4.

3. The dug channel of the Intracoastal Waterway is cut into the organic-rich muds of the estuarine basin and subdivides it into the western and eastern platforms.

This is the terminology that is utilized in the following discussion and represented on the geologic cross-sections.

Sediment Composition and Facies

The composition of the sediments in the North Landing River are summarized in Table 1. The major sediment component within this estuarine basin is an organic-rich, sandy mud. However, there are many different sediment facies with a significant variability in sediment composition. This variability is largely dependent upon the specific sample location and processes that are operating upon the sediments.

The sketch at the bottom of Table 1 is a schematic cross-sectional representation that displays general variations in facies and sand/clay ratios across a schematic west to east profile of the North Landing River. Figures 6, 7, and 8 (Profiles P1, P8, and P6, respectively on Fig. 4) are geologic cross-sections along three profiles based upon the sediment cores and associated analytical data. The following discussion is based upon the data in these Figures and Table 1.

The main, nondredged sediment that comprises the subbottom in the North Landing River is organic-rich (9%), sandy (17%), mud (74%) with sand/clay ratios ranging from 0.0 to 0.8 (Table 1). When this natural or in situ sediment on the estuarine floor is exposed to biological activity in combination with erosional processes of waves and tidal currents, mud is systematically winnowed from the sediment and increasing the relative concentration of sand. In addition, on the eastern platform some surface sand is also derived from the erosion of Pleistocene sediment bank shorelines. Consequently, surface sediments on the exposed eastern platform estuarine floor are very muddy (40%) sands (54%) with sand/clay ratios that are significantly over 1 and range up to 3.6 (Table 1).

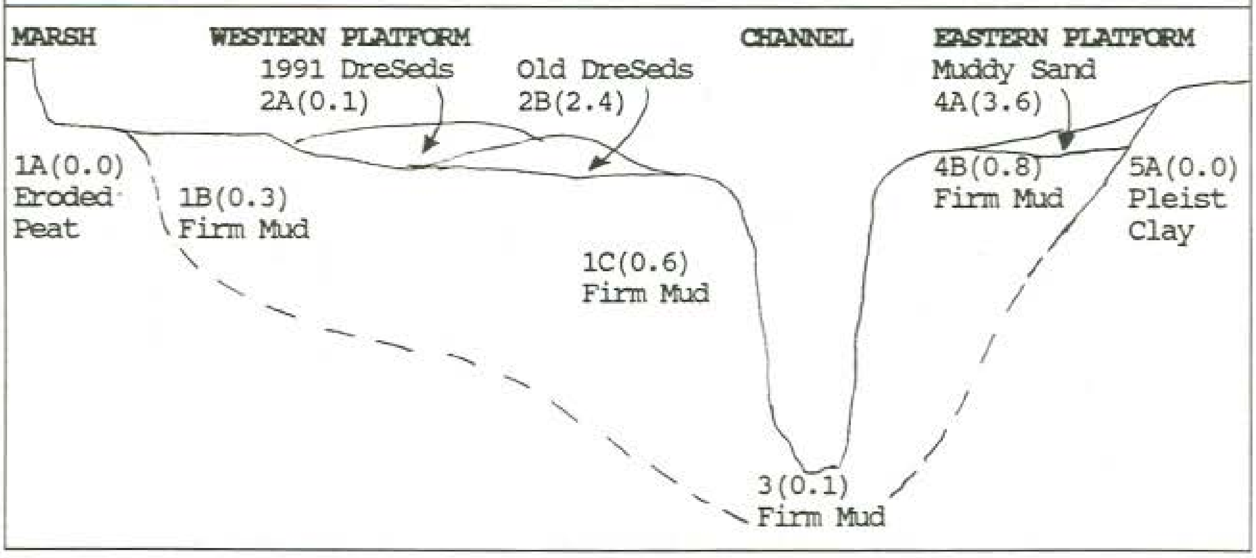
Shallow cores demonstrate that the surface sediments are not uniform muddy sands, but rather consist of interlaminated sand and mud sediments. This is the situation on both the shallow eastern and western platforms adjacent to the Intracoastal Waterway where surface sand/clay ratios are considerably higher than the subsurface sediments from which they were derived (Table 1). This interlaminated sediment grades with depth to a uniform, firm mud with decreasing sand/clay ratios that range between 0.0 and 0.8 and are similar to the material that the channel is dredged into (Figs. 6, 7, and 8).

Figure 5 presents the geologic description of a 6 meter vibracore through a pile of dredged material (see location on Figs. 4 and 8) and into undisturbed underlying sediments. This core depicts 0.94 meters of interlaminated sand and mud in sharp contact with 4.07 meters of firm, slightly sandy, organic-rich mud. The interlaminated sediment is from a bathymetric mound that rises 0.94 meters above the adjacent estuarine surface. About 10 cm of new 1991 dredged material had been deposited on top of this old

TABLE 1. Mean composition of major sediment types occurring within the North Landing River study area. The facies numbers correspond to the numbers on the schematic profile drawn below.

LOCATION AND SEDIMENT TYPE		SEDIMENT COMPOSITION				SAND/CLAY
FACIES	N	SAND %	SILT %	CLAY %	ORGANIC %	RATIO
1. Western Platform						
A. Marsh Peat	1	0.7	46.1	35.6	17.6	0.0
B. In Situ Firm Mud West of Dredge Disposal	3	9.0	49.2	30.2	11.6	0.3
C. In Situ Firm Mud East of Dredge Disposal	8	16.7	48.3	25.8	9.2	0.6
2. Dredged Material						
A. New Dredged Sed/91 Proj.	16	10.4	49.6	30.3	9.7	0.3
B. Old Dredged Sed/Old Proj.	8	44.9	30.0	18.6	6.5	2.4
3. Channel						
A. Mud Dredged in 91 Proj.	3	4.4	51.3	30.8	13.5	0.1
B. Mud Outside of 91 Proj.	3	22.7	42.1	22.1	13.1	1.0
4. Eastern Platform						
A. Winnowed Surface Sandy Mud	2	53.5	25.5	14.8	6.2	3.6
B. Subsurface Firm Mud	4	25.2	39.6	29.8	5.4	0.8
5. Pleistocene Sediments						
A. Basal Clay	2	Very Tight, Gray to Orange Clay				0.0

LOCATION OF FACIES AND (SAND/CLAY RATIO INDEX)



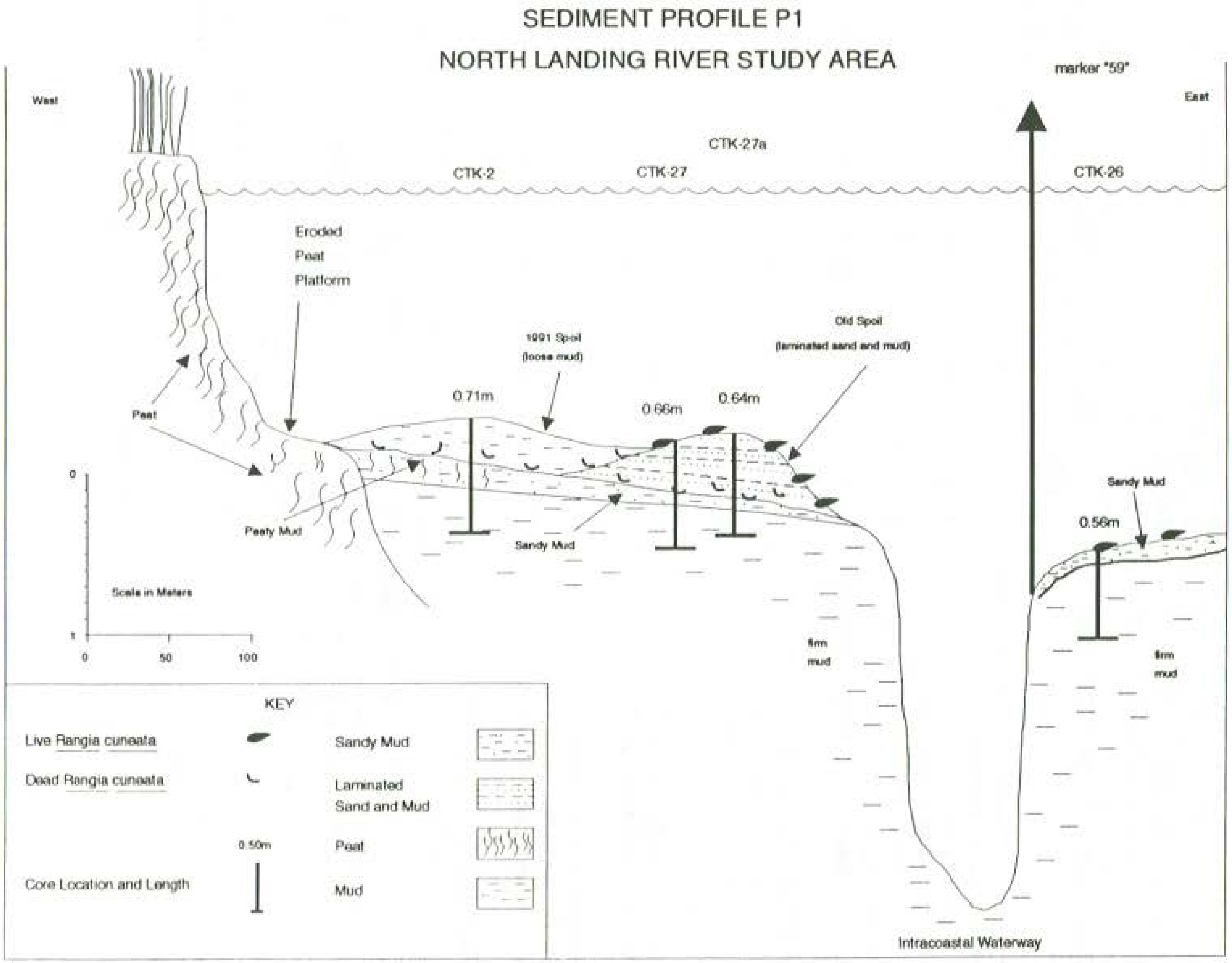


FIGURE 6. Geologic cross-section displaying sedimentologic and morphologic data for profile P1. Profile and sample locations are indicated on Figure 4.

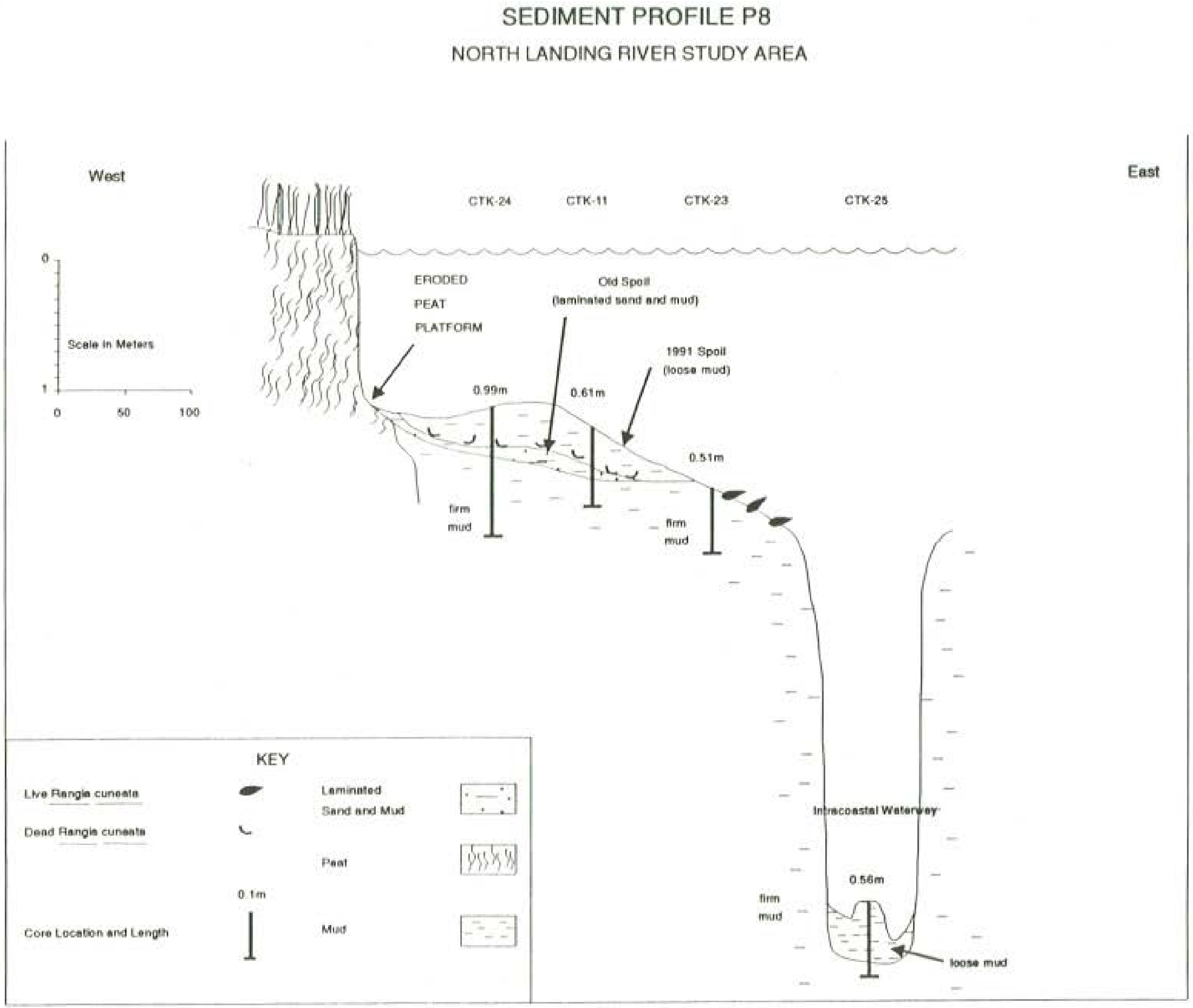


FIGURE 7. Geologic cross-section displaying sedimentologic and morphologic data for profile P8. Profile and sample locations are indicated on Figure 4.

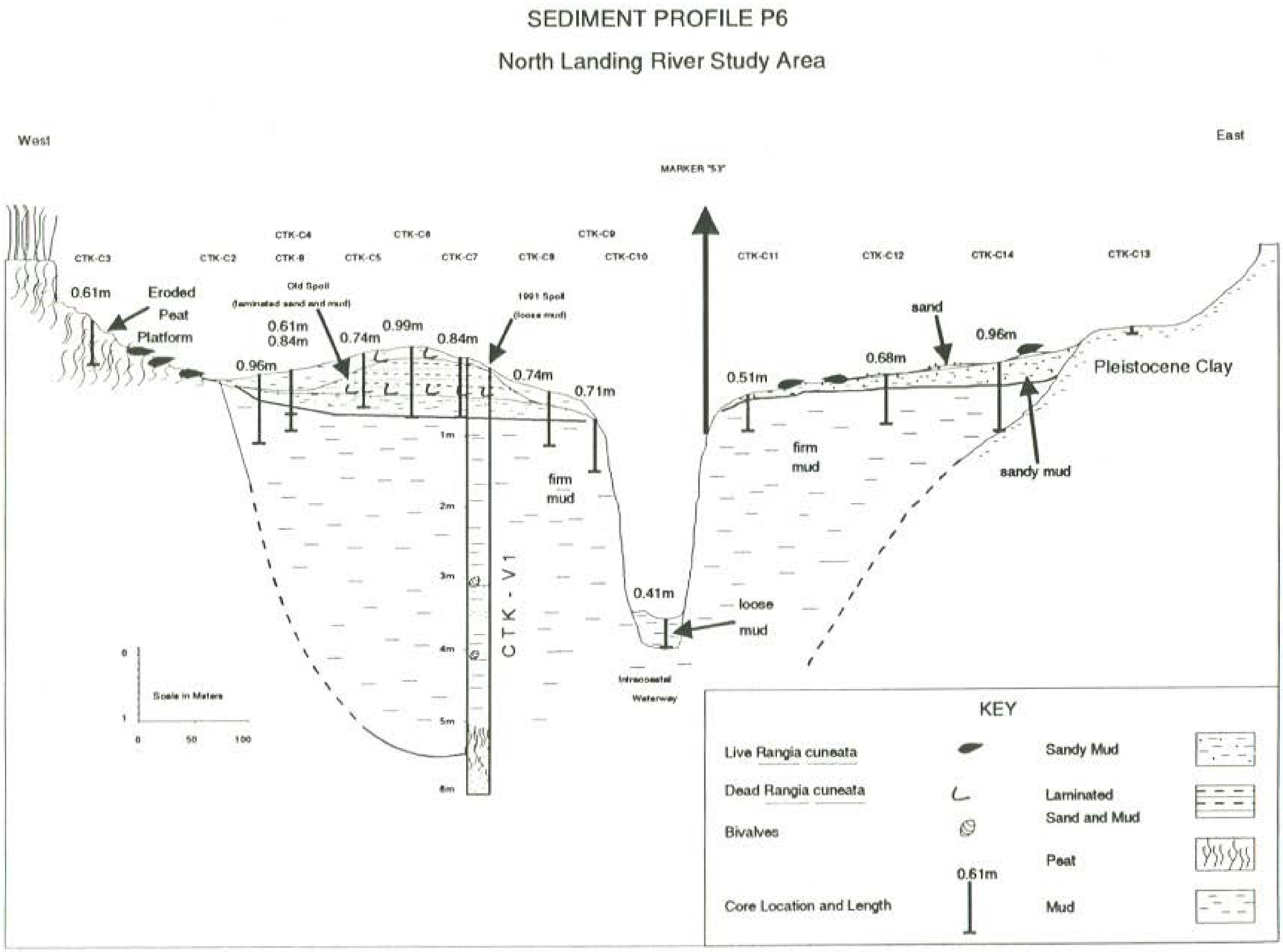


FIGURE 8. Geologic cross-section displaying sedimentologic and morphologic data for profile P6. Profile and sample locations are indicated on Figure 4.

dredged material pile at this site, however, it was so loose that it was lost when recovering the vibracore (Fig. 5). The underlying thick firm mud bed is the sediment into which the Intracoastal Waterway channel has been dredged and represents the primary sediment.

TRACE ELEMENTS IN BOTTOM SEDIMENTS

Chemical Analyses

Fourteen trace elements were utilized in this study (Table 2) and include 7 of the U.S. EPA "priority pollutant metals" plus seven other environmentally important trace elements. The North Landing River samples are considered to be part of the same sediment regime as the Albemarle estuarine system; consequently, they were collected and analyzed as part of the Albemarle sample set. The analytical procedures utilized are the same as those developed for the Neuse River and Albemarle Sound studies and are described in detail in Riggs et al. (1991, 1993), respectively. The analytical data were synthesized and statistically analyzed and represent the data base for the following discussion and conclusions.

An estimate of background levels for each trace element was determined for each of the 14 trace elements within the sediments of the Albemarle Sound estuarine system (Riggs et al., 1993). This estimate was derived by the following procedure and results in a value hereafter referred to as the Albemarle trimmed mean (ATM). Table 3 is the ATM data for the Albemarle Sound estuarine area, which includes the North Landing River (from Riggs et al., 1993).

1. Mean concentrations and standard deviations were computed for each trace element in all surface samples within the Albemarle Sound estuarine system.

2. Those samples with values greater than two standard deviations from this original mean were then excluded. These 'outliers' were assumed to represent either anthropogenically contaminated sediments or depleted relict sediments and should not be incorporated into any process intended to derive a general background value.

3. Mean values were then calculated for these trimmed data sets resulting in the ATM for each element.

4. The ATM for each element serves as a reference point against which every sample, including the outliers excluded from the trimmed data set and samples from depth, were compared.

5. This comparison represents the enrichment factor (EF) for each element in each sample (EF is the ratio of actual concentration for the sample to the ATM). This provides a measure of either excess or depletion compared to an approximate 'background' level. It also provides a convenient and uniform method to graphically depict spatial distributions of concentrations of the elements.

TABLE 2. Concentrations of 14 trace elements and enrichment factors for all surface and shallow subsurface samples collected in the North Landing River in Currituck Sound. Depths of the shallow subsurface samples range from 13 to 63 cm below the sediment surface for an average depth of 40 cm. Elements with underlined enrichment factors are substantially enriched (EF = or >2X ATM) relative to the Albemarle trimmed mean, whereas those in bold are slightly enriched (EF >1.5X to <2X ATM).

		CONCENTRATIONS (µg/g or ppm) ALL SAMPLES			ENRICHMENT FACTORS SUBSURF SPLS N = 20		ENRICHMENT FACTORS SURFACE SAMPLES N = 35	
TRACE ELEMENTS	N	MEAN	MINIMUM	MAXIMUM	MEAN	MAXIMUM	MEAN	MAXIMUM
NORTH LANDING RIVER--CURRITUCK SOUND								
Mo	55	0.66	0.21	2.90	2.7	8.4	2.0	10.1
As *	55	3.94	0.75	10.3	1.4	2.7	0.8	2.5
Ti	55	103.	57.3	180.	1.7	2.3	1.2	2.4
Ni	55	5.51	1.52	10.3	1.3	**1.9**	1.3	2.4
Pb	55	14.8	3.46	143.	0.7	6.6	0.7	1.0
Cr	55	9.78	3.89	15.6	0.9	1.2	0.9	**1.5**
Zn	55	34.7	3.20	83.2	0.7	**1.7**	0.7	1.0
V	55	17.5	7.93	33.1	0.8	1.4	0.7	1.4
P	55	317.	38.1	523.	0.6	0.9	0.9	1.3
Co	55	4.91	2.25	6.16	0.7	0.9	0.7	0.9
Cd	55	0.15	0.15	0.15	0.7	0.7	0.7	0.7
Cu	55	5.53	1.71	7.97	0.4	0.6	0.5	0.7
Mn	55	123.	27.0	257.	0.4	0.8	0.3	0.4
Sn *	55	0.21	0.20	0.56	0.0	0.0	0.0	0.1

* analyses have poor reproducibility, hence somewhat low reliability.

TABLE 3. Albemarle trimmed mean (ATM) data for all surface samples that are less than 2 standard deviations from the mean total population. The standard deviation, coefficient of variation, and the minimum and maximum concentration values used in this calculation for 22 elements (in µg/g or ppm) in surface sediments of the Albemarle Sound estuarine system, are also included.

ELEMENT	N	ALBEMARLE TRIMMED DATA TRIMMED MEAN µg/g	COEFFICIENT OF VARIATION %	STANDARD DEVIATION µg/g	MINIMUM VALUE µg/g	MAXIMUM VALUE µg/g
TRACE ELEMENTS						
As *	184	3.95	73.7	2.77	0.75	10.4
Cd	184	0.22	69.7	0.16	0.15	0.72
Cr	175	10.7	38.0	4.04	2.30	21.8
Co	175	6.67	44.9	3.00	1.78	13.2
Cu	175	10.8	53.7	5.80	2.03	33.3
Hg	149	0.14	88.1	0.12	0.02	0.63
Ni	175	4.28	36.1	1.54	0.67	7.31
Pb	175	21.7	62.0	13.5	3.62	69.3
Mn	175	329.	100.7	331.	30.4	1227.
Mo	183	0.29	31.8	0.09	0.25	0.60
P	175	401.	52.1	209.	92.1	1109.
Sn *	182	5.64	73.7	4.16	0.20	13.2
Ti	175	75.2	42.3	31.8	19.9	148.
V	175	23.4	47.5	11.1	4.39	47.7
Zn	175	50.4	48.5	24.4	10.9	114.
MAJOR ELEMENTS						
Al	175	5088.	34.7	1766.	1373.	8804.
Ca	175	2340.	43.9	1027.	775.	5103.
Fe	175	13340.	33.5	4466.	2699.	21256.
K	175	555.	38.1	211.	129.	952.
Mg	175	1713.	39.7	680.	361.	3029.
Na	175	609.	69.2	421.	51.	1633.
Si	175	1533.	29.7	456.	694.	2592.

* Analyses have poor reproducibility, hence somewhat less reliability.

6. The following definitions with respect to enrichment factors (EF) will be utilized in the remainder of this report:

a. EF = 1 is equal to the ATM,
b. EF < 1 is depleted relative to the ATM,
c. EF > 1 is enriched relative to the ATM,
d. EF between 1.5 X and 1.99 X the ATM is "slightly enriched",
e. EF = 2 X the ATM or greater is "substantially enriched".

Chemical data for 55 surface and shallow subsurface samples are summarized in Table 2. This data set is permanently stored in two formats: 1) in data base spreadsheets using SYMPHONY software compatible with IBM PC type computers and 2) in Statistical Analysis System (SAS) software data sets on the East Carolina University IBM 4381 mainframe computer disks. All raw data have been placed into the Albemarle/Pamlico Estuarine Study data base in the Department of Environment, Health, and Natural Resources in Raleigh, N.C. or are available from the senior author.

Analytical Results

Table 2 demonstrates that only 5 of the 14 trace elements are substantially enriched with maximum enrichment factors as follows: Mo = 10.1 X, Pb = 6.6 X, As = 2.7 X, Ni = 2.4 X, and Ti = 2.4 X the ATM. Two additional elements are slightly enriched with maximum enrichment factors as follows: Zn = 1.7 X and Cr = 1.5 X the ATM. No samples are enriched in the following 7 trace elements: Cd, Co, Cu, Mn, P, Sn and V. None of the samples were analyzed for mercury.

Table 4 demonstrates that 3 of the 7 enriched elements (Pb, Zn, and Cr) are only enriched in 1 of 55 samples each with all 54 of the other samples having very low mean enrichment factors (Pb = 0.7 X, Zn = 0.7 X, and Cr = 0.9 X the ATM). This data suggests that these individual enriched samples represent anomalies and reflect a single, localized contaminant that occurs in one sample only.

TABLE 4. Number and percent of samples in the North Landing River that are substantially and slightly enriched in 7 trace elements above the trimmed mean for Albemarle Sound estuarine system (Riggs et al., 1993).

ENRICHED ELEMENT	TOTAL NO. SAMPLES SURF/SUBS	SUBSTANT. SURFACE NO. / %	ENRICHED SUBSURF. NO. / %	SLIGHTLY SURFACE NO. / %	ENRICHED SUBSURF. NO. / %	TOTAL EN-RICHED SPLS NO. / %
Mo	35/20	12/34%	13/65%	18/51%	4/20%	47/85%
Ni	35/20	1/ 3%	0/ 0%	11/31%	7/35%	19/35%
Ti	35/20	1/ 3%	5/25%	0/ 0%	9/45%	15/27%
As	35/20	1/ 3%	3/15%	5/14%	5/25%	14/25%
Pb	35/20	1/ 3%	0/ 0%	0/ 0%	0/ 0%	1/ 2%
Zn	35/20	0/ 0%	0/ 0%	0/ 0%	1/ 5%	1/ 2%
Cr	35/20	0/ 0%	0/ 0%	1/ 3%	0/ 0%	1/ 2%

On the other hand, Table 4 demonstrates that trace elements Mo, Ni, Ti, and As are enriched in significant portions of the 55 samples (85%, 35%, 27%, and 25% of the samples, respectively). The mean enrichment factor for all samples for each of these elements is as follows: Mo = 2.3 X, Ti = 1.4 X, Ni = 1.3 X, and As = 1.1 X the ATM. This data suggest that Mo is a major contaminant throughout most of the North Landing River area; it is substantially enriched (up to 10.1 X the ATM) in 25 of the 55 total samples and slightly enriched in another 22 samples. Ti enrichment is generally in the sediment subsurface with 14 of the 15 enriched samples occurring in the shallow subsurface. Eighteen of the 19 samples enriched in Ni are only slightly enriched with enrichment factors between 1.5 and <2.0 X the ATM; the one substantially enriched sample is 2.4 X the ATM. Arsenic is substantially enriched in 4 samples (up to 2.7 X the ATM) and slightly enriched in an additional 10 samples.

Consequently, the elements that are enriched and represent the major contaminants in the North Landing River area are Mo, Ni, Ti, and As. Of these four enriched elements, only As and Ni are included on the U.S. EPA list of "priority pollutants". Also, the As and Mo data have large analytical variances and uncertainties (see Riggs et al., 1993). Actual concentrations of arsenic, even though it is relatively enriched in 25% of the samples, are similar to the trimmed mean concentrations of all samples for the Albemarle Sound estuarine system, and are quite low when compared with the Pamlico and Neuse estuarine systems (Table 5). Whereas the Mo, Ni, and Ti mean concentration values for the North Landing River are significantly higher than the trimmed mean values for the Albemarle, Neuse, and Pamlico estuarine systems (Table 5).

TABLE 5. Comparison of mean concentrations of enriched elements in the North Landing River with trimmed means for the Albemarle, Neuse, and Pamlico estuarine systems (in μg/g or ppm). Highest mean concentration for each element is underlined, whereas lowest mean concentration is in bold print. Trimmed mean data are from Riggs et al., 1993, 1991, and 1989, respectively.

ENRICHED ELEMENT	MEAN CONCENTRATION	TRIMMED MEAN CONCENTRATIONS		
	NORTH LANDING RIVER μg/g	ALBEMARLE SOUND μg/g	NEUSE RIVER μg/g	PAMLICO RIVER μg/g
Mo	<u>0.66</u>	**0.29**	0.54	0.50
Ni	<u>5.51</u>	4.28	4.64	**2.66**
Ti	<u>103.</u>	75.2	**31.8**	38.6
As	3.94	**3.75**	5.98	<u>12.8</u>
Pb	**14.8**	21.8	34.9	<u>35.9</u>
Zn	**34.7**	50.5	<u>95.0</u>	77.0
Cr	**9.78**	10.7	<u>16.8</u>	10.5

Three of the substantially enriched elements (Mo, Ni, and As) have no apparent distribution patterns. Each of the elements are enriched in both surface and deep samples, in dredged and nondredged areas, in dredge material and undisturbed sediments, on the shallow platforms and in the deep channel, and appear to be independent of the composition of sand, clay, and organic matter. No obvious pattern or factor appears to be controlling the distribution and concentration of any of these three elements. Also, there is a total lack of enrichment in more common anthropogenic metals (i.e., lead, zinc, copper, and chromium). Titanium is generally enriched with depth in the cores, suggesting there could be sedimentologic or geochemical control for this element.

EFFECTS OF DREDGE MATERIAL DISPOSAL UPON ESTUARINE BOTTOMS

Three methods were utilized to evaluate the effects of disposal of dredged materials upon the estuarine bottom. These methods include the following: 1) documentation of the presence and nature of layers of dead Rangia clams; 2) determination of presence, distribution, and pattern of sand lenses; and 3) interpretation of bathymetric profiles.

Rangia Clams

The first method utilized to define the different disposal events and their three dimensional geometry was the presence and nature of layers of the clam *Rangia cuneata*. *Rangia* was introduced into North Carolina estuarine waters during the mid 1950's and expanded rapidly, occupying fresh to low-brackish estuarine sandy mud to muddy sand environments throughout the estuarine system (Wells, 1961). An extensive population of mature *Rangia* occurs throughout the study area contrary to the declaration that there is a "scarcity of benthic animals resident in the proposed disposal areas" (USACE, Environmental Assessment).

Delineation of the recent disposal (February to March 1991) of dredged material was easily accomplished by mapping the distribution of these ubiquitous clams. Areas that received no discharged dredged material had a fairly dense and uniform distribution of multi-year old clams. Whereas, areas that received dredged material had no clams living on the surface of the newly disposed sediment. However, everywhere under the recently deposited dredged material was a fairly dense and uniform distribution of dead *Rangia* clams. Three months later, there were still no live clams on the surface of the disposed dredged material and the buried articulated clams still contained decaying meat and gas.

Since the clams in these estuarine environments can repopulate new sediment surfaces fairly quickly, the process of killing the clam population would have been repeated with each period of dredging and disposal of dredged material since the clam was introduced in the 1950's. The consequence is that the sediments from each dredging event have a time event marker represented by a layer of dead *Rangia* clams at the base. These layers of dead clams generally occur on top of the original platform sediments and on top of each lens of sand sediment resulting from long periods of winnowing of the previous dredge material. Sediment cores alone were not able to separate these layers or to sort out and map specific disposal events; to follow these horizons it was essential to utilize skin diving with extensive hand probing. Consequently, in this report we have grouped all older disposal events into one unit and have only distinguished between these older events and the last disposal event of 1991.

Sand Lenses

The process of dredging the firm, slightly sandy mud from the channel, would mix the sediment with water producing a loose sediment which probably had the capability of "flowing" out over the estuarine bottom. Disposal of dredge material would have resulted in very broad mounds of decreased water depth; this shallowing increases the potential impact of wave activity from storms and boat wakes from traffic moving through the adjacent Intracoastal Waterway. The continued expenditure of energy on bathymetrically higher piles of loose mud sediments could rapidly modify the disposal piles. Waves and currents from either storms and/or boat wakes could winnow the muds, putting the fines into suspension, and potentially transporting them throughout the Currituck estuarine system. Whether waves and currents resulting from boat wakes are an important process and capable of winnowing these loose sediments becomes blatantly obvious when you observe these disposal piles with mask and snorkel as the heavy boat traffic moves along the Waterway. The winnowing of fine-grained material would systematically increase the relative sand composition and with time would smooth out and diminish the size of dredged sediment banks. This is demonstrated on all of the second set of profiles made three months after disposal (Figs. 11 through 14).

Consequently, the sand lenses are interpreted to be the winnowed products of either high energy storm events and/or boat wakes operating through time rather than artifacts of the dredging process. This interpretation is based upon the following lines of evidence.

1. Field observations of the processes,

2. Presence of layers of dead Rangia clams on top of buried sand lenses,

3. Sedimentologic character and geometry of the sand lenses,

4. Minor amounts of sand disseminated within the mud sediments being dredged (Table 1), and

5. Comparisons of the composition of new dredge material with old dredge material, which suggest major increases in relative sand concentrations with time (Table 1).

The end result of extended winnowing are lenses of sandy mud occurring on predredge sediments which grade eastward into pure sands on the front or eastern side of the dredged material piles. One dredged material profile (P3 in Fig. 13) consisted of an entire sand bank on the channel side which could result from selected disposal of dredge residuals. However, most dredged material piles consisted of a surface layer of loose mud on top of alternating sequences of sand and firmer mud suggesting modern disposal on top of

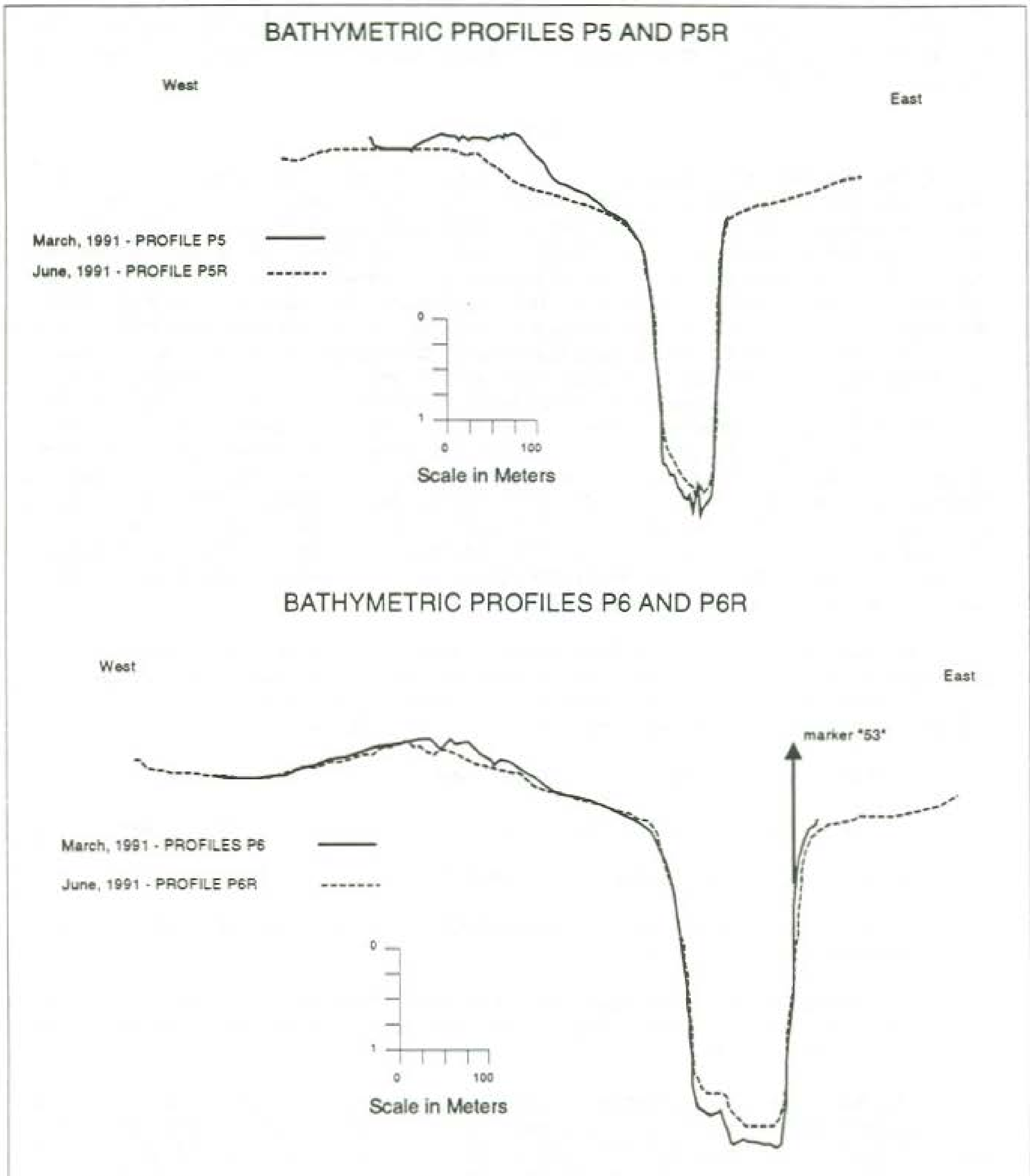


FIGURE 9. Bathymetric profiles P5, P5R, P6, and P6R across the Intracoastal Waterway channel and portions of the western estuarine platform in dredge disposal site A. Profile locations are indicated on Figures 3 and 4.

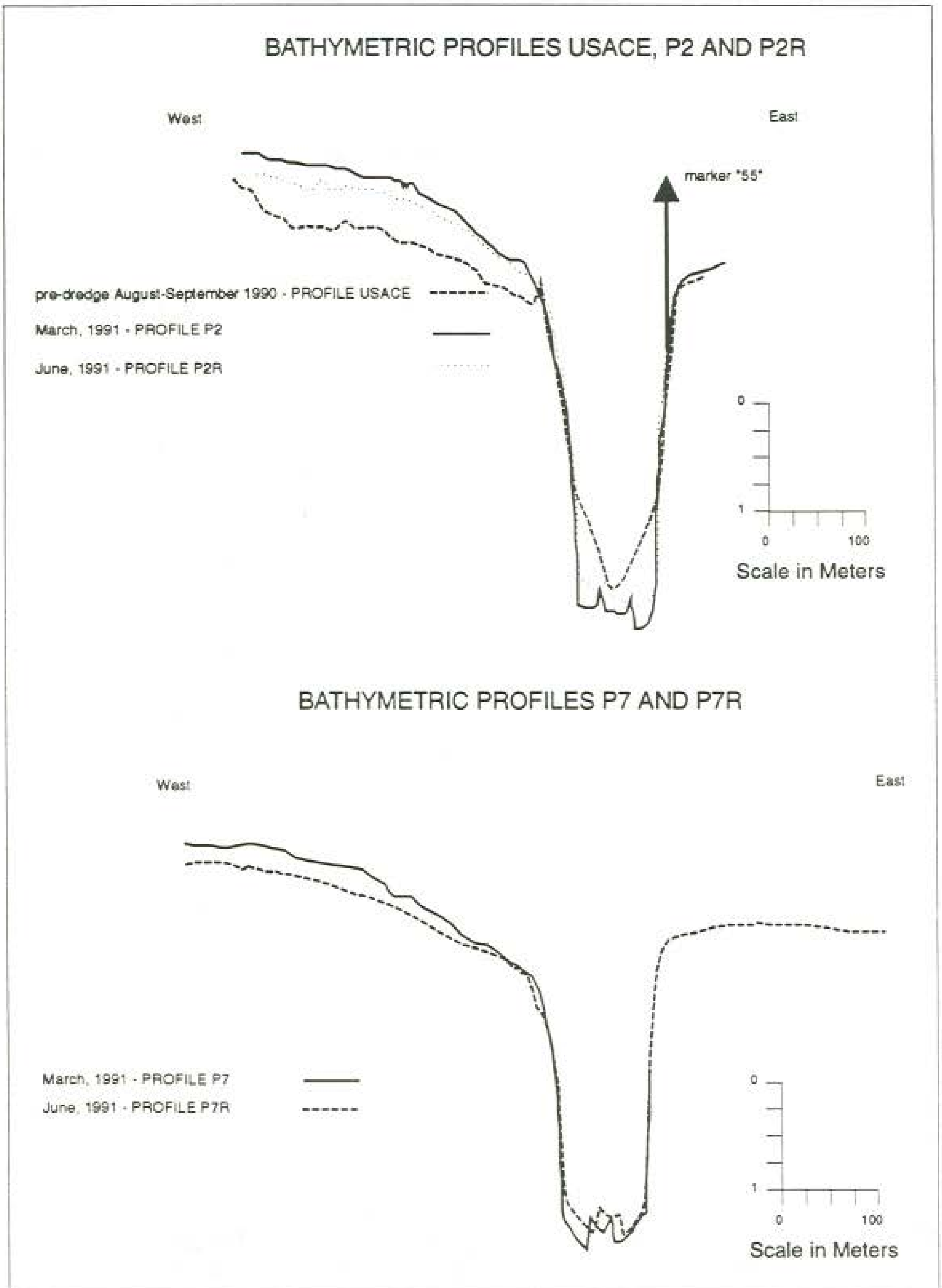


FIGURE 10. Bathymetric profiles USACE, P2, P2R, P7, and P7R across the Intracoastal Waterway channel and portions of the western estuarine platform in dredge disposal site B. Profile locations are indicated on Figures 3 and 4.

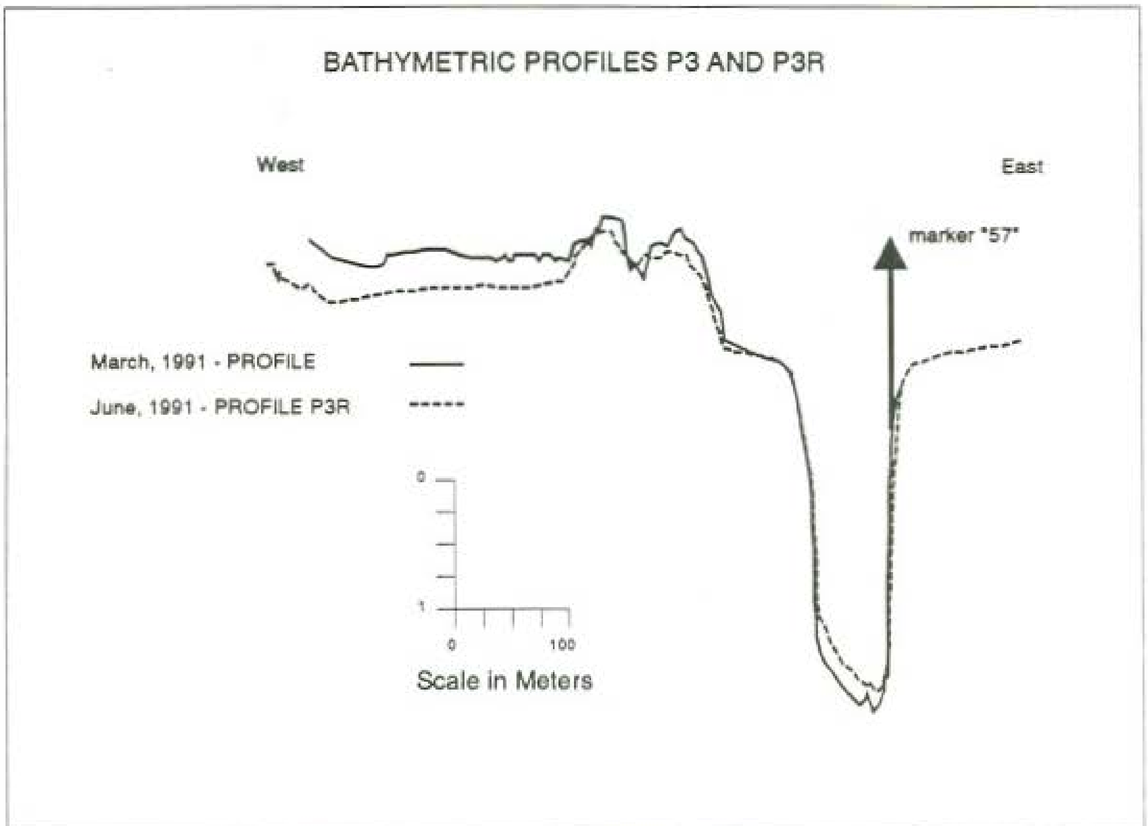


FIGURE 11. Bathymetric profiles P3 and P3R across the Intracoastal Waterway channel and a portion of the western estuarine platform in dredge disposal site C. Profile location is indicated on Figures 3 and 4.

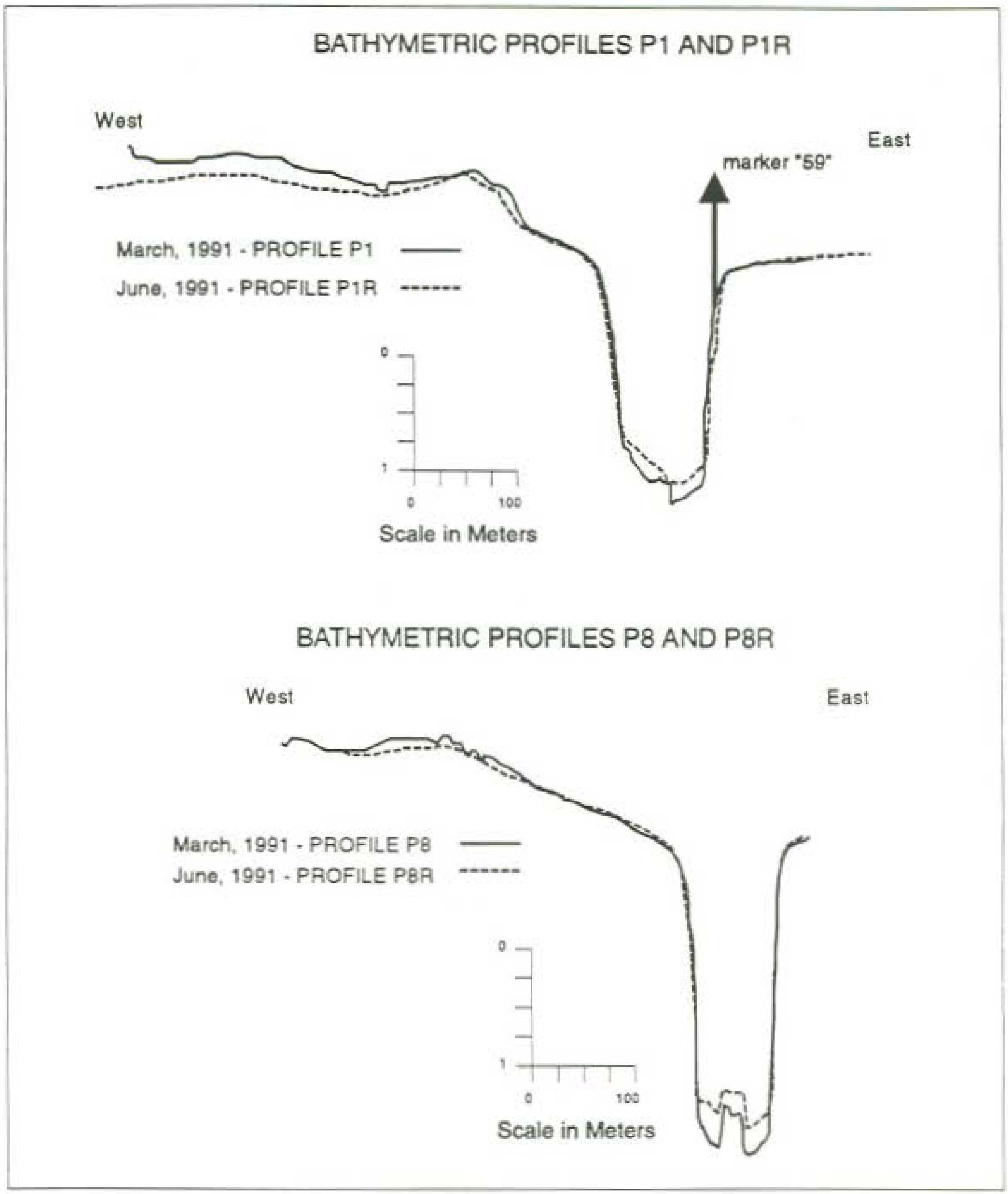


FIGURE 12. Bathymetric profiles P1, P1R, P8, and P8R across the Intracoastal Waterway channel and portions of the western estuarine platform in dredge disposal site D. Profile locations are indicated on Figures 3 and 4.

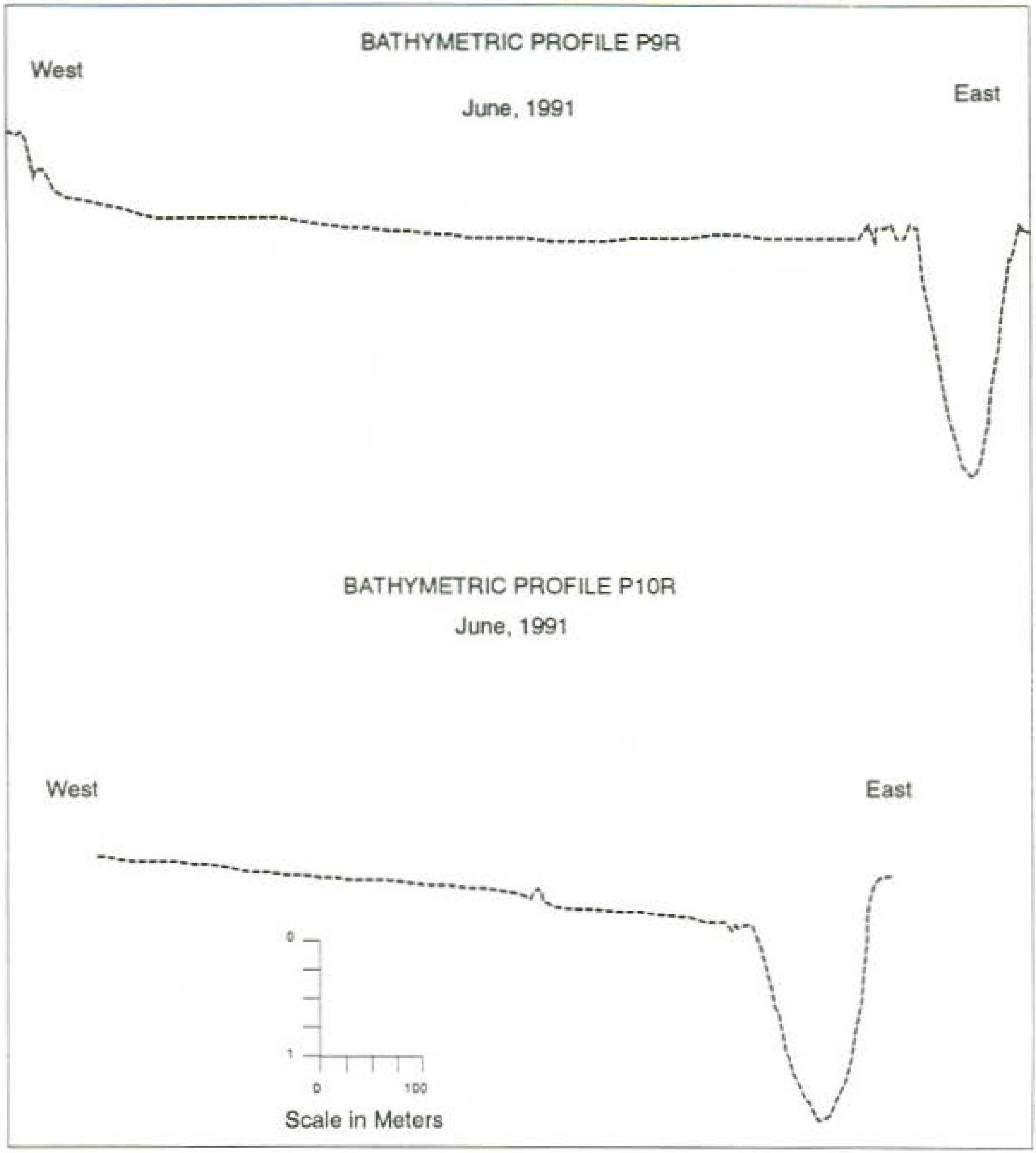


FIGURE 13. Bathymetric profiles P9R and P10R across the Intracoastal Waterway channel and portions of the western estuarine platform. These areas are south of dredge disposal site D and theoretically have not experienced the disposal of dredged material. Thus, these profiles should approximate the natural estuarine profiles. Profile locations are indicated on Figures 3 and 4.

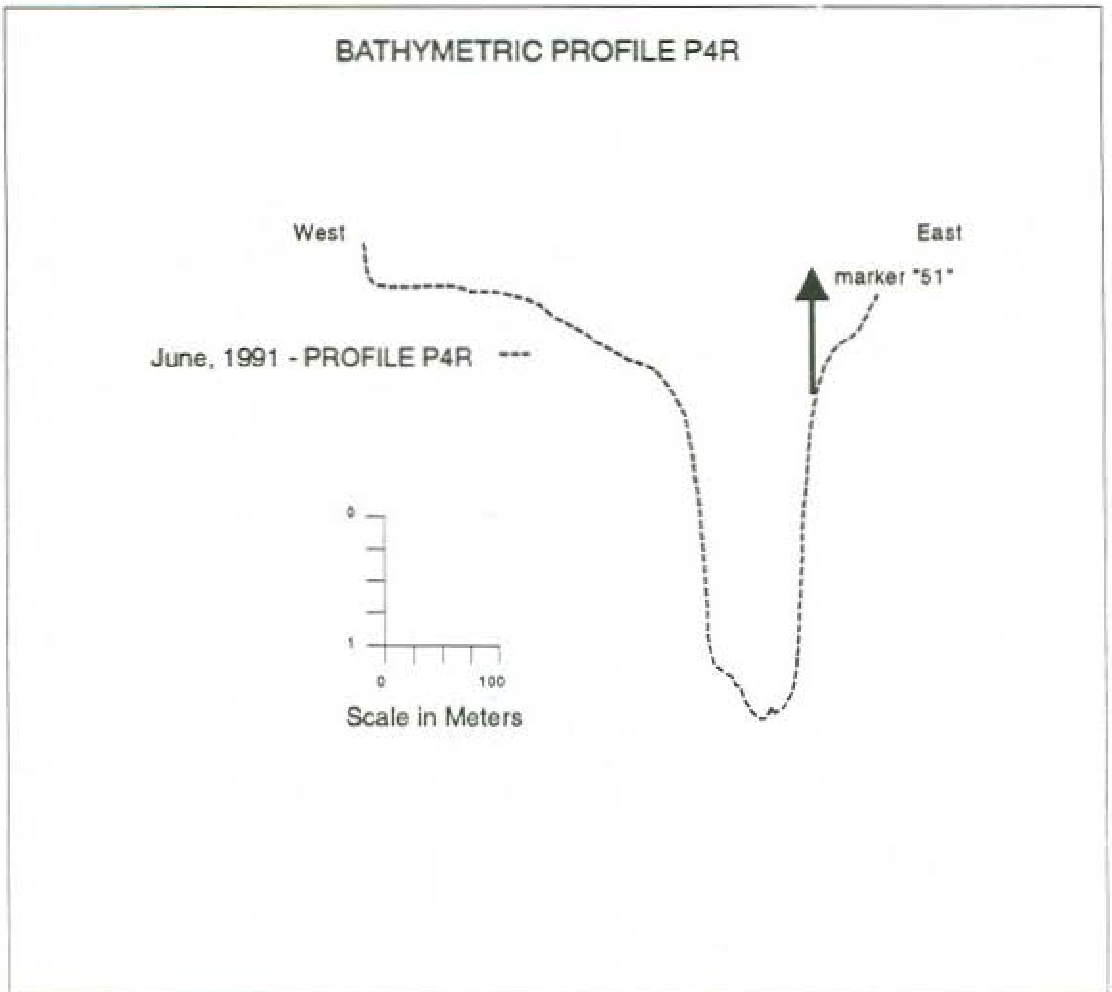


FIGURE 14. Bathymetric profile P4R across the Intracoastal Waterway channel and the western estuarine platform. This area is north of disposal site A and theoretically has not experienced disposal of dredged material. Thus, this profile should approximate the natural estuarine profile. Profile location is indicated on Figures 3 and 4.

multiple, older disposal events followed by periods of winnowing. Dredge material piles (P5 and P6 in Fig. 9) contained up to 5 sand lenses and associated dead Rangia clam layers. Continued disposal over the years has actually built up the western platform in Virginia relative to the eastern platform (P2 and P7 in Fig. 10; P3, P1, and P8 in Figs. 11 and 12) whereas in North Carolina the opposite situation occurs (P10 in Fig. 13).

Bathymetric Profiles

Dredged sediment disposal over the years has obviously changed the basic shape and geometry of the estuarine system. Figures 3 and 4 show the location of 10 general bathymetric profiles established during this study. These profiles were developed by running a recording fathometer along a set of control stakes placed in the ground for each transect. The profiles were reduced to a common scale based upon the control stakes and were corrected for tide level. The assumption was made that the channel shoulders have not changed, and thus, the shoulders represent the match points and all changes are relative to this. Since no stations were surveyed, locations of repeat tracks should be considered as good approximations only. However, based upon our control stakes, the rerun profiles are close and do suggest that some changes have taken place in response to daily processes since disposal.

Profiles P9R and P10R (Fig. 13) were run on the south side of the dredge disposal area (Fig. 3), while profile P4R (Fig. 14) was run on the north side. Thus, these profiles (Figs. 13 and 14) should approximate the natural estuarine profiles for the narrow northern and wide southern portions of the study area, respectively. Profiles P1 through P8 (Fig. 3) were first measured between March 8 and 25, 1991, immediately after the disposal project was completed. Profiles P1R through P8R were rerun between June 19 and 21, 1991. Profile P2 (Fig. 10) is along a preproject profile surveyed by the U.S. Army Corps of Engineers and includes its surveyed profile line. Profiles P5 and P6 (Fig. 9) are in the northern dredge disposal site A. Profiles P2 and P7 are in dredge disposal site B (Fig. 10). Profile P3 is in disposal site C (Fig. 11) and profiles P1 and P8 (Fig. 12) are in the southern disposal site D.

Profiles P4R, P10R, and P9R (from north to south in Fig. 3) display the general bottom shape of the natural estuarine system, with the exception of the dug channel. P4R displays the profile in the transition zone between the estuarine and riverine environments, whereas P10R and P9R display more typical estuarine profiles. These profiles represent a gradual sloping bowl that becomes flatter and wider further into the estuary with the channel cut into the bottom of the bowl. Assuming that the dredged material from the channel in Virginia has always been disposed on the western platform (Fig. 3), then the eastern platform in Virginia should reflect the more natural portion of the profile. However, in North Carolina dredge material has previously been disposed on the eastern platform (Fig. 3). Assuming that this has always been the case, the western platform should reflect the more natural portion of the profile in North Carolina. Each profile in the dredge disposal areas recorded bathymetrically high disposal piles of dredged sediment. It was easy to distinguish between the most recent disposal material, which consisted of very loose sediment, and the older dredge disposal material, which was compact and moderately tight.

In general, there was an overall lowering of dredged material profile height between the March and June profiles (Figs. 9 through 12). The change in profiles could in part be due to dewatering; however, some of this change is interpreted to reflect winnowing and removal of clay, fine silt, and organic fractions and concentration of sands into discreet lenses. This is particularly true on the east and top sides of the disposal piles which are dominated by sandy muds. The production of interlaminated depositional patterns of sand and mud are clearly demonstrated in the geologic profiles in Figures 6, 7, and 8 and supported by the associated sediment data presented in Table 1.

Generally, channel profiles produced three months after dredging compared to those made immediately after the project (Figs. 9 through 12), suggest that there has been subsequent channel filling with up to 0.4 meters of mud (Figs. 7 and 8). Surface sediments in the dredged channel were very soft, loose, and difficult to sample. Much of this loose mud may be portions of the dredged material that "flowed" back into the channel in response to initial storm waves operating upon the new and loose dredged material piles; dredged sediment was commonly found in the nondisposal areas between 100 and 200 meters from the channel. In contrast, the nondredged portions of the channels at either end of the 1991 project consisted of firm mud sediments.

SUMMARY AND DISCUSSION

Estuarine Sedimentation and Dredging

The North Landing River estuary can be subdivided into a series of subenvironments, each with characteristic morphology and associated sediments (Figs. 6, 7, and 8). The western platform consists of an erosional marsh shoreline and wave-cut peat platform which grades downslope into a lower mud platform. The eastern platform consists of an erosional sediment bank shoreline and wave-cut terrace into dense Pleistocene clays. A westward thickening wedge of Holocene mud sediments laps onto the Pleistocene clay and forms the lower mud platform. The central basin is a shallow, mud-filled basin with gradual slopes up onto the adjacent platforms. However, this surface has been modified by the Intracoastal Waterway channel, whose steep sides have been cut 4 to 5 meters into the firm mud of the central basin. Subsequently, the loose mud dredged material from the channel has been deposited on the western platform modifying the original bathymetry and producing shallow-water, shoal features.

Composition of the in situ estuarine basin sediments is the same as the channel deposits and the resulting dredge materials from the channel. However, winnowing processes operating on the dredge materials result in sediments with significantly different compositions as follows: a) average composition of in situ mud sediment (n = 22) is 9.4% sand, 49.7% silt, 30.4% clay, and 10.4% organic matter; b) average composition of winnowed dredge materials (n = 10) is 46.6% sand, 29.1% silt, 17.8% clay, and 6.4% organic matter.

Disposal of dredge materials on the shallow-water, perimeter platforms adjacent to the Intracoastal Waterway channel in Virginia creates shallow water mounds with bathymetry significantly different from the normal estuarine equilibrium slope. These shallow mounds of dredged material receive increased impact from storm waves, currents, and boat wakes with significant erosion of the loose dredged material. Increased erosion of the mounds of dredged material may cause an initial movement or "flowage" of some near channel loose sediment back into the dredged channel before compaction sets up the dredged material.

Continued erosion of the mounds of dredged materials leads to winnowing of the clay, fine silt, and organic components from the dredged material and puts them into suspension within the water column. The ongoing winnowing process is probably greatest during the first year when the sediment is the loosest and has the following long-term consequences.

1. Fine-grained sediments are removed, which concentrates the sands and leads to a major change in average composition of dredged material sediment: a) average initial composition of dredged material (n = 16) is 10.4% sand, 49.6% silt, 30.3% clay, and 9.7% organic matter; b) average winnowed composition of old dredged material (n = 8) is 44.6% sand, 30.0% silt, 18.6% clay, and 6.5% organic matter.

2. The removal of fine sediment modifies the shape of the initial pile of dredged material by smoothing out the cross-sectional profile, which also diminishes the overall size. In addition, the composition of the resulting sediment will be significantly changed.

Approximately 361,677 yds^3 of dredged material with the composition of the average mud was deposited in shallow waters during the February to March 1991 channel dredging project. Modification of composition, size, and shape of piles of dredged material, by the ongoing winnowing processes, would result in a significant volume of fine-grained sediment contributed to the estuary and increasing water column turbidity.

Many biologists have demonstrated a direct relationship between submersed aquatic vegetation (SAV) and water turbidity in Currituck Sound estuarine system. 1. Bourn (1932) concluded that turbidity was the primary cause for the environmental deterioration and demise of submersed macrophytes in Currituck Sound which began in 1914 with the dredging of the Albemarle and Chesapeake Canal. Davis and Brinson (1983) believe that the suspended sediments causing increased turbidity changes described by Bourn (1932) were associated with channel dredging rather than urban and industrial wastewaters moving down from the Norfolk area as suggested by Bourn.

The sharp decline of macrophytes in Back Bay in 1963 was attributed to extensive dredging and filling, which began in the Bay in 1963 (Sincock, 1966). Davis and Brinson (1983, 1989) concluded that major changes in biomass and species composition of submersed macrophytes in the Currituck Sound can be directly correlated with changes in suspended sediment turbidity. They found that "prolonged increases in suspended sediment turbidity are almost certain to result in lasting deterioration of SAV beds." Holman (1993) summarized the water quality data for Currituck Sound. He stated that "some of the highest values for suspended solids for the entire Albemarle Pamlico estuarine system have been recorded in the Currituck Sound".

It is our opinion that open disposal of mud sediments resulting from maintenance dredging of the Intracoastal Waterway channel have previously and will continue to have significant impacts upon turbidity levels of associated estuarine waters for several years after dredging has been completed. Increased turbidity negatively impacts water quality in the North Landing River and adjacent portions of Currituck Sound with possible effects upon light penetration and growth of submersed aquatic vegetation.

Sediment Quality

Lead is substantially enriched in only 1 deep sample (maximum enrichment factor = 6.6 X the ATM) with all other samples having a very low mean enrichment factor (mean EF = 0.7 X the ATM). Although this one sample is substantially enriched, it probably reflects a single contaminant in that particular sample such as a duck hunter's lead shot, fishing sinker, or was in the proximity of a discarded battery, etc. Two elements (Zn and Cr) are only slightly enriched in 1 of 55 samples each with all 54 of the other samples having very low mean enrichment factors (Zn = 0.7 X and Cr = 0.9 X the ATM). This suggests that these individual samples represent anomalies and reflect a single, localized contaminant that occurs in that particular sample only. Therefore, the general sediment system within the North Landing River is not considered to be contaminated with Pb, Zn, or Cr nor by any of the other 6 trace elements (Cd, Co, Cu, Mn, P, Sn and V) that were not enriched in any samples.

Four elements are substantially enriched and represent the most pervasive contaminants for the North Landing River area and include molybdenum (Mo), arsenic (As), nickel (Ni), and titanium (Ti) with maximum enrichment factors up to Mo = 10.1 X, As = 2.7 X, Ni = 2.4 X, and Ti = 2.4 X the ATM. These elements are enriched in 85%, 35%, 27%, and 25% of the samples, respectively. Three (Mo, Ni, and Ti) of these four elements are significantly enriched in North Landing River relative to the trimmed means for the Albemarle, Neuse, and Pamlico River estuarine system. Even though As is enriched relative to the Albemarle, actual concentrations of As are not that high when compared to either the Neuse or Pamlico River estuarine systems. Only Ni and As are included on the U.S. EPA list of "priority pollutants".

Molybdenum has a low level of analytical reliability with low concentrations; thus, even though it is substantially enriched, it probably does not represent a major sediment quality problem within the North Landing River. Titanium is generally enriched with depth in the cores, suggesting there could be sedimentologic or geochemical control for this element. Also, titanium probably has a high potential for having major geologic sources within the sediments. That leaves only nickel, which is considered to be a "priority pollutant" to be a potential problem concerning sediment quality within the North Landing River; however, it is only slightly enriched in less than 35% of the samples.

Thus, the concentration data and patterns of elemental enrichment in the North Landing River suggest the following. Enrichment of these four elements

(Mo, As, Ni, and Ti) does not appear to be the direct result of anthropogenic point source discharges. It is also highly probable that this enrichment could represent a natural component that is dependent upon variations in the sediment mineralogy and chemistry. Evaluation of the latter was beyond the scope of the present study.

The random distribution of 3 substantially enriched elements (Mo, As, and Ni) and the general absence of other important anthropogenic elements (i.e., lead, zinc, copper, and chromium) suggest that there is no point source discharges or movement of trace elements into Currituck Sound from the Elizabeth River. However, enrichment resulting from long-term, nonpoint source input and mixing, which is much more difficult to evaluate, can not be ruled out.

Benkert (1992) analyzed heavy metals (Hg, Pb, Cd, Cr, Cu, Ni, and Zn) in sediment, Rangia clams, and several other types of organisms from the North Landing River side of the Mackay Island National Wildlife Refuge. The conclusion was that metal residues in both sediment and organisms suggest that there is not a significant resource degradation due to metal contaminants.

CONCLUSIONS

Conclusions for the first four objectives are presented below. However, objective five was not resolvable considering the small amount of resources available and due to the fact that this study specifically considered only the sediments and sediment quality and not the associated water quality.

1. What are the sedimentological characteristics of surface and shallow subsurface sediments?

A. The Intracoastal Waterway channel has been cut into a very uniform organic-rich mud sediment that is flanked on the west by modern marsh peat and on the east by older Pleistocene sediments. A major channel was eroded into Pleistocene sediments during the last sea-level lowstand. With the subsequent Holocene flooding event, the very uniform and contemporaneous shallow-water peat deposits and central basin organic-rich muds systematically backfilled the channel through time.

B. The sedimentological facies of surface and shallow subsurface units within the North Landing River have been identified and mapped and their compositional and textural characteristics have been defined. The composition of the two dominant estuarine sediment types are a muddy peat and a slightly sandy, organic-rich mud. The latter is the sediment in which the channel has been cut and the material dredged from the channel. Within the surface sediment regime there are many variations on these two basic sediment types depending on the proximity to eroding peat and Pleistocene scarps and the modern operating processes such as boat wakes and storms.

C. The loose mud dredged from the Intracoastal Waterway channel and deposited on the western platform modifies the original bathymetry and produces shallow-water shoal features. These shallow shoals of dredged material change the normal estuarine equilibrium slope which increases the potential impact from boat wakes and storm waves. Erosion of the mounds of loose dredged materials leads to winnowing of the clay, fine silt, and organic components through time and production of a significantly different sediment (muddy sand to clean sand). This process not only leads to a major change in composition, but also smooths out the cross-sectional profile and diminishes the size of piles of dredged material. The winnowing modification of the composition, size, and shape of piles of dredged material would result in a substantial volume of fine-grained sediment contributed to the estuarine system and thus, increase water column turbidity.

D. Prior to disposal of the 1991 dredged materials, the estuarine surface consisted of thin lenses of winnowed muddy sand and sand, particularly on the top and east sides of the old disposal mounds, with an abundant population of Rangia cuneata clams. Disposal of dredged material buried the clams living on the estuarine platforms. This resulted in a layer of dead clams on top of the old winnowed sandy surface in sharp contact with the organic-rich mud of the new dredge material. The surface of the organic-rich mud, which is actively being winnowed to produce a new muddy sand lens, will also be repopulated with clams. The shallow subsurface is characterized by numerous such sandy layers with articulated dead clams on top which are interpreted to represent the historic dredge disposal events. If this is true, then we have a basis for evaluating the history of dredging and calculating the amount of suspended sediment contributed to Currituck Sound by shallow-water dredge disposal through time.

2. What are the concentrations and distributions of heavy metal contaminants within the bottom sediments?

A. The concentrations and distributions of heavy metal contaminants have been identified within the bottom sediments. Ten common trace element contaminants have generally low concentrations within the sediments of the North Landing River. Therefore, the general sediment system within the North Landing River does not appear to be contaminated with Cd, Co, Cr, Cu, Mn, P, Pb, Sn, V, and Zn.

B. Four elements are substantially enriched and represent the major contaminants in the North Landing River area and include Mo, As, Ni, and Ti with maximum enrichment factors up to Mo = 10.1 X, As = 2.7 X, Ni = 2.4 X, and Ti = 2.4 X the ATM. These elements are enriched in 85%, 25%, 35%, and 27% of the surface and subsurface samples, respectively. Of these, only nickel is considered to be a potential sediment quality problem; however, it is substantially enriched in only one sample and is slightly enriched in 18 other samples.

3. Could trace element contaminants in the sediments be re-introduced into Currituck Sound through the processes of open-water disposal of dredged materials?

A. The apparent random distribution pattern for most of the enriched elements within the organic-rich muds, would suggest that the processes of open-water disposal of dredged materials will, to some extent, further expose the enriched elements to the biological community in the surface sediments in North Landing River. However, due to the generally low enrichment levels and low levels of criticalness of most elements that are enriched, this is presently considered to be a potentially minor problem.

4. Are any toxic trace element contaminants being transported from the Norfolk harbor area, down the Waterway and into Currituck Sound?

A. Three of the substantially enriched elements (Mo, As, and Ni) have random distribution patterns. Only titanium displays a downcore increase in concentration with 14 of the 15 enriched samples occurring in the subsurface. These distributions, plus the general absence of other important anthropogenic elements (i.e., Pb, Zn, Cu, and Cr), suggest that enrichments of Mo, As, Ni, and Ti may be related to natural phenomenon associated with the mineralogy and chemistry of the clay minerals and organic matter, rather than being anthropogenically derived from point source discharges. Also, the general lack of any distribution patterns suggests that there is no movement of metals into Currituck Sound from the Elizabeth River.

5. Could shallow, open-water disposal of dredged materials from routine channel maintenance contribute to the long-term environmental degradation in Currituck Sound?

A. Since this study did not consider water quality, it can not directly answer this question. However, this study has produced major implications concerning the shallow, open-water disposal of organic-rich mud dredged sediments in the North Landing River and their potential impact upon water quality. This report lays the necessary groundwork for a more definitive coring and monitoring program that could readily resolve this very important environmental question concerning the long-term environmental degradation of the Currituck Sound estuarine system.

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APPENDIX I

SAMPLE AND SEDIMENT DATA

CURRITUCK SEDIMENT DATA

SAMPLE NUMBER	CORE NUMBER	LONGITUDE	LATITUDE	H2O DEPTH (m)	SAMPLE DEPTH (cm)	SAND %	SILT %	CLAY %	TOTAL ORGANIC %	ORGANIC FINE %	ORGANIC SAND %
CTK1-0	CTK1	76.0329	36.5570	1.47	0	9.9	62.3	27.8	10.2	76.7	23.3
CTK2-0	CTK2	76.0370	36.5608	0.91	0	3.3	59.9	36.8	12.7	90.2	9.8
CTK2-42	CTK2	76.0370	36.5608	0.91	42	10.0	50.7	39.4	11.0	63.5	36.5
CTK4-0	CTK4	76.0411	36.5671	1.34	0	-1.0	77.0	24.0	11.5	95.1	4.9
CTK4-37	CTK4	76.0411	36.5671	1.34	37	8.9	58.2	32.9	5.8	81.7	18.3
CTK6-0	CTK6	76.0495	36.5862	1.37	0	18.2	60.3	21.5	12.9	59.8	40.2
CTK7-0	CTK7	76.0484	36.5818	1.14	0	6.7	62.2	31.1	13.7	81.4	18.6
CTK7-44	CTK7	76.0484	36.5818	1.14	44	40.0	37.8	22.2	9.4	59.1	40.8
CTK8-0	CTK8	76.0473	36.5789	1.52	0	3.1	54.1	42.7	15.3	89.0	11.0
CTK8-34	CTK8	76.0473	36.5789	1.52	34	43.8	35.5	20.7	5.9	64.1	35.9
CTK9-0	CTK9	76.0434	36.5721	0.91	0	4.2	68.3	27.4	11.6	89.0	11.0
CTK9-37	CTK9	76.0434	36.5721	0.91	37	76.0	19.1	4.8	4.9	26.0	74.0
CTK10-0	CTK10	76.0352	36.5599	4.88	0	6.8	70.4	22.8	9.7	85.2	14.8
CTK11-0	CTK11	76.0321	36.5542	1.07	0						
CTK11-40	CTK11	76.0321	36.5542	1.07	40	64.0	22.8	13.2	4.2	43.1	56.9
CTK12-0	CTK12	76.0298	36.5397	1.22	0	5.4	37.0	57.5	12.2	67.3	32.7
CTK14-0	CTK14	76.0605	36.6028	5.33	0	26.6	51.2	22.2	24.4	83.2	16.8
CTK15-0	CTK15	76.0517	36.5927	1.52	0	15.6	52.4	32.0	13.7	72.5	27.5
CTK16-0	CTK16	76.0516	36.5920	4.88	0	1.6	56.1	42.3	17.3	79.5	20.5
CTK16-0	CTK16	76.0516	36.5920	4.88	37						
CTK17-0	CTK17	76.0251	36.5410	1.83	0	28.5	44.5	27.0	6.6	87.5	12.5
CTK18-0	CTK18	76.0274	36.5404	1.98	0	36.5	44.1	19.4	6.6	56.4	43.6
CTK19-0	CTK19	76.0242	36.5413	3.96	0	36.5	40.7	22.8	6.3	68.6	31.4
CTK20-0	CTK20	76.0296	36.5493	2.13	0	12.3	54.7	33.0	7.0	86.8	13.2
CTK21-0	CTK21	76.0274	36.5498	3.96	0	15.2	53.6	31.2	8.7	86.8	13.2
CTK23-0	CTK23	76.0307	36.5543	1.83	0	13.9	54.0	32.0	8.1	84.5	15.5
CTK24-0	CTK24	76.0330	36.5541	1.22	0	22.9	55.9	21.3	7.8	67.5	32.5
CTK24-34	CTK24	76.0330	36.5541	1.22	34	20.4	51.4	28.2	8.1	81.0	19.0
CTK24-50	CTK24	76.0330	36.5541	1.22	50	3.2	61.4	35.4	6.1	88.0	12.0
CTK25-0	CTK25	76.0292	36.5545	4.88	0	9.4	63.0	27.5	9.1	87.3	12.7
CTK26-0	CTK26	76.0318	36.5632	2.13	0	25.1	45.3	29.6	4.8	91.6	8.4
CTK27-43	CTK27	76.0349	36.5615	1.37	43	15.4	52.2	32.4	4.9	70.9	29.1
CTK27A-56	CTK27A	76.0344	36.5617	1.22	56	14.0	47.5	38.5	5.9	79.4	20.6
CTK28-0	CTK28	76.0320	36.5715	1.83	0						
CTKC1-0	CTKC1	76.0493	36.5819	0.91	0	11.2	63.4	25.4	12.6	78.3	21.7
CTKC1-63	CTKC1	76.0493	36.5819	0.91	63	40.2	40.4	19.4	11.0	39.0	61.0
CTKC2-0	CTKC2	76.0479	36.5784	1.47	0	17.2	56.4	26.4	11.1	72.7	27.3
CTKC3-0	CTKC3	76.0485	36.5780	0.61	0	0.9	55.9	43.2	17.6	82.5	17.5
CTKC4-0	CTKC4	76.0477	36.5795	1.47	0	3.6	52.4	44.0	12.9	85.2	14.8
CTKC4-25	CTKC4	76.0477	36.5795	1.47	25	11.0	53.6	35.4	7.4	81.8	18.2
CTKC5-0	CTKC5	76.0469	36.5794	1.22	0	14.5	52.6	32.8	11.7	76.7	23.3
CTKC6-0	CTKC6	76.0464	36.5797	1.07	0	34.6	40.2	25.2	8.3	72.2	27.8
CTKC6-25	CTKC6	76.0464	36.5797	1.07	25	42.6	29.4	27.9	3.7	67.0	33.0
CTKC6-47	CTKC6	76.0464	36.5797	1.07	47	42.0	31.9	26.1	4.9	88.1	11.9
CTKC6-56	CTKC6	76.0464	36.5797	1.07	56	21.7	41.0	37.4	6.3	76.6	23.4
CTKC7-0	CTKC7	76.0460	36.5801	1.19	0	9.8	61.1	29.1	12.9	75.6	24.4
CTKC7-50	CTKC7	76.0460	36.5801	1.19	50	19.0	41.6	39.3	5.6	72.0	28.0
CTKC8-0	CTKC8	76.0456	36.5803	1.65	0	17.4	56.2	26.4	14.6	61.8	38.2
CTKC8-58	CTKC8	76.0456	36.5803	1.65	58	11.4	54.5	34.0	3.6	85.0	15.0
CTKC9-0	CTKC9	76.0452	36.5806	1.98	0	8.7	57.0	34.3	13.8	78.7	21.3
CTKC10-0	CTKC10	76.0446	36.5812	4.88	0	4.2	58.9	36.9	14.2	85.0	15.0
CTKC11-0	CTKC11	76.0436	36.5819	1.98	0	58.4	26.5	15.1	5.2	72.0	28.0
CTKC11-13	CTKC11	76.0436	36.5819	1.98	13						
CTKC12-0	CTKC12	76.0432	36.5823	1.68	0	55.7	27.9	16.4	7.1	74.5	25.5
CTKC12-26	CTKC12	76.0432	36.5823	1.68	26	14.8	45.1	40.0	6.3	86.3	13.7
CTKC14-32	CTKC14	76.0427	36.5826	1.22	32	38.0	32.8	29.2	4.0	81.9	18.1