APPENDIX E

ENVIRONMENTAL INFORMATION REPORT

NORFOLK HARBOR AND CHANNELS, VIRGINIA

LONG-TERM DISPOSAL (INNER HARBOR)

US Army Corps
Of Engineers

Norfolk District
June 1990

Draft Information Report

APPENDIX E
ENVIRONMENTAL INFORMATION REPORT

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3	CULTURAL RESOURCES REPORT
4	VIMS BENTHIC PROFILING WORK
5	WES MODEL STUDY OF NEWPORT NEWS CHANNEL 70' DEEPENING

ENVIRONMENTAL INFORMATION REPORT
LONG-TERM DISPOSAL STUDY
NORFOLK HARBOR AND CHANNELS, VIRGINIA
INNER HARBOR

SUMMARY

MAJOR CONCLUSIONS AND FINDINGS

1. A maintenance plan approaching 50 years has been developed for Norfolk Harbor and Channels, Virginia, inner harbor, for dredging the Federal project to authorized dimensions as well as state and private projects and disposing the dredged material in an economical, technically feasible, and environmentally sound manner. The two primary disposal options which have been selected from numerous alternatives which appeared in the final array of alternatives are continued use of CIDA plus ocean disposal of dredged material in a designated ocean disposal site or a 2,500-acre expansion of the existing CIDA.

2. From an environmental standpoint, the 2500-acre expansion of the present CIDA would not have significant impact on circulation or sedimentation patterns in the Hampton Roads Harbor or its adjoining tributaries. Water quality effects would be short-term during construction, at which time suspended solids levels in the water column would be elevated somewhat. There would be some minor impact on wetlands with the proposed expansion (i.e. less than 1 acre). The most significant major impact of the expansion is the loss of 2,500 acres of shallow water habitat and those organisms living on and in the sediment bottom. While this particular parcel does not appear to be overly productive from a biological standpoint, once covered and converted to terrestrial habitat, all possibility for recovery would be lost permanently. The value of the resource is recognized and its compensation is the primary aim of the mitigation plan as presented in this Environmental Information Document.

3. The environmental impacts associated with use of either the Dam Neck Ocean Disposal Site or the Norfolk Disposal Site are well documented in separate EIS's. Deposition of suitable dredged material at either of these ocean sites is not expected to have any major adverse environmental impacts.

Beneficial uses of dredged material for beach nourishment, highway construction, reinforcement of earth levees, etc., will always be part of any plan for disposition of dredged material. Dredged material which does not meet ocean disposal criteria (unsuitable material) would continue to be placed in the existing CIDA.

AREAS OF CONTROVERSY

4. The primary focus of controversy concerns some social and environmental impacts associated with the proposed 2,500-acre expansion of CIDA. The chief social concern is that the proposed westward expansion would create major social impacts on residents along the affected shoreline. Environmentally, the loss of shallow water habitat may appear to hinder the accomplishment of the 1987 Chesapeake Bay Agreement to enhance, protect, and restore the resources of the Bay. The value of this aquatic habitat is recognized and its compensation is the primary goal of the mitigation plan as presented in this Environmental Information Report.

UNRESOLVED ISSUES

5. The issue of the extent of social impacts associated with the proposed expansion is not resolved except for an estimate of damages caused thereby. The environmental mitigation plan is presented as a number of different mitigation options which are technically and environmentally feasible. Final resolution of the mitigation package would likely include several of these options. Also, the final recommendation to provide 50 year disposal capacity is unresolved. The final choice to select from the alternatives presented in this document will be up to the local sponsor of this project, the Commonwealth of Virginia.

RELATIONSHIP OF PROPOSED ACTION TO ENVIRONMENTAL REQUIREMENTS

6. Table 1 displays the environmental quality protection statutes and their compliance status relative to the proposed recommendations. Compliance must be met for all of the environmental quality protection statutes with the coordination of appropriate documents at the discretion of the Commonwealth of Virginia. Whether any proposed plan is ultimately determined to be environmentally acceptable and permittable will be dependent on the outcome of the NEPA process and 404(b)(1) analysis (Clean Water Act).

Table 1. RELATIONSHIP OF PROPOSED ACTIONS TO ENVIRONMENTAL REQUIREMENTS

Environmental Statutes

1. Preservation of Historic and Archaeological Data Act of 1974, as amended, 16 U.S.C. 469 et seq.

CIDA Expansion:
Compliance: The State Historic Preservation Officer (SHPO) and the Virginia Department of Historic Resources (DHR) have been coordinated with concerning historic and /or archaeological resources in the project area. Continued coordination with DHR and the SHPO, and mitigation of lost resources, if required, signifies compliance.

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

2. Clean Air Act, as amended, 42 U.S.C. 7401 et seq.

CIDA Expansion:
Compliance: Submission of this report as a NEPA document to the Regional administrator of the Environmental Protection Agency for review pursuant to Sections 176c and 309 of the Clean Air Act signifies compliance.

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

3. Clean Water Act of 1977 (Federal Water Pollution Control Act Amendments of 1972 and Water Quality Act of 1987) PL 100-4, 33 U.S.C. 1251 et seq.

CIDA Expansion:
Compliance: A Section 404(b)(1) Evaluation and Compliance Review would have to be prepared. An application would be filed for State Water Quality Certification pursuant to Section 401 of the Clean Water Act.

Table 1. RELATIONSHIP OF PROPOSED ACTIONS TO ENVIRONMENTAL REQUIREMENTS
(Cont'd)

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

4. Coastal Zone Management Act of 1972, as amended, 16 U.S.C. 1431 et seq.

CIDA Expansion:
Compliance: Coordination with the Virginia Council on the Environment via NEPA and a determination of consistency signifies compliance.

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

5. Endangered Species Act of 1973, as amended, 16 U.S.C. 1531 et seq.

CIDA Expansion:
Compliance: Coordination with the U.S. Fish Wildlife Service (F&WS) has yielded no formal consultation requirements pursuant to Section 7 of the Endangered Species Act.

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

6. Estuarine Areas Act, 16 U.S.C. 1221 et seq.

CIDA Expansion:
Compliance: Full adherence to NEPA signifies compliance.

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

7. Federal Water Project Recreation Act, as amended, 16 U.S.C. 4601-12 et seq.

CIDA Expansion:
Compliance: Coordination with the National Park Service (NPS) and the Virginia Department of Conservation and Recreation, relative to the Federal and State comprehensive outdoor recreation plans via NEPA signifies compliance with this Act.

Table 1. RELATIONSHIP OF PROPOSED ACTIONS TO ENVIRONMENTAL REQUIREMENTS
(Cont'd)

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

8. Fish and Wildlife Coordination Act, as amended, 16 U.S.C. 661 et seq.

CIDA Expansion:
Compliance: Coordination with the F&WS, National Marine Fisheries Service (NMFS) and VA Department of Game and Inland Fisheries signifies compliance with this Act.

Ocean Disposal:
Compliance: Coordination with the F&WS and National Marine Fisheries Service (NMFS) signifies compliance with this Act.

9. Land and Water Conservation Fund Act of 1965, as amended, 16 U.S.C. 4601-4 et seq.

CIDA Expansion:
Compliance: Submission of NEPA document to the National Park Service (NPS) and the Virginia Department of Conservation and Recreation relative to the Federal and State comprehensive outdoor recreation plans signifies compliance with this Act.

Ocean Disposal:
Compliance: Not applicable.

10. Marine Protection, Research, and Sanctuaries Act of 1972, as amended 33 U.S.C. 1401 et seq.

CIDA Expansion:
Compliance: Not Applicable; expansion does not involve the transportation nor disposal of dredged material in ocean waters pursuant to Sections 102 and 103 of the Act, respectively.

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

11. National Historic Preservation Act of 1966, as amended, 16 U.S.C. 470 et seq.

Table 1. RELATIONSHIP OF PROPOSED ACTIONS TO ENVIRONMENTAL REQUIREMENTS
(Cont'd)

CIDA Expansion:
Compliance: Underwater investigations and coordination with the State Historic Preservation Officer (SHPO) and the Department of Historic Resources have yielded no evidence of impacted historic or archaeological resources. NEPA documentation of these findings signifies compliance.

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

12. National Environmental Policy Act of 1969, as amended, 42 U.S.C. 432 et seq.

CIDA Expansion:
Compliance: Preparation and coordination of a NEPA document signifies compliance with this Act. Full compliance is noted with the signing and issuing of the Record of Decision (ROD).

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

13. Wild and Scenic Rivers Act, as amended, 16 U.S.C. 1271 et seq.

CIDA Expansion:
Compliance: Project has been evaluated in reference to this act. The proposed expansion will not adversely impact any section of the Virginia Scenic Rivers System. Coordination with the National Park Service (NPS) and the Virginia Department of Conservation and Recreation, relative to the Virginia Scenic Rivers System signifies compliance with this Act.

Ocean Disposal:
Compliance: Not applicable to ocean waters.

Executive Orders

1. Executive Order 11988, Floodplain Management, 24 May 1977 as amended by Executive Order 12148, 20 July 1979.

CIDA Expansion:
Compliance: Circulation of a NEPA document for public review fulfills the requirements of Executive Order 11988, Section 2(a)(2).

Table 1. RELATIONSHIP OF PROPOSED ACTIONS TO ENVIRONMENTAL REQUIREMENTS
(Cont'd)

Ocean Disposal:
Compliance: Not applicable to ocean disposal.

2. Executive Order 11990, Protection of Wetlands, 24 May 1977.

CIDA Expansion:
Compliance: Circulation of a NEPA document for public review fulfills the requirements of Executive Order 11990, Section 2(b).

Ocean Disposal:
Compliance: Not applicable to ocean disposal.

Executive Memorandum

1. Analysis of Impacts of Prime or Unique Agricultural Lands in Implementing NEPA, 11 August 1980.

CIDA Expansion:
Compliance: Not applicable; expansion would not involve nor impact agricultural lands.

Ocean Disposal:
Compliance: Not applicable.

Memorandum of Agreement (MOA)

1. EPA and the Department of the Army, Concerning the Determination of Mitigation Under the Clean Water Act Section 404 (b) (1) Guidelines, November 14, 1989.

CIDA Expansion:
Compliance: Full adherence to NEPA and this MOA signifies compliance.

Ocean Disposal:
Compliance: Full adherence to NEPA and EPA's Ocean Dumping Criteria, 40 CFR, Parts 220-229 signifies compliance.

Table 1. RELATIONSHIP OF PROPOSED ACTIONS TO ENVIRONMENTAL REQUIREMENTS
(Cont'd)

Regional Agreements

1. Chesapeake Bay Agreement (CBA), 1987.

CIDA Expansion:
Compliance: Circulation of NEPA document for agency/public review and comment to determine consistency with initiatives of CBA signifies compliance.

Ocean Disposal:
Compliance: Circulation of NEPA document by EPA for agency/public review and comment to determine consistency with initiatives of CBA signifies compliance.

PURPOSE AND NEED

INTRODUCTION

7. The Port of Hampton Roads Virginia, among the largest natural harbors in the world, is located within the major metropolitan area that includes the cities of Norfolk, Hampton, Portsmouth, Chesapeake, and Virginia Beach (figure 1). Hampton Roads and the surrounding estuarine systems of Tidewater Virginia provide the setting for one of the most highly industrialized coastal areas on the eastern seaboard, as well as the largest military port in the world. The Norfolk District COE is responsible for maintaining the navigation channels of this seaport system in order to insure the safe passage of military and commercial vessels. On the average, about 4 to 5 million cubic yards of dredged material are dredged annually by Federal, state, and/or local entities and private interests. It is primarily composed of clay and silt taken primarily from the highly industrialized Hampton Roads Harbor/Elizabeth River complex.

8. The Elizabeth River is the principal deepwater channel in this seaport system, attracting an extremely high concentration of industrial and military activity in an area that extends for nearly 22 miles.The Elizabeth River System is

an area of intensive commerce, industry, shipping and military activity. It supports a large urban population and to a limited degree, rural communities. Marinas, docking facilities and yacht clubs are also quite common. Considering these extensive activities and the system's poor flushing characteristics it becomes obvious why the area reflects degraded environmental conditions.

9. The Hampton Roads Area is generally recognized as the southernmost boundary of the Boston-New York-Washington complex of industrial, commercial, residential, and recreational developments. Within this area are the headquarters of the Fifth Naval District, which is the largest naval concentration in the world; the Newport News Shipbuilding and Drydock Company; 28 miles of oceanfront; over 50 miles of bay front; several hundred square miles of lake, bay, and inland waters; several hundred thousand acres of farmland; and an excellent network of air, water, rail, and highway systems. Population in the Hampton Roads metropolitan area has increased from 972,759 in 1970 to 1,015,761 in 1980. Of principal importance to the economic base of the area are agriculture, Government installations, manufacturing, port-related activities, and tourism. Hampton Roads is the principal U.S. outlet for exportation of bituminous coal. This coal is mined in western Virginia and West Virginia.

10. The overall purpose of this investigation is to address the long-term dredged material disposal problem facing the Port of Hampton Roads and adjacent waters and to develop environmentally and politically acceptable, technically feasible and economical disposal plans. More specifically, the purpose of this Environmental Information Report is to determine and evaluate the anticipated impacts of the disposal alternatives and provide information developed for the Norfolk Harbor and Channels to the Commonwealth of Virginia. It is primarily an information document for the Commonwealth of Virginia to review and conclude on that plan best adapted to the needs for the inner harbor of Hampton Roads, considering environmental, social, economic and engineering criteria.

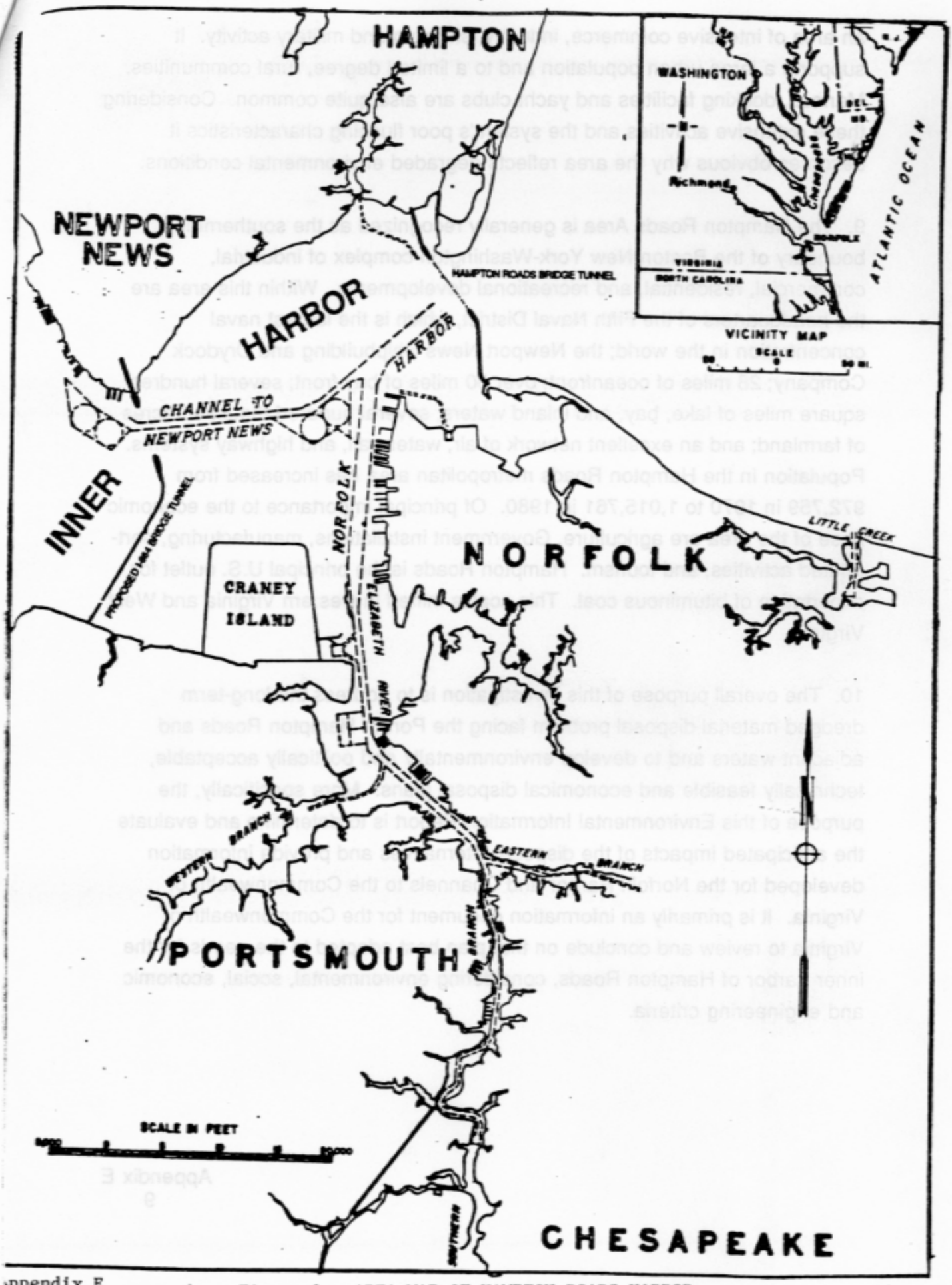


Figure 1. AREA MAP OF HAMPTON ROADS HARBOR

PROJECT HISTORY

11. A chronological listing of early dredging efforts in the Hampton Roads Harbor is given below:

1870 - "Common Council" of Norfolk requested that material excavated from the harbor channels be used to fill up the low grounds within the city. Open water disposal in sites such as Craney Island Flats and Tanner's Creek (now the Lafayette River) was prevalent.

1900-1913 - Millions of cubic yards of dredged materials were being placed in the "Ripraps" dumping ground, so called because of its proximity to Fort Wool.

1918-1940 - Lynnhaven Dumping Ground was established for the use of hopper dredges and scows.

1913-1939 - Large quantities of material were placed by pipeline dredge on and around Craney Island, a quarantine area used by Norfolk and Portsmouth.

1941-42 - Disposal area was established in the lower James River just above Newport News; discontinued because of adverse effects on adjacent navigable waters.

1942-45 - During World War II a wartime disposal area was established within the harbor 1.5 miles west of Fort Wool. Capacity and retaining characteristics of the area did not permit continued use after the war's end.

1946 - River and Harbor Act of 1946 authorized the construction of the Craney Island Disposal Area

1957-1966 - Material dredged from Thimble Shoal and Cape Henry Channels were used for tunnel cover and beach restoration or were dumped in undesignated ocean areas.

1967-1988 - Norfolk District began using Dam Neck Ocean Disposal Site (DNODS) in 1967 shortly after work began on deepening Thimble Shoal Channel. In 1977, the EPA designated Dam Neck as an interim ocean disposal site for dredged material. In 1988, an expanded DNODS received final designation from EPA. To date, about 20.4 million cubic yards of dredged material have been placed at DNODS.

PROJECT AUTHORIZATION

12. Authority for deepening various elements of the Norfolk Harbor and Channels, Virginia and the disposal of dredged material, was included in the Water Resources Development Act of 1986 (Public Law 99-662). Due to the importance of establishing a long-term disposal area for dredged material, the Norfolk District requested approval from higher authority for further investigation of this matter under authority contained in WRDA 86. In accordance with direction from the Chief of Engineers, under the provision of House Document 99-85 (Feasibility Report on Norfolk Harbor and Channels), the District obtained a Letter of Assurance (LOA) dated September 24, 1986 from the Virginia Port Authority (VPA) indicating the state's intent to pursue the 55-foot project, its support for the long-term disposal study, and its willingness to cost share in the study during construction of future elements of the deepening project. Permission and funds to continue the investigation under authority of WRDA 86 were received in March 1987.

PUBLIC CONCERNS

13. The public concerns about the project fall into two major categories. First is that the harbor be adequately maintained over the long-term and access channels and berthing areas maintained so that ship traffic can flow in and out of the harbor efficiently and safely. The second is that long-term maintenance of the harbor does not have significant adverse impacts on the environment. Both of these issues are thoroughly addressed in the project document and in this Environmental Information Report.

PLANNING OBJECTIVES

14. In line with the public concerns, the major planning objective was to develop a plan for completion of the new work deepening required in PL 99-662 and a maintenance plan that would provide adequate maintenance for Federal, state

and/or local entities and private interests approaching 50 years with minimal impacts on the environment.

ALTERNATIVES

DEVELOPMENT AND SCREENING OF ALTERNATIVES

15. A summary of the formulation and evaluation criteria for disposal areas utilized in this study is presented in this section. These criteria involve physical, economic, environmental, and social factors which tend, to varying degrees, to constrain the options and/or ultimate selection of an alternative which would meet the needs for long term disposal.

16. Although all of the formulation and evaluation criteria were considered for the various alternatives, key factors or constraints can be further summarized as follows. Among the constraints by which the alternatives were screened were the following:

- A disposal site should have a useful life of about 50 years.

- The costs associated with a disposal site should be minimized.

- The destruction of bottom lands, wetlands, coastal zones, and wildlife resources in the Hampton Roads area should be minimized.

- The adverse social impacts associated with providing a disposal area should be minimized.

PLANS CONSIDERED IN DETAIL

17. As a result of this screening process, the following alternatives were presented in a Public Scoping Meeting held on August 6, 1987 in Portsmouth, Virginia. The site alternatives are shown on figure 2 .

- No action (continued use of existing CIDA)
- Expansion of Craney Island
- Willoughby Bay

- Ocean View
- Hampton Flats
- Horseshoe Area off Buckroe Beach
- Ragged Island
- Suffolk
- Chesapeake Bay
- Ocean disposal

No Action

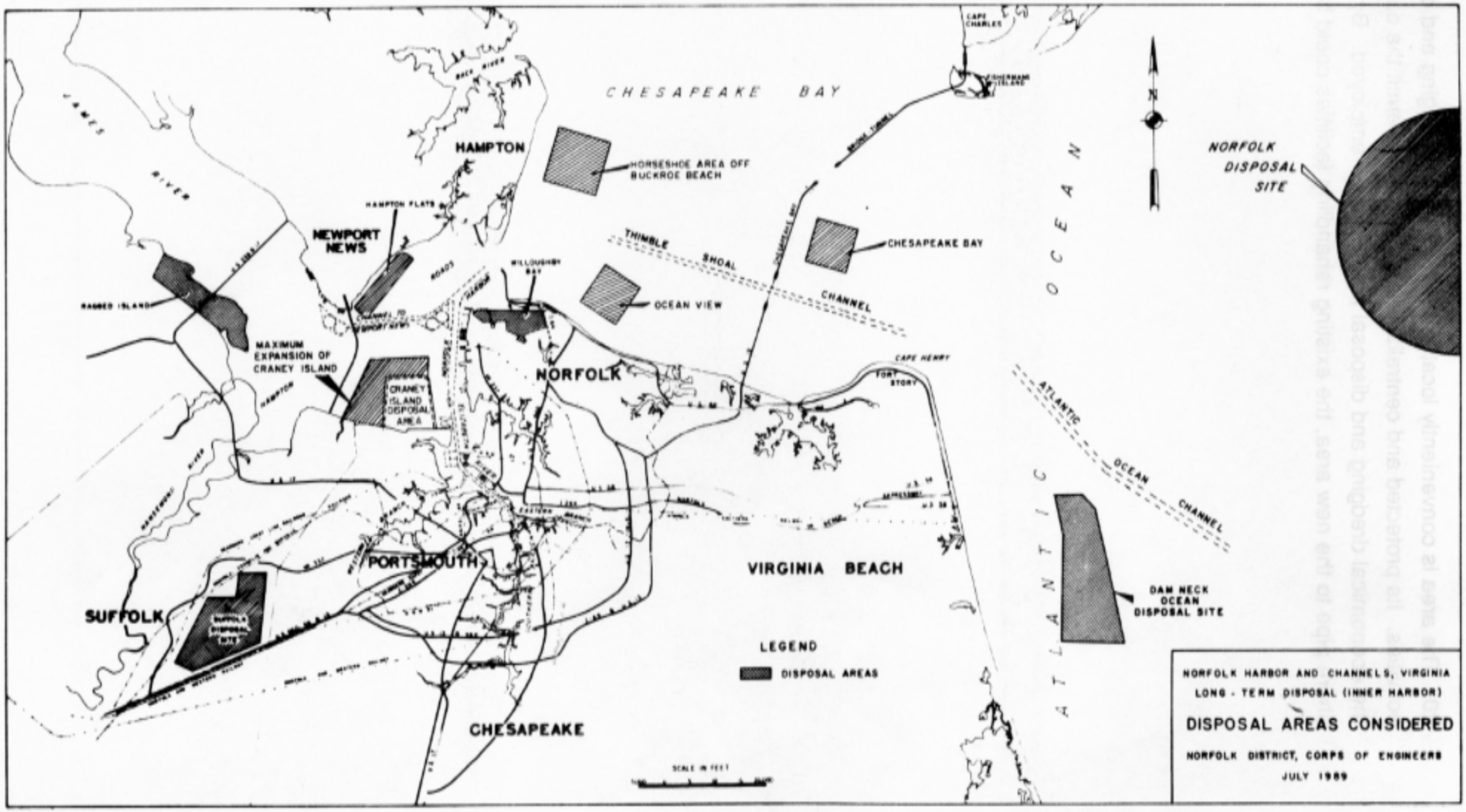
18. Under the No Action alternative, new dredged material disposal areas would not be sought and additional material management concepts would not be utilized. The current amount and frequency of dredging in the Norfolk Harbor and Channels, inner harbor project, would continue until such time as the Craney Island Disposal Area reaches capacity. This could be as soon as 1997 given certain dredging scenarios. After that time, dredging in the Norfolk Harbor and Channels Federal Navigation project would be halted due to lack of disposal areas.

Expansion of Craney Island

19. One obvious plan for inner harbor disposal is the expansion of the existing Craney Island Disposal Area. A western extension was initially given consideration during the feasibility study on Norfolk Harbor and Channels, Virginia, Deepening and Disposal which was completed in 1980. At that time, it was estimated that a westward extension would not provide a 50-year useful life. Also, plans for the I-664 crossing were being formulated in the area which would likely impact the proposed westward extension. The highway department now indicates that the expansion of CIDA would not affect the new I-664 crossing provided the expansion remains a minimum of 2,000 feet away from the structures. Also present field data indicate that any expansion planned would not interfere with a 54-inch sewer outfall line in this vicinity. Furthermore, recent detailed useful life investigations, made by the Corps of Engineers Waterways Experiment Station, now indicate that an expansion plan approaching 50 years for disposal of dredged material can be established. Thus, although a plan for expansion was not recommended in this feasibility study, current revelations warrant reconsideration of this alternative.

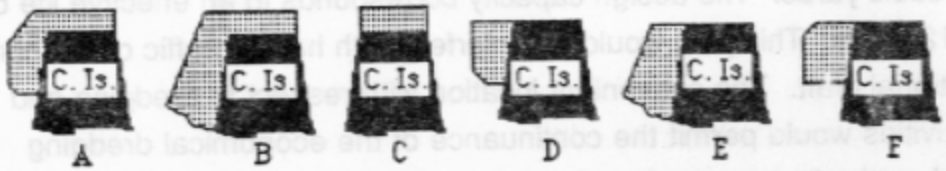
20. The area is conveniently located with respect to dredging and disposal activities. Its protected and centralized location would permit the continuance of the economical dredging and disposal methods now employed. By extending shore pipe to the new area, the existing rehandling facilities could be used.

Figure 2. Long - Term Disposal Site Alternatives



21. Expansion of Craney Island would accomplish maintenance and improvement of the navigational features as follows: (1) initial removal of in situ (in-place) shoal material by current methods--hopper, hydraulic pipeline, and bucket-scow dredges; and (2) transfer of the material using the existing rehandling facilities to the diked area for final disposal. The existing rehandling facilities were described previously. Essentially, the rehandling operation would be the same as at present, with the qualification that additional shore pipe would be used from the rehandling area to the new disposal area. In hydraulic pipeline dredging, the outfall end of the pipe would be inside the new disposal area.

22. As indicated by table 2, Plan B essentially meets the 50-year useful life objective for long-term disposal. Plans A and E alone provide storage for dredged material for a period estimated at 31 years and 22 years respectively (assuming dredging scenario in S4 on table 2).



Plan A - 1700 acres **Plan C** - 740 acres **Plan E** - 1500 acres

Plan B - 2500 acres **Plan D** - 660 acres **Plan F** - 1000 acres

Willoughby Bay

23. Another alternative is Willoughby Bay which is located at the northwest tip of the city of Norfolk, adjacent to the Norfolk Naval Base, as shown on figure 2. The bay is approximately 1.5 by 1 miles, the average depth being about -9 feet below m.l.w. The entire southern shoreline of Willoughby Bay is on the Norfolk Naval Station property while the opposite shoreline is almost entirely residential property. Interstate 64 crosses about 4,000 feet of the northern edge of Willoughby Bay.

24. The bay is conveniently located with respect to dredging and disposal activities, by virtue of being adjacent to the entrance reach of the Norfolk Harbor Channel. The Navy has filled portions of the bay, including the mouth of Mason Creek and the east end of the bay.

25. A channel would be provided on the south side of Willoughby Spit to assure continued access to the water from the Willoughby Beach area. Otherwise, the bay would be filled to an elevation of about 18.0 feet above m.l.w. The ultimate fill height was limited to this elevation due to the relative proximity of the Naval airfield and heliport activities. Approximately 15,000 feet of levee would be required for this plan. The levee would inclose about 1,280 acres. With the water depth averaging about 9 feet, a levee with an ultimate height of 18.0 feet above m.l.w. would provide a storage capacity of about 60,000,000 cubic yards. The design capacity corresponds to an effective life of only about 12 years. This plan would not interfere with harbor traffic other than local recreational craft. The convenient location with respect to dredging and disposal activities would permit the continuance of the economical dredging and disposal methods now employed.

26. The plan would accomplish maintenance and improvement of the navigational features as follows: (1) removal of shoal material by current methods--namely, hopper, hydraulic pipeline, and bucket-scow dredges, and (2) transfer of the material through rehandling facilities to the diked area for final disposal. The rehandling facilities would be similar to those at the Craney Island Disposal Area, consisting of a rehandling basin for dumping scows and a pipeline for hopper dredge unloading.

Table 2. PLANS INVESTIGATED FOR EXPANDING CRANEY ISLAND

Scenario (a)	Existing CI	Plan A w/o CI	Plan A with CI	Plan B w/o CI	Plan B with CI	Plan C w/o CI	Plan C with CI	Plan D w/o CI	Plan D with CI	Plan E w/o CI	Plan E with CI	Plan F w/o CI	Plan F with CI
		Number of years available for storage of dredged material from 1993(b)											
S1	1997	39	46	56	62	12	19	10	16	29	36	15	20
S4	1994	34	40	51	56	8	14	5	11	25	32	10	17
S5	1994	25	33	43	50	4	6	3	5	17	27	5	12

S1 = Maintenance dredging of inner harbor channels to their existing depths up to 50 feet plus other Federal, State and private dredging.
S4 = Item a plus b plus dredging of Elizabeth River and its Southern Branch to depths of 40 and 45 feet.
S5 = Item a plus new work dredging of outbound channels to a depth of 55 feet.
CI = Craney Island (both sites managed simultaneously)
w/o CI = Without Craney Island (existing site no longer available)
(a) As referred to by Waterways Experiment Station
(b) Base year 1993 (year site is assumed to be available)

Ocean View

27. An area north of Willoughby Spit and Ocean View in Chesapeake Bay was considered. The site location is in open, deep water which gives rise to comparatively high construction costs.

28. The location of the disposal area is shown on figure 2. The facility would be located offshore in order to prevent disruption of existing shoreline use. It would be filled to an elevation of 30 feet above m.l.w. Approximately 37,300 feet of levee would be required. The levee would enclose about 2000 acres. With the water depth averaging close to 24 feet, a levee with an ultimate height of 30 feet above m.l.w. would provide a storage capacity of 250,000,000 cubic yards. This capacity corresponds to a useful life of 50 years.

29. Maintenance and improvement of the navigational features would be accomplished as follows: (1) initial removal of in situ shoal material by current methods--namely, hopper, hydraulic pipeline, and bucket-scow dredges, and (2) transfer of the material through rehandling facilities to the diked area for final disposal. The rehandling facilities would be similar to those at the Craney Island Disposal Area.

Hampton Flats

30. Another possibility for a new disposal site is the area called Hampton Flats, located in Hampton Roads just southeast of the cities of Hampton and Newport News. This area is conveniently located with respect to dredging and disposal activities in that it is adjacent to the Channel to Newport News and the entrance reach of the Norfolk Harbor Channel as shown on figure 2. Access to the present shoreline would be assured by building the levees away from the shore as shown. Drainage from the nearby cities would not be affected.

31. Approximately 43,000 feet of levee would be required in this plan. The levee would enclose about 1,800 acres. With the water depth averaging about 11 feet, a levee with an ultimate height of 30 feet above m.l.w. would provide a storage capacity of about 128,000,000 cubic yards. The capacity corresponds to a life of about 26 years. Current dredging methods could be continued with this convenient and protected area as a disposal site. The plan calls for

construction of a rehandling basin and hopper dredge pumpout facility similar to those at the Craney Island Disposal Area.

32. This plan would accomplish maintenance and improvement of the navigational features as follows: (1) removal of shoal material by current methods--namely, hopper, hydraulic pipeline, and bucket-scow dredges, and (2) transfer of the material through rehandling facilities to the diked area for final disposal.

Horseshoe Area off Buckroe Beach

33. A disposal area could be built off the Buckroe Beach area in what is known as the Horseshoe. The area is somewhat removed from harbor facilities where the majority of dredging is required. A disposal area at Buckroe as shown on figure 2, would be one to two miles offshore in waters ranging from 9- to 20-feet-deep. The site lies directly north of the Thimble Shoal Channel and about 3 miles beyond the entrance to Hampton Roads. The deeper waters of the lower Chesapeake Bay are directly east of this site.

34. Rehandling areas would be located on the south side of the area where they would be protected from northern exposure. The entire facility, located offshore, would avoid conflict with existing development and costly disruption of present use and would permit continued access to the present shoreline. Drainage of the adjacent land areas would not be affected.

35. In the above plan, approximately 42,000 feet of levee would be required. The levee would enclose about 2,500 acres. With the water depth averaging 14 feet, a disposal area with an ultimate fill height of 30.0 feet m.l.w. would provide a storage capacity of 250,000,000 cubic yards over an effective life of 50 years. Current dredging methods could be continued. The plan calls for the construction of a rehandling area similar to that at Craney Island Disposal Area.

36. The plan would accomplish maintenance and/or improvement of the navigational features as follows: (1) removal of shoal material by current methods--namely, hopper, hydraulic pipeline, and bucket-scow dredges, and (2) transfer of the material through rehandling facilities to the diked area for final disposal.

Ragged Island

37. Ragged Island is a wetland marsh that projects into the James River near the south end of the James River Bridge. It is located about 9 miles from the center of the dredging activity and is shown on figure 2. This area is now a wildlife management area of the Commonwealth of Virginia.

38. In the Ragged Island proposal, approximately 64,000 feet of levee would be required which would inclose about 2,300 acres. Elevation of the area averages +4 feet m.l.w. A disposal area with an ultimate fill height of 18 feet m.l.w. would provide a storage capacity of about 64,000,000 cubic yards. This capacity corresponds to an effective life of 13 years. The ultimate fill height was limited to 18 feet m.l.w. due to its proximity to the James River Bridge crossing (U.S. Route 17).

39. Removal of shoal material would be accomplished by current methods--namely, hopper, hydraulic pipeline, and bucket-scow dredges; material would be transferred through rehandling facilities to the diked area for final disposal. The rehandling facilities would be similar to those at Craney Island.

Suffolk Site

40. It is technologically feasible to transport dredged material by pipeline over long distances. Such a transport capability allows the consideration of alternative disposal areas far removed from the harbor itself. The nearest onshore area feasible is located in the eastern sector of the city of Suffolk as shown on figure 2. The entire area is about 6,000 acres in size and is bounded by U.S. Route 460 on the southeast; a pipeline on the southwest; the Atlantic Coastline and Norfolk, Franklin, and Danville Railroads on the west and north; and by the Suffolk-Chesapeake boundary line on the east. The area is not accessible by navigable water routes; however, it is feasible to connect Craney Island to the Suffolk area by pipeline. The pipeline considered would be 20 inches in diameter and approximately 55,000 feet in length. It would utilize five successive booster stations. As envisioned, the line would run from a rehandling basin formed from part of the west side of Craney Island, alongside the existing rail line, to the northern tip of the Suffolk Disposal Site. Water would be returned to Craney Island by means of a separate 16-inch pipeline.

41. In this plan, approximately 70,000 feet of levee would be required. The levee would be a simple, non-riprapped, earth-raised type. It would enclose about 6,000 acres. The area elevation averages +20 feet m.s.l., which, with a levee of ultimate height +47 feet m.s.l., would provide a storage capacity of about 275,000,000 cubic yards. The capacity corresponds to an effective life of over 50 years.

42. This plan would permit continuance of the economical dredging and disposal methods now employed. The existing rehandling facilities at Craney Island would be used for hopper dredge pumpout and scow unloading. The dredged material would be pumped through pipelines across the filled portion of Craney Island Disposal Area to the confined rehandling basin on the west side of the disposal area. The material would be injected into a long pipeline by a rehandling unit and pumped to the Suffolk area by successive booster stations. Several pipeline rights-of-way would be reserved in this plan; other than these and the rehandling area, the filled Craney Island Disposal Area would be available for development.

43. This plan would accomplish maintenance and improvement of navigational features as follows: (1) initial dredging, which consists of removing shoal material by hopper, pipeline, and bucket dredges; (2) rehandling through pipeline from hopper dredge pumpout facilities and scow dumping basin (hydraulic pipeline dredges discharge directly into the diked rehandling basin); (3) temporary storage in the diked harborside rehandling basin; and (4) removal from the rehandling basin by pipeline for final disposal in the diked remote land disposal area in Suffolk. Rehandling and final disposal of the dredged material would be accomplished by a rehandling unit and pipeline.

Chesapeake Bay

44. A Chesapeake Bay alternative was considered for the east side of the Chesapeake Bay Bridge-Tunnel complex as shown on figure 2. The facility would be located between the Thimble Shoal Channel Tunnel and the Chesapeake Channel Tunnel. This location would not interfere with harbor traffic. However, it is removed from the center of dredging activity within the inner harbor area.

45. In the above plan, approximately 37,000 feet of levee would be required. The levee would inclose about 2,000 acres. The water depth averages 28 feet in this area; therefore, a disposal area with an ultimate fill height of 30 feet above m.l.w. would provide a storage capacity of 250,000,000 cubic yards. This capacity corresponds to an effective life of 50 years. Present dredging methods could be continued as the plan calls for construction of a rehandling basin and hopper dredge pumpout facility similar to those at Craney Island Disposal Area. The rehandling facilities would be located on the south side of the facility so as to be protected from adverse weather factors of a northern exposure.

Ocean Disposal

46. The dredging of new work and/or maintenance would be accomplished either by hopper dredge and/or bucket dredge with the suitable material disposed of at sea. In the case of the hopper dredge, the dredge pumps the material slurry into its hoppers, which gradually fill with a water/sediment mixture. Once the hoppers are full, they will have only a small amount of solids (10 to 30%), so pumping is continued with the hoppers overflowing until the dredge has an economical load of solids. Thus, in actual practice the dredge is discharging the overflow water with varying concentrations of suspended solids until a point is reached where it is not economical to continue pumping. The "economical load" will differ depending on the particular dredge and the characteristics of the material. For example, with sand a greater load can be accomplished than can be with slower-settling silts and clays. In any case, the dredge must discharge a large amount of excess slurry water overboard in order to achieve its economical load for a given type of channel sediment.

47. In the case of the bucket dredge, the dredged material would be discharged into attendant barges.The barges, when loaded, would be towed to sea by tug, and the material dumped. The considered open sea disposal areas are: (a) Dam Neck Ocean Disposal Site (DNODS), and (b) Norfolk Disposal Site (NDS). They are shown on figure 2 and discussed in the paragraphs that follow.

Other Disposal Plans

48. Consideration was also given to the following:

(a) Raising the existing Craney Island Disposal Area

(b) Emptying Craney Island Disposal Area

(c) Hauling dredged material by truck to abandoned borrow pits

(d) Disposal of dredged material by rail to abandoned mines in western Virginia

(e) Transporting unsuitable material to sea and capping it with sand or other clean material

(f) Constructing a long pipeline to sea and pumping dredged material through it into the ocean

49. None of the above were found to be practical and/or economical. Further details on the economic and engineering evaluations of the plans are provided in the Plan Formulation section of the main report which accompanies this document.

SELECTION OF THE PLANS

Evaluation of Alternatives

50. The alternatives were evaluated from both economic and environmental perspectives. The Plan Formulation section of the main report, which accompanies this document, evaluates the economic feasibility of the alternatives in detail. Table 28 of the main report is an economic summary of the plans which were evaluated. Table 3 presents an environmental impact matrix evaluating the proposed alternatives as they relate to various environmental categories. The following paragraphs elaborate on the anticipated impacts associated with various alternatives.

Table 3. ENVIRONMENTAL IMPACT MATRIX FOR DISPOSAL ALTERNATIVES

Environmental Category	*Craney Island Expansion*	*Willoughby Bay*	*Ocean View*	*Hampton Flats*	*Suffolk Site*
Water Quality	No additional impact	Mixing zone decreased in size; effluent may impact w.quality	Mixing zone decreased in size; effluent may impact w.quality	Mixing zone decreased in size; effluent may impact w.quality	Saltwater intrusion to aquifers
Fish/Shellfish/Wildlife	Loss of feeding area & habitat/Baylor Grounds	Loss of protected habitat for juvenile fish	Loss of prime clamming area	Adverse to larval oyster transport; loss of comm. clamming area	Two endangered species threatened
Benthos	Smothering & loss of all benthos max. 2500 acres	Smothering & loss of all benthos - 1280 acres	Smothering & loss of all benthos - 2000 acres	Smothering & loss of all benthos - 1800 acres	No impact
Hydrodynamics	WES study indicates no significant change	Severe changes in circulation expected	Changes could impact erosion rates @ area beaches	Oyster larval transport to James River may be impeded	No impact
Wetlands	1 acre loss	Loss of fringe marsh	No impact	No Impact	6000 acres wooded wetlands lost
Navigation	Loss of comm. & rec. boating areas	Loss of comm. & rec. boating areas	Loss of comm. & rec. boating areas	Loss of comm. & rec. boating areas	No impact
Cultural/Historical Resources	Survey performed - no impact	Possible impact - survey required	Possible impact - survey required	Possible impact - survey required	Possible impact - survey required
Social Impact	Reduced waterfront property values	Reduced waterfront property values	Loss of income - comm. clammers	Reduced waterfront property values; Loss of income-comm. clammers	Property values near site may decline; Lost income - timber product.
Aesthetics	Disposal site would replace open water	Disposal site would replace open water	Disposal site would replace open water	Disposal site would replace open water	Disposal site would replace natural area

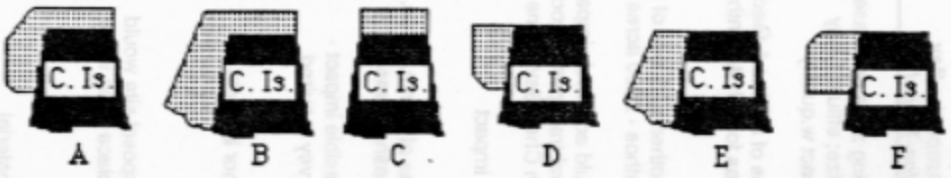
Table 3. ENVIRONMENTAL IMPACT MATRIX FOR DISPOSAL ALTERNATIVES
(Cont'd)

Environmental Category	*Horseshoe Area/Buckroe*	*Chesapeake Bay Bridge-Tunnel*	*Ragged Island*	*Disposal @ Sea (a)*
Water Quality	Mixing zone decreased in size; effluent may impact w.quality	Mixing zone decreased in size; effluent may impact w.quality	Mixing zone decreased in size; effluent may impact w.quality	Short-term impacts; return to ambient rapidly
Fish/Shellfish/Wildlife	Loss of habitat & feeding areas for fish & benthos	Loss of habitat & feeding areas for fish & benthos	Wildlife Management Area severely impacted	Minor & short term impact
Benthos	Smothering & loss of all benthos - 2500 acres	Smothering & loss of all benthos - 2000 acres	Smothering & loss in James R.	Temporary loss
Hydrodynamics	Changes could impact erosion rates @ beaches	Could adversely impact larval transport assoc. with Ches Bay plume	Could change circulation /sedimentation near seed oyster beds in James R.	No impact
Wetlands	No impact	No impact	Loss of 2320 acres of saltmarsh	No impact
Navigation	Loss of comm. & rec. boating areas	Loss of comm. & rec. boating areas	Loss of comm. & rec. boating areas	No impact
Cultural/Historical Resources	Possible impact - survey required	Possible impact - survey required	Possible impact - survey required	No impact
Social Impact	Minor impacts	Minor impacts	Minor impacts	No impact
Aesthetics	Disposal site would replace open water	Disposal site would replace open water	Disposal site would replace natural area	No impact

(a) Material which meets ocean disposal criteria. Unsuitable material must be disposed in a contained area

51. No Action. The waterborne commerce that passes through the Hampton Roads Harbor accounts for a significant portion of the region's economy. As one the world's largest naval bases, naval vessels which transit the harbor are critical to National defense. If no action were taken, the Port would be forced to close its facilities to all but shallow-draft vessels as the Norfolk Harbor and channels would eventually shoal to their natural depths. This alternative is considered unacceptable because it would result in a major adverse impact to the region's and national economy and the Nation's defense.

52. Expansion of Craney Island.



53. As indicated on table 2, Plan B meets the 50-year useful life objective for long-term disposal. Plans A and E provide storage for dredged material for a period of 31 years and 22 years respectively, assuming dredging scenario S4 on Table 2. Expansion of Craney Island would mean the permanent loss of between 660 to 2,500 acres of estuarine bottom.

54. The "Environmental Effects" section of this Environmental Information Report describes the environmental consequences associated with this plan.

55. Willoughby Bay. Implementation of this plan would mean the permanent loss of approximately 1,280 acres of natural harbor area. The intangible effects include damage to marine life, loss of the bay view, air pollution (odor), and the loss of water-oriented recreation within the project area. Willoughby Bay water quality and drainage into the bay would be effected by this proposal. Drainage of the surrounding area, notably the aqueduct outfall from Mason Creek, would be affected with this plan. The total mixing zone within the bay would be reduced in size and water quality would further suffer as a result.

56. Willoughby Bay supports some recreational fishing but probably is more important as a protected area for juvenile fish. Shellfish growing areas within the Bay have been condemned for direct commercial harvesting by the State Department of Health but private catches continue in the Willoughby Bay area, especially of the blue crab.

57. This proposal would severely alter circulation in Willoughby Bay.

58. Where wetlands are present bordering Willoughby Bay (approximately 7.64 acres according to VIMS Tidal Marsh Inventory), there would be a loss or change of wetlands in those areas adjacent to the proposed disposal site.

59. An extensive area of open water occupied by this proposal would be lost to shallow draft commercial and recreational vessel use (approximately 1,280 acres). Elimination of recreational boating within the protected waters of the bay constitute a major impact of this alternative. A public boat ramp at Willoughby Bay is heavily used throughout the year. Depending on the westward extent of the disposal area in Willoughby Bay, the Navy's small boat basin might also be adversely affected.

60. The chief objections to this site center on aesthetics, anticipated decreases in property values, and loss of a resource for water-oriented recreation. The residents of the area, especially those whose property fronts Willoughby Bay, would lose their view of the water, which would be substituted by a view of a disposal area and ultimately whatever development was allowed there. The elimination of a relatively secluded area for water-based recreation would reduce an already limited resource, intensifying the use of other bodies of water nearby, most of which are already heavily used. All of these negative effects would undoubtedly lead to some decrease in property values for those structures located adjacent to Willoughby Bay and possibly for other buildings nearby.

61. The chief positive effect of this plan as well as all others that involve creation of new land is that after the site is filled, there would be additional land for development in an urban area that is almost totally developed now. This

would be an asset to a city such as Norfolk, which has almost no large tracts of vacant land left.

62. Opposition to the use of Willoughby Bay as a new disposal area logically stems from individuals living in that area including the Willoughby Civic League. The objections are based on risk of air pollution, aesthetic and recreational losses, and lowered area property values resulting from the use of the bay for disposal activities. A similar view was expressed by the city of Norfolk in a letter dated August 3, 1987:

> "1. Willoughby Bay - The City would not support any filling of Willoughby Bay. The City's concerns are the negative impact on adjacent property values and on recreational use of the Bay as well as the negative environmental impacts associated with this option."

63. Ocean View. Implementation of this plan would result in the permanent loss of approximately 2,000 acres of benthic habitat in Chesapeake Bay. Water quality would be impacted by the construction and operation of a confined disposal site at this location. The total mixing zone within the bay would be reduced in size and water quality might further suffer as a result.

64. There would be a total impact of benthic organisms and their habitat permanently lost to the estuarine ecosystem. The Crumps Bank area which lies just north of Ocean View was found by Diaz (1983) to have the greatest density and number of clams of six different areas in the lower bay which were being considered for sand mining. Impacts on clam resources would be direct and indirect. There would be the direct loss of bottom habitat and the clams which inhabit this bottom and the hydrodynamic changes caused by the presence of the disposal facility could substantially change current patterns on Crumps Bank, thereby altering potential recruitment of clam larvae. Fish migrations into and out of major tributaries could be affected by this proposal.

65. Changes in circulation and sedimentation could impact resources and recruitment and also could change erosion rates at area beaches.

66. There would be a drastic change in the appearance of this open water area. From the vantage point of either land or water, this proposal would cause a negative impact aesthetically.

67. Although this plan would have fewer effects than the Willoughby Bay plan, it would still be objectionable to the residents of Ocean View. It would present a visual intrusion for those residents of Central Ocean View whose property fronts the Chesapeake Bay and for any users of the beach in this vicinity. Any increase in erosion along this section of the beach could reduce further the area's recreational potential and hinder the ongoing efforts at redevelopment.

68. A flood dominated channel exists off Ocean View and facilitates tidal exchange between bay and ocean waters. Fish and other aquatic organisms migrate into and out of the bay along this corridor. The location of the beach to the lee side of the disposal site island (to the northeasterly and easterly winds) may have beneficial effects in reducing beach erosion. However, a major feature, such as a disposal site, in the vicinity of this corridor, could seriously impact hydrodynamics, water quality, and could impede migration into and out of the bay. Although this plan would not interfere with the navigation of large vessels, it would inconvenience fishermen and pleasure boaters by obstructing their access to the Chesapeake Bay. It would also remove a section of the bay from use for commercial and recreational fishing, clamming and crabbing or other recreational uses such as water sports.

69. All of the above reasons make this site unacceptable to local residents and to city officials as well. The Ocean View Coordinating Committee has requested that additional problems not be created in an effort to solve the dredging disposal problems. The city of Norfolk, via letter dated August 3,1987, stated:

> "2. Ocean View. The City would not support the Ocean View disposal area option. The City's concerns are the negative impact on adjacent property values and on boating and fishing in the Chesapeake Bay as well as the negative environmental impacts associated with this option."

70. Hampton Flats. Approximately 1800 acres of benthic habitat would be lost in its conversion to a disposal site. Finfish pass through the harbor en route to spawning grounds in tributaries. A disposal area located in Hampton Flats may impede this passage or affect circulation in such a way that larval recruitment (especially oysters) may be hindered. A previous study of a proposed New Port Island conducted by the Virginia Institute of Marine Science (Byrne, et al., 1987) concluded that an artificially created island off Newport News Point would present a high probability of adverse impact on seed oyster beds in the James River. It is probable that a similar consequence could be expected from the proposed use of Hampton Flats as an enclosed disposal site.

71. Hampton Flats is worked by oystermen, clammers, and other commercial fishermen. Recreational usage is also high, with much boating, sailing, and sport fishing in the area. Investigations concerning the benthic productivity of this area were conducted in connection with the Newport Island study. The study concluded that Newport Island construction, as proposed, would present a high probability of adverse impact on seed oyster beds in the James River and hard clam habitat on Hampton Flats (direct impact and formation of blanket mud deposits in the area between the island and the mainland). Since Hampton Flats is one of the most productive commercial clam beds in Hampton Roads, a significant impact to this industry would result from construction of a disposal area at this site.

72. An extensive area of open water occupied by this proposal would be lost to shallow draft commercial and recreational vessel use (approximately 1800 acres). A change in circulation and sedimentation patterns may cause more rapid shoaling of nearby navigation channels.

73. Waterfront property owners in Hampton would be affected by implementation of this alternative. The present unrestricted view of the harbor would be interrupted by the aesthetically less-desirable presence of the disposal site. In many ways the adverse effects of this plan are similar to those of the Ocean View site. One of the chief negative effects would be the reduction in available area for boating, sailing, and sport fishing, all of which are popular in this area. Since Hampton Flats is also used by oystermen, crabbers, and fishermen, construction of a disposal site here would reduce the available area

for watermen to work in and would remove some of the resources that provide their livelihood.

74. In spite of the many potential negative effects of this plan, there might be some support for this alternative because of the valuable land that would be created after the Hampton Flats area was filled. As previously stated, Newport News has been interested in building an offshore island as a means of creating developable land in the vicinity of the city's downtown section. However, various studies have pointed out many problems with such an island, and the probability of its construction currently appears remote.

75. The Virginia Council on the Environment, in a letter dated September 8, 1987, stated that the Hampton Flats is an area where water circulation patterns are critical to shellfish larvae in the James River. Due to the potential for serious environmental effects, no further consideration has been given to a plan of development at Hampton Flats.

76. Horseshoe Area Off Buckroe Beach. The area off Buckroe Beach is a known clamming area of moderate commercial value according to Diaz (1983). Fish migrate through this area on the way to spawning and nursery areas in the upper tributaries of the bay. Bottom feeding species such as spot, croaker, and crabs rely directly on the benthos for food. Pelagic predatory species such as bluefish, striped bass, and trout rely directly on the benthos as juveniles or indirectly on benthic production passed through the food chain. Blue crabs are actively sought in this area from April through August.

77. There would be a loss of about 2,500 acres of subaqueous bottom with this proposal. This constitutes a sizeable portion of the bottom near the mouth of the Chesapeake Bay. The Horseshoe Area off Buckroe Beach was recently investigated by Diaz (1983) for macrobenthos. Together with 5 other sites, it was found to be one of the most productive in the lower bay area.

78. Placing a 2,500-acre site in the lower bay has the potential to significantly impact the hydrodynamics of this area. There is a material probability that this proposal could impact larval recruitment, community biological make-up, or erosion at nearby shorelines.

79. Construction of this alternative would not interfere with navigation of large vessels, although it would inconvenience pleasure boaters and fishermen.

80. The Hampton beach front is a mixture of private, municipal, and Federally-owned lands. The southern limit includes Fort Monroe where a major seawall exists with practically no beach. Adjoining this area is Buckroe Beach which is intensively used and includes a dense residential development. Adjoining Buckroe Beach are privately owned beaches with little public access, relatively few houses and cottages, and with adjoining salt ponds, marshes, and a nature preserve.

81. Since a dredged material disposal site in this vicinity would be a substantial distance offshore, it should reduce any aesthetic complaints from site construction or visual intrusion to the users of the beach front. The location of the beach to the lee side of the disposal site island (to the northeasterly and easterly winds) may have beneficial effects in reducing beach erosion. There would not be any conflict with existing or future development on shore and access to the shoreline would not be disrupted. Undoubtedly, numerous recreational boaters, sports fishermen who frequent this water section in favorable weather, and the watermen who use this site and the surrounding areas for generating their livelihood would object to this site as a dredged material disposal area.

82. In a letter dated September 10, 1987, the City Manager of Hampton stated the following:

> ".... Under a comprehensive shoreline policy adopted by Hampton City Council in June 1986 much in the way of public improvement, parks and recreational development, beach access, and economic development is actively taking place. A significant investment is being made to upscale residential projects and water associated amenities. All of this raises concern from Hampton's viewpoint pertaining to an offshore disposal site and we are opposed to a disposal site at this location. Any change in this

position would have to be based on overriding benefits that may provide additional economic development opportunity and shoreline protection."

83. Ragged Island. The use of Ragged Island as a disposal site would result in the loss of 2300 acres of wetland salt marsh. Ragged Island is a state wildlife management area operated so as to make the land produce a sustained crop of wildlife for recreational purposes. Wildlife management areas are managed primarily for the development of wildlife habitat with only minimal facilities necessary to carry out the program. The intent is to keep each area attractive to wildlife, hunters, fishermen, trappers, naturalists, hikers, and the thousands who enjoy being outdoors. The scarcity of this type of open and undeveloped land in the state is obviously one reason for its establishment.

84. Depending on where dikes were constructed and how the effluent from the site was handled, there may be some impact on benthos in the adjoining James River. This area of the James is one of the most productive seed oyster areas in the state.

85. Circulation patterns in this portion of the James River are critical to the recruitment of oyster larvae to the James River seed beds. By changing shoreline configurations, there is the potential for changing the hydrodynamics of the area; this would have to be evaluated using physical or numerical modeling.

86. The use of Ragged Island as a disposal site would result in the loss of 2,300 acres of wetland saltmarsh. Managers consider this area to have had little, if any, use by man over the years and is generally an unspoiled section of river marsh. Much of the area is subjected to tidal flooding making it a contributor to the food chain in the form of detrital and organic matter. The loss of this wetland habitat may be in conflict with the Federal Executive Order 11990 (Protection of Wetlands) which advocates "...avoidance to the extent possible the long and short term adverse impacts associated with the destruction or modification of wetlands and avoidance of direct or indirect support of new construction in wetlands wherever there is a practicable alternative." Prior to issuance of E.O. 11990, the Corps of Engineers

recognized that wetlands are productive and valuable public resources and through its regulatory program, as a matter of policy, gives special consideration to applications for activities in wetlands. The current Corps wetland policy can be found in Title 33 of the Code of Federal Regulations at Part 320.4(b).

87. Due to the remoteness of the area, this plan would not impact on residential and/or commercial properties. Ragged Island is a state wildlife management area with hunting and fishing allowed in season. Game available here includes deer, rabbit, raccoon, fox, squirrel, and ducks; fish caught here include striped bass, catfish, and perch. Therefore, the most important social impact would be the removal of a recreation area for hunting and fishing.

88. In a letter dated September 8, 1987, the Governor's Council on the Environment (Virginia) stated the following:

> "Ragged Island is a Wildlife Management Area belonging to the Department of Game and Inland Fisheries. It is one of the wetland areas in the United States placed on the list of 'Wetlands of International Importance Especially as Waterfowl Habitat' in an international treaty, also known as the Ramsar Convention, to which the United States is party. Therefore, the Army Corps of Engineers should delete this site as a possible dredged material disposal site."

89. Due to the serious environmental effects, no further consideration will be given to a plan of development for the storage of dredged material at Ragged Island.

90. Suffolk Site. The Suffolk Disposal Site alternative encompasses approximately 6,000 acres of primarily wooded wetland just north of U.S. Route 460 between the Chesapeake city limits and Suffolk. Approximately 6,000 acres of wooded wetland would be lost with this alternative. The heavily timbered land is relatively flat with highest elevations ranging about 25 feet m.s.l. Numerous drainage canals have been cut through the area, primarily to

regulate water levels and to afford fire prevention measures. The surface soils are primarily peat and are usually less than 5 feet thick. Subsurface mineral deposits of economic value, with the exception of a thin veneer of sand, are not known to exist.

91. Major concerns with the Suffolk Site include the possibility of saltwater intrusion into freshwater aquifers and the possibility that the site may be a recharge area for the Dismal Swamp. Another concern is salt seepage from the disposal site into surrounding swamp forest and ditches.

92. Animal forms found in the Suffolk Site are those which are adapted to both dense woods and standing water. There are a variety of mammals, birds, reptiles, and amphibians found here. The U.S. Fish and Wildlife Service has indicated the presence of two endangered species, the southern bald eagle and the red-cockaded woodpecker. Habitat of these species, especially the woodpecker would be jeopardized with the use of this site. The Dismal Swamp Southeastern Shrew (Sorex longirostris fisheri) is also found in this area and is listed as threatened on both the Federal and state levels. Habitat could be adversely impacted by use of the Suffolk site for dredged material disposal.

93. This site would be disruptive in terms of social impacts. About 6,000 acres of property would be enclosed with levees that eventually would be 27 feet above the height of the surrounding terrain. There would be approximately 10 miles of pipeline from Craney Island through Portsmouth, to the site in Suffolk.

94. In Suffolk, those individuals who would be most directly affected are the landowners of the proposed disposal site who would suffer the loss of their land and the income it could produce from current and future timber sales and the residents of the housing area known as Wonderland Forest who would be adjacent to the proposed site. Other groups affected would be the hunters who use the area and the residents of the city as a whole. The city itself would lose the revenues produced from real estate taxes on the disposal site for the life of the site. Land values in the vicinity might also be adversely affected although this is more difficult to project and is highly dependent on development patterns in the areas adjacent to the proposed site. The appearance of the proposed site would be changed through disposal operations, affecting the neighboring

residents most directly. This effect could be lessened by the use of a buffer zone of natural vegetation between the disposal operation and the surrounding areas.

95. Another area of concern is the potential effect of this alternative on the expansion plans and daily operation of the Hampton Roads Airport, a general aviation airport located directly east of the proposed disposal site. Current Federal Aviation Administration regulations prohibit construction of an airport within 10,000 feet of a landfill, unless the landfill is used exclusively for the disposal of rocks and earth. However, this approximate area is presently being considered as the site of a regional landfill by the Southeastern Public Service Authority (SPSA).

96. Because of the potential negative impacts discussed above and numerous environmental concerns, many residents of Suffolk and the local governmental officials are opposed to this disposal site. Such opposition would be likely to be a source of community disruption and discontent if this plan were selected.

97. In a letter dated July 17, 1987, the City Manager of Suffolk stated that the City Council unanimously reaffirms its position to adamantly oppose the disposal of dredged material at any location within the city of Suffolk and is prepared to take all possible legal action to prevent the use of the area for such disposal purposes.

98. As previously stated, the Norfolk District and North Atlantic Division recommended the Suffolk Disposal Site in the 1980 Feasibility Report on Norfolk and Channels, Virginia, Deepening and Disposal. However, the Board of Engineers for Rivers and Harbors recommended that the Suffolk Site should not be constructed at that time. The Chief of Engineers and the Assistant Secretary of the Army for Civil Works concurred with this position.

99. Due to the serious environmental effects, no further consideration will be given to a plan of development for the storage of dredge disposal at the Suffolk site.

100. Chesapeake Bay. In evaluating this plan, consideration must be given to the fact that the Chesapeake Bay is currently under study by a multiagency group including the Corps, EPA, Fish and Wildlife Service, National Marine Fisheries Service, the states bordering the Chesapeake Bay, and the District of Columbia. This group was formed in 1983 to coordinate actions to enhance, restore, and protect the resources of the Bay. The 1987 Chesapeake Bay Agreement further outlines specific actions or initiatives to be taken in accomplishing these goals. The State and Federal governments have been tasked with developing and executing programs to reverse the environmental decline of the bay. The potential environmental and social impacts of constructing a disposal site in the Chesapeake Bay may seriously impact the realization of these goals.

101. Water quality in the lower Chesapeake Bay could be impacted by this alternative. The disposal area would be located near the mouth of the Bay where there is strong tidal flushing; whether the above proposal would adversely impact hydrodynamics, and thus water quality, would have to be determined from model investigations.

102. The lower Chesapeake Bay represents a very popular site used by local commercial and sport fishermen as well as commercial crabbers. Adult finfish pass through this area en route to spawning grounds in tributaries and the upper bay. A disposal area located in lower Chesapeake Bay may impede this passage or affect circulation in such a way that larval recruitment may be adversely impacted.

103. The lower Chesapeake Bay is known as an overwintering area for adult blue crabs. Depending on the exact location of the disposal area, this resource could be adversely impacted. The total benthic biomass lost would include a variety of polychaete worms, bryozoans, mussels, clams, and oysters. The 2,000 acres of bottom that this proposal would eliminate would further affect the food resources of local and migrant fish which frequent this area of the Bay en route to upstream tributaries or locations on the eastern seaboard.

104. The circulation and sedimentation patterns in the lower Chesapeake Bay which could potentially be changed by this proposal are serious considerations.

Among other detrimental effects, hydrodynamic changes could impact larval recruitment (finfish and shellfish) into the bay and its tributaries.

105. An extensive area of open water occupied by this proposal would be lost to shallow draft commercial and recreational vessel use. A change in circulation and sedimentation patterns might cause more rapid shoaling of nearby navigation channels such as the very important Thimble Shoal Channel.

106. The major social effect of this plan would be the removal of a section of a popular area from recreational use. The Chesapeake Bay in the vicinity of the bridge-tunnel is a very popular area for local sports fishermen. Construction of a disposal area here would eliminate part of this area from use by pleasure boaters as well as fishermen. Since the supply of water areas available to small craft is limited, any reduction in this supply will intensify use of the remaining areas, which are all heavily used during the peak parts of the season.

107. There would also be a greater threat of vessel accidents in the vicinity of the site and the Bridge-Tunnel during site construction and disposal operations. This problem was discussed in a letter dated August 3, 1987 from the Executive Director of the Chesapeake Bay Bridge and Tunnel District, who stated:

> "...It is our understanding that the Chesapeake Bay disposal area would contain approximately 2500 acres and could be utilized as a disposal site for the next 30 to 40 years. The activity involving many tug boats, barges, and other vessels in close proximity to the Bridge-Tunnel during the construction stage of the confinement area, and the subsequent years of utilizing the disposal area, is of great concern to us due to the potential of damage to our structure by a vessel.
>
> "Since we opened to traffic in April of 1964, the Bridge-Tunnel has been struck on several occasions by vessels that experienced mechanical

problems or vessels that were driven off course because of severe weather conditions. On three occasions, as a result of ship collisions, we were completely closed to traffic for periods ranging from 14 to 42 days. During the fiscal year July 1, 1986 through June 30, 1987, 2,240,450 vehicles crossed the Bridge-Tunnel. An accident causing the Bridge-Tunnel to be closed would be devastating to us financially and would also adversely impact the citizens and businesses of the cities of Southeastern Virginia, the two counties of the Eastern Shore of Virginia, and other surrounding areas.

"The Chesapeake Bay Bridge and Tunnel Commission, at its meeting on July 14, 1987, went on record expressing its concern and objection to the proposed Chesapeake Bay disposal site. Your consideration in eliminating the Chesapeake Bay site as a proposed area for the disposal of dredged material will be greatly appreciated."

108. Ocean Disposal. In order for open ocean disposal of dredged materials to be an environmentally sound alternative, the potential ecological impact at each site must be assessed. The Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers (COE) have done extensive work in developing criteria by which the potential environmental impact of open ocean disposal can be assessed on a site-specific basis (Lee and Plumb, 1974; Lee et al., 1975; EPA, 1976, 1978; Hirsch et al., 1978; Pequegnat et al., 1977, 1978, 1981; and others). The final criteria specified in 40 CFR, Part 228 have been incorporated into an implementation manual (EPA/COE, 1978) which sets the technical guidelines by which the ecological effects of dredged material disposal must be evaluated before an open ocean site may be permitted. The criteria are designed to minimize or prevent unacceptable environmental impacts to open ocean ecosystems.

109. After a careful application of these criteria, the Dam Neck Ocean Disposal Site (DNODS) was designated as an approved ocean disposal site under the Corps of Engineers authority contained in Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA). The Final Supplement, containing evaluations with respect to the criteria contained in Parts 228.5 and 228.6 of the Code of Federal Regulations, Title 40 (40 CFR 228), was filed with EPA and appeared in the Federal Register on June 14, 1985 (Corps of Engineers, 1985). The Record of Decision, giving DNODS final site designation, was signed by the Division Engineer, North Atlantic Division, U.S. Army Corps of Engineers, on September 23, 1985.

110. More recently, EPA gave DNODS final designation under authority in Section 102(c) of MPRSA. This final designation by EPA appeared in the Federal Register on March 31, 1988.

111. The Final Environmental Impact Statement (FEIS) for the Norfolk Disposal Site was filed by the Norfolk District with EPA on July 23, 1982 (Corps of Engineers, 1982). The purpose of the FEIS was to supply environmental evaluations and supporting data for the NDS designation process.

112. The EIS discusses the need for the action and examines ocean disposal site alternatives to the proposed action. The EIS presents the information needed to evaluate the suitability of NDS for final designation and the conclusions of the EIS are based on an extensive series of environmental studies. After considering benthic and bioassay data as well as other existing information concerning the various alternatives, the EIS recommended designation of the NDS for dredged materials meeting EPA/Corps ocean disposal criteria.

The Selected Plans

113. The process of plan formulation and screening of alternative plans as presented in the main report has terminated with identification of the two selected plans which could provide the long-term disposal capacity requirements for Norfolk Harbor and Channels port maintenance and expansion. These alternatives are the most preferable ones of those evaluated

given the economic, engineering and environmental considerations discussed previously.

Plan Description

114. The components of the two selected plans are as follows:

115. Craney Island Expansion Plan B. This includes 2,500 acres of shallow Hampton Roads bottomland to the west and north of the existing Craney Island. It would contain sufficient space, up to elevation 30 m.l.w., to accept about 250 million cubic yards of dredged material from Federal, state, and private interests operating along the channels and waterfront of the inner harbor of Hampton Roads. It would thus provide sufficient storage for the deposition of dredged material for about 50 years. Any available space, up to elevation 30 m.l.w., remaining in the existing Craney Island after Expansion Plan B has been constructed would be additional storage.

116. Existing Craney Island plus DNODS plus NDS. As previously stated, under this plan, Craney Island would be used only for the disposal of dredged material unsuitable for ocean disposal. Sufficient storage would be available for 50 years for such material from the Southern and Eastern Branches of the Elizabeth River. Clean dredged material would be disposed in DNODS for only a relatively few years to insure that sufficient storage remains therein to hold (1) new work dredging from the proposed 55-foot Thimble Shoal and 60-foot Atlantic Ocean Channels, and (2) the future maintenance required from these two channels and the Cape Henry Channel (leading to Baltimore Harbor) for 50 years. Following disposal of suitable dredged material from the inner harbor into DNODS for a relatively short period, all further material from the inner harbor would be disposed in NDS where space is available indefinitely.

117. Thus, either of these two plans would satisfy the requirement in the inner harbor for the future disposal of dredged material obtained from Federal, state, and private interests in the Hampton Roads area well into the future.

118. One important factor should be considered prior to the deposition of dredged material under any plan. This is whether any of the material can be used beneficially. Such uses include arresting or diminishing erosion along

beaches and/or shorelines, reinforcing existing levees, and use as borrow material in highway or building construction.

119. Design and construction considerations and operation and maintenance considerations are discussed in the "Plan Formulation" section of the main report.

AFFECTED ENVIRONMENT

NATURAL ENVIRONMENT

Water Resources

120. Hydrology. The James River is a narrow, funnel-shaped, shallow estuary with a mean low-water average depth of 12.1 feet. Riverbed channels have an average depth of 32.8 feet. Some channel scour holes exceed 98.4 feet in depth. At Hampton Roads, where the James River becomes wider as the Elizabeth and Nansemond Rivers enter the estuary, the harbor deepens to about 59 feet with a channel dredged at its mouth.

121. The James River, a partially mixed estuary of the Chesapeake Bay estuary system, drains the geological provinces of the Blue Ridge, the Piedmont, and the Coastal Plain of Virginia. The three major tributaries entering the James River are the north branch of the James River, with a drainage area of 6,757 square miles; the Appomattox River, which enters the James River at Hopewell, Virginia, with a drainage area of 1,344 square miles; and the Chickahominy River, which enters the James River along Hog Island, with a drainage area of 248 square miles (Nichols 1972). Minor tributaries include the Pagan, the Nansemond, the Elizabeth, and the Warwick Rivers. The three major tributaries have gaging stations and have recorded the following average discharges: the North James River, 7,098 cfs; the Appomattox River, 1,095 cfs; and the Chickahominy River, 247 cfs (Nichols 1972). Minor tributaries have not been gaged and are assumed to have comparatively low discharges.

122. During a mean tide, tidal currents vary from -1.15 to +1.48 fps from Newport News to Jamestown. Tidal currents reach their peak 3 hours after

slack. There is a density circulation in the James River that is potentially important in transporting sediment up the estuary.

123. Salinity varies with distance downstream from 0 ppt at Richmond, Virginia, to 24 ppt at the mouth. High river inflow produces the greatest stratification in the upper estuary. The limit of saltwater intrusion varies from Hog Island, 24 miles above the mouth, during high river discharge to a location approximately 54 miles above the mouth during low discharge in the summer and fall.

124. The seasonal variations in river inflow change the estuary from moderately stratified to well mixed. At low river inflow, tidal mixing reduces stratification, producing a vertically homogeneous estuary.

125. Sediment and Water Quality. The Virginia State Water Control Board's (VWCB) Water Quality Standards (1982) designate the Hampton Roads area as Class II, (a) waters. The enforceable water quality standard for Class II waters require that no condition be allowed which depresses the dissolved oxygen level below 4.0 mg/l, lowers pH below 6.0 or raise pH above 8.5 and raise the temperature above normal by 4F° in the summer or 1.5F° in the winter.

126. Special standard (a) is applicable to the waters of Hampton Roads. Standard (a) applies to all waters capable of propagating shellfish including those restricted or condemned by the State Department of Health. The shellfish beds of Hampton Roads which lie in the immediate project area are condemned for harvest but may be transplanted to acceptable areas for later harvests.

127. Suspended sediment concentrations increase from an average of about 30 mg/l above Jamestown to more than 100 mg/l at the limit of saltwater intrusion (Deep Water Shoal). Concentrations decrease to 12 mg/l at the mouth. Although concentrations vary during the tidal cycle, this overall pattern persists. Measured concentrations are low compared with other east coast estuaries.

128. The turbidity maximum is located at the upstream limit of salinity intrusion. This maximum persists most of the year, being most pronounced in the spring when river inflow is high and weak in the fall when inflow is low. Nichols (1972)

reports the following: "It is evident that about 20 percent of the suspended load remains in suspension at slack water, whereas the greater part is alternately suspended and settled out. These changes are not symmetrical about slack water or maximum current. Concentrations near the surface are slightly higher at the end of ebb than at the end of flood, a trend ascribed to the shifting of the longitudinal concentration gradient."

129. The sediment quality of both the channels to be dredged and the disposal area sediments were investigated. In concert with investigating sediment quality, extensive bioassay testing was performed in compliance with the final criteria as specified in the Federal Register (January 1977) and the complementary Implementation Manual (COE/EPA, 1978) which sets the technical guidelines by which the ecological effects of dredged material disposal must be evaluated before an ocean disposal site may be permitted.

130. The findings of the ODU studies confirm that all sediments derived from the proposed 55' deepening would meet COE/EPA criteria for ocean disposal (Alden and Young, 1984). Those sediments from the lower and intermediate reaches of the Southern Branch of the Elizabeth River (upstream of the 55' project) were also investigated. These sediments produced significant lethal and sublethal effects in suspended solid and solid phase bioassays. Subsurface samples taken in the Southern Branch appeared to be less contaminated than surface samples, which indicates that deepening operations should produce dredged materials which are less contaminated than those routinely taken by maintenance dredging in the same areas (Alden and Hall, 1984). During the course of the 3 year investigation, maintenance dredging took place in the Southern Branch. Sediments which were subsequently tested in the dredged areas showed a reduced degree of toxicity in bioassays . The results suggest that dredging may actually improve environmental quality by removing toxic sediments.

131. Bioaccumulation investigations were performed using sediments from throughout the Port of Hampton Roads (Rule, 1984). Exposure to most of the sediments taken from navigational channels throughout the Port produced no significant effects on body burdens of toxins. However, the treatments involving exposure to sediments from the highly industrialized portion of the Southern

Branch of the Elizabeth River (outside the 55' project) produced statistically significant accumulation of chlorinated hydrocarbons, polynuclear aromatic hydrocarbons, and heavy metals. Again, the unsuitability of these sediments for ocean disposal is emphasized.

132. Currently, forty-eight industrial and fifteen domestic discharges enter the Elizabeth River (VWCB, 1983). In addition, the river receives a wide variety of non-point source loadings from its 300 square mile drainage area, in which approximately one-half million people reside (Cerco and Kuo 1981). All totaled, such loadings represent a tremendous impact. To complicate matters, the Elizabeth River system has very poor flushing characteristics resulting from little freshwater input and a slight topographic relief. Any freshwater entering the system is a result of stormwater runoff and Dismal Swamp drainage. This poor flushing tends to increase the amount of sediment and associated pollutants that are trapped within the river system (Neilson and Kuo 1973-74).

133. The Hampton Roads Harbor also has a number of potential sources of pollution: those primarily associated with heavy shipping and anchorage activities; shipyards and ship terminals; and the large naval base (figure 2). Currently, the dredged material taken from Hampton Roads Harbor, the Elizabeth River complex, and other surrounding tributaries is being disposed at the onshore Craney Island Disposal Site (figure 2). Unfortunately, the CIDA is expected to be filled to capacity within several years time. The search for alternate disposal areas has therefore reached a critical stage.

134. Some sediments in portions of the Elizabeth River contain trace metals and polynuclear aromatic hydrocarbons (PAHs) in potentially toxic concentrations. The potential sources of these compounds are numerous: petroleum products, coal, creosote, and the incomplete combustion of fossil fuels (e.g. automobile exhausts, industrial smoke stacks, home heating, incinerators, etc.), among others (EPA, 1979).

135. Alden and Hall (1984) observed a change in sediment quality in the Southern Branch Elizabeth River associated with dredging which occurred in the Southern Branch between the summer of 1981 and the spring of 1982. Toxicity of the sediments diminished during this period and PAHs in sediments

decreased in concentration by nearly two orders of magnitude. However, upon subsequent analysis in 1983, levels of toxicity and concentration of PAHs appeared to have increased once again to toxic levels. This indicated a "re-invasion" of contamination into the area. The post-dredging return of contamination tends to suggest that the source(s) of contamination (i.e. creosote-saturated river and upland soils, industrial discharges, other non-point sources, etc.) are still prevalent and will be for some time to come.

136. There are at least two abandoned creosote plants on the Elizabeth River, and the Atlantic Wood Industries continues to operate a creosote plant on the river and is on EPA's National Priority List (Superfund). The VWCB indicates that while EPA has designated this area as a high priority for clean-up, there is presently no money available for clean-up of this or other sites in the area.

137. The VWCB is presently pushing to bring the Elizabeth River into compliance with national water quality standards by the early 1990's. The Board will spend $1.1 million in 1988 and 1989 to launch the Elizabeth River Initiative, an enormous cleanup effort that has long been dismissed as an impossible task. During the first two years of the initiative the board will toughen permit restrictions and closely inspect the 60 industrial, military, and municipal entities that discharge toxic pollutants into the river. In research funded by the water board, Old Dominion University targeted about 50 locations for its study. Of these 50 locations, 17 water quality problem areas were identified which are spread all along the river's main stem and Southern and Eastern Branches, including one site in the Lafayette River in Norfolk. The board selected 12 of those locations to represent various uses of the waterfront for future studies.

138. Clean-up of all the sources of contamination on the Elizabeth River is an enormous task which would require extensive coordination efforts and the expenditure of huge sums of money. It is extremely doubtful that this type of clean-up would be economically feasible or even within the jurisdiction of the Corps of Engineers. Without being able to arrest the incoming pollution at its source, it is not anticipated that dredged materials coming from the Southern Branch will be acceptable for anything other than disposal at CIDA any time soon. For the purposes of planning, we must assume that there will continue to

be a need for CIDA for contaminated dredged materials, even though this need may diminish over time.

139. The quality of sediments within the contained dredged material disposal facility, Craney Island Disposal Area (CIDA), was analyzed by ODU (Alden, Young, Hall and Jackman, 1984). The sediments were characterized from both a geological and geochemical perspective to assist in establishing sub-regions and station locations. Sediments from a total of 42 sites were evaluated by a series of 10 lethal and sublethal experiments during 1981 and 1982. A series of bioaccumulation investigations were also performed during this period. It was found that the vast majority of the sediments which were tested appeared to meet the EPA criteria for ocean disposal. Most of the sediments of the CIDA, it was observed, appeared to have been rendered fairly innocuous by dilution and "weathering" processes.

140. Other sediments in the project area, particularly those sediments offshore of Newport News Point are contaminated with heavy metals, volatile organics and solids, nutrients, and pesticides such as kepone (Marshall, McMillan - Sverdrup and Parcel, 1972).

141. The construction operations, including overboard placement of dredged material, would be carried out in accordance with the provisions of the Federal Water Pollution Control Act as amended by the Water Quality Act of 1987, Public Law 100-4, by obtaining both a 401 State Water Quality Certificate and appropriate permit(s).

AQUATIC ECOLOGY

Benthic Invertebrates

142. The benthic invertebrates of the Hampton Roads Harbor have value from both a commercial/recreational standpoint and from an ecological standpoint as a food source for benthic feeders (e.g., finfish). The commercial and non-commercial benthos in the vicinity of the CIDA were quantified by Dauer and Ewing (1985) in August, October and November 1985.

143. For the non-commercial benthos six stations were allocated within the nearshore stratum and six stations within the offshore stratum. Two stations within each stratum were placed on the east, north and west sides of Craney Island (figure 3). All non-commercial benthos sampled were sieved on a 0.5 mm screen and were sorted, identified and enumerated.

144. For the commercial benthos five clam dredge hauls of five minutes were collected on 22 August 1985 and again on 25 October 1985 (figure 3). All commercial species were identified, counted and the maximum length of each individual measured and recorded.

145. The data acquired by Dauer and Ewing (1985) were compared to Site Group 4 of the Norfolk Harbor and Channels Deepening impact study conducted by Dauer and documented in "Macrobenthic communities of the lower Chesapeake Bay. DACW65-81-C-0051, Work Order No. 51, October 1984". Site Group 4 (Station K) was geographically closest to Craney Island (figure 4). Table 4 shows a comparison of the top 15 density dominants from Site Group 4 compared to those of the 1985 study. There were no major differences between the nearshore and offshore samples of the Craney Island study and for the rank analysis comparison all stations were combined. The similarity of the ranked dominants of the two studies indicates that both studies sampled the same general benthic community . The top five dominants in both studies were the same (table 4) and a rank correlation analysis of the dominant species resulted in an r value of 0.751 (t-value = 7.218, p value less than 0.001). Both studies were dominated by species usually characterized as ubiquitous in all types of sediments (e.g. Paraprionospio pinnata, Acteocina canaliculata) or as euryhaline opportunists (e.g. Glycinde solitaria, Nereis succinea, Streblospio benedicti). Dauer and Ewing (1985) also show a

similarity between the two studies using a Principal Components Analysis Model.

Table 4. Comparison of density dominants from the Craney Island study to Site Group 4 from Dauer (1984). Shown are the top 15 ranked dominants from the harbor deepening and other species of interest.

Species	Rank in Site Group 4	Rank in Craney Island
Paraprionospio pinnata	1	2
Acteocina canaliculata	2	1
Mediomastus ambiseta	3	3
Glycinde solitaria	4	4
Phoronis psammophila	5	5
Leucon americanus	6	12
Macoma balthica	7	41
Nereis succinea	8	7
Streblospio benedicti	9	13
Ampelisca abdita	10	11
Sabellaria vulgaris	11	10
Pectinaria gouldii	12	35
Polydora ligni	13	37
Leitoscoloplos fragilis	14	9
Leptocheirus plumulosus	15	Not Collected
Other selected species:		
Loimia medusa	44	6
Sigambra tentaculata	23	8
Spiochaetopterus oculatus	46	14

146. Table 5 shows the results of Dauer and Ewing's commercial clam dredge samples. The greatest concentrations of hard shell clams (Mercenaria mercenaria) were found on the north to northeast side of Craney Island. There were some patchy areas with oyster clumps. The data of table 5 are very similar to the previous results of Dauer (1984).

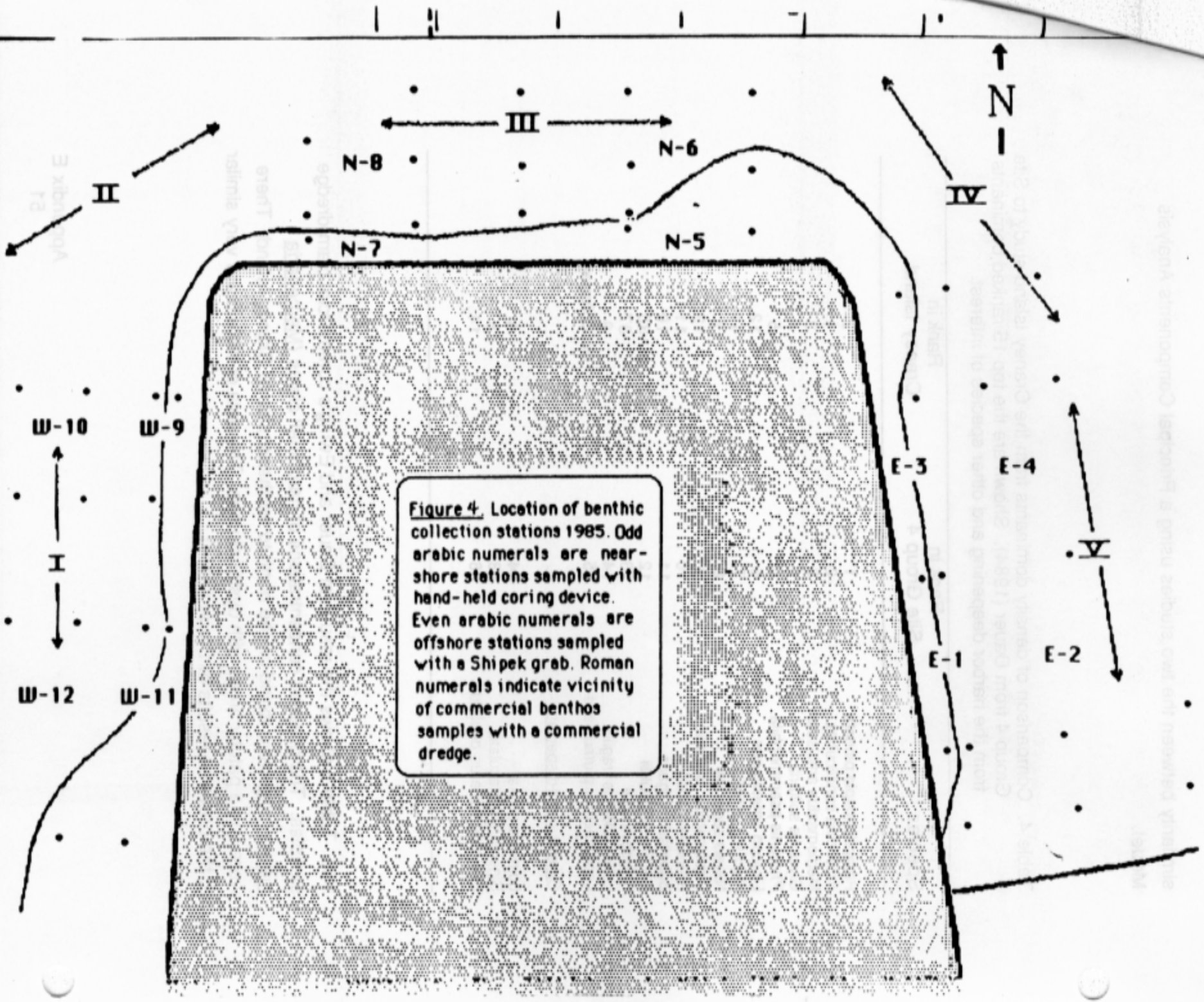


Figure 3. 1985 Old Dominion University benthos sampling stations in vicinity of Craney Island Disposal Area (from Dauer and Ewing, 1985)

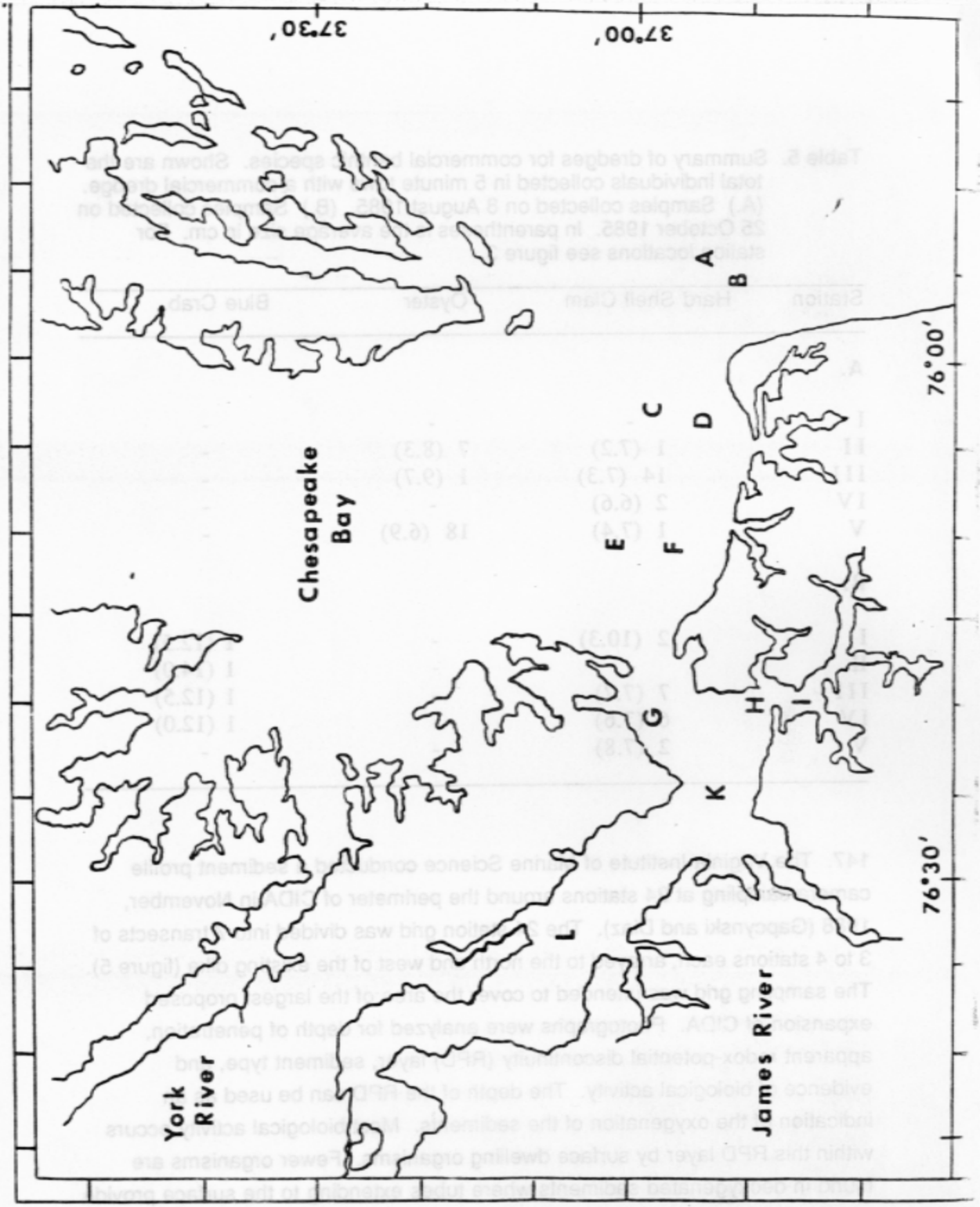


Figure 4. 1984 Old Dominion University benthos sampling stations in lower Chesapeake Bay and vicinity (from Dauer, 1984)

Table 5. Summary of dredges for commercial benthic species. Shown are the total individuals collected in 5 minute tows with a commercial dredge. (A.) Samples collected on 8 August 1985. (B.) Samples collected on 25 October 1985. In parentheses is the average size in cm. For station locations see figure 3.

Station	Hard Shell Clam	Oyster	Blue Crab
A.			
I	-	-	-
II	1 (7.2)	7 (8.3)	-
III	14 (7.3)	1 (9.7)	-
IV	2 (6.6)	-	-
V	1 (7.4)	18 (6.9)	-
B.			
I	2 (10.3)	-	1 (12.5)
II	-	-	1 (14.0)
III	7 (7.7)	-	1 (12.5)
IV	6 (7.6)	-	1 (12.0)
V	2 (7.8)	-	-

147. The Virginia Institute of Marine Science conducted a sediment profile camera sampling at 24 stations around the perimeter of CIDA in November, 1988 (Gapcynski and Diaz). The 24 station grid was divided into 7 transects of 3 to 4 stations each, arrayed to the north and west of the existing dike (figure 5). The sampling grid was intended to cover the area of the largest proposed expansion of CIDA. Photographs were analyzed for depth of penetration, apparent redox-potential discontinuity (RPD) layer, sediment type, and evidence of biological activity. The depth of the RPD can be used as an indication of the oxygenation of the sediments. Most biological activity occurs within this RPD layer by surface dwelling organisms. Fewer organisms are found in deoxygenated sediments where tubes extending to the surface provide oxygen requirements. The full contract report furnished to the Norfolk District Corps of Engineers which describes the methods and materials that were employed to carry out this investigation is found in Attachment 4.

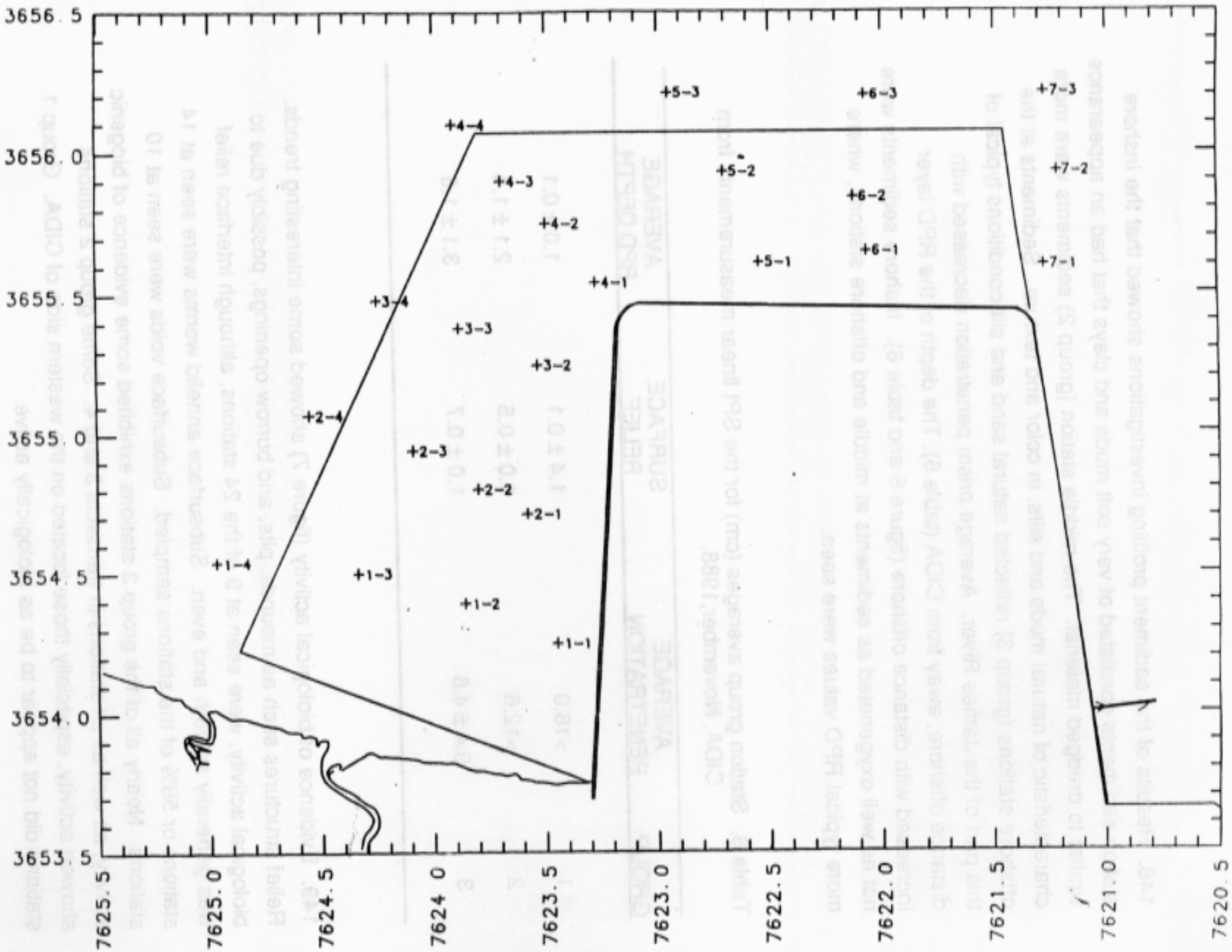


Figure 5. Locations for the SPI images from Craney Island, November, 1988.

148. Results of the sediment profiling investigations showed that the inshore station sediments consisted of very soft muds and clays that had an appearance similar to dredged material. The middle station (group 2) sediments were more characteristic of natural muds and silts, in color and texture. Sediments at the offshore stations (group 3) reflected natural sand and silt conditions typical of this part of the James River. Average prism penetration decreased with distance offshore, away from CIDA (table 6). The depth of the RPD layer increased with distance offshore (figure 6 and table 6). Inshore sediments were not as well oxygenated as sediments at middle and offshore stations, where more typical RPD values were seen.

Table 6. Station group averages (cm) for the SPI linear measurements from CIDA, November,1988.

GROUP	AVERAGE PENETRATION	SURFACE RELIEF	AVERAGE RPD DEPTH
1	>16.0	1.4 ± 0.1	1.0 ± 0.1
2	>12.6	1.0 ± 0.5	2.1 ± 1.4
3	9.4 ± 4.8	1.0 ± 0.7	3.1 ± 1.8

149. Evidence of biological activity (figure 7) showed some interesting trends. Relief structures such as mounds, pits, and burrow openings, possibly due to biological activity, were seen at 9 of the 24 stations, although interface relief was generally smooth and even. Subsurface annelid worms were seen at 14 stations or 58% of the stations sampled. Subsurface voids were seen at 10 stations. Nearly all of the group 3 stations exhibited some evidence of biogenic activity, as well as all stations in transects 3 and 4. Some group 2 stations showed activity, especially those located on the western side of CIDA. Group 1 stations did not appear to be as biologically active.

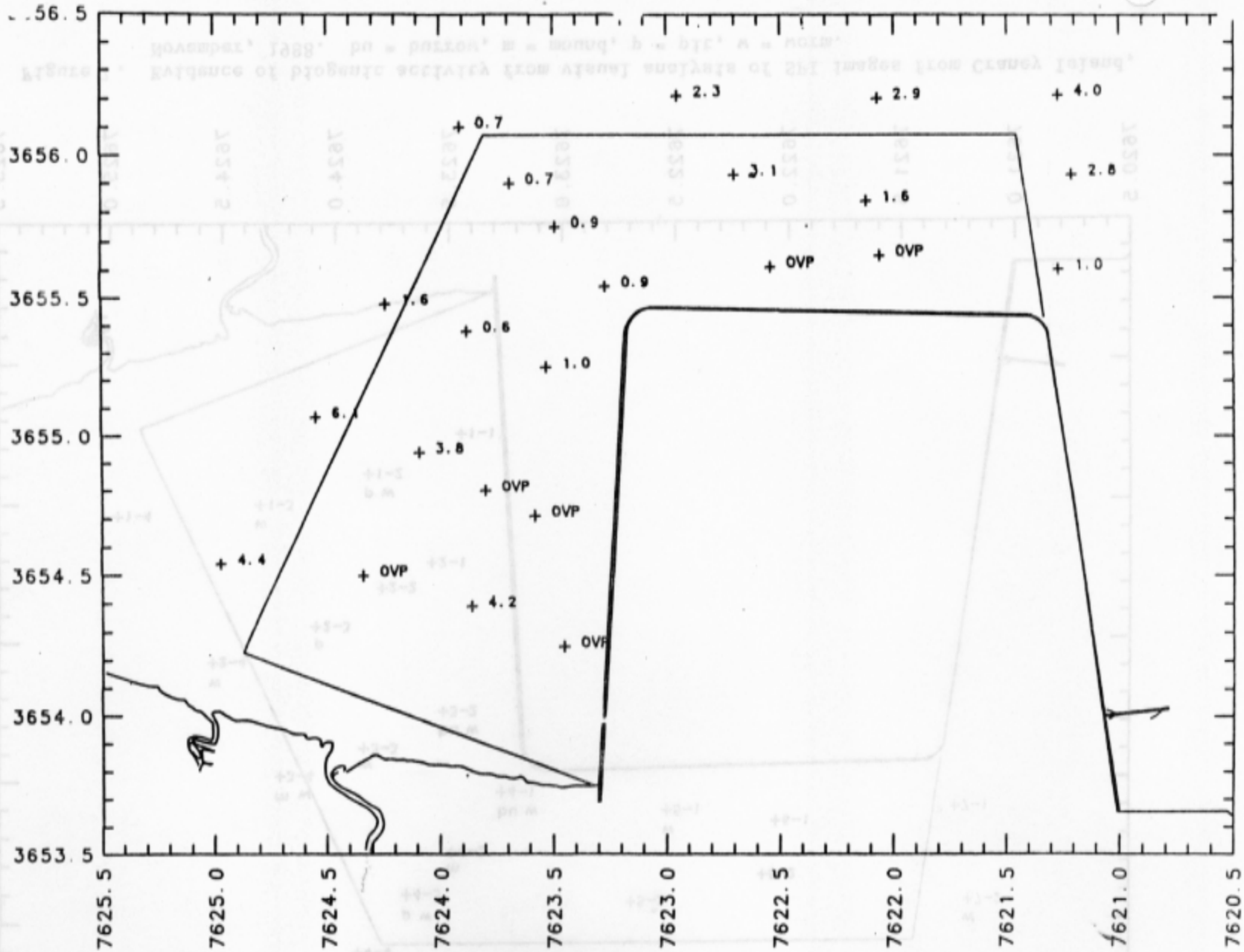


Figure 6. Average RPD depth (cm) for SPI images from Craney Island, November, 1988. OVP is overpenetrated.

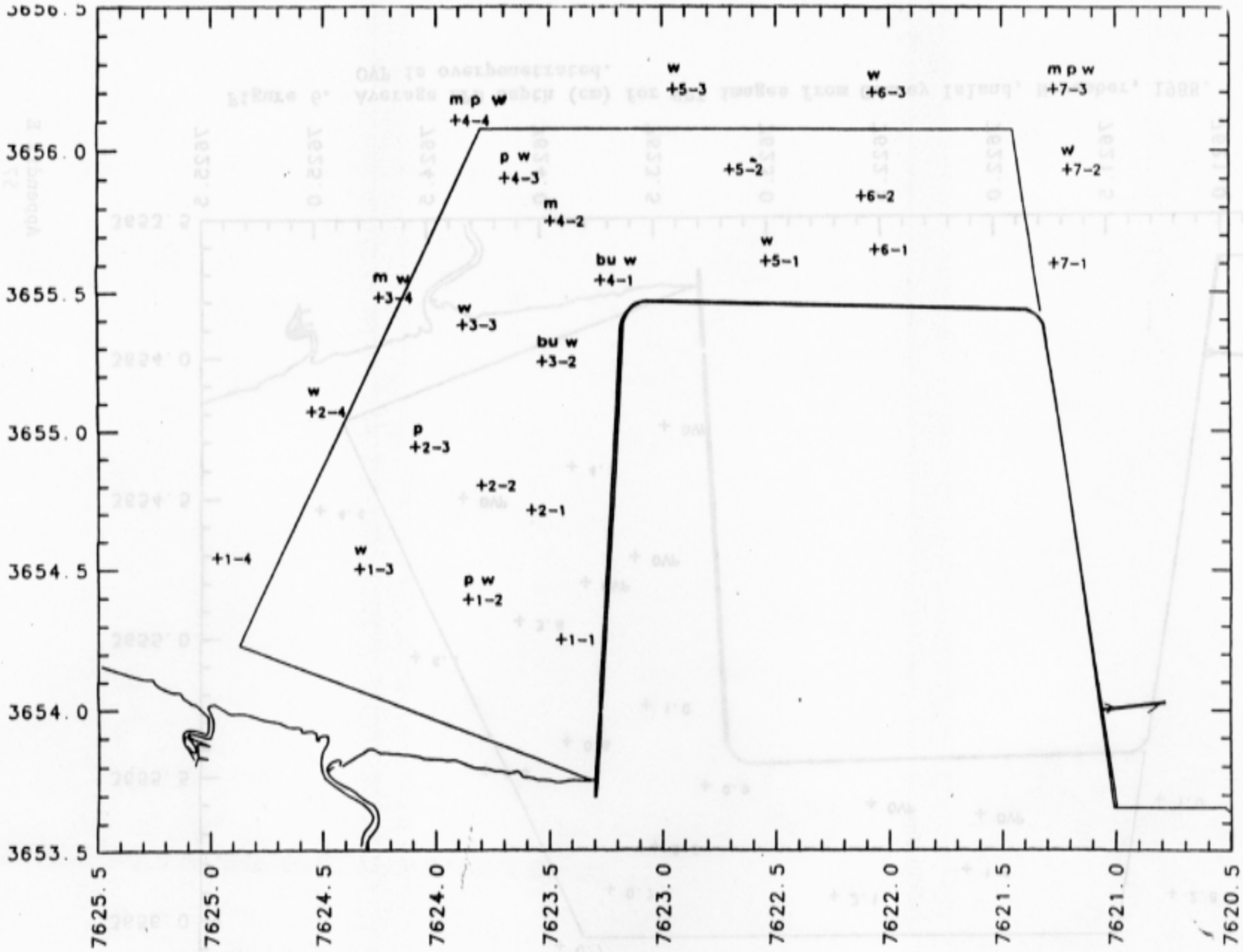


Figure 7. Evidence of biogenic activity from visual analysis of SPI images from Craney Island, November, 1988. bu = burrow, m = mound, p = pit, w = worm.

150. As indicated by the above literature review, benthic communities depend upon, to a large extent, sediment type. Byrne, et al. (1982) conducted a study of the sediment types in the Hampton Roads area. Their study indicated that sandy substrates dominate the area known as Hampton Flats and the area along Riverview shoreline west of Craney Island. Muddy or mixed substrates dominate to the west, north and east of Craney Island. Dauer and Ewing (1986) and Gapcynski and Diaz (1989) conducted benthic surveys in the immediate vicinity of Craney Island. Dauer and Ewing identified a nearshore (within 150 feet) silty sand habitat and an offshore mud habitat with a high silt-clay content. Their stations extended a maximum distance of about 2000 feet from Craney Island. Gapcynski and Diaz, whose sample sites extended up to 8200 feet from Craney Island, found three bottom types. They identified an inshore zone with very soft muds and clays, a middle zone of muds and silts, and an offshore zone of sand and silt. The three sediment studies (Byrne, et al., 1982, Dauer and Ewing, 1986, and Gapcynski and Diaz, 1989) found similar distributions of sediment types in the vicinity of CIDA. The nearshore areas are dominated by finer materials, the offshore areas have higher percentages of coarse materials (i.e., sand).

151. As stated above, the Gapcynski and Diaz survey was conducted immediately after the placement of dredged material around the outer perimeter of the north and west sides of Craney Island. Gapcynski and Diaz found a difference in biological activity with distance from Craney Island, the innermost stations showing the least biological activity and the outermost stations showing the greatest biological activity. This is in contrast with Dauer and Ewing's (1986) study, which found the highest densities of benthic organisms as stations closest to Craney Island. The differences appear to be due to the disposal of the dredged material in the fall of 1988. Since benthic organisms usually recolonize disturbed areas within a year, it is anticipated that the area around Craney Island will regain its normal benthic community.

152. Haven, et al. (1981) examined the oyster and hard clam distribution and abundance in Hampton Roads and the lower James River (figure 8). According to Haven's report, three plots surveyed in the vicinity of CIDA (two west and one extending north and east, ranged in clam density from 0.3 bu/acre (plot 13), to 11 bu/acre (plot 12), to 25 bu/acre (plot 18). These findings are consistent with

the Dauer and Ewing studies mentioned previously in that the plots north of Craney Island show greater concentrations.

153. The oyster industry has been declining in the study area due to two major oyster diseases which occur within Virginia waters: Perkinsus marinus (Dermo) and Haplosporidium nelsoni (MSX). Both can cause extensive oyster mortality under conditions of high salinity (over 15 parts per thousand) and warm water temperatures. In addition, extensive areas of the James River have been closed to the harvesting of marketable shellfish due to fecal coliform contamination. These areas can be utilized for seed production, but no longer contribute directly to oyster landings, even though marketable oysters may be present. Seed oyster production is important in the James River and currently amounts to about 90 percent of the state total.

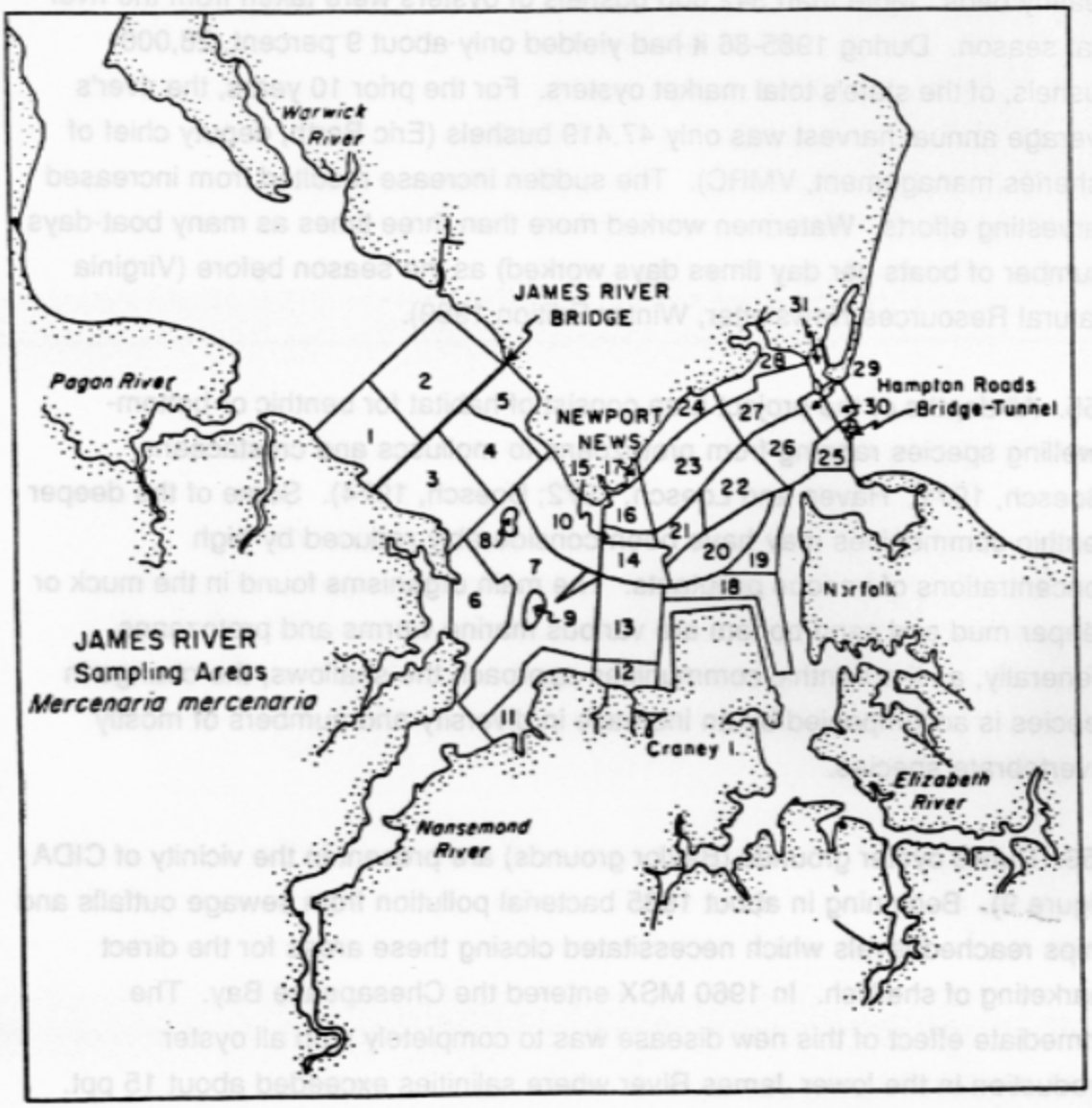


Figure 8. Division of lower James River into system of numbered plots used to estimate bottom acreage and standing crop of the hard clam Mercenaria mercenaria (from Haven, et al., 1981)

154. Diseases that killed oysters over much of the Chesapeake Bay drove many oystermen in 1986 and 1987 to the James River, one of the last areas of healthy beds. More than 342,000 bushels of oysters were taken from the river that season. During 1985-86 it had yielded only about 9 percent, 28,000 bushels, of the state's total market oysters. For the prior 10 years, the river's average annual harvest was only 47,419 bushels (Eric Barth, deputy chief of fisheries management, VMRC). The sudden increase resulted from increased harvesting efforts. Watermen worked more than three times as many boat-days (number of boats per day times days worked) as the season before (Virginia Natural Resources Newsletter, Winter Edition,1989).

155. All depths of the project area consist of habitat for benthic or bottom-dwelling species ranging from protozoans to molluscs and crustaceans (Boesch, 1971; Haven and Loesch, 1972; Boesch, 1974). Some of the deeper benthic communities may have been considerably reduced by high concentrations of various pollutants. The main organisms found in the muck or deeper mud and sand bottom are various marine worms and protozoans. Generally, as the benthic communities approach the shallows, the change in species is accompanied by an increase in diversity and numbers of mostly invertebrate species.

156. Public oyster grounds (Baylor grounds) are present in the vicinity of CIDA (figure 9). Beginning in about 1935 bacterial pollution from sewage outfalls and ships reached levels which necessitated closing these areas for the direct marketing of shellfish. In 1960 MSX entered the Chesapeake Bay. The immediate effect of this new disease was to completely stop all oyster production in the lower James River where salinities exceeded about 15 ppt. The presence of MSX has effectively eliminated oysters from Public Ground Number 1 (Figure 10).

157. To the west of CIDA, productive private oyster leases are present at the mouth of the Nansemond River and the VMRC maintains public oyster grounds at the mouth of the Nansemond (figure 10), with natural spat set occurring at low to moderate levels during most years (Haven and Kendall, 1979). The closest border of this public ground lies approximately 1,400 feet northeast of the deepwater terminus of the proposed Nansemond River entrance channel.

There are apparently no hard clams, Mercenaria mercenaria, in the Nansemond River area (Haven and Kendall, 1979).

158. Hard clams are restricted in habitat to polyhaline and upper mesohaline salinity zones. They are sedentary animals and lie buried in the bottom sediments. Clams are filter feeders and utilize plankton as their food source. A significant hard clam fishery exists in the project area (table 7). Approximately 30 percent of Virginia hard clam production comes from the James River Basin.

159. During the fall of 1987 the state Health Department "permanently condemned" a major commercial clamming area at the mouth of Hampton Roads because of increased bacterial pollution. The designation guarantees that the grounds will be closed for at least two months. These clam grounds stretch more than 1000 acres in the Chesapeake Bay between Interstate 64 to Harrison's Pier in Norfolk's Ocean View section. The Bureau of Shellfish Sanitation closes shellfish grounds when concentrations of fecal coliform bacteria in the water rises above an acceptable limit of 14 parts per 100 milliliters. The bacterial count is used as an indicator of potential human disease.

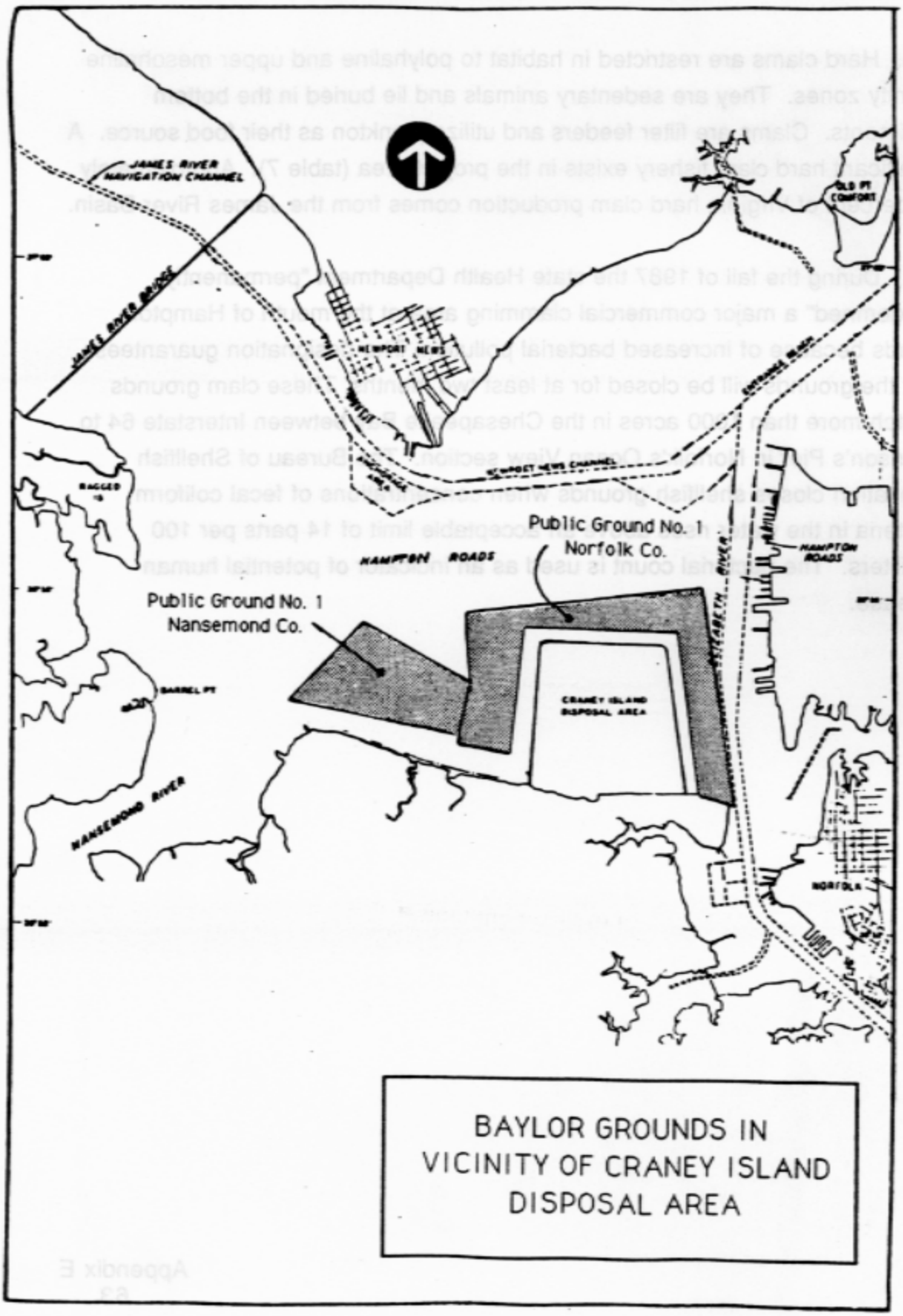


Figure 9. Baylor Grounds in vicinity of existing CIDA

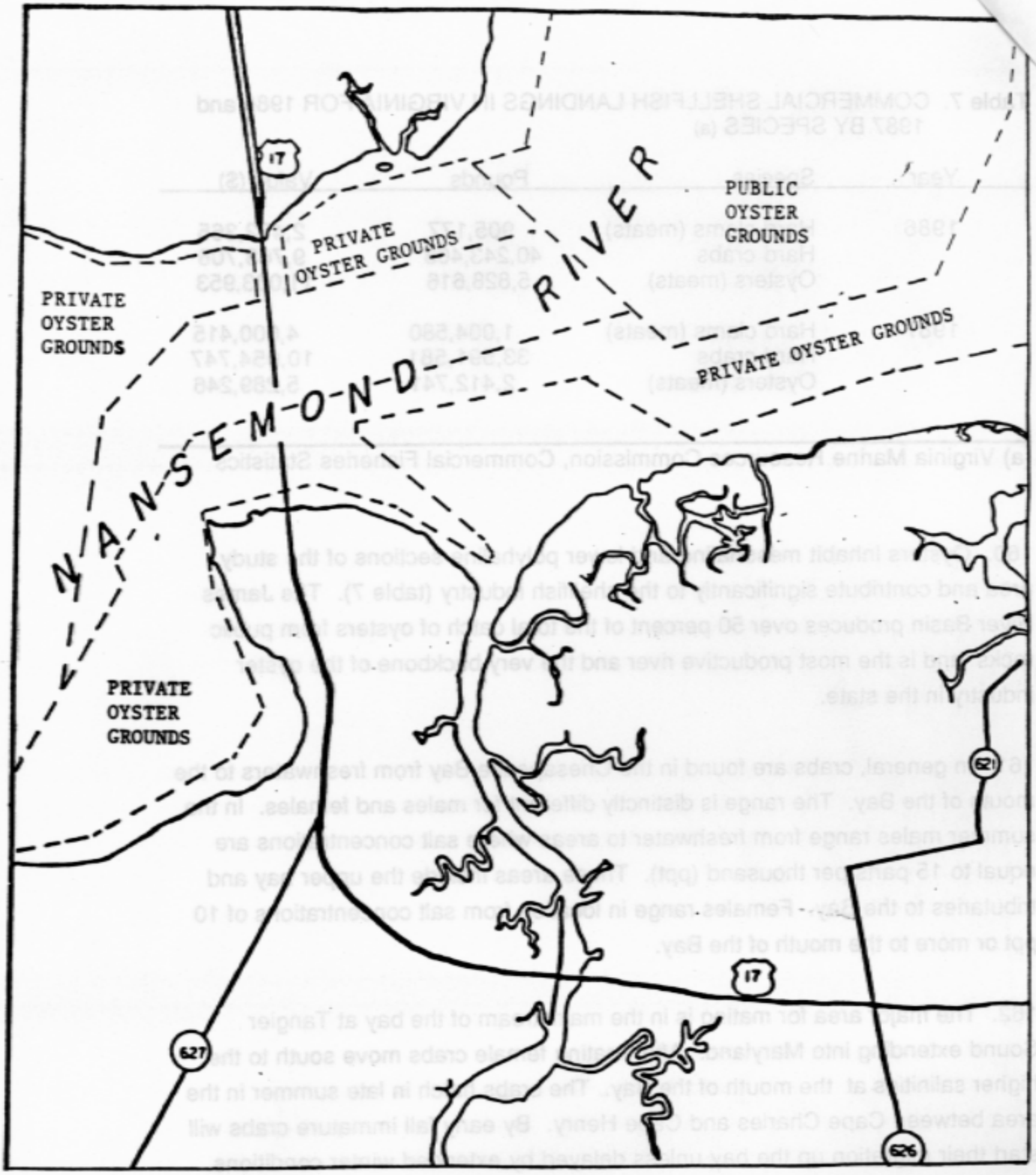


Figure 10 . Nansemond River Oyster Grounds

Table 7. COMMERCIAL SHELLFISH LANDINGS IN VIRGINIA FOR 1986 and 1987 BY SPECIES (a)

Year	Species	Pounds	Value ($)
1986	Hard clams (meats)	905,177	2,472,365
	Hard crabs	40,243,408	9,763,706
	Oysters (meats)	5,828,616	11,003,953
1987	Hard clams (meats)	1,004,580	4,000,415
	Hard crabs	33,591,581	10,054,747
	Oysters (meats)	2,412,741	5,289,246

(a) Virginia Marine Resources Commission, Commercial Fisheries Statistics

160. Oysters inhabit mesohaline and lower polyhaline sections of the study area and contribute significantly to the shellfish industry (table 7). The James River Basin produces over 50 percent of the total catch of oysters from public rocks and is the most productive river and the very backbone of the oyster industry in the state.

161. In general, crabs are found in the Chesapeake Bay from freshwaters to the mouth of the Bay. The range is distinctly different for males and females. In the summer males range from freshwater to areas where salt concentrations are equal to 15 parts per thousand (ppt). These areas include the upper bay and tributaries to the Bay. Females range in location from salt concentrations of 10 ppt or more to the mouth of the Bay.

162. The major area for mating is in the mainstream of the bay at Tangier Sound extending into Maryland. After mating female crabs move south to the higher salinities at the mouth of the Bay. The crabs hatch in late summer in the area between Cape Charles and Cape Henry. By early fall immature crabs will start their migration up the bay unless delayed by extended winter conditions.

163. In the winter both sexes of crabs move from the shallow to the deeper waters of the Bay. The winter habitat for males is in waters that are deeper than 40 feet and salinities over 5 ppt. Major areas are the canyons off Tangier Island

and within the Potomac River. Female crabs over winter in the lower bay in depths in excess of 30 feet which have salinities of greater than 20 ppt.

164. The lower bay is the major wintering ground for the female crab. Over 90% of the lower bay winter dredge catch is female. Female crabs often exhibit schooling at the wintering grounds and will move in mass from one location to another. Crab boats often dredge at depths of 20 feet to 30 feet and can be seen working together on the York Spit, Horseshoe, and Willoughby Bank. It is rare that crabs are taken at less than 15 feet during the winter season.

165. From this information it can be concluded that the winter ranges of crabs are very distinct with males overwintering in deeper waters of the upper bay and tributaries. Female blue crabs winter in the deeper waters of the lower bay. However, significant numbers of crabs are not known to overwinter in the Hampton Roads inner harbor area.

166. Commercial harvesting of blue crabs occurs throughout the James River, Hampton Roads, and Elizabeth River. Jones (1989) reports that commercial crab potters harvest in the area to the west of CIDA. However, Pleasants (1971 as reported in NUS, Corp. 1975) reports that the harvest of blue crabs in the lower James River/Hampton Roads area is lower than other areas of the Chesapeake Bay, probably due to the extensive commercial and recreational boat traffic that leads to the destruction and vandalism of the crab pots.

167. Plankton. The major zooplankton groups represented in the waters adjacent to CIDA include the copepods, mysids, amphipods, decapods, cladocera, ostracods, and cirripedians. The most abundant forms are the copepods and decapods. Common throughout the year, with peak numbers occurring between late fall and winter is the copepod *Acartia tonsa*. Blue crab larvae are abundant during the early summer and fall months coincident with their peak spawning periods. The major phytoplankters in Hampton Roads are neritic north temperate species dominated by diatom species. The diatoms are generally the most common group throughout the year, with the phytoflagellates the most abundant during the summer months.

168. The phytoplankton and zooplankton populations are what might be considered as typical for such an estuary system. Their entry and departure from the estuary is mainly a result of tidal movements; however, their abundance and diversity are determined by many environmental factors such as temperature, pH, salinity, season, and available nutrients. The nutrient rich waters that are typical of this estuary support these populations. Unusual bursts of growth are common during the summer months when blooms of dinoflagellates occur in adjacent rivers, and occasionally in Hampton Roads. These surges of population growth frequently follow a period of rain in the drainage basin and the subsequent transport of nutrients to river and bay waters.

169. Finfishes. Over the past decade several studies of fish abundance and distribution have been conducted in the general Hampton Roads area, most as a portion of the environmental impact assessment of one project or another. Two which apply to the study area are the environmental assessment report for the Portsmouth Refinery, NUS Corp. (1975) and a study of dredging effects in Hampton Roads edited by Priest (1981). Musick (1972) lists 209 species of marine estuarine and diadromous fishes as at least occasionally found in the Chesapeake Bay. Of these, 109 were considered by him to be sporadic or rare in occurrence. Only 27 estuarine and anadromous species, and 2 marine species were noted as occupants of the bay throughout their entire life cycle. The resident species are made up largely of small species inhabiting grass beds, oyster reefs and marsh fringes. None are of more than minor commercial importance and all are widely distributed.

170. The Craney Island Disposal Area (CIDA) is located in the Hampton Roads estuarine complex. A study of the estuarine ecology was conducted in the area west of CIDA. Water depths range from about 15 feet adjacent to the northern levee to less than 1 foot near the Portsmouth shoreline. The waters in this area support rather diverse benthic and neretic communities and a survey of existing conditions was conducted by Old Dominion University Research Foundation. Between November 1972 and October 1973, monthly fish trawls were taken. The sampling consisted of at least two ten-minute trawl hauls with a standard 10-foot otter trawl. Additional sampling using dredges, seines, and commercial clam tongs supplemented the trawl collections. A total of 33 species of fish

were collected and identified at this site. A high percentage of the fish biomass at this site consists of commercially important species (e.g., croaker, spot, flounder, and shad). Commercial crabbing and recreational fishing are limited in the area; however, the site supports a rather large commercial shad fishery in March and April.

171. Birdsong et al. (1984) investigated the finfish seasonality and utilization of Hampton Roads and its entrance channels for the U.S. Army Corps of Engineers. Eight trawl stations (figure 11), which each comprised of three 10-minute tows with a 16 foot wide otter trawl, were collected monthly from January 1982 through January 1984. During this study 104 species of fishes were taken. Summation of the trawl catch data for Station 5, located at the mouth of the Elizabeth River near CIDA, is shown in table 8.

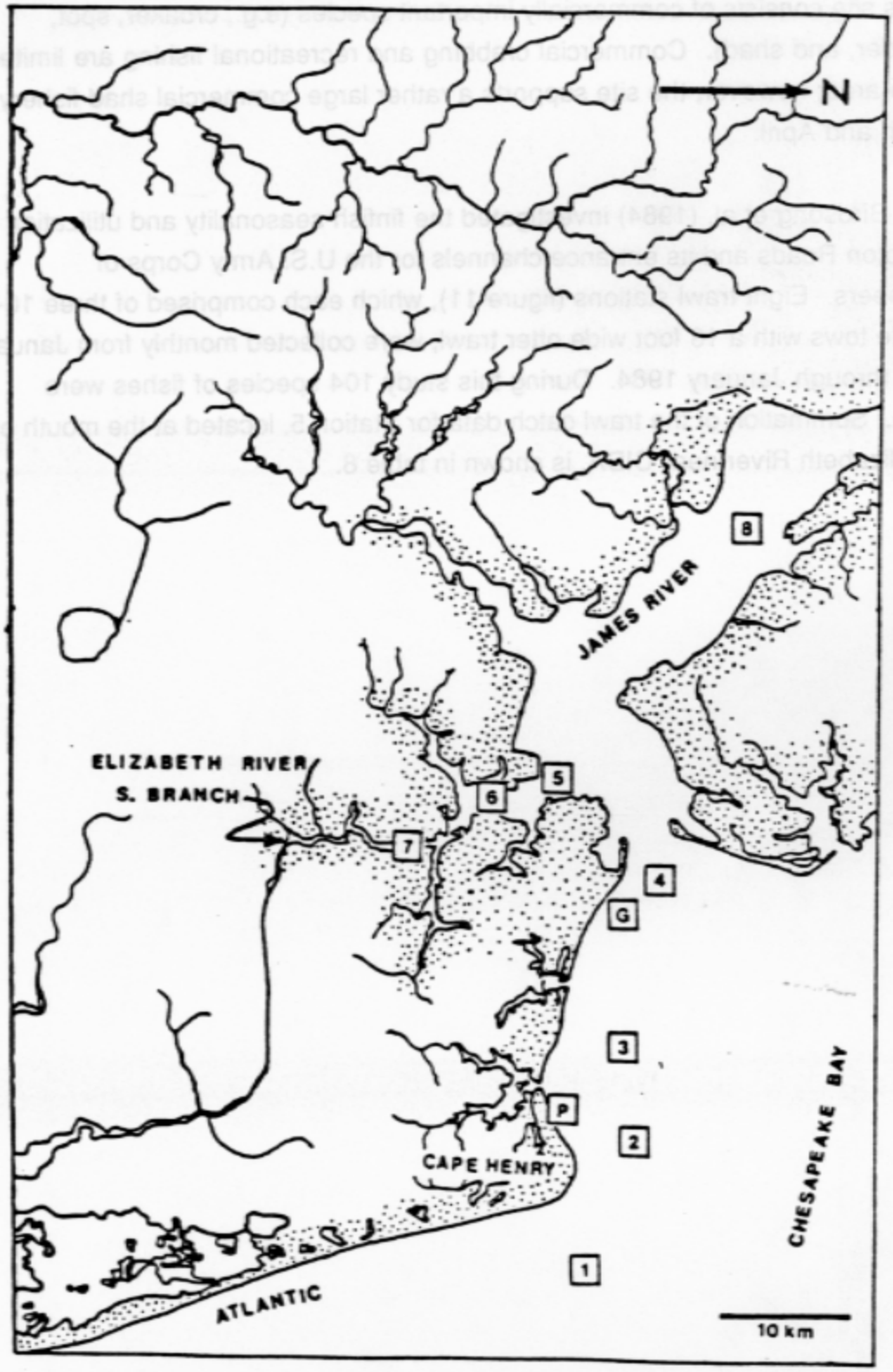


Figure 11. Hampton Roads and entrance channel - Eight trawl stations (numbered squares), gillnet station (G), poundnet station (P) (from Birdsong, et al., 1984)

Table 8. FINFISH IN VICINITY OF CRANEY ISLAND DISPOSAL AREA (CIDA) AND ELIZABETH RIVER

Species	Number Caught	Rank Among Stations
Fishes		
Anchoa mitchilli	9,750	2
Leiostomus xanthurus	2,261	5
Cynoscion regalis	338	6
Brevoortia tyrannus	213	2
Urophycis regia	206	4
Micropogonias undulatus	174	7
Trinectes maculatus	96	5
Paralichthys dentatus	95	6
Alosa aestivalis	50	3
Menidia menidia	28	7
Urophycis chuss	27	3
Opsanus tau	19	4
Squids		
Lolliguncula brevis	58	4
Total Species Caught	**33**	**6**
Total Specimens Caught	**13,309**	**3**

172. Finfish were the focus of study under several contracts associated with the Norfolk Harbor and Channels and Deepening Study. Primarily of interest in these investigations was the distribution and abundance and seasonal use patterns of commercial and recreational fisheries of Hampton Roads, the lower Chesapeake Bay and adjoining offshore waters. Trawl nets, gill nets, and pound nets were employed in the field studies to attempt to obtain the information desired. There were also interviews conducted with local charter boat captains and commercial fisherman and an extensive review of the literature accomplished to supplement the field investigations. A physical model was used to evaluate salinity-related habitat impacts associated with the proposed deepening.

173. The findings of the studies performed confirm that the study area supports a relatively abundant and diverse commercial and recreational fishery. Distribution and abundance of the individual species depend on the spawning habits and environmental preferences of the fish and the season of the year. Fish migrate into and out of the Bay throughout the year en route to spawning grounds and juvenile development areas. Individual species of commercial and recreational importance are highlighted in the study reports with regard to their seasonal and size distribution, spawning areas and nursery areas (Birdsong, Bedenbaugh and Owen, 1984 and 1984a). These studies are summarized in the Supplemental Information Report (SIR) entitled "Summary of Field Investigations, 1982-1985, Norfolk Harbor and Channels, Virginia, Deepening and Disposal", dated April 1986.

174. In spite of the heavy industrialization of the Elizabeth River, many fishes use it as a nursery area, and some for spawning. Work done by Ecological Analysts, Inc. in 1979 (as cited in Priest, 1981) shows the presence in the Southern Branch of eggs or larvae of gizzard shad, bay anchovy, tidewater silverside, Atlantic silverside, white perch, gobies, and hogchoker. Hedgepeth, et al. (1981) indicates the probability of some spawning in the upstream tidal creeks of the Elizabeth River by blueback herring, alewife, American shad, and striped bass. Birdsong, et al. (1984) found the Elizabeth River mainstem stations among the most prolific producers of fishes. Station 6 (figure 11) ranked first in the abundance of the bay anchovy, Atlantic croaker, spotted hake, weakfish, blueback herring, Atlantic silverside, and silver perch. This station was also the second largest producer of spot and the largest producer of all species combined. Station 7, located 4 miles upstream, differed markedly in having a significantly lower abundance of fishes and the lowest species diversity of any station sampled.

175. Many species of commercial importance utilize the James River as a spawning ground, including some sections of the study area (table 9). The Hampton Roads harbor area is considered polyhaline (18 to 30 parts per thousand) and is used by many marine species as a nursery area.

Table 9. APPROXIMATE SPAWNING AND NURSERY AREA LOCATIONS OF SOME IMPORTANT FISHES OF THE PROJECT AREA (a)

Anadromous Species

Miles above James River Mouth	Alewife S(b)	Alewife N(c)	Blueback Herring S	Blueback Herring N	American Shad S	American Shad N	Striped Bass S	Striped Bass N
0-10								
11-20				X				
21-30		X		X		X		
31-40	X	X	X	X		X		X
41-50	X	X	X	X		X		X
51-60	X	X	X	X		X	X	X
61-70	X	X	X	X	X	X	X	
71-80	X	X	X	X		X		
81-90	X		X					
91-100	X		X					

Estuarine and Oceanic Species

Miles above James River Mouth	Croaker S	Croaker N	Gray Trout S	Gray Trout N	Spot S	Spot N	Menhaden S	Menhaden N
0-10		X		X		X	X	
11-20		X		X		X		
21-30		X		X		X		
31-40		X						
41-50		X						

Freshwater Species

Miles above James River Mouth	White Perch S	White Perch N	Catfish S	Catfish N
0-10				
11-20				
21-30				
31-40				
41-50	X	X		
51-60	X	X	X	
61-70	X	X	X	X
71-80				X

(a) Hampton Roads Sanitation District. 1976. Hampton Roads Water Quality Management Plan. Appendix 9 Environmental Assessment. Volume A.
(b) Spawning locations.
(c) Nursery areas.

Table 10 identifies several important commercial and recreational fishes found in the Hampton Roads estuary by both common and scientific names.

Table 10. IMPORTANT FINFISH SPECIES - HAMPTON ROADS ESTUARY

Common Name	Scientific Name
Sea Lamprey	*Petromyzon marinus*
Atlantic Sturgeon	*Acipenser oxyrhynchus*
Longnose Gar	*Lepisosteus osseus*
American Shad	*Alsoa sapidissima*
Blueback Herring	*A. aestivalis*
Alewife	*A. pseudoharengus*
Hickory Shad	*A. mediocris*
Bay Anchovy	*Anchoa mitchilli*
Atlantic Menhaden	*Brevoortia tyronnus*
Gizzard Shad	*Dorosoma cepedianum*
White Catfish	*Ictalurus catus*
American Eel	*Anguilla rostrata*
Striped Bass	*Morone saxitalis*
White Perch	*M. americana*
Atlantic Croaker	*Micropogon undulatus*
Spot	*Leiostomus xanthurus*

Wetlands

176. Wetlands are extremely important entities to the natural aquatic ecosystem in that they are highly productive systems which produce large volumes of organic matter available to estuaries and they provide spawning grounds for various species of finfish, particularly shad and herring (Silberhorn, 1976). Large flocks of duck and geese feed in marsh areas during migration and numerous birds make their homes in wetland areas. Fringing marshes protect the shoreline and pocket marshes at the upper ends of tidal creeks, and filter out sediments from upland run-off. Small cove marshes, fringed with saltmarsh cordgrass, support large numbers of juvenile fish. Marshes also improve water quality and help control erosion and flooding. Virginia's coastal wetlands represent one-half of one percent of the state's total area, yet approximately 95 percent of the commercial and recreational fishes in Virginia are dependent upon the existence of these marshes (Silberhorn, 1976).

177. Man's impact on wetlands has been great and for many years marshes have been filled in, channeled, and destroyed for various reasons. In 1972, the Virginia General Assembly took a positive step to protect and enhance the marine environment of the Commonwealth by passing the Wetlands Act. Since

July 1 of that year, a permit has been required before any activity may be performed in the Commonwealth that may affect tidal wetlands. The definition of wetlands according to the Act is "all land lying between and contiguous to mean low water and an elevation above mean low water equal to the factor 1.5 times the mean tide range...and upon which grow one or more specific types of vegetation". Nonvegetated wetlands include the land lying between and contiguous to mean low water to an elevation of mean high water not otherwise considered "vegetated wetlands". State and Local wetlands are limited to tidal areas of the Commonwealth. There are about forty species of plants listed which are the most common types found in the tidal salt water, brackish water, and freshwater wetlands.

178. The Federal definition of wetlands is "Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions." Federal wetlands generally include swamps, marshes, bogs, and similar areas. It should be noted that in many cases the federal definition of wetlands includes areas at higher elevation than 1.5 times the mean tide range and are not limited to tidal areas.

179. Most marshes are dominated by a single plant species with other characteristic species present in varying degrees by abundance. For purposes of management (VIMS Tidal Marsh Inventories) the marsh types are described according to their dominant species. The brackish water mixed community in the study area is described as having no dominant species present. Associated vegetation found in this type of wetland is as follows: saltmarsh cordgrass (Spartina alterniflora), saltmeadow hay (Spartina patens), saltgrass (Distichlis spicata), black needlerush (Juncus roemerianus), salt bushes (Iva frutescens), three-square (Scirpus americanus), big cordgrass (Spartina cynosuroides), and cattails (Typha spp.). There is a heterogeneous mixture of plants in wet areas, and this community extends from about mean sea level to the upland margin. The average density is highly variable, and the annual productivity and detritus availability is 3 to 4 tons per acre. Detritus is readily available in the intertidal zone.

180. The major tidal marshes greater than 200 acres and located in the James River study area are as follows:

a. A 270 acre marsh (Ballard Marsh) is located on a point above Ragged Island on the west shore of the James River. This marsh contains 30 percent saltmarsh cordgrass; 10 percent big cordgrass; and 40 percent black needlerush.

b. A 214-acre marsh (East Island Marsh) located on Ragged Island contains 30 percent saltmarsh cordgrass; 35 percent black needlerush; and 20 percent saltmarsh hay.

c. A 310-acre marsh is located on Ragged Island bordering Ragged Island Creek and it contains 25 percent saltmarsh cordgrass; 40 percent black needlerush; and 20 percent saltmarsh hay.

181. The faunal constituents of the brackish water marsh generally make use of both the terrestrial and aquatic portion of their total habitat and the most common group of animals associated with marshes are the wading birds. Wading birds common to the study area include the great blue heron (Ardea herodias), snowy egret (Leucophoyx thula), common egret (Casmerodius albus), green-backed heron (Butorides virescens), and little blue heron (Florida caerulea).

182. The shore birds (sandpipers, willets, and plovers) are associated with brackish or salt water systems on exposed shores and mudflats. Typical salt marsh inhabitants are the rails, including sora (Porzana carolina), clapper rail (Rallus longirostris), Virginia rail (R. limicola), and king rail (R. elegans). A wide variety of ducks, geese, loons, and brants utilize such marshes as feeding and resting places.

Endangered Species

183. The Endangered Species Act of 1973 (Public Law 93-205) provides a means to conserve the ecosystems upon which endangered species and threatened species depend. Endangered species are those in danger of extinction throughout all or a significant portion of their ranges; threatened

species are those which are likely to become endangered within the foreseeable future throughout all or a significant portion of their ranges.

184. The following is a list, provided by the U.S. Fish and Wildlife Service, of endangered or threatened animals which may occur in the Hampton Roads harbor area:

SPECIES	STATUS
Birds	
Bald eagle (Haliaeetus leucocephalus)	Endangered
American peregrine falcon (Falco peregrinus)	Endangered
Red-cockaded woodpecker (Picoides (=Dendrocopos) borealis)	Endangered
Piping plover (Charadrius melodus)	
Mammals	
Dismal Swamp Southeastern Shrew (Sorex longirostris fisheri)	Threatened
Reptiles	
Green sea turtle (Chelonia mydas)	Threatened
Hawksbill sea turtle (=carey) (Eretmochelys imbricata)	Endangered
Leatherback sea turtle (Dermochelys coriacea)	Endangered
Loggerhead sea turtle (Caretta caretta)	Threatened
Kemp's (=Atlantic) ridley sea turtle (Lepidochelys kempii)	Endangered

Fishes

Shortnose sturgeon (Acipenser brevirostrum)	Endangered

185. The shortnose sturgeon is an anadromous subspecies and was formerly known from the Atlantic seaboard rivers from New Brunswick to Florida, but recent records are limited to the Hudson River and one Florida species. The shortnose sturgeon has previously been reported in the Chesapeake Bay; however, it has recently been scarce and its status is uncertain.

186. The only endangered or threatened species which would occur in the study area on more than an occasional or transient basis are marine turtles. The lower Chesapeake Bay is a summer foraging area for several populations of juvenile sea turtles. Evidence suggests that Chesapeake Bay is an important nursery for immature loggerheads (C. caretta) and Kemp's ridleys (L. kempii) turtles. The Virginia Institute of Marine Science (VIMS) has initiated a sighting program in which they have positively identified over 1,000 turtles. Other data accumulated indicates an estimated 3600 loggerheads and 270 Kemp's ridleys moving into the Bay each summer to forage. Migration from wintering sites near Cape Hatteras, North Carolina and from as far south as Florida begins about the end of May, as water temperatures reach 20 degrees C (Musick, et. al., 1984).

187. The lower Chesapeake Bay is known to be a summer foraging area for several populations of juvenile sea turtles. Five species of sea turtles have been recorded in the Bay: the loggerhead (C. caretta), the Kemp's ridley (L. kempii), the leatherback (D. coriacea), the green turtle (C. mydas), and the hawksbill (E. imbricata). All are afforded "threatened" or "endangered" status. Only two species occur regularly and in large numbers: C. caretta and L. kempii. The loggerhead is the most common of the Chesapeake Bay's sea turtles and can be found during the spring, summer, and fall. The Kemp's ridley, which is much smaller in size, is the next most abundant. Both of these species penetrate far up the estuary into the James and York Rivers, among others. Foraging occurs in the river mouths and in the channels of the Bay. The

occurrence of substantial numbers of immature turtles in Chesapeake Bay suggests that these species rely upon the Bay as a nursery ground.

188. In addition to a large winter population of bald eagles on the James River, there were three active nests on the river in 1981 between Charles City and Surry Counties. There is, however, no active nesting within the immediate project area. The red cockaded woodpecker requires mature pine forests for habitat and no extensive areas of this type forest exist adjacent to the study area; however, this bird's range extends into the Dismal Swamp. The only known rookery in the study area occurs on Craney Island where the least tern (Sterna antillarum) nests each year. The least tern is a Federally listed endangered species in certain ranges within the U.S.A. (Virginia excluded).

189. The peregrine falcon (Falco peregrinus), whose subspecies F. peregrinus anatum (American) is listed as endangered and F. peregrinus tundris (Artic) is listed as threatened, are commonly found in the vicinity of Craney Island. Davis (1988) indicates that the concentrations of waterfowl and shorebirds within the Craney Island Disposal Area and to the west of the site provide an extensive prey base for peregrine falcons. The open expanse of the disposal area and adjacent area in Hampton Roads is important for the peregrine's foraging strategy. Davis questioned ornithologists who regularly observed birds at Craney Island over a number of years. These ornithologists indicated that the Craney Island area is an important wintering and fall migratory stop for peregrines, acting as an "ecological magnet" for the birds. Recently, peregrine falcons have nested at a site on the James River approximately 22 miles upriver from Craney Island. Davis states that the Craney Island area may, therefore, be used by both resident and migrant falcons throughout the year.

190. Sorex longirostris fisheri, the Dismal Swamp southeastern shrew, is on both state and Federal lists as "threatened", primarily because of its very limited range and because of the alteration of its habitat (i.e., draining of the Dismal Swamp and related activities of man, such as logging and control of fires). Almost nothing is known of the life history of the southeastern shrew, for no studies involving mark-and-release methods have been attempted (Rose, 1983).

191. The U.S. Fish and Wildlife Service and the National Marine Fisheries Service have been consulted regarding responsibilities under Section 7 of Public Law 93-205, the Endangered Species Act, as amended, as they pertain to this long term disposal investigation.

SOCIOECONOMIC ENVIRONMENT

192. The Hampton Roads study area for this report is made up of the Norfolk-Virginia Beach-Newport News Metropolitan Statistical Area (MSA) with Gloucester County excluded and Isle of Wight County included. The MSA is made up of the old Norfolk-Virginia Beach-Portsmouth Standard Metropolitan Statistical Area(SMSA) and the Newport News-Hampton SMSA. The specific political jurisdictions encompassed in this area are listed in table 11.

Table 11. Population Data

	1970	1980	1987	1990	2000	2010	2020	2030	2040*
SOUTHSIDE HAMPTON ROADS									
Chesapeake	89,580	114,486	141,500	143,000	163,000	183,000	203,000	223,000	243,000
Isle of Wight County	18,285	21,603	25,100	24,500	26,200	27,900	29,600	31,300	33,300
Norfolk	307,951	266,979	280,800	274,700	280,000	285,300	290,600	295,900	301,200
Portsmouth	110,963	104,577	110,100	114,800	117,100	119,400	121,700	124,000	126,300
Suffolk	45,024	47,621	52,200	55,500	64,500	73,500	82,500	91,500	100,500
Virginia Beach	172,106	262,199	350,100	362,600	426,200	489,800	553,400	617,000	680,600
PENINSULA									
Hampton	120,779	122,617	128,000	128,700	132,500	136,300	140,100	143,900	147,700
James City County	17,853	22,339	27,200	30,900	36,600	42,300	48,000	53,700	59,400
Newport News	138,177	144,903	162,800	165,100	176,600	188,100	199,600	211,100	222,600
Poquoson	5,441	8,726	10,900	11,700	14,300	16,900	19,500	22,100	24,700
Williamsburg	9,069	10,294	12,000	11,400	12,600	13,800	15,000	16,200	17,400
York County	27,762	35,463	41,100	44,000	49,600	55,200	60,800	66,400	72,000
TOTAL	1,062,990	1,161,807	1,341,800	1,366,900	1,499,200	1,631,500	1,763,800	1,896,100	1,956,700

*Projections based on continuation of trend

Sources: Virginia Dept. of Planning and Budget
1987 population figures are provisional estimates from Tayloe Murphy Institute

Population

193. The Hampton Roads area is the second most populous metropolitan complex in the state. The area's population grew from 1,062,990 in 1970 to 1,161,807 in 1980, an increase of about 9 percent. Provisional estimates published by the Tayloe Murphy Institute give the area a 1987 estimated population of 1,341,800, an increase of slightly over 15 percent in 7 years. This rate of growth is significantly higher than that of the state as a whole, which showed an increase of about 10 percent for the same time period, and indicates that the pace of growth is currently fairly high.

194. Within the the study area, growth rates vary considerably from place to place. An examination of table 11, which shows past and projected population for the study area cities and counties, reveals that most of the growth is occurring in the jurisdictions that have large tracts of vacant land for expansion. On the southside most of the growth has been and will continue to be in Chesapeake and Virginia Beach, while on the Peninsula the growth centers are the counties and northern Newport News.

195. Projections for population through the year 2040 show continued growth but at a decreasing rate. The more developed cities are projected to maintain roughly their existing population counts with very small increments of growth while the the more suburban cities and counties will expand as development spreads to the currently vacant areas.

196. One area of particular interest in this study is the northwestern section of Portsmouth and the northeastern portion of Suffolk because of its proximity to the existing Craney Island. Any changes in the use or operation of Craney Island (an inevitability) could potentially affect this geographical area directly. This area has been growing at a much faster rate than either Portsmouth or Suffolk as a whole have been. The census tracts which encompass this section of these cities showed a 46 percent increase in population between 1970 and 1980, offsetting population losses in other parts of the cities. Growth has continued here since 1980 primarily because there is still vacant land which is conveniently located to employment and commercial centers in the region. Projections for the near future by regional planning officials show major growth

in the Portsmouth portion of the area and even faster growth in the Suffolk portion, which would more than double its population by the year 2010.

Housing

197. The number of housing units has been increasing in every locality within the study area since 1970 in spite of population declines in some cities and relatively little change in other cities. Housing increases in slow or no growth areas can be attributed to the decline in the persons per housing unit, a figure which has been decreasing nationwide in recent years. In the cities and counties where growth is more rapid in-migration has fueled much of the new housing construction.

198. Housing patterns throughout the region vary from locality to locality with the faster growing areas having higher median home prices. The 1980 U.S. Census figures showed Portsmouth at $36,600 with the lowest value for owner-occupied housing units followed closely by Suffolk and Norfolk. The highest median values were found in Williamsburg, Poquoson, York County, and Virginia Beach, which averaged about $60,000. Since 1980, housing costs have escalated considerably, in some cases as much as doubling. However, the overall ranking of housing prices within the region has remained relatively constant during this same period.

199. Housing throughout the region is predominantly owner-occupied except in the cities of Williamsburg and Norfolk, where there is more rental housing. In Norfolk the presence of large numbers of military personnel has created a large market for rental housing, while in Williamsburg the high proportion of such housing is due, in large part, to the existence of a major college.

200. The housing in the area in Portsmouth adjacent to Craney Island, which is known as Churchland, is very heavily owner-occupied with values considerably above the median for the city as a whole. The area is one of the most stable sections of the city with less housing turnover than much of the rest of the city and the region as a whole. Housing in the section of Suffolk next to this area is almost totally owner-occupied and has values slightly less than those of the Churchland area, based on 1980 census data.

201. The area along the water immediately west of Craney Island, known as River Shores, was originally farm land. In the early 1950's it was divided into residential lots, with home construction beginning at that time and continuing through the early 1970's. The construction of the levees for Craney Island took place from August 1954 to January 1957, about the same time as the River Shores area began to be developed. After levee construction was completed, significant amounts of material began to be deposited in the containment area, a practice which still continues. Residential development in the area adjacent to and in the vicinity of Craney Island continues to flourish even with the presence of the disposal area.

Development and Economy

202. The economy of the Hampton Roads area is based on the military, port-related activity, and tourism. These are the basic industries that generate an inflow of income from outside the region, which then provides the impetus for the trade, services, and other sectors of the economy. Conditions in the basic industries play a large role in determining the health and growth patterns of the area's overall economy.

203. Employment. The military establishment in the Hampton Roads area is the largest concentration of military activity in the country. Over 40 percent of the area's population is associated in some manner with the military. As of 1984 military earnings made up 20 percent of the area's total earnings and almost a fourth of the total earnings on the southside. The largest regional military facilities are the naval installations in the Norfolk-Portsmouth area and the Army and Air Force bases in the Newport News-Hampton area.

204. The port of Hampton Roads is the leader in export tonnage and second only to the port of New York in total export-import tonnage in the United States. The Hampton Roads port is oriented chiefly toward bulk cargo, with coal being the major export product. U.S. Department of Commerce figures quoted by the Hampton Roads Maritime Association show that the value of exports moving through Hampton Roads has fluctuated in the years between 1983 and 1987 and was valued at approximately $6.8 billion in 1987.

205. Although the manufacturing sector of the area's economy is somewhat smaller proportionally compared to the state's economy, it is still a significant part of the regional employment picture. Much of the manufacturing that occurs is related to the military or to the commercial port facilities. The largest private employer in the area, Newport News Shipbuilding and Drydock Company, provides 70 percent of the the Peninsula's manufacturing employment and 17 percent of the Peninsula's total employment. Newport News Shipbuilding performs all the area's naval construction, which makes up almost all of the regional shipbuilding activity, and some repair work. However, the majority of the commercial and military ship repair work is done on the southside.

206. The third basic sector of the economy, tourism, employs roughly the same number of people on the southside as on the Peninsula. Jobs generated by tourism are a part of the services sector, which is the largest employment category for the region in the census classification system. On the southside the tourist industry is centered in Virginia Beach, which attracts a broad range of visitors primarily because of its beaches and the recreational facilities associated with them. By contrast, the Peninsula's attractions are more heavily historical and educational, which appeal to a more homogeneous upper-middle class type of visitor.

207. Hampton Roads, including the ports of Norfolk, Portsmouth, Chesapeake, Newport News, and Hampton, comprises Virginia's greatest port complex. Deep-draft navigation has long been a key to its commercial, agricultural, and industrial development. The movement of a large volume of waterborne commerce, together with the presence of major naval facilities, has made Hampton Roads one of the nation's leading ports. In fact, it is by far the largest port exporting bituminous coal from the United States. For a maritime economy to grow and accommodate the diversified needs of the area, adequate navigation channels must be maintained and deepened and disposal areas for dredged material must be provided.

208. Income. Income levels for the Hampton Roads area are slightly below those for the state and the nation although there is quite a bit of variation among the cities and counties in the area. Census data for median family income in 1979 showed Norfolk with the lowest figure and Poquoson with the highest. For

per capita income Norfolk and Portsmouth had the lowest figure and Poquoson and Virginia Beach the highest, based on census data.

209. Within the region, the northwest portion of Portsmouth and northeastern section of Suffolk are prosperous sections of their respective cities. Median family income levels in this area in 1979 were significantly higher than the state average and $7,000 to $9,000 higher than the medians for cities these areas are located in. Data on household income for 1987 for the zip code areas which encompass these tracts indicate that these characteristics have not changed significantly in the past decade.

210. Land Use. Waterfront land use varies throughout the study area. Most of the industrial and commercial development is located in Norfolk, Chesapeake, Portsmouth, Hampton, Newport News, and one section of Virginia Beach's oceanfront. Waterfront land use in Suffolk and Isle of Wight County is predominantly undeveloped or residential with a small amount of agricultural. There are also substantial sections of residential development along the James River in Newport News, the Chesapeake Bay in Norfolk and Virginia Beach, the Atlantic Ocean in Virginia Beach, and tributaries to these waterways throughout the region. Portsmouth, Norfolk, Virginia Beach, and Newport News have significant portions of waterfront property owned by the Federal or state government, particularly for military uses.

211. In general, the greatest concentrations of development occur in the older cities of Norfolk, Portsmouth, Hampton, and Newport News. Chesapeake, Virginia Beach, James City County, and York County have major residential sections with commercial centers to provide services to these areas. These localities also have some industrial development, but not the concentration of the older cities. The city of Suffolk and Isle of Wight County are primarily rural, with large tracts of agricultural and wooded land, although residential development is expanding into these areas from the more densely populated cities to the east.

Air Quality and Noise

212. Ambient air quality monitoring data are regularly collected at a number of sampling stations throughout the Commonwealth of Virginia. Hampton Roads

harbor is located in Air Quality Control Region (AQCR) -6. Pollutants sampled include suspended particulates (very small particles of matter which remain suspended in the air for long periods of time), sulfur dioxide (a gas which is emitted when coal or oil is burned), carbon monoxide (a gas which is produced by the incomplete burning of fossil fuels) and photochemical oxidants (such as gas ozone). Data for the pollutants monitored are available in the form of monthly summaries from the Virginia Air Pollution Control Board. The applicable Virginia Air Quality Standards are presented in table 12.

Historical and Cultural Resources

213. The Hampton Roads area is endowed with many archaeological and historic features, ranging from Yorktown (site of the British surrender during Revolutionary War) to Hampton Roads (site of the famous Civil War naval battle between the Monitor and the Merrimac). Several national and state registered historic sites exist in the Hampton Roads harbor area. Twenty-nine land archaeological sites, 18 nautical archaeological sites, and 13 historic landmarks have been identified as significant cultural and historic features.

214. The Virginia Department of Conservation and Historic Resources, Division of Historic Landmarks Commission, Research Center for Archaeology (VRCA) was contacted about the stabilization of the perimeter dikes of CIDA by letter of 6 February 1986. The project, which took place during 1987, involved reinforcement of the perimeter dikes using 3 to 5 million cubic yards of dredged material, extending from the base approximately 1000 feet. Their response, dated 14 February 1986, stated that " ...due to the archaeological potential of this location, as well as the project impacts, a Phase I archaeological field survey is necessary". They stated that "..the following five vessels are recorded as being located within the proposed project limits, therefore an underwater survey is recommended prior to stabilization of the Craney Island facility: (1) Schooner Mayflower - 1831, (2) Brig Eleanora - 1831, (3) Schooner Cleopatras Bargel - 1831, (4) Schooner Hero - 1831, (5) Sloop Anti-Tarriff - 1847". The Norfolk District has met with the Virginia Historic Landmarks Commission (VHLC). The VHLC assisted in designing the Phase I archaeological survey

TABLE 12

SUMMARY OF VIRGINIA AMBIENT AIR QUALITY STANDARDS

Pollutant	Time of Average	Primary Standard**	Secondary** Standard
Particulate matter	Annual (Geometric mean)	75 $\mu g/m^3$	60 $\mu g/m^3$
	24-hour	260 $\mu g/m^3$	150 $\mu g/m^3$
SO_x (Measured as SO_2)	Annual (Arithmetic mean)	80 $\mu g/m^3$ (0.03 ppm)	Same as Primary
	24-hour	365 $\mu g/m^3$ (0.14 ppm)*	Same as Primary
	3-hour	———	1300 $\mu g/m^3$ (0.5 ppm)
CO	8-hour	10mg/m^3 (9 ppm)*	Same as Primary
	1-hour	40mg/m^3 (35 ppm)*	Same as Primary
Hydrocarbons (nonmethane measured as CH_4)	3-hour (6 to 9 a.m.)	160 $\mu g/m^3$ (0.24 ppm)*	Same as Primary
NO_2	Annual (Arithmetic mean)	100 $\mu g/m^3$ (0.05 ppm)	Same as Primary
Oxidants (Measured as O_3)	1-hour	160 $\mu g/m^3$ (0.08 ppm)*	Same as Primary

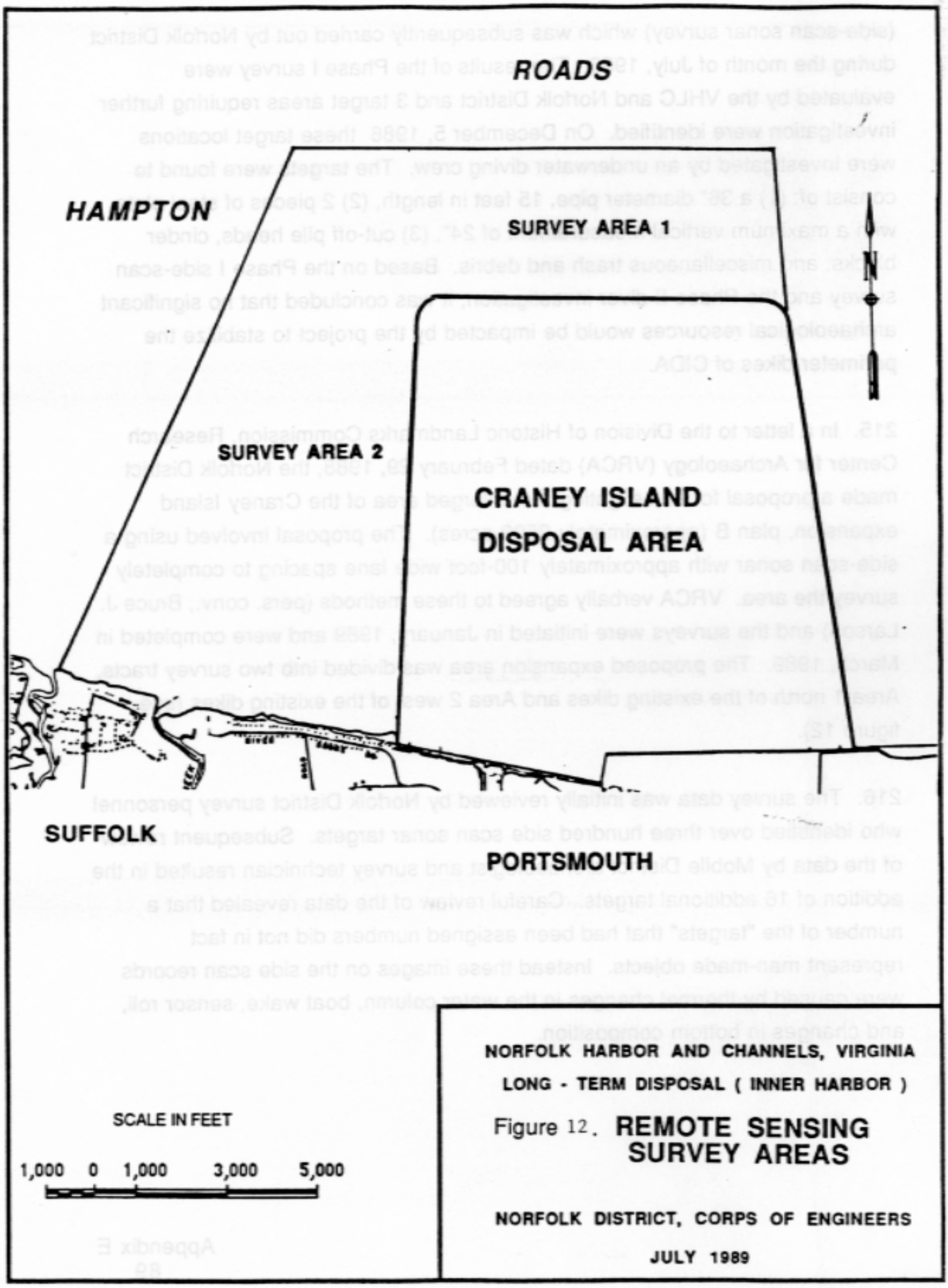
* Concentration not to be exceeded more than once per year

** Concentration in weight per cubic meter (corrected to 25°C and 760 mm of Hg)

(side-scan sonar survey) which was subsequently carried out by Norfolk District during the month of July, 1986. The results of the Phase I survey were evaluated by the VHLC and Norfolk District and 3 target areas requiring further investigation were identified. On December 5, 1986 these target locations were investigated by an underwater diving crew. The targets were found to consist of: (1) a 36" diameter pipe, 15 feet in length, (2) 2 pieces of steel plate with a maximum vertical measurement of 24", (3) cut-off pile heads, cinder blocks, and miscellaneous trash and debris. Based on the Phase I side-scan survey and the Phase II diver investigation, it was concluded that no significant archaeological resources would be impacted by the project to stabilize the perimeter dikes of CIDA.

215. In a letter to the Division of Historic Landmarks Commission, Research Center for Archaeology (VRCA) dated February 29, 1988, the Norfolk District made a proposal for investigating the enlarged area of the Craney Island expansion, plan B (approximately 2500 acres). The proposal involved using a side-scan sonar with approximately 100-foot wide lane spacing to completely survey the area. VRCA verbally agreed to these methods (pers. conv., Bruce J. Larson) and the surveys were initiated in January, 1989 and were completed in March, 1989. The proposed expansion area was divided into two survey tracts, Area 1 north of the existing dikes and Area 2 west of the existing dikes (see figure 12).

216. The survey data was initially reviewed by Norfolk District survey personnel who identified over three hundred side scan sonar targets. Subsequent review of the data by Mobile District archaeologist and survey technician resulted in the addition of 16 additional targets. Careful review of the data revealed that a number of the "targets" that had been assigned numbers did not in fact represent man-made objects. Instead these images on the side scan records were caused by thermal changes in the water column, boat wake, sensor roll, and changes in bottom composition.


ROADS
HAMPTON
SURVEY AREA 1
N
SURVEY AREA 2
CRANEY ISLAND
DISPOSAL AREA
SUFFOLK
PORTSMOUTH
SCALE IN FEET
1,000 0 1,000 3,000 5,000
NORFOLK HARBOR AND CHANNELS, VIRGINIA
LONG - TERM DISPOSAL (INNER HARBOR)
Figure 12. REMOTE SENSING SURVEY AREAS
NORFOLK DISTRICT, CORPS OF ENGINEERS
JULY 1989

217. As would be expected in any active harbor, numerous small isolated targets ranging from crab traps to cable and pipe were seen throughout the survey area. Sunken dredge pipes and associated trenches were seen throughout the survey areas. Trawl and anchor scars were also noted throughout the areas. No clustering of targets that might represent vessel remains were identified in the side scan data nor were any of the individual targets of sufficient size or configuration to represent a sunken vessel. It was the conclusion of the Mobile District archaeologist that "...no additional underwater archaeological investigations appear to be warranted for the Craney Island Disposal (expansion) Site."

ENVIRONMENTAL EFFECTS

COMPARATIVE EFFECTS OF ALTERNATIVES

218. The environmental effects associated with the broad range of dredged material disposal alternatives initially considered is discussed in the "Plan Formulation" section of the main report and is shown in table 3. Environmental, economic, and engineering considerations discussed in "Evaluation of Alternatives" led to selection of the selected plans. The following detailed discussion of environmental effects deals with the selected plans of CIDA expansion (plan B) and ocean disposal alternatives.

ENVIRONMENTAL EFFECTS OF THE SELECTED PLANS

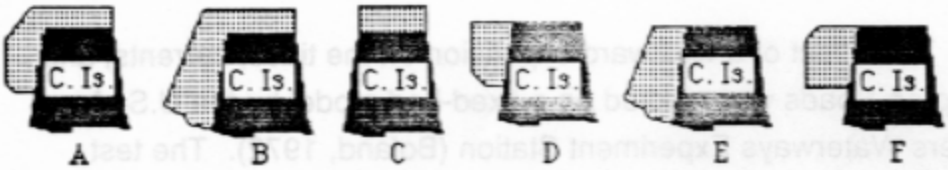
Significant Resources

Water Resources

219. *Hydrology*. The effect of a westward expansion on the tides, currents, and salinities of Hampton Roads was studied on a fixed-bed model by the U.S. Army Corps of Engineers Waterways Experiment Station (Boland, 1972). The test results indicated that using either one of two suggested levee configurations would have no significant effects on the local current velocities, salinities, or tidal heights. Questions concerning circulation patterns and resulting water quality in the area between the south dike of the proposed expansion and the

adjacent shoreline were raised. A careful study of the model results indicated that there will be essentially no flood flow in the eastern third of this area. The marsh areas adjacent to the two creeks that empty into this area, Hoffler Creek on the east and Streeter Creek on the west, total about 0.3 square mile and were not reproduced on the model. The addition of these marsh areas to the 0.5 square mile of area between the dike and the shoreline would considerably increase the tidal prism into the area, and this increase would be accompanied by increased current velocities. The resulting currents and tidal exchange should be of an amplitude to cause mixing of the new and old waters and prevent deterioration of water quality in the western two-thirds of the area. Very little water movement occurred in the area east of the mouth of Hoffler Creek, and it is suggested that the dike alignment be designed so as to avoid creation of a possible stagnant water area (Boland, 1972). This will be done during the advanced engineering and design phase and every effort will be made to insure that the tidal prism within Hoffler and Streeter Creeks remains comparable to that which exists at present.

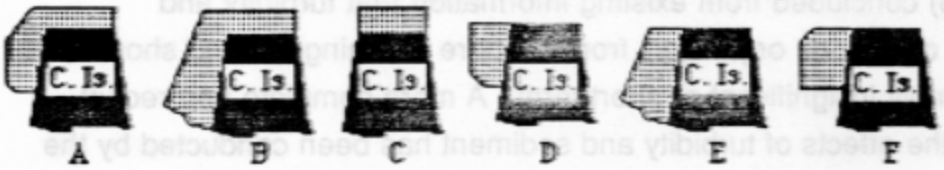
220. WES also performed a numerical model investigation during 1987 and 1988 (Heltzel and Granat, 1988). The primary objective of this investigation was to assess general changes in circulation, currents, and sedimentation associated with six proposed alternative expansion geometries of the Craney Island Disposal Area. An additional objective of the study was to assess the effects of each of the proposed expansions on the estuarine circulation cell (flow convergence) off Hampton Flats and Newport News Point. The following configurations were evaluated:



221. Circulation. With exception of the Newport News Channel, results from the modeling indicate no plan to base velocity differences greater than ±0.06 fps at several critical areas of interest (Willoughby Bay entrance, Hampton Flats,

Nansemond River entrance, and Burwell Bay). Velocity differences greater than 0.10 fps were indicated for the Newport News Channel. The greatest changes, less than 0.35 fps on ebb and 0.25 fps on flood, were indicated for plans A and B, the largest expansion alternatives also involving westward expansions.

222. Sedimentation. Results from sedimentation modeling showed that plan to base shoaling index values were all within ±10 percent at the critical points of interest. The Nansemond River entrance was the only area considered to demonstrate any distinct changes in base and plan sedimentation. Considering the existing low sedimentation in the critical areas examined (Nansemond R., Hampton Flats, Willoughby Bay, James River/Burwell Bay), the indicated differences are well within ordinary field survey detection limits. Shoaling rates in each of six areas of interest is low (less than 0.5 ft/yr). Plans D, E, and F (see below) resulted in increased sedimentation rates in the Nansemond River area (decreases in sedimentation were found for other configurations - Plans A, B, and C).



Plan A - 7% decrease (0.5 X .07 = .035 ft ≈ 2/5 inch per year)
Plan B - 6% decrease (0.5 X .06 = .03 ft ≈ 1/3 inch per year)
Plan C - 9% decrease (0.5 X .09 = .045 ft ≈ 1/2 inch per year)
Plan D - 4% increase (0.5 X .04 = .02 ft ≈ 1/4 inch per year)
Plan E - 3% increase (0.5 X .03 = .015 ≈ 1/5 inch per year)
Plan F - 7% increase (0.5 X .07 = .035 ft ≈ 2/5 inch per year)

223. The complete results of this investigation are found in Attachment 1 entitled Lower James River Circulation Study, Virginia, Evaluation of Craney Island Enlargement Alternatives (Heltzel and Granat, 1988).

224. *Water Quality*. Turbidity levels from construction activities are not expected to adversely impact anadromous fish that pass through the Hampton Roads Harbor into adjoining tributaries. The Corps conducted a study in which

estimates of turbidity resulting from construction activity involving 2 typical dredges were compared to ambient turbidity levels. The first was an 18-inch dredge with an average discharge rate of 500 cubic yards per hour. The second was a 30-inch dredge with an average discharge rate of 1500 cubic yards per hour. The study concluded that for the 18-inch and 30-inch dredges, a 1 to 5 percent increase, respectively, in the gross suspended sediment load can be expected. Moreover, the location of the discharge on the shallow, somewhat sheltered margin of the harbor would tend to confine the potential increase in suspended solids concentrations. Also, as it is constructed, the dike would be sequenced so as to increasingly impound suspended sediment within the confines of the dike impoundment.

225. Turbidity plumes at the construction site should have no significant direct physical impacts on aquatic organisms; however, the indirect impacts of lowered dissolved oxygen levels could be detrimental to aquatic life. Thompson (1973) concluded from existing information that turbidity and sediment effects on marine organisms from offshore dredging of sand should be considered generally insignificant or short term. A more complete and recent investigation on the effects of turbidity and sediment has been conducted by the U.S. Army Waterways Experiment Station (WES) in connection with their Dredged Material Research Program. Their conclusion, based on turbidity studies using marine, estuarine, and freshwater organisms, showed lethal concentrations of suspended material to be significantly higher than concentrations observed in actual dredging activities.

226. Overboard disposal of dredged materials, especially finer clays and silts, would cause the water column to become turbid, likely reducing light transmission and dissolved oxygen (DO) levels during construction activities. Open-water pipeline disposal operations and the associated distribution and concentration of DO was investigated by the WES Dredged Material Research Program (DMRP). Schubel, et. al. (1978). In this study they noted that in the receiving waters off the discharge site a clear depression in the levels of DO was observed and oxygen depression increased with depth. It is expected that water quality would return to ambient fairly rapidly following cessation of construction, however the increased suspended solids concentrations associated with overboard disposal during construction and the resulting

biochemical oxygen demand could have adverse effect on aquatic resources. In Hampton Roads Harbor the water quality standard for DO set by the Virginia State Water Control Board (VWCB) is 5.0 mg/l daily average and 4.0 mg/l minimum (4 mg/l is considered the minimum level for sustaining aquatic life in estuarine environments). In Hampton Roads Harbor the months of concern would be July through September when water temperatures are naturally higher and DO levels are lower.

227. During the construction of the CIDA stabilization project approximately 3 million cubic yards of dredged material from the Channel to Newport News were placed outside the existing CIDA dike structures to give lateral stability to the dikes. A monitoring plan for dissolved oxygen (DO) was recommended by the VWCB and was implemented during the period of June 1 through 30 September, 1987. Stations were located 250 feet, 750 feet and 2,000 feet (control) from the site of dredged material deposition. It was observed that DO levels stayed consistently near saturation, ranging from 7.8 to 9.1 mg/l during the construction period. Strong currents, wave action and winds in the harbor contribute to the elevated DO conditions.

228. The construction of the dike system and the early deposit of dredged materials would contribute fine silt to the surrounding waters. In order to minimize potential dissolved oxygen problems within the progressively confined site, a dike construction sequence of south-west-north should be considered. As the dike construction is completed and a sluice system becomes operable, a continual release of some fine silt would be expected from the settling area. This product would replace what is now being released from the present disposal area. This type of material, if present in excessive concentrations, could have a detrimental effect on the immediate environment. Heavy siltation could blanket the substrate, smothering many benthic species and even undergoing decomposition to the extent that reduced oxygen levels of the local water would follow. Such conditions are not anticipated, based on the operational results of the present disposal area which has been in operation for 30 years. Palermo, et al. (1981), sampled the effluent from CIDA for suspended solids. The results of this sampling indicated that CIDA is greater than 99.9% efficient in retaining suspended solids. If needed, there are operational adjustments that can be made to allow for longer residence time of the

deposited material. This would further minimize or eliminate the escape of suspended materials from the enclosed site.

229. *Sediment Quality (Unsuitable material only into CIDA)*. In the case of a recommendation involving the existing CIDA and DNODS and/or NDS, the existing CIDA must be preserved promptly for containment of dredged material not suitable for ocean disposal. Contrary to existing conditions, wherein unsuitable material represents about 9 percent of the total material deposited in CIDA, under this proposal, practically all the material placed into CIDA would be unsuitable. Various concerns may be expressed regarding this mode of operation, these include degradation of effluent water quality, public perception of CIDA as a toxic dump site, and jeopardized future use of the site, to mention a few. Concerns over the impacts associated with this management strategy are addressed by the following considerations:

230. Studies conducted by Old Dominion University have demonstrated that, over time, toxic materials placed in CIDA go through a weathering process which eventually renders them innocuous and they are at least suitable for ocean disposal. In fact, most of the sediments in CIDA today meet ocean disposal criteria as specified by EPA and the Corps. Although it may take longer to change the chemical structure of the sediments, weathering would continue even if *only* unsuitable sediments were placed in the site.

231. While it is true that dilution of unsuitable sediments with suitable sediments within CIDA would be reduced with the proposed management strategy (reserving CIDA for unsuitable materials only), dilution within the site would still take place. As proposed, only 37 % of new work and 50% of maintenance materials going into CIDA would be taken from the most contaminated reaches of the Southern Branch (Town Point to Mile 15). The remainder of the new work and maintenance (2,667,000 cubic yards and 110,000 cubic yards respectively) would be dredged from transitional or buffer areas to the north and south of the most contaminated reach of the Southern Branch. These buffer areas contain sediments which are "marginal", i.e., they are not suitable for ocean disposal but are marginally unacceptable by the EPA/Corps testing procedures. In this regard then, dilution of the most unsuitable materials coming from the Southern Branch would still be occurring

by a factor of almost two to one with the transitional or buffer sediments coming from the reaches to the north and south.

232. Scientifically, the dilution question may be a moot point since CIDA will receive the same total volume of unsuitable sediments whether it is managed to receive both types of material or only unsuitable material. The adage, "the solution to pollution is dilution", has long been dismissed as inadequate to answer the pollution question. In the case of CIDA, regardless of the management strategy employed, there is still the same total volume of contaminated material that must be handled, stored, and carefully monitored and managed over time.

233. The City of Portsmouth, in 1987, formed a Craney Island Study Commission and contacted representatives from the Virginia Institute of Marine Science, Old Dominion University, the Virginia Water Control Board and the Army Corps of Engineers (Washington, D.C.). The City of Portsmouth presented its recommendations based upon the Commission findings in a letter to the Norfolk District dated November 13, 1987. The recommendations of the Commission Chairman included: (1) placing all suitable dredged material from the inner harbor in the Norfolk Disposal Site; (2) that all unsuitable dredged material from the Southern Branch and other private sources be placed in the CIDA until the Southern Branch is cleaned up; and (3) when the Southern Branch is cleaned up, all suitable material should then go in the ocean disposal site. Based upon these recommendations, it is doubtful that Portsmouth, or the other agencies represented by the Commission, would have any problem with placing all suitable materials in the ocean and reserving CIDA for unsuitable materials only.

234. Studies by WES and others have demonstrated that the operation of CIDA is greater than 99.9% efficient when it comes to retaining the sediments placed therein (Palermo, et al., 1981). Trace metals and most organic compounds of concern in the Southern Branch display a strong affinity to fine-grained (cohesive) sediment. The transport, deposition and resuspension of such sediment-bound chemicals determines the exposure to, and effects on, organisms in the water column as well as those on or in the sediment substrate. Since the toxics (heavy metals and organics) are tightly bound to the sediments,

they too are being retained along with the sediments in the confined site. Because of this efficiency in retaining sediments, there is no apparent concern over the toxicity of the effluent coming from CIDA, and this should not change - even if *only* unsuitable materials are placed in the site.

235. The Virginia Water Control Board (VWCB) has an ongoing program for the management of toxics in discharges from point sources such as those located in the Southern Branch. The Toxics Management Regulation was adopted by the VWCB and became effective in 1988. This regulation is designed to provide standards and procedures to minimize, correct or prevent discharge of toxic pollutants. The regulation is already being vigorously enforced with industrial dischargers on the Southern Branch (personal communication, Roger Everton, VWCB). In addition, the VWCB is developing a sediment quality management plan in concert with VIMS, ODU, and the Norfolk District Corps. This endeavor will involve mapping the areal and vertical distribution of toxic sediments in the Elizabeth River and developing a long-term strategy for management and clean-up. As part of the 1987 Chesapeake Bay Agreement, an implementation plan for the reduction and control of toxics entering the Chesapeake Bay ecosystem from point and nonpoint sources and from bottom sediments was developed and adopted by Federal and state participants in December 1988. These developments indicate a concern for reducing and controlling pollution in the Elizabeth River which, if realized, will result in smaller proportions of unsuitable sediments to suitable sediments being dredged from the Southern Branch in the future.

236. There are several management strategies that could be employed at CIDA that would serve to alleviate concerns over using CIDA for unsuitable materials only. These include:

(1) Suitable materials could be placed in the site periodically, if monitoring so warrants, to mix with the unsuitable sediments.

(2) If effluent suspended solids concentrations (and toxics) rise above acceptable limits, the ponding depth at the weirs could be increased to allow longer retention (settling) time.

(3) The inflow rates could be decreased by operating intermittently or temporarily diverting flow to an inactive subcontainment.

(4) During the final years of operation, CIDA could be capped with clean material to an acceptable depth so as to seal off any unsuitable materials.

Aquatic Ecology

237. *Benthic Ecology*. The aquatic habitats in the Hampton Roads area have been significantly altered between the time of settlement and the present day due to dredge and fill projects. As a result, over 4740 acres of marsh, shallow, and open water have been filled for residential, commercial, industrial, and other purposes within the project area over the years (USFWS, 1984). This figure excludes the 2,500 acre fill for the present CIDA and several recent U.S. Navy fills amounting to over 700 acres in Willoughby Bay at the Sewell's Point Complex. Many of the fills were historically early and were small, piecemeal projects such as the expansion of the City of Norfolk along the Elizabeth River and Eastern Branch. A review of an 1894 Hampton Roads navigation chart shows many small tidal creeks and adjacent wetlands filled by 1980. The 1894 chart shows extensive wetlands and tidal creeks throughout the area, particularly at Sewell's Point, which have since been filled by the U.S. Navy. These fills completely eliminated tidal creeks (Brush Creek) and adjacent wetlands, thereby removing habitat for many species such as striped bass, river herrings, blue crabs, oysters, and clams were eliminated from these areas. Because these habitat alterations were small and unconnected, and many wetlands and open water areas were yet unaltered, no comprehensive analysis was done to determine the impacts of such large scale removal of aquatic areas upon the species dependent upon them. Such a trend analysis has not, to date, been undertaken. It appears that such a historical perspective of aquatic habitat loss is necessary in order to make appropriate management decisions which will affect species using the Chesapeake Bay and its tributaries. Although an in depth discussion of historical aquatic habitat losses and the relationship between these losses and the species affected is not feasible for this project, it is acknowledged that the proposed expansion of CIDA (plan B) will further alter existing habitat therefore affecting the cumulative impacts upon the aquatic resources of the Chesapeake Bay.

238. The Chesapeake Bay Agreement (1987) has brought recent awareness and focus upon the deteriorated conditions of the Chesapeake Bay system. This awareness forces all those involved in decisions which affect any portion of that system, to any degree, to thoroughly analyze what immediate and long-term impacts will occur to the Bay's ecosystem as a result of the decisions made. The proposed expansion of CIDA will in and of itself impact important resources within the Chesapeake Bay system. Its impact is further magnified when viewed with past dredge and fill projects mentioned previously. However, efforts to minimize the impacts from the proposed expansion will be employed, as will the implementation of one or more mitigation proposal (see "Mitigation" section of this EIS), thereby reducing the cumulative impact of the project upon the aquatic resources of the Chesapeake Bay.

239. The major impact of constructing an expansion to Craney Island on the natural environment would be the loss of an extensive amount of estuarine bottom land. The Plan B westward extension of CIDA would include about 2,500 acres of estuarine bottom land being irrevocably transferred to a disposal site eventually destined to become dry land. The designated area would be impounded by a levee system. Along the northern margin, the levee would be in waters of depths of 12 to 15 feet. The area becomes more shallow toward the natural shoreline. About one-third of this site is presently in water between one and three feet deep. The bottom generally consists of a dark sandy mud which emits a strong hydrogen sulfide odor when brought to the surface. Within the substrate are mainly polychaete worms and mud snails, with scattered hydroids present. Migrant species of significance include the blue crab and invertebrates common to the diets of the local fish. If this site were covered with dredged materials, bottom fauna would be destroyed. Migrant crabs, fish, and invertebrate species would be forced to other locales in the area. There is a lack of active recreational fishing in the area; however, the site supports a rather large commercial shad fishery in March and April. Numerous crab pots are also common along the central and outer margins. There are no significant oyster or hard shell clam resources within this area which would be directly affected by the proposed westward expansion.

240. Most of Public Ground Number 1 (Norfolk County) and some of Public Ground Number 1 (Nansemond County) would be eliminated with expansion plan B of CIDA. Baylor grounds are protected by Article XI, Section 3 of the Virginia Constitution. The area of Baylor grounds affected by the proposed expansion must be removed from designation as Public Oyster Ground before the Virginia Marine Resources Commission (VMRC) could process a permit application. This would require action by the Virginia General Assembly.

241. The development of a westward expansion of Craney Island Disposal Area would result in the loss of approximately 2500 acres of shallow water habitat, and would impact, in varying degrees, the faunal communities that use it. The loss of benthic macroinvertebrates would be through direct smothering, the impact to fish would be indirect, resulting primarily in the displacement of organisms from the affected area with some attendant reduction in total aquatic productivity in the region. Hampton Roads Harbor is not unique or critical to the aquatic species occurring there. Areal measurements indicate that the proposed site comprises about five percent of the intertidal and benthic habitat within the Hampton Roads Harbor (75 square mile harbor). The loss of this aquatic habitat, while not critical, is considered significant and its compensation is a primary goal of the mitigation plan. Construction impacts are expected to be minor but contingency actions that will minimize unexpected impacts will be included in the construction plans.

242. *Plankton*. The impacts of dredging and disposal on plankton has been the subject of investigation in recent studies performed for Norfolk District by Old Dominion University's Applied Marine Research Laboratory. Alden and Crouch (1984) performed suspended solid phase bioassays using the copepod *Acartia tonsa* and sediments from the Norfolk Harbor and channels (including Newport News Channel sediments). Literature investigations suggest that the lowest suspended sediment concentration for which any harmful effect has been reported to occur on a planktonic organism is 40 mg/l, at which concentration Stern and Stickle (1978) found that feeding rates of the copepod *Acartia tonsa* were substantially decreased. In general, it has been documented, that fish eggs and larvae have been found to be extremely tolerant of uncontaminated suspended sediment and that substantial mortality is probably rare even in extremely turbid environments (Devonald and Ausubel, 1984). Construction

material, mostly coarse-grained materials, which will be used for the dike construction to enclose expansion plan B are not expected to cause any adverse impact to plankton in the vicinity of construction activities, however, water quality monitoring for suspended solids may be required.

243. The primary potential impacts of dredging activities on phytoplankton and zooplankton are the increase in suspended sediment concentrations and turbidity and entrainment of the organisms by pipeline dredges. Turbidity equal to or greater than that created by dredging is usually found in the James River/Hampton Roads Harbor under natural conditions. Therefore, no impacts to plankton are anticipated beyond those which are expected to occur naturally.

244. *Finfishes*. The impact of the proposed construction on fisheries resources is expected to be minimal. The fishes which inhabit the Hampton Roads Harbor and adjoining tributaries, including juveniles, are extremely tolerant of the rapidly fluctuating and periodically increased sediment loads common to the water column in Hampton Roads Harbor and its adjoining tributaries. The water is naturally turbid and periodic increases in sediment load often accompany storm events and other natural phenomena in the estuary. If warranted, the monitoring of DO levels during the critical summer months will serve to further protect this resource from any adverse impact.

245. The potential for interruption of the movement of estuarine fish and shellfish and particularly anadromous species of fish to and from nursery and spawning areas in the adjoining tributaries by the physical presence of dredging equipment or by the physical-chemical water quality alterations associated with dredging is not well known. However, river currents or flows upon which larval organisms depend for transport will not be interrupted or reduced. Dredged induced water quality conditions will only be short-term and impact a small cross-sectional area of the Harbor; therefore, the potential for blockage of migration routes will be minimal.

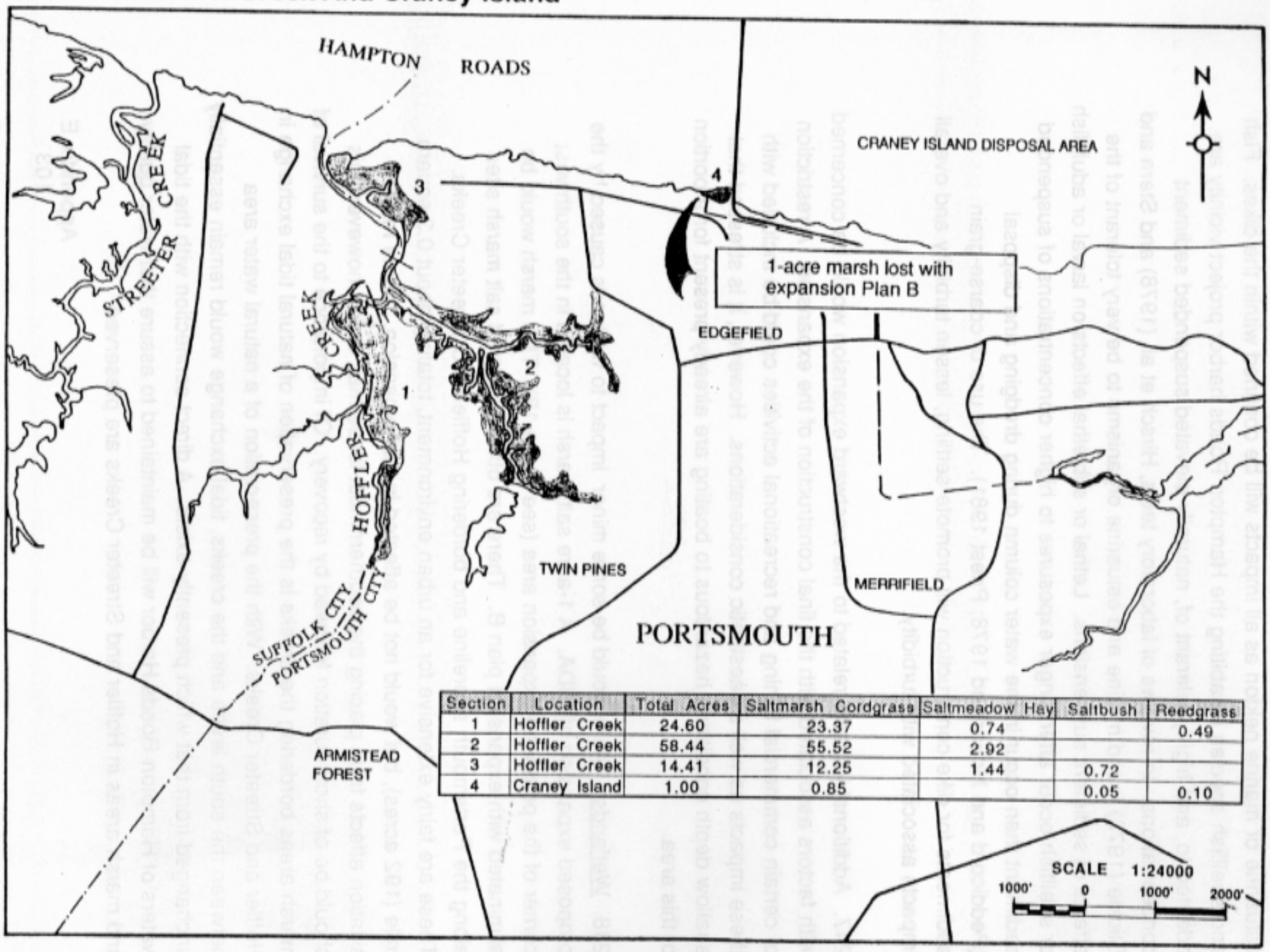
246. The water quality effects produced in the Hampton Roads Harbor during construction of an expansion to Craney Island with either a hydraulic pipeline dredge, clamshell dredge, or hopper dredge will be short term and are not expected to have significant adverse impacts on estuarine or marine nekton

(open water swimmers). Also, disposal of dredged material within the constructed dikes is not expected to have significant adverse impacts on estuarine or marine nekton as all impacts will be confined within the dikes. Fish and shellfish species inhabiting the Hampton Roads harbor project vicinity are adapted to, and highly tolerant of, naturally elevated suspended sediment concentrations. In reviews of laboratory tests, Hirsch et al. (1978) and Stern and Stickle (1978) found marine and estuarine organisms to be very tolerant of the effects of sediment suspensions. Lethal or sublethal effects on larval or adult fish or shellfish occur after longer exposures to higher concentrations of suspended sediment than occur in the water column during dredging and disposal (Peddicord and McFarland 1978; Priest 1981). The use of coarse-grain sediments for dike construction will promote settling, lessen turbidity and overall impacts associated with turbidity.

247. Additional impacts related to the westward expansion would be concerned with factors associated with the final construction of the expansion. A restriction of certain commercial fishing and recreational activities could be included with these impacts as well as aesthetic considerations. However, it is stressed that shallow depth conditions hazardous to boating are already present for a portion of this area.

248. Wetlands. There would be some minor impact to wetlands caused by the proposed expansion of CIDA. A 1-acre salt marsh is located in the southwest corner of the proposed expansion area (see figure 13). This marsh would be eliminated with expansion plan B. There are other scattered salt marsh sites along the Portsmouth shoreline and bordering Hoffler and Streeter Creeks. These are fairly extensive for an urban environment, totaling about 0.3 square mile (192 acres), but would not be affected by an expansion. Some minor siltation effects from placing the southernmost levee may occur; however, this should be of short duration followed by recovery. Of importance to the survival of marsh areas bordering the creeks is the preservation of natural tidal exchange in Hoffler and Streeter Creeks. With the preservation of a natural water area between the south levee and the creeks, tidal exchange would remain essentially unchanged from that which presently exists. A direct connection with the tidal waters of Hampton Roads Harbor will be maintained to assure that water quality and marsh areas in Hoffler and Streeter Creeks are preserved.

Section I. Hoffler Creek And Craney Island



Section	Location	Total Acres	Saltmarsh Cordgrass	Saltmeadow Hay	Saltbush	Reedgrass
1	Hoffler Creek	24.60	23.37	0.74		0.49
2	Hoffler Creek	58.44	55.52	2.92		
3	Hoffler Creek	14.41	12.25	1.44	0.72	
4	Craney Island	1.00	0.85		0.05	0.10

Figure 13. Tidal Wetlands in Vicinity of Craney Island Disposal Area
(VIMS Tidal Marsh Inventory - City of Portsmouth, 1989)

249. Endangered Species. There is no known critical habitat for endangered species in the specific area of the CIDA expansion. It is not anticipated that the plan will disrupt the seasonal movements of endangered species that temporarily may move into the area during certain times of the year. Two sea turtles, the loggerhead (Caretta caretta) and the Kemp's ridley (Lepidochelys kempii) are endangered species which may penetrate up the estuary and into the James River. These sea turtles are not believed to nest or over winter in Virginia or its offshore waters and may be transient to the proposed expansion area.

250. The spatially limited effects of the proposed construction including suspended solids and water quality impacts would not adversely effect these sea turtles. All evidence to date indicates that sea turtles do not overwinter in Chesapeake Bay or its tributaries so there would be no effect during this period. During the summer months sea turtles are found mainly in open areas and channels, and forage in the mouth of the Chesapeake Bay and tributaries where they are generally confined to the river channels. These areas would be subject to little, if any, effect from the proposed construction and actively swimming turtles could avoid the immediate construction area.

251. The peregrine falcon (Falco peregrinus), whose subspecies F. peregrinus anatum (American) is listed as endangered and F. peregrinus tundris (Artic) is listed as threatened, are commonly found in the vicinity of Craney Island. Expansion plan B would not jeopardize the extensive prey base for the peregrine falcon within the existing CIDA and may actually contribute to the prey base by providing additional habitat where birds and other small animals upon which the falcon is feeding may flourish. There would be loss of shallow water habitat for the prey base, but there is ample shallow water habitat within flying distance of CIDA so that expansion of CIDA should not negatively influence these bird populations.

Socioeconomic Environment

252. Expansion of CIDA would have a number of effects, many of which are not quantifiable. Those which can be quantified center on the loss of property values, while the intangible effects involve such areas as esthetics and development opportunities foregone. The regional impact of a westward

expansion appears to be limited to the impact on those properties immediately adjacent to the proposed expansion. The area adjacent to the westward expansion is already substantially developed as residential. There is no indication of properties which would be rendered undevelopable or ones which the highest and best use would change based on a westward expansion.

253. There are 39 residences whose owners would suffer property losses with the construction of proposed expansion plan B. These houses are located on property which fronts Hampton Roads and have a 1988 value of $6,755,000. The amount of real estate value lost as a result of construction of Craney Island expansion (plan B) is estimated to be $2,003,000, which amounts to the cumulative difference in value between property either on the waterfront or with a water view and property without such features. Such a loss would mean a combined loss of real estate tax revenue for the cities of Portsmouth and Suffolk of $24,000 or more a year. Real Estate studies which were conducted as part of this long term disposal study are presented in Appendix D which accompanies this document.

254. In addition to the losses in property values, the residents of the property along River Shore Road and along the water between Hoffler and Streeter Creeks in Suffolk would also have a major change in the appearance of their area. They would have a view of a disposal site to replace their current view of Hampton Roads and the harbor facilities in the distance, an extremely negative change from the perspective of the neighborhoods affected. Access to the harbor for waterfront residents would be severely reduced, one of the factors that is involved in the loss of property value associated with project construction.

255. Development opportunities for the existing Craney Island would not be affected significantly by this plan. Craney Island would continue to be used for disposal in conjunction with the expansion area to optimize the capacity of both areas. There is a possibility that the eastern levee area could be developed and used by a non-Corps agency, but this would have to be determined in the future. Many agencies and groups, including the city of Portsmouth, have expressed an interest in the development potential of Craney Island although the date it would actually be available is unknown. With construction of the expansion area there would be more property ultimately available for

development in the harbor when both sites reached capacity than with just the existing Craney Island.

256. One of the most significant negative impacts which would result from plan implementation is the adverse effect on the community. Opposition to this alternative from residents and governmental officials of both Portsmouth and Suffolk has been strong and unwavering throughout the course of this and other studies in the past concerning disposal for the Hampton Roads Harbor. There is a strong perception by residents in the study area that if this plan was implemented, they would have to endure all the negative effects of a disposal area located adjacent to their property while all the cities in the Hampton Roads region would derive the benefit of dredged harbor channels. Because this group of citizens is highly unified, politically astute, supported by civic leaders and local governmental officials, recommending the Craney Island expansion would very likely lead to protracted legal battles.

257. Social Effects/Ocean Disposal. Implementation of an ocean disposal plan would create no significant, negative social impacts directly. It would increase costs to dredgers, which could affect the profitability of their operations. However, there are so many factors which affect the economic viability of a company that it is impossible to predict accurately what the effect of this plan would be on these companies.

258. The major positive effect of selecting this plan would be the elimination of the citizen opposition which is associated with the Craney Island expansion plan and all other plans which were initially considered. To date, there has been no strong public opposition to ocean disposal although there has been concern expressed by commercial maritime interests about increased costs of ocean disposal; nevertheless, this plan appears to be much more acceptable to citizens and local governments than any of the other alternatives.

259. Social Effects/Use of CIDA For Unsuitable Dredged Material Only. This plan, which would be combined with open ocean disposal if implemented, would create very little change in terms of social effects when compared to current conditions. The same complaints about odor, insects, and appearance that occur now by residents near the disposal site would probably continue.

Resolving the issue of the ultimate use of a filled Craney Island would not be necessary in the near future if this plan was selected. Opposition to this continued use of the site from the City of Portsmouth can be expected since the city would like to have the property as part of the city. Nevertheless, residents near Craney Island would almost certainly prefer this plan to the expansion alternative.

Air Quality and Noise

260. Because of increased construction activity air pollution levels may increase during construction. However, all reasonable measures would be taken to reduce or even eliminate this temporary impact on air quality.

Historical and Cultural Resources

261. Based upon the underwater remote sensing survey performed in the area of the proposed CIDA expansion during 1989 (described in the "Historical and Cultural Resources" section), there should be no adverse impact to cultural or archaeological resources associated with the covering and filling of 2500 acres of the harbor bottom to the west and east of the existing CIDA facility.

Borrow Area

262. Over 18 million cubic yards (mcy) of good material is required to construct the western expansion dike(s) for the proposed Craney Island expansion (plan B). About 27 mcy can be obtained from areas shown in figure 14. Maintenance material from channels and dockage areas is primarily silt and clay and is unsatisfactory for dike construction. Material can be pumped from a distance of about 15,000 feet for $1.62 per cubic yard to construct the dike enclosure. The Virginia Department of Highways and Transportation (VDHT) obtained 500,000 cubic yards of good material from Thimble Shoal Channel and the remainder from Hopewell to construct the I-664 islands. The average cost was $5 to $6 per cubic yard. Appendix B details the Corps geological investigations which led to recommendation of the proposed borrow areas (Bowen, 1989). Some of the borrow sites have overburden material; this material would require disposal in an approved site.

263. At an interagency coordination meeting on November 16, 1988, the proposed borrow areas were discussed. There were no major concerns

expressed concerning the options presented, except one. VIMS stated that obtaining good material along the James River from the western limits of the proposed expansion to Pig Point would involve about 1,000 acres in this area and could seriously affect the hydrodynamics of the Nansemond River in this critical area. USFWS expressed concern over the further loss of shallow water habitat which is used extensively as feeding and resting area for waterfowl. By consensus it was decided that this area would not be used as a borrow site.

264. The Norfolk District suggested that additional dike construction material could be obtained from the Newport News Channel by going beyond the authorized depth of 55 feet. The channel has been modeled to 57 feet (Norfolk Harbor and Channels deepening project) and further deepening of the Newport News Channel to 65 or 70 feet can be modeled. VIMS believed that such deepening could affect the circulation pattern in the James River and that adequate study on hydrodynamic impacts of such a proposal would be required. This could in turn affect oyster larvae recruitment. Based on these discussions, the Norfolk District contracted with the Waterways Experiment Station (WES) to study the changes associated with additional Newport News Channel deepening to 70 feet.

265. The objective of the WES study was to use available numerical models to evaluate general changes in circulation, currents, and sedimentation associated with the over-deepening of the Newport News Channel. Three alternative depths of 57, 64, and 70 feet were evaluated. Additionally, the effects of the over-deepening on the reported estuarine circulation cell (flow convergence) off Hampton Flats and Newport News Point was assessed.

266. The numerical modeling was designed to evaluate relative changes in hydrodynamics and sedimentation adjacent to the study area. The sedimentation comparisons focused on two areas adjacent to the Newport News Channel and the deepened portion of the channel. The off-channel areas were designated A and B and were the same as those reported by Heltzel and Granat (1988) (Attachment 1). These zones are shown in figure 15. In these relatively low velocity areas, the sediment study focused on changes in cohesive sediment transport. The channel comparisons were made in an area of relatively high velocities and focused on non-cohesive sediment transport.

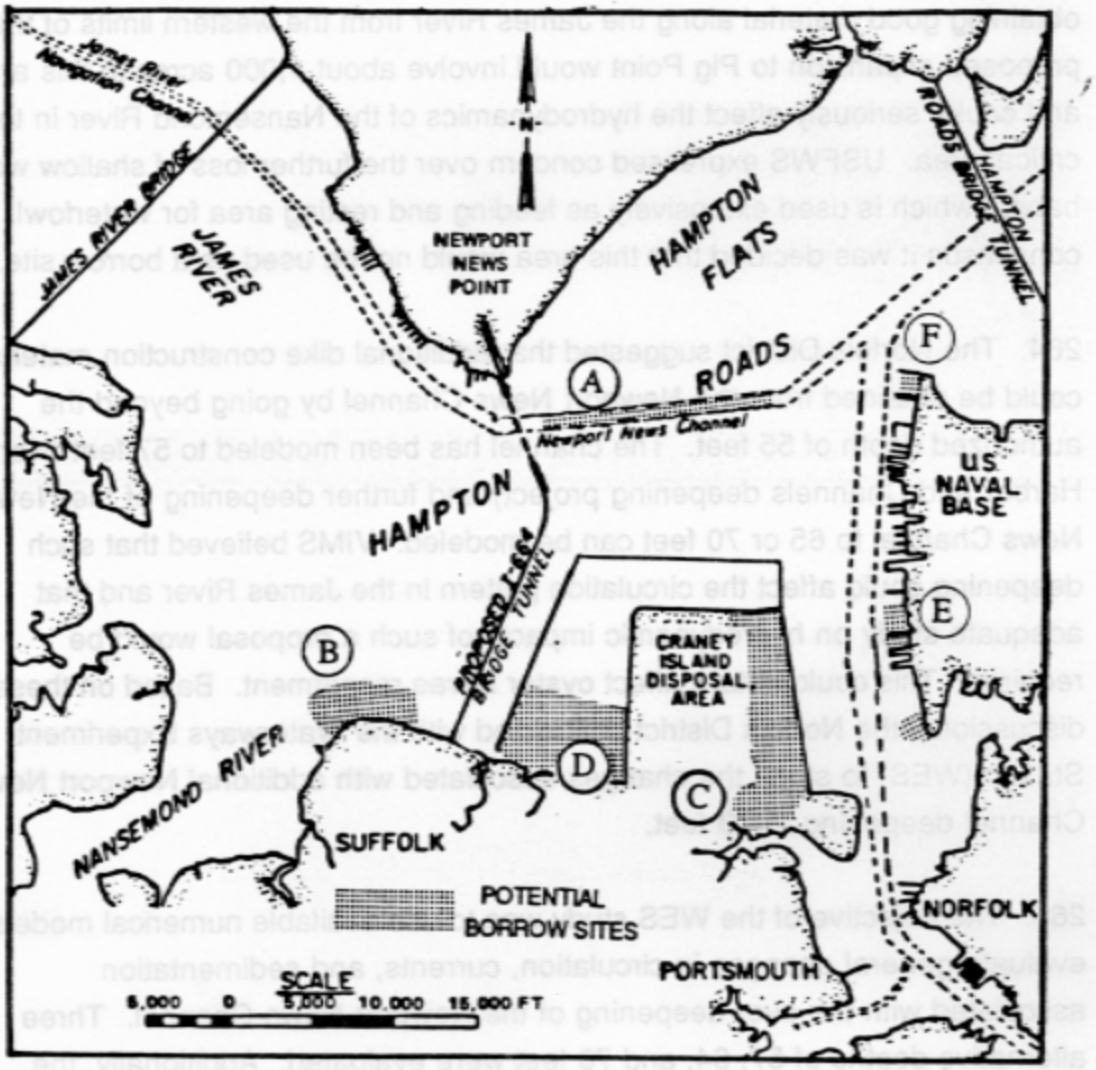


Figure 14. Availability of sand for dike construction, Craney Island Disposal Area expansion proposal Plan B.

LOCATION	QUANTITY (millions yds^3)	CUMULATIVE (millions yds^3)
A - Newport News Channel (70')	6.1	6.1
B - Pig Point	7.8*	13.9
C - Craney Island (present boundaries)	4.5	18.4
D - Craney Island (within expansion)	4.4*	22.8
E - NIT Terminals	1.8	24.6
F - Navy Pier 13	2.3	26.9

*removal of 7 to 10 feet of surface

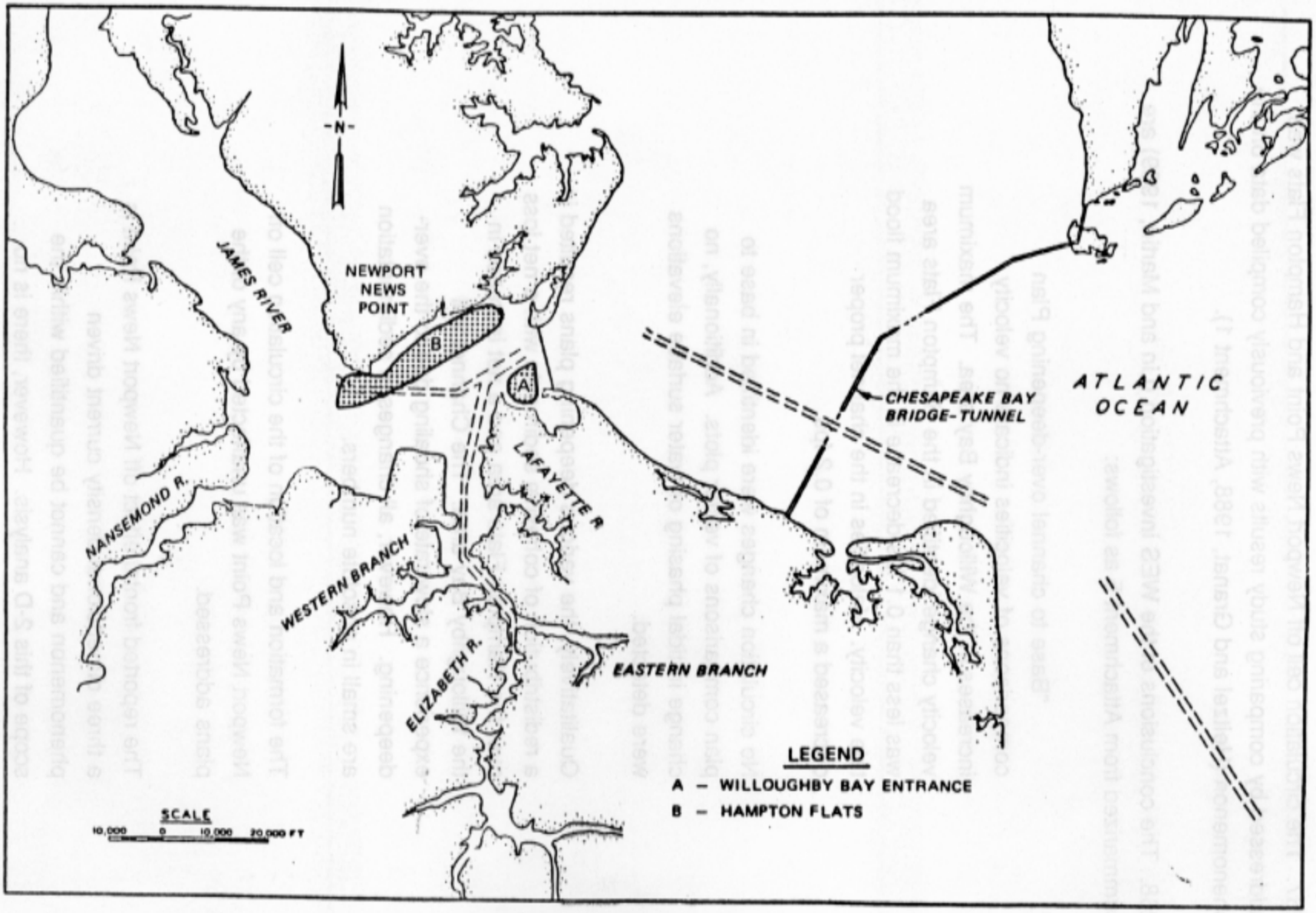


Figure 15. Critical sedimentation zones of interest

267. The circulation cell off Newport News Point and Hampton Flats was addressed by comparing study results with previously compiled data on the phenomenon (Heltzel and Granat, 1988, Attachment 1).

268. The conclusions of the WES investigation (Lin and Martin, 1989) are summarized from Attachment 5 as follows:

> "Base to channel over-deepening Plan comparisons of velocities indicate no velocity increases in the Willoughby Bay area. The maximum velocity change identified in the Hampton Flats area was less than 0.1 fps decrease in the maximum flood tide velocity. Velocities in the channel proper decreased a maximum of 0.2 fps.
>
> No circulation changes were identified in base to plan comparisons of vector plots. Additionally, no change in tidal phasing or water surface elevations were detected.
>
> Qualitatively, the various deepening plans resulted in a redistribution of cohesive sediments with a net loss over the Hampton Flats area and a net increase in the Willoughby Bay area. The Channel will experience a slow rate of shoaling due to the over-deepening. However, all changes in sedimentation are small in absolute numbers.
>
> The formation and location of the circulation cell off Newport News Point was unaffected by any of the plans addressed.
>
> The reported frontal effect off Newport News Point is a three dimensional density current driven phenomenon and cannot be quantified within the scope of this 2-D analysis. However, there is no

evidence generated by this study which would indicate that the channel over-deepening will affect the frontal formation or propagation."

269. Based upon the conclusions of the WES investigation, it is not anticipated that the over-deepening of the Newport News Channel, to obtain borrow material for dike construction, would have any significant adverse effect on the hydrodynamics of the Hampton Roads harbor area.

270. Dredging from subaqueous borrow areas involves disturbance and removal of parts of the bottom. These actions impact the surrounding environment and, in particular, the benthic fauna of the borrow area. Other more mobile organisms, such as fish and crabs, would also be affected but in a more indirect manner as they have the ability to avoid and escape the borrow area when the dredging operation begins. When the removal of a food source occurs, such as during dredging in a borrow area, this would cause pelagic predators, like fish, to redistribute seeking new food sources.

271. The most obvious effect from dredging in the proposed borrow areas is mechanical due to the direct removal of substrate and the fauna associated with it. All of the benthic fauna in dredged areas would be destroyed. Total recolonization of the disturbed area should occur within 2 years, although a difference in site specific environmental situations could vary this period. This relatively rapid recolonization is partially due to the short life cycles of many of the organisms, plus their pelagic life stages, which facilitate recolonization from surrounding undisturbed areas. Preliminary investigations conducted by VIMS at borrow sites in the lower Bay used by the Virginia Highway Department indicate this rapid, and perhaps enhanced, recruitment of benthic populations in the borrow areas.

272. Turbidity and sediment created by the dredging operation would produce indirect effects on the biota surrounding the borrow areas. These effects should be minimal as the material to be dredged would be fairly large in grain size causing impacts to be short-lived. Sherk and Cronin (1970) have summarized the information available on effects of turbidity and sediments on estuarine

organisms. They revealed little concrete, long-range detrimental effect due to either turbidity or sediment deposition.

Ocean Disposal

273. Dam Neck Ocean Disposal Site. The ocean disposal site at Dam Neck Ocean Disposal Site (DNODS), 37 miles from Craney Island, has been in use since 1967 when the Corps dredged Thimble Shoal Channel in Chesapeake Bay to a depth of 45 feet. Since that time all new work and maintenance dredged material from Cape Henry Channel and Thimble Shoal Channel (with limited exceptions) have been deposited at DNODS. These deposits included a variety of naturally occurring marine sediments, ranging from silts and clays to fine, medium, and coarse sands. As of May 1985, about 20.4 million cubic yards of dredged material have been placed at Dam Neck.

274. In 1977, the Environmental Protection Agency (EPA) designated Dam Neck as an interim ocean disposal site for dredged material. The EPA approval of this site was for an interim period pending final designation for continuing use. The use specification (dredged material) and size were based on historical use.

275. DNODS was designated as an approved ocean disposal site under the Corps of Engineers authority contained in Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA). The Final Supplement, containing evaluations with respect to the criteria contained in Parts 228.5 and 228.6 of the Code of Federal Regulations, Title 40 (40 CFR 228), was filed with EPA and appeared in the Federal Register on June 14, 1985. The Record of Decision, giving DNODS final site designation, was signed by the Division Engineer, North Atlantic Division, U.S. Army Corps of Engineers, on September 23, 1985.

276. More recently, EPA gave DNODS final designation under authority in Section 102(c) of MPRSA. This final designation by EPA appeared in the Federal Register on March 31, 1988.

277. In accordance with the Draft Memorandum of Agreement (MOA) between the Corps and EPA on management of DNODS,

> "...The DNODS, as designated, is the primary disposal site for three Federal navigation channels: the Atlantic Ocean Channel (proposed in connection with the 55-foot channel into Hampton Roads), the Cape Henry Channel, and the Thimble Shoal Channel. Approximately 70 million cubic yards of materials are predicted to be dredged from these 3 channels over the life of the site (50 years) based on a predicted 35-foot minimum clearance depth for any management area within the site."

Also in accordance with the Draft MOA,

> "...Use of the DNODS for dredged materials, other than from the channels identified above, is not precluded. However, all dumping must be compatible and consistent with the long-term primary need for the Federal navigation channels. Further, all dumping must conform to the ocean dumping criteria, to the site designation environmental assessment, and to the objectives of the site management."

278. During the process of coordinating the environmental documents which were required to designate DNODS, various concerns were expressed by the environmental resource agencies. These included:

a. Impacts of dredged material disposal on breeding, spawning, nursery, and passage activities of commercially important finfish and shellfish in and out of the Chesapeake Bay.

b. Sediment transport from the disposal site toward area beaches at Virginia Beach.

c. Impacts to sea turtle migration through the site during the spring migration.

d. The effects on area water quality (especially dissolved oxygen) of dredged material disposal at DNODS and the operation of the Hampton Roads Sanitation District outfall located off Virginia Beach.

e. Impacts of dredged material disposal on meroplankton including blue crab, bay anchovy, and sand shrimp larvae.

f. Impacts to commercially important benthos.

279. The National Marine Fisheries Service, U.S. Fish and Wildlife Service, and the Chesapeake Bay Foundation continue to express the above as unresolved concerns.

280. Ocean disposal at either DNODS or NDS would not adversely impact fisheries. There should be no impact to breeding grounds. The most extensive breeding, spawning, and nursery activities occur either in offshore waters or in the adjacent Chesapeake Bay estuarine waters that is offshore or inshore of the dredged material disposal sites. In addition, the total area of the disposal sites represent only a small portion of the total breeding, spawning, and nursery areas along the mid-Atlantic coast for these species. Due to the mobility of finfish, it is unlikely that dumping will have a significant impact on either anadromous or pelagic species.

281. Sediment transport at the DNODS is expected to be minimal. The majority of sediments released would be expected, based on the historical use of the site, to sink to the bottom and remain in place. After 20 years of use, no apparent adverse impacts to beaches have been associated with the previous dredged material disposal at the site. Thus, use of the site should not adversely affect recreation, coastal development or other uses of the shoreline.

282. Dumping of dredged material over 20 years has not significantly affected water quality. Therefore, use of the site is not expected to have significant water

quality or ecology impacts. Water quality monitoring has taken place at DNODS during the summer months (June - September) since 1987 and will continue in order to assure that no significant changes in water quality are attributed to ocean disposal. To date, only dissolved oxygen near the Hampton Roads Sanitation District Atlantic sewage treatment plant outfall have shown depressed levels. Other stations in the vicinity of dumping operations have shown no decreased levels of dissolved oxygen over ambient.

283. Studies indicate the migration of thousands of the loggerhead and Ridley turtles into the Chesapeake Bay. However, there is little evidence that a significant number of turtles would in fact traverse the dump site during migration. During EPA's surveys over a four year period, no turtles were sighted nor were any recovered from extensive benthic trawls at the site.

284. Studies by EPA and the Corps showed that during larvae development, a significant fraction of the blue crab reside in the Chesapeake Bay plume, only a fraction of which includes the DNODS. Therefore, the potential impacts would be very small, especially since the crab larvae are primarily in the surface waters and dredged material is deposited well below the surface.

285. The DNODS supports a productive benthic faunal population which is typical of the mid-Atlantic inner Continental Shelf. However, no commercial quantities of any shellfish were identified in the DNODS. A small conch fishery occurs inshore of the site and the surf clam and sea scallop are found offshore of the site. Ocean disposal of dredged material at either DNODS or NDS will impact benthic populations to some degree. As dredged material settles to the bottom, the benthic community is usually smothered. Although benthic communities generally recover from infrequent perturbations, the consistent placement of dredged material in an area would result in a decrease or potential loss of the area as suitable habitat for the original benthic community. This will not usually be the case, however, since both sites are relatively large and dredged material will be placed so as to make optimum use of the entire site.

286. Table 13 summarizes the capability of the existing DNODS to accept dredged material in accordance with its formal designation in 1985 and

assuming only construction of the 55-foot outbound channel. (All amounts are in millions of cubic yards [mcy]).

Table 13. CAPACITY OF EXISTING DNODS

	Deposition (mcy)	Remaining Capacity (mcy)
a. Total design capacity (to fill site to a maximum height of 35 feet below m.l.w.) (based on site designation document)		70
b. Material placed to date (Thimble Shoal 50-foot outbound)	4.7	65.3
c. Estimated amount of new work to be dredged from Thimble Shoal and Atlantic Ocean 60-foot outbound Channels and for the 50-foot Cape Cape Henry Channel	18.2	47.1
d. Estimated amount of new work to be dredged from inner harbor	14.6	32.5*

* Remaining capacity of 32.5 mcy will accommodate maintenance of inner and outer harbor channels for about 11 to 12 years.

287. In a letter dated September 9, 1988, EPA stated that dredged material from the inner harbor which is suitable for ocean disposal can be deposited in DNODS.

288. Norfolk Disposal Site. The area described as the Norfolk Disposal Site (NDS) is a dredged material disposal site delineated by a circle with a radius of 4 nautical miles centered at 36°59' N latitude and 75°39' W longitude in the coastal waters off the mouth of the Chesapeake Bay. The site is shown on figure 2 and is located beyond the 10-fathom depth contour line, approximately

17 nautical miles due east of the Chesapeake Bay mouth and about 45 miles from Craney Island. It is approximately 50 square nautical miles in area.

289. The Final Environmental Impact Statement (FEIS) for the Norfolk Disposal Site was filed by the Norfolk District with EPA on July 23, 1982 (Corps of Engineers, 1982). The action discussed in the FEIS is the designation for use of an ocean dredged material disposal site located as described in the preceding paragraph. The purpose of the FEIS was to supply environmental evaluations and supporting data for the NDS designation process.

290. The EIS discusses the need for the action and examines ocean disposal site alternatives to the proposed action. The EIS presents the information needed to evaluate the suitability of NDS for final designation and the conclusions of the EIS are based on an extensive series of environmental studies. After considering benthic and bioassay data as well as other existing information concerning the various alternatives, the EIS recommended designation of the NDS for dredged materials meeting EPA/Corps ocean disposal criteria.

291. There were no areas of controversy or unresolved issues in the EIS relating to the use of NDS as an ocean disposal site for dredged materials. There are no foreseeable impacts which would preclude the use of NDS for Norfolk Harbor and Channels materials.

292. By letter of March 31, 1988, EPA has requested that Norfolk District give it direction as to which way the district wants to proceed with NDS (to designate or not). EPA expressed that,

> "...Use of Norfolk Site would provide a viable option for materials which pass EPA's criteria but may not be compatible with disposal at Dam Neck."

293. Site designation by EPA under Section 102 of the Marine Protection, Research, and Sanctuaries Act, as stated in their letter,

> "...normally takes one to two years to complete."

Norfolk District requested EPA designation of NDS by letter dated 1 August 1989.

Beneficial Effects

294. The beneficial impacts on the local biota, brought about by the construction of the westward expansion, would be limited. The riprap (over eleven acres of intertidal and subaqueous surface area) which will be placed on the outside face of the dike embankment will provide habitat diversity and food for aquatic organisms similar to that provided by an artificial reef structure. Other benefactors would be various resident bird populations and possibly migrant species.With the pumped dredged materials, dikes, and ponds there would be expanded feeding resources and habitat provided to the birds. In time, as the site developed, new nesting areas and roosting locations would be provided. This benefit would probably be of finite duration, but during the useful life of CIDA, endangered and threatened species using the site would be given the opportunity to recover. A classic example of recovery is the brown pelican, which is listed as endangered, but was recently removed from this status over the U.S. Atlantic coast range. The brown pelican is known to nest heavily on Corps disposal sites in the southeast (e.g., Gaillard Island located in Mobile Bay, Alabama). It is conceivable that in the future, CIDA, or a portion thereof, could be reserved for wildlife, especially avifauna. If this were done, the site would contribute environmental benefit indefinitely. The exact future environmental benefits gained from such plans cannot be quantified at this time.

295. A westward expansion (Plan B) of the existing facility would provide a site for the disposal of dredged materials for the next several decades. In doing so, the project would assure that unsuitable dredged materials were properly disposed. As a direct result, the expansion would have a beneficial impact on the environmental conditions of polluted areas such as the Elizabeth River Southern Branch.

296. There are both direct and indirect beneficial effects associated with use of open ocean disposal sites for suitable dredged materials. These primarily include: (1) extending the useful life of the present CIDA facility to receive unsuitable materials; and (2) preservation of shallow water aquatic habitat and associated organisms that would be lost with an expansion.

MITIGATION

297. Since mitigation is not required for ocean disposal at either DNODS or NDS, the discussion on mitigation which follows applies to expansion of CIDA only.

Mitigation Authority and Guidelines

298. The mitigation policy of the U.S. Army Corps of Engineers and the U.S. Fish and Wildlife Service includes that fish and wildlife conservation should receive equal consideration with other project purposes. Mitigation is allowed by Public Law 85-624, Fish and Wildlife Coordination Act of 1958 (FWCA); Public Law 91-90, National Environmental Policy Act (NEPA); and guided by Corps of Engineers' Engineering Regulations 200-2-2 and 1105-2-50. The definition of mitigation used by both agencies is taken from the National Environmental Policy Act (NEPA) guidelines developed by the Council on Environmental Quality (1978). These guidelines (40 CFR, Part 1508.20) state that mitigation includes:

(a) Avoiding the impact altogether by not taking a certain action or parts of an action

(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation

(c) Rectifying the impact by repairing, rehabilitating, or restoring the affected environment

(d) Reducing or eliminating the impact over time by a preservation and maintenance operation during the life of the action

(e) Compensating for the impact by replacing or providing substitute resources or environments

299. An EPA/U.S. Army Memorandum of Agreement (MOA), signed on 15 November 1989, provides general guidance about the type and level of mitigation necessary to comply with the Clean Water Act Section 404 (b)(1) Guidelines. The MOA interprets and provides general procedures for

implementing existing requirements found in Corps and EPA Section 404 regulations. The agreement outlines guidance for Corps and EPA field offices to use in evaluating individual Section 404 permit applications for work (discharges of dredged or fill material) in all waters of the United States, including wetlands. The agreement provides guidance that mitigation will be considered in sequence as mentioned above (i.e., avoid, minimize, compensate). The MOA limits the use of compensatory mitigation as a means of reducing environmental impacts during selection of the least damaging practicable alternative except in special circumstances. The MOA applies to standard individual permit applications only.

300. An evaluation of alternatives presented in this document indicates that the first four elements can be implemented to only a limited degree with the proposed expansion of CIDA (plan B). Therefore, with the exception of some minimization of project impacts with standard engineering practice/environmental design, the mitigation plan is limited to compensation for impacts by replacing or providing substitute resources or environments (i.e., loss compensation).

301. There is general agreement among the resource agencies in regard to the alternatives recommended for replacement of habitat losses. These priorities are:

Priority 1	Replacement of habitat types lost on or adjacent to the project site (in kind, on site)
Priority 2	Replacement of habitat types lost at an alternative site (in kind, off site)
Priority 3	Development of alternative habitat types at the project site (out-of-kind, on site)
Priority 4	Development of alternative habitat types at other sites (out-of-kind, off site)

302. "In-kind" compensation refers to the replacement of the lost habitat value by the same biological and physical resources, or resources which approximate those lost so that total loss of habitat value will be eliminated. The replacement of habitat values with biologically or physically different ones is referred to as "out-of-kind" replacement.

303. According to USFWS policy, the level of mitigation (priority) required should be consistent with the value and scarcity of the fish and wildlife resource being affected. As a result, the USFWS has developed a system of mitigation planning goals based on four resource categories (table 14). It is the opinion of the USFWS that the habitat affected in Norfolk Harbor by the proposed expansion of CIDA (plan B) belongs to both Resource Categories 2 and 3. The shallow water habitat less than 2 feet mlw falls into Category 2 (approximately 540 acres*). Intertidal wetlands and flats also fall into Category 2 and comprise approximately 80 acres* according to USFWS. Deep water habitat greater than 2 feet mlw falls into Category 3 (approximately 2,000 acres*). Since habitat replacement or creation within the boundaries of Hampton Roads Harbor is impracticable, off-site restoration of tidally influenced waters (Priorities 2 and 3) is the only available and feasible mitigation measure.

304. Based on the information presented above, the USFWS biological mitigation goal for CIDA expansion plan B is: no net loss of in-kind habitat value for 620 acres* of shallow water and intertidal habitat and no net loss of habitat value while minimizing loss of in-kind habitat value for 2,000 acres* of aquatic habitat, where "in-kind" refers to estuarine, tidally influenced habitat with value to aquatic resources located in the Chesapeake Bay and its tributaries.

*These figures are subject to change (not yet resolved with F&WS).

Table 14. USFWS RESOURCE CATEGORIES AND MITIGATION PLANNING GOALS

Resource Category	Designation Criteria	Mitigation Planning Goal
1	High value for evaluation species and unique and irreplaceable	No loss of existing habitat value
2	High value for evaluation species and scarce or becoming scarce	No net loss of in-kind habitat value
3	High to medium value for evaluation species and abundant	No net loss of habitat value while minimizing loss of in-kind habitat value
4	Medium to low value for evaluation species	Minimize loss of habitat value

Source: USFWS (1981). U.S. Fish & Wildlife Service Mitigation Policy. Federal Register 46(15):7644-7663.

Mitigation Formulation

305. Chesapeake Bay and its adjoining tributaries are subject to the impacts of commercial, industrial, and urban development. Due to the deep water port potential of the Hampton Roads Harbor, numerous proposals to expand port facilities and activities have challenged the Corps of Engineers and Federal and state resource agencies to protect fisheries and other living marine resources in these waters against the potential adverse environmental and economic effects of dredging and filling, land reclamation, and pollution. In order to preserve and maintain the fisheries resources of the Chesapeake Bay, new approaches for mitigating or compensating for the impacts of necessary development are required.

306. Several methods of compensation for the loss of aquatic habitat, such as salt marsh creation and sea grass bed creation or restoration, have been effectively utilized at some sites for the replacement of these intertidal or shallow water communities. Relatively few attempts, however, have been made to compensate for the loss or degradation of open water estuarine habitat. For many developed areas such as the Hampton Roads Harbor, enhancement of the remaining open water habitat may be the only practical method of compensating for such losses. Several different mitigation alternatives were

developed as a cooperative effort between the Corps and the USFWS. These alternatives were presented to a joint committee of Federal and state environmental agencies on November 16, 1988. There were differing viewpoints expressed as to the competency of the alternatives to mitigate the loss of aquatic habitat. It was generally agreed that a mitigation plan which included several of the mitigation alternatives would be the most desirable from a resource compensation standpoint.

Project Mitigation

307. Mitigative Benefits of Proposed Design/Construction. The proposed project design and construction procedures have features that provide mitigative benefits. Minimization of project impacts will be attempted through the implementation of standard engineering practice and environmental design. Specifically, minimization of impact was attempted by evaluating at least six different expansion configurations for design capacity and life expectancy. Proposed construction features could lessen overall project impacts to some degree.

Riprap - The riprap to be placed on the outer face of the dikes would not only have benefits of erosion protection, but would increase heterogenity of aquatic habitat.

Dike Construction - Use of material within CIDA for dike construction, as much as possible, to extend useful life. Proper sedimentation and erosion control measures during construction. Water quality monitoring program during construction to insure no excessive turbidity or dissolved oxygen problems.

Dike Slope - That section of the dike slope which is located below mean low water would effectively replace a portion of the shallow water habitat lost. The total area of intertidal and shallow-water habitat created by the dike would be approximately 11 acres.

308. Mitigation Plan. The primary goal of mitigation is to maintain the long-term functional and productive capacity of the impacted habitat by reducing or offsetting resource losses attributed to a development project or management procedure. In the case of the Hampton Roads Harbor, where the habitat

available for possible compensatory enhancement is limited or restricted, an approach to mitigation which provides a more reliable and effective method of increasing selected habitat features or area carrying capacity for selected species is required. These features can be developed outside the immediate project area (i.e., "off-site") and still provide specific benefits to the James River Basin and adjoining Chesapeake Bay ecosystems.

309. Described in more detail, the following alternatives were developed with the USFWS in consultation with state and Federal environmental agencies and have emerged as potential mitigation compensation strategies which fulfill the suggested criteria:

310. Oyster Reef Construction/Enhancement. The Virginia Marine Resources Commission (VMRC) oversees an oyster replenishment program in the state. Approximately 2 million bushels of shell were planted on public grounds during the last fiscal year (1987), representing an expenditure of about $1.25 million. The goal of the program is to maintain and revitalize the oyster industry in Virginia. This is accomplished by:

(1) cleaning and turning existing shell material (cultivation);

(2) transplanting seed to viable growing areas;

(3) planting shell or other hard substrates to provide attachment surfaces for oysters.

311. Participation in this program would allow more intensive effort to be placed on oyster replenishment. VMRC indicates that there are many areas that could benefit from the implementation of such replenishment efforts and that funding, not lack of available sites, is the major obstacle to accomplishing more extensive work in this area.

Shoreline Stabilization at Ragged Island Wildlife Management Area

312. Ragged Island WMA is located on the James River just northwest of Craney Island. The 1,475 acre marsh and natural area is state-owned and managed. The shoreline at Ragged Island is eroding at a rate of approximately

2 feet per year over its entire 3 mile length. This represents a loss of about one acre per year. Proposed mitigation involves construction of offshore gapped breakwaters to provide erosion protection for the marsh. Benefits include preservation of wetlands, reduction of sediment input and turbidity and reclamation of marsh habitat in backfill areas.

Artificial Reefs

313. Artificial reefs are being used in numerous locations throughout the world to enhance fisheries and/or enhance recreational fishing opportunities. The Virginia Marine Resources Commission (VMRC) is involved in a pilot program of placing concrete "igloos" (reef structures) at various locations in the lower Chesapeake Bay and offshore in order to provide attachment surfaces for food organisms, cover, and habitat for resident fish populations. This mitigation strategy would involve participation with VMRC in developing fisheries habitat in the Chesapeake Bay through placement of artificial reef structures. Benefits include enhancement of fisheries stocks through provision of juvenile habitat and lower level food chain productivity.

Acquisition of Wooded Wetlands (within developing SE Virginia)

314. Some wetland areas are not considered "jurisdictional" and may not be protected. In some instances, wooded wetlands are being filled, drained, logged, etc. which results in cumulative losses over time. This mitigation strategy would allow a certain portion of this dwindling resource to be permanently preserved.

Fish Passage Facilities on the James River

315. The 1987 Chesapeake Bay Agreement includes a commitment that the signatories will "provide for fish passage at dams, and remove stream blockages wherever necessary to restore passage for migratory fish." This commitment was made in response to precipitous declines in the Bay's migratory fisheries and because of the recognition that these declines may be attributable, in part, to the loss of historic spawning and nursery habitat as a consequence of dams and other impediments. Several dam structures are present on the James River near Richmond which effectively impede the passage of anadromous fish to the upstream reaches of the river. The construction of fish passage facilities and stocking of fish upstream has greatly

enhanced or reintroduced anadromous stocks in New England and other areas after long absences. In January of 1988 the Living Resources Subcommittee appointed a work group to develop a strategy for implementing the Bay Agreement's commitments regarding fish passage. There was a consensus among work group members that construction of fish passages on the James near Richmond could similarly enhance commercial and recreational anadromous fishery stocks in the James and adjoining Chesapeake Bay. A goal of the states and Federal government as part of the Chesapeake Bay Initiative is the restoration of fish passage on both the James and Rappahannock Rivers. Fish passage through Richmond, according to the National Marine Fisheries Service (NMFS), is expected to increase standing crop of american shad by 600,000, striped bass by 156,000, river herring by 14,000,000, with an annual value of $7.7 to $12.5 million. The first two dams on the James in Richmond, the Manchester Dam and the Brown's Island Dam were breached in January, 1989, enabling fish to swim eight miles further upstream to spawn. According to officials, it will be 2 or 3 seasons before biologists can determine where the next dams upstream should be breached, because it will take that long to see where fish are congregating. The opening of the traditional Richmond-area spawning grounds is being funded by a $900,000 appropriation from the General Assembly, $300,000 from the city and $140,000 from the game and fish department's budget.

316. It should be emphasized that these mitigation plans come to the state merely as suggestions as options from which the state may choose. At its discretion, the numbers of options may be subtracted or added to. Once the state decides on a course of action regarding long-term disposal, it is then up to it to select mitigation option(s) and work out details with the environmental agencies. It is not anticipated that ocean disposal would require mitigation.

317. Mitigation Economics. In November 1988 a meeting was held with the advisory and regulatory state and Federal agencies that are involved in the review of the long-term disposal study to discuss the mitigation alternatives under consideration. The meeting resulted in no clear consensus as to the most appropriate types of compensation. The alternatives that seemed to have the most support included wetland stabilization at Ragged Island, oyster reef creation and enhancement in the James River, and restoration of anadromous

fish passage. Rather than select a preferred compensation alternative at this time, the consensus appeared to be to try to put a dollar value on the cost of compensation so that the environmental "costs" of the project could be factored into the overall economic analysis of the feasibility of the various alternatives. Recognizing that all compensation alternatives were out of kind, it was acknowledged that it would be difficult to arrive at a dollar value for the compensation. One alternative discussed was to base the mitigation cost on the value of existing upland area at CIDA. The Real Estate Division (Norfolk District) at this time determined that the fair market value for the Craney Island Disposal Area would be approximately $7000 per acre. This cost value was used, and the maximum compensation value for the plan B alternative (2500 acres) was calculated to be $17,500,000. The rationale for this method of deriving a compensation cost for the disposal project is that the compensation for the loss of estuarine habitat should be at least equal to the value of the upland area that would be created. The F&WS subsequently agreed upon this method for determining costs (see Attachment 2, Final F&WS Planning Aid Report, page 59).

318. The $17,500,000 figure for mitigation is offset somewhat by mitigative benefits of the constructed expansion project. The constructed project offers a riprap perimeter dike, providing diversity of habitat, shelter, feeding and attachment surfaces for aquatic organisms. That section of the dike slope which is located at and below mean high water would effectively replace a portion of the shallow water and intertidal habitat lost. The existing CIDA is known to be a high quality avian habitat. An expansion will enhance the productivity of the area as avian habitat, providing additional foraging and resting areas for waterfowl and shorebird species for at least 50 years and perhaps well into the future. These major benefits have been determined to contribute approximately 600 acres credit to the mitigation formula. Based upon this rationale, the following mitigation costs (expansion plan B) have been determined:

Mitigation @ $7000/acre for 2500 acres	$17,500,000
Credit @ $7000/acre for 600 acres	(($ 4,200,000))
Mitigation Cost	$13,300,000
Contingency and administration	1,286,000
Total cost of mitigation	14,586,000

319. Mitigation Trust Fund/Endowment. One method of funding various mitigation alternatives is to use the dollar figure arrived at above for mitigation, then establish an endowment with the money to fund designated mitigation alternatives. If a trust fund or endowment were to be set up, a specific set of guidelines would be established as to how, what, when and where these funds would be expended. A joint committee of state and Federal environmental agencies would be coordinated to establish these guidelines and then administer the expenditure of funds for specific mitigation projects which they identify. Possible guidelines or boundaries which the committee might establish:

(1) Projects should be accomplished within the state of Virginia, preferably within the James River Basin/lower Chesapeake Bay ecosystems.

(2) Proposed mitigation projects should be evaluated as to the adequacy of the proposal to restore the form and function of the habitat lost.

(3) In-kind mitigation which favors restoration or creation to duplicate the original habitat is preferable. Out-of-kind mitigation which emphasizes restoration of function of the lost habitat is next most preferable strategy to compensate for unavoidable losses.

(4) Majority concensus among committee members on mitigation projects would dictate how, when, where and what type of mitigation should be accomplished.

(5) Mitigation measures which fulfill the initiatives of the Chesapeake Bay Agreement should be strongly considered. Several areas of interest and

concern which would apply include living resources (tidal and non-tidal wetlands, fish passages, stock assessment for commercially, recreationally and ecologically valuable species, SAV's, monitoring plan for living resources, etc.), water quality (nutrient reduction, toxics and conventional pollutants reduction, toxics loading inventory, etc.), public information, education and participation, and public access.

320. This funding arrangement would require prior approval of all applicable resource agencies in order to be a viable option.

LIST OF PREPARERS

321. The following individuals were primarily responsible for the preparation of this Environmental Information Report.

Individual	Responsibility
Helene W. Haluska B.A. Sociology 15 yrs. EA & EIS Prep & Review	Socioeconomics
Craig L. Seltzer B.A. Biology M.S. Oceanography 12 yrs. EA & EIS Prep & Review	Scoping, overall EIR preparation, mitigation analysis
Thomas Yancey B.S. Civil Engineering M.S. Civil Engineering 21 yrs. Water Resources Plng	Project management & plan formulation

PUBLIC INVOLVEMENT

Public Involvement Program

322. The public involvement program (scoping process) pursuant to the preparation of this document formally began with the printing of the Notice of Intent to prepare an EIS in the Federal Register on August 6, 1987. At the same time, copies were sent to the regional and national offices of the U.S. Environmental Protection Agency. Approximately one and one-half years following the publication of this announcement, it was decided to prepare the study as an information document to the Commonwealth rather than a Corps decision-making document with a formal EIS. The title and format of the document has, therefore, been changed from that of an EIS to an Environmental Information Report. Five public meetings were held in connection with the preparation of the feasibility report which led to authorization of the deepening of the channels in Norfolk Harbor to as much as 55 feet. At that time, problems pertinent to dredged material disposal were discussed A public scoping meeting was held for this particular study in August, 1987.

323. Continued dialogue has been maintained with representatives of local governments in the study area and with various Federal, state, and local agencies. The U.S. Fish and Wildlife Service (USFWS) has participated in the evaluation of alternatives, project impacts, mitigation proposals, and has provided information included in this document. A coordination meeting which included Federal and state environmental agencies was held at the Norfolk District on 23 July, 1987. A later meeting of these agencies on 16 November, 1988, served as an arena to discuss mitigation proposals developed by the Corps and the USFWS. The Virginia Port Authority (VPA), a partner in this investigation, participated in a meeting with the USFWS at the Norfolk District on 9 January, 1989 at which time various mitigation proposals were discussed on a very preliminary basis.

324. In addition to the meetings mentioned previously, the coordination process also consisted of less formal meetings, personal contacts, and correspondence to selected agencies and organizations. These agencies provided valuable input and have been, in turn, kept informed of the progress of and the problems encountered during the study.

Required Coordination

325. Prior to any positive action toward implementation of any plan, this Environmental Information Report would be used in connection with preparation and processing of appropriate NEPA documentation for a particular plan. Appropriate coordination would include, but not be limited to, the following Federal, state, and other interests:

U.S. Environmental Protection Agency
U.S. Fish and Wildlife Service
National Marine Fisheries Service
National Park Service
Department of the Navy
Va. Historic Landmarks Commission
Va. Research Center for Archaeology
Va. State Water Control Board
Va. Council on the Environment (A-95 Clearinghouse)
Va. Department of Game and Inland Fisheries
Va. Dept. of Conservation and Economic Development
Va. State Dept. of Health
Va. Institute of Marine Science
Va. Marine Resources Commission
Va. Soil and Water Conservation Commission
City of Chesapeake
City of Hampton
City of Newport News
City of Norfolk
City of Portsmouth
City of Suffolk
City of Virginia Beach
Isle of Wight County

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ATTACHMENT 1

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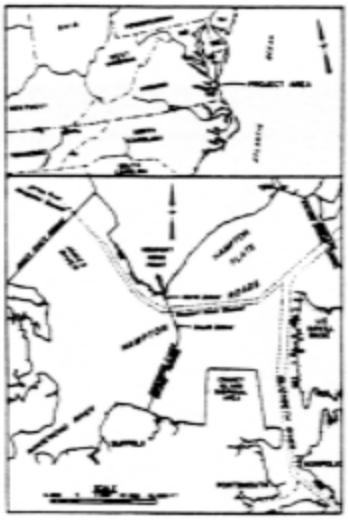

HYDRAULICS LABORATORY

TECHNICAL REPORT HL-88-8

LOWER JAMES RIVER CIRCULATION STUDY VIRGINIA, EVALUATION OF CRANEY ISLAND ENLARGEMENT ALTERNATIVES

by

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Hydraulics Laboratory

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This report presents results from the numerical model investigation whose primary objective was to assess general changes in circulation, currents, and sedimentation associated with six proposed alternative expansion geometries of the Craney Island confined disposal facility. An additional objective of the study was to assess the effects of each of the six alternative geometries on the reported estuarine circulation cell (flow convergence) off Hampton Flats and Newport News Point.

This numerical model investigation used the TABS-2 finite element numerical models RMA-2V for hydrodynamics and STUDH for sedimentation with a modified version of an existing numerical mesh of the Lower James River. Other information presently available regarding the estuarine circulation and flow convergence observed off Newport News Point and Hampton Flats was reviewed.

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19. ABSTRACT (Continued).

With the exception of the Newport News Channel, results from the numerical hydrodynamic modeling indicated no plan to base velocity differences greater than ±0.06 fps at any of the critical areas of interest. Velocity differences greater than 0.10 fps were indicated for the Newport News Channel; channel plan velocities always exceeded base velocities with maximum ebb velocity differences greater than maximum flood velocity differences. Plans with northward extensions resulted in the largest increases. The greatest changes, less than 0.35 fps on ebb and 0.25 fps on flood, were indicated for plans A and B, the largest expansion alternatives also involving westward expansions.

Subtle localized circulation variations, generally within 16,000 ft adjacent to and north and northwest of Craney Island, were identified in base to plan comparison vector plots.

Results from the numerical sedimentation modeling showed that plan to base shoaling index values (plan-predicted sedimentation divided by base-predicted sedimentation) were all within 90 to 110 percent at the critical areas of interest. The Nansemond River entrance was the only area considered to demonstrate any distinct changes in base and plan sedimentation. Considering the existing low sedimentation in the critical areas examined, the indicated differences are well within ordinary field survey detection limits.

Alternatives A, D, and F may impact water quality characteristics as a result of a reduced circulation zone between the Craney Island extension and the mainland.

Appendix A contains general information on the finite element method. A brief description of RMA-2V and STUDH appears in Appendices B and C, respectively.

PREFACE

In March 1987, the Norfolk District Corps of Engineers requested that the US Army Engineer Waterways Experiment Station (WES) conduct an investigation to assess general changes in circulation, currents, and sedimentation associated with six proposed alternative expansion geometries of Craney Island, the confined dredged material disposal site located in the lower James River.

The study was conducted by personnel of the Hydraulics Laboratory, WES, under the general direction of Messrs. F. A. Herrmann, Jr., Chief of the Hydraulics Laboratory; R. A. Sager, Assistant Chief of the Hydraulics Laboratory; W. H. McAnally, Jr., Chief of the Estuaries Division; and W. D. Martin, Chief of the Estuarine Engineering Branch. The project was conducted by Messrs. S. B. Heltzel and M. A. Granat, Estuarine Engineering Branch. This report was prepared by Messrs. Heltzel and Granat and edited by Mrs. Marsha C. Gay of the Information Technology Laboratory, WES.

The valuable technical and nontechnical contributions of Mr. J. R. Melchor, Norfolk District Corps of Engineers, are gratefully acknowledged.

COL Dwayne G. Lee, CE, is the Commander and Director of WES. Dr. Robert W. Whalin is the Technical Director.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENTS

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
acres	4,046.873	square metres
cubic feet	0.02831685	cubic metres
cubic yards	0.7645549	cubic metres
feet	0.3048	metres

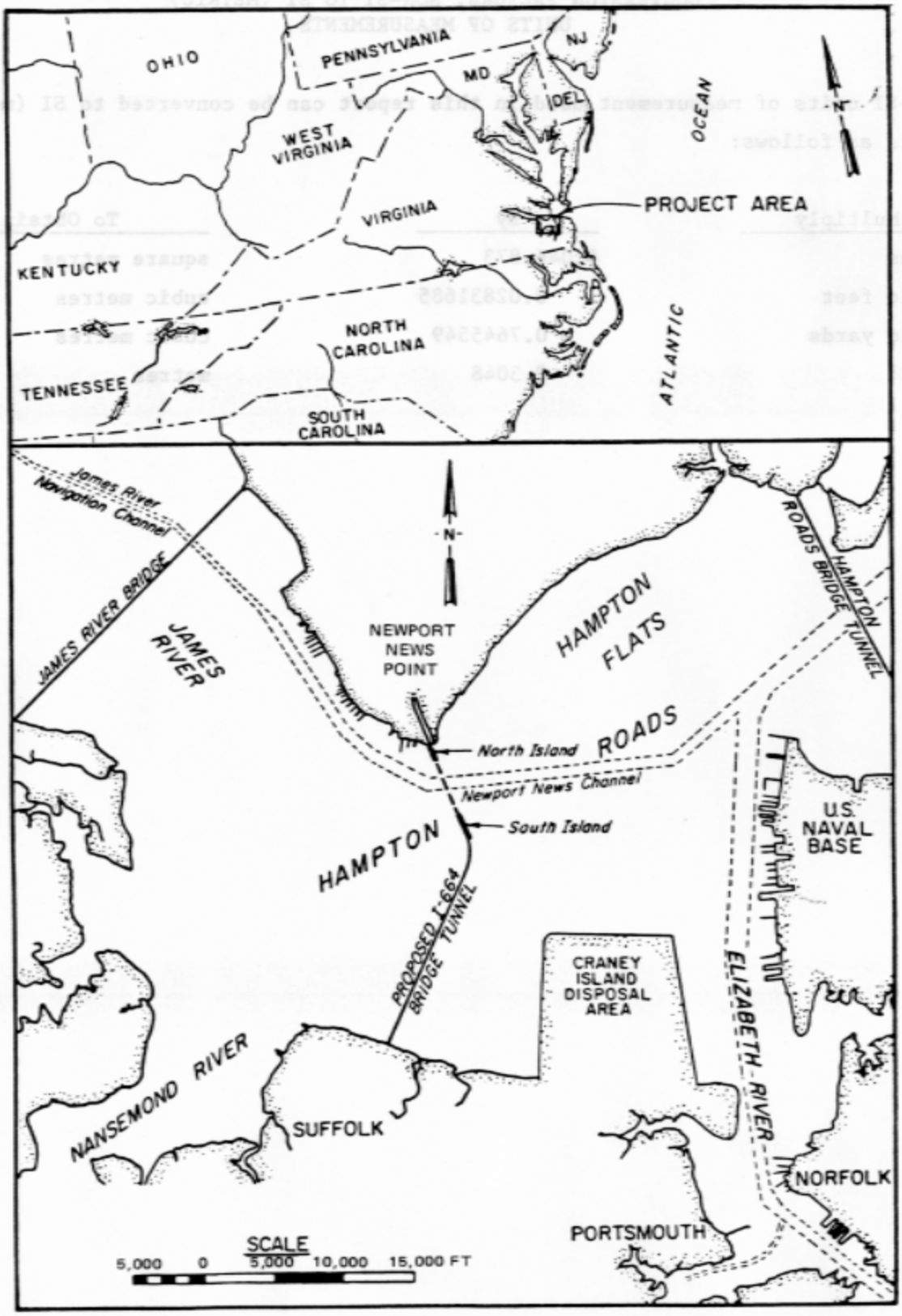

Figure 1. Project location

LOWER JAMES RIVER CIRCULATION STUDY, VIRGINIA

EVALUATION OF CRANEY ISLAND ENLARGEMENT ALTERNATIVES

PART I: INTRODUCTION

Background

1. The existing Craney Island disposal area is a 2,500-acre* confined disposal facility located near Norfolk, Virginia (Figure 1). Design plans for the facility were developed in the early 1940's, and construction was undertaken between 1954 and 1957. Several retaining dike elevation increases and the implementation of a management plan developed specifically for Craney Island (Palermo, Shields, and Hayes 1981) have greatly extended the useful life of the facility beyond initial expectations. At present, approximately 5 million cubic yards of predominately fine-grained maintenance dredged material from the channels and ports in the Hampton Roads area are annually disposed of in the facility.

2. Additional new work dredged material from the Norfolk Harbor and channels deepening and improvement project will also be placed into Craney Island. This new work dredged material will greatly reduce the storage capacity and active life of Craney Island. An expansion of the existing site or the development of an alternate site will be necessary to contain future new work and maintenance dredged material once the existing disposal site has reached its capacity. Six alternative expansion configurations for Craney Island are presently being considered by the Norfolk District Corps of Engineers.

3. An assessment of the impact of each alternative on circulation and sedimentation in the lower James River was undertaken as a preliminary planning level task. Other concurrent tasks included analyses to determine the storage capacity and active dredged material disposal life of each of the proposed alternatives and development of preliminary guidelines for management

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* A table of factors for converting non-SI to SI (metric) units of measurement is presented on page 3.

of the new areas* and an evaluation of the required retaining dike geotechnical engineering characteristics (stability, constructibility, and cost) for each alternative (Spigolon and Fowler 1987).

Purpose

4. The primary objective of the present study was to use available numerical models to assess general changes in circulation, currents, and sedimentation associated with each of the six proposed alternative expansion geometries of Craney Island. An additional objective of the study was to assess the effects of each of the six alternative geometries on the reported estuarine circulation cell (flow convergence) off Hampton Flats and Newport News Point.

Scope

5. The numerical modeling portion of this study was designed to address relative alternative-induced changes in overall hydrodynamics and to assess relative sedimentation changes in four specific critical zones of interest. The primary focus was circulation and sedimentation in relatively low velocity areas, so the cohesive version of a numerical sediment code was used since it more directly reflected circulation and suspended sediment transport. Figure 2 illustrates the James River study area with the four zones of interest highlighted: Area A, the entrance to Willoughby Bay; Area B, the Hampton Flats; Area C, the entrance to the Nansemond River; and Area D, Burwell Bay.

6. The circulation cell off Newport News Point and Hampton Flats was addressed using results from the numerical model study, comparison with surface current pattern mosaics from earlier physical model investigations** of the James River, review of a recent investigation of the area (Byrne et al. 1987) conducted by the Virginia Institute of Marine Science (VIMS), and a

---

* G. F. Goforth. 1986. "Disposal Life Evaluation of Alternative Expansion Configurations for Craney Island Disposal Facility," Draft Report, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

** N. J. Brogdon, Jr., and W. H. Bobb. 1967. "Effects of Proposed Waterfront Developments at Newport News Point on Tides, Currents, Salinities, and Shoaling," Draft Report, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

PART II: NUMERICAL MODELING APPROACH

The Numerical Models

7. The Corps numerical modeling system, Open-Channel Flow and Sedimentation, TABS-2 (Thomas and McAnally 1985), was used in this investigation. The two primary finite element numerical model codes used were A Two-Dimensional Model for Free Surface Flows (RMA-2V) and Sediment Transport in Unsteady Two-Dimensional Flows, Horizontal Plane (STUDH). Both codes employ the finite element method to solve the depth-integrated governing equations. Appendix A contains general information on the finite element method. A brief description of RMA-2V and STUDH appears in Appendices B and C, respectively.

Lower James River Computational Meshes

8. The computational mesh used during this investigation was a modified version of the mesh developed for the I-664 bridge tunnel crossing study (Heltzel, in preparation). Modifications to this mesh included (a) revising the schematization around Craney Island by adding additional elements to incorporate the six Craney Island enlargement alternatives, (b) extending the mesh into lower Chesapeake Bay to improve modeling of hydrodynamic and sedimentation processes in the Willoughby Bay area, and (c) effectively doubling the mesh resolution in the critical zones of Burwell Bay, the Nansemond River entrance, and Newport News Point/Hampton Flats area. All of the conditions tested included the completed I-664 bridge tunnel crossing and the 55-ft Newport News and Norfolk Harbor channels.

9. The basic revised mesh, presented in Figure 3, contains 2,326 nodes and 806 elements. This mesh incorporates all six alternative geometries to eliminate the possibility of required mesh resolution refinement between conditions as a possible cause for anomalous plan variations in hydrodynamic or sedimentation results. An enlarged view of the Craney Island area illustrating the schematization used for each of the proposed enlargement alternatives is provided in Figure 4. The highlighted areas in each schematization indicate the elements that were deleted from the computational space for each of the conditions considered. During testing, the boundary of each mesh conformed to the new geometry for each of the respective alternatives. Figure 5

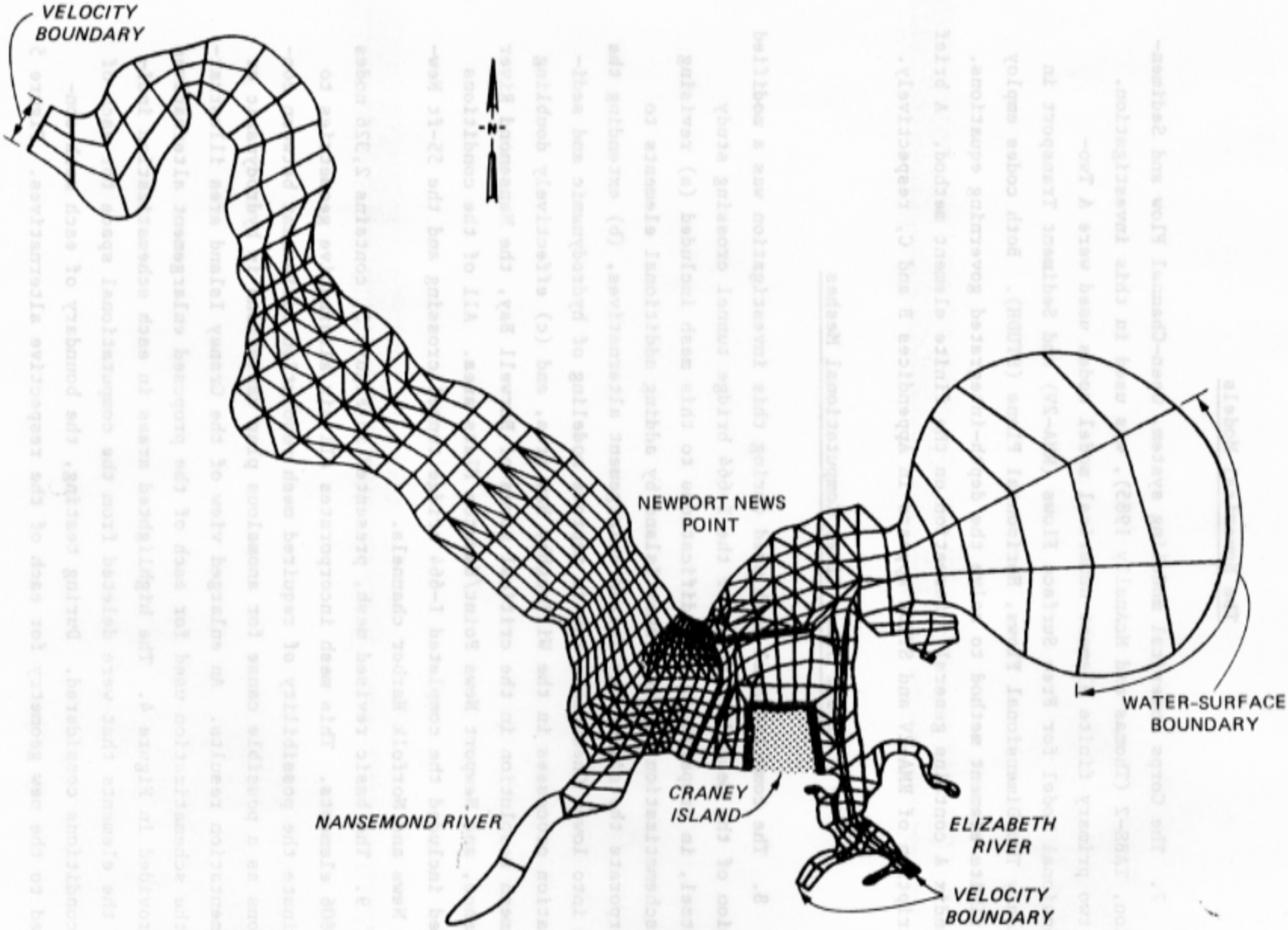
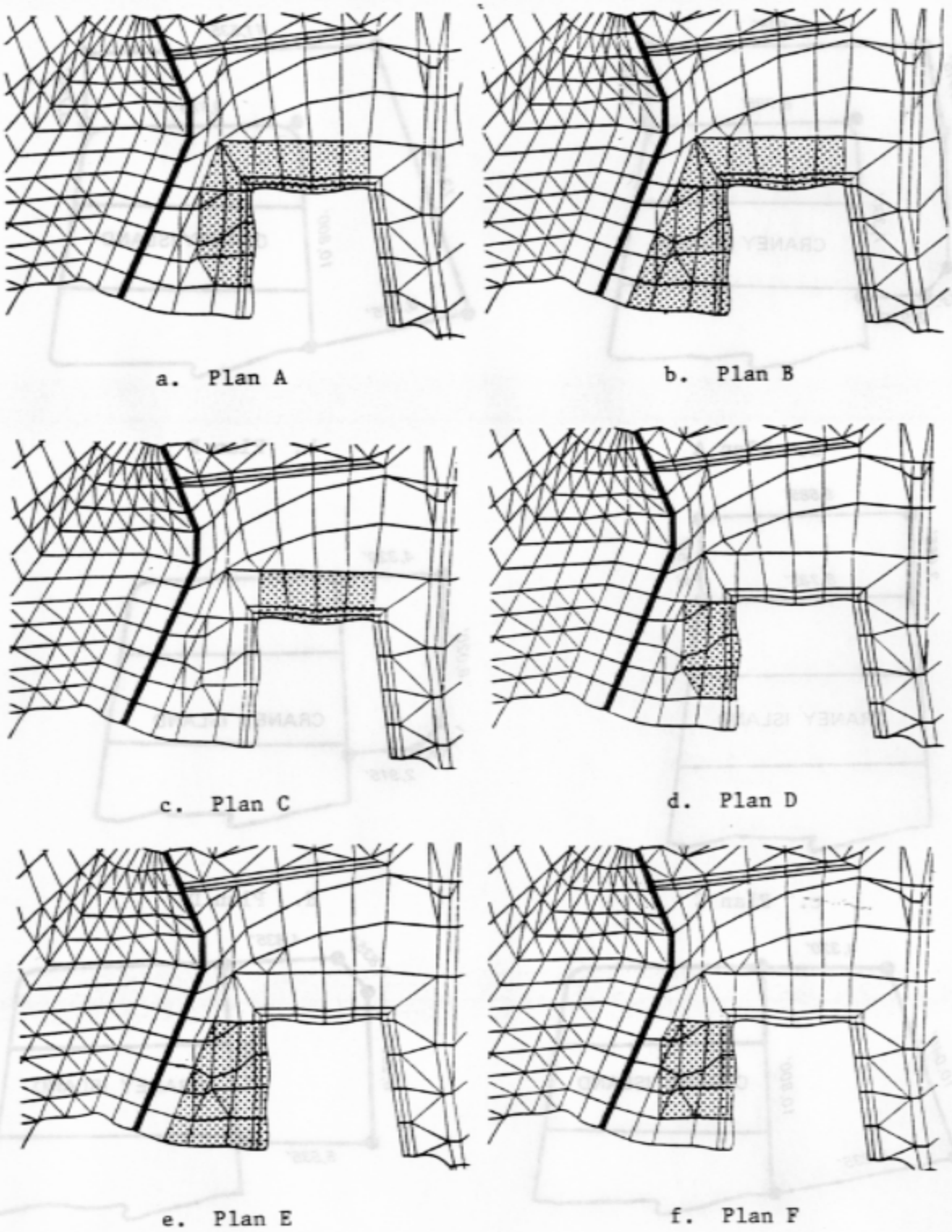


Figure 3. Numerical model mesh for lower James River-Craney Island study



NOTE: SHADED AREAS REPRESENT ALTERNATIVE EXTENSIONS.

Figure 4. Mesh schematization of Craney Island enlargement alternatives

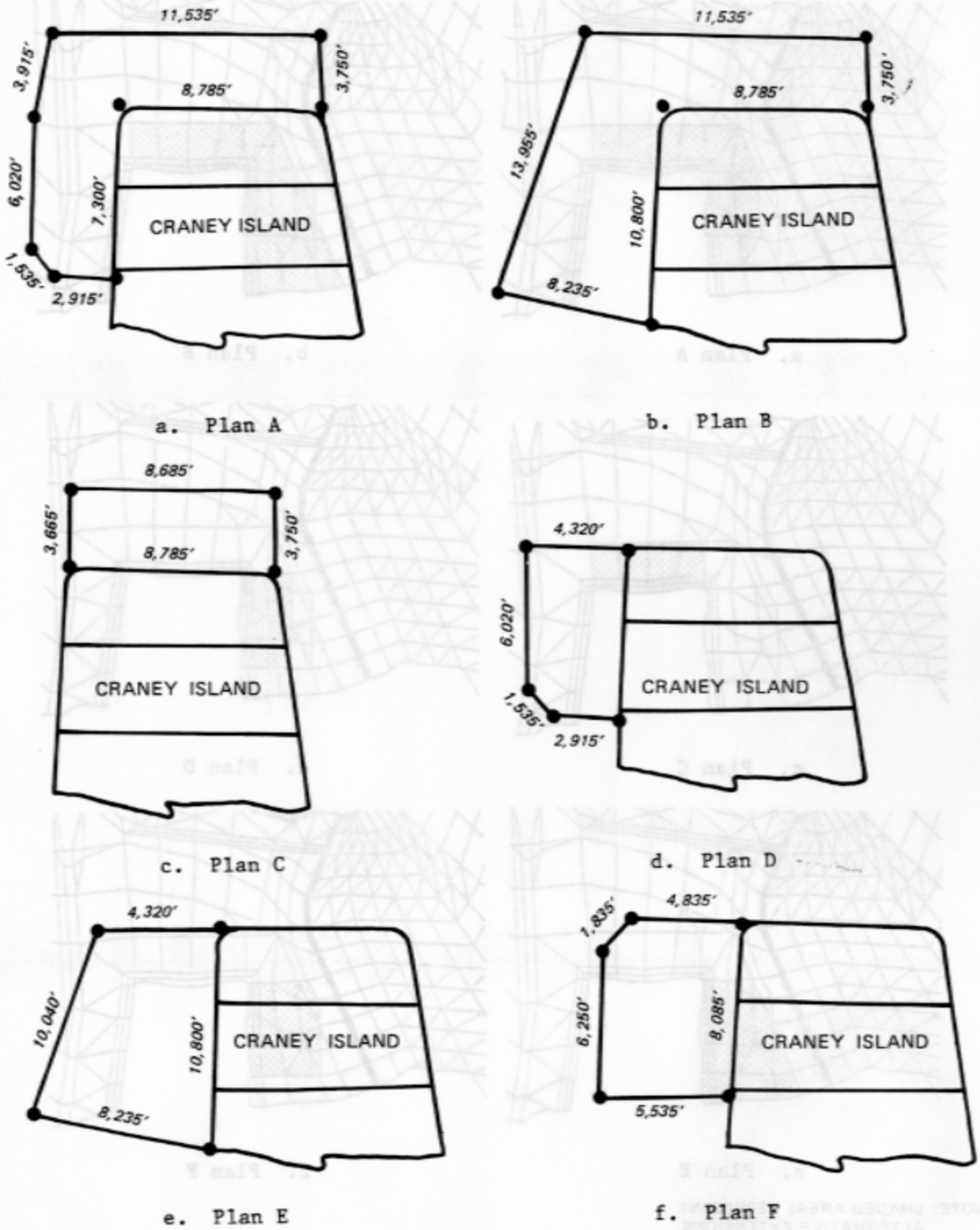
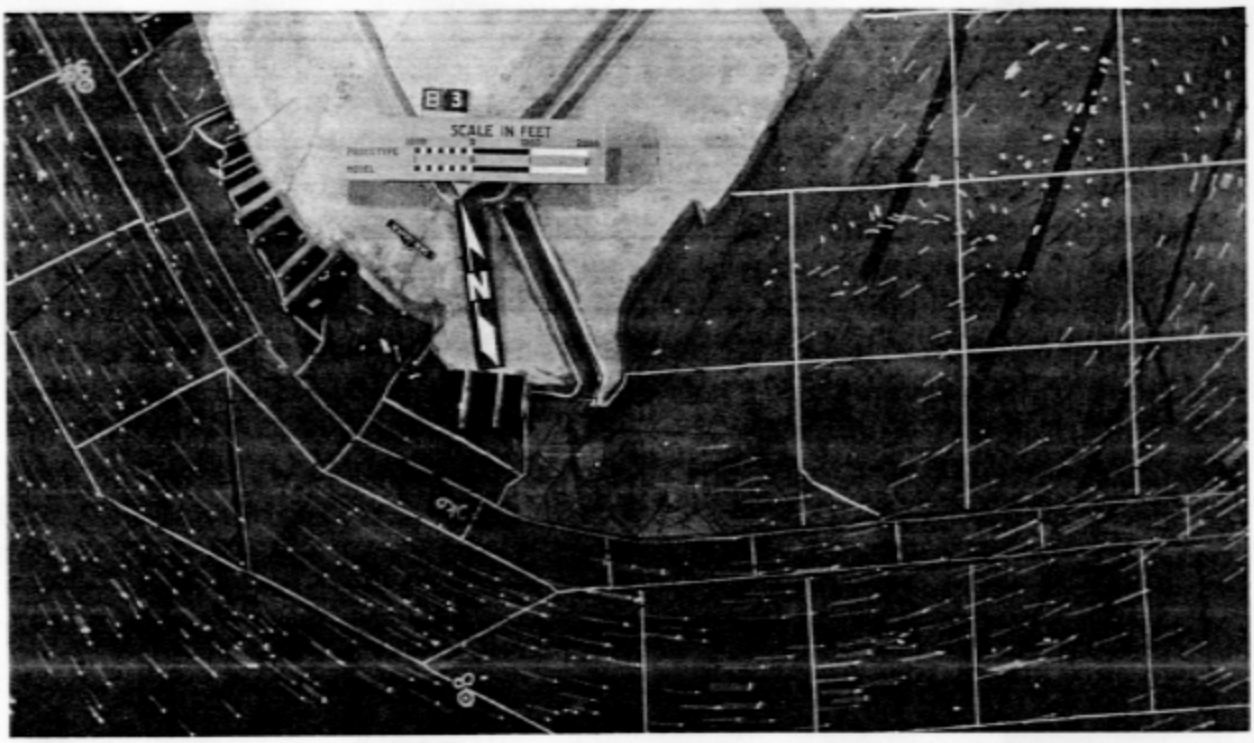
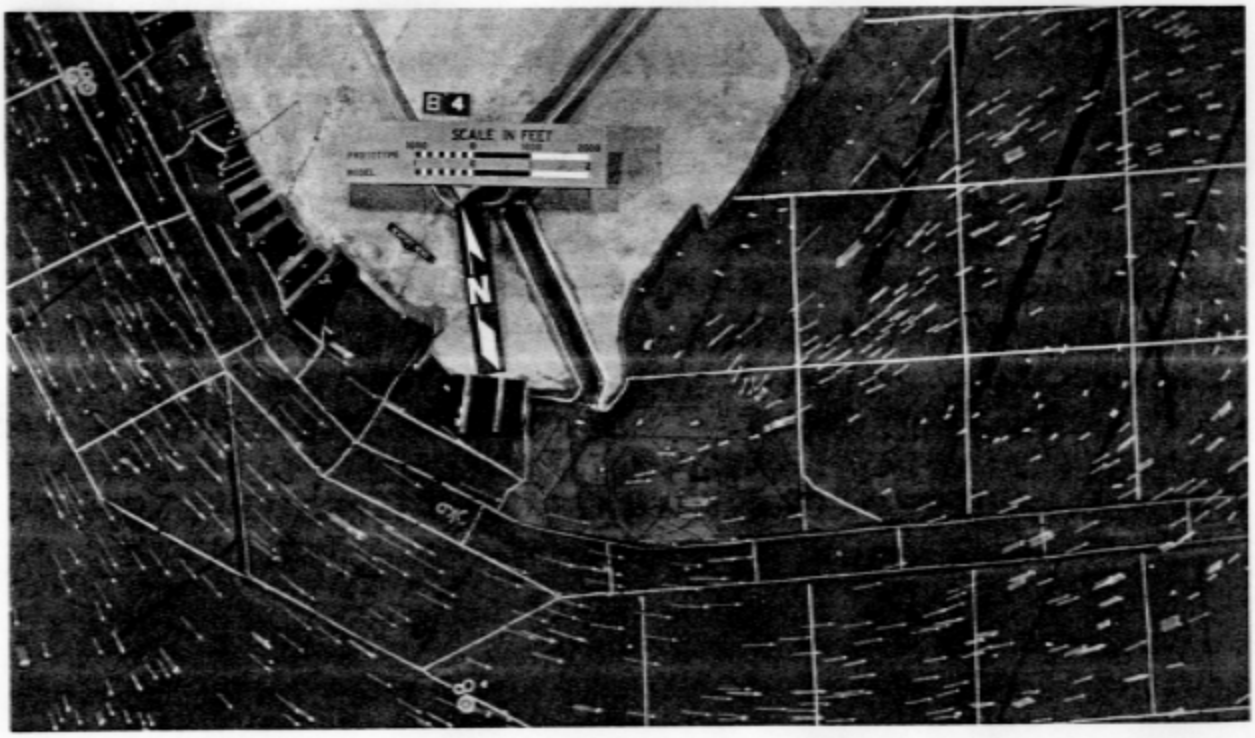


Figure 5. Dimensions of Craney Island enlargement alternatives

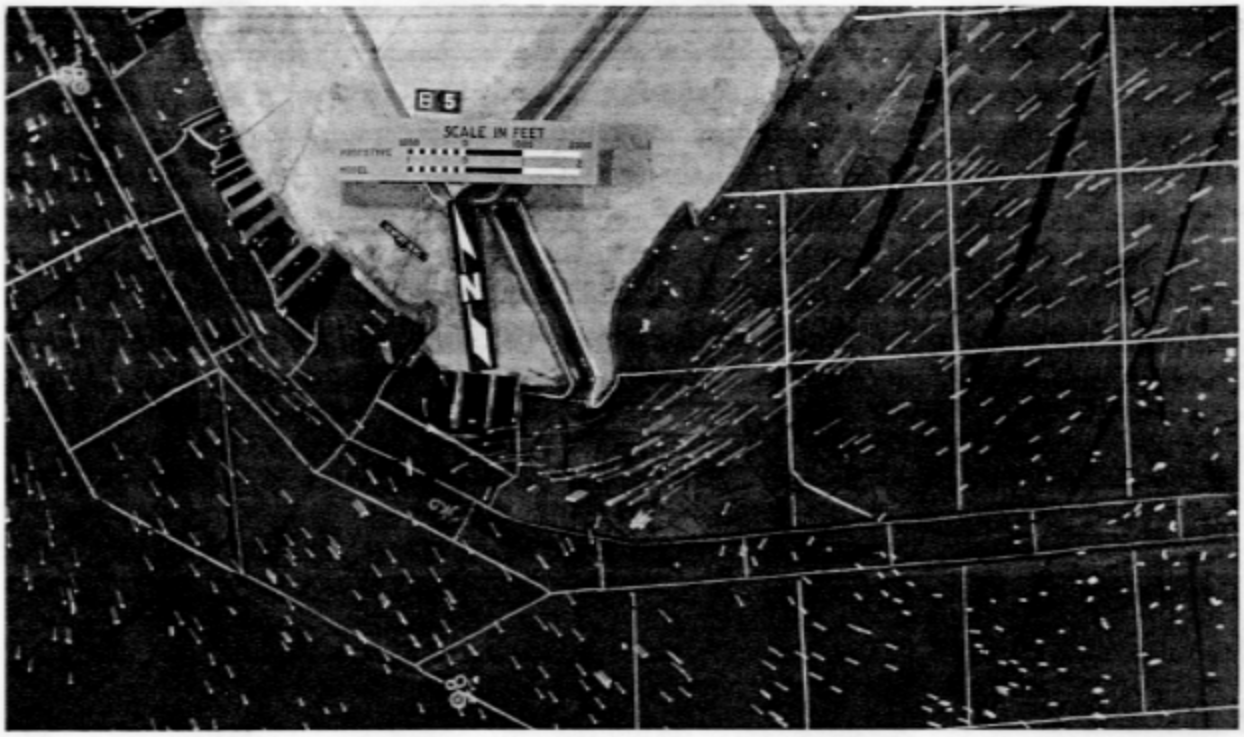


a. Hour 3

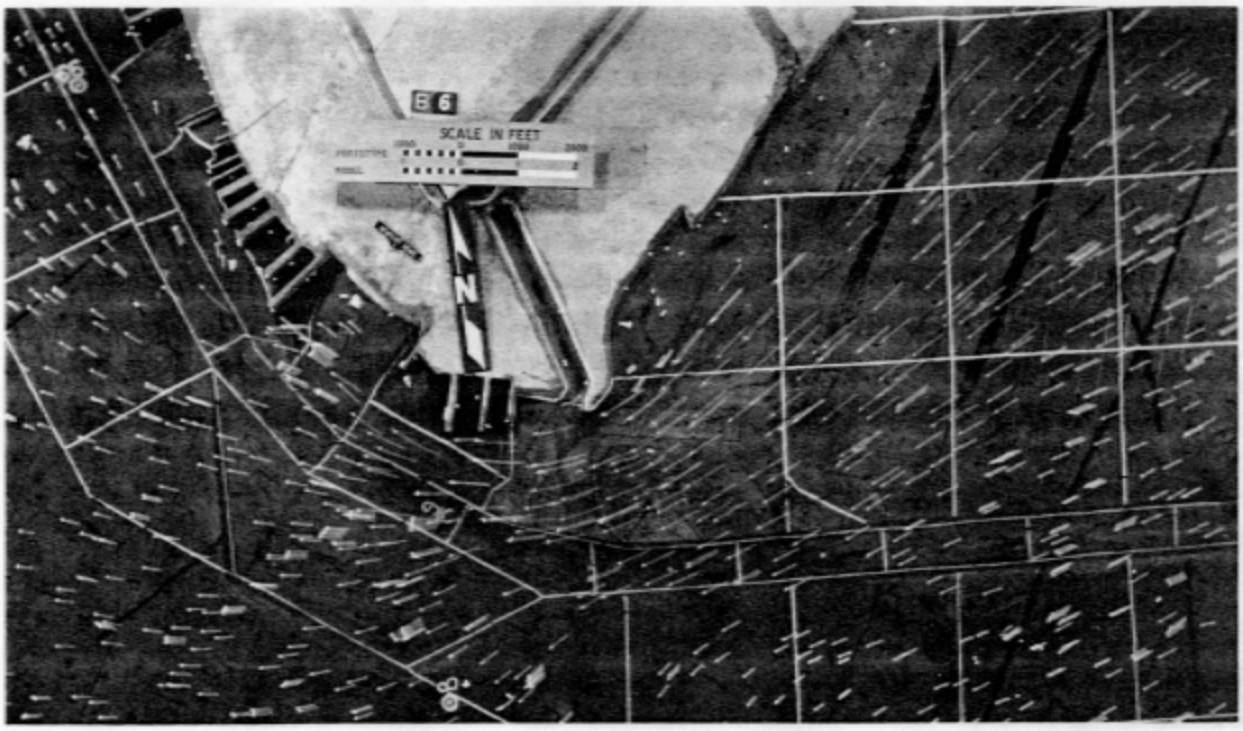


b. Hour 4

Figure 6. Surface currents, hours 3-6 (from Brogdon and Bobb, op. cit.) (Continued)



c. Hour 5



d. Hour 6

Figure 6. (Concluded)

The illustrated base condition included the proposed 35-ft channel from Newport News to Richmond and the proposed enlargement of Newport News Channel and anchorages. The boundary conditions included a 2.5-ft mean tide range condition at Hampton Roads, a Chesapeake Bay sump salinity of 24.2 ppt, and the long-term average freshwater inflow of 7,500 cfs for the James at Richmond, 1,000 cfs for the Appomattox, 300 cfs for the Chickahominy, and 700 cfs for the Nansemond which included the discharges of the Warwick, Pagan, Chuckatuck, and Elizabeth rivers.

17. As indicated in Figure 6, an early onset of the flood current over the Hampton Flats area began at hour 3 while the flow upstream of Newport News Point and south of Hampton Flats was still at strength of ebb. As demonstrated at hour 4, flood flow over Hampton Flats was fully developed while flows west of Newport News Point and in Newport News Channel were still ebbing. The flood current was not fully developed in Newport News Channel and west of Newport News Point until hour 6. Similar circulation patterns were demonstrated in the other physical model studies.

New Port Island Investigation

18. The New Port Island study recently completed by VIMS (Byrne et al. 1987) was an extensive multitasked investigation conducted to evaluate potential lower James River marine resources impacts associated with the development of New Port Island, a recreational/port facility, to be located on Hampton Flats. A major emphasis of this study was the estuarine circulation off Newport News Point, its effects on oyster larvae transport, and the potential impacts associated with various alternative configurations for the proposed island.

19. The VIMS study concluded that the flow convergence off Newport News Point, described as a frontal system, was a persistent phenomenon expected to occur during times of flood current under normal tidal range, freshwater inflow, and meteorological conditions. The flow convergence was said to be the result of geometry-induced local phase (time of arrival) differences between initial flood currents on Hampton Flats and Newport News Channel and ebbing flows west of Newport News Point. The local salinity distribution was said to be another essential factor to the formation of the front. During development of the flow convergence, the currents on Hampton Flats, and later

in the Newport News Channel, began to flood while the currents west of Newport News Point were still ebbing. The study also concluded that the depth transition at Newport News Point enhanced and stabilized the location of the convergence zone. Dye studies demonstrated that the surface floodwaters downstream of the convergence zone were transported to depths of 13 to 16 ft upstream of the convergence zone.

WES Supplemental Field Survey

20. WES conducted a limited field survey* in the lower James River on 22-24 July 1986 to acquire additional supplemental field data during a preliminary stage in the development of a three-dimensional James River modeling effort. Four boats were used to collect vertical velocity and salinity data at 13 stations during a complete 13-hr tidal cycle on 22 and 24 July. Data were collected at five locations in the vertical and at approximately half-hour intervals where station spacing permitted.

21. Environmental conditions were not representative of normal conditions in the lower James River. The freshwater discharge of approximately 1,000 cfs was well below the long-term average condition. In addition, strong winds were blowing and gusting from the east and southeast during the survey effort. The boat located at Newport News Point was unable to complete the entire tidal cycle survey due to high wave conditions; data were collected only during the later stages of ebb and the early stages of flood, the predicted period of time for the convergence phenomenon. As confirmed by the vertical salinity data, these conditions resulted in a reduced stratification.

22. Instantaneous middepth velocities were analyzed for the 13 stations during this period of time. These data demonstrated the early flood on Hampton Flats relative to the Newport News Channel station. Tidally averaged bottom velocities generally illustrated net upstream movement onto the Hampton Flats and net downstream movement in the Newport News Channel. The velocities averaged over depth and then over the tidal cycle illustrated the same general trends with some magnitude changes. The existence of this circulation and the convergence phenomenon, despite the unfavorable conditions for its formation (low freshwater discharge and high winds and waves), clearly demonstrates its

---

* Heltzel, op. cit.

persistence. The acquired data did not confirm or disprove the plunging current concept discussed in the VIMS report.

PART IV: MODELING RESULTS AND DISCUSSION

Hydrodynamic Impacts

23. Localized and subtle base to plan hydrodynamic differences were indicated. Hydrodynamic vector plots for maximum ebb* (hr 14.00) and maximum flood (hr 20.00) conditions in the lower James River for each of the plan conditions are printed in red in Plates 1-12. The corresponding base condition is printed in black on each plate. Except for the Craney Island extension area, where only base vectors occur, the plan velocity was identical to base conditions (i.e., when red plan vectors exactly overlay black base vectors, only the black vector is visible). Closeup hydrodynamic vector plots for the Newport News/Hampton Flats area for the period around slack before flood (hr 15.00, 16.00, and 17.00) for each of the plan conditions are printed in red in Plates 13-18. These plots illustrate the Hampton Flats circulation cell and the convergence zone for each plan condition. Again, the corresponding base circulation is printed in black on each plot. Each of the vector plots is based on a regular grid pattern that uses the finite element shape functions and the calculated nodal velocity vectors.

24. Subtle localized variations, generally within 16,000 ft adjacent to and north and northwest of Craney Island, are indicated on the vector plots comparing the plan conditions to the base condition. Plans A-C (Plates 1-6), which all involve northward Craney Island extensions, appear to illustrate the largest hydrodynamic impacts. Plans A and B, which also involve westward extensions, illustrate the largest changes. Some of the indicated variation may be the result of small plan to base phase shifts or simply numerical noise.

25. The vector plots provide an excellent visual presentation of the circulation for each condition; however, quantifying variations between the various plans is difficult from these plots. Figure 7 illustrates the locations of 13 nodes that were examined in detail to summarize the actual

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* As in the physical model investigations, the indicated times are referenced to the moon's transit over the entrance to Chesapeake Bay (the 76th meridian). A repetitive 12.42-hr tidal cycle was used in the numerical model runs; i.e., hr 13.00 (the first time-step in cycle 2) corresponds to hr 0.58 of the first tidal cycle.

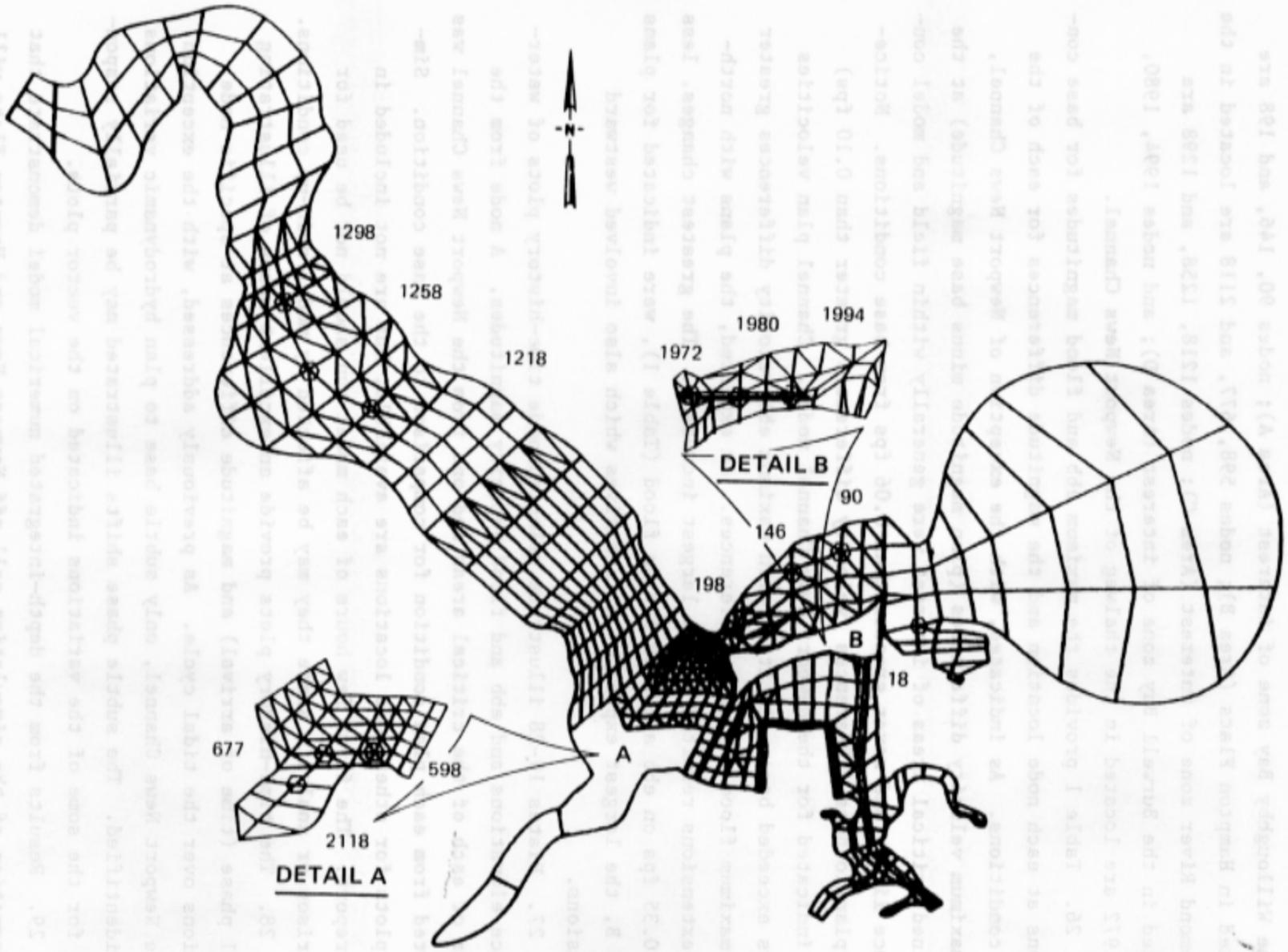

Figure 7. Numerical model nodes examined in detail

differences in magnitude between the velocities of the base condition and each of the plan conditions. In the order listed, node 18 is located in the center of the Willoughby Bay zone of interest (Area A); nodes 90, 146, and 198 are located in Hampton Flats (Area B); nodes 598, 677, and 2118 are located in the Nansemond River zone of interest (Area C); nodes 1218, 1258, and 1298 are located in the Burwell Bay zone of interest (Area D); and nodes 1994, 1980, and 1972 are located in the thalweg of the Newport News Channel.

26. Table 1 provides the maximum ebb and flood magnitudes for base conditions at each node location and the magnitude differences for each of the plan conditions. As indicated, with the exception of Newport News Channel, all maximum velocity differences (plan magnitude minus base magnitude) at the examined critical areas of interest were generally within field and model confidence limits and never greater than 0.06 fps from base conditions. Noticeable plan to base differences (velocity differences greater than 0.10 fps) were indicated for the Newport News Channel nodes. Channel plan velocities always exceeded base velocities with maximum ebb velocity differences greater than maximum flood velocity differences. As expected, the plans with northward extensions resulted in the largest increases. The greatest changes, less than 0.35 fps on ebb and 0.25 fps on flood (Table 1), were indicated for plans A and B, the largest expansion alternatives which also involved westward expansions.

27. Plates 19-28 illustrate selected node time-history plots of water-surface elevations and ebb and flood velocity magnitudes. A node from the center of each of the critical areas and one from the Newport News Channel was selected from each plan condition for comparison to the base condition. Similar plots for other node locations are available, but are not included in this report. The first few hours of each model run should not be used for comparison or analysis since they may be affected by model spin-up conditions.

28. The time-history plots provide an excellent means of illustrating actual phase (time of arrival) and magnitude differences at specific node locations over the tidal cycle. As previously addressed, with the exception of the Newport News Channel, only subtle base to plan hydrodynamic variations were identified. The subtle phase shifts illustrated may be partially responsible for the some of the variations indicated on the vector plots.

29. Results from the depth-integrated numerical model demonstrate that the formation of the circulation cell off Newport News and Hampton Flats will

continue under all of the alternative plans examined. This circulation cell is the result of the early onset of the flood currents over Hampton Flats associated with bathymetric shielding of the ebb currents over the flats by Newport News Point. This large-scale geometry-induced phase difference existed during all of the plans tested.

30. The differences indicated in the time-history and vector plots are subtle and indicate the impacts to be localized, within 16,000 ft of Craney Island (see paragraph 24), with no impacts identified to the general estuarine circulation outside of this region. The bathymetric shielding, combined with the depth transition as described in the VIMS study (Byrne et al. 1987) and summarized in paragraph 19, has the effect of stabilizing the location of the convergence zone.

31. Potential impacts to the reported frontal system, a three-dimensional phenomenon, should not be quantified with the information from the present investigation. The following generalizations can be made, however, based upon the available information and present estuarine experience. Hydrodynamic impacts to the general three-dimensional circulation will be small, if any, and will be extremely difficult to measure. Alternatives with northward Craney Island expansions will have the greatest potential to affect the three-dimensional circulation processes.

Sedimentation Impacts

32. Sedimentation rates are generally sensitive to subtle variations in circulation characteristics. Small changes in hydrodynamic processes are usually amplified in the sedimentation responses. Sedimentation comparisons therefore provide an excellent means of quantitatively assessing overall base to plan impacts.

33. For reporting purposes, the predicted shoaling volume for each element in the zone of interest was combined to estimate yearly shoaling rates for each zone. Table 2 provides a summary of the plan-predicted sedimentation divided by the base-predicted sedimentation, the plan to base shoaling index value, for the four critical areas of interest for each of the six alternative plans. Based on available field data, shoaling rates in each of these areas are generally low (less than 0.5 ft/year), and the indicated shoaling index values are generally well within normal hydrographic survey detection limits.

34. Of the four zones examined, the Nansemond River entrance, Area C, is the only zone considered to demonstrate any distinct change in base to plan sedimentation. It should be stressed that even these variations are rather subtle, especially considering the generally low sedimentation rates. Plans A, B, and C, which all involve northward extensions of Craney Island, resulted in reduced sedimentation in the Nansemond area for the alternative conditions. The largest sedimentation change, about a 9 percent reduction in shoaling, was indicated for plan C, the alternative that involved expansion only to the north.

35. Plans D, E, and F, which involve only westward extensions of Craney Island, resulted in increased sedimentation in the Nansemond area. Plan F resulted in the largest increase, about a 7 percent increase from the base shoaling rate. The second largest increase, about 4 percent, was indicated for plan D. It is interesting to note that none of alternatives A, D, nor F extends to the mainland (Figure 4), allowing additional sluggish circulation between the disposal site and the mainland. Plan E extends to the mainland. Although this alternative encompasses a larger area than either plans F or D, it appears to have a reduced impact on sedimentation. An additional consideration associated with plans A, D and F is a potential impact on water quality associated with reduced circulation between the mainland and the disposal site (Plates 1 and 2, 7 and 8, and 11 and 12).

PART V: CONCLUSIONS

36. No plan to base velocity differences greater than ±0.06 fps were identified at any of the four critical areas of interest. With the exception of the Newport News Channel, only localized and subtle base to plan velocity differences were indicated. Plan to base magnitude increases greater than ±0.10 fps were identified in the Newport News Channel. The greatest increases, less than 0.35 fps on ebb and 0.25 fps on flood, were indicated for plans A and B, which involved both northward and westward Craney Island extensions.

37. Subtle localized circulation variations were identified in base to plan comparison vector plots. When these variations occurred, they were generally within 16,000 ft north and northwest of Craney Island. In some instances, these variations were associated with slight hydrodynamic phase shifts.

38. Plan to base shoaling index values (plan-predicted sedimentation divided by base-predicted sedimentation) for all conditions were well within hydrographic survey detection limits. The Nansemond River entrance was the only zone that demonstrated any distinct change in plan to base sedimentation. These variations were rather subtle, less than ±10 percent.

39. Plans A, B, and C, involving extensions to the north, resulted in reduced sedimentation within the Nansemond zone. The largest change, about a 9 percent reduction in sedimentation, was indicated for plan C, the alternative that involved only northward extension.

40. Increased sedimentation within the Nansemond zone was indicated for plans D, E, and F, which involve only westward extensions of Craney Island. The largest increases were for plans D and F (about 4 and 7 percent, respectively), Craney Island extensions which do not extend to the mainland.

41. Alternate plans A, D, and F may impact water quality characteristics as a result of a reduced circulation zone between the Craney Island extension and the mainland.

42. Formation of the circulation cell off Newport News and Hampton Flats will continue under all of the alternatives examined. The general location of the convergence zone was also unaffected.

43. Potential three-dimensional circulation impacts to the reported frontal phenomenon cannot be quantified with the available two-dimensional

numerical model results. Alternatives with northward expansions have the greatest potential for any hydrodynamic impact, although even these impacts are felt to be small relative to the capability to measure them in the field.

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Table 1

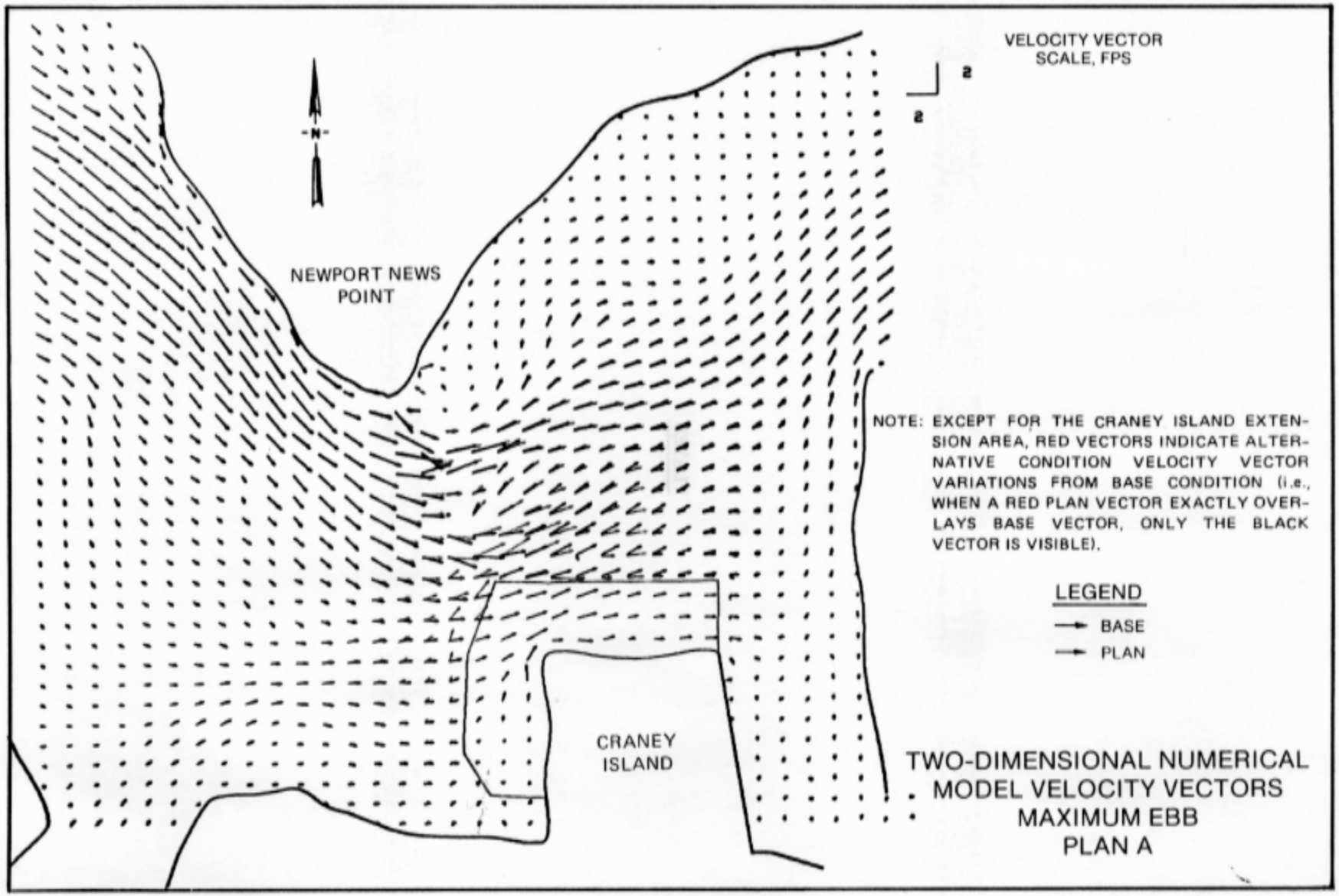
Velocity Changes at Selected Nodes (Plan Minus Base)

Area	Node No.	Base Maximum, fps		Change, fps											
				Plan A		Plan B		Plan C		Plan D		Plan E		Plan F	
		Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood
Willoughby Bay (Area A)	18	0.68	0.70	-0.02	-0.02	-0.03	-0.03	-0.02	-0.02	-0.01	-0.01	-0.01	-0.02	-0.01	-0.01
Hampton	90	0.58	0.60	-0.04	-0.01	-0.02	-0.01	-0.01	0.00	-0.01	0.00	-0.01	-0.01	-0.01	-0.01
Flats	146	0.63	0.55	0.02	0.02	0.01	0.02	0.02	0.02	0.01	0.01	0.00	0.00	0.01	0.01
(Area B)	198	0.82	0.65	0.00	0.06	0.00	0.06	0.00	0.04	0.04	0.00	-0.05	0.00	-0.04	0.00
Nansemond	598	0.43	0.54	-0.04	-0.01	-0.03	-0.01	-0.01	0.00	-0.02	0.00	-0.02	0.00	-0.03	-0.01
River	677	0.52	0.73	-0.01	-0.04	-0.01	-0.04	0.00	-0.02	0.00	-0.02	0.00	-0.02	0.00	-0.02
(Area C)	2118	0.67	0.71	-0.02	-0.03	-0.02	-0.03	-0.02	-0.01	-0.02	-0.01	-0.02	-0.01	-0.02	-0.01
Burwell	1218	1.43	1.26	-0.03	0.00	-0.03	0.00	-0.02	0.00	-0.02	0.01	-0.02	0.01	-0.02	0.01
Bay	1258	1.13	1.39	-0.01	-0.03	-0.01	-0.03	0.00	-0.02	0.00	-0.01	0.00	-0.01	0.00	-0.01
(Area D)	1298	1.24	1.32	0.02	-0.02	0.02	-0.02	0.02	-0.01	0.02	0.00	0.02	-0.01	0.02	-0.01
Newport	1994	1.10	1.06	0.10	0.04	0.09	0.03	0.12	0.06	0.00	-0.01	-0.01	-0.01	0.00	-0.01
News	1980	1.30	1.22	0.27	0.17	0.25	0.16	0.17	0.15	0.05	0.00	0.04	-0.01	0.05	0.00
Channel	1972	2.05	1.24	0.33	0.23	0.32	0.22	0.18	0.12	0.15	0.04	0.14	0.04	0.16	0.05

Table 2

Shoaling Index (Plan/Base)

Area	Plan A	Plan B	Plan C	Plan D	Plan E	Plan F
A	0.99	0.99	0.99	0.99	0.99	0.99
B	1.01	1.01	1.01	1.00	1.01	1.01
C	0.93	0.94	0.91	1.04	1.03	1.07
D	1.00	0.99	1.00	1.00	0.99	0.99



TWO-DIMENSIONAL NUMERICAL
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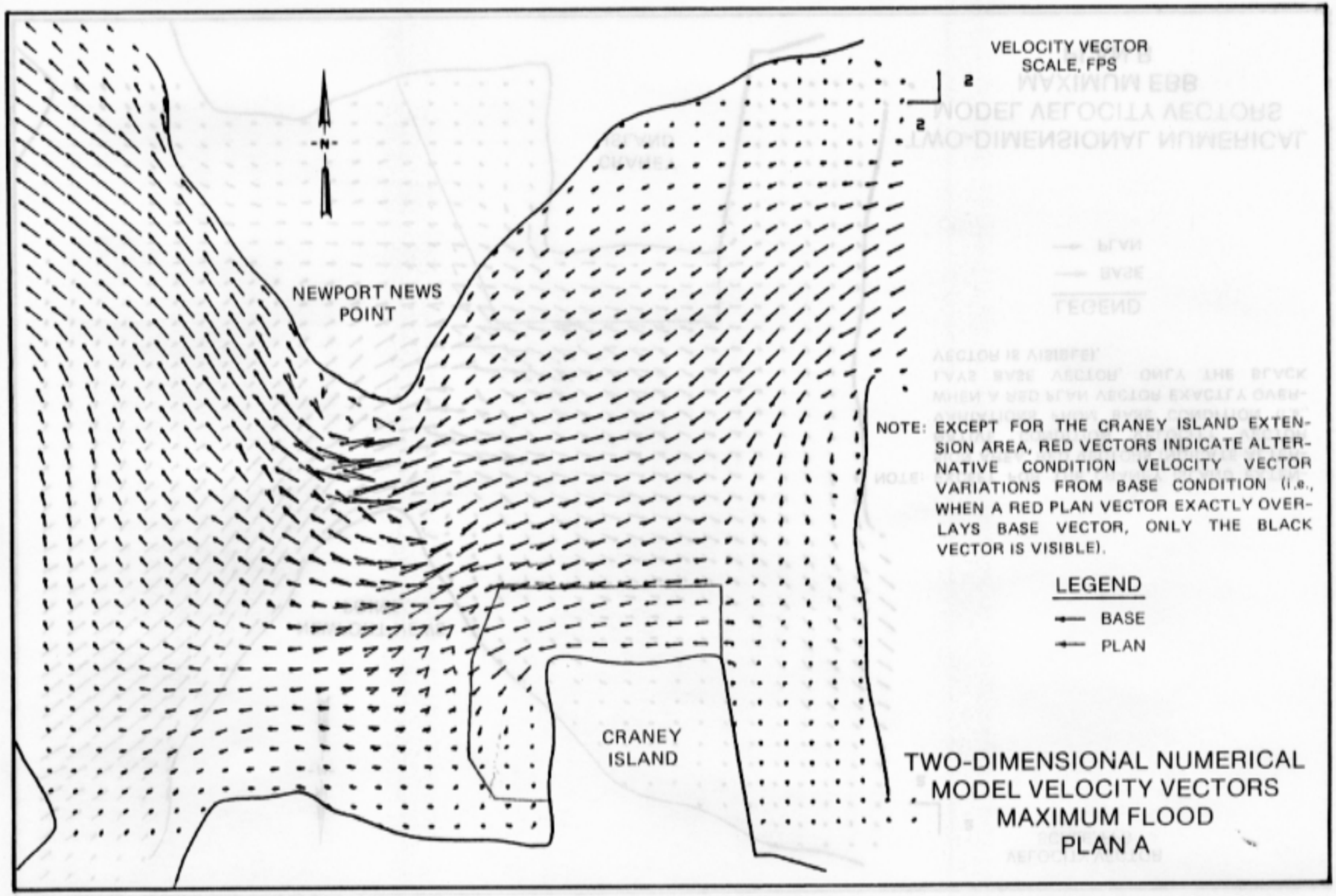
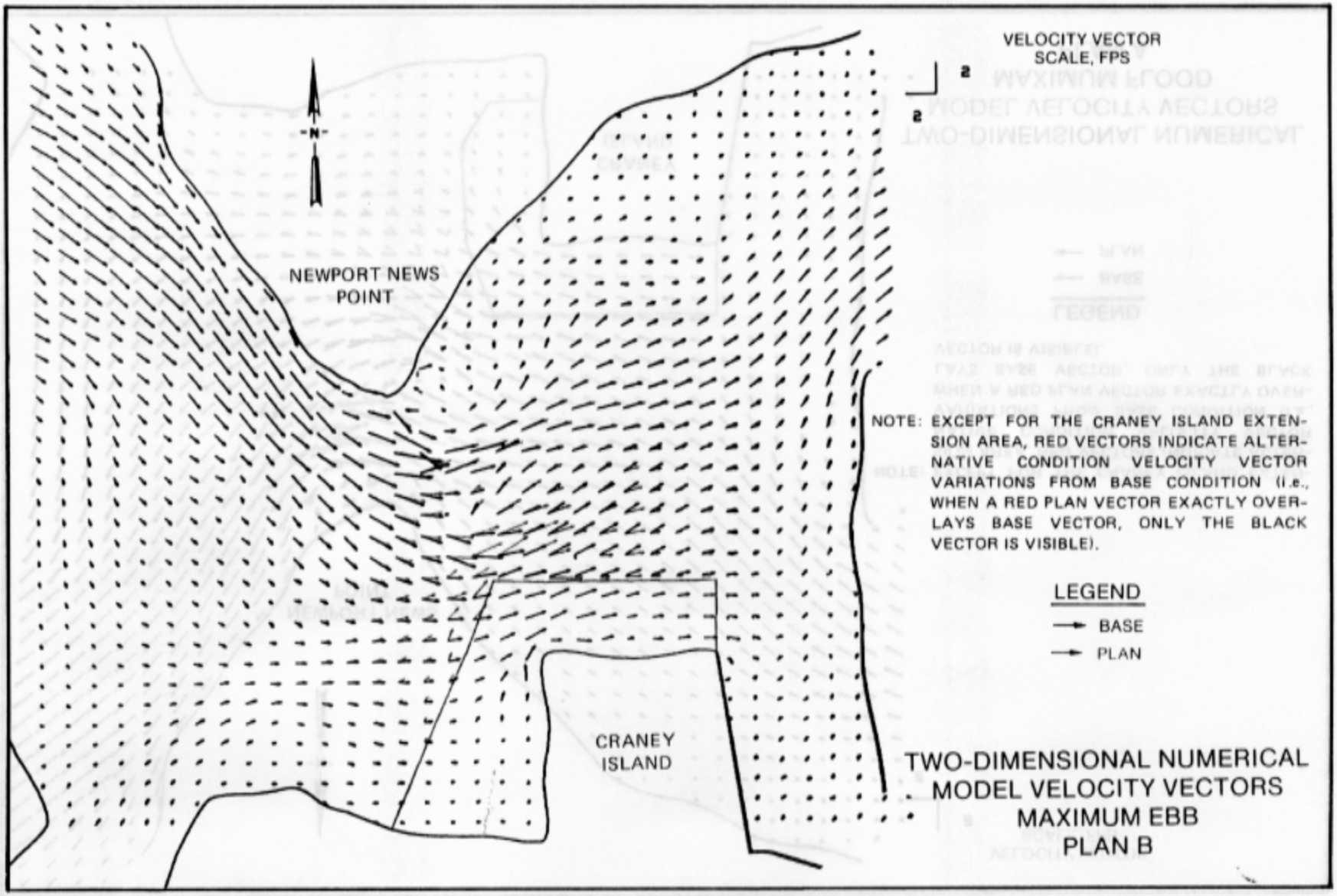
MAXIMUM EBB
PLAN A



TWO-DIMENSIONAL NUMERICAL
MODEL VELOCITY VECTORS
MAXIMUM FLOOD
PLAN A


VELOCITY VECTOR
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NOTE: EXCEPT FOR THE CRANEY ISLAND EXTENSION AREA, RED VECTORS INDICATE ALTERNATIVE CONDITION VELOCITY VECTOR VARIATIONS FROM BASE CONDITION (i.e., WHEN A RED PLAN VECTOR EXACTLY OVERLAYS BASE VECTOR, ONLY THE BLACK VECTOR IS VISIBLE).
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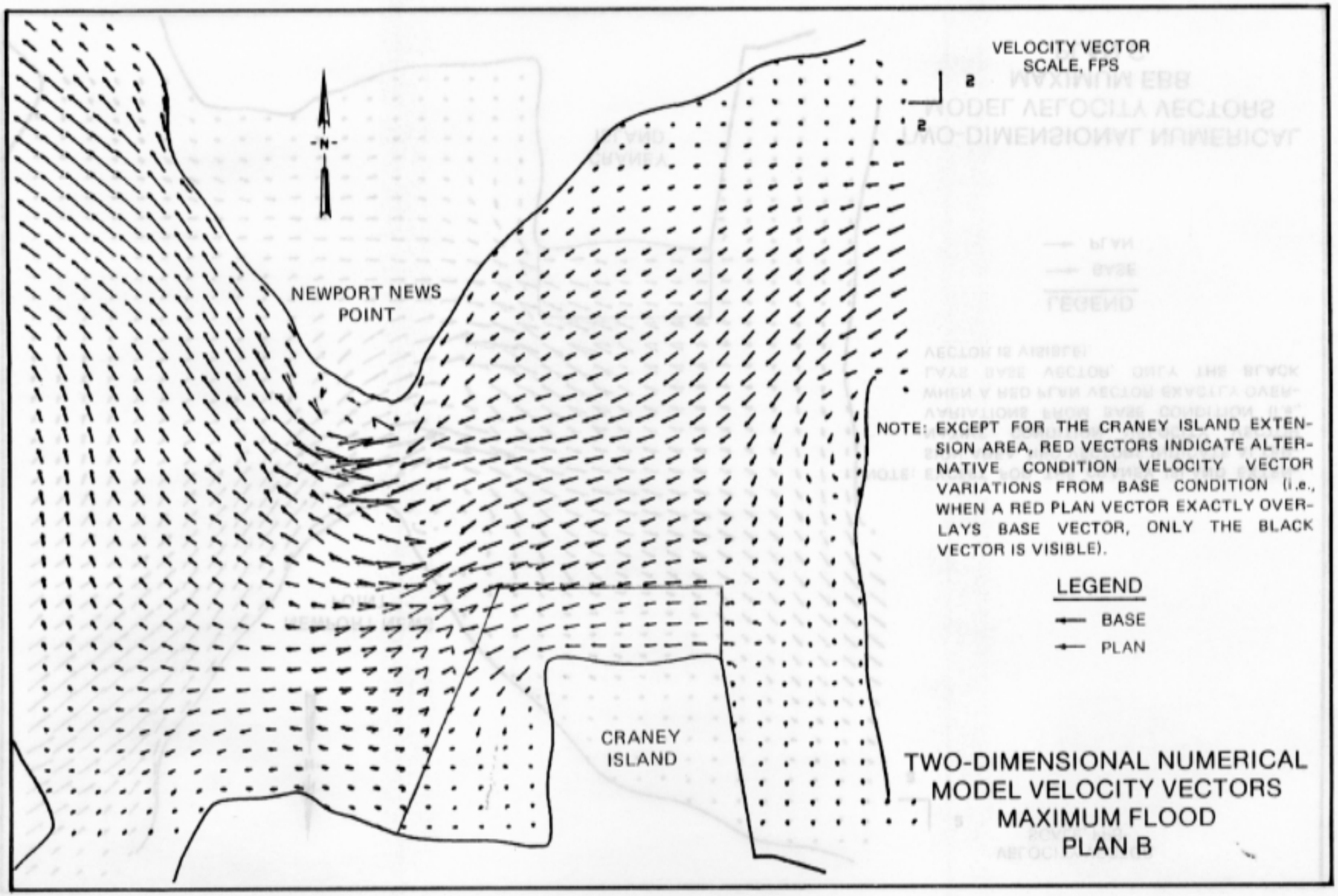
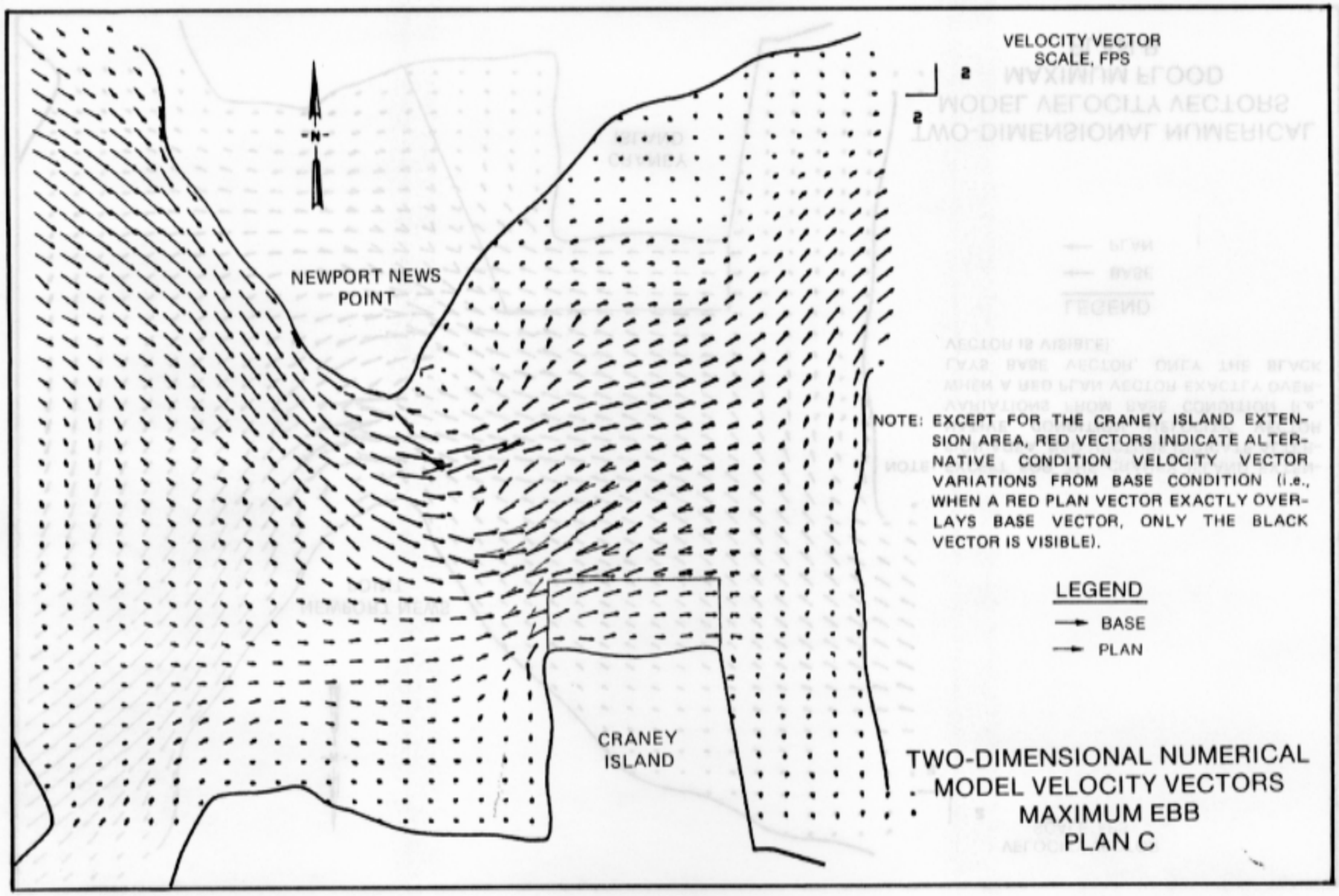
TWO-DIMENSIONAL NUMERICAL
MODEL VELOCITY VECTORS
MAXIMUM EBB
PLAN B



TWO-DIMENSIONAL NUMERICAL
MODEL VELOCITY VECTORS
MAXIMUM FLOOD
PLAN B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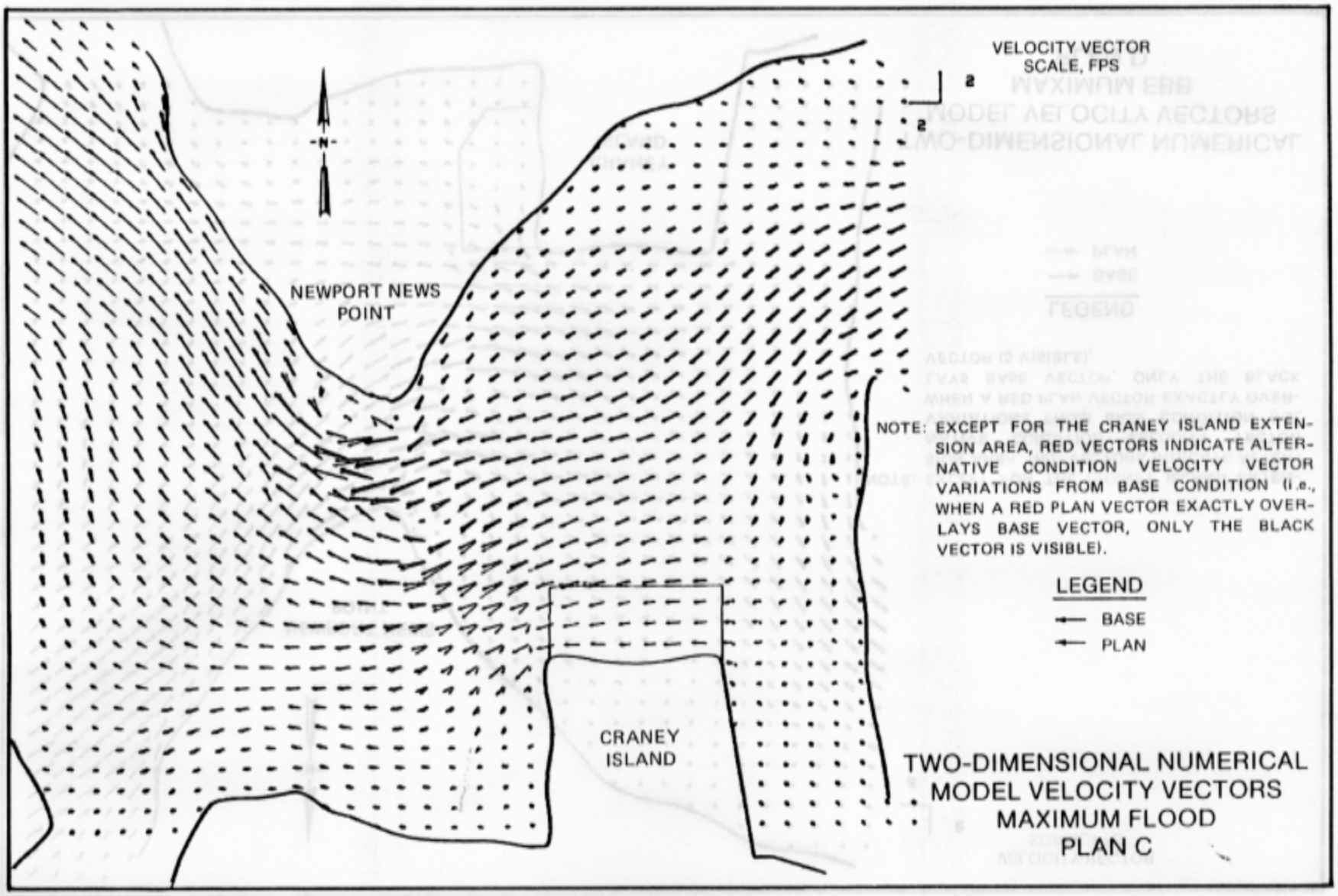
MAXIMUM EBB
PLAN C



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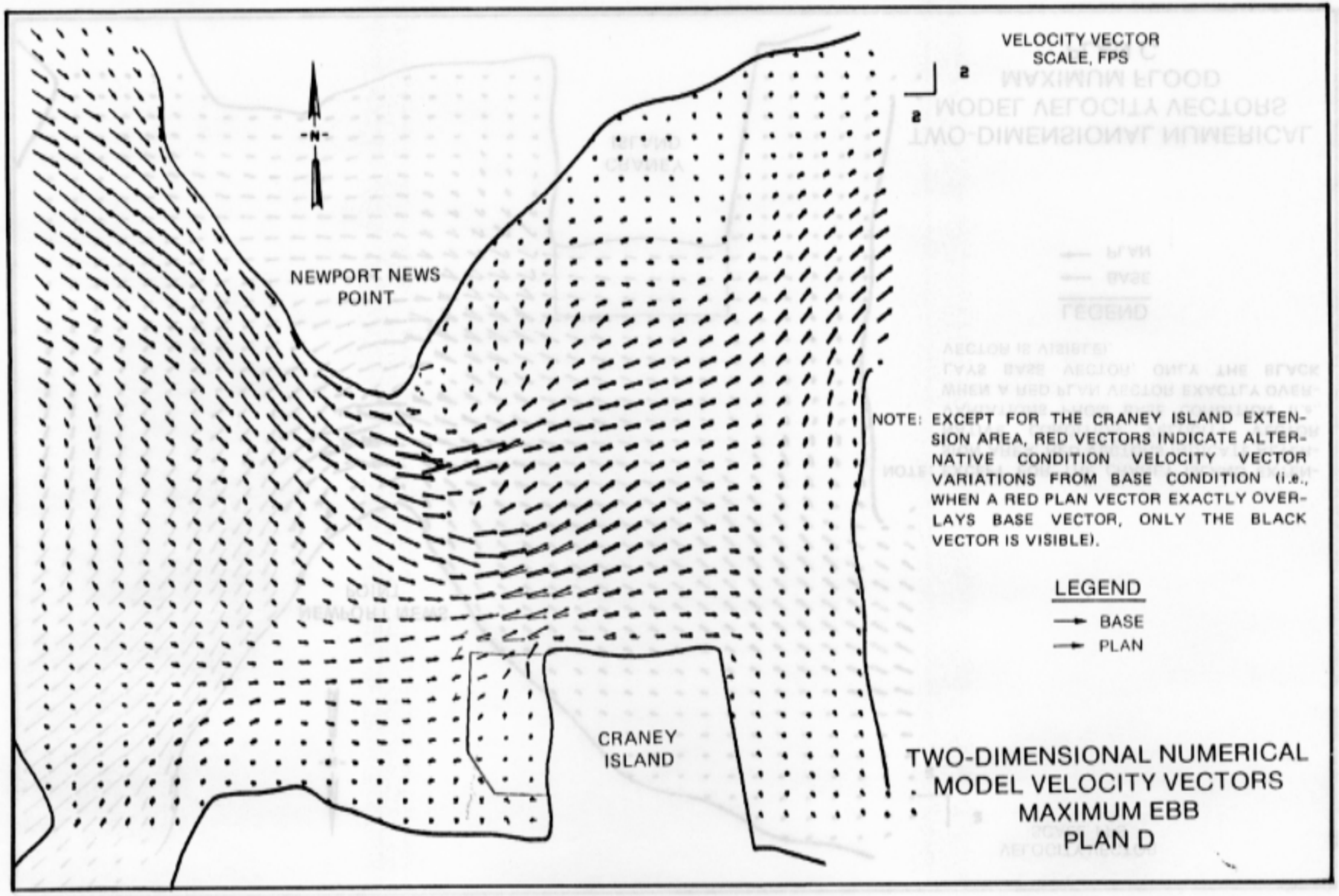
PLAN C


VELOCITY VECTOR
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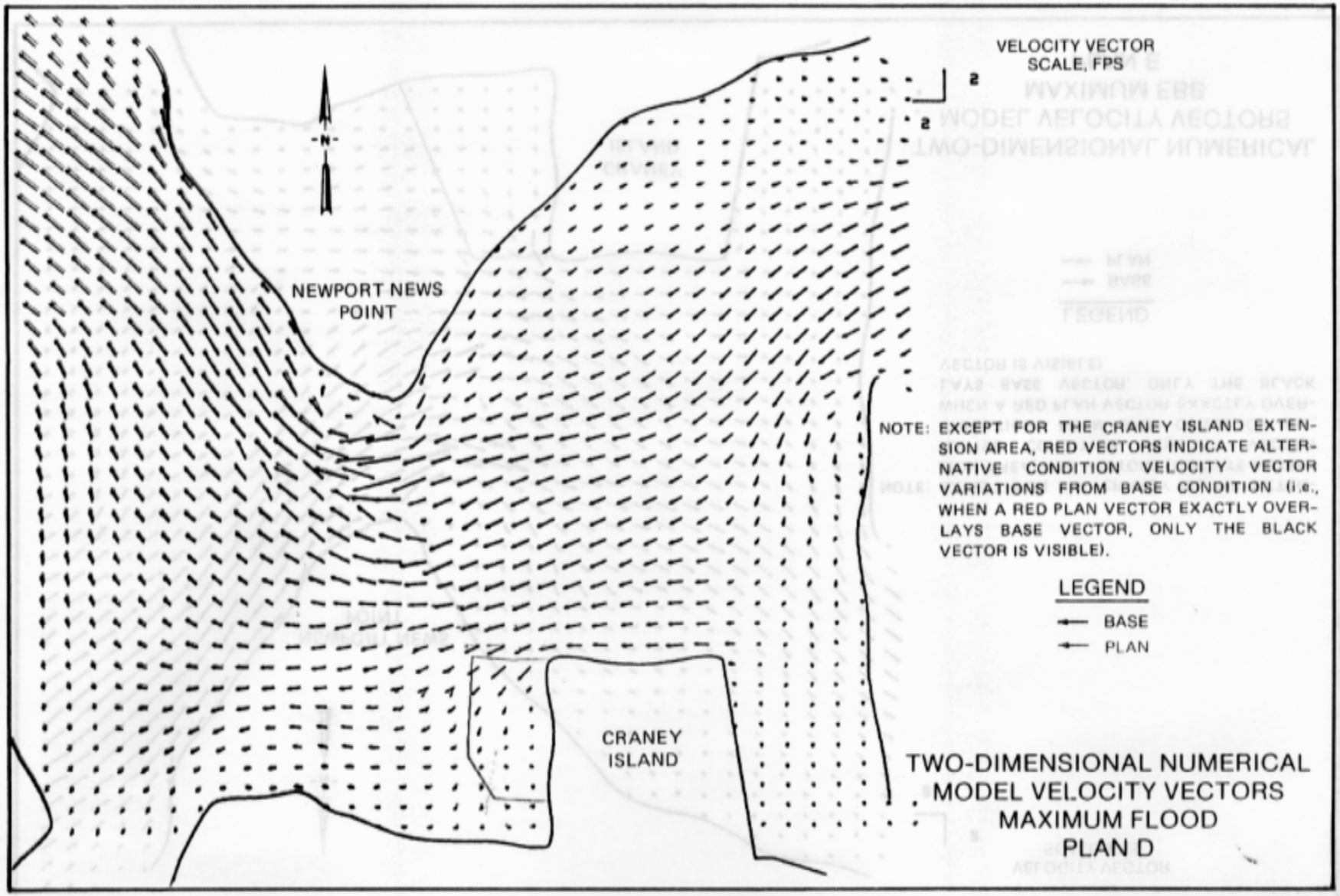
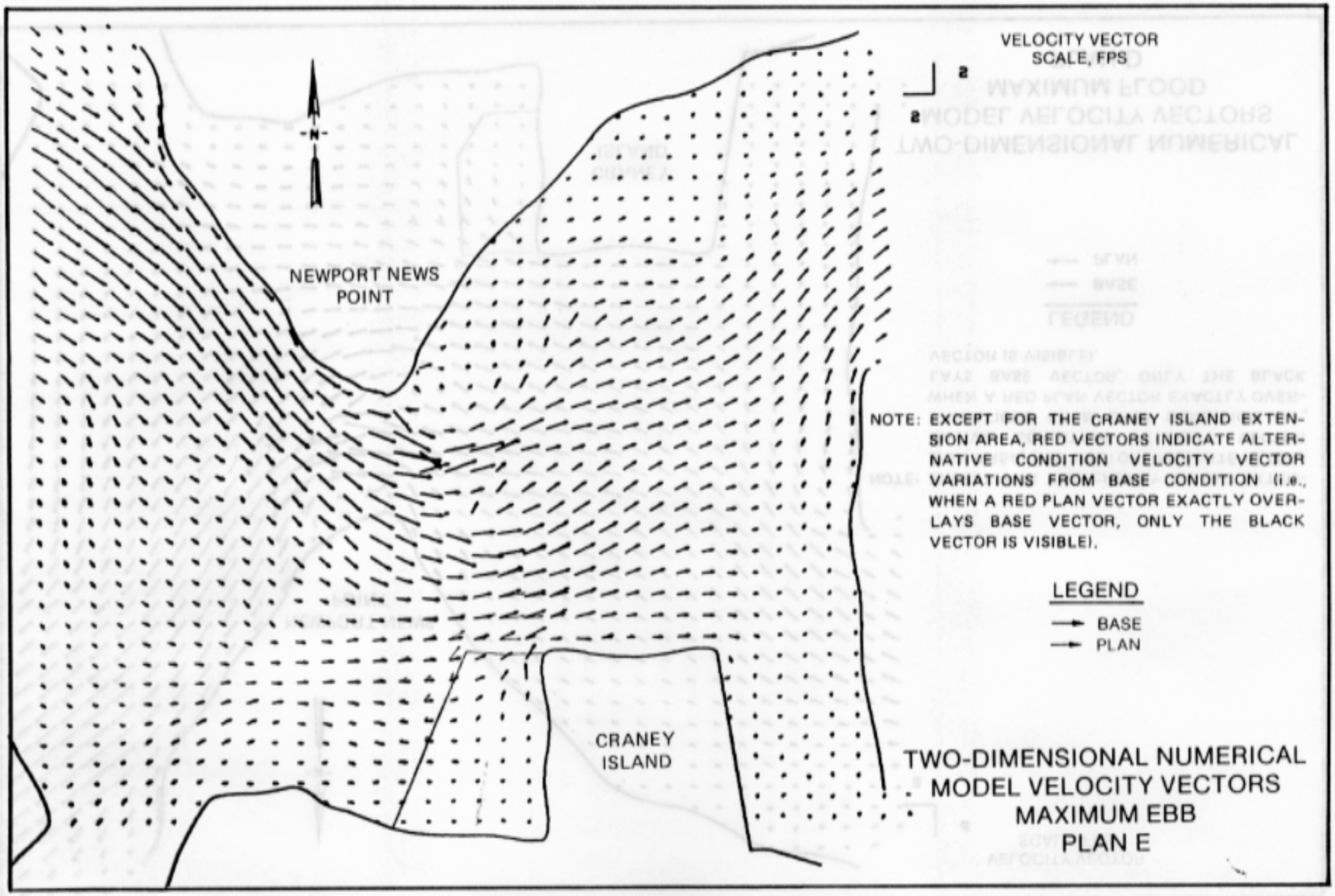
MAXIMUM EBB
PLAN D



TWO-DIMENSIONAL NUMERICAL
MODEL VELOCITY VECTORS
MAXIMUM FLOOD
PLAN D


VELOCITY VECTOR
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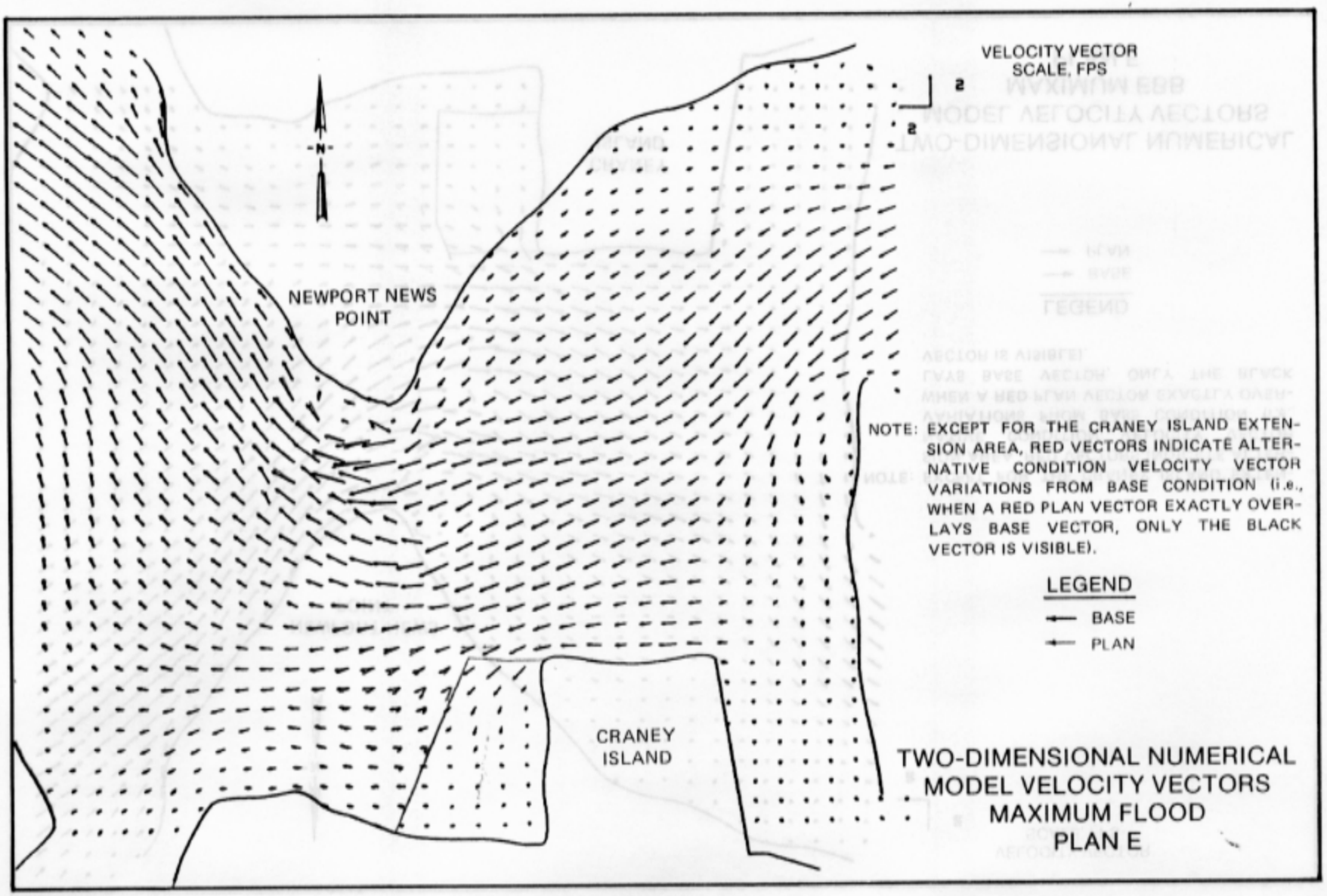
PLAN E



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MODEL VELOCITY VECTORS
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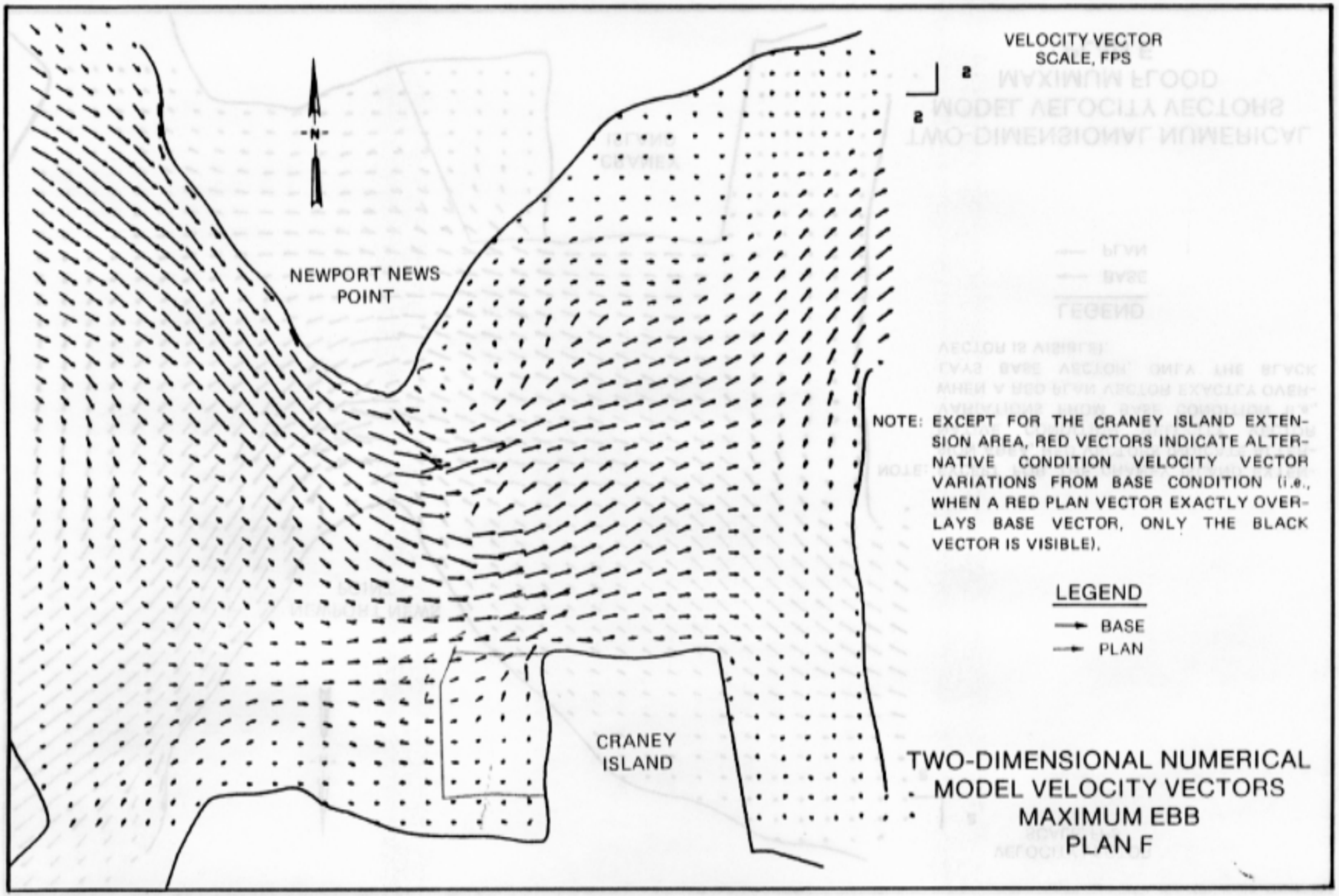
PLAN E



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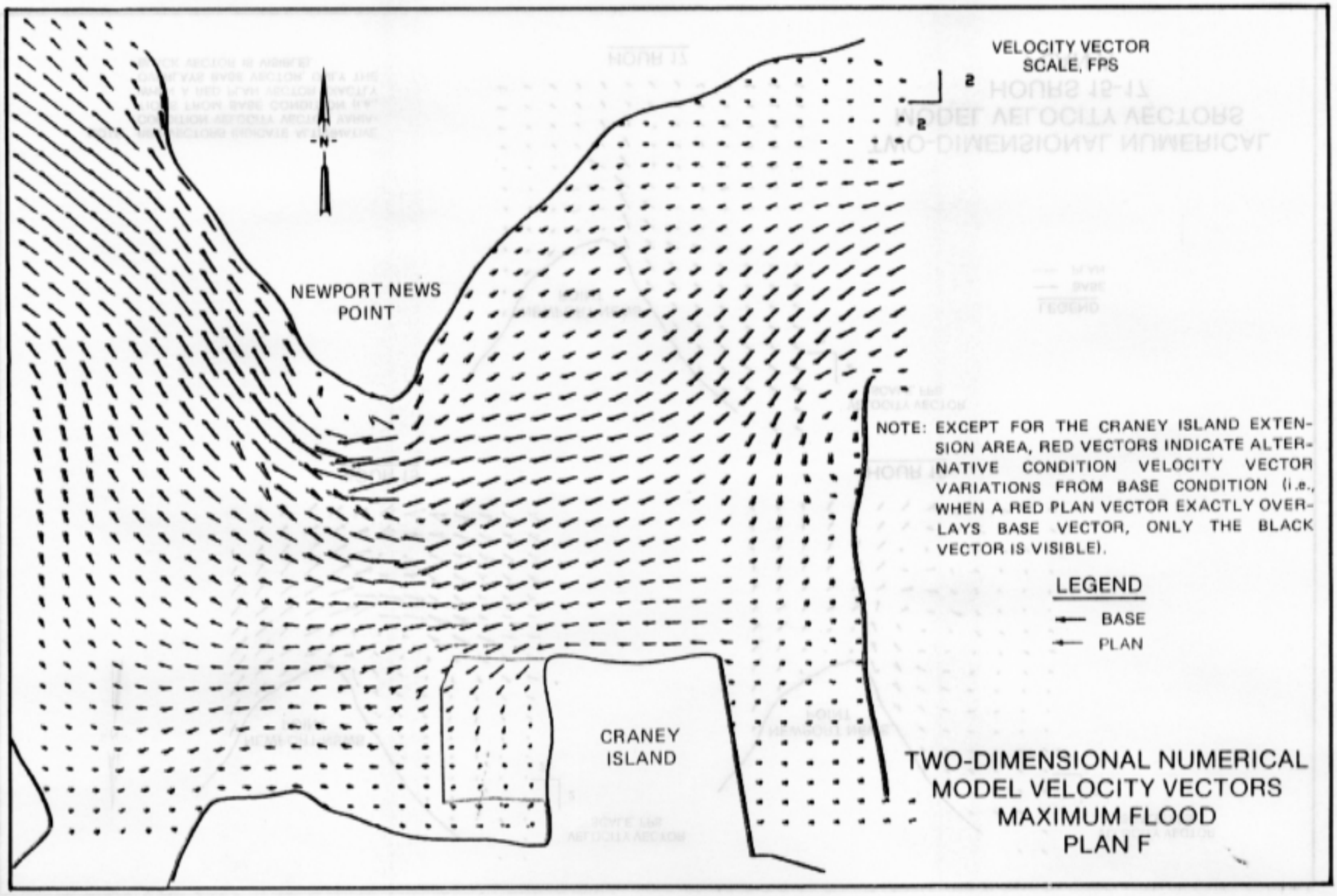
PLAN F


VELOCITY VECTOR
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NOTE: EXCEPT FOR THE CRANEY ISLAND EXTENSION AREA, RED VECTORS INDICATE ALTERNATIVE CONDITION VELOCITY VECTOR VARIATIONS FROM BASE CONDITION (i.e., WHEN A RED PLAN VECTOR EXACTLY OVERLAYS BASE VECTOR, ONLY THE BLACK VECTOR IS VISIBLE).
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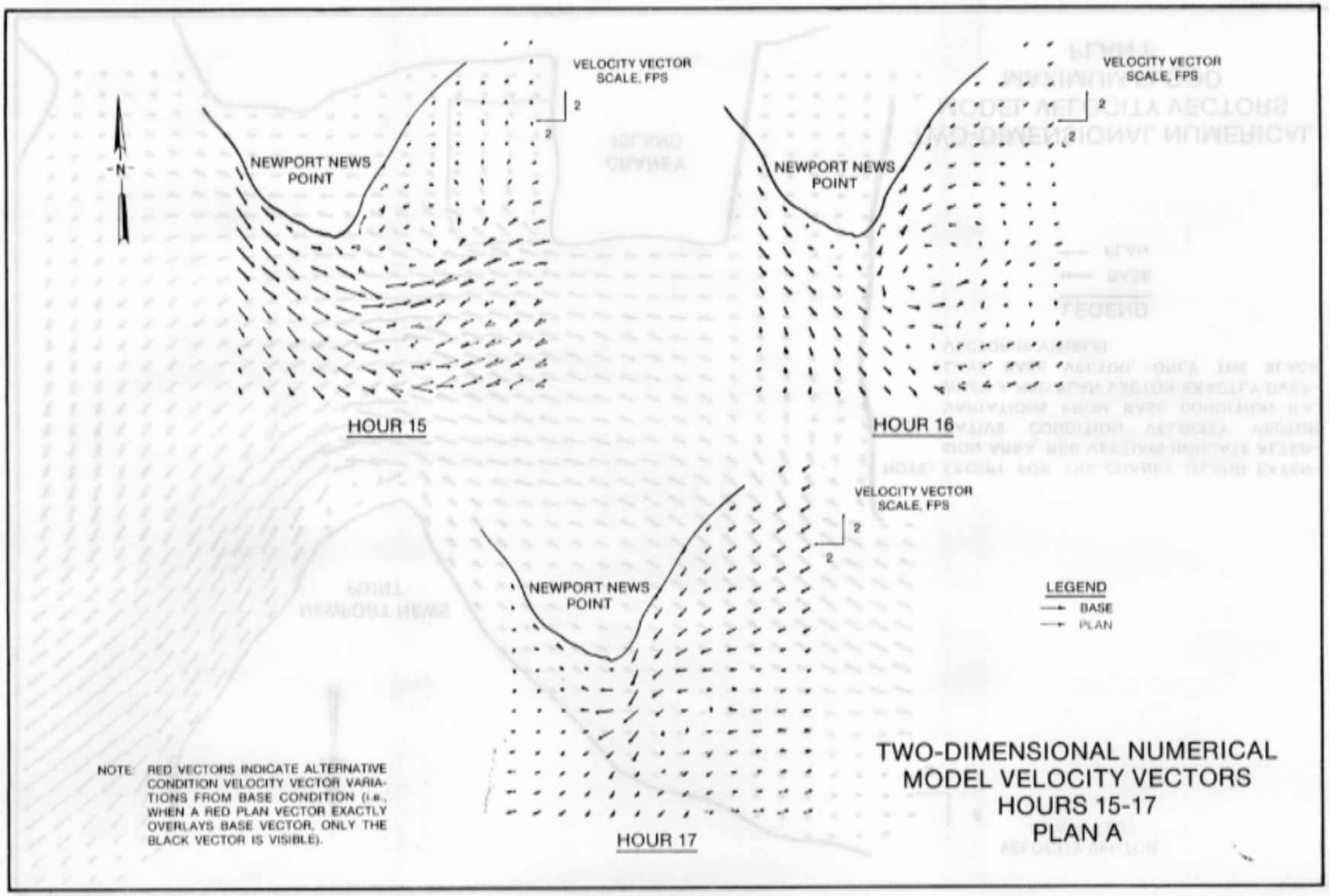
TWO-DIMENSIONAL NUMERICAL
MODEL VELOCITY VECTORS
MAXIMUM FLOOD
PLAN F



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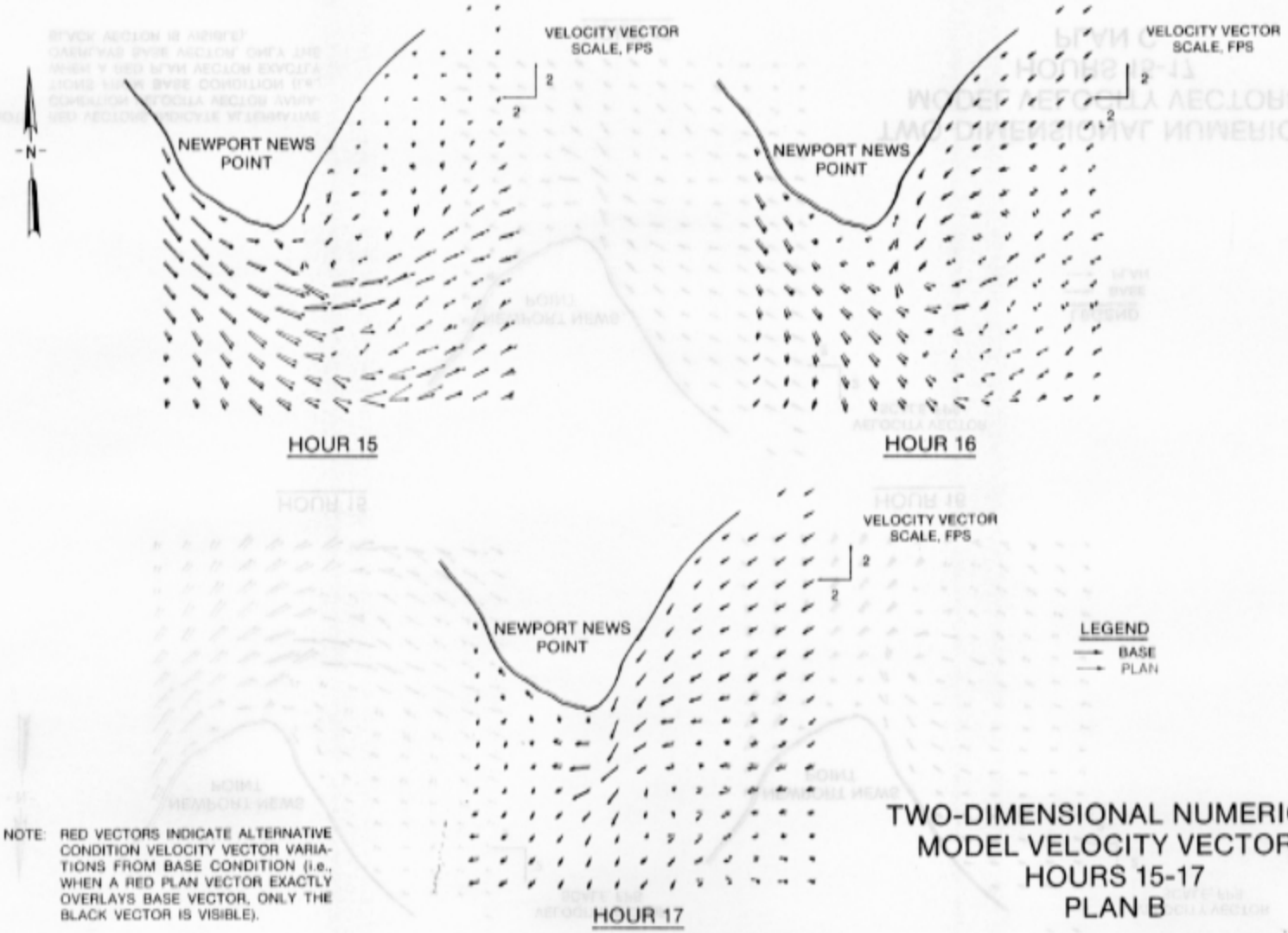
TWO-DIMENSIONAL NUMERICAL MODEL VELOCITY VECTORS HOURS 15-17 PLAN A



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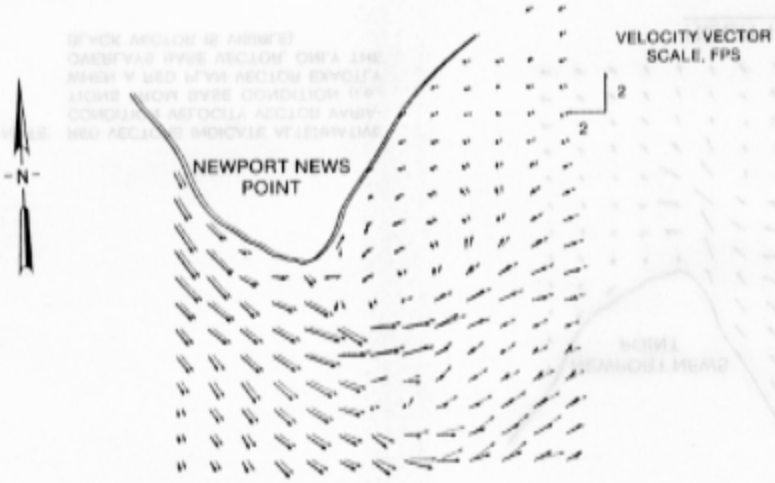
TWO-DIMENSIONAL NUMERICAL MODEL VELOCITY VECTORS
HOURS 15-17
PLAN B



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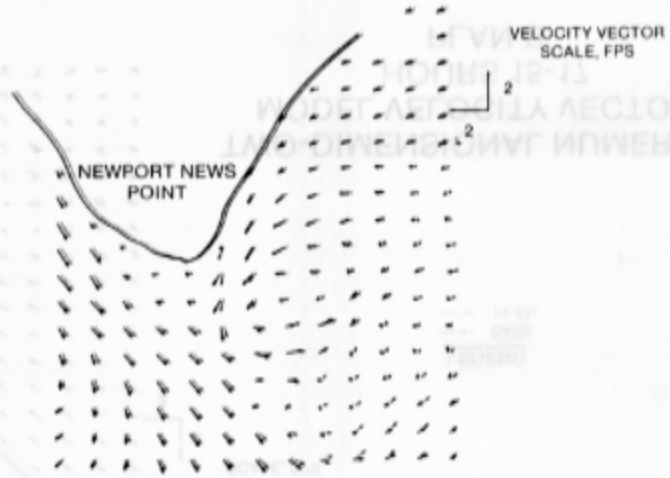

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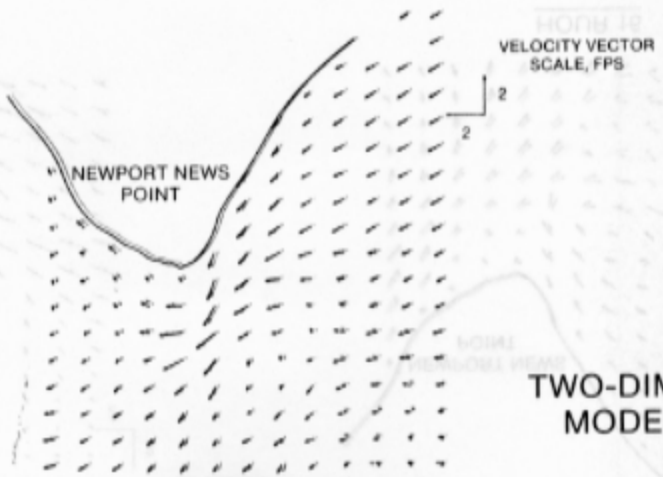

HOUR 17

LEGEND
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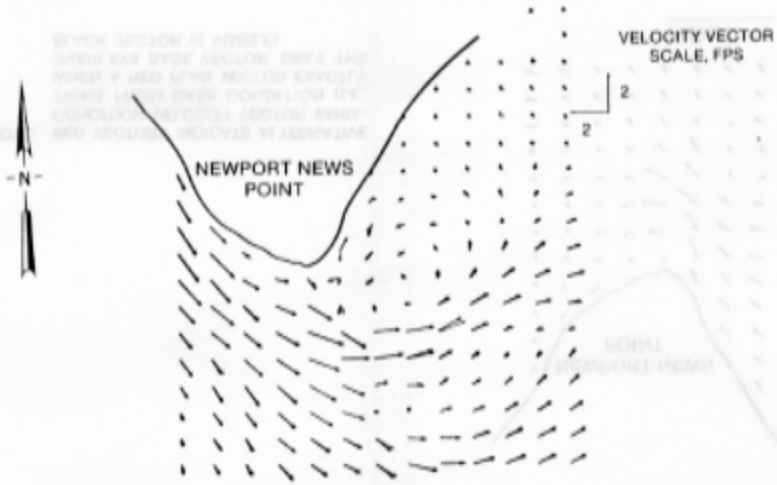
NOTE: RED VECTORS INDICATE ALTERNATIVE CONDITION VELOCITY VECTOR VARIATIONS FROM BASE CONDITION (i.e., WHEN A RED PLAN VECTOR EXACTLY OVERLAYS BASE VECTOR, ONLY THE BLACK VECTOR IS VISIBLE).

TWO-DIMENSIONAL NUMERICAL MODEL VELOCITY VECTORS HOURS 15-17 PLAN C



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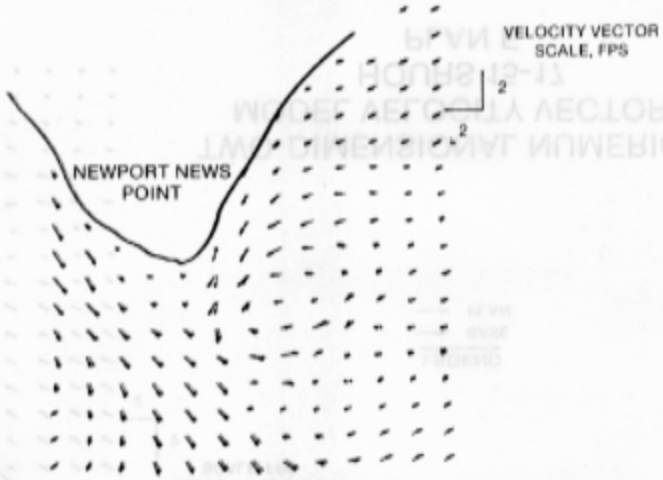

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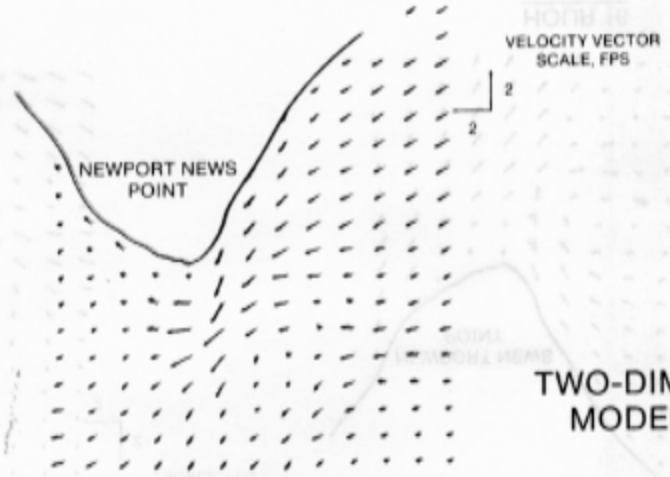
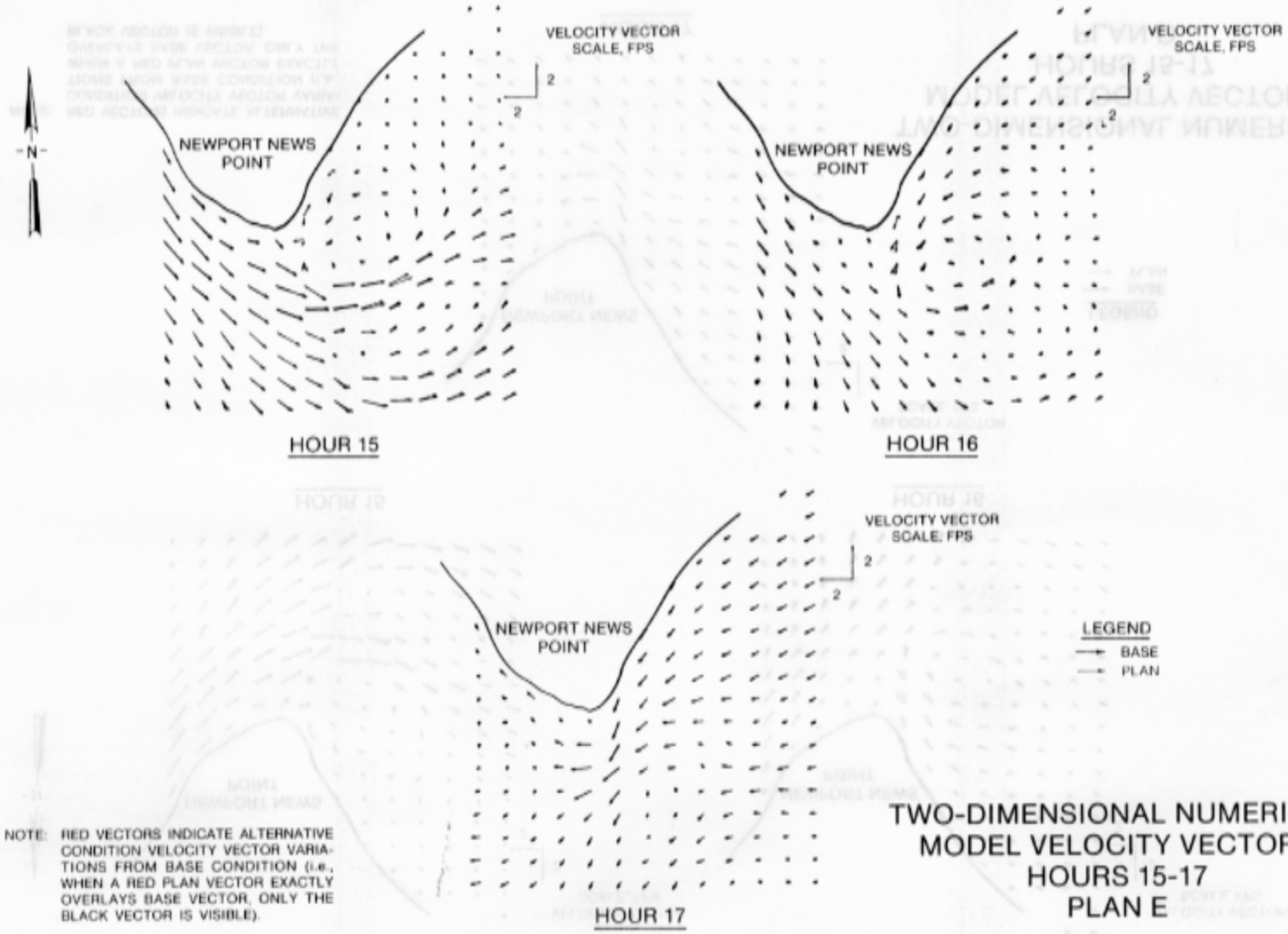


HOUR 17

LEGEND
BASE
PLAN

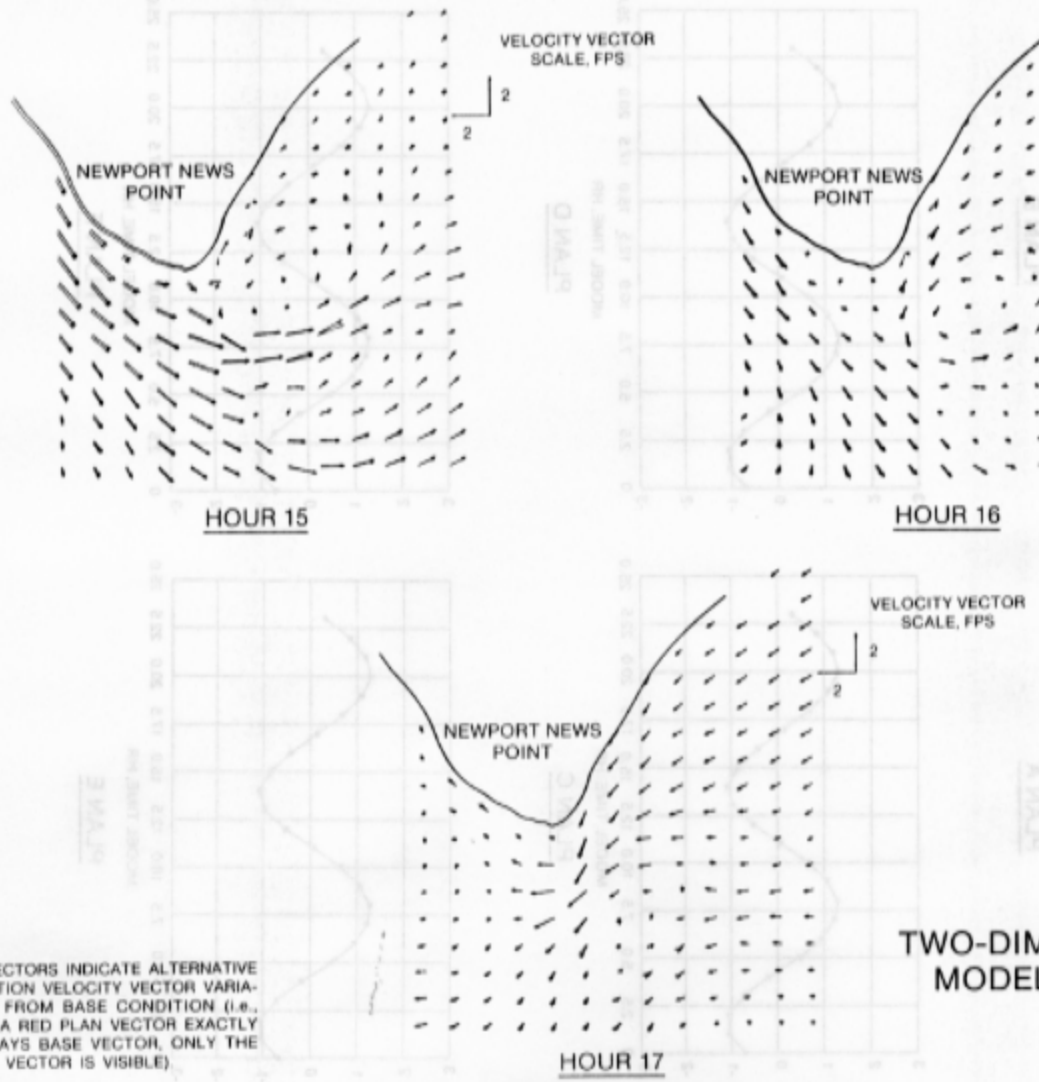
NOTE: RED VECTORS INDICATE ALTERNATIVE CONDITION VELOCITY VECTOR VARIATIONS FROM BASE CONDITION (i.e., WHEN A RED PLAN VECTOR EXACTLY OVERLAYS BASE VECTOR, ONLY THE BLACK VECTOR IS VISIBLE).

TWO-DIMENSIONAL NUMERICAL MODEL VELOCITY VECTORS HOURS 15-17 PLAN D



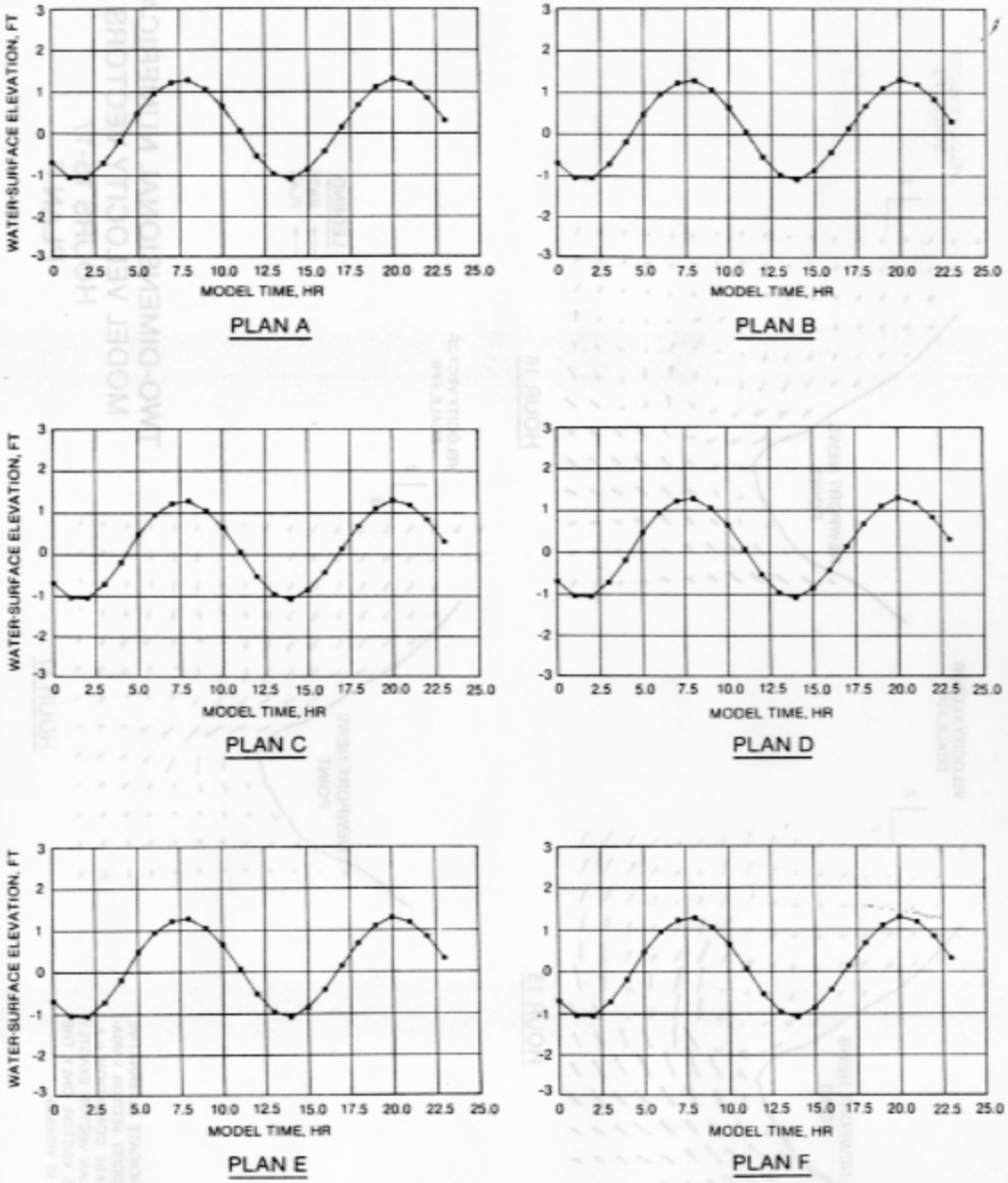
NOTE: RED VECTORS INDICATE ALTERNATIVE CONDITION VELOCITY VECTOR VARIATIONS FROM BASE CONDITION (i.e., WHEN A RED PLAN VECTOR EXACTLY OVERLAYS BASE VECTOR, ONLY THE BLACK VECTOR IS VISIBLE).

TWO-DIMENSIONAL NUMERICAL MODEL VELOCITY VECTORS
HOURS 15-17
PLAN E



NOTE: RED VECTORS INDICATE ALTERNATIVE CONDITION VELOCITY VECTOR VARIATIONS FROM BASE CONDITION (i.e., WHEN A RED PLAN VECTOR EXACTLY OVERLAYS BASE VECTOR, ONLY THE BLACK VECTOR IS VISIBLE).

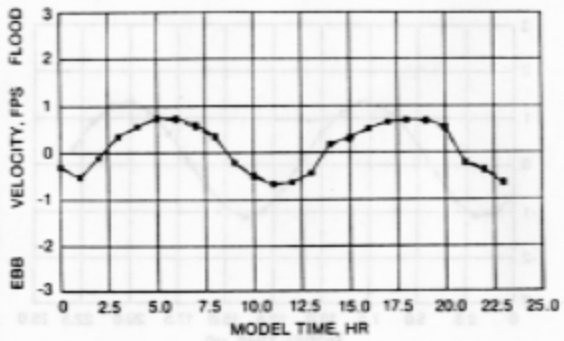
TWO-DIMENSIONAL NUMERICAL MODEL VELOCITY VECTORS HOURS 15-17 PLAN F



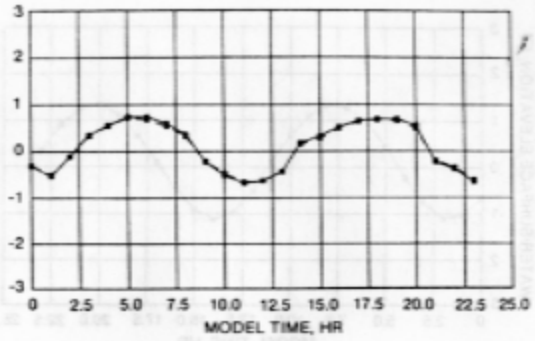
LEGEND
—— BASE
- - - PLAN

NOTE. SOLID CURVE INDICATES NO CHANGE

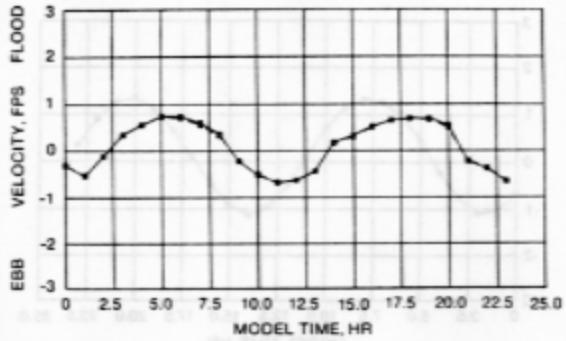
WATER-SURFACE TIME-HISTORIES
BASE AND PLANS A-F
NODE 18



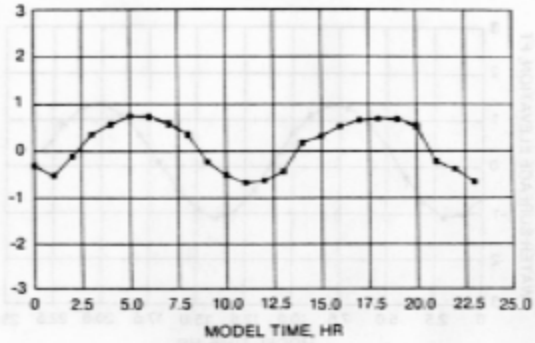
PLAN A



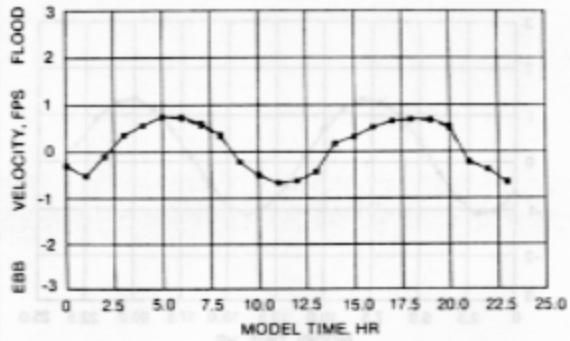
PLAN B



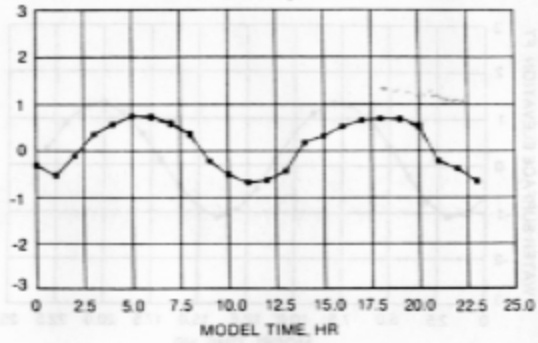
PLAN C



PLAN D



PLAN E



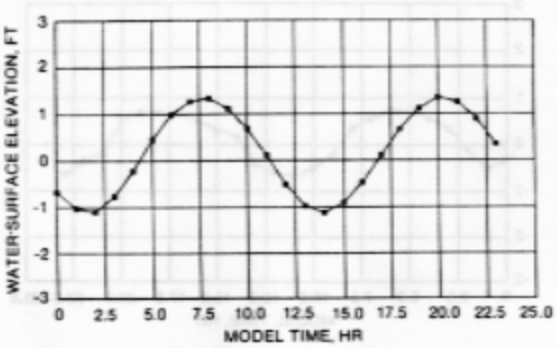
PLAN F

LEGEND

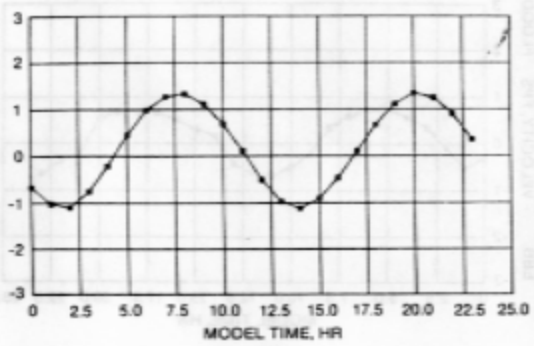
—— BASE
- - - PLAN

NOTE: SOLID CURVE INDICATES NO CHANGE

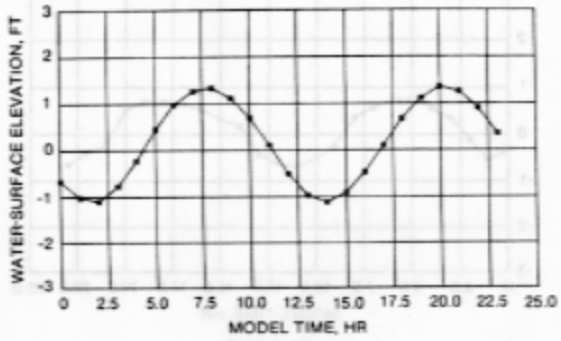
VELOCITY TIME-HISTORIES
BASE AND PLANS A-F
NODE 18



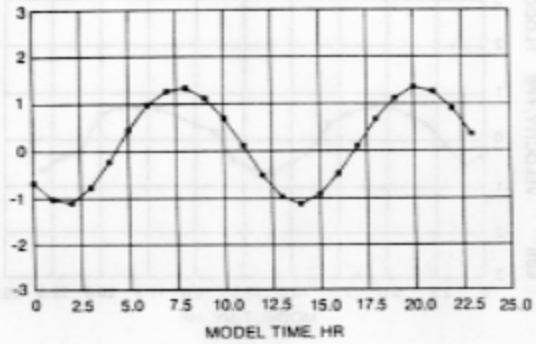
PLAN A



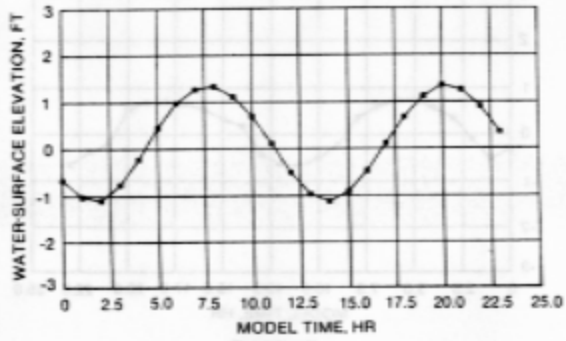
PLAN B



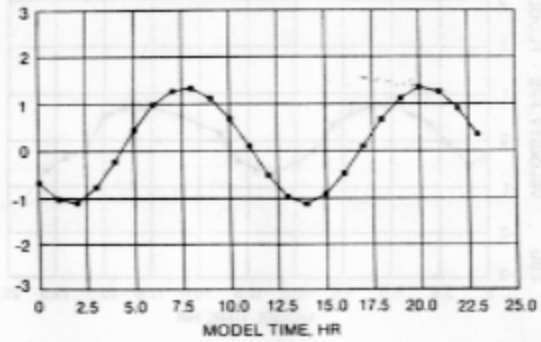
PLAN C



PLAN D



PLAN E

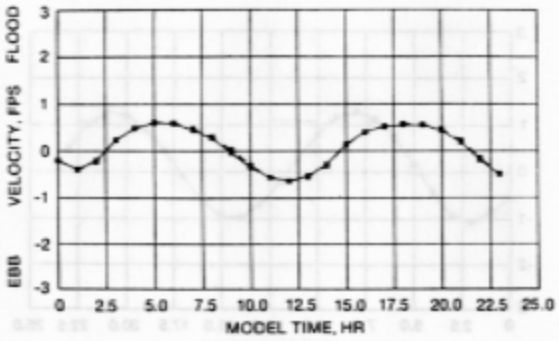


PLAN F

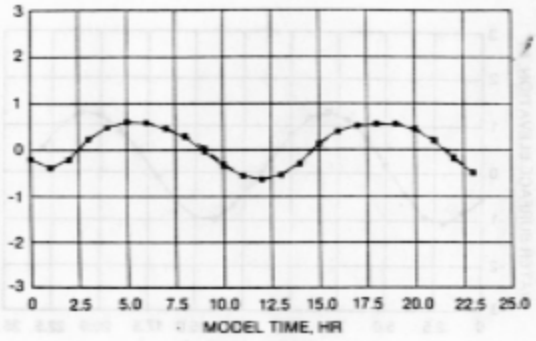
LEGEND
—— BASE
- - - PLAN

NOTE: SOLID CURVE INDICATES NO CHANGE

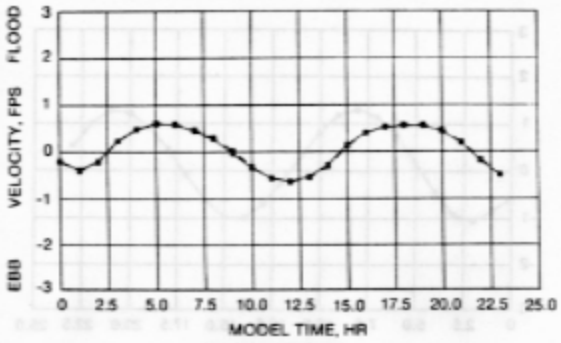
WATER-SURFACE TIME-HISTORIES
BASE AND PLANS A-F
NODE 146



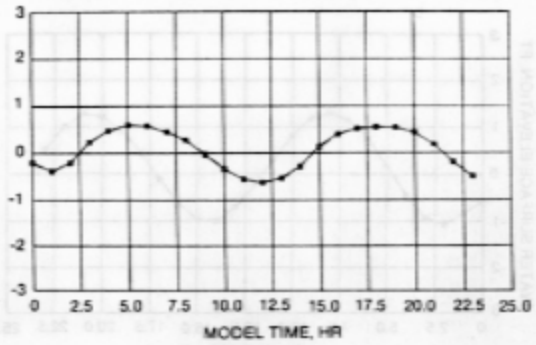
PLAN A



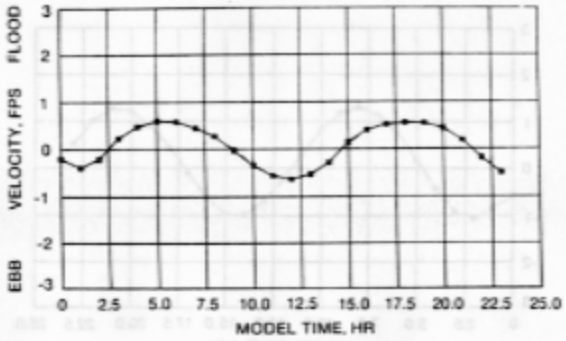
PLAN B



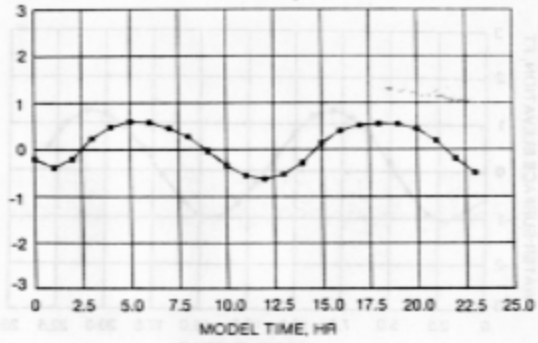
PLAN C



PLAN D



PLAN E



PLAN F

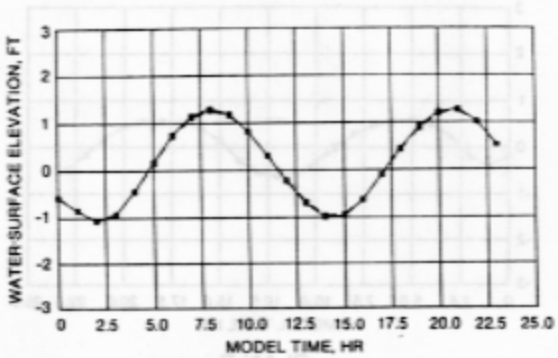
LEGEND

—— BASE

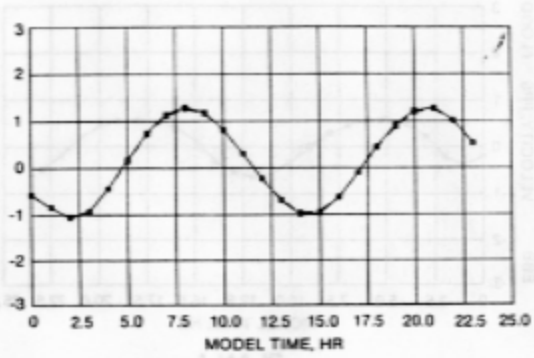
- - - PLAN

NOTE: SOLID CURVE INDICATES NO CHANGE

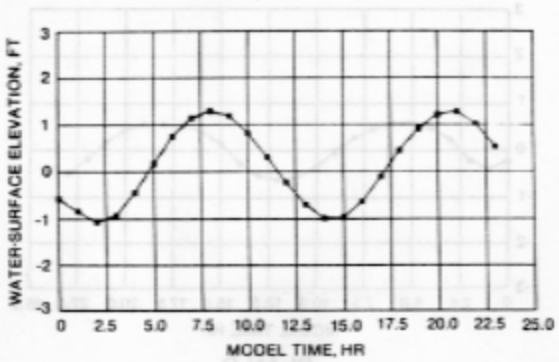
VELOCITY TIME-HISTORIES
BASE AND PLANS A-F
NODE 146



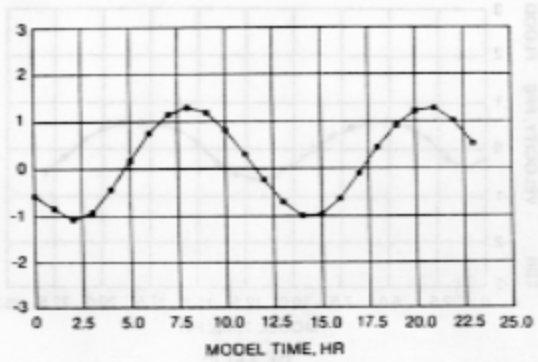
PLAN A



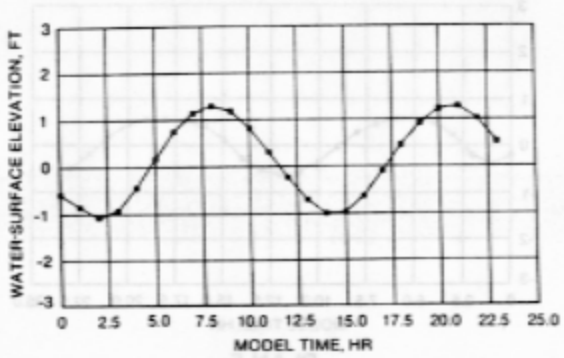
PLAN B



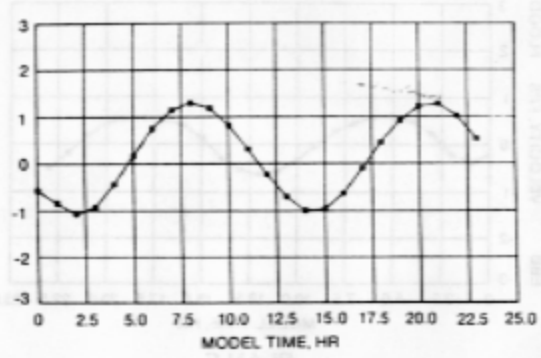
PLAN C



PLAN D



PLAN E

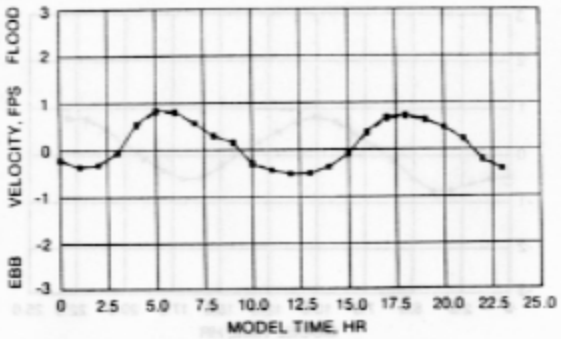


PLAN F

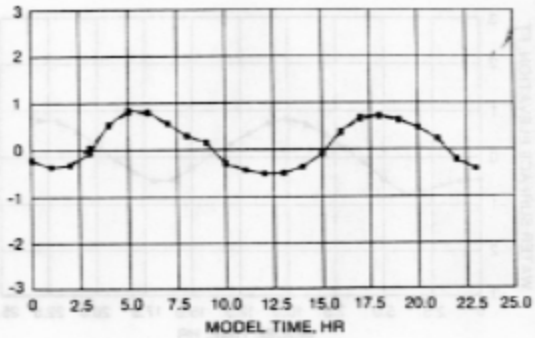
LEGEND
—— BASE
- - - PLAN

NOTE: SOLID CURVE INDICATES NO CHANGE

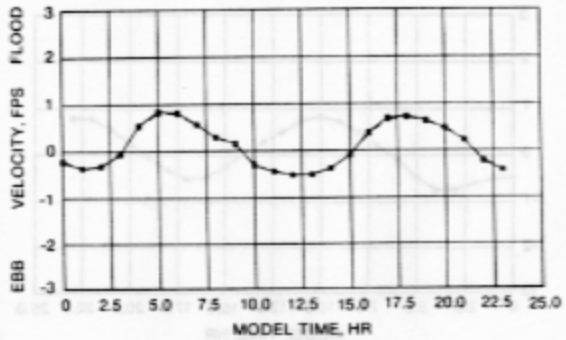
WATER-SURFACE TIME-HISTORIES
BASE AND PLANS A-F
NODE 677



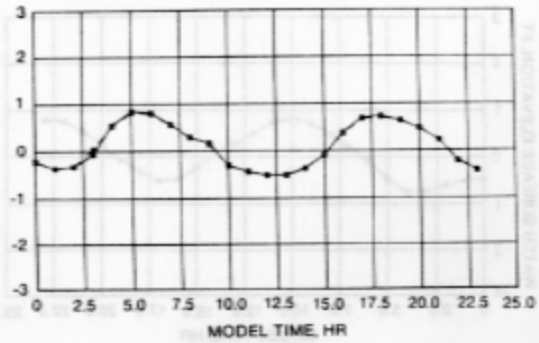
PLAN A



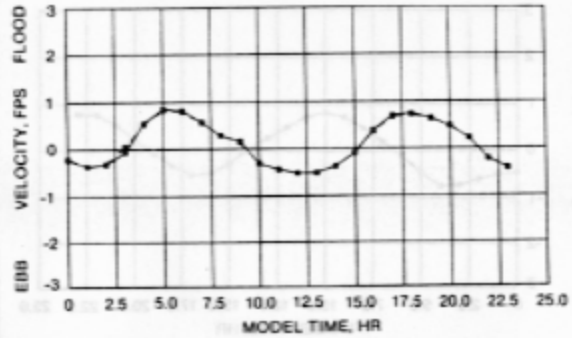
PLAN B



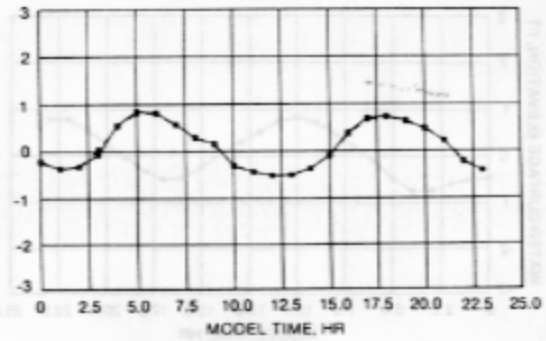
PLAN C



PLAN D



PLAN E



PLAN F

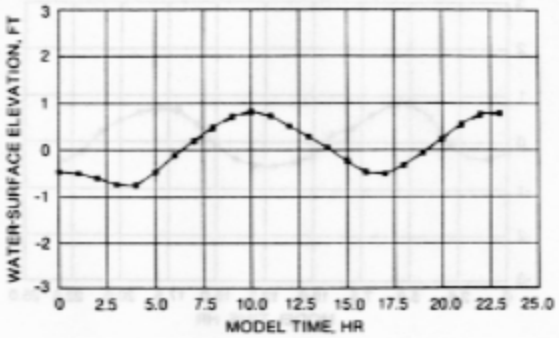
LEGEND

—— BASE

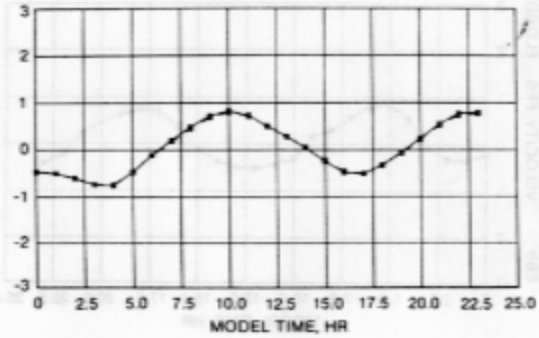
– – – PLAN

NOTE: SOLID CURVE INDICATES NO CHANGE

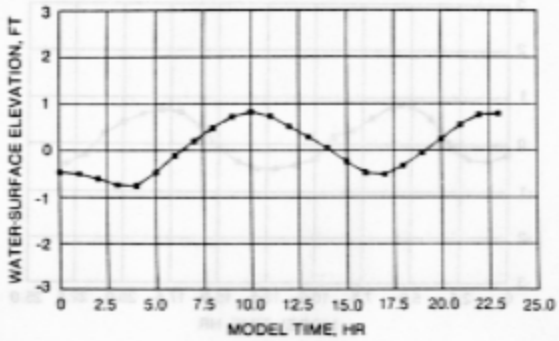
VELOCITY TIME-HISTORIES
BASE AND PLANS A-F
NODE 677



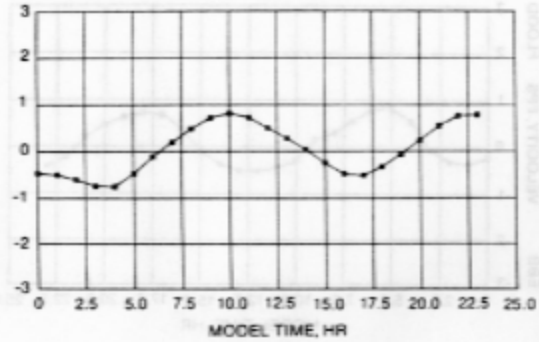
PLAN A



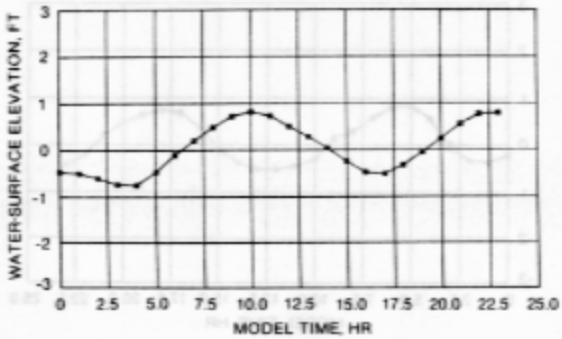
PLAN B



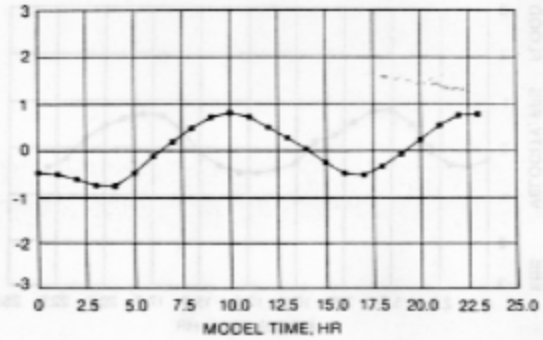
PLAN C



PLAN D



PLAN E

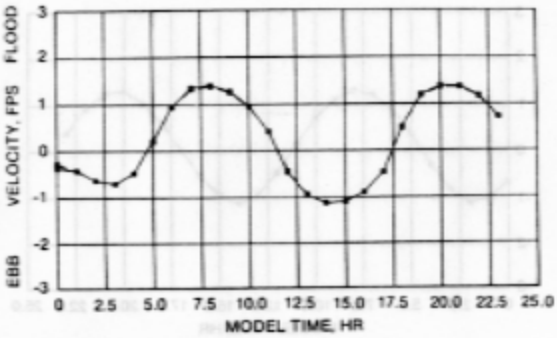


PLAN F

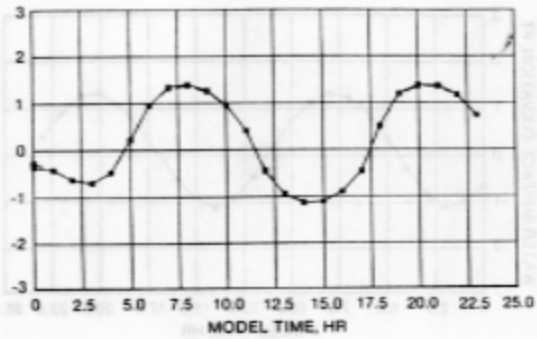
LEGEND
—— BASE
- - - PLAN

NOTE: SOLID CURVE INDICATES NO CHANGE

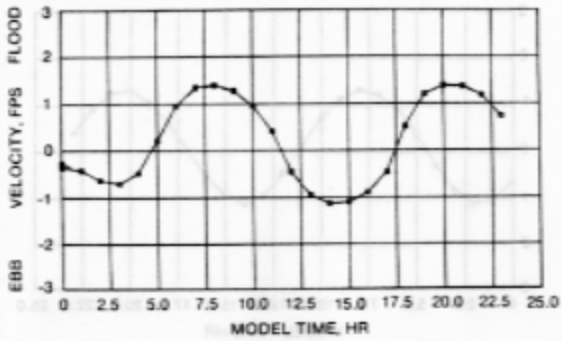
WATER-SURFACE TIME-HISTORIES
BASE AND PLANS A-F
NODE 1258



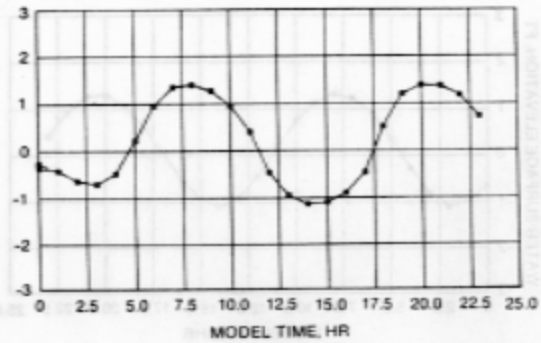
PLAN A



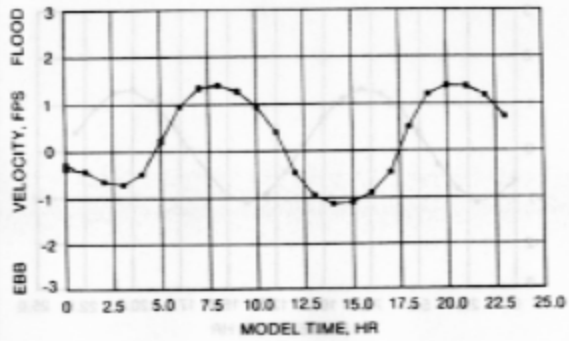
PLAN B



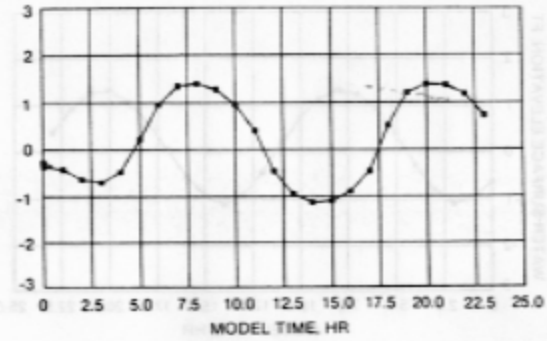
PLAN C



PLAN D



PLAN E



PLAN F

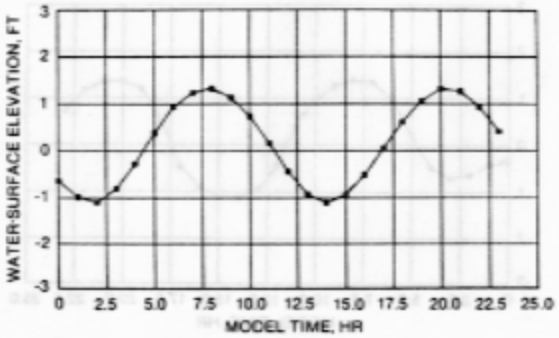
LEGEND

—— BASE

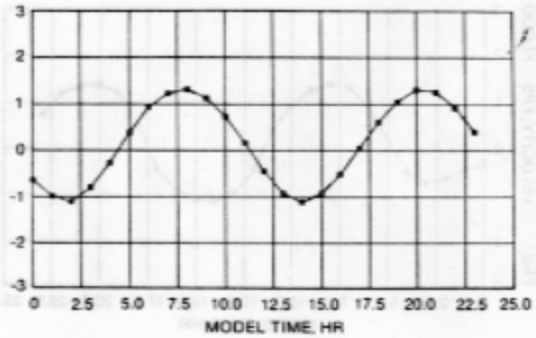
- - - PLAN

NOTE: SOLID CURVE INDICATES NO CHANGE

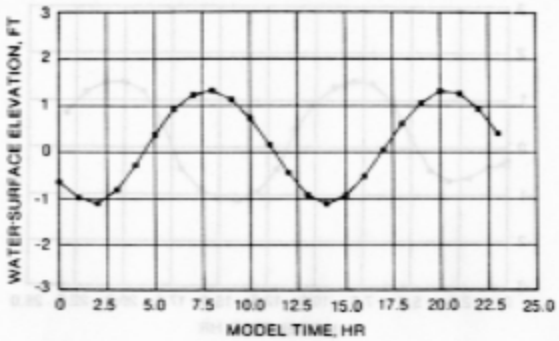
VELOCITY TIME-HISTORIES
BASE AND PLANS A-F
NODE 1258



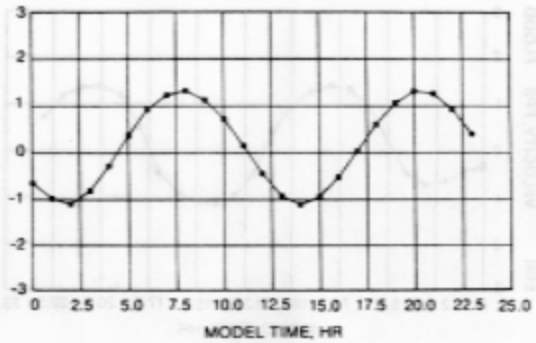
PLAN A



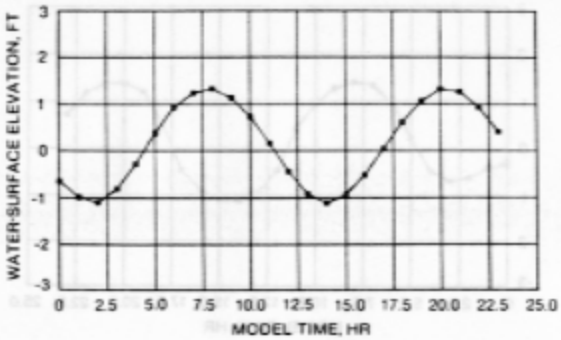
PLAN B



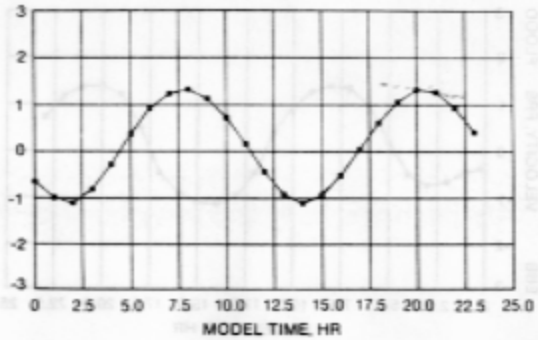
PLAN C



PLAN D



PLAN E



PLAN F

LEGEND

—— BASE

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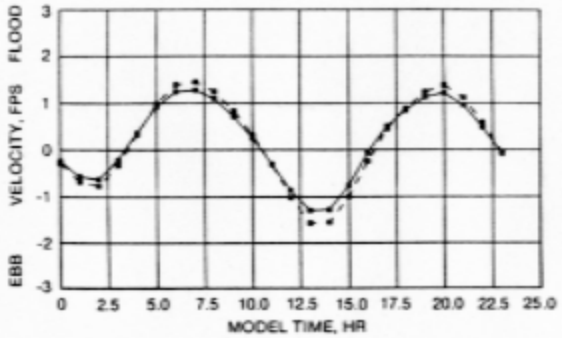
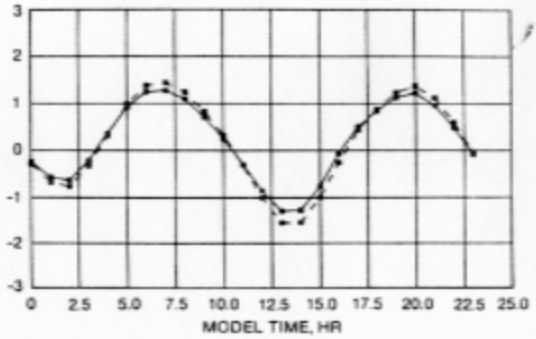
NOTE: SOLID CURVE INDICATES NO CHANGE

WATER-SURFACE TIME-HISTORIES
BASE AND PLANS A-F
NODE 1980



PLAN A



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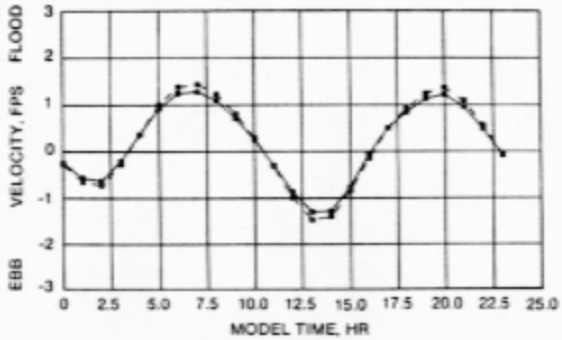

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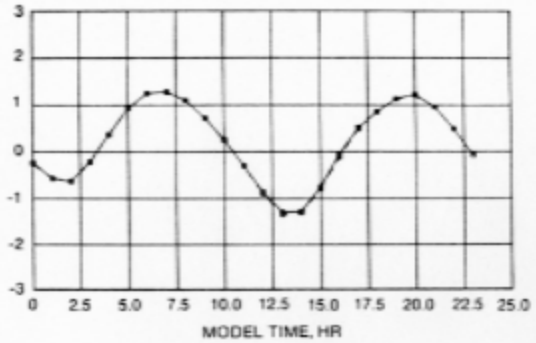

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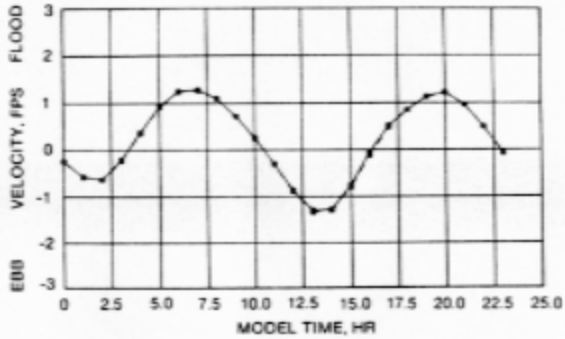

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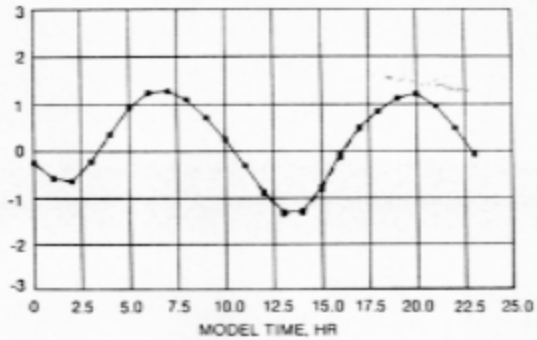

PLAN F

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NOTE: SOLID CURVE INDICATES NO CHANGE

VELOCITY TIME-HISTORIES
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APPENDIX A: FINITE ELEMENT MODELING*

1. The TABS-2 numerical models used in this effort employ the finite element method to solve the governing equations. To help those who are unfamiliar with the method to better understand this report, a brief description of the method is given here. For a more thorough treatment, see Zienkiewicz (1971)** or Desai (1979).

2. The finite element method approximates a solution to equations by dividing the area of interest into smaller subareas, which are called elements. The dependent variables (e.g., water-surface elevations and sediment concentrations) are approximated over each element by continuous functions which interpolate in terms of unknown point (node) values of the variables. An error, defined as the deviation of the approximation solution from the correct solution, is minimized. Then, when boundary conditions are imposed, a set of solvable simultaneous equations is created. The solution is smooth and continuous over the area of interest.

3. In one-dimensional problems, elements are line segments. In two-dimensional problems, the elements are polygons, usually either triangles or quadrilaterals. Nodes are located on the edges of elements and occasionally inside the elements. The interpolating functions may be linear or higher order polynomials. Figure A1 illustrates a quadrilateral element with eight nodes and a linear solution surface.

4. Most water resource applications of the finite element method use the Galerkin method of weighted residuals to minimize error. In this method the residual, the total error between the approximate and correct solutions, is weighted by a function that is identical with the interpolating function and then minimized. Minimization results in a set of simultaneous equations in terms of nodal values of the dependent variable (e.g., water-surface elevations or sediment concentration). Time-dependent problems can have the time portion solved by the finite element methods, but it is generally more efficient to express derivatives with respect to time in finite difference form.

5. The finite difference method, sometimes called FDM, is another technique used in numerical modeling. The FDM solves mathematical models by

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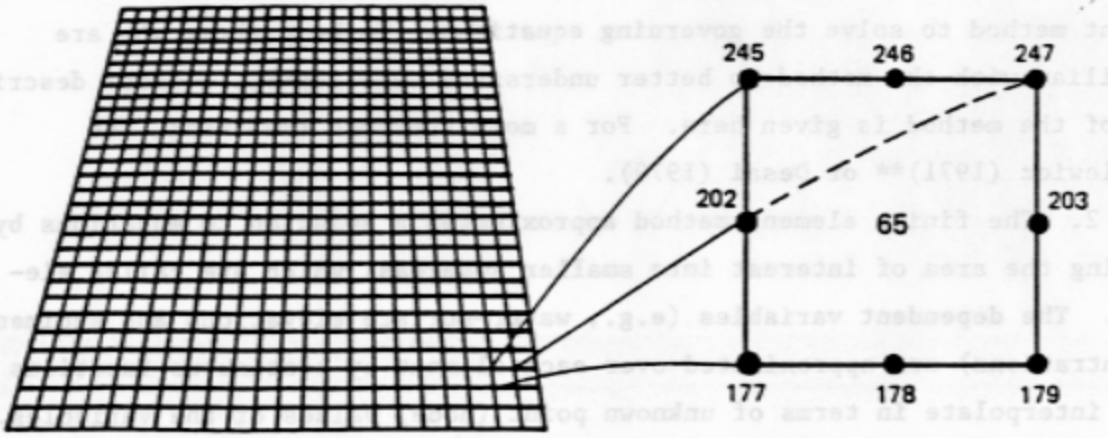
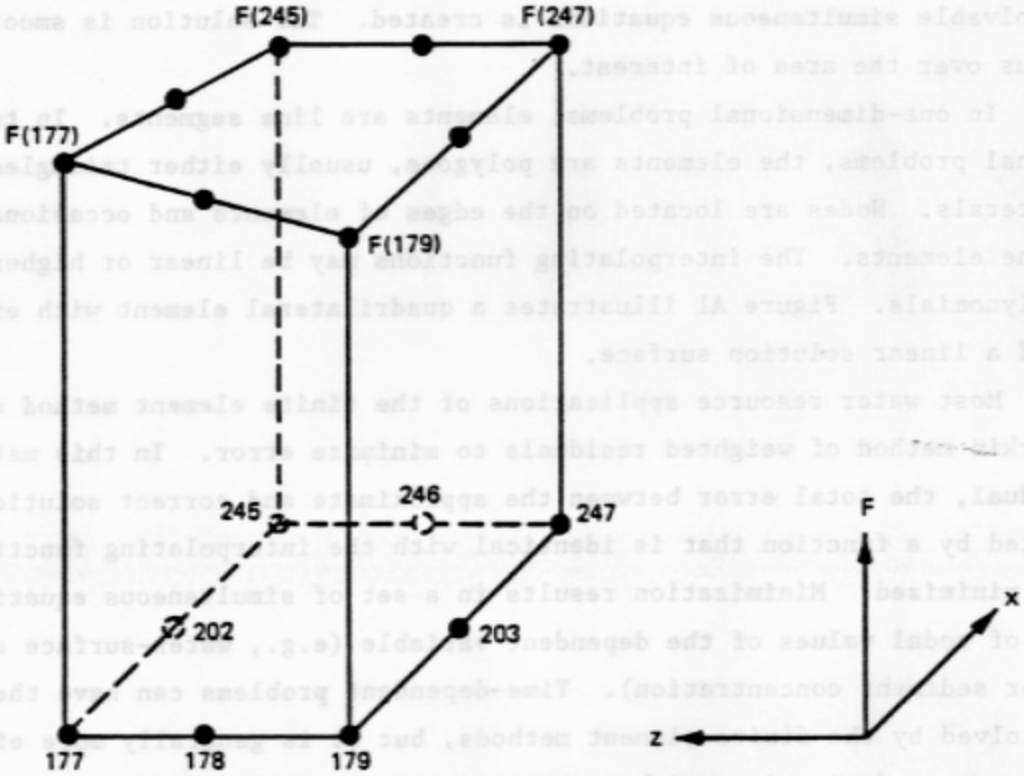
* Paragraphs 1-4 of this appendix from Stewart, Daggett, and Athow (1985).
** All references cited in this appendix are listed in the References at the end of the main text.



a. Eight nodes define each element



b. Linear interpolation function

Figure A1. Two-dimensional finite element mesh

approximating derivatives with differences in the value of variables over finite intervals of space and time. It requires discretization of space and time into more or less regular grids of computational points. The finite difference method obtains solutions to approximate equations.

6. In summary, the finite element method, sometimes called FEM, provides a means of obtaining an approximate solution to a system of governing equations; the partial differential equations are transformed into finite element form and then solved in a global matrix system. The solution is smooth over each element and continuous over the computational network, and the spatial integral of the error is minimized. In comparison, conventional finite difference methods provide a means of obtaining a solution to approximate equations of the governing equations; the partial differential equation terms are usually replaced by difference quotients and solved at discrete points.

7. Simply stated, conventional finite difference methods approximate the equations to be solved, then provide solutions to the approximate equations giving approximate answers for discrete points. Finite element methods approximate the form of the solution and then solve the governing equations providing a continuous approximate solution over the modeled area of interest. Both finite difference and finite element methods provide approximate solutions to the same basic equations for conservation of mass and momentum.

APPENDIX B: THE HYDRODYNAMIC MODEL, RMA-2V*

1. The generalized computer program RMA-2 solves the depth-integrated equations of fluid mass and momentum conservation in two horizontal directions. The form of the solved equations is

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + w\frac{\partial u}{\partial z} + g\left(\frac{\partial h}{\partial x} + \frac{\partial a_o}{\partial x}\right) - \frac{\varepsilon_{xx}}{\rho}\frac{\partial^2 u}{\partial x^2} - \frac{\varepsilon_{xz}}{\rho}\frac{\partial^2 u}{\partial z^2}$$

$$-2\omega w \sin\phi + \frac{gu}{C^2 h}(u^2 + w^2)^{1/2} - \frac{\xi}{h}V_a^2 \cos\Psi = 0 \qquad \text{(B1)}$$

$$\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + w\frac{\partial w}{\partial z} + g\left(\frac{\partial h}{\partial z} + \frac{\partial a_o}{\partial z}\right) - \frac{\varepsilon_{zx}}{\rho}\frac{\partial^2 w}{\partial x^2} - \frac{\varepsilon_{zz}}{\rho}\frac{\partial^2 w}{\partial z^2} + 2\omega u \sin\phi$$

$$+ \frac{gw}{C^2 h}(u^2 + w^2)^{1/2} - \frac{\xi}{h}V_a^2 \sin\Psi = 0 \qquad \text{(B2)}$$

$$\frac{\partial h}{\partial t} + \frac{\partial}{\partial x}(uh) + \frac{\partial}{\partial z}(wh) = 0 \qquad \text{(B3)}$$

where

u = horizontal flow velocity in the x-direction

t = time

x = distance in the x-direction (longitudinal)

w = horizontal flow velocity in the z-direction

z = distance in the z-direction (lateral)

g = acceleration due to gravity

h = water depth

a_o = elevation of the bottom

ε_{xx} = normal turbulent exchange coefficient in the x-direction

ρ = fluid density

ε_{xz} = tangential turbulent exchange coefficient in the x-direction

---

* This appendix from Stewart, Daggett, and Athow (1985).

ω = angular rate of earth's rotation

ϕ = latitude

C = Chezy roughness coefficient

ξ = coefficient relating wind speed to stress exerted on the fluid

V_a = wind velocity

Ψ = angle between wind direction and x-axis

ε_{zx} = tangential turbulent exchange coefficient in the z-direction

ε_{zz} = normal turbulent exchange coefficient in the z-direction

2. The Chezy roughness formulation of the original code was modified in the input portion so that Manning's n roughness coefficients may be specified from input Manning's n values and initial water depth.

3. Equations B1, B2, and B3 are solved by the finite element method using Galerkin weighted residuals. The elements may be either quadrilaterals or triangles and may have curved (parabolic) sides. The shape functions are quadratic for flow and linear for depth. Integration in space is performed by Gaussian integration. Derivatives in time are replaced by a nonlinear finite difference approximation. Variables are assumed to vary over each time interval in the form

$$f(t) = f(0) + at + bt^c \qquad t_o \leq t < t_1 \tag{B4}$$

which is differentiated with respect to time, and cast in finite difference form. Letters a , b , and c are constants. It has been found by experiment that the best value for c is 1.5 (Norton and King 1977).*

4. The solution is fully implicit and the set of simultaneous equations is solved by Newton-Raphson iteration. The computer code executes the solution by means of a front-type solver that assembles a portion of the matrix and solves it before assembling the next portion of the matrix. The front solver's efficiency is largely independent of bandwidth and thus does not require as much care in formation of the computational mesh as do traditional solvers.

5. The code RMA-2V is based on the earlier version RMA-2 (Norton and King 1977) but differs from it in several ways. First, it is formulated in

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* All references cited in this appendix are listed in the References at the end of the main text.

terms of velocity (v) instead of unit discharge (vh), which improves some aspects of the code's behavior; it permits drying and wetting of areas within the grid; and it permits specification of turbulent exchange coefficients in directions other than along the x- and z-axis.

APPENDIX C: THE SEDIMENT TRANSPORT MODEL, STUDH

1. The generalized computer program STUDH solves the depth-integrated convection-dispersion equation in two horizontal dimensions for a single sediment constituent. The form of the solved equation is

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + w\frac{\partial C}{\partial z} = \frac{\partial}{\partial x}\left(D_x\frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial z}\left(D_z\frac{\partial C}{\partial z}\right) + \alpha_1 C + \alpha_2 \qquad \text{(C1)}$$

where

C = concentration, kg/m^3

t = time, sec

u = flow velocity in x-direction, m/sec

x = primary flow direction, m

w = flow velocity in z-direction, m/sec

z = direction perpendicular to x, m

D_x = effective diffusion coefficient in x-direction, m^2/sec

D_z = effective diffusion coefficient in z-direction, m^2/sec

α_1 = coefficient for the source term, 1/sec

α_2 = equilibrium concentration portion of the source term, $kg/m^3/sec$

STUDH is related to the generalized computer program SEDIMENT II (Ariathurai, MacArthur, and Krone 1977)* developed at the University of California, Davis, under the direction of R. B. Krone. STUDH is the product of joint efforts of WES personnel (under the direction of W. A. Thomas) and R. Ariathurai (Resource Management Associates).

2. The source/sink terms in Equation C1 are computed in routines that treat the interaction of the flow and the bed. Separate sections of the code handle computations for clay bed and sand bed problems. In the tests described here, only clay beds were considered. Equation C1 is solved by the finite element method using Galerkin weighted residuals. Like RMA-2V, which uses the same general solution technique, elements are quadrilateral and may have parabolic sides. Shape functions are quadratic. Integration in space is Gaussian. Time-stepping is performed by a Crank-Nicholson approach with a

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* All references cited in this appendix are listed in the References at the end of the main text.

weighting factor (theta) of 0.66. The solution is fully implicit and a front-type solver is used similar to that in RMA-2V.

3. Several options are available for computing bed shear stress, τ_b, using

$$\tau_b = \rho u_*^2 \tag{C2}$$

where

ρ = water density

u_* = shear velocity

The Manning form of the shear stress equation was used in this study

$$u_* = \frac{un\left(g^{1/2}\right)}{CME\left(D^{1/6}\right)} \tag{C3}$$

where

u = flow velocity

n = Manning's roughness value

g = acceleration due to gravity

CME = coefficient of 1 for SI units and 1.486 for non-SI units

D = flow depth

4. Deposition rates for clay beds were calculated with the equations of Krone (1962):

$$S = \begin{cases} \dfrac{-2V_s}{D} C \left(1 - \dfrac{\tau_b}{\tau_d}\right) \text{ for } C < C_c & \text{(C4)} \\[2ex] \dfrac{-2V_k}{D} C^{5/3} \left(1 - \dfrac{\tau_b}{\tau_d}\right) \text{ for } C > C_c & \text{(C5)} \end{cases}$$

where

V_s = fall velocity of a single particle

τ_d = critical shear stress for deposition

C_c = critical concentration = 300 mg/ℓ

$V_k = V_s/C_c^{4/3}$

5. Erosion rates were computed by a simplification of Partheniades (1962) for particle-by-particle erosion. The source term was computed by

$$S = \frac{P}{D}\left(\frac{\tau_b}{\tau_e} - 1\right) \tag{C6}$$

where

P = erosion rate constant

τ_e = critical shear stress for particle erosion

ATTACHMENT 2

United States Department of the Interior

FISH AND WILDLIFE SERVICE
DIVISION OF ECOLOGICAL SERVICES
1825 VIRGINIA STREET
ANNAPOLIS, MARYLAND 21401

January 12, 1990

Colonel J.J. Thomas
District Engineer
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, VA 23510-1096

RE: Norfolk Harbor and Channels,
Virginia, Long-Term Disposal Study

Dear Colonel Thomas:

Enclosed please find the Planning Aid Report of the Fish and Wildlife Service (Service) on the Norfolk Harbor and Channels, Virginia, Long-Term Disposal Study. This report is submitted in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401 as amended; 16 U.S.C. 661 et seq.).

The report discusses the fish and wildlife resources and potential impacts associated with the two primary alternatives under consideration for the long-term disposal of dredged material from the Federal navigation channels within the Port of Hampton Roads. These alternatives are the expansion of the existing Craney Island Disposal Area and ocean disposal at either the Dam Neck Ocean Disposal Site or the Norfolk Ocean Disposal Site.

Based on the significant impacts that the expansion of the Craney Island Disposal Site would have on the fish and wildlife resources of the Hampton Roads area and unanswered questions on the physical effects of the expansion on the hydrodynamics of the lower James River estuary and the seed oyster beds, the Fish and Wildlife Service does not recommend the expansion of the Craney Island site. The Service does support the use of the Norfolk Ocean Disposal Site for all dredged material from the port that meets ocean disposal criteria. Craney Island should be reserved for material that does not meet ocean disposal criteria and, if necessary, clean material should be removed from the facility to extend its useful life. Our report recommends further studies before either the expansion of Craney Island or the Dam Neck alternatives are given further consideration. The report also recommends studies of the effluent from Craney Island and the Rehandling Basin to evaluate whether the current facility is having an effect on the aquatic ecosystem. If the expansion of Craney Island is selected as the long-term disposal alternative, losses of aquatic resource values should be mitigated. Our report recommends several types of mitigation that would be appropriate for this project, including wetland stabilization, oyster reef creation, restoration of anadromous fish

passage, and the maintenance of Craney Island as a wildlife management area. Finally, our report indicates that if Craney Island expansion is chosen as the preferred alternative, consultation with the Service pursuant to Section 7 of the Endangered Species Act will be necessary due to potential impacts on the endangered peregrine falcon (Falco peregrinus) and the threatened piping plover (Charadrius melodus).

The Service appreciates this opportunity to participate in the long-term disposal study and we look forward to continuing discussions with the Corps and the Virginia Port Authority. Please contact Karen Mayne of our Gloucester, Virginia Field Office at (804) 693-6694 if you have questions regarding this report.

Sincerely yours,

John P. Wolflin
Supervisor
Annapolis Field Office

PLANNING AID REPORT
on the
NORFOLK HARBOR AND CHANNELS, VIRGINIA
LONG-TERM DISPOSAL STUDY
(INNER HARBOR)

SUBMITTED UNDER PROVISIONS
of
THE FISH AND WILDLIFE COORDINATION ACT
to
THE U.S. ARMY CORPS OF ENGINEERS
NORFOLK DISTRICT

Prepared By
DIVISION OF ECOLOGICAL SERVICES
GLOUCESTER FIELD OFFICE
U.S. FISH AND WILDLIFE SERVICE

October, 1989

Prepared by: Karen L. Mayne
Project Leader: John P. Wolflin

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I. INTRODUCTION

The U.S. Fish and Wildlife Service (Service) has participated with the U.S. Army Corps of Engineers in the study and evaluation of alternatives for the disposal of dredged material from the Port of Hampton Roads. The study is entitled, Norfolk Harbor and Channels, Virginia, Long-Term Disposal. This report constitutes the Service's Planning Aid Report on this study, in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.).

The Corps of Engineers (Corps) is responsible for the maintenance of the Federal navigation channels for the Port of Hampton Roads. The Water Resources Development Act of 1986 authorized the deepening of most of the Port's Federal channels, which would be paid for by the Federal government and the Virginia Port Authority. The Corps has divided the Federal navigation channels into the inner and outer channels. The outer channels include the Atlantic Ocean Channel at the entrance of the Chesapeake Bay and the Thimble Shoal Channel from the mouth of the Chesapeake Bay to the mouth of Hampton Roads. The inner harbor channels include the channels to Newport News, the Elizabeth River, and the Southern and Eastern Branches of the Elizabeth River.

In the mid-1950s, the Corps constructed the 2500 acre Craney Island Disposal Area to contain dredged material from the Federal channels within Hampton Roads and the Elizabeth River, as well as material from private dredging projects. The Craney Island Disposal Area was created from shallow estuarine habitat in Hampton Roads and includes an open water rehandling basin immediately to the east of the site. Dredged material can either be pumped directly into Craney Island, or the material can be dumped into the rehandling basin and redredged at a later time and placed in Craney Island.

In 1980 the Norfolk District and the North Atlantic Division of the Corps completed a Feasibility Report (USACE 1980) that addressed the alternatives that were available for the long term disposal of dredged material from the Port of Hampton Roads, based on the recognition that the Craney Island site had a limited capacity for dredged material. This study included the recommendations of a task force convened in 1976 by Governor Mills E. Godwin, Jr. of Virginia to evaluate disposal alternatives. The Corps' 1980 report analyzed a number of contained disposal sites throughout the lower Chesapeake Bay and Hampton Roads area, as well as an ocean disposal site located approximately 17 miles east of the mouth of the Chesapeake Bay. The Corps recommended the use of the ocean disposal site for dredged material from the Thimble Shoal and Atlantic Ocean Channels and the construction of a 6000 acre contained disposal site within the City of Suffolk for dredged material from the inner harbor channels and private dredging projects. That site consisted primarily of wetlands that are part of the Great Dismal Swamp. Due to a number of concerns and unanswered questions about the Suffolk site, the Corps' Board of Engineers for Rivers and Harbors rejected the recommended alternative. Instead, the Board advised the Norfolk District to: 1) study the feasibility of ocean disposal of dredged material from the deepening of the Port's Federal

navigation channels, 2) develop new management techniques to extend the life of the Craney Island Disposal Area, and 3) further evaluate long-term options for dredged material disposal from both the inner and outer harbor channels.

The Norfolk District subsequently undertook studies and implemented a revised management plan for the Craney Island Disposal Area that included creating subimpoundments within the facility and raising the perimeter dikes (Palermo, et al. 1981; USACE 1987a). The Corps also undertook studies and evaluation of two ocean disposal sites. The Norfolk Ocean Disposal Site, located approximately 17 miles east of the mouth of the Chesapeake Bay, was studied but never designated as an approved ocean disposal site (USACE 1982). The Dam Neck Ocean Disposal Site, located 3 miles east of Virginia Beach, was studied (USACE 1985) and designated by the Corps as the disposal site for dredged material from the deepening and maintenance of the Thimble Shoal, Cape Henry and Atlantic Ocean Federal navigation channels.

The present Corps study, of which this report is a part, undertakes the further evaluation of long-term disposal options for dredged material from the inner harbor channels of the Port of Hampton Roads. The Corps plans to also study long-term disposal options for the outer harbor channels, which will be the subject of a separate evaluation and report. Upon completion of this present study the local sponsor of the project, the Virginia Port Authority will be provided with an analysis of the alternatives and recommendations on those that are most environmentally, economically and socially acceptable.

The Service's report will address the environmental impacts of the disposal alternatives under consideration, with emphasis on the expansion of the Craney Island Disposal Area, and recommendations on the selection of alternatives that minimize and mitigate environmental impacts to fish and wildlife resources.

II. OVERVIEW OF DISPOSAL ALTERNATIVES UNDER CONSIDERATION

At its public meeting in August, 1987 (USACE 1987b), the Norfolk District indicated that it was undertaking a study of 12 alternatives for the disposal of dredged material from the inner harbor Federal navigation channels and private dredging projects. These alternatives, shown in Figure 1, have been previously considered by the Corps (USACE 1980) and include:

1. Expansion of the Craney Island Disposal Area consisting of a maximum increase of approximately 2500 acres, with a life expectancy of 50 years.

2. Confined disposal site in Willoughby Bay consisting of 1280 acres with a life expectancy of 16 years.

3. Confined disposal site on the Hampton Flats area of Hampton Roads consisting of 1800 acres with a life expectancy of 24 years. The City of Newport News' previous proposal for a smaller 300 acre contained site would also be considered.

4. Confined disposal site at the Ragged Island Wildlife Management Area consisting of 2320 acres with a life expectancy of 17 years.

5. Confined disposal site in the Chesapeake Bay north of Ocean View consisting of 2700 acres with a life expectancy of 50 years.

6. Confined disposal site in the Chesapeake Bay east of the Chesapeake Bay Bridge-Tunnel and north of the Thimble Shoal Channel consisting of 2450 acres with a life expectancy of 50 years.

7. Confined disposal site in the Chesapeake Bay southeast of Buckroe Beach consisting of 3500 acres with a life expectancy of 50 years.

8. Contained disposal site in Suffolk north of the Great Dismal Swamp National Wildlife Refuge consisting of 6000 acres with a life expectancy of 50 years.

9. Open water disposal at the Dam Neck Ocean Disposal Site located in the Atlantic Ocean approximately 3 miles east of Virginia Beach. Life expectancy would vary according to the size of the disposal area.

10. Open water disposal at the Norfolk Ocean Disposal Site located in the Atlantic Ocean approximately 17 miles east of the mouth of the Chesapeake Bay. Based on an area of approximately 50 square nautical miles, the life expectancy of the site should be unlimited.

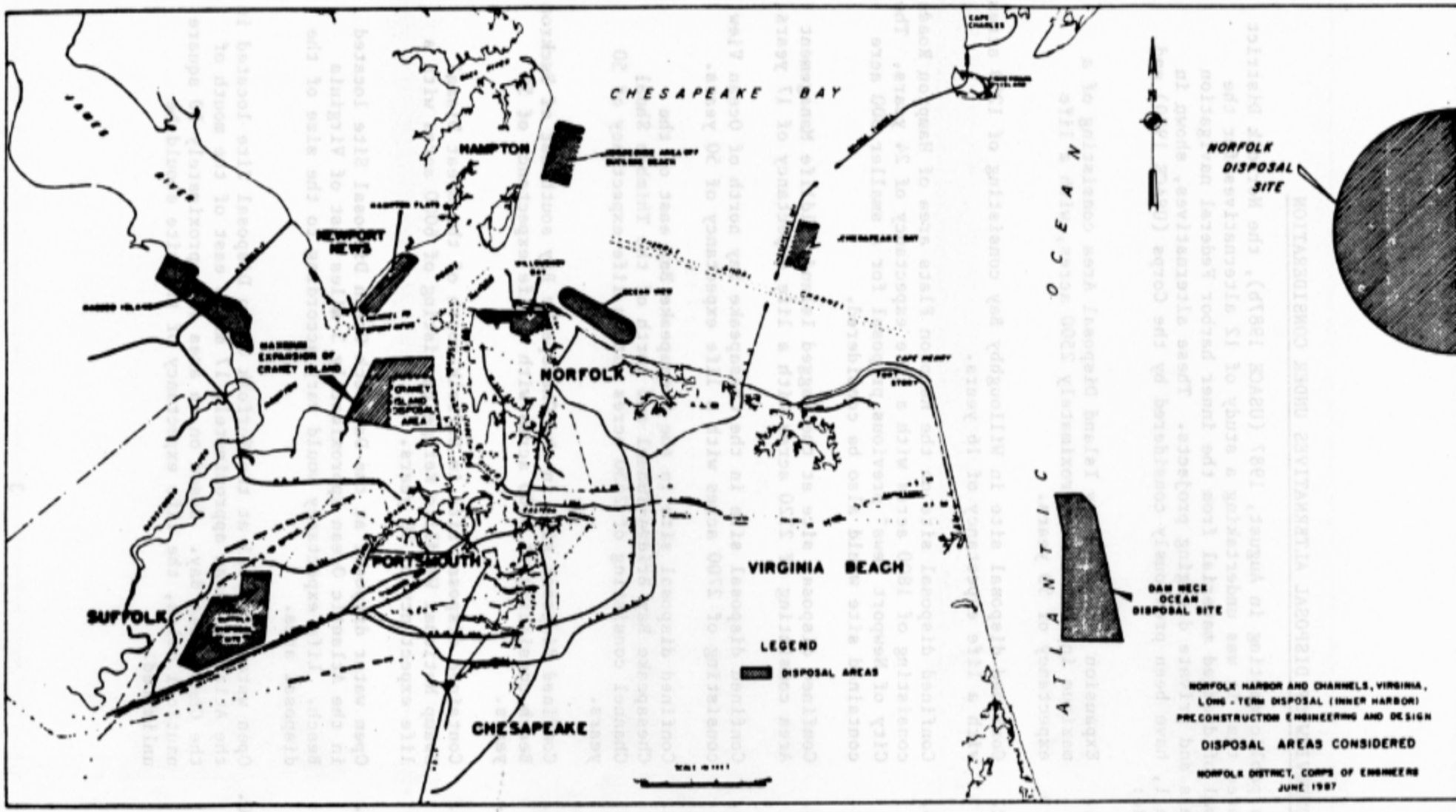

Figure 1. Disposal Alternatives Under Consideration for the Norfolk Harbor and Channels Long-Term Disposal Study.

11. Placement of dredged material in abandoned borrow pits and mines through the use of truck and rail hauling.

12. Beneficial use of suitable dredged material for such purposes as beach nourishment and construction grade soils.

Most of these alternatives have been studied at various levels of detail by the Corps or others in the past (USACE 1980, 1982, 1985; Byrne et al. 1987). Table 1, taken from the Corps' 1980 Feasibility Report, indicates the major advantages and disadvantages of all alternatives except the beneficial use of dredged material, which was not considered in the previous study. In the 1980 report, the Corps rejected all alternatives except the Suffolk site and ocean disposal from further consideration based on environmental and/or economic concerns. As stated above, the Suffolk site was subsequently dropped from further consideration because of unanswered environmental concerns.

In undertaking the present study, the Norfolk District has indicated that they intend to concentrate on the evaluation of two disposal options -- the expansion of Craney Island and ocean disposal at either the Norfolk or Dam Neck Ocean Disposal Sites. The concentration on these alternatives is based on the recognition that the other confined disposal sites in the Chesapeake Bay and Hampton Roads area, as well as the confined sites at Ragged Island and Suffolk, all have significant environmental impacts that would be unacceptable. The expansion of the Craney Island Disposal Site is also recognized as having significant environmental, social, and economic impacts; however, the cost of constructing this site would be less than any of the other contained sites.

Table 1. Major Advantages and Disadvantages of Long-Term Disposal Alternatives Considered by the Corps of Engineers in 1980 Report Entitled "Norfolk Harbor and Channels, Virginia, Deepening and Disposal, Feasibility Report and Final Environmental Impact Statement." (Source: USACE, 1980)

Plan	Advantages	Disadvantages	Action
Raising levees	Cost, environmental features, accessibility	Short useful life, levees will be raised under Water Resources Development Act of 1976 to serve as a buffer prior to implementing new site	No further consideration
Westward Extension (Raised)	Cost, useful life, environmental features, accessibility	I-664 crossing will preclude full development of this plan, cannot be expanded to accommodate potential new work and associated increased maintenance, loss of open water space, aesthetics, decrease in surrounding property values	No further consideration
Willoughby Bay	Cost, accessibility	Short useful life, preclude extensive recreational use, destroy small boat harbor, aesthetics, cannot be expanded to accommodate potential new work and associated increased maintenance	No further consideration
Ocean View area	Useful life, can be expanded to accommodate potential new work and associated increased maintenance, cost, accessibility	Loss of bay bottom, loss of recreational resources, aesthetics, possible changes in current patterns causing beach erosion	Retain for further consideration
Hampton Flats	Accessibility, cost	Short useful life, cannot be expanded to accommodate potential new work and associated increased maintenance, destroy fishery resources, possible effects on natural current patterns to cause shore erosion	No further consideration

III. RESOURCES OF THE PROJECT AREA

The primary focus of this report will be on the resources of the James River in the vicinity of the Craney Island Disposal Area. Information on the resources of the other disposal sites within the Chesapeake Bay and the Suffolk and Ragged Island sites can be found in USACE (1980). Information on the ocean disposal sites can be found in USACE (1982) and USACE (1985).

The James River estuary is approximately 100 miles long, extending from the fall line at Richmond to the mouth of Hampton Roads. Its major tributaries include the Chickahominy, Nansemond, Elizabeth and Lafayette Rivers. Hampton Roads is actually the lower end of the James River estuary and is bound on the east by the City of Norfolk, on the south by the Cities of Portsmouth and Suffolk, and on the west by the Cities of Newport News and Hampton. The construction of the 2500 acre Craney Island Disposal Area in the mid-1950s into Hampton Roads, in effect "extended" the length of the main stem of the Elizabeth River by two miles.

The James River estuary is Virginia's most highly industrialized river system. It is also important as the Chesapeake Bay's largest port, a major oyster production area, and for its commercial and recreational fisheries. Recently, the Elizabeth River has gained notoriety as one of the most polluted rivers in the world. Despite the highly industrialized nature of the Hampton Roads area, the lower James River estuary continues to provide valuable habitat for fish and wildlife resources.

The area under consideration for the westward and northward expansion of Craney Island consists primarily of shallow open water habitat. Water depths in the area vary between intertidal flats and fringe wetlands along the perimeter of Craney Island and the natural shoreline of the River Shore section of Portsmouth, to approximately 25 feet mean low water (MLW) along the northward extension. Average depths over most of the area that would be encompassed by the westward expansion are approximately 10 feet MLW. The mean tide range is 2.5 feet. Hampton Roads is within the meso- to polyhaline section of the Chesapeake Bay, with salinities averaging between 15 and 28 parts per thousand, depending on the depth and amount of freshwater inflow (Richards and Morton 1983).

Finfish

A number of general studies of finfish in the lower James River estuary have been conducted, primarily in association with environmental assessments of Federal and private projects. A wide variety of resident and migratory finfish utilize or migrate through the Hampton Roads area. Detailed information on species, distribution, and habitat requirements of the dominant finfish in the lower James River can be found in USACE (1975), NUS Corp. (1975), Ecological Analysts (1979), Hedgepeth et al. (1981) and Birdsong et al. (1984).

Anadromous fish, species that live in saline water and spawn in freshwater rivers, pass through the Hampton Roads area to reach their spawning and

nursery grounds in the upper James River estuary between the Chickahominy River and Richmond. These species include the striped bass (Morone saxatilis), American shad (Alosa sapidissima), hickory shad (A. mediocris), blueback herring (A. aestivalis), alewife (A. pseudoharengus), gizzard shad (Dorosoma cepedianum), Atlantic herring (Clupea harengus) and white perch (Morone americana). The adults of these species enter the Hampton Roads area between February and April on their migration to their spawning grounds. The area of the proposed expansion previously supported a large commercial shad fishery in March and April (USACE 1975). Juveniles migrate down the James and may spend up to the first three years of life in the lower sections of the James River.

Many species of finfish that spawn in the ocean or lower Chesapeake Bay utilize the lower James River estuary as a nursery area or as adults. Dominant species include:

- Spot (Leiostomas xanthurus)
- Atlantic croaker (Micropogon undulatus)
- Menhaden (Brevoortia tyrannus)
- Weakfish (Cynoscion regalis)
- Summer flounder (Paralichthys dentatus)
- Bluefish (Pomatomus saltatrix)
- American eel (Anguilla rostrata)
- Striped mullet (Mugil cephalus)
- Silver perch (Bairdiella chrysura)
- Black drum (Pogonias cromis)
- Southern lungfish (Menticirrhus americanus)

A number of resident estuarine finfish are found in the lower James River estuary. Dominant species include:

- Hogchoker (Trinectes maculatus)
- Bay anchovy (Anchoa mitchilli)
- Atlantic silverside (Menidia menidia)
- Gobies (Gobiosoma sp.)
- Striped killifish (Fundulus majalis)
- Blennies (Chasmodes bosquianus and Hypsoblennius hentzi)
- Oyster toadfish (Opsanus tau)

Hedgepeth et al. (1981) conducted a two year demersal (bottom) finfish survey of the lower James River estuary, including Hampton Roads and the Elizabeth River. The survey indicated that temperature is the major factor in the winter distribution of finfish, while food is the major factor in summer distribution. Their study concluded that the principal uses of the area by finfish are 1) as nursery grounds for spot, American shad, striped bass and weakfish; 2) feeding grounds for adult spot, Atlantic croaker, weakfish, and summer flounder; and 3) spawning grounds for resident forage species such as bay anchovy and Atlantic silverside.

Two finfish surveys have included stations in the immediate vicinity of the Craney Island Disposal Area. Birdsong et al. (1984) utilized otter trawls on a monthly basis between January 1982 through January 1984 at a station

at the mouth of the Elizabeth River, between Craney Island and the Federal navigation channel. The station was located in 25 feet of water. The Corps of Engineers (USACE 1975) funded Old Dominion University Research Foundation to conduct monthly otter trawls between November 1972 and October 1973 in an area between one and 15 feet of water, located northwest of Craney Island. The results of these two surveys are presented in Tables 2, 3 and 4. Old Dominion University collected 33 species of fish, dominated by the bay anchovy, spot, Atlantic croaker, summer flounder, and hogchoker. Birdsong et al. also collected a total of 33 species, dominated by the bay anchovy, spot, weakfish, menhaden, spotted hake (Urophycis regalis) and Atlantic croaker. These studies, as well as others in the Hampton Roads area, indicate that the shallow water area west of Craney Island is an important foraging and nursery area for resident and migratory estuarine finfish.

Benthic Resources

Benthic (bottom dwelling) communities are a diverse assemblage of organisms which play integral roles in the functioning of estuarine ecosystems. The benthos is usually divided into the epibenthos, organisms which live on the surface of the sediment and are thus subject to passive or active transport along the bottom, and the infauna, organisms which live within the sediment. Benthic invertebrates are the predominant food source for many estuarine fishes, including the young of many sport and commercial species, and many motile invertebrates, such as the blue crab. Species such as oysters and clams are also an important commercial resource. Studies have suggested that while the densities of the benthos of shallow sandy areas in the Chesapeake Bay are lower than that of deeper and offshore areas, the populations turn over rapidly and are exploited by predators (Virnstein, 1976). The bottom community as a whole is important in the regulation of energy flow and the cycling of essential nutrients through the estuarine system. The composition and stability of bottom sediments profoundly affect the role of the benthic community in serving these functions.

There have been a number of studies of the benthic resources of the lower Chesapeake Bay and James River. Major studies include: Boesch 1973; Boesch and Rackley 1974; NUS Corp. 1975; Robinson 1978; Schaffner and Diaz 1982; Hawthorne and Dauer 1983; and Dauer 1984.

Boesch (1971, 1972, and 1973) conducted a study of the macrobenthos of Hampton Roads, the lower James River and the Elizabeth River during February, May and August of 1969. This study resulted in the collection of 175 taxa. The dominant taxa were Polychaeta (54 forms), Gastropoda (23 forms), Amphipoda (22 forms) and Bivalvia (18 forms). Boesch conducted a

Table 2. Seasonal Distribution of Fishes Collected at a Station to the Northwest of Craney Island in Monthly Surveys Between November 1972 and October 1973, Average Catch per Trawl. (Source: USACE 1975)

Species	Common Name	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
Alosa aestivalis	Blueback herring	2	-	-	1	-	-	-	-	-	-	-	-
Alosa pseudoharengus	Alewife	1	2	1	5	-	1	-	-	-	-	-	-
Anchoa mitchilli	Bay anchovy	315	28	15	517	40	405	102	-	2	4	3	10
Alosa sapidissima	American shad	1	1	-	1	-	-	-	-	-	-	-	-
Bairdiella chrysura	Silver perch	-	1	-	-	-	-	-	-	-	-	2	-
Brevoortia tyrannus	Atlantic menhaden	-	-	1	5	-	1	-	-	-	-	-	-
Centropristis striata	Black seabass	-	-	-	-	-	-	1	-	-	-	-	1
Cynoscion regalis	Weakfish	1	1	-	-	-	-	-	-	1	-	1	-
Etropus microstomus	Smallmouth flounder	-	-	-	-	-	-	-	-	-	1	1	1
Gobiesox stromosus	Skilletfish	-	-	-	-	-	-	1	-	-	-	-	-
Gobiosoma bosci	Naked goby	-	-	1	-	-	-	-	-	-	-	1	-
Leiostomus xanthurus	Spot	2	13	-	1	-	1	1	29	21	21	34	52
Morone americana	White perch	-	1	-	-	-	-	-	-	-	-	-	-
Morone saxatilis	Striped bass	-	-	-	1	-	-	-	-	-	-	-	-
Menidia menidia	Atlantic silverside	-	5	1	-	-	-	-	-	-	-	-	-
Menticirrhus americanus	Southern kingfish	-	-	-	-	-	-	-	-	-	-	2	-
Micropogon undulatus	Atlantic croaker	5	35	1	49	1	-	2	47	18	9	6	26
Microgobius thalassinus	Green goby	-	1	-	-	-	-	-	-	-	-	-	-
Opisthonema oglinum	Atlantic thread herring	3	1	-	-	-	-	-	-	-	-	-	-
Opsanus tau	Oyster toadfish	-	-	-	-	-	1	-	-	-	-	-	-
Paralichthys dentatus	Summer flounder	-	-	-	-	-	1	1	3	3	2	4	6
Peprilus alepidotus	Harvestfish	-	-	-	-	-	-	-	-	-	-	2	2
Prionotus carolinus	Northern searobin	-	-	-	-	-	-	1	1	1	-	-	-
Prionotus evolans	Striped searobin	-	-	-	-	-	-	-	-	1	1	1	1
Pseudopleuronectes americanus	Winter flounder	-	1	1	-	-	-	-	-	-	-	-	-
Sphoeroides maculatus	Northern puffer	-	-	-	-	-	-	-	-	-	-	1	-
Stenotomus chrysops	Scup	-	-	-	-	-	-	-	-	-	-	1	-
Sygnathus fascus	Northern pipefish	-	-	-	1	-	-	-	-	-	-	-	-
Symphurus plagiusa	Blackcheek tonguefish	-	-	-	-	1	-	1	1	-	-	1	-
Tautoga onitis	Tautog	-	-	-	-	-	-	-	-	-	-	1	-
Trinectes maculatus	Hogchoker	-	-	-	1	-	1	1	4	13	-	16	1
Urophycis regia	Spotted hake	-	-	-	-	1	6	3	-	-	-	-	-
Selene setapinnis	Atlantic moonfish	-	-	-	-	-	-	-	-	-	-	1	1
Total Trawls		2	6	4	4	6	5	4	3	3	3	5	3

Table 3. Species and Abundance of Fish Collected at a Station to the East of Craney Island in Monthly Trawls Between January 1982 and January 1984 (x = less than 100 taken; * = more than 100 taken). (Source: Birdsong et al. 1984).

Species	Abundance
Eels	
Anguilla rostrata (American eel)	x
Herrings	
Alosa aestivalis (blueback herring)	x
Alosa sapidissima (American shad)	x
Brevoortia tyrannus (Atlantic mehaden)	*
Dorosoma cepedianum (gizzard shad)	x
Anchovies	
Anchoa mitchilli (bay anchovy)	*
Lizardfishes	
Synodus foetens (inshore lizardfish)	x
Toadfishes	
Opsanus tau (oyster toadfish)	x
Clingfishes	
Gobiesox strumosus (skillet fish)	x
Codfishes	
Urophycis chuss (red hake)	x
Urophycis regia (spotted hake)	*
Cusk-eels	
Ophidion marginatum (striped cusk-eel)	x
Silversides	
Menidia menidia (Atlantic silverside)	x
Pipefishes	
Syngnathus fuscus (northern pipefish)	x
Sea Basses	
Centropristis striata (blacks sea bass)	x
Bluefishes	
Pomatomus saltatrix (bluefish)	x

Table 3, continued.

Species	Abundance
Drums	
Bairdiella chrysoura (silver perch)	x
Cynoscion regalis (weakfish)	*
Leiostomus xanthurus (spot)	*
Micropogonias undulatus (Atlantic croaker)	*
Spadefishes	
Chaetodipterus faber (Atlantic spadefish)	x
Blennies	
Chasmodes bosquianus (striped blenny)	x
Hypsoblennius hentzi (feather blenny)	x
Gobies	
Gobiosoma bosci (naked goby)	x
Butterfishes	
Peprilus alepidotus (harvestfish)	x
Peprilus triacanthus (butterfish)	x
Searobins	
Prionotus carolinus (northern searobin)	x
Lefteye Flounders	
Eutropus microstomus (smallmouth flounder)	x
Paralichthys dentatus (summer flounder)	x
Scophthalmus aquosus (windowpane)	x
Soles	
Trinectes maculatus (hogchoker)	x
Tonguefishes	
Symphurus plagiusa (blackcheek tonguefish)	x
Squids	
Lolliguncula brevis (brief squid)	x

Table 4. Summary of Trawl Catches at a Station to the East of Craney Island from Monthly Surveys in 1982-1983 for the Thirteen Most Abundant Species. (Source: Birdsong et al. 1984).

Species	Number Caught	Rank Among All Stations in Study
Fishes		
Anchoa mitchilli (bay anchovy)	9,750	2
Leiostomus xanthurus (spot)	2,261	5
Cynoscion regalis (weakfish)	338	6
Brevoortia tyrannus (Atlantic menhaden)	213	2
Urophycis regia (spotted hake)	206	4
Micropogonias undulatus (Atlantic croaker)	174	7
Trinectes maculatus (hogchoker)	96	5
Paralichthys dentatus (summer flounder)	95	6
Alosa aestivalis (blueback herring)	50	3
Menidia menidia (Atlantic silverside)	28	7
Urophycis chuss (red hake)	27	3
Opsanus tau (oyster toadfish)	19	4
Squids		
Lolliguncula brevis (brief squid)	58	4
Total Species Caught	33	6
Total Specimens Caught	13,309	3

rank-analysis of the species and stations and detected a difference in dominant species based on substrate type. The dominant species for each substrate, ranked from most to least abundant were:

Sand: Heteromastus filiformis
Polydora ligni
Unicola irrorata
Ensis directus
Retusa (= Acteocina) canalidulata
Ampelisca vadorum

Muddy sand: Spiochaetopterus occulatus
Paraprinospio pinnata
Phoronis architecta
Pseusoeurythoe paucibranchiata
Retusa (= Acteocina) canaliculata
Unicola irrorata

Mud: Mulinia lateralis
Paraprionospio pinnata
Spiochaetopterus oculatus
Retusa (= Acteocina) canaliculata
Balanus improvisus
Ensis directus

Boesch (1973) stated that the benthic assemblages in the Hampton Roads area were comprised of either species that are restricted to sand or species that were not bottom-type specific and could be found in both sand and mud bottoms. After reviewing the literature on the dominant macrobenthos within the Chesapeake Bay and other estuarine and marine areas of North America, Boesch concluded that the dominant species found in the Hampton Roads area were similar to those generally found in the lower Chesapeake Bay but that the overall benthic associations were different from those reported outside the Chesapeake Bay region.

In his evaluation of community structure, Boesch (1971) reported population densities ranging between 150 and 8865 organisms per square meter (m^2), with a mean for sand substrates of 3045 organisms/m^2 and for mud substrates of 1839/m^2. This disparity between sand and mud substrates was also seen in the number of species (49 for sand versus 33 for mud), and species diversity ($H' = 3.95$ for sand versus 3.40 for mud). The differences in species diversity between the bottom types was not due to differences in the equability of organisms among the species, but rather to differences in species richness. Boesch (1973) concluded that the higher species richness in sand was related to a greater number of epifauna which could colonize the hard sand bottom and shell and worm tube fragments, and to a greater number of deposit feeders. In mud bottoms, attachment sites for epifauna would be rapidly silted over and the thin oxidation layer would limit deposit feeders to just the surface sediments.

Boesch (1973) observed seasonal variations in the abundance and presence of benthic species and developed a hypothetical model of community structure

for the benthos in the Hampton Roads area. Sand communities showed an increase in community structure parameters in March with a large peak from late April through early June, a decrease during the summer, a much smaller peak in October and November, followed by a decline to a stable winter level. In contrast, mud communities exhibited a much greater fluctuation with low community structure parameters in the winter, which increased significantly during the late summer and early fall. These seasonal variations reflect the spring and fall spawning and recruitment periods of most benthic organisms in the Chesapeake Bay.

Duncan (1974) studied the benthic community in dredged channels in Hampton Roads over a 14-month period from 1971 to 1972. The substrata at the stations in this study were soft, fluid muds with a thin oxidation layer. There were 48 taxa identified, dominated by annelids (46% of the species) and arthropods (27% of the species). Ten species comprised 88% of the individuals. Ranked from most to least abundant these species were:

Leucon americanus
Peloscolex gavriellae
Heteromastus filiformis
Streblospio benedicti
Paraprionospio pinnata
Acteocina canaliculata
Sigambra tentaculata
Glycinde solitaria
Scoloplos robustus
unidentified Hemichordate

Community structure parameters showed peaks in the early fall (September and October) and a smaller peak in April and May. Species diversity (H´) ranged from 0.95 to 3.44, species richness (SR) ranged from 0.98 to 3.70, and species evenness (J´) ranged from 0.29 to 0.84.

Boesch and Rackley (1974) conducted a one-year benthic study at the mouth of Hampton Roads around the Hampton Roads Bridge-Tunnel, Sewell´s Point Spit and Willoughby Bank from 1973 to 1974. The purpose of the study was to evaluate the impacts of the construction of the second tunnel crossing and the dredging of sand for borrow material from Sewell´s Point Spit and Willoughby Bay. The study identified 179 taxa, the most abundant being polychaetes (47), amphipods (29), bivalves (21) and gastropods (21). They determined that the Hampton Roads entrance channel between Fort Wool and Old Point Comfort had a benthic community that was less diverse, species rich, and abundant than other areas of Hampton Roads and the lower Chesapeake Bay due to the instability of the bottom sediments. The dominant species, which are all adapted for survival in dynamic habitats, included the isopod *Chiridotea nigrenscens*, the tellin shell *Tellina agilis*, the bivalves *Mulinia lateralis* and *Nucula promima*, and the polychaete *Peloscolex gabriellae*.

In contrast to the channel, the shoal areas exhibited a much larger benthic community. Boesch and Rackley (1974) found there was a difference in abundance and dominants between the crest and the deeper sections of the

banks, and the borrow pits. The crest of the banks had a low number of species and densities due to sediment instability and wave action. Dominant species were the gem shell Gemma, the isopod Chiridotea nigrescens, the tellin shell Tellina agilis, the potato sponge Craniella laminaris and an unidentified polychaete of the Order Archiannelida. The deeper sections of the shoals were dominated by a larger number of species including the oligochaete Peloscolex gabriellae, the polychaetes Glycera dibranchiata, Nereis succinea, Clymenella torquata, Pectinaria gouldii, Pseudeurythoe paucibranchiata and Heteromastus filiformis, the molluscs Acteocina canaliculata, Lyonsia hyalina, Tellina agilis and Mulinia lateralis, the phoronid worm Phoronis spammophila, and the amphipod Ampelisca vadorum. While these species were also found in the borrow pits, they were less abundant. Recently dredged areas of the pits exhibited low infaunal species diversity, dominated by the opportunistic polychaetes Glycera dibranchiata and Streblospio benedicti and the bivalve Mulinia benedicti. A further difference between the borrow pits and the undredged areas of the banks was that the pits had a larger epibenthic community dominated by the sea squirt Molgula manhattensis, the polychaete Sabellarria vulgaris, the barnacle Balanus improvisus, the blue mussel Mytilus edulis and the hydroid Sertularia argentea. Associated with these larger epifauna was a diverse assemblage of amphipods including Caprella penantis, Unicola irrorata and U. serrata, Elasmopus levis, Gammarus mucronatus, Melita nitida, Corophium simile and C. acherusicum and Stenothoe minuta.

Species diversity (H′) values for the Boesch and Rackley (1974) study ranged from 0.62 to 3.72 for the channel stations, 2.12 to 3.95 for the Willoughby Bank stations, and 1.87 to 2.91 for the Sewell′s Point Spit stations. Species richness (SR) values ranged from 1.04 to 6.14 for channel stations, 2.23 to 7.12 for Willoughby Bank stations and 2.21 to 4.42 for Sewell′s Point Spit stations.

Diaz and Boesch (1976) conducted a three year winter study of the benthos on Hampton Bar located north of the Hampton Roads entrance channel and west of the north island of the Hampton Roads Bridge-Tunnel. The purpose of the study was to evaluate the effects of a large borrow pit located on the bar. Diaz and Boesch identified 67 taxa in 1974, 76 taxa in 1975 and 94 taxa in 1976. The reduced number of taxa at the Hampton Bar stations compared to the 179 taxa Boesch and Rackley (1974) identified probably reflects the winter sampling period more than any inherent differences between Hampton Bar and Sewell′s Point Bar and Willoughby Bank. Diaz and Boesch conducted a cluster analysis and were able to group benthic assemblages based on bottom substrate, depth, and length of time since dredging occurred. The dominant species were similar to those identified by Boesch and Rackley (1974) and exhibited similar differences in abundance and dominant species between the crest and deeper areas of Hampton Bar and the borrow pit. Densities ranged from 75 to 8435 organisms/m^2. Species diversity (H′) ranged from 1.93 to 4.46, species richness (SR) ranged from 1.85 to 7.14, and evenness (J′) ranged from 0.42 to 0.95.

Dauer (1984) conducted a year long study of macroinvertebrates at 12 stations located along the major navigation channels in the lower Chesapeake Bay, Hampton Roads, Elizabeth River and James River. A total of 227 taxa were identified. Polychaetes comprised 45% of the taxa, bivalves 12%, amphipods 12%, and gastropods 11%. Mean densities ranged between 1571 and 4485 organisms per square meter. Mean species diversity ranged from 2.24 to 3.74. Species richness means ranged from 2.55 to 5.41. Evenness values ranged from 0.57 to 0.80.

Dauer's cluster analysis grouped the benthos into four species groups that exhibited similarities in species composition based primarily on sediment type, salinity, and water depth. Group I included the dominants Spiophanes bombyx, Tellina agilis, Nephtys picta and Polygordius sp. and were comprised of stations on the sandy sediments of the Chesapeake Bay and nearshore Atlantic Ocean. Group II species were found in the sandy sediments of the lower Chesapeake Bay and were dominated by Ensis directus, Amatigos caperatus, and Glycera dibranchiata. Group III species were found in both sandy and mud bottoms of the lower Bay and outer Hampton Roads and were dominated by Mediomastus ambiseta, Paraprionospio pinnata, Glycinde solitaria, and Acteocina canaliculata. Group IV species were found in the high silt-clay sediments of inner Hampton Roads, Elizabeth River, and James River and were dominated by Leucon americanus, Streblospio benedicti, Nereis succina, Eteone heteropoda, and Leitoscoloplos fragilis.

As indicated by the above literature review, benthic communities depend upon, to a large extent, the type of sediment. Byrne et al. (1982) conducted a study of the sediment types in the Hampton Roads area, shown in Figure 2. Their study indicated that sandy substrates dominate the area known as Hampton Flats and the area along the River Shore shoreline west of Craney Island. Muddy or mixed substrates dominate to the west, north and east of Craney Island. Dauer and Ewing (1986) and Gapcynski and Diaz (1989) conducted benthic surveys in the immediate vicinity of Craney Island. Dauer and Ewing identified a nearshore (within 150 feet) silty sand habitat and an offshore mud habitat with a high silt-clay content. Their stations extended a maximum distance of about 2000 feet from Craney Island. In contrast, Gapcynski and Diaz, whose sample sites extended up to 8200 feet from Craney Island, found three bottom types. They identified an inshore zone with very soft muds and clays, a middle zone of muds and silts, and an offshore zone of sand and silt. The differences in the sediment types between these two studies can be explained by the fact that Gapcynski and Diaz conducted their study immediately after the placement of dredged material from the Newport News navigation channel over an area approximately 1000 feet wide around the north and west sides of Craney Island. This dredged material disposal, undertaken to stabilize the dikes at Craney Island, has significantly changed the bottom topography and sediment type of the area.

Dauer and Ewing's (1986) benthic survey of the nearshore area to the east, north and west of Craney Island was conducted in August, October, and November of 1985. Station locations are shown in Figure 3. The community dominants and structure are given in Table 5. Dauer and Ewing compared

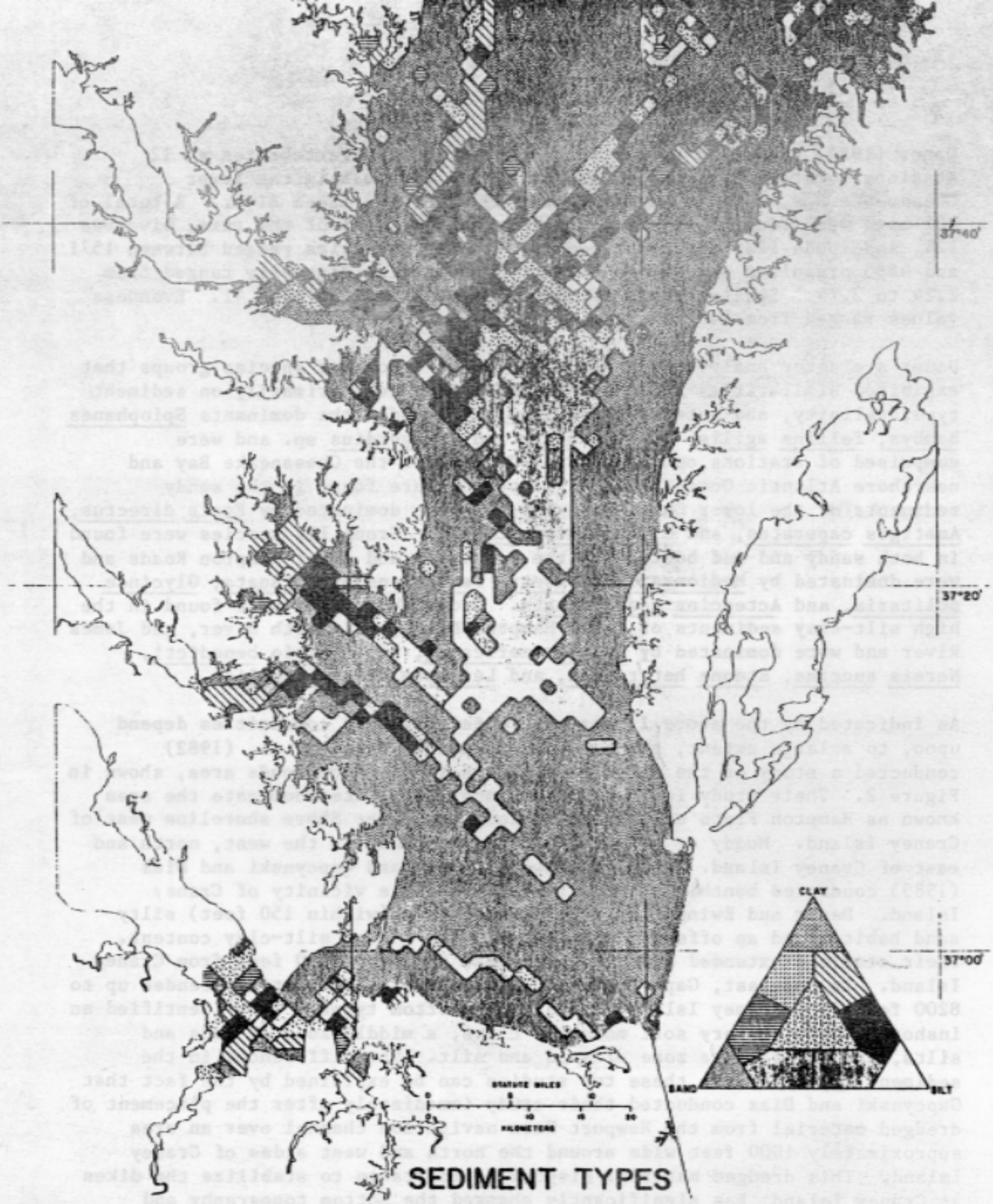

Figure 2. Sediment Types of the Chesapeake Bay Showing Hampton Roads Sediments. (Source: Byrne et al. 1982)

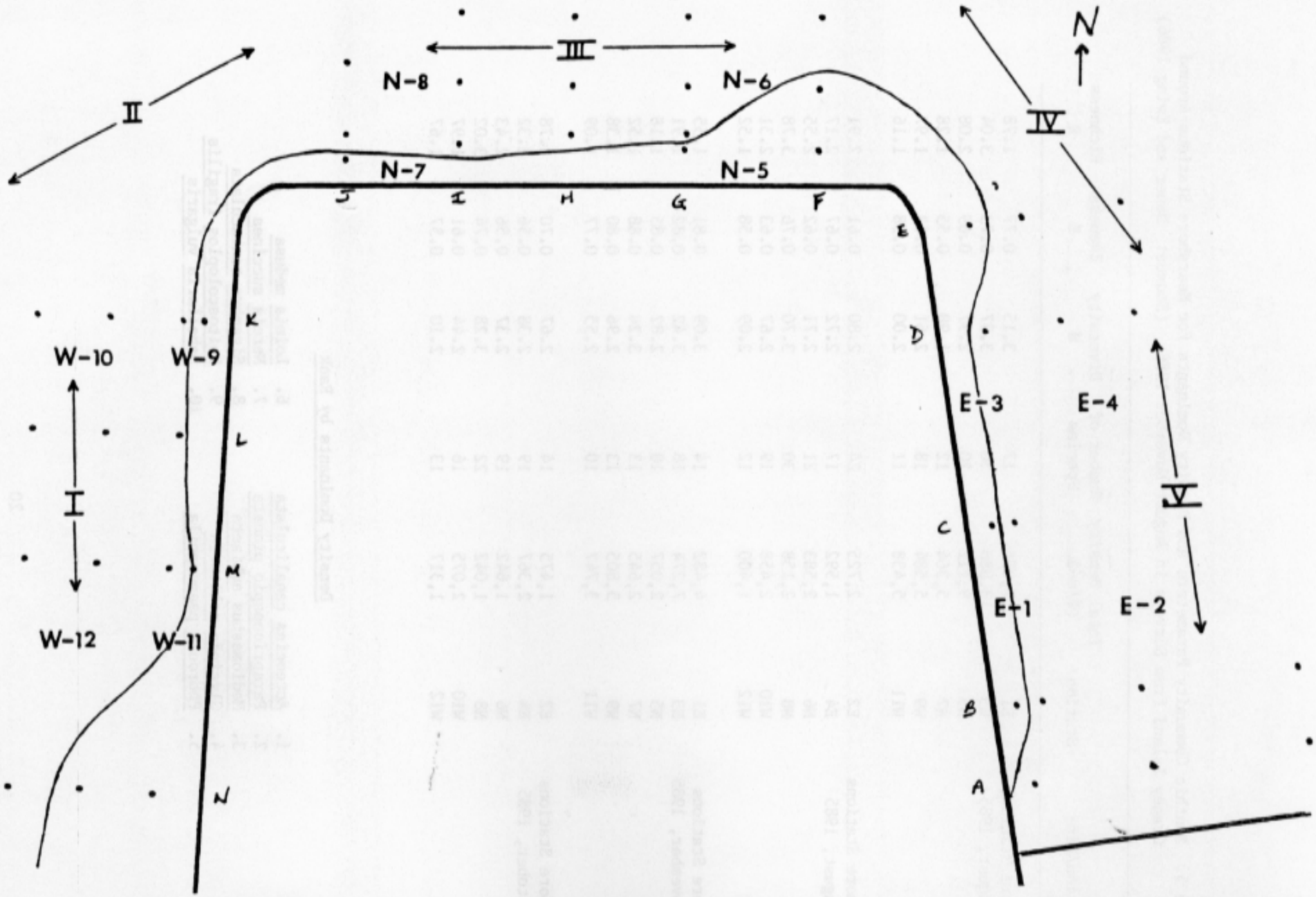

Figure 3. Location of Table 5 Benthic Sampling Stations in the Vicinity of Craney Island. Odd Arabic Numerals are Nearshore Stations Sampled with Hand-held Corer. Even Arabic Numerals are Offshore Stations Sampled with a Shipek Grab. Roman Numerals Indicate Vicinity of Commercial Benthos Samples Taken with a Commercial Dredge. (Source: Dauer and Ewing 1986)

Table 5. Benthic Community Parameters and Density Dominants for Nearshore Stations Around Craney Island from Surveys in August-November 1986. (Source: Dauer and Ewing 1986)

Location/Date	Station	Total Density (#/m^2)	Number of Species	Diversity H	Eveness E	Richness R
Inshore Stations August, 1985	E1	7,936	17	3.15	0.77	1.78
	E3	13,888	30	3.57	0.73	3.04
	N5	9,112	20	2.97	0.69	2.08
	N7	5,364	12	1.98	0.55	1.28
	W9	5,584	18	2.61	0.63	1.97
	W11	5,438	11	2.00	0.58	1.16
Offshore Stations August, 1985	E2	2,725	24	2.80	0.61	2.91
	E4	1,592	17	2.72	0.67	2.17
	N6	2,583	21	2.71	0.62	2.55
	N8	2,158	30	3.70	0.76	3.78
	W10	2,458	19	2.67	0.63	2.31
	W12	1,400	12	2.09	0.58	1.52
Inshore Stations November, 1985	E1	4,482	14	3.09	0.81	1.55
	E3	7,274	18	3.42	0.82	1.91
	N5	2,057	10	2.82	0.85	1.18
	N7	2,645	13	3.24	0.88	1.52
	W9	5,805	13	2.96	0.80	1.38
	W11	3,747	10	2.55	0.77	1.09
Offshore Stations October, 1985	E2	1,475	14	2.67	0.70	1.78
	E4	2,367	19	2.38	0.56	2.32
	N6	1,642	19	2.37	0.56	2.43
	N8	1,042	22	3.28	0.74	3.02
	W10	2,075	16	2.44	0.61	1.97
	W12	1,317	13	2.10	0.57	1.67

Density Dominants by Rank

1. *Acteocina canaliculata*
2. *Paraprionospio pinnata*
3. *Mediomastus ambiseta*
4. *Glycinde solitaria*
5. *Phoronis psammophila*
6. *Loimia medusa*
7. *Nereis succinea*
8. *Sigambra tentaculata*
9. *Leitoscoloplos fragilis*
10. *Sabellaria vulgaris*

Table 6. Benthic Community Parameters and Density Dominants for Site Group IV from Dauer (1984). Site Group IV Includes Stations to the East of Craney Island in the Elizabeth River and to the West of Craney Island in the Mouth of the Nansemond River Surveyed Between January 1982 and October 1983.

Parameter	Site Group 4
Total Density (#/m^2)	2196
Diversity (H)	3.45
Eveness (J)	0.71
Species Richness (R)	4.97

Density Dominants

Species	Density
1. *Paraprionospio pinnata*	514
2. *Acteocina canaliculata*	366
3. *Mediomastus ambiseta*	202
4. *Glycinde solitaria*	132
5. *Phoronis psammophila*	120
6. *Leucon americanus*	118
7. *Nereis succinea*	46
8. *Streblospio benedicti*	44
9. *Ampelisca abdita*	42
10. *Odostomia* sp.	38

this information with information collected by Dauer (1984) for Site Group IV, which consisted of stations to the east of Craney Island in the Elizabeth River Federal navigation channel and to the west of Craney Island in the Nansemond River entrance channel. A synopsis of Dauer's 1984 results for Site Group IV are found in Table 6. Dauer and Ewing found that there were no major differences between the inshore and offshore samples around Craney Island and that the top five dominant species were the same in both the 1984 and 1986 studies. The density dominants in both studies included Paraprionospio pinnata, Acteocina canaliculata, Mediomastus ambiseta, Glycinde solitaria, and Phoronis psammophila. Densities of benthic organisms in Dauer and Ewing's study ranged between 1041 and 9111 organisms per square meter with a mean value of 4261 for the August survey and 2541 for the November survey. Species diversity ranged between 1.98 and 3.70, species evenness between 0.55 and 0.88, and species richness between 1.16 and 3.78.

The results of Dauer and Ewing's benthic survey of the Craney Island area are not directly comparable to some of the earlier studies in the Hampton Roads area because of differences in the size of the screen used to collect the organisms. Earlier studies generally used a screen size of 1.0 millimeter (mm), while more recent studies, including Dauer and Ewing's, generally use 0.5 mm screens. Some of the more recent studies in the Elizabeth River and lower Chesapeake Bay have been limited in temporal extent, location, substrate type, or toxics levels, and thus may show somewhat differing species composition. However, results of studies conducted at what may be considered more "pristine" areas of the lower Chesapeake Bay (Dauer et al. 1984; Hobbs et al. n.d.; Hall n.d.) compared with Dauer and Ewing's results, indicate that the benthic resources of the area that would be filled by the expansion of Craney Island are substantially similar in terms of dominant species, number of organisms, and community structure.

Gapcynski and Diaz (1989) surveyed the benthic community of the area surrounding Craney Island in November 1988 using a sediment profile camera. This methodology uses photographs to evaluate biological activity in the sediments; however, it does not determine species composition or densities of organisms. As stated above, this survey was conducted immediately after the placement of dredged material around the outer perimeter of the north and west sides of Craney Island. Gapcynski and Diaz found a difference in biological activity with distance from Craney Island, the innermost stations showing the least biological activity and the outermost stations showing the greatest biological activity. This is in contrast with Dauer and Ewing's (1986) study, which found the highest densities of benthic organisms at stations closest to Craney Island. The differences appear to be due to the disposal of the dredged material in the fall of 1988. Since benthic organisms usually recolonize disturbed areas within a year, it is anticipated that the area around Craney Island will regain its normal benthic community.

Commercial Resources

The most important commercial species in the Hampton Roads area are the American oyster (Crassostrea virginica), the hard clam (Mercenaria), the blue crab (Callinectes sapidus) and a number of finfish species. The highest commercial catches of finfish in the Hampton Roads area include shad, spot and croaker (Jones 1989).

Haven and Kendall (1975), Haven, Morales-Alamo and Priest (1981) and Haven, Whitcomb and Kendall (1981) have conducted extensive surveys of the oyster and hard clam in the James River estuary. The James River has historically provided the majority of Virginia's commercial catch of oysters. The James River seed oyster beds, located primarily between the U.S. Route 17 bridge and Mulberry Point, provide the major source of seed oysters for the Chesapeake Bay and are among the most productive along the East Coast. Watermen from throughout Virginia harvest oysters from the James River.

Densities of oysters in the Hampton Roads area have declined drastically from their historic levels, due primarily to the presence of two major disease organisms, MSX (Haplosporidium nelsoni) and dermo (Perkinsus marinus), which appeared in the Chesapeake Bay in the late 1950s to 1960s. Another predator of the oyster, the oyster drill (Urosalpinx cinerea) is also found in the Hampton Roads area. As a result, there is currently no commercial harvest of oysters within Hampton Roads. However, Byrne et al. (1987) indicate that, prior to the oyster epidemic caused by MSX, the oyster beds on Hampton Flats were probably the largest contributor of larvae to the seed beds in the James River.

Within the immediate vicinity of Craney Island, public oyster grounds (Baylor Grounds) are present to the west, north, and east of the site, as shown in Figure 4. At one time these areas apparently supported high quantities of oysters. However, Haven and Kendall (1975) and Haven, Whitcomb and Kendall (1981) indicate there are presently very low densities of oysters around Craney Island. Dauer (1984) and Dauer and Ewing (1986) confirm these previous studies. The closest public oyster bed that contains high densities of oysters or suitable substrate for oyster production is the Nansemond Ridge, at the mouth of the Nansemond River, approximately 2 miles west of the proposed expansion of Craney Island. This public ground is indicated as "Nansemond County Ground Number 2" in Figure 4.

Hard clams reach their upstream limit in the James River at about the U.S. Route 17 bridge. Below this area, hard clams are found in commercially harvestable quantities immediately west of Newport News Point, on Hampton Flats between Newport News Point and Old Point Comfort, and on the Newport News Middle Ground, located northwest of Craney Island. Jones (1989) reports that up to 100 commercial clammers harvest within the James River, Hampton Roads, and lower Chesapeake Bay area. Table 7 and Figure 5 show estimates of hard clam densities in the Hampton Roads area.

Haven, Morales-Alamo and Priest (1981) conducted surveys for hard clams in the areas surrounding Craney Island that are within the area of the

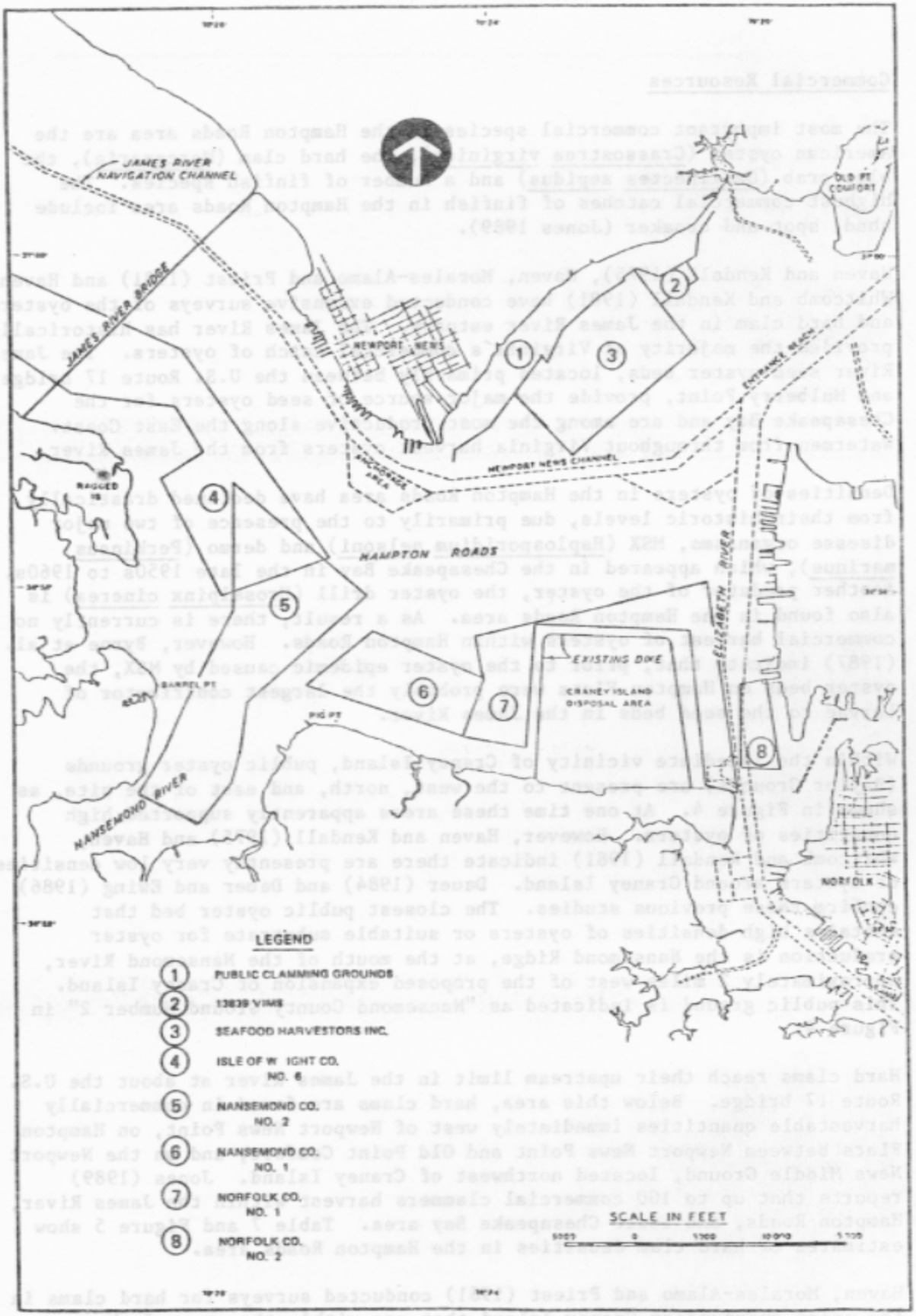

Figure 4. Public and Private Oyster and Clam Ground Locations in Hampton Roads. (Source: Heltzel 1988 and Virginia Marine Resources Commission)

Table 7. Estimate of Bottom Acreage and Densities of the Hard Clam, *Mercenaria mercenaria*, in Plots Surveyed Between 1970 and 1974 in the Lower James River. Location of Sample Plots given in Figure 5. (Source: Haven et al. 1981)

Source of Data (Footnotes)	Plot No.	No. Acres	Clam Density (Bu/Acre)	Total No. (Bushels)
-	1	508	(0.3)[5]	152
1	2	4321	6.9	29,815
-	3	427	(0.3)[5]	128
1	4	1221	40.0	48,840
1	5	1928	36.1	69,601
-	6	528	(0.3)[5]	158
2	7	5410	1.1	5,951
2	8	71	0	0
2	9	242	5.5	1,331
2	10	2352	12.1	28,459
-	11	305	(1.0)[5]	305
3	12	610	11.0	6,710
3	13	1126	0.3	338
3	14	1323	62.0	82,026
3	15	109	6.0	654
3	16	680	65.0	44,200
3	17	183	58.0	10,614
-	18	1075	(25.0)[5]	26,875
-	19	698	(25.0)[5]	17,450
-	20	1474	(25.0)[5]	36,850
-	21	890	(5.0)[5]	4,450
-	22	1202	(5.0)[5]	6,010
-	23	2266	109.8	248,807
-	24	488	109.8	53,582
4	25	571	16.08	9,182
-	26	1486	(5.0)[5]	7,430
4	27	1473	24.12	35,529
-	28	691	(25.0)[5]	17,275
4	29	386	10.05	3,879
4	30	352	3.35	1,179
4	31	182	8.04	1,471
TOTALS		34,579		565,712

[1] Haven, D. S., J. G. Loesch and J. P. Whitcomb. 1973. An investigation into commercial aspects of the hard clam fishery and development of commercial gear for the harvest of molluscs. Final Report, Contract 3-124-R with the Virginia Marine Resources Commission, for the National Marine Fisheries Service. 119 pp. Virginia Institute of Marine Science, Gloucester Point, Virginia.

[2] Haven, D. and P. Kendall. 1975. A survey of commercial shellfish in the vicinity of Newport News Point and Pig Point in the lower James River. Final Report to McGaughy, Marshall and McMillan - Hazen and Sawyer. In: Fang, C.S. (Project Manager): Oceanographic, Water Quality and Modeling Studies

for the Outfall from a Proposes Nansemond Waste Water Treatment Plant, Volume 4. p. 1-28 and summary. Special Report No. 86 in Applied Marine Science and Ocean Engineering. Virginia Institute of Marine Science, Gloucester Point, Virginia.

[3] Haven, D. S. and J. G. Loesch. 1972. Hampton Roads corridor survey report for the Virginia Department of Highways. Final Report. 12 pp. + 6 tables. Virginia Institute of Marine Science, Gloucester Point, Virginia.

[4] Haven, D. and P. Kendall. 1974. A final report to the Virginia Department of Highways on hard clam (Mercenaria mercenaria) populations in the vicinity of the Hampton Roads Bridge-Tunnel (I-64). 15 pp + 6 tables + 18 figures. Virginia Institute of Marine Science, Gloucester Point, Virginia.

[5] Density given represents a guess-estimate based on familiarity with the area and data from surrounding areas.

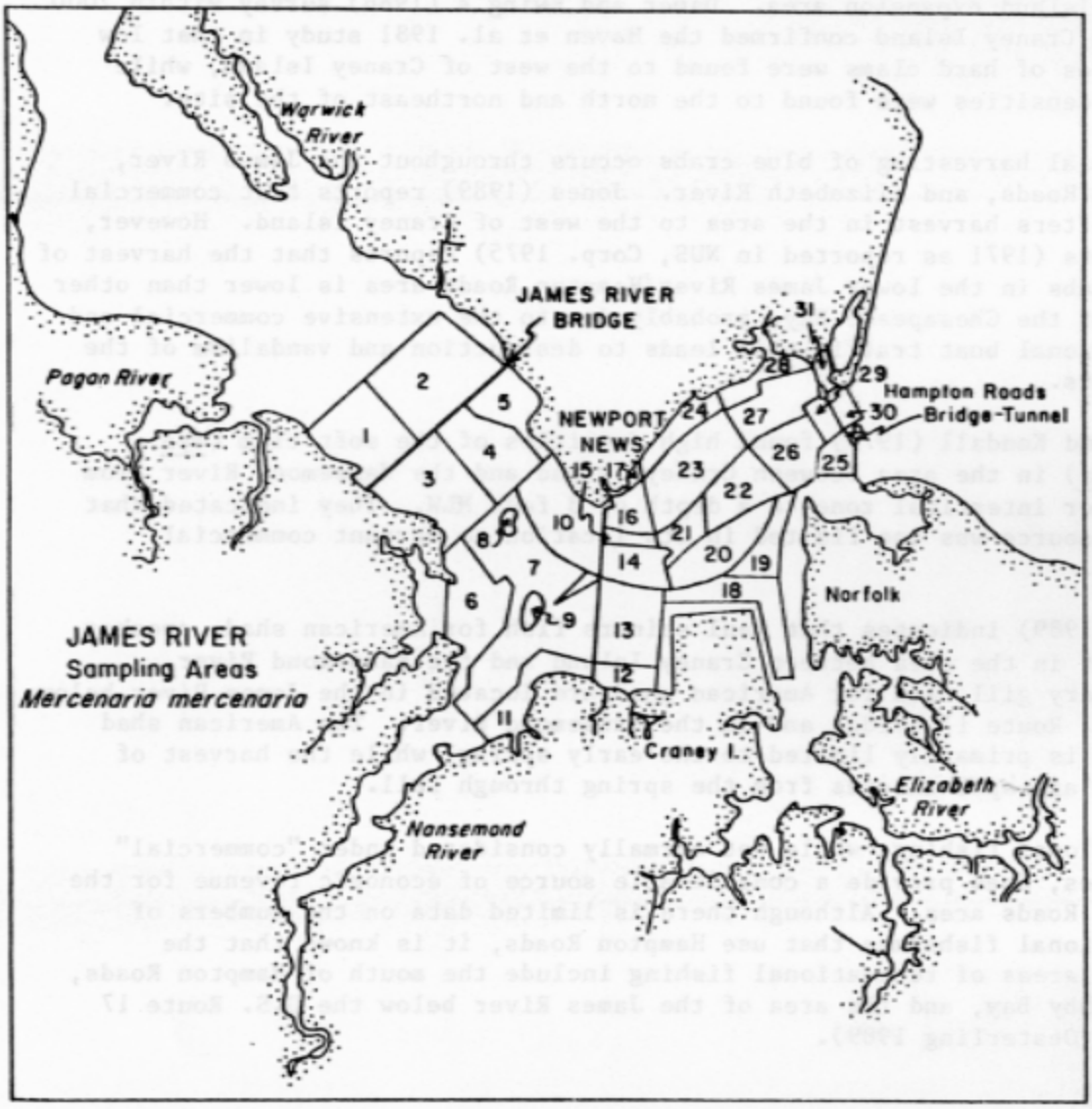

Figure 5. Division of Lower James River into System of Numbered Plots Used to Estimate Bottom Acreage and Standing Crop of the Hard Clam Mercenaria mercenaria given in Table 7. (Source: Haven et al. 1981)

proposed expansion. Immediately to the north and east of Craney Island, they estimated hard clam densities of about 25 bushels per acre, a density considered to be marginal as a commercial resource. To the west of Craney Island, densities of 11 bushels of hard clams per acre were found closest to the shoreline between Craney Island and Streeter Creek. Further offshore, between Craney Island and the Nansemond River entrance channel, hard clam densities were quite low, averaging 0.3 bushels per acre. High densities of hard clams (62 bushels per acre) were found on the Newport News Middle Ground, located one half mile or less north of the proposed Craney Island expansion area. Dauer and Ewing's (1986) survey within 2000 feet of Craney Island confirmed the Haven et al. 1981 study in that low densities of hard clams were found to the west of Craney Island, while higher densities were found to the north and northeast of the site.

Commercial harvesting of blue crabs occurs throughout the James River, Hampton Roads, and Elizabeth River. Jones (1989) reports that commercial crab potters harvest in the area to the west of Craney Island. However, Pleasants (1971 as reported in NUS, Corp. 1975) reports that the harvest of blue crabs in the lower James River/Hampton Roads area is lower than other areas of the Chesapeake Bay, probably due to the extensive commercial and recreational boat traffic that leads to destruction and vandalism of the crab pots.

Haven and Kendall (1975) found high densities of the soft clam (*Mya arenaria*) in the area between Craney Island and the Nansemond River from the lower intertidal zone to a depth of 3 feet MLW. They indicated that this resource was too limited in its location to warrant commercial harvest.

Jones (1989) indicates that haul seiners fish for American shad, croaker and spot in the area between Craney Island and the Nansemond River. Stationary gill nets for American shad are located in the James River below the U.S. Route 17 bridge and in the Nansemond River. The American shad fishery is primarily limited to the early spring, while the harvest of croaker and spot extends from the spring through fall.

Recreational fishing, while not normally considered under "commercial" resources, does provide a considerable source of economic revenue for the Hampton Roads area. Although there is limited data on the numbers of recreational fishermen that use Hampton Roads, it is known that the primary areas of recreational fishing include the mouth of Hampton Roads, Willoughby Bay, and the area of the James River below the U.S. Route 17 bridge (Oesterling 1989).

Avifauna

The Hampton Roads area is used for feeding and resting by a number of important bird groups, primarily shorebirds, waterbirds and waterfowl. The Craney Island Disposal Area receives high use by these groups because the extensive shallow water areas within the disposal site provide a source

of food and/or relative safety. The following synopsis of bird use in Craney Island and the surrounding area is taken from USACE (1975):

"A number of birds use Craney Island as a resting stop during fall and spring migrations. An occasional flock of Canada geese, Branta canadensis, was observed on the margins of Phragmites beds on the interior. Large numbers of shovelers, Spatula clypeata, use the inland lake and pools along the southern border. At the time of observation, they appeared in fall and lasted through the winter, but it is believed they represented a succession of different flocks using the area rather than a resident population. They did not appear to be feeding in the area. Black ducks were seen in varying numbers throughout the year. In winter, they were seen in both the lake and pools along the southern margin, but in summer, only in the latter. During fall and winter months, a number of species were attracted to the waters along the margin of the area. These species included the surf scoter, bufflehead, lesser scaup, ruddy duck, American coot, American widgeon, mallard, and horned grebe. Of these, only the bufflehead, mallard, and American widgeon ventured onto the interior lake with the shovelers. These species were observed from fall through winter and into spring and did not feed inside the disposal area.

During the summer months, the species of birds change drastically. Along the exterior margins, especially on the western border, a modest number of cormorants replace the ducks. They are especially attracted to the area immediately surrounding the effluent from the sluiceway draining the interior lake. On the interior, a large number of species congregate along the margins of the interior lake. These include the snowy egrets, American avocets, black-bellied plovers, lesser yellowlegs, dunlins, semi-palmated sandpipers, dowitchers, willets, black-backed gulls, herring gulls, ringbilled gulls, laughing gulls, least terns, royal terns, common terns, caspian terns, and black skimmers. The gulls and terns apparently use the area as resting ground. They obtain most of their food from excursions to the surrounding bay, although some food is picked up from dredged spoils as it is pumped in. It should be noted that a majority of the gulls were in an immature stage; however, no nesting was observed. The remaining birds actively fed on organisms in the shallow margins. The sandpipers, plovers, dowitchers, lesser yellowlegs, dunlins, and willets fed inside during high water but migrated to exposed mudflats along the shore on the western exterior during low water. The food sources available inside are mainly sheepshead minnows, and polychaete worms pumped in with dredge spoil. Water boatmen (Corixidae) are another possible food source. The most important mechanism enabling them [water boatmen] to populate this area is their ability to take flight."

In addition to the species of birds discussed in the USACE 1975 report, Beck (1986) has noted nesting within Craney Island by the killdeer (Charadrius vociferus), red-winged blackbird (Agelaius phoeniceus), song sparrow (Melospiza melodia), eastern meadowlark (Sturnella magna) and mallard (Anas platyrhynchos).

Results of the mid-winter waterfowl survey of the lower James River conducted by the Virginia Department of Game and Inland Fisheries and the U.S. Fish and Wildlife Service are provided in Table 8. These surveys confirm the observations of the species of waterfowl found in the vicinity of Craney Island. Davis (1989) reported seeing several thousand canvasback ducks in Craney Island in the early 1970s. He says the area west of Craney Island consistently has supported approximately 1000 gadwalls throughout the winter, as well as black ducks, mallards, shovelers and red-breasted mergansers. Davis reports that diving ducks, such as greater and lesser scaup, are more often seen to the east of Craney Island. Settle (1989) reports the highest waterfowl use of the area surrounding Craney Island is in the shallow water areas along the western side of Craney Island and the shoreline between Craney Island and the mouth of the Nansemond River.

The least tern (Sterna albifrons), unofficially listed as threatened in Virginia (Linzey 1979), nests within the Craney Island Disposal Area. This colonial nesting shorebird has consistently used Craney Island for nesting since at least the early 1970s and has been provided special protection by the Corps of Engineers during its nesting season. In USACE (1975) it is reported that the least tern feeds on small fish obtained from the waters immediately outside the disposal area. In 1989 a total of 300 pairs of least terns nested at four sites at Craney Island. Two common tern (Sterna hirundo) nests were located with the smallest of the four least tern colonies.

Beck (1989) has reported that other species of water birds regularly observed at Craney Island in 1989 include over 150 brown pelicans (Pelecanus occidentalis), 50 to 75 royal terns (Thalasseus elegans), 80 to 100 black skimmers (Rynchops nigra), and two black-necked stilts (Himantopus mexicanus). The brown pelican was recently removed from the Federal Endangered Species Act list as threatened. The royal tern is listed as a species of special concern in Virginia (Linzey 1979).

Endangered Species

Several species that are listed as threatened or endangered by the U.S. Fish and Wildlife Service and the Virginia Department of Game and Inland Fisheries occur in the project area. The bald eagle (Haliaeetus leucocephalus), listed as endangered, and the piping plover (Charadrius melodus), listed as threatened, are transients in the Hampton Roads area during migration periods in the spring and fall. The bald eagle, which feeds on finfish and carrion such as waterfowl and shorebirds, has been observed in the Hampton Roads area (Davis 1989). Beck (1989) reports that piping plovers have been regularly observed in late April and early May at Craney Island since 1987. A pair of piping plovers nested at Craney Island during 1989 and successfully raised 3 young. This is the first known nesting by this species at Craney Island or in Hampton Roads.

The peregrine falcon (Falco peregrinus), whose subspecies F. peregrinus anatum (American) is listed as endangered and F. peregrinus tundrius

Table 8. Midwinter Waterfowl Surveys for Virginia Segment 1 (James River from Hampton Roads to U.S. Route 17 Bridge), 1973 to 1989. (Source: U.S. Fish and Wildlife Service)

Species	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Mallard	5	50	300	50		71	60	97	271	500	100	700	175	137	137	517	102
Black Duck		205	tr*		30	216	100	163	185	300	tr	300	42	51	11	110	73
Gadwall		55					1510		6				25				
Widgeon		700		11		35	160		133	600	300	100	100	34	65	85	16
Green Winged Teal							1500	40						12			
Shoveler		350					3150	360		400							
Pintail		10					2	50		400	200	100					
Wood Duck											tr		50				
Total Dabblers	5	1370	300	61	30	322	6482	710	595	2200	600	1200	392	234	213	712	191
Redhead		15			100					100							
Canvasback	180	775	700	590		1536	1231	1690	1414	1500	2800	1200	1684	749		1327	150
Scaup			200	130		1072	35	17		100		200	75	15		365	
Ringneck								297	30	700		100		400		125	
Goldeneye	10	10	tr	9	50	22	1182		4	200	tr	tr	28	3	35	10	24
Bufflehead	35	45	tr	14	40	215	353	149	235	300	100	200	128	53	33	37	173
Ruddy Duck		300	200	100		100	162	100	103			100	20	5			
Total Divers	225	1145	1100	843	190	2972	2963	2253	1786	2900	2900	1800	1935	1225	68	1864	347
Scoter				23		89		38	29	300	tr			31		1	
Oldsquaw				73	150	12	5	50	163	300	100		71	7	16		
Total Seaducks				96	150	101	5	88	192	600	100		71	38	16	1	
Merganser		2	tr		100	19	10	3	71	800	200	200	125	6	44		19
TOTAL DUCKS	230	2517	1400	1000	470	3414	9460	3054	2644	6500	3800	3200	2523	1503	341	2610	557
Brant										800		200					
Snow Goose												200					
Canada Goose		400				249	114	363	309	300	100	1900	700	225	337	1736	2500
TOTAL GEESE		400				249	114	363	309	1100	100	2300	700	225	337	1736	2500
Whistling Swan												tr			2		
Coot							100				100				500		
GRAND TOTAL	230	2917	1400	1000	470	3663	9674	3417	2953	7600	4000	5500	3220	1728	1180	4346	3057

*tr = trace

Table 8. (continued)

Common Name	Scientific Name
Mallard	Anas platyrhynchos
Black Duck	Anas rubripes
Gadwall	Anas strepera
Widgeon, American	Mareca americana
Green Winged Teal	Anas carolinensis
Shoveler	Spatula clypeata
Pintail	Anas acuta
Wood Duck	Aix sponsa
Red Head	Aythya americana
Canvas Back	Aythya valisineria
Scaup	Aythya marila and affinis
Ringneck Duck	Aythya collaris
Goldeneye, Common	Bucephala clangula
Bufflehead	Bucephala albeola
Ruddy Duck	Oxyrua jamaicensis
Scoter	Oidemia nigra and Melanitta spp.
Merganser, Red-Breasted	Mergus serrator
Brant	Branta bernicla
Snow Goose	Chen hyperborea
Canada Goose	Branta canadensis
Whistling Swan (or Tundra Swan)	Olor columbianus
Coot, American	Fulica americana

(Arctic) is listed as threatened, are commonly found in the vicinity of Craney Island. Davis (1988) indicates that the concentrations of waterfowl and shorebirds within the Craney Island Disposal Area and to the west of the site provide an extensive prey base for peregrine falcons. The open expanse of the disposal area and adjacent area in Hampton Roads is required for the peregrine's foraging strategy. Davis questioned ornithologists who regularly observed birds at Craney Island over a number of years. These ornithologists indicated that the Craney Island area is an important wintering and fall migratory stop for peregrines, acting as an "ecological magnet" for the birds. Recently, peregrine falcons have nested at a site on the James River approximately 22 miles upriver from Craney Island. Davis states that the Craney Island area may, therefore, be used by both resident and migrant falcons throughout the year.

The Chesapeake Bay is also a foraging area for five species of sea turtles. The loggerhead (Caretta) and the green (Chelonia mydas) turtles are listed as threatened, while the hawksbill (Eretomchelys imbricata), leatherback (Dermochelys coriacea), and the Kemp's ridley (Lepidochelys kempii) turtles are listed as endangered. The Kemp's ridley is the world's most endangered species and is near extinction. All of these species are primarily oceanic but do forage within the Chesapeake Bay during the summer. The hawksbill and green turtles are infrequent in the Chesapeake Bay. The leatherback turtle is regularly found in the lower Bay during the summer but in low numbers. Both juvenile loggerhead and Kemp's ridley are found in large numbers in the lower Bay. The Virginia Institute of Marine Science has conducted turtle surveys since 1979 in the Bay and estimates that up to 10,000 juvenile loggerheads and 500 to 700 Kemp's ridleys regularly use the Chesapeake Bay in the summer (Brown and Savitzky 1984), making the Bay an important nursery ground for these two species. The turtles have been observed to forage primarily within the Chesapeake Bay proper, only moving a short distance up into the mouths of the Bay's major tributaries, including the James (Musick et al. 1984). Loggerheads forage for benthic species, primarily horseshoe crabs and other shelled invertebrates, within the channels. Atlantic ridleys forage primarily in shallow areas and seagrass beds, feeding heavily on blue crabs. However, Musick et al. (1984) acknowledge there is limited information on the use of the major tributaries by either the loggerhead or the Kemp's ridley. It is probable, therefore, that both species of turtles could occur within the Hampton Roads area.

The shortnose sturgeon (Acipenser brevirostrum) is an endangered species that historically occurred in the Chesapeake Bay. There have been no recent documented records of this species in the Bay, however it could potentially occur within the James River and other tributaries in extremely limited numbers.

IV. HISTORIC CHANGES IN AQUATIC HABITAT IN THE LOWER JAMES RIVER ESTUARY

The Hampton Roads and Elizabeth River area has undergone significant shoreline and channel modifications for over 200 years as the port facilities and surrounding cities have developed. Nichols and Howard-Strobel (1986) provide an excellent summary of the man-induced changes in the Elizabeth River since the 1700s. Much of the following discussion is based on their information.

While some filling of low lying areas in Hampton Roads began after the arrival of the colonists in the 1600s to 1700s, large scale filling of wetlands, creeks, and shoreline areas started in the late 1800s. Many creek systems were totally filled in for either storm sewer systems or to create additional upland. Major fills have occurred between Sewells Point and Tanners Point along the Norfolk shoreline of Hampton Roads and in Willoughby Bay. Eckles (U.S. Fish and Wildlife Service, as cited in Va. Dept. of Highways and Transportation 1985) estimates that the U.S. Navy has filled in over 700 acres in Hampton Roads and Willoughby Bay, including the entire Brush Creek system and a large portion of the Mason Creek system. There has also been extensive filling along the Eastern and Southern Branches of the Elizabeth River for port and commercial facilities. Extensive fills have taken place along the Newport News shoreline for terminal loading facilities and the Newport News Shipyard. For example, the Newport News Shipyard and Drydock facility has been granted permits since 1972 to fill approximately 300 acres of the James River. Other fills have resulted from the construction of the islands for the I-64 and I-664 tunnels. The existing Craney Island Disposal Area filled in approximately 2500 acres of Hampton Roads.

Nichols and Howard-Strobel (1986) indicate that the Elizabeth River system itself has had a 27 percent reduction in open water area (which includes wetlands and intertidal areas) since the late 1800s. Their study did not, however, include the Hampton Roads and Newport News shorelines. Therefore, for this report, the U.S. Coast and Geodetic Survey charts for Hampton Roads and the Elizabeth River from the 1909-1913 period were compared with charts from 1983 to determine changes in open water area. Boundaries of the area included in this comparison were the mouth of Hampton Roads, the western boundary of Coast Chart 12245 (approximately the U.S. Route 17 Bridge), the Norfolk and Western Railroad bridge over the Eastern Branch of the Elizabeth River, and the Southern Branch of the Elizabeth River downstream of New Mill Creek. Some small creek systems were excluded in the analysis, as were the Western Branch of the Elizabeth, Lafayette River, and the Hampton River. The islands of the I-64 and I-664 tunnels were also excluded. Acreage figures for aquatic habitat below the mean high water shoreline from the Coast Charts from the two time periods were determined using a Numonics digital planimeter with a resolution of 0.005 inches.

The results of the comparison of the Coast Charts from 1909-1913 and 1983 indicate there has been a net loss of at least 4600 acres (since some areas were not planimetered) of aquatic habitat in the lower James River/Hampton Roads/Elizabeth River over this period. This is an

approximately 13 percent decrease. A larger overall habitat loss would have been seen if maps from the 1800s and all creek systems in the area and the tunnel fills had been used in the analysis.

Nichols and Howard-Strobel (1986) also indicate that significant deepening of the channels of the port started in the late 1800s. The Norfolk Harbor Reach and Elizabeth River channels have been deepened from an average natural depth of about 20 feet to between 35 and 45 feet. The Newport News Channel has been deepened from natural depths between 20 and 30 feet to 45 feet, although there are some naturally occurring areas of up to 70 feet in depth. Nichols and Howard-Strobel state that the channels of the Elizabeth River now comprise approximately 25 percent of the original river area and have resulted in a 50 percent increase in the volume of the river. Dredging projects to create and expand shipyards, port facilities, and anchorages and to obtain borrow material have deepened other areas, as well. Large-scale borrow areas for the construction of the I-64 tunnel islands were located in the vicinity of Hampton Flats and Willoughby Banks. Access channels have been dredged for the I-664 tunnel.

The various deepening projects have resulted in changes in sedimentation rates and hydrodynamics. Nichols and Howard-Strobel have found a direct correlation between increasing channel depths and the frequency of maintenance dredging. Sedimentation rates in the Elizabeth River have increased by 1000 to 10,000 percent over natural sedimentation rates. The largest sedimentation rate is found in the Norfolk Harbor Reach, which receives sediments from both incoming flow from the Chesapeake Bay and outgoing flow from the James River. Nichols and Howard-Strobel estimate that, based on the correlation between channel depth and maintenance dredging frequency, the current deepening of the harbor channels to between 40 and 55 feet will result in a 50 percent increase in the future frequency of maintenance dredging. This will also increase the volume of dredged material that will have to be disposed.

Hydrodynamic changes have not been well studied but are evident. Nichols and Howard-Strobel state that 24 percent of the tidal prism of the Elizabeth River has been lost as a result of filling, and that tidal currents at the mouth of the river have been reduced by 17 percent. Salinity values have also probably increased from historic levels. These changes have likely contributed to the low flushing rates in the Elizabeth. While such changes have exacerbated the poor water quality of the Southern Branch, they have also contained the high loading of contaminants within the Southern Branch.

Fang (1975) states that hydrodynamic studies between the 1950s and 1960s showed an increase from 24 percent to 36 percent in the volume of flow in the natural channel to the south of the Newport News Middle Ground and a decrease from 27 percent to 18 percent in the volume of flow over the shallows in the area. This change resulted from the construction of the Craney Island Disposal Area, which shifted flows northward into Hampton Roads.

Richards and Morton (1983) in a model study of the deepening of the port channels, showed that there would be a decrease in velocities within the

Elizabeth River. Salinities in the Elizabeth River and Hampton Roads will increase by up to 4 parts per thousand in some areas.

There has been a long history of open water disposal within Hampton Roads and the lower Chesapeake Bay. Nichols and Howard-Strobel report that during the 1800s most dredged material was placed overboard adjacent to dredged areas, in deep holes, and in the vicinity of Craney Island and the mouth of the Lafayette River, or used to fill in low lying areas of the port's cities. Beginning in the late 1800s and early 1900s most dredged material was placed in the Chesapeake Bay north of Willoughby Spit and in the vicinity of Lynnhaven Roads. During the 1940s and 1950s, deep water areas at the mouth of Hampton Roads were the major disposal sites. Since the construction of the Craney Island Disposal Area in the mid-1950s, dredged material from the port has been placed in this facility or other contained private disposal sites.

Over the past few years there have been other plans or actual projects to fill in additional areas of the port. For example, the U.S. Navy had plans to fill in up to 45 acres in Willoughby Bay and the City of Newport News planned to fill in approximately 300 acres on Hampton Flats for a new port facility. There have been several smaller projects at the various ship terminal facilities throughout the port that have filled aquatic habitat. The Commonwealth of Virginia has also discussed the feasibility of dredging areas within the lower Chesapeake Bay as a source of construction or beach grade sand and for oyster shell.

While the impacts of the loss of aquatic habitat and physical changes in the Hampton Roads and Elizabeth River subestuaries would be difficult to quantify, it is apparent that these cumulative changes have been significant. Many of the areas that have been filled or dredged within the port were wetlands and shallow water habitat, two of the most important aquatic habitat types. As a result, there has been a loss of foraging and nursery habitat for the many finfish and benthic species, including such commercially important species as striped bass, shad, herring, blue crabs, oysters, and clams as well as waterfowl and shorebirds. The dredging of deep channels and borrow areas and the increased sedimentation by fine grained and contaminated sediments has created bottom areas that have lower water quality and that are inhabited by a less diverse assemblage of benthic species that are tolerant of polluted conditions.

It is clear that an historical perspective of the loss of and change in aquatic habitat in the lower James River and Elizabeth River estuaries is necessary to make management decisions that will result in additional habitat losses, such as the expansion of the Craney Island Disposal Area. Since 1983 the Federal government, Chesapeake Bay Commission and the states of Virginia, Maryland, Pennsylvania, and the District of Columbia have joined in formal cooperative agreements to restore and maintain the water quality and fish and wildlife resources of the Chesapeake Bay. The "1987 Chesapeake Bay Agreement" states that one of the goals of agreement is to "Provide for the restoration and protection of the living resources, their habitats, and ecological relationships." Two of the objectives of this goal are to "Protect, enhance, and restore wetlands, coastal sand dunes,

forest buffers and other shoreline and riverine systems, important to water quality and habitat" and "Restore, enhance and protect waterfowl and wildlife." The filling of an additional 2500 acres of aquatic habitat of value to finfish, shellfish, waterfowl, and shorebirds for a disposal area would appear to be inconsistent with the goals and objectives of the Bay Agreement, unless it is shown to be the least damaging practicable alternative and the impacts of the project are fully mitigated.

V. PROJECT IMPACTS

The following discussion focuses on the impacts associated with the expansion of the Craney Island Disposal Area. Figure 6 shows the six alternatives under consideration for the expansion of Craney Island. Impacts associated with the Norfolk Ocean Disposal Site and the Dam Neck Ocean Disposal Site can be found in USACE (1982) and USACE (1985), respectively. A brief synopsis of the impacts associated with ocean disposal will be included in this report. In addition, Appendix A contains the previous report of the Fish and Wildlife Service on the Dam Neck Ocean Disposal Site.

Habitat Losses

Table 9 indicates the approximate amount of aquatic habitat that would be filled by the various alternatives for the expansion of the Craney Island Disposal Area. Plan B, which is the alternative with the largest habitat loss, would result in the loss of approximately 2450 acres -- 1 acre of intertidal wetlands dominated by saltmarsh cordgrass (*Spartina alterniflora*), 42 acres of intertidal flats, 356 acres of shallow water habitat (defined as areas with a depth of 0 to 2 feet at mean low water), and 1692 acres of deep water habitat (defined as areas with a depth greater than 2 feet at mean low water). Plan A would result in the loss of a total of approximately 1698 acres, Plan C in 766 acres, Plan D in 688 acres, Plan E in 1436 acres, and Plan F in 1005 acres. Plans involving the westward expansion of Craney Island (Plans A, B, D, E, and F) will result in the loss of aquatic habitat that is generally shallower than ten feet at mean low water.

As indicated in the previous section, losses of aquatic habitat within the lower James River and Elizabeth River estuaries over the past two hundred years have primarily been associated with wetlands and shallow water, while there has been an increase in the amount of habitat over twenty feet in depth. The filling of 2450 acres under Plan B would result in an almost 8 percent further decrease in the amount of aquatic habitat in Hampton Roads proper. Based on the historical losses of aquatic habitat in Hampton Roads, this additional filling would result in a total loss of 7040 acres, an approximately 19 percent decrease in the aquatic habitat in Hampton Roads proper since the early 1900s.

The loss of between approximately 688 and 2450 acres of aquatic habitat, generally less than ten feet in depth, will result in the loss of benthic habitat that is used for foraging and as nursery areas by a number of commercially and ecologically important finfish species. While the impacts of this habitat loss on finfish populations can not be quantified, the cumulative losses associated with a 19 percent reduction in wetlands and shallow aquatic habitat over the past century have undoubtedly reduced the productivity of the Hampton Roads area.

Avifauna

The expansion of Craney Island will also lead to a long-term decline in the availability of foraging and resting habitat for waterfowl and shorebird

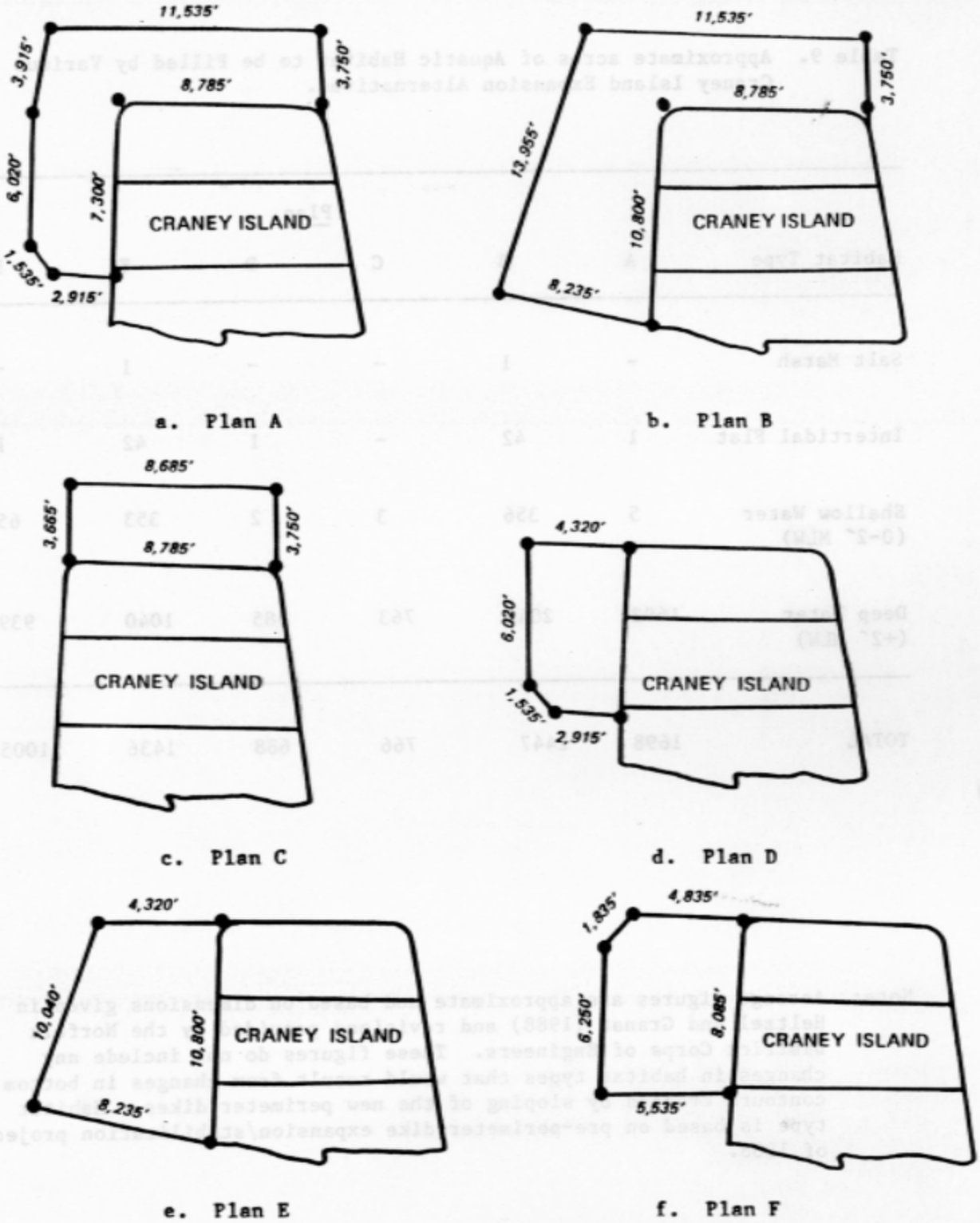

Figure 6. Craney Island Disposal Area Expansion Alternatives. (Source: Heltzel and Granat 1988)

Table 9. Approximate acres of Aquatic Habitat to be Filled by Various Craney Island Expansion Alternatives.

Habitat Type	Plan A	B	C	D	E	F
Salt Marsh	-	1	-	-	1	-
Intertidal Flat	1	42	-	1	42	1
Shallow Water (0-2′ MLW)	5	356	3	2	353	65
Deep Water (+2′ MLW)	1692	2048	763	685	1040	939
TOTAL	1698	2447	766	688	1436	1005

Note: Acreage figures are approximate and based on dimensions given in Heltzel and Granat (1988) and revisions provided by the Norfolk District Corps of Engineers. These figures do not include any changes in habitat types that would result from changes in bottom contours created by sloping of the new perimeter dikes. Habitat type is based on pre-perimeter dike expansion/stabilization project of 1988.

species. Currently, the Craney Island Disposal Area and the area of Hampton Roads between the disposal area and the Nansemond River provides one of the most extensive and best areas within the lower James River estuary for foraging and resting for these groups of birds. As stated above, Craney Island is recognized for its high use by avifauna, and in fact, may receive higher bird use now than did the original open water area it replaced due to its concentration of food sources and safe habitat for waterfowl and shorebirds. However, assuming that the existing disposal site is filled to capacity and converted to some type of industrial or commercial use, there will be an eventual loss of this 2500 acre site as suitable habitat for birds. The expansion of the disposal site may enhance the productivity of that area as avian habitat during the time frame that it is actively receiving dredged material, but at the end of its life expectancy (up to 50 years depending on its size), the expanded area will also likely be converted to industrial/commercial use. Thus, there will be a long-term net loss of up to 4950 acres of high quality avian habitat in the Hampton Roads area as a result of the existing and proposed Craney Island disposal projects.

On January 23, 1989 the Corps of Engineers and the Fish and Wildlife Service entered into a Cooperative Agreement regarding the North American Waterfowl Management Plan. In 1986 the Secretary of the Interior and the Canadian Minister of the Environment signed this Waterfowl Management Plan (Canadian Wildlife Service and U.S. Fish and Wildlife Service 1986), which provides a framework for waterfowl conservation and management through established goals for waterfowl population numbers and habitat protection. The Management Plan was based on the recognition by the two countries that waterfowl, the most economically important group of migratory birds in North America, have undergone drastic population declines primarily due to losses of nesting, migratory, and wintering habitat. The Cooperative Agreement between the Corps and the Fish and Wildlife Service states that the two agencies will use their authorities to further the goals of the North American Waterfowl Management Plan.

One of the overall goals of the Waterfowl Management Plan is to maintain the current distribution of waterfowl populations and to "maintain the habitat value of designated areas of international significance to waterfowl." As part of the specific goals and recommendations for waterfowl habitat included in the Plan is the recommendation that "Public works projects planning should include the prevention or mitigation of destruction or degradation of waterfowl habitats."

The entire Chesapeake Bay basin east of the fall line has been included in Area 20 (Middle-Upper Atlantic Coast) of waterfowl habitat areas of major international concern. The net loss of up to 4950 acres of waterfowl habitat from the long-term conversion of Craney Island and its expansion from open water to upland would be inconsistent with the goals of the North American Waterfowl Management Plan.

Commercial Resources

Expansion of Craney Island to the west would result in the loss of an area used by watermen to harvest finfish, blue crabs, and hard clams. The

expansion of Craney Island to the west and/or north will eliminate all of the Virginia public oyster ground known as Norfolk County Public Ground Number 1, except for that portion of the ground to the east of Craney Island. Although this oyster ground is currently unproductive for oysters, its loss would preclude the reestablishment of oysters in this area if disease resistant oysters are developed in the future.

Endangered Species

Of the threatened and endangered species that may be found in the Hampton Roads area, the bald eagle, shortnose sturgeon, and the loggerhead, green, hawksbill, leatherback and Kemp's ridley turtles are all considered transients and should not be affected by any of the alternatives involving the expansion of Craney Island.

The peregrine falcon is known to consistently forage in the vicinity of Craney Island due to the concentration of its major prey base, waterfowl and shorebirds, in this area. As described under "Habitat Losses" the expansion of the disposal site and the long-term conversion of up to 4950 acres of aquatic habitat to upland will result in the eventual loss of the major foraging area of the peregrine falcon in Hampton Roads. In addition, one pair of piping plovers nested for the first time in Hampton Roads in recent history at the Craney Island facility in 1989. A full assessment of the extent of the impacts of the expansion of Craney Island on the piping plover and the peregrine falcon would be required under Section 7(a)(2) of the Endangered Species Act. Section 7(a)(1) of the Act requires that Federal agencies "shall . . . utilize their authorities in furtherance of the purposes of this act by carrying out programs for the conservation of endangered species. . . ."

Recreational Resources

Westward expansion of Craney Island would result in the loss of an area used by recreational boaters. This would eliminate one of the few protected areas in Hampton Roads that recreational fishermen can use. Most other areas, with the exception of Hampton Flats, Willoughby Bay, and the south side of the lower James River cannot be safely used by recreational boaters due to conflicts with commercial channels and anchorages.

Water Quality

Dredged material disposed in the expanded Craney Island will include some materials containing high levels of contaminants such as heavy metals and polynuclear aromatic hydrocarbons. These contaminated materials will come primarily from the Southern Branch of the Elizabeth River. Recent studies (Virginia State Water Control Board 1983 and Alden et al. 1988) have shown that levels of nutrients and heavy metals in the waters of the Southern

Branch have declined since the 1970s, which may indicate that levels of these substances may also be decreasing in the sediments. However, levels of organic contaminants in the sediments of the Southern Branch, particularly polynuclear aromatic hydrocarbons, remain among the highest found to date in the world. It is assumed that, over time, with the current emphasis of the Virginia State Water Control Board on improving the water quality of the Elizabeth, the level of organic contaminants within dredged material from the Elizabeth will also decline.

There have been no recent, thorough evaluations of the levels of contaminants in the effluent from Craney Island or the sediments to the west of the disposal area, nor of any biological effects. However, in a study of the contaminant levels and toxicities of material within the Craney Island Disposal Area, Alden et al. (1984a) found generally low toxicities or bioaccumulation of heavy metals and polynuclear aromatic hydrocarbons. No chlorinated hydrocarbons were found within Craney Island during this study. However, Alden et al.'s study did show that the highest levels of both metals and organic contaminants were associated with fine grained sediments. Alden and Crouch (1984) and Alden et al. (1984b), in a study of sediments from the Norfolk Harbor navigation channels, have also found that the highest mortalities and chronic effects from contaminated dredged material are associated with the suspended solid phase. There is a possibility, therefore, that if significant amounts of suspended material are leaving the Craney Island Disposal Area through its effluent, there could be proportionately higher levels of contaminants leaving as well. Palermo et al. (1981) indicate that over 90 percent of the suspended material is retained within Craney Island. However, Adams and Young (1975) found total suspended solid levels in the effluent from Craney Island to vary between 60 to 3599 milligrams per liter (mg/l), with an annual mean of 237 mg/l (standard deviation of 356 mg/l). In a follow-up study, Adams and Park (1976) found that there was a statistically significant difference between the effluent from Craney Island and a control station for total Kjeldahl nitrogen, total phosphorus, total suspended solids, particulate organic carbon, dissolved organic carbon, ammonia, nitrite, pH, chlorophyll-a, fecal coliform, and dissolved inorganic orthophosphate. While there were no definite trends in heavy metals, high concentrations of particulate mercury, zinc, chromium, and copper were found in the effluent. All parameters returned to background levels within 160 meters (0.1 mile) of the discharge point. It should be noted that this study monitored the spillway that was furthest away from the input of dredged material at the time and the study did not monitor organic compounds.

A comparison of navigation charts from the late 1800s and early 1900s to current charts indicates that the surface sediments to the west of the Craney Island Disposal Area have probably changed as a result of the disposal site from fine sands and mixed sediments to predominately muddy sediments. The Corps' modeling study of the expansion of Craney Island (Heltzel and Granat 1988) has indicated there will be a small increase in sedimentation in the vicinity of the mouth of the Nansemond River under Plans D, E, and F. The combined effects of increased sedimentation from the effluent from Craney Island and from changes in circulation patterns

could result in some impacts to the oyster beds within the lower Nansemond River and on the Nansemond Ridge. Heltzel and Granat (1988) state that under Plans A, D, or F there could be a reduction in water quality in the shallow area between the expanded disposal area and the natural shoreline due to a reduction in circulation. This could result in a decrease in aquatic productivity and aesthetic impacts on the nearby residents of the River Shore area.

With present information, definitive statements about the effect of the expansion of Craney Island on water quality, contaminant levels, and sedimentation can not be made. It appears that there could be subtle changes in bottom type and sediment contaminant levels in the vicinity of the mouth of the Nansemond River, including oyster grounds, under the alternatives that involve expansion to the west. Based on the results of bioassessment studies of the material within Craney Island, however, it is probable that there will be little increase in toxicity of the sediments outside of the disposal area. Synergistic effects of the Craney Island outfall and the outfall of the Nansemond Sewage Treatment Plant, located at Pig Point, have not been evaluated. Such impacts are assumed to be minor and could only be assessed through long term bioassessment monitoring of the sediments.

Physical Impacts

The Corps of Engineers conducted a two-dimensional finite element numerical model study to evaluate the impacts of the various Craney Island expansion alternatives on circulation and sedimentation (Heltzel and Granat 1988). The numerical model vertically integrates salinity and current velocities to produce an "average" value for these parameters at the test nodes. The model results indicate there will be some changes in current velocities and sedimentation rates as a result of the expansion of Craney Island. The only area with significant base to plan condition differences in current velocities is in the vicinity of the Newport News Channel. The most significant changes in current velocities occur under Plans A and B, where up to a 16 percent increase in velocities will occur in the vicinity of the Newport News Channel. The maximum changes under Plan A and B would be an increase of 0.35 feet per second (fps) at maximum ebb tide and 0.25 fps at maximum flood tide. Plan C shows a velocity increase of up to 9 percent within the Newport News Channel. Plans D, E, and F show up to a 4 percent velocity increase within the Newport News Channel; however, the Corps report indicates that this change could be the result of a shift in the tidal cycle.

Increased velocities in the area between Newport News Point and Craney Island could result in increased scouring in the Newport News Middle Ground. This is an important commercial clamming and crabbing area and bottom scouring could reduce the suitability of the Middle Ground as habitat for these species.

The Corps report also analyzed the circulation patterns within the Hampton Roads area through the use of vertically integrated velocity vectors under base and plan conditions. Changes in circulation patterns, while subtle,

were seen in the areas of the thalweg of the Newport News Channel, the Newport News Middle Ground, and to the northwest of Craney Island. A visual comparison of the velocity vectors in the Corps report indicates that Plans A, B, and C, those with a northward extension of Craney Island, would have the greatest effect on circulation patterns in Hampton Roads. Plans D, E, and F, those with only westward extension, would have the least effect on circulation.

Potential sedimentation changes were also addressed in the Corps study. Four areas of ecological concern--Willoughby Bay, Hampton Flats, Burwell Bay, and the mouth of the Nansemond River--were evaluated to determine whether the expansion of Craney Island would result in changes in sedimentation rates associated with changes in circulation patterns. Of the four areas examined, only the mouth of the Nansemond River showed a distinct difference in base to plan sedimentation rates. Plans D, E, and F, which involve westward expansions of Craney Island, resulted in a small increase in sedimentation in the Nansemond area. Plan F resulted in the largest increase of 7 percent from base to plan. The second largest increase was 4 percent for Plan D. Boland (1972) indicates that shoaling rate changes of less than 10 percent are generally insignificant. This statement was confirmed by Byrne (1989).

While the Corps study provides some indication of the types of hydrodynamic impacts the expansion of Craney Island will have on the Hampton Roads area, a thorough evaluation of the extent of these impacts cannot be obtained from the two-dimensional model study. There are several areas of concern that require further analysis.

Of primary concern is the extent of the changes in circulation patterns and current velocities within Hampton Roads. Estuarine circulation is of concern because such processes transport organisms, sediments, and contaminants. Of particular importance is the effect of circulation on the distribution of larval forms that are not free swimming and thus depend on currents for their transport to suitable habitat. Based on a number of model studies (Fang 1975, Chen 1978, Byrne et al. 1987, and Heltzel and Granat 1988) the general circulation pattern for Hampton Roads is known. On a flood tide, water from the Chesapeake Bay generally enters Hampton Roads across Hampton Flats and through the Newport News Channel into the James River, with a lesser amount flowing into the Elizabeth River. On an ebb tide, water generally flows out of the James River through both the Newport News Channel and the area to the south of the Newport News Middle Ground, joining with the water flowing out of the Elizabeth River along the Norfolk Reach channel. The geometry of Hampton Roads results in differences in tidal phasing that set up circulation cells and a strong frontal system off of Newport News Point. Based on the work of Byrne et al. (1987) it is known that this frontal system is critical to the maintenance of planktonic oyster larvae within Hampton Roads and the lower James River estuary. Salinity is also a major factor in these circulation patterns in that higher salinities are found at deeper depths, which sets up density differentials. The fact that the Corps' two-dimensional model was vertically integrated for salinity means that these salinity induced

density gradients could not be evaluated. Changes in the frontal system off Newport News could affect the retention of oyster larvae in the James River system. However, Heltzel and Granat (1988) indicate that such impacts cannot be quantified using the present modeling method and state that "alternatives with northward Craney Island expansion will have the greatest potential to affect the three-dimensional circulation process."

An expansion of Craney Island to the north could also result in a shift and increase in ebb flow into Hampton Roads along the Norfolk Reach channel area. Potential results could be an increase in the volume of water that enters the Chesapeake Bay from Hampton Roads and a decrease in the water exchange in the Elizabeth River. Flushing within the Elizabeth River is already low and Berger et al. (1985) found that the present and proposed deepening of the Elizabeth River channels would increase the sedimentation rate in the river by 23 percent.

The impacts of increased velocity within the Newport News Channel on ship navigation have not been addressed. This is an important question, not only from the standpoint of human safety, but also from the standpoint of whether there will be an increased likelihood of oil spills if the chances for navigational difficulties increase.

Man's activities within the Hampton Roads area over the past century have resulted in significant physical changes in the geometry of the area. The construction of the U.S. Route 17 bridge, the I-64 and I-664 bridge-tunnels, Craney Island Disposal Area, major channel deepening projects, and major fill projects along the Newport News and Norfolk shorelines have radically altered the subestuary's natural size and bathymetry. A number of modelling studies (Boland 1972, Nichols 1972, Fang 1979, Richards and Morton 1983, Heltzel 1988, and Heltzel and Granat 1988) have all indicated some change in salinities, current velocities, and circulation from these various activities. In each study, impacts have generally been considered subtle or insignificant. However, there has been no extensive, thorough evaluation of the cumulative impacts of these man-induced changes. The Corps is also considering deepening the Newport News Channel to approximately 70 feet to obtain borrow material for the expansion of Craney Island. Unless a three-dimensional model study is conducted to analyze the impacts of the expansion of Craney Island and the deepening of the Newport News Channel, the extent and significance of changes in circulation patterns and current velocities within the lower James River, Hampton Roads, and Elizabeth River cannot be adequately assessed.

Construction

During construction of the perimeter dikes for the expansion of Craney Island, there will be large increases in sedimentation and turbidity in the surrounding area. Such increases will be difficult to control since turbidity curtains may not be effective in the dynamic wave environment of Hampton Roads. High turbidity levels could result in subtle changes in primary productivity, dissolved oxygen, nutrient levels, and effects on benthic organisms and larval forms, including oyster and clam larvae. These impacts are impossible to quantify and are not expected to result in

long term effects on the biota of this area. Mitigation measures could be implemented to minimize impacts and will be discussed under the section on mitigation.

Operation

Associated with the Craney Island Disposal Area is an open water rehandling basin that is located adjacent to the southeast side of the facility. According to Huggett (1989), this rehandling basin may be the only or one of only a few open water disposal facilities of its kind in use in the United States. Since the discovery of extremely high levels of polynuclear aromatic hydrocarbons (PAHs) in the Elizabeth River during the early 1980s, questions have been raised as to whether the disposal of dredged material containing these contaminants into the rehandling basin results in the release of PAHs into the water column and the downstream areas of the Elizabeth River and Hampton Roads. Although there have been some studies of the rehandling basin (Adams and Park 1976, Bender et al. 1984), results of these studies have been inconclusive as to whether liquid phases of PAHs are released from the rehandling basin. It appears, however, that most sediments are retained within the rehandling basin. Further study is needed to address this issue.

Impacts Associated with Ocean Disposal

As previously mentioned, the effects of ocean disposal have been generally addressed in previous Corps environmental documents on the Norfolk Ocean Disposal Site and the Dam Neck Ocean Disposal Site. Studies have shown that most of the dredged material from the port's channels meets ocean disposal criteria, with the exception of material from portions of the main stem of the Elizabeth River and its Southern Branch. Contaminated dredge material could not be disposed of in the ocean.

Most impacts of the ocean disposal of dredged material are associated with the effects of the release of the dredged material into the water column and bottom as related to the biota, water quality, hydrodynamics, and sediment stability. The release of dredged material generally results in increased levels of turbidity within the water column of the disposal site. Associated with the dredged material are varying levels of nutrients, toxics, and organic materials that can reduce dissolved oxygen levels and increase toxicity to sensitive organisms. Larval stages may experience increased mortalities from the effects of high suspended solids, low oxygen, and contaminants; however, adult forms, particularly finfish, can usually tolerate or avoid the areas of high suspended material. As dredged material settles to the bottom, the benthic community is usually smothered. Although benthic communities generally recover from infrequent perturbations, the consistent placement of dredged material in an area would result in a decrease or potential loss of the area as suitable habitat for the original benthic community. This could result in a loss of foraging habitat for bottom feeding fish and epibenthic crustaceans and molluscs.

Ocean disposal of dredged material can also affect hydrodynamic patterns of an area if there are significant changes in bottom topography. Sediments can move out of the disposal area into adjacent areas if current and wave patterns and strengths are sufficient to move the deposited dredged material.

Although the Dam Neck Ocean Disposal Site has received authorization for the disposal of dredged material from the deepening and maintenance of the Norfolk Harbor Channels, the site was approved over the objections of a number of state and Federal agencies, including the Fish and Wildlife Service, as well as private groups. Appendix A is the Service's previous Fish and Wildlife Coordination Act report on the Dam Neck Disposal Site. The issues of concern raised by the Service in 1985 have not been addressed. In summary of our previous report, questions regarding the impacts of the use of Dam Neck on finfish migration, blue crab spawning grounds, water quality, hydrodynamics, and shoreline stability remain unanswered. Without further study of the site the extent of these potential impacts are unknown.

The Norfolk Ocean Disposal Site has undergone extensive studies, most of which have confirmed that there should minimal biological, chemical, or physical effects from the placement of dredged material at this site. The major issue of concern regarding the site is its location within the blue crab spawning grounds for the Chesapeake Bay population of this species. There could be some mortality of blue crab larvae from the disposal of dredged material at the site; however, the significance of this mortality can not be quantified. Considering the large size of the blue crab's spawning zone, and the patchiness of the distribution of the larvae over a spawning season, it is likely that the impacts to overall population numbers of this species will be minimal.

Recent surveys by the Fish and Wildlife Service, the National Marine Fisheries Service, and the State of North Carolina, have identified a wintering and migratory corridor for striped bass off the coasts of Virginia and North Carolina. Although no surveys were conducted within the area of the proposed Norfolk Ocean Disposal Site, concentrations of striped bass were found further to the south of the site in areas of approximately the same water depth. Inshore concentrations of striped bass were also found in North Carolina. Wooley (1989) indicates that concentrations of this species probably vary in location throughout this area depending on the time of year and water temperatures. Further surveys are anticipated to determine whether there are readily identifiable and consistent concentration areas off the coast of Virginia.

The confirmation of the expected use of the nearshore continental shelf of Virginia by striped bass, a species undergoing intensive management due to recent extremely low population numbers, raises questions about potential effects of ocean disposal on this species. As the Service has previously stated with respect to the Dam Neck site, disposal of material in this location could result in interference with the ability of striped bass, and other finfish as well, to migrate into the Chesapeake Bay. The mechanisms fish use to find their spawning grounds are incompletely known but it is

likely that subtle sensory cues play a part. The disposal of dredged material from the Hampton Roads area, while suitable for ocean disposal, will still contain low levels of contaminants. It is possible that long term subtle changes in the water quality of the Dam Neck area could adversely effect finfish migration into the Chesapeake Bay. Such impacts are not considered of significance at the Norfolk Ocean Disposal Site, because of the relatively small size of the disposal area in relation to the wide area that finfish use to migrate up and down the Atlantic coast, and the greater mixing area that would minimize the concentration of low levels of contaminants.

VI. OPTIONS FOR MITIGATION

The U.S. Fish and Wildlife Service, in its Mitigation Policy (FR Vol. 46, No. 15, January 23, 1981, pg. 7644-7663), adopted the definition of mitigation found in the regulations implementing the National Environmental Policy Act (140 CFR 1508.20 (a-e)). The elements of mitigation include:

(a) avoiding the impact altogether by not taking a certain action or parts of an action;

(b) minimizing impacts by limiting the degree or magnitude of the action and its implementation;

(c) rectifying the impact by repairing, rehabilitating, or restoring the affected environment;

(d) reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action; and

(e) compensating for the impact by replacing or providing substitute resources or environments.

The Service considers these aspects of mitigation to be sequential steps, that is, avoidance is the preferred type of mitigation, proceeding through the other elements, with compensation as the last step of the mitigation process.

Under its Mitigation Policy, the Fish and Wildlife Service evaluates the type and importance of fish and wildlife habitats in developing mitigation recommendations. The basis of this policy is that habitat types that are of higher value to important resources and/or that are declining should receive a higher level of protection.

The Service places the estuarine intertidal marsh, intertidal flats, and shallow water areas less than 2 feet in depth at mean low water within the project area of Hampton Roads in Resource Category 2 under our Mitigation Policy, defined as habitats that are of high resource value that are scarce or becoming scarce on a national or ecoregion basis. The Service's goal for Resource Category 2 habitats is no net loss of in kind habitat value.

The variety of functional values served by intertidal wetlands are well documented in the literature and are highlighted by the Chesapeake Executive Council's (1988) "Chesapeake Bay Wetlands Policy," which states that:

> "The Policy establishes an immediate goal of no net loss with a long-term goal of a 'net resource gain.' The gain of wetland acreage and function over present day conditions serves as a means of recovering the values of wetlands already lost over years of inadequate protection. These values include not only traditional habitat values for breeding, spawning, nesting and wintering of living resources but also benefits in water quality, flood protection, and the regional economy."

Intertidal flats and shallow water areas are also extremely valuable components of the estuarine system. We have defined "shallow water habitat" as areas less than 2 feet in depth at mean low water (MLW). Recognizing that there is no standard definition of "shallow water," we have chosen a definition based upon the depth at which wading birds, such as herons and egrets, are able to forage because of the dependence of these sensitive species on this habitat type as a food source.

Although the proportion of the estuary's total primary productivity that occurs on tidal flats is small relative to that of vegetated tidal wetlands or the photic zone of the water column, tidal flats increase the productivity of the water column by providing a substrate for photosynthetic activity, maintain ecosystem productivity by rapidly recycling mineral nutrients, and continue to produce plant materials during all seasons of the year. Most importantly, the bacteria and algae produced on tidal flats and shallow waters is directly utilizable by primary consumers (Peterson and Peterson 1979).

A major role of intertidal flats and shallow subtidal bottoms is as a substrate where primary production is consumed and converted into animal biomass. Contrary to salt marshes and seagrass beds, where most of the plant biomass is carried away by currents rather than being consumed in situ, most of the algae produced on tidal flats is directly consumed by deposit-feeding and suspension-feeding benthic invertebrates present on the substrate. Tidal flats and shallow water are also sites where much of the plant material from tidal marshes and seagrass beds is deposited, consumed, and converted into animal biomass by resident benthic invertebrates (Peterson and Peterson op cit.).

The benthic invertebrates that live in and on the substrate of tidal flats and shallow water areas in turn provide a critical food resource for many higher trophic level consumers. Virtually all shorebirds and wading birds are dependent upon these habitats for foraging sites. In addition, many commercially and recreationally important finfish and shellfish, such as spot, Atlantic croaker, flounder, and blue crabs, forage extensively in these areas for benthic invertebrates. Many important forage fishes, such as Atlantic menhaden, Atlantic silverside, bay anchovy, mummichog, and striped mullet, are primarily planktivores or detritivores and depend heavily upon the production of tidal flats and shallows. These forage fish provide an essential food source for larger predatory fish and piscivorous birds. The molluscs produced in the tidal flats and shallows are also important food sources for the waterfowl that overwinter in the Hampton Roads area.

Tidal flats and shallow water areas provide important nursery areas for a variety of estuarine finfish and shellfish. These habitats act to physically exclude larger predatory fish while providing a productive environment for growth and development.

Shoreline erosion control is also enhanced by the presence of extensive tidal flats and shallows channelward of the shoreline. Waves crossing these areas will decrease in velocity and energy before reaching the shore

(Theberge and Boesch 1978). Although not as effective for shoreline protection as vegetated wetlands, they are important for maintaining an energy environment where vegetated wetlands can be established and maintained.

Vegetated wetlands, intertidal flats, and shallow water habitat have undergone extensive alteration and loss within the Chesapeake Bay. Estuarine intertidal emergent wetlands within the Bay watershed have undergone an approximately 11,250 acre or 8 percent loss between 1956 and 1979 (Tiner and Finn 1986). Unfortunately, there is no statistically accurate analysis available of the changes in intertidal flats and shallow estuarine habitat. However, as discussed in Section IV of this report, within the Hampton Roads/Elizabeth River area alone there has been at least a 4600 acre loss of aquatic habitat since the early 1900s, most of which consisted of wetlands, flats, and shallow water.

The Service places the estuarine open water habitat deeper than 2 feet MLW within the project area of Hampton Roads in Resource Category 3, defined as habitat of high to medium value to important resources and that is relatively abundant on a national basis. The mitigation goal for this habitat type is no net loss of habitat value while minimizing the loss of in-kind habitat value.

The open water habitat greater than 2 feet MLW within the project area is used by several commercially important benthic species, including hard clams and blue crabs, and may potentially be used by the American oyster. The area also provides foraging habitat for a number of ecologically and/or commercially important finfish species, including spot, Atlantic croaker, menhaden, flounder, hogchoker, shad, striped bass, and river herrings. Numerous waterfowl species also feed and rest in the area. Because the project area is generally shallower than 10 feet MLW, there is no problem with low dissolved oxygen levels as occurs in some of the deeper areas of the Chesapeake Bay and its tributaries. The open water habitat within the project area is considered to have high value to these and other important resources. Open water habitat within the Chesapeake Bay has been relatively stable over time, with the exception of the portions of the Bay and its tributaries that have been deepened.

The first priority of the Service for mitigation for this dredged material disposal project is to avoid impacts to the aquatic habitat of Hampton Roads. Such impacts can be avoided by the long term disposal of dredged material that meets open water disposal criteria at the Norfolk Ocean Disposal Site. The existing Craney Island Disposal Area could be reserved for dredged material that does not meet ocean disposal criteria. Most of the material presently contained within Craney Island meets ocean disposal criteria (Alden et al. 1984a). Removal of this material for construction purposes, shoreline stabilization, or ocean disposal would greatly extend the life of the facility.

Impacts to the fish and wildlife resources of Hampton Roads could be minimized through the use of ocean disposal at the Norfolk Ocean Disposal Site, with a minimum expansion of the Craney Island facility for material

that does not meet ocean disposal criteria. Although Plan C, expansion of Craney Island to the north, is the smallest of the alternatives under consideration, it also is one of the alternatives most likely to result in hydrodynamic changes. Plan D, the smallest expansion to the west, while resulting in a larger habitat loss than Plan C, is less likely to result in hydrodynamic changes. However, as stated in Section V of this report, further three dimensional modeling will be needed prior to the selection of any of the expansion plans as the preferred alternative.

Impacts from the construction of an expansion of Craney Island could be minimized through several measures. The dikes could be constructed from material within the existing facility or from within the boundary of the expansion site itself. Alternatively, dike material could be obtained from the deepening projects within the Thimble Shoal and Atlantic Ocean Channels or Navy piers. Potential hydrodynamic changes can be avoided if dike material is not obtained from deepening the Newport News Channel below its currently authorized depth. Sedimentation and erosion control measures could be implemented during construction of the perimeter dikes. Although the use of siltation curtains would not be feasible under the wave conditions in Hampton Roads, siltation could be reduced by the placement of riprap along the outside perimeter of the dike area as it is filled. The construction of the north dike first may reduce siltation and erosion by reducing waves and currents along the western side of the dike area. A program to monitor dissolved oxygen and turbidity would insure that established water quality criteria are not violated during critical summer periods. Construction could be temporarily stopped if low dissolved oxygen levels were observed or if extremely high turbidity levels were considered to have an adverse effect on nearby oyster beds. Oyster beds on the Nansemond Ridge are the most likely to be affected by siltation. These beds could be monitored, and if found to be adversely affected, could be reworked to remove the sediments and lift the oysters and shell back up to the surface of the bed.

The Craney Island Rehandling Basin will likely continue to be used as part of the long term disposal plan for the harbor area. As stated previously, questions have been raised as to whether contaminants within the dredged material stay within the basin or are released into the lower Elizabeth River and Hampton Roads. Section 1135(a) of the Water Resources Development Act of 1986 authorizes the Secretary of the Army to review the operation of existing projects to determine the need for modifications of such projects to improve environmental quality in the public interest. Such a study of the rehandling basin is needed to determine whether restrictions on the chemical characteristics of the material that is placed in the basin is necessary to minimize impacts to water quality and aquatic resources.

Impacts from the expansion of Craney Island on waterfowl and shorebird habitat can be reduced or rectified by the maintenance of suitable foraging and resting habitat within the existing facility and within the expanded facility once it reaches its capacity. There will be a long term net loss of up to 4950 acres of high value avian habitat if the largest expansion alternative is constructed. Once filled, the disposal sites could be

maintained as a waterfowl and shorebird wildlife management area through the use of water control measures.

Compensation alternatives have been evaluated and discussed in detail between the Fish and Wildlife Service and the Corps of Engineers. The Service participated in the evaluation of compensation alternatives with the understanding by the Corps that the Service's first priority for mitigation is avoidance and that we would recommend against the expansion of the Craney Island facility. However, the Service recognizes that other factors in addition to environmental concerns will be considered in the selection of a long term disposal plan; therefore, acceptable compensation proposals must be developed for all the alternatives under consideration.

The development of compensation alternatives was an iterative process in which the Service and the Corps used a "brainstorming" technique to list alternatives that may have some feasibility. These alternatives were then evaluated and discussed with other Federal and state regulatory and advisory agencies, who also suggested other possible alternatives. Although rough estimates of costs were developed for many of the alternatives, it was recognized that at the current level of project planning, detailed mitigation plans and costs were not warranted.

The following is a summary of each of the compensation alternatives considered with their advantages and disadvantages. General cost estimates are included where possible.

1. Creation of intertidal flats around the perimeter of the expanded disposal area - During construction of the perimeter dikes, fill material will likely be placed in a manner that will result in the creation of some intertidal habitat. Since detailed design plans are not available, the extent of this intertidal habitat can not be quantified. To the extent that intertidal flats are created by the project, it will offset the loss of the existing intertidal area that would be filled. There would be no separable cost associated with this alternative.

2. Stabilization of the face of the perimeter dikes with riprap - Riprap has been placed along the face of the existing Craney Island facility in order to reduce erosion and it is likely that the same would be done at the expanded facility. A small portion of the riprap is within the intertidal and/or subtidal zone and thus provides attachment sites for epibenthic organisms, which contribute to the aquatic food web and are grazed upon by some species of finfish and crabs. The extent of habitat created by the placement of the riprap has not been quantified. There would be no separable cost associated with this alternative if it was accomplished as part of the engineering design of the project.

3. Marsh stabilization at the Ragged Island Wildlife Management Area - The Ragged Island Wildlife Management Area is located on the James River to the northwest of the mouth of the Nansemond River. This approximately 1500 acre state owned wetland/upland complex is maintained as a natural area by the Virginia Department of Game and Inland Fisheries. The shoreline at Ragged Island is eroding at a rate of approximately 2 feet per year over its 3 mile length, resulting in a loss of about 1 acre of salt marsh per year. This erosion rate is expected to continue in the future as sea level rises. Proposed mitigation would involve the construction of gapped breakwaters to provide erosion protection for the wetlands. Based on a 50 year project planning period, an effective and well maintained breakwater system could preserve 50 acres of tidal wetlands that would otherwise have been lost over this time. The cost for the breakwater, including backfill, is approximately $250 per linear foot of shoreline. Total cost for this alternative would be approximately $1.32 million. Costs could be reduced if the breakwater was constructed without backfill.

4. Oyster reef construction/enhancement in the James River - Productive oyster beds within the James River have declined from historical levels due to a number of factors, including siltation, disease and overharvest. The Virginia Marine Resources Commission (VMRC) conducts an oyster repletion program to replant and maintain public oyster beds. This program includes the cultivation of existing shell, placement of shell to provide additional attachment surfaces for oysters, and the transplanting of seed oysters to viable growing areas. Under this mitigation alternative, currently unproductive areas within the public oyster beds of the James River could be restored through the placement and maintenance of shell material. This would provide attachment sites for oysters and other epibenthic organisms and enhance the value of the area for benthic feeding finfish. The most likely area for this alternative would be the most upstream portion of the James River oyster beds, since the effects of oyster diseases would be less. The limitations of this alternative are obtaining a source of oyster shell and the need for the created oyster beds to be maintained and cultivated over the life of the project if the mitigation is to remain viable with time. The initial estimated cost for this alternative is approximately $5700 per acre of created oyster reef. Additional costs would be associated with the maintenance of the reef. For example, if the created oyster beds were allowed to be harvested, the shell material would have to be replaced approximately every five years. If the beds were not harvested, maintenance would involve the cultivation of the beds to remove siltation and to keep the oysters on the surface of the reef.

5. Acquisition and restoration of wooded wetlands in the Great Dismal Swamp - Although nontidal forested wetlands are in theory protected under Federal law, in many cases they are not protected due to interpretations of the limits of Federal jurisdiction, exemptions in the permitting program, and lack of enforcement capabilities by the regulatory agencies. Nontidal forested wetlands in Virginia have undergone a decline of approximately 61,000 acres between 1956 and

1977 (Tiner and Finn 1986). The Service estimates that within southeastern Tidewater Virginia alone there has probably been a loss of up to 2000 acres of wooded wetlands during the 1980s. The concept of this mitigation alternative would be to acquire and protect a nontidal wetland area within the James River estuary system that is under threat of loss. The Service evaluated 40 wetland complexes within the James River estuary system that have been considered for nomination as "Priority Wetlands" under the Emergency Wetlands Resources Act (Public Law 99-645). Of these 40 sites, a 5000 acre wetland that comprises the northernmost extent of the Great Dismal Swamp in Suffolk, Virginia was considered to be the site under greatest threat that is closest to the project area. This portion of the Dismal Swamp is connected with the Nansemond and Elizabeth River systems. Part of the wetland complex has been recently ditched and logged and a plan to use a portion of the area for a regional landfill has been proposed. Purchase of this wetland complex, restoration of its hydrological and biological components, and protection as a public management area would insure the continued wildlife habitat and water quality functions of the site. Since this mitigation alternative would be out-of-kind and far removed from any direct contribution to the estuary, at least a two to one mitigation ratio was considered necessary for this alternative. The estimated acquisition cost for this alternative is approximately $1500-$2000 per acre (Rybolt 1988), with a total first cost of approximately $10 million for acquisition and water control structures to restore wetland hydrology. Costs for long term operation and maintenance have not been determined.

6. Construction of artificial finfish reefs - Artificial reefs are in use in a number of locations throughout the world to enhance both commercial and recreational fisheries. There is a wide variety in the type of construction and materials used for artificial reefs. The Virginia Marine Resources Commission has an artificial reef program that includes reefs of varying design in the Chesapeake Bay and the Atlantic Ocean. This mitigation alternative would involve participation with VMRC in developing fisheries habitat in the lower Chesapeake Bay and/or James River through the placement of artificial reef structures. Potential benefits would include the enhancement of juvenile finfish habitat and lower level food chain productivity through the creation of epibenthic attachment sites. An extensive search of the literature and discussions with experts on artificial reefs were conducted by the Service to evaluate the feasibility of this alternative. Since there is no consensus on the extent to which reefs actually enhance fisheries productivity because they are often heavily harvested by fishermen, and since there is also no consensus as to the most appropriate type of reef design to maximize productivity, resource managers and scientists involved with the Virginia reef program were asked for recommendations for the most appropriate type of reef structure within the lower Chesapeake Bay. Meier (1988) and Feigenbaum (1988) recommended a reef design used within the lower Bay that consists of concrete igloo structures with holes. Feigenbaum and Blair (1986) and Feigenbaum (1988) suggest that a density of 15 igloo structures per acre, placed in five groups of

three igloos each, would be the optimum design to enhance an area and create a productive finfish reef. However, it would be difficult to compare the net habitat value between an acre of artificial reef and natural bottom since the two habitat types would consist of different benthic organisms of value to potentially different species of fish. For the purposes of this evaluation it was assumed that an acre of "enhanced" reef bottom of this design would enhance the productivity of the area by an amount equivalent to the natural bottom that was being mitigated. It is acknowledged that this decision was based on professional judgement and can not be confirmed through the literature since there have been few studies of reef primary and lower food chain productivity. Four sites of 250 acres each were considered in the areas of Lynnhaven Roads, Crumps Bank, Horseshoe Bank, and west of Craney Island. Based on an estimated cost of approximately $1500 per unit, this alternative would cost approximately $22,500 per acre of reef. Further work on the design and location of artificial reefs within the Bay would be necessary before this alternative could be given detailed consideration.

7. Protection of riparian buffers within the anadromous fish spawning ground of the James River - The anadromous fish spawning zone of the James River, located between the mouth of the Chickahominy River and Richmond, is one of Virginia's most important fishery areas. The area of the James between Jordan Point and Kennon Marsh supports the largest summer roost along the East Coast for the Federally endangered species, the bald eagle, while the area between Turkey Neck and Jones Neck supports a large winter population of eagles. Protection of the riparian zone along this section of the James River was considered as a mitigation alternative since many of these riparian areas are under increasing development pressures. Protection of the riparian zone would help to maintain water quality through the maintenance of natural buffers, protect important habitat for birds and other wildlife species, and protect the bald eagle concentration areas from intensive development. It was assumed that a 1000 foot riparian buffer would be needed to protect these values of the James River, which could be patterned after the Maryland Critical Areas program in terms of allowable development. The cost of acquiring permanent conservation easements over this 1000 foot buffer zone would depend on the restrictions contained in the easement and could be close to the fair market value of the property. Considering that a majority of this area is currently rural and consists of agricultural lands and wetlands, it was assumed that the purchase of conservation easements on undeveloped land would be $1500 per acre. There are very generally approximately 22,000 acres of land within this 1000 foot riparian zone between the Chickahominy River and Richmond. A major limitation of this alternative is that it would be difficult, if not impossible, to obtain conservation easements from the hundreds of property owners along the river. Without a large scale easement project, however, this could not be considered a viable mitigation option.

8. Construction of anadromous fish passage facilities on the James River - A significant portion of the historic spawning grounds for anadromous fish in Virginia has been lost due to the construction of

dams that have blocked the passage of fish. A goal of the states and Federal government as part of the 1987 Chesapeake Bay Agreement is the restoration of fish passage on the James River, as well as the Rappahannock River. To this end, the Commonwealth of Virginia, the Fish and Wildlife Service, and the National Marine Fisheries Service, have been participating in efforts to develop and implement fish passage projects. It is estimated that the restoration of fish passage through the five dams at Richmond will open an estimated 140 miles of the James River, totalling 9000 acres, to anadromous fish. This does not include the areas of tributary streams that would also become available as spawning habitat for river herring. The National Marine Fisheries Service has estimated that the opening of the James above Richmond will result in a standing crop of 600,000 American shad, 156,000 striped bass, and 14 million river herring, with a total annual commercial harvest value of $7.7 to $12 million. At the present time fish passage facilities are needed at the Williams Island Dam, with a design and construction cost of $3.75 million, and at the Boshers Dam, with a design and construction cost of $2.5 million. Annual operation and maintenance costs are estimated to be $30,000 for each of the fish passage facilities. There are also an additional seven dams on the James in the vicinity of Lynchburg that would block the passage of anadromous fish from reaching their historical limits of spawning above Covington. Four dams block fish passage on the Appomattox River at Petersburg. Cost estimates for fish passage at the Lynchburg and Petersburg dams have not been developed. This mitigation alternative would include the funding of fish passage facilities at Richmond, or at Lynchburg or Petersburg if fish passage had already been established at Richmond by the time the long term disposal project is initiated. Another option is the restoration of fish passage on the Rappahannock River.

9. Creation of submerged aquatic vegetation beds - Submerged aquatic vegetation (SAV) has undergone significant declines in the Chesapeake Bay during the 1970s. These underwater plants, primarily eelgrass and widgeon grass within the lower Chesapeake Bay, have historically been important as a food source for waterfowl, and as a source of food and shelter for juvenile blue crabs and finfish. Major research efforts are underway to define the reasons for the decline in SAV and ways to restore this important habitat type. However, to date no consistently reliable techniques have been developed to assure successful creation of SAV. Although the James River at one time supported extensive SAV beds, the planting of SAV in this area is not considered to be a viable mitigation option at this time.

10. Removal of contaminated sediments from the Southern Branch of the Elizabeth River - As previously discussed in this report, the Southern Branch of the Elizabeth River has some of the highest levels of polynuclear aromatic hydrocarbons in the world, and the sediments have been shown to have toxicity to aquatic organisms. In addition, finfish from the Southern Branch have been found to have a higher than expected incidence of skin lesions and other abnormalities. This mitigation alternative would seek to improve the habitat quality of

the Southern Branch through the dredging and removal of highly contaminated bottom sediments. Although this alternative would have positive environmental values, it is considered to be practicably infeasible due to the large quantity of contaminated dredged material that would have to be disposed. If the material was placed within Craney Island or its expansion, it would further reduce the useful life of the facility. Both the Federal and state levels of government are presently undertaking programs to clean up and reduce future contaminants in the Southern Branch. With time this waterway may clean itself as contaminant inputs are eliminated.

In November 1988 a meeting was held with the advisory and regulatory state and Federal agencies that are involved in the review of the disposal study to discuss the compensation alternatives under consideration. The meeting resulted in no clear consensus as to the most appropriate types of compensation. The alternatives that seemed to have the most support included wetland stabilization at Ragged Island, oyster reef creation and enhancement in the James River, and restoration of anadromous fish passage. Rather than select a preferred compensation alternative at this time, the consensus appeared to be to try to put a dollar value on the cost of compensation so that the environmental "costs" of the project could be factored into the overall economic analysis of the feasibility of the various alternatives. Recognizing that all compensation alternatives were out of kind, it was acknowledged that it would be difficult to arrive at a dollar value for the compensation. One alternative discussed was to base the mitigation cost on the cost of creating open water habitat through the grading down of existing upland areas. The Real Estate Division of the Norfolk District has determined that the condemnation value for the Craney Island Disposal Area would be approximately $7000 per acre. This value differs greatly from the waterfront land costs in many areas of Hampton Roads, which can be hundreds of thousands of dollars an acre for commercial property. Nevertheless, if this cost value is used, the maximum compensation value for the Plan B alternative (with the largest habitat loss - 2450 acres) would be $17,150,000. The rationale for this method of deriving a compensation cost for the disposal project is that the compensation for the loss of estuarine habitat should at least equal the value of the upland area that would be created. This rationale is similar to the recent guidance by the Congress in the Water Resources Development Act of 1986, which acknowledges that for Federally funded projects, the value of an environmental enhancement project is considered to be at least equal to its cost.

Mitigation of Ocean Disposal Alternatives

The placement of dredged material at the Norfolk Ocean Disposal Site is not expected to have significant ecological impacts. However, to insure that there are no long term impacts and that such impacts are properly mitigated if they do occur, a monitoring program for the site would be needed. The monitoring program should include assessments of the extent of sediment movement, water quality and sediment contaminant levels, benthic and finfish resources, blue crab larvae, and bioassessment studies.

The Service can not recommend the use of the Dam Neck Ocean Disposal Site due to the important resources of the area and the number of significant, unanswered questions regarding finfish migration, blue crab spawning, hydrodynamics, water quality, and shoreline stability. If the Dam Neck site is continued to be used, its size should be reduced and only the eastern half of the site used. In addition, only material from the Atlantic Ocean Channel, the Cape Henry Channel, and the eastern portion of the Thimble Shoal Channel should be placed at the site. A detailed monitoring program should also be implemented to evaluate the impacts of disposal operations at this site. These changes in the Dam Neck project would serve to minimize impacts, while not eliminating impacts altogether.

VII. RECOMMENDATIONS

Based upon the information available at this time, the Fish and Wildlife Service makes the following recommendations on the Long-Term Disposal Study, including alternatives that are preferred based on environmental considerations and areas that need additional study prior to any final decisions on the selection of a long-term disposal plan. It is expected that these recommendations may be modified after the opportunity for public and agency review and comment.

Several issues require additional study prior to a final decision on the selection of a long term disposal alternative for the Port of Hampton Roads. Prior to any decision to expand Craney Island, a three dimensional hydrodynamic model study that includes prototype vertically stratified salinities should be completed and analyzed by both the Corps and the Virginia Institute of Marine Science (VIMS). It is our understanding that a three dimensional model is currently near completion by both the Corps and VIMS. A three dimensional model study is critical in order to better quantify and evaluate the likely impacts of the further constriction of the open water area of Hampton Roads on circulation patterns, the frontal system off Newport News Point, and the recruitment of oyster larvae into the James River seed oyster beds. Considering the importance of the James River seed oyster beds to the maintenance of oyster populations throughout Virginia, the Service can not support any expansion of Craney Island until such studies have confirmed there will be no adverse impacts on the hydrodynamics of the lower James River and on larval transport.

Additional studies and evaluation of the suitability of the use of the Dam Neck Ocean Disposal Site for dredged material disposal are needed in order to determine the impacts of disposal on hydrodynamics, shoreline stability, finfish migration into the Chesapeake Bay, blue crab spawning, and water quality. Such studies have previously been recommended by the Service and other state and Federal agencies. If the Dam Neck site is to be used prior to the completion of these studies, the use of the site should be limited to dredged material from the Cape Henry, Atlantic Ocean, and eastern portion of the Thimble Shoal Channels. Further, the western half of the disposal site should be eliminated in order to reduce the possibility of hydrodynamic impacts on the nearshore Atlantic Ocean environment and Virginia Beach.

The currently unanswered question of whether the open water disposal of contaminated dredged material from the Elizabeth River into the Craney Island Rehandling Basin is resulting in the resuspension and redistribution of polynuclear aromatic hydrocarbons at the mouth of the river or Hampton Roads should be addressed though a detailed monitoring study. The Corps should use their authority under Section 1135 (a) of the Water Resources Development Act of 1986 to undertake such a study in order to determine whether there is a need for modification of the operation of the project to improve environmental quality in the public interest. Until such a study has been completed, it is the recommendation of the Service that dredged material from the Southern Branch of the Elizabeth River between its junction with the Eastern Branch and the U.S. Route 13/460

Bridge, and material from the main stem and Eastern Branch of the Elizabeth between Lamberts Point and the Campostella Bridge, which contains significant levels of PAHs be placed directly into the Craney Island facility and not the Rehandling Basin. A joint Federal-State task force should be established to determine what would constitute a "significant" level of PAHs to warrant direct disposal into Craney Island. This task force should include the Corps, Fish and Wildlife Service, Environmental Protection Agency, National Marine Fisheries Service, the Virginia Water Control Board, Virginia Marine Resources Commission, the Virginia Institute of Marine Science, and Old Dominion University.

A monitoring program of the effluent from the Craney Island Disposal Area and sediments to the west of the Disposal Area that concentrates on polynuclear aromatic hydrocarbons, as well as other standard contaminant parameters, is recommended to determine whether the disposal operation is resulting in any significant accumulation of contaminants in the Hampton Roads area. Alden et al. (1988) recommends that monitoring studies must use proper statistical designs and sensitive chemical and biological analysis techniques since standard methods may not evaluate the chronic impacts to aquatic organisms of long-term exposure to low levels of contaminants. Alden et al. recommend the use of sorbent containing devices for water bioassessment analyses since this method better approximates the adsorption of toxicants on and into the biota and sediments than do standard grab samples.

The Service's recommendation for the most environmentally acceptable alternative for the long term disposal of dredged material from the Port of Hampton Roads is the use of the Norfolk Ocean Disposal Site for all dredged material, private and public, that meets ocean disposal criteria. This should include all further material from the deepening of the Newport News and Norfolk Harbor Channels that is unsuitable for other beneficial uses. Although the Federal navigation channels have been evaluated for the suitability of the sediments for ocean disposal, this alternative will require either the implementation of a thorough evaluation of all other potential private dredge sites within the port for the contaminant levels, or a site by site evaluation by individual project proponents.

Material currently within the Craney Island facility that meets ocean disposal criteria should be removed and disposed at the Norfolk Ocean Disposal Site in order to extend the useful life of the Craney Island facility. Future use of Craney Island should be restricted to contaminated material from the areas of the port that do not meet ocean disposal criteria. There should also be an evaluation of the feasibility of the establishment of several smaller upland contained disposal sites throughout the port area that could be used for the disposal of contaminated dredged material. To insure the continued viability of the port's facilities, all levels of government and industry must initiate increased measures to reduce the input of contaminants into the Elizabeth River system so that at some point in the future, even currently unsuitable areas of this river may qualify for ocean disposal.

The establishment of an ocean disposal site as the primary method of disposal of most of the dredged material from the port will require that the disposal of small quantities of dredged material be considered. It is likely that it would be more economical to reserve a section of the existing Craney Island facility or rehandling basin for the disposal of small quantities of dredged material that meet ocean disposal criteria, with later transfer to the ocean.

If the Norfolk Ocean Disposal Site is selected as the recommended alternative for a disposal project, a monitoring study is recommended to evaluate the long term impacts to sediment stability, water and sediment quality, benthic and finfish resources, and blue crab larvae, as well as bioassessment studies of contaminant impacts.

Although not recommended by the Service, Plan D, the smallest expansion of Craney Island to the west appears, based on current information, to have the least likely impact on hydrodynamics and sedimentation in Hampton Roads. Until a three dimensional model study is made of the effects of the various alternatives on the hydrodynamics of the lower James River and Elizabeth River systems, however, this alternative should not be implemented. This alternative should only be selected after the three dimensional model study confirms that there will be no significant impacts on hydrodynamics or the James River oyster beds. It should be recognized that this alternative can not be considered as a permanent solution to the disposal of contaminated material from the port. In conjunction with ocean disposal and the removal of material from the existing site, however, this alternative may provide an interim solution.

Should an alternative be selected that involves the filling of aquatic habitat, compensation should be based, as a minimum, on the equivalent value of the created upland area. At present values, this is estimated to be about $7000 per acre. The Service's recommendations for the type of mitigation that would be appropriate for this project include:

1. Wetland stabilization of the Ragged Island Wildlife Management Area for the loss of vegetated wetland and intertidal habitats.

2. Oyster reef creation in the James River for the loss of shallow water habitat.

3. Restoration of anadromous fish habitat in the James and/or Rappahannock Rivers for the loss of deep water habitat. Restoration would be accomplished through the construction of fish passage facilities.

4. Maintenance of the existing Craney Island facility and the expansion area as a permanent wildlife management area.

Should the Corps recommend an alternative that will result in the expansion of the Craney Island Disposal Area, consultation with the Service under Section 7 of the Endangered Species Act will be required since the project

would result in the loss of foraging habitat for the peregrine falcon and, potentially, nesting and foraging habitat for the piping plover. The Corps is advised that the Service's recommendations under a Section 7 consultation are likely to be to avoid or minimize expansion in order to maintain the habitat for these endangered and threatened species.

VIII. SUMMARY

The evaluation of long-term disposal alternatives for dredged material from the inner channels of the port of Hampton Roads has included a number of sites within the Chesapeake Bay and lower James River, in wetland areas, and in the Atlantic Ocean. Most of these alternatives have been previously rejected due to their environmental impacts. This report has focussed on the impacts of disposal alternatives that would involve the expansion of the Craney Island Disposal Area, the currently used site for the disposal of a majority of the port's dredged material.

The expansion of Craney Island would result in the loss of estuarine aquatic habitat that is used by a number of commercially and ecologically important finfish, shellfish, waterfowl, shorebirds, and threatened and endangered species. The alternative with the largest expansion of Craney Island, Plan B, would result in an approximately 8 percent decrease in aquatic habitat in Hampton Roads proper. When combined with other filling projects that have taken place in the port since the early 1900s, this additional loss would amount to an overall 19 percent reduction in estuarine habitat in Hampton Roads since the early part of this century. The impacts of the expansion of Craney Island will contribute to the cumulative loss of aquatic productivity of the Hampton Roads area.

The expansion of Craney Island will also result in hydrodynamic changes that may affect circulation, current velocities, and water quality in the lower James River subestuary. These impacts have not been sufficiently quantified to predict the extent of changes and whether there will be impacts on the James River seed oyster beds.

The construction of an expansion of the Craney Island facility will have short-term impacts on water quality in the form of increased sediment levels and potential decreases in dissolved oxygen levels. These impacts are considered to be temporary and could be mitigated through proper construction and monitoring techniques.

Associated with the current disposal site and with any expansion project is an open water rehandling basin on the east side of Craney Island and an effluent discharge point on the west side of the facility. The use of the rehandling basin for dredged material containing high levels of polynuclear aromatic hydrocarbons may result in the transport of these contaminants to the downstream areas of the Elizabeth River and Hampton Roads. Further study is needed to determine whether such impacts are occurring. Likewise, the effluent from the discharge on the western side of Craney Island has probably resulted in subtle changes in sediment types and contaminant levels in the area between Craney Island and the Nansemond River. There is no indication that such changes have resulted in any adverse impacts to the fish and wildlife resources of the Hampton Roads area, although long-term monitoring studies would be needed to confirm this.

Ocean disposal at either the Dam Neck Ocean Disposal Site or the Norfolk Ocean Disposal Site is also under consideration. Serious questions have been raised about the suitability of the Dam Neck site due to unknown

effects on water quality, finfish, blue crabs, and hydrodynamics. Despite these unanswered questions, the Dam Neck site is currently being used for the disposal of dredged material from the Federal navigation channels in the lower Chesapeake Bay.

The Norfolk Ocean Disposal Site has undergone extensive study. The use of this site for the disposal of dredged material that meets the Environmental Protection Agency's ocean disposal criteria is not expected to result in any significant impacts to the resources of the Atlantic Ocean. Long-term monitoring of the site would be needed, however, to insure that no significant impacts do occur or that modifications to the site are made if necessary.

It is the recommendation of the Fish and Wildlife Service that the Norfolk Ocean Disposal Site be selected as the preferred environmental alternative for the disposal of all dredged material, both public and private, from the Port of Hampton Roads that meets ocean disposal criteria. It is recommended that the Corps use their authority under Section 103 of the Marine Protection, Research and Sanctuaries Act to immediately designate this site. Further deepening of the sections of the Federal navigation channels that meet ocean disposal criteria should not be placed in Craney Island since such placement will significantly reduce the remaining life of the facility. Associated with the ocean disposal alternative should be a long term monitoring study that focuses on sediment stability, water and sediment quality, benthic and finfish resources, and blue crab larvae. Bioassessment studies should be included as well.

Dredged material from the portions of the port that do not meet ocean disposal criteria should continue to be placed in the Craney Island Disposal Area. It is recommended that material currently within Craney Island that meets ocean disposal criteria be removed and disposed at the Norfolk Ocean Disposal Site if necessary to extend the life of Craney Island. In addition, a study should be undertaken to determine if several smaller upland disposal sites within the port area can be developed for the disposal of contaminated dredged material.

The Fish and Wildlife Service does not support the expansion of Craney Island. Further studies are needed to quantify the likely hydrodynamic impacts of an expansion of Craney Island on circulation, current velocities, water quality, and the James River seed oyster beds. Until such studies have been conducted, the potential risks to the aquatic resources of the Hampton Roads area from the expansion of Craney Island are too significant to undertake such a project.

Should an alternative be selected that involves the expansion of Craney Island, the Fish and Wildlife Service will recommend the full compensation for the loss of fish and wildlife habitat. Appropriate compensation measures would include wetland stabilization at the Ragged Island Wildlife Management Area, oyster reef creation in the James River, restoration of anadromous fish habitat by the construction of fish passage facilities on the James and/or Rappahannock Rivers, and the maintenance of Craney Island as a wildlife management area.

If an alternative is selected that will involve the expansion of the Craney Island Disposal Area, consultation with the Fish and Wildlife Service under Section 7 of the Endangered Species Act will be required to evaluate the impacts of the project on the Federally listed piping plover and peregrine falcon. The Service is likely to recommend that the expansion of Craney Island be avoided or minimized in order to protect these species.

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APPENDIX A

Fish and Wildlife Coordination Act Report

on

the Dam Neck Ocean Disposal Site

Virginia Beach, Virginia

July 19, 1985

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
DIVISION OF ECOLOGICAL SERVICES
1825B Virginia Street
Annapolis, Maryland 21401

July 19, 1985

Colonel Claude D. Boyd III
District Engineer
Norfolk District, Corps of Engineers
Fort Norfolk, 803 Front Street
Norfolk, Virginia 23510

Dear Colonel Boyd:

The U.S. Fish and Wildlife Service has reviewed Norfolk District Public Notice NAOPL-R-1, dated June 24, 1985, and the associated Site Evaluation Study and Final Supplement to the Final Environmental Impact Statement (SFEIS) regarding the Dam Neck Ocean Disposal Site. The Norfolk District is proposing to designate a site in the Atlantic Ocean off the coast of Virginia Beach, Virginia identified as the Dam Neck Ocean Disposal Site for the disposal of dredged material. This designation is pursuant to the to the authority of Section 103 of the Marine Protection, Research and Sanctuaries Act of 1972. The public notice addresses the designation and use of the Dam Neck Site for new work and maintenance dredging from three channels in the lower Chesapeake Bay (Thimble Shoal, Cape Henry, and Atlantic Ocean Channels); however, the Site Evaluation Study and SFEIS indicate that upon designation, the site may be used for the disposal of any dredged material that meets the ocean dumping criteria.

This letter constitutes the report of the Service and the Department of the Interior on the site designation and federal project, and is submitted in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). The Service has previously provided a Planning Aid Report and preliminary Coordination Act comments on this project dated February, 1984 and May 25, 1984, respectively.

The Service continues to disagree with the Corps' position that the proposed use of the Dam Neck Site conforms with its past use. The proposed site is over 2½ times the size of the existing interim site and the rate and volume of dredged material disposal will exceed that of historical use. It is therefore inaccurate to state that predictions of impacts can be based on an evaluation of past activities at the site. Of further concern to the Service is the fact that the proposed site designation of Dam Neck will allow the disposal of dredged material from other federal or private dredging projects.

The Service has serious concerns regarding the suitability of the Dam Neck Site as a long term ocean disposal site. It should be noted that these concerns have also been expressed by the Corps' other environmental advisory agencies as well as state agencies and private groups. These

concerns center around the resources of the project area, physical processes, and water quality. Despite the conclusions reached in the SFEIS and Site Evaluation Study, the Service believes that the existing information relative to the Dam Neck area does not support the Corps' contention that the site is suitable for dredged material disposal.

The Dam Neck Site is within an ecologically important area adjacent to the mouth of the Chesapeake Bay. The blue crab (Callinectes sapidus) utilizes this area as a spawning and nursery zone. The area is influenced by the Bay "plume", a complex water system that affects the retention and migration of planktonic and adult forms into the Chesapeake Bay. The Corps has concluded, based on the results of the studies conducted by Old Dominion University (ODU), that the area is not used to any important extent as a migratory or spawning and nursery area for finfish. However, the studies conducted by ODU were extremely limited in both scope and sampling methods and are not sufficient to refute other literature and evidence that both larval and adult finfish do utilize the area in high numbers. The larval forms are found near the bottom and in patchy distribution and the daytime oblique sampling trawls used by ODU do not adequately sample their abundance. In fact, Butt and Alden (1985) point out that "information on detailed community structures, abundance and seasonality of meroplankton is basically absent." Furthermore, the statistical analysis utilized by ODU (principal components analysis) is heavily weighted toward the most abundant species. In the case of ichthyoplankton, the commercially important finfish larvae are normally found in numbers less than the 10 per cubic meter utilized by ODU to screen for statistical analysis (Grant, 1985, personal communication). It is therefore erroneous to conclude that blue crab, bay anchovy, shrimp larvae and larvaceans are the only species present in significant numbers. With respect to adult fish migrating through the area, Birdsong (undated) states that "the importance of the study area as a migratory pathway for fishes can not be assessed from existing information other than to state that fishes do make some use of the area." While it is true that the exact migratory routes used by both larval and adult finfish to enter and exit the Bay are not precisely known (and probably vary from year to year), the fact that there is an extensive commercial fishery within 4 miles of the coast indicates that the Dam Neck area is an important migratory corridor.

Potential changes in physical processes at the Dam Neck Site have not been adequately evaluated and the available literature refutes the Corps' position that the site will be stable and not affect wave amplitude or refraction patterns. Hughes (1983) conducted a computer evaluation of the impacts of an offshore bar concept on the wave climate; however, the simulation was not carried into shore nor did the model simulate tidal current flows. Despite these limitations, Hughes concluded that bottom velocities in the area were well above that necessary for the initiation of sediment transport and that reworking of the dredged material should be expected. Watts (1983) pointed out that the stability of most existing nearshore disposal bars is due to the fact that in most cases the sand utilized to construct these sites was coarser than the natural bottom. Watts further states that existing data on the Dam Neck area indicate bottom currents range from

0.5 to 2.0 feet per second, which are above the threshold velocity to induce movement of sand in the 100 to 200 micron size. It is noted that, during the last disposal operation at Dam Neck, material from the Thimble Shoal Channel had an average grain size less than 200 microns (COE, 1985) and that during a two year period from February, 1983 to February, 1985 there was a two foot decrease in the crest of the disposal mound.

In a detailed bathymetric and geochemical study of the Norfolk Disposal Site, Oertel (1983) and Wong (1983) concluded that even at depths of 45 to 70 feet, the seabed is highly dynamic and that movement of natural sediments occurs during storm events. The shallowest areas at the Norfolk Site were 45 feet deep and Oertel (1983) states that "at these depths, wave orbital currents in combination with coastal currents may be of sufficient strength to erode or winnow fine grained material from the seabed. . . .(68 to 75 feet deep) is believed to be slightly below the depth of wave disturbance. However, moderate storm waves would most likely generate the shear stress necessary to move sediment smaller than 0.15 mm." Considering the fact that the Dam Neck Site is shallower than the Norfolk Disposal Site, and that a large quantity of the dredged material to be placed at the site consists of fine grained clays, silts and sands, it can reasonably be concluded that the Dam Neck Site will not be stable. The question of how much movement of the dredged material will occur and where the fine materials will go has not been answered. A proposed detailed physical study of the Dam Neck area and evaluation of dredged material disposal by the Coastal Engineering Research Center was terminated after only 3 months of field work and the resulting report (Weishar and Briggs, 1985) did not reach any conclusions regarding bottom stability or hydrodynamic impacts of dredged material disposal other than to state, "Bottom processes are dominated by meterological effects. The exact coupling mechanism is unknown at this time. The presence of the Chesapeake Bay complicates any attempt at quantifying the physical processes within the study area." Ludwick (1985, personal communication) has stated that his previous evaluation of the Dam Neck Site (Ludwick and Saumsiegle, 1976) looked only at current velocities necessary to move fine to medium grained sand and found a net transport to the south. However, he states that the disposal of fine grained material at the site might not necessarily result in the same transport pattern since the threshold velocity and direction of net movement depends on the sediment's grain size and specific gravity.

Based upon our review of the literature cited above, it is the Service's conclusion that the Dam Neck Site will not exhibit bottom stability and it may be expected that the finer grained dredged material deposited at the site will be transported. The extent and direction of transport has not been determined, nor has the potential for changes in wave amplitude and refraction patterns. Since 1983, the Service and five other federal and

state agencies have requested that the Corps conduct a formal detailed hydrodynamic study of the Dam Neck Site, however, no such study has been conducted. Due to the important fishery resources that utilize the Dam Neck area and the valuable commercial, recreational and governmental beachfront properties along the Atlantic Ocean coast, we believe that this formal evaluation is imperative prior to any designation or use of the Dam Neck Site.

Studies by Old Dominion University and the Hampton Roads Sanitation District have shown that the Dam Neck Site is within a nearshore zone that experiences low dissolved oxygen levels. This phenomenon appears to be due to the outflow of estuarine waters from the Chesapeake Bay which exert a high biochemical oxygen demand (BOD). Although the extent of this depressed dissolved oxygen zone is not known, Alden and Butt (1985a) found that dissolved oxygen levels improved in an easterly direction and stated that depressed levels may be found as far south as False Cape. Alden and Butt found bottom dissolved oxygen levels in the vicinity of the Dam Neck Site during the late summer to be considerably below the 6.0 parts per million level established by the Virginia State Water Control Board for the protection of marine biota. Alden and Butt (1985a) conclude that "considering the ecological problems believed to be associated with anoxia in the Chesapeake Bay and in the coastal waters of the New York Bight, the low oxygen phenomenon off Dam Neck should be seen as a potentially significant environmental problem." In contrast, during four years of study at the Norfolk Disposal Site, dissolved oxygen levels remained at near saturation levels year round and bottom levels were not significantly lower than surface levels (Alden and Butt, 1985b).

Based on the important fishery resources in the vicinity of the Dam Neck Site and the potential changes in physical processes, sediment stability and water quality, long term chronic impacts could result from the use of the site for the disposal of dredged material on an ongoing basis. The combination of the placement of fine grained sediments at the site and bottom instability could result in a change in the benthic community over a 10 square mile area. Ranasinghe et al. (1985) indicate that the abundance of benthic species was less in fine grained material than in coarse grained material in the vicinity of Dam Neck. Diaz (1985, personal communication) estimates that if the disposal site sediments are changed to less than 20% sand, there will be a change in benthic community structure and abundance that may be less valuable to the fish populations feeding in the area.

Disposal of fine grained material at the Dam Neck Site may also have an additive effect on water quality with the already low dissolved oxygen levels in the area. Fine grained materials out of the Chesapeake Bay and its tributaries should be expected to have a fairly high biochemical oxygen demand. Considering that the dissolved oxygen levels at the site are already low during the summer and fall, any further reduction could stress both planktonic and benthic communities.

Although dredged material proposed to be placed in the Dam Neck Site will meet ocean dumping toxicity criteria, it should not be assumed that the material will be completely free from pollutants. Fine grained material from within the Chesapeake Bay will have a number of toxic compounds bound to the sediments at low levels as well as a high biochemical oxygen demand, as previously discussed. The long term buildup of these toxics and BOD could potentially alter the water quality of the site and result in subtle impacts to the aquatic and benthic communities. In view of the important fishery resources found in the area and its proximity to the Chesapeake Bay, it is imperative that disposal operations should be monitored to detect any changes in water quality or resources before such effects become acute. However, Alden (1984) and Alden and Butt (1985b) point out that their statistical analysis for calculating "minimum detectable impacts" requires the use of a probability greater than 0.001 to detect statistically significant changes because of the range of natural variations in both living resources and water quality. Such an analysis requires extreme changes in parameters before statistical significance can be detected. Large scale changes in water quality or living resources would be totally unacceptable at the Dam Neck Site. The limitation of conducting adequate trend assessments without the establishment of a detailed baseline data base and ongoing site monitoring suggests that costs associated with an adequate monitoring program make the use of the Dam Neck Site infeasible.

Based upon the important resources that are found in the vicinity of the Dam Neck Site and the potential impacts to these resources due to changes in sediment type, bottom stability, dissolved oxygen levels and long term water quality, and the unknown effects on shoreline erosion, the Fish and Wildlife Service cannot support the designation or use of the Dam Neck Site as an ocean disposal site. We recommend that the Corps designate and use the Norfolk Disposal Site since there are fewer critical resources at that site and little likelihood of hydrodynamic or water quality impacts. In addition, the Norfolk Disposal Site has a well established baseline data base that will allow for the development of a monitoring program.

If the Corps intends to designate the Dam Neck Site over the objections of the Service, then the following recommendations should be incorporated into the project:

1. The Dam Neck Site should only be designated and used for dredged material from the deepening of the Atlantic Ocean Channel, the Cape Henry Channel and that portion of the Thimble Shoal Channel east of the Chesapeake Bay Bridge-Tunnel. These areas contain predominately fine sands which should minimize any impacts to water quality or living resources. All other new work dredging from the harbor deepening projects and all future maintenance dredging material from all the channels should be disposed of at the Norfolk Disposal Site.

2. The size of the proposed Dam Neck Site should be reduced. Dredged material suitable for beach nourishment (that is, with an average grain size larger than 0.2 millimeters) should be placed in Sub Area f. All other new work material from the three channels should be placed in Sub Areas 5, 6, and 7. Areas 2, 3 and 4 should be eliminated to reduce the chances of hydrodynamic changes.

3. The formal hydrodynamic studies of the Dam Neck area that have been previously recommended by the Service and other agencies should be conducted prior to final designation or use of the site.

4. The Corps should implement a detailed monitoring plan which includes the development of baseline data to evaluate long term impacts on living resources, water quality, and site stability. The sampling design should be adequate to allow a statistical analysis for trend assessment. The Service would be pleased to work with the Corps in developing this monitoring plan.

The Service is concerned that the Corps has persisted in designating an ocean disposal site that has been shown to have important living resources, potential water quality problems, and which is in an unstable nearshore area adjacent to a major resort city and several large federal properties. While the Service shares the Corps' desire to develop the most cost effective federal project for the deepening of the Norfolk Harbor and Baltimore Harbor projects, we believe that due consideration should be given to the extremely valuable nearshore area off the mouth of the Chesapeake Bay. We do not believe that the risk to these resources is justified when the Norfolk Disposal Site has also been shown to be a cost effective alternative. If the Corps chooses to let economic factors outweigh environmental concerns, we hope that you will at least incorporate our alternative recommendations to minimize environmental impacts to the greatest extent possible.

Sincerely yours,

/s/ Glenn W. Kinser

Glenn W. Kinser, Ph.D.
Supervisor
Annapolis Field Office

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ATTACHMENT 3

UNDERWATER REMOTE SENSING SURVEY

CRANEY ISLAND DISPOSAL SITE

NORFOLK HARBOR AND CHANNELS, VIRGINIA

I. INTRODUCTION.

The Norfolk District, U.S. Army Corps of Engineers is investigating several alternative plans for long term disposal of dredged material for the Norfolk Harbor and Channels Project, Norfolk, Virginia. One of the plans under consideration is the enlargement of the existing Craney Island diked open water disposal site at Hampton Roads Harbor. An additional 2500 acres of Harbor bottom would be enclosed to the north and west of the existing disposal area. Detailed descriptions of the Craney Island site and other alternatives considered can be found in the Norfolk Harbor and Channels Environmental Impact Statement.

II. AUTHORITY.

Under several historic preservation laws and Executive Order 11593, dated May 13, 1971, the Norfolk District, U.S. Army Corps of Engineers has the responsibility to identify and preserve cultural resources, or mitigate losses thereto, on lands under their jurisdiction or affected by their actions.

The pertinent authorities for this responsibility include the Antiquities Act of 1906, the Historic Sites Act of 1935, The National Historic Preservation Act of 1966, as amended by the National Historic Preservation Act amendments of 1980, the Reservoir Salvage Act of 1960 as amended by the Archeological and Historic Preservation Act of 1974, Executive Order 11593, and the National Environmental Policy Act.

In compliance with these laws and Executive Order, underwater remote sensing surveys were conducted within the area to be included in the Craney Island disposal site in January and March 1989. The surveys were conducted by Norfolk District personnel. The survey data was interpreted and this report prepared by Mobile District archeologist, Dottie Gibbens.

III. PREVIOUS INVESTIGATIONS.

In July, 1986, Norfolk District personnel conducted an underwater remote sensing survey of in the vicinity of the Craney Island disposal area containment dike. As a result of this survey three side scan sonar targets were recommended for diver identification. On December 5, 1986 the targets were identified and proved to be modern ferrous debris.

IV. SURVEY METHODOLOGY.

The underwater cultural resources survey of the Craney Island Disposal Site was conducted by personnel from the Norfolk District, U.S. Army Corps of Engineers. The surveys were initiated in January, 1989, however severe winter storms prevented completion of the surveys until March 1989. The proposed expansion area was divided into two survey tracts, Area 1 north of the existing dikes and Area 2 west of the existing dikes, see Map 1.

In January the 31 foot vessel Sounder 6 was used for the survey. Equipment array included a Del Norte electronic positioning system, Raytheon fathometer and Klein Model 531 side scan sonar with 500 Khz sensor. During the March surveys, the 40 foot vessel Lynnhaven was used. Equipment included a Teleurometer 3 range electronic positioning system, Ross fathometer and the Klein side scan system. During both surveys the side scan sensor was deployed off the bow of the vessel three feet below the surface. Distance of the sensor from the positioning antennae was 20 feet. Vessel speed was maintained at 4 - 41/2 knots dependent on tides and currents..

The side scan sonar is used to examine sea floor topography, to identify obstacles and in the search mode. The side scan sonar tow fish contains transmitting circuitry to energize transducers which project high intensity, high frequency bursts of energy (sound) in fan-shaped beams which are narrow in the horizontal plane and wide in the vertical plane. These sound beams project along the seabed, bay bottom/river bottom on both sides of the moving vessel. Objects or topographic features on the bottom surface produce echoes which are received by the transducers. The graphic recorder processes the incoming echoes and prints them on a special multi-channel writing mechanism.

A 500 Khz sensor was used for the side scan sonar throughout the surveys. Coverage to either side of the side scan sensor was set at 50 meters for the north survey area (Area 1) and at 37 1/2 meters for the west survey area (Area 2). Survey lines were spaced at 100 feet intervals. Prior to the start of the survey, a survey grid was established for each of the two areas thus allowing the boat operator to maintain a true course down each line. Position fixes were noted on the side scan sonar records at 500 feet intervals in Survey Area 1 and 250 feet intervals in Survey Area 2.

V. SURVEY RESULTS

The survey data was initially reviewed by Norfolk District survey personnel who identified over three hundred side scan sonar targets. Subsequent review of the data by the Mobile District archeologist and Mobile District survey technician resulted in the addition of 16 additional targets. Targets identified by Norfolk District are numbered 1 - 337. Additional targets noted by Mobile District personnel were assigned numbers starting at 400. Careful review of the data revealed that a number of the "targets" that had been assigned numbers did not in fact represent man made objects. Instead these images on the side scan records were caused by thermal changes in the water column, boat wake, sensor roll, and changes in bottom composition. For example, in Survey Area 2, a large oblong area of more dense bottom sediments

was seen on several adjacent survey lines 42, 43, 45 and 46. Targets representing bottom disturbance or changes in bottom composition were retained in the list of side scan targets. Thermal shadows, boat wake, etc have been deleted from the final tabulation of targets. Tables 1 and 2 provide a list of side scan targets recorded during the surveys.

As would be expected in any active harbor, numerous small isolated targets ranging from crab traps to cable and pipe were seen throughout the survey area. Sunken dredge pipes and associated trenches were seen throughout both survey areas. Trawl and anchor scars were also noted throughout the areas. No clustering of targets that might represent vessel remains were identified in the side scan data nor were any of the individual targets of sufficient size or configuration to represent a sunken vessel. No additional underwater archeological investigations appear to be warranted for the Craney Island Disposal site.

Table 1

Craney Island Disposal Area

Survey Area 1:

Survey Line	Target Number	Remarks
0+00	57	trench with dredging pipeline
	415	unidentified square target 20'x20'
	416	unidentified object with chain or cable
1+00	55	trench with dredging pipeline; same target as 57 on line 0+00
	417	same target as 415 on line 0+00
	418	cable
	419	cable
	56	dredge pipeline trench
2+00	54	dredge pipeline trench
	53	same target as 56; line 1+00
3+00	52	unidentified linear target; 30' long protrudes 3' above bottom (pipe?)
4+00	50	very small isolated square target (crab trap?)
5+00	49	dredge pipeline with attached buoy
6+00	48	" " " " "
7+00	no targets	
8+00	42	dredge pipeline
	45	" "
	46	" "

Table 1

Survey Area 1:

Survey Line	Target Number	Remarks:
9+00	41	dredge pipeline
	40	" "
	38	" "
10+00	33	dredge pipeline; same as target 42 line 8
	36	dredge pipeline
	37	" "
11+00	29	" "
	30	" "
	31	" "
12+00	28	disturbed bottom
	26	dredge pipeline
13+00	24	" "
	25	" "
14+00	22	unidentified small rectangular target may be associated with dredge pipe
15+00	19	cable
	18	dredge pipe
16+00	no targets	
17+00	14	dredge pipe
18+00	no targets	

Table 1

Survey Area 1:

Survey Line	Target Number	Remarks:
19+00	no targets	
20+00	9	very small isolated target
21+00	no targets	
22+00	4	crab pot
	3	" "
	5	" "
23+00	1	cable

Table 2

Craney Island Disposal Site

Survey Area 2:

Survey Line	Target Number	Remarks:
0+00	400	multiple (4) linear targets (pipe?)
	401	small isolated target
1+00	402	linear target 30'long (pipe?)
	403	two circular objects within scoured area
	3	single narrow linear target
2+00	8	sand ridges
	6	small isolated target
	7	ridge on bottom
	5	" " "
	4	linear target; same as target 402 on line 1+00
	404	bottom ridge with small rectangular object associated
3+00	no targets	
4+00	11	small isolated target
5+00	406	narrow linear target (pipe?)
	337	anchor or buoy
6+00	336	small isolated target
7+00	332	" " "
8+00	329	rubble mound

Table 2

Survey Area 2:

Survey Line	Target Number	Remarks:
9+00	no targets	
10+00	no targets	
11+00	407	2 narrow linear targets 25'/35' long
	325	isolated small target
	326	mounded area with linear target protruding from bottom
12+00	322	isolated linear target
	324	small unidentified target
13+00	no targets	
14+00	no targets	
15+00	no targets	
16+00	no targets	
17+00	no targets	
18+00	no targets	
19+00	no targets	
20+00	no targets	
21+00	no targets	
22+00	no targets	

Table 2

Survey Area 2:

Survey Line	Target Number	Remarks
23+00	no targets	
24+00	no targets	
25+00	no targets	
26+00	320	isolated unidentified target protrudes 3' above bottom
27+00	319	same target as 320; line 26+00
	408	dredge pipe with pontoons
28+00	316	same target as 408, line 27+00
	409	dredge pipe associated with targets 316/408
29+00	133	dredge pipeline
30+00	134	pipeline trench
31+00	no targets	
32+00	410	pipeline trench
	411	small isolated target
	412	small isolated target
33+00	311	trench; same target as target 410 on 32+00
	310	same target as 411 on line 32+00
34+00	no targets	

Table 2

Survey Area 2:

Survey Line	Target Number	Remarks:
35+00	306	large oblong shadow; 80 - 85' long/ 60 - 65' wide
36+00	303	same target as 306
	304	small isolated linear target
37+00	147	fairly large oblong target 20' x 30'
38+00	149	same target as 147 line 37+00
39+00	no targets	
40+00	no targets	
41+00	151	small isolated target
	152	small isolated target, 1' high
	154	oblong target, edge of survey tract
42+00	301	oblong target, 35 x 40'; same target as 154, line 41+00
43+00	160	same target as 301, line 42+00
44+00	161	disturbed bottom
45+00	164	change in bottom sediments/oblong area/ similar to features seen at targets 147/149/;154/301/160
	165	disturbed bottom
46+00	167	same target as 164, line 45+00

Table 2

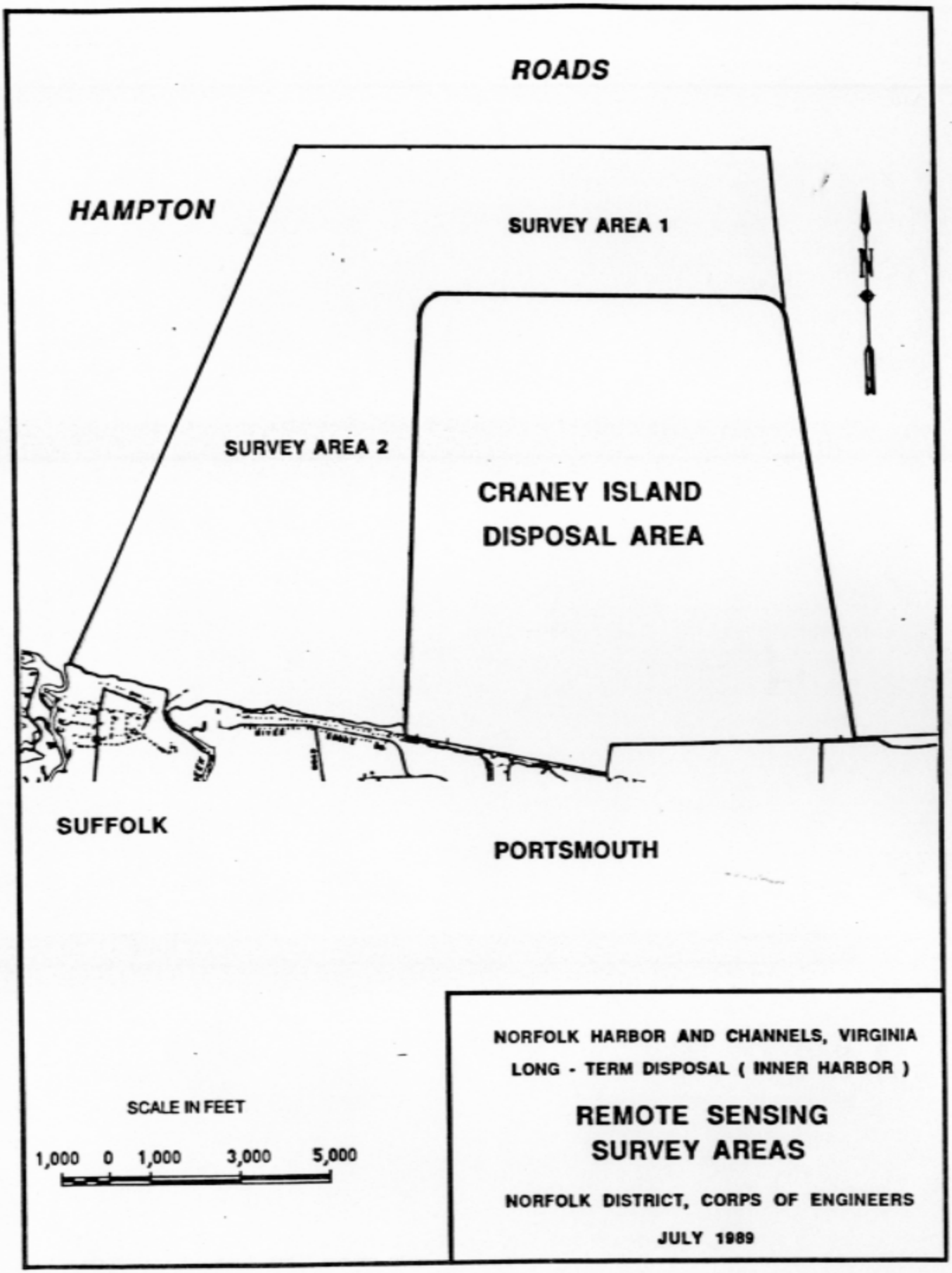
Survey Area 2:

Survey Line	Target Number	Remarks:
47+00	168	small area of bottom disturbance
	169	" " " " "
48+00	no targets	
49+00	no targets	
50+00	no targets	
51+00	177	old dock
52+00	178	old dock, same target as 177
53+00	179	old dock, same target as 177/178
54+00	no targets	
55+00	no targets	
56+00	no targets	
57+00	no targets	
58+00	no targets	
59+00	no targets	
60+00	no targets	
61+00	no targets	

Table 2

Survey Area 2:

Survey Line	Target Number	Remarks:
62+00	183	disturbed bottom
63+00	187	small unidentified target
	188	disturbed bottom
64+00	no targets	
65+00	191	small isolated target
66+00	192	small isolated target; possibly same target as 191 on line 65+00
	193	small linear target
67+00	no targets	
68+00	no targets	


ROADS
HAMPTON
SURVEY AREA 1
SURVEY AREA 2
CRANEY ISLAND
DISPOSAL AREA
SUFFOLK
PORTSMOUTH
SCALE IN FEET
1,000 0 1,000 3,000 5,000
NORFOLK HARBOR AND CHANNELS, VIRGINIA
LONG - TERM DISPOSAL (INNER HARBOR)
REMOTE SENSING
SURVEY AREAS
NORFOLK DISTRICT, CORPS OF ENGINEERS
JULY 1989

PLATE

ATTACHMENT 4

THE COLLEGE OF WILLIAM AND MARY
VIRGINIA INSTITUTE OF MARINE SCIENCE
SCHOOL OF MARINE SCIENCE

22 February 1989

Mr. Craig Seltzer
Norfolk District
U.S. Army Corps of Engineers
803 Front Street
Norfolk, Virginia 23510

Dear Craig:

Please find enclosed the final report for the sediment profile camera survey we did around Craney Island in November, 1988. I hope this information will be useful. Unfortunately, our matrix slide copier is out of service, so we are not able to provide you with copies of the SPI images at this time. As soon as we get it fixed, we will send copies to you. I trust everything is going well and if you have any questions, feel free to call.

Sincerely,

Paul Gapcynski

Paul Gapcynski
Laboratory Specialist
Division of Geological
and Benthic Oceanography

PG:lm
Encls.

Gloucester Point, Virginia 23062 (804) 642-7000

a

SEDIMENT PROFILE CAMERA SAMPLING
AT THE CRANEY ISLAND DISPOSAL AREA

November 1988

by

Paul Gapcynski
Robert J. Diaz

Virginia Institute of Marine Science
College of William and Mary
Gloucester Point, Virginia 23062

to

Craig Seltzer

Norfolk District
U.S. Army Corps of Engineers
803 Front Street
Norfolk, Virginia 23510

Final Report

February 1989

b

SEDIMENT PROFILE CAMERA SAMPLING
AT THE CRANEY ISLAND DISPOSAL AREA

November 8, 1988

Sediment profile camera sampling at 24 stations around the perimeter of Craney Island Disposal Area took place on November 8, 1988 (Figure 1). The 24 station grid was divided into 7 transects of 3 to 4 stations each, arrayed to the north and west of the existing dike (Figure 2). The sampling grid was intended to cover the area being considered as the primary option for the expansion of Craney Island by the Norfolk District of the Army Corps of Engineers (WES Technical Report HL-88-8, p. 12, Plan B). A modified Benthos Model 371 sediment profile camera was used to collect three replicates (one picture per replicate) at each station. A description of the Surface and Profile Imaging (SPI) system, and of the camera modifications can be found in Diaz and Schaffner (1988).

The photographs were analyzed on an International Imaging I2S Model 75 image processor for measurements of several parameters, including depth of penetration and depth of the apparent redox-potential discontinuity (RPD) layer. Results of visual analysis of the photographs, and an explanation of abbreviations used, are included in Appendices I and II. Station position information is listed in Table 1. Loran navigation signals were uncorrected for signal bias, such that actual station positions may vary somewhat from those shown in Figure 1.

RESULTS

Results of the SPI analysis for all stations are listed in Table 2. In analyzing the data, the 24 stations were divided into three groups, depending on location. Group 1 consists of the 6 inshore stations closest

to the current disposal area boundary (1-1, 2-1, 4-1, 5-1, 6-1, 7-1). Group 2 consists of 11 "middle" stations, located between group 1 stations and the proposed expansion boundary (1-2, 1-3, 2-2, 2-3, 3-2, 3-3, 4-2, 4-3, 5-2, 6-2, 7-2). Finally, group 3 consists of the 7 offshore stations, located outside of the proposed expansion boundary (1-4, 2-4, 3-4, 4-4, 5-3, 6-3, 7-3). Although Figure 1 shows transect 7 stations located outside of the proposed expansion area, loran signal bias corrections would place these stations close enough that they are included. Averages for the three parameters measured, for each group, are listed in Table 3.

Average prism penetration, which can be a measure of sediment compaction, ranged from 3.7 to >20 cm, indicating a wide range of sediment types (Figure 3). Sediment composition ranged from natural fine sands and muddy silts (1-4, 2-3), to soft, clayey mud with high water content (6-1). These soft muds also exhibited color and texture patterns similar to dredged material. The average prism penetration for group 1 was >16 cm (4 stations overpenetrated the camera prism), >12.6 cm for group 2 (2 stations overpenetrated), and 9.4 ± 4.8 cm for group 3.

Sediment-water interface relief averaged 1.3 ± 1.0 cm, ranging from 0.4 to 2.3 cm. Relief structures such as mounds, pits, and burrow openings, possibly due to biological activity, were seen at 9 of the 24 stations, although interface relief was generally smooth and even. Interface relief was similar for the 3 station groups.

The average depth of the RPD was 1.0 ± 0.1 cm for group 1, 2.1 ± 1.4 cm for group 2, and 3.1 ± 1.8 cm for group 3 (Figure 4). This depth of RPD can be used as an indication of the oxygenation of sediments.

Additional evidence of biological activity was also noted in the visual analysis (see Appendix I). Subsurface annelid worms were seen at 14 stations (3-4), and subsurface aerobic voids were seen at 10 stations

(7-2), ranging from 0.1 to 2.8% of the sediment column. Stations exhibiting possible biological activity are shown in Figure 5.

CONCLUSION

Results show several interesting trends (Table 3). Average prism penetration decreased with distance offshore, away from Craney Island. The inshore station (group 1) sediments consisted of very soft muds and clays that had an appearance similar to dredged material. The middle station (group 2) sediments were more characteristic of natural muds and silts, in color and texture. Sediments at the offshore stations (group 3) reflected natural sand and silt conditions for this part of the James River.

The depth of the redox-potential discontinuity (RPD) layer increased with distance offshore (Table 3). Inshore sediments were not as well oxygenated as sediments at middle and offshore stations, where more typical RPD values were seen.

Evidence of biological activity, as seen in Figure 5, was interesting as well. Nearly all of the group 3 stations exhibited some evidence of biogenic activity, as well as all stations in transects 3 and 4. Some group 2 stations showed activity, especially those located on the western side of Craney Island. Group 1 stations did not appear to be as biologically active.

Overall, the bottom sediments immediately adjacent to the dike (group 1 stations), seem to have been modified from the operation of Craney Island. Sediments outside of the proposed extension (group 3 stations) seem to be unaffected, and are typical for this area of the James River. Sediments in group 2 stations seem to be transitional, with some appearing to have been impacted, while others appear more natural, as in group 3.

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Heltzel, S.B. and M.A. Granat. 1988. Lower James River circulation study, Virginia: Evaluation of Craney Island enlargement alternatives. Final Report, Waterways Experiment Station Technical Report HL-88-8. Army Corps of Engineers, Vicksburg, MS, 30 pp.

Table 1. Location information for SPI images from Craney Island, November, 1988.

STATION	DATE	TIME	DEPTH	LORAN X	LORAN Y	LAT. N	LONG. W
1-1	11-8-88	1248	10	27264.04	41212.48	3654.25	7623.35
1-2		1256	11	27266.24	41213.14	3654.39	7623.86
1-3		1305	11	27268.32	41213.71	3654.50	7624.34
1-4		1316	9	27270.86	41213.04	3654.54	7624.97
2-4		1327	10	27270.01	41220.15	3655.07	7624.49
2-3		1336	10	27268.28	41219.32	3654.94	7624.09
2-2		1347	9	27266.55	41217.70	3654.76	7623.73
2-1		1354	9	27265.72	41217.35	3654.71	7623.58
3-4		1408	15	27269.70	41225.44	3655.48	7624.19
3-3		1415	14	27268.26	41224.81	3655.38	7623.88
3-2		1425	12	27266.66	41223.93	3655.25	7623.53
4-4		1437	24	27269.79	41232.85	3656.06	7623.91
4-3		1442	26	27268.55	41231.30	3655.90	7623.69
4-2		1449	23	27267.46	41229.92	3655.75	7623.49
4-1		1455	22	27266.16	41227.80	3655.54	7623.27
5-1		1506	13	27263.54	41229.92	3655.61	7622.54
5-2		1515	27	27264.76	41233.50	3655.93	7622.70
5-3		1524	27	27266.25	41236.29	3656.21	7622.95
6-3		1532	28	27262.85	41237.72	3656.20	7622.07
6-2		1539	20	27262.25	41233.29	3655.84	7622.12
6-1		1547	11	27261.71	41231.28	3655.65	7622.06
7-3		1556	19	27259.69	41239.20	3656.21	7621.27
7-2		1604	14	27258.88	41235.98	3655.93	7621.21
7-1		1614	13	27258.49	41231.94	3655.60	7621.27

Table 2. Linear measurements (cm) for SPI images from Craney Island, November, 1988. OVP is overpenetrated.

STATION		PENETRATION MIN	MAX	AVE.	SURFA. RELIEF	RPD MIN	MAX	AVE. DEPTH
1-1	12:48			OVP	OVP			OVP
1-2	12:56	14.1	16.0	15.2	2.0	2.6	5.2	4.2
1-3	1:05			OVP	OVP			OVP
1-4	1:16	6.3	7.8	4.7	1.2	5.2	7.1	4.4
2-4	1:27	18.2	19.1	18.6	0.9	2.8	8.5	6.1
2-3	1:36	17.5	18.6	16.0	0.7	1.9	5.2	3.8
2-2	1:47			OVP	OVP			OVP
2-1	1:53			OVP	OVP			OVP
3-4	2:08	6.1	6.8	6.6	0.5	2.3	6.8	1.6
3-3	2:15	9.1	9.8	9.2	0.7	0.0	1.1	0.6
3-2	2:25	9.6	10.0	9.2	1.0	0.0	2.2	1.0
4-4	2:37	7.9	8.1	7.9	0.4	0.4	1.0	0.7
4-3	2:42	6.6	7.1	7.8	1.8	0.3	1.0	0.7
4-2	2:49	5.4	6.1	4.6	0.9	0.1	2.2	0.9
4-1	2:55	3.6	4.3	3.7	1.5	0.1	1.0	0.9
5-1	3:06			OVP	OVP			OVP
5-2	3:15	6.0	6.7	6.4	0.7	0.1	6.6	3.1
5-3	3:24	4.2	4.6	6.4	0.5	1.2	3.2	2.3
6-3	3:32	13.4	15.9	8.8	2.3	1.0	6.4	2.9
6-2	3:39	15.8	16.2	16.1	0.4	0.2	3.2	1.6
6-1	3:47			OVP	OVP			OVP
7-3	3:56	10.5	11.9	13.0	1.5	2.3	10.9	4.0
7-2	4:04	14.7	15.7	14.4	0.9	1.8	5.0	2.8
7-1	4:14	12.8	14.1	13.2	1.3	0.2	1.8	1.0

Table 3. Station group averages (cm) for the SPI linear measurements from Craney Island, November, 1988.

GROUP	AVERAGE PENETRATION	SURFACE RELIEF	AVERAGE RPD DEPTH
1	>16.0	1.4 ± 0.1	1.0 ± 0.1
2	>12.6	1.0 ± 0.5	2.1 ± 1.4
3	9.4 ± 4.8	1.0 ± 0.7	3.1 ± 1.8

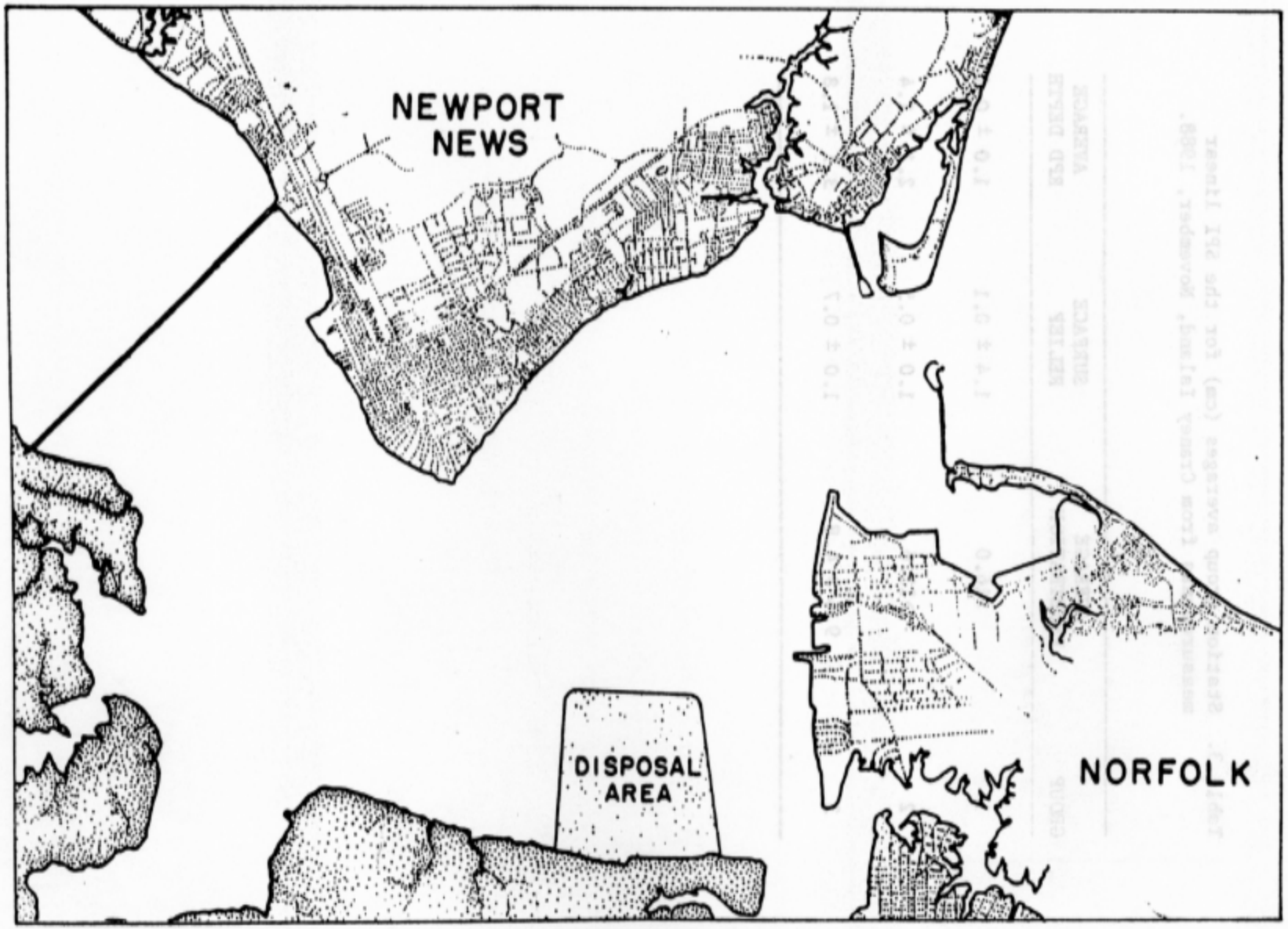


Figure 1. Location of Craney Island Disposal Area in Hampton Roads, Virginia.

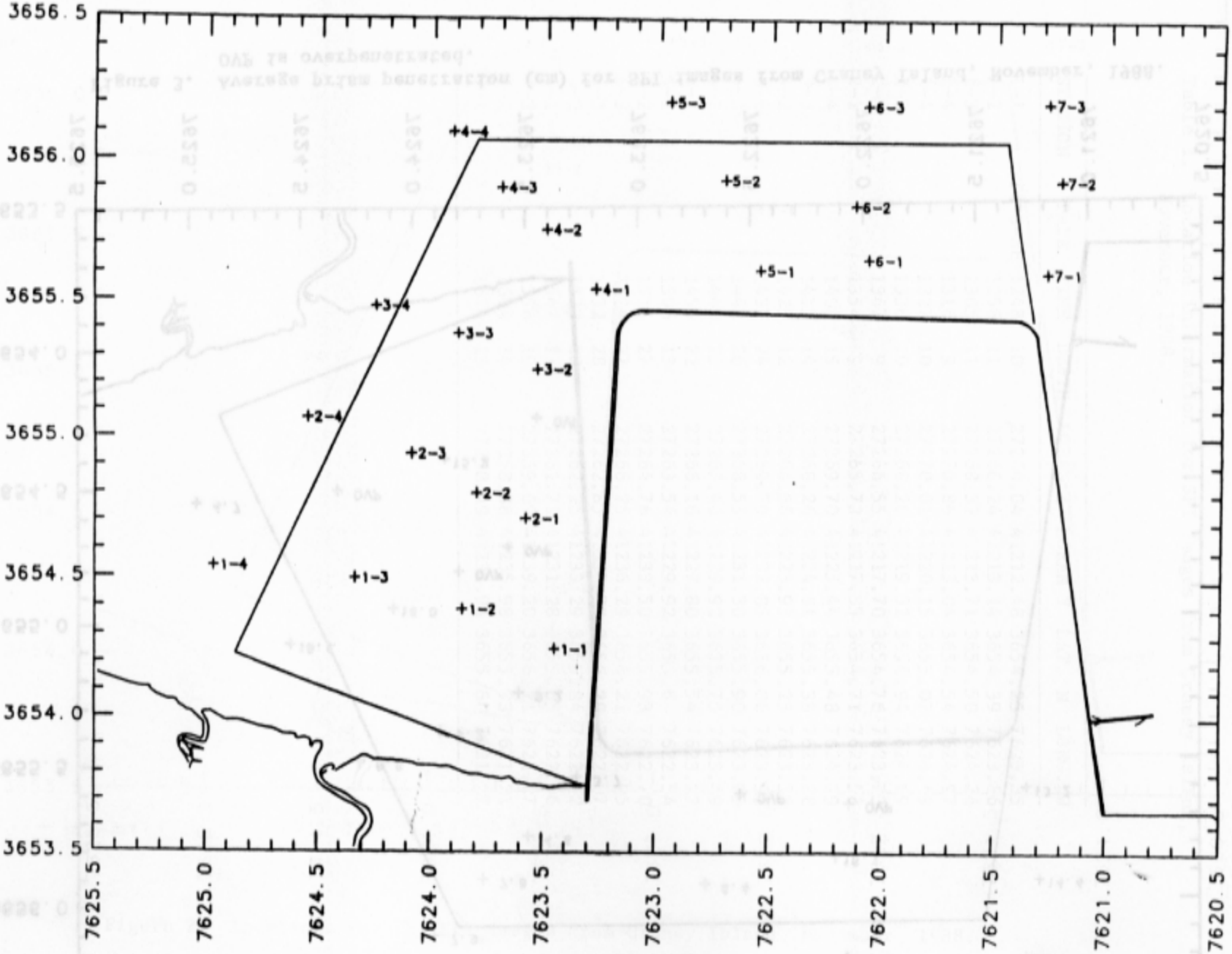


Figure 2. Locations for the SPI images from Craney Island, November, 1988.

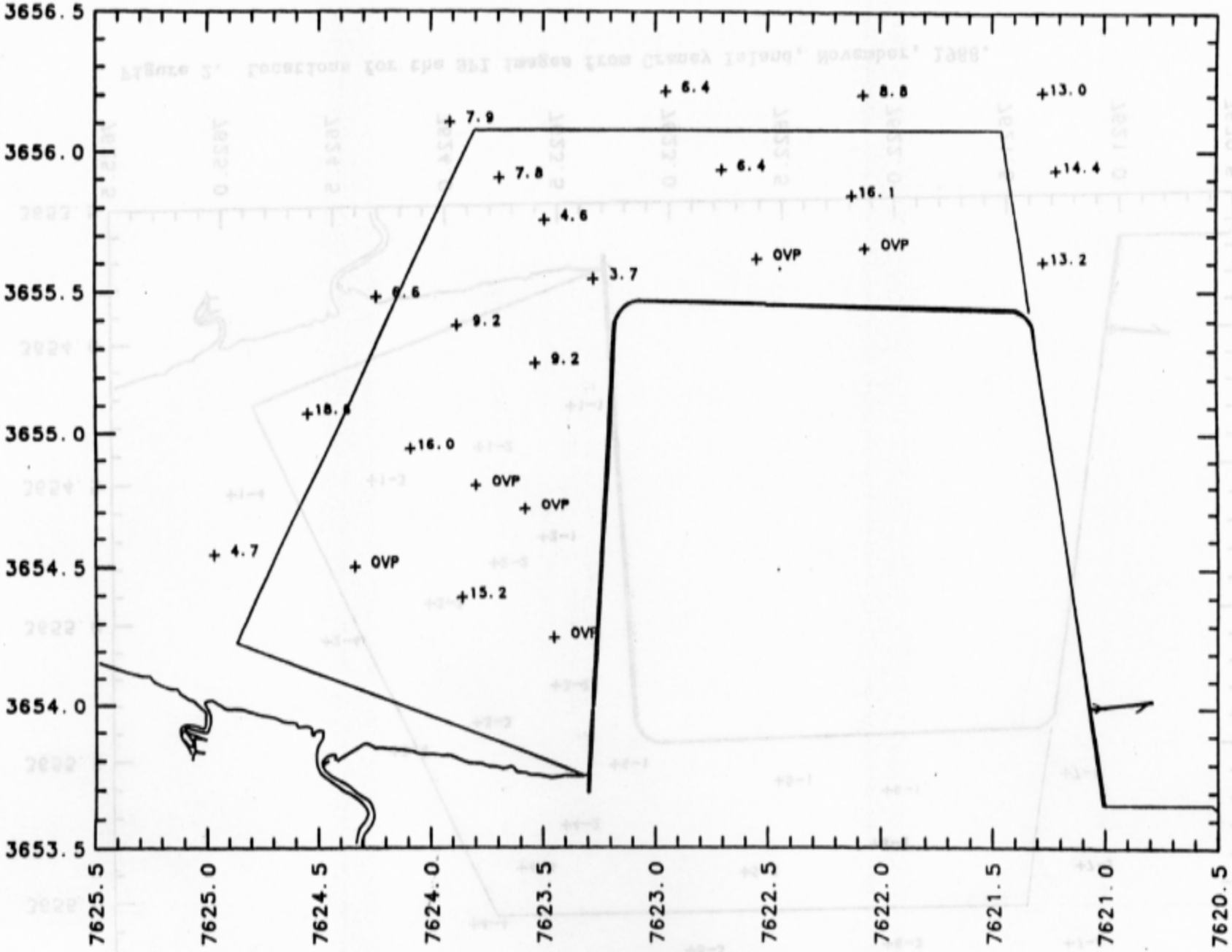


Figure 3. Average prism penetration (cm) for SPI images from Craney Island, November, 1988. OVP is overpenetrated.

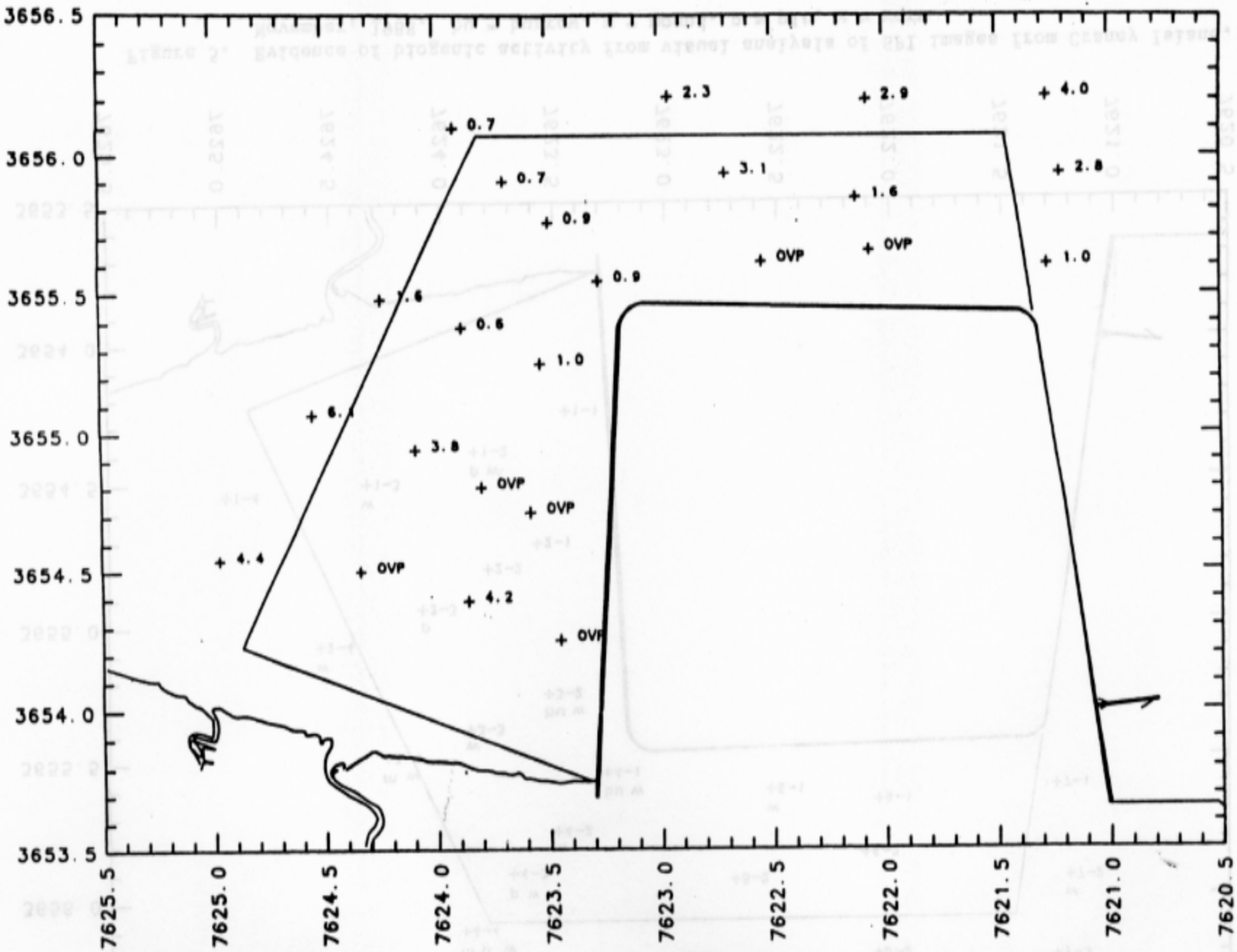


Figure 4. Average RPD depth (cm) for SPI images from Craney Island, November, 1988. OVP is overpenetrated.

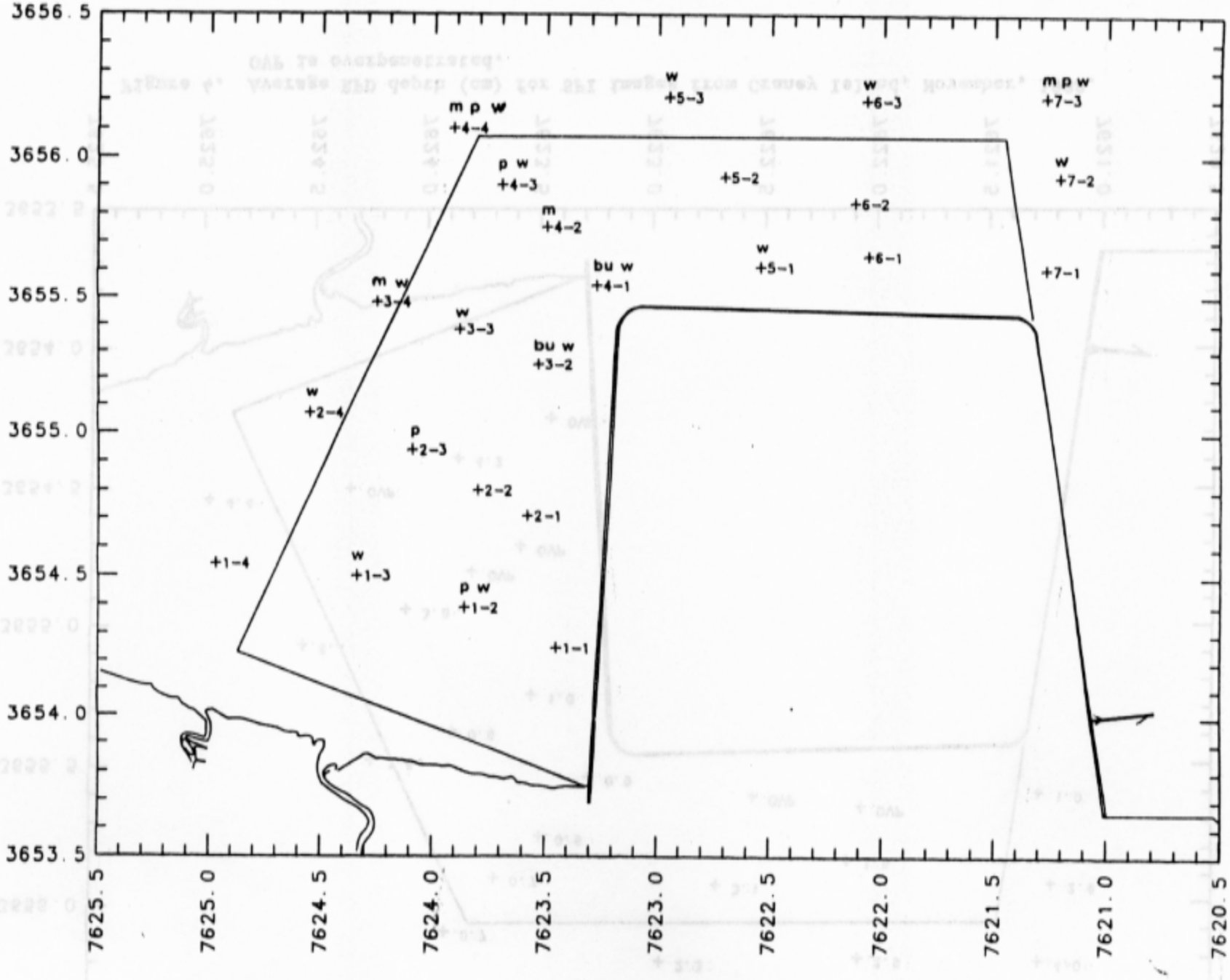


Figure 5. Evidence of biogenic activity from visual analysis of SPI images from Craney Island, November, 1988. bu = burrow, m = mound, p = pit, w = worm.

APPENDICES

Appendix I. Visual analysis of the SPI images from Craney Island, November, 198
Explanation of abbreviations is in Appendix II.

STATION	TIME	PENET-RATION	SEDI. LAYERS	SEDI. TYPE	SURFACE INTER.	TUBES	SUBSURFACE FAUNA	VOIDS	BURROW	BIOL. STATE	OTHER
CR1-1A	12:47	14		MU	U,D						6-8cm DIST. DM?
CR1-1B	12:48	OVP	COLOR	MU	-	-		1-?	-		lg,mg. DM?
CR1-1C	12:49	OVP		MU	-	-			-		lg DM?
CR1-2A	12:56	15		MU	U,P						SEDS SLIGHTLY DIST.
CR1-2B	12:57	OVP		MU	-	-	2WR>8	2-0	-		
CR1-2C	12:58	NO ANALYSIS - CAMERA PULLED OUT									
CR1-3A	1:04	OVP		MU	-	-			-		SEDS SLIGHTLY DIST.
CR1-3B	1:05	OVP		MU,C	-	-	1WR>8		-		SEDS SLIGHTLY DIST.
CR1-3C	1:06	OVP		MU	-	-		1-0	-		
CR1-4A	1:15	2		SF	E,C-A						
CR1-4B	1:16	7		SF	U,B						
CR1-4C	1:19	NO ANALYSIS - NO IMAGE									
CR2-4A	1:27	19		SI/MU	E		1WR@9				
CR2-4B	1:27	NO ANALYSIS - CAMERA PULLED OUT									
CR2-4C	1:28	OVP		SI/MU	-	-	1WR>5		-		
CR2-3A	1:36	12		SI/MU	E,P						
CR2-3B	1:36	18		SI/MU	E,C-A						
CR2-3C	1:37	18		SI/MU	E			3-0	1?		
CR2-2A	1:46	OVP	COLOR	MU	-	-			-		lg,mg. DM?
CR2-2B	1:47	OVP	COLOR	MU	-	-			-		lg,mg,dg. DM?
CR2-2C	1:48	OVP	COLOR	MU	-	-		1-0	-		lg,mg. DM?
CR2-1A	1:52	OVP	COLOR	MU	-	-			-		lg,mg,dg. DM?
CR2-1B	1:53	OVP	COLOR	MU	-	-			-		mg,lg. DM? SEDS DIST.
CR2-1C	1:54	OVP	COLOR	MU	-	-			-		lg/g,mg,lg. DM? SEDS DIST.
CR2-1D	1:55	NO ANALYSIS - CAMERA ANGLE IS WRONG									
CR3-4A	2:07	6		SF/SI	E		1WR@2	1-0			
CR3-4B	2:08	6		SF/SI	E,M				1		
CR3-4C	2:09	7		SI	E		1WR@5				
CR3-3A	2:15	10		SI	E		2WR@4	1-0			
CR3-3B	2:16	NO ANALYSIS - NO IMAGE									
CR3-3C	2:17	NO ANALYSIS - NO IMAGE									
CR3-2A	2:24	10		SI	U,BU				1		
CR3-2B	2:25	9		SI	E	?		2-0			HYDROIDS? ON SURF.
CR3-2C	2:25	8		SI	E	1?	1WR@3				
CR4-4A	2:35	8		SI/MU	E,C-A, P	1?	1WR@7				HYDROID STEM IN PIT?
CR4-4B	2:37	8		SI/MU	E		1WR@3				
CR4-4C	2:38	7		SI/MU	E,M	?					FP/PA ON SURF?
CR4-3A	2:41	10		SI/MU	U,P						
CR4-3B	2:42	7		SI/MU	E	FEW?	1WR@2	1-0			
CR4-3C	2:43	NO ANALYSIS - NO IMAGE									
CR4-2A	2:48	4		SI	U						
CR4-2B	2:49	5		SI	E			1-0			HYDROIDS IN BACKGROUND?
CR4-2C	2:50	13		MU?	U,M			2-0	1?		SEDS DIST.
CR4-1A	2:54	4		SI/CL?	U,C-A, BU?,P?	2?	1WR@3		1?		DIOPATRA TUBE? DM?
CR4-1B	2:55	4		SI,CL?	E,SH						DM?
CR4-1C	2:56	5		SI,CL?	U,BU, SH	1?			1		DM?

Appendix I (cont'd.)

STATION	TIME	PENET-RATION	SEDI. LAYERS	SEDI. TYPE	SURFACE INTER.	TUBES	SUBSURFACE FAUNA	VOIDS	BURROW	BIOL. STATE	OTHER
CR5-1A	3:04	OVP	COLOR	MU?	-	-			-		ALL lg. DM?
CR5-1B	3:06	OVP	COLOR	MU?	-	-			-		ALL lg. DM?
CR5-1C	3:06	OVP	COLOR	MU?	-	-			-		ALL lg. DM?
CR5-1D	3:07	OVP	COLOR	MU?	-	-			-		ALL lg. DM?
CR5-1E	3:09	11	COLOR	MU?	E,C-A		ZWR@4				SURF. DIST. ALL lg. DM?
CR5-2A	3:14	<1		SH?	U,SH,R						LITTLE PENETRATION
CR5-2B	3:15	6		SI	E,BU?			1-0	1?		
CR5-2C	3:16	<1		SH,R?	U,SH,R						LITTLE PENETRATION
CR5-3A	3:23	8		SI	E		IWR@6				
CR5-3B	3:24	5		SI	E			1-0			
CR5-3C	3:25	7		SF/SI	E						
CR6-3A	3:31	8		SI	U,P?		IWR@3				
CR6-3B	3:32	15		SI	U		IWR@7	3-0			
CR6-3C	3:33	5		SI	U,SH	1?					DIOPATRA TUBE? HYDROIDS?
CR6-2A	3:39	17	COLOR	MU	E						SEDS DIST. 1b,lg,mg. DM?
CR6-2B	3:39	18	COLOR	MU	E						SEDS DIST. 1b/g,lg. DM?
CR6-2C	3:40	17	COLOR	MU	E						SEDS DIST. 1b/g,lg. DM?
CR6-1A	3:46	OVP	COLOR	MU	-	-			-		ALL lg. DM?
CR6-1B	3:47	OVP	COLOR	MU	-	-			-		ALL lg. DM?
CR6-1C	3:48	OVP	COLOR	MU	-	-			-		ALL lg. DM?
CR7-3A	3:55	17		MU	U,P?	1?		2-0			
CR7-3B	3:56	12		MU	U,P?		IWR@6	1-0			
CR7-3C	3:57	11		MU	U,M			3-0			
CR7-2A	4:03	14		SI/MU	E			2-0			
CR7-2B	4:04	16		SI/MU	E		IWR@7	2-0			
CR7-2C	4:05	15		SI/MU	E			1-0			
CR7-1A	4:11	OVP	COLOR	MU	-			5G	-		lg,mg,dg. DM?
CR7-1B	4:12	OVP	COLOR	MU	-				-		SAME AS ABOVE
CR7-1C	4:14	14	COLOR	MU	E/U						ALL lg. DM? SURF SEDS SLIGHTLY DISTURBED.

Appendix II. List of abbreviations for visual analysis of SPI images.

THE FOLLOWING TERMS AND ABBREVIATIONS ARE USED IN VISUAL ANALYSIS OF SLIDES TAKEN BY THE SEDIMENT PROFILE CAMERA, AND RECORDING THE ANALYSIS ON THE SPI FORM. THIS LIST CAN ALSO BE USED FOR THE SURFACE SHOTS:

SURFACE CHARACTERISTICS

INTERFACE

- E - SMOOTH,EVEN - LESS THAN 1 CM OF RELIEF
- U - UNEVEN OR IRREGULAR - MORE THAN 1 CM OF RELIEF
- UNC - UNCONSOLIDATED, BROKEN UP
- SU - SOUPY, HIGH WATER CONTENT
- D - DISTURBED
- OVP - OVERPENETRATED
- ST - STREAKED (SURFACE SHOTS)
- C - CLASTS - NOTE AS:
  - O - OXIC (AEROBIC)
  - A - ANOXIC (ANEROBIC)
- M - MOUNDS
- B - BEDFORMS (SAND WAVES OR RIPPLES)
- P - PIT
- BU - BURROW OPENINGS
- GR - ROCKS AND/OR GRAVEL AT SURFACE

- F - FLOCK LAYER
- DT - DETRITUS
- FP - FECAL PELLETS PRESENT
- PA - FEEDING PALPS PRESENT
- SH - SHELLS, OR SHELL PIECES ON SURFACE

TUBES

- FEW - 1 TO <6
- SOME - 6 - 24
- MANY - >24
- MAT - VERY DENSE LAYER OF TUBES

SEDIMENT TYPE

- MU - MUD
- SI - SILT
- CL - CLAY
- S - SAND - NOTE AS:
  - C - COARSE
  - M - MEDIUM
  - F - FINE
- MS - MUDDY SAND
- GR - GRAVEL
- R - ROCKS
- SH - SHELL

Appendix II (cont'd.)

SUBSURFACE CHARACTERISTICS

FAUNA

- DEPTH FROM SURFACE
- NUMBER AND KIND(WR FOR WORM)

VOIDS - COUNT AND LABEL

O - OXIC (AEROBIC)
A - ANOXIC (ANEROBIC)
G - GAS BUBBLE, OR VOID (USUALLY METHANE)

BURROWS - COUNT

SEDIMENT COLOR LAYERS

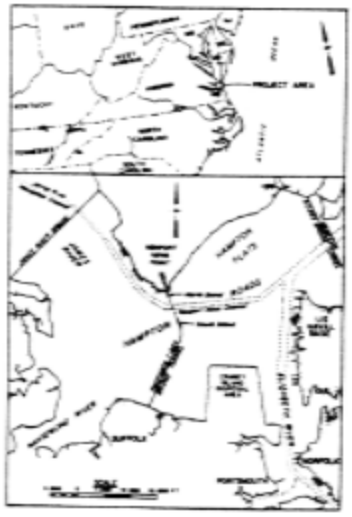
PRESENCE OF DIFFERENT COLOR LAYERS IN THE SEDIMENT ARE NOTED IN THE "SEDI. LAYERS" COLUMN, AND DESCRIBED IN THE "OTHER" COLUMN. LAYERS ARE DESCRIBED FROM TOP TO BOTTOM, SEPARATED BY COMMAS.

lg - LIGHT GREY
mlg - BETWEEN LIGHT AND MEDIUM GREY
mg - MEDIUM GREY
dg - DARK GREY
lb - LIGHT BROWN
mb - MEDIUM BROWN
bl - BLACK
lblu - LIGHT BLUE

s - DENOTES THE LAYER AS SOUPY (HIGH WATER CONTENT), i.e. sdg
lg/mg - DENOTES A MIXED LAYER, NOT CLEARLY DEFINED AS ONE OR THE OTHER, BUT DEFINEABLE AS A SEPARATE LAYER

ATTACHMENT 5

US Army Corps of Engineers



HYDRAULICS LABORATORY

TECHNICAL REPORT HL-89-12

NEWPORT NEWS CHANNEL DEEPENING STUDY, VIRGINIA

Numerical Model Investigation

by

Hsin-Chi J. Lin, William D. Martin

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39181-0631

June 1989

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Approved For Public Release; Distribution Unlimited

Prepared for Norfolk District Corps of Engineers
Norfolk, Virginia 23510-1096

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I-664 James River Bridge-Tunnel
James River
Lower James River
Numerical modeling

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

This report presents results from the numerical model investigation whose primary objective was to evaluate general changes in circulation, currents, and sedimentation associated with the overdeepening of the Newport News Channel. An additional objective of the study was to assess the effects of the overdeepening on the reported estuarine circulation cell (flow convergence) off Hampton Flats and Newport News Point. Three alternative plans of overdeepening, 57, 64, and 70 ft, were evaluated.

This numerical model investigation used the TABS-2 finite element numerical models RMA-2V for hydrodynamic analysis and STUDH for sediment transport computation with a modified version of an existing numerical mesh (expansion plan B) of the Lower James River.

(Continued)

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19. ABSTRACT (Continued).

Results from the numerical hydrodynamic modeling indicated no velocity increases in the Willoughby Bay area. The maximum velocity change identified in the Hampton Flats area was less than 0.1 fps during the maximum flood tide. The maximum velocity change in the channel was 0.2 fps. No circulation changes were identified in the base-to-plan comparison of velocity vector plots. Additionally, no change in tidal phasing or water-surface elevation was detected. The formation and location of the two-dimensional circulation cell off Newport News Point were unaffected by any of the plans.

Results from the sedimentation modeling showed that a maximum decrease in shoaling in the Hampton Flats area was about 7 percent, a maximum increase in shoaling in the Newport News Channel was less than 1 percent, and a maximum increase in shoaling in the Willoughby Bay areas was about 6 percent. The various deepening plans resulted in a redistribution of sediments with a net loss over the Hampton Flats area and a net increase in the Willoughby Bay area. The channel will experience a slow rate of shoaling due to the overdeepening. However, all changes in sedimentation were small in absolute volumes.

The reported frontal effect off Newport News Point is a three-dimensional density current-driven phenomenon and cannot be quantified within the two-dimensional analysis. However, no evidence was generated by this study that would indicate that the channel overdeepening will affect the front formation or propagation.

PREFACE

In December 1988, the Norfolk District Corps of Engineers requested that the US Army Engineer Waterways Experiment Station (WES) conduct an investigation to assess general changes in circulation, currents, and sedimentation associated with three proposed overdeepening plans for the Newport News Channel between the I-664 Bridge-Tunnel crossing and the Hampton Roads Bridge-Tunnel crossing.

The study was conducted by personnel of the Hydraulics Laboratory, WES, under the general direction of Messrs. F. A. Herrmann, Jr., Chief of the Hydraulics Laboratory; R. A. Sager, Assistant Chief of the Hydraulics Laboratory; W. H. McAnally, Jr., Chief of the Estuaries Division; and W. D. Martin, Chief of the Estuarine Engineering Branch. The study was conducted by Dr. Hsin-Chi J. Lin, with technical consultation supplied by Messrs. S. B. Heltzel and M. A. Granat, all of the Estuarine Engineering Branch. This report was prepared by Mr. Martin and Dr. Lin and edited by Mrs. Marsha C. Gay of the Information Technology Laboratory, WES.

Acting Commander and Director of WES during preparation of this report was LTC Jack R. Stephens, EN. Technical Director was Dr. Robert W. Whalin.

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Finite Element Modeling	A2
The Hydrodynamic Model, RMA-2V	A4
The Sediment Transport Model, STUDH	A7
References	A15

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic feet	0.02831685	cubic metres
feet	0.3048	metres
pounds (force)-second per foot per foot	47.88026	pascals-second

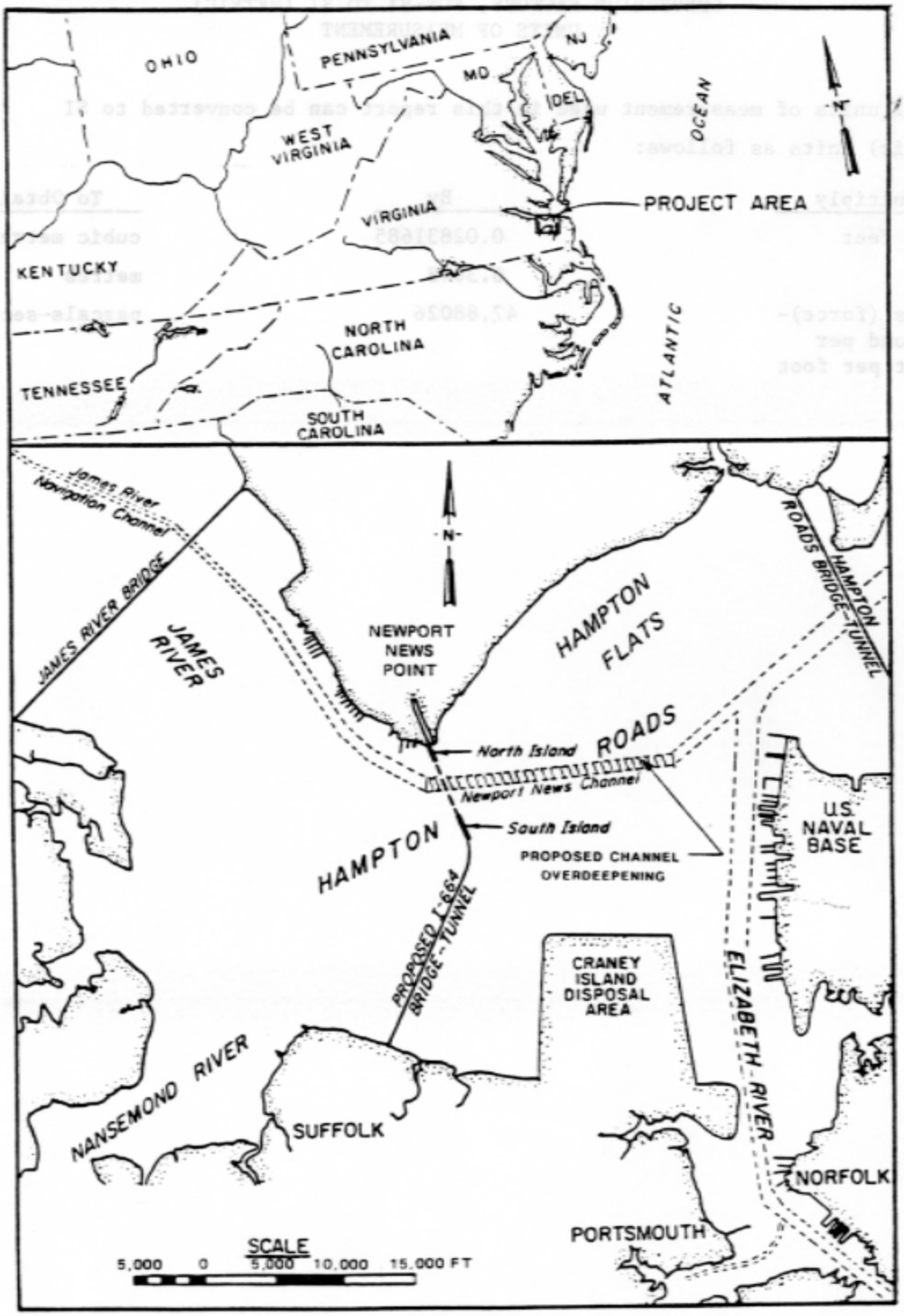

Figure 1. Project location

NEWPORT NEWS CHANNEL DEEPENING STUDY, VIRGINIA

Numerical Model Investigation

PART I: INTRODUCTION

Background

1. The deepening of the Newport News Channel from 45 to 55 ft* was studied by the US Army Engineer Waterways Experiment Station (WES) as a portion of the Norfolk Harbor and Channels deepening study (Richards and Morton 1983). That study was conducted on the Chesapeake Bay physical model located on Kent Island in Matapeake, MD.

2. The effects on sedimentation of this deepening were also investigated by WES using the hybrid modeling approach. This approach combined the physical model results with a numerical analysis using the WES TABS-2 system of numerical models (Berger et al. 1985).

3. Other WES studies in this area evaluated the effects of the I-664 Bridge-Tunnel crossing (Heltzel 1988) and the enlargement of the Craney Island disposal area (Heltzel and Granat 1988 and Bottin 1984).

4. To expand the Craney Island facility, a levee is to be constructed using expansion Plan B (Heltzel and Granat 1988). The Norfolk District Corps of Engineers wished to investigate obtaining the material to construct the levee by overdeepening the Newport News Channel between the I-664 crossing and the Hampton Roads Bridge-Tunnel crossing (Figure 1) from the current depth of 55 ft. Three alternative depths of 57, 64, and 70 ft were evaluated.

Purpose

5. The objective of this study was to use available numerical models to evaluate general changes in circulation, currents, and sedimentation associated with the overdeepening of the Newport News Channel. Additionally, the effects of the overdeepening on the reported estuarine circulation cell (flow

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* A table of factors for converting non-SI units of measurement to SI (metric) units of measurement is found on page 3.

convergence) off Hampton Flats and Newport News Point was to be assessed.

Scope

6. The numerical modeling was designed to evaluate relative changes in hydrodynamics and sedimentation adjacent to the study area. The sedimentation comparisons focused on two areas adjacent to the Newport News Channel and the deepened portion of the channel. The off-channel areas were designated A and B and were the same as those reported by Heltzel and Granat (1988). These zones are shown in Figure 2. In these relatively low velocity areas, the sediment study focused on changes in cohesive sediment transport. The channel comparisons were made in an area of relatively high velocities and focused on noncohesive sediment transport.

7. The circulation cell off Newport News Point and Hampton Flats was addressed by comparing study results with previously compiled data on the phenomenon (Heltzel and Granat 1988).

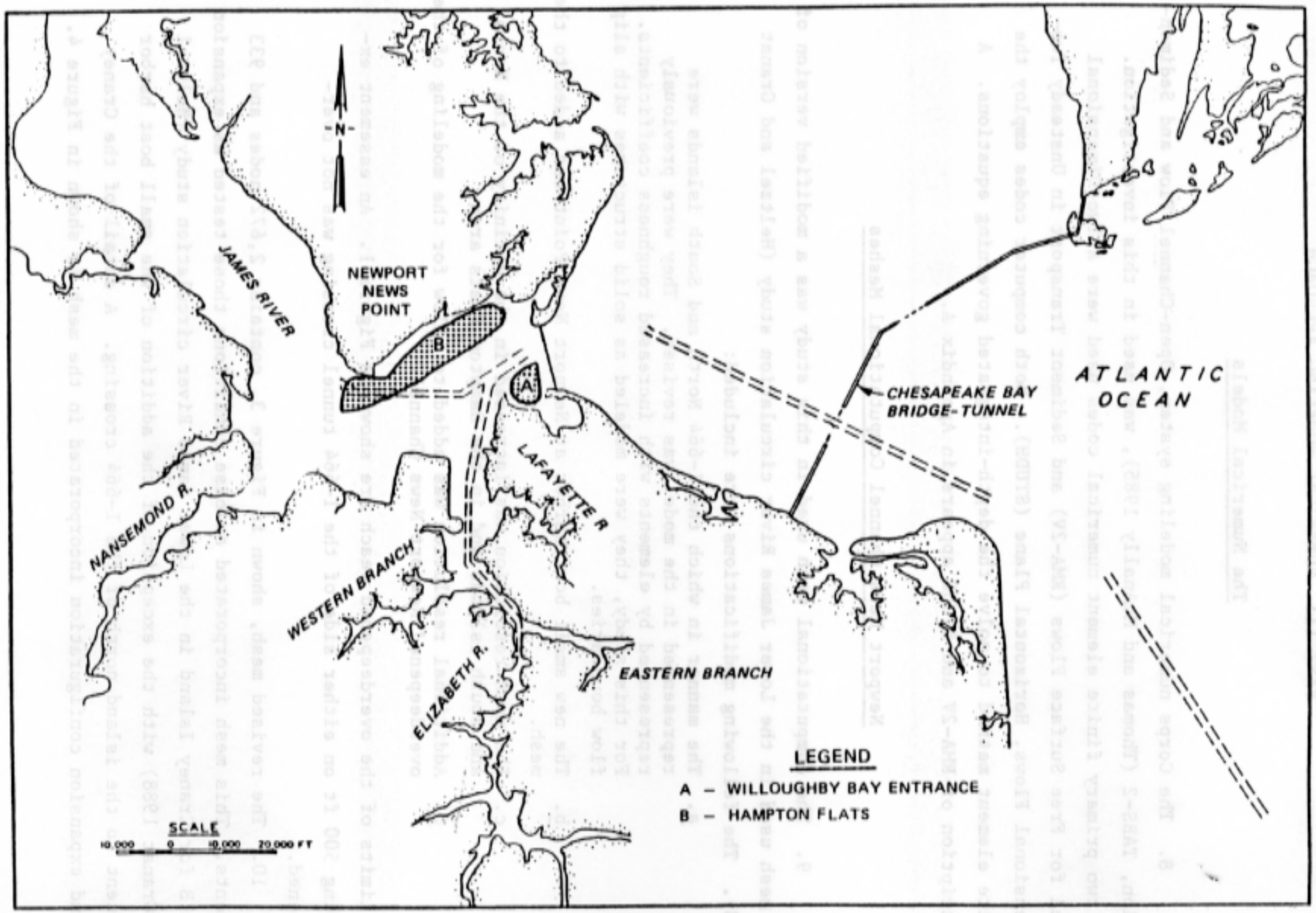


Figure 2. Critical sedimentation zones of interest

PART II: NUMERICAL MODELING APPROACH

The Numerical Models

8. The Corps numerical modeling system, Open-Channel Flow and Sedimentation, TABS-2 (Thomas and McAnally 1985), was used in this investigation. The two primary finite element numerical codes used were A Two-Dimensional Model for Free Surface Flows (RMA-2V) and Sediment Transport in Unsteady Two-Dimensional Flows, Horizontal Plane (STUDH). Both computer codes employ the finite element method to solve the depth-integrated governing equations. A description of RMA-2V and STUDH appears in Appendix A.

Newport News Channel Computational Meshes

9. The computational mesh used in this study was a modified version of the mesh used in the Lower James River circulation study (Heltzel and Granat 1988). The following modifications were included:

- a. The manner in which the I-664 North and South islands were represented in the model was revised. They were previously represented by elements with increased roughness coefficients. For this study, they were modeled as solid structures with slip flow boundaries.
- b. The new small boat harbor at Newport News Point was added to the mesh.
- c. The mesh resolution was increased in the vicinity of the North and South islands and in the Hampton Flats area.
- d. Additional resolution was added to allow for the modeling of the overdeepened Newport News Channel.

The limits of the overdeepened reach are shown in Figure 1. An easement extending 500 ft on either side of the I-664 tunnel crossing was not overdeepened.

10. The revised mesh, shown in Figure 3, contains 2,672 nodes and 933 elements. This mesh incorporated as base conditions those tested as expansion Plan B for Craney Island in the Lower James River circulation study (Heltzel and Granat 1988) with the exception of the addition of the small boat harbor adjacent to the island north of the I-664 crossing. A detail of the Craney Island expansion configuration incorporated in the mesh is shown in Figure 4.

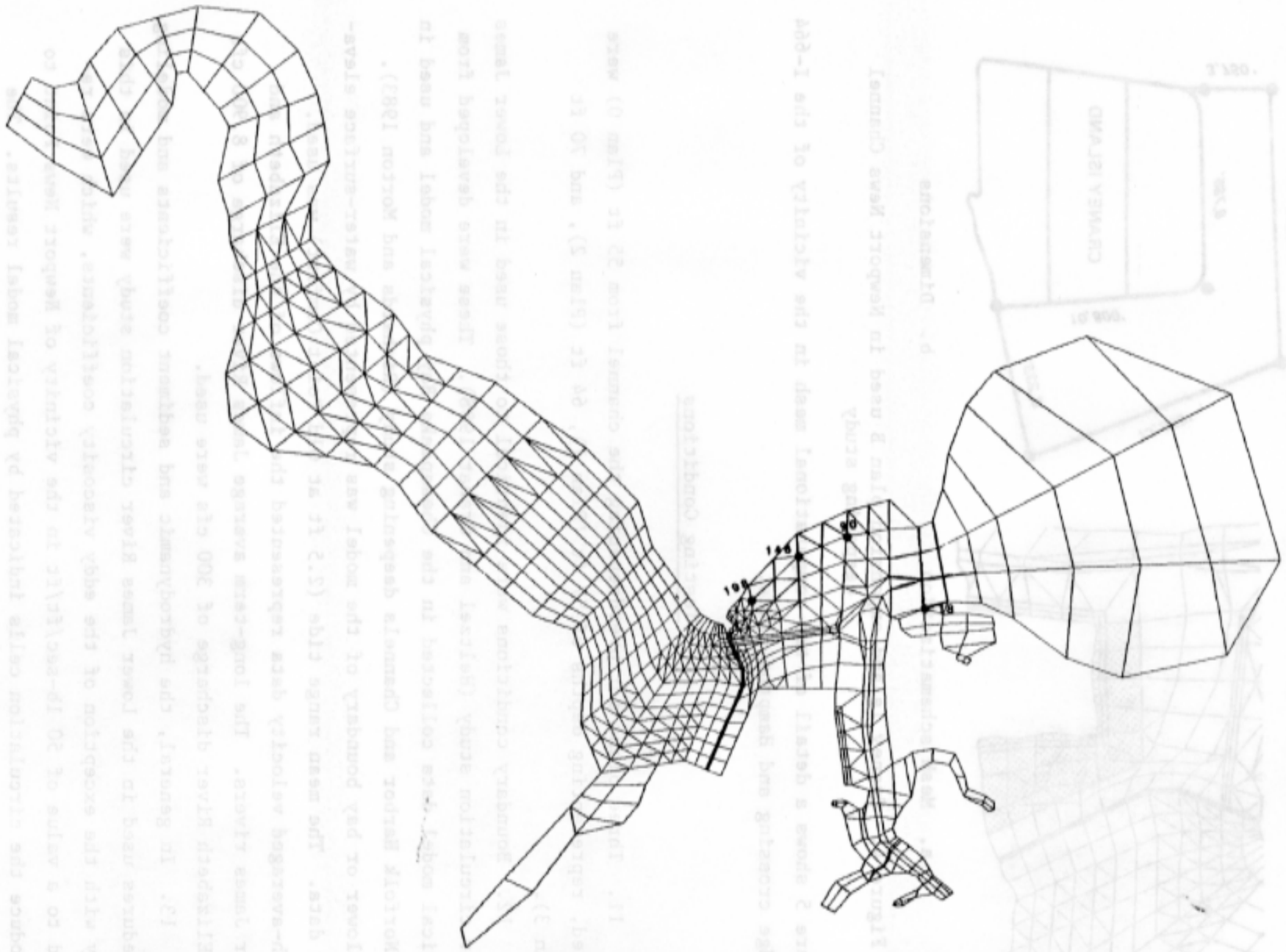
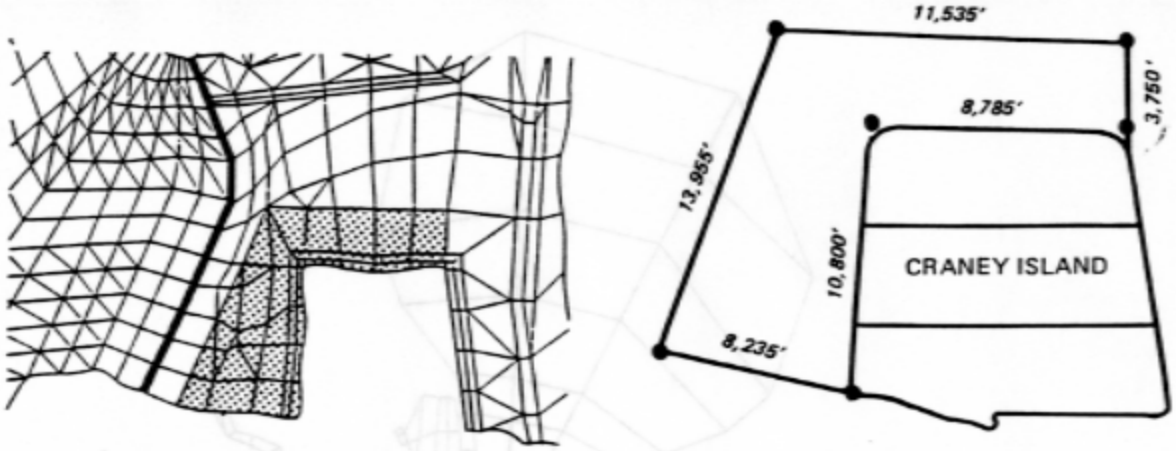


Figure 3. Numerical model mesh for Newport New Channel Deepening Study



a. Mesh schematization b. Dimensions

Figure 4. Craney Island expansion plan B used in Newport News Channel deepening study

Figure 5 shows a detail of the computational mesh in the vicinity of the I-664 bridge crossing and Hampton Flats.

Testing Conditions

11. Three plans for overdeepening the channel from 55 ft (Plan 0) were tested, representing depths of 57 ft (Plan 1), 64 ft (Plan 2), and 70 ft (Plan 3).

12. Boundary conditions were identical to those used in the Lower James River circulation study (Heltzel and Granat 1988). These were developed from physical model data collected in the Chesapeake Bay physical model and used in the Norfolk Harbor and Channels deepening study (Richards and Morton 1983). The lower or bay boundary of the model was represented by water-surface elevation data. The mean range tide (2.5 ft at Old Point Comfort) was used. Depth-averaged velocity data represented the inflows of the Elizabeth and Upper James rivers. The long-term average James River discharge of 8,900 cfs and Elizabeth River discharge of 300 cfs were used.

13. In general, the hydrodynamic and sediment coefficients and modeling procedures used in the Lower James River circulation study were used in this study with the exception of the eddy viscosity coefficients, which were relaxed to a value of 50 lb-sec/ft/ft in the vicinity of Newport News Point to reproduce the circulation cells indicated by physical model results. The Plan B expansion scheme from the Lower James study was reactivated and tested

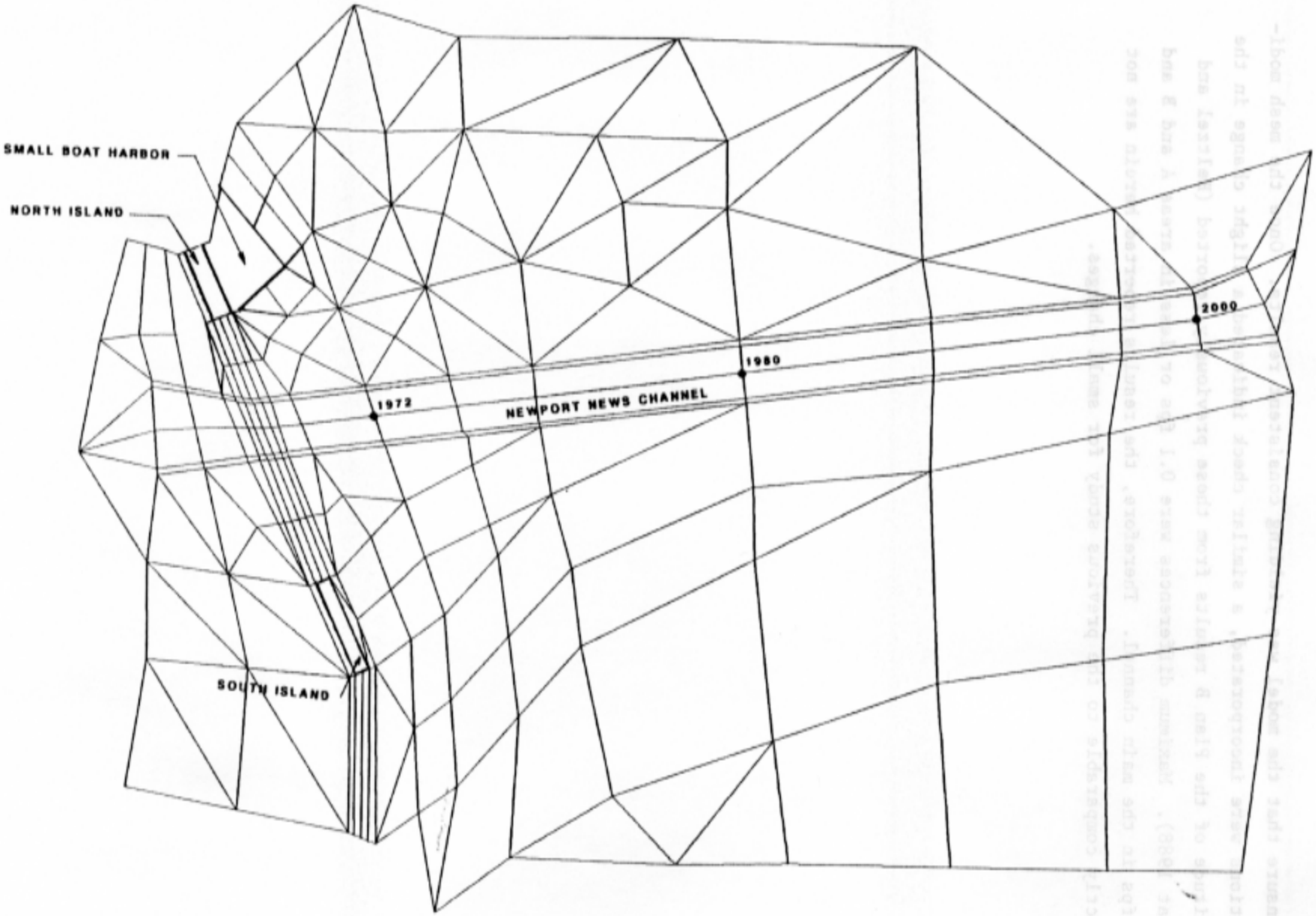


Figure 5. Numerical model mesh, vicinity of Hampton Flats

to ensure that the model was yielding consistent results. Once the mesh modifications were incorporated, a similar check indicated a slight change in the magnitude of the Plan B results from those previously reported (Heltzel and Granat 1988). Maximum differences were 0.1 fps or less in areas A and B and 0.3 fps in the main channel. Therefore, the results reported herein are not directly comparable to the previous study for small changes.

PART III: MODELING RESULTS AND DISCUSSION

Hydrodynamic Results

14. The channel overdeepening resulted in no discernible change in the two-dimensional circulation patterns in the Lower James River. The addition of the small boat harbor and the increased mesh resolution resulted in a more clearly defined eddy over the Hampton Flats off Newport News Point than that previously reported (Heltzel and Granat 1988) during the period around slack before flood (hours 15, 16, and 17). Detailed vector plots for hours 15, 16, 17, and 18 for each plan are shown in Plates 1-16.

15. Figures 3 and 5 show the location of seven nodes that were used for comparison of the three deepening plans. Differences in the magnitudes of the maximum ebb and flood velocities for the base and the three plans were compared, and the results are summarized in Table 1. Node 18 is located in the center of the Willoughby Bay area of interest. Nodes 90, 146, and 198 are located in the Hampton Flats area. Nodes 1972, 1980, and 2000 are located in the Newport News Channel proper.

16. As can be seen in Table 1, there was no difference in the velocity magnitudes for any of the plans tested in the Willoughby Bay area. Plans 1 and 2 had virtually no effect on the velocities in the Hampton Flats area. Plan 3 showed a slight but measurable decrease in velocities of the flats, the maximum decrease being less than 0.1 fps at node 198. Velocities in the Newport News channel were uniformly reduced, as would be expected, by the channel overdeepening. The maximum reduction in ebb velocity was 0.2 fps at node 1972. The maximum decrease in flood velocity was 0.1 fps at node 1972.

17. Plates 17 and 18 illustrate the time-history plots of the ebb and flood velocities for the selected nodes comparing Plan 0 (55-ft depth) with Plan 1 (57-ft depth). It can be seen that these plots are virtually identical. Plates 19 and 20 illustrate the same comparison for Plan 0 and Plan 2 (64-ft depth). Only slight reductions in the ebb and flood velocities were noted for nodes 1972 and 2000, both of which are located in the channel proper. Plates 21 and 22 illustrate the comparison for Plan 0 and Plan 3 (70-ft depth). Again, little discernible change in velocities is observed outside the channel area, while slight reductions were observed at nodes 1972, 1980, and 2000 in the channel.

18. Water-surface elevations were also compared for the base and three plan deepenings. These time-histories were identical for each comparison, indicating no effect on water-surface elevations or phasing of the tide. These plots are, therefore, not included in this report.

Sediment Results

19. The approach to analyzing the sediment results consisted of qualitative comparisons between the base (Plan 0) and the three deepening plans. The procedure followed and parameters selected duplicated those used in the I-664 Bridge-Tunnel study (Heltzel 1988).

20. The areas with relatively low velocity that were of interest in Willoughby Bay and Hampton Flats were analyzed using cohesive sediment modeling techniques. The higher velocity areas in the channel proper were analyzed using noncohesive sediment modeling techniques.

21. The sediment analysis was limited to three areas, area A (see Figure 2) in Willoughby Bay, area B in Hampton Flats, and the overdeepened portion of the Newport News Channel. For reporting purposes, the predicted shoaling volume for each element in the zone of interest was combined to produce a cumulative rate for each area. The plan rate was then divided by the base (Plan 0) rate to produce a shoaling index, which could then be used as a basis for comparison between the plans. The results of this comparison are summarized in the following tabulation. Plans 1 and 2 showed a slight increase in shoaling in the Willoughby Bay area. Plan 3 indicated a 6 percent increase in shoaling. All plans showed a decrease in shoaling in the Hampton Flats area, with the maximum decrease being 7 percent. The Newport News Channel showed very slight increases in the shoaling rate, the increases amounting to less than 1 percent.

	Shoaling Index*		
Area	Plan 1	Plan 2	Plan 3
A	1.01	1.03	1.06
B	0.93	0.94	0.95
Newport News Channel	1.00+	1.00+	1.00+

* 1.00+ indicates amount less than 1 percent.

22. The deepening will cause a redistribution of concentrations of cohesive sediments that will account for generally decreased shoaling in the Hampton Flats area and increased shoaling in the Willoughby Bay area. It should be pointed out that the increases are reported as percentages and represent relatively small absolute increases in shoaling. Reduced velocities in the channel proper and a small but definite tendency to shoal will result in a gradual filling of the overdeepened areas and an eventual return to base conditions.

PART IV: ESTUARINE CIRCULATION AND FLOW CONVERGENCE: HAMPTON FLATS AND NEWPORT NEWS POINT

23. A previous WES report (Heltzel and Granat 1988) summarized the information available regarding the estuarine circulation and flow convergence observed off Newport News Point and the Hampton Flats. This summary included information from previous model studies, both physical and numerical (Brogdon and Bobb 1967,* Heltzel 1988), data collected by the Virginia Institute for Marine Sciences (VIMS) (Byrne et al. 1987), and WES field data collected in 1986.

24. The potential impacts to the reported frontal system, a three-dimensional phenomenon, cannot be quantified with information from either past or present studies. However, inferences can be drawn from the present two-dimensional study.

25. Based on the hydrodynamic results, there will be no discernible changes in two-dimensional circulation patterns in the area off Newport News Point or over the Hampton Flats due to the channel overdeepening. Velocity magnitudes will decrease by such a small amount that the impacts of this change should also be negligible. The tide phasing and elevations were also unaffected by the deepening.

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* N. J. Brogdon, Jr., and W. H. Bobb. 1967. "Effects of Proposed Waterfront Developments at Newport News Point on Tides, Currents, Salinities, and Shoaling," Draft Report, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

PART V: CONCLUSIONS

26. Comparisons of base and channel velocities for overdeepening plans indicate no velocity increases in the Willoughby Bay area. The maximum velocity change identified in the Hampton Flats area was a less than 0.1-fps decrease in the maximum flood tide velocity. Velocities in the channel proper decreased a maximum of 0.2 fps.

27. No circulation changes were identified in base-to-plan comparisons of vector plots. Additionally, no change in tidal phasing or water-surface elevations was detected.

28. Qualitatively, the various deepening plans resulted in a redistribution of cohesive sediments with a net loss over the Hampton Flats area and a net increase in the Willoughby Bay area. The channel will experience a slow rate of shoaling due to the overdeepening. However, all changes in sedimentation were small in absolute volumes.

29. The formation and location of the two-dimensional circulation cell off Newport News Point were unaffected by any of the plans addressed.

30. The reported frontal effect off Newport News Point is a three-dimensional density current-driven phenomenon and cannot be quantified within the scope of this two-dimensional analysis. However, no evidence was generated by this study that would indicate that the channel overdeepening will affect the frontal formation or propagation.

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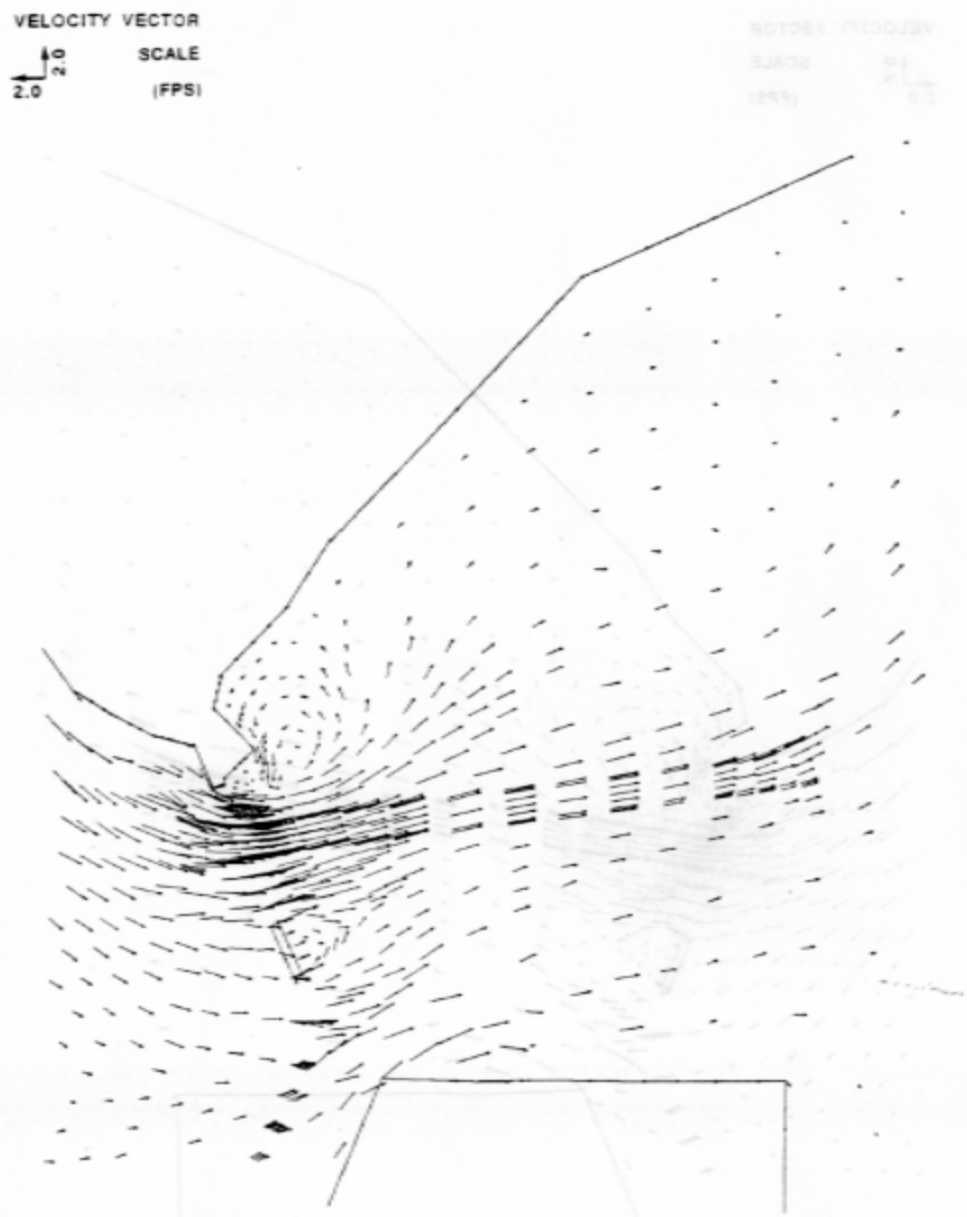
Table 1

Maximum Velocity Changes at Selected Nodes, fps

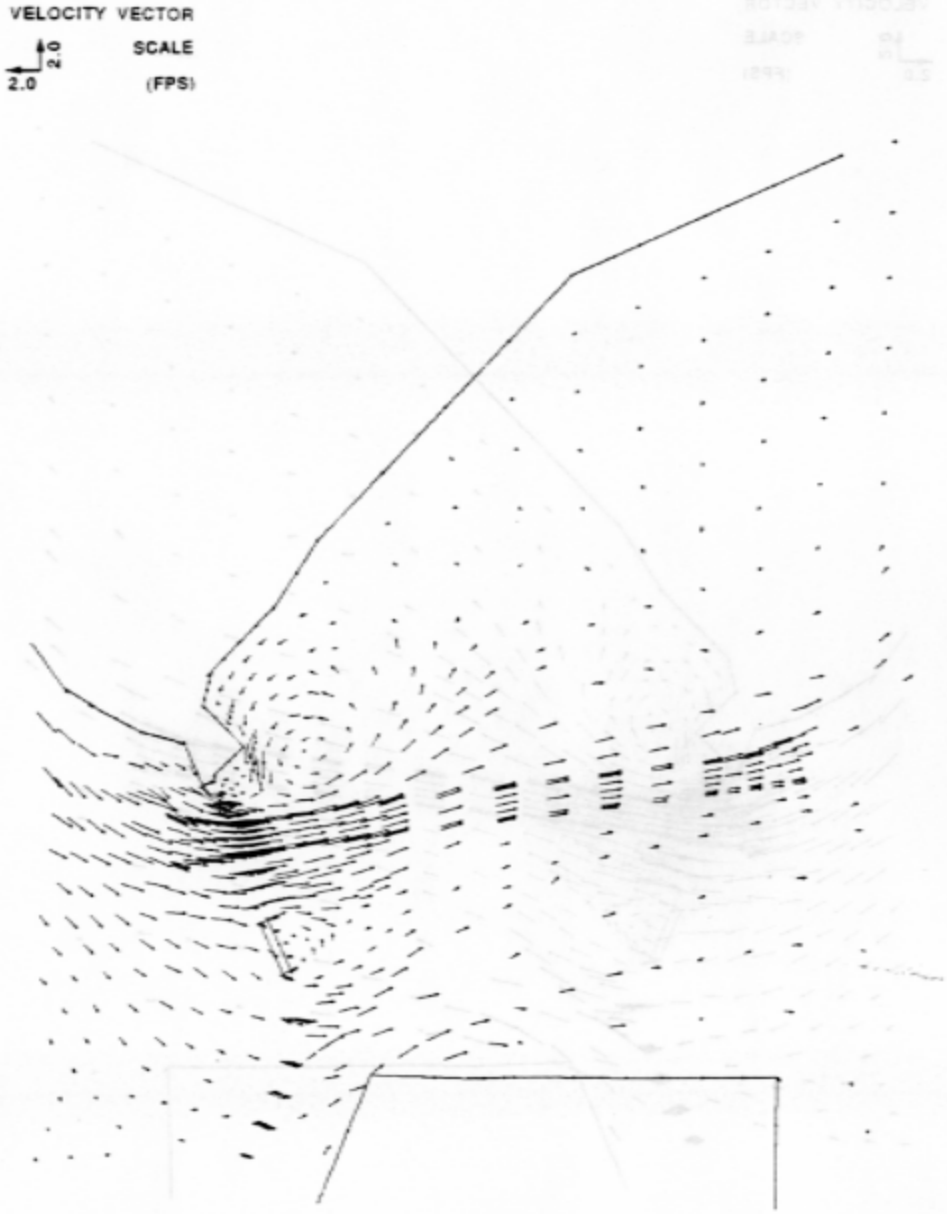
(Plan Minus Base)

Area	Node No.	Plan 0 Velocity		Change, Plan Minus Base					
				Plan 1		Plan 2		Plan 3	
		Ebb	Flood	Ebb	Flood	Ebb	Flood	Ebb	Flood
Willoughby Bay (area A)	18	0.77	0.75	0.0	0.0	0.0	0.0	0.0	0.0
Hampton Flats (area B)	90	0.58	0.62	0.0	0.0	0.0	T+	0.0	T+
	146	0.64	0.60	0.0	0.0	0.0	0.0	0.0	0.0
	198	0.83	0.85	0.0	0.0	T-	T-	T-	T-
Newport News Channel	1972	2.53	1.94	-0.1	T-	-0.1	-0.1	-0.2	-0.1
	1980	1.80	1.58	0.0	0.0	T-	T-	T-	T-
	2000	1.20	1.07	0.0	T-	T-	T-	T-	-0.1

Note: Velocities rounded to nearest 0.1 fps.
T+ or T- indicates values less than 0.1 fps.

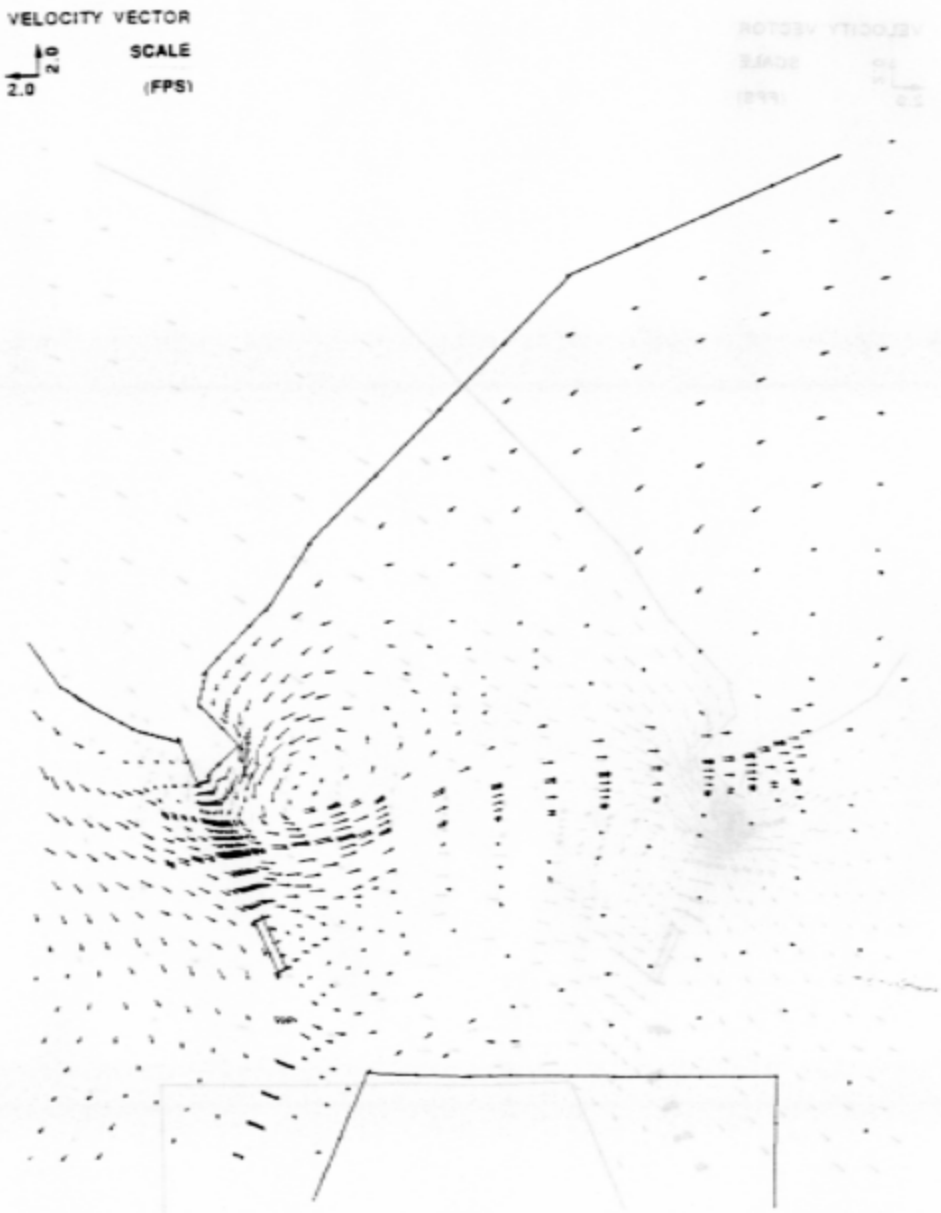


DEEPENING PLAN 0
(55-FT DEPTH)
EXPANSION PLAN B
HOUR 15

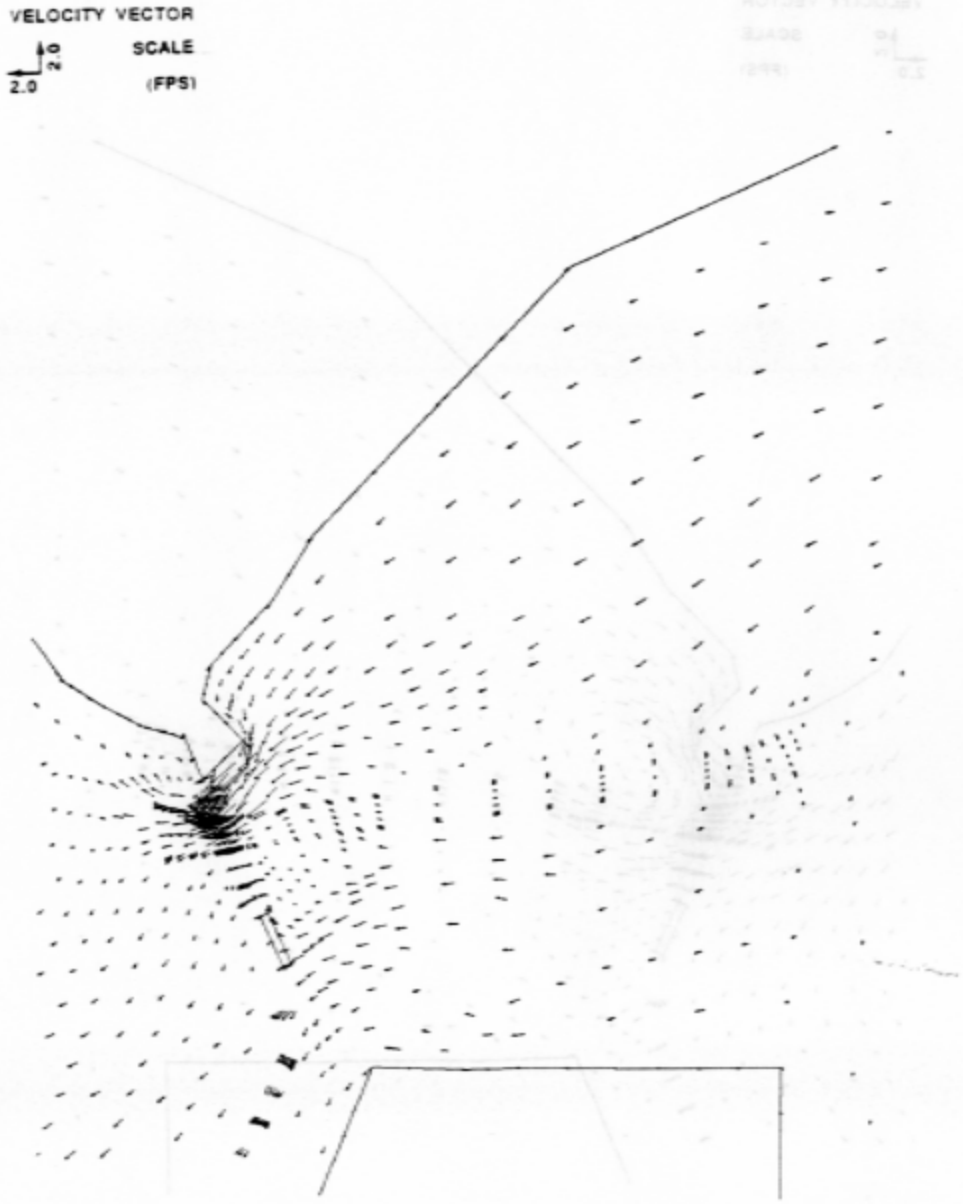


DEEPENING PLAN 0
(55-FT DEPTH)
EXPANSION PLAN B
HOUR 16

PLATE 2

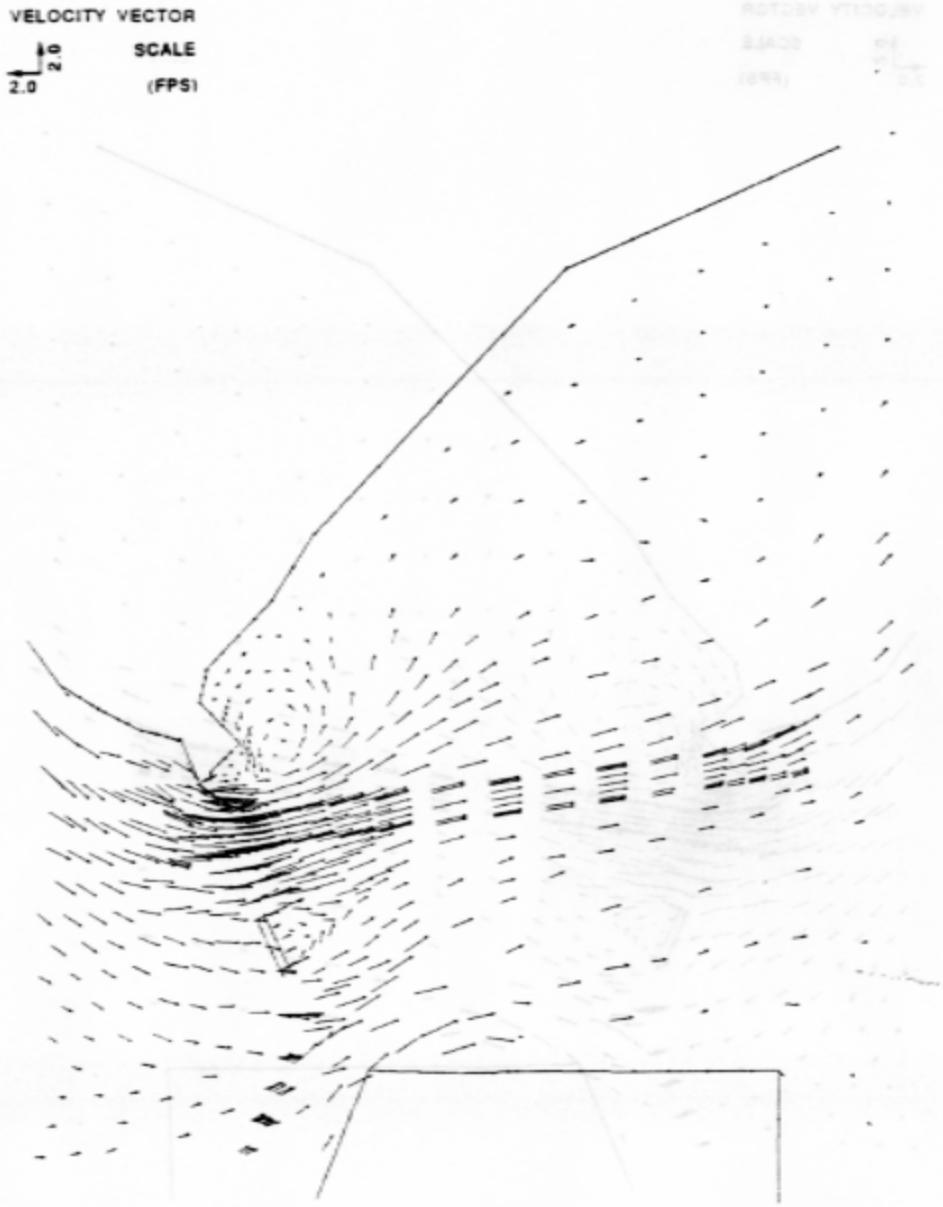


DEEPENING PLAN 0
(55-FT DEPTH)
EXPANSION PLAN B
HOUR 17

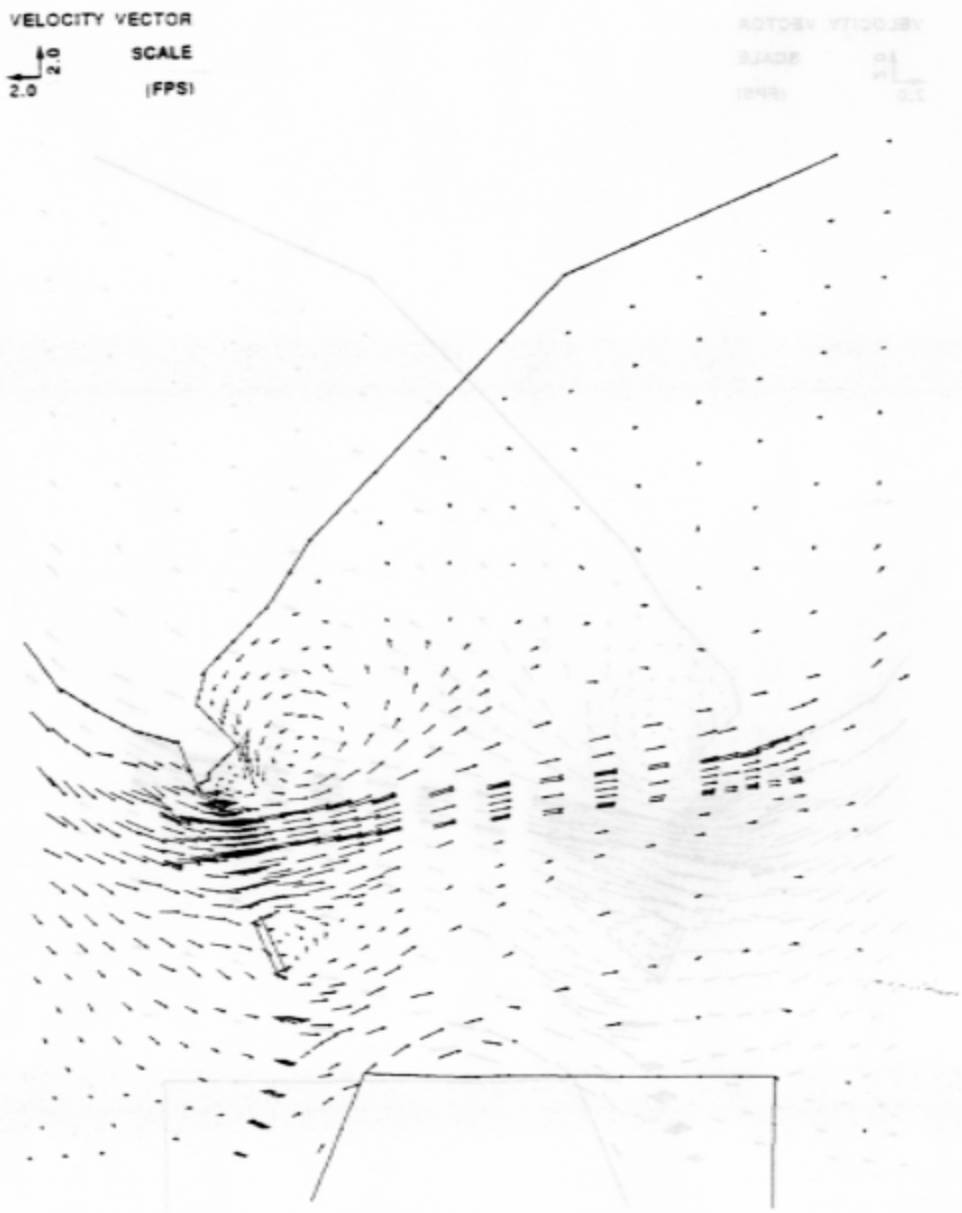


DEEPENING PLAN 0
(55-FT DEPTH)
EXPANSION PLAN B
HOUR 18

PLATE 4

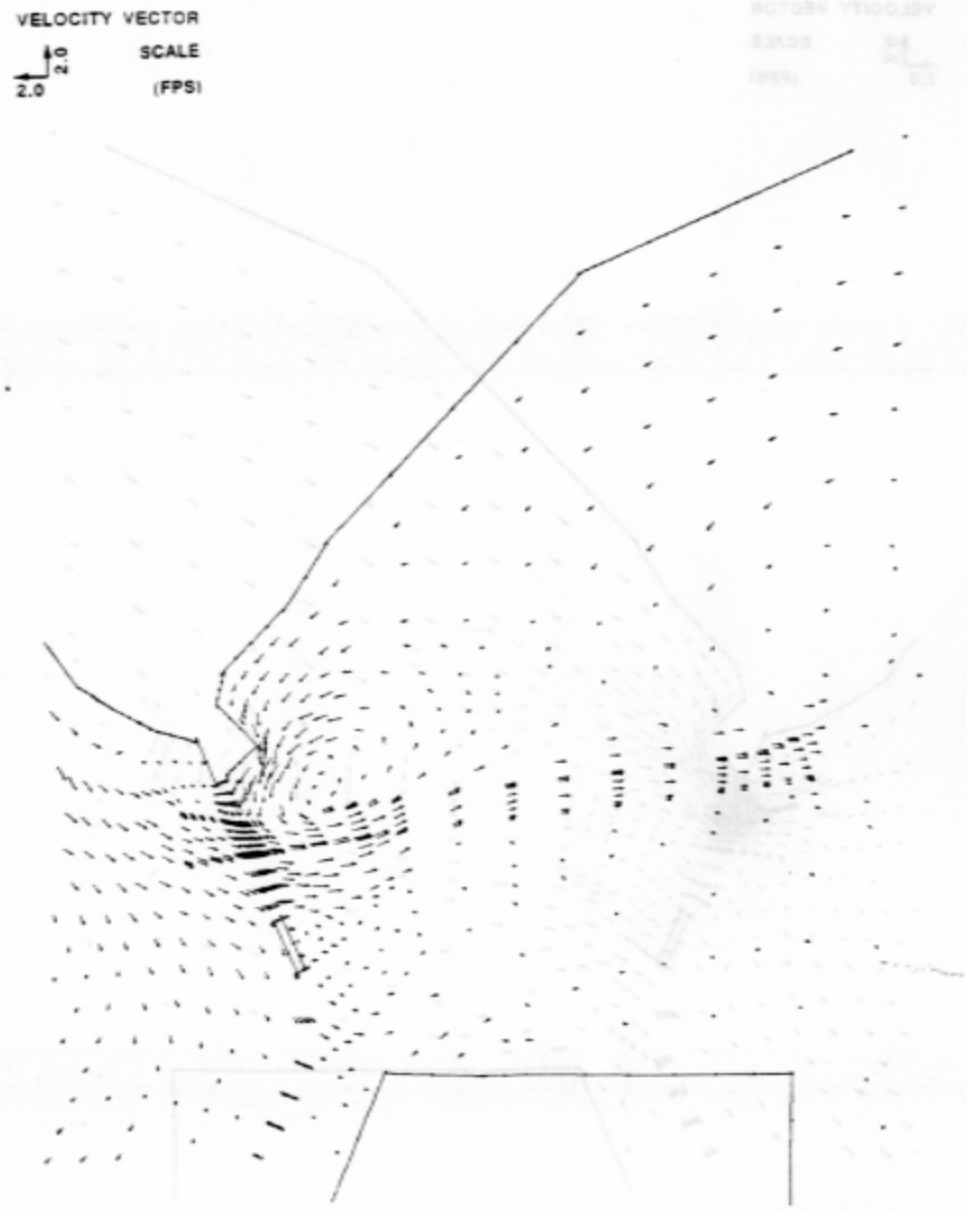


DEEPENING PLAN 1
(57-FT DEPTH)
EXPANSION PLAN B
HOUR 15



DEEPENING PLAN 1
(57-FT DEPTH)
EXPANSION PLAN B
HOUR 16

PLATE 6



DEEPENING PLAN 1
(57-FT DEPTH)
EXPANSION PLAN B
HOUR 17

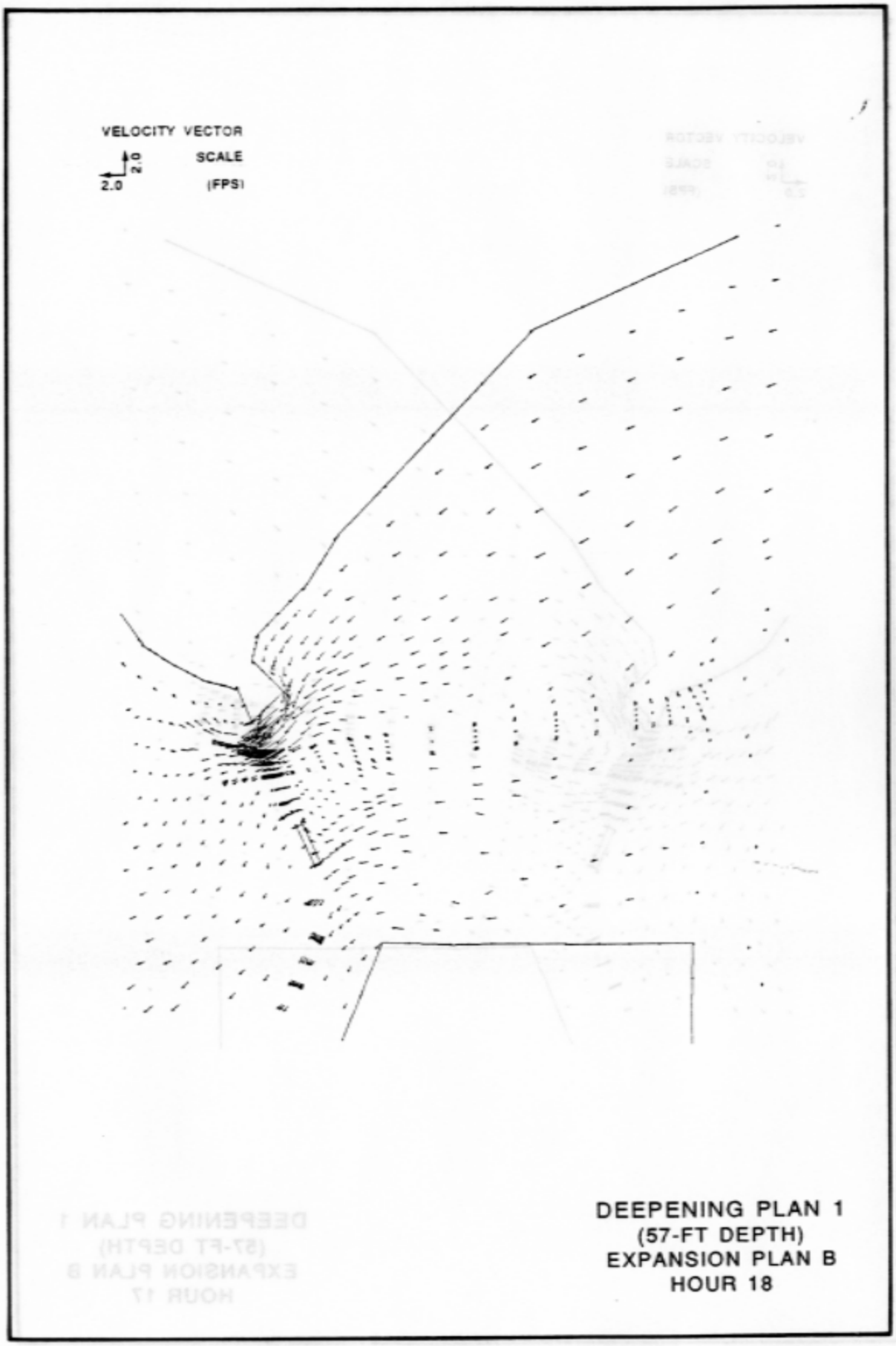
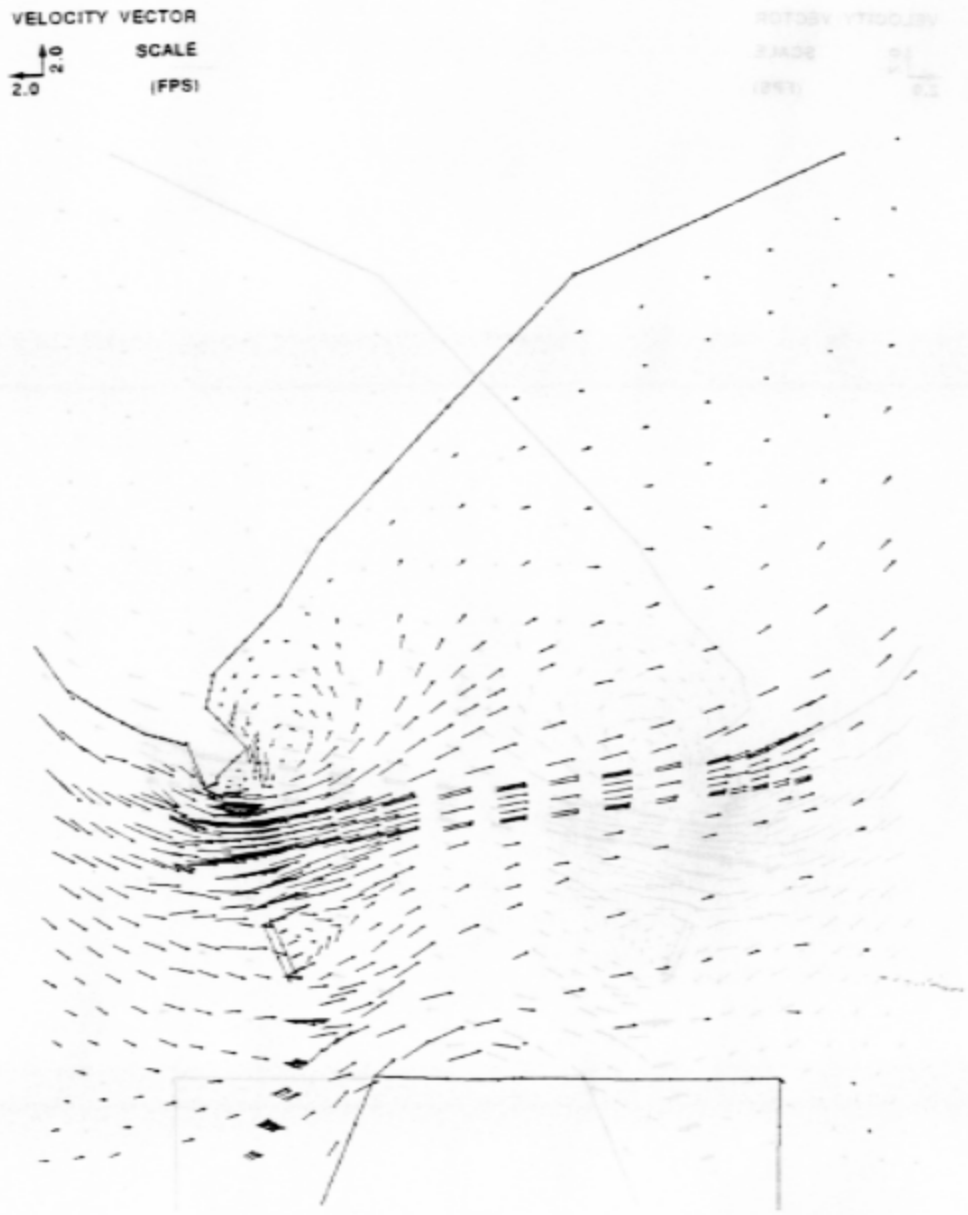
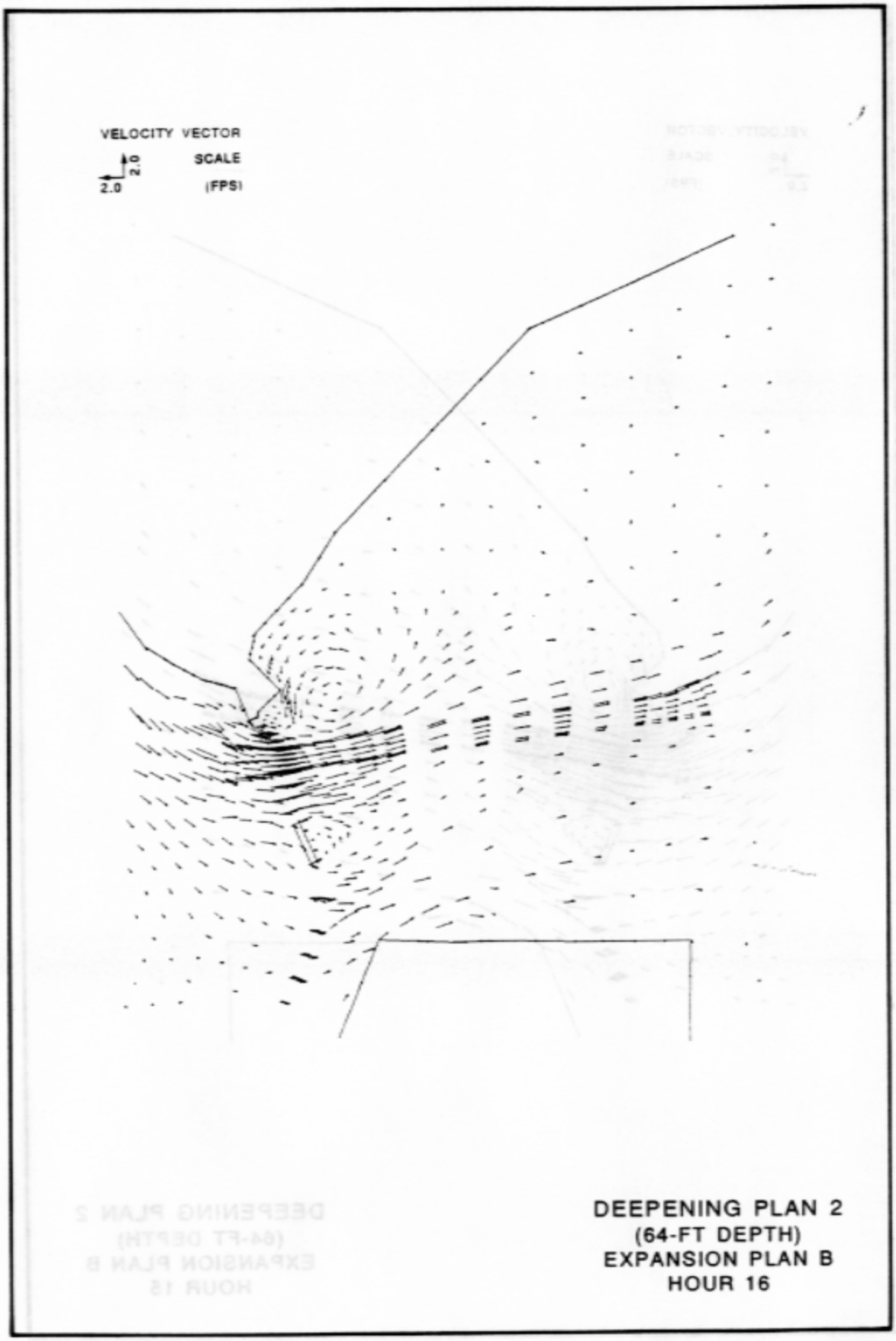

VELOCITY VECTOR
SCALE
2.0
(FPS)
DEEPENING PLAN 1
(57-FT DEPTH)
EXPANSION PLAN B
HOUR 18

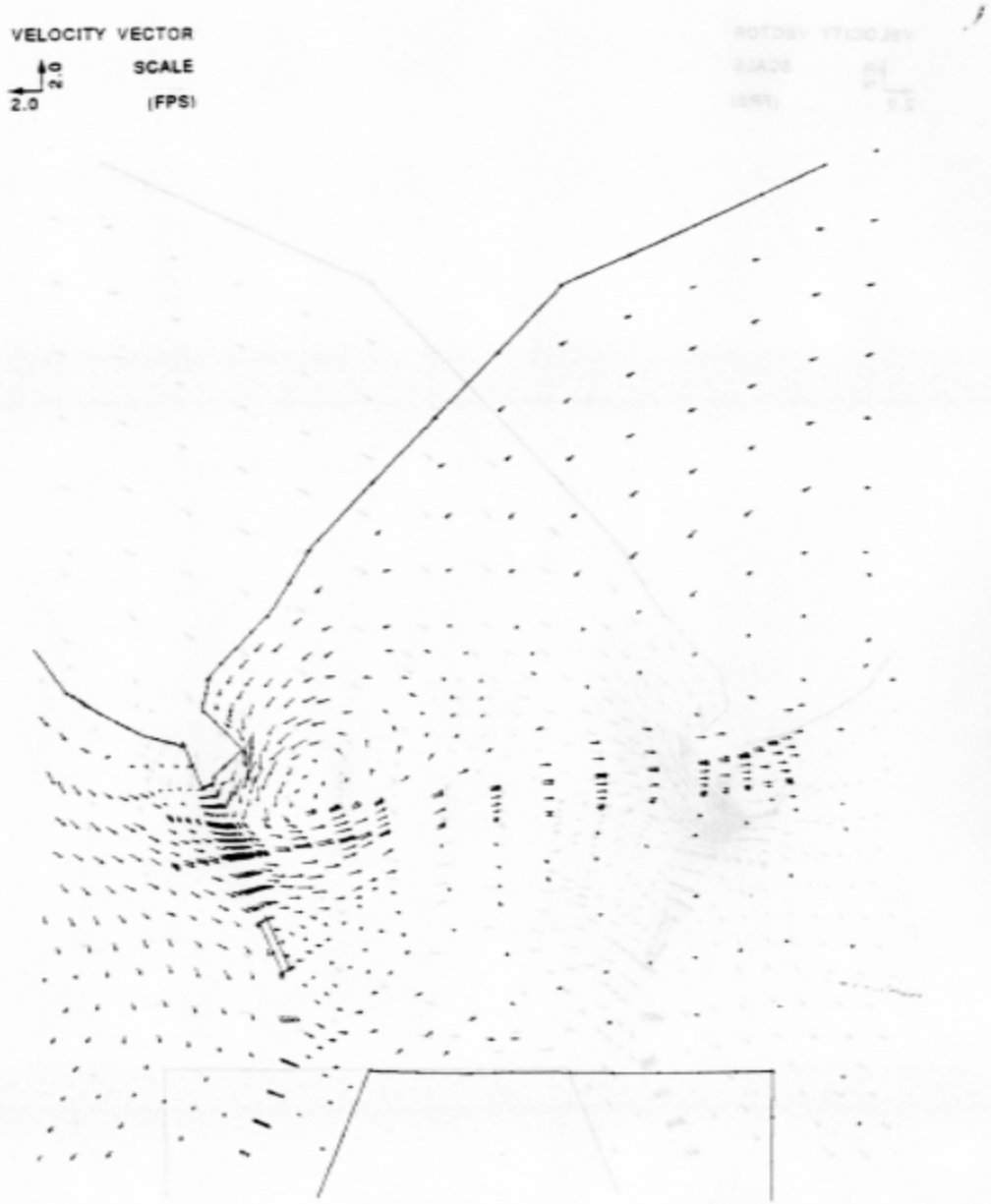
PLATE 8



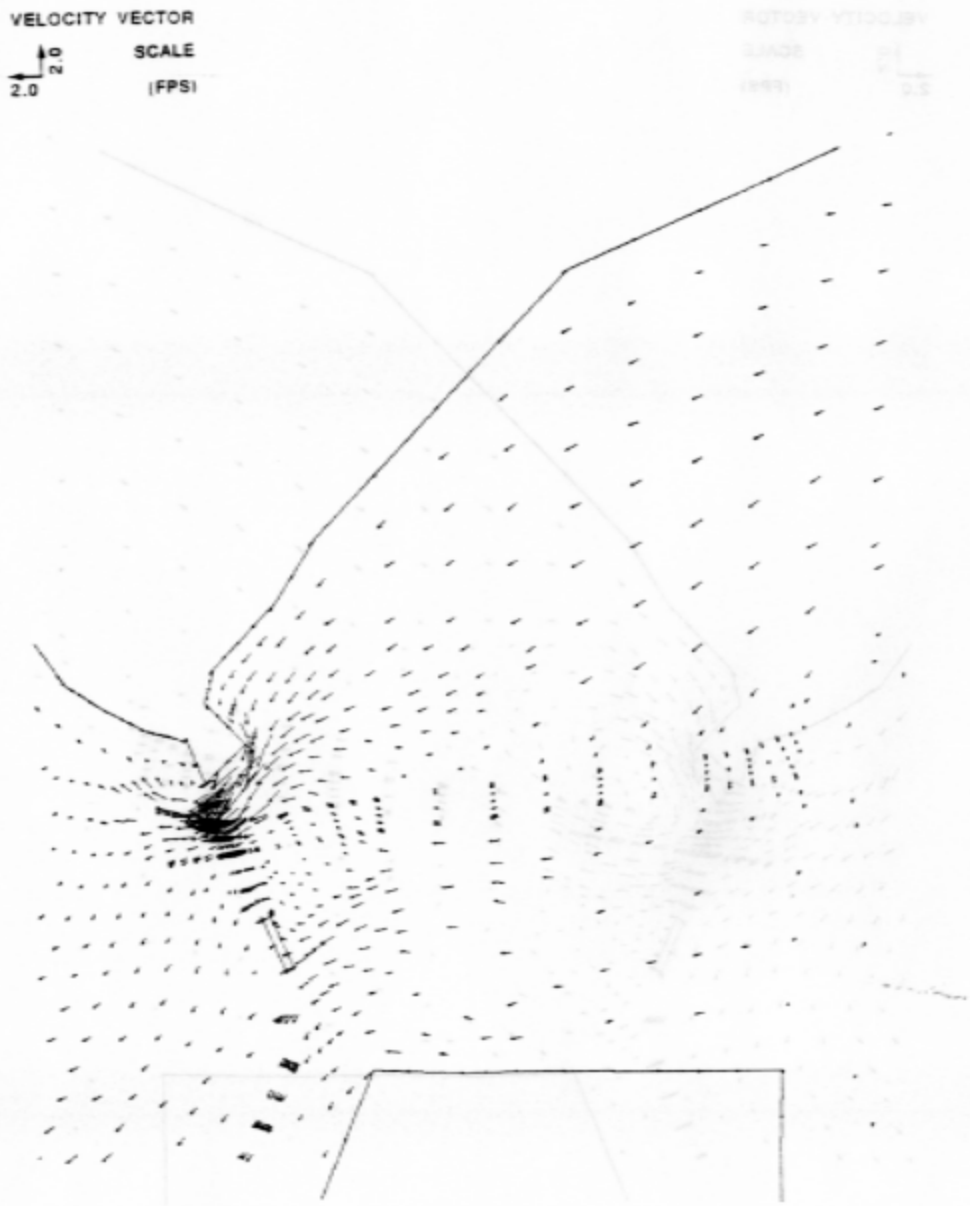
DEEPENING PLAN 2
(64-FT DEPTH)
EXPANSION PLAN B
HOUR 15



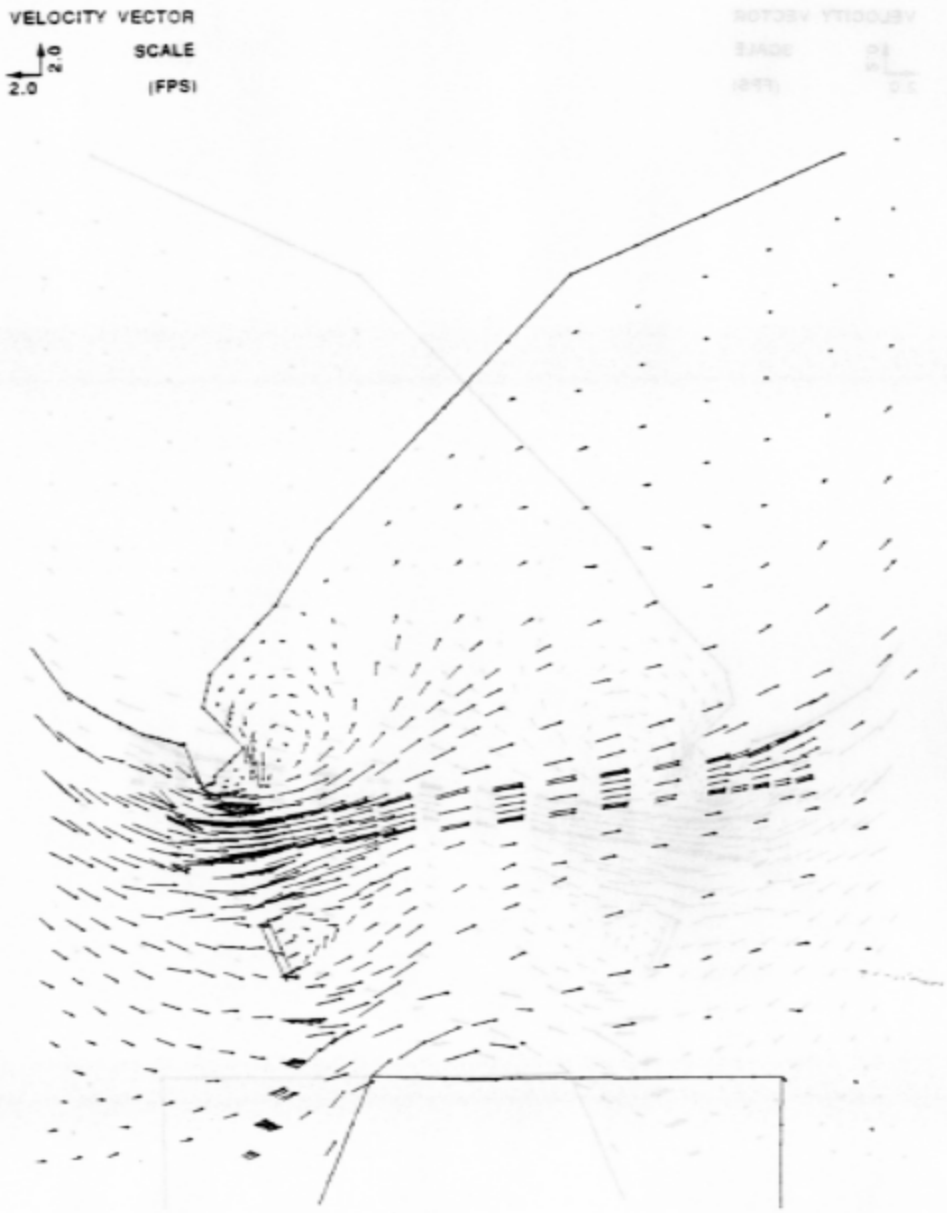
DEEPENING PLAN 2
(64-FT DEPTH)
EXPANSION PLAN B
HOUR 16



DEEPENING PLAN 2
(64-FT DEPTH)
EXPANSION PLAN B
HOUR 17



DEEPENING PLAN 2
(64-FT DEPTH)
EXPANSION PLAN B
HOUR 18



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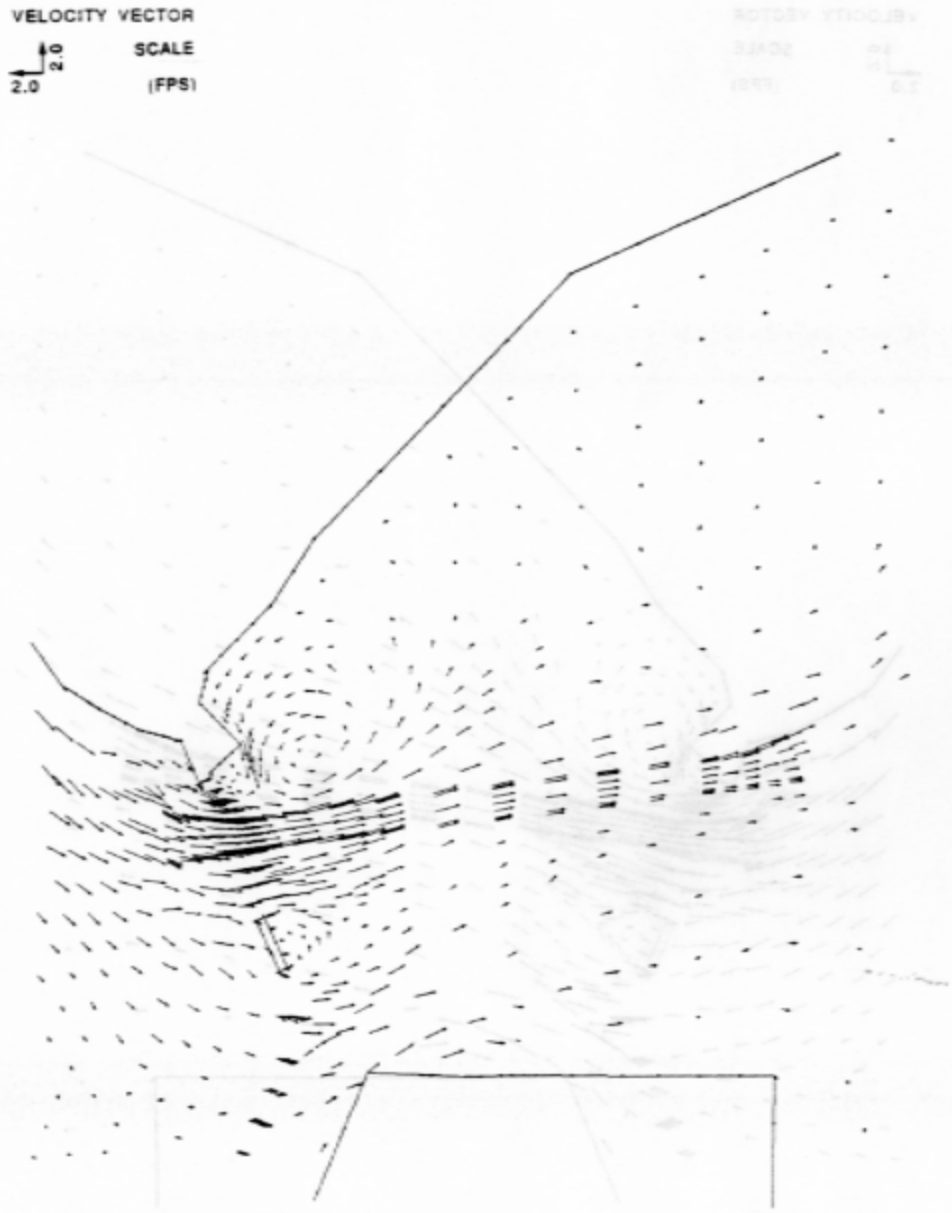
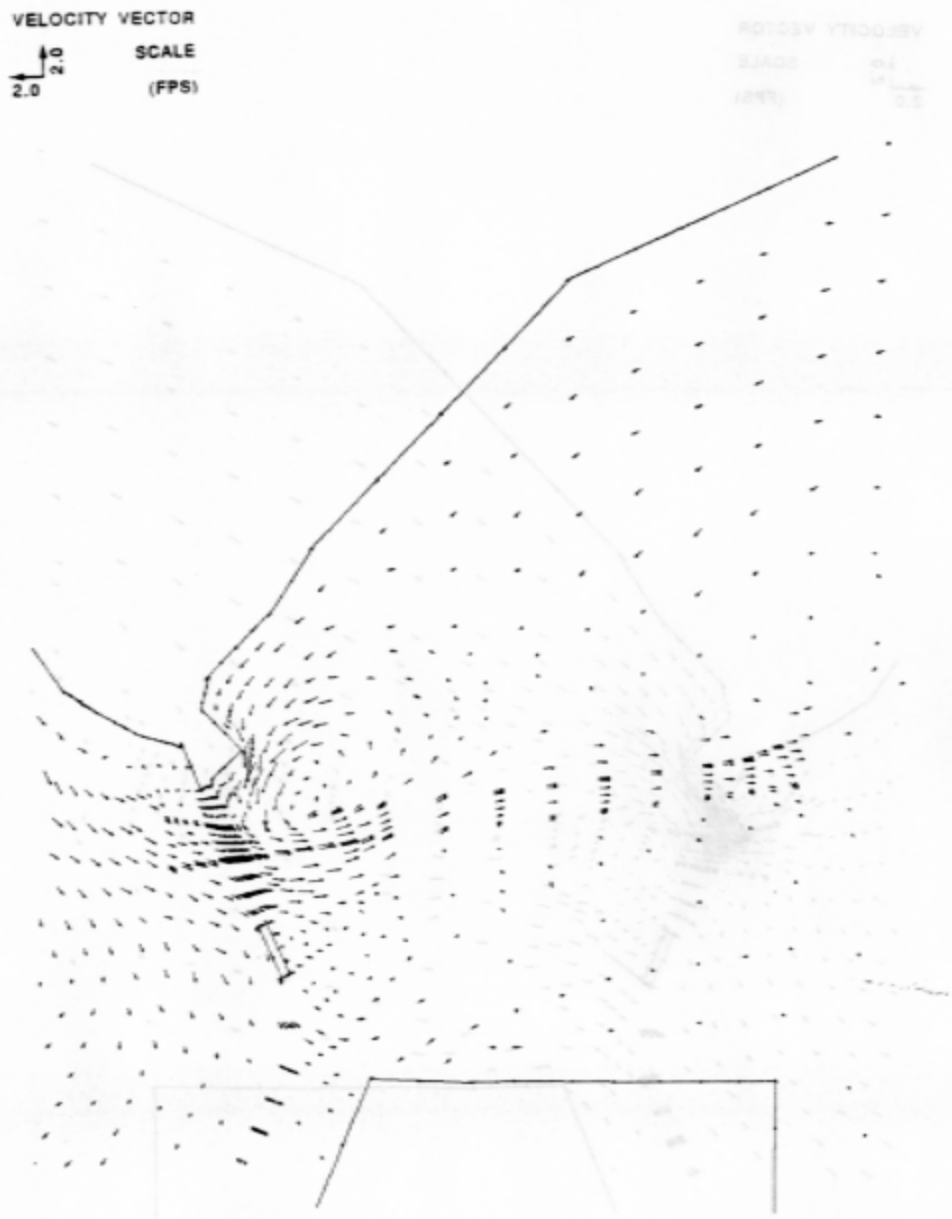
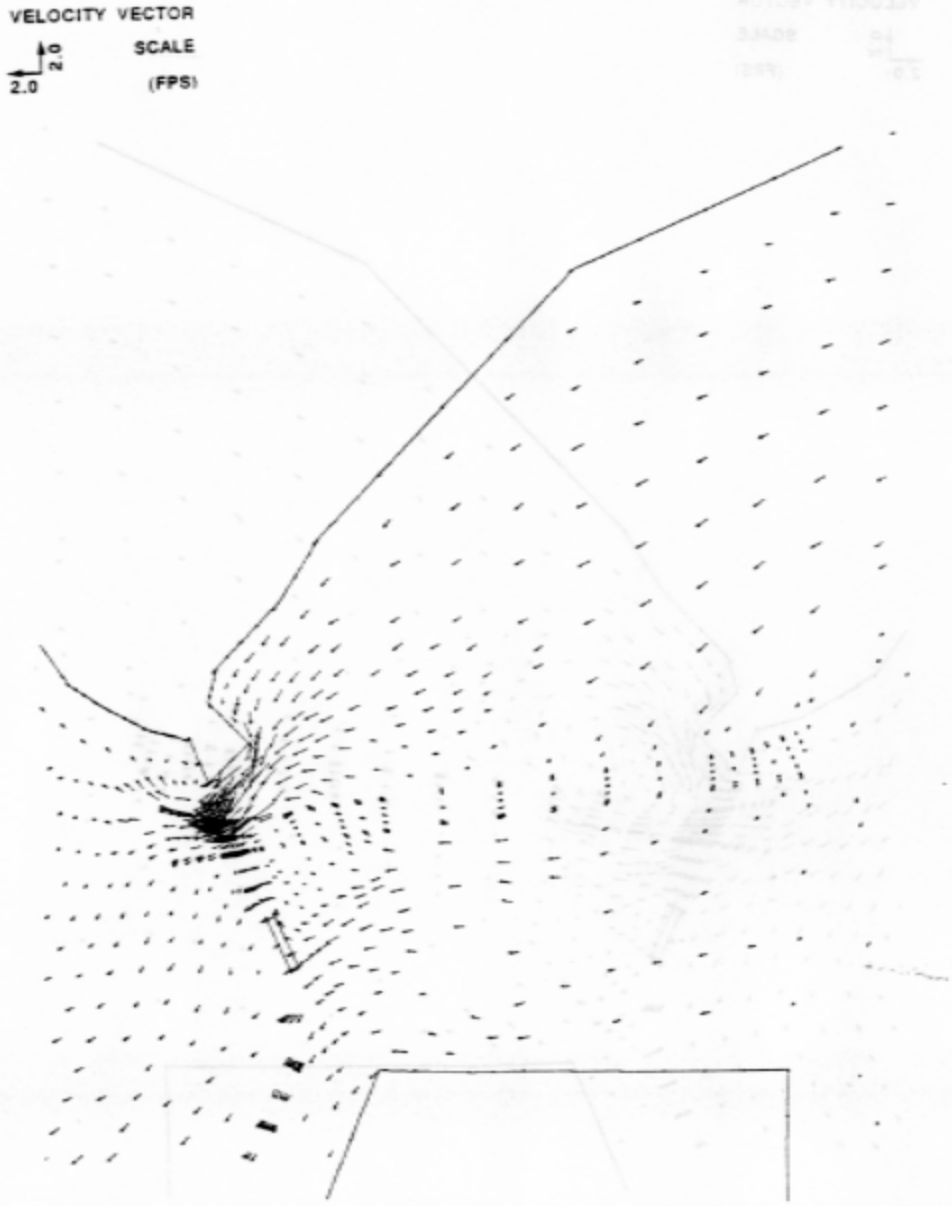
(70-FT DEPTH)
EXPANSION PLAN B
HOUR 15



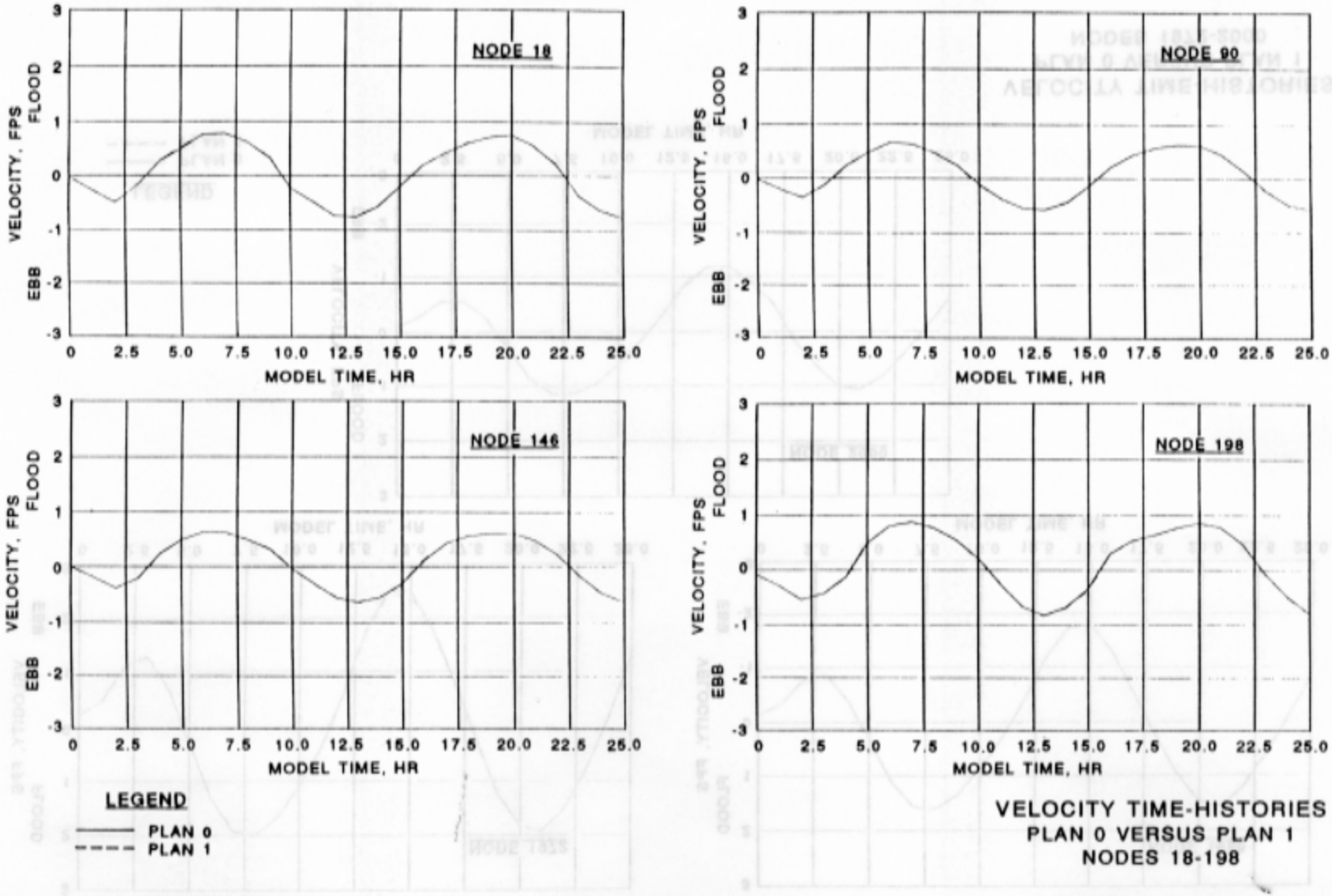
DEEPENING PLAN 3
(70-FT DEPTH)
EXPANSION PLAN B
HOUR 16



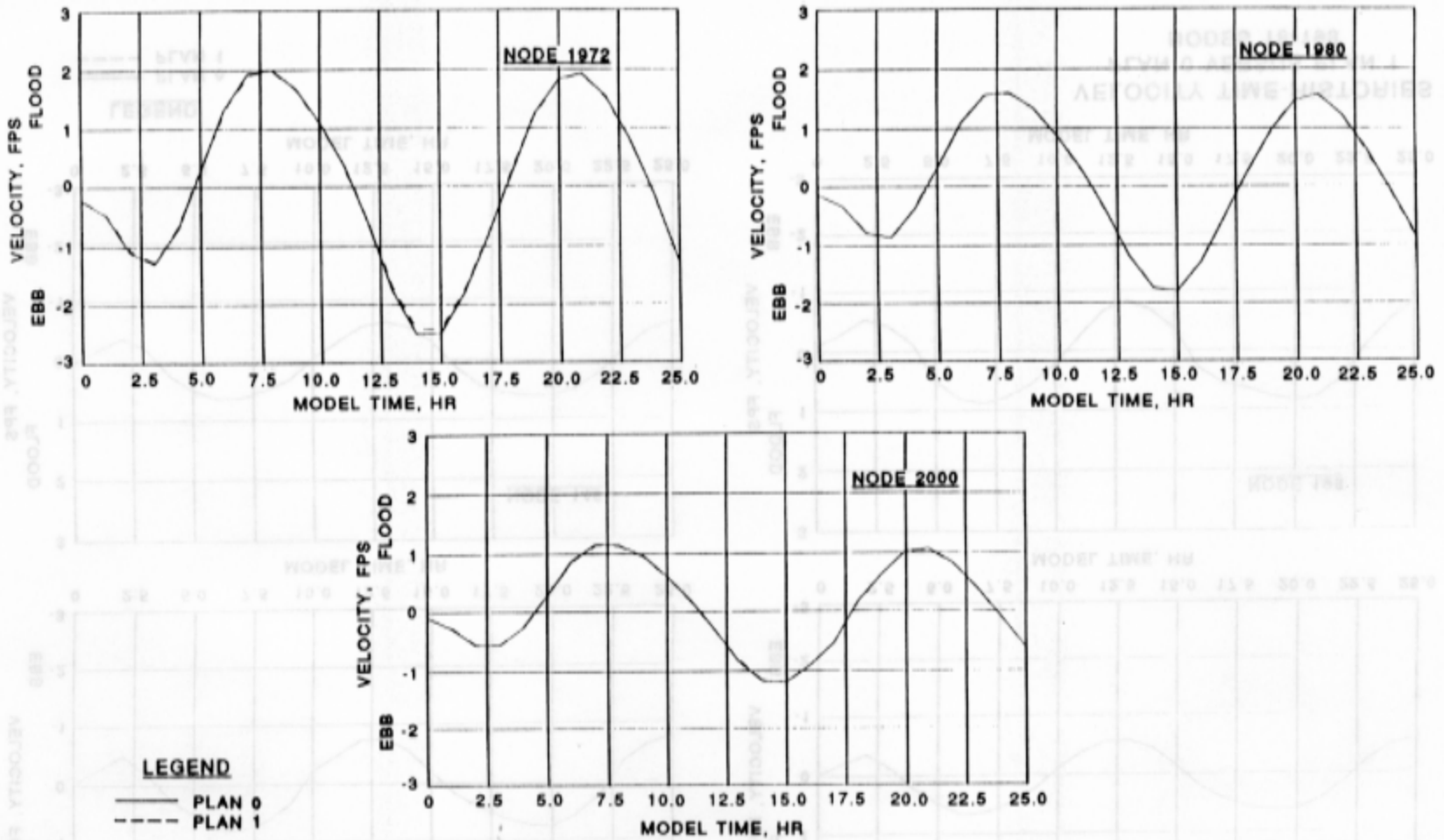
DEEPENING PLAN 3
(70-FT DEPTH)
EXPANSION PLAN B
HOUR 17



DEEPENING PLAN 3
(70-FT DEPTH)
EXPANSION PLAN B
HOUR 18



VELOCITY TIME-HISTORIES
PLAN 0 VERSUS PLAN 1
NODES 18-198



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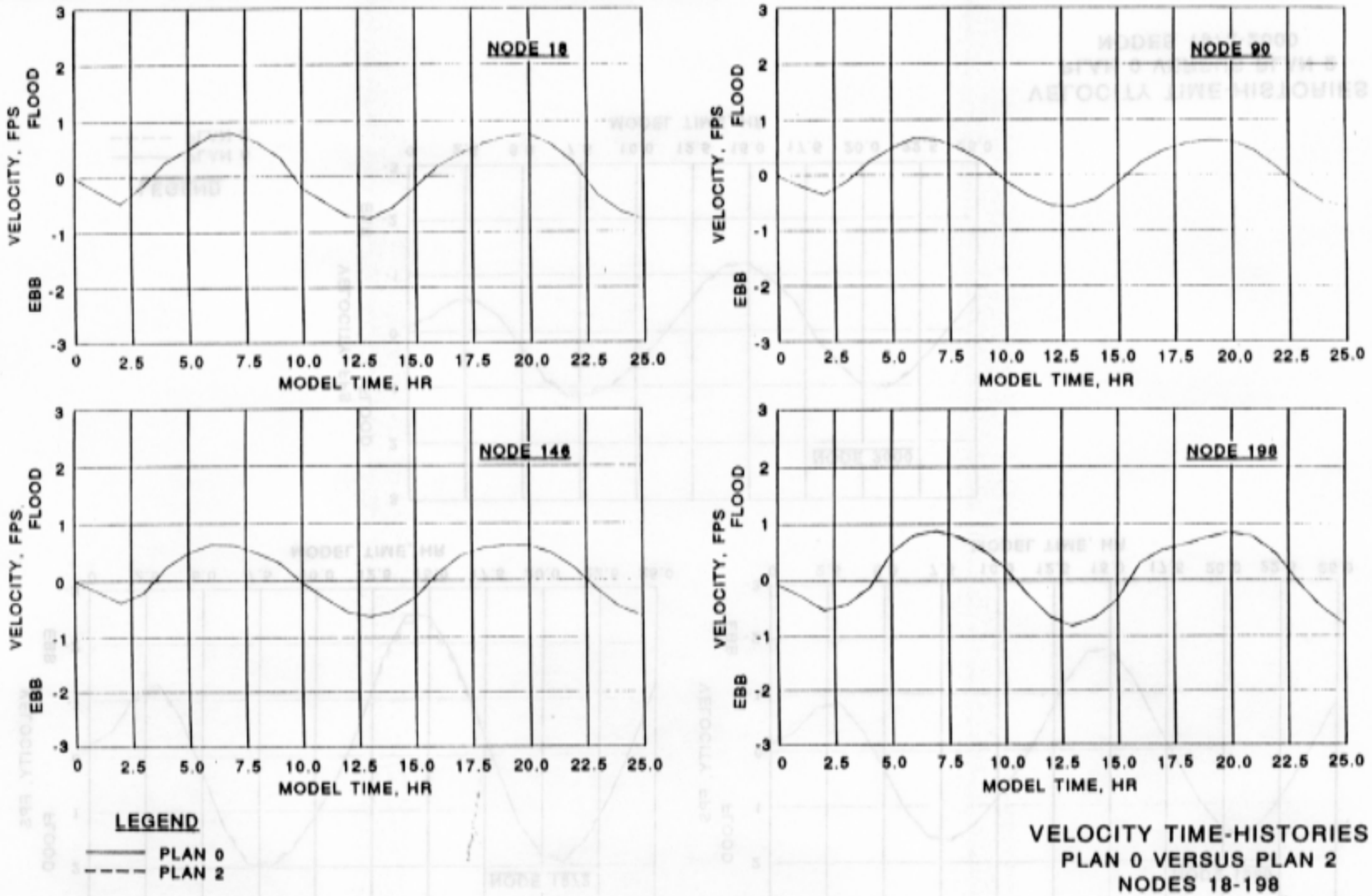

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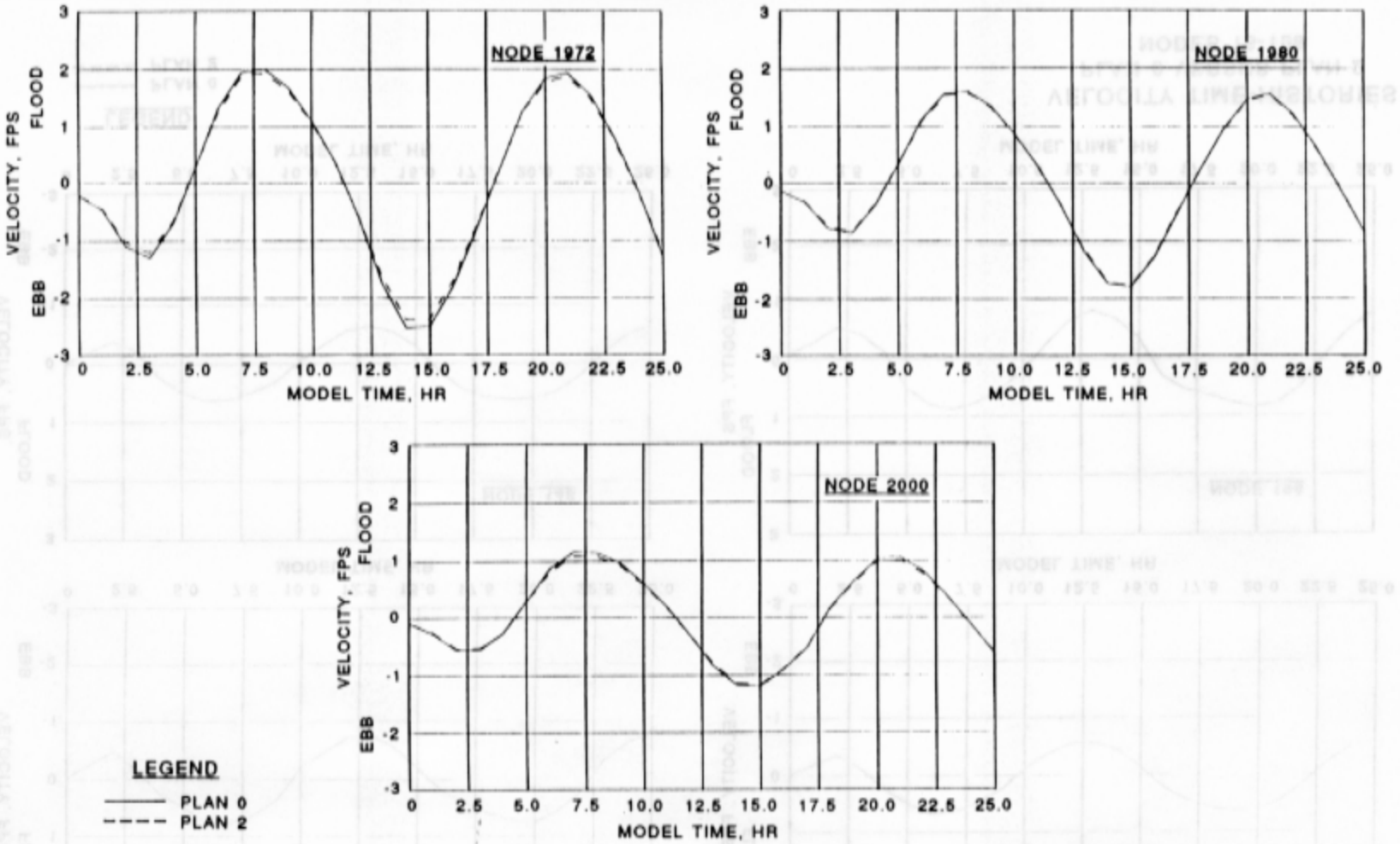

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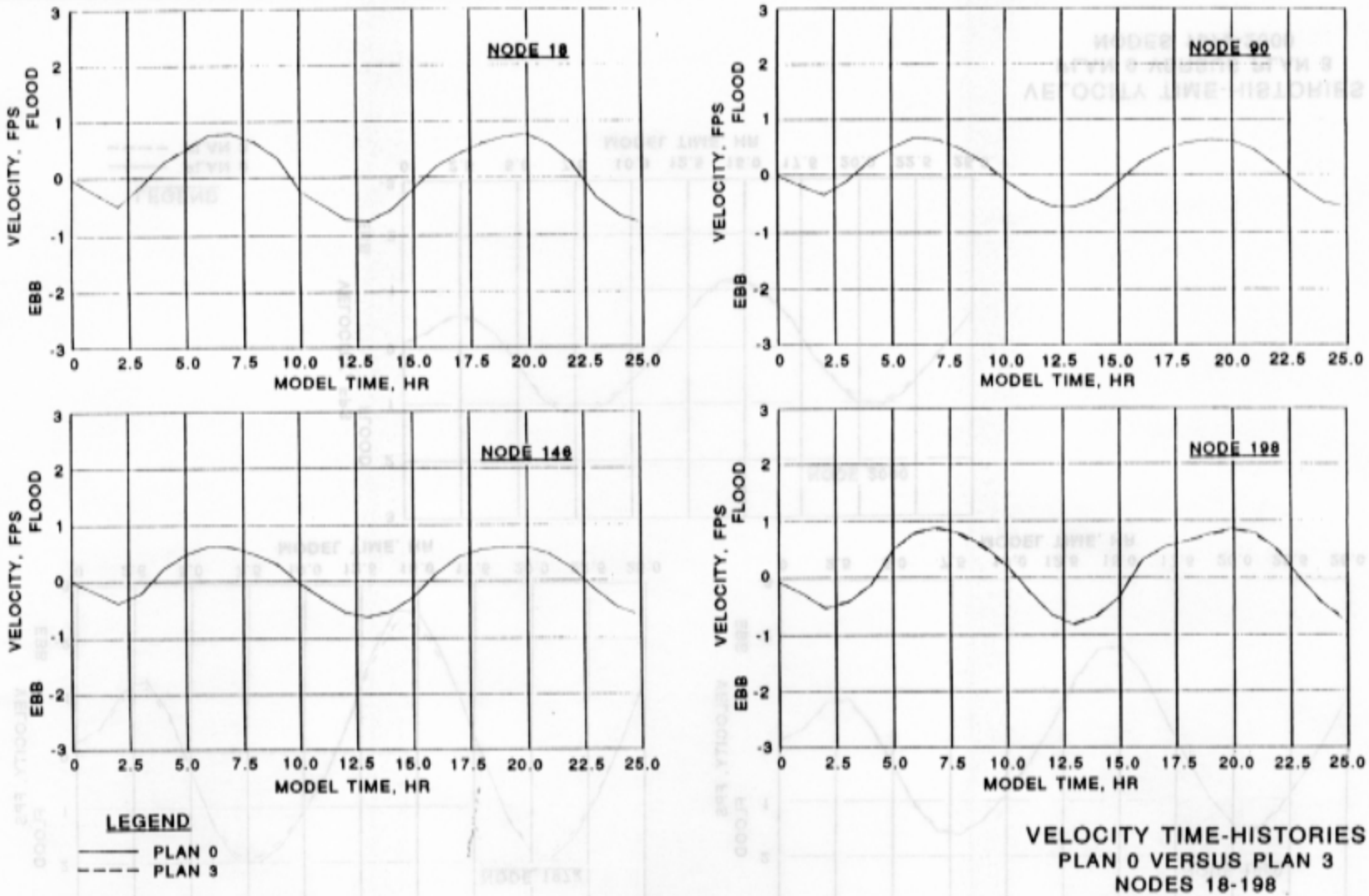

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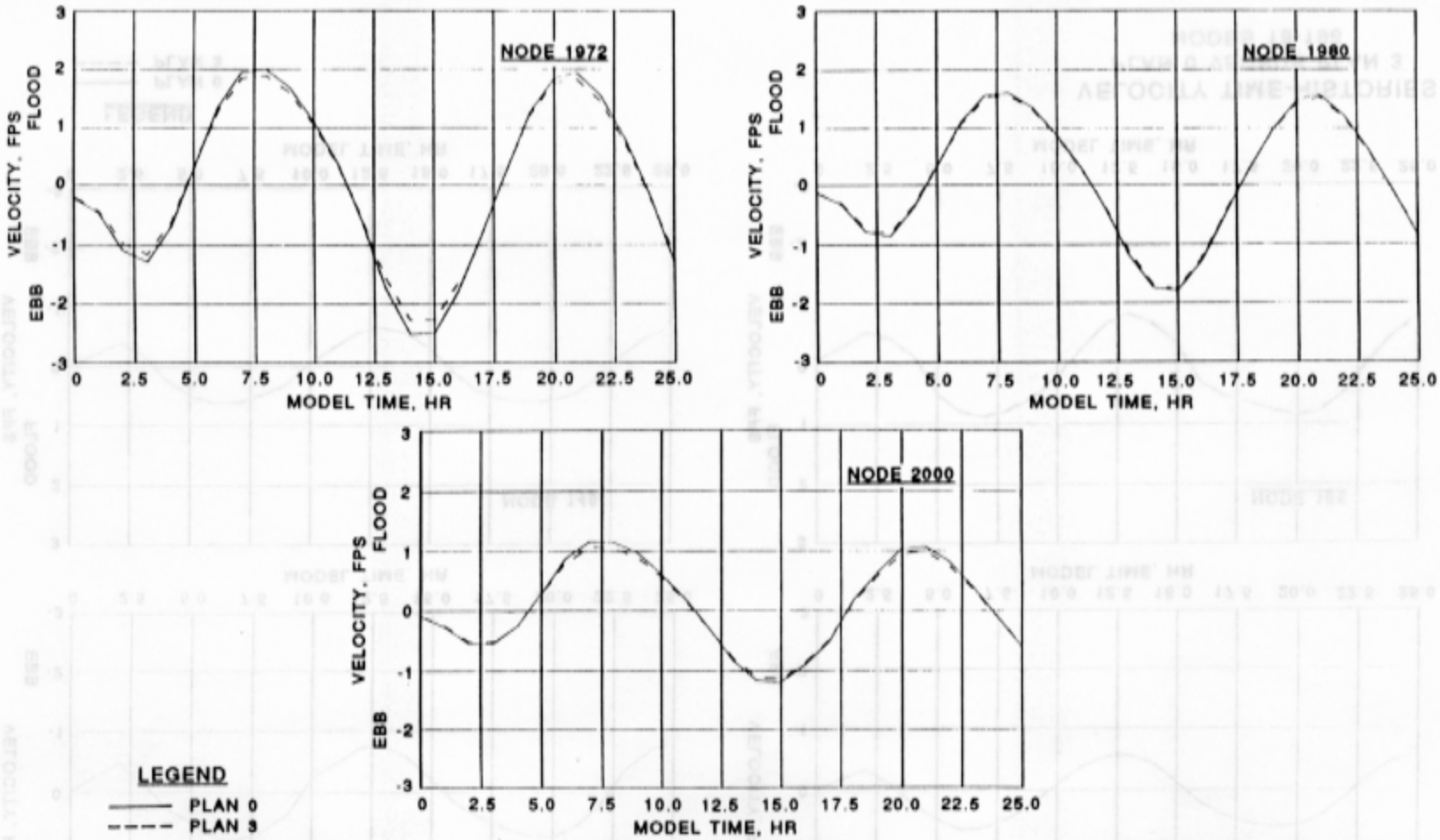

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APPENDIX A: THE TABS-2 SYSTEM

1. TABS-2 is a collection of generalized computer programs and utility codes integrated into a numerical modeling system for studying two-dimensional hydrodynamics, sedimentation, and transport problems in rivers, reservoirs, bays, and estuaries. A schematic representation of the system is shown in Figure A1. It can be used either as a stand-alone solution technique or as a step in the hybrid modeling approach. The basic concept is to calculate water-surface elevations, current patterns, sediment erosion, transport and deposition, the resulting bed surface elevations, and the feedback to hydraulics. Existing and proposed geometry can be analyzed to determine the impact on sedimentation of project designs and to determine the impact of project designs on salinity and on the stream system. The system is described in detail by Thomas and McAnally (1985).

2. The three basic components of the system are as follows:

   a. "A Two-Dimensional Model for Free Surface Flows," RMA-2V.

   b. "Sediment Transport in Unsteady 2-Dimensional Flows, Horizontal Plane," STUDH.

   c. "Two-Dimensional Finite Element Program for Water Quality," RMA-4.

3. RMA-2V is a finite element solution of the Reynolds form of the Navier-Stokes equations for turbulent flows. Friction is calculated with Manning's equation and eddy viscosity coefficients are used to define the turbulent losses. A velocity form of the basic equation is used with side boundaries treated as either slip or static. The model automatically recognizes dry elements and corrects the mesh accordingly. Boundary conditions may be water-surface elevations, velocities, or discharges and may occur inside the mesh as well as along the edges.

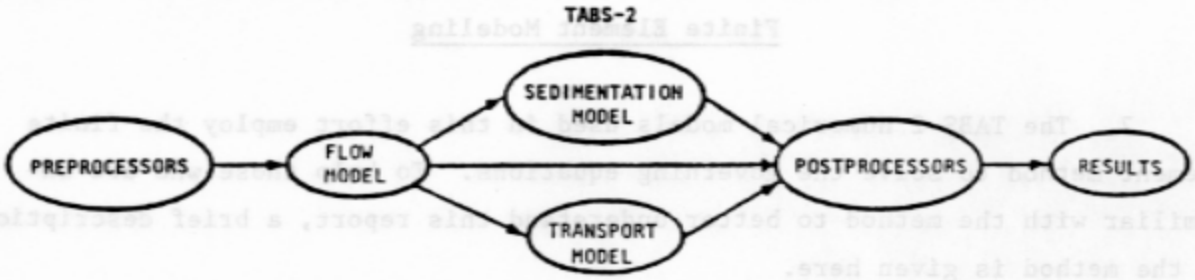


Figure A1. TABS-2 schematic

4. The sedimentation model, STUDH, solves the convection-diffusion equation with bed source terms. These terms are structured for either sand or cohesive sediments. The Ackers-White (1973) procedure is used to calculate a sediment transport potential for the sands from which the actual transport is calculated based on availability. Clay erosion is based on work by Partheniades (1962) and Ariathurai and the deposition of clay utilizes Krone's equations (Ariathurai, MacArthur, and Krone 1977). Deposited material forms layers, as shown in Figure A2, and bookkeeping allows up to 10 layers at each node for maintaining separate material types, deposit thickness, and age. The code uses the same mesh as RMA-2V.

5. Salinity calculations, RMA-4, are made with a form of the convective-diffusion equation which has general source-sink terms. Up to seven conservative substances or substances requiring a decay term can be routed. The code uses the same mesh as RMA-2V.

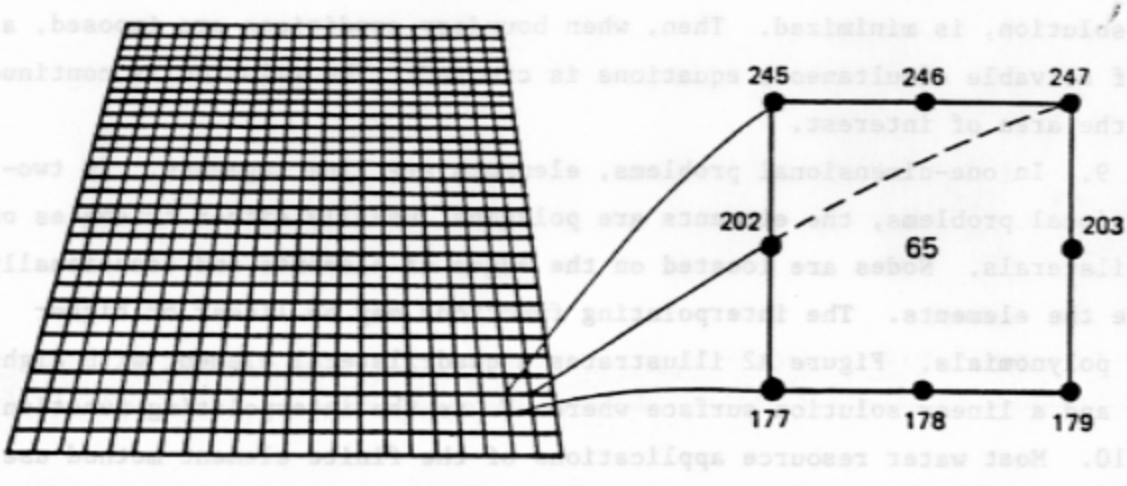
6. Each of these generalized computer codes can be used as a stand-alone program, but to facilitate the preparation of input data and to aid in analyzing results, a family of utility programs was developed for the following purposes:

a. Digitizing
b. Mesh generation
c. Spatial data management
d. Graphical output
e. Output analysis
f. File management
g. Interfaces
h. Job control language

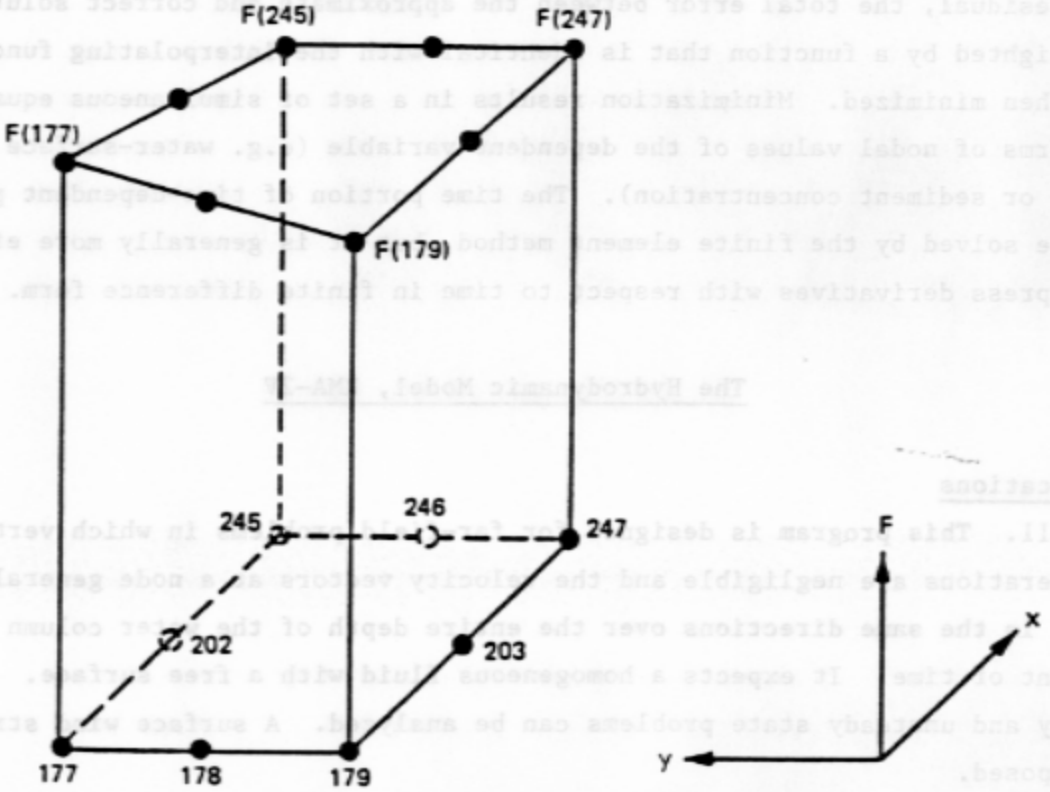
Finite Element Modeling

7. The TABS-2 numerical models used in this effort employ the finite element method to solve the governing equations. To help those who are unfamiliar with the method to better understand this report, a brief description of the method is given here.

8. The finite element method approximates a solution to equations by dividing the area of interest into smaller subareas, which are called elements. The dependent variables (e.g., water-surface elevations and sediment



a. Eight nodes define each element



b. Linear interpolation function

Figure A2. Two-dimensional finite element mesh

concentrations) are approximated over each element by continuous functions which interpolate in terms of unknown point (node) values of the variables. An error, defined as the deviation of the approximation solution from the correct solution, is minimized. Then, when boundary conditions are imposed, a set of solvable simultaneous equations is created. The solution is continuous over the area of interest.

9. In one-dimensional problems, elements are line segments. In two-dimensional problems, the elements are polygons, usually either triangles or quadrilaterals. Nodes are located on the edges of elements and occasionally inside the elements. The interpolating functions may be linear or higher order polynomials. Figure A2 illustrates a quadrilateral element with eight nodes and a linear solution surface where F is the interpolating function.

10. Most water resource applications of the finite element method use the Galerkin method of weighted residuals to minimize error. In this method the residual, the total error between the approximate and correct solutions, is weighted by a function that is identical with the interpolating function and then minimized. Minimization results in a set of simultaneous equations in terms of nodal values of the dependent variable (e.g. water-surface elevations or sediment concentration). The time portion of time-dependent problems can be solved by the finite element method, but it is generally more efficient to express derivatives with respect to time in finite difference form.

The Hydrodynamic Model, RMA-2V

Applications

11. This program is designed for far-field problems in which vertical accelerations are negligible and the velocity vectors at a node generally point in the same directions over the entire depth of the water column at any instant of time. It expects a homogeneous fluid with a free surface. Both steady and unsteady state problems can be analyzed. A surface wind stress can be imposed.

12. The program has been applied to calculate flow distribution around islands; flow at bridges having one or more relief openings, in contracting and expanding reaches, into and out of off-channel hydropower plants, at river junctions, and into and out of pumping plant channels; and general flow patterns in rivers, reservoirs, and estuaries.

Limitations

13. This program is not designed for near-field problems where flow-structure interactions (such as vortices, vibrations, or vertical accelerations) are of interest. Areas of vertically stratified flow are beyond this program's capability unless it is used in a hybrid modeling approach. It is two-dimensional in the horizontal plane, and zones where the bottom current is in a different direction from the surface current must be analyzed with considerable subjective judgement regarding long-term energy considerations. It is a free-surface calculation for subcritical flow problems.

Governing equations

14. The generalized computer program RMA-2V solves the depth-integrated equations of fluid mass and momentum conservation in two horizontal directions. The form of the solved equations is

$$h \frac{\partial u}{\partial t} + hu \frac{\partial u}{\partial x} + hv \frac{\partial u}{\partial y} - \frac{h}{\rho}\left(\varepsilon_{xx} \frac{\partial^2 u}{\partial x^2} + \varepsilon_{xy} \frac{\partial^2 u}{\partial y^2}\right) + gh\left(\frac{\partial a}{\partial x} + \frac{\partial h}{\partial x}\right)$$

$$+ \frac{gun^2}{\left(1.486h^{1/6}\right)^2}\left(u^2 + v^2\right)^{1/2} - \zeta V_a^2 \cos\psi - 2h\omega v \sin\phi = 0 \qquad \text{(A1)}$$

$$h \frac{\partial v}{\partial t} + hv \frac{\partial v}{\partial x} + hv \frac{\partial v}{\partial y} - \frac{h}{\rho}\left(\varepsilon_{yx} \frac{\partial^2 v}{\partial x^2} + \varepsilon_{yy} \frac{\partial^2 v}{\partial y^2}\right) + gh\left(\frac{\partial a}{\partial y} + \frac{\partial h}{\partial y}\right)$$

$$+ \frac{gvn^2}{\left(1.486h^{1/6}\right)^2}\left(u^2 + v^2\right)^{1/2} - \zeta V_a^2 \sin\psi + 2\omega hu \sin\phi = 0 \qquad \text{(A2)}$$

$$\frac{\partial h}{\partial t} + h\left(\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y}\right) + u \frac{\partial h}{\partial x} + v \frac{\partial h}{\partial y} = 0 \qquad \text{(A3)}$$

where

h = depth

u,v = velocities in the Cartesian directions

x,y,t = Cartesian coordinates and time

ρ = density

ε = eddy viscosity coefficient, for xx = normal direction on x-axis surface; yy = normal direction on y-axis surface; xy and yx = shear direction on each surface

g = acceleration due to gravity

a = elevation of bottom

n = Manning's n value

1.486 = conversion from SI (metric) to non-SI units

ζ = empirical wind shear coefficient

V_a = wind speed

ψ = wind direction

ω = rate of earth's angular rotation

ϕ = local latitude

15. Equations A1, A2, and A3 are solved by the finite element method using Galerkin weighted residuals. The elements may be either quadrilaterals or triangles and may have curved (parabolic) sides. The shape functions are quadratic for flow and linear for depth. Integration in space is performed by Gaussian integration. Derivatives in time are replaced by a nonlinear finite difference approximation. Variables are assumed to vary over each time interval in the form

$$f(t) = f(0) + at + bt^c \qquad t_0 \leq t < t \tag{A4}$$

which is differentiated with respect to time, and cast in finite difference form. Letters a , b , and c are constants. It has been found by experiment that the best value for c is 1.5 (Norton and King 1977).

16. The solution is fully implicit and the set of simultaneous equations is solved by Newton-Raphson iteration. The computer code executes the solution by means of a front-type solver that assembles a portion of the matrix and solves it before assembling the next portion of the matrix. The front solver's efficiency is largely independent of bandwidth and thus does not require as much care in formation of the computational mesh as do traditional solvers.

17. The code RMA-2V is based on the earlier version RMA-2 (Norton and King 1977) but differs from it in several ways. It is formulated in terms of velocity (v) instead of unit discharge (vh), which improves some aspects of the code's behavior; it permits drying and wetting of areas within the grid;

and it permits specification of turbulent exchange coefficients in directions other than along the x- and z-axes. For a more complete description, see Appendix F of Thomas and McAnally (1985).

The Sediment Transport Model, STUDH

Applications

18. STUDH can be applied to clay and/or sand bed sediments where flow velocities can be considered two-dimensional (i.e., the speed and direction can be satisfactorily represented as a depth-averaged velocity). It is useful for both deposition and erosion studies and, to a limited extent, for stream width studies. The program treats two categories of sediment: noncohesive, which is referred to as sand here, and cohesive, which is referred to as clay.

Limitations

19. Both clay and sand may be analyzed, but the model considers a single, effective grain size for each and treats each separately. Fall velocity must be prescribed along with the water-surface elevations, x-velocity, y-velocity, diffusion coefficients, bed density, critical shear stresses for erosion, erosion rate constants, and critical shear stress for deposition.

20. Many applications cannot use long simulation periods because of their computation cost. Study areas should be made as small as possible to avoid an excessive number of elements when dynamic runs are contemplated yet must be large enough to permit proper posing of boundary conditions. The same computation time interval must be satisfactory for both the transverse and longitudinal flow directions.

21. The program does not compute water-surface elevations or velocities; therefore these data must be provided. For complicated geometries, the numerical model for hydrodynamic computations, RMA-2V, is used.

Governing equations

22. The generalized computer program STUDH solves the depth-integrated convection-dispersion equation in two horizontal dimensions for a single sediment constituent. For a more complete description, see Appendix G of Thomas and McAnally (1985). The form of the solved equation is

$$\frac{\partial C}{\partial t} + u\frac{\partial C}{\partial x} + v\frac{\partial C}{\partial y} = \frac{\partial}{\partial x}\left(D_x\frac{\partial C}{\partial x}\right) + \frac{\partial}{\partial y}\left(D_y\frac{\partial C}{\partial y}\right) + \alpha_1 C + \alpha_2 = 0 \qquad \text{(A5)}$$

where

C = concentration of sediment

u = depth-integrated velocity in x-direction

v = depth-integrated velocity in y-direction

D_x = dispersion coefficient in x-direction

D_y = dispersion coefficient in y-direction

α_1 = coefficient of concentration-dependent source/sink term

α_2 = coefficient of source/sink term

23. The source/sink terms in Equation A5 are computed in routines that treat the interaction of the flow and the bed. Separate sections of the code handle computations for clay bed and sand bed problems.

Sand transport

24. The source/sink terms are evaluated by first computing a potential sand transport capacity for the specified flow conditions, comparing that capacity with the amount of sand actually being transported, and then eroding from or depositing to the bed at a rate that would approach the equilibrium value after sufficient elapsed time.

25. The potential sand transport capacity in the model is computed by the method of Ackers and White (1973), which uses a transport power (work rate) approach. It has been shown to provide superior results for transport under steady-flow conditions (White, Milli, and Crabbe 1975) and for combined waves and currents (Swart 1976). Flume tests at the US Army Engineer Waterways Experiment Station have shown that the concept is valid for transport by estuarine currents.

26. The total load transport function of Ackers and White is based upon a dimensionless grain size

$$D_{gr} = D \left[\frac{g(s - 1)}{\nu^2} \right]^{1/3} \tag{A6}$$

where

D = sediment particle diameter

s = specific gravity of the sediment

ν = kinematic viscosity of the fluid

and a sediment mobility parameter

$$F_{gr} = \left[\frac{\tau^{n'} \tau'^{(1-n')}}{\rho g D(s - 1)} \right]^{1/2} \tag{A7}$$

where

τ = total boundary shear stress

n' = a coefficient expressing the relative importance of bed-load and suspended-load transport, given in Equation A9

τ' = boundary surface shear stress

The surface shear stress is that part of the total shear stress which is due to the rough surface of the bed only, i.e., not including that part due to bed forms and geometry. It therefore corresponds to that shear stress that the flow would exert on a plane bed.

27. The total sediment transport is expressed as an effective concentration

$$G_P = C\left(\frac{F_{gr}}{A} - 1\right)^m \frac{sD}{h} \left(\frac{\rho}{\tau} U\right)^{n'} \tag{A8}$$

where U is the average flow speed, and for $1 < D_{gr} \leq 60$

$$n' = 1.00 - 0.56 \log D_{gr} \tag{A9}$$

$$A = \frac{0.23}{\sqrt{D_{gr}}} + 0.14 \tag{A10}$$

$$\log C = 2.86 \log D_{gr} - (\log D_{gr})^2 - 3.53 \tag{A11}$$

$$m = \frac{9.66}{D_{gr}} + 1.34 \tag{A12}$$

For $D_{gr} < 60$

$$n' = 0.00 \tag{A13}$$

$$A = 0.17 \tag{A14}$$

$$C = 0.025 \tag{A15}$$

$$m = 1.5 \tag{A16}$$

28. Equations A6-A16 result in a potential sediment concentration G_p. This value is the depth-averaged concentration of sediment that will occur if an equilibrium transport rate is reached with a nonlimited supply of sediment. The rate of sediment deposition (or erosion) is then computed as

$$R = \frac{G_p - C}{t_c} \tag{A17}$$

where

C = present sediment concentration

t_c = time constant

For deposition, the time constant is

$$t_c = \text{larger of} \begin{cases} \Delta t \\ \text{or} \\ \dfrac{C_d h}{V_s} \end{cases} \tag{A18}$$

and for erosion it is

$$t_c = \text{larger of} \begin{cases} \Delta t \\ \text{or} \\ \dfrac{C_e h}{U} \end{cases} \tag{A19}$$

where

Δt = computational time-step

C_d = response time coefficient for deposition

V_s = sediment settling velocity

C_e = response time coefficient for erosion

The sand bed has a specified initial thickness which limits the amount of erosion to that thickness.

Cohesive sediments transport

29. Cohesive sediments (usually clays and some silts) are considered to be depositional if the bed shear stress exerted by the flow is less than a critical value τ_d. When that value occurs, the deposition rate is given by Krone's (1962) equation

$$S = \begin{cases} -\dfrac{2V_s}{h} C \left(1 - \dfrac{\tau}{\tau_d}\right) & \text{for } C < C_c \quad \text{(A20)} \\[2ex] -\dfrac{2V_s}{hC_c^{4/3}} C^{5/3} \left(1 - \dfrac{\tau}{\tau_d}\right) & \text{for } C > C_c \quad \text{(A21)} \end{cases}$$

where

S = source term

V_s = fall velocity of a sediment particle

h = flow depth

C = sediment concentration in water column

τ = bed shear stress

τ_d = critical shear stress for deposition

C_c = critical concentration = 300 mg/ℓ

30. If the bed shear stress is greater than the critical value for particle erosion τ_e, material is removed from the bed. The source term is then computed by Ariathurai's (Ariathurai, MacArthur, and Krone 1977) adaptation of Partheniades' (1962) findings:

$$S = \frac{P}{h}\left(\frac{\tau}{\tau_e} - 1\right) \quad \text{for } \tau > \tau_e \qquad \text{(A22)}$$

where P is the erosion rate constant, unless the shear stress is also greater than the critical value for mass erosion. When this value is exceeded, mass failure of a sediment layer occurs and

$$S = \frac{T_L P_L}{h \Delta t} \quad \text{for } \tau > \tau_s \tag{A23}$$

where

T_L = thickness of the failed layer

P_L = density of the failed layer

Δt = time interval over which failure occurs

τ_s = bulk shear strength of the layer

31. The cohesive sediment bed consists of 1 to 10 layers, each with a distinct density and erosion resistance. The layers consolidate with overburden and time.

Bed shear stress

32. Bed shear stresses are calculated from the flow speed according to one of four optional equations: the smooth-wall log velocity profile or Manning equation for flows alone; and a smooth bed or rippled bed equation for combined currents and wind waves. Shear stresses are calculated using the shear velocity concept where

$$\tau_b = \rho u_*^2 \tag{A24}$$

where

τ_b = bed shear stress

u_* = shear velocity

and the shear velocity is calculated by one of four methods:

a. Smooth-wall log velocity profiles

$$\frac{\bar{u}}{u_*} = 5.75 \log \left(3.32 \frac{u_* h}{\nu} \right) \tag{A25}$$

which is applicable to the lower 15 percent of the boundary layer when

$$\frac{u_* h}{\nu} > 30$$

where $\bar{u}$ is the mean flow velocity (resultant of u and v components)

b. The Manning shear stress equation

$$u_* = \frac{(\bar{u}n)\sqrt{g}}{CME\ (h)^{1/6}} \tag{A26}$$

where CME is a coefficient of 1 for SI (metric) units and 1.486 for non-SI units of measurement.

c. A Jonsson-type equation for surface shear stress (plane beds) caused by waves and currents

$$u_* = \sqrt{\frac{1}{2}\left(\frac{f_w u_{om} + f_c \bar{u}}{u_{om} + \bar{u}}\right)\left(\bar{u} + u_{om}\right)^2} \tag{A27}$$

where

f_w = shear stress coefficient for waves

u_{om} = maximum orbital velocity of waves

f_c = shear stress coefficient for currents

d. A Bijker-type equation for total shear stress caused by waves and current

$$u_* = \sqrt{\frac{1}{2} f_c \bar{u}^2 + \frac{1}{4} f_w u_{om}^2} \tag{A28}$$

Solution method

33. Equation A5 is solved by the finite element method using Galerkin weighted residuals. Like RMA-2V, which uses the same general solution technique, elements are quadrilateral and may have parabolic sides. Shape functions are quadratic. Integration in space is Gaussian. Time-stepping is

performed by a Crank-Nicholson approach with a weighting factor (θ) of 0.66. A front-type solver similar to that is RMA-2V is used to solve the simultaneous equations.

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