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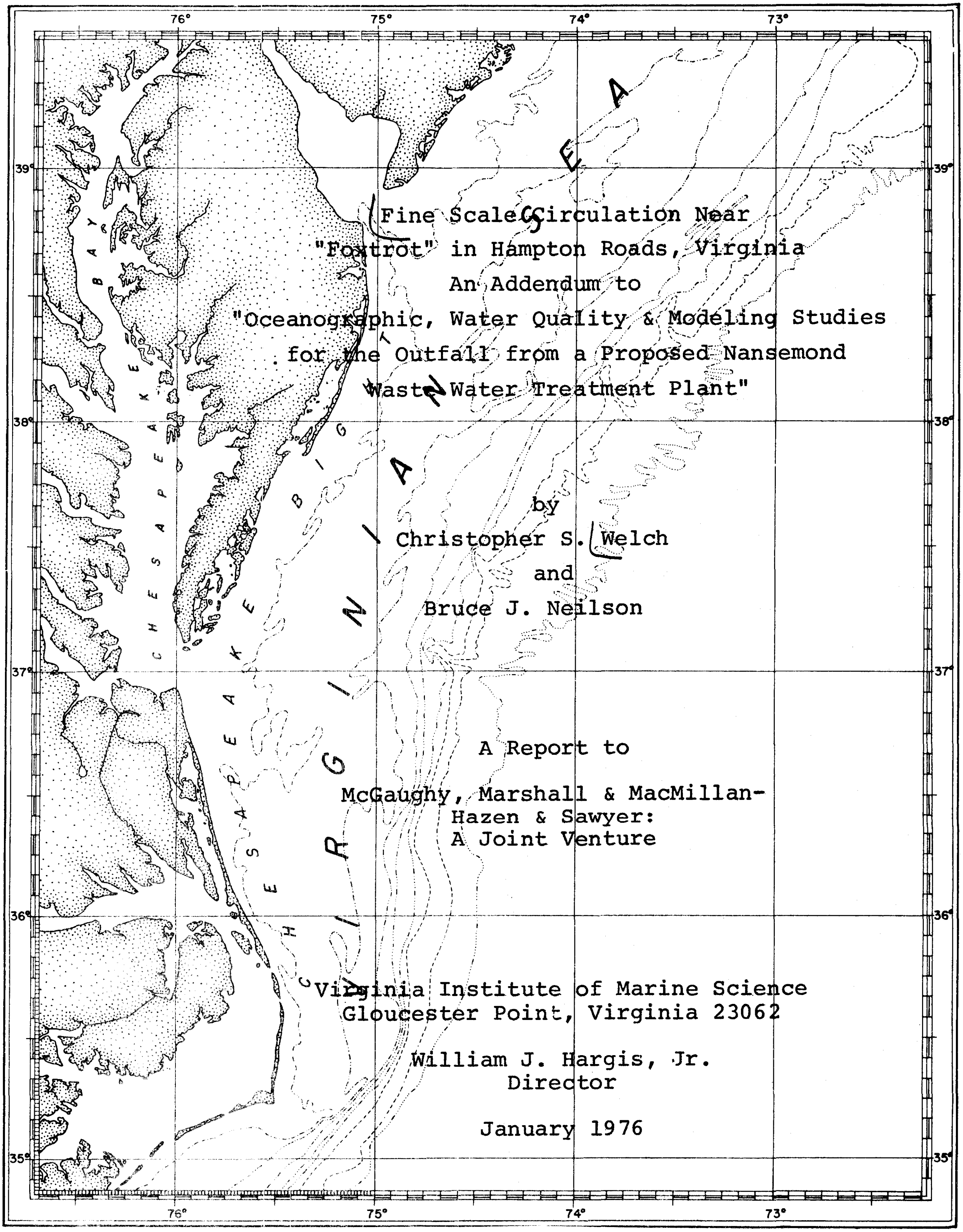

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An Addendum to "Oceanographic, Water Quality & Modeling Studies for the Outfall from a Proposed Nansemond Waste Water Treatment Plant"

by

Christopher S. Welch

and

Bruce J. Neilson

A Report to

McGaughy, Marshall & MacMillan-
Hazen & Sawyer:
A Joint Venture

Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

William J. Hargis, Jr.
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1. Summary, Conclusions and Recommendations

1.1 The application of results from the dye study performed with a release point at the naval munitions pier (Foxtrot) to a site a kilometer or more to the east was questioned. In particular, there was concern that effluent released from a site to the east of Foxtrot would pass over Nansemond Ridge and other oyster beds.

1.2 A volumetric analysis of the intertidal volume of the Nansemond shows that it is plausible for water from a site a couple of kilometers east of the Foxtrot pier to enter the Nansemond River or to pass over Nansemond Ridge. The analysis was not conclusive, but did justify the performance of a field experiment to investigate the question.

1.3 An examination of the Tidal Current Tables led to two hypothetical paths by which water passing the study area, chosen two kilometers east of Foxtrot, might enter the Nansemond River.

1.4 An experiment using the remote sensing - dye buoy technique was designed and performed to test the validity of the two hypothesized routes.

1.5 The results of the experiment were that the direct route was possible less than 30% of the time for less than 30% of the effluent released during flood tide, and that the effluent that entered the Nansemond would be quickly flushed out again. The indirect route was not found for flow from the outer part of the study site (stations 1 & 2), and no conclusion was drawn for flow from the inner part of the study site (stations 3 & 4).

1.6 The flow past the study site was shown to have two distinct types of path. The first was along the edge of Craney Island to the Nansemond County shoreline, and then west towards Pig Point. This path occurred for about the first third of the tidal cycle. The second type of path was jet-like and directed past Foxtrot, veering slightly towards the north with later flood tide. This path occurred during much of the flood tide including the final two thirds.

1.7 It was concluded that the flow taking the early path past the outer sites (stations 1 & 2) would be directed towards the mouth of the Nansemond River. The flow past the inner sites (stations 3 & 4) would beach on the Nansemond County shore during times of northeast to west winds.

1.8 Because the flow from the outer sites (stations 1 & 2) passed north of Foxtrot, it was concluded that the effect on the Nansemond River and Nansemond Ridge areas would be less than that reported for the dye study conducted at Foxtrot in 1974.

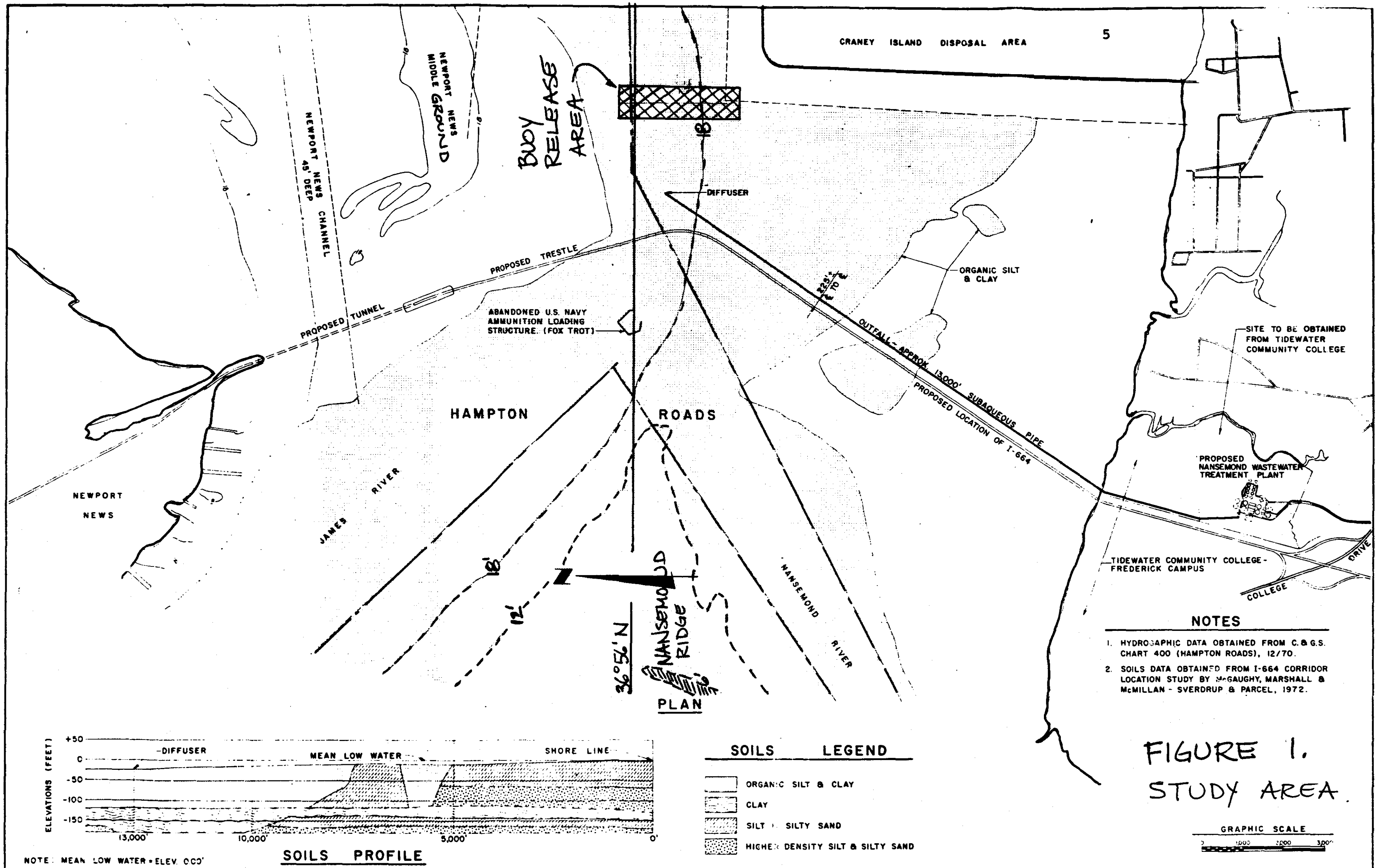
1.9 No firm conclusions were reached regarding mid to late flood flows past the inner sites (stations 3 & 4) in the study area because the possibility exists that surface flow might collect in a stagnant area over Nansemond Ridge and perhaps also enter the Nansemond River by the direct route.

1.10 Based on our study, we recommend that any sewage outfall constructed in the area between Foxtrot, Newport News Middle Ground and the northwest corner of the Craney Island Disposal Area be located north of the $36^{o}56'$N latitude.

2. Statement of Problem

During 1974 the Virginia Institute of Marine Science conducted a series of oceanographic, water quality and modeling studies for the outfall from the proposed Nansemond Wastewater Treatment Plant (VIMS, 1975). One of these studies included dye releases to determine the dispersion and transport of material discharged to Hampton Roads near Pig Point. These dye releases were made from the munitions loading piers known as "Foxtrot". The proposed outfall, as given in the Facilities Plan (McGaughy et al., 1975) is located roughly one kilometer to the east-south-east of Foxtrot as shown in Figure 1. Tidal circulation in Hampton Roads is quite complex and there was concern that the distribution patterns for material released at the two sites would differ appreciably. Therefore a fine scale circulation study was conducted in the vicinity of Foxtrot.

The particular concern that prompted this study was that effluent released at the outfall would pass over the highly productive oyster grounds known as Nansemond Ridge which are located off Barrel Point and to the north of the Nansemond River channel. If this were the case, then the shellfish would be exposed to wastewater constituents, which might include heavy metals, chlorinated hydrocarbons, pesticides and other such compounds, on a regular basis and they would be exposed to pathogenic bacteria and viruses



NOTES

1. HYDROGRAPHIC DATA OBTAINED FROM C.& G.S. CHART 400 (HAMPTON ROADS), 12/70.
2. SOILS DATA OBTAINED FROM I-664 CORRIDOR LOCATION STUDY BY McGAUGHY, MARSHALL & McMILLAN - SVERDRUP & PARCEL, 1972.

FIGURE 1. STUDY AREA.

McGAUGHY, MARSHALL & McMILLAN NORFOLK, VIRGINIA HAZEN AND SAWYER NEW YORK, N.Y.	SCALE GRAPHIC	HAMPTON ROADS SANITATION DISTRICT NANSEMOND WASTEWATER TREATMENT PLANT	PLANT OUTFALL	DATE APR. 1975 SHEET ___ OF ___ DWG ___

DESIGNED / DRAWN / CHECKED / SECT CHIEF / PROJ ENGR if an accident or other malfunction should reduce the disinfection capability of the treatment plant. This situation would necessitate the closure of some shellfish grounds.

While there was concern that some outfall sites might result in the above-mentioned situation, it was believed that there was a large region in Hampton Roads which would have the necessary dispersion characteristics and result in the transport of effluent away from the shellfish beds. The purpose of the study was to determine the likely end point for material released at selected sites near Foxtrot during flood tide and to use that information to delineate a region with the desired characteristics.

An estimate of the tidal excursion for this region was obtained by volumetric considerations. Field studies included the release of drifting and anchored floating dye buoys and aerial photography to determine their locations at subsequent times. This information was used to arrive at a description of the fine scale circulation in the Foxtrot area.

3. Volumetric Estimate of Tidal Excursion

Volumetric data compiled by the Chesapeake Bay Institute (Cronin, 1971) can be used to estimate the source of water entering the Nansemond River during a flood tide. The rationale for the calculation is simply stated: If the intertidal volume of the Nansemond River is supplied by a slug of water following the channel, how long is that slug of water? The cumulative intertidal volume of the Nansemond River from its head to a line between Pig Point and Barrel Point is $25.89 \times 10^6 m^3$ (Cronin, 1971). If that volume is contained in a square cross-section channel 4 meters deep and 1 km wide (a rough approximation to the actual channel area), the slug of water must be 6.3 km long. This distance is nearly identical to the distance between Pig Point and the study area. The results of this calculation are presented in figure 2 in the form of a chart of the area. The assumed equivalent channel is drawn to approximate the path of the actual channel, and its extension to the vicinity of the study area is clear. The results of this crude calculation indicate that further study in the form of a field program is warranted, to determine if water flowing past the study area will enter the Nansemond River or pass over Nansemond Ridge.

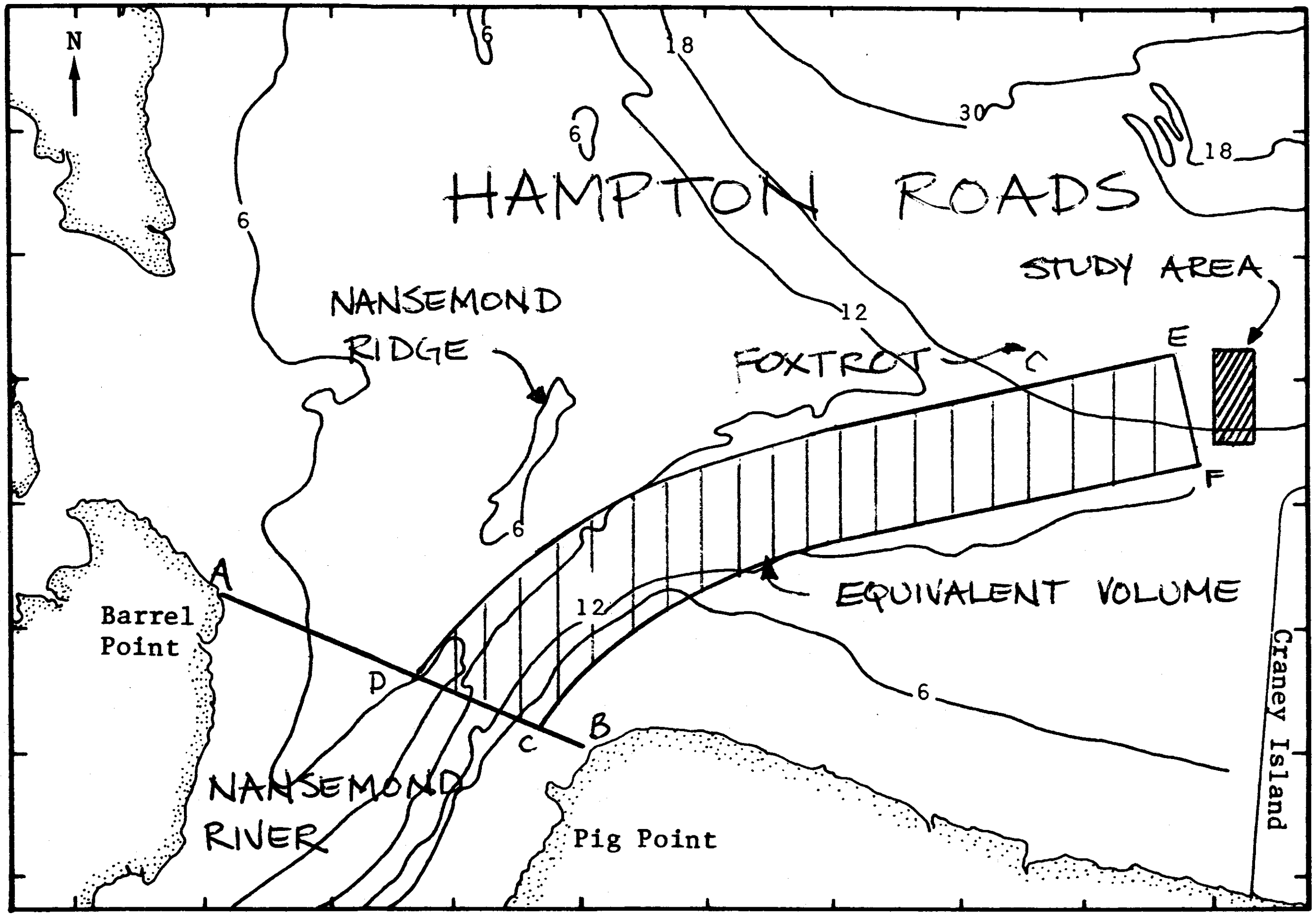


Figure 2. Equivalent volume tidal excursion estimate. The intertidal volume of the entire Nansemond River upriver of section AB can be filled with the water contained in a channel of 4 meters (approx. 13 feet) depth bounded by perimeter CDEF.

4. Experimental Design

4.1 The tidal current in the Nansemond River is not precisely in phase with that of the James River, a common situation for a small branch of a large tidal estuary. The flood tide in the Nansemond begins while the James is still ebbing, and ends while the James is still in late flood. Because of this phase difference, there are two possible routes by which water from the vicinity of the study area might flow into the Nansemond. These flow hypotheses are illustrated schematically in figure 3. In one case, called Route A, the water flowing past the study site is hypothesized to travel in a direct line between the study area and the mouth of the Nansemond River, reaching the Nansemond before the start of ebb tide there. In the other case, called Route B, the water passing the study area follows the James River through its flood phase, slack water and into ebb in time to enter the Nansemond during its late flood. This route is of particular interest because it carries the surface water over the oyster producing areas of Nansemond Ridge. The field experiment was designed to determine whether routes A and B do or do not carry surface water from the study area into the Nansemond River.

4.2 Several considerations including cost of operation, direct applicability of results, and familiarity with and

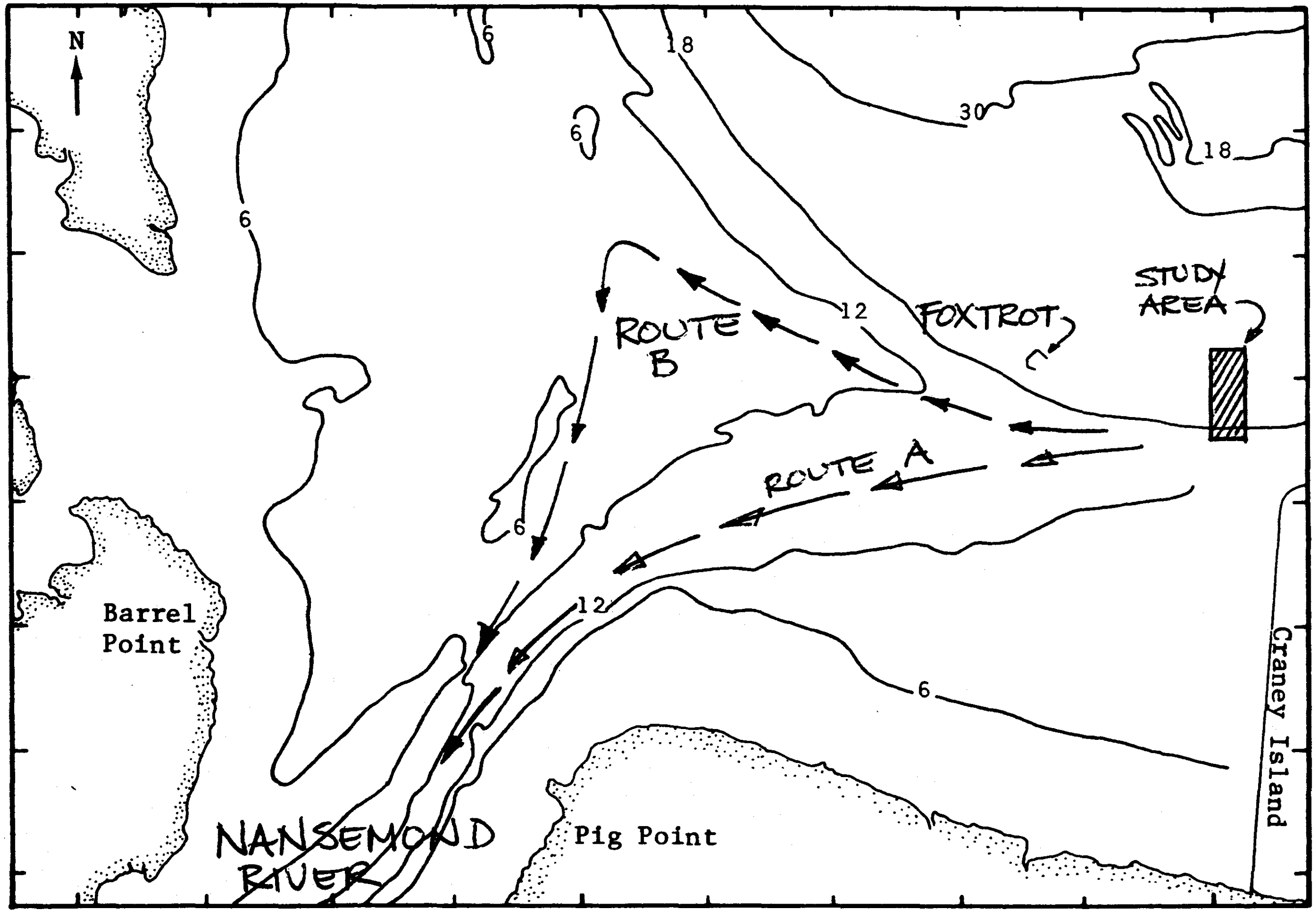


Figure 3. Hypothetical routes for surface flow from the study area towards the Nansemond River. Route A is the most direct path while route B is a possible path due to tidal current phase differences between the James and Nansemond Rivers.

ease of operations led to the adoption of the remote sensing-dye buoy method for the performance of the critical experiment. This method has been described extensively in several reports (Neilson, 1975 and Fang, et al., 1975, Munday, et al., 1975). Briefly, surface markers are added to the natural flow which emit a highly visible fluorescent dye. These are recorded on sequential aerial photographs, and the paths of the buoys (and the flow pattern) are determined by analysis of the resulting photographs.

An extension of the technique was planned to assure a satisfactory answer for route B, if required. The dye buoy experiment, as currently practiced is limited to daylight hours because of the requirements of photography. To guard against the possibility that obtaining conclusive evidence about route B would require a longer time than available daylight allows, a two stage experiment was formulated. In the first stage, the buoys would be released at the study area and allowed to drift until the available daylight was over. The last photographed positions of the buoys would then be transferred to Loran C coordinates, and another set of buoys placed in the same positions for another run on a later day, when the tidal cycle was relatively earlier. This two phase experiment assured us that a sufficient portion of the tidal cycle could be observed to provide conclusive evidence about route B despite the photographic daylight constraint.

4.3 The resulting experiment design incorporated the use of four anchored buoys emitting dye plumes (streamers) and sixteen floating buoys to be deployed in four sets (floaters). The deployment positions for the experiment designs are shown in figure 4. Four assumed positions for the outfall were chosen as shown by points 1 through 4. These were to be release points for floating buoys throughout the flood tide to achieve fine scale resolution within the study area such as was achieved in a similar study at Newport News Point (Neilson, 1975). They were also to be marked by anchored streamer buoys for determining the change of the tide in the study area as well as for marking the release points clearly for subsequent floater releases. In the second realization of the experiment three more positions for fixed markers were added (5,6,7) in order to obtain specific information about the flow across Nansemond Ridge during the tidal cycle. As noted above, a second experiment was planned if required to extend the tracks of the floaters beyond the time available during the first experiment. This consisted of deploying buoys at the positions occupied by the floaters at the end of the day on another day, when the tidal cycle occurred earlier and treating the new tracks as continuations of the old tracks.

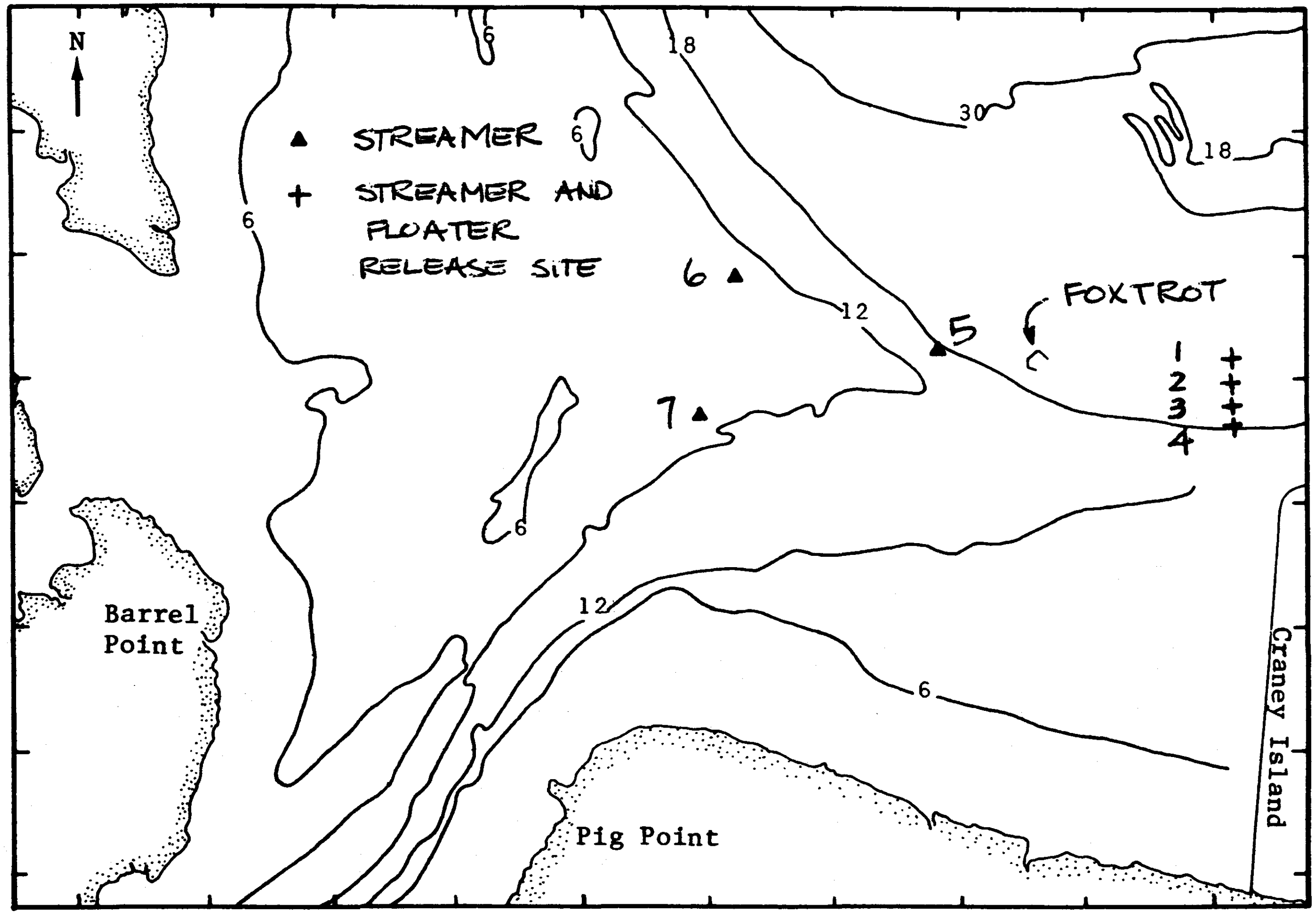


Figure 4. Experimental design. Floating dye buoys were released at positions 1, 2, 3, 4 throughout the flood tide. Streamers were placed at these same positions and, in the second realization, at positions 5, 6 and 7.

5. Description of Experiment

5.1 The field work was first attempted on August 12, 1975. The R/V Bernoulli was selected since it is equipped with an automatic recording system and a Loran C navigation system. The boat, a converted 26' cabin cruiser, was to go to the study area and establish communications with the aircraft, at which time buoy deployment and tracking would begin. However, the experiment was terminated after about two hours because the aircraft experienced a failure which required an early landing and a loose propeller strut restricted vessel speeds. The inability of the boat personnel to see the buoys (which are highly visible from the air) resulted in greatly reduced data acquisition. The experiment was rescheduled for the next tidal "window", the coincidence of daylight hours with the desired tidal phase, two weeks following.

In the interim, the experiment design was improved in the light of the partial data gathered during the first attempt. Notably, traveling distances were shortened, the anchored streamers at points 2 and 3 were eliminated as being redundant, and the streamers at 5, 6 and 7 were added. A Loran C chart for the local area was constructed based on positions obtained during the first attempt and Loran lane gradient information provided by another VIMS project (Baker, 1975).

5.2 The experiment was run again on August 28, this time to completion. The wind was moderate and steady all day blowing out of the northeast. This was fortunate, for the purpose of this study, because it corresponded to "worst case conditions" which would push water from the study area into the Nansemond River. The events for this experiment are shown as a function of time in figure 5. The first two fixed buoys (1,4) were deployed at about 1030 DST, with the A set of floaters (A1-A4) deployed immediately after, about twenty minutes after the expected time of slack water before flood in the study area. The far field streamers, (5,6,7) were deployed next by directing the vessel (R/V Bernoulli) to the appropriate Loran C coordinates. Floater sets B and C were deployed at about 90 minute intervals after A, with photographic and Loran positioning being used to fix these positions. The aircraft left the area at about 1345 and returned at about 1505. During this time, the vessel, rather than attempt to search blindly for the buoys, stayed near the buoy from the A set judged most likely to enter the Nansemond River. The vessel record was interrupted during this period in order to refuel the generator used to power the data acquisition systems. Also, after about 4.5 hours of operation, the floater ran out of dye, as anticipated, and was replaced with a fresh floater. (The fresh floater lasted for less than three hours for some, yet unknown

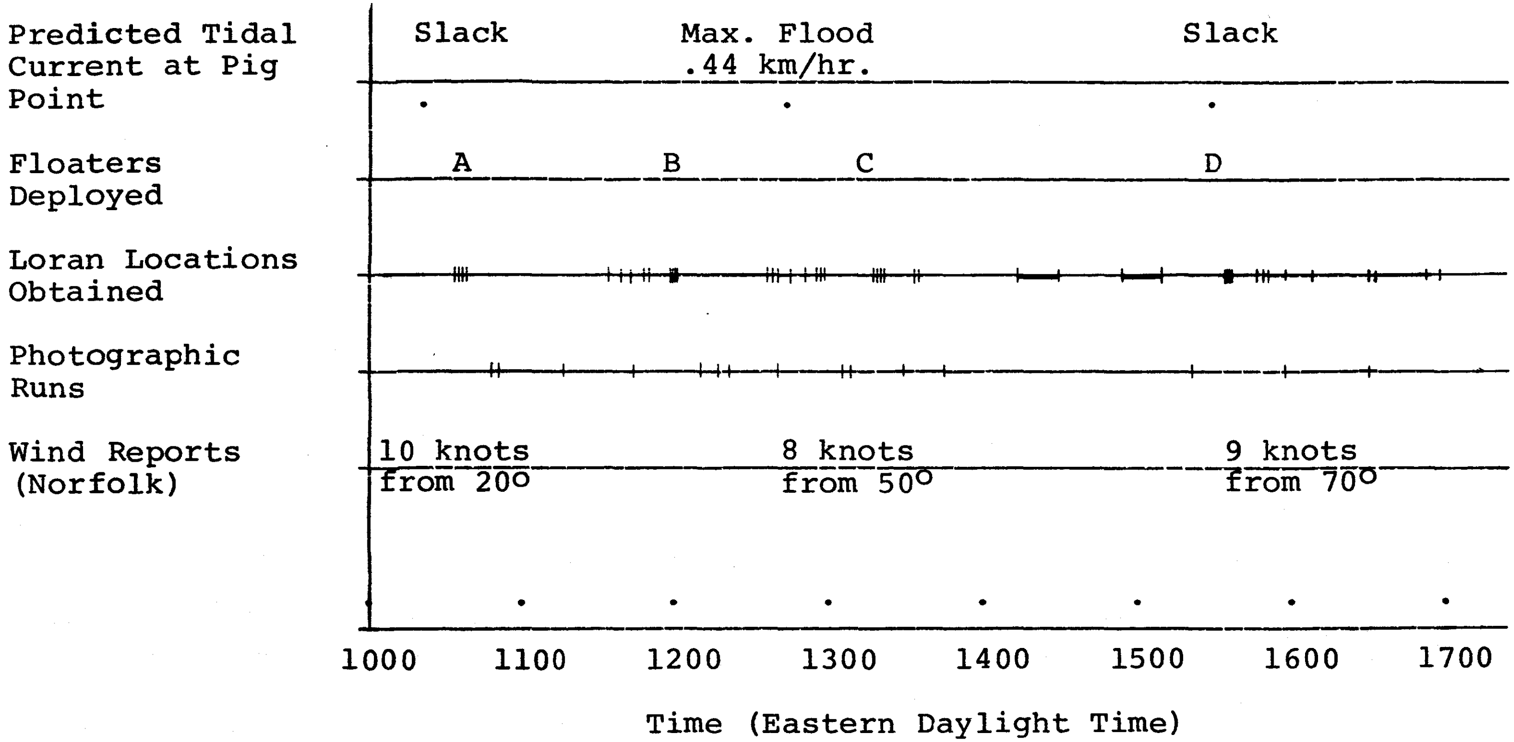


Figure 5. Event Diagram - August 28, 1975.

reason). When the aircraft returned, the fourth set of floaters was deployed, and the normal operation resumed. The near field streamers (1,4) were replenished, but the far field streamers allowed to run out.

Another extension of the technique was implemented late in the day. The western part of the study area is generally featureless as viewed from the air. There is a large expanse of water with neither shoreline nor channel markers for use in aligning aerial photographs with reference points. To provide a reference point when a set of buoys drifted into this area, the study boat anchored and obtained a several minute sequence of Loran positions to fix its position. In this way, the study boat itself became the needed reference point.

The experiment was continued until the tide had been observed to turn to ebb over much of the area of the experiment, and no floaters were apparently headed for the Nansemond River. At this time, the vessel retrieved the surface floaters and departed while the aircraft obtained one more set of photographs of the area before departing.

The analysis of the data (see section 8) indicated that the Route B path was not realized, so the follow-on part of the experiment was not run.

6. Methods of Data Analysis

6.1 LORAN C

The data from the data recording system on board the Bernoulli (Bolus et al., 1971) is in the form of records on 9 track computer compatible magnetic tape. Each record consists of 122 EBCDIC characters, among which are the day of the year and twenty-four hour time resolved to the second and one of two LORAN C coordinates resolved to .01 microseconds (roughly equivalent to 3 meters). A given LORAN C time difference is repeated every other record and the records are generated every three seconds in real time. An external thumbwheel switch can be used to enter a code (01-99) on each record. This switch was used during these experiments to identify records during which the boat was next to specific markers. The day's run generated a total of about 8,000 records, only a small fraction of which were of interest.

The field tapes were pre-edited with a PL-I program TCØPY, which removed the few records on the field tape having unrecoverable read errors. This procedure is required by the VIMS computer FORTRAN system, which can neither tolerate nor recover from such errors. Next, the records of interest (those with a non-zero switch value) were culled from the tape and printed out for further analysis with FORTRAN program NØNZER. For each valid buoy location, the mean and standard deviation of the LORAN coordinates was calculated and this information entered on the calculator-plotter (Hewlett-Packard 9010) at the VIMS

Department of Physical Oceanography and Hydraulics and plotted directly in UTM coordinates for direct comparisons with and additions to the positions plotted from the aerial imagery. For the limited area of Hampton Roads, a linear transformation was considered sufficient between LORAN-C and UTM coordinates, the transformation being empirically determined to plot a point in the source area exactly.

6.2 Data Reduction

Buoy positions were charted onto photocopies of topographic maps using the Bausch and Lomb Zoom Transfer Scope Model ZT-4 at NASA Langley Research Center.

The Zoom Transfer Scope permits simultaneous viewing of a transparency and a topographic map. The scale of the transparency is adjusted to match that of the topographic map (SCALE 1:24,000) by varying the magnification. Scale matching is accomplished by matching the transparency to prominent shoreline features and water structures charted on the topographic map. Once the scale is matched, charting of the buoys is accomplished by marking the image of the "head" of the dye marker with pencil. Buoy positions were crosschecked by plotting positions from adjacent frames whenever possible. Buoy positions are also identified with run number, frame number, and time of photograph. Our experience indicates that buoy positions can be located within a radius of 10 meters from an altitude of 5000 feet using this method.

A Universal Transverse Mercator (UTM) grid was added to the charts to aid in determining the coordinates of the buoys. Positions taken from the UTM coordinate system are accurate to ± 5 meters.

Velocities were calculated by measuring the UTM coordinate values for each charted position and calculating the vector difference between sequential positions of a single marker. Since the time of each position was observed, the mean speed between two points is calculated as the distance between points divided by the difference of the observation times.

Since the calculated speeds are derived from straight line measurement, they will always be lower than the actual velocities. However, we believe that the error is small and need not be considered here.

7. Data Analyses

The data from the aerial photography and the LORAN positioning are consistent and complimentary and they are combined in a single set of charts, figures 6a-d. Each of these charts illustrates the paths taken by a set of floaters, with the addition of isochronous lines drawn approximately connecting the paths. The data from which these figures are drawn are presented separately for the LORAN C and the aerial photography analyses in appendix 1. Because these data were sufficient to draw the conclusions appropriate to this report, no further analyses were performed.

The paths from the first set of floaters are shown in figure 6a. They were released in an approximate North-South line at about 1040 in the morning; the goal of equal spacing was not achieved. Throughout the day, this set of floaters seemed to form two groups, the first group consisting of the single most northerly floater (A1) and the second consisting of the other three (A2, A3, A4).

The tracks of these three buoys are difficult to distinguish on the chart, but the effort need not be made in the present context. The most important point to note is that this similarity of behavior indicates a very low dispersion in the surface flow. The most northerly floater in this set headed more directly towards the Nansemond River and had a higher speed after the other group entered the shallows. Because of this behavior, it was judged to represent the most critical case,

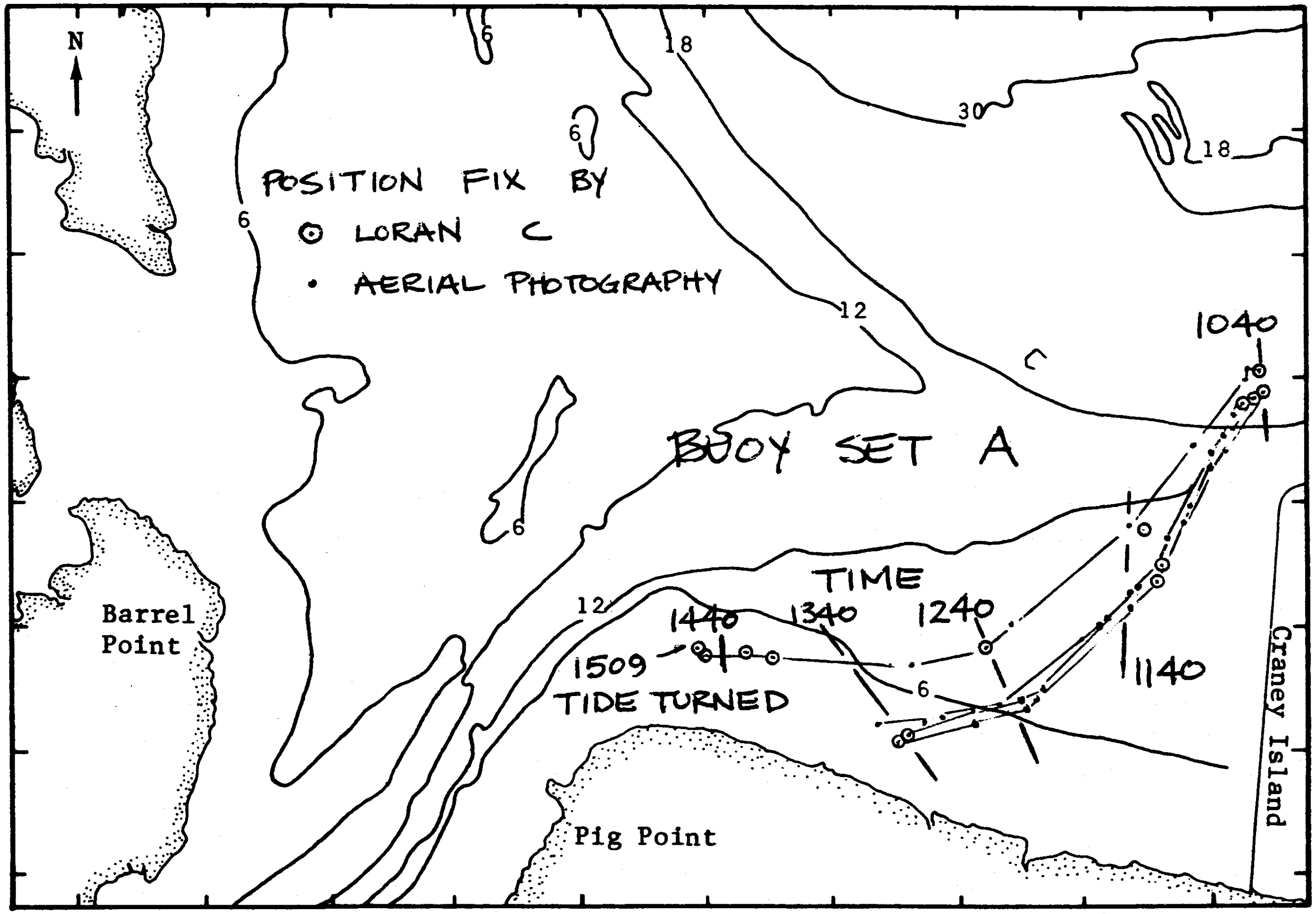


Figure 6a. Position tracks for Buoy Set A released at 1040.

and the experiment was run to assure that its furthest extent was recorded. This occured at 1509, which marks the beginning of ebb tide at the mouth of the Nansemond, at least on the Pig Point side.

The second set of floaters was released shortly before noon, and behaved in a manner entirely unlike the first set. They did drift more nearly as anticipated, heading primarily towards the west. Two of the buoys (B1 and B3) have tracks of just over an hour in duration, at which time dye was exhausted. They might have lasted as long as three hours, since the aircraft was absent during the last part of that period. The southernmost buoy track has its last point at 1600, but we do not know whether it was still moving with the flood current or had started to ebb. The time lines for 1400 and 1500, which are interpolations along the path, must be interpreted with a corresponding uncertainty. The tracks of B2 and B4 do exhibit substantial divergence verifying the concept that the shallow area west of the 12 foot depth contour acts as a flow splitter for the water passing the study area. The track of floater B2 shows the turning of the tide from the joining of the three observations at its end. This turning is towards the main channel, rather than in towards the Nansemond River mouth. It occurs at about 1600, almost a full hour after the tide near Pig Point turned, as observed using buoy A1. This progression of the time of slack water is in accordance with the work of Neilson and Boule (in VIMS, 1975) in which the relative time of slack water in the Hampton Roads area was deduced from a

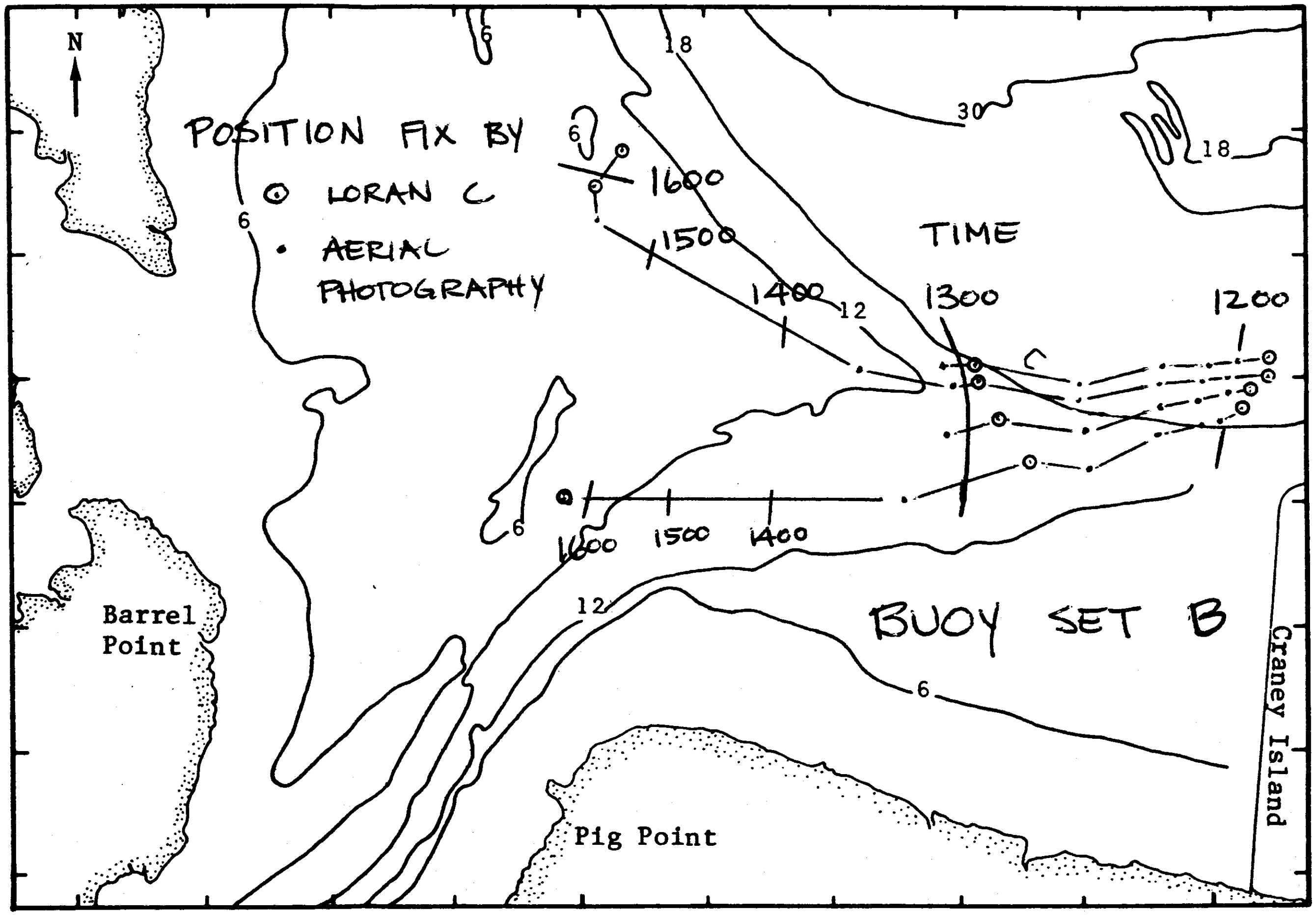


Figure 6b. Position tracks for Buoy Set B released at 1155.

review of existing current meter data. The final point to note is that, for floaters B1 and B2, the FOXTROT ammunition pier is nearly directly downstream of the study site with a transit time of 45 minutes. For this part of the cycle, thus, the dispersion estimates from the dye release at Foxtrot are probably applicable as well to the two more northerly sites investigated here.

The third set of floaters was released at 1320 and travelled directly towards the west. During the two hours following release, this set experienced only the lateral divergence which would be associated with a laminar-like flow of constant velocity in a channel with variation in depth. In particular, there was no evidence during this run that the Nansemond Ridge acts as a flow splitter. This behavior is at variance with that observed from the previous release, eighty minutes before. The time of slack water obtained from the partial turning observed for these buoys could be anywhere between 1600 and 1715, depending on where the curve through the two points at the ends of the paths is given its maximum westward extent. It is notable that at about 1600, this set of buoys is nearly as far west as the previous set. The outer buoys (C1 and C2) both passed near to FOXTROT, so the dispersion estimates from the FOXTROT dye study are as valid for this set as for the last set of buoys.

The fourth set of floaters was released soon after the aircraft returned from refueling. This set of floaters drifted to the west with the tide, but they went much more slowly than

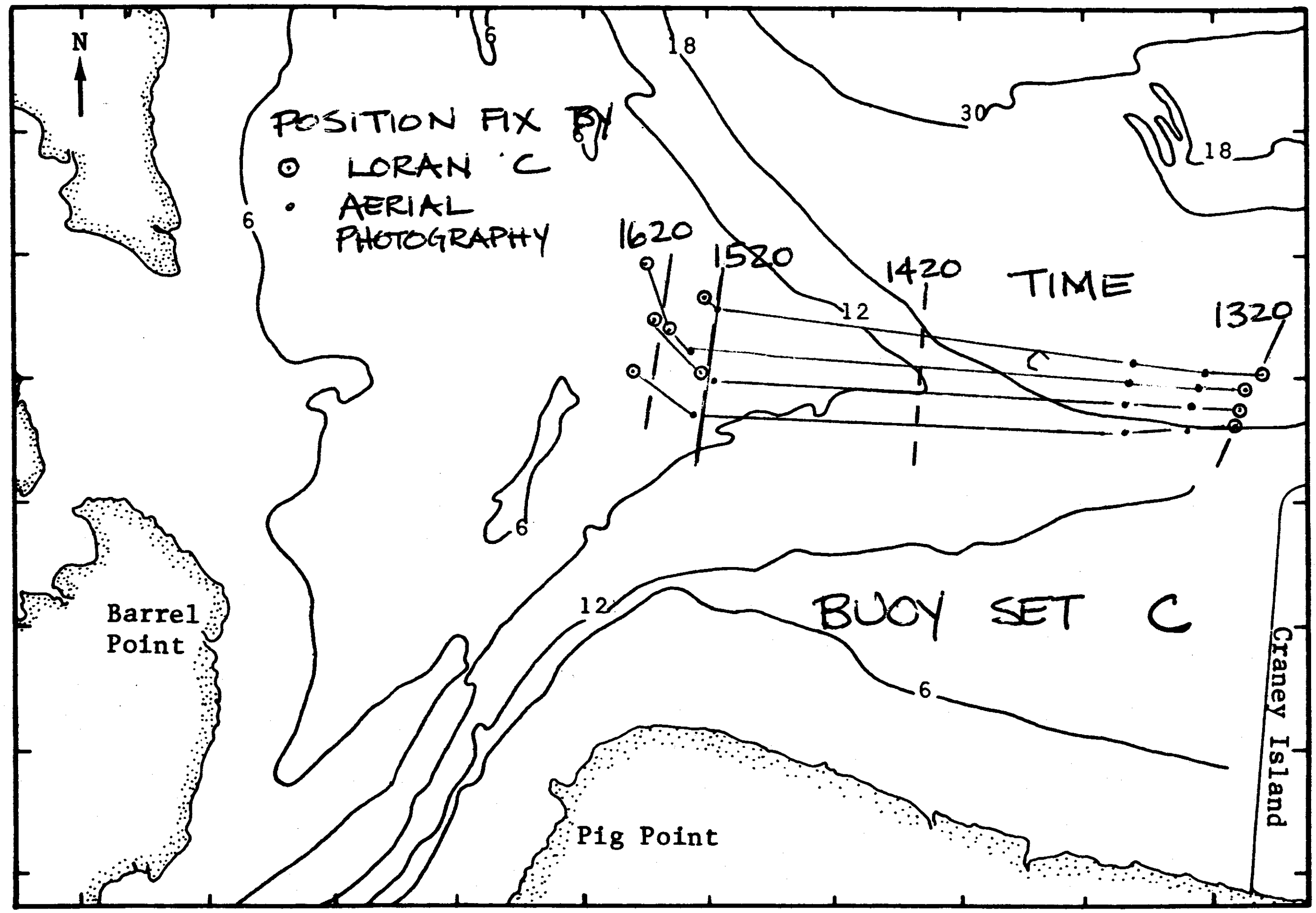


Figure 6c. Position tracks for Buoy Set C released at 1320.

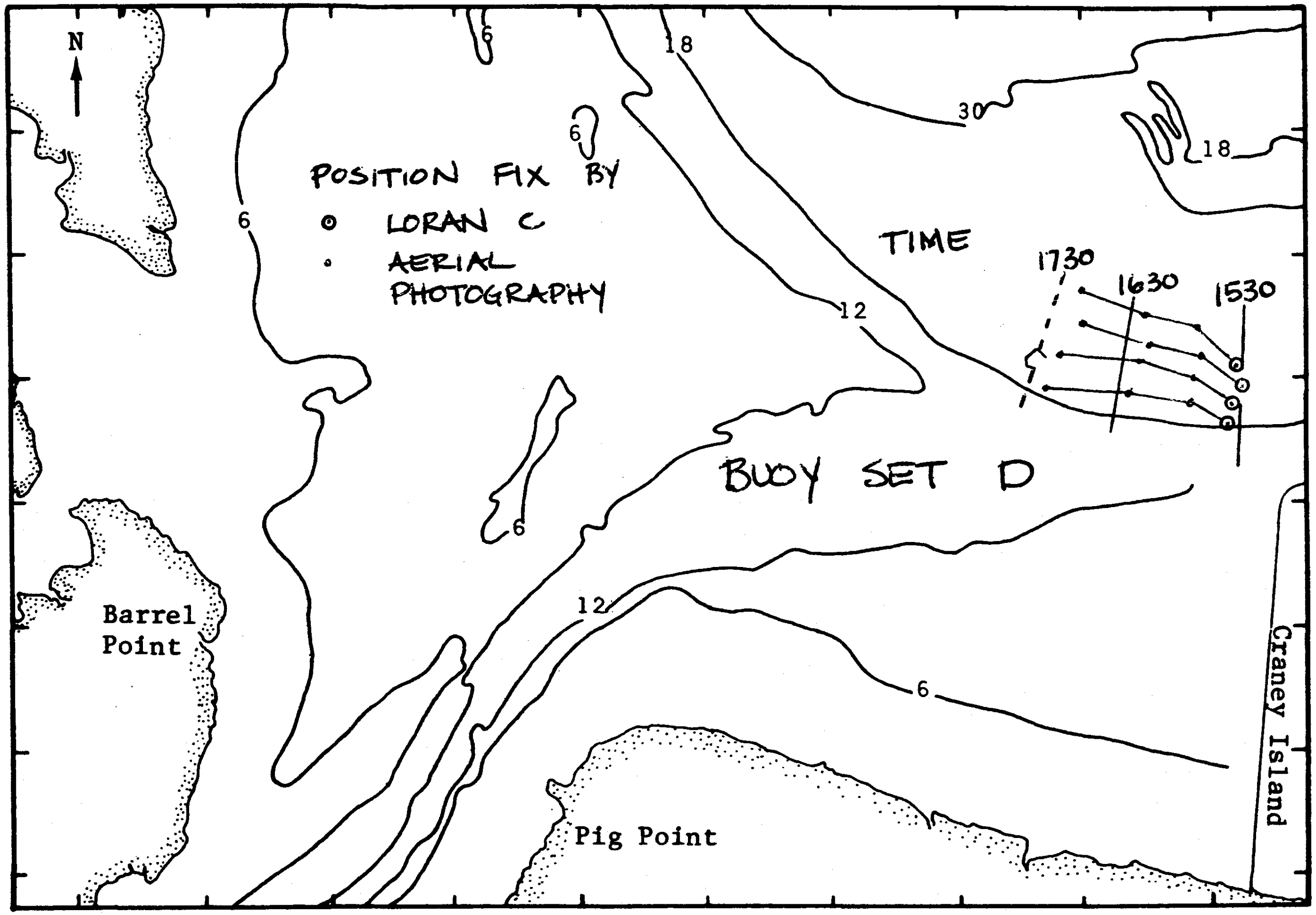


Figure 6d. Position tracks for Buoy Set D released at 1530.

the previous sets, an extrapolation of their paths requiring two hours rather than forty-five minutes to pass by FOXTROT. Although the paths of buoy sets B, C, and D are all directed to the west past FOXTROT, there is a consistent clockwise veering throughout the flood tide phase. Because of the slow speed, indicating the ending of the flood tide, and the general direction towards the middle of the James River channel rather than the Nansemond River mouth, these buoys are not analyzed further. A single point is noted that, as with sets B and C, buoy set D approached FOXTROT closely enough that the dispersion results obtained from the FOXTROT dye study are likely to apply to effluent released from the study area during the late part of the flood tide.

8. Discussion & Interpretation

The flow of water past the study site was observed on a day with more than usual wind stress for August, winds towards the Nansemond River and less than usual (0.8 out of a range from 0.4 to 1.7 with median 0.9) predicted flood tidal currents at Chesapeake Bay mouth (Tidal Current Tables). For at least the latter two-thirds of the flood phase, the water leaving the study site passes by the site (FOXTROT) from which the dye was released during the 1974 study. This indicates that much of the dispersion information based on that study is likely to be applicable to the more easterly study site.

An important difference between FOXTROT and the site of the present study is evident during the first part of the flood phase of the tidal current cycle. During this time the water passing the study site does not head past FOXTROT, but rather heads parallel to the Craney Island Landfill shoreline towards Nansemond County, then west in the shallows towards Pig Point. No conclusions about the dispersion of this water can be made directly from the data of the earlier dye experiment.

It is the flow during this early part of the flood tide which is most likely to enter the mouth of the Nansemond River. Extrapolating from the data taken during this study, effluent from the outer part of the study area (Stations 1&2) can be expected to cross the line between Pig Point and Barrel Point by the end of the flood tide in between 10% and 30% of the flood tides, and so be said to enter the Nansemond River. It is likely that such water almost immediately would be flushed out of the Nansemond on the succeeding ebb. The total percentage of time during which effluent from the study site would be across that line is between 1% and 5%, according to the same extrapolation with the condition existing, when it occurred, for a maximum of three hours.

A more noticeable impact of effluent from the study area would be on the shoreline between the Craney Island Dike and Pig Point. Judging from the observed paths and the fact that no other major source of water supplies that section of Hampton Roads during flood tide, it is our opinion that effluent will come ashore somewhere on that shoreline for about two hours during virtually every flood tide when a strong and steady wind is blowing from the northeast to west sector. This effluent will be relatively young, having emerged from the outfall pipe between two and four hours before going ashore. The amount of effluent going ashore may depend on the distance of the outfall from the corner of the Craney Island Landfill.

The effect on Nansemond Ridge of effluent from the study area depends strongly on the location of the outfall within the study area. If the outfall is in the outer part of the study area (positions 1 and 2), the effect will be less than that determined from the earlier dye experiment made at FOXTROT. This is because the flow passes FOXTROT from only two thirds of the flood cycle release. If the release is from the inner part of the study area (positions 3 and 4) such a clear conclusion cannot be directly drawn. The reason for this is that the relative behavior of the B and C sets of buoys indicates that a relatively stagnant zone may form over the Nansemond Ridge during late flood. The divergence of the paths of the B floaters, the non-divergence of the C floaters, and the ability of the B floaters to "catch up" with the C floaters are all consistent with a flow pattern of a jet past Craney Island impinging on a wall (the western shore of the study region) and forming two eddies, one on either side of the jet axis. In this case, the southern eddy would form over the Nansemond Ridge. The result of such a flow would be an area of stagnant water between Barrel Point and FOXTROT where 4-6 hour old effluent might consistently sit with little dispersion during the latter part of each flood tidal current phase. The results of the FOXTROT dye release suggest that the northern eddy may form as well.

A final note should be added concerning the Craney Island landfill. A suggestion has been made that the existing landfill be enlarged by extending the dike from its current northwest corner towards Pig Point and back along the Nansemond County shoreline to the base of the present dike, forming a triangular extension and roughly doubling the landfill area. If this suggestion were carried out, one result would be to force the early flow past Craney Island into a more direct path towards the mouth of the Nansemond River. In this instance, the amount of surface water passing the study site and entering the mouth of the Nansemond River would be increased.

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Appendix A1

Buoy Positions From Loran Fixes

Event No.	Buoy No.	Time (EDT)	No. of Samples	Loran Positions SS7 Y	Loran Positions SS7 Z
50	A1	1038	2	53827.00 ± .20	70813.71 ± .12
50	A1	1146	12	53837.24 ± .08	70817.85 ± .07
50	A1	1242	10	53847.18 ± .07	70819.89 ± .07
50	A1	1412	10	53854.18 ± .05	70817.39 ± .09
50	A1	1428	11	53854.71 ± .05	70816.89 ± .04
50	A1	1456	11	53855.67 ± .05	70816.33 ± .08
50	A1	1506	11	53856.12 ± .08	70816.22 ± .07
50	A1	1509	11	53855.97 ± .16	70816.06 ± .06
51	A2	1037	1(2)	53828.40 -	70814.78 (± .13)
51	A2	1137	2	53838.09 ± .10	70819.27 ± .04
51	A2	1238	3	53848.08 ± .01	70822.28 ± .04
51	A2	1334	2	53852.31 ± .07	70821.65 ± .08
52	A3	1037	2	53829.09 ± .05	70814.83 ± .05
52	A3	1138	4	53839.06 ± .08	70819.83 ± .09
52	A3	1237	4	53848.28 ± .04	70822.38 ± .06
52	A3	1332	3	53852.94 ± .04	70821.71 ± .02
53	A4	1036	3	53830.18 ± .17	70815.33 ± .15
53	A4	1141	8	53840.70 ± .06	70820.08 ± .10
53	A4	1234	8	53848.97 ± .06	70822.11 ± .07
54	B1	1156	3	53826.33 ± .13	70813.40 ± .08
54	B1	1259	3	53835.71 ± .02	70809.78 ± .12

Appendix A1

Buoy Positions from Loran Fixes

Event No.	Buoy No.	Time (EDT)	No. of Samples	Loran Positions SS7 Y	Loran Positions SS7 Z
55	B2	1156	3	53827.23 ± .13	70813.89 ± .04
55	B2	1257	2	53836.11 ± .07	70810.37 ± .02
55	B2	1558	2	53839.85 ± .05	70798.43 ± .07
55	B2	1659	2	53837.47 ± .02	70797.60 ± .03
56	B3	1157	2	53828.16 ± .16	70814.33 ± .10
56	B3	1255	2	53837.18 ± .03	70811.91 ± .05
57	B4	1158	2	53829.26 ± .21	70814.82 ± .09
57	B4	1251	13	53837.85 ± .09	70813.90 ± .07
57	B4	1607	6	53851.56 ± .04	70807.67 ± .08
58	C1	1320	3	53827.31 ± .17	70813.55 ± .06
58	C1	1551	2	53841.06 ± .03	70803.69 ± .02
59	C2	1319	2	53828.31 ± .17	70814.20 ± .14
59	C2	1548	2	53843.49 ± .05	70804.33 ± .10
59	C2	1653	3	53841.47 ± .08	70801.67 ± .11
60	C3	1319	2	53829.31 ± .10	70814.78 ± .03
60	C3	1546	4	53844.28 ± .06	70806.22 ± .04
60	C3	1635	3	53843.54 ± .02	70803.85 ± .06
61	C4	1318	2	53830.22 ± .06	70815.20 ± .25
61	C4	1630	4	53846.38 ± .05	70805.30 ± .10
62	D1	1531	2	53827.29 ± .16	70813.37 ± .10
63	D2	1531	2	53828.11 ± .02	70814.10 ± .00
64	D3	1532	2	53829.10 ± .12	70814.57 ± .10
65	D4	1532	2	53830.10 ± .20	70815.16 ± .15

End of Data

Appendix A2

Buoy Locations From Aerial Photography
UTM Coordinates

Date: August 25, 1975

Floater Set A

	A1		A2		A3		A4		
Image	North	East	North	East	North	East	North	East	Time
1	88061	76378	87732	76268	87548	76195	87390	76097	1049
2	87963	76353	87598	76244	87415	76171	87268	76073	1054
3	87463	75963	86975	75902	86841	75854	86695	75732	1115
4	86817	75415	86134	75390	86244	75439	86000	75195	1145
5	86000	74451	85524	74707	85463	74683	85426	74402	1234
6	85695	73646	85243	74146	85244	74146	85292	73902	1304
7	85817	72012	85243	73634	85170	73634	85232	73341	1335

Floater Set B

	B1		B2		B3		B4		
Image	North	East	North	East	North	East	North	East	Time
1	88182	76220	88049	76159	87914	76109	87732	76085	1204
2	88159	75993	88000	75946	87866	75902	87665	75910	1209
3	88158	75646	88000	75622	87836	75617	87598	75622	1219
4	88000	74968	87871	74976	87610	74983	87305	75049	1238
5	88073	74122	87970	73975	87598	73895	87163	74171	1307
6	88109	73878	88079	73178			87056	73524	1335
7			89329	71073					1558
8			90305	71317					1659

Floater Set C

	C1		C2		C3		C4		
Image	North	East	North	East	North	East	North	East	Time
1	88109	75975	87951	75915	87805	75853	87622	75829	1327
2	88183	75390	87993	75341	87853	75329	87641	75341	1341
3	88573	72017	88232	71793	88007	71976	87720	71841	1522

Floater Set D

	D1		D2		D3		D4		
Image	North	East	North	East	North	East	North	East	Time
1	88439	75951	88183	75951	88000	75890	87817	75878	1541
2	88524	75512	88292	75537	88146	75439	87939	75390	1611
3	88719	74985	88451	75012	88195	74829	87951	74732	1716

Appendix A3

Computer and Calculator Programs

The computer programs which were used to edit, transfer and transform the data were written for the machines available at VIMS. They have not been reproduced in the sake of brevity but the programs and other information are available upon request.