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WATER QUALITY IN THE SMALL COASTAL BASINS

by

Bruce J. Neilson
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A REPORT TO THE

HAMPTON ROADS WATER QUALITY AGENCY

The preparation of this report was financed through a grant from the U. S. Environmental Protection Agency under Section 208 of the Federal Water Pollution Control Act Amendments of 1972.

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August 1976

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I. DESCRIPTION OF THE STUDY AREA

The Small Coastal Basins portion of the Hampton Raods 208 study area includes the Back and Poquoson Rivers on the Virginia Peninsula and Little Creek Harbor and the Lynnhaven Bay system on the southern shore of Chesapeake Bay, as shown in Figure 1. The drainage areas are characteristically small, ranging from only 63 square kilometers for Little Creek Harbor to 156 sq. km. for the Lynnhaven Bay system. All four basins lie entirely within the geological Coastal Plain Province, the lowlying area between the Fall Line and the Atlantic Ocean. The soft sediments typical of this province erode easily, so that the rivers have branching or dendritic patterns. Because the topographic reflief is slight and the drainage areas are small, none of the basins has continuous free flowing tributaries typical of larger estuaries. The U. S. Geological Survey has no stream gaging stations within the Small Coastal Basins area.

All four river basins lie within the Hampton Roads metropolitan area, but are far enough removed from the urban centers that land use ranges from agriculture and pasture land to industry and dense residential developments. These basins are experiencing a faster rate of development than the nearby urban areas. Some problems are encountered with this urbanization. The lowlying areas are subject to flooding, especially that due to the storm surge associated with "Northeasters". Much of the area is marsh protected by recent wetlands legislation but still susceptible to the indirect

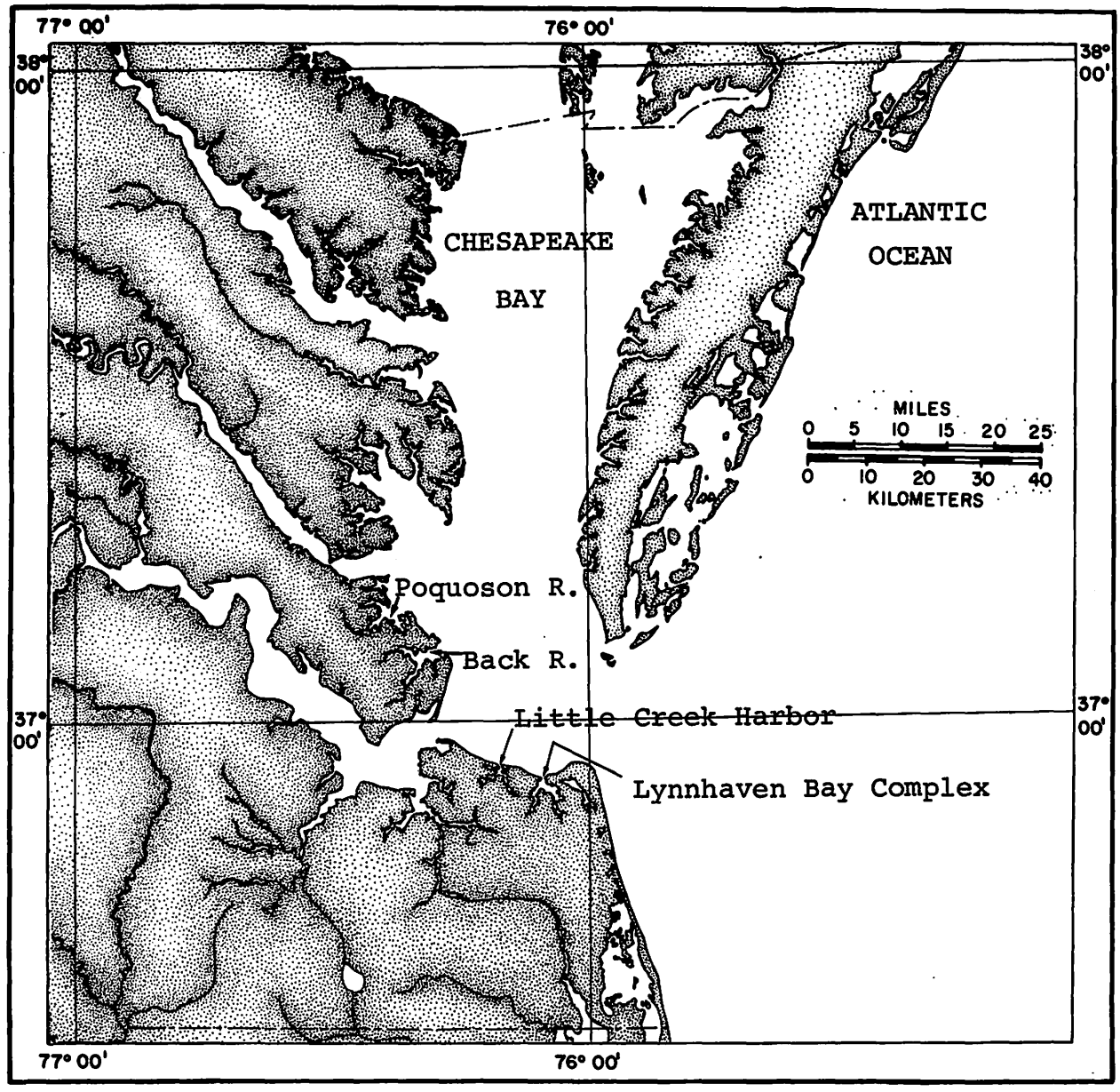


Figure 1a. Lower Chesapeake Bay and Small Coastal Basins.

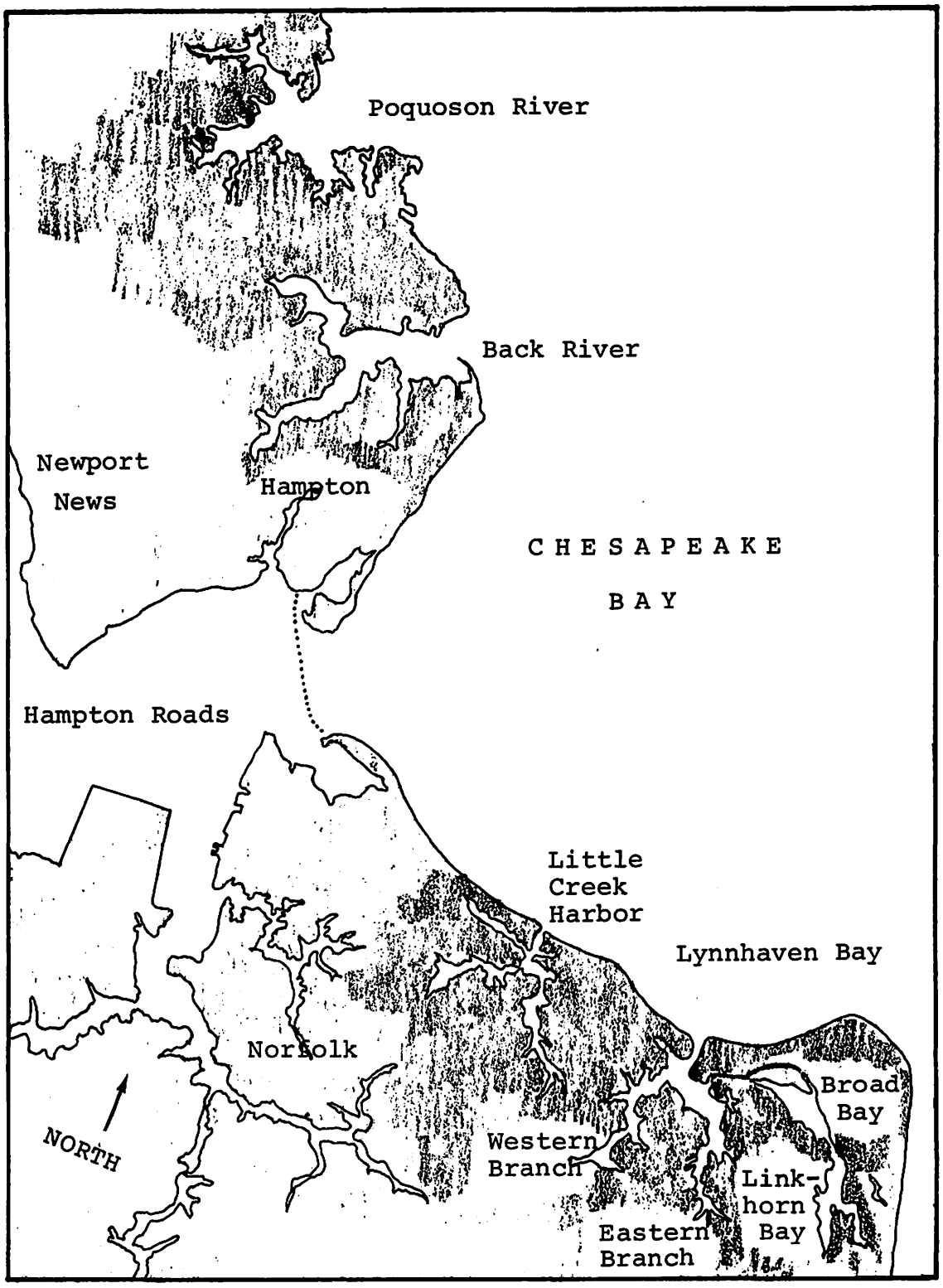


Figure 1b. Small Coastal Basins.

effects of development. A high water table during much of the year often causes difficulties with domestic septic tank systems resulting in pollution of adjacent water bodies. In general, water quality problems for these estuaries arise from non-point sources of pollution rather than point discharges of treated sewage or industrial wastewaters.

The climate for this area is classified as humid-subtropical. The mean annual precipitation of 115 centimeters is distributed rather evenly throughout the year. The average seasonal snowfall accounts for less than 20 cm of the total precipitation. The average annual mean temperature is around 15°C with monthly mean temperatures ranging from 5°C in January to 26°C in July. The moderating influence of the near-by Atlantic Ocean has a major effect on the local climate. The summers tend to be hot and humid with higher than average monthly rainfall. The fall is often the driest season of the year, but heavy rainfall and strong winds due to tropical storms and hurricanes may develop during late summer and fall. Coastal "Northeasters" occur from late fall to spring and can cause heavy winds and unusually high tides or storm surge.

II. WATER QUALITY DATA SOURCES

A problem common to most environmental and water quality studies is that the available data were collected for a variety of reasons over a period of many years. Usually it is very difficult to piece together the information so that an understanding of the whole system appears. This situation exists for the Small Coastal Basins. Fortunately, a great deal of technical information and background material has been included in the planning bulletins done by the Department of Conservation and Economic Development and the Division of Water Resources of the Commonwealth of Virginia. In addition to such basic information as a stream gazeteer, lists of water withdrawals and wastewater discharges, etc., which are included in the introductory volume, other volumes cover the economic base, hydrology, water resource requirements and problems, and river basin water quality plans. Included in these excellent reports is a general analysis of water quality problems and the likely causes. However, due to the scope of these studies, very little data on water constituents is presented.

The State Health Department and the State Water Control Board both collect water samples from the coastal basins on a regular basis. These samples are analyzed for bacteria (total and fecal coliforms) and for chemical and biochemical constituents. These data provide a means to chart trends in water quality and to highlight problem areas. In general, no other state, federal or local agencies routinely study water quality.

Many special studies have been made, especially in the south shore estuaries. The Corps of Engineers conducted geological

and hydraulic studies of the Lynnhaven Bay system before and after dredging of the Long Creek Canal and the mouth of Lynnhaven Bay. The City of Virginia Beach has had studies made relative to bacterial contamination of shellfish growing waters in the Lynnhaven Bay system. Studies of both Little Creek Harbor and Lynnhaven Bay conducted by students and faculty of Old Dominion University have tended to focus on important, but limited, aspects of water quality. The Virginia Institute of Marine Science made a tidal survey of the Lynnhaven system, as well as wetlands and shoreline studies. Tidal marsh inventories and shoreline situation reports on York County and Hampton include the Back and Poquoson Rivers. Similar reports for the south shore estuaries will be available in the future. The Hampton Roads Sanitation District funded a monitoring program which included stations in Chesapeake Bay close to the Small Coastal Basins, but no stations within any of the four estuaries.

To summarize, a few stations have been monitored routinely and regularly for several years. More intensive surveys have been conducted which have focused on special problems or particular geographic areas. But comprehensive and synoptic surveys of water quality in the small coastal basins were not available. It was for this reason that the Hampton Roads Water Quality Agency contracted the Virginia Institute of Marine Science to conduct a field sampling program. This program had two elements: intensive surveys, when water samples were collected hourly throughout a complete tidal cycle or longer, and "slack water surveys". The intensive surveys provide both

a picture of water quality throughout the estuary and documentation of how water quality varies through the tidal cycle. Ideally, water samples would have been analyzed frequently for a wide range of constituents, but the need for economy dictated that basic hydrographic parameters would be measured often and water quality analyses performed on samples taken less frequently. That is, temperature, salinity and dissolved oxygen were measured hourly, but water samples for nutrients, coliforms and chlorophyll "a" were taken every three hours.

A slack water survey or same slack survey provides a means to capture a picture of water quality within an estuary with limited resources. A single boat follows the progress of either the high or the low water slack wave from the estuary mouth upriver with water samples taken at designated points along the route. Details of the field sampling program and laboratory methods are given in Appendix A.

The data from the surveys will be used to construct mathematical models of all four estuaries. These models are designed to simulate the real world and, therefore, include essentially all important features. However, it is not possible technically and economically to measure every thing which has an effect on water quality. The data from the intensive survey are used to "calibrate" the model so that it duplicates the real world. The many factors which are included in the model are adjusted so that predicted conditions are the same as those observed in the field. Examples of factors which can be varied are the decay rate for organic matter, the rate of dispersion of

a wastewater stream and the amount of oxygen taken up by the bottom sediments. The dissolved oxygen concentrations in the estuary change as these factors are varied. Once the model has been calibrated, the waste loads and other input information for a slack water run are entered into the computer. If the model gives predictions similar to the conditions measured, then one says that the model is also verified. Often further adjustments are required. Reports describing the models and documenting calibration and verification will be issued at a later date. In the following sections of this report, water quality conditions in each of the four coastal basins will be reviewed.

III. WATER QUALITY CONDITIONS: 1975

The critical issue for estuarine water quality is whether conditions promote or work against the propagation of marine and estuarine organisms. The salinity of the water precludes its use as a source of drinking water, as well as use for many industrial processes. But numerous economically important recreational and commercial activities are based on the shellfish and finfish populations, which can be very abundant if water quality conditions are suitable. The presentation of water quality data will be guided primarily by the ways that these data relate to the marine resources. First a brief presentation of pollution sources will be given, followed by consideration of the tidal hydraulics of the systems. The two aspects of water quality which will be presented are nutrient cycling as it affects the dissolved oxygen regime, and bacterial contamination, especially as it affects shellfish harvesting.

A. Sources of Pollution

Usually when pollution in a water body is mentioned, the visual image of a large pipe issuing a noxious liquid comes to mind. For the case of the Small Coastal Basins, this image is almost completely inappropriate. During recent years numerous small sources of pollution, many of them sewage systems for schools, have been eliminated by connection to regional sewerage systems. The largest point source in the four basins, the Oceana Naval Air Station's sewage treatment plant, went off-line in September of 1975 when the flow to that plant was redirected to the Chesapeake-Elizabeth plant of the Hampton Roads Sanitation

District (HRSD). In June of 1976 the only remaining point sources were the Harwood's Mill water filtration plant, discharging to the Poquoson River basin, and the Birchwood Gardens sewage treatment plant discharging to the Western Branch of Lynnhaven Bay. The filtration plant discharges back-wash water when filtration beds are cleaned. For May, 1976, the flow was 1060 cubic meters (280,000) gallons) per day of water having a pH of 6.8 and a suspended solids concentration of 520 mg/l. The Birchwood Gardens systems includes holding ponds so that the effluent quality tends to be both steady and relatively good. During June, 1976, this plant discharged at the rate of 1450 cubic meters (0.383 million gallons) per day effluent containing 19 mg/l of Biochemical Oxygen Demand (BOD) and 40 mg/l of suspended solids. Additional effluent data for the Birchwood Gardens unit are given in Table 1.

For the Small Coastal Basins, non-point sources of pollution appear to be the dominant factor for water quality. These sources cover a broad range of land types and activities. For example, marshes may be considered a source of some kinds of pollution. A very simplistic description of their role is that dissolved nutrients in the water are utilized by marsh plants for growth. These plants provide cover for many animals and when the plants die, the resulting detritus provides a food source as well. But an oxygen demand also can be exerted by the decaying matter, gases such as methane can be produced and turbidity can be increased. Similarly, agriculture can cause problems due to runoff containing artificial fertilizers or

TABLE 1.

Birchwood Gardens STP Performance

	Flow (MGD)	BOD5 (mg/l)	SS (mg/l)
Permit	0.800	30	50
June 1976	0.383	19	40
1974			
January	0.550	15	34
February	0.557	0	35
March	0.569	16	29
April	0.574	15	35
May	0.580	24	34
June	0.591	33	35
July	0.568	25	39
August	0.548	20	32
September	0.577	18	29
October	0.636	22	40
November	0.620	16	36
December	0.644	24	20
1975			
January	0.676	22	24
February	0.639	29	35
March	0.664	16	55
April	0.525	25	30
May	0.563	24	44
June	0.521	19	50
July	0.566	26	60
August	0.499	15	48
September	0.548	22	50

wastes from farm animals. While these sources do exist, usually the load they place on the water body is not especially large. Of far greater importance for the Small Coastal Basins is the rapid development of the surrounding area. Streets, parking lots, houses, patios, etc., greatly increase the percentage of the ground that is impervious, with the result that a far greater portion of the rainfall reaches the rivers as runoff and peak flow rates are greatly increased. This runoff will clean the surfaces of solids which accumulate, including lawn fertilizers, fecal matter from pets, and the whole spectrum of pollutants which accumulates in streets. The impact on water bodies can be great, and indeed, the residential developments are believed to be one of the major sources of pollution for the Small Coastal Basins.

Another common problem in the coastal plains is that the water table is very close to the surface for much of the year. This often results in malfunctioning septic tanks and drain fields. The septic tank effluent may flow laterally to reach the water (this is often the case for fill over marsh land) or may even rise to the surface and flow overland. This situation results in both oxygen depletion and eutrophication of the receiving water as well as bacterial contamination. Such malfunctioning units are not allowed under Public Health Laws, but normally the number of inspectors is too small to detect more than the most blatant failures.

Another land use which could have a significant impact is federal installations. The Small Coastal Basins encompasses the Langley Air Force Base and NASA facility, the Little Creek

Navy Amphibious Base and the Oceana Naval Air Station. Federal installations are not within the purview of state regulatory agencies, so little information is available to document what, if any, pollution results from these facilities. However, given the large number of persons involved and the very special nature of the installations, it is difficult to believe that no pollution occurs. This area warrants further study.

The other major potential source of pollution is boating activities. These range from large naval craft at Little Creek Harbor to commercial and leased fishing vessels as well as small pleasure craft. The United States Navy has undertaken a program to eliminate discharges from their vessels in ports. Regulations promulgated by the State Water Control Board will make discharges by small craft illegal. But since there is virtually no means to effectively police these regulations and since foreign vessels enter these waters as well, it is unlikely that boat related pollution will disappear entirely. It is very likely that the quanitity of wastewaters discharged will be reduced greatly over the next few years, but these releases will never by completely eliminated. Therefore, although water quality in general will be improved, some shellfish restrictions probably will be required in order to protect public health.

The types and quantities of materials which reach the water bodies as "non-point source pollution" is the subject of other studies in the 208 program. At this time, we can only state that urbanization, unsuitable conditions for septic tank sewage systems, and boating appear to be the major contributors of waste substances in the Small Coastal Basins.

B. Circulation

An old adage in water pollution control is that "the solution to pollution is dilution". While this phrase over-simplifies the situation, it does emphasize the fact that the dispersion and transport of waste waters are very important factors. For free flowing streams and rivers, the general path of a pollutant can be predicted easily, but for estuaries, the circulation patterns can be very complex since additional factors come into play. When there is either a very small tidal range or a large freshwater flow, the flow of freshwater controls the dispersion and transport of materials. When freshwater flow is small and/or tide range is large, tidal flushing predominates. This latter case applies to the Small Coastal Basins. For the lower portion of Chesapeake Bay, the mean tidal range is on the order of 75 centimeters and the spring tide range is roughly 90 centimeters. While these ranges are not especially large they are of sufficient magnitude to promote mixing. For example, during periods of low runoff even Hampton Roads tends to be well-mixed.

As mentioned earlier, none of the four basins is large in drainage area. Because the sediments of the Coastal Plains are unconsolidated, they erode easily. Therefore, the rivers have dendritic patterns and the tidal influence extends to reaches that are far upriver. In addition, many of the tributaries of the coastal rivers are dammed for water supply systems. The Big Bethel reservoir on the Back River, the Harwood's Mill reservoir on the Poquoson River and the Little Creek Reservoir,

Lake Whitehurst, Lake Lawson and Lake Smith in the Little Creek basin all impound water for use by the nearby urban areas. Since much of the water which comes down the tributaries is diverted for this purpose, only during periods with abundant rainfall is there any flow over the spillways. Thus for some branches of these estuaries freshwater flow may be non-existent during parts of the year. At these times the concentration of salt will increase as the small volume of freshwater is mixed with the saltier Bay-derived water. In general, when tidal mixing is strong, the longitudinal salinity gradient is mild (less then one part per thousand per kilometer), vertical stratification is often nearly eliminated and variations in salinity during the tidal cycle are not great. Slack water data for the Back River during July and September, 1975, show how the salinity varies with distance upriver (see figure 2). The longitudinal salinity gradient is on the order of 1 ppt for every two kilometers. The Back River channel is only about 4 meters deep and surface to bottom differences were usually less than one part per thousand. If this salinity gradient were to apply to the entire river, then fresh water would be reached 35 to 40 kilometers upriver. But most arms of these estuaries are much shorter than this. Therefore, one must assume that all of the open areas have brackish waters and only in the very small rills far upriver is fresh water found.

The differing salinities between surveys illustrates how the estuary reacts to freshwater inflow. During the first part of July more than 30 cm of precipitation were measured at Norfolk. On four occasions a daily rainfall of more than 4 cm was recorded. One can note the salinity drop of roughly one

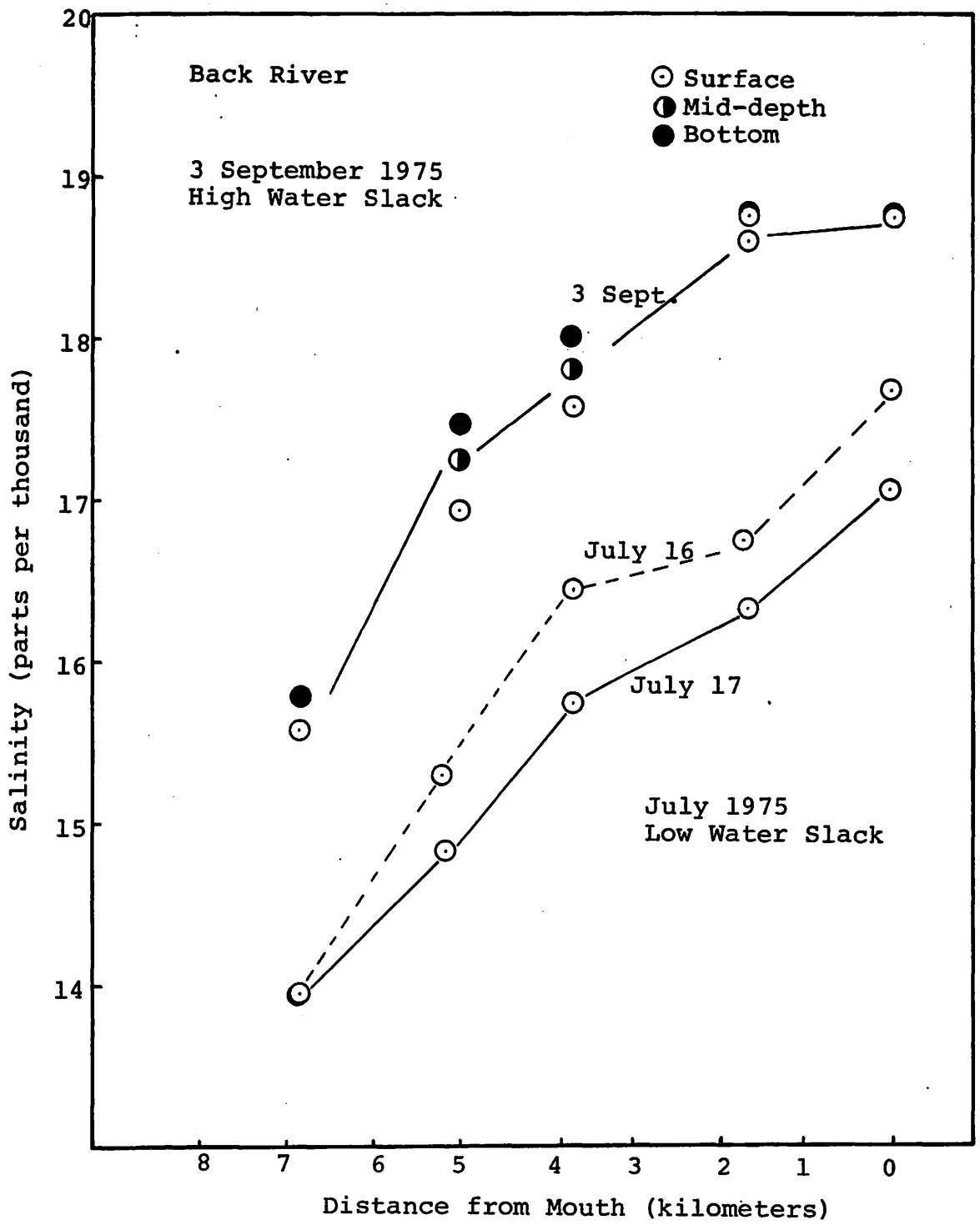


Figure 2. Longitudinal salinity profiles for Back River.

half part per thousand from the 16th to the 17th. The month of August was dry, with a total monthly rainfall of less than 2 cm, compared to a long term average monthly rainfall of over 15 cm for August. As a result of these conditions, salinity concentrations throughout the river had increased by September 3rd.

The time variation of salinity for the six intensive survey stations is plotted in Figure 3. One can note that the variation at each station was on the order of one part per thousand for the whole tidal cycle. Since the longitudinal salinity gradient both before and after these dates was roughly one half ppt per kilometer, one must conclude that the tidal excursion for the Back River is on the order of two kilometers, since the salinity at any given point varied by about one ppt during a complete tidal cycle.

The data for the Poquoson River show very similar characteristics. Little Creek Harbor also is generally similar, but since it is smaller in area and has a smaller drainage basin, salinity variations are even smaller than those seen in the Back River. This is due in part to a location close to the mouth of Chesapeake Bay and therefore a greater influence of the Atlantic Ocean. Furthermore, the saltier sea water is able to enter Little Creek more easily because of the greater depth. In general, the upper four or five meters of the water column are well-mixed with only minor variations (around one half ppt) within the harbor. The salinity concentrations at greater depths, 5 to 9 meters, were usually three

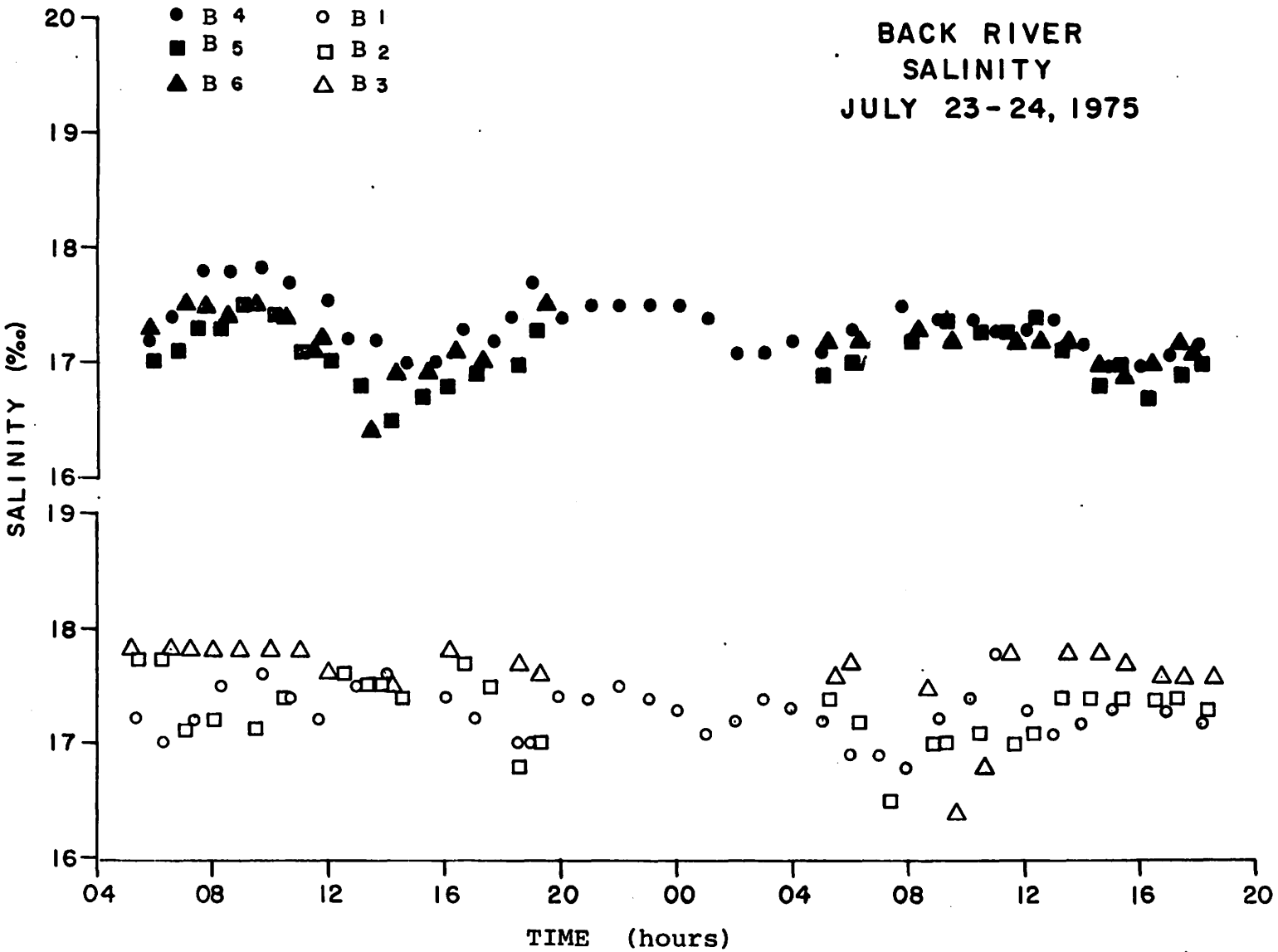


Figure 3. Time variation of salinity at six stations in Back River.

to five parts per thousand greater than those measured in the upper layer.

The Lynnhaven Bay system, with its numerous branches and several bays, is more complex. Generally, the Eastern and Western Branches of Lynnhaven Bay behave in a manner similar to Back River. Longitudinal salinity gradients comparable to that in the Back River occur up both branches. Broad Bay also has a longitudinal gradient since the northwestern portion is influenced by the waters flowing through Long Creek. Linkhorn Bay, on the other hand, is far enough removed from Lynnhaven Inlet so that the tidal range is only one-half that which occurs at Lynnhaven Inlet, and the exchange of waters between Linkhorn Bay and Chesapeake Bay is not rapid or great. For example, on October 6, 1975, salinity concentrations in the two branches of Linkhorn Bay were roughly 2 ppts greater than the concentration at Lynnhaven Inlet (see Figure 4). Since these bays are relatively shallow and the latter half of September was relatively dry (total rainfall for September 15-30 was only 3.5 cms) it is not impossible that evaporation could have been greater than freshwater inflow. However, a more likely cause is a large slug of fresh water flowing down a major tributary and into Chesapeake Bay caused the salinity near Lynnhaven Inlet to be reduced. In fact, the salinity at Lynnhaven Inlet on July 29 was 19.5 ppt whereas it was only 18.1 ppt on October 10th. Similarly, the surface salinity at Old Point Comfort at the mouth of the James River was 18.5 ppt on September 10 but only

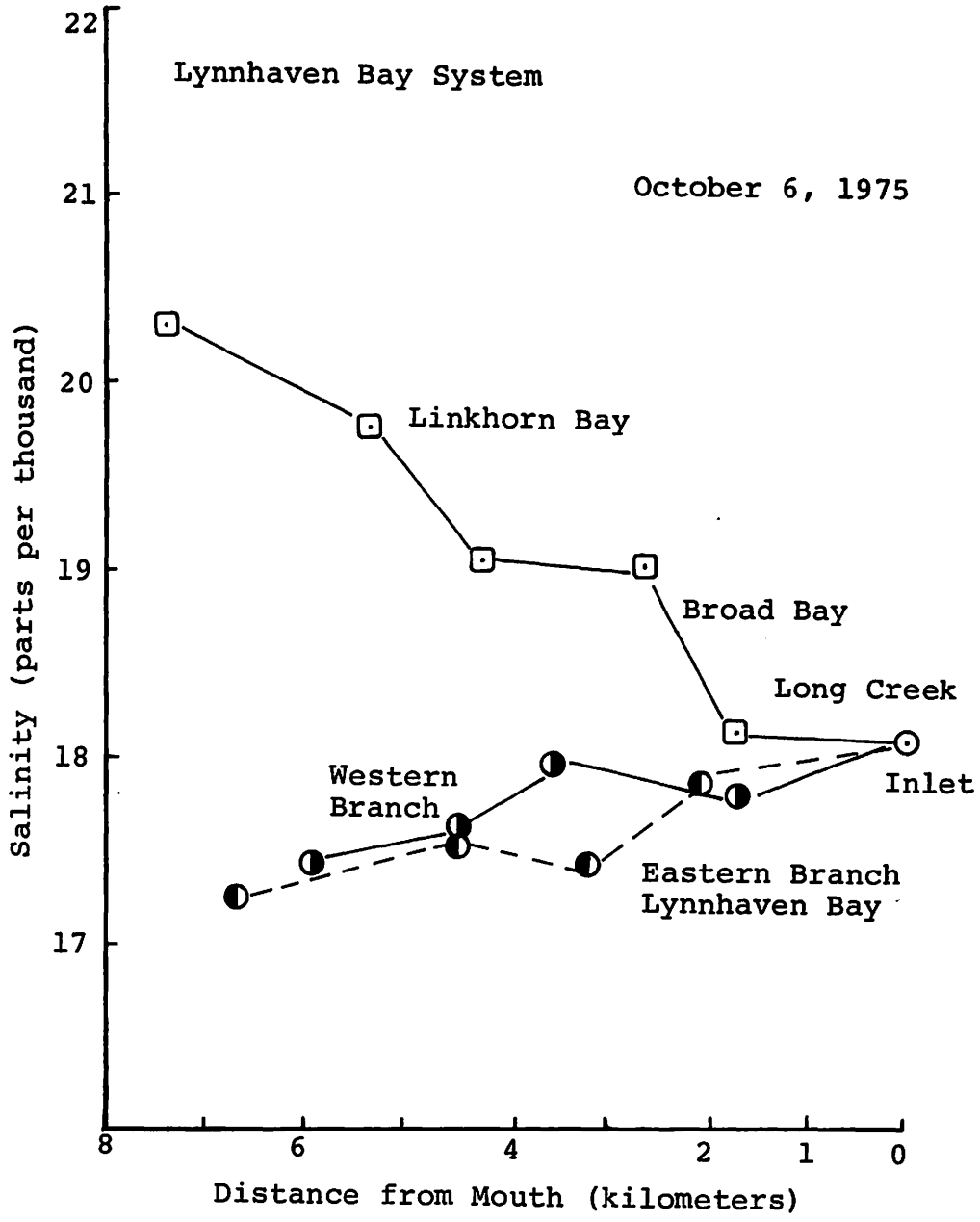


Figure 4a. Longitudinal salinity gradients in Lynnhaven Bay System.

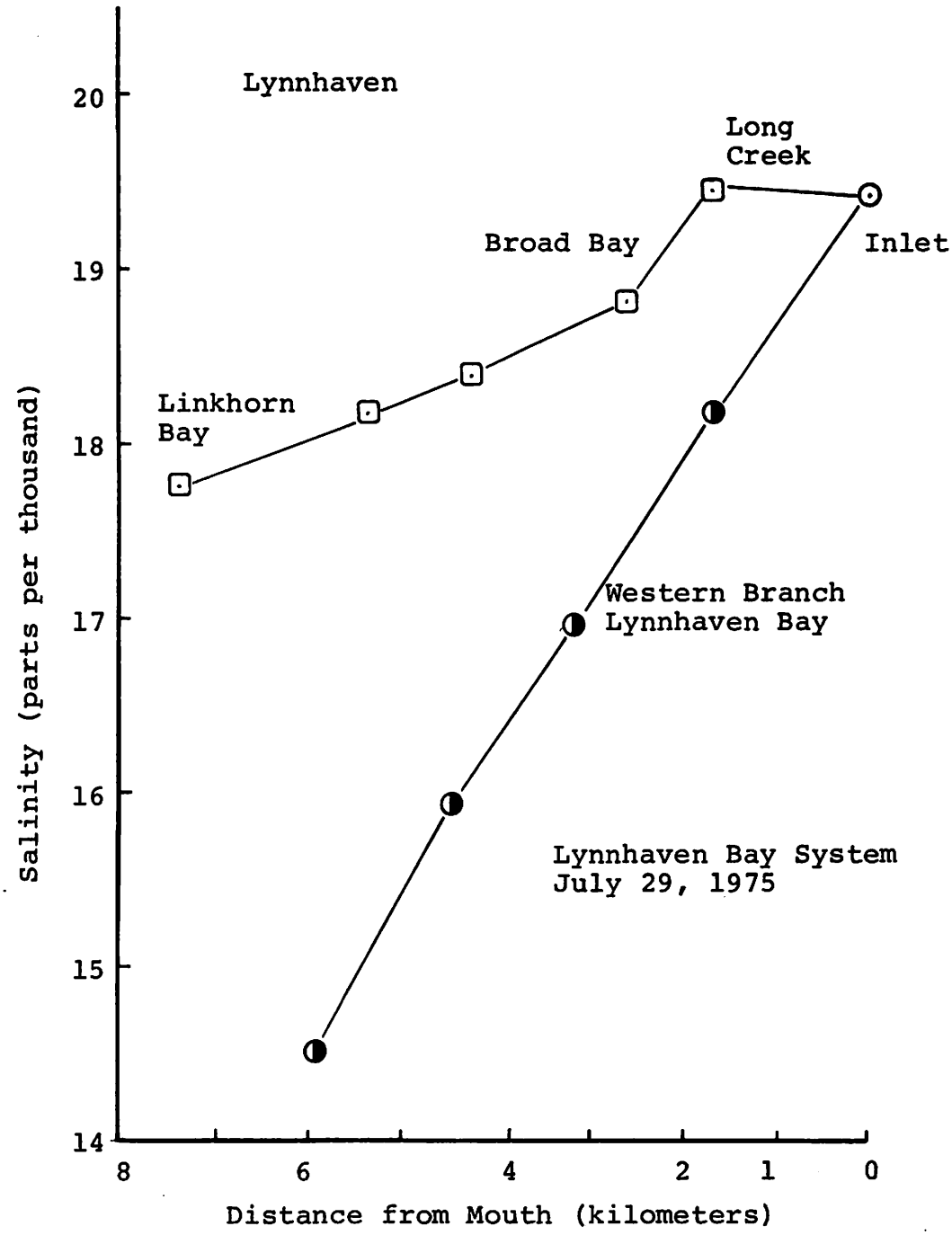


Figure 4b. Longitudinal salinity gradients in Lynnhaven Bay System.

15.3 ppt on October 10. Thus, a possible interpretation of the available data is that a freshet in the James River Basin caused high freshwater runoff with accordingly lower salinities in Hampton Roads and the Lower Bay in late September and early October. Interchange between Chesapeake and Lynnhaven Bays was sufficiently great that a slight, but normal longitudinal salinity gradient was observed. Exchange of waters between Chesapeake and Linkhorn Bays was sufficiently slow that an easily measured reverse salinity gradient developed. This example illustrates the point that circulation in estuarine systems can be very complex indeed.

In addition to tidal circulation, there can be a net non-tidal circulation due to density gradients. However, since most of these rivers are shallow, vertical stratification is normally weak and the gravitational circulation will be weak too. Only Little Creek Harbor with depths of 7 to 9 meters shows strong vertical salinity stratification. For this case, there would be a net flow of salty water in near the bottom and a net flow of fresher water out of the harbor near the surface. This circulation pattern will greatly increase flushing and remove pollutants from the area.

In general water bodies with characteristics such as those described above are able to assimilate wastewaters primarily by dispersion and mixing of these wastewaters throughout the water body. Since freshwater flow is small, there is no driving force to push the wastewaters through and out of the system. Rather transport occurs due to tidal

exchange. Therefore, the time that a substance resides in the system may be long and on the order of weeks. Therefore, these estuaries have a very limited capacity to assimilate wastewaters without serious degradation of water quality.

C. Eutrophication and Dissolved Oxygen

Eutrophication means the overenrichment of a water body with the nutrients essential for plant growth. When nutrients are plentiful and other conditions are right, abundant growths of algae can occur. These growths can cause odor problems, may give drinking water an undesirable taste and add a large daily variation to the fluctuations in dissolved oxygen in the water. The United States Environmental Protection Agency has conducted long term, in-depth studies of nutrient enrichment in the Potomac River and the Upper Chesapeake Bay. As a result of these studies they have set as an upper limit for the desirable concentrations of algae, 40 µg/l of chlorophyll "a", a measure of the alga concentration. In order to constrain algae levels within this limit, the corresponding levels for inorganic nitrogen and phosphorus are 800 µg/l and 120 µg/l respectively. Since comparable comprehensive and detailed studies are not available for the Lower Chesapeake Bay, and since the estuaries tributary to Chesapeake Bay are similar in many respects, these limits will be assumed to be appropriate for the Small Coastal Basins as well.

A review of data collected during the intensive surveys in the summer of 1975 indicates that eutrophication is not a

serious problem in any of the four coastal basins. Chlorophyll "a" concentrations were usually less than 15 µg/l, well below the EPA standard of 40 µg/l. The maximum value observed was slightly under 30 µg/l in Lynnhaven Bay. Thus, field measurements for 1975 do not indicate any problems associated with intense growths of algae. Nutrient data corroborate this finding. Total inorganic nitrogen concentrations (ammonia plus nitrite-nitrate) were generally below 100 µg/l and phosphorus concentrations (soluble reactive phosphorus) were approximately 30 µg/l for Back River, Poquoson River and Broad Bay. These values are well below the EPA standards of 800 µg/l and 120 µg/l for nitrogen and phosphorus respectively. Therefore, it is entirely reasonable that the standing crop of phytoplankton, as measured by chlorophyll "a", should also be well within the EPA criterion.

Nutrient levels in Little Creek Harbor and Lynnhaven Bay proper were somewhat higher. Phosphorus concentrations for both water bodies averaged around 60 µg/l, but values close to 100 µg/l were observed in Lynnhaven Bay. Inorganic nitrogen levels were around 300 µg/l in Little Creek Harbor and about 200 µg/l in Lynnhaven Bay. The presence of nutrients in Little Creek Harbor could be due to the release of treated wastewaters from the HRSD Chesapeake-Elizabeth plant to the nearby waters of Chesapeake Bay. Tidal currents probably bring some small portion of these wastewaters into the harbor. While the concentrations were higher than those observed in the other coastal estuaries, they were still well within all of the EPA criteria. Higher

nutrient levels in Lynnhaven Bay are probably the result of runoff from the surrounding land, and the HRSD-operated Oceana NAS sewage treatment plant. Field observations from a July 29 slack water run and the September 16 intensive survey show that soluble reactive phosphorus, nitrite-nitrate and ammonia concentrations in Lynnhaven Bay are roughly twice those found in Broad and Linkhorn Bays. The Oceana STP went off-line in mid-September, and by October 6, soluble reactive phosphorus concentrations were essentially equal between the two water bodies. Nitrite-nitrate on the other hand remained at elevated levels in Lynnhaven Bay. Concentrations were several times those found in Broad and Linkhorn Bays. It is likely that this disparity would eventually disappear, although data are not available to document this.

Dissolved oxygen (DO) concentrations are controlled by many factors. As salinity and temperature increase, the saturation value (the amount of oxygen that can be dissolved in water) decreases. Pollutants normally exert an oxygen demand (consume DO) due to chemical reactions and bacterial decomposition. Bacteria, phytoplankton, zooplankton and larger organisms in general require oxygen to live. The phytoplankton do produce oxygen as a by-product of photosynthesis, but the major supply of oxygen is the atmosphere. When field measurements of DO are made, temperature and salinity usually are recorded so that the saturation value can be computed. BOD (biochemical oxygen demand) is a

measure of the amount of oxygen which will be consumed as water constituents are oxidized by a variety of biological and chemical reactions. In general, none of the small coastal basins receives any significant point source pollutant streams so that BOD levels will be controlled by natural processes and the non-point pollution loadings entering from the surrounding land, especially during rainy periods. In both Little Creek Harbor and the Lynnhaven system, BOD values were usually only one or two mg/l and dissolved oxygen concentrations were at or close to the saturation value. BOD concentrations in Back and Poquoson Rivers were slightly higher, a mean value of around 2 mg/l and maximum values of about 4 mg/l, and production of oxygen by phytoplankton appeared to be important. A distinct diurnal trend to the DO values can be seen, as illustrated by the data for the Back River in Figure 5. Oxygen is produced by the algae during daylight hours resulting in supersaturated DO concentrations. The saturation values for the ambient temperature and salinity is approximately 7.4 mg/l but DO values up to 9 mg/l were observed. The algae require oxygen to live, and since they cannot produce it during the night, there is a net consumption of the DO in the water. As a result DO concentrations fall during the night; for the case of Back River, values as low as 4.5 mg/l were observed. It must be remembered that the chlorophyll "a" concentrations at this time were less than

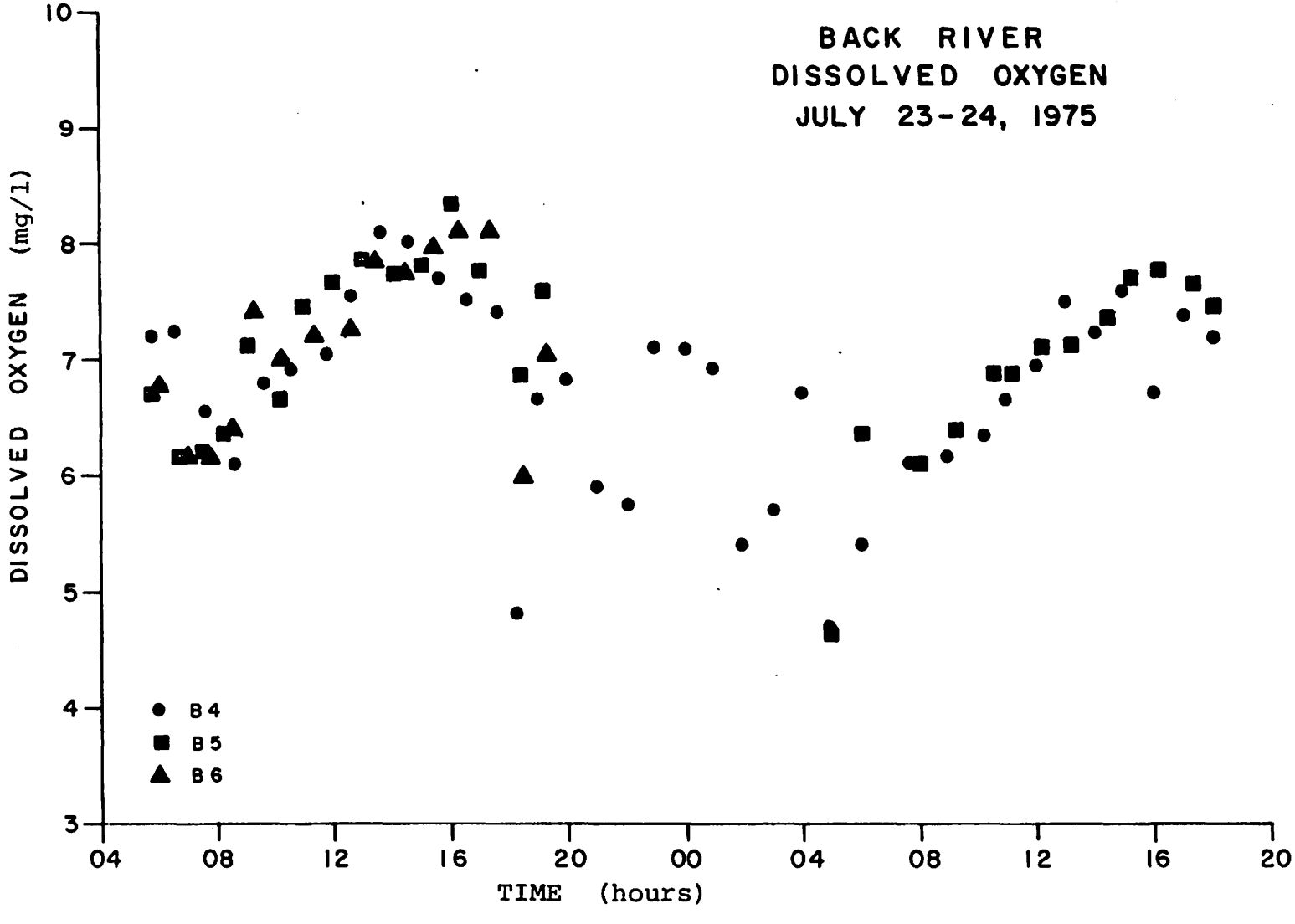


Figure 5. Diurnal variations in dissolved oxygen concentrations observed in Back River.

half the value recommended by EPA as an acceptable upper limit for the Potomac River and Upper Chesapeake Bay. Although the chlorophyll and nutrient criteria appear to be appropriate from biological considerations, they may be high for the small coastal basins since these water bodies are more shallow than those studied by EPA. Oxygen consumption (or production) due to plankton dynamics will be averaged over a relatively shallow water column. Therefore the impact can be great. For deeper water bodies, the oxygen uptake will be spread throughout a large water column and the changes in DO concentration will not be so large. For Back and Poquoson Rivers, the chlorophyll "a" concentrations observed are probably close to the desired upper limit, for if denser plankton blooms were to occur, extremely low dissolved oxygen levels could result during nights and the marine organisms living there would be killed.

D. Bacterial Contamination

Pollution of waters by fecal matter from warm-blooded animals is a means whereby disease can be spread. Recreational activities, such as swimming, require clean waters to protect the participants from sickness. Thus, the Water Control Board has set water quality standards for various water uses. The measure of bacterial contamination is a statistical value, called the Most Probable Number (MPN), for the number of organisms in a given volume of

water. For secondary contact recreation (e.g. fishing) and propagation of marine organisms, the mean fecal coliform level cannot exceed 1000/100 milliliters of water. For primary contact recreation (e.g. swimming) the mean fecal coliform count should not exceed 200 MPN/100 ml.

A second use of estuarine waters which requires clean waters is the propagation of shellfish. Clams and oysters pump large volumes of water and filter out suspended matter. In this process they can accumulate substances to levels far in excess of that found in the water. Standards for shellfish growing waters are set by both the State Department of Health and the Federal Food and Drug Administration which regulates interstate transport of shellfish. At present both total coliform and fecal coliform standards exist, although it is anticipated that in the near future the fecal coliform criterion will be used exclusively. These standards are 70 and 14 MPN/100 ml for total coliforms and fecal coliforms respectively. Since these standards are more restrictive than those for recreation, they will be used as the measure of water quality with respect to bacteria. Areas which have coliform counts in excess of the standards are classified as restricted areas. Shellfish can be taken from these areas but not for direct harvesting. Rather they can be taken as seed stock and replanted in other growing areas, or they can be removed, replanted in clean waters and reharvested after a specified period of time all under the supervision and control of the

Marine Resources Commission. In addition, there are permanently closed zones which are established around sewage treatment plant outfalls. Shellfish cannot be harvested from these "buffer zones".

All four coastal basins include restricted areas. A reasonably complete description of all condemned shellfish areas in the Small Coastal Basins is included in Appendix C. Restricted areas in the Back River as listed as "Condemned Shellfish Area No. 21", which was enacted on August 18, 1961. The map showing these restricted areas issued by the Virginia State Department of Health indicates sewage treatment plants discharging to sections A, B and C (see Figure 6 and Appendix C). This area was enlarged in 1973 to include the entire Southwest Branch and the Harris River. A subsequent modification in 1975 eliminated the condemned areas near Tabbs Point and opened a portion of the Southwest Branch near the mouth and on the eastern bank. The Health Department condemns areas on the basis of analyses of water samples taken from the area. Condemnation notices do not indicate the cause of the pollution, but rather simply state which areas are restricted. During the intensive survey July 23 and 24, 1975, coliform levels in excess of the standards were noted for stations in or close to the restricted zones in the Back River.

Condemned shellfish area number 137 was established on May 1, 1972, for the upper reaches of Patrick's Creek and Chisman Creek in the Poquoson River System, as shown in

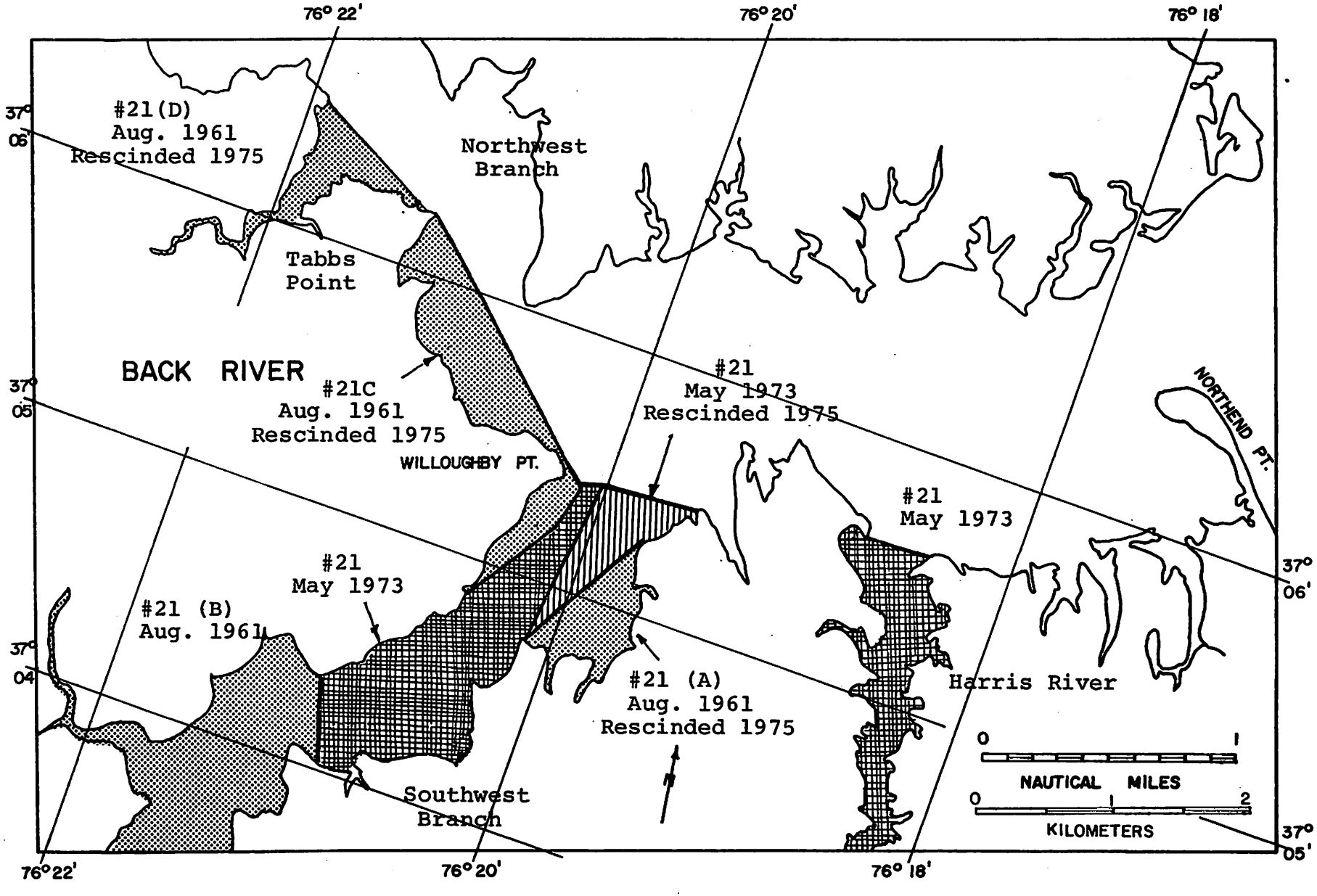


Figure 6. Condemned areas in Back River.

Figure 7. In 1975 both areas were enlarged and an additional closure in White House Cove of Bennetts Creek was added. The causes for the restrictions in the Peninsula rivers are not known, although one must assume that the continued development of the area was at least partially responsible. When areas become "urbanized", not only may new sources of pollution be introduced, but those which existed previously can have a greater effect since the impervious areas promote more rapid runoff and therefore more pollutants can be carried to the rivers.

Water samples taken during the intensive survey in July 1975, showed high fecal coliform levels in the upper reaches of the Poquoson River. Above standard total coliform counts observed at several other stations, do not necessarily indicate contamination by fecal matter. The total coliform group includes some bacteria which are present in the soil and on decaying leaves so that the total coliform count is not always a good indicator of the type of pollution for which we are concerned. It is for that reason that the fecal coliform standard will be used probably exclusively in the future.

The restricted shellfish area number 17 was established in April of 1935 and includes all of Little Creek (see Figure 8). Presumably the use of the harbor by large naval vessels, which rarely had treatment facilities on board, was a potential, if not actual, source of contamination. Since Public Health, rather than simply an esthetic appreciation for water quality, is the motivating factor for restricting shellfish areas, it

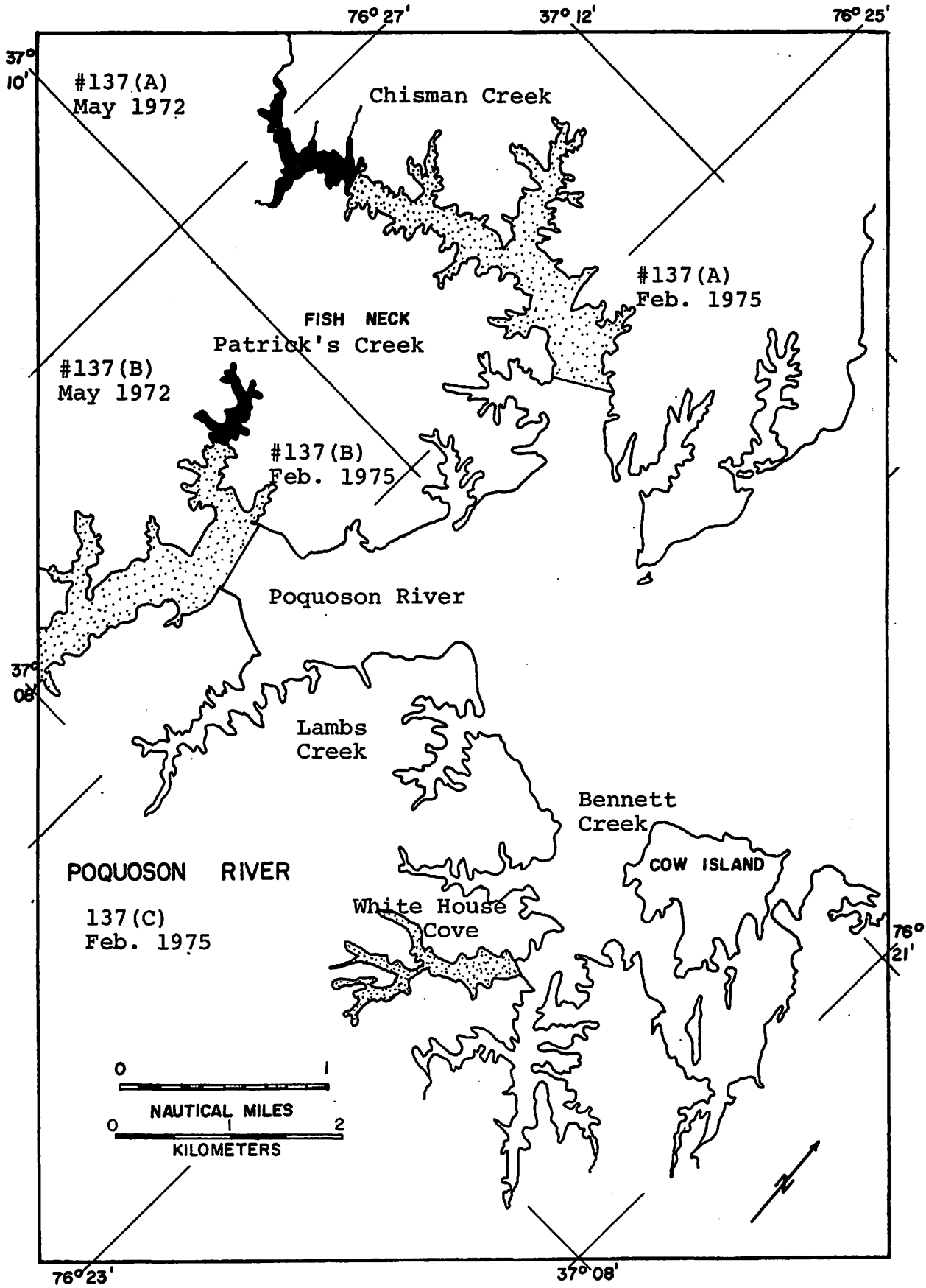


Figure 7. Condemned areas in Poquoson River.

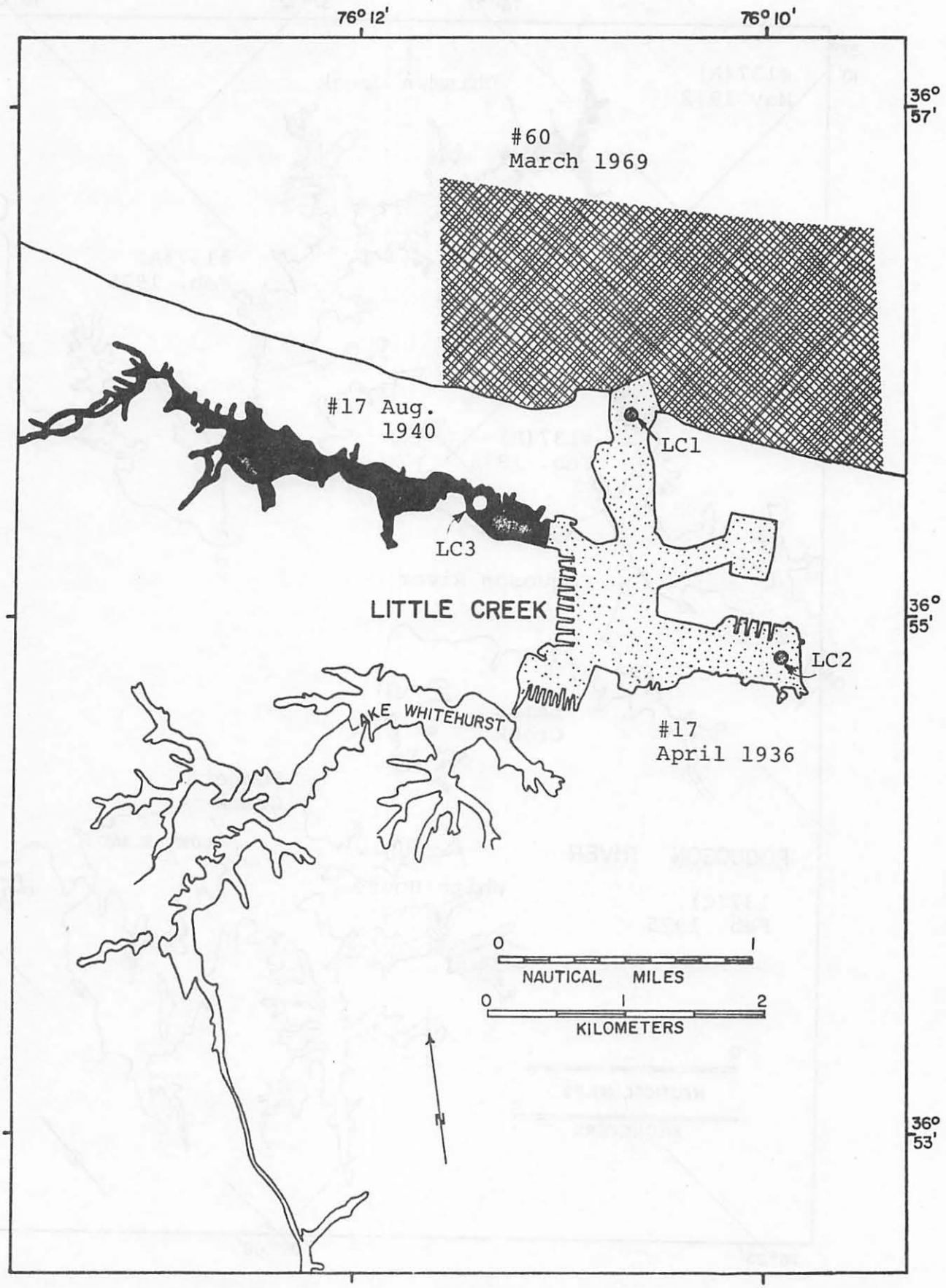


Figure 8. Condemned areas in and near Little Creek Harbor.

is necessary to take conservative measures. Lacking statements by the Health Department, one must assume that this closure was a precautionary measure related to the naval activities. The subsequent closure of shellfish grounds in Chesapeake Bay near Little Creek, enacted in March 1969, is most likely related to the outfall for the HRSD Chesapeake-Elizabeth sewage treatment plant.

During the intensive survey of Little Creek Harbor in September 1975, both the total and the fecal coliform standards were exceeded at all stations sampled and for most of the sampling periods. Fecal coliforms ranged up to 500 MPN/100 ml (see Figure 9). The need for the shellfish restrictions for Little Creek Harbor is obvious.

The history of shellfish ground closures in the Lynnhaven system is long and complicated (see Figure 10). Restricted shellfish area number 10 was established for Linkhorn Bay in 1930, the earliest closure in the coastal basins and surely one of the oldest in the Commonwealth. All portions of Linkhorn Bay upriver of the "Narrows" were closed at that time. Mill Dam Creek and Day Cove, both tributary to Broad Bay (Area #95) were condemned in April 1972 and Long Creek and small canals nearby (Area #31) were closed in 1964. One motivation for dredging the Long Creek Canal was to enhance the tidal flows so that Broad and Linkhorn Bays would be flushed more readily, and perhaps then the closure zones could be reduced or eliminated. Indeed, the canal did increase the amount of water entering and leaving Broad Bay during a

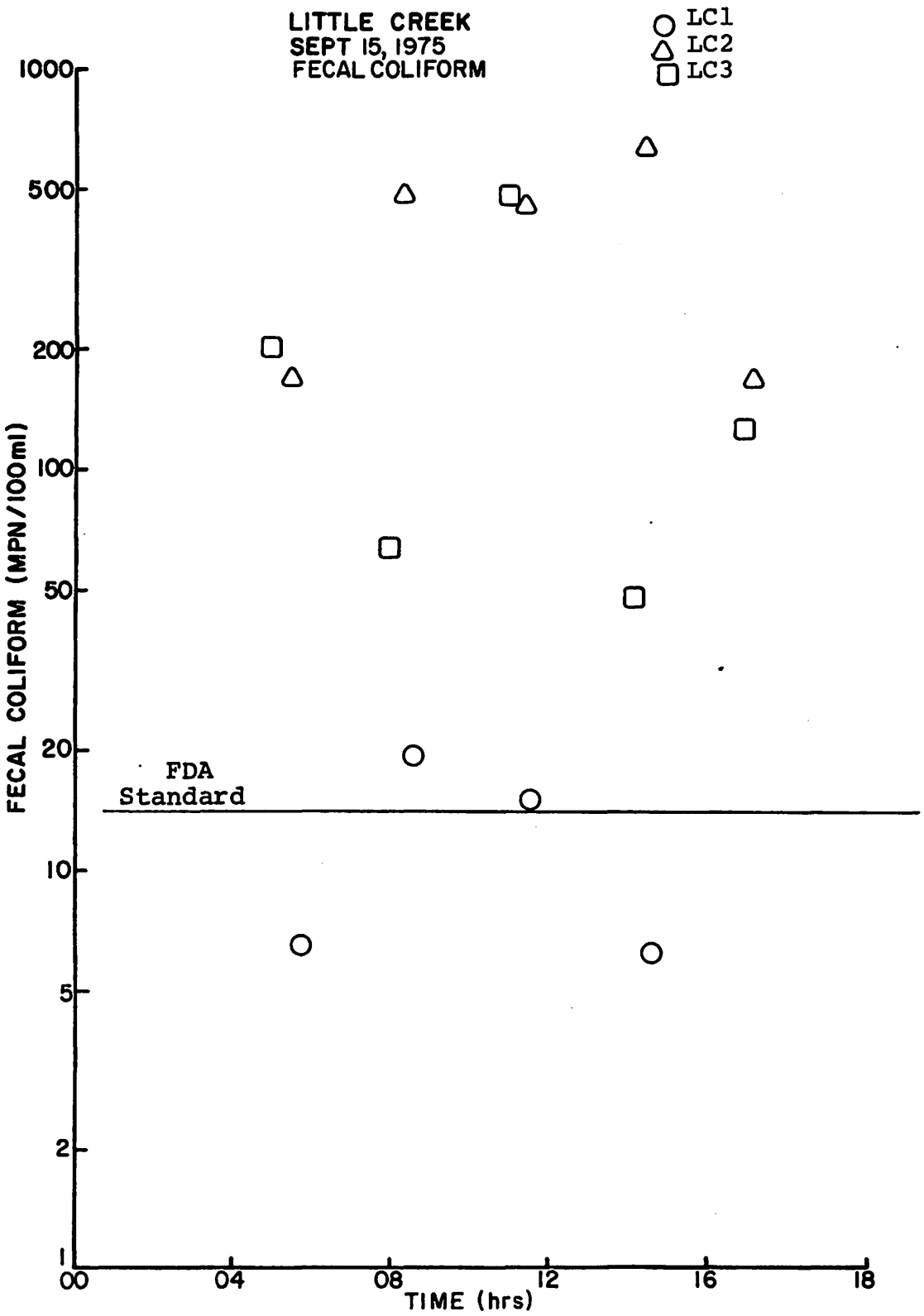


Figure 9a. Fecal coliform levels in Little Creek Harbor.

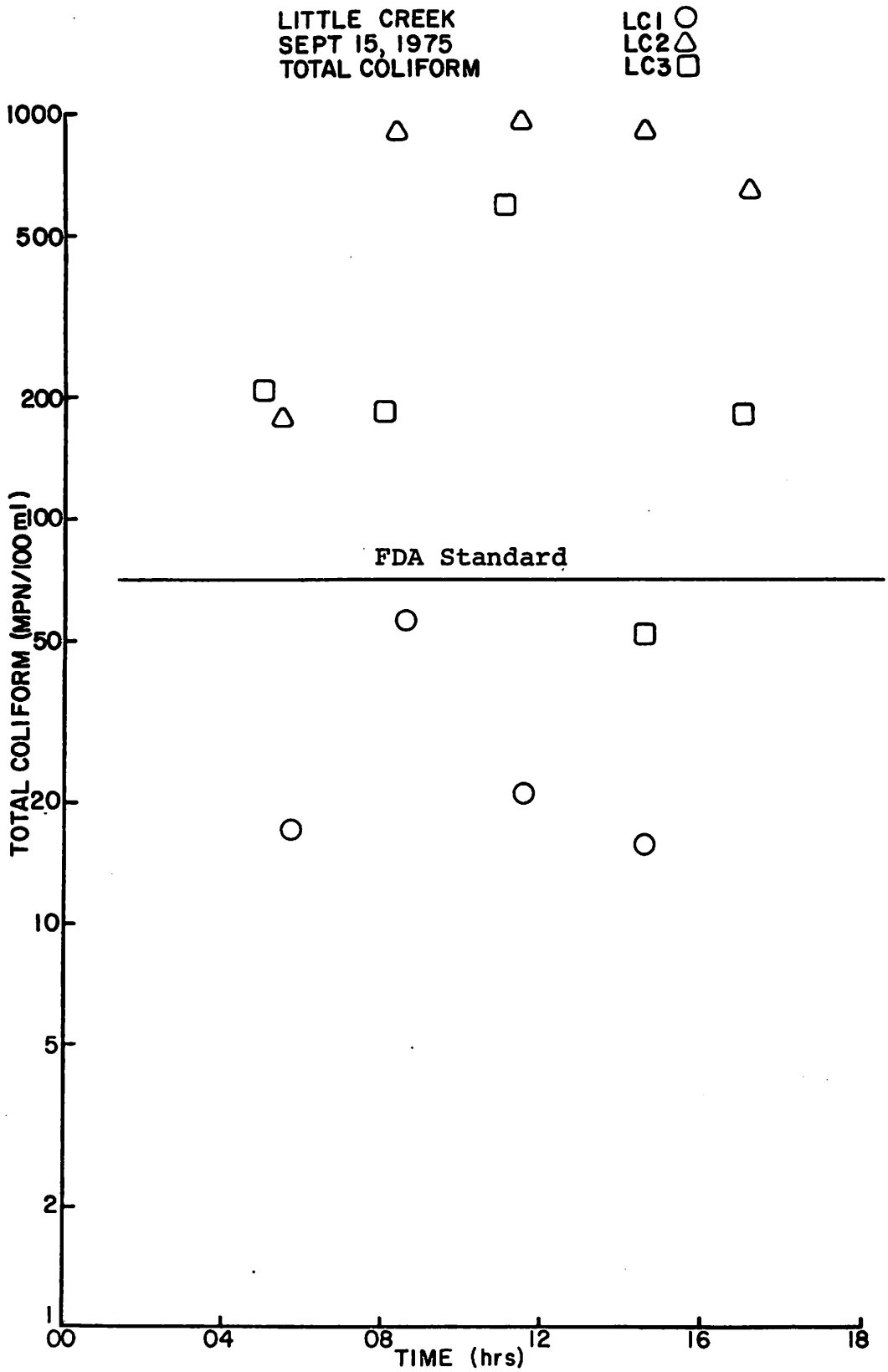


Figure 9b. Total coliform levels in Little Creek Harbor.

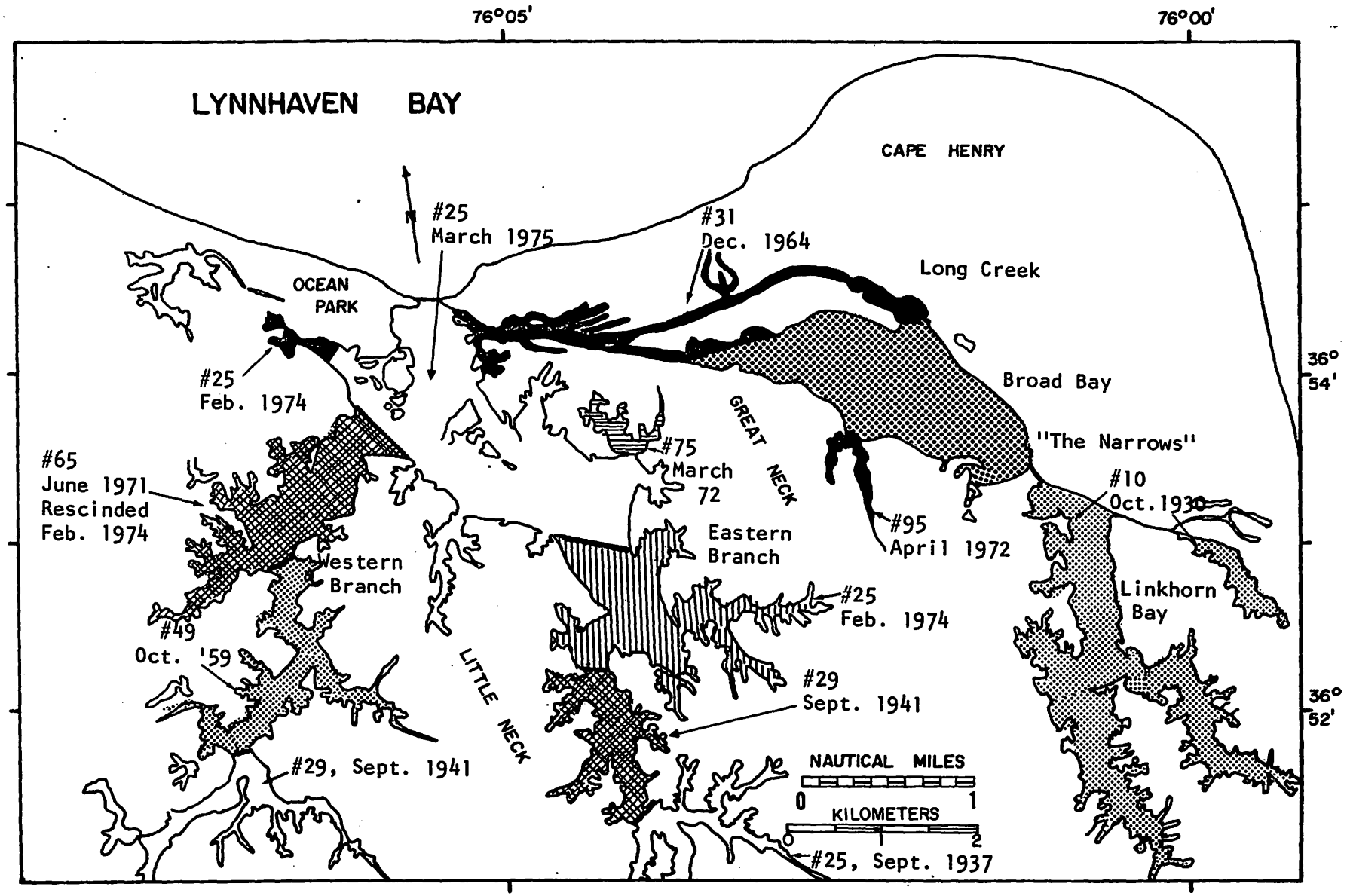


Figure 10. Condemned areas in the Lynnhaven Bay System.

tide, but the impact on water quality was not measured.

The first restricted area in Lynnhaven Bay proper (Area #25) was established in 1937 for the upper portion of the Eastern Branch. In 1941 this area was enlarged and a similar area in the Western Branch was included too (Area #29). In 1959, this condemned area also was extended downriver to Witch Duck Road (Area #49) and in 1971 the entire Western Branch was closed for shellfish harvesting (Area #65) although the ban for the area near the mouth was lifted shortly thereafter. 1971 was apparently a bad year with respect to bacterial contamination because large sections of Hampton Roads and Chesapeake Bay, as well as the entire Lynnhaven complex were closed from October 6, 1971 to February 8, 1972. In March of that year, Brock Cove was condemned (Area #75) and in February of 1974 another segment of the Eastern Branch was closed. In March 1975, the entire Lynnhaven complex was condemned; this closure is still in effect today (August, 1976).

Water samples collected from Lynnhaven, Broad and Linkhorn Bays during slack water runs in July and October and the intensive survey in September, 1975, all showed above standard concentrations of fecal coliforms. In July, fecal counts as high as 1,300 MPN/100 ml were recorded, and most stations had counts above the standard of 14. In October, the counts were significantly lower, but roughly one third of the stations were found to have fecal coliform levels in excess of the standard. The only stations which

consistently showed low readings were those located very close to the Inlet.

E. Summary

All four of the Small Coastal Basins have very little continuous freshwater inflow. Consequently circulation within these water bodies is controlled primarily by the tides. Materials discharged to these estuaries will be dispersed by tidal mixing, but will tend to reside in the system for periods on the order of weeks. As a result of this type of circulation these water bodies have limited capacity to assimilate wastes. Materials released to Little Creek Harbor could be flushed more rapidly since the deeper waters allow for a density driven gravitational circulation with salty water entering near the bottom and fresher water leaving near the surface. Broad and Linkhorn Bays on the other hand have very long residence times since all exchange of waters with Chesapeake Bay is via Long Creek and a portion of Lynnhaven Bay.

Fortunately there are very few "point sources" of wastes in the Coastal Basins and none of these is large. Some pollutants from natural processes and agriculture undoubtedly enter the rivers, but the major contributions appear to be those related to the development of the surrounding land. In particular, malfunctioning or poorly designed septic systems are suspected as the major continual source of pollution. During wet periods, problems with septic systems

are exacerbated and runoff from streets and parking lots create additional problems. The other remaining sources of contamination, are boating activities and wildlife. These, too, are difficult to measure and virtually no quantitative information is available.

Field studies conducted during 1975 showed that chlorophyll "a" and nutrient levels in all four basins were well within criteria established by EPA for other areas in the Chesapeake Bay System. For the Back and Poquoson Rivers, phytoplankton growth did have a significant impact on the dissolved oxygen regime despite the fact that nutrient and chlorophyll levels were within the EPA criteria. It appears that the Back and Poquoson Rivers are relatively rich and substantial increases in nutrient loads should not be permitted. Excepting supersaturation in daytime and oxygen depression at night due to plankton growth, dissolved oxygen concentrations were generally well above the water quality standards and close to saturation values. Thus it appears that the BOD loadings to the rivers are within their assimilative capacities.

Bacterial contamination is apparent in all four estuaries. The precise causes and sources of this pollution are not known. Since tidal flushing is greatest near the estuary mouth, the shellfish closure zones tend to be located up the small tributaries. As conditions worsen these restricted areas are enlarged and include more of the

particular branch. Little Creek Harbor will probably always be closed as a precautionary measure since large vessels are usually docked there. In addition, there is the Chesapeake-Elizabeth STP outfall in the nearby waters of Chesapeake Bay. Conditions in the Back and Poquoson Rivers are not especially bad and have improved in recent years, as evidenced by removal of some restrictions. The Lynnhaven complex has the most severe situation since the entire system is condemned. With the removal of the Oceana NAS sewage treatment plant in 1975, it should be possible to locate malfunctioning septic tanks and other sources of bacterial contamination. The interconnected drainage ditches are likely to confound these efforts and in fact, may be a major part of the problem. Non-point source sampling and modelling efforts included within the 208 study are expected to improve our understanding of the causes and sources of this type of pollution.

APPENDIX A - Data Gathering Program

Details of the intensive and slack water surveys for each of the four coastal basins are given in tabular and graphical form (Tables 1 to 4 and Figures 1 to 4). Quality control procedures and laboratory methods and procedures for chemical analyses are given as well.

Table 1

Back River Sampling Program
6 Intensive Survey Stations
9 Slack Water Stations
6 Current Stations
4 Tide Gages

Parameter	1 Intensive Survey			2 Slack Surveys		
	Sampling Period	Sampling Frequency	Sampling Depths	Sampling Period	Sampling Frequency	Sampling Depths
Currents	3 days	every 20 min.	T,M,B			
Tide	5 days	every 15 min.				
Temperature	25 hrs.	hourly	T,B	SBE,SBF	1 each	T,B
Salinity	"	hourly	"	"	"	"
DO	"	hourly	"	"	"	"
TKN	"	every 3 hrs.	T,B	"	"	"
Ammonia	"	"	"	"	"	"
Nitrite	"	"	"	"	"	"
Nitrate	"	"	"	"	"	"
Total P	"	"	"	"	"	"
Ortho P	"	"	"	"	"	"
Coliforms	"	"	"	"	"	"
Chlorophyll "A"	"	"	"	"	"	"
Light & Dark Bottle	"	"	Surface			
Secchi Disk	"	"	Surface	"	"	Surface
BOD5	25 hrs.	every 3 hrs.	T,B	SBE,SBF	1 each	T,B
Ultimate BOD				"	"	Top
Benthic O_2 Demand					once	Bottom

T = 1 meter below surface
M = mid-depth
B = 1 meter off bottom

SBE = slack water before ebb
SBF = slack water before flood

Figure 1

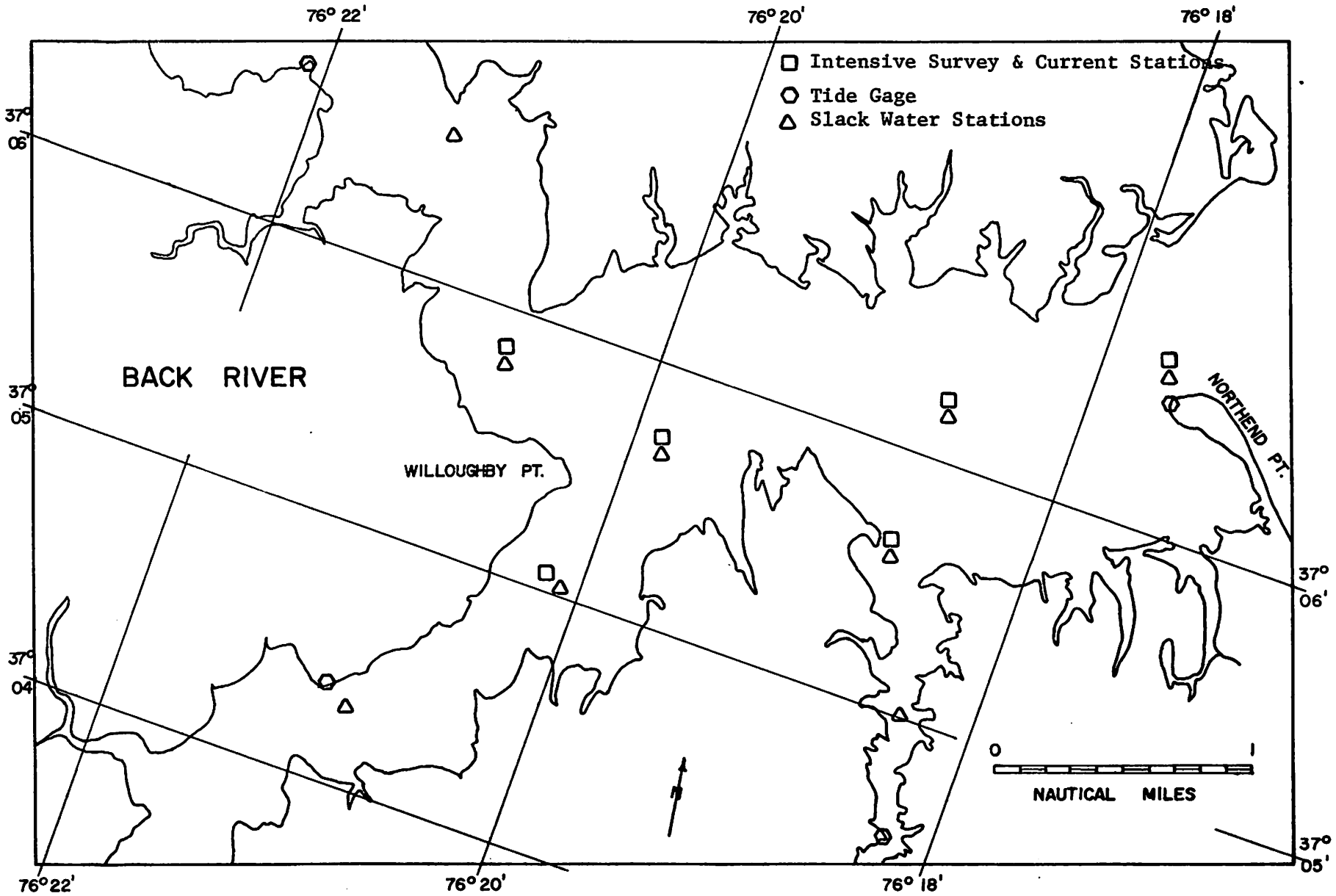

76° 22'
76° 20'
76° 18'
Intensive Survey & Current Stations
Tide Gage
Slack Water Stations
37° 06'
37° 05'
37° 04'
BACK RIVER
WILLOUGHBY PT.
NORTHEND PT.
0
1
NAUTICAL MILES
N
37° 06'
37° 05'
76° 22'
76° 20'
76° 18'

Table 2

Poquoson River Sampling Program
6 Intensive Survey Stations
10 Slack Water Stations
6 Current Meter Stations
4 Tide Gages

Parameter	1 Intensive Survey			2 Slack Surveys		
	Sampling Period	Sampling Frequency	Sampling Depths	Sampling Period	Sampling Frequency	Sampling Depths
Currents	3 days	every 20 min.	T,B			
Tide	5 days	every 15 min.				
Temperature	25 hrs.	hourly	T,B	SBE,SBF	1 each	T,B
Salinity	"	hourly	"	"	"	"
DO	"	hourly	"	"	"	"
TKN	"	every 3 hrs.	T,B	"	"	"
Ammonia	"	"	"	"	"	"
Nitrite	"	"	"	"	"	"
Nitrate	"	"	"	"	"	"
Total P	"	"	"	"	"	"
Ortho P	"	"	"	"	"	"
Coliforms	"	"	"	"	"	"
Chlorophyll "A"	"	"	"	"	"	"
Light & Dark Bottle	"	"	Surface			
Secchi Disk	"	"	Surface	"	"	Surface
BOD5	25 hrs.	every 3 hrs.	T,B	SBE,SBF	1 each	T,B
Ultimate BOD				"	"	Top
Benthic O_2 Demand					once	Bottom

T = 1 meter below surface
B = 1 meter off bottom

SBE = slack water before ebb
SBF = slack water before flood

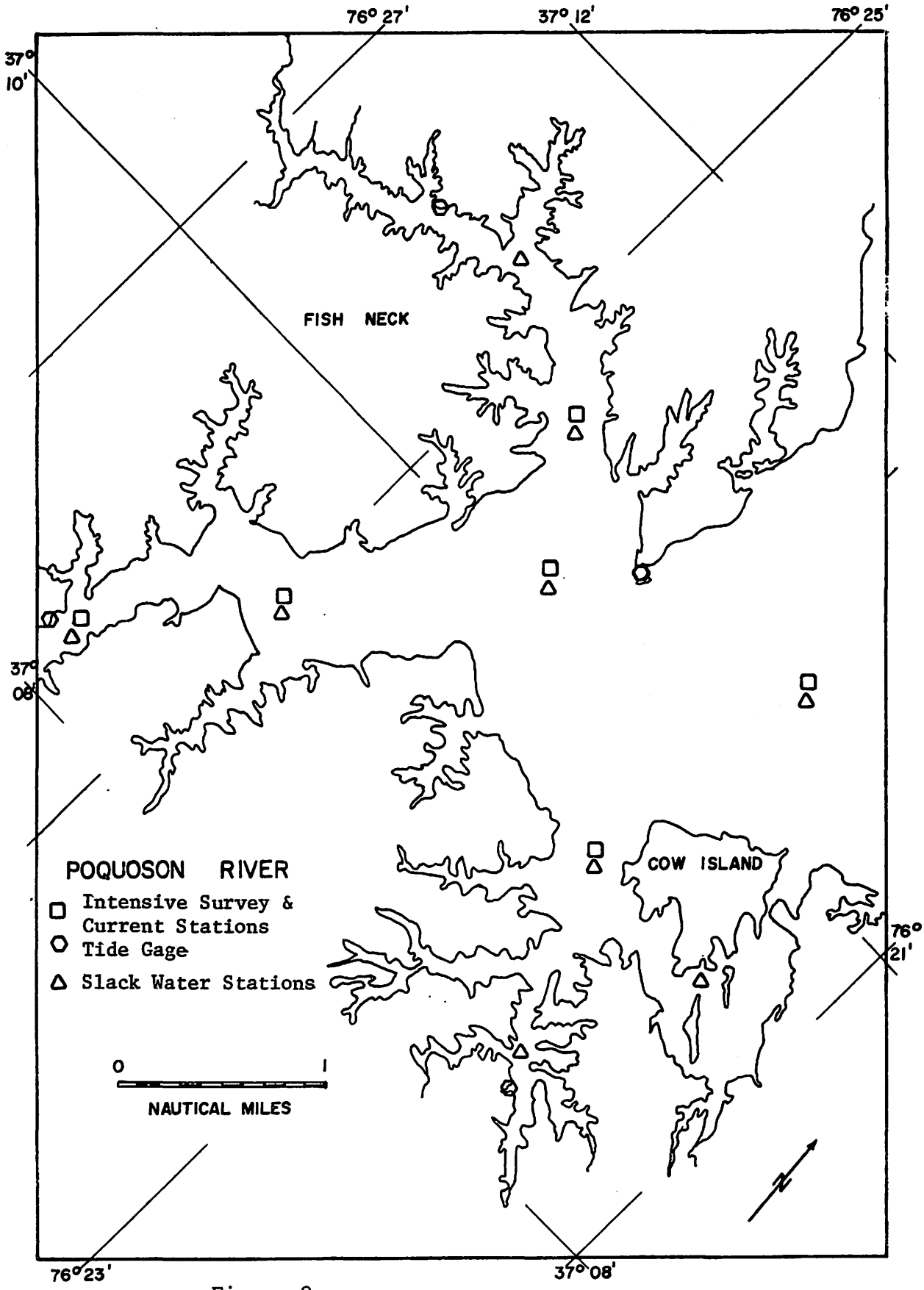

76° 27'
37° 12'
76° 25'
37° 10'
FISH NECK
37° 08'
POQUOSON RIVER
Intensive Survey & Current Stations
Tide Gage
Slack Water Stations
COW ISLAND
76° 21'
0
1
NAUTICAL MILES
76° 23'
37° 08'

Figure 2

Table 3

Little Creek Sampling Program
3 Intensive Survey Stations
6 Slack Water Stations
3 Tide Gages

Parameter	1 Intensive Survey			2 Slack Surveys		
	Sampling Period	Sampling Frequency	Sampling Depths	Sampling Period	Sampling Frequency	Sampling Depths
Tide	5 days	every 15 min.				
Temperature	13 hrs.	hourly	T,B	SBE,SBF	1 each	T,B
Salinity	"	hourly	"	"	"	"
DO	"	hourly	"	"	"	"
TKN	"	every 3 hrs.	T,B	"	"	"
Ammonia	"	"	"	"	"	"
Nitrite	"	"	"	"	"	"
Nitrate	"	"	"	"	"	"
Total P	"	"	"	"	"	"
Ortho P	"	"	"	"	"	"
Coliforms	"	"	"	"	"	"
Chlorophyll "A"	"	"	"	"	"	"
Light & Dark Bottle	"	"	Surface			
Secchi Disk	"	"	Surface	"	"	Surface
BOD5	13 hrs.	every 3 hrs.	T,B	SBE,SBF	1 each	T,B
Ultimate BOD				"	"	Top
Benthic O_2 Demand					once	Bottom

T = 1 meter below surface
B = 1 meter off bottom

SBE = slack water before ebb
SBF = slack water before flood

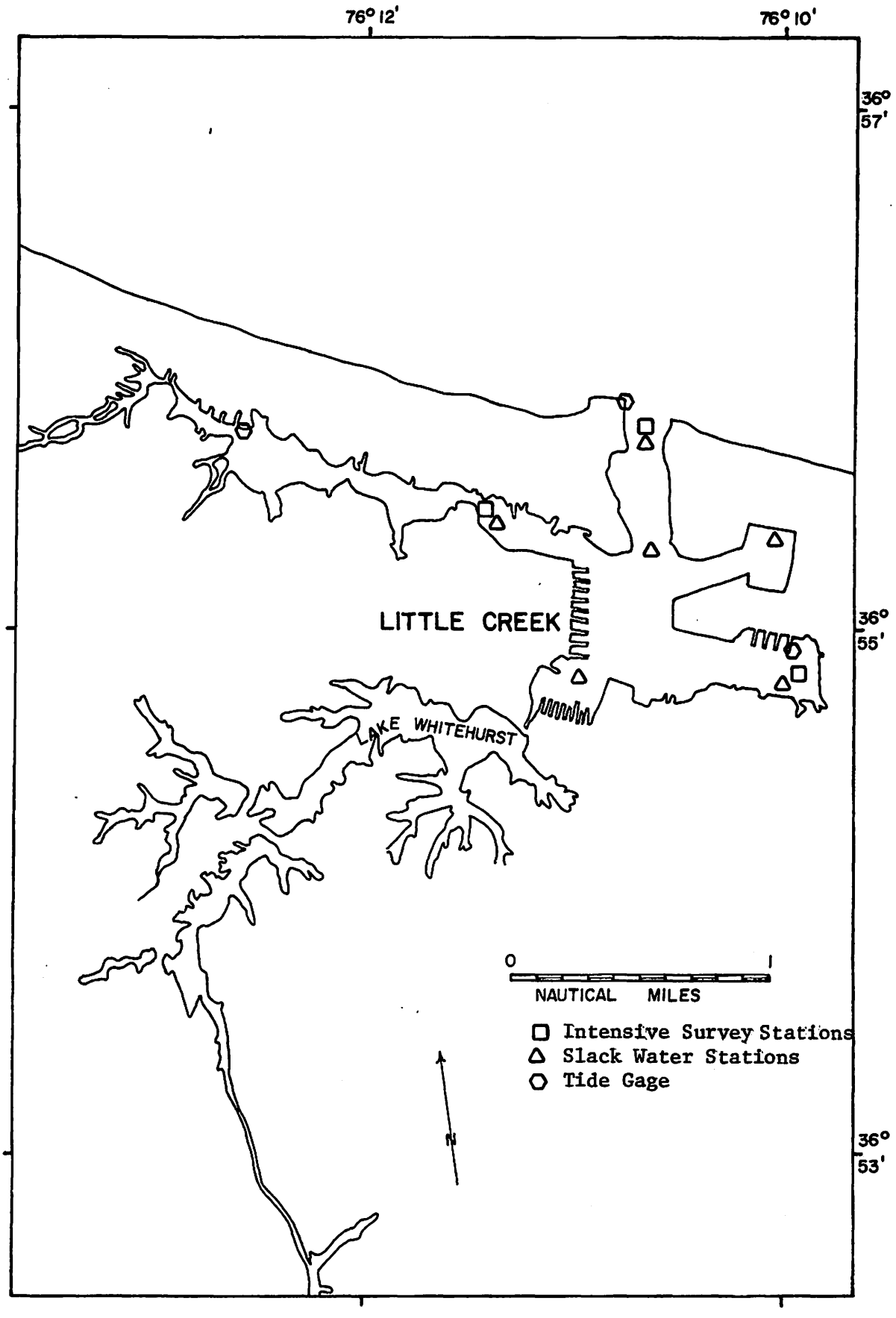

76° 12'
76° 10'
36° 57'
36° 55'
36° 53'
LITTLE CREEK
LAKE WHITEHURST
0
1
NAUTICAL MILES
Intensive Survey Stations
Slack Water Stations
Tide Gage
N

Figure 3

Table 4

Lynnhaven Bay Sampling Program
5 Intensive Survey Stations
16 Slack Water Stations
5 Tide Gages

Parameter	1 Intensive Survey			2 Slack Surveys		
	Sampling Period	Sampling Frequency	Sampling Depths	Sampling Period	Sampling Frequency	Sampling Depths
Tide	5 days	every 15 min.				
Temperature	13 hrs.	hourly	T,B	SBE,SBF	1 each	T,B
Salinity	"	hourly	"	"	"	"
DO	"	hourly	"	"	"	"
TKN	"	every 3 hrs.	T,B	"	"	"
Ammonia	"	"	"	"	"	"
Nitrite	"	"	"	"	"	"
Nitrate	"	"	"	"	"	"
Total P	"	"	"	"	"	"
Ortho P	"	"	"	"	"	"
Coliforms	"	"	"	"	"	"
Chlorophyll "A"	"	"	"	"	"	"
Light & Dark Bottle	"	"	Surface			
Secchi Disk	"	"	Surface	"	"	Surface
BOD5	13 hrs.	every 3 hrs.	T,B	SBE,SBF	1 each	T,B
Ultimate BOD				"	"	Top
Benthic O_2 Demand					once	Bottom

T = 1 meter below surface
B = 1 meter off bottom

SBE = slack water before ebb
SBF = slack water before flood

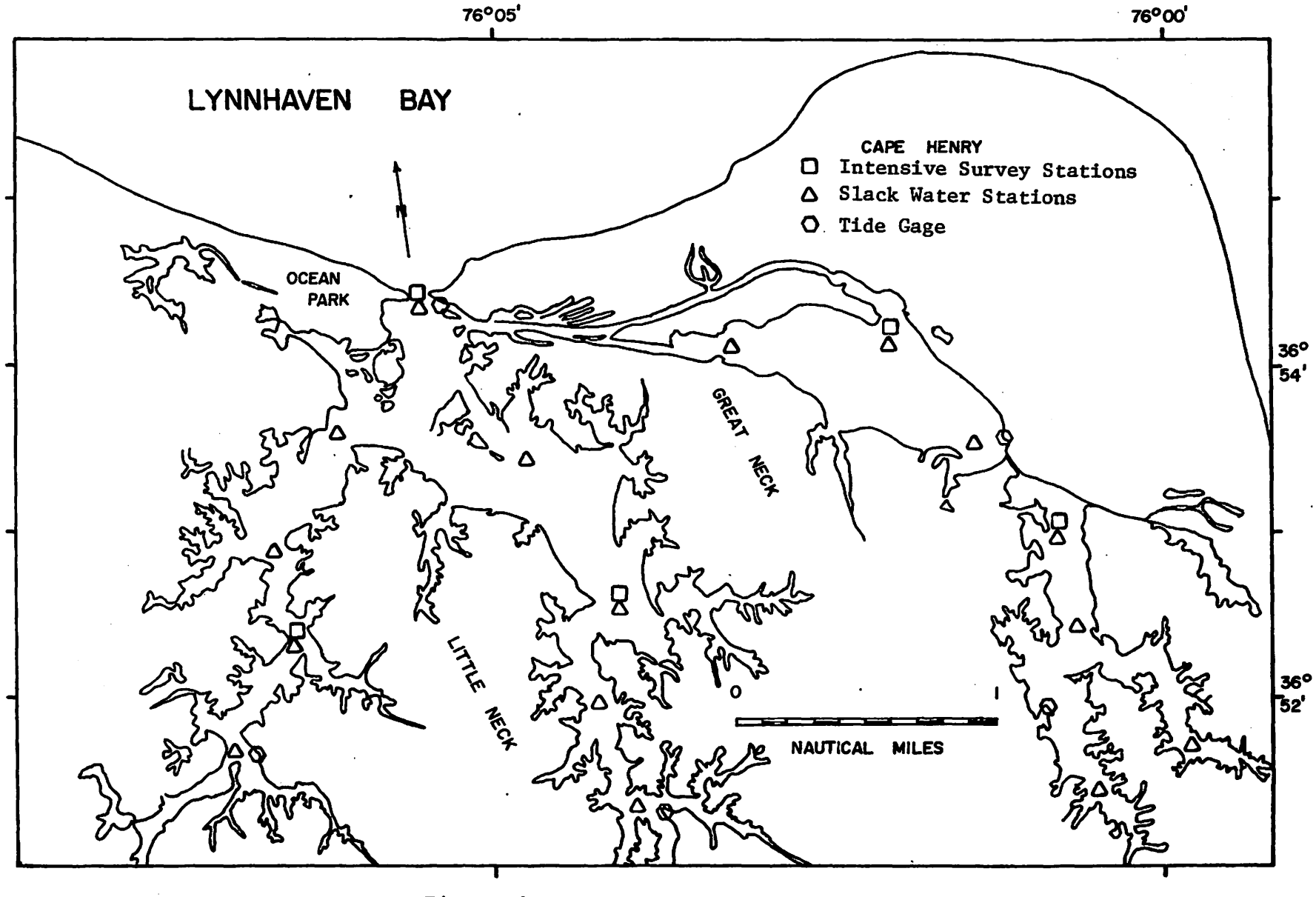

76°05'
76°00'
LYNNHAVEN BAY
CAPE HENRY
Intensive Survey Stations
Slack Water Stations
Tide Gage
OCEAN PARK
GREAT NECK
LITTLE NECK
36° 54'
36° 52'
0
1
NAUTICAL MILES

Figure 4

Quality Control Procedures

1) Temperature

   a. Interocean CTD Model 513/514
   Accuracy ±0.1°C
   Calibrated before and after every intensive field survey

   b. Applied Research Austin Model ET 100 Marine
   Accuracy ±0.1°C
   Calibrated before and after every intensive field survey

2) Conductivity

   a. Interocean CTD Model 513/514
   Accuracy ±0.05 millimhos
   Calibrated before and after every intensive field study

3) Salinity

   a. Bottle grab sample analyzed in the laboratory on an Industrial Instrument Laboratory Salinometer Model RS7A
   Accuracy ±0.01 ppt
   Standardized every day before using

   b. Interocean CTD Model 513/514
   Temperature and conductivity readings used in a CBI equation to calculate salinity
   Accuracy ±0.05 ppt

4) Current Speed

   a. Braincon Histogram Current Meter
   Type 1381
   Accuracy ±0.15 knots
   Calibrated in CBI flume in 1973

5) Current Direction

   a. Braincon Histogram Current Meter
   Type 1381
   Accuracy ±10°

6) Tidal Height

   a. Fisher Porter Model 35-1550
   Accuracy ±0.05 ft

   b. Surveyor Service Co.
   Accuracy ±0.1 ft

   c. Potentiometer w/Braincon Model 710 Data Acquisition System
   Accuracy ±0.05 ft

7) Dissolved Oxygen

a. Bottle grab sample pickled in the field and titrated in the laboratory using the azide modification of the Winkler method.
Accuracy ±0.1 mg/l
Standardized every day before using

8) Biochemical Oxygen Demand (5 Day)

a. Grab sample collected in a dark bottle in the field, nitrification inhibitor is added to the sample and it is incubated for 5 days at 20°C. The sample is then titrated using the azide modification of the Winkler method.
Accuracy ±0.1 mg/l
Standardized every day before using

9) Chemical Analyses

Analytical methods used are those listed in "Standard Methods for the Examination of Water & Wastewater" or modifications of those methods necessitated by extant conditions, e.g., saline waters.

Blanks are determined for the reagents and for the analytical methods following step by step procedures. Solutions of known concentrations are used to prepare standard curves. These standards are run routinely and regularly, normally after every 20 water samples, for both automated and chemist-performed analyses. In addition, the laboratory, procedures and personnel are tested periodically through comparison with analyses performed at other institutions.

Laboratory Methods and Procedures

Orthophosphate: This phosphorus fraction was determined using an automated single solution method (Technicon Autoanalyzer II, industrial method No. 155-71W). The detection limit is 0.8 µg-at P/l, and the coeffecient of variation (95% confidence interval at 2 µg-at P/l) is quoted as 2.96%.

Total Phosphorus (Soluble Reactive Phosphorus): Samples were digested by the persulfate oxidation technique and run by the single solution method, using ascorbic acid as the reducing agent. The developed samples were read on a Klett-Summerson Photoelectric colormeter, model 900-3.

Nitrite and Nitrate-N: These nitrogen forms were determined using an automated copper-cadmium reduction method (Technicon Autoanalyzer II, industrial method No. 158-71W). In this method nitrate is first reduced to nitrite by a copper-cadmium reduction column. The nitrite then reacts with sulfanilamide under acidic conditions to form a diazo compound, which then couples with N-1-napthyl-ethylene-diamine dihydrochloride, forming a reddish-purple azo dye which is read on a colormeter. Omission of the reduction column permits determination of the initial concentration.

Chlorophyll "a": Concentrations of this phytopigment were measured by the fluorescence method, employing a turner F Fluorometer, model III. The seston in aliquots of the preserved samples was concentrated on glass fiber filters, homogenized with 90% acetone, and centrifuged to yield extracts that could be read on the instrument. The limit of detection with this method is approximately 1 µg chlorophyll "a" per liter. No corrections were applied to compensate for other phytopigments and pigment breakdown products, which are known to influence the fluorescence readings obtained. Therefore, the resulting concentrations include a variable and unknown positive bias.

Coliform: Water samples were analyzed for total and fecal coliform in accordance with Standard Methods for the Examination of Water and Wastewater, 13 edition, 1971. Five tube replicate series of the presumptive lactose media were inocculated with 10 ml., 1 ml., and dilutions thereof to 10^{-4}. Total and fecal coliform densities were determined using Brilliant Green Bile Broth and EC Broth respectively.

Appendix B. Intensive Survey Data

Small Coastal Basins:

1. Poquoson River
2. Back River
3. Little Creek Harbor
4. Lynnhaven Bay
5. Broad (+ Linkhorn) Bay

Water Quality Parameters

a) Salinity
b) Chlorophyll "a"
c) Ammonia Nitrogen
d) Nitrite & Nitrate Nitrogen
e) Total Kjeldahl Nitrogen
f) Organic Phosphorus
g) Total (Soluble Reactive) Phosphorus
h) 5-Day Biochemical Oxygen Demand
i) Dissolved Oxygen
j) Total Coliforms
k) Fecal Coliforms

All water quality data, from both intensive surveys and slack water surveys, all current measurements, and tide gage data have been supplied to the Agency in computer printouts. These graphical presentations are included to provide information additional to that in the text.

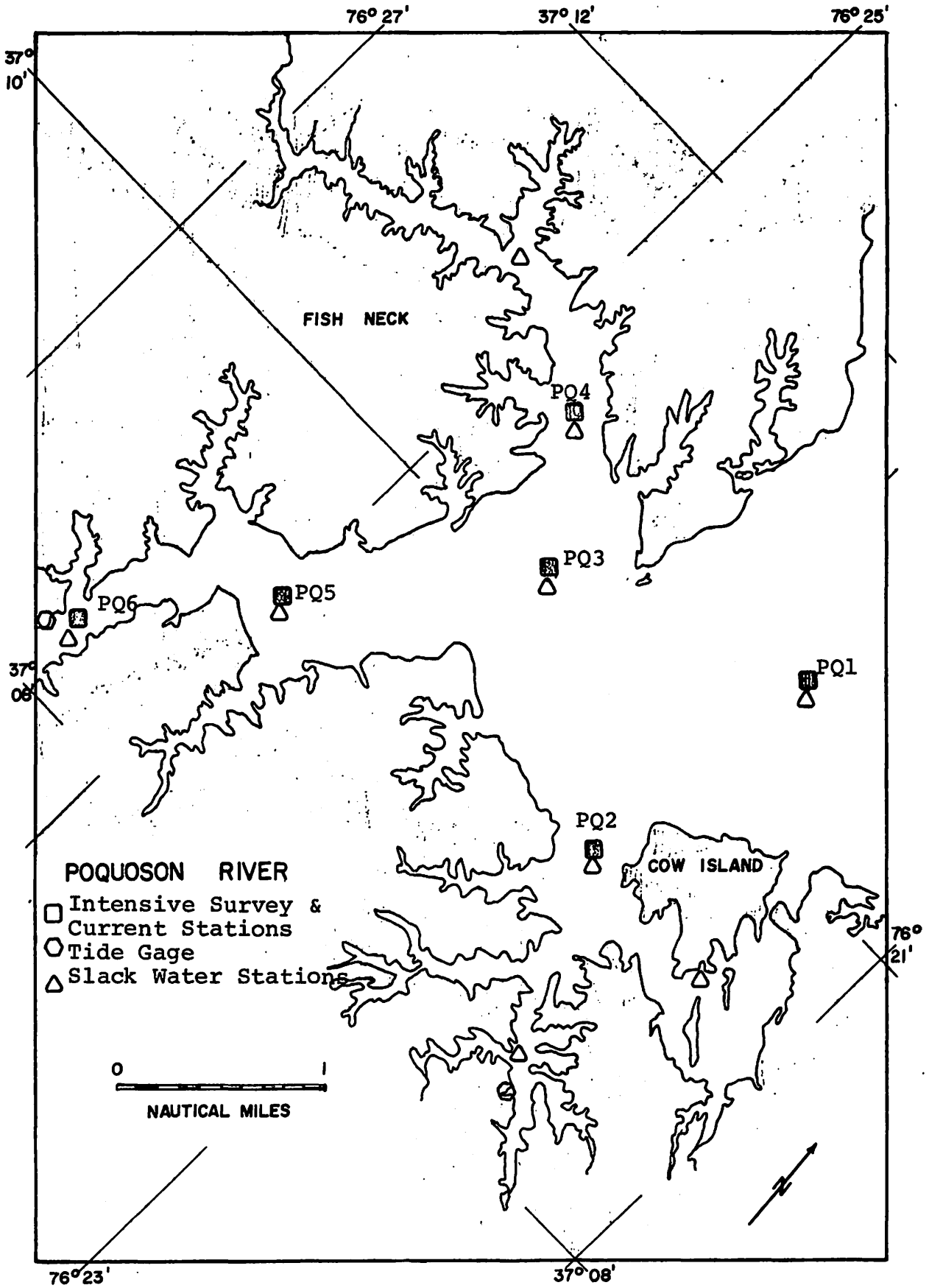
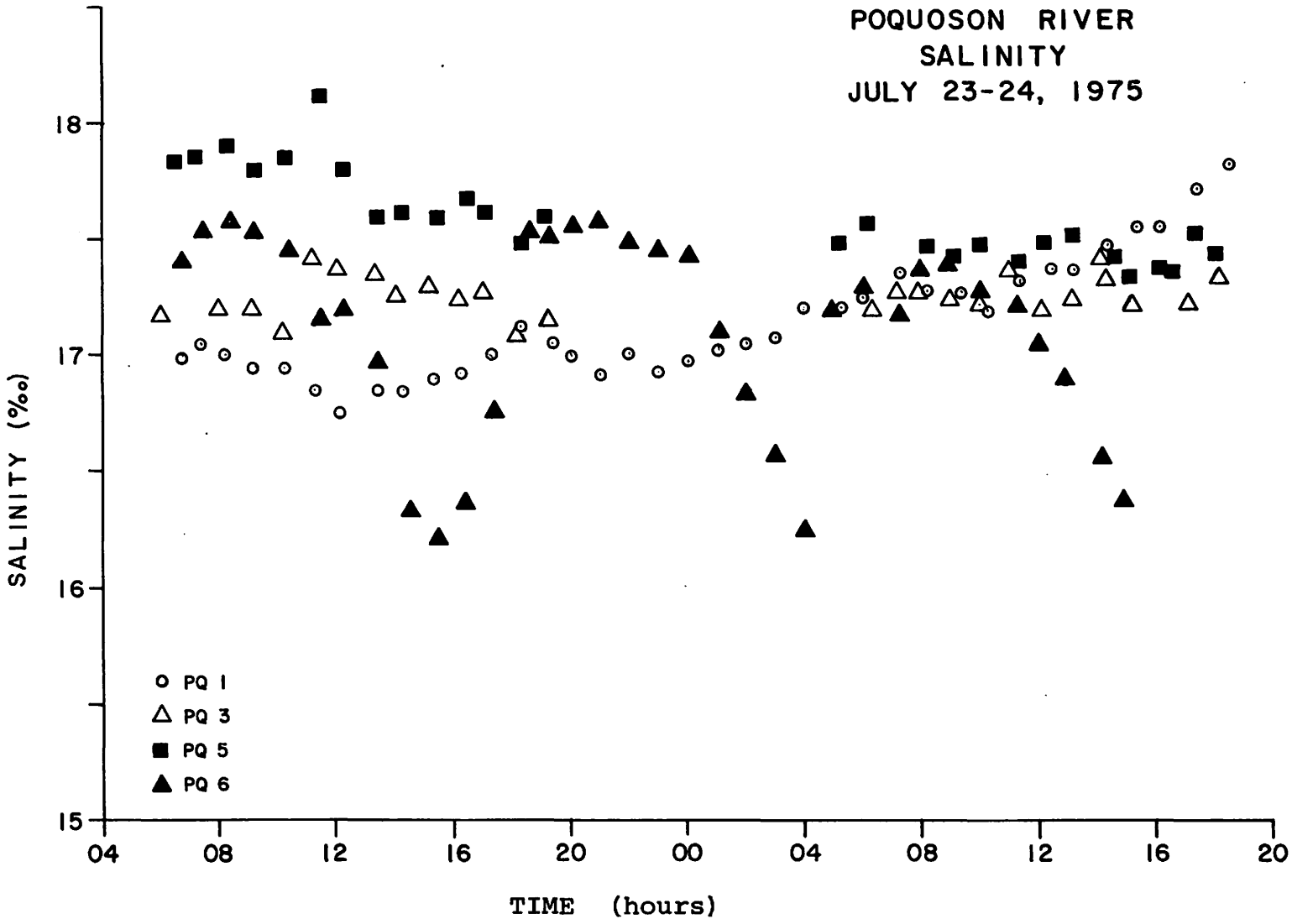
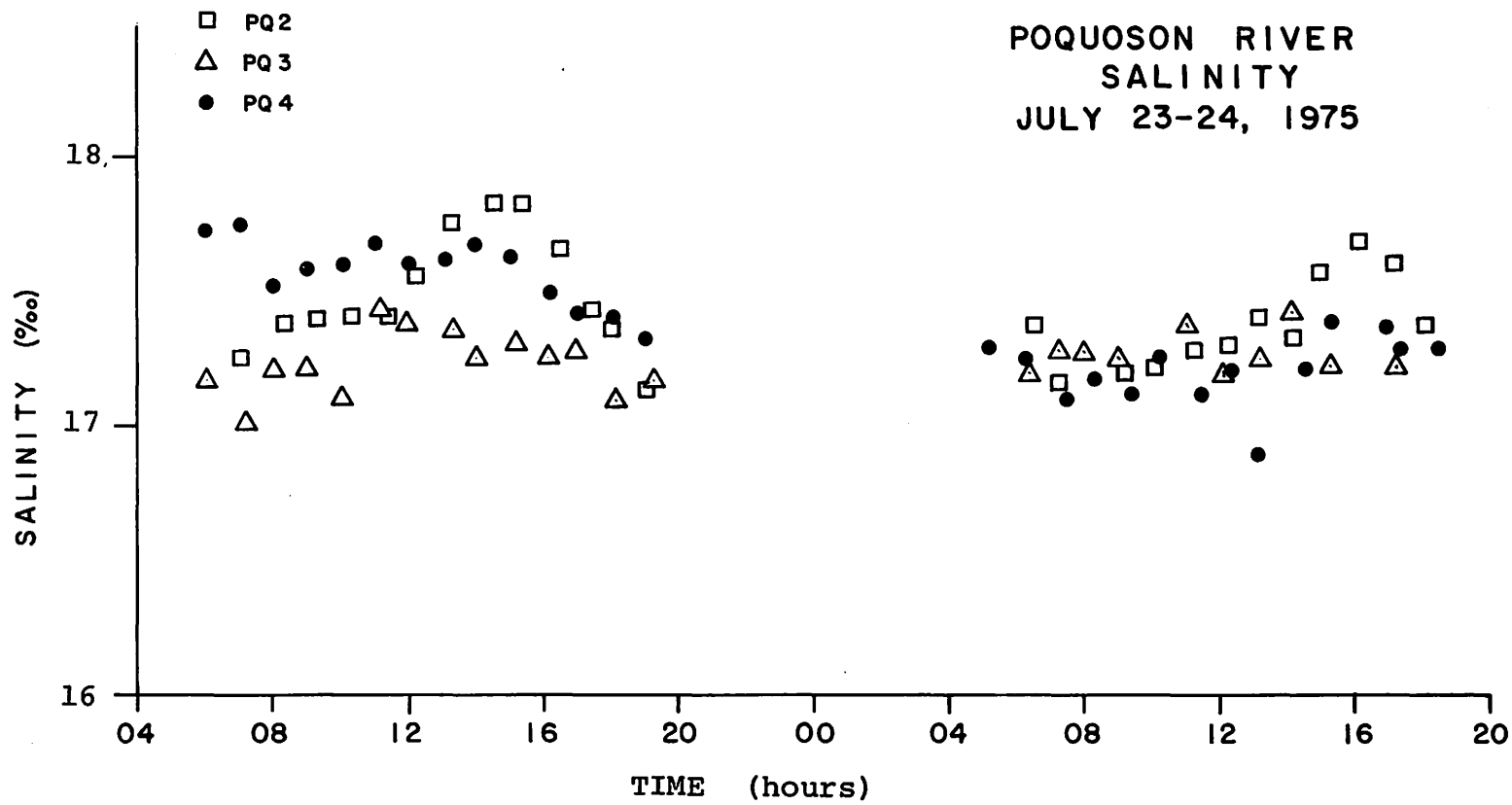
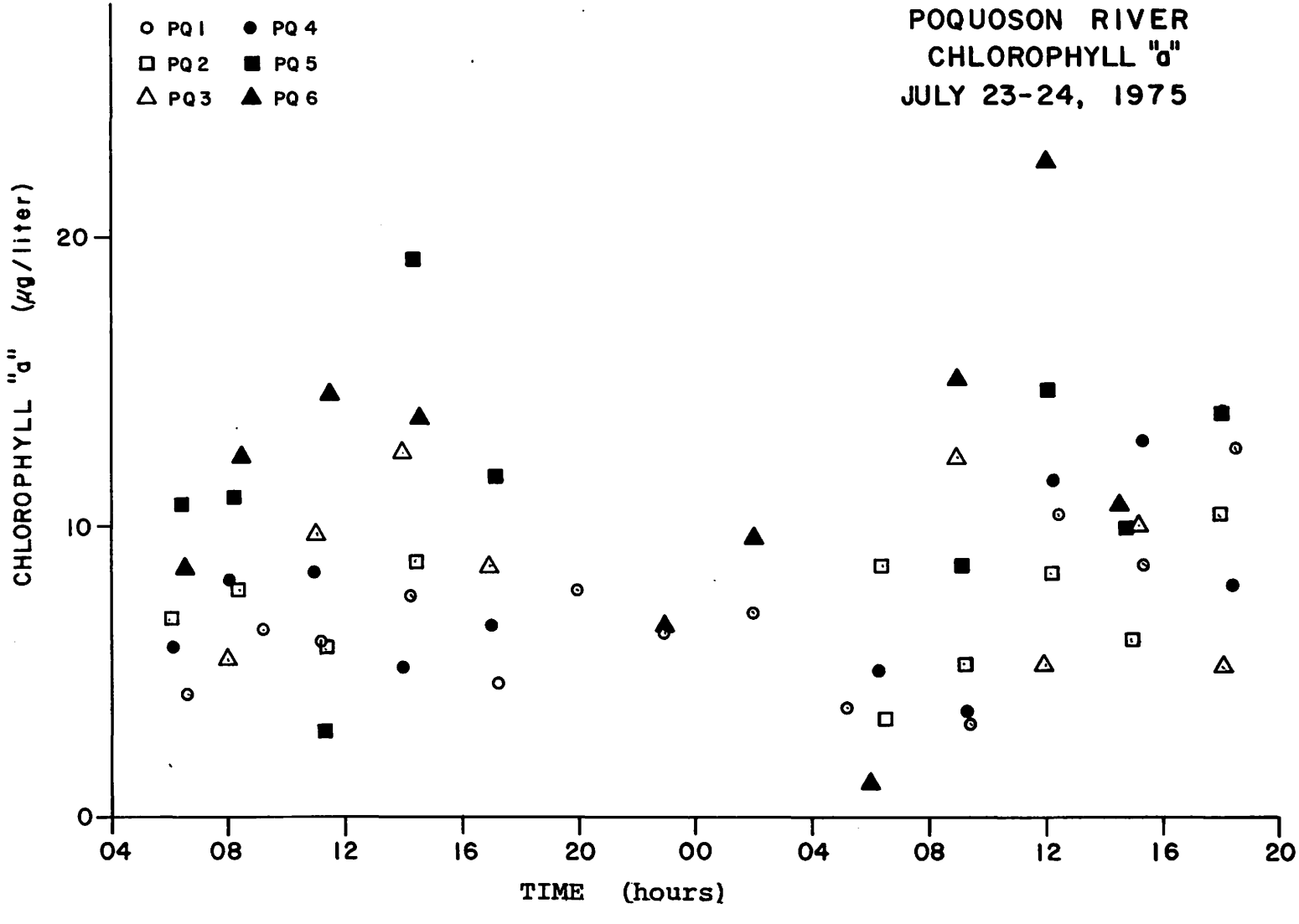
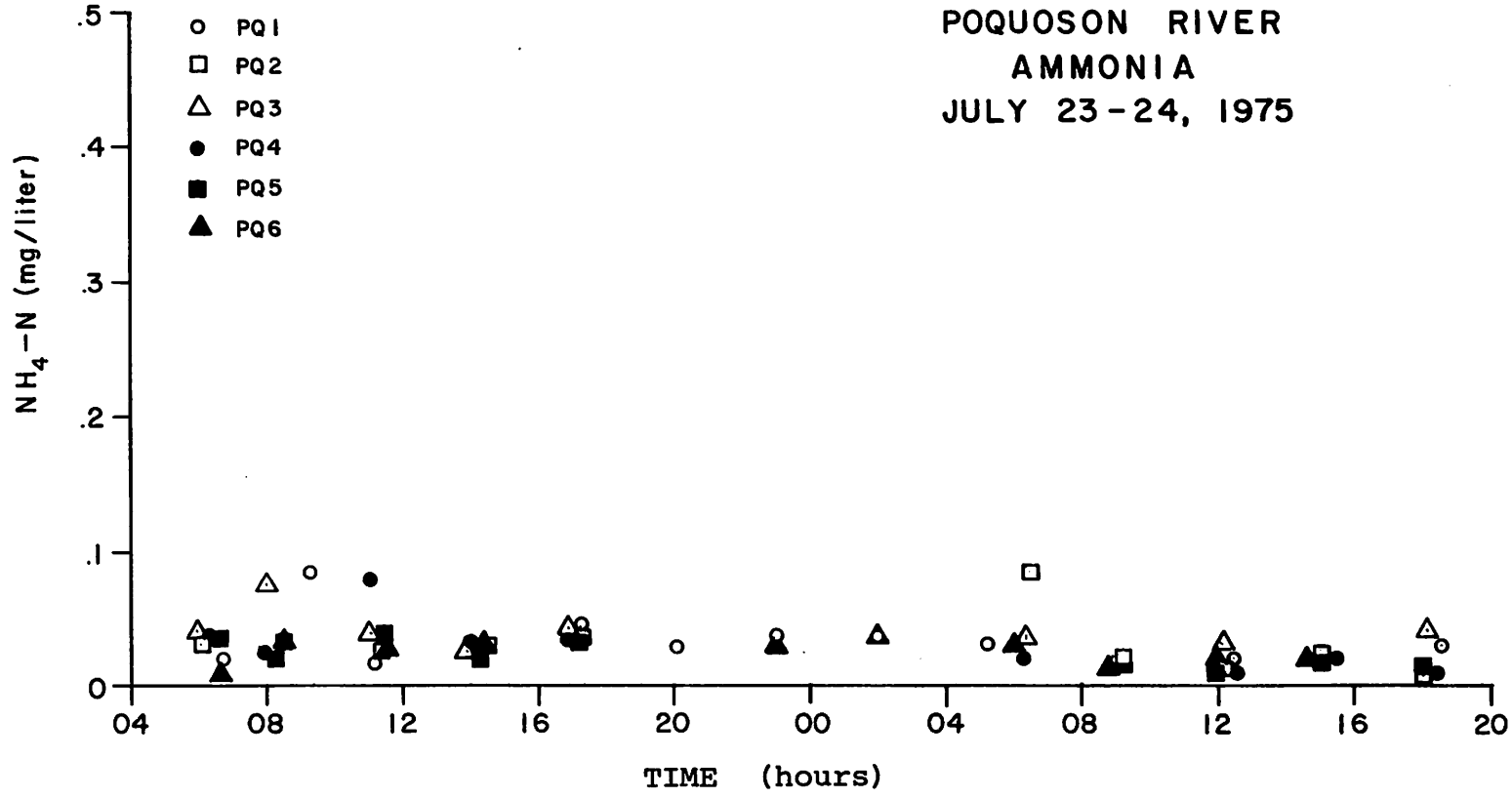


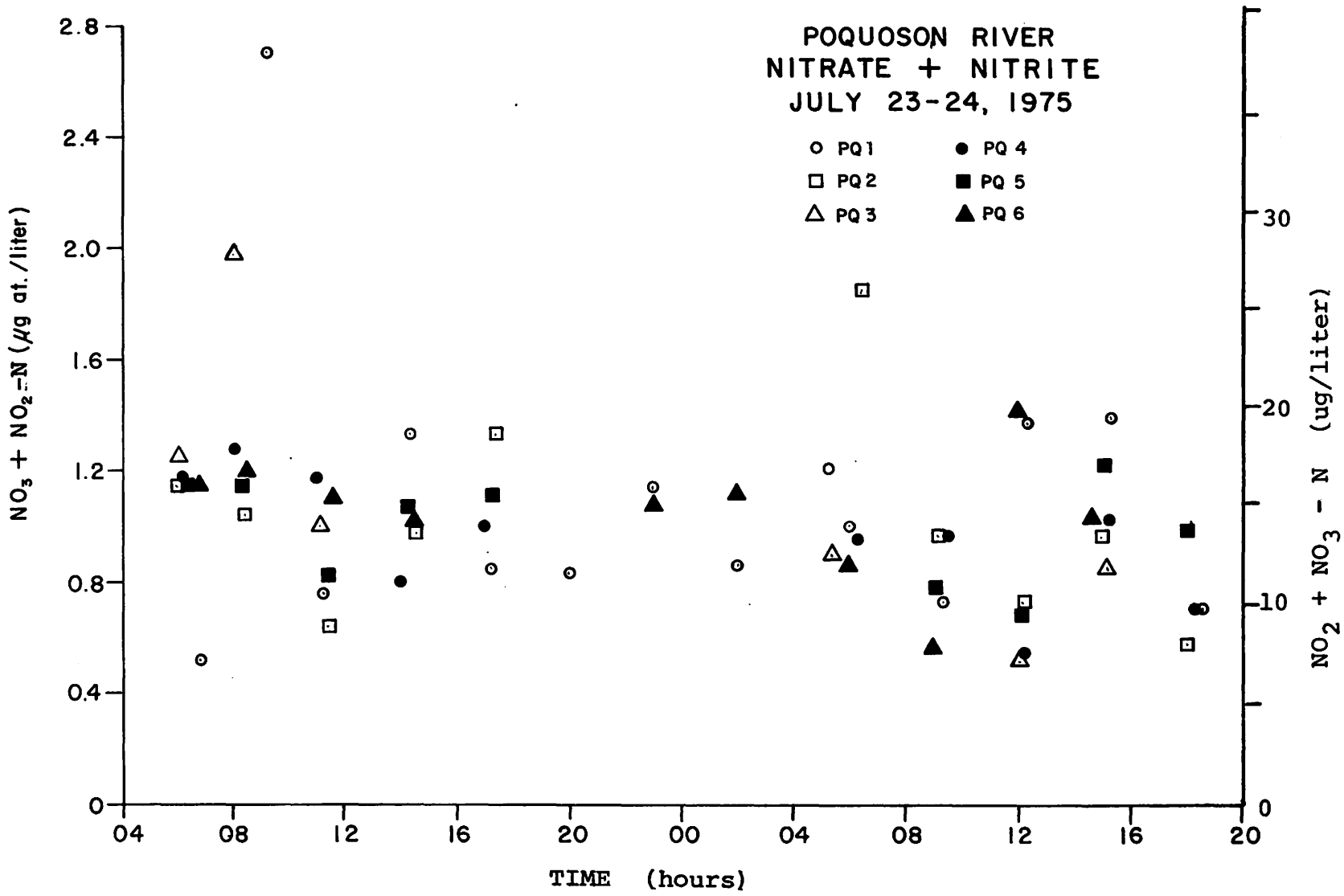
Figure 3. Study sites in Poquoson River.

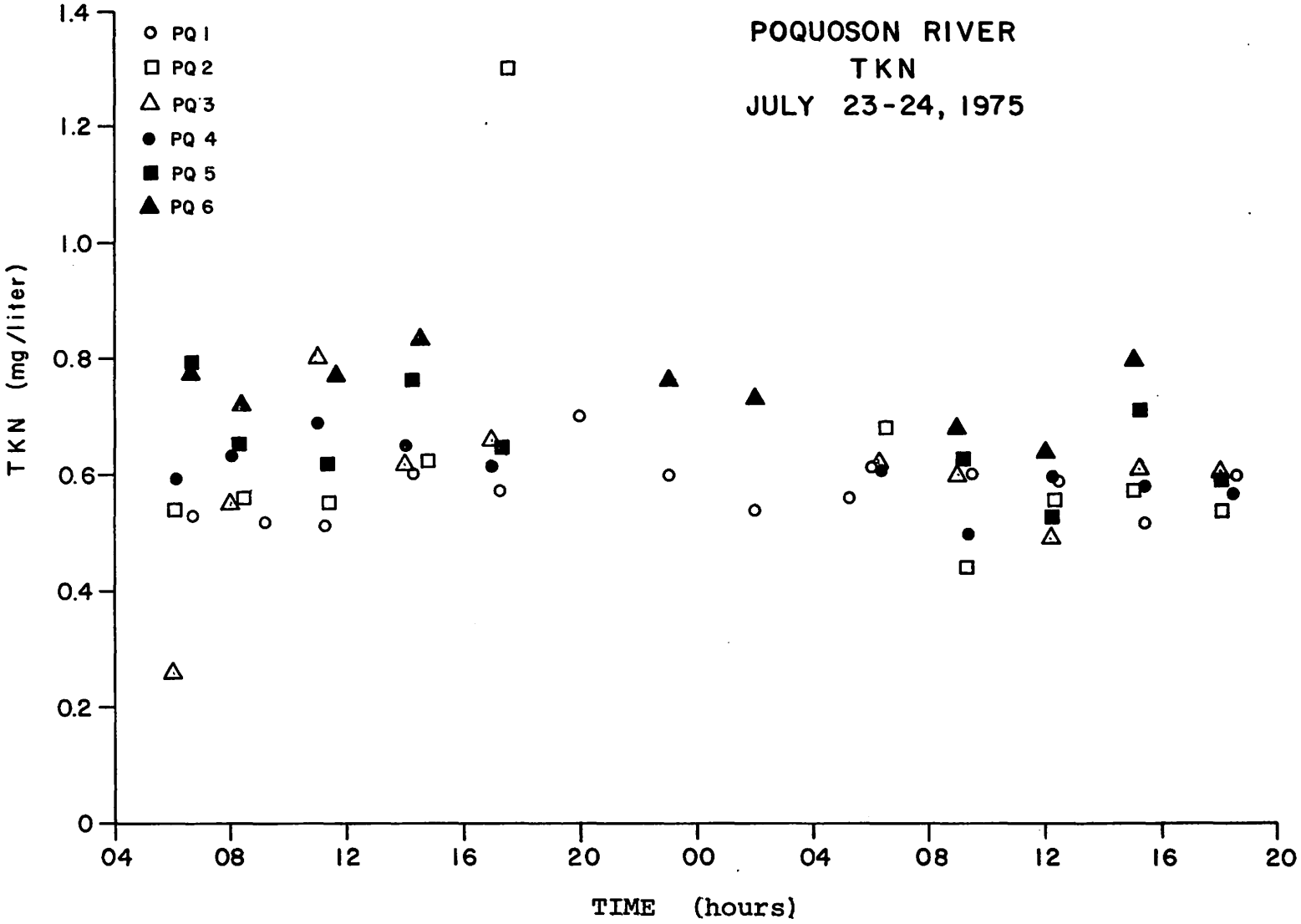

POQUOSON RIVER
SALINITY
JULY 23-24, 1975
SALINITY (‰)
18
17
16
15
PQ 1
PQ 3
PQ 5
PQ 6
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

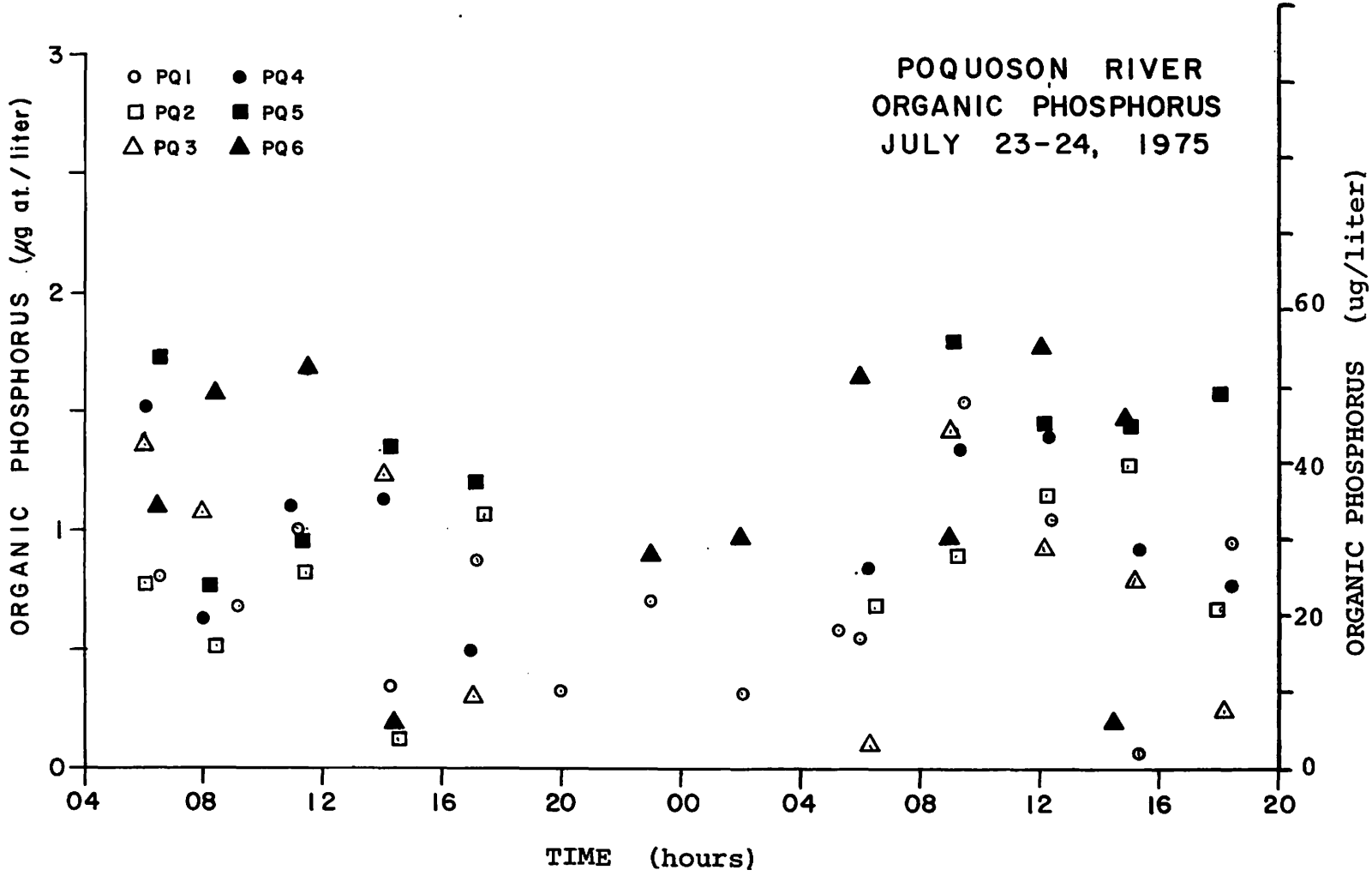

PQ2
PQ3
PQ4
POQUOSON RIVER
SALINITY
JULY 23-24, 1975
SALINITY (‰)
18
17
16
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

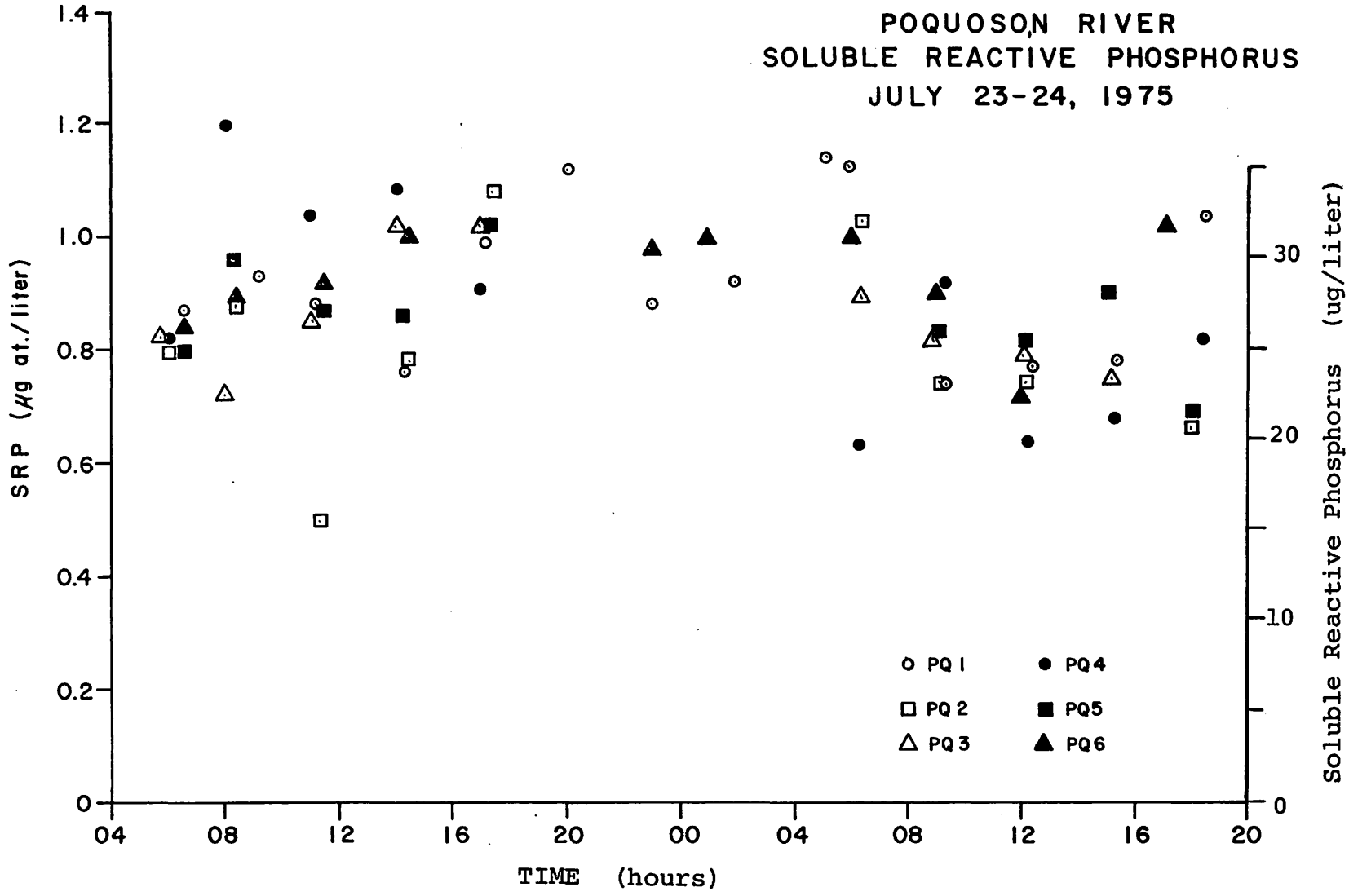

POQUOSON RIVER
CHLOROPHYLL "a"
JULY 23-24, 1975
PQ 1
PQ 2
PQ 3
PQ 4
PQ 5
PQ 6
CHLOROPHYLL "a" (µg/liter)
0
10
20
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

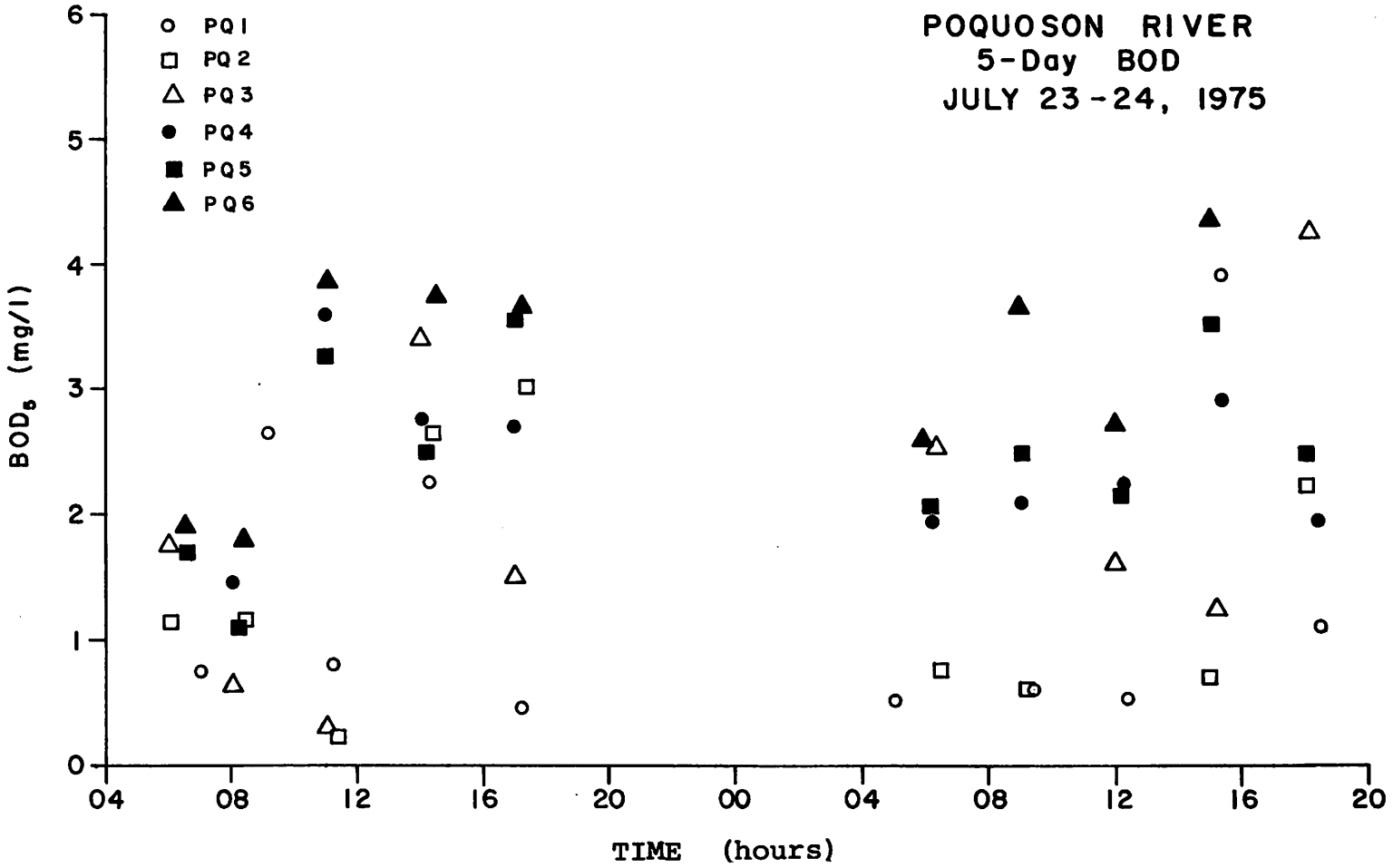

POQUOSON RIVER
AMMONIA
JULY 23-24, 1975
PQ1
PQ2
PQ3
PQ4
PQ5
PQ6
NH_4-N (mg/liter)
.5
.4
.3
.2
.1
0
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

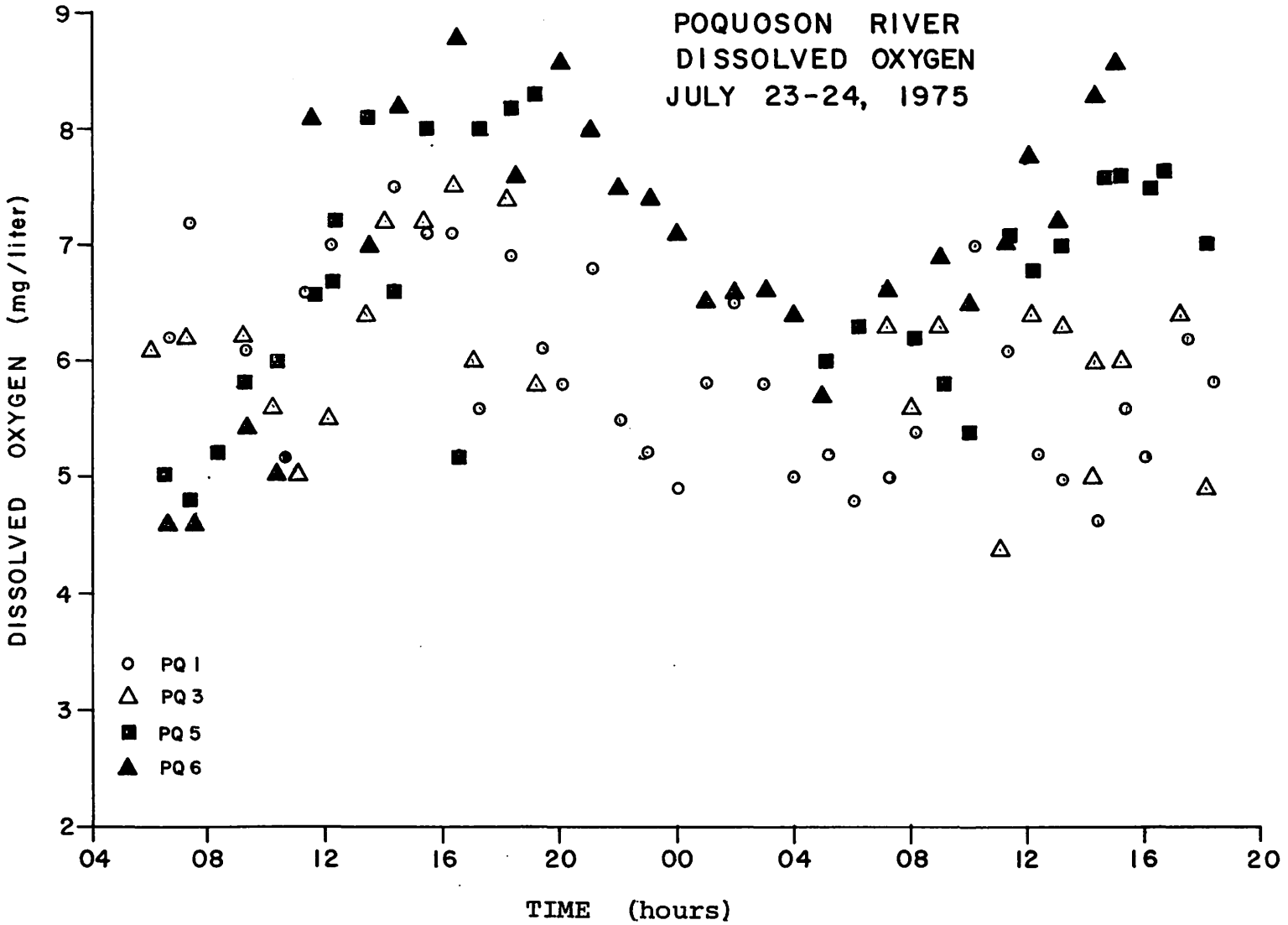

POQUOSON RIVER
NITRATE + NITRITE
JULY 23-24, 1975
PQ1
PQ2
PQ3
PQ4
PQ5
PQ6
$NO_3 + NO_2$-N (µg at./liter)
$NO_2 + NO_3$ - N (ug/liter)
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
30
20
10
0
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

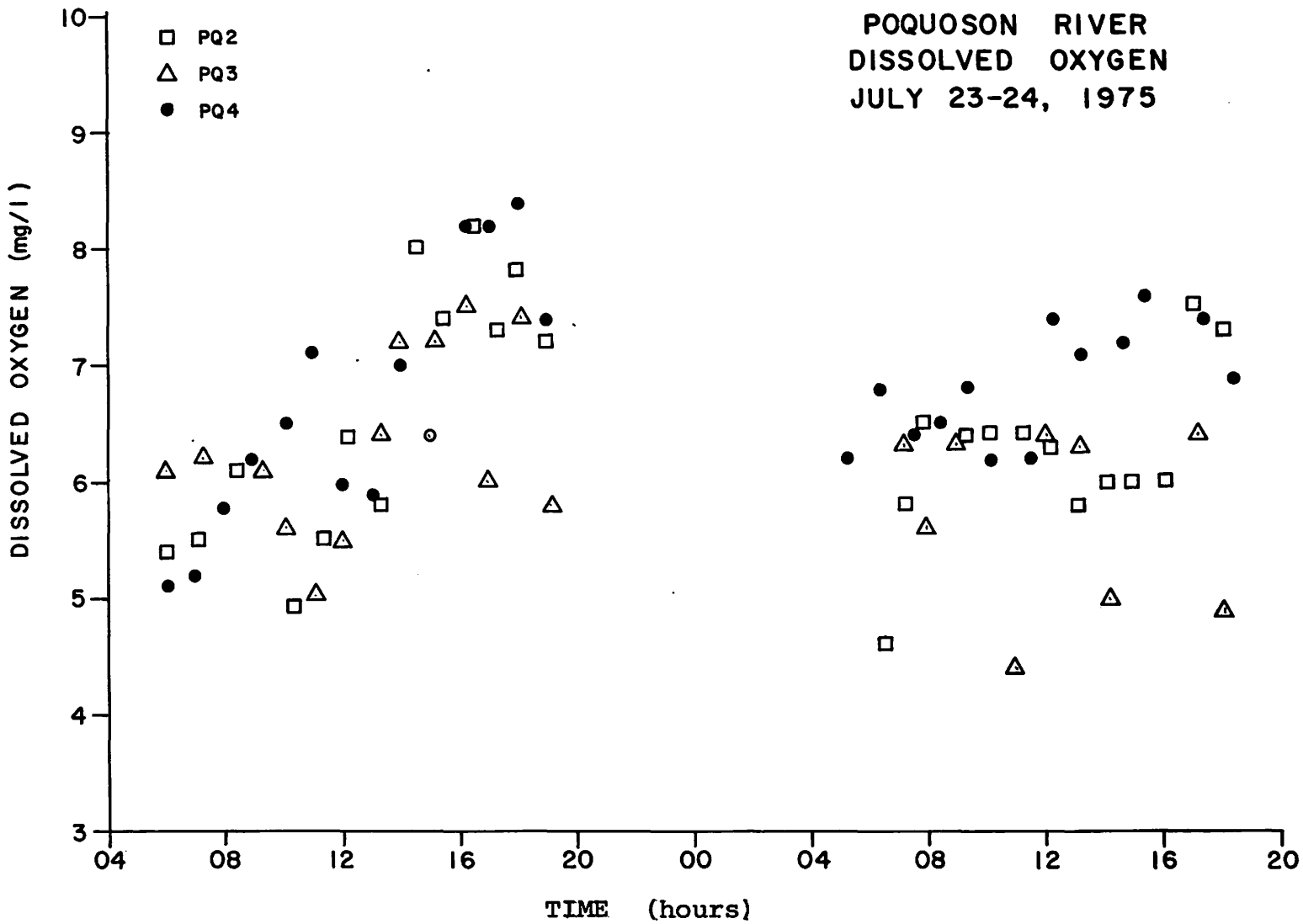

POQUOSON RIVER
TKN
JULY 23-24, 1975
PQ 1
PQ 2
PQ 3
PQ 4
PQ 5
PQ 6
TKN (mg/liter)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

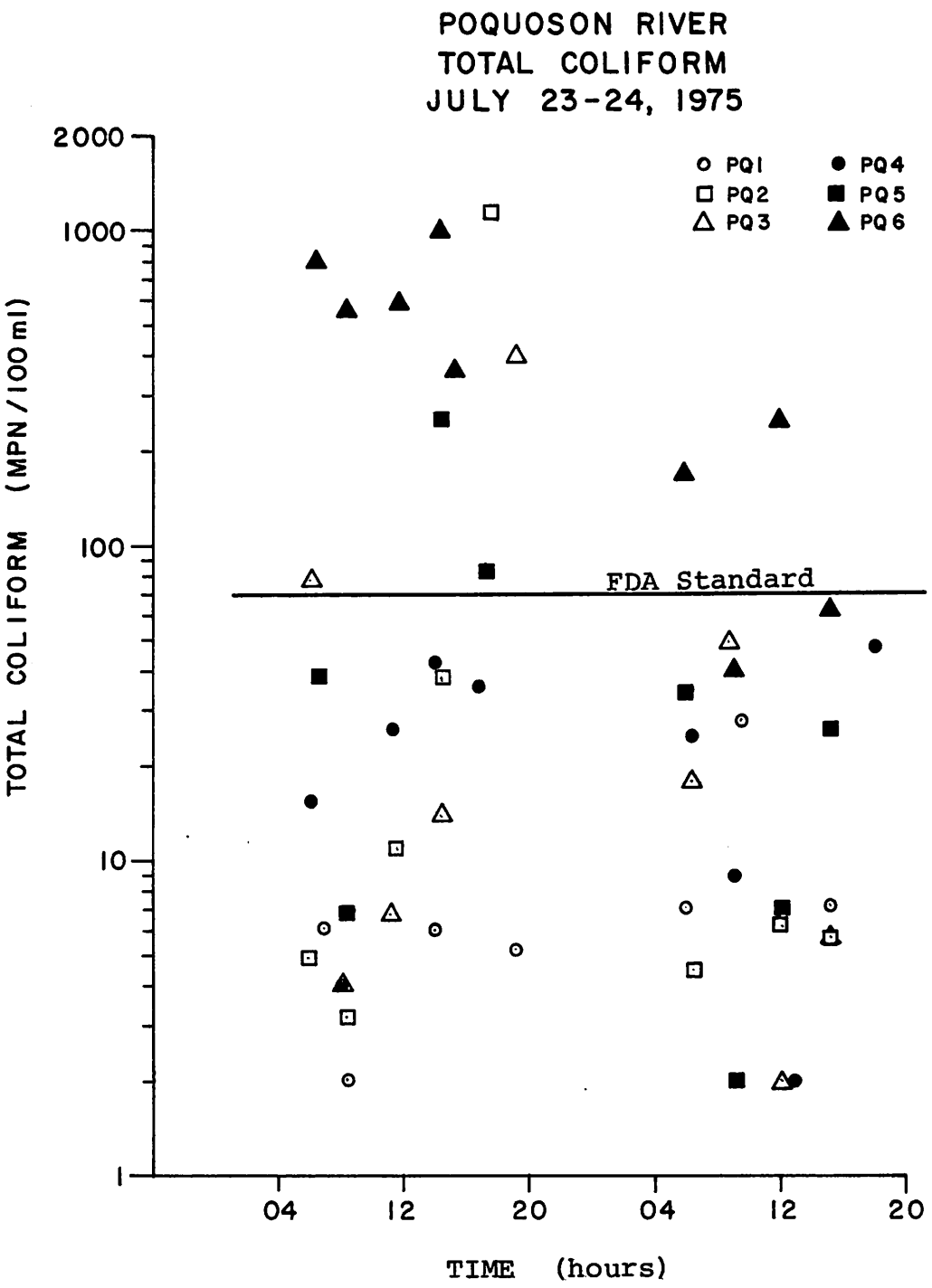

POQUOSON RIVER
ORGANIC PHOSPHORUS
JULY 23-24, 1975
PQ1
PQ2
PQ3
PQ4
PQ5
PQ6
ORGANIC PHOSPHORUS (μg at./liter)
ORGANIC PHOSPHORUS (ug/liter)
TIME (hours)
0
1
2
3
0
20
40
60
04
08
12
16
20
00
04
08
12
16
20

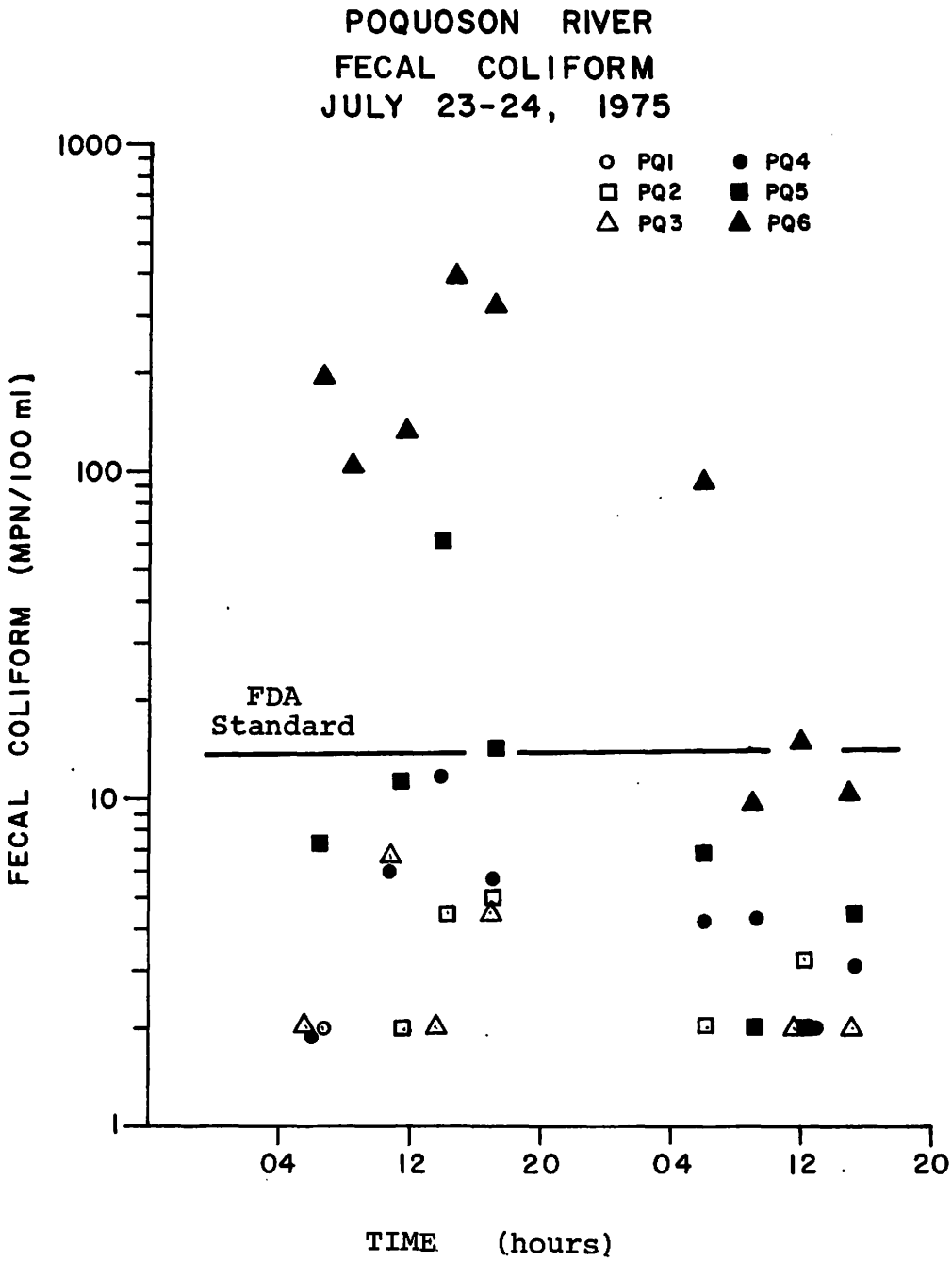

POQUOSON RIVER
SOLUBLE REACTIVE PHOSPHORUS
JULY 23-24, 1975
SRP (µg at./liter)
Soluble Reactive Phosphorus (ug/liter)
TIME (hours)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
30
20
10
0
04
08
12
16
20
00
04
08
12
16
20
PQ1
PQ2
PQ3
PQ4
PQ5
PQ6

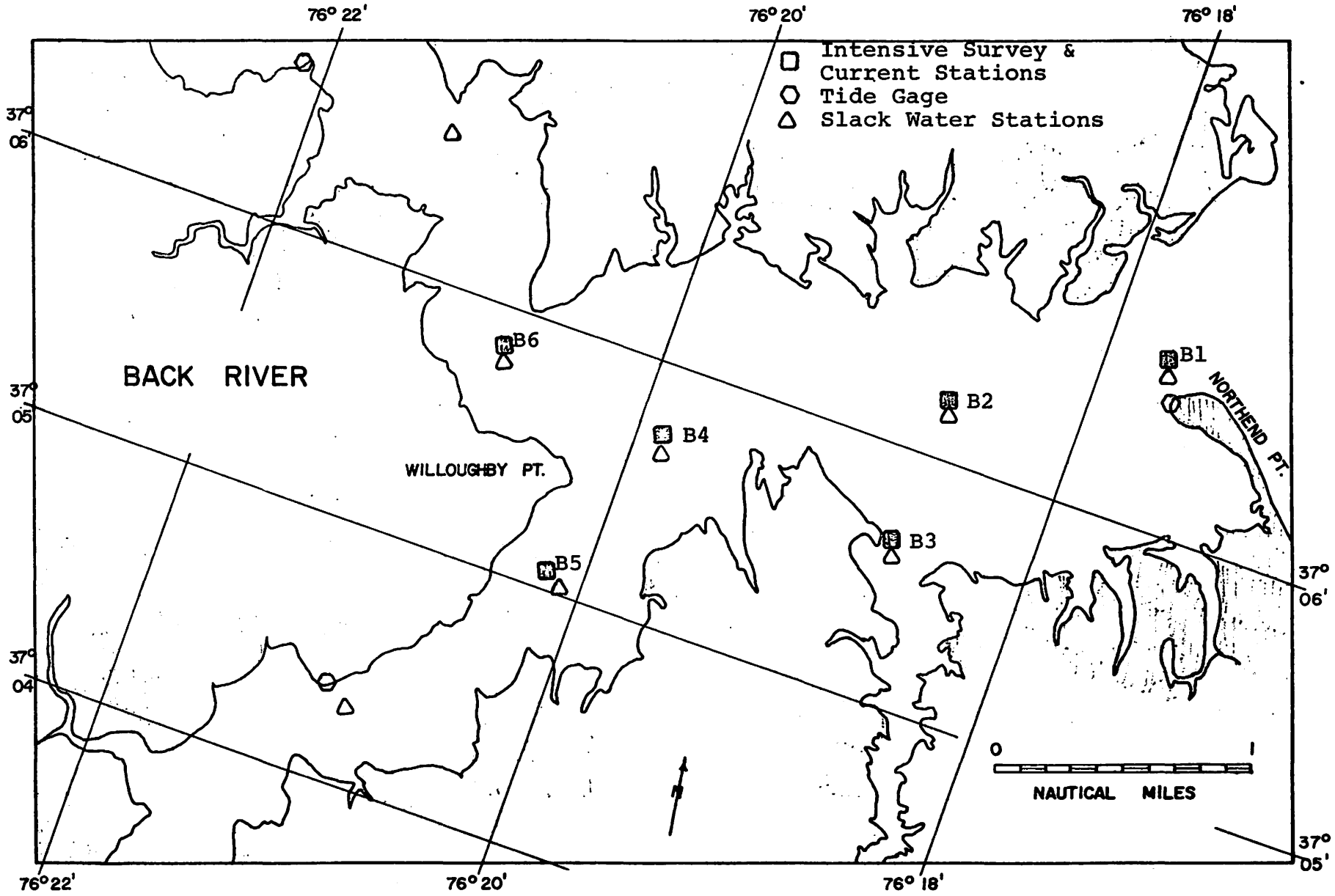

POQUOSON RIVER
5-Day BOD
JULY 23-24, 1975
PQ1
PQ2
PQ3
PQ4
PQ5
PQ6
BOD5 (mg/l)
0
1
2
3
4
5
6
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)


POQUOSON RIVER
DISSOLVED OXYGEN
JULY 23-24, 1975
DISSOLVED OXYGEN (mg/liter)
TIME (hours)
PQ 1
PQ 3
PQ 5
PQ 6
9
8
7
6
5
4
3
2
04
08
12
16
20
00
04
08
12
16
20

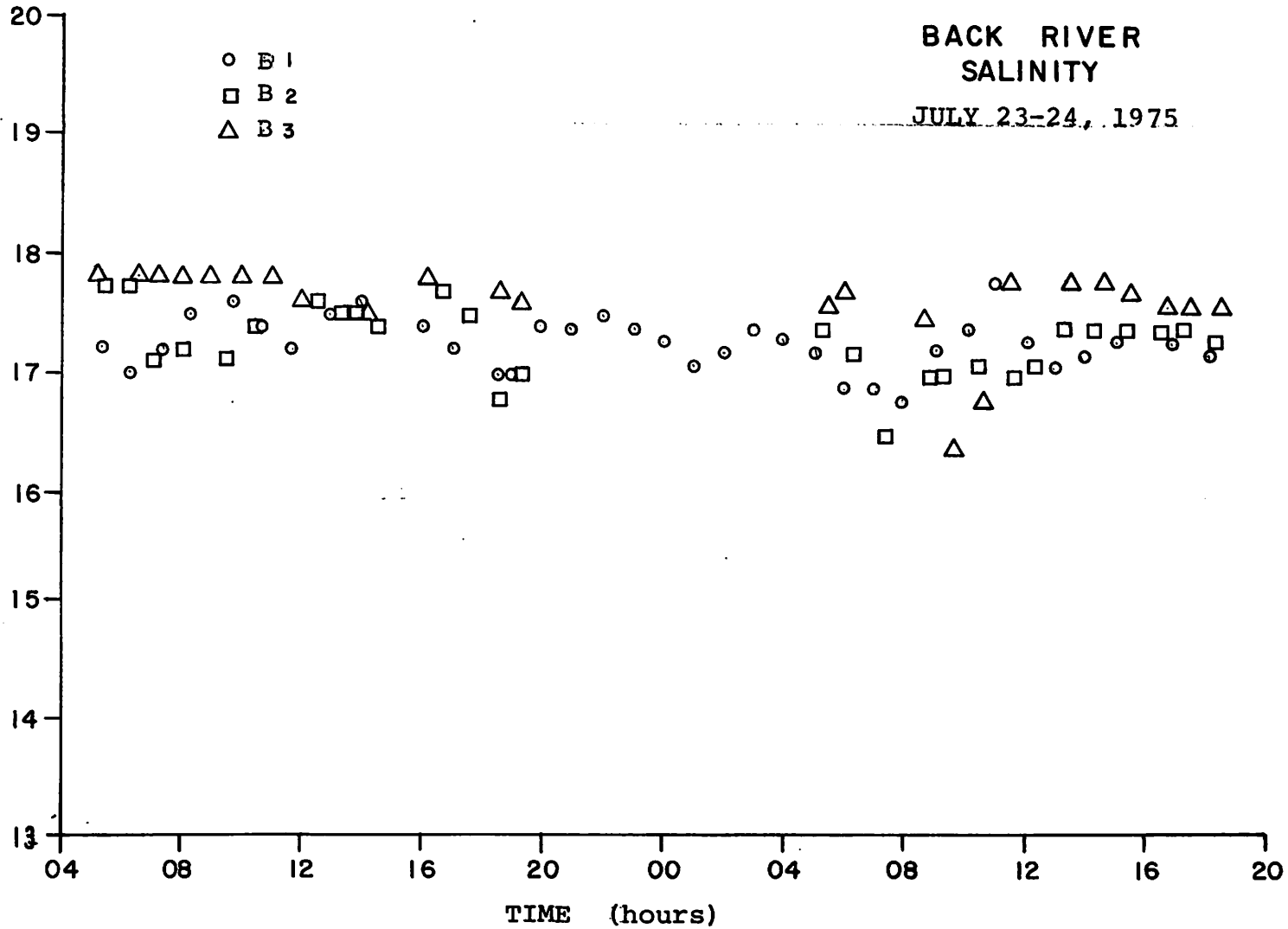

POQUOSON RIVER
DISSOLVED OXYGEN
JULY 23-24, 1975
PQ2
PQ3
PQ4
DISSOLVED OXYGEN (mg/l)
10
9
8
7
6
5
4
3
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

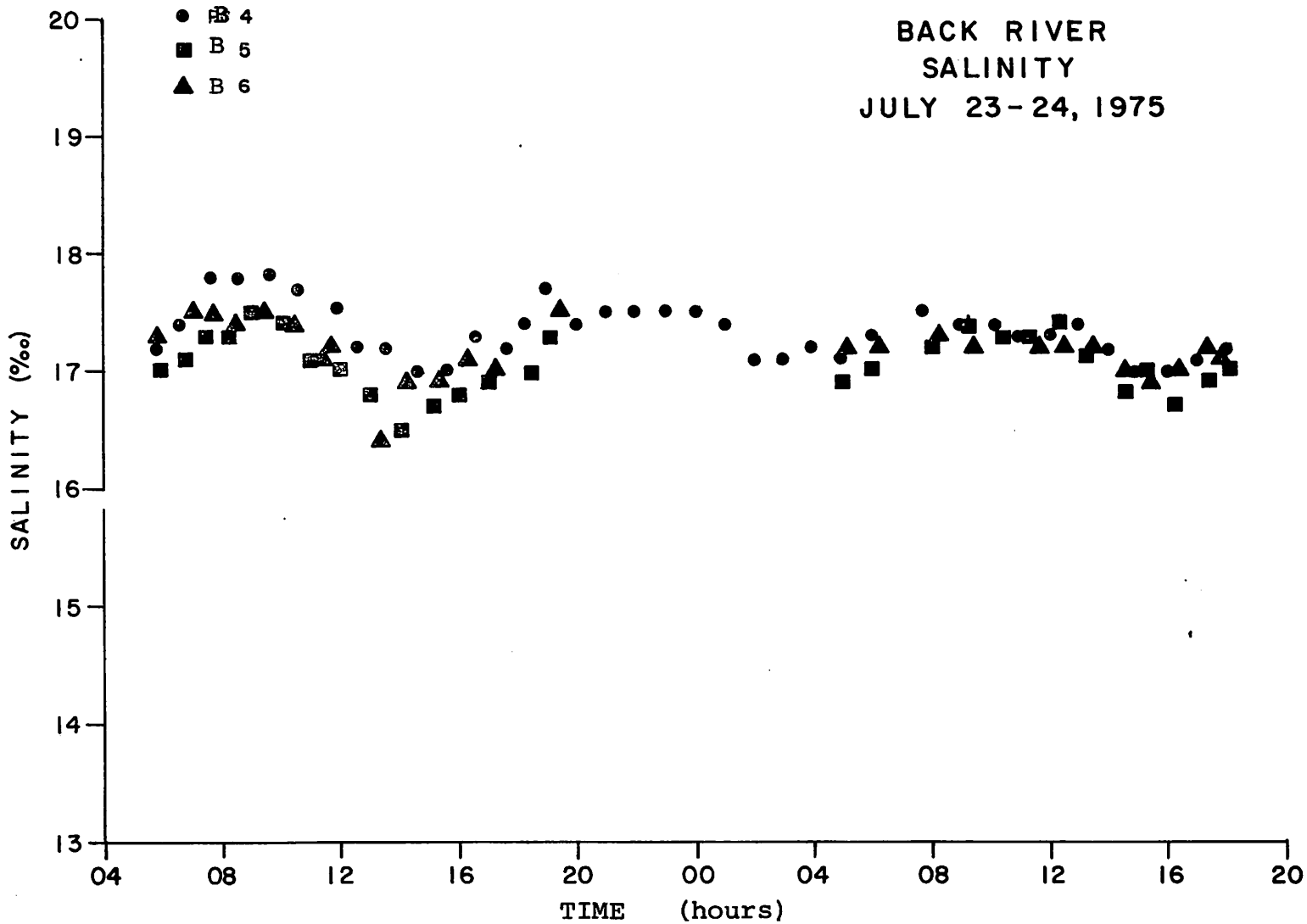

POQUOSON RIVER
TOTAL COLIFORM
JULY 23-24, 1975
PQ1
PQ2
PQ3
PQ4
PQ5
PQ6
FDA Standard
TOTAL COLIFORM (MPN/100 ml)
2000
1000
100
10
1
04
12
20
04
12
20
TIME (hours)

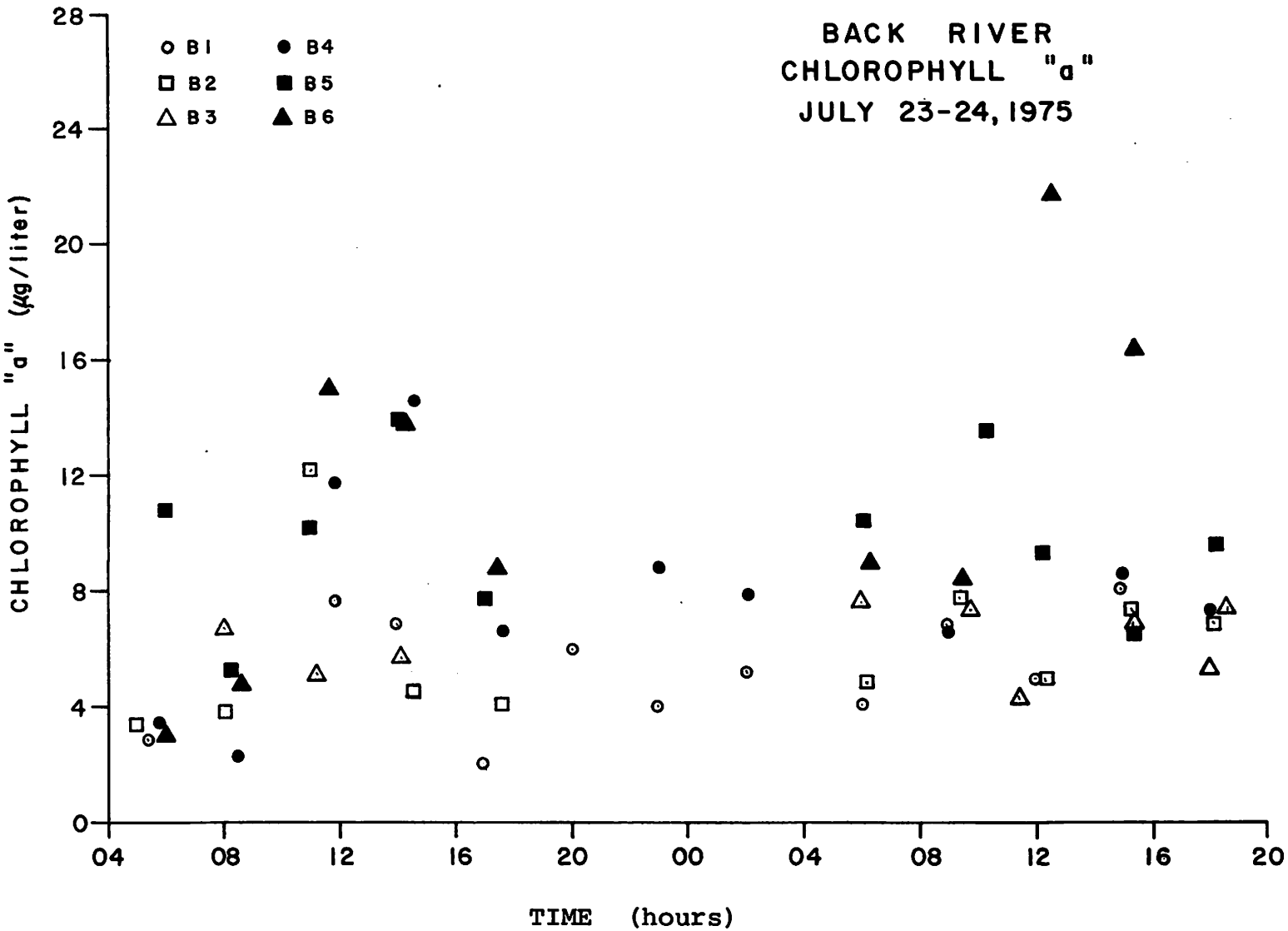

POQUOSON RIVER
FECAL COLIFORM
JULY 23-24, 1975
PQ1
PQ2
PQ3
PQ4
PQ5
PQ6
FDA
Standard
1000
100
10
1
FECAL COLIFORM (MPN/100 ml)
04
12
20
04
12
20
TIME (hours)

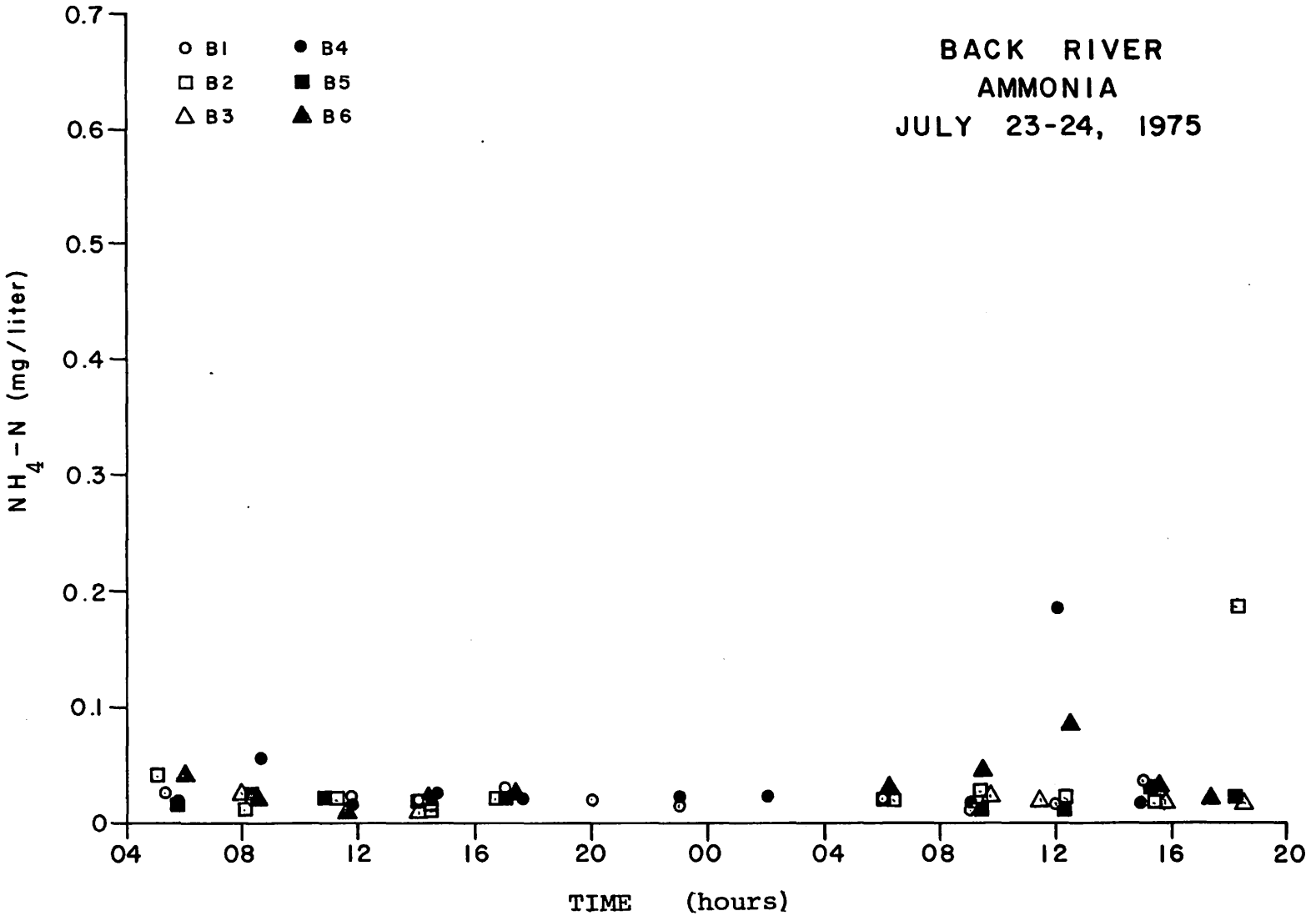


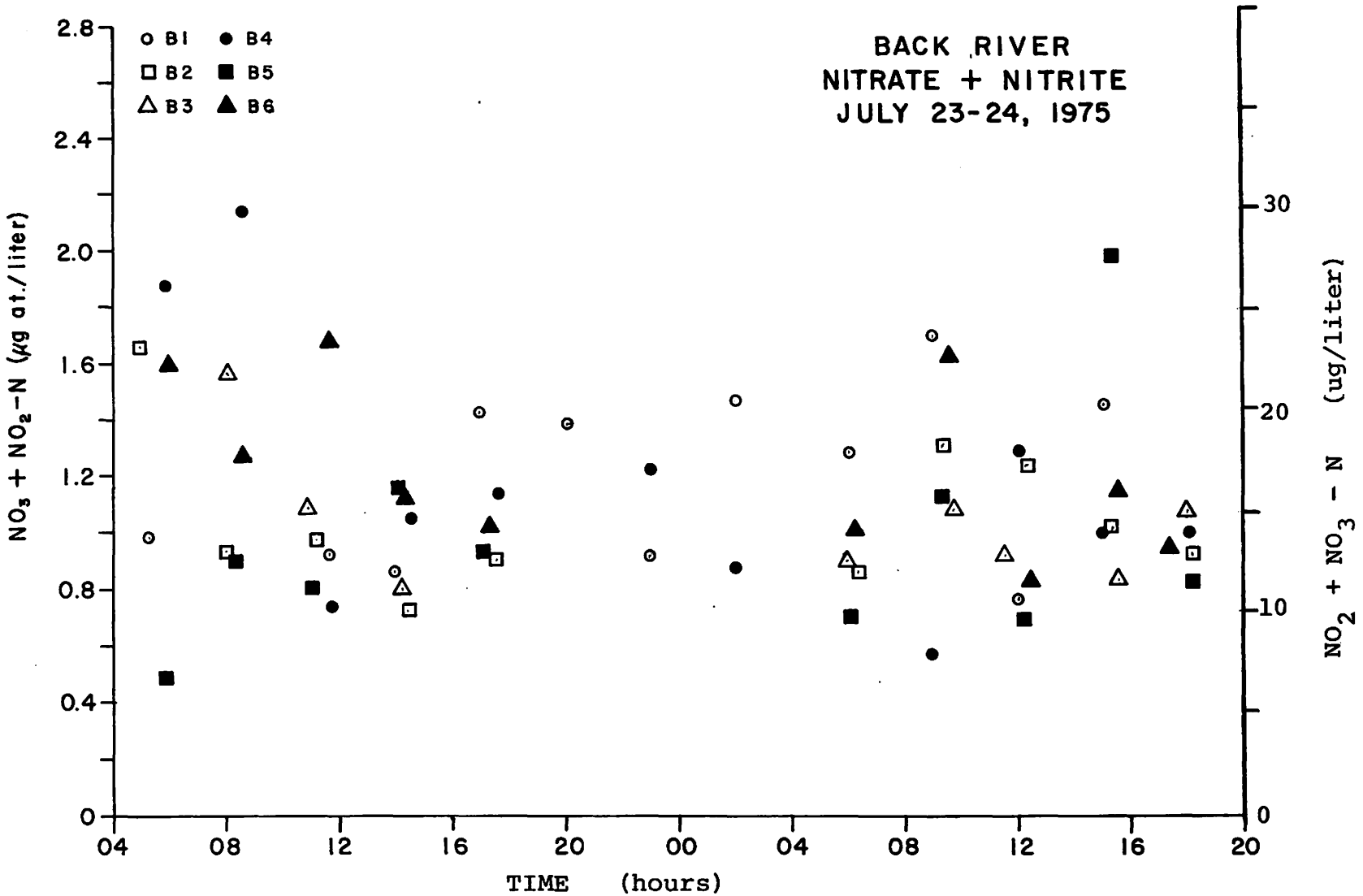
Study sites in Back River.

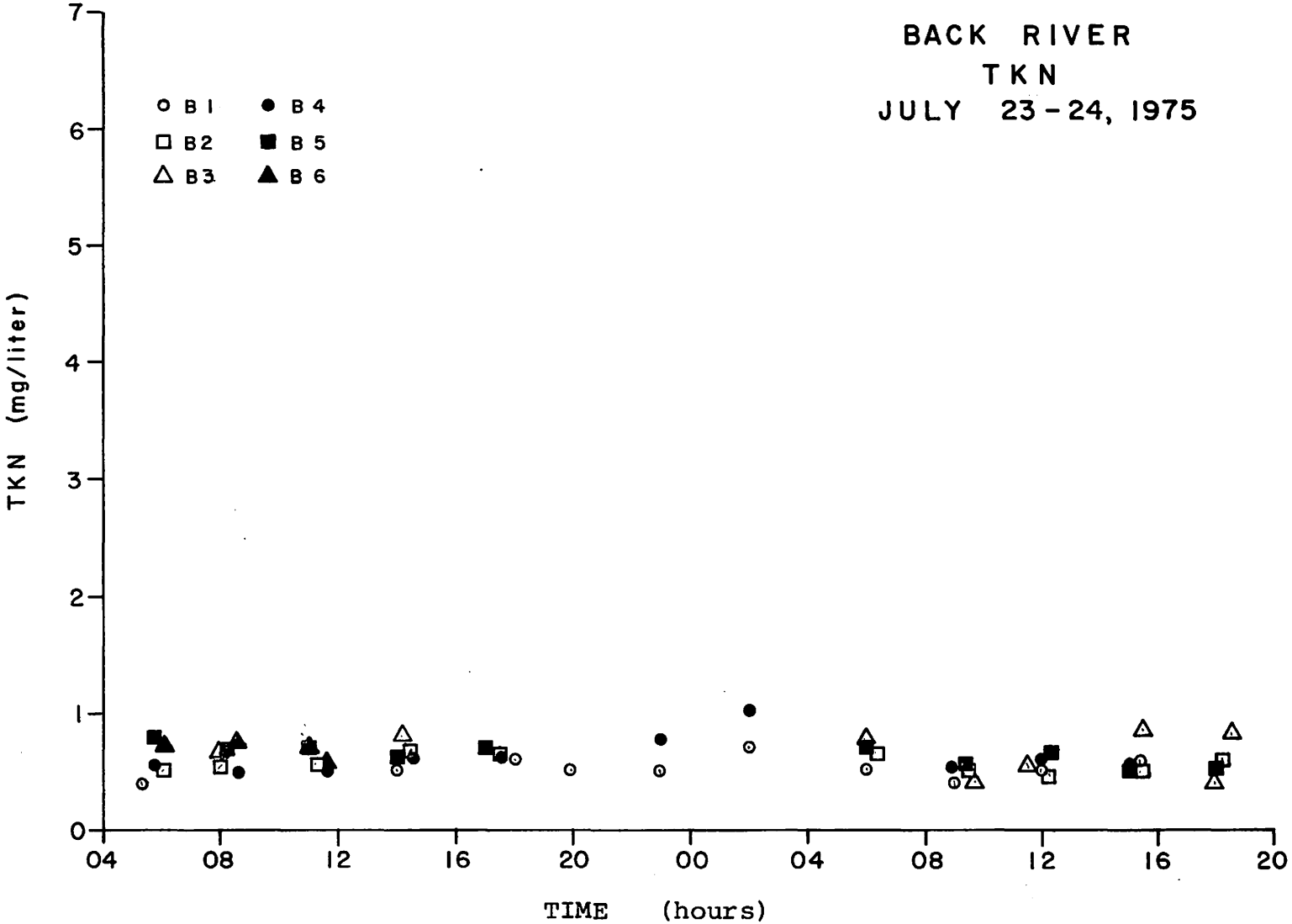

BACK RIVER
SALINITY
JULY 23-24, 1975
B 1
B 2
B 3
20
19
18
17
16
15
14
13
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

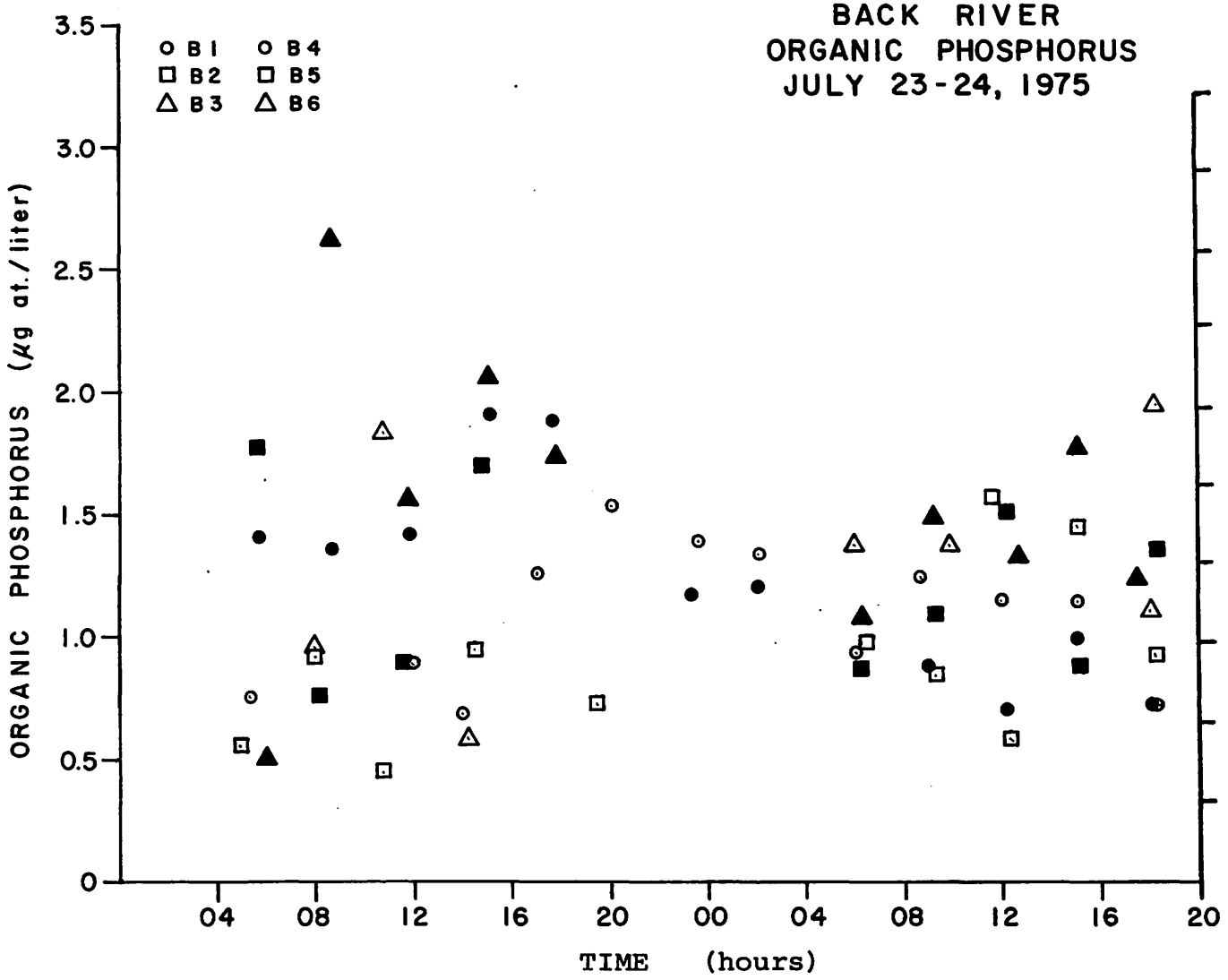

BACK RIVER
SALINITY
JULY 23-24, 1975
B 4
B 5
B 6
SALINITY (‰)
20
19
18
17
16
15
14
13
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

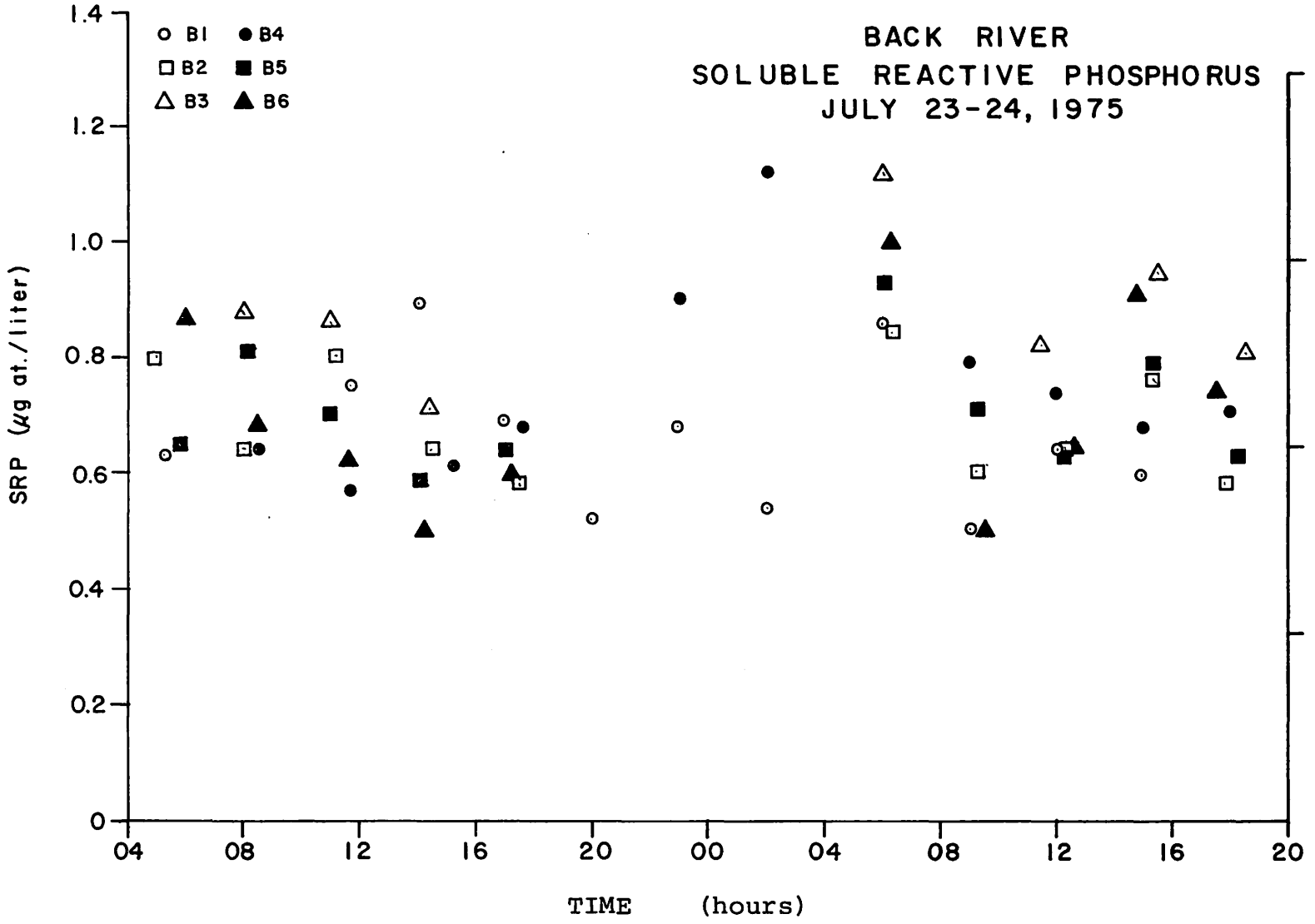

BACK RIVER
CHLOROPHYLL "a"
JULY 23-24, 1975
B1
B2
B3
B4
B5
B6
CHLOROPHYLL "a" (µg/liter)
0
4
8
12
16
20
24
28
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

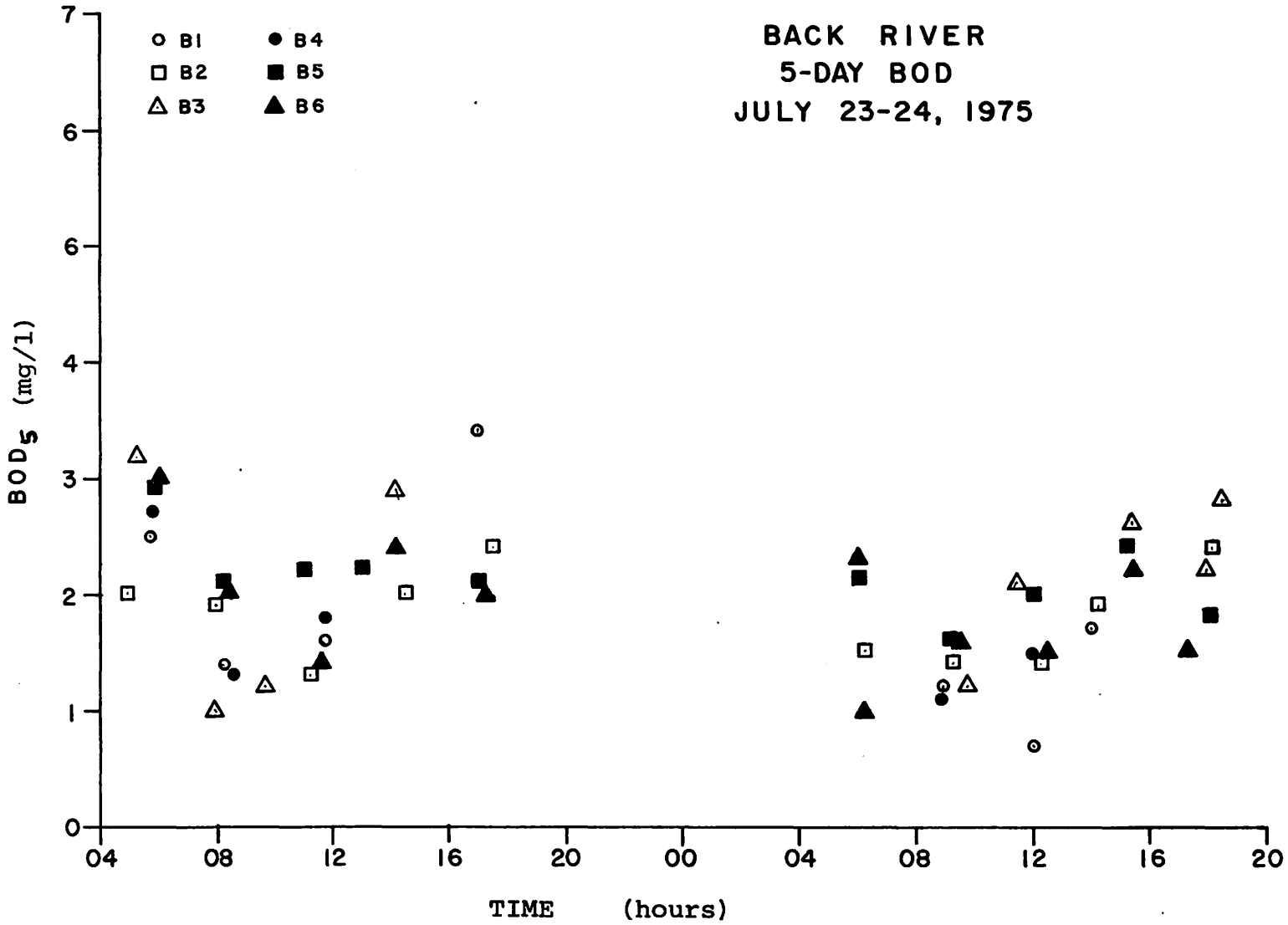

BACK RIVER
AMMONIA
JULY 23-24, 1975
B1
B2
B3
B4
B5
B6
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
NH_4-N (mg/liter)
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

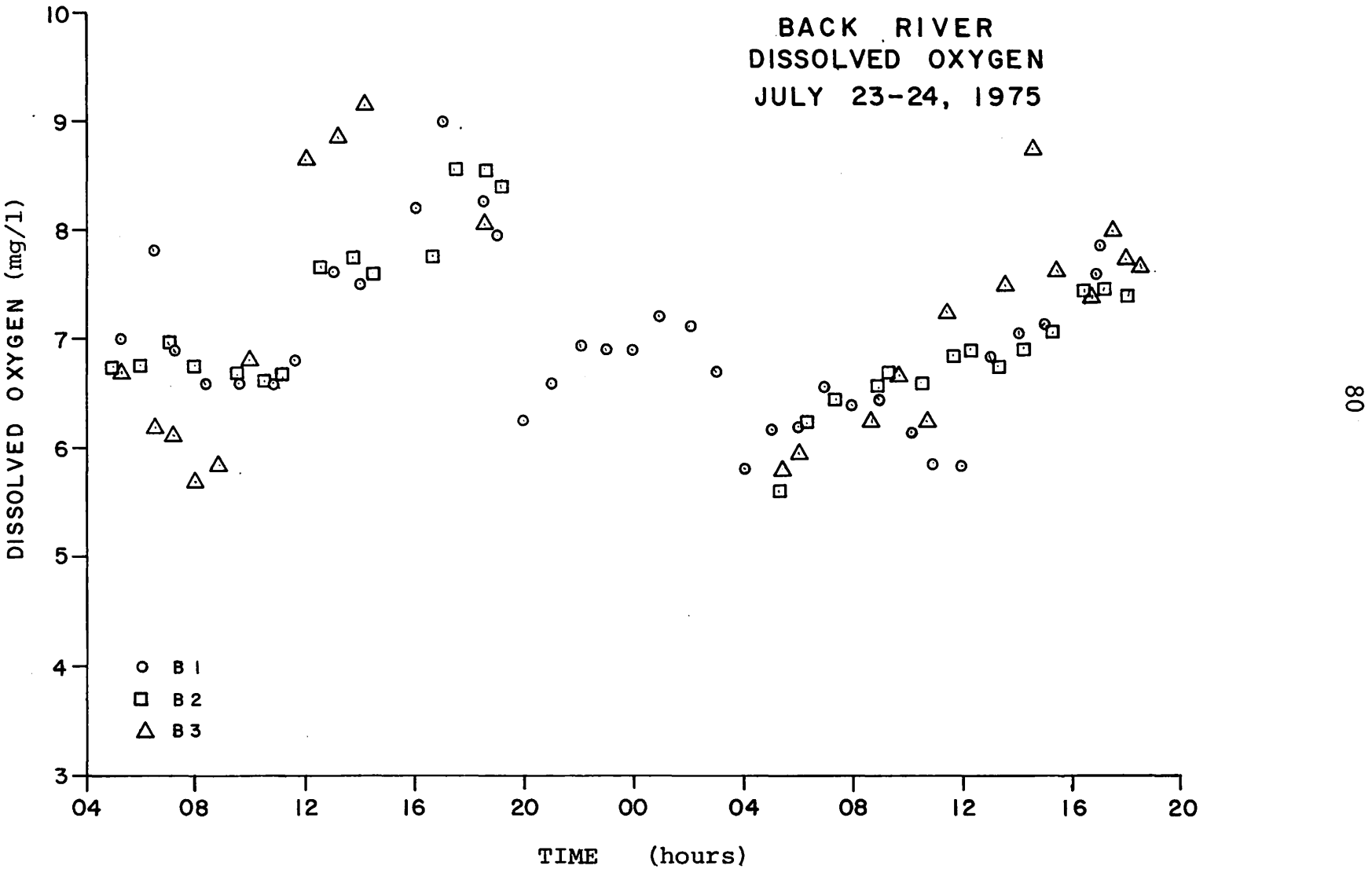

BACK RIVER
NITRATE + NITRITE
JULY 23-24, 1975
B1
B2
B3
B4
B5
B6
$NO_3 + NO_2 - N$ (µg at./liter)
$NO_2 + NO_3 - N$ (ug/liter)
2.8
2.4
2.0
1.6
1.2
0.8
0.4
0
30
20
10
0
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

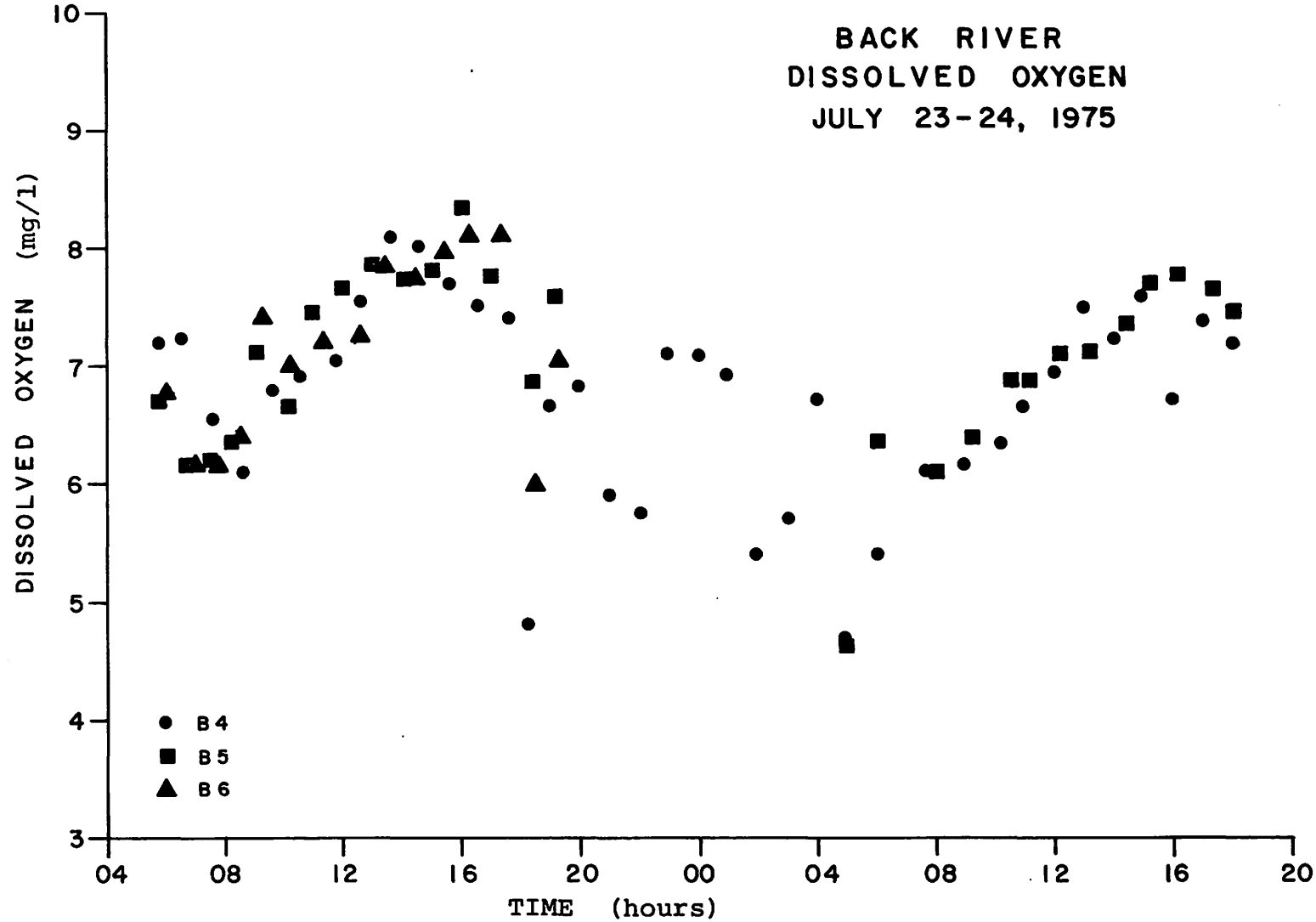

BACK RIVER
TKN
JULY 23-24, 1975
B1
B2
B3
B4
B5
B6
TKN (mg/liter)
0
1
2
3
4
5
6
7
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

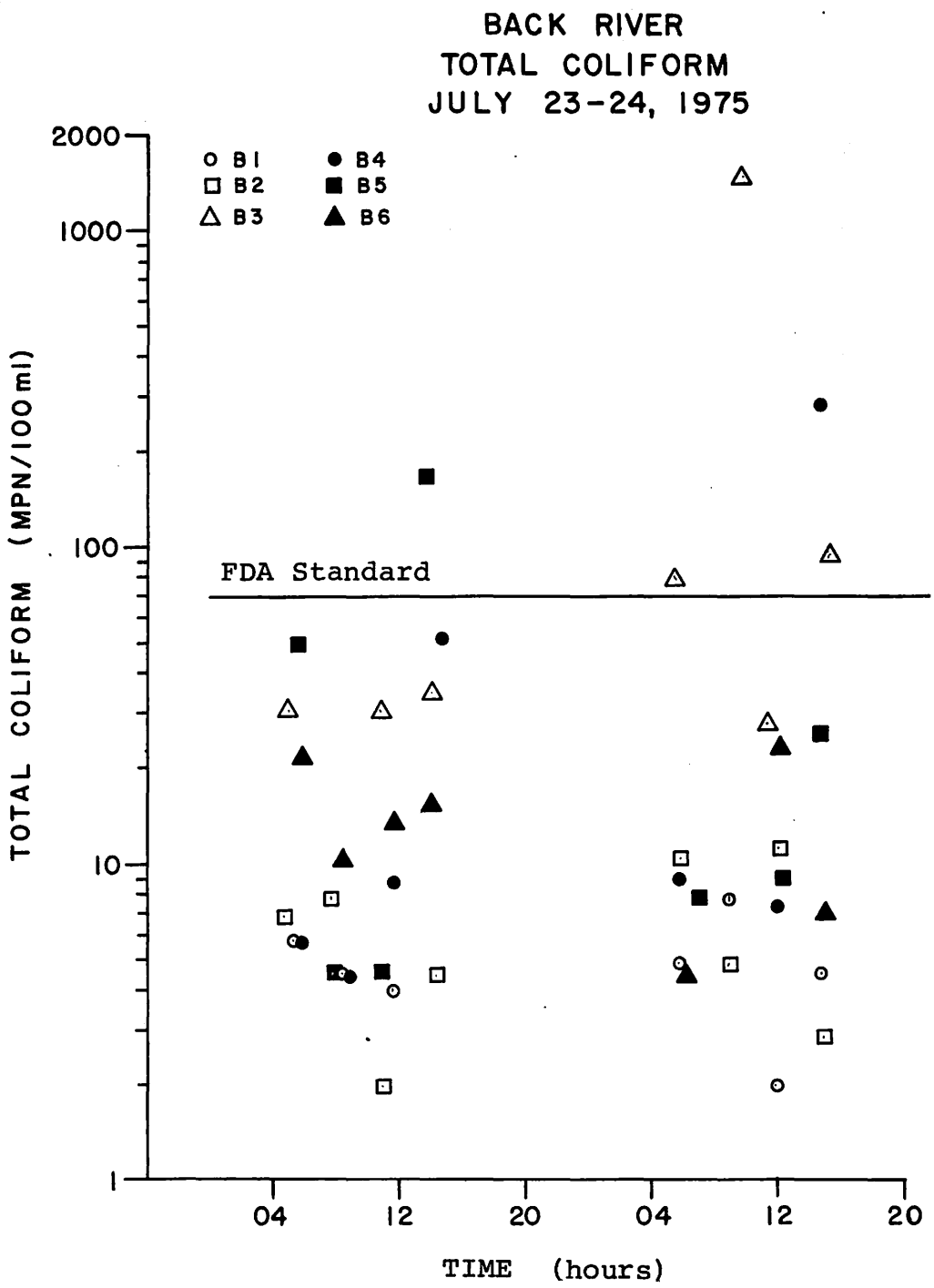

BACK RIVER
ORGANIC PHOSPHORUS
JULY 23-24, 1975
B1
B2
B3
B4
B5
B6
ORGANIC PHOSPHORUS (µg at./liter)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

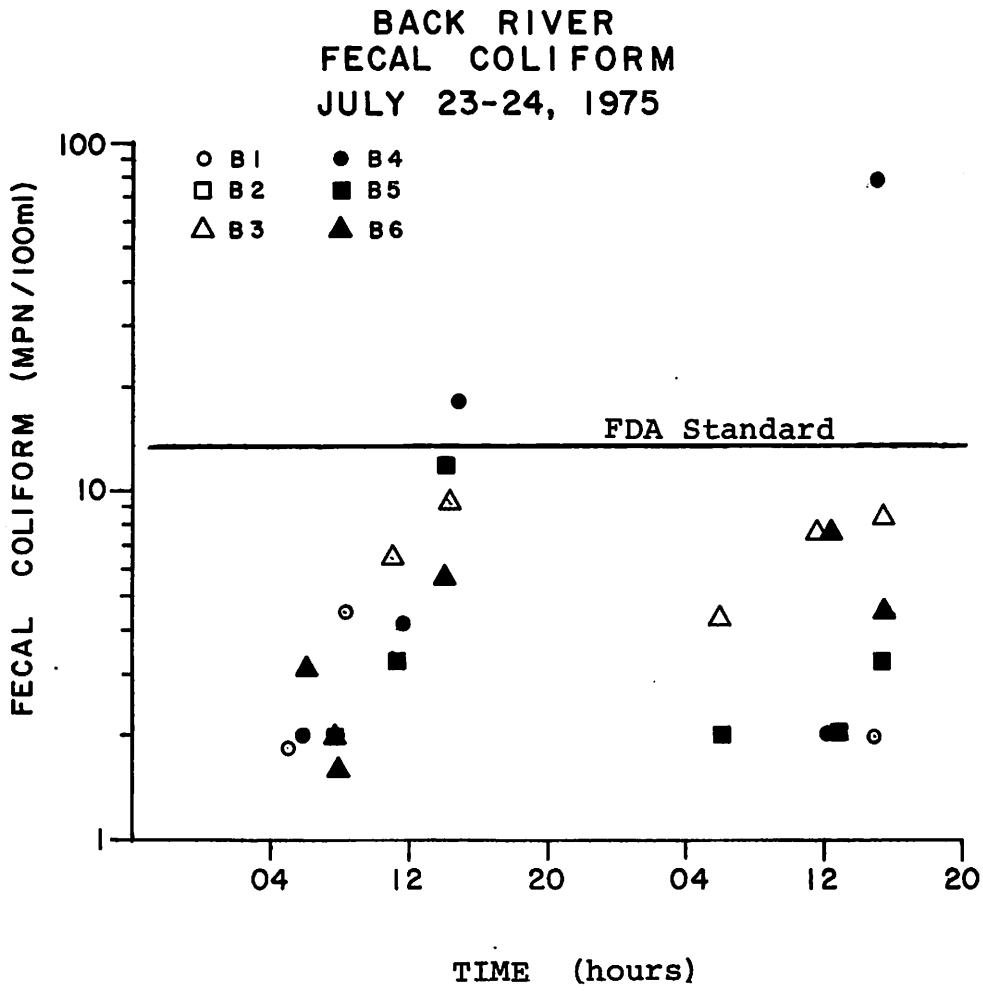

BACK RIVER
SOLUBLE REACTIVE PHOSPHORUS
JULY 23-24, 1975
B1
B2
B3
B4
B5
B6
SRP (µg at./liter)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

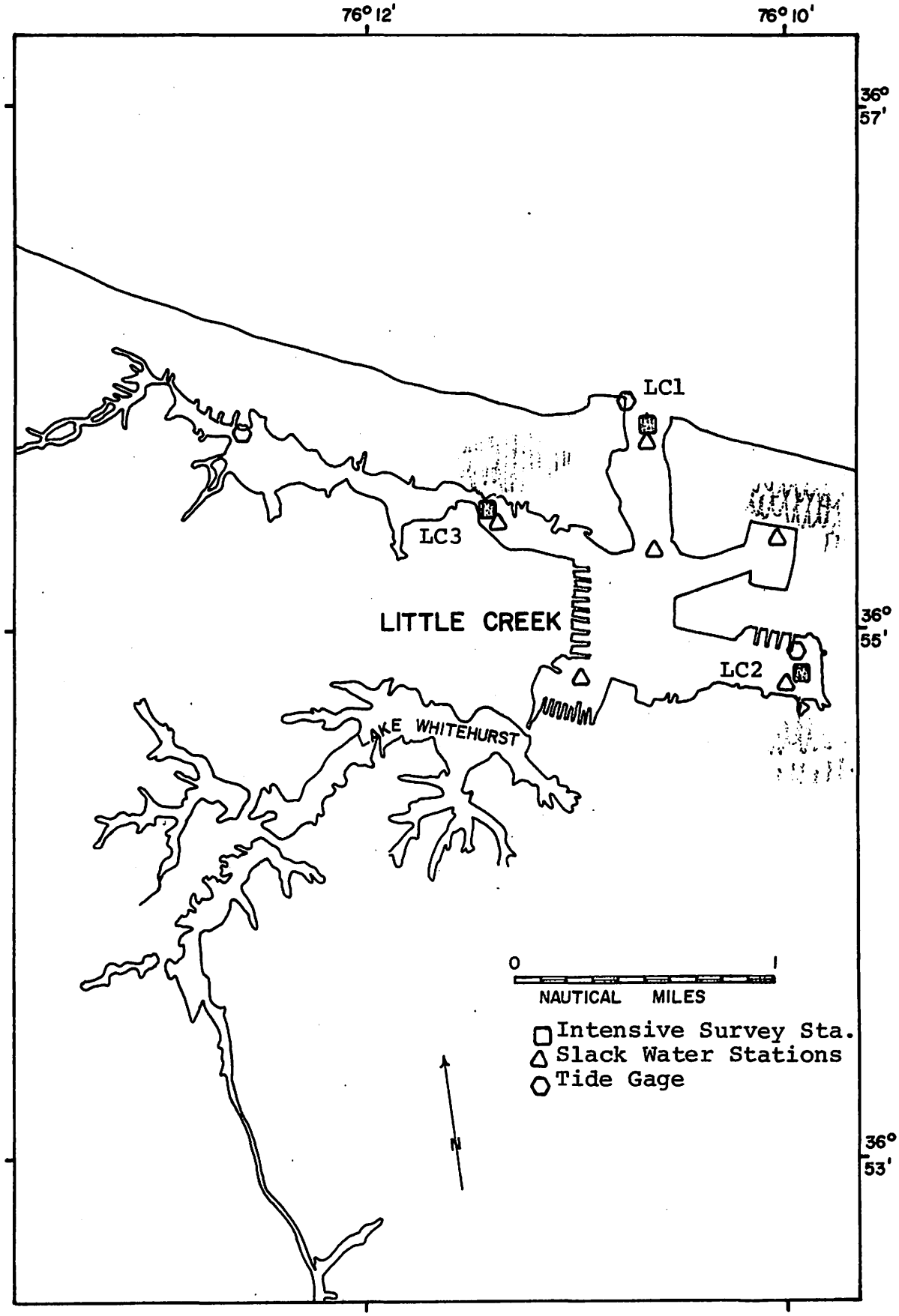

BACK RIVER
5-DAY BOD
JULY 23-24, 1975
B1
B2
B3
B4
B5
B6
BOD5 (mg/l)
0
1
2
3
4
6
6
7
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)


BACK RIVER
DISSOLVED OXYGEN
JULY 23-24, 1975
DISSOLVED OXYGEN (mg/l)
10
9
8
7
6
5
4
3
B 1
B 2
B 3
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

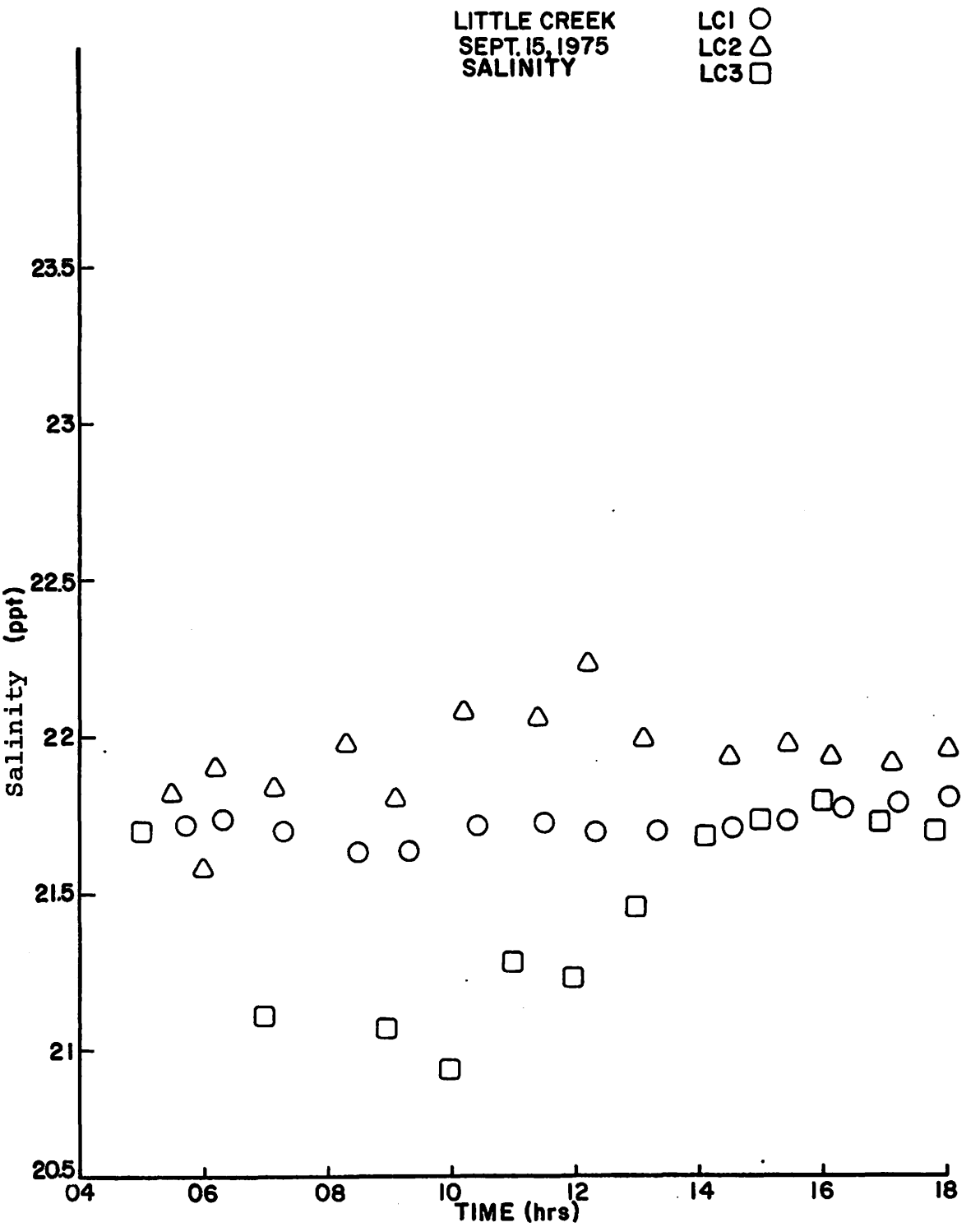

BACK RIVER
DISSOLVED OXYGEN
JULY 23-24, 1975
DISSOLVED OXYGEN (mg/l)
10
9
8
7
6
5
4
3
B4
B5
B6
04
08
12
16
20
00
04
08
12
16
20
TIME (hours)

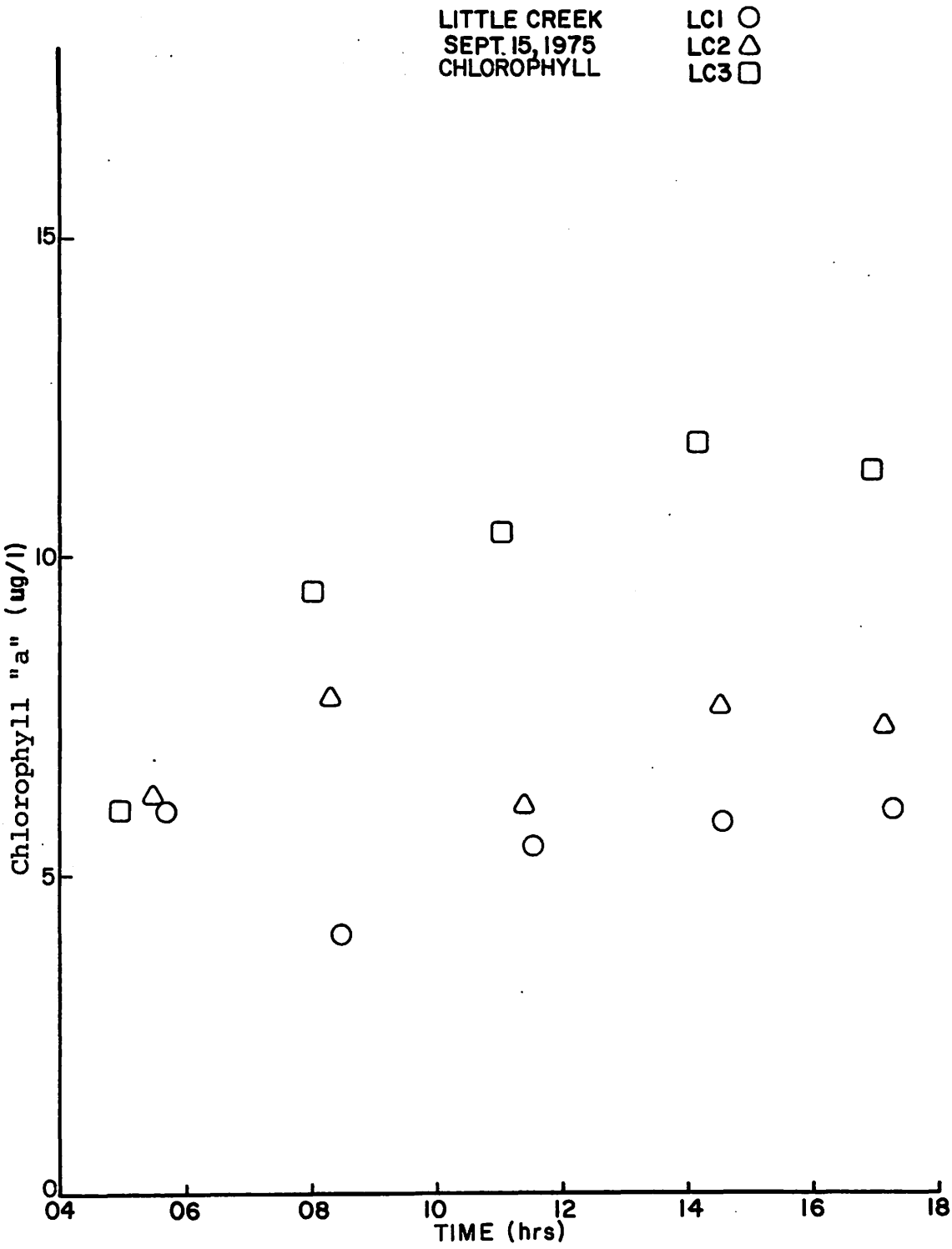

BACK RIVER
TOTAL COLIFORM
JULY 23-24, 1975
B1
B2
B3
B4
B5
B6
FDA Standard
2000
1000
100
10
1
TOTAL COLIFORM (MPN/100 ml)
04
12
20
04
12
20
TIME (hours)

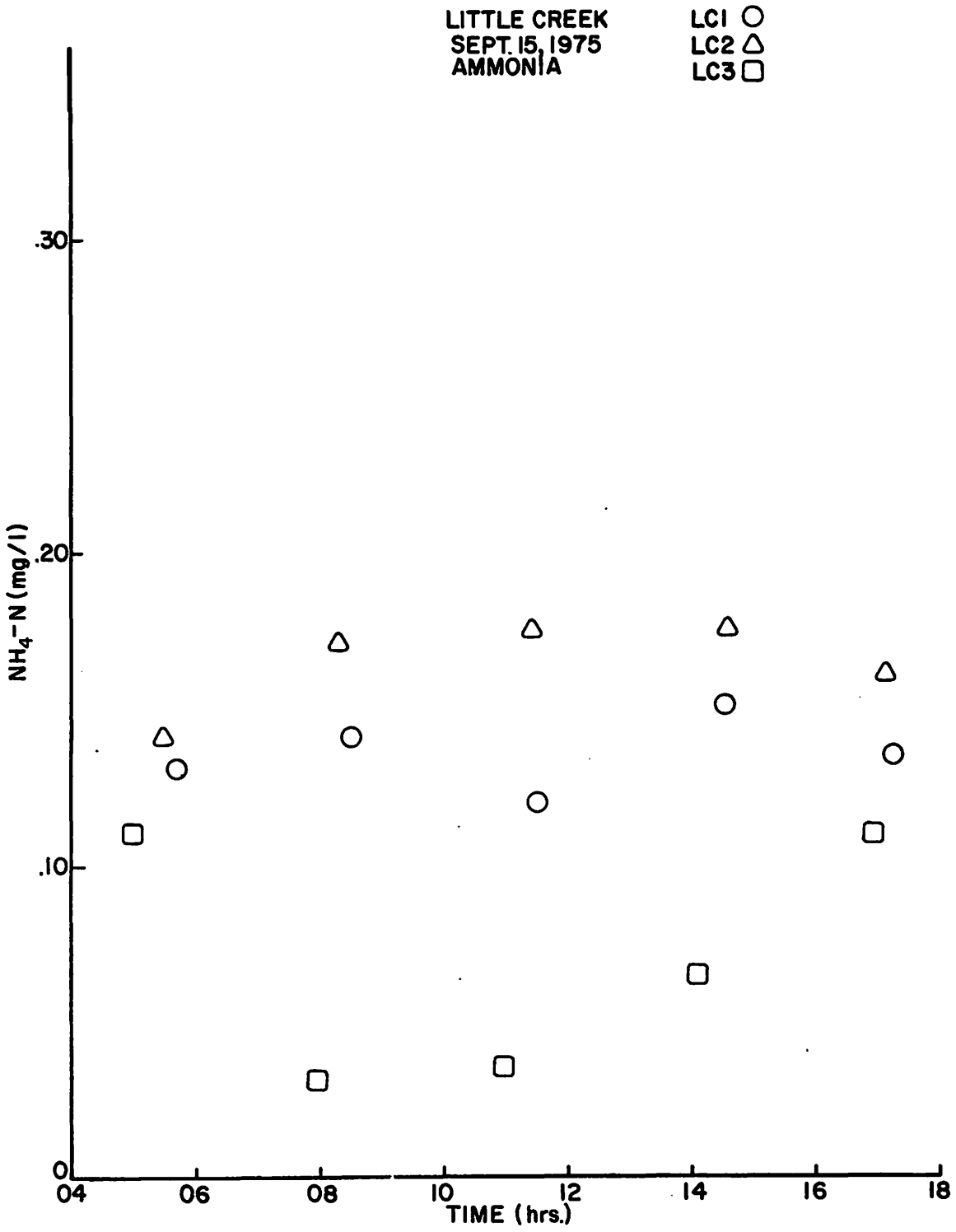

BACK RIVER
FECAL COLIFORM
JULY 23-24, 1975
100
10
1
FECAL COLIFORM (MPN/100ml)
B1
B2
B3
B4
B5
B6
FDA Standard
04
12
20
04
12
20
TIME (hours)

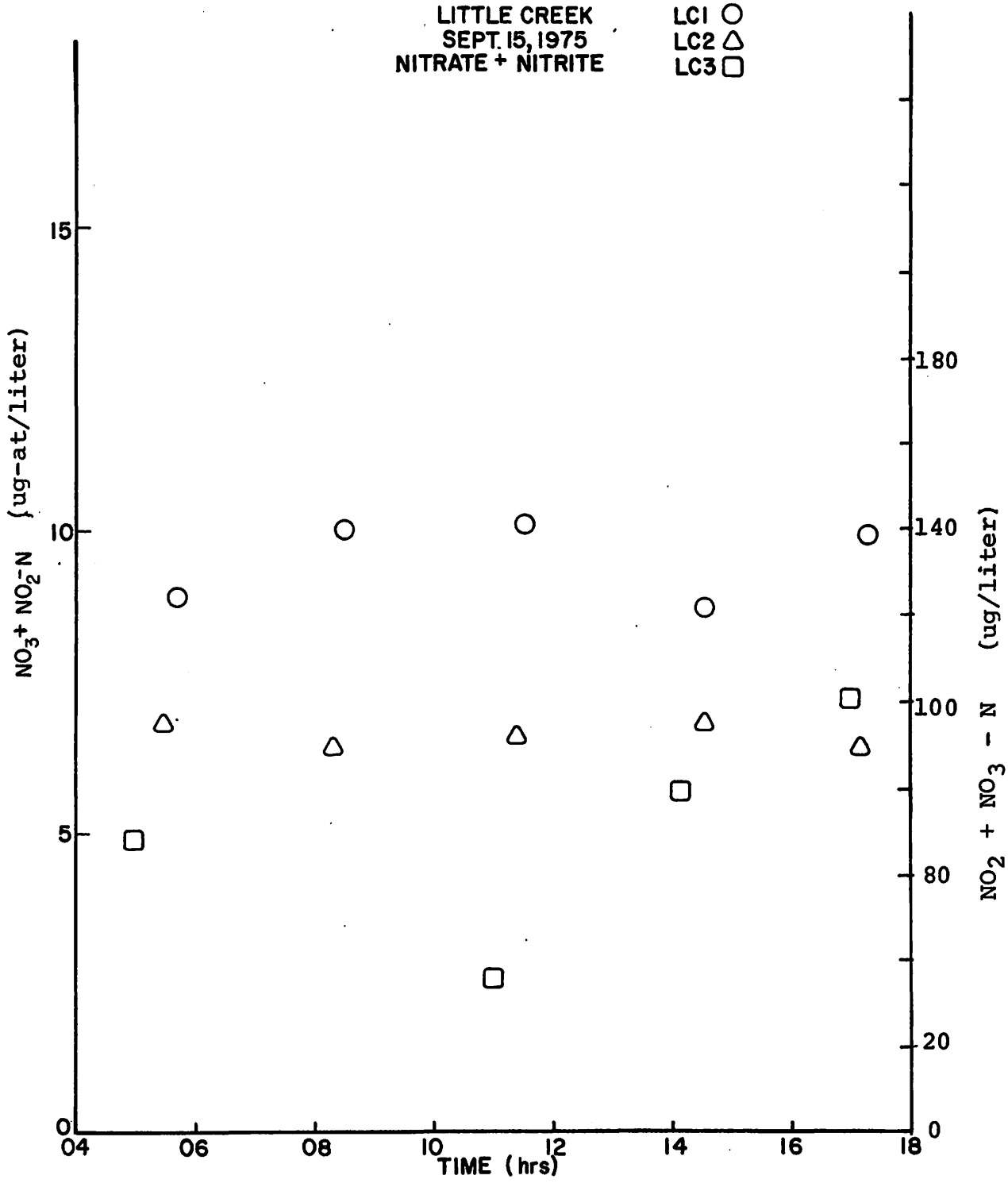


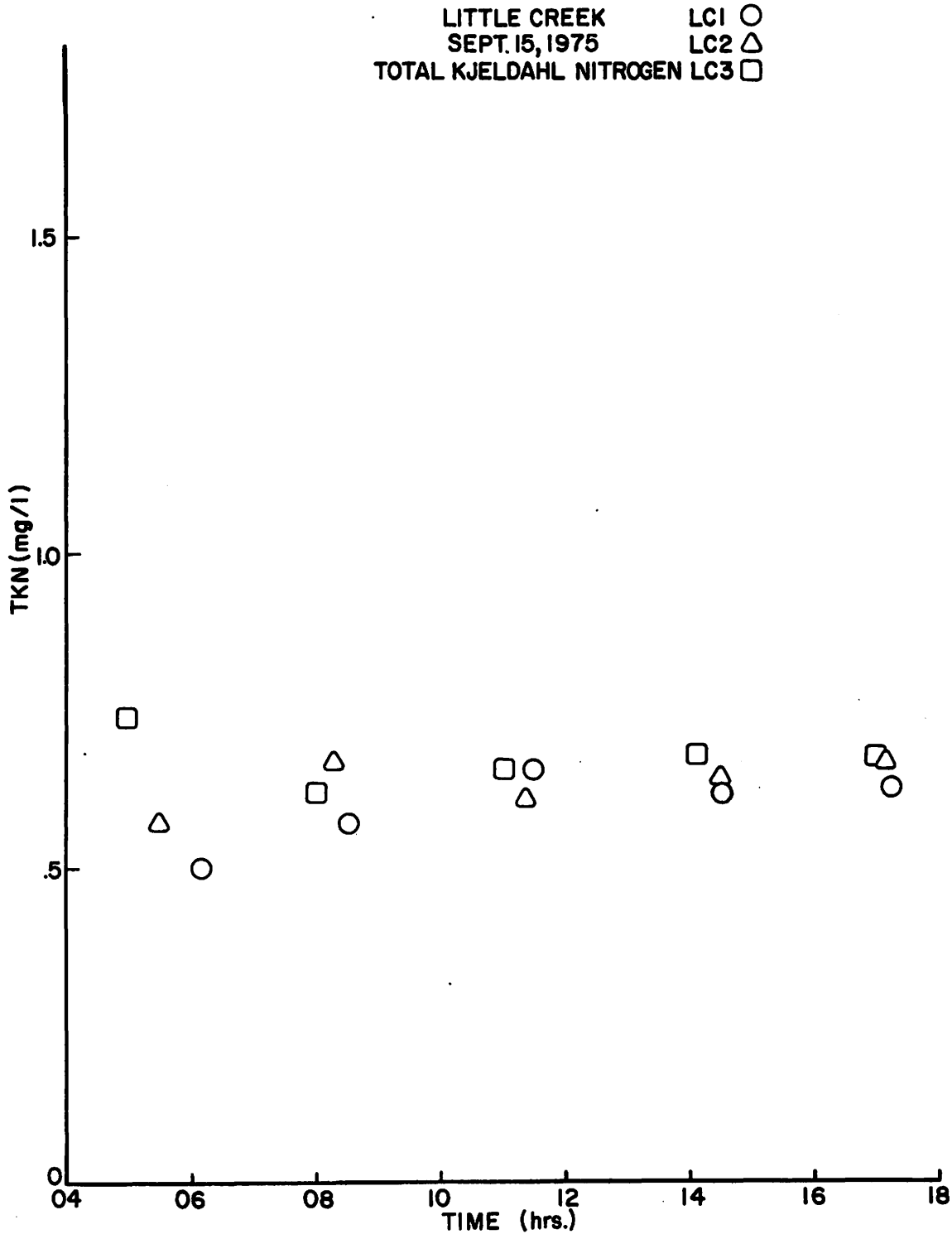
Study sites in Little Creek.

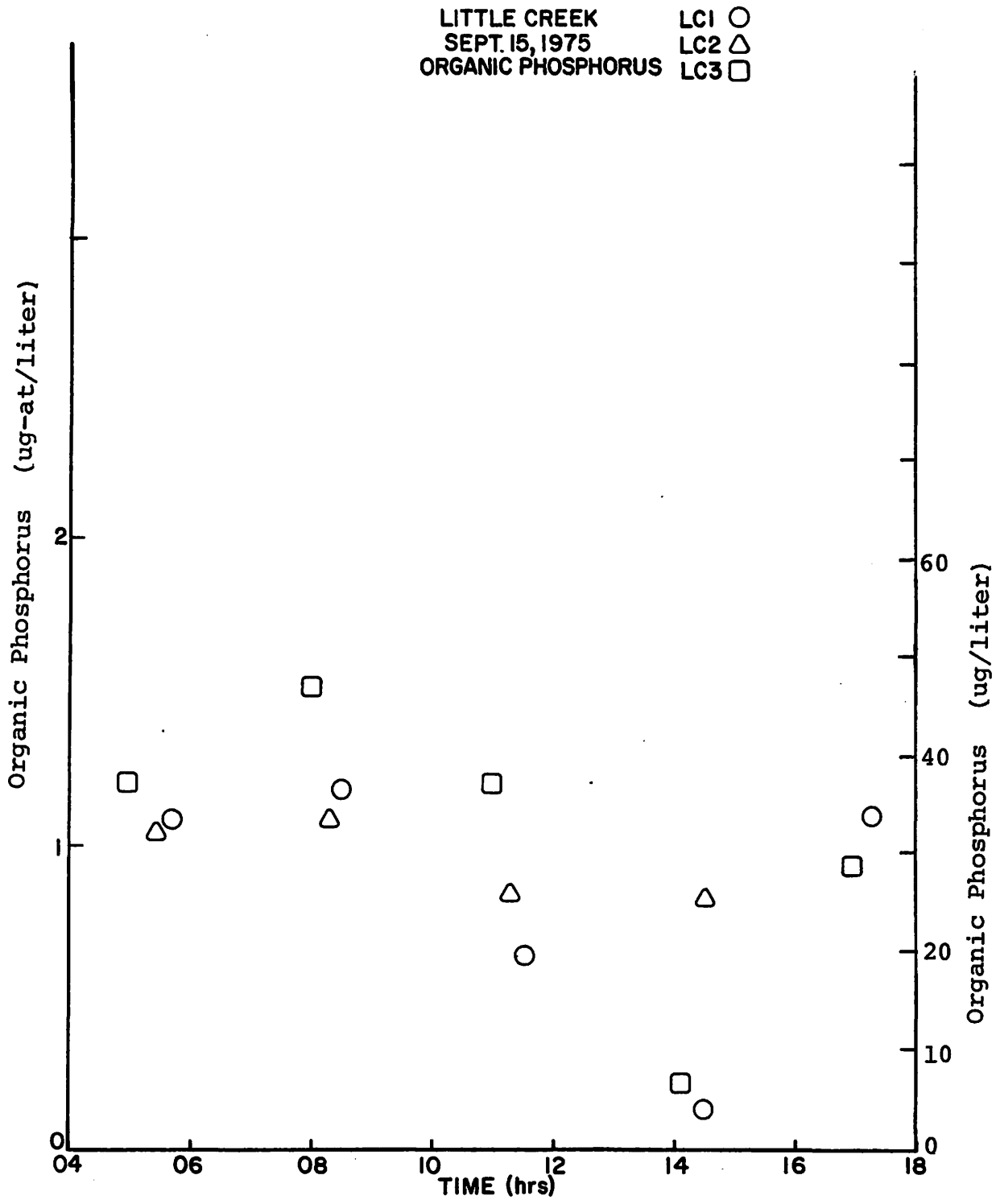

LITTLE CREEK
SEPT. 15, 1975
SALINITY
LC1
LC2
LC3
Salinity (ppt)
23.5
23
22.5
22
21.5
21
20.5
04
06
08
10
12
14
16
18
TIME (hrs)

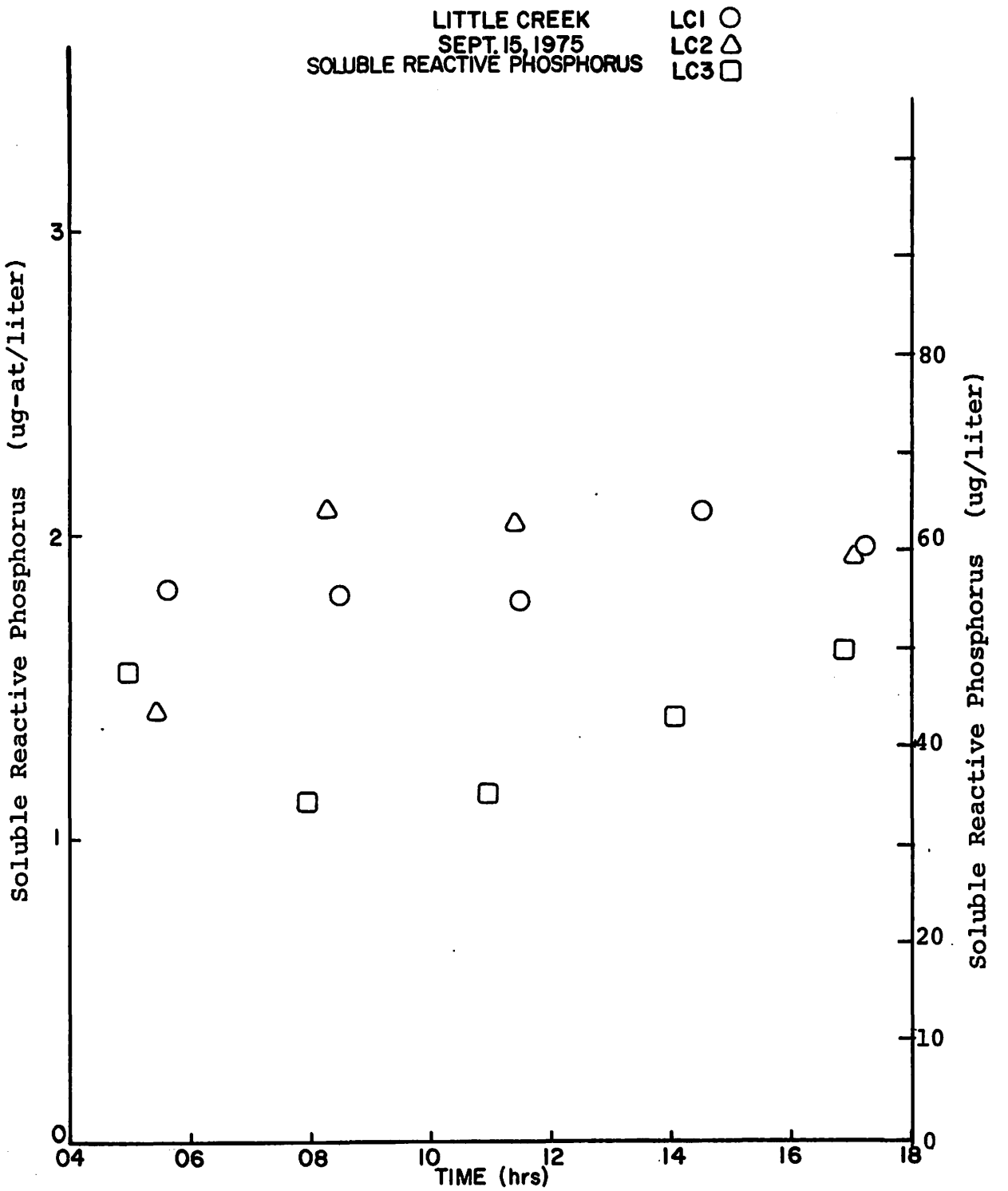

LITTLE CREEK
SEPT. 15, 1975
CHLOROPHYLL
LC1
LC2
LC3
Chlorophyll "a" (ug/l)
0
5
10
15
04
06
08
10
12
14
16
18
TIME (hrs)

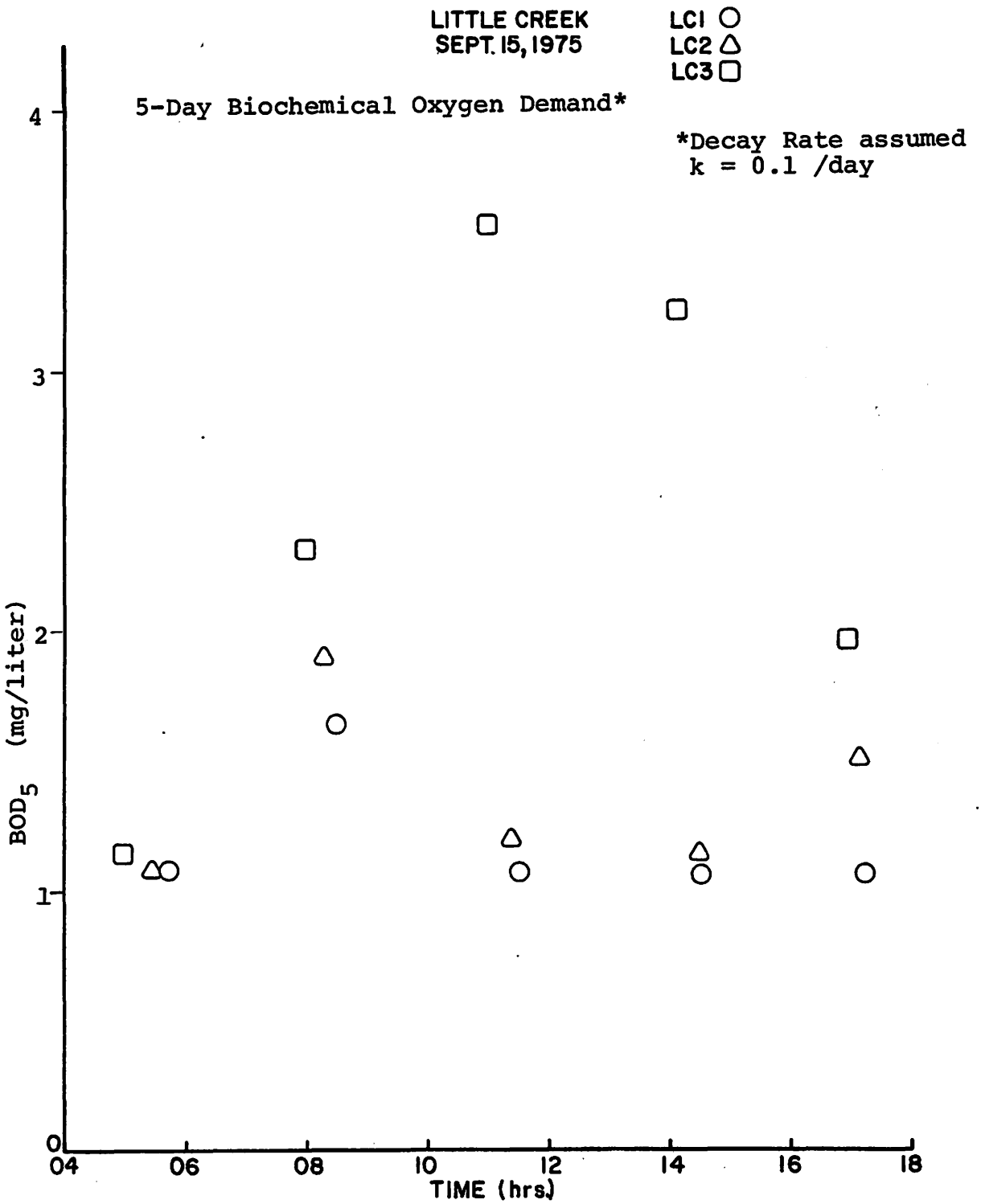

LITTLE CREEK
SEPT. 15, 1975
AMMONIA
LC1 ○
LC2 △
LC3 □
.30
.20
.10
0
NH_4-N (mg/l)
04
06
08
10
12
14
16
18
TIME (hrs.)

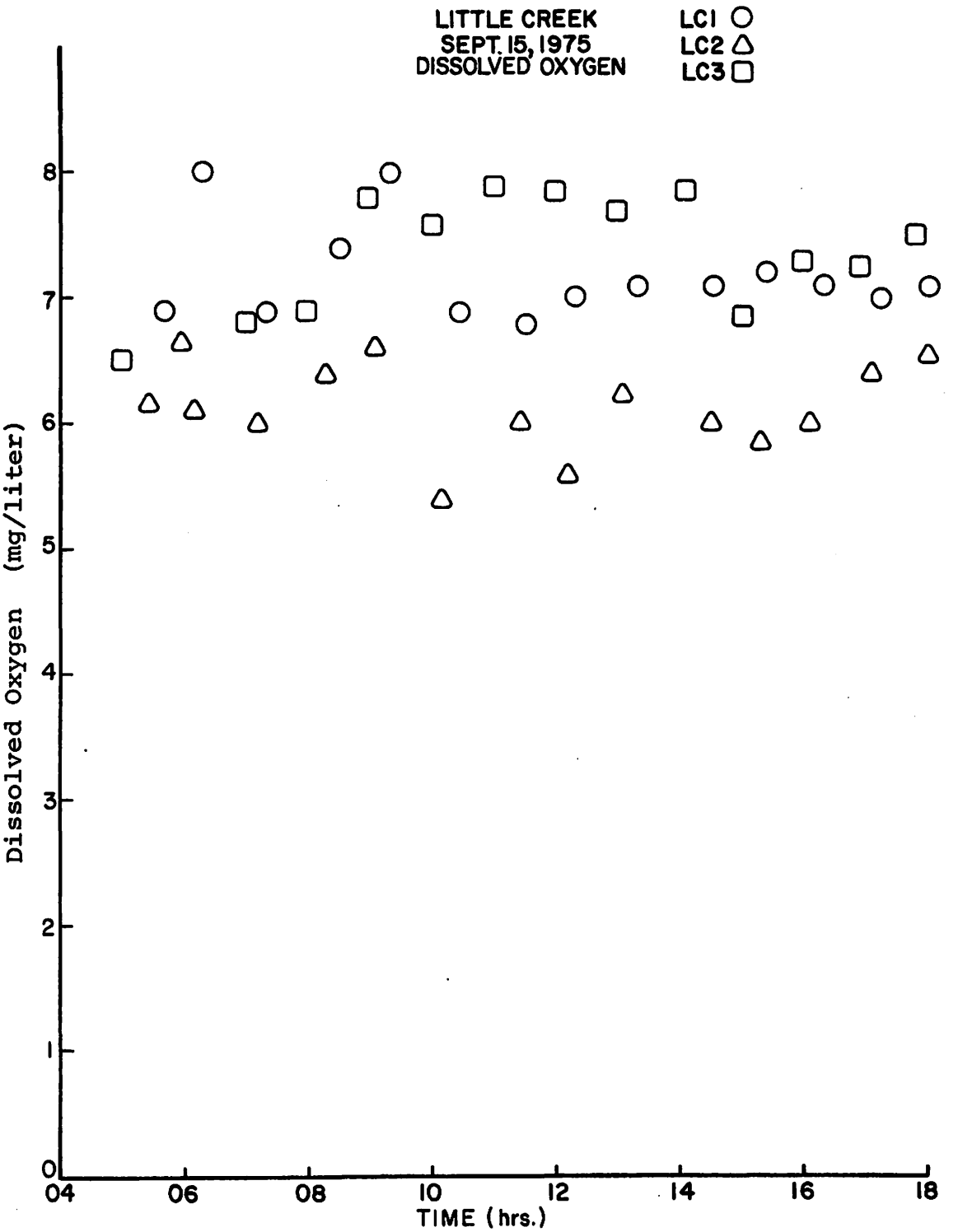

LITTLE CREEK
SEPT. 15, 1975
NITRATE + NITRITE
LC1 ○
LC2 △
LC3 □
$NO_3 + NO_2$-N (ug-at/liter)
$NO_2 + NO_3$ - N (ug/liter)
TIME (hrs)
0
5
10
15
0
20
80
100
140
180
04
06
08
10
12
14
16
18

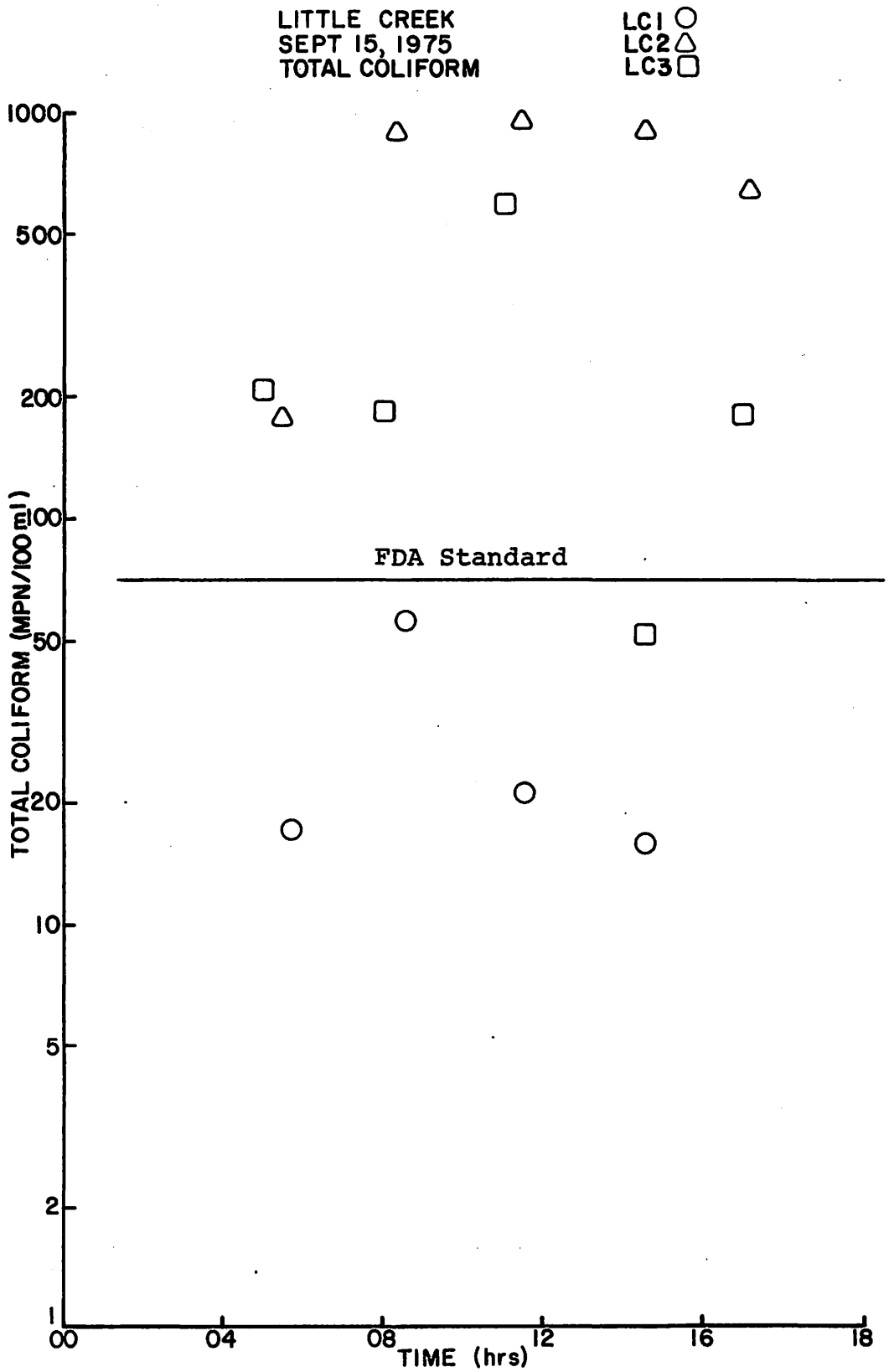

LITTLE CREEK LC1 ○
SEPT. 15, 1975 LC2 △
TOTAL KJELDAHL NITROGEN LC3 □
TKN (mg/l)
1.5
1.0
.5
0
04
06
08
10
12
14
16
18
TIME (hrs.)

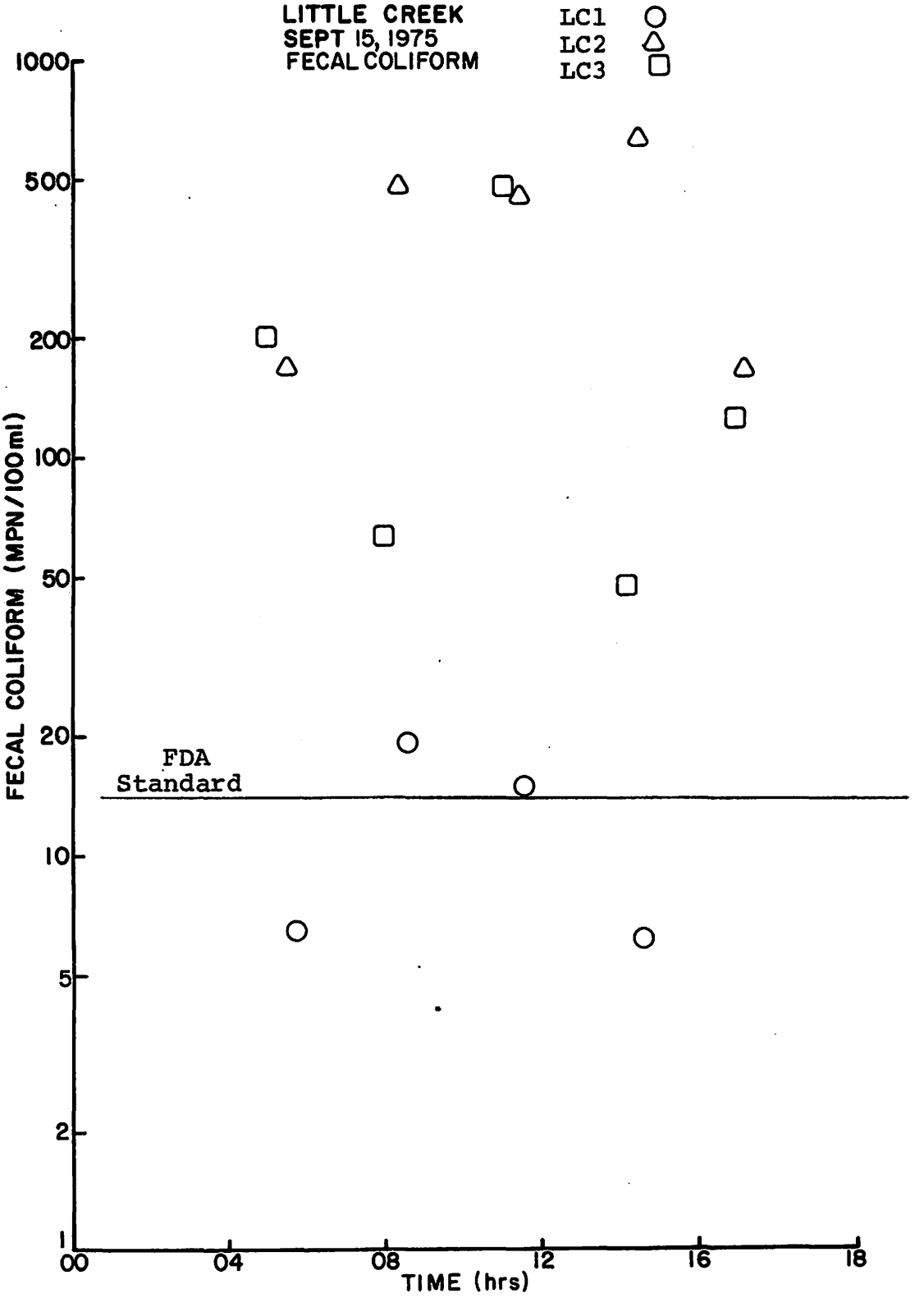

LITTLE CREEK
SEPT. 15, 1975
ORGANIC PHOSPHORUS
LC1
LC2
LC3
Organic Phosphorus (ug-at/liter)
Organic Phosphorus (ug/liter)
TIME (hrs)
0
1
2
0
10
20
40
60
04
06
08
10
12
14
16
18

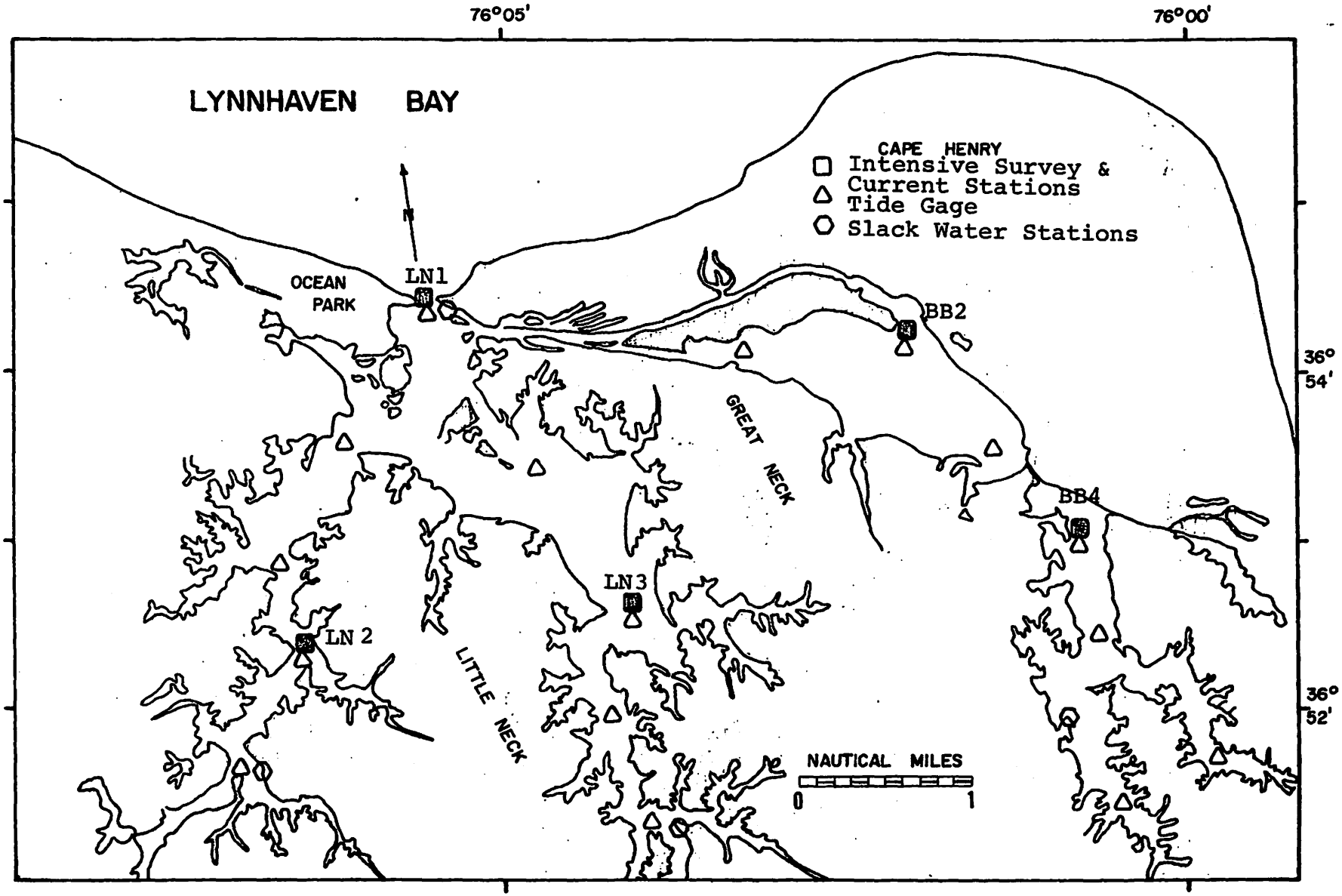

LITTLE CREEK
SEPT. 15, 1975
SOLUBLE REACTIVE PHOSPHORUS
LC1 ○
LC2 △
LC3 □
Soluble Reactive Phosphorus (ug-at/liter)
Soluble Reactive Phosphorus (ug/liter)
TIME (hrs)
0
1
2
3
0
20
40
60
80
04
06
08
10
12
14
16
18


LITTLE CREEK
SEPT. 15, 1975
LC1 ○
LC2 △
LC3 □
5-Day Biochemical Oxygen Demand*
*Decay Rate assumed
k = 0.1 /day
BOD5 (mg/liter)
0
1
2
3
4
04
06
08
10
12
14
16
18
TIME (hrs.)

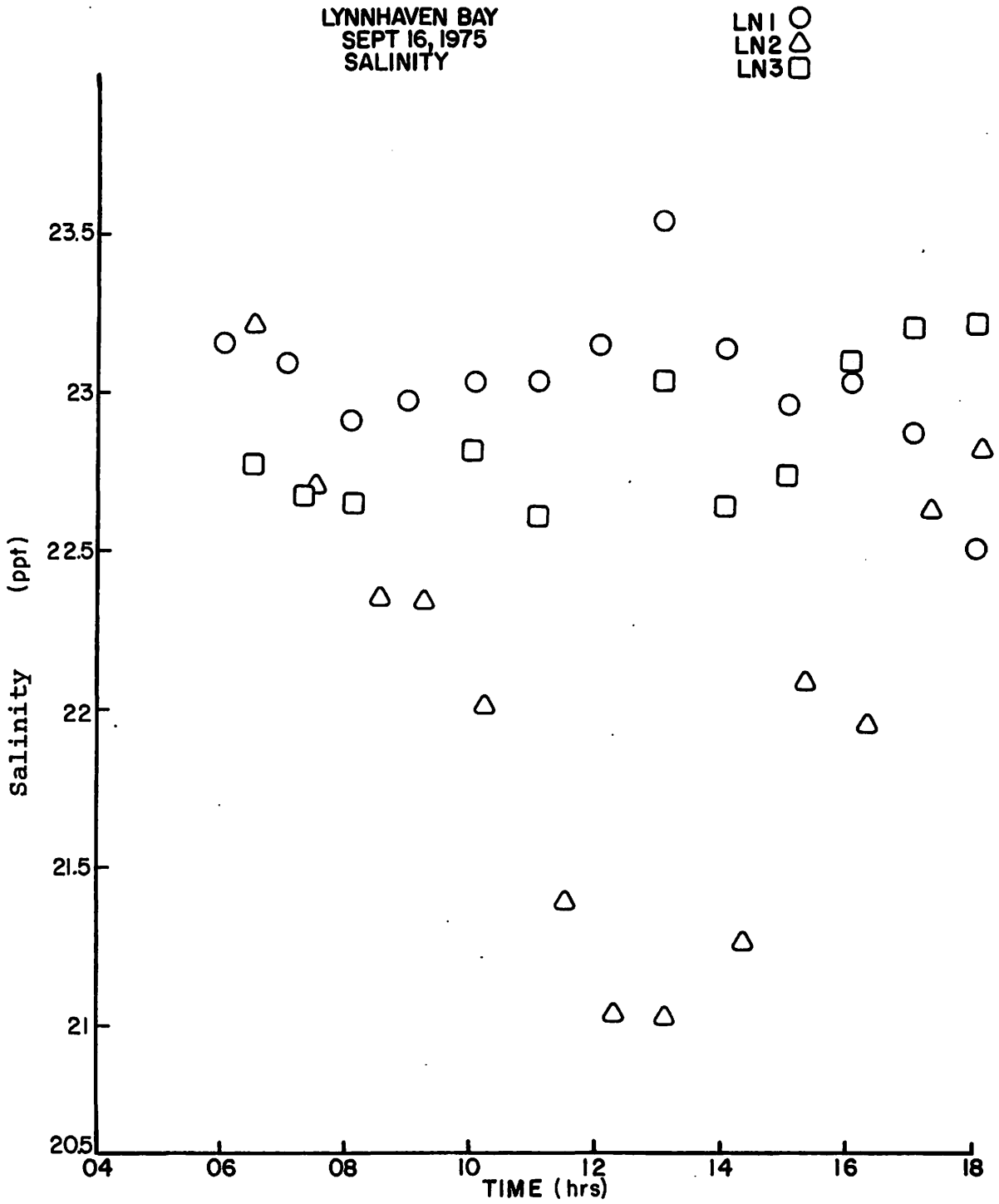

LITTLE CREEK
SEPT. 15, 1975
DISSOLVED OXYGEN
LC1
LC2
LC3
Dissolved Oxygen (mg/liter)
0
1
2
3
4
5
6
7
8
04
06
08
10
12
14
16
18
TIME (hrs.)

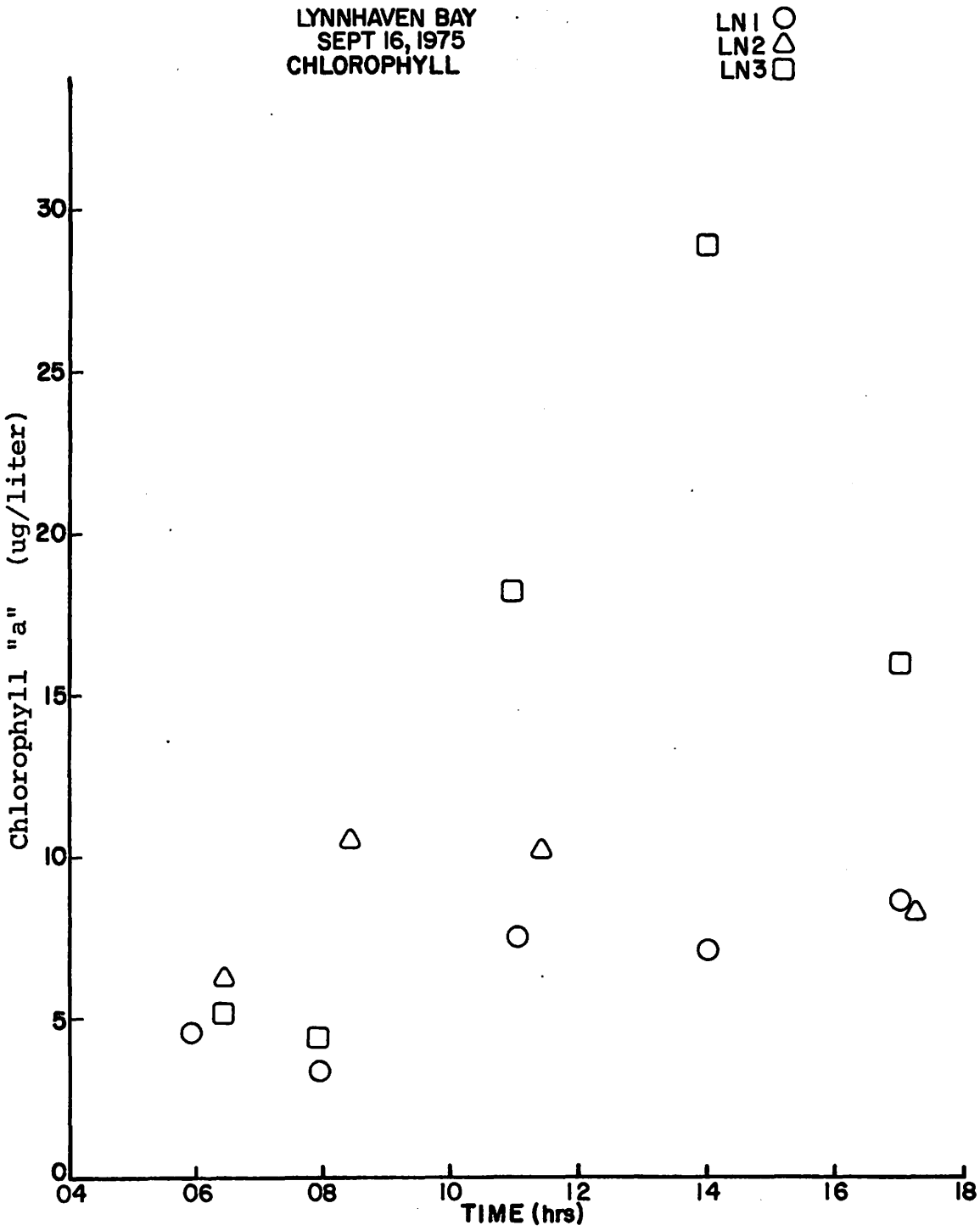

LITTLE CREEK
SEPT 15, 1975
TOTAL COLIFORM
LC1
LC2
LC3
1000
500
200
100
50
20
10
5
2
1
TOTAL COLIFORM (MPN/100ml)
FDA Standard
00
04
08
12
16
18
TIME (hrs)

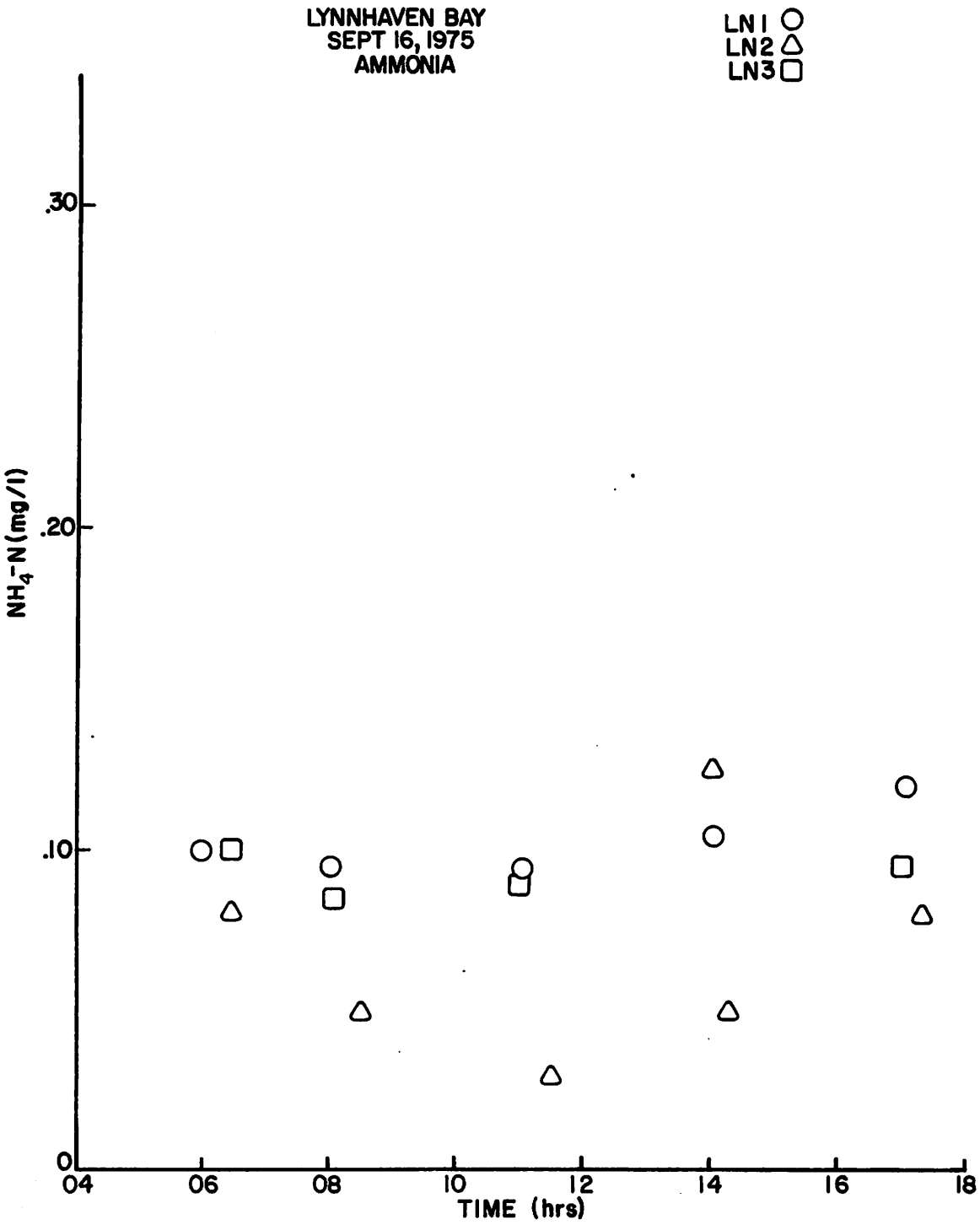

LITTLE CREEK
SEPT 15, 1975
FECAL COLIFORM
LC1
LC2
LC3
1000
500
200
100
50
20
10
5
2
1
FECAL COLIFORM (MPN/100ml)
FDA
Standard
00
04
08
12
16
18
TIME (hrs)

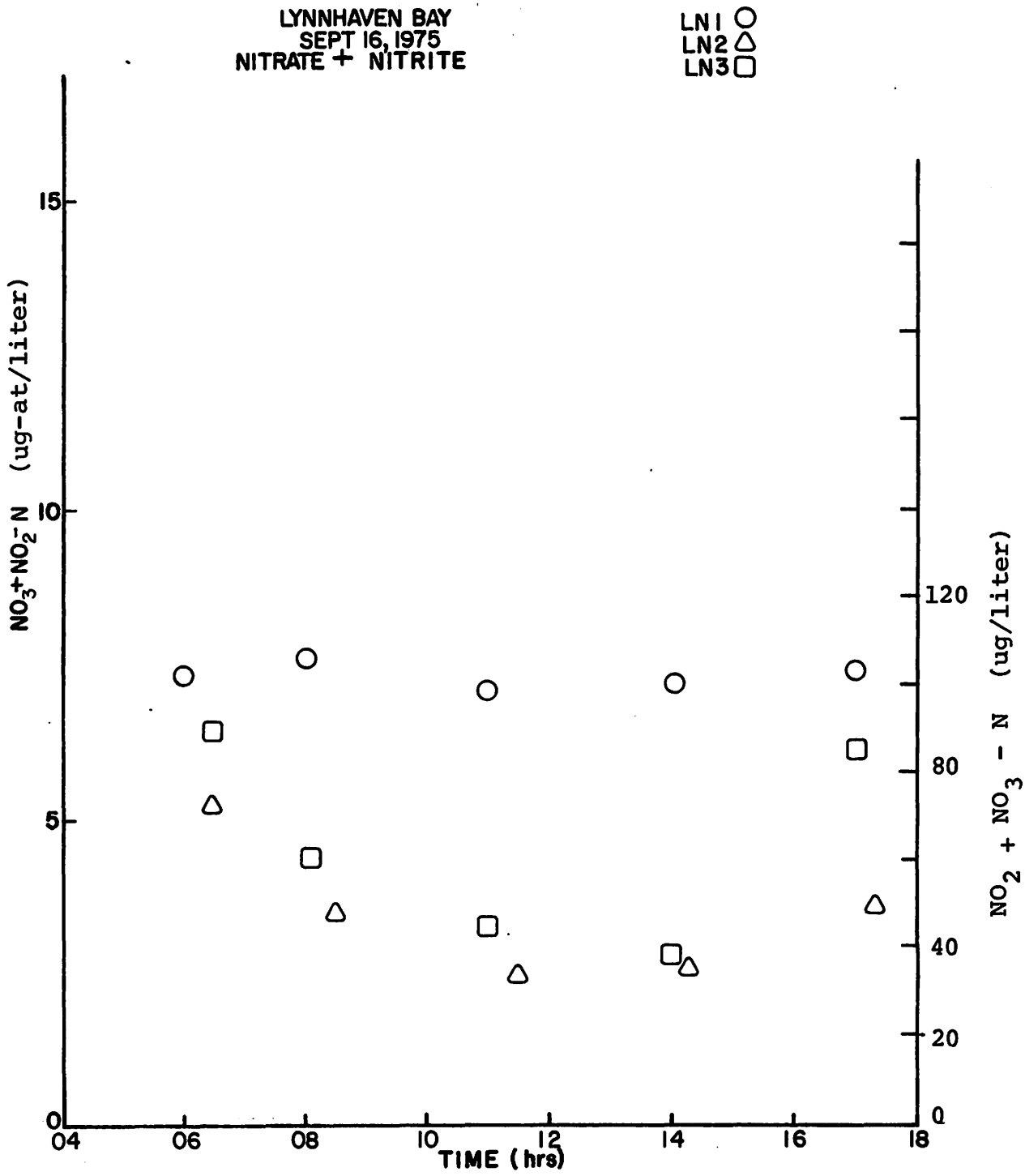


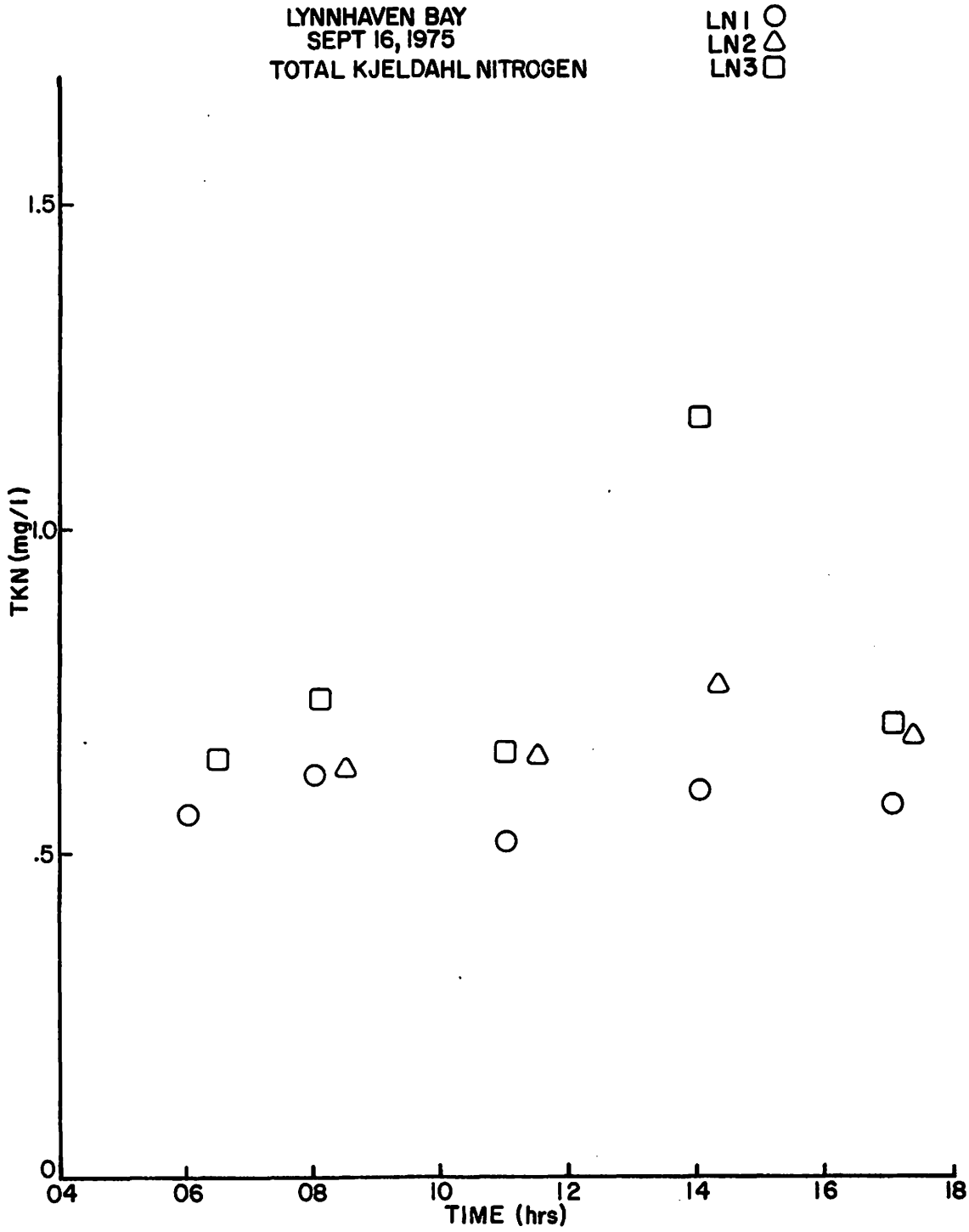
Study sites in Lynnhaven Bay and Broad Bay.

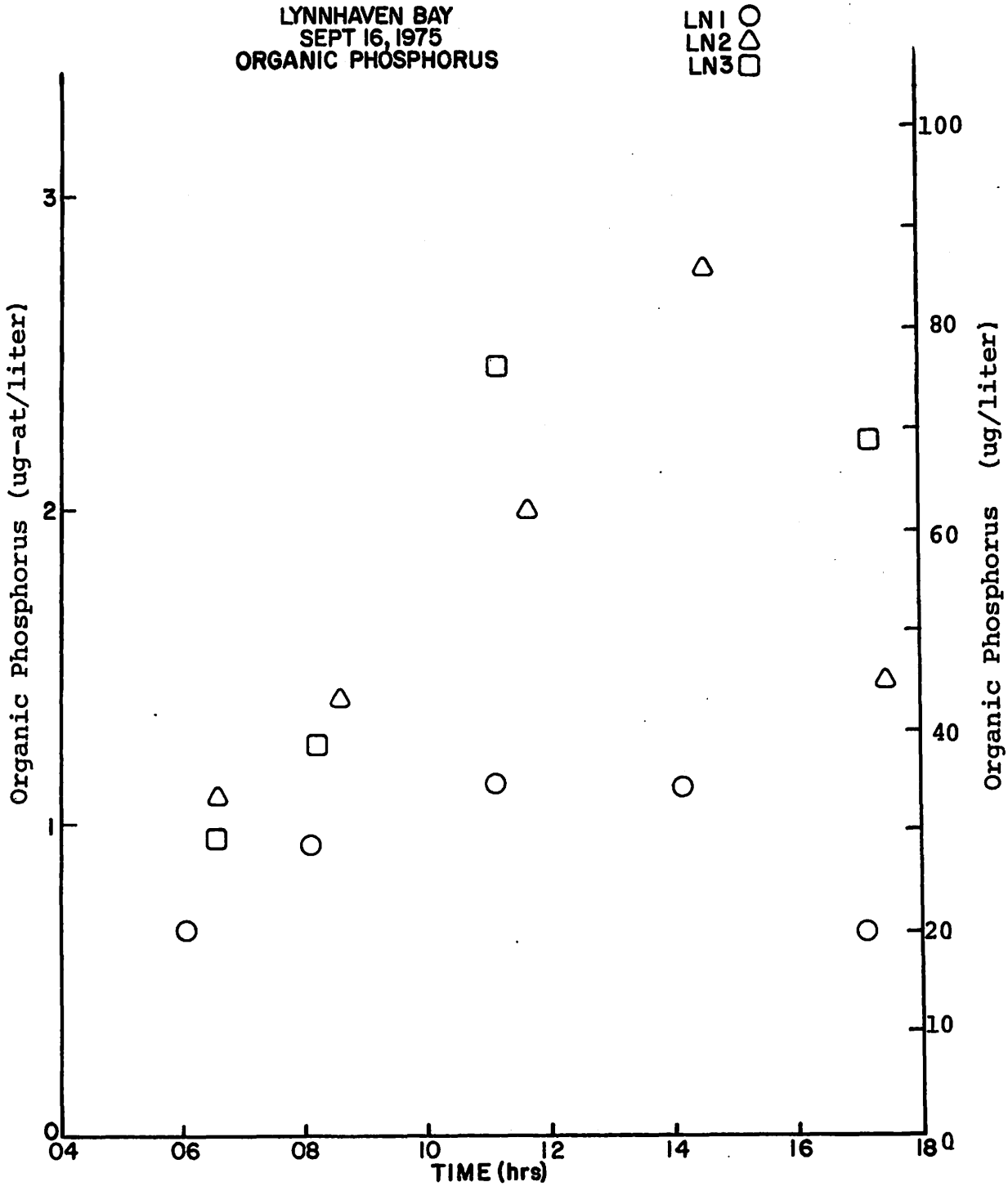

LYNNHAVEN BAY
SEPT 16, 1975
SALINITY
LN1
LN2
LN3
Salinity (ppt)
23.5
23
22.5
22
21.5
21
20.5
04
06
08
10
12
14
16
18
TIME (hrs)

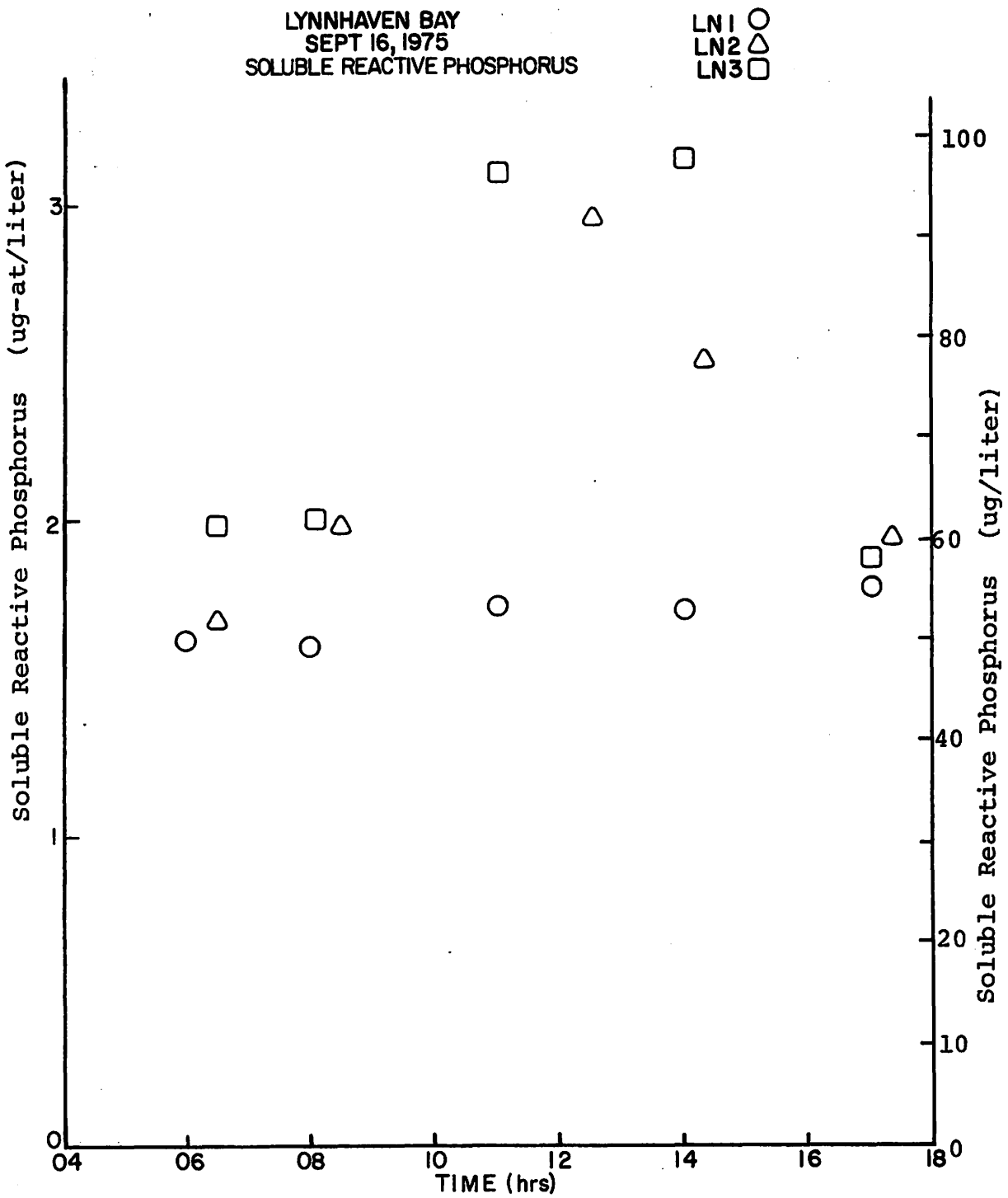

LYNNHAVEN BAY
SEPT 16, 1975
CHLOROPHYLL
LN1
LN2
LN3
Chlorophyll "a" (ug/liter)
0
5
10
15
20
25
30
04
06
08
10
12
14
16
18
TIME (hrs)

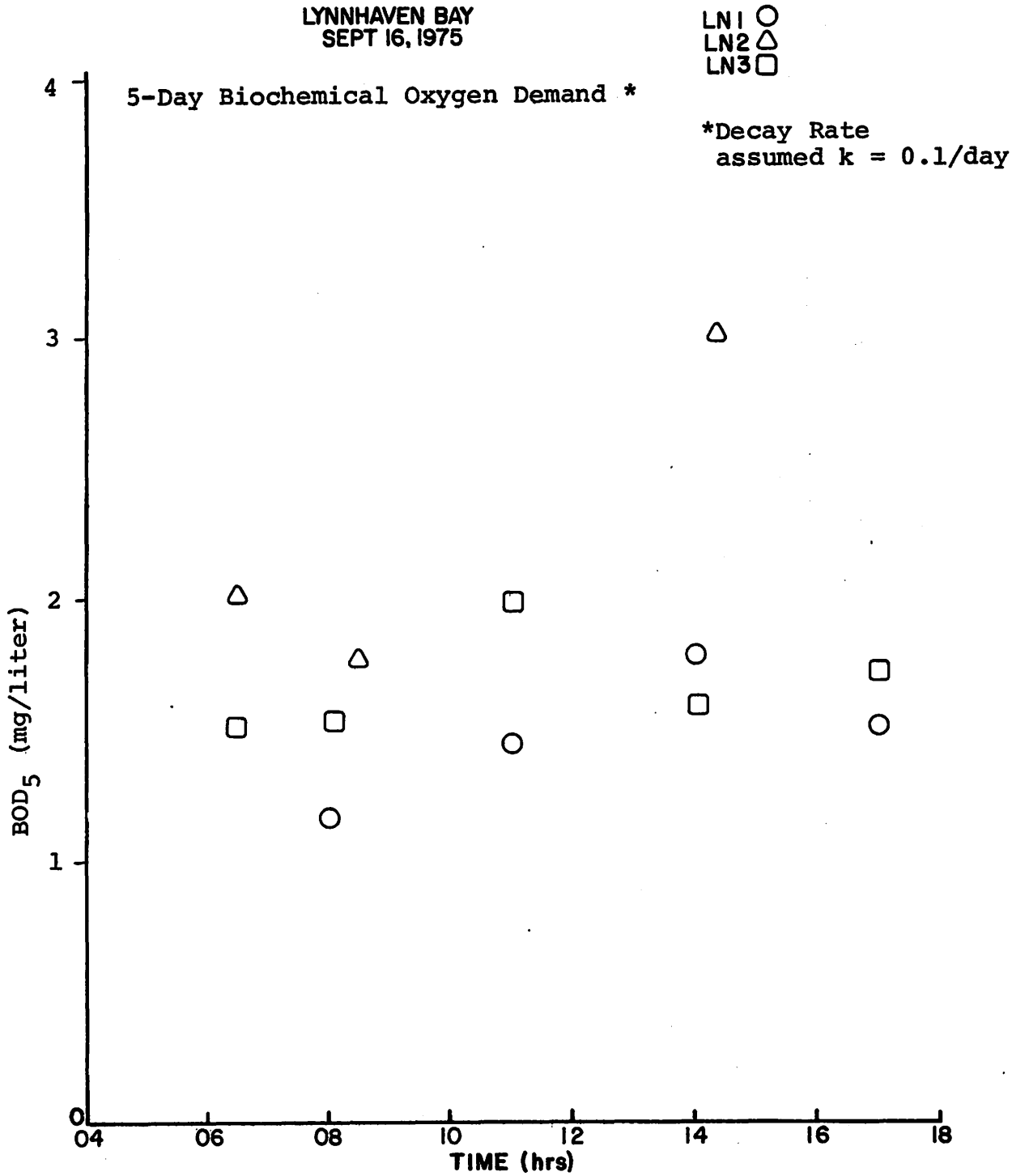

LYNNHAVEN BAY
SEPT 16, 1975
AMMONIA
LN1
LN2
LN3
.30
.20
.10
0
NH_4-N (mg/l)
04
06
08
10
12
14
16
18
TIME (hrs)

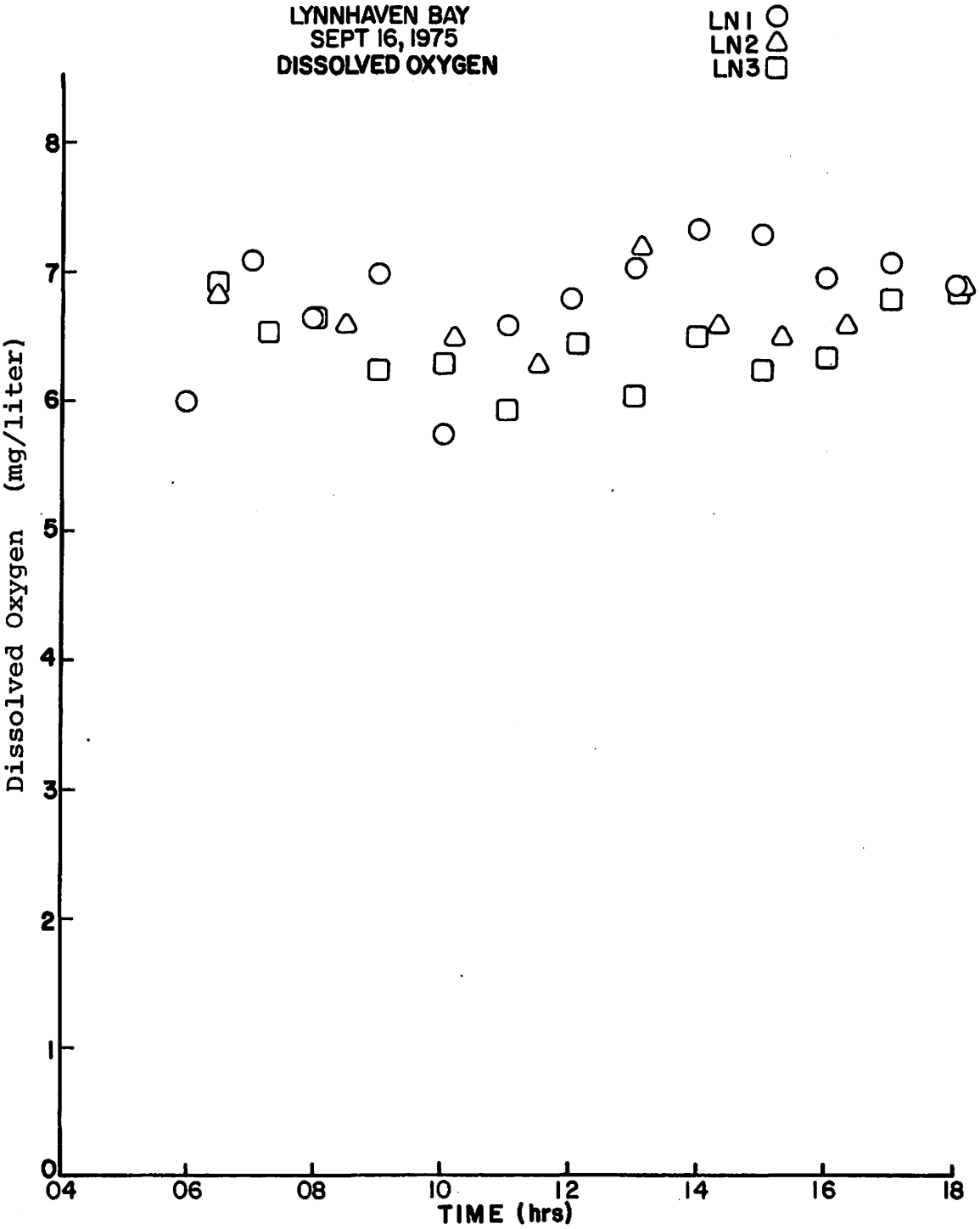

LYNNHAVEN BAY
SEPT 16, 1975
NITRATE + NITRITE
LN1 ○
LN2 △
LN3 □
NO_3+NO_2-N (ug-at/liter)
$NO_2 + NO_3 - N$ (ug/liter)
TIME (hrs)
0
5
10
15
0
20
40
80
120
04
06
08
10
12
14
16
18

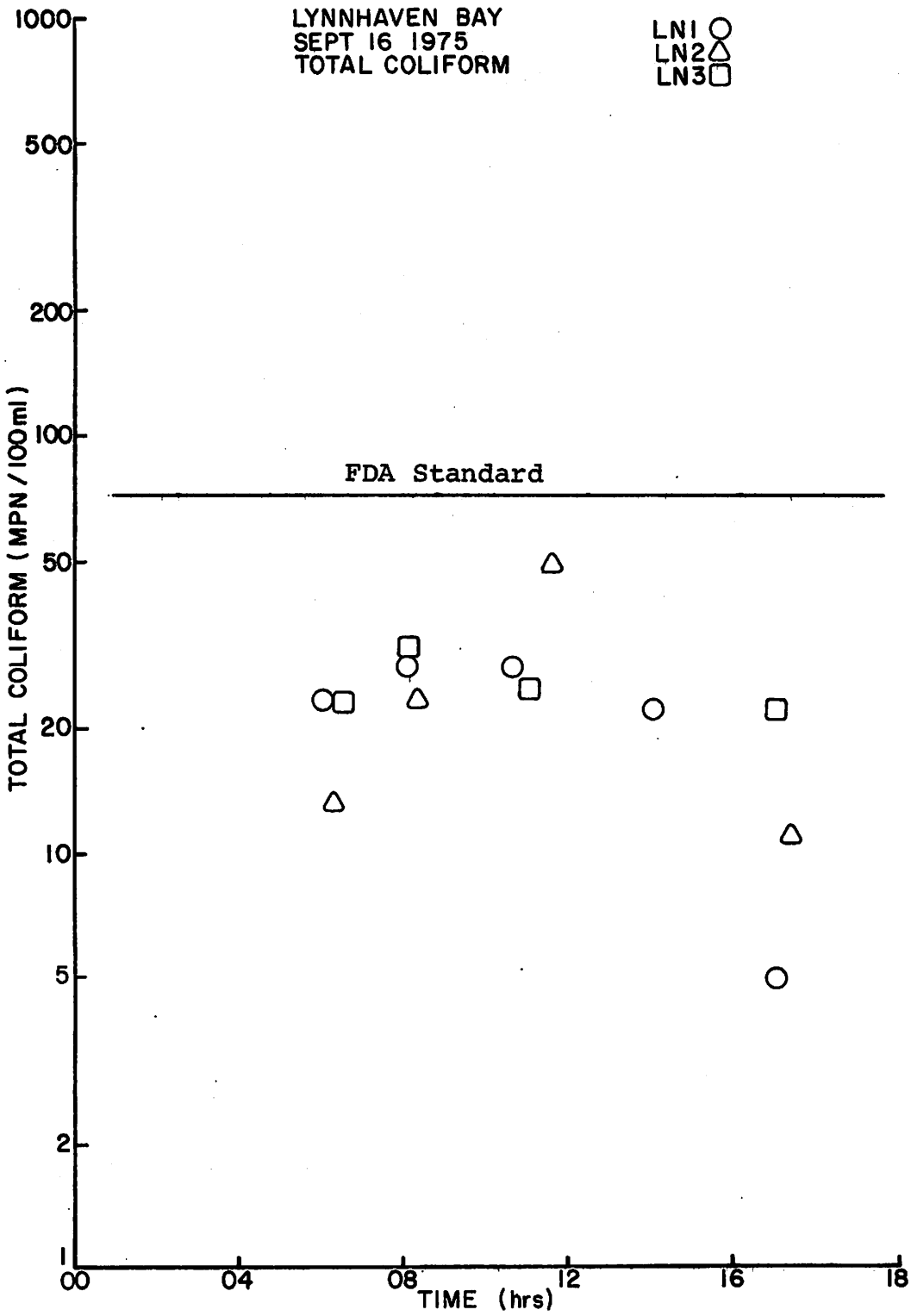

LYNNHAVEN BAY
SEPT 16, 1975
TOTAL KJELDAHL NITROGEN
LN1 ○
LN2 △
LN3 □
TKN (mg/l)
1.5
1.0
.5
0
04
06
08
10
12
14
16
18
TIME (hrs)

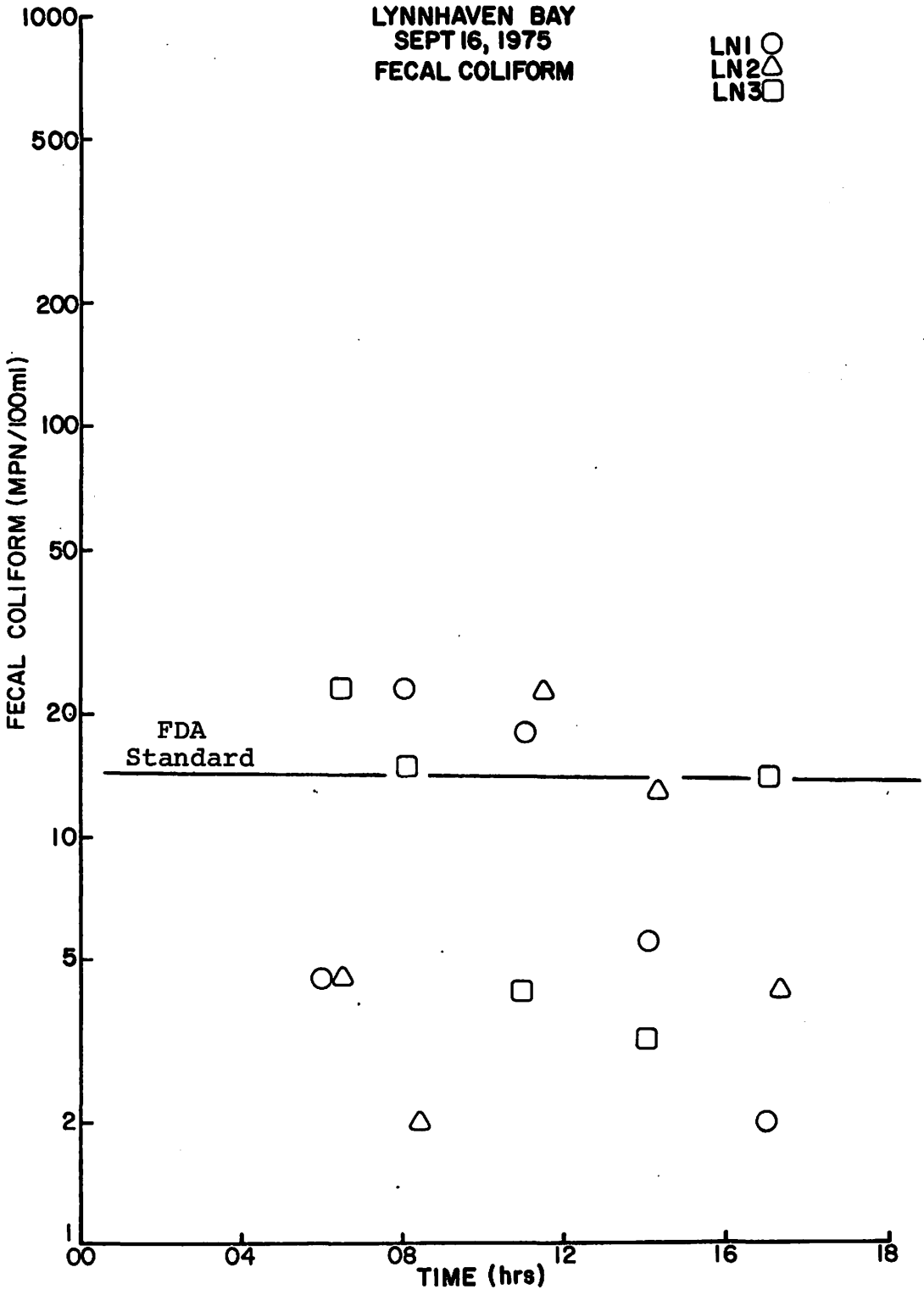

LYNNHAVEN BAY
SEPT 16, 1975
ORGANIC PHOSPHORUS
LN1 ○
LN2 △
LN3 □
Organic Phosphorus (ug-at/liter)
Organic Phosphorus (ug/liter)
TIME (hrs)
0
1
2
3
04
06
08
10
12
14
16
18
0
10
20
40
60
80
100

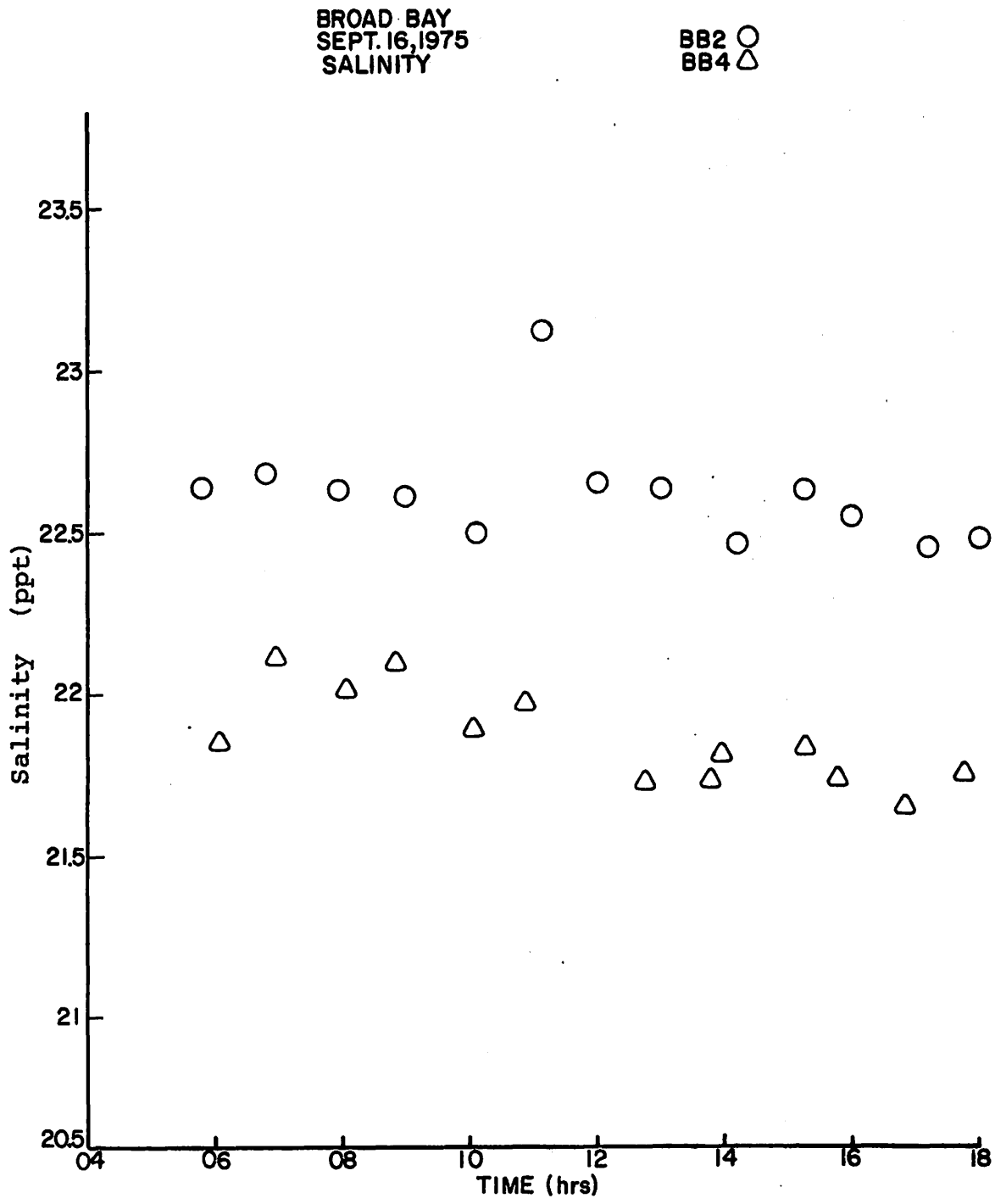

LYNNHAVEN BAY
SEPT 16, 1975
SOLUBLE REACTIVE PHOSPHORUS
LN1 ○
LN2 △
LN3 □
Soluble Reactive Phosphorus (ug-at/liter)
Soluble Reactive Phosphorus (ug/liter)
TIME (hrs)
0
1
2
3
0
20
40
60
80
100
04
06
08
10
12
14
16
18

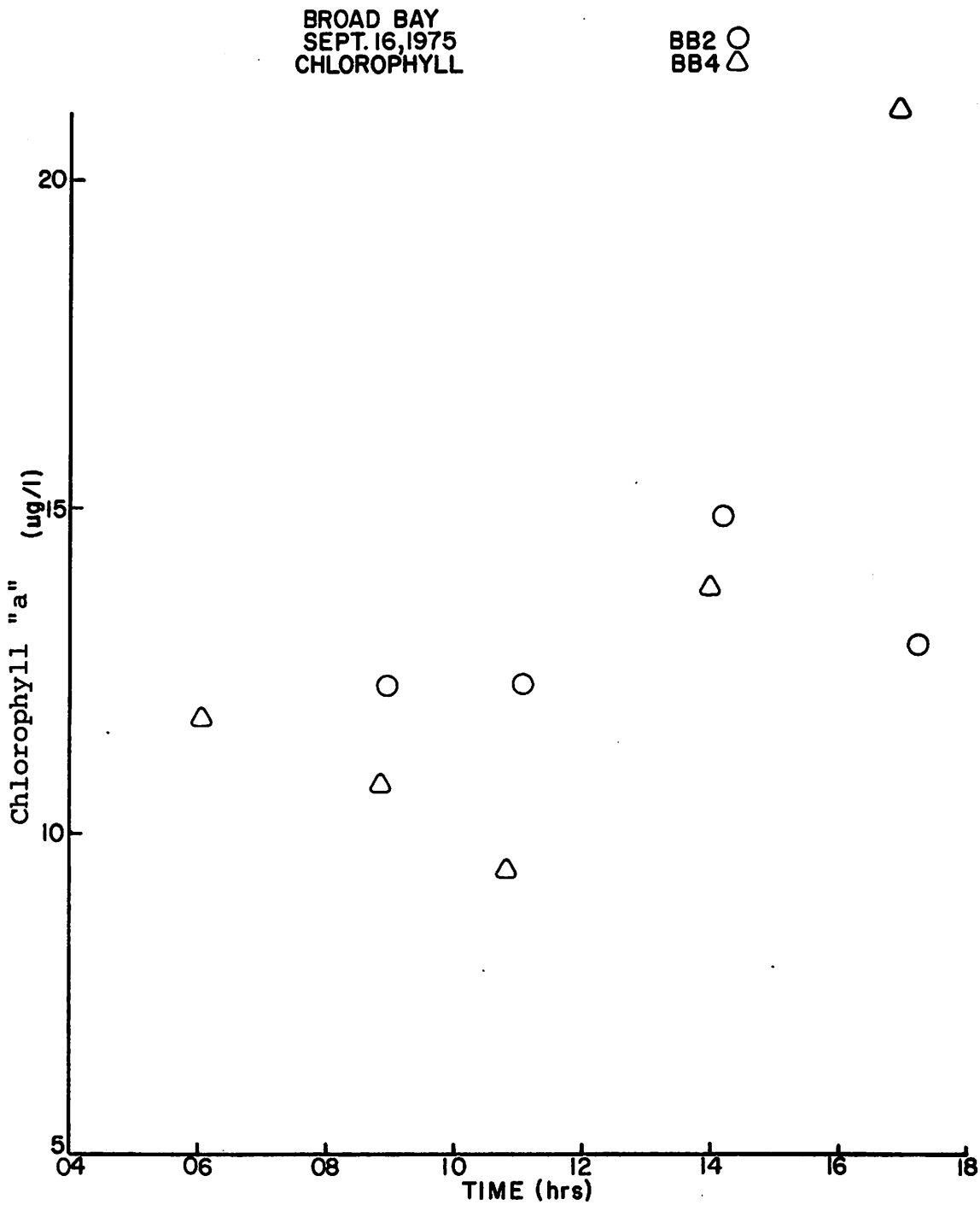

LYNNHAVEN BAY
SEPT 16, 1975
LN1 ○
LN2 △
LN3 □
5-Day Biochemical Oxygen Demand *
*Decay Rate
assumed k = 0.1/day
BOD5 (mg/liter)
TIME (hrs)
0
1
2
3
4
04
06
08
10
12
14
16
18

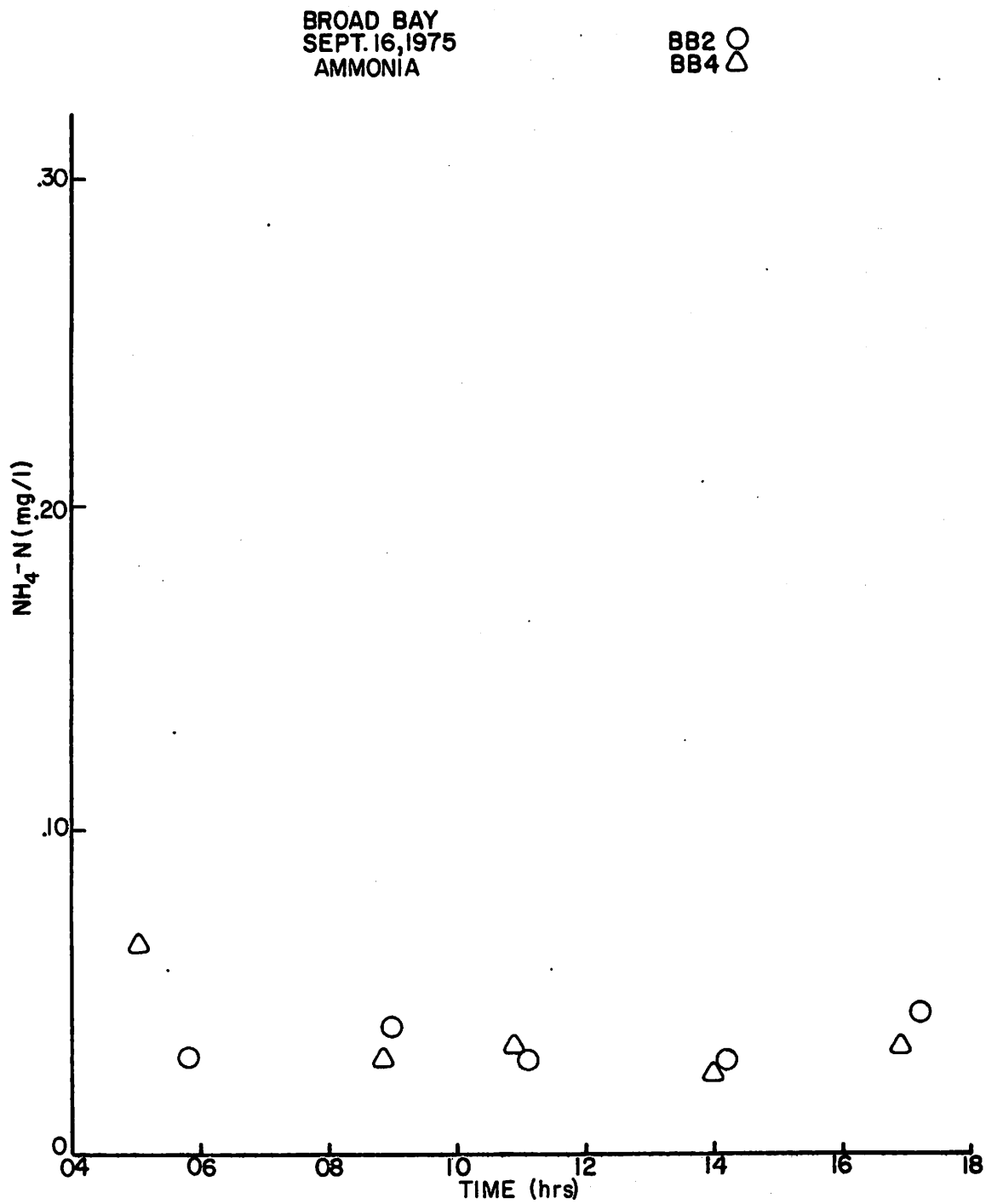

LYNNHAVEN BAY
SEPT 16, 1975
DISSOLVED OXYGEN
LN1
LN2
LN3
Dissolved Oxygen (mg/liter)
0
1
2
3
4
5
6
7
8
04
06
08
10
12
14
16
18
TIME (hrs)

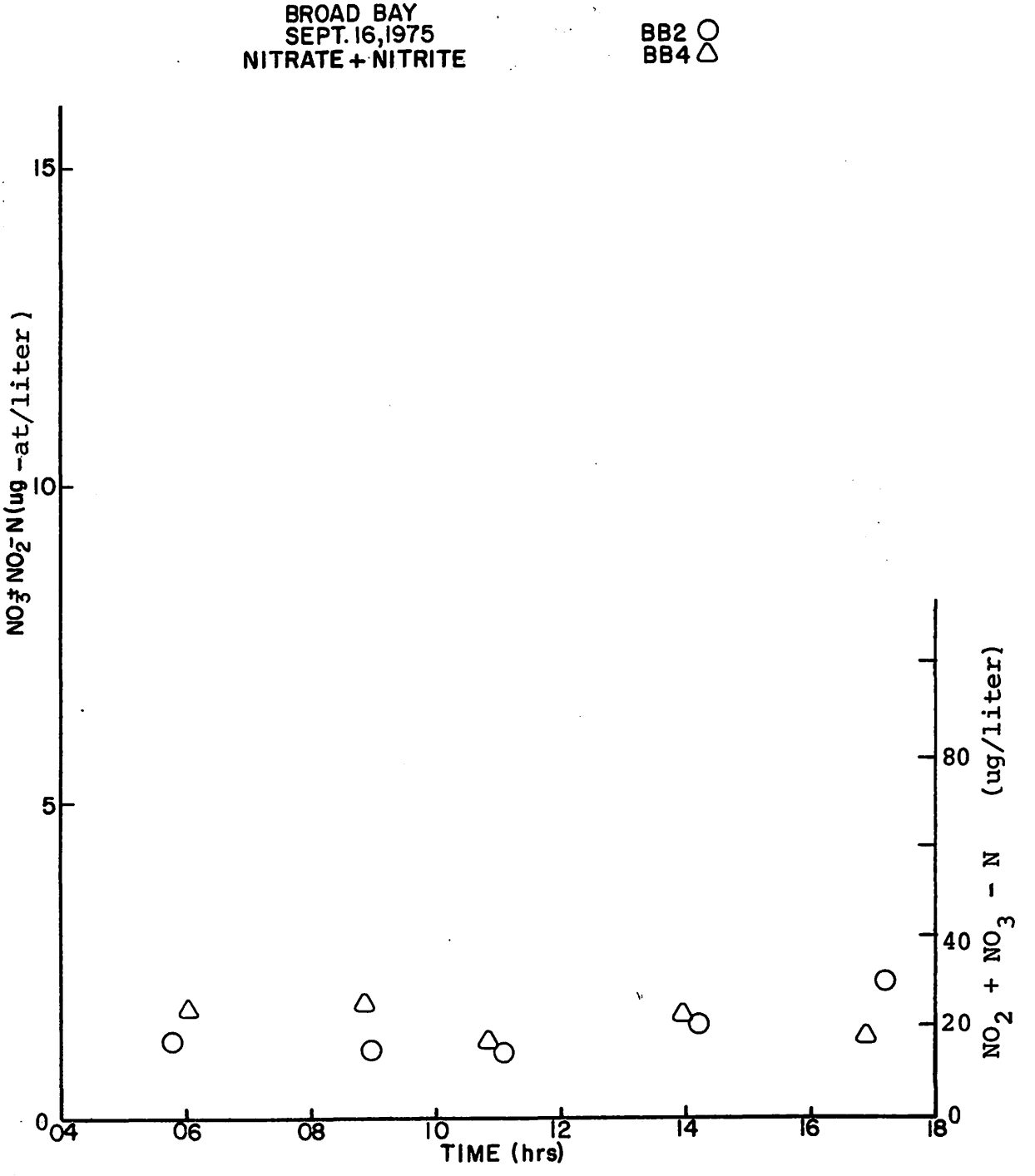

LYNNHAVEN BAY
SEPT 16 1975
TOTAL COLIFORM
LN1
LN2
LN3
FDA Standard
TOTAL COLIFORM (MPN/100ml)
1000
500
200
100
50
20
10
5
2
1
00
04
08
12
16
18
TIME (hrs)

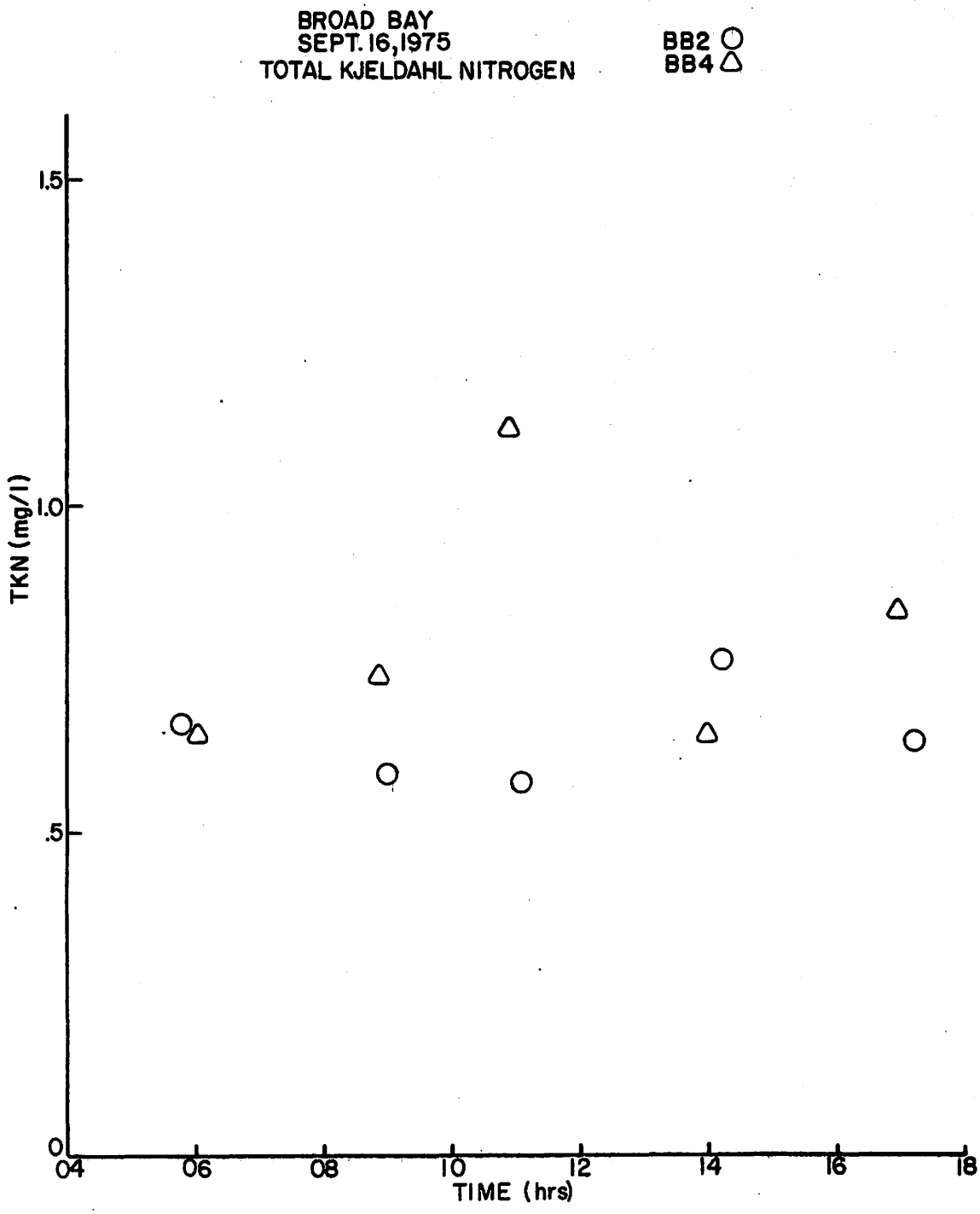

LYNNHAVEN BAY
SEPT 16, 1975
FECAL COLIFORM
LN1
LN2
LN3
1000
500
200
100
50
20
10
5
2
1
FECAL COLIFORM (MPN/100ml)
FDA
Standard
00
04
08
12
16
18
TIME (hrs)

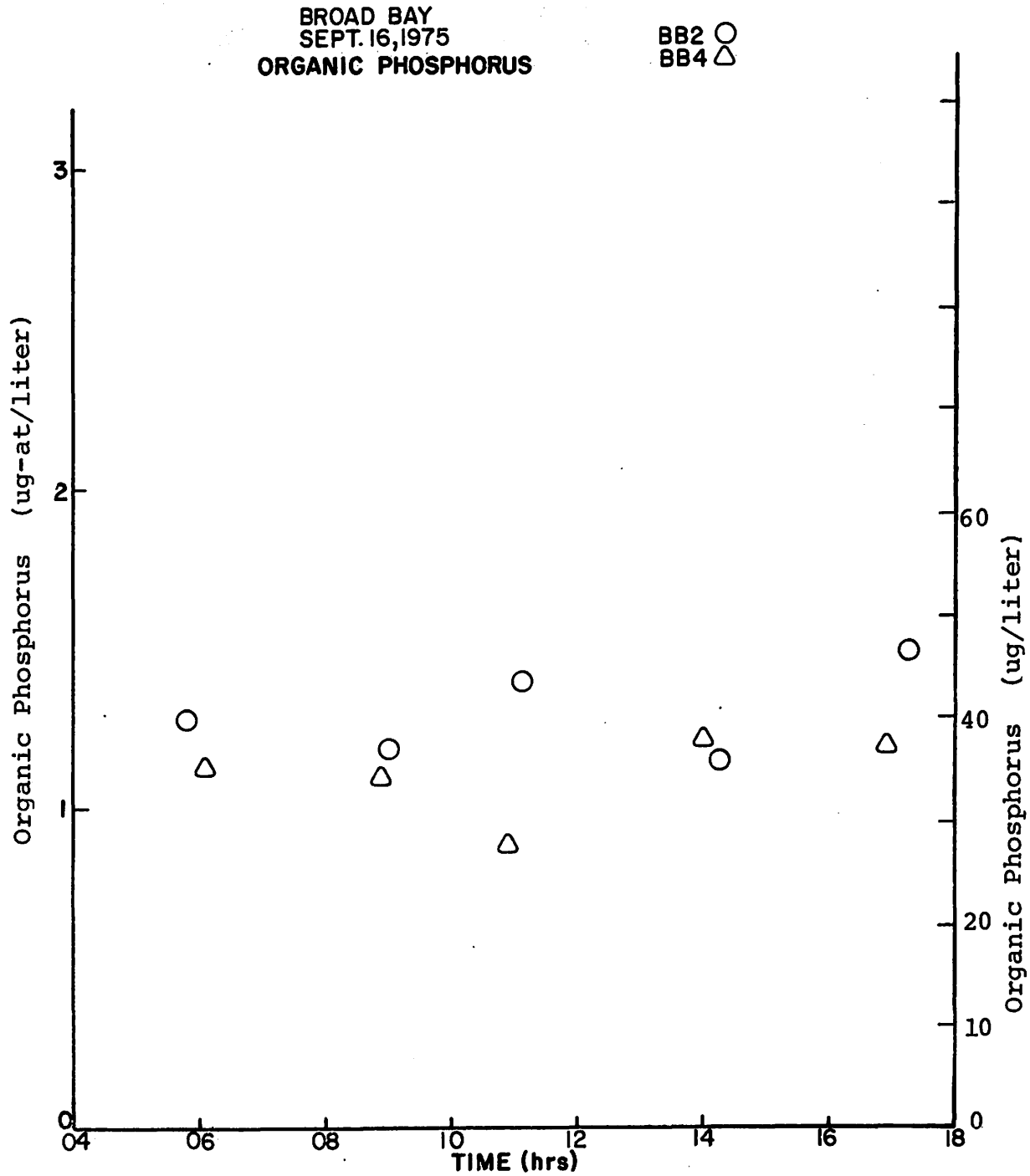

BROAD BAY
SEPT. 16, 1975
SALINITY
BB2
BB4
23.5
23
22.5
22
21.5
21
20.5
Salinity (ppt)
04
06
08
10
12
14
16
18
TIME (hrs)

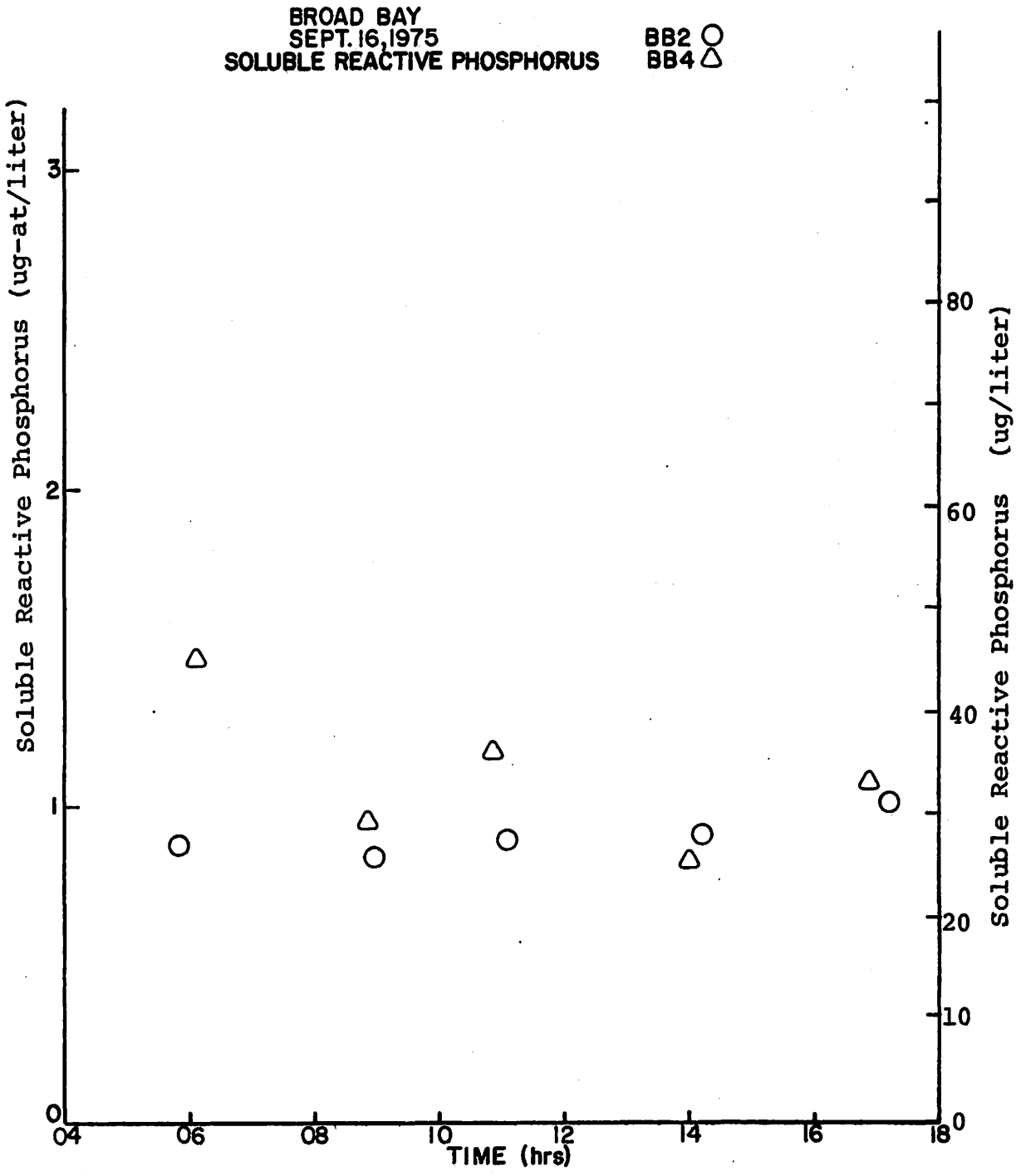

BROAD BAY
SEPT. 16, 1975
CHLOROPHYLL
BB2
BB4
Chlorophyll "a" (ug/l)
20
15
10
5
04
06
08
10
12
14
16
18
TIME (hrs)

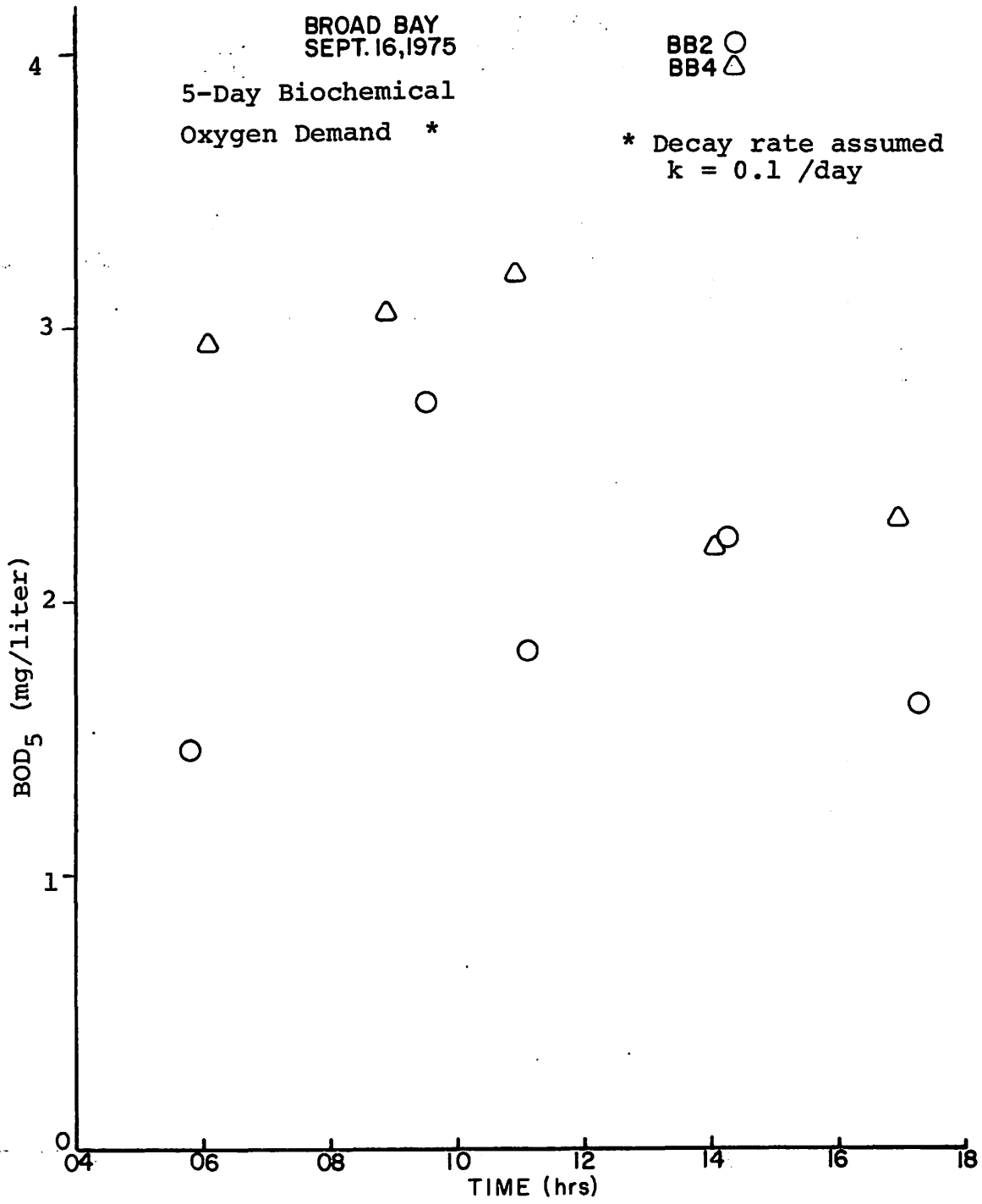

BROAD BAY
SEPT. 16, 1975
AMMONIA
BB2
BB4
.30
.20
.10
0
NH_4^-N (mg/l)
04
06
08
10
12
14
16
18
TIME (hrs)

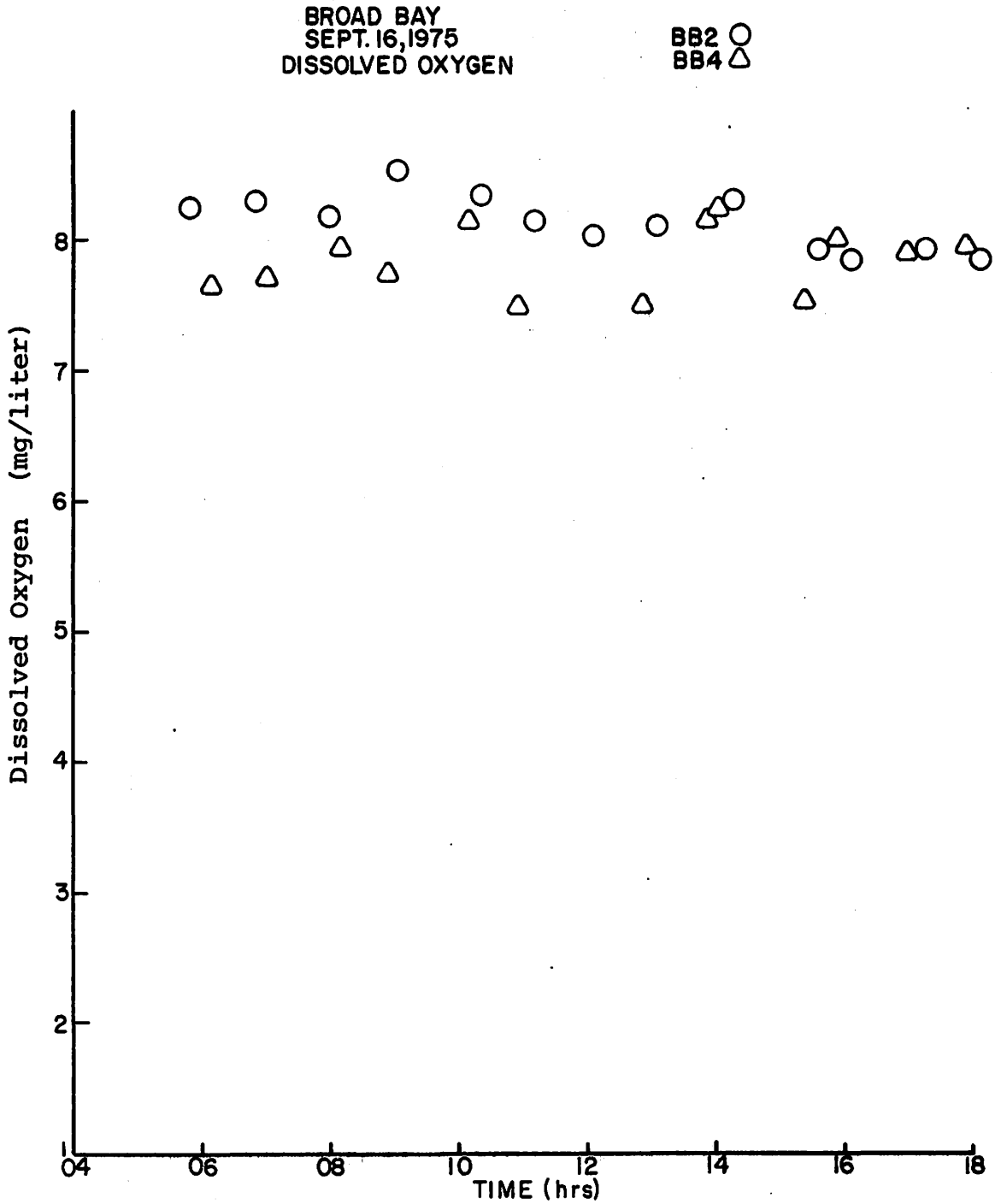

BROAD BAY
SEPT. 16, 1975
NITRATE + NITRITE
BB2
BB4
$NO_3 + NO_2 - N$ (ug-at/liter)
15
10
5
0
04
06
08
10
12
14
16
18
TIME (hrs)
80
40
20
0
$NO_2 + NO_3 - N$ (ug/liter)

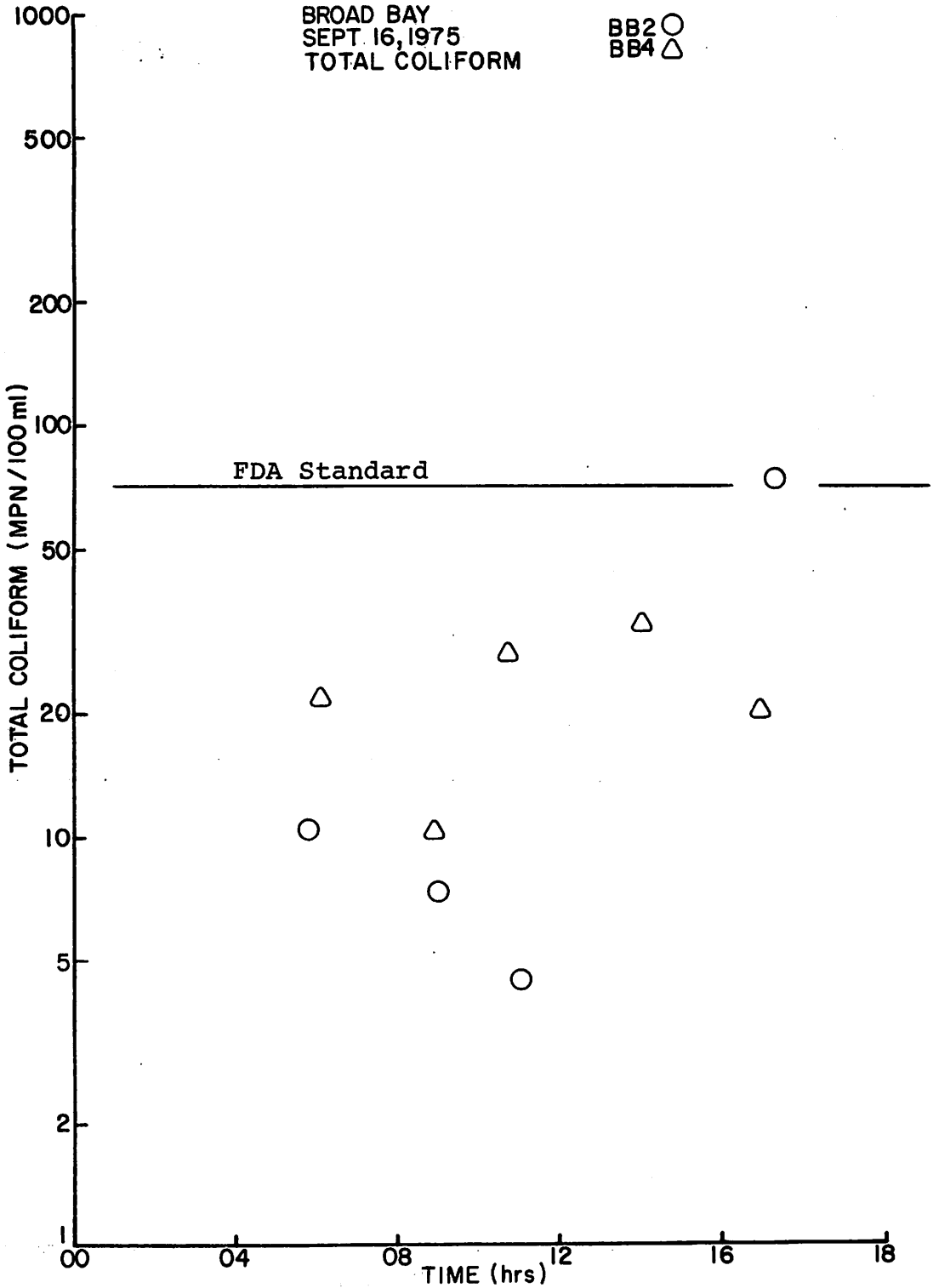

BROAD BAY
SEPT. 16, 1975
TOTAL KJELDAHL NITROGEN
BB2
BB4
TKN (mg/l)
1.5
1.0
.5
0
04
06
08
10
12
14
16
18
TIME (hrs)

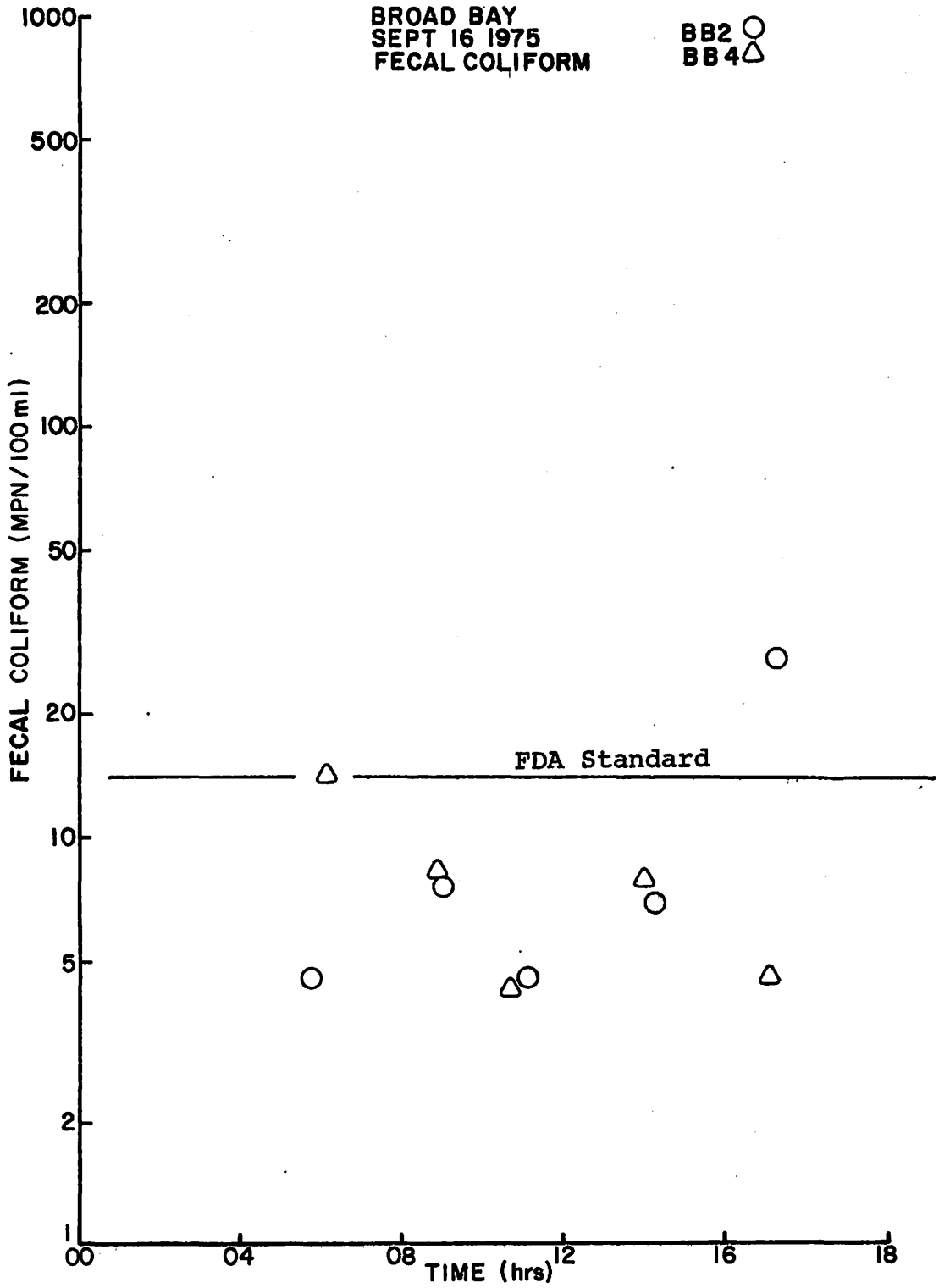

BROAD BAY
SEPT. 16, 1975
ORGANIC PHOSPHORUS
BB2
BB4
Organic Phosphorus (ug-at/liter)
Organic Phosphorus (ug/liter)
TIME (hrs)
0
1
2
3
0
10
20
40
60
04
06
08
10
12
14
16
18


BROAD BAY
SEPT. 16, 1975
SOLUBLE REACTIVE PHOSPHORUS
BB2
BB4
Soluble Reactive Phosphorus (ug-at/liter)
Soluble Reactive Phosphorus (ug/liter)
TIME (hrs)
0
1
2
3
0
20
40
60
80
04
06
08
10
12
14
16
18


BROAD BAY
SEPT. 16, 1975
5-Day Biochemical
Oxygen Demand *
BB2
BB4
* Decay rate assumed
k = 0.1 /day
BOD5 (mg/liter)
TIME (hrs)
0
1
2
3
4
04
06
08
10
12
14
16
18

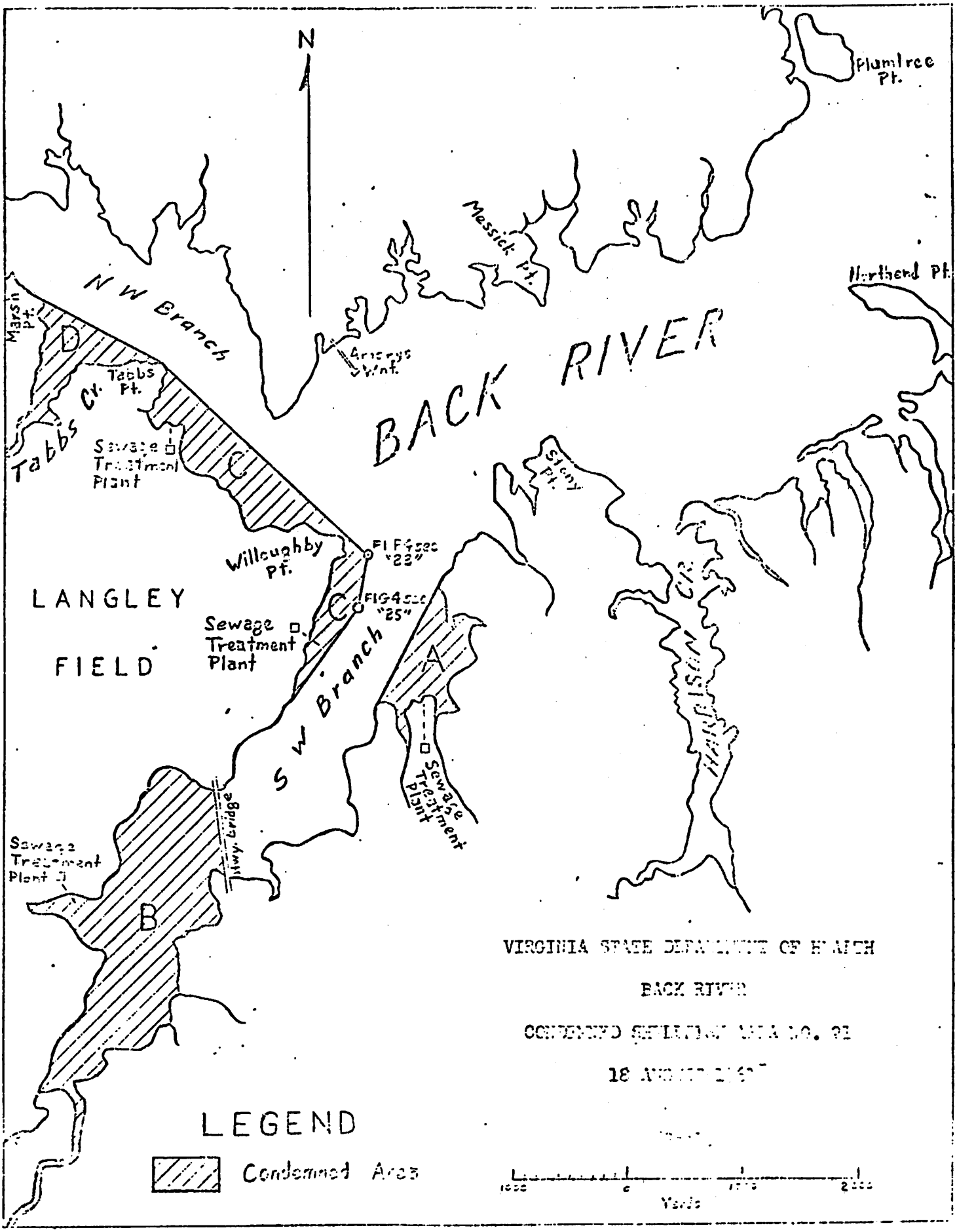

BROAD BAY
SEPT. 16, 1975
DISSOLVED OXYGEN
BB2
BB4
Dissolved Oxygen (mg/liter)
1
2
3
4
5
6
7
8
04
06
08
10
12
14
16
18
TIME (hrs)


BROAD BAY
SEPT. 16, 1975
TOTAL COLIFORM
BB2
BB4
FDA Standard
TOTAL COLIFORM (MPN/100 ml)
1000
500
200
100
50
20
10
5
2
1
00
04
08
12
16
18
TIME (hrs)


BROAD BAY
SEPT 16 1975
FECAL COLIFORM
BB2
BB4
FDA Standard
FECAL COLIFORM (MPN/100 ml)
1000
500
200
100
50
20
10
5
2
1
00
04
08
12
16
18
TIME (hrs)

Appendix C. Shellfish Condemnation Areas

Back River	#21 - 18 August 1961
	#21 - 18 May 1973
	#21 - 14 March 1975
Poquoson River	#137 - 1 May 1972
	#137 - 21 February 1975
Little Creek	#17 - 16 April 1936
	#60 - 28 March 1969
Lynnhaven Bay Complex	#10 - 15 October 1930
	#95 - 11 April 1972
	#31 - 30 December 1964
	#25 - 27 September 1937
	#29 - 9 September 1941
	#49 - 13 October 1959
	#65 - 28 June 1971
	#66 - 6 October 1971
	#75 - 7 March 1972
	#25 - 20 February 1974
	#25 - 24 March 1975

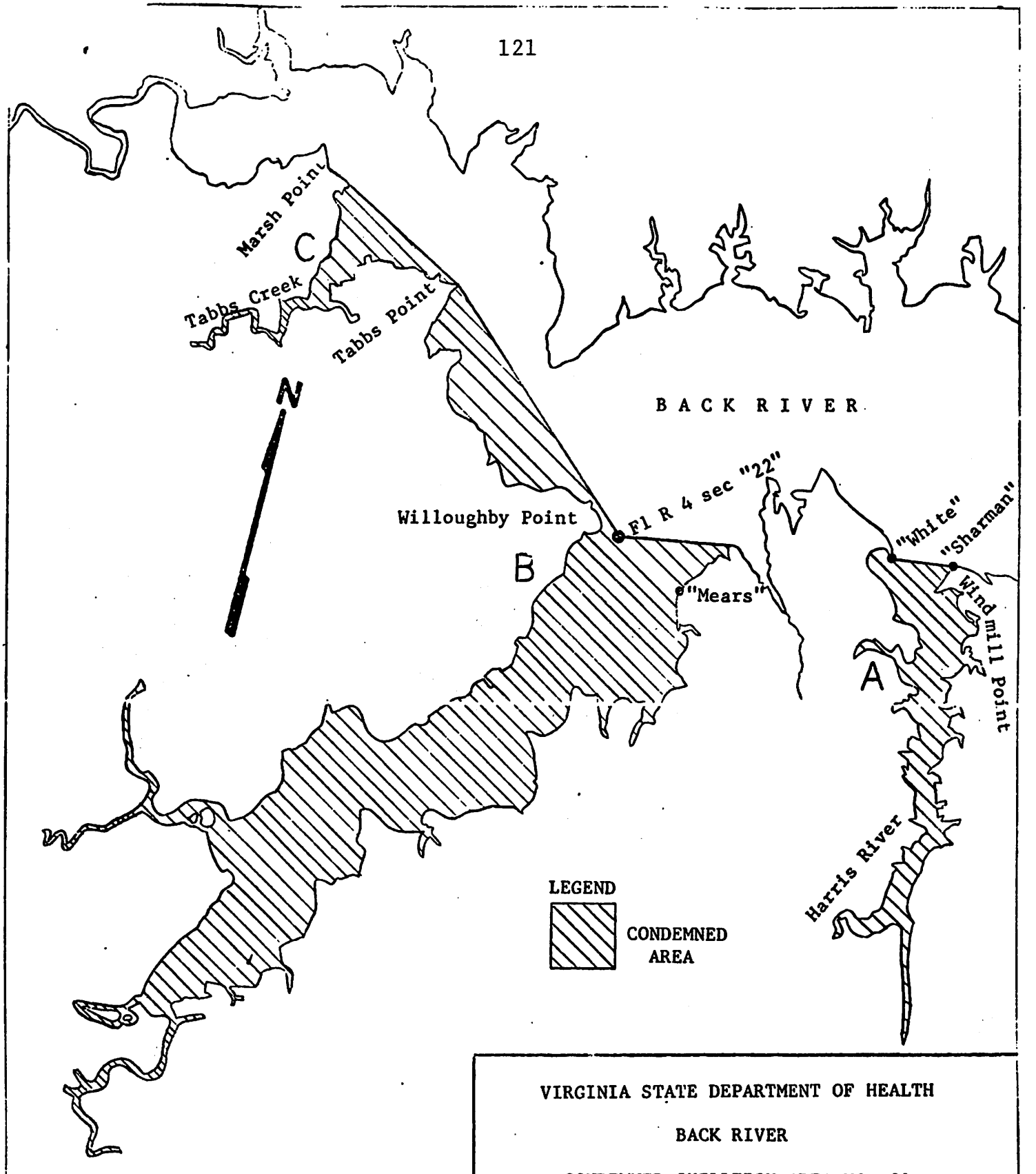


VIRGINIA STATE DEPARTMENT OF HEALTH

BACK RIVER

CONDEMNED SHELLING AREA NO. 21

18 AUGUST 1947



VIRGINIA STATE DEPARTMENT OF HEALTH

BACK RIVER

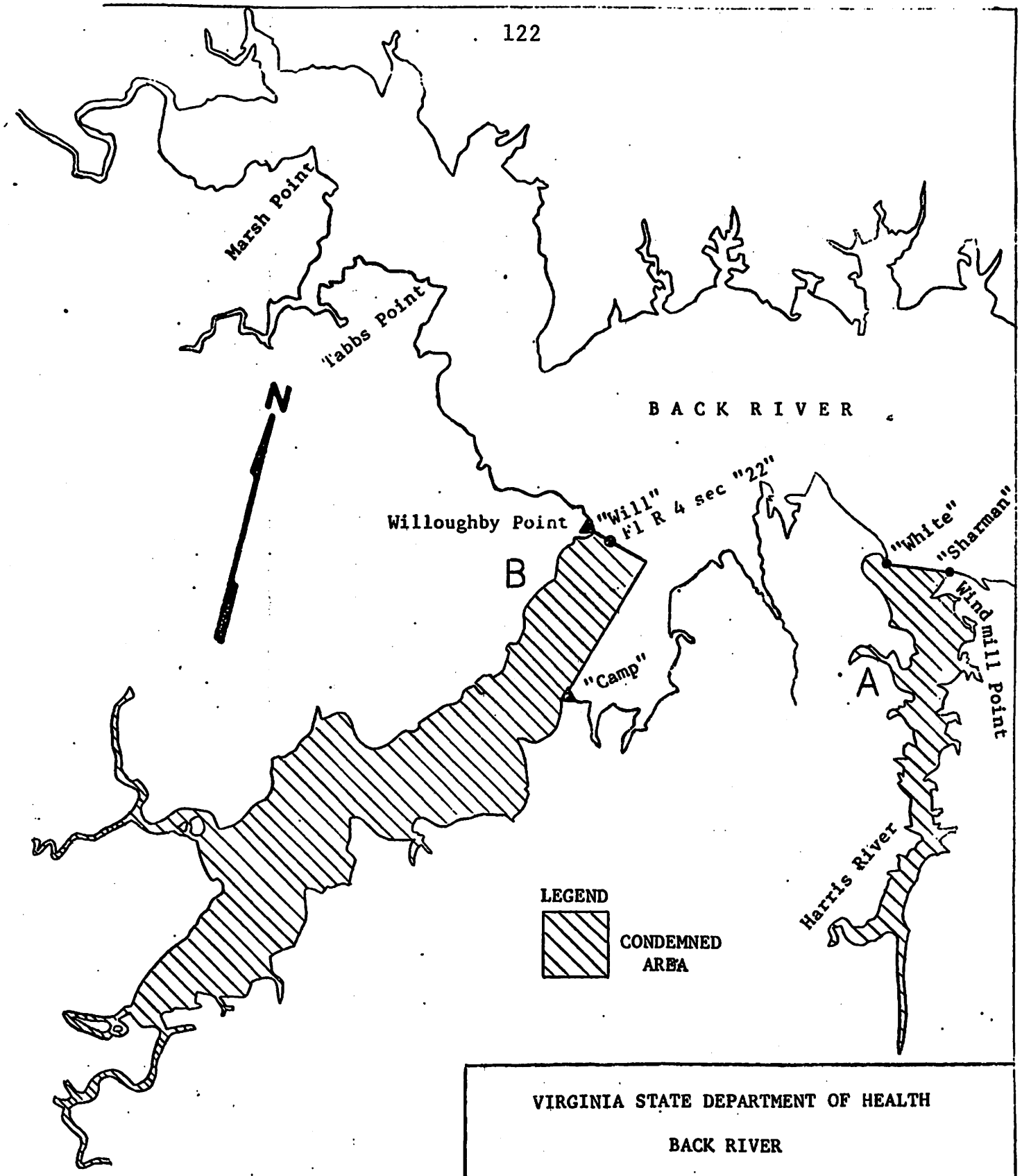
CONDEMNED SHELLFISH AREA NO. 21

18 MAY 1973

SCALE 1:40,000

1000 0 1000

YARDS



VIRGINIA STATE DEPARTMENT OF HEALTH

BACK RIVER

CONDEMNED SHELLFISH AREA NO. 21

14 MARCH 1975

SCALE 1:40,000

1000 0 1000

YARDS

VIRGINIA STATE DEPARTMENT OF HEALTH

123

POQUOSON RIVER: CHISMAN & PATRICKS CREEKS

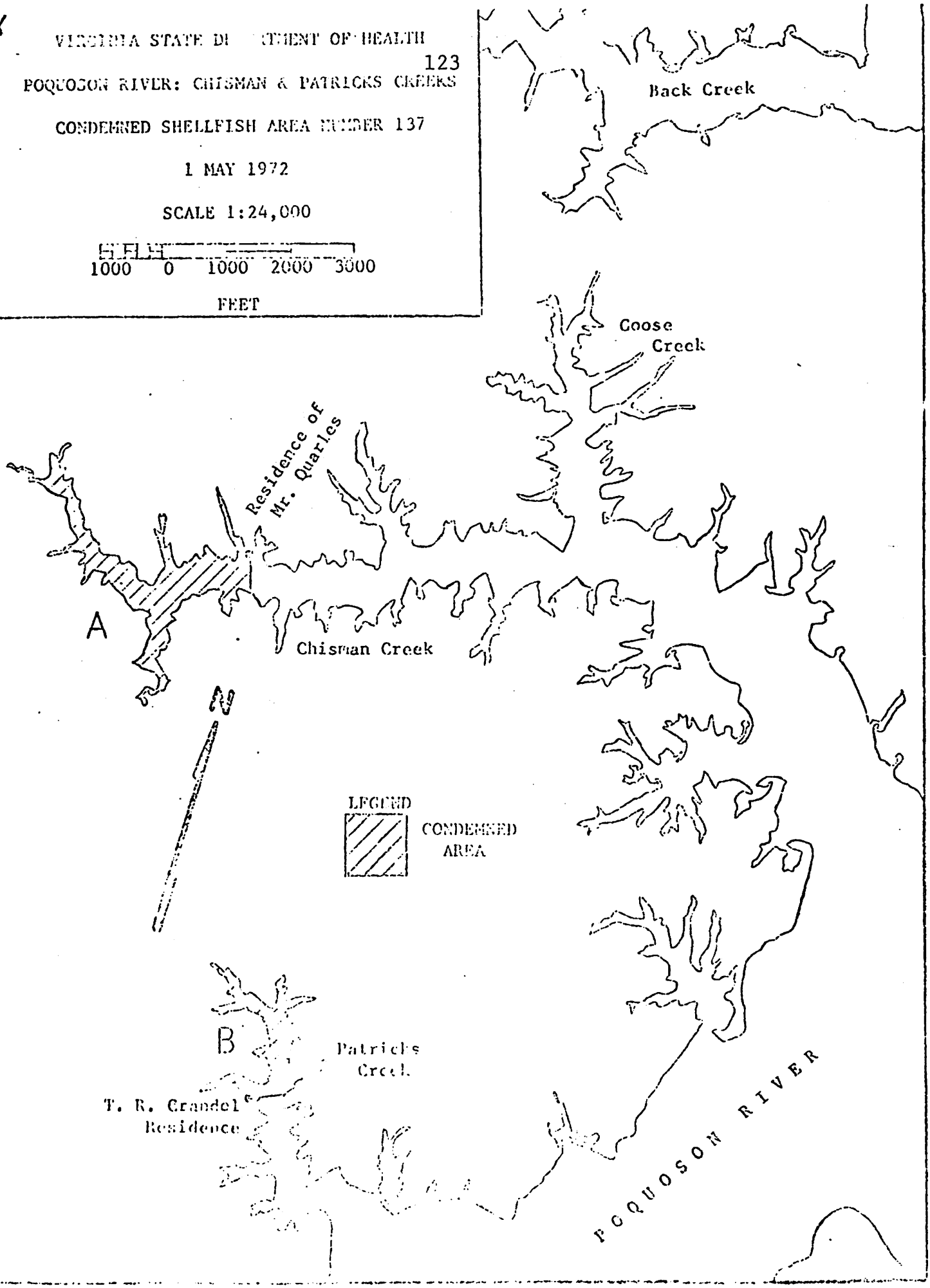
CONDEMNED SHELLFISH AREA NUMBER 137

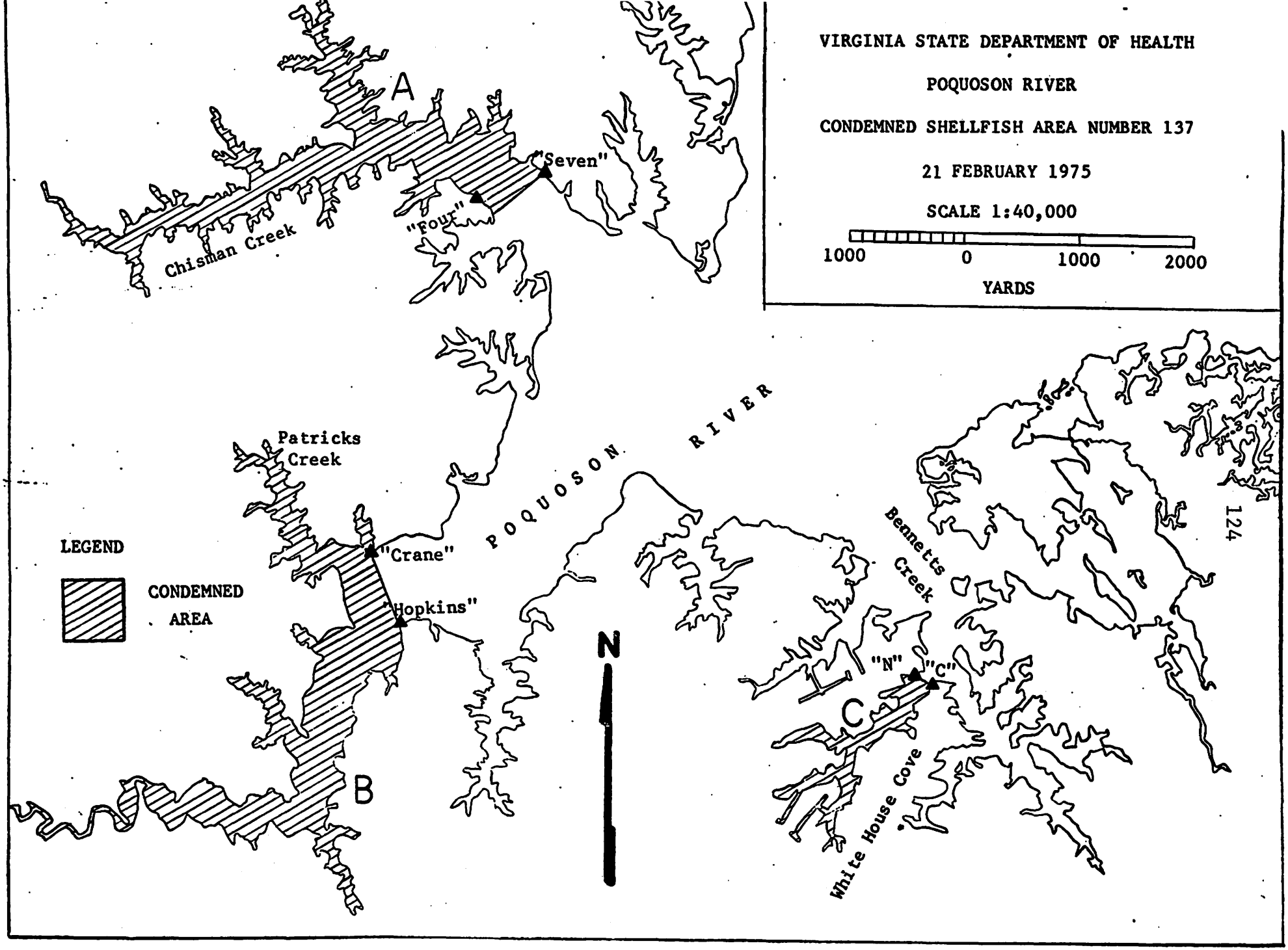
1 MAY 1972

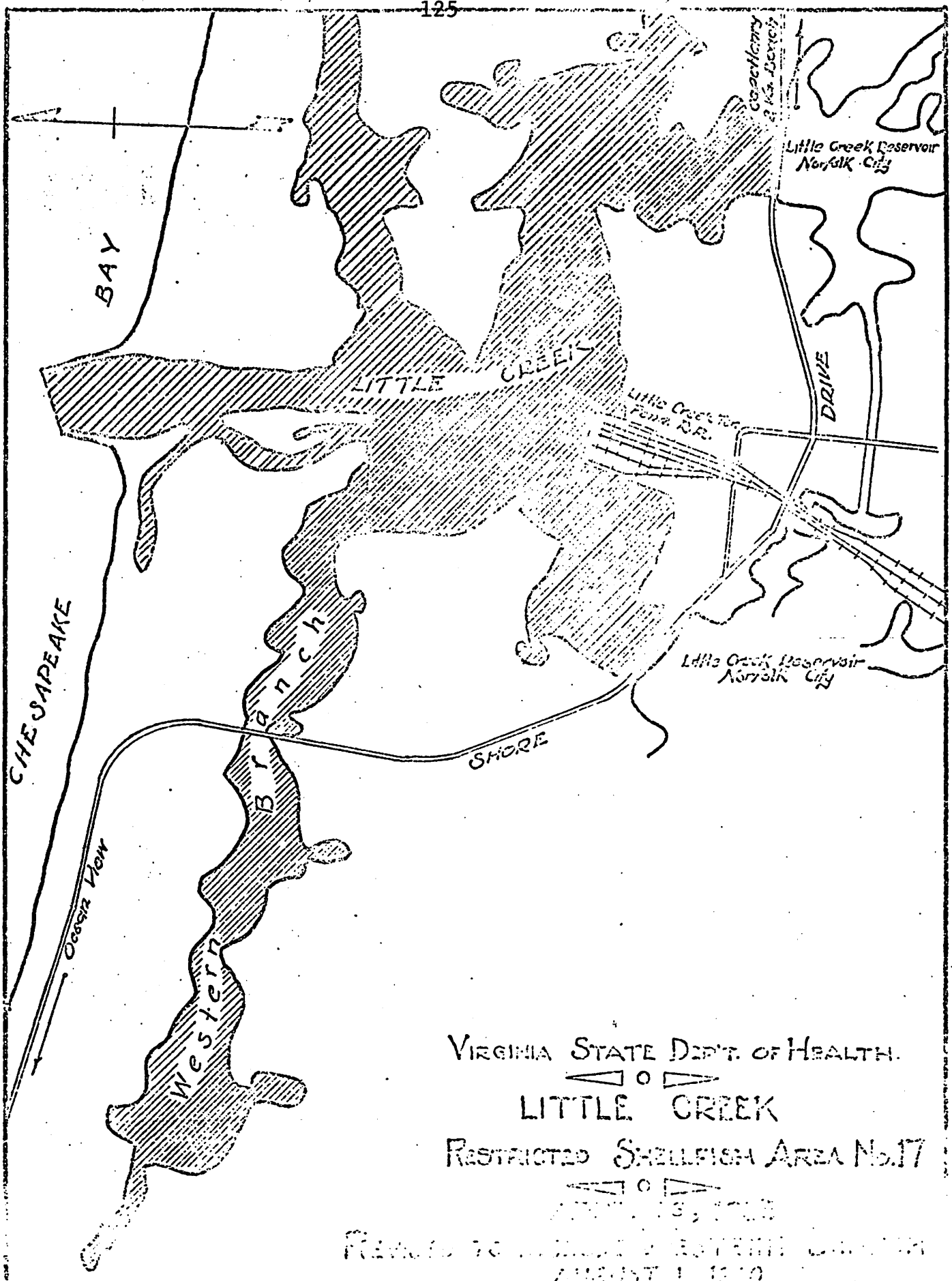
SCALE 1:24,000

1000 0 1000 2000 3000

FEET




VIRGINIA STATE DEPARTMENT OF HEALTH
POQUOSON RIVER
CONDEMNED SHELLFISH AREA NUMBER 137
21 FEBRUARY 1975
SCALE 1:40,000
1000 0 1000 2000
YARDS
A
"Seven"
"Four"
Chisman Creek
Patricks Creek
POQUOSON RIVER
"Crane"
"Hopkins"
B
LEGEND
CONDEMNED AREA
N
Bennetts Creek
"N"
"C"
C
White House Cove
124

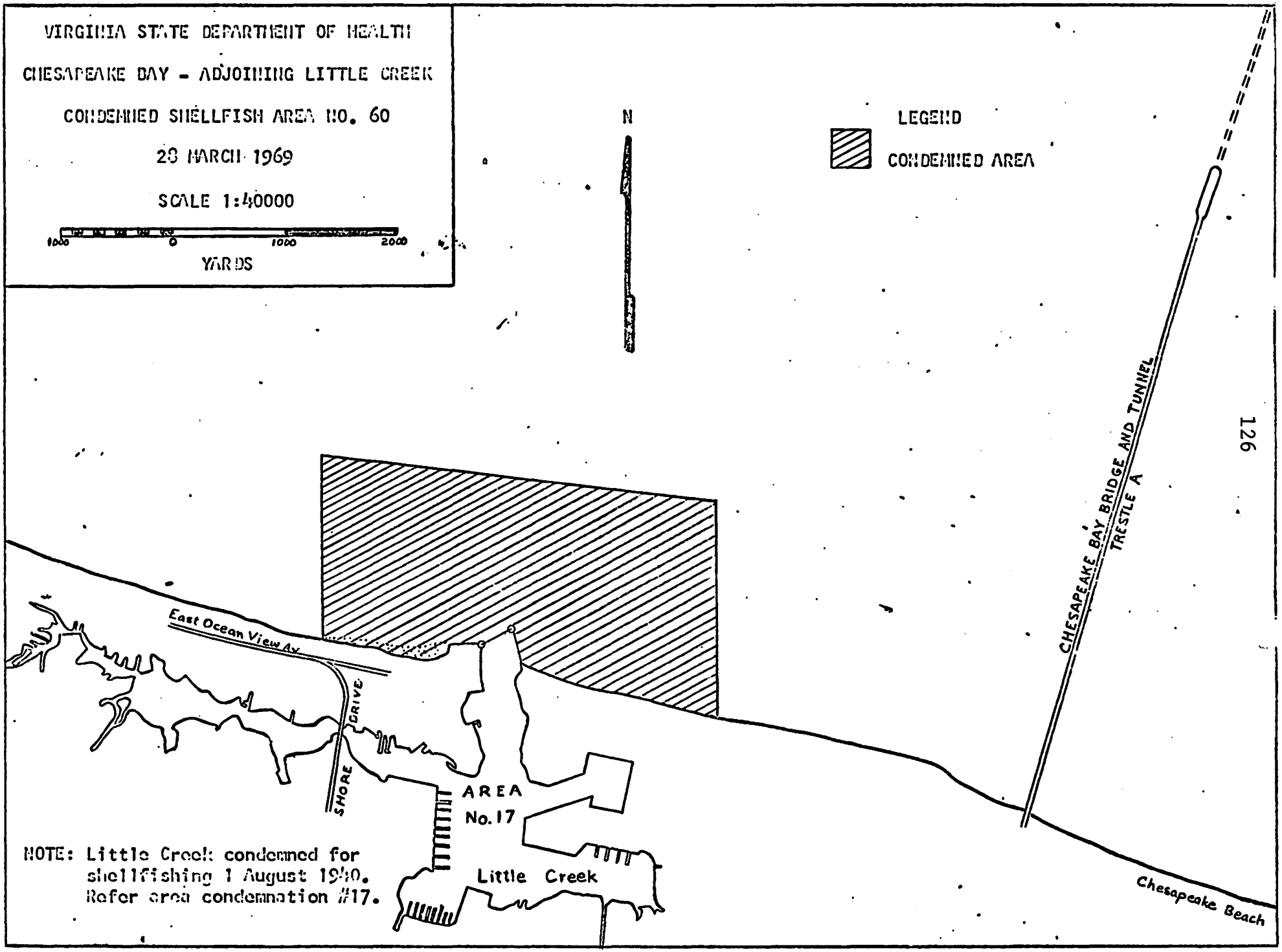


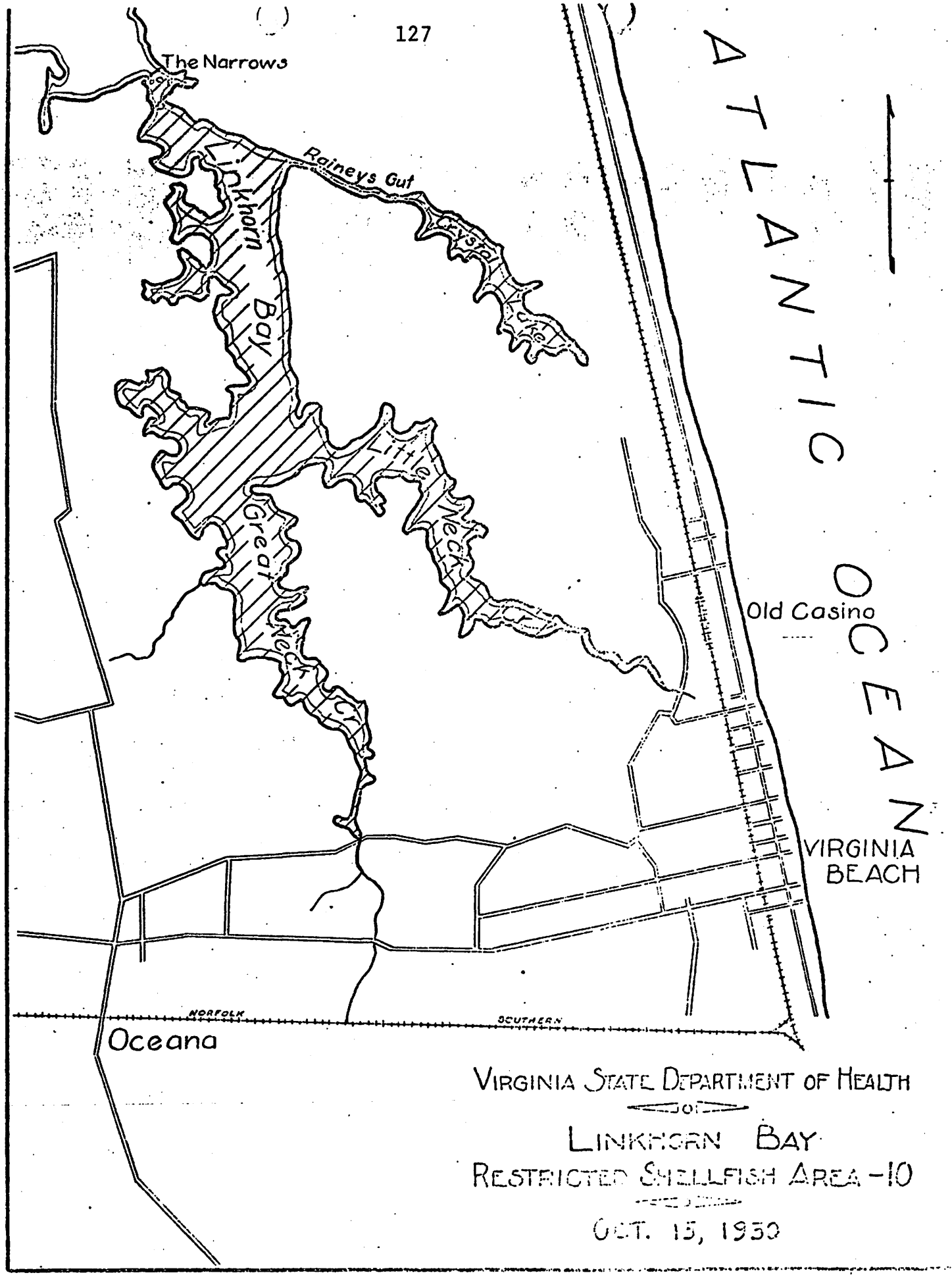
VIRGINIA STATE DEP'T. OF HEALTH.

LITTLE CREEK

RESTRICTED SHELLFISH AREA No. 17

REVISED TO AUGUST 1, 1940


VIRGINIA STATE DEPARTMENT OF HEALTH
CHESAPEAKE BAY - ADJOINING LITTLE CREEK
CONDEMNED SHELLFISH AREA NO. 60
28 MARCH 1969
SCALE 1:40000
1000 0 1000 2000
YARDS
N
LEGEND
CONDEMNED AREA
126
CHESAPEAKE BAY BRIDGE AND TUNNEL
TRESTLE A
East Ocean View Av
SHORE DRIVE
AREA
No. 17
Little Creek
Chesapeake Beach
NOTE: Little Creek condemned for shellfishing 1 August 1940. Refer area condemnation #17.



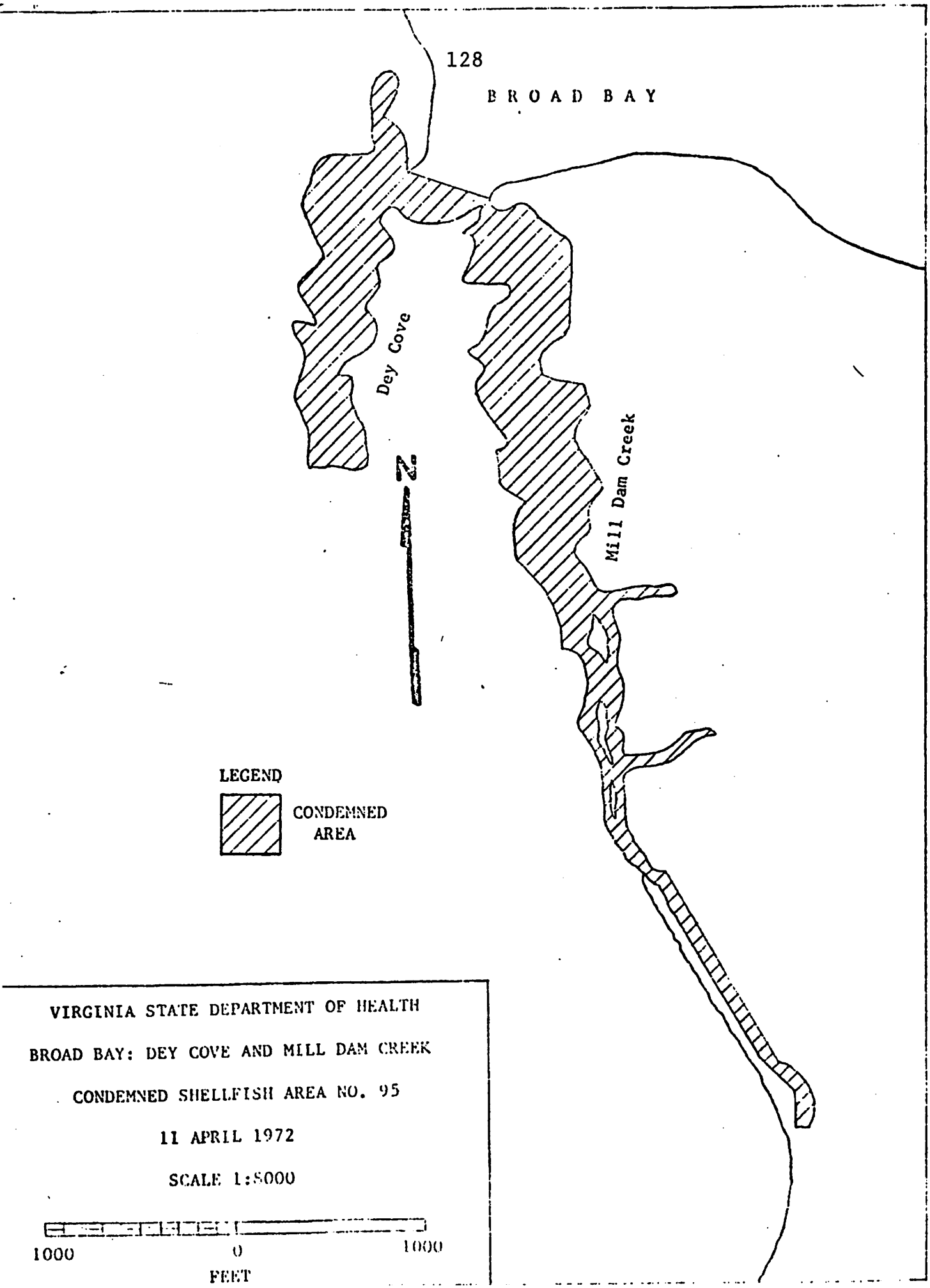
VIRGINIA STATE DEPARTMENT OF HEALTH

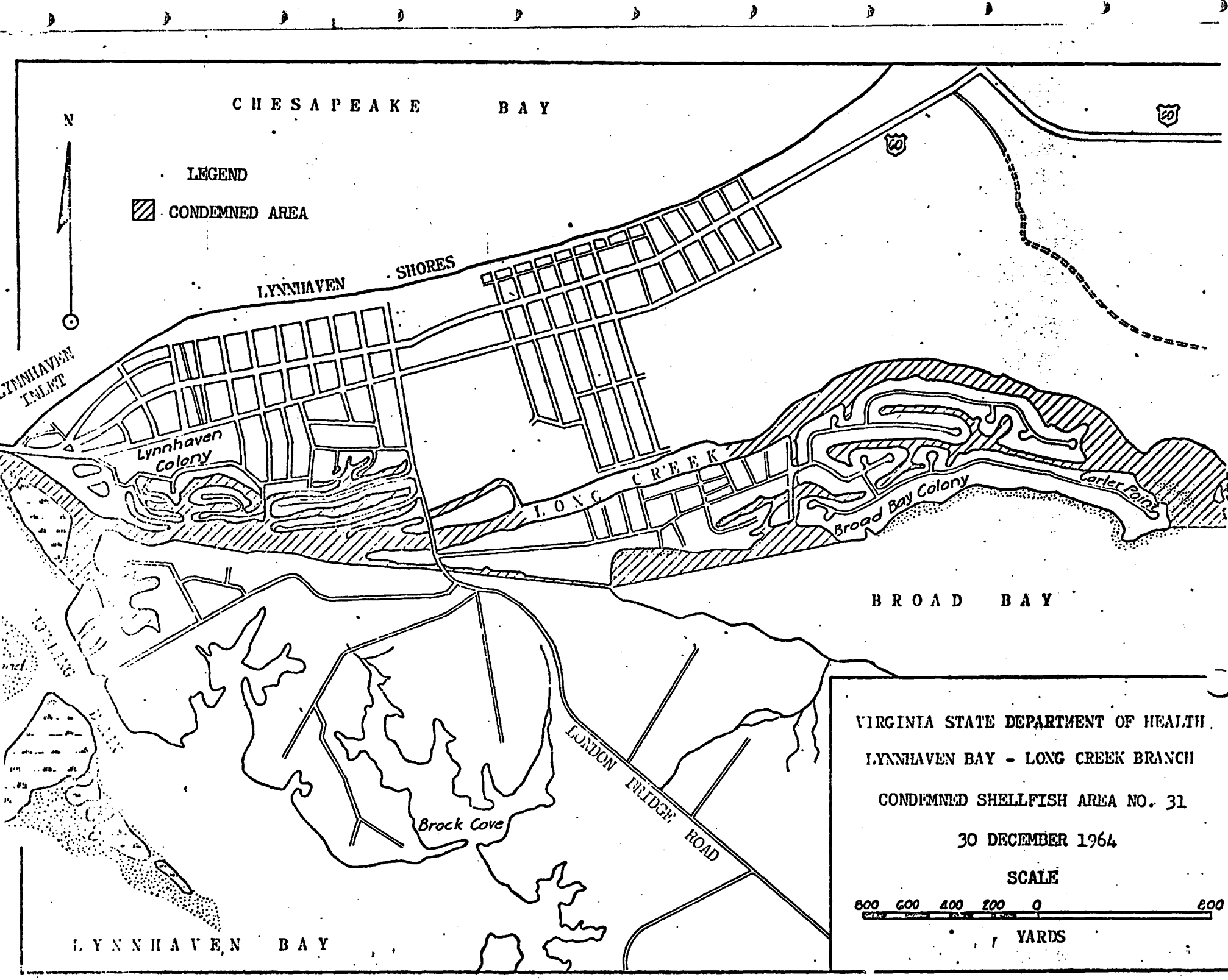
OF

LINKHORN BAY

RESTRICTED SHELLFISH AREA -10

OCT. 15, 1959


128
BROAD BAY
Dey Cove
Mill Dam Creek
N
LEGEND
CONDEMNED AREA
VIRGINIA STATE DEPARTMENT OF HEALTH
BROAD BAY: DEY COVE AND MILL DAM CREEK
CONDEMNED SHELLFISH AREA NO. 95
11 APRIL 1972
SCALE 1:8000
1000
0
1000
FEET


CHESAPEAKE BAY
N
LEGEND
CONDEMNED AREA
LYNNHAVEN SHORES
60
60
Lynnhaven Colony
LONG CREEK
Broad Bay Colony
Carter Point
129
BROAD BAY
Brock Cove
LONDON BRIDGE ROAD
LYNNHAVEN BAY
VIRGINIA STATE DEPARTMENT OF HEALTH
LYNNHAVEN BAY - LONG CREEK BRANCH
CONDEMNED SHELLFISH AREA NO. 31
30 DECEMBER 1964
SCALE
800 600 400 200 0 800
YARDS

Commonwealth of Virginia

DEPARTMENT OF HEALTH

RICHMOND

September 27, 1937

NOTICE And DESCRIPTION Of SHELLFISH RESTRICTION NO. 25
COMPRISING THE HEADWATERS ON THE EASTERN BRANCH Of
LYNNHAVEN RIVER AND TRIBUTARIES ABOVE.

As a result of sanitary surveys and bacteriological studies of Lynnhaven Bay and the branches thereof, it has been found necessary, at this time, to restrict the following described portion for the taking of shellfish for direct marketing.

BOUNDARIES Of AREA RESTRICTED

The area restricted includes all waters and shellfish beds within the Eastern Branch of Lynnhaven River and tributaries located above and south of a line across the stream extending due southwest from the extreme point of land which marks the north side entrance to the mouths of Wolfsnare and London Bridge Creeks and the third unnamed tributary extending southwest.

Therefore, in accordance with the provisions of Section 3255 of the Laws of Virginia Relating to Fisheries of Tidal Waters, you are hereby notified that the area described above is listed as a restricted area. You are also hereby advised that from the date of this notification, it shall be unlawful to take any oysters or clams from the above described area for any purpose except as specified in Section 3257 and Section 3258 of the above mentioned laws, providing for the removal of shellfish from condemned areas.

You are further advised that, during times of heavy or continuous rainfall, a considerable additional area in the Eastern branch extending below that now being restricted, has also been found to be subject to excessive pollution from animal wastes and surface drainage from the vicinity of homes. However, final action with respect to this condition, is being temporarily deferred pending the out come of efforts to secure certain sanitary improvements which have been recommended to eliminate sources of contamination.

Very truly yours,

State Health Commissioner

Encl. Map #25

RESTRICTED AREA NO. 25 - LYNNHAVEN RIVER
EASTERN BRANCH HEADWATERS & TRIBUTARIES ABOVE

Commonwealth of Virginia

DEPARTMENT OF HEALTH

RICHMOND

September 9, 1941

NOTICE AND DESCRIPTION OF SHELLFISH RESTRICTION NO. 29, COMPRISING AREAS IN THE EASTERN AND WESTERN BRANCHES OF LYNNHAVEN RIVER AND PLEASURE HOUSE CREEK TRIBUTARY TO LYNNHAVEN BAY

In accordance with the provisions of Section 3255 of the Laws of Virginia Relating to Fisheries of Tidal Waters, you are hereby notified that the areas in the Eastern and Western Branches of Lynnhaven River, Pleasure House Creek, and the tributaries thereof, as described below, are listed as restricted areas and that from the date of this notification it shall be unlawful to take any oysters or clams from the areas described below for any purpose except as specified in Section 3257 and Section 3258 of the above mentioned laws, providing for the removal of shellfish from condemned areas.

Boundaries of Areas Restricted

The areas restricted include all waters and shellfish beds in the Eastern and Western Branches of Lynnhaven River and Pleasure House Creek, which are within the boundaries described as follows:

EASTERN BRANCH

29-A All of that area within the Eastern Branch of Lynnhaven River and tributary coves located between the northern boundary line of the area previously restricted September 27, 1937, (See Restricted Shellfish Area No. 25), and a line extending due east to the opposite shore from the point of land east of the home, on the west side of the stream approximately southwest of Trants Point, owned by Mrs. Cora Gill, of Portsmouth, Virginia.

WESTERN BRANCH

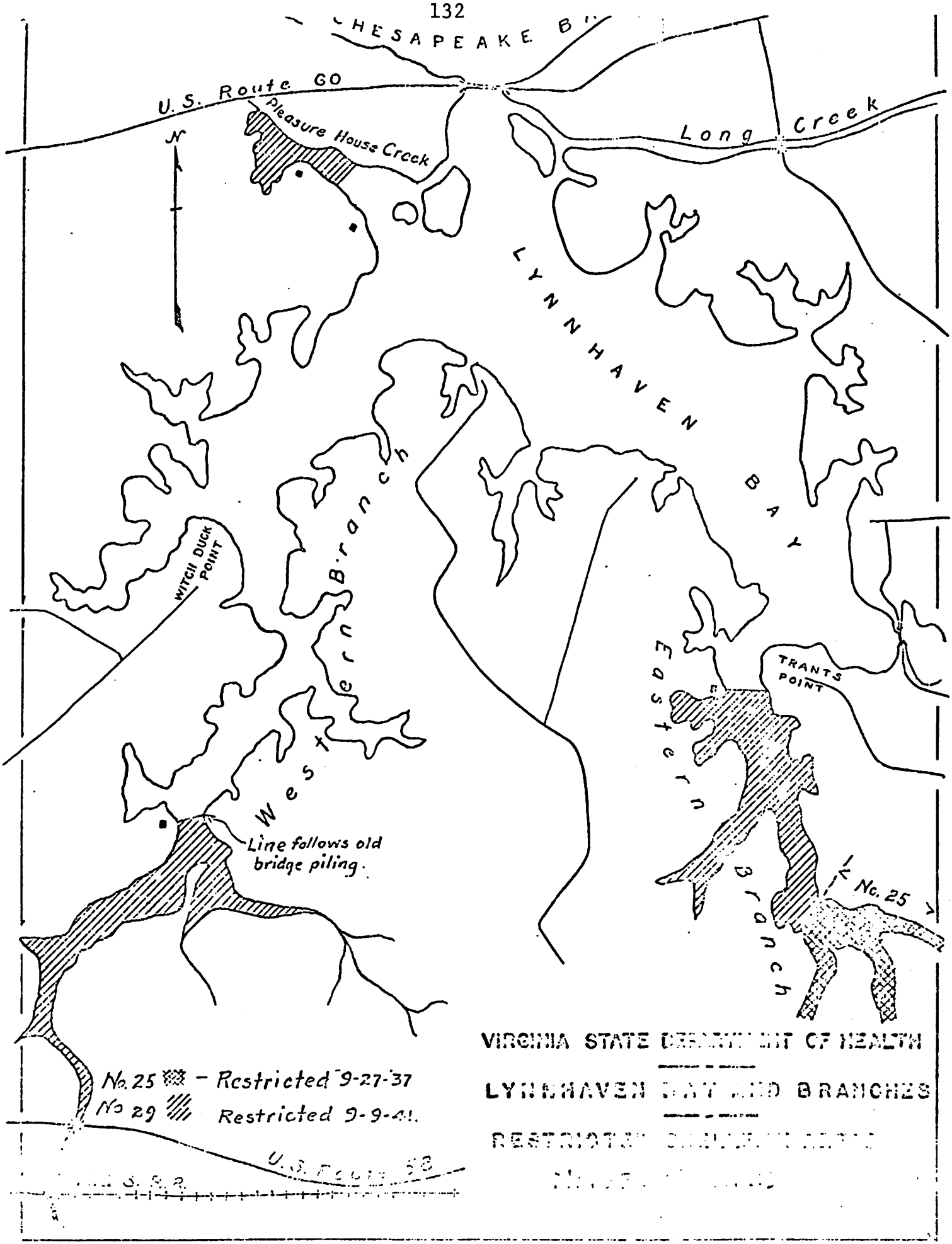
29-B All of that area within the Western Branch of Lynnhaven River and tributaries located upstream from and south of a line across the stream following the old bridge piling in an approximately easterly direction from the home known as "The Old Donation House", owned by Mr. L. C. Hudgins, of Lynnhaven, Virginia.

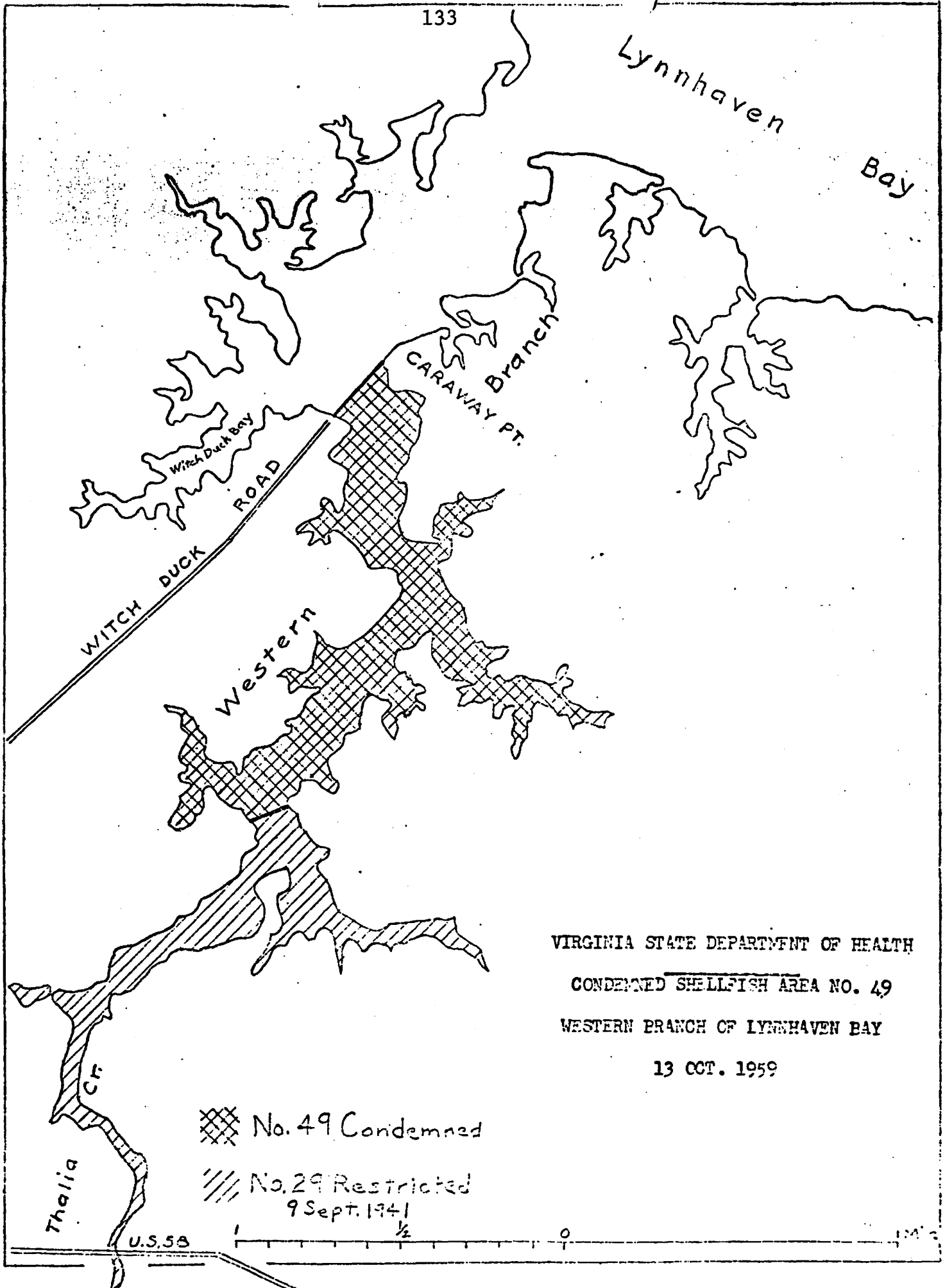
29-C All of that area within Pleasure House Creek, from the headwaters to a line extending across the creek northeast from a point on the southern shore, located midway between the tenant house owned by Bayville Farms and occupied by J. W. Bowman, located on the south side of the stream, and the next home northwest from the above, owned by the same (Bayville Farms), and also located just adjacent to the southern shore of the creek.

S. L. Riggin

State Health Commissioner

RESTRICTED AREA NO. 29 - LYNNHAVEN RIVER


CHESAPEAKE B
U.S. Route 60
Pleasure House Creek
Long Creek
N
LYNNHAVEN BAY
WITCH DUCK POINT
Western Branch
Line follows old bridge piling.
TRANTS POINT
Eastern Branch
No. 25
No. 25 - Restricted 9-27-37
No 29 Restricted 9-9-41.
U.S. Route 60
VIRGINIA STATE DEPARTMENT OF HEALTH
LYNNHAVEN BAY AND BRANCHES
RESTRICTED SHELLFISH AREAS

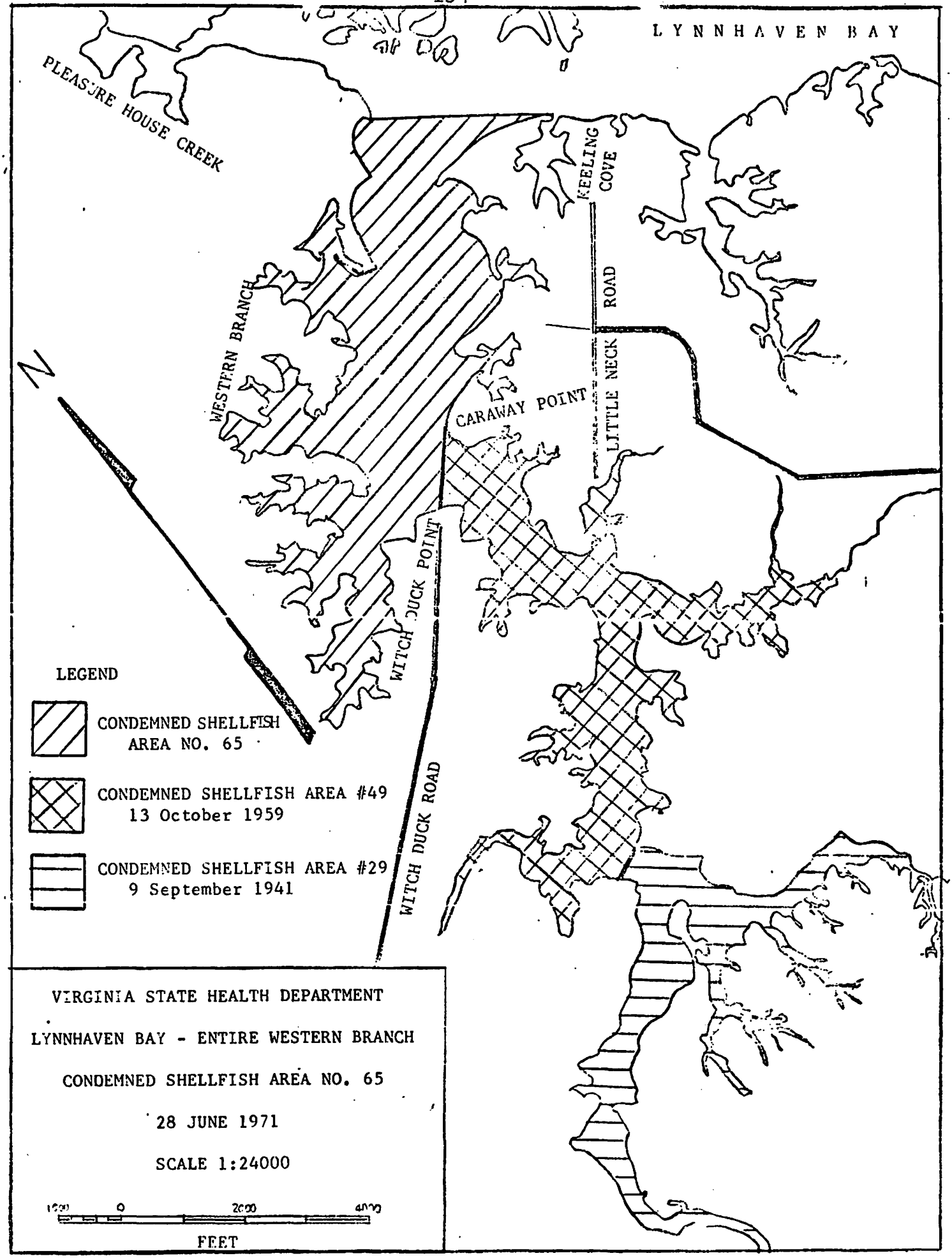


VIRGINIA STATE DEPARTMENT OF HEALTH

CONDEMNED SHELLFISH AREA NO. 49

WESTERN BRANCH OF LYNNHAVEN BAY

13 OCT. 1959


LYNNHAVEN BAY
PLEASURE HOUSE CREEK
KEELING COVE
WESTERN BRANCH
LITTLE NECK ROAD
CARAWAY POINT
WITCH DUCK POINT
WITCH DUCK ROAD
N
LEGEND
CONDEMNED SHELLFISH AREA NO. 65
CONDEMNED SHELLFISH AREA #49
13 October 1959
CONDEMNED SHELLFISH AREA #29
9 September 1941
VIRGINIA STATE HEALTH DEPARTMENT
LYNNHAVEN BAY - ENTIRE WESTERN BRANCH
CONDEMNED SHELLFISH AREA NO. 65
28 JUNE 1971
SCALE 1:24000
0
2000
4000
FEET

COMMONWEALTH OF VIRGINIA

135

MACK I. GHANHOLTZ, M. D.
COMMISSIONER

DEPARTMENT OF HEALTH
RICHMOND, VA. 23219

NOTICE OF RESCISSION OF SHELLFISH AREA CONDEMNATION NUMBER 66, LOWER JAMES & NANSEMOND RIVERS & TRIBUTARIES-HAMPTON ROADS-CHESAPEAKE BAY-LYNNHAVEN COMPLEX

EFFECTIVE 8 FEBRUARY 1972

In accordance with the provisions of Title 28.1, Chapter 7, Sections 28.1-175 through 28.1-177, Code of Virginia, the condemnation of Shellfish Area Number 66 as specified in "Notice and Description of Shellfish Area Condemnation Number 66, Lower James & Nansemond Rivers & Tributaries-Hampton Roads-Chesapeake Bay-Lynnhaven Complex, effective 6 October 1971" is rescinded effective 8 February 1972.

The boundaries of the areas thus reopened for the direct marketing of shellfish are described as:

A. James River - Hampton Roads. All the area in the James River and Hampton Roads lying southeast of a line extending due north from USE triangulation station "Day" located on Days Point at the mouth of the Pagan River to a point on Mulberry Island marked "Stumps", including all tributaries in the area not previously condemned and joining Condemned Shellfish Area Number 7, Hampton Roads.

B. Chesapeake Bay. The area begins at the southwest corner of Condemned Shellfish Area Number 60 (Chesapeake Bay Adjoining Little Creek); thence along this line due north ± 1 mile to the northwest corner of Condemned Shellfish Area Number 60 which is a point on the 24' contour (approximately 36°56'30" 76°09'25"); thence in a northwesterly direction to Thimble Shoal Light; thence in a west-southwest direction to the Bell on Old Point Comfort; thence westerly to the principal Army Dock on Fort Monroe; thence (along eastern boundary of Restricted Shellfish Area Number 15) which extends southeasterly to a point 1000 yards off shore which bisects a line extended from Traffic Control Aero at the Naval Air Station to Thimble Shoal Light; thence southwesterly along this line to the shore; thence southeasterly along the shore to the point of beginning.

C. Lynnhaven Complex. All the area lying upstream from the Lesner Bridge (U. S. Route 60) not previously condemned in Lynnhaven Bay, Lynnhaven River, Broad Bay and their tributaries.

All shellfish condemnations in this area established prior to Shellfish Area Condemnation Number 66 remain valid and in effect.

Virginia State Health Department

Lynnhaven Bay: Brock Cove

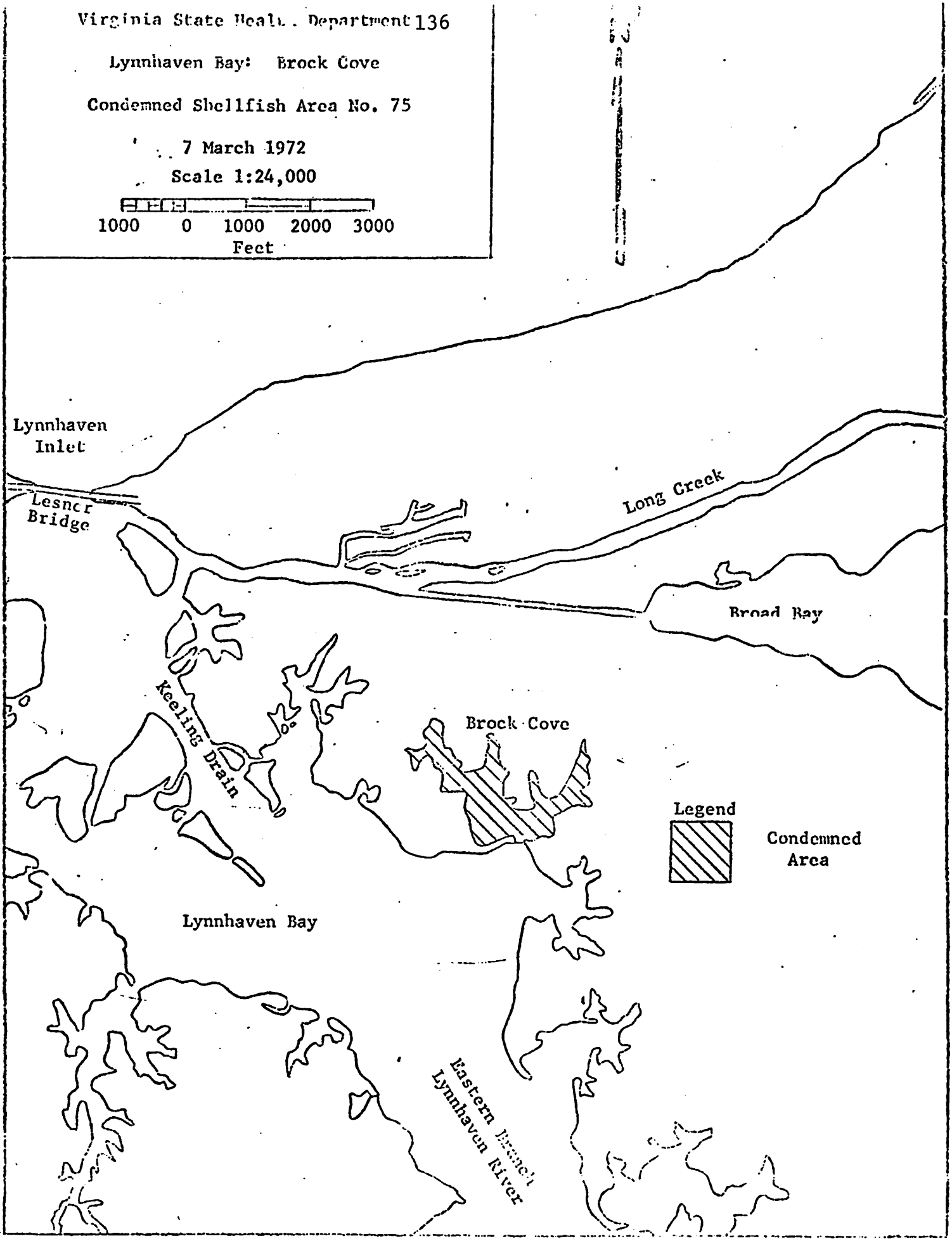
Condemned Shellfish Area No. 75

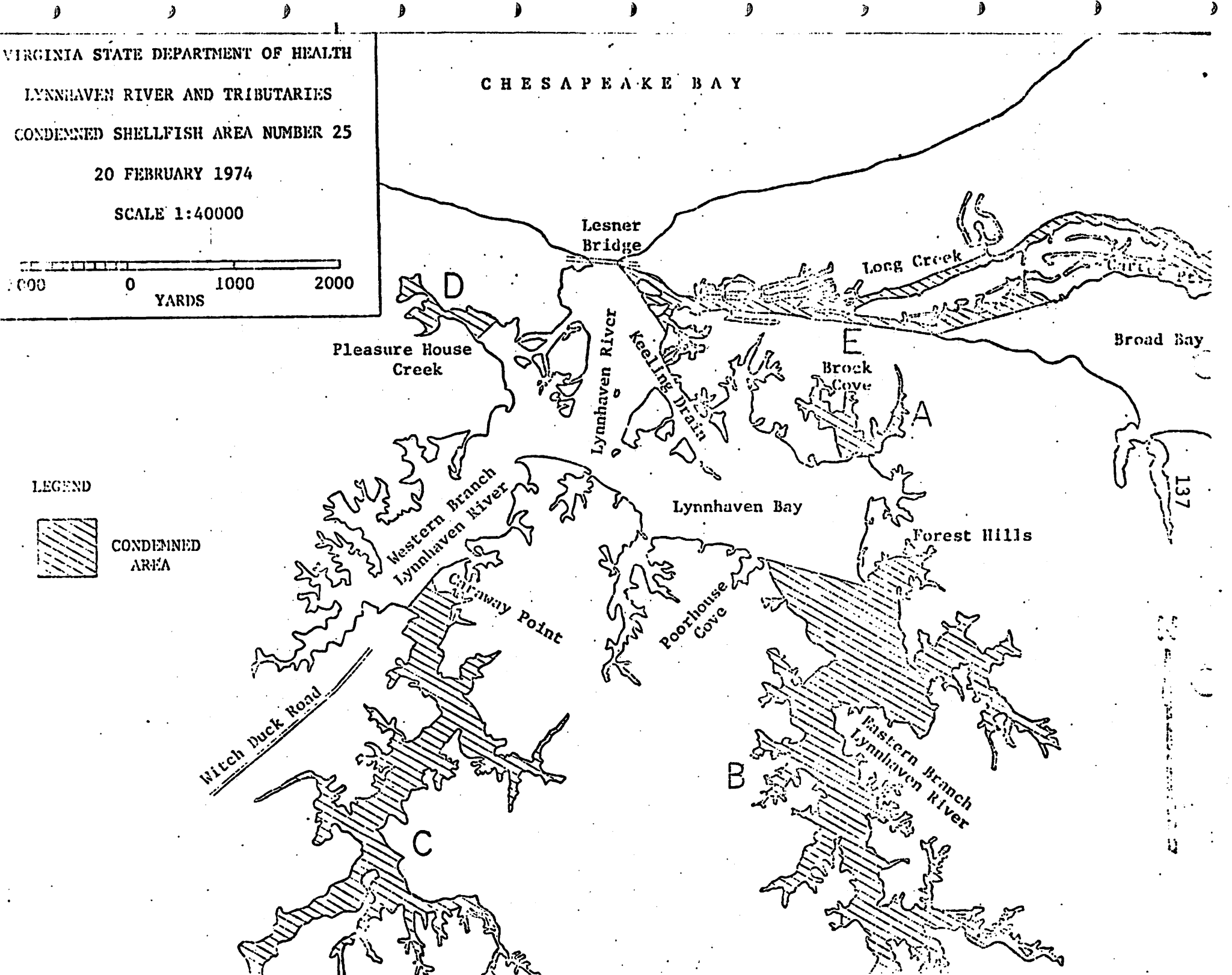
7 March 1972

Scale 1:24,000

1000 0 1000 2000 3000

Feet




VIRGINIA STATE DEPARTMENT OF HEALTH
LYNNHAVEN RIVER AND TRIBUTARIES
CONDEMNED SHELLFISH AREA NUMBER 25
20 FEBRUARY 1974
SCALE 1:40000
000 0 1000 2000
YARDS
CHESAPEAKE BAY
Lesner Bridge
Long Creek
Broad Bay
D
E
A
B
C
Pleasure House Creek
Lynnhaven River
Keeling Drain
Brock Cove
Western Branch Lynnhaven River
Lynnhaven Bay
Forest Hills
137
Caraway Point
Poorhouse Cove
Witch Duck Road
Eastern Branch Lynnhaven River
LEGEND
CONDEMNED AREA

COMMONWEALTH OF VIRGINIA

MACK I. SHANHOLTZ, M. D.
COMMISSIONER

DEPARTMENT OF HEALTH
RICHMOND, VA. 23219

NOTICE AND DESCRIPTION OF SHELLFISH AREA CONDEMNATION NUMBER 25, LYNNHAVEN, BROAD, AND LINKHORN BAYS AND TRIBUTARIES

EFFECTIVE 24 MARCH 1975

Pursuant to Title 28.1, Chapter 7, Section 28.1-175 through 28.1-177, Code of Virginia, notice is hereby given that:

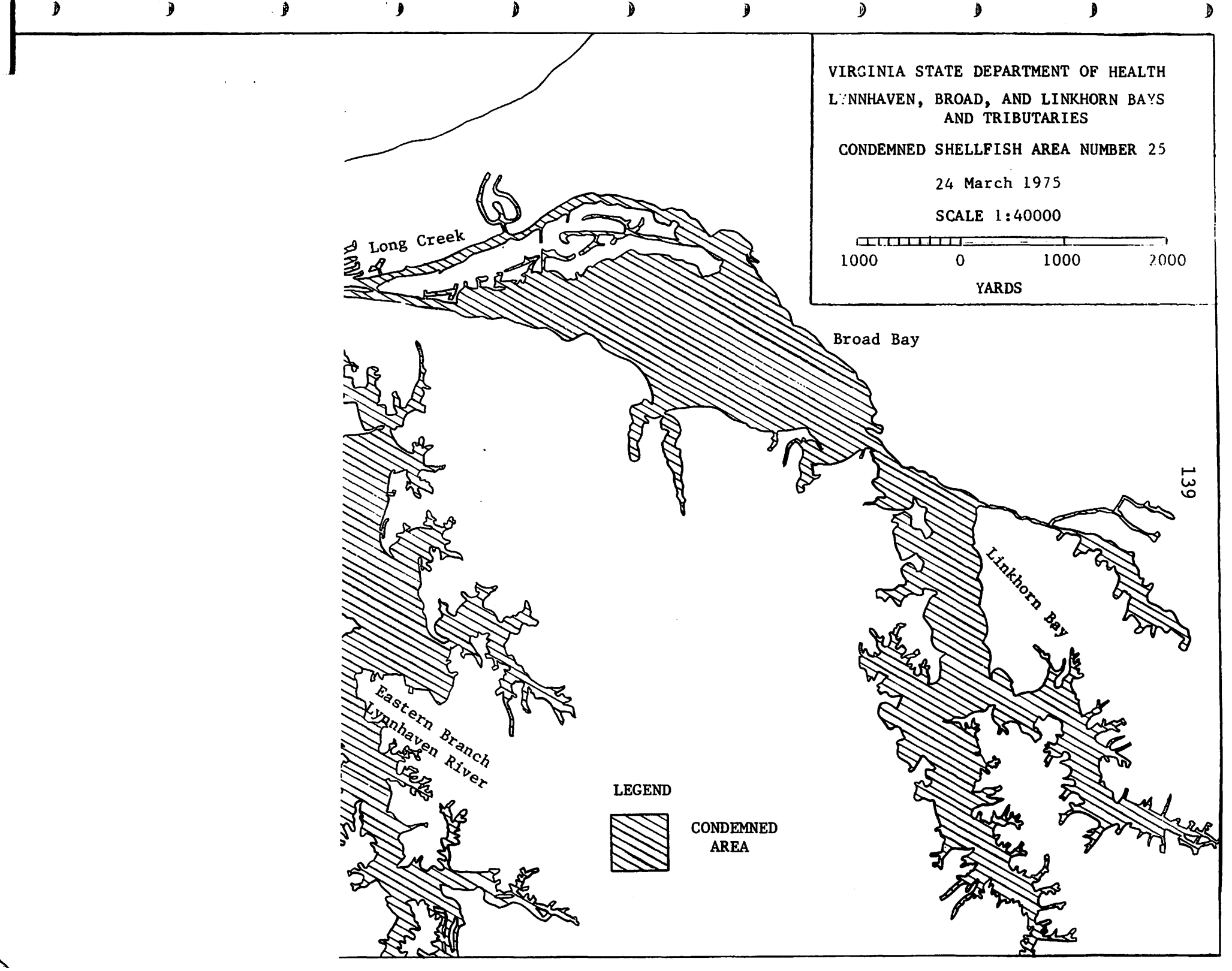
1. The "Notice and Description of Shellfish Area Condemnation Number 25, Lynnhaven River and Tributaries, Effective 20 February 1974," the "Description of Shellfish Area Condemnation Number 10, Linkhorn Bay, Effective 15 October 1930," and the "Notice and Description of Shellfish Area Condemnation Number 95, Broad Bay: Dey Cove and Mill Dam Creek, Effective 11 April 1972" are all cancelled.

2. Condemned Shellfish Area Number 25, Lynnhaven, Broad, and Linkhorn Bays and Tributaries, Effective 24 March 1975 is established. It shall be unlawful for any person, firm, or corporation to take shellfish from this area for any purpose, except by permit granted by the Marine Resources Commission, as provided in Title 28.1, Chapter 7, Section 28.1-179, Code of Virginia. The boundaries of this area are shown on map titled "Lynnhaven, Broad, and Linkhorn Bays and Tributaries, Condemned Shellfish Area Number 25, Effective 24 March 1975" which is a part of this notice.

BOUNDARIES OF CONDEMNED AREAS

The condemned area includes all of Broad, Linkhorn, and Lynnhaven Bays and all of their tributaries lying upstream of the upstream side of the Lesner Bridge.

Mack I. Shanholtz
State Health Commissioner


VIRGINIA STATE DEPARTMENT OF HEALTH
LYNNHAVEN, BROAD, AND LINKHORN BAYS AND TRIBUTARIES
CONDEMNED SHELLFISH AREA NUMBER 25
24 March 1975
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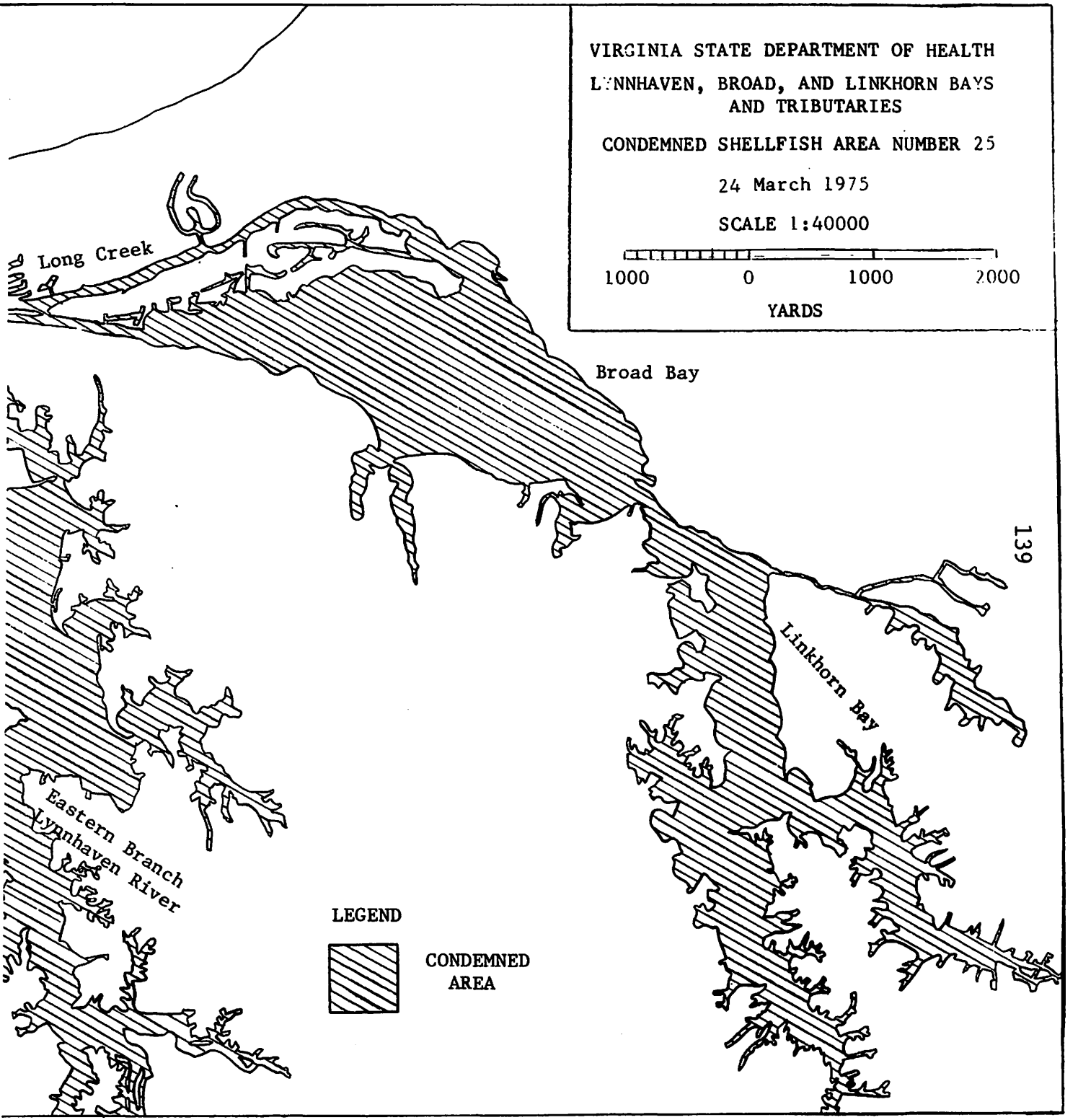
YARDS
Long Creek
Broad Bay
Linkhorn Bay
Eastern Branch Lynnhaven River
LEGEND
CONDEMNED AREA
139


VIRGINIA STATE DEPARTMENT OF HEALTH
LYNNHAVEN, BROAD, AND LINKHORN BAYS AND TRIBUTARIES
CONDEMNED SHELLFISH AREA NUMBER 25
24 March 1975
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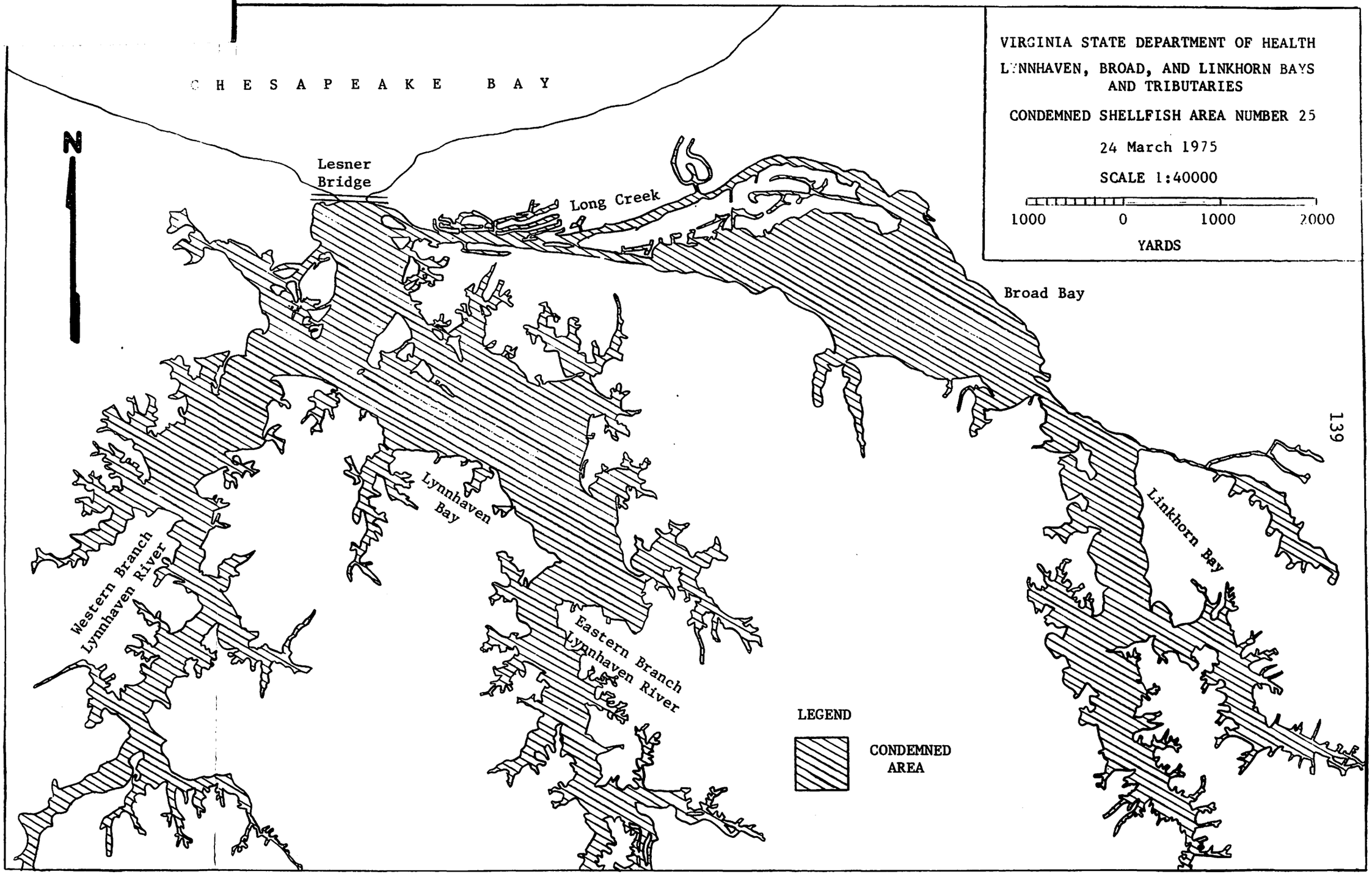
YARDS
Long Creek
Broad Bay
Linkhorn Bay
Eastern Branch Lynnhaven River
LEGEND
CONDEMNED AREA


VIRGINIA STATE DEPARTMENT OF HEALTH
LYNNHAVEN, BROAD, AND LINKHORN BAYS AND TRIBUTARIES
CONDEMNED SHELLFISH AREA NUMBER 25
24 March 1975
SCALE 1:40000
1000 0 1000 2000
YARDS
CHESAPEAKE BAY
N
Lesner Bridge
Long Creek
Broad Bay
Lynnhaven Bay
Western Branch Lynnhaven River
Eastern Branch Lynnhaven River
Linkhorn Bay
LEGEND
CONDEMNED AREA