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National Estuarine Inventory
Data Atlas

Volume 1: Physical and Hydrologic Characteristics

Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
United States Department of Commerce

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U.S. DEPARTMENT OF COMMERCE
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Preface

Estuaries are among our most productive natural systems. The freshwater and nutrients that estuaries provide to coastal areas are critically important to sustaining the health of most living marine resources in these areas, and in providing important habitat, particularly during early life stages. Society also places a high value on these areas as places for living, working, and recreating. Because of their importance to both economic development and ecological processes, estuaries are among our most heavily used and highly stressed natural systems.

In spite of their high value, intense use, and frequent overuse, estuaries have not been widely recognized as a unique or important depleted resource base of national significance. Unlike our forests, farmlands, parks, and wildlife refuges, no Federal program is dedicated to developing a comprehensive and consistent national policy on the use and management of estuaries. Although several Federal laws have been enacted, including the Clean Water Act, the Coastal Zone Management Act, and the Marine Protection, Research, and Sanctuaries Act, they only partially or indirectly affect how estuaries are used. Most decision makers and scientists continue to address selected estuaries on an individual basis only, with little or no directed, comprehensive national focus.

Two previous studies completed over 15 years ago, the *National Estuary Study* (U.S. Department of the Interior, 1970) and the *National Estuarine Pollution Study* (U.S. Department of the Interior and the Federal Water Pollution Control Administration, 1969), remained until NOAA's current effort the only attempts to inventory comprehensively the estuaries of the USA and assess their condition. The neglect of estuaries as a natural resource is symbolized by the fact that the data gathered during the *National Estuarine Pollution Study* are lost and unaccounted for. Without a comprehensive national data base, the assessment and comparison of conditions of estuaries and the development of effective national policies are not possible.

NOAA has unique capabilities to conduct comprehensive assessments of estuaries throughout the USA. Its collective scientific expertise, research laboratories, and data collection technology and platforms (from ships to satellites) are unparalleled. Within this context, the Ocean Assessments Division (OAD) conducts research, assessment, and monitoring activities on environmental quality problems of the Nation's estuaries, as well as coastal and oceanic areas. Through its National Status and Trends Program, OAD is conducting the largest national field monitoring program ever undertaken to measure and assess chemical contamination in estuarine and coastal areas of the USA. Through its National Coastal Pollutant Discharge Inventory, OAD is developing a capability to analyze the sources and discharges of pollutants throughout estuarine areas of the USA. In close cooperation with scientists of the National Marine Fisheries Service, OAD is working to quantify better the effects of estuarine pollution, compile and assess information on the status and trends of classified shellfishing waters, and determine the status and trends of coastal wetlands of the USA. Results of these NOAA efforts will be incorporated into the "National Estuarine Inventory (NEI) Data Base."

This data atlas is the first major product of NOAA's efforts to develop a National Estuarine Inventory. The atlas and inventory are integral parts of a national program of comprehensive "strategic assessments" through which NOAA is developing information useful for identifying or modifying national objectives for coastal and oceanic resource development and conservation (Ehler and Basta, 1984). Current plans are to add to the National Estuarine Inventory available information on the distribution and abundance of living resources within estuaries, as well as to expand the information base on human activities that affect estuaries. Depending upon an evaluation of the utility of the inventory, geographic coverage may be expanded to include additional estuaries, such as those in the State of Alaska, which were initially excluded because of their relatively undisturbed state, or smaller estuaries which did not meet our preliminary selection criteria.

When the inventory is completed, it will be used to make comparisons, rankings, statistical correlations, and other analyses related to resource use, environmental quality, and economic values among estuaries. We strongly encourage scientists, analysts, and managers in both the public and private sector to review carefully this work and provide us with their thoughts on refining, developing further, and using the National Estuarine Inventory.

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Introduction

Estuaries provide the Nation with a rich variety of goods and services. They are important features of the Nation's coastal regions, especially along the Atlantic Coast and the Gulf of Mexico, and represent the transition zone between freshwater and marine ecosystems. They are most commonly defined as semi-enclosed coastal bodies of water having a free connection with the open sea and within which seawater is measurably diluted with freshwater from land drainage (Pritchard, 1967).

The important role that estuaries play in sustaining the health and abundance of marine fishes, shellfish, and birds has been recognized for a long time. However, only recently has attention been focused on the total mix of multiple goods and services that estuarine systems provide. The Nation values its estuaries as sources of food, recreation, and aesthetic pleasure. It also demands that estuaries provide cooling waters for industry and energy production, accommodate the needs of large ships and tanker traffic, sacrifice wetland and bottom habitat to supply space for coastal development, and transfer pollutant loads from the Nation's rivers and streams into coastal and oceanic waters. Dense populations are another feature of the coastal areas that estuaries occupy. They are among the most intensely populated and used spaces in the Nation: more than 75 percent of the population of the USA will live within 50 miles of the coastline by 1990 (Council on Environmental Quality, 1984). As the demand for the services and resources that estuaries provide continues to increase, so will conflicts among the competing users of this important national resource base.

I. Purpose

The *National Estuarine Inventory: Data Atlas* is the first product from a series of activities now underway in the Ocean Assessments Division to develop a national estuarine assessment capability. The atlas does not compile all characteristics on all estuaries in the USA. Its objectives were more modest. The first objective was to identify and specify the extent of most of the estuaries on each coast of the contiguous USA. The second was to compile information in a consistent manner on the basic physical and hydrologic characteristics of each estuary. The third was to determine the boundaries and land use characteristics of the drainage basins that directly affect each estuary. The fourth objective was to provide a comprehensive framework for initiating discussion among estuarine scientists, resource managers, and government officials on the uses and health of the estuaries of the USA.

This is the first of two volumes of the *National Estuarine Inventory: Data Atlas*. It presents information, through maps and tables, on the most important physical and hydrologic characteristics of each estuary. The 92 estuaries included in the inventory and portrayed in this volume represent approximately 90 percent of the surface area of estuarine waters along the northeast coast, the southeast coast, the Gulf of Mexico coast, and the west coast of the USA. These estuaries also account for more than 90 percent of the freshwater inflow entering each of the four coastal regions. Figure 1 shows the approximate national coverage of the drainage areas that directly affect the 92 estuaries. Some of the 92 estuaries do not fit exactly the classic definition of an estuary. They have been included, however, because they are important coastal features, often display estuarine characteristics, and provide important habitat for many marine animals.

Volume II presents land use information for each of the 92 estuaries in both mapped and tabular form. Acreage estimates for each of 25 categories of land use are organized by: (1) the drainage area that directly affects each estuary (estuarine drainage area); (2) U.S. Geological Survey Cataloging Unit; and (3) the counties that fall within each estuarine drainage area.

The information presented in these volumes can be used to understand the general characteristics of each estuary and the similarities and differences among individual estuaries or groups of estuaries. This atlas will help to demonstrate the various ways information about the Nation's estuarine resource base can be organized and characterized through a comprehensive national assessment capability.

II. Making the Atlas

Preliminary planning and data collection for developing the National Estuarine Inventory and assessment capability began in the summer of 1983. It soon became clear that an important and necessary first step was to develop a set of maps that clearly identified the relevant boundaries of each estuary. Without a consistent identification of boundaries for all estuaries, it would not be possible to compile a complete and consistent data base for the Nation. Consequently, the concept of an atlas began to take shape, from a simple set of maps to be used for data collection, to a rough workbook of reference maps, and finally to an atlas containing maps and data summaries. The data collected and portrayed in the atlas represent the first comprehensive, consistent, and complete set of information to be incorporated into the National Estuarine Inventory Data Base.

Actual work on systematic development of the atlas began October 1984 when the firm of Dalton • Dalton • Newport (DDN, now URS Dalton), Cleveland, Ohio, was awarded a contract by NOAA to produce the atlas. As development of the atlas proceeded, many revisions in its content and portrayal were made by the NOAA/DDN project team. Four important aspects of this process are described below.

Base Maps

An initial design objective was to portray each estuary in the atlas on a single page, including all tabular data on its characteristics. However, a second volume in this series will present the land use data on each estuary and related maps. In this volume (Volume I), each estuary is mapped with only its physical and hydrologic characteristics portrayed.

U.S. Geological Survey (USGS) State Hydrologic Unit maps (1:500,000) were used as a standard base to identify and map estuarine boundaries and features. The USGS maps were chosen because they clearly and consistently depict the boundaries of coastal drainage basins, identify numerous features important for plotting information, and provide reasonable coastline definition. Because of the large size of some estuaries, such as Chesapeake Bay and Long Island Sound, some of the original 1:500,000 maps had to be reduced to fit each estuary on one page. Consequently, six map scales appear in the atlas: 1:500,000; 1:750,000; 1:1,000,000; 1:1,280,000; 1:1,500,000; and 1:2,750,000 (Puget Sound only). For a few extremely large estuaries, important subsystems were mapped separately to capture their individual characteristics.

Several modifications were made to the original USGS base maps to enhance the portrayal of each estuary and its important features. First, most place names, small streams, and certain geographic features were removed to simplify presentation. The USGS maps were never intended to emphasize estuarine features and contained considerable information not necessary for the portrayal of estuarine characteristics. Second, coastal and estuarine shorelines, estuarine zones, and drainage basin boundaries were enhanced to emphasize these features. Third, tones and symbols were added to distinguish more clearly zones and boundaries and to locate specific items, such as head of tide, tide gages, and flow gages.

The maps are a schematic representation of each estuary. They are not intended to provide detailed information for navigation or locating specific facilities. Collectively, they provide a simple and consistent picture of the major physical and hydrologic characteristics of the estuarine resource base of the USA.

Selecting and Organizing the Data

Preliminary planning and data collection for the National Estuarine Inventory indicated that the physical, chemical, biological, and economic data necessary for conducting a comprehensive assessment of the use and health of the Nation's estuaries were either unavailable, incomplete, or in a very difficult form to use. It would not be possible to develop a comprehensive data base and transform these data into meaningful information in a short period of time.

Criteria were established to determine the subset of data that would be compiled and mapped in the atlas. First, the data would have to describe as completely as possible at least one set of important characteristics of the Nation's estuaries. Second, they would have to provide a foundation upon which information on other important characteristics, for example, living resources or economic activities, could be added. Third, the data would have to be sufficient to permit at least a preliminary analysis of the use and health of the estuaries of the USA. Fourth, the data had to be either generally available for most estuaries from existing sources or be easily derived by standard estimation procedures applied uniformly to all estuaries. Fifth, the data selected could be compiled, organized, mapped, and an atlas produced with the resources available.

Three categories of data that met these criteria were selected: (1) physical dimensions and characteristics; (2) hydrologic parameters, including both tidal and freshwater inflow data; and (3) distribution of land use. Each of these is discussed below in more detail (Data Categories). All physical and hydrologic data are summarized in a table adjacent to the map showing the boundaries and major features of each estuary. Cross-section diagrams of the mouths and natural outlets of each estuary also are shown next to the map. Twenty-five categories of land use are summarized in tabular form in Volume II and organized by estuarine drainage area, USGS Hydrologic Cataloging Unit, and county. All tabular data in Volumes I and II have been organized for easy entry into the National Estuarine Inventory Data Base.

Data Collection and Validation

Collecting the best available data on the physical, hydrologic, and land use characteristics of 92 estuaries, and processing it into a reasonably consistent data base was a major undertaking, even for the relatively

small number of parameters that appear in this data atlas. With the exception of prevailing tide type and location of measuring stations, comprehensive and consistent data bases from which parameter values could be selected, directly entered into a data table, or mapped could not be located. Every parameter required development of estimation procedures. For example, all of the data needed to estimate tidal prism volume required some data development and modification. Even requisite tidal data, which were thought to be available readily in NOAA tide tables, had to be augmented through special computer runs of NOAA's national tidal data base.

Reasonably strict criteria were used to evaluate the data needed to estimate each parameter. For example, freshwater inflow data obtained from the USGS were used only if: (1) the gaging station at which the data were collected had a high USGS internal accuracy and integrity rating; (2) was an active gage; and (3) covered a minimum period of 10 years. For simple parameters, such as depth and surface area, existing published sources did not provide consistent and reliable estimates that could eventually be used to compare estuarine systems. Consequently, rather than using available published values, these parameters were estimated by digitizing the appropriate features from more than 200 standard NOAA nautical charts and following uniform and consistent estimation procedures.

Personal communication with estuarine experts within each region and on individual estuaries was particularly helpful. Experts not only identified local data sources and assessed the appropriateness of various data and estimation techniques, but gave crucial assistance in estimating certain parameters. This was especially true for determining the boundaries and variability between the tidal fresh, mixing, and seawater zones in each estuary. The data needed to estimate the location of these features for most estuaries are either incomplete or nonexistent. Consequently, in many cases, the zones shown on the estuarine maps often represent the "best guess" by informed experts. Communication with experts was also important for classifying estuaries according to stratification and, in several cases, determining the most important openings to the sea for developing cross-section profiles.

The process of validating the data developed for each estuary consisted of two parts. The first was checking and rechecking to ensure that no errors had been made in applying estimation procedures. Most parameters were computed at least twice, once by DDN and once by NOAA. Second, all parameters and mapped information were assessed to determine whether they reasonably represented each estuary. This again was done independently by NOAA and DDN. Values for individual estuaries were compared where possible with those in the published literature, compared among similar estuaries, and reviewed by regional and local experts. Given the inherent natural variability of these parameters, reasonableness was defined as those values and mapped data that represent long-term averages for each estuary as they are now known.

Although it was impossible to assess exactly the level of certainty associated with each parameter for every estuary, the following general rules should guide the user:

- Information on estuaries along the west coast, except Puget Sound, the Columbia River and San Francisco Bay, is less certain than for estuaries on the other coasts. Because this region has fewer estuaries, west coast estuaries have received much less attention by individual researchers and institutions than other estuaries of the USA;
- Physical dimensions are the most accurate information portrayed, followed by information on freshwater inflow and tidal characteristics;
- Information on tidal prism volume, estuarine zones, and stratification tends to be less accurate for estuaries with complex topography and geometry, except for those that have been heavily studied such as Chesapeake Bay; and
- Information on estuarine zones and stratification also tends to be less accurate for estuaries that do not fit exactly the classical definition of an estuary, have not been studied in depth, or routinely experience dramatic variability.

The data collected represent the only comprehensive, complete, and reasonably consistent information base on the physical, hydrologic, and land use characteristics of the estuaries of the USA. In spite of the variability and uncertainty mentioned, scientists, analysts, managers, and other interested parties in the public and private sector should find the data and maps useful. A detailed discussion of how land use data were collected and validated is contained in Volume II.

III. Data Categories

Physical Characteristics and Dimensions

The physical characteristics of an estuary are primary determinants of estuarine processes and ultimately affect the ecology of a system. Important physical parameters for which information was compiled include the dimensions of an estuary, its drainage area, its stratification classification, and the areas of the tidal fresh, mixing, and seawater zones.

Estuarine and Fluvial Drainage Areas The estuarine drainage area (EDA) is that land and water component of an entire watershed (measured in square miles) that most directly affects an estuary. The purpose of identifying an estuarine drainage area is to establish the spatial unit for compiling land use, flow data, and factors that affect each estuary. The EDA is outlined on each map and shaded on the regional inset map; its dimensions are listed in the physical and hydrologic characteristics tables.

EDAs were defined based on the limits of tidal influence within an estuarine system and the boundaries of U.S. Geological Survey (USGS) hydrologic cataloging units. A hydrologic unit is a geographic area representing part or all of a surface drainage basin or a distinct hydrologic feature. Cataloging units, the smaller of four levels of hydrologic units, are usually greater than 700 square miles in area.

EDAs were drawn to coincide with hydrologic cataloging unit(s) that contain the heads of tide and seaward estuarine boundaries. In many cases, this means the EDA extends landward beyond the head of tide. In other more limited instances, the EDA may intersect a cataloging unit.

Where the EDA coincided with cataloging units, area estimates were obtained from USGS. In cases where the EDA did not coincide with cataloging unit boundaries, areas were measured with a planimeter to derive a value for the total estuarine drainage area.

In addition to identifying the EDA, the fluvial drainage area (FDA) was determined by inspection of hydrologic unit maps and reviews of USGS state water resource reports. The FDA is the land and water portion of the entire watershed upstream of the EDA. In some instances, the FDA coincides with the EDA. This often occurs where the total drainage to the system is small and may consist of only one or two hydrologic units. Fluvial drainage areas are shown only on the inset map.

Estuary Surface Area The surface water area of an estuary was estimated from the physical head of tide of the estuary and its tributaries to the mouth, where the estuary empties into an ocean, bay, gulf, sound, or other water body. Head of tide was interpreted from coastal ecological inventory maps prepared by the U.S. Fish and Wildlife Service (DOI, 1980-81, scale 1:250,000). These maps indicate areas of change in the distribution of living marine resources due to salinity concentrations and approximate the average point on a stream where surface water elevation is no longer influenced by the rise and fall of the tide. In addition, data were obtained from *U.S. Coast Pilots*, published by NOAA, and from USGS district offices, U.S. Army Corps of Engineers, and state water or natural resource agencies.

The seaward boundary for each estuary was determined by inspection of USGS hydrologic unit maps and NOAA nautical charts to identify significant physiographic characteristics and other features, such as barrier islands, rock outcrops, and manmade structures. If no clear physiographic limits existed, the charts were used to decipher bottom features that can affect circulation patterns and mixing processes. These include overall bathymetry, sills, and reefs. In addition, the point at which a subestuary enters a main system was delineated as the mouth of the subestuary. The shoreline at mid-tide level was measured with a planimeter to obtain the surface area. These data are represented on the physical and hydrologic characteristics table as the total sum of the three estuarine zones.

Estuary Length Estuary length (shown in miles) was delineated along the main axis of the estuary from the head of tide of the principal tributary stream to the midpoint of the estuary mouth or principal opening to the sea. In cases where the seaward opening or estuary boundaries were not clearly defined by shoreline morphometry, the axis was drawn following the approximate centerline of the direction of net flow for the estuarine water mass. This was determined on the basis of prevailing currents and major subsurface features.

Estuary Width Average width (shown in miles) was determined by measuring a series of regularly spaced perpendiculars to the main axis of the water body on NOAA nautical charts, drawn at mid-tide level, and averaged. The number of perpendiculars for an individual system was a function of estuary length and the shoreline irregularity. Maximum and minimum estuary widths were measured on NOAA nautical charts along perpendiculars to the main axis at approximately mid-tide level.

Introduction *(continued)*

Depth Average estuary depth (shown in feet) was calculated by overlaying a transparent grid of equal horizontally- and vertically-spaced lines on NOAA nautical charts that show depth soundings. Depths were recorded at the intersection of these lines or interpolated, where necessary, and summed and divided by the number of intersections. Because depth soundings are recorded for low-water level, the final average depth was obtained by adding the difference in elevation between low-water datum and mid-tide elevation.

Average Depth to Width Ratio This parameter provides an indication of the depth of an estuary relative to its width. It was calculated as a ratio of the values obtained for average depth and average width.

Cross Section The physical communication of estuarine waters with the coastal ocean affects many processes, including circulation and flushing rates. This interaction of ocean and estuary is controlled by the physical dimensions of an estuary mouth. A cross section of each estuary mouth and/or major opening to the sea is shown adjacent to each map. These figures depict width, depth at mean high water, bottom contours, and other salient features such as ship channels and landmarks.

Scale ratio is an indication of vertical exaggeration. Vertical exaggeration is a deliberate increase in the vertical scale of a cross section, while retaining the horizontal scale, in order to make the cross section more clear. For example, if the scale ratio is 10:1, this means that if one inch vertical distance on the cross section equals one foot, then one inch in the horizontal dimension equals ten feet.

Estuary Classification Estuaries are classified based upon the degree of salinity stratification, which is often used to infer circulation features. Salinity profiles, being governed by circulation, are affected by such factors as the amount of freshwater inflow, the size and shape of the basin, and the effects of tides and strong winds. Since estuaries are dynamic, circulation patterns may vary and salinity structures will change as a result. When using any classification scheme, it is important to recognize this dynamic quality and to realize that generalizations concerning salinity profiles do not reflect such variability.

Stratification classification was determined for each estuary from published and unpublished data, and by consulting local experts. The classification assigned to an estuary is specific to the mixing zone of a system where freshwater interfaces with seawater. Variability in classification therefore could exist between zones. In certain cases, such as the estuaries in Maine, the area of the mixing zone is limited due to the strong influence of tides. However, stratification occurs within this band as freshwater maintains its continuity over a limited distance before its dispersion into the seawater zone. Three classes of stratification based on the degree of vertical stratification and circulation are reported:

- Highly stratified (salt wedge estuary) - Very little mixing occurs between the surface and the bottom layers; mixing that does occur results from shear forces at the junction of upper and lower layers.
- Moderately stratified (surface salinity less than bottom salinity) - Moderate amount of mixing occurs between surface and bottom water; the dominant mixing agent is turbulence caused by tidal action; surface salinities are normally lower than bottom salinities.
- Vertically homogenous (surface salinity equals bottom salinity) - An estuary is vertically homogenous when tidal mixing and turbulence is sufficient to break down stratification.

Because freshwater inflow and tidal prism volumes can vary during the year, the classification of an estuary can vary seasonally. To account for this, salinity classifications are reported for the three-month period of highest freshwater inflow and the three-month period of lowest freshwater inflow for each estuary.

Determination of circulation and stratification classification of an estuary is important for resource managers. Knowledge of the cirulation and mixing processes in an estuary allows a better understanding of the movement and dispersion of pollutants introduced into a system. This information allows managers to estimate better the impacts from waste load allocations, channel dredging, and alterations in freshwater inflow.

The dominant mixing processes operating in an estuary can be inferred by comparing freshwater inflow, tidal conditions, and physical dimension data for a number of estuaries. Development of these data may permit stratification classification and prediction of circulation of an estuary not previously classified.

Estuarine Zones Each estuary was subdivided into three zones between the heads of tide and the seaward boundaries based on average annual depth-averaged salinity concentrations. Salinity zones are important to determine since they often dictate the distribution of biological communities and contribute to estuarine circulation. These zones correspond to the following salinity regimes:

Approximate Salinity Ranges for Estuarine Zones
(parts per thousand)

Tidal Fresh	0.0 to 0.5
Mixing	0.5 to 25.0
Seawater	25.0 and greater

Salinity data were obtained, and subsequent boundaries determined, from published and unpublished sources, and through consultation with experts.

Segmentation of an estuary on the basis of salinity is highly variable due to the many interacting factors affecting salinity concentrations, such as variations in freshwater inflow, wind, and tides. Several guidelines were therefore developed to provide a uniform approach and to account for variability in data presentation.

First, episodic anomalies of salinity conditions that occur during low or high freshwater inflows were screened out to provide an average annual scenario of the system. Second, surface and bottom salinities were averaged to determine salinity gradients along the length of the estuary. Finally, delineation between zones was depicted by a band which indicated the spatial variability which could be experienced over an annual cycle. Low, moderate, and high variability classifications are a function of the relative proportion of the variability to the length of the estuary. For example, an estuary with a length of five miles and salinity zone boundary of four miles, would be classified as highly variable.

Freshwater Inflow

Estuaries have been degraded in many coastal areas and much of the documented damage has been attributed to alteration and reduction of freshwater inflow. The volume and rate of freshwater inflow into an estuary is a major factor that determines the physical, geological, chemical, and biological characteristics of an estuarine system. For example, freshwater inflow is a contributing factor to the concentration, distribution, and retention of pollutants in an estuary. Freshwater inflow also affects salinity concentrations and is a factor in stratification.

Flow statistics were determined for the entire drainage basin from flows measured by USGS flow gages, through estimation techniques for ungaged areas, and from records of significant diversions of flow regulations (dams) unaccounted for by flow gages. Long-term average flow and extreme low- and high-flow conditions were determined for each estuary. These conditions best characterize the overall hydrology of a system and are important for determining estuarine hydrodynamics.

Flow Rates Gaged Flows - Average daily freshwater inflow data for streams discharging to an estuary were obtained from the USGS WATSTORE hydrologic data base system. This information was accessed from the U.S. Environmental Protection Agency's (EPA) Flow Data File, which is part of EPA's STORET water quality data base. The statistics developed for each gage were long-term daily average flows calculated on an annual and monthly basis, 7-day, 10-year low flow, and the 50- and 100-year high flows. Gage data quality was assessed by inspecting the USGS integrity code and accuracy rating, and confirming that the gage is active and that the period of record covers a minimum of 10 years. In addition, it was verified that no major flow regulations or diversions were constructed during the period of record which would have significant effect on flow.

Ungaged Flows - Localized regression equations and unit runoff factors were used to estimate average flow conditions for ungaged areas for which flow contributions had to be determined. Regression equations, obtained from USGS district (state) offices, were used to calculate ungaged flows based on data from nearby gaged areas. If regression equations were unavailable or impractical, unit runoff factors (URF) were used to determine ungaged flows. The URF represents the ratio of gaged flow to the drainage contributing to this flow, calculated from nearby gaged areas that were comparable in size and land use to the ungaged area. The area of ungaged drainage was then multiplied by the URF to derive its flow contribution to the estuary. These additional flow data were then added to the gaged portion of a gaged stream, or were substituted for unacceptable gaged data.

Precipitation data were used as a supplement to gaged and ungaged flow in those estuaries whose estuarine water area was greater than or equal to 20 percent of the total watershed. Precipitation data were also added to calculations of freshwater inflow for estuaries where this contribution to total flow was significant. This was the case in large enclosed bays where runoff from the land is low and evapotranspiration is high, such as Laguna Madre, Texas.

Introduction *(continued)*

Flow Ratios Flow ratio is the proportion of the volume of freshwater entering a coastal system during a tidal cycle to the volume of the tidal prism. This ratio provides an initial prediction of whether freshwater inflow or tidal influence is the dominant factor affecting the water body. Higher ratios indicate freshwater or riverine inputs dominate the system. Conversely, tidal domination is indicated by a small flow ratio value. Average annual, high- and low-flow period ratios were calculated for each estuary.

Tidal Data

Tides are the cyclical rise and fall of sea level caused by the gravitational attraction of the sun and moon on the earth. Tidal currents play an important role in the physical dynamics of an estuary, including their influence on the flushing and retention time. The prevailing tide was determined for each estuary from National Ocean Service (NOS) tide tables. In addition, the average tidal prism was calculated for each estuary.

Tides Tides are grouped into two types based on the number of high and low tides per day, the relationship between the heights of successive highs or lows, and the time between corresponding high or low stands of sea level. The two types of tides are diurnal (one high and low per day) and semidiurnal or mixed (two highs and two lows per day). The prevailing tide is reported for each estuary. In general, tides along the east and west coasts are semidiurnal and those along the Gulf of Mexico are diurnal or semidiurnal. A tidal period corresponds to the time between successive passes of the moon over any point on the earth. The time of tidal period is either 12 hours and 25 minutes (semidiurnal), or 24 hours and 50 minutes (diurnal). The tidal range calculated for each estuary is the difference in water level between mean high water (MHW) and mean low water (MLW) for semidiurnal and diurnal tides. Tidal ranges were obtained from NOS tidal observation stations.

Tidal Prism The tidal prism is the volume of water entering a coastal system during flood tide. Data for each estuary were obtained from NOS mean tidal range information and nautical charts. Tidal prisms were calculated using the cubature method (Jarrett, 1976). The cubature method takes into account the time required for a flood wave to propagate through the system, rather than assuming a uniform and simultaneous rise and fall of tide over the entire estuary.

Each estuary was segmented based upon areas that experience the same phase range. The phase range is defined as the difference in tidal elevation at a particular location relative to the occurrence of flood and ebb tide at a tidal reference station, which is usually located at the mouth of the estuary. The time interval between two succeeding flood and ebb tides represents the time during which water flows into the estuary. The surface water elevation at each tide gage station was plotted versus time for each station on a common chronological scale, assuming a 12-hour 25-minute period for semidiurnal tide and a 24-hour, 50-minute period for a diurnal tide. From this curve, the high and low water elevations for each tide gage were determined. The difference between these two elevations for a specific station represents its phase range.

After determining the phase range for each station, the estuary was segmented into subareas of approximately the same phase range. The mean surface area of each subarea was measured with a planimeter. The tidal prism for each subarea was then computed by multiplying the mid-tide water surface area for each subarea by the average phase range corresponding to that segment. The sum of the tidal prisms for each subarea is the average tidal prism volume for the estuary. The tidal prism, which does not represent seasonal anomalies, was calculated for each estuary.

Land Use

Land use within an estuarine drainage basin indicates the overall extent to which human activities may affect the environmental quality of the basin and its waters. For example, the surface area occupied by different land use activities affects the amount of stormwater runoff and types of associated pollutants that eventually drain into estuarine waters. Major categories of land use include urban and built-up land, agricultural cropland, range land, and forest lands. A consistent compilation of estimates for 25 land use types organized by 92 estuarine drainage basins, 278 USGS cataloging units, and their associated coastal counties appear in Volume II: *Land Use Characteristics.*

The primary source of these estimates is the Land Use Data Analysis (LUDA) program of the U.S. Geological Survey (Fegeas, et al., 1983). This program compiles data on land use for the entire USA, developed primarily from LANDSAT satellite imagery taken from 1973 to 1981. Depending on land use type, the spatial resolution (the size of an area to which a specific land use can be assigned) is either 10 or 40 acres. For example, urban and built-up land is assigned by 10-acre areas, while wetlands are assigned by 40-acre areas. In the few areas where LUDA data were unavailable, other sources from regional, state, local, and Canadian agencies were used.

The information compiled provides a consistent set of estimates that can be used to make comprehensive comparisons of land use among the Nation's estuarine areas. These data, however, are not necessarily the best available for making detailed "tactical" assessments of land use within individual estuarine basins because of their spatial resolution. Depending on the area and the land use categories of interest, more detailed data may be available from other sources. For example, the spatial resolution of the U.S. Fish and Wildlife Service "National Wetlands Inventory" maps is about one acre, compared to 40 acres for wetland areas in LUDA.

IV. Uses and Future Plans

This atlas and data base can be used to understand and compare better than ever before the physical, hydrologic, and land use relationships among the estuaries of the USA. This is the first time that these relationships have been defined in a systematic and comprehensive manner for so large a number of estuaries. Individually, the maps and data tables provide an easy-to-understand overview of each estuary's characteristics that is useful on its own, particularly for estuaries that have not been studied in depth. Collectively, the maps and data tables can be used for comparative analyses among estuaries. They can also be used to pose questions and develop hypotheses for future research efforts for individual estuaries, logically organized groups of estuaries, or all estuaries in the USA.

As the data compiled in this atlas are entered into the overall National Estuarine Inventory Data Base, and it becomes possible to use any of a number of computer-assisted analytical tools, considerably greater flexibility and complexity will be possible in the types of estuarine comparisons that can be examined. However, the relatively simple visual displays of this atlas remain critically important for understanding the estuaries of the USA and the data used to describe them.

The knowledge and information base required to manage and conserve effectively the Nation's estuarine resource base remains limited. Consequently, the work of the Ocean Assessments Division (OAD) toward developing a capability for conducting strategic assessments of the Nation's estuarine resources does not end with completion of this atlas and data base.

On the contrary, completion of this atlas and data base is only the beginning of a process to organize and apply the best available information and develop an operational capability to assess the use and health of estuaries of the USA.

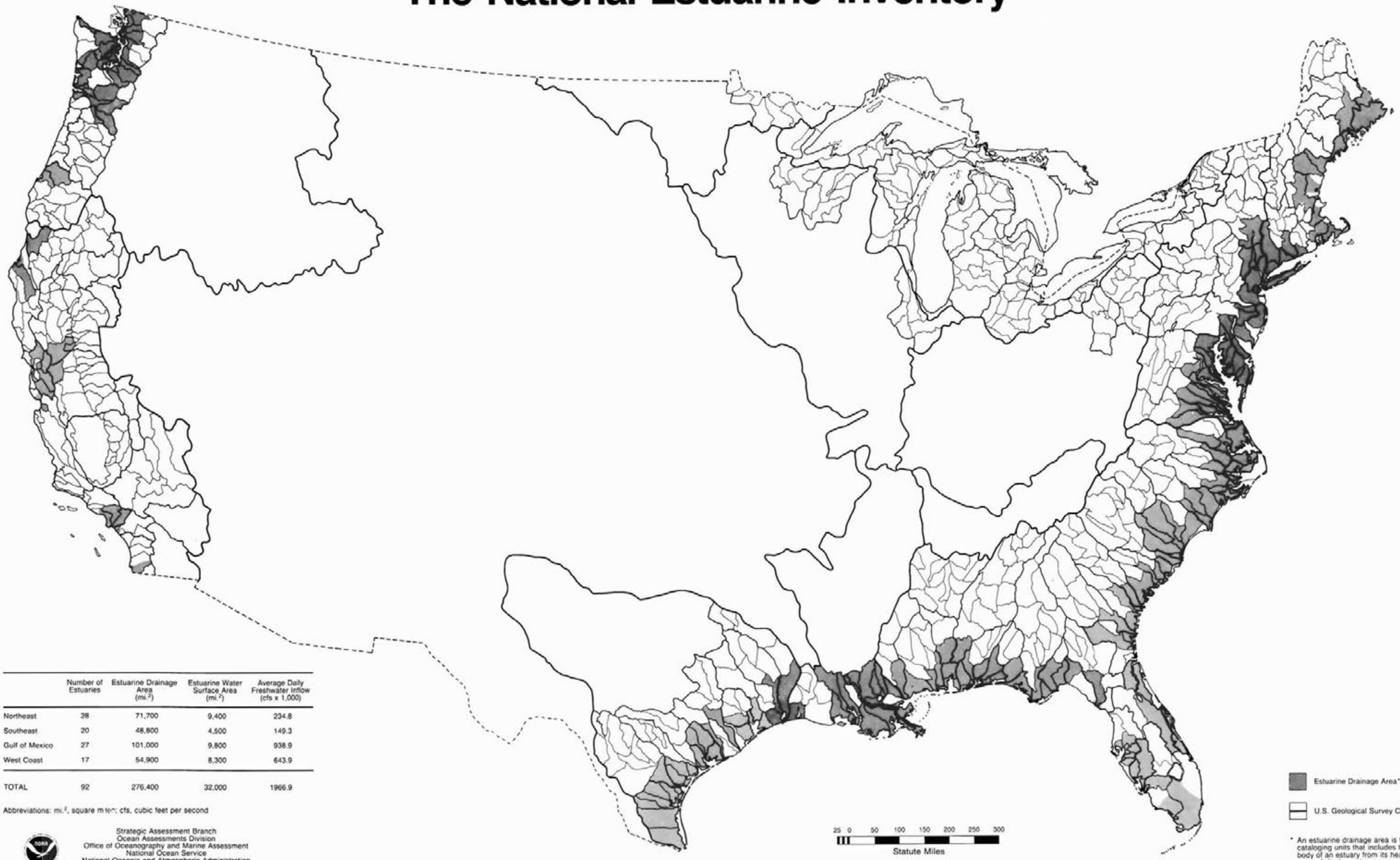
Several major OAD efforts are underway developing additional information that will be added to the National Estuarine Inventory Data Base. These include: (1) the National Coastal Pollutant Discharge Inventory (Basta, et al., 1985) which when completed will include estimates of all point, nonpoint, and riverine sources of pollutant discharges in the estuarine, coastal, and oceanic waters of the contiguous USA; (2) the compilation of data on classified shellfishing waters in each of the 92 estuaries; (3) an inventory of outdoor marine recreation facilities throughout the USA; and (4) the organization of information on living marine resource distributions in estuaries.

As more information is developed and organized by estuary, this atlas will eventually be revised, with considerably more information added. Comments on this atlas or questions about current or future activities should be addressed to:

Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service
National Oceanic and Atmospheric Administration
11400 Rockville Pike
Rockville, Maryland 20852

Figure 1.

The National Estuarine Inventory



	Number of Estuaries	Estuarine Drainage Area (mi.^{2})	Estuarine Water Surface Area (mi.^{2})	Average Daily Freshwater Inflow (cfs x 1,000)
Northeast	28	71,700	9,400	234.8
Southeast	20	48,800	4,500	149.3
Gulf of Mexico	27	101,000	9,800	938.9
West Coast	17	54,900	8,300	643.9
TOTAL	92	276,400	32,000	1966.9

Abbreviations: mi.^{2}, square miles; cfs, cubic feet per second

Estuarine Drainage Area*

U.S. Geological Survey Cataloging Units

* An estuarine drainage area is the set of cataloging units that includes the entire water body of an estuary from its head of tide to its point of discharge to an ocean, bay, gulf, sound, or other coastal water body.

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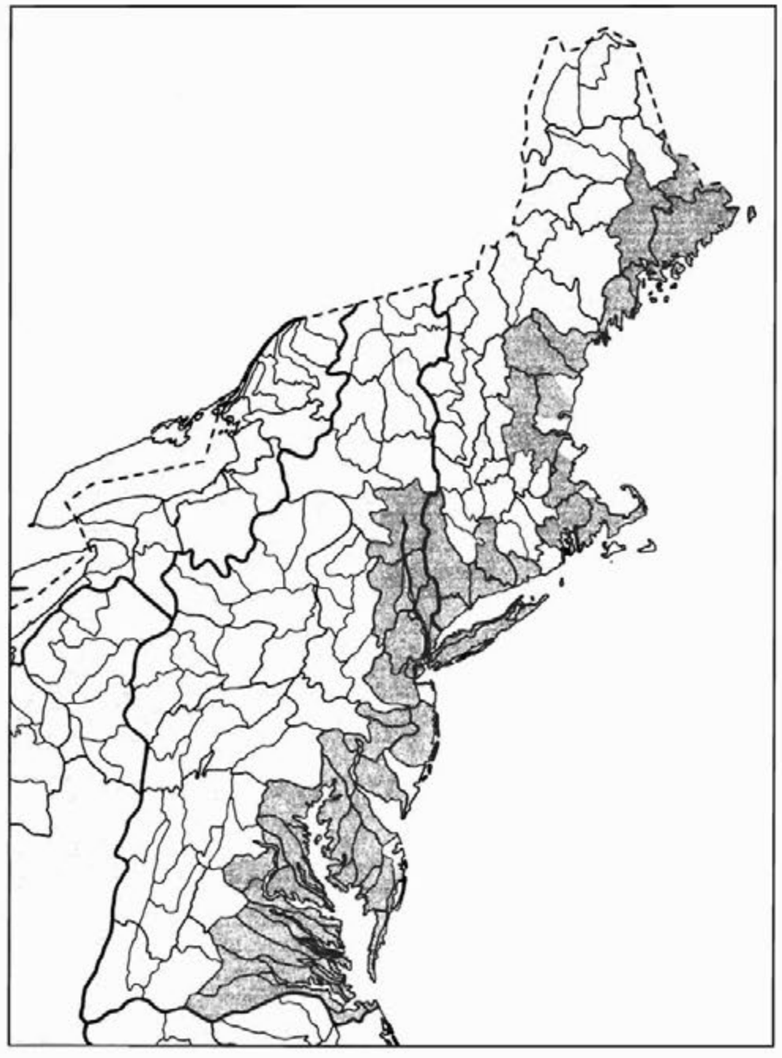
Northeast



Introduction

The Northeast region extends from Maine through Virginia. Twenty-eight estuaries are portrayed here, representing approximately 95% of the total estuarine area in the region. Within the region there are two unique geomorphological zones. The first extends from the Canadian border to Cape Cod and is commonly referred to as the Gulf of Maine. Estuaries within this zone were formed by glaciers that removed the soil cover leaving a rocky shoreline, and deeply carved, steep-sided channels through which rivers now run to the ocean. Although these systems are referred to as fjords, they lack the typical shallow sill mouths normally associated with fjords such as those found along the coastline of British Columbia. Strong tides and basin geometry in fjords of the Gulf of Maine result in tidal domination of circulation.

The second zone extends from Cape Cod through Virginia. The topography in this zone was affected less directly by glaciers. Rising sea levels, however, resulting from melting glaciers, drowned the mouths of ancient rivers extending across the continental shelf. These estuaries are referred to as coastal plain estuaries, and are generally restricted to temperate latitudes. Volume of water introduced by tidal action is large compared to river inflow. Tides remain the dominant factor in estuarine circulation in this part of the region. Tides throughout the region are semidiurnal and range on average from about 18 feet in northern Maine to 10.5 feet in southern Maine, and 2.5 feet in Virginia.

In the northern zone, freshwater inflows into estuaries generally carry low sediment loads, because of the heavy forest cover and rocky soils that dominate coastal drainage areas. Sediment loads to estuaries increase moving south as the coastal plain widens and agricultural activity increases. Long-term precipitation, approximately 40 to 44 inches per year, increases only slightly from north to south. Freshwater inflows tend to correlate with variations in winter runoff. High-flow periods in the northern portion of the region occur from March through May, while high-flow periods in the central and southern portions of the region occur slightly earlier. Low-flow periods throughout the region are July through September. Northeast estuaries account for about 65% of freshwater discharge to coastal waters along the East Coast.

As a group, estuaries in the Northeast are the most intensively studied in the Nation. This is to a large extent due to the research programs conducted by the many universities and colleges in the area. Consequently, Northeast data are generally the most reliable and accurate in this atlas. For example, relatively reliable estimates can be made for freshwater inputs due to the extensive monitoring stations maintained by the United States Geological Survey and various state agencies. Information on salinity, stratification, and tides was also locally available.

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1.02 Englishman Bay
1.03 Narraguagus Bay
1.04 Blue Hill Bay
1.05 Penobscot Bay
1.06 Muscongus Bay
1.07 Sheepscot Bay
1.08 Casco Bay
1.09 Saco Bay
1.10 Great Bay
1.11 Merrimack River
1.12 Boston Bay
1.13 Cape Cod Bay
1.14 Buzzards Bay
1.15 Narragansett Bay
1.16 Gardiners Bay
1.17 Long Island Sound
a. Connecticut River*
1.18 Great South Bay
1.19 Hudson River/Raritan Bay
1.20 Barnegat Bay
1.21 Delaware Bay
1.22 Chincoteague Bay
1.23 Chesapeake Bay
a. Potomac River*
b. Rappahannock River*
c. York River*
d. James River*

* estuarine subsystems

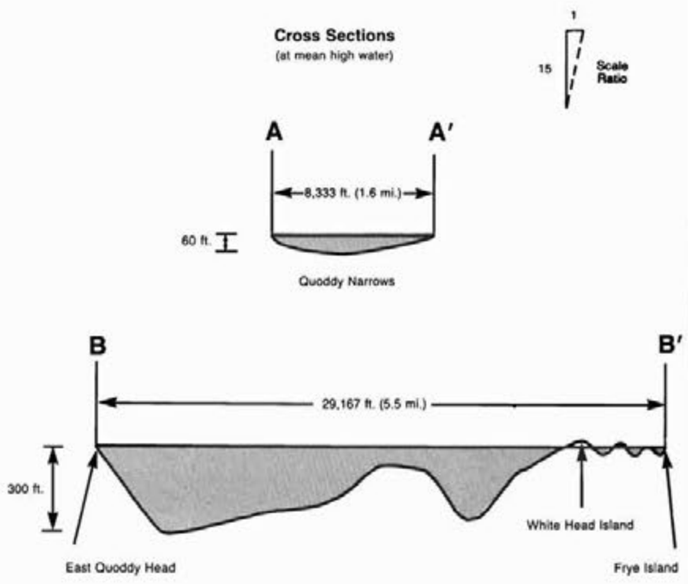
National Estuarine Atlas

Passamaquoddy Bay
ME, NB

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

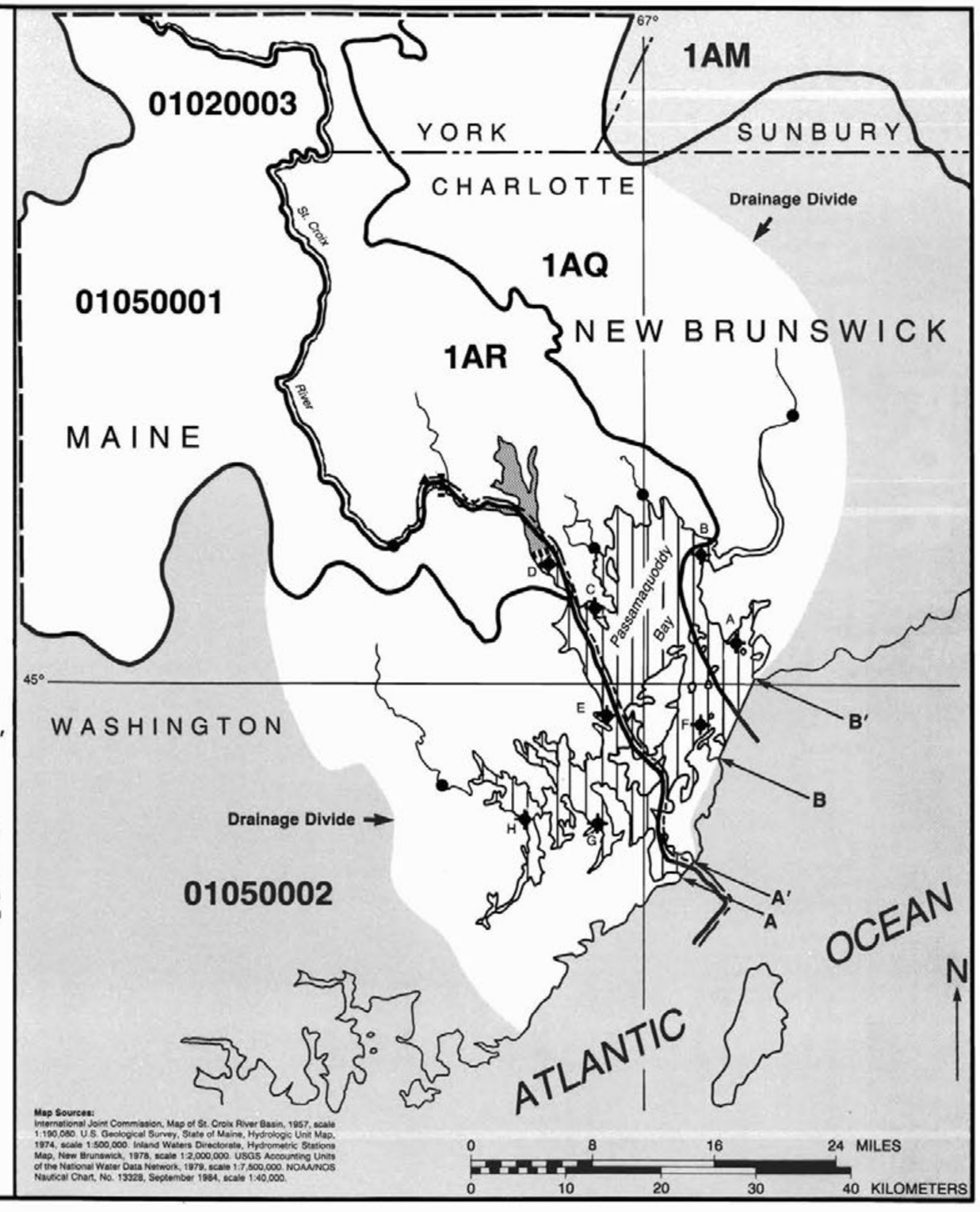
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			1972-1983	Tidal Prism (cf)		7.90×10^{10}
Estuarine Drainage	3,200					*Phase Range of Tide (ft.)*		
Estuarine Zones		Long Term Average Daily			6.2	Map Key	Station	Range
Tidal Fresh	5	Long Term Average Monthly	J	4.8	J 3.5	A	622	17.3
Mixing Zone	16		F	5.0	A 3.1	B	623	18.6
Seawater	136		M	6.2	S 3.0	C	624	18.4
Total	157		A	14.7	O 4.1	D	633	19.0
Dimensions			M	11.7	N 5.7	E	629	17.9
Length (mi.)	30.3		J	5.9	D 6.1	F	621	17.0
Width (mi.): Average	6.4	7-Day, 10-Year Low Flow			0.5	G	647	18.6
Minimum	1.0					H	645	14.7
Maximum	15.2							
Average Depth (ft.)	68.7	50-Year Flood			30.9			
Average Depth to Width Ratio	2.0×10^{-3}	100-Year Flood			35.0			
Stratification Classification		*Flow Ratios*						
3-Month High Flow	MS	Average Annual			0.004			
3-Month Low Flow	MS	High Flow Period			0.006			
		Low Flow Period			0.002			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable, NA (see notes).



Notes:
Approximately 65% of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area.

References:
Fontaine, 1978. Fontaine, 1982. Larsen and Doggett, 1976. Morrill, 1975. Morrill, et al., 1982. Parker, 1978. U.S. Department of Commerce, 1983a.



Map Sources:
International Joint Commission, Map of St. Croix River Basin, 1957, scale 1:190,080. U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. Inland Waters Directorate, Hydrometric Stations Map, New Brunswick, 1978, scale 1:2,000,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13328, September 1984, scale 1:40,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

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National Ocean Service/NOAA

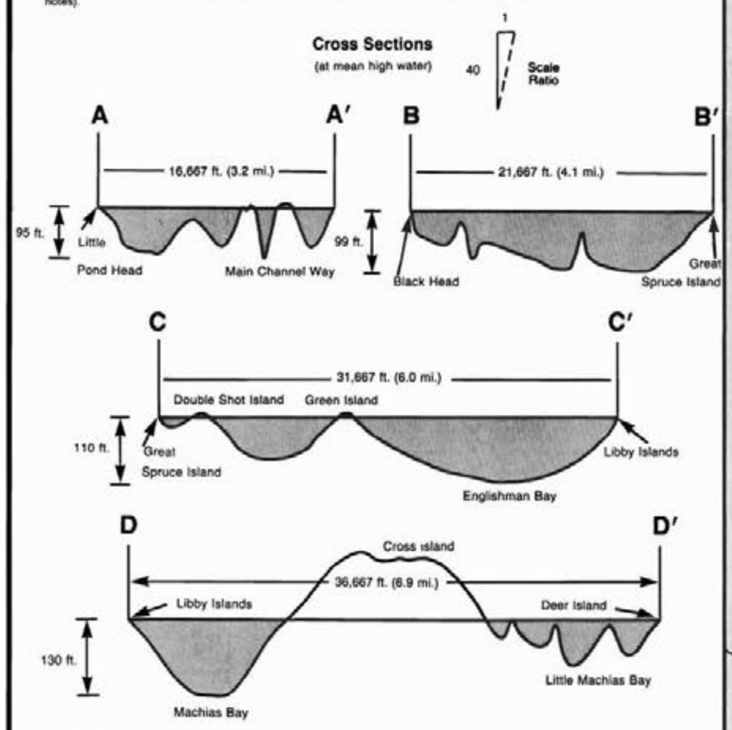
National Estuarine Atlas

Englishman Bay
ME

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			No Gages	Tidal Prism (cf)		2.65×10^{10}
Estuarine Drainage	883							
Estuarine Zones		Long Term Average Daily			1.6	***Phase Range of Tide (ft.)***		
						Map Key	Station	Range
Tidal Fresh	2	Long Term Average Monthly	J	1.0	J 0.8	A	665	11.5
Mixing Zone	9		F	0.8	A 0.6	B	661	12.1
Seawater	65		M	1.5	S 0.6	C	657	12.4
Total	78		A	4.8	O 0.9			
Dimensions			M	4.3	N 1.8			
Length (mi.)	16.0		J	1.6	D 1.6			
Width (mi.): Average	4.9							
Minimum	0.8	7-Day, 10-Year Low Flow			< 0.1			
Maximum	14.8							
Average Depth (ft.)	26.9	50-Year Flood			38.7			
Average Depth to Width Ratio	1.1×10^{-3}	100-Year Flood			43.8			
		Flow Ratios						
Stratification Classification		Average Annual			0.003			
3-Month High Flow	HS	High Flow Period			0.006			
3-Month Low Flow	MS	Low Flow Period			0.001			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable NA (see notes).



Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area. Flows are calculated from published regression equations.

References:
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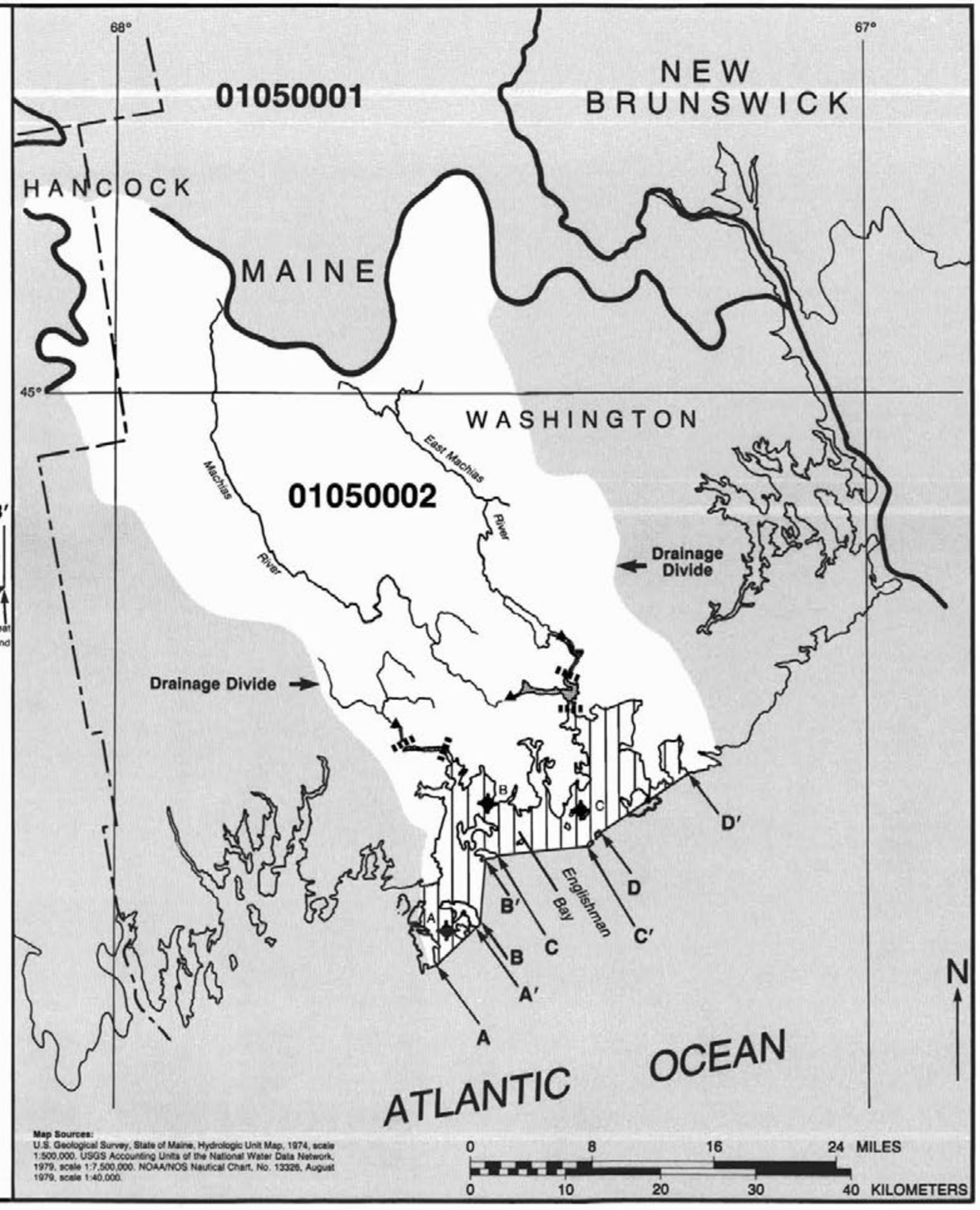
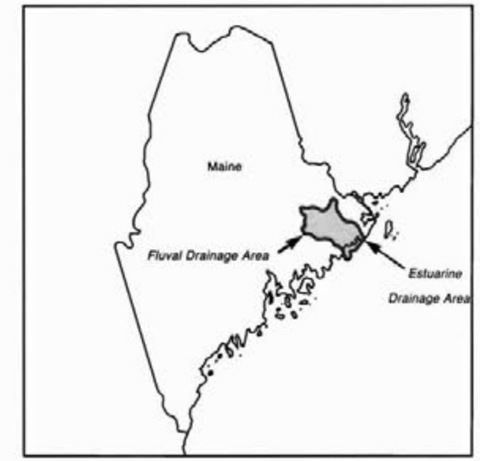


Map Sources:
U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13326, August 1979, scale 1:40,000.



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National Estuarine Atlas

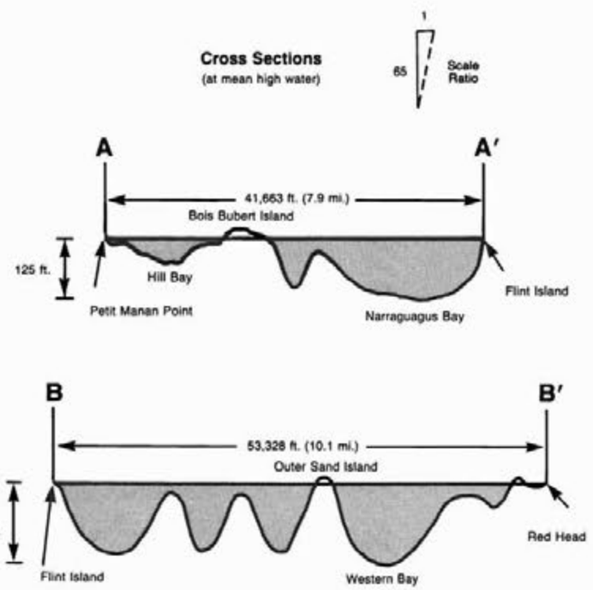
Narraguagus Bay
ME

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record		1948-1983		Tidal Prism (cf)		2.17×10^{10}
Estuarine Drainage	416							
Estuarine Zones		Long Term Average Daily		0.9		*Phase Range of Tide (ft.)*		
Tidal Fresh	1					Map Key	Station	Range
Mixing Zone	5	Long Term Average Monthly	J 0.8	J 0.3		A	677	11.1
Seawater	64		F 0.7	A 0.2		B	669	11.3
Total	70		M 1.2	S 0.3		C	671	11.7
Dimensions			A 2.4	O 0.5				
Length (mi.)	15.5		M 1.5	N 1.0				
Width (mi.): Average	5.5		J 0.6	D 1.1				
Minimum	0.3	7-Day, 10-Year Low Flow		0.1				
Maximum	14.5							
Average Depth (ft.)	29.3	50-Year Flood		18.2				
Average Depth to Width Ratio	1.0×10^{-3}	100-Year Flood		20.6				
Stratification Classification		*Flow Ratios*						
3-Month High Flow	HS	Average Annual		0.002				
3-Month Low Flow	HS	High Flow Period		0.004				
		Low Flow Period		0.001				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable NA (see notes).

Cross Sections
(at mean high water)



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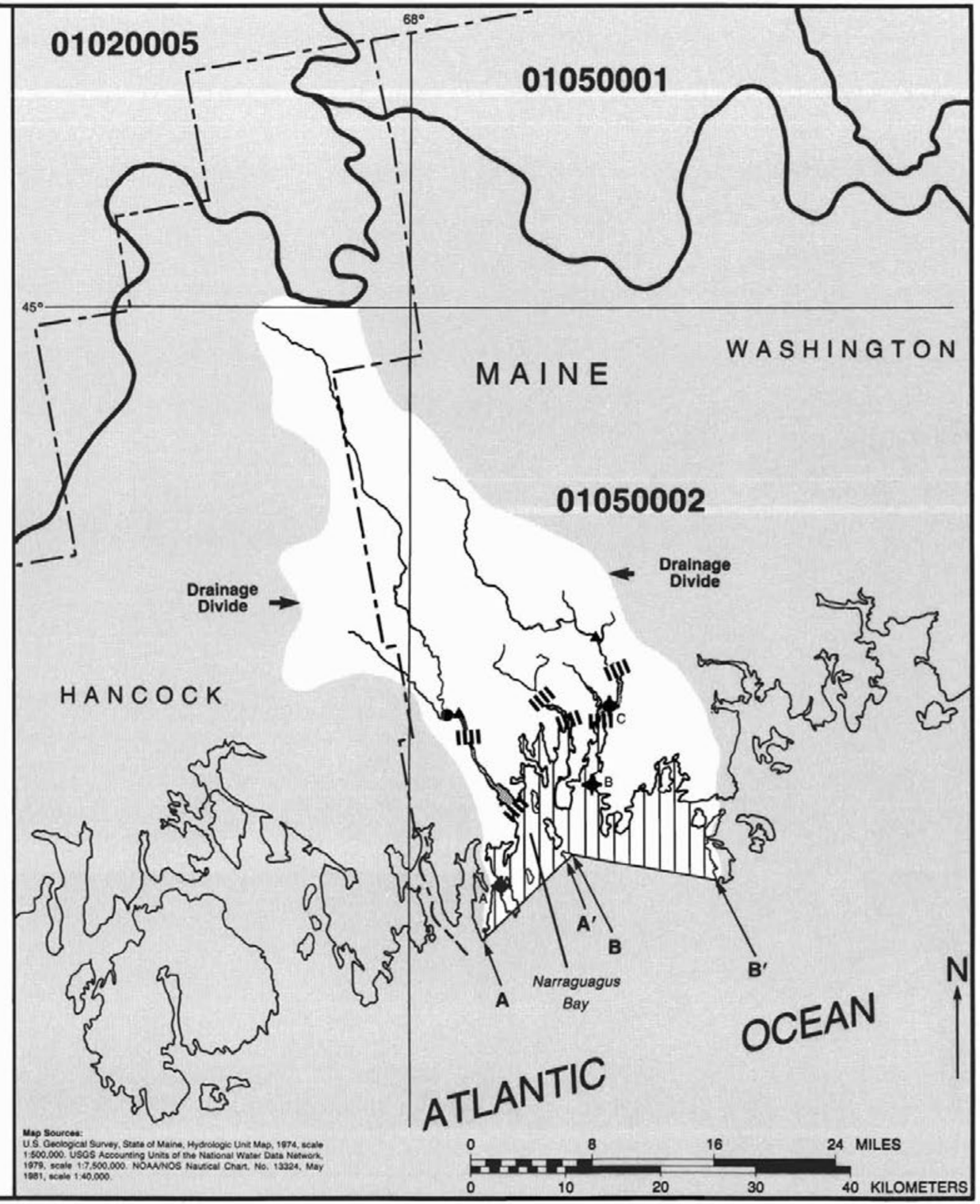
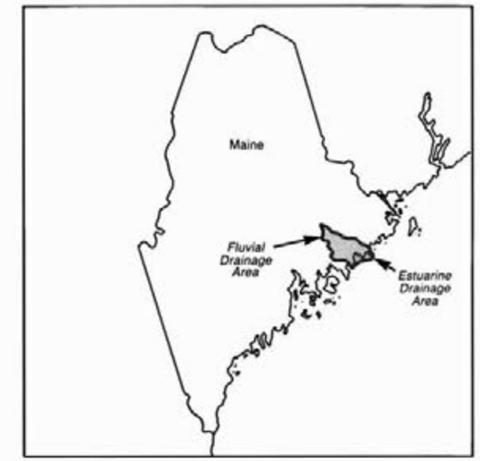


Map Sources:
U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13324, May 1981, scale 1:40,000.



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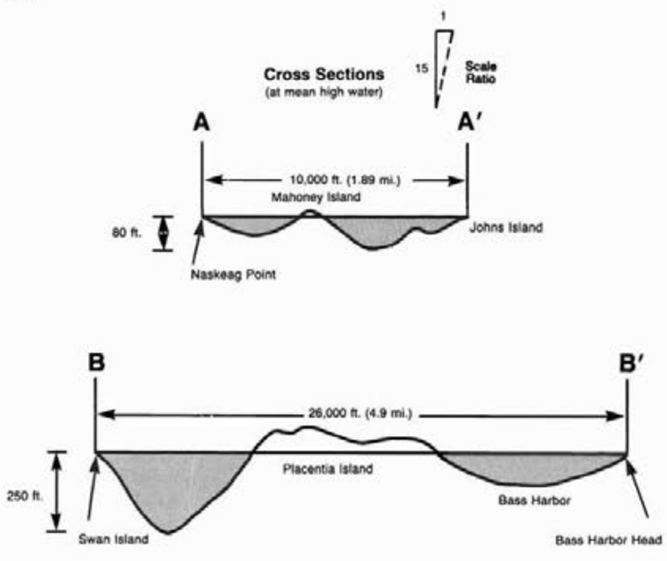
National Estuarine Atlas

Blue Hill Bay
ME

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

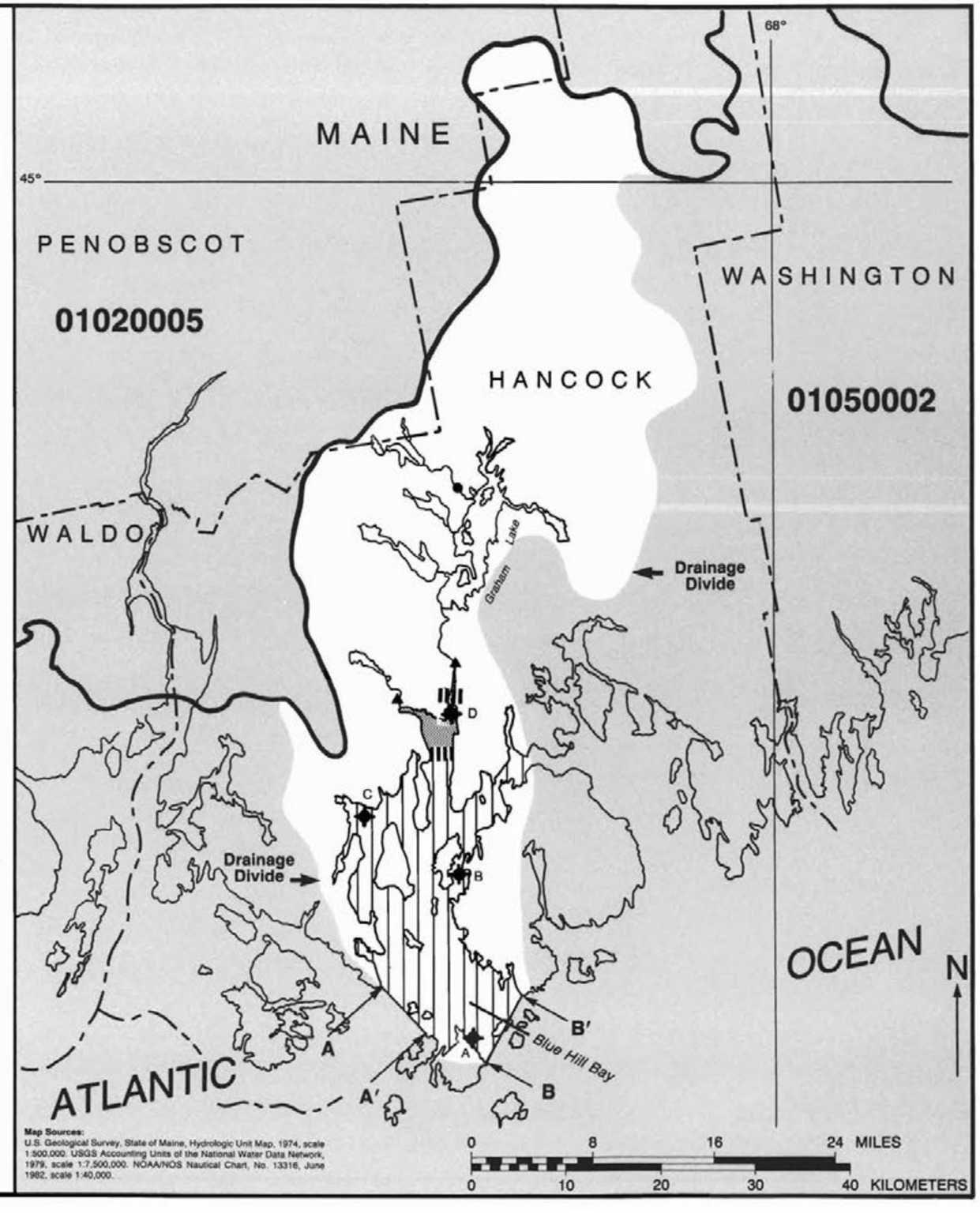
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			1964-1982	Tidal Prism (cf)		3.24×10^{10}
Estuarine Drainage	825							
Estuarine Zones		Long Term Average Daily			1.3	***Phase Range of Tide (ft.)***		
Tidal Fresh	1					Map Key	Station	Range
Mixing Zone	4	Long Term Average Monthly	J	0.9	J 0.6	A	727	9.9
Seawater	110		F	0.8	A 0.4	B	719	10.1
Total	115		M	1.4	S 0.5	C	723	10.0
Dimensions			A	4.0	O 0.5	D	721	10.3
Length (mi.)	28.8		M	3.3	N 1.5			
Width (mi.): Average	5.4		J	1.2	D 1.4			
Minimum	0.3	7-Day, 10-Year Low Flow			0.1			
Maximum	10.6							
Average Depth (ft.)	83.9	50-Year Flood			31.8			
Average Depth to Width Ratio	1.9×10^{-4}	100-Year Flood			36.2			
Stratification Classification		***Flow Ratios***						
3-Month High Flow	HS	Average Annual			0.002			
3-Month Low Flow	HS	High Flow Period			0.004			
		Low Flow Period			0.001			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable NA (see notes).



Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area.

References:
Fontaine, 1978. Fontaine, 1982. Larsen and Doggett, 1976. Morrill, 1975. Morrill, et al., 1982. Parker, 1978. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13316, June 1982, scale 1:40,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
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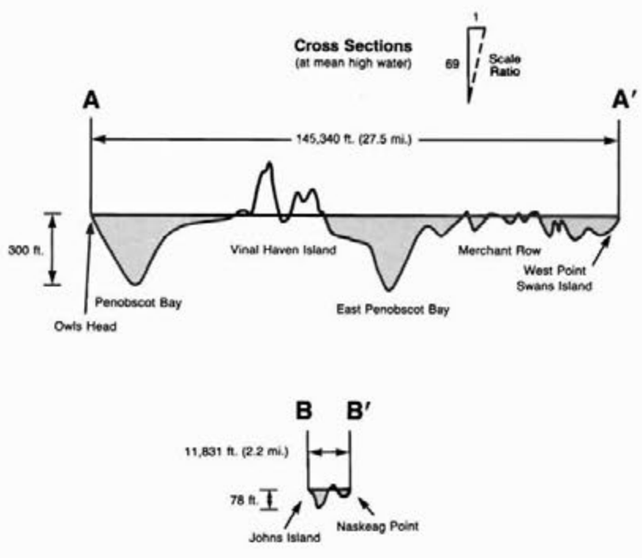
National Estuarine Atlas

Penobscot Bay
ME

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

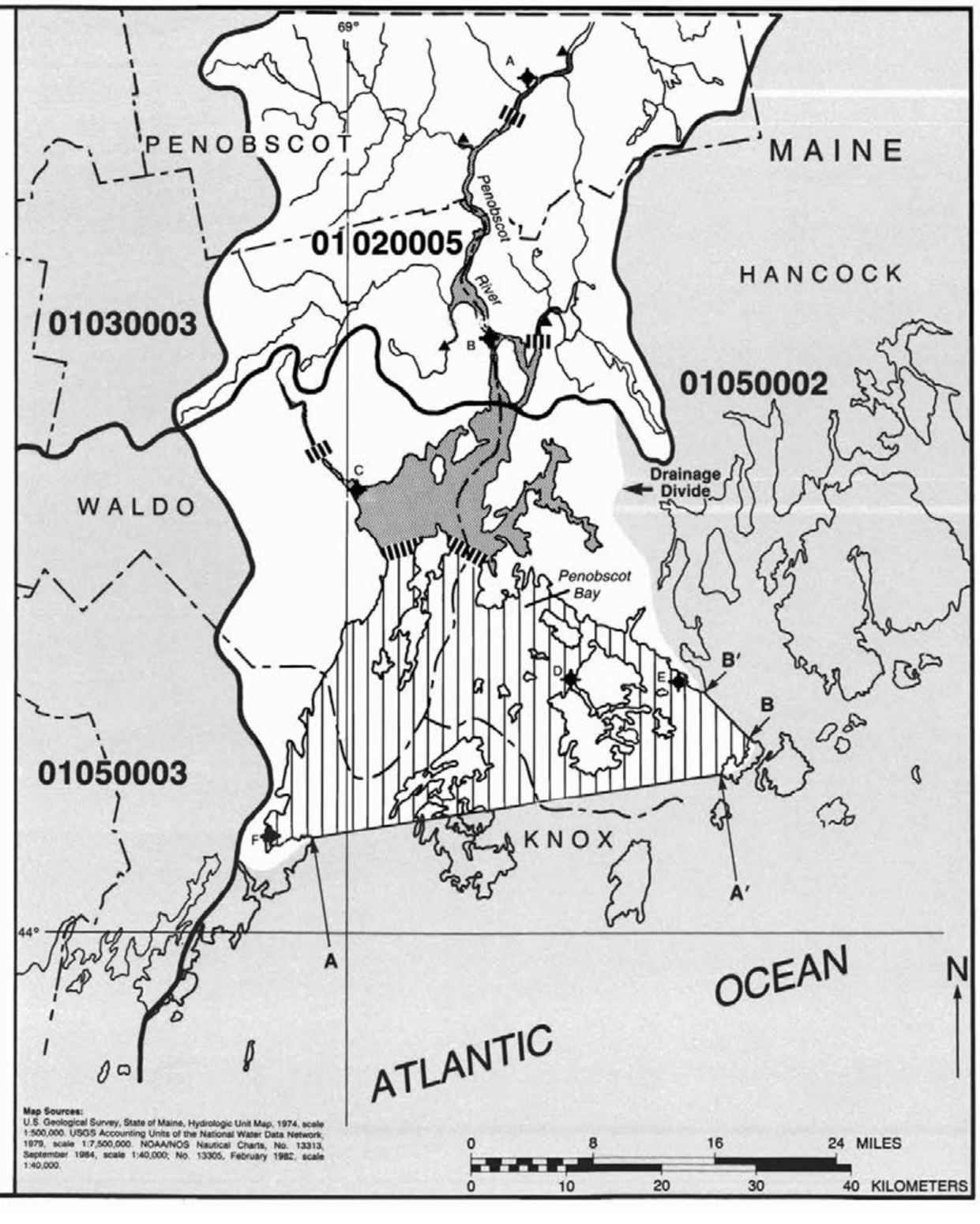
PHYSICAL		FRESHWATER INFLOW			TIDAL DATA		
Surface Areas (mi²)		***Flow Rates (1000 cfs)***			Prevailing Tide: Semidiurnal		
Fluvial Drainage	6,250	Period of Record		1902-1982	Tidal Prism (cf)		9.9×10^{10}
Estuarine Drainage	3,160						
Estuarine Zones		Long Term Average Daily		16.1	***Phase Range of Tide (ft.)***		
					Map Key	Station	Range
Tidal Fresh	45	Long Term Average Monthly	J 10.8	J 9.9	A	767	13.0
Mixing Zone	70		F 9.5	A 8.1	B	761	10.9
Seawater	246		M 14.7	S 8.2	C	769	9.9
Total	361		A 41.5	O 11.0	D	745	10.0
Dimensions			M 25.8	N 18.9	E	731	10.0
Length (mi.)	62.6		J 16.1	D 14.4	F	773	9.6
Width (mi.): Average	7.6	7-Day, 10-Year Low Flow		3.7			
Minimum	0.2						
Maximum	27.5						
Average Depth (ft.)	77.1	50-Year Flood		151.0			
Average Depth to Width Ratio	1.9×10^{-3}	100-Year Flood		169.0			
		Flow Ratios					
Stratification Classification		Average Annual		0.007			
3-Month High Flow	HS	High Flow Period		0.013			
3-Month Low Flow	MS	Low Flow Period		0.004			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.



Notes:
Approximately 50% of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary.

References:
Fink, et al., 1980. Fontaine, 1978. Fontaine, 1981. Fontaine, 1982. Haefner, 1967. Hatch, 1971. Morrill, 1975. Morrill et al., 1982. Muirhead and Wartha, 1971. Parker, 1978. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Charts, No. 13313, September 1984, scale 1:40,000; No. 13305, February 1982, scale 1:40,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
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National Estuarine Atlas

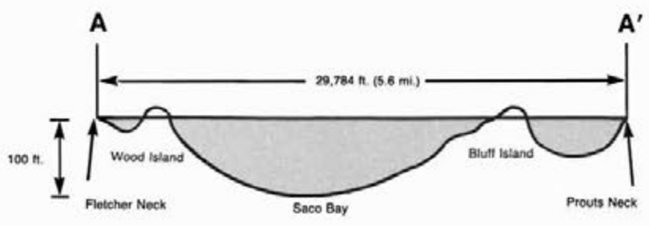
Saco Bay
ME, NH

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record		1950-1982		Tidal Prism (cf)		4.16×10^9
Estuarine Drainage	1,771					***Phase Range of Tide (ft.)***		
Estuarine Zones		Long Term Average Daily		3.6		Map Key	Station	Range
Tidal Fresh	1					A	881	8.7
Mixing Zone	2	Long Term Average Monthly	J 2.5	J 1.9		B	883	8.6
Seawater	14		F 2.4	A 1.3				
Total	17		M 4.1	S 1.4				
Dimensions			A 10.0	O 2.0				
Length (mi.)	7.5		M 7.9	N 3.3				
Width (mi.): Average	2.5		J 3.4	D 3.4				
Minimum	0.2	7-Day, 10-Year Low Flow		0.4				
Maximum	6.2							
Average Depth (ft.)	28.9	50-Year Flood		40.0				
Average Depth to Width Ratio	2.2×10^{-3}	100-Year Flood		45.5				
		Flow Ratios						
Stratification Classification		Average Annual		0.039				
3-Month High Flow	HS	High Flow Period		0.079				
3-Month Low Flow	HS	Low Flow Period		0.016				

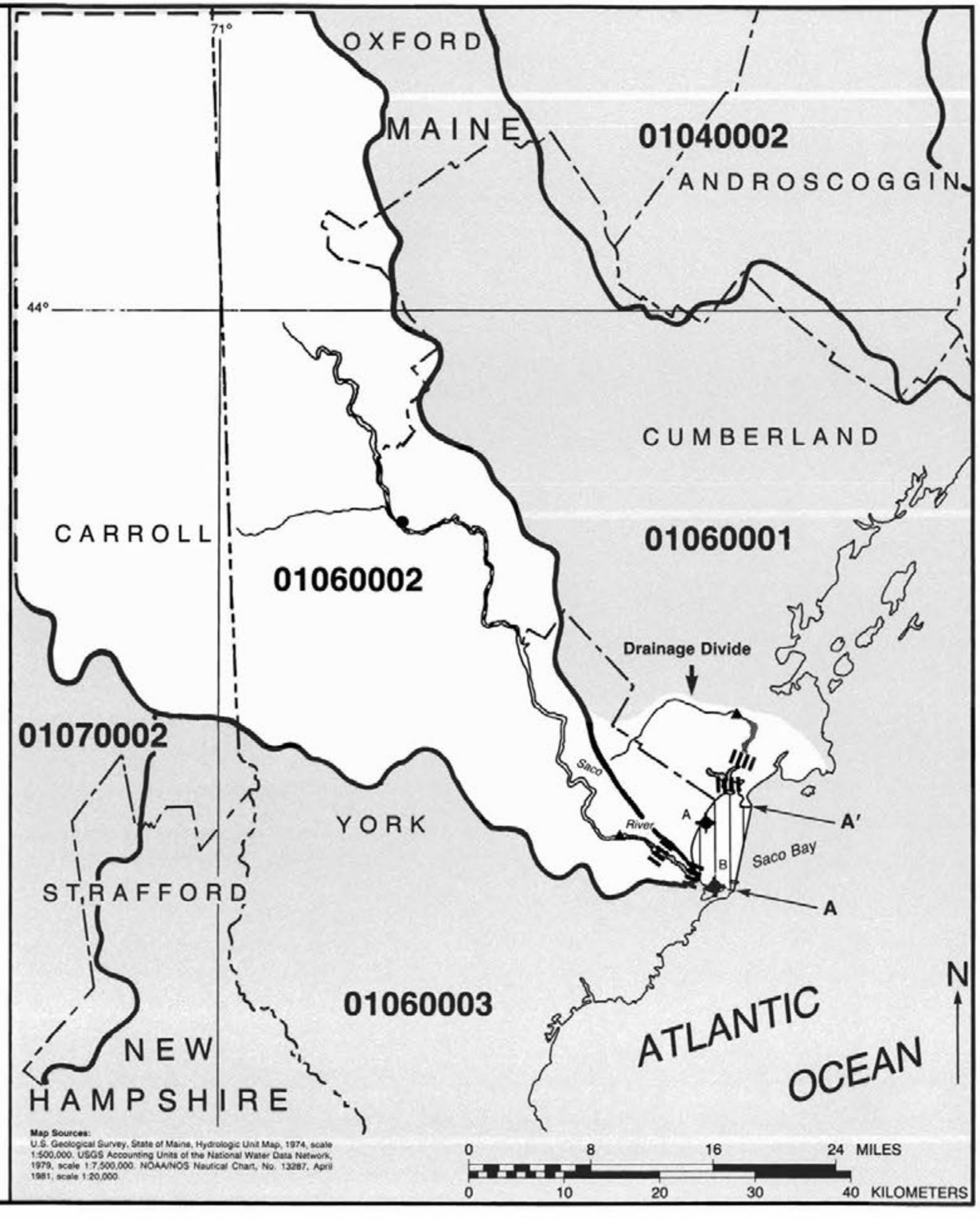
Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable, NA (see notes).

Cross Section
(at mean high water)



Notes:
Approximately 50% of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area.

References:
Farrell, 1970. Fontaine, 1978. Fontaine, 1982. Morrill, 1975. Morrill, et al., 1982. Parker, 1978. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13287, April 1981, scale 1:20,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
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- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

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National Estuarine Atlas

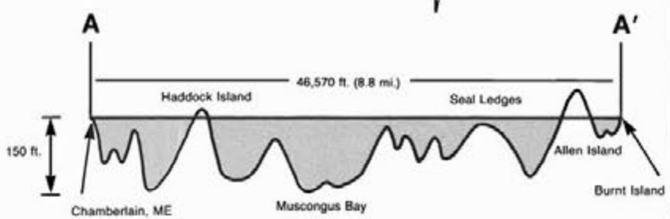
Muscongus Bay
ME

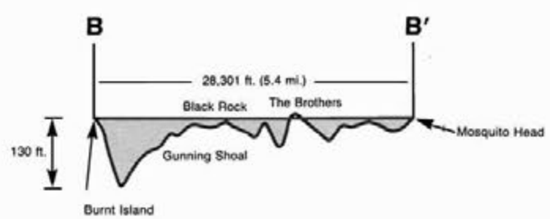
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			No Gages	Tidal Prism (cf)		1.80×10^{10}
Estuarine Drainage	346							
Estuarine Zones		Long Term Average Daily			0.6	*Phase Range of Tide (ft.)*		
						Map Key	Station	Range
Tidal Fresh	1	Long Term Average Monthly	J	0.5	J 0.3	A	783	8.8
Mixing Zone	7		F	0.4	A 0.2	B	795	8.9
Seawater	64		M	0.8	S 0.2	C	793	8.9
Total	72		A	2.1	O 0.3	D	799	9.4
Dimensions			M	1.6	N 0.8			
Length (mi.)	15.9		J	0.6	D 0.7			
Width (mi.): Average	4.9	7-Day, 10-Year Low Flow			< 0.1			
Minimum	0.6							
Maximum	11.8							
Average Depth (ft.)	40.7	50-Year Flood			16.9			
Average Depth to Width Ratio	1.6×10^{-3}	100-Year Flood			20.0			
		Flow Ratios						
Stratification Classification		Average Annual			0.002			
3-Month High Flow	HS	High Flow Period			0.004			
3-Month Low Flow	MS	Low Flow Period			0.001			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable NA (see notes).

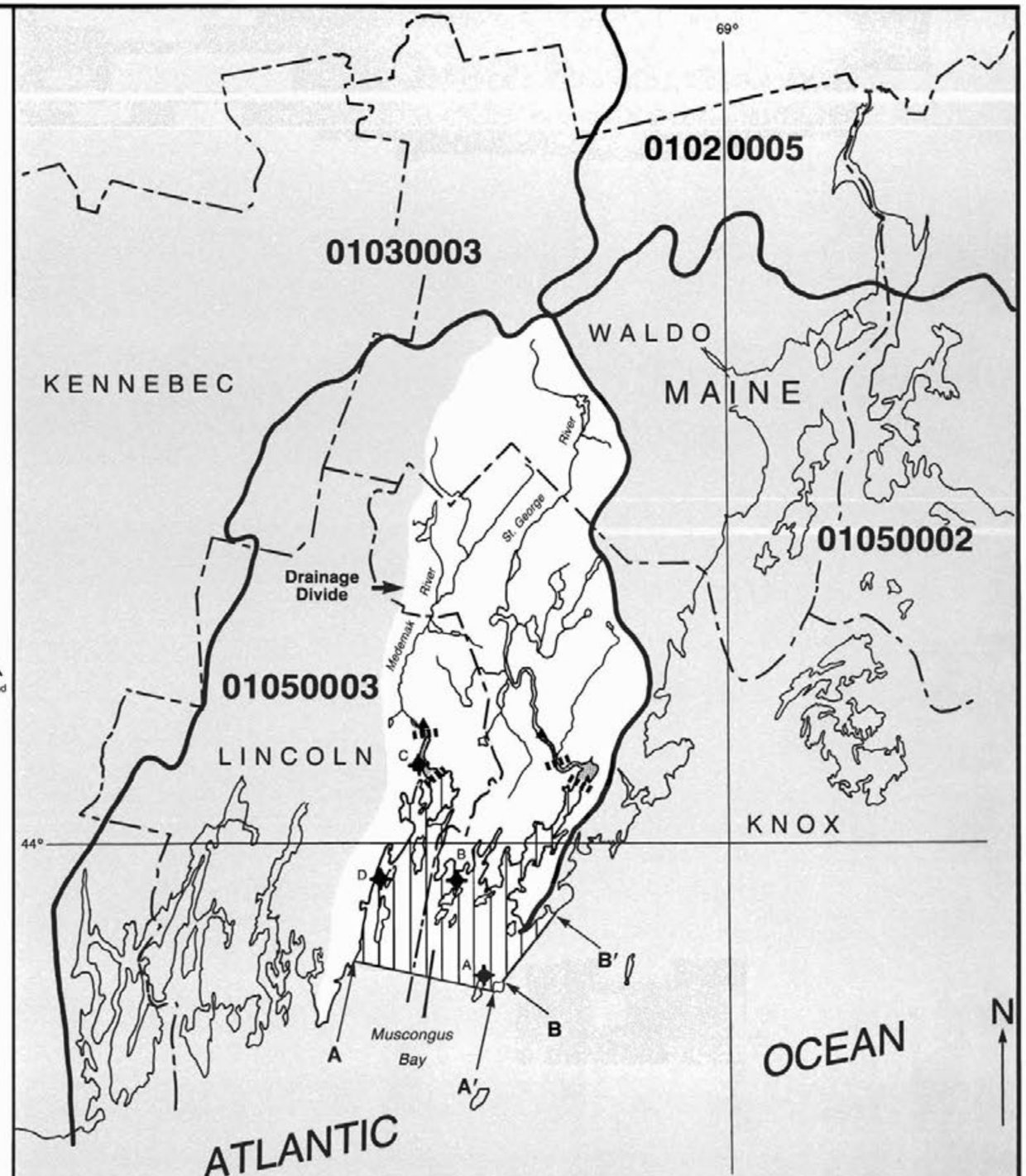
Cross Sections
(at mean high water)





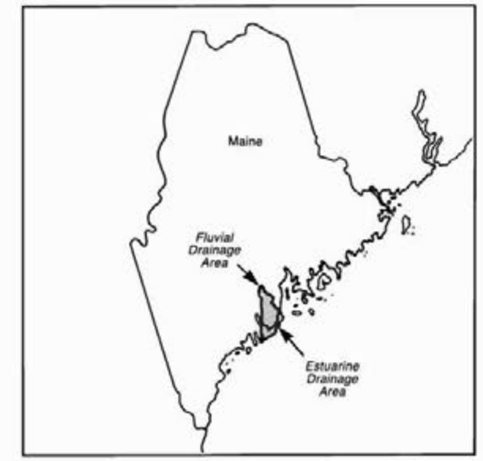
Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area. Flows are calculated from published regression equations.

References:
Fontaine, 1978. Fontaine, 1982. Larsen and Doggett, 1976. Morrill, 1975. Morrill, et al., 1982. Parker, 1978. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13301, June 1979, scale 1:40,000.

0 8 16 24 MILES
0 10 20 30 40 KILOMETERS



- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
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National Estuarine Atlas

Sheepscot Bay
ME , NH

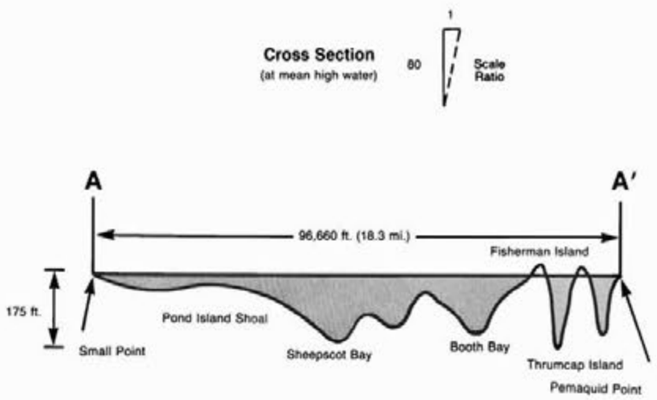
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL	
Surface Areas (mi^2)	
Fluvial Drainage	3920
Estuarine Drainage	6150
Estuarine Zones	
Tidal Fresh	8
Mixing Zone	17
Seawater	78
Total	103
Dimensions	
Length (mi.)	44.0
Width (mi.): Average	6.3
Minimum	0.1
Maximum	14.5
Average Depth (ft.)	40.4
Average Depth to Width Ratio	1.2×10^{-3}
Stratification Classification	
3-Month High Flow	HS
3-Month Low Flow	MS

FRESHWATER INFLOW		
Flow Rates (1000 cfs)		
Period of Record		1928-1982
Long Term Average Daily		17.6
Long Term Average Monthly	J 13.2	J 8.2
	F 12.4	A 7.4
	M 18.4	S 7.6
	A 42.6	O 8.9
	M 41.4	N 11.2
	J 17.1	D 11.3
7-Day, 10-Year Low Flow		3.5
50-Year Flood		222.5
100-Year Flood		249.2
Flow Ratios		
Average Annual		0.036
High Flow Period		0.070
Low Flow Period		0.016

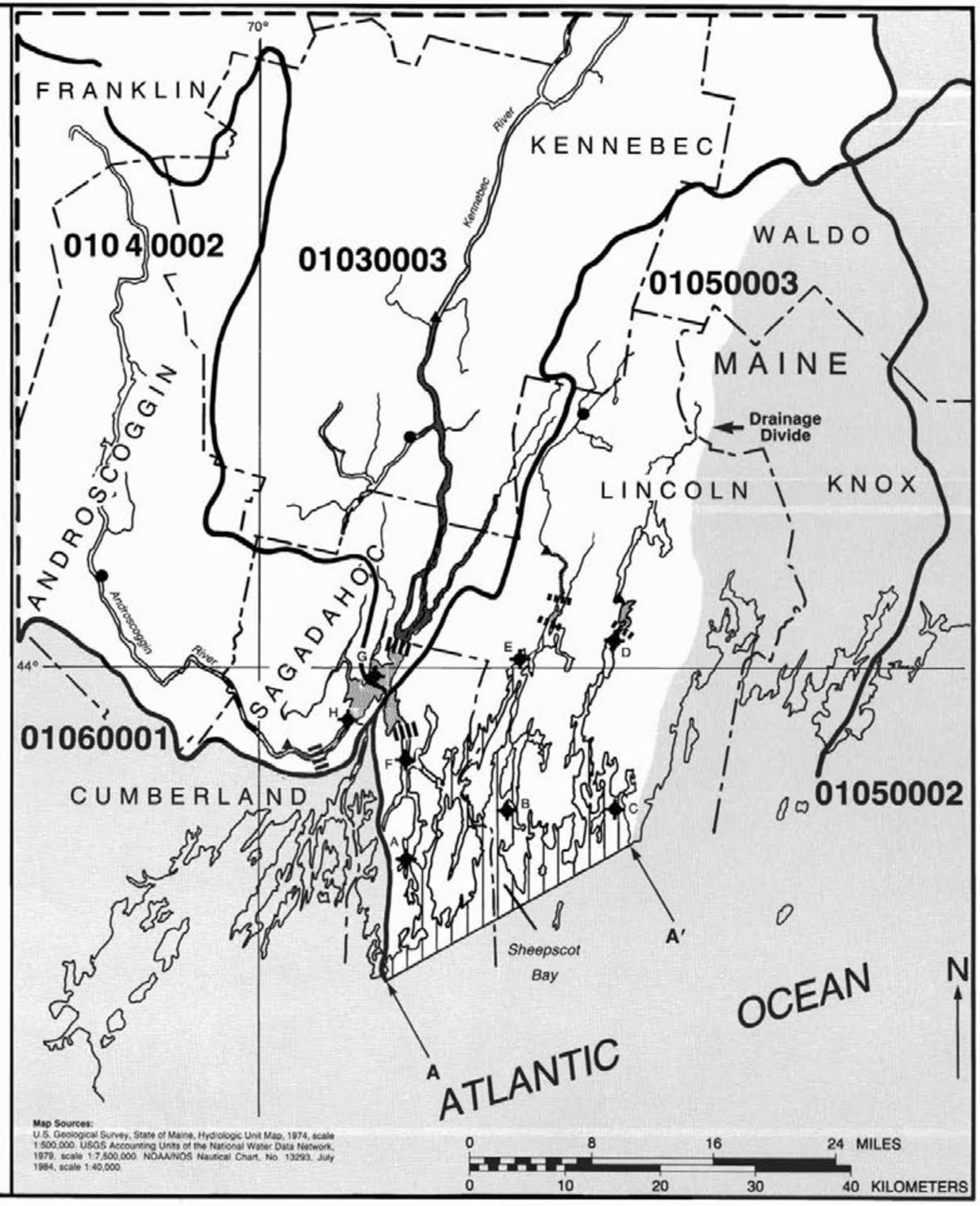
TIDAL DATA		
Prevailing Tide: Semidiurnal		
Tidal Prism (cf)		2.19×10^{10}
Phase Range of Tide (ft.)		
Map Key	Station	Range
A	831	8.0
B	811	8.8
C	801	8.7
D	805	9.1
E	817	9.3
F	833	5.5
G	835	3.6
H	837	2.0

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable NA (see notes).



Notes:
Approximately 45% of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary.

References:
Fontaine, 1978. Fontaine, 1979. Fontaine, 1980. Fontaine, 1982. Larsen, 1975. Larsen and Doggett, 1976. McAlice, 1977. Morrill, 1975. Morrill, et al., 1982. Parker, 1978. Stickney, 1959. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13293, July 1984, scale 1:40,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
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National Estuarine Atlas

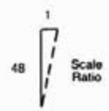
Casco Bay
ME

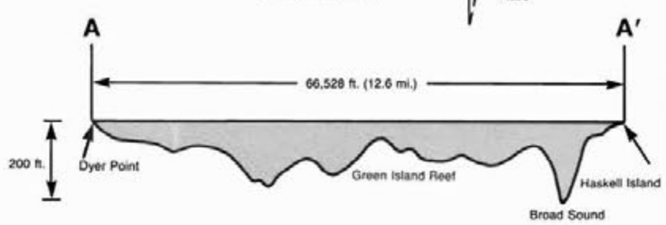
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

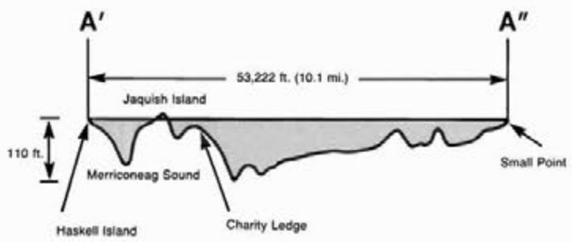
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			1975-1983	Tidal Prism (cf)		4.06×10^{10}
Estuarine Drainage	1159	Long Term Average Daily			2.1	*Phase Range of Tide (ft.)*		
Estuarine Zones						Map Key	Station	Range
Tidal Fresh	3	Long Term Average Monthly	J	1.7	J 1.1	A	875	8.9
Mixing Zone	5		F	1.8	A 1.0	B	869	8.9
Seawater	156		M	3.7	S 0.8	C	865	9.0
Total	164		A	4.8	O 1.2	D	859	8.7
Dimensions			M	3.5	N 2.5	E	853	8.7
Length (mi.)	28.7		J	1.9	D 2.0			
Width (mi.): Average	8.1	7-Day, 10-Year Low Flow			0.3			
Minimum	0.4							
Maximum	16.4							
Average Depth (ft.)	32.3	50-Year Flood			22.6			
Average Depth to Width Ratio	7.6×10^{-4}	100-Year Flood			27.0			
		Flow Ratios						
Stratification Classification		Average Annual			0.002			
3-Month High Flow	MS	High Flow Period			0.004			
3-Month Low Flow	VH	Low Flow Period			0.001			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable NA (see notes).

Cross Sections
(at mean high water)







Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area.

References:
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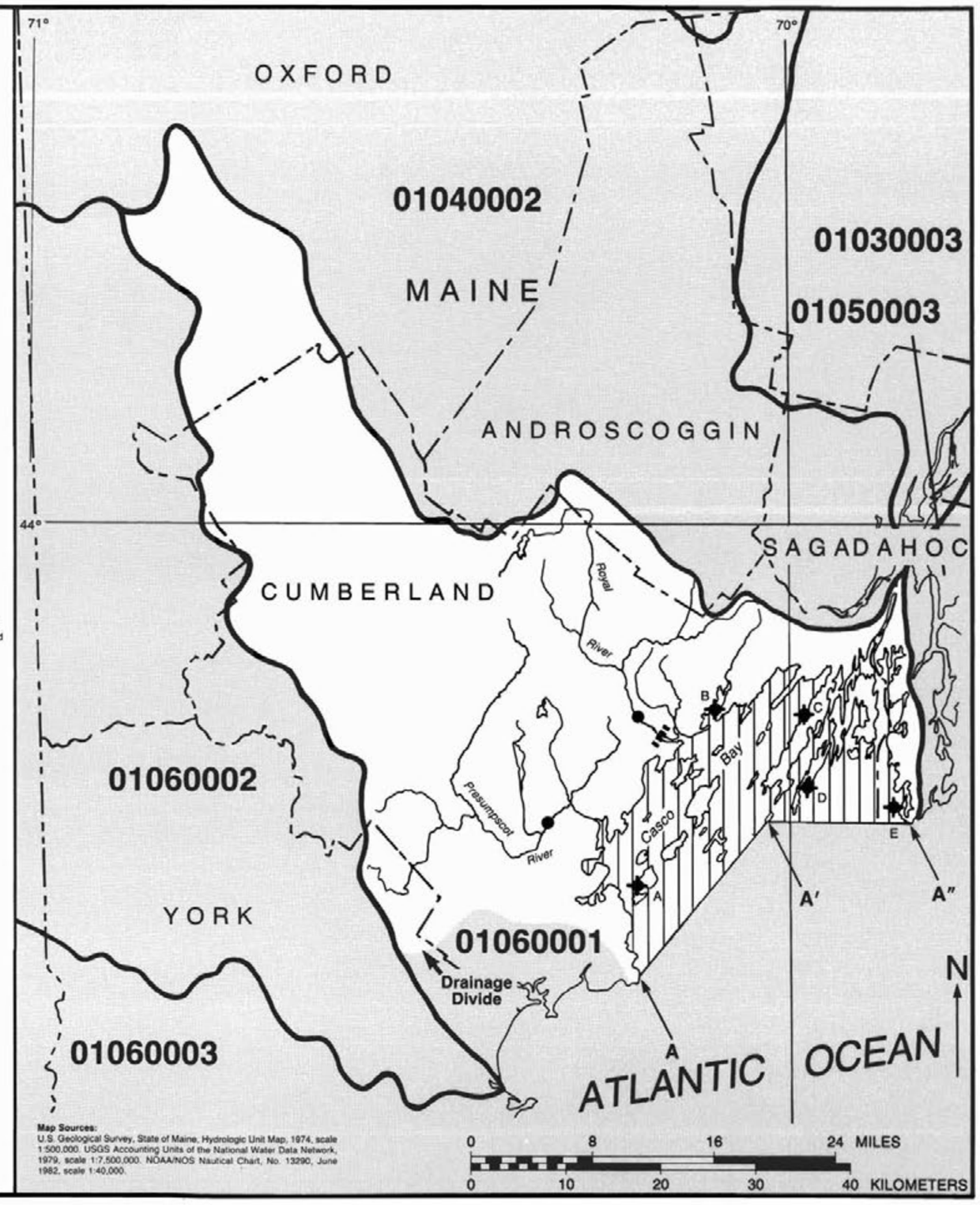
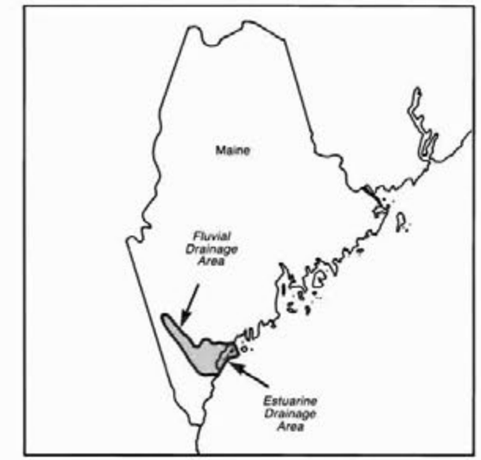


Map Sources:
U.S. Geological Survey, State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13290, June 1982, scale 1:40,000.



- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
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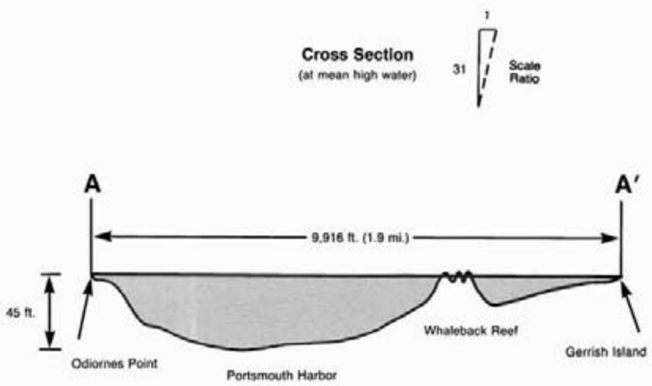
National Estuarine Atlas

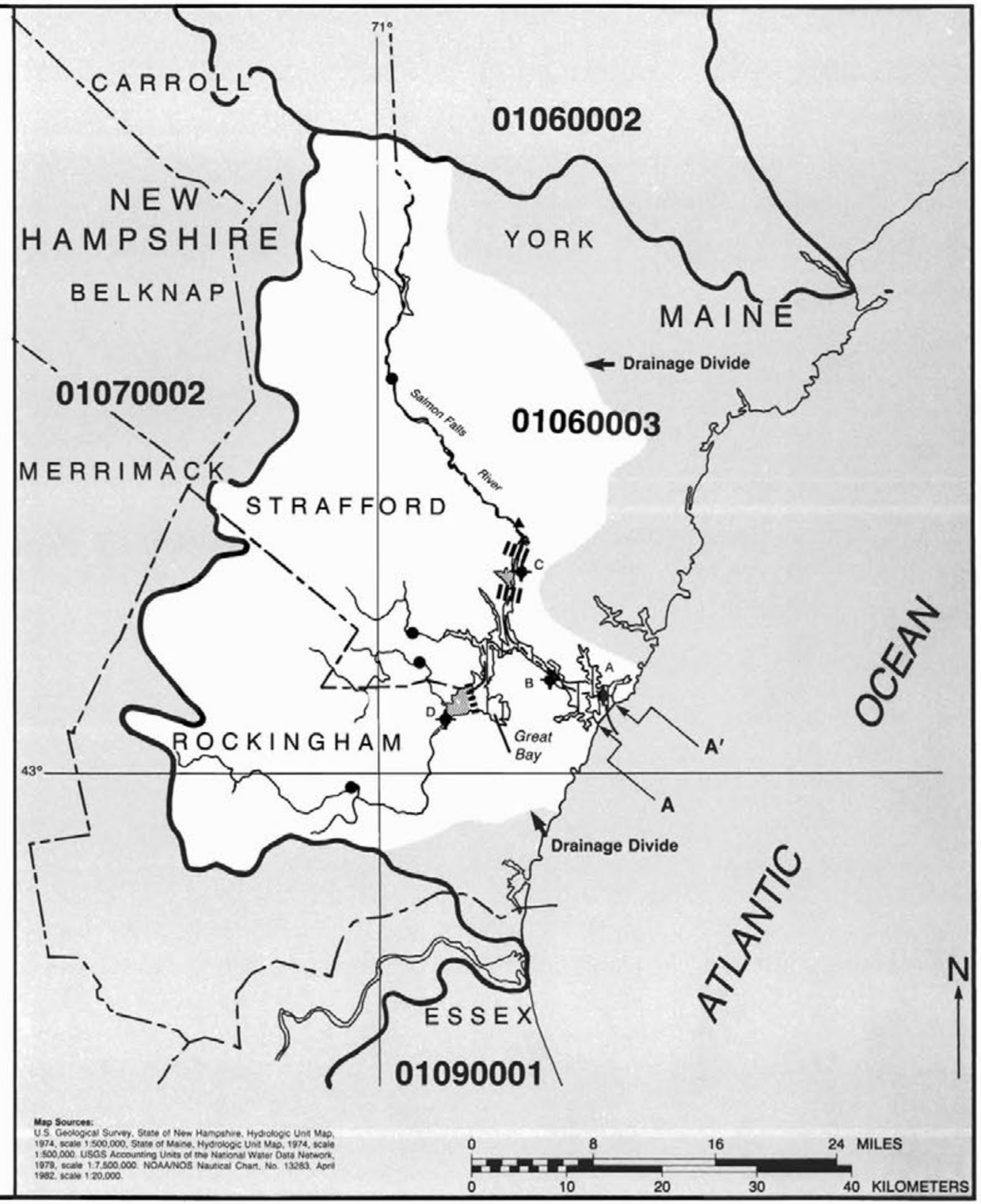
Great Bay
NH, ME

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record		1934-1984		Tidal Prism (cf)	2.27×10^9	
Estuarine Drainage	950							
Estuarine Zones		Long Term Average Daily		2.0		***Phase Range of Tide (ft.)***		
Tidal Fresh	1					Map Key	Station	Range
Mixing Zone	8	Long Term Average Monthly	J 1.4	J 0.9		A	895	8.5
Seawater	6		F 1.4	A 0.5		B	903	7.2
Total	15		M 2.6	S 0.6		C	907	5.0
Dimensions			A 5.1	O 1.2		D	909	3.2
Length (mi.)	15.7		M 3.6	N 1.9				
Width (mi.): Average	1.0		J 1.7	D 1.9				
Minimum	0.1	7-Day, 10-Year Low Flow		0.2				
Maximum	3.7							
Average Depth (ft.)	15.7	50-Year Flood		12.0				
Average Depth to Width Ratio	3.0×10^{-3}	100-Year Flood		13.6				
		Flow Ratios						
Stratification Classification		Average Annual		0.039				
3-Month High Flow	MS	High Flow Period		0.074				
3-Month Low Flow	VH	Low Flow Period		0.013				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable NA (see notes).





Map Sources:
U.S. Geological Survey, State of New Hampshire, Hydrologic Unit Map, 1974, scale 1:500,000. State of Maine, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13283, April 1982, scale 1:20,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
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Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area.

References:
Fontaine, 1978. Fontaine, 1982. Morrill, 1975. Morrill, et al., 1982. Parker, 1978. Silver and Brown, 1975. U.S. Department of Commerce, 1983a.

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National Ocean Service/NOAA

National Estuarine Atlas

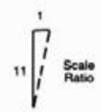
Merrimack River
MA, NH

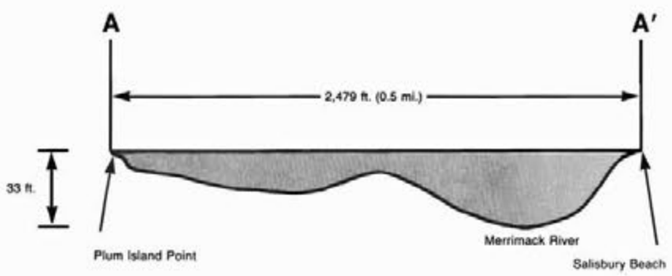
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

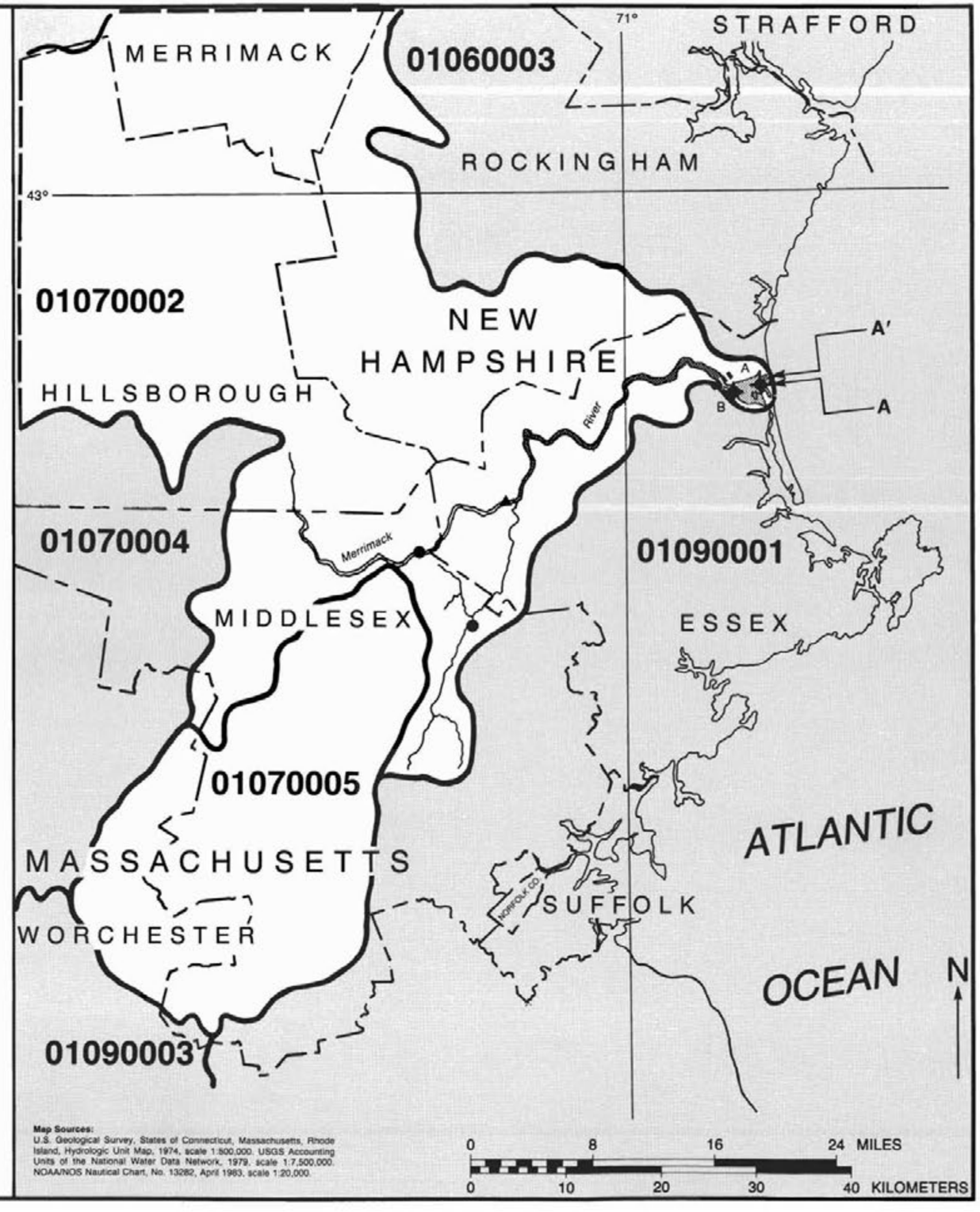
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi²)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	2,080	Period of Record			1952-1982	Tidal Prism (cf)		1.18×10^8
Estuarine Drainage	2,300	Long Term Average Daily			8.4	***Phase Range of Tide (ft.)***		
Estuarine Zones						Map Key	Station	Range
Tidal Fresh	3	Long Term Average Monthly	J	7.9	J 3.4	A	915	8.2
Mixing Zone	3		F	8.7	A 2.8	B	917	7.5
Seawater	0		M	14.2	S 3.0			
Total	6		A	21.9	O 4.8			
Dimensions			M	13.1	N 6.8			
Length (mi.)	25.4		J	6.2	D 8.4			
Width (mi.): Average	0.7	7-Day, 10-Year Low Flow			0.9			
Minimum	0.2							
Maximum	1.6							
Average Depth (ft.)	6.7	50-Year Flood			63.5			
Average Depth to Width Ratio	1.8×10^{-3}	100-Year Flood			65.9			
		Flow Ratios						
Stratification Classification		Average Annual			0.319			
3-Month High Flow	MS	High Flow Period			0.622			
3-Month Low Flow	VH	Low Flow Period			0.116			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.

Cross Section
(at mean high water)







Map Sources:
U.S. Geological Survey, States of Connecticut, Massachusetts, Rhode Island, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13282, April 1983, scale 1:20,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

Notes:
Approximately 75% of Estuarine Drainage Area is shown on map.

References:
Gadoury, et al., 1982. Gay and Delaney, 1980. Tasker, 1975. U.S. Department of Commerce, 1983a.

Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service/NOAA

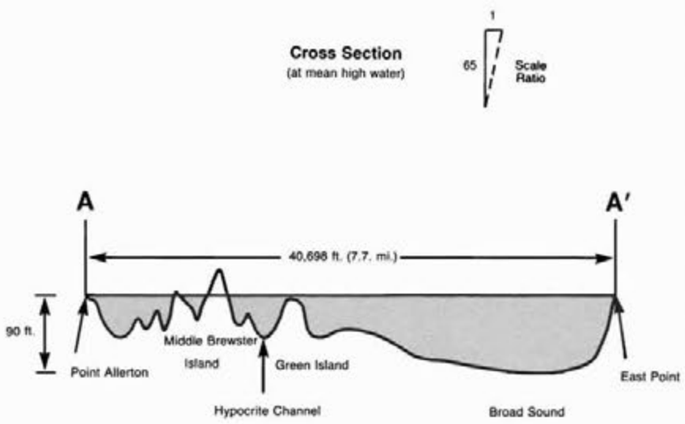
National Estuarine Atlas

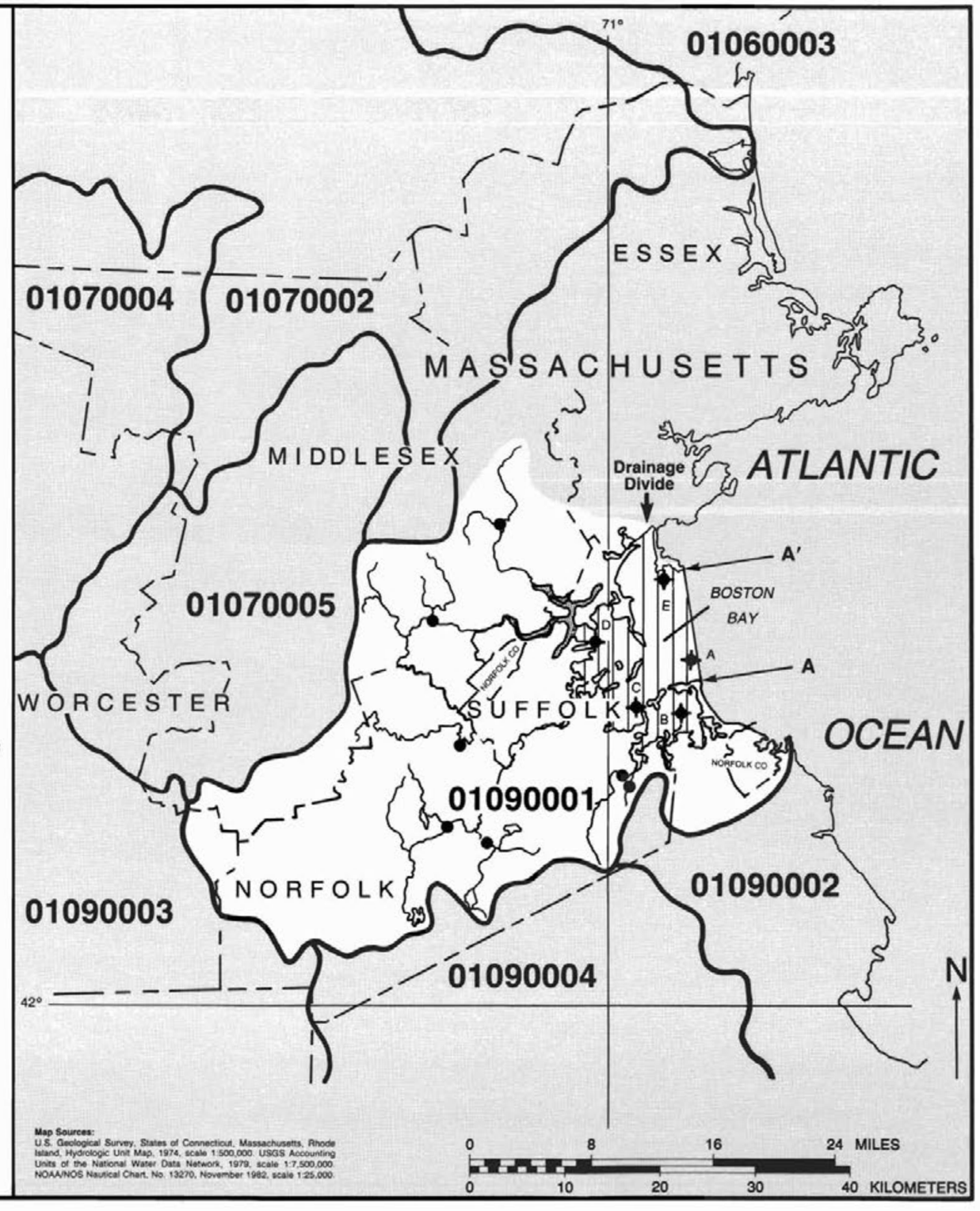
Boston Bay
MA

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			1960-1982	Tidal Prism (cf)		1.77×10^{10}
Estuarine Drainage	670					*Phase Range of Tide (ft.)*		
Estuarine Zones		Long Term Average Daily			1.8	Map Key	Station	Range
Tidal Fresh	0					A	939	9.0
Mixing Zone	1	Long Term Average Monthly	J	2.2	J 1.0	B	973	9.5
Seawater	68		F	2.1	A 0.9	C	971	9.2
Total	69		M	3.3	S 0.9	D	949	9.5
Dimensions			A	3.0	O 1.1	E	935	9.0
Length (mi.)	11.7		M	2.0	N 1.5			
Width (mi.): Average	7.0		J	1.7	D 2.0			
Minimum	0.5	7-Day, 10-Year Low Flow			< 0.1			
Maximum	14.9							
Average Depth (ft.)	19.1	50-Year Flood			6.3			
Average Depth to Width Ratio	5.2×10^{-4}	100-Year Flood			7.3			
		Flow Ratios						
Stratification Classification		Average Annual			0.005			
3-Month High Flow	VH	High Flow Period			0.007			
3-Month Low Flow	VH	Low Flow Period			0.002			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.





- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area.

References:
Bumpus, 1974. Cotton and Delaney, 1975. Gadoury, et al., 1982. Tasker, 1972. Tasker, 1975. U.S. Department of Commerce, 1983a.

Map Sources:
U.S. Geological Survey, States of Connecticut, Massachusetts, Rhode Island, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13270, November 1982, scale 1:25,000.

Strategic Assessment Branch
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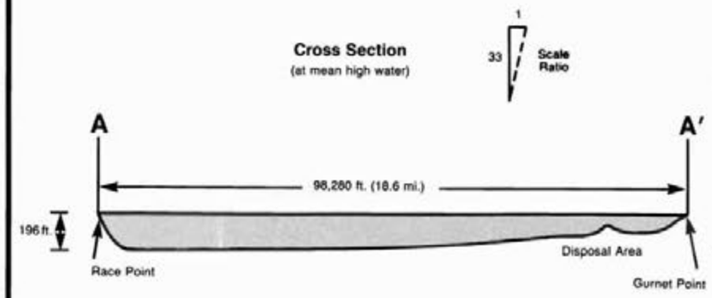
National Estuarine Atlas

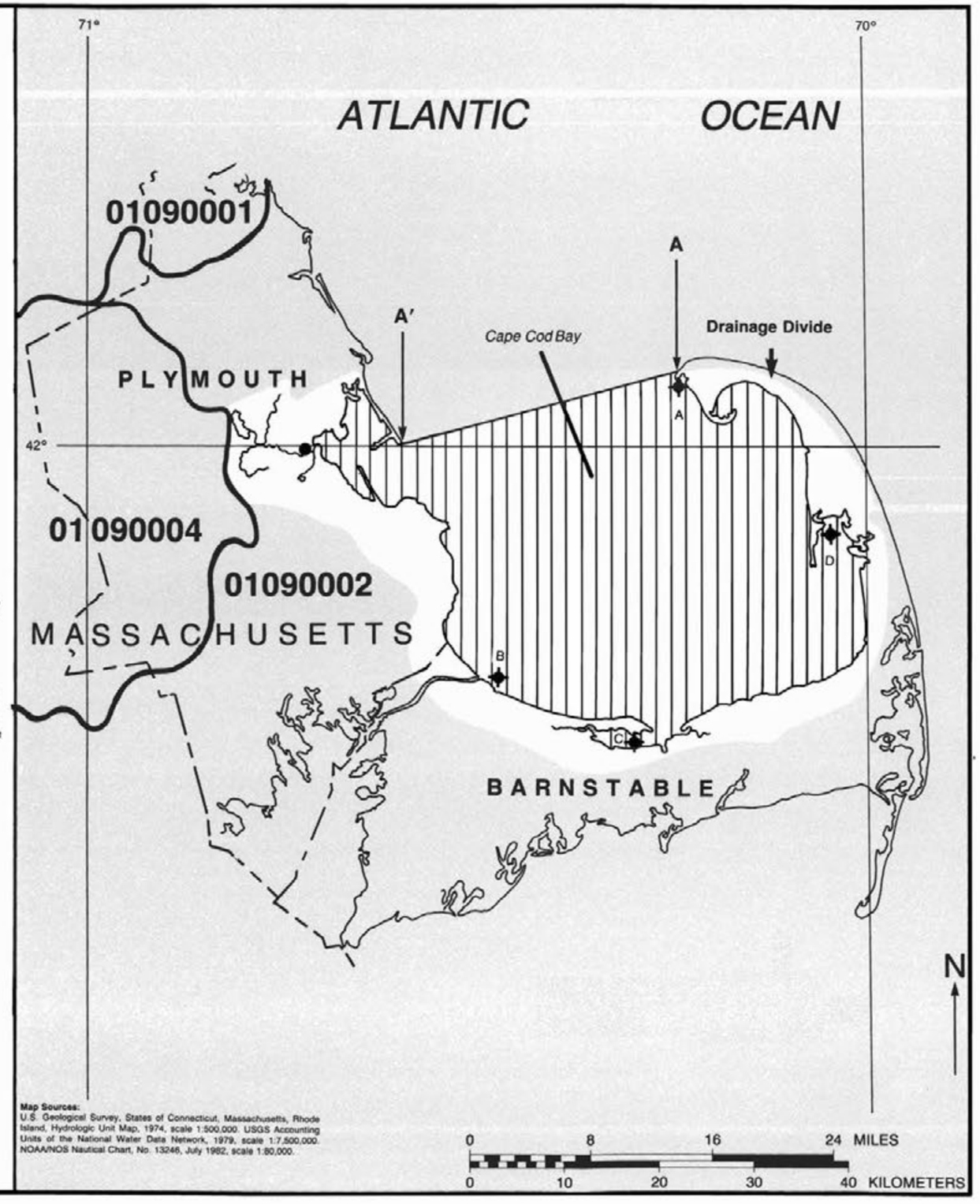
Cape Cod Bay
MA

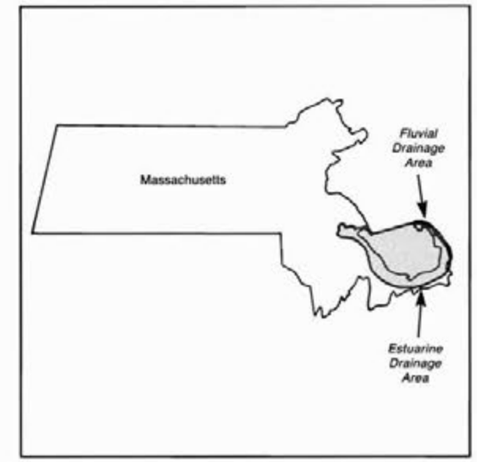
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi²)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			1971-1982	Tidal Prism (cf)		1.38×10^{11}
Estuarine Drainage	771							
Estuarine Zones		Long Term Average Daily			1.8	*Phase Range of Tide (ft.)*		
Tidal Fresh	0					Map Key	Station	Range
Mixing Zone	5	Long Term Average Monthly	J	2.0	J 1.3	A	1005	9.0
Seawater	543		F	1.9	A 1.8	B	997	8.7
Total	548		M	2.0	S 1.9	C	999	9.4
Dimensions			A	1.9	O 1.7	D	1001	10.0
Length (mi.)	23.2		M	1.7	N 2.1			
Width (mi.): Average	25.3		J	1.6	D 2.0			
Minimum	18.6	7-Day, 10-Year Low Flow			ND			
Maximum	38.6							
Average Depth (ft.)	80.2	50-Year Flood			ND			
Average Depth to Width Ratio	6.0×10^{-4}	100-Year Flood			ND			
Stratification Classification		*Flow Ratios*						
3-Month High Flow	VH	Average Annual			0.006			
3-Month Low Flow	VH	High Flow Period			0.007			
		Low Flow Period			0.005			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable, NA (see notes); Not Determined, ND (see notes).







- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
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- Seawater Zone
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- Salinity Zone Boundary - High Variability

Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area. ND: These statistics were not calculated because flood and low flow estimating equations have not been developed for this area. Flows include freshwater input from precipitation.

References:
Bumpus, 1974. Gadoury, et al., 1982. Ryan, 1980. U.S. Department of Commerce, 1981. U.S. Department of Commerce, 1983a.

Map Sources:
U.S. Geological Survey, States of Connecticut, Massachusetts, Rhode Island, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13246, July 1982, scale 1:80,000.

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National Estuarine Atlas

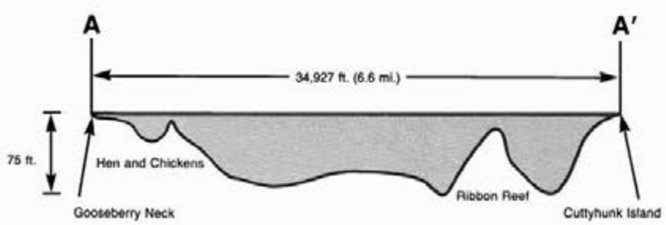
Buzzards Bay
MA

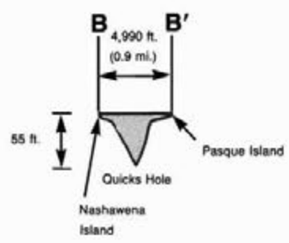
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			No Gages	Tidal Prism (cf)		2.40×10^{10}
Estuarine Drainage	576							
Estuarine Zones		Long Term Average Daily			1.2	*Phase Range of Tide (ft.)*		
Tidal Fresh	0					Map Key	Station	Range
Mixing Zone	2	Long Term Average Monthly	J	1.5	J 0.6	A	1107	3.4
Seawater	226		F	1.6	A 0.9	B	1109	3.8
Total	228		M	1.8	S 0.9	C	1131	3.7
Dimensions			A	1.6	O 0.9	D	1111	4.0
Length (mi.)	29.9		M	1.2	N 1.3	E	1025	4.2
Width (mi.): Average	6.9		J	0.9	D 1.4	F	1023	4.1
Minimum	0.7	7-Day, 10-Year Low Flow			< 0.1			
Maximum	12.6							
Average Depth (ft.)	35.0	50-Year Flood			2.4			
Average Depth to Width Ratio	9.8×10^{-4}	100-Year Flood			2.8			
		Flow Ratios						
Stratification Classification		Average Annual			0.002			
3-Month High Flow	VH	High Flow Period			0.003			
3-Month Low Flow	VH	Low Flow Period			0.001			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable NA (see notes).

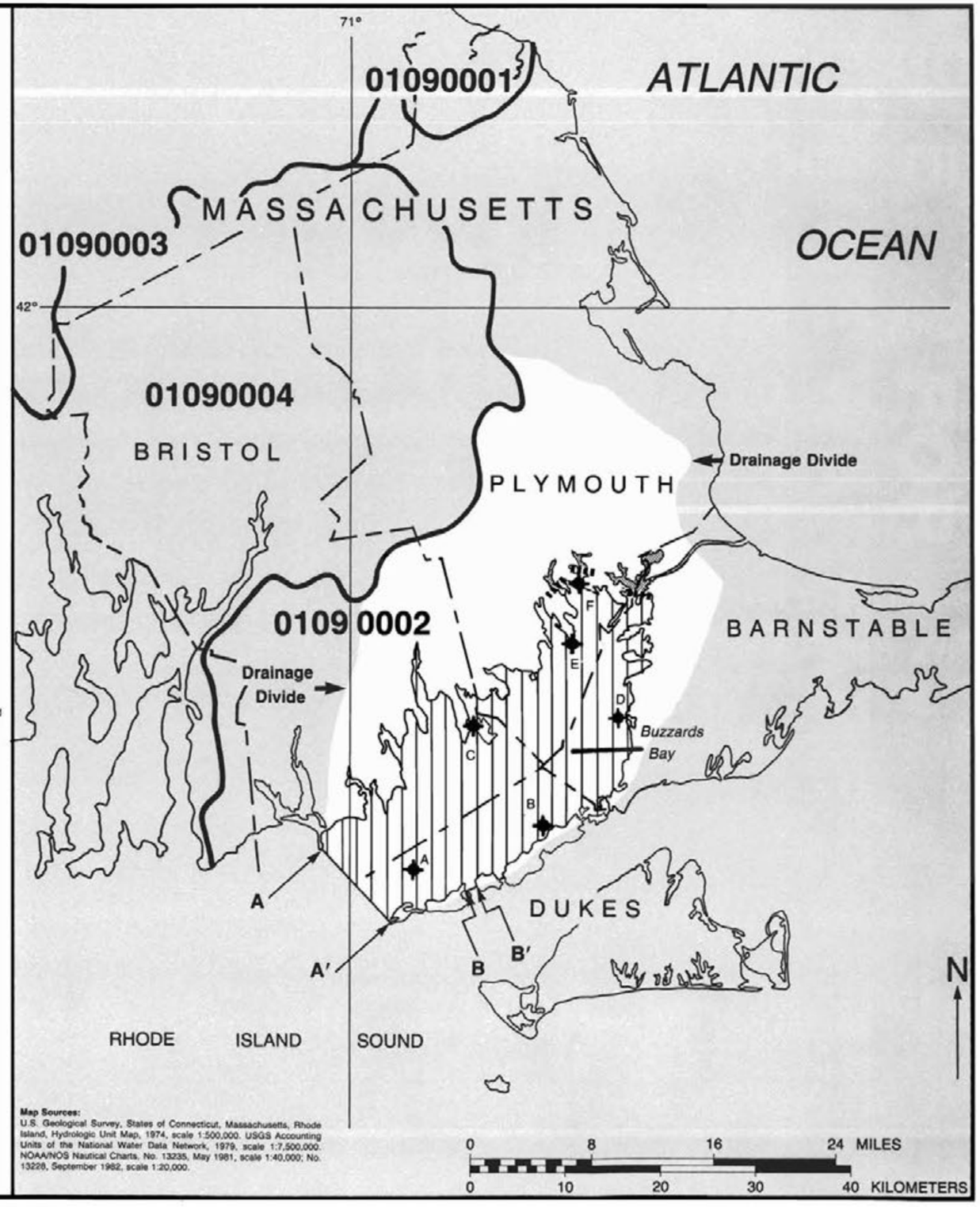
Cross Sections
(at mean high water)





Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area. Flows include freshwater input from precipitation.

References:
Gadoury, et al., 1982. U.S. Department of Commerce, 1983a. Wandle, 1982. Williams and Tasker, 1978. Williams, et al., 1980.



Map Sources:
U.S. Geological Survey, States of Connecticut, Massachusetts, Rhode Island, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Charts, No. 13235, May 1981, scale 1:40,000; No. 13228, September 1982, scale 1:20,000.

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Ocean Assessments Division
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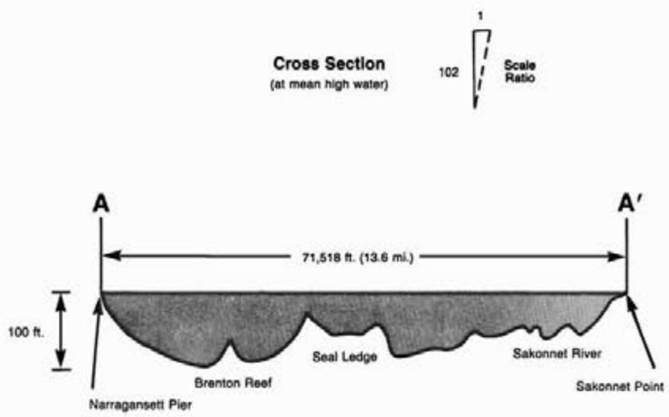
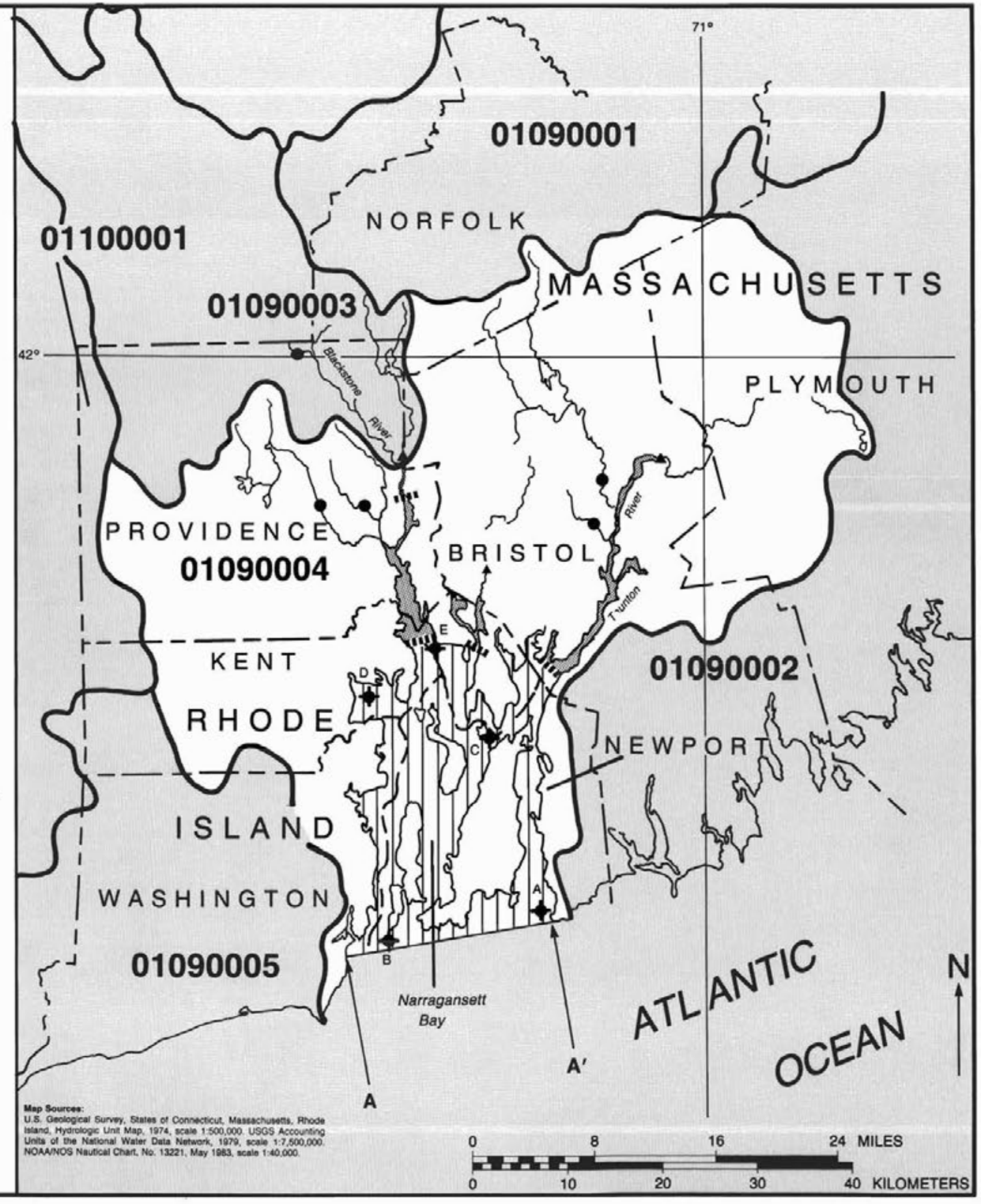
Narragansett Bay
MA, RI

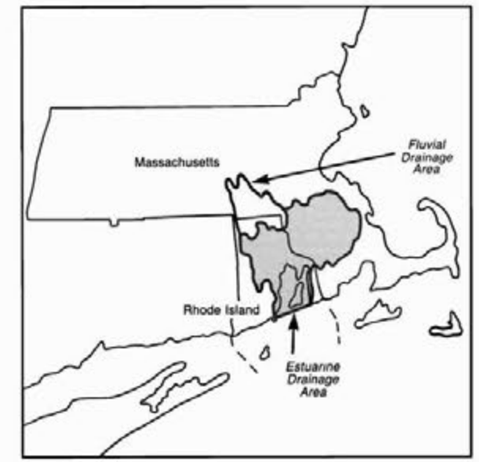
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	451	Period of Record		1966-1982		Tidal Prism (cf)		1.74×10^{10}
Estuarine Drainage	1,330							
Estuarine Zones		Long Term Average Daily		3.2		*Phase Range of Tide (ft.)*		
Tidal Fresh	3					Map Key	Station	Range
Mixing Zone	20	Long Term Average Monthly	J 4.6	J 1.3		A	1147	3.1
Seawater	142		F 4.5	A 1.2		B	1151	3.4
Total	165		M 6.0	S 1.2		C	1157	4.0
Dimensions			A 5.3	O 1.6		D	1173	4.0
Length (mi.)	29.3		M 3.6	N 2.6		E	1167	4.5
Width (mi.): Average	9.1		J 2.8	D 3.9				
Minimum	0.5	7-Day, 10-Year Low Flow		0.2				
Maximum	12.8							
Average Depth (ft.)	32.9	50-Year Flood		34.2				
Average Depth to Width Ratio	6.8×10^{-4}	100-Year Flood		38.6				
		Flow Ratios						
Stratification Classification		Average Annual		0.008				
3-Month High Flow	VH	High Flow Period		0.014				
3-Month Low Flow	VH	Low Flow Period		0.003				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.







- Tide Gage
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Notes:
One hundred percent of Estuarine Drainage Area is shown on map.

References:
Brackley and Thomas, 1978. Cerivone, 1982. Gadoury, et al., 1982. Hess, 1976. Nixon, et al., 1984. Pilson, 1985. Shonting and Cook, 1970. U.S. Department of Commerce, 1983a. Weiss, 1983.

Map Sources:
U.S. Geological Survey, States of Connecticut, Massachusetts, Rhode Island, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13221, May 1983, scale 1:40,000.

Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service/NOAA

National Estuarine Atlas

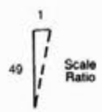
Gardiners Bay NY

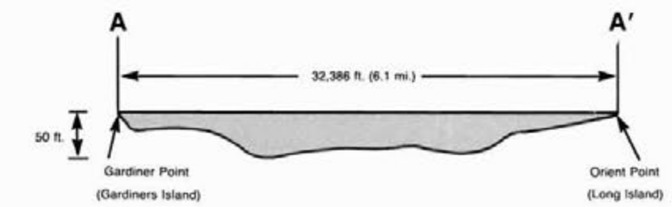
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

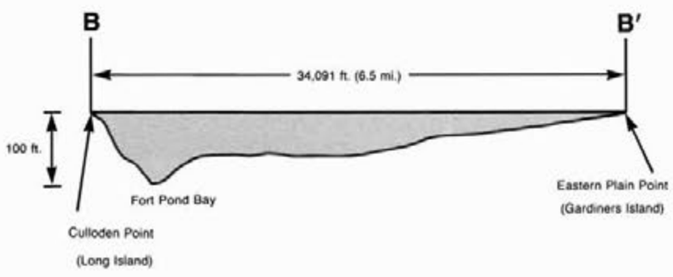
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record		1942-1983		Tidal Prism (cf)	1.15×10^{10}	
Estuarine Drainage	400	Long Term Average Daily		0.7		***Phase Range of Tide (ft.)***		
Estuarine Zones						Map Key	Station	Range
Tidal Fresh	0	Long Term Average Monthly	J 0.7	J	0.7	A	1405	1.9
Mixing Zone	2		F 0.7	A	0.8	B	1399	2.3
Seawater	195		M 0.8	S	0.7	C	1381	2.5
Total	197		A 0.7	O	0.6	D	1393	1.8
Dimensions			M 0.7	N	0.7	E	1397	1.5
Length (mi.)	31		J 0.6	D	0.7			
Width (mi.): Average	8.7	7-Day, 10-Year Low Flow		< 0.1				
Minimum	1.0							
Maximum	13.7							
Average Depth (ft.)	20.0	50-Year Flood		0.2				
Average Depth to Width Ratio	4.4×10^{-4}	100-Year Flood		0.2				
		Flow Ratios						
Stratification Classification		Average Annual		0.003				
3-Month High Flow	VH	High Flow Period		0.003				
3-Month Low Flow	VH	Low Flow Period		0.003				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS. Not Applicable, NA (see notes).

Cross Sections
(at mean high water)

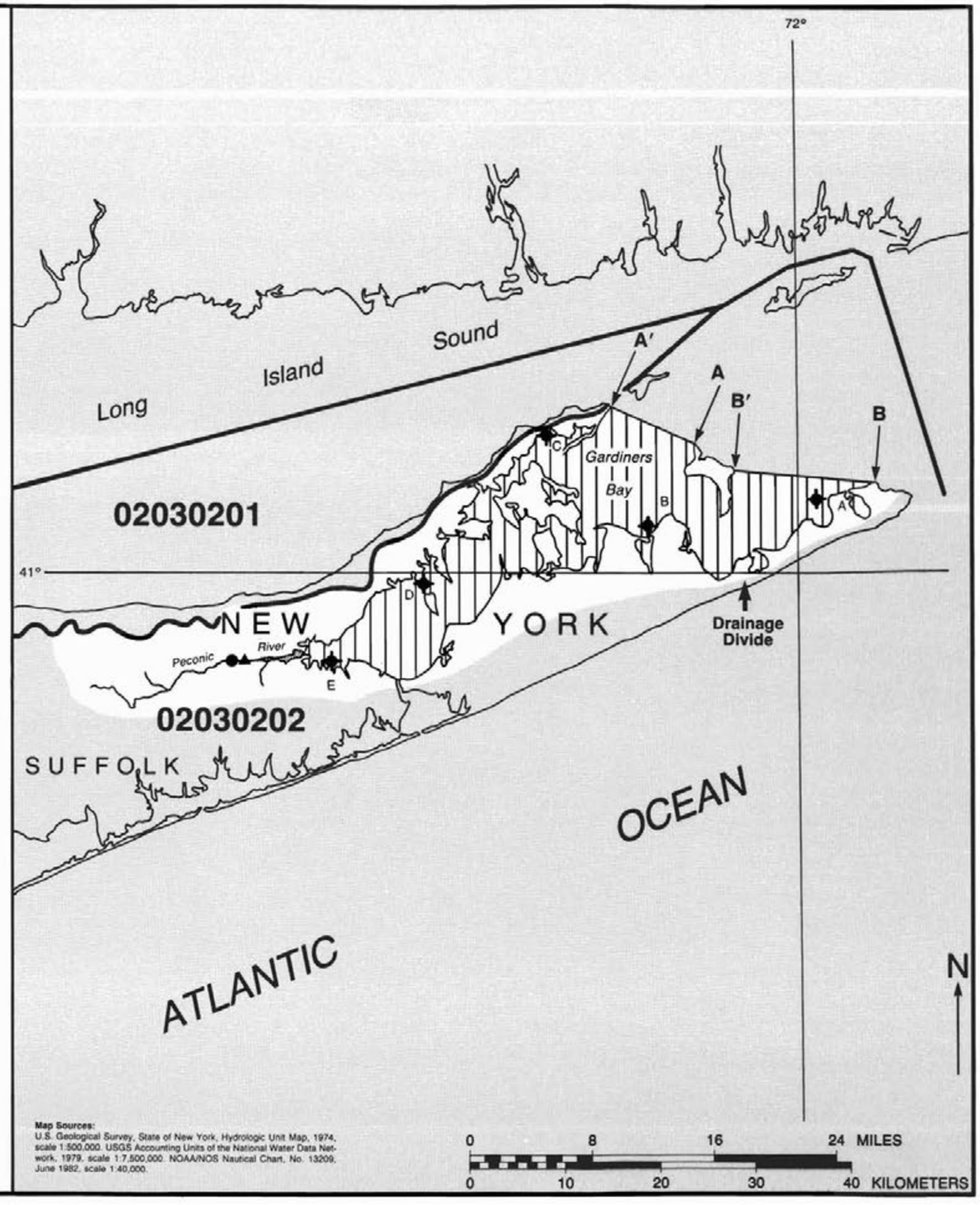






Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area. Flows include freshwater input from precipitation.

References:
Cerivone, et al., 1982. Koppelmann, 1972. Reid, 1961. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of New York, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13209, June 1982, scale 1:40,000.

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National Estuarine Atlas

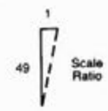
Gardiners Bay NY

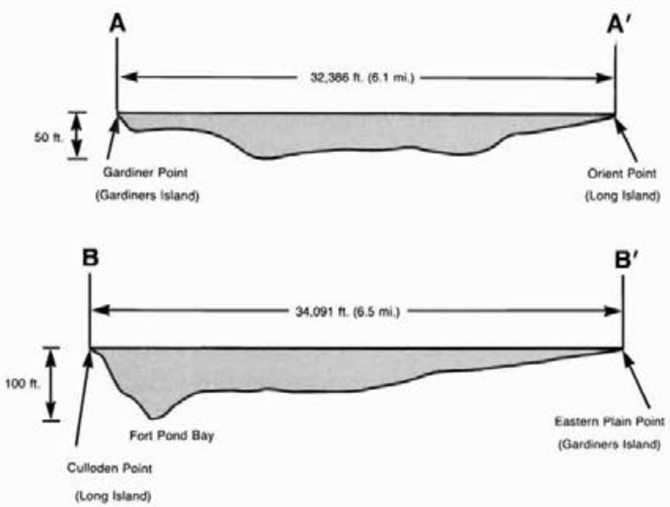
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record		1942-1983		Tidal Prism (cf)	1.15×10^{10}	
Estuarine Drainage	400	Long Term Average Daily		0.7		*Phase Range of Tide (ft.)*		
Estuarine Zones						Map Key	Station	Range
Tidal Fresh	0	Long Term Average Monthly	J 0.7	J 0.7		A	1405	1.9
Mixing Zone	2		F 0.7	A 0.8		B	1399	2.3
Seawater	195		M 0.8	S 0.7		C	1381	2.5
Total	197		A 0.7	O 0.6		D	1393	1.8
Dimensions			M 0.7	N 0.7		E	1397	1.5
Length (mi.)	31		J 0.6	D 0.7				
Width (mi.): Average	6.7	7-Day, 10-Year Low Flow		< 0.1				
Minimum	1.0							
Maximum	13.7							
Average Depth (ft.)	20.0	50-Year Flood		0.2				
Average Depth to Width Ratio	4.4×10^{-4}	100-Year Flood		0.2				
		Flow Ratios						
Stratification Classification		Average Annual		0.003				
3-Month High Flow	VH	High Flow Period		0.003				
3-Month Low Flow	VH	Low Flow Period		0.003				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS. Not Applicable, NA (see notes).

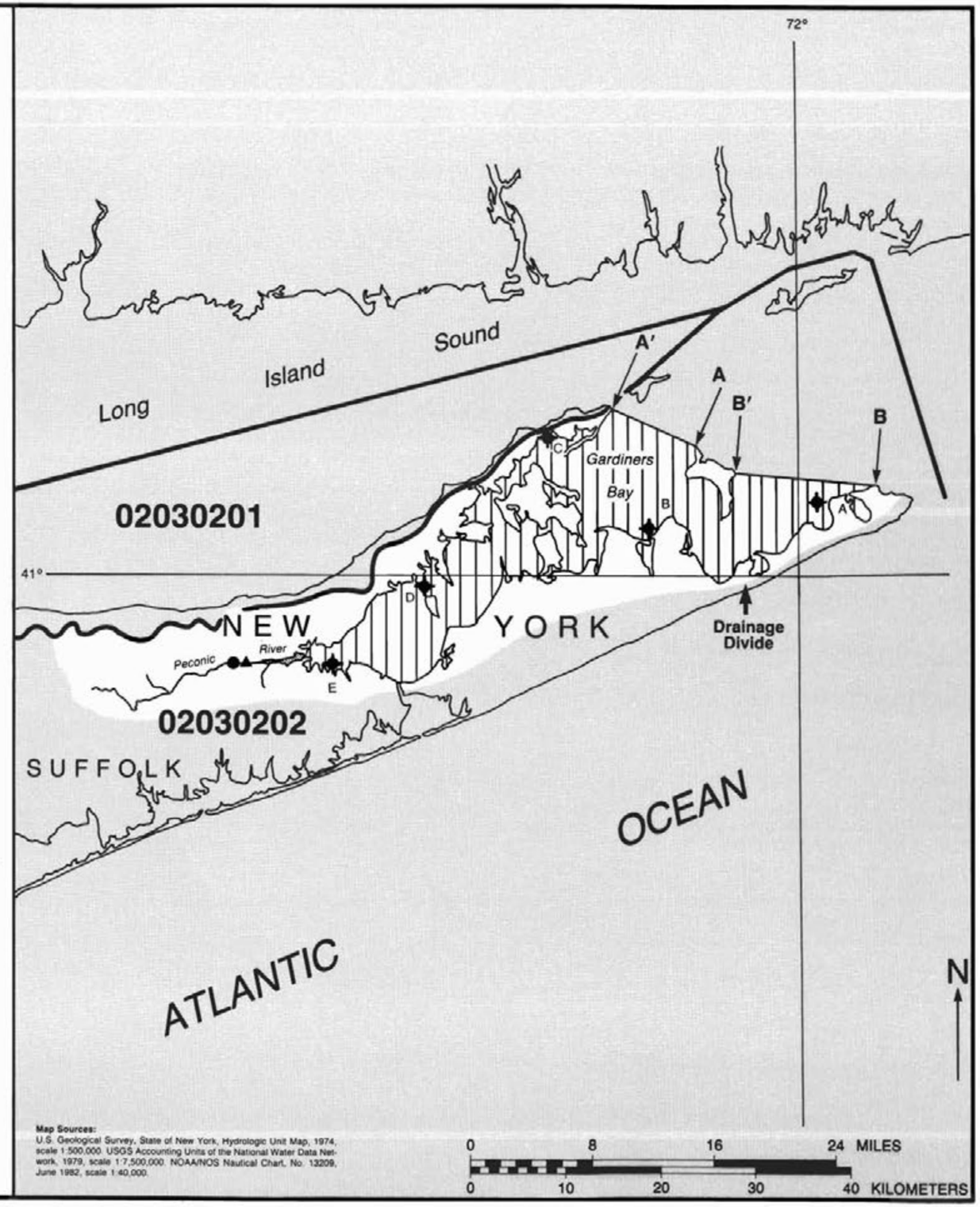
Cross Sections
(at mean high water)





Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area. Flows include freshwater input from precipitation.

References:
Cerivone, et al., 1982. Koppelmann, 1972. Reid, 1961. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of New York, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 13209, June 1982, scale 1:40,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

Strategic Assessment Branch
Ocean Assessments Division
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National Ocean Service/NOAA

National Estuarine Atlas

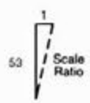
Long Island Sound
NY, CT, MA

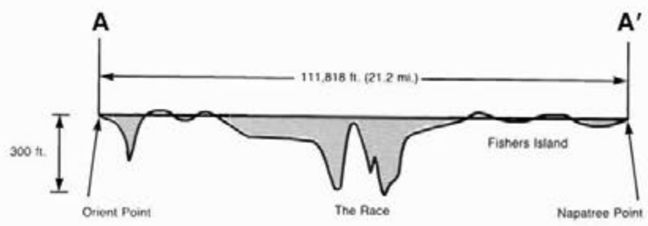
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	10,010	Period of Record			1970-1982	Tidal Prism (cf)		1.33×10^{11}
Estuarine Drainage	7,230					*Phase Range of Tide (ft.)*		
Estuarine Zones		Long Term Average Daily			30.0	Map Key	Station	Range
Tidal Fresh	29					A	1191	2.4
Mixing Zone	165	Long Term Average Monthly	J	29.9	J 14.4	B	1375	2.8
Seawater	1087		F	33.4	A 11.8	C	1215	3.3
Total	1281		M	53.0	S 12.2	D	1370	3.0
Dimensions			A	66.4	O 19.1	E	1223	4.2
Length (mi.)	199.0		M	44.5	N 24.0	F	1367	3.7
Width (mi.): Average	12.4		J	21.7	D 31.2	G	1239	4.5
Minimum	0.7	7-Day, 10-Year Low Flow			3.0	H	1249	4.2
Maximum	22.6							
Average Depth (ft.)	63.8	50-Year Flood			222.9	I	1339	3.9
Average Depth to Width Ratio	9.7×10^{-4}	100-Year Flood			234.1	J	1257	4.1
		Flow Ratios				K	1261	2.6
Stratification Classification		Average Annual			0.010	L	1267	2.0
3-Month High Flow	VH	High Flow Period			0.018			
3-Month Low Flow	VH	Low Flow Period			0.004			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.

Cross Section
(at mean high water)





Map Sources:
U.S. Geological Survey. State of New York, Hydrologic Unit Map, 1974, scale 1:500,000, States of Connecticut, Massachusetts, Rhode Island, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Charts, No. 13214, August 1979, scale 1:20,000; No. 13209, June 1982, scale 1:40,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
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- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary.

References:
Cerivone, et al., 1982. Garvine, 1974. Hill and Sheridan, 1970. Koppelmann, 1972. Spaulding and Beauchamp, 1983. Thomas, et al., 1983. U.S. Department of Commerce, 1983a.

Strategic Assessment Branch
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National Ocean Service/NOAA

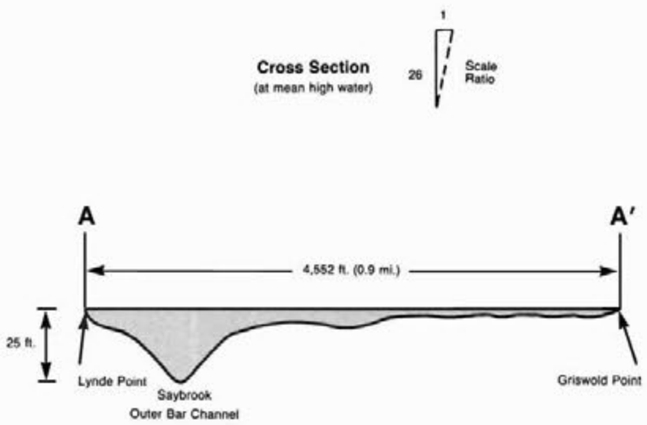
National Estuarine Atlas

Connecticut River
CT, MA

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

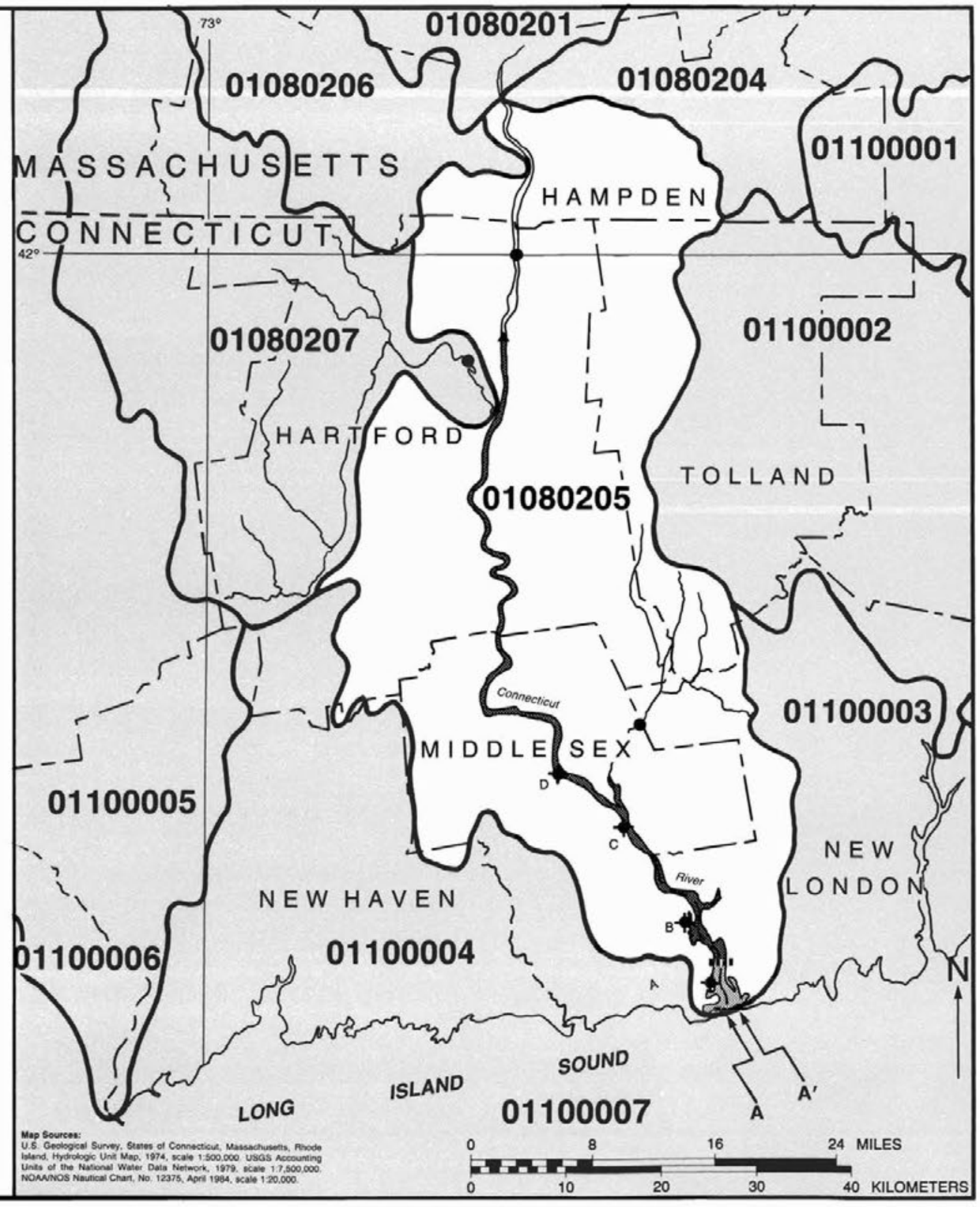
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	10,010	Period of Record		1970-1982		Tidal Prism (cf)		9.12×10^8
Estuarine Drainage	1,090	Long Term Average Daily		21.0		*Phase Range of Tide (ft.)*		
Estuarine Zones						Map Key	Station	Range
Tidal Fresh	18	Long Term Average Monthly	J 18.5	J 10.6		A	1201	3.2
Mixing Zone	2		F 21.1	A 8.7		B	1203	2.8
Seawater	0		M 35.3	S 8.7		C	1205	2.1
Total	20		A 49.4	O 14.4		D	1207	1.5
Dimensions			M 33.9	N 17.0				
Length (mi.)	55.5		J 16.7	D 20.6				
Width (mi.): Average	0.3	7-Day, 10-Year Low Flow		2.7				
Minimum	0.2							
Maximum	0.9							
Average Depth (ft.)	12.6	50-Year Flood		141.2				
Average Depth to Width Ratio	8.0×10^{-3}	100-Year Flood		146.1				
		Flow Ratios						
Stratification Classification		Average Annual		1.031				
3-Month High Flow	HS	High Flow Period		1.937				
3-Month Low Flow	MS	Low Flow Period		0.459				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.



Notes:
One hundred percent of Estuarine Drainage Area is shown on map.

References:
Cerivone, et al., 1982. Hill and Sheridan, 1970. Spinello, et al., 1983. Thomas, et al., 1983. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, States of Connecticut, Massachusetts, Rhode Island, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12375, April 1984, scale 1:20,000.

- Tide Gage
- Flow Gage
- Head of Tide
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- Tidal Fresh Zone
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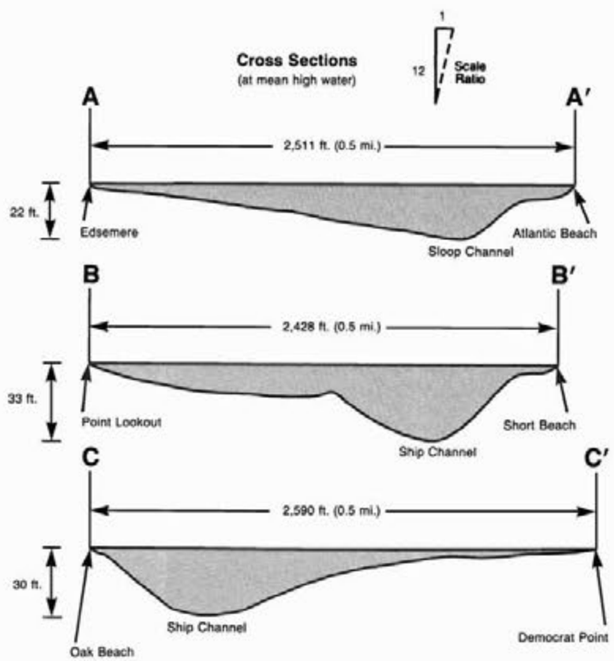
National Estuarine Atlas

Great South Bay
NY

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

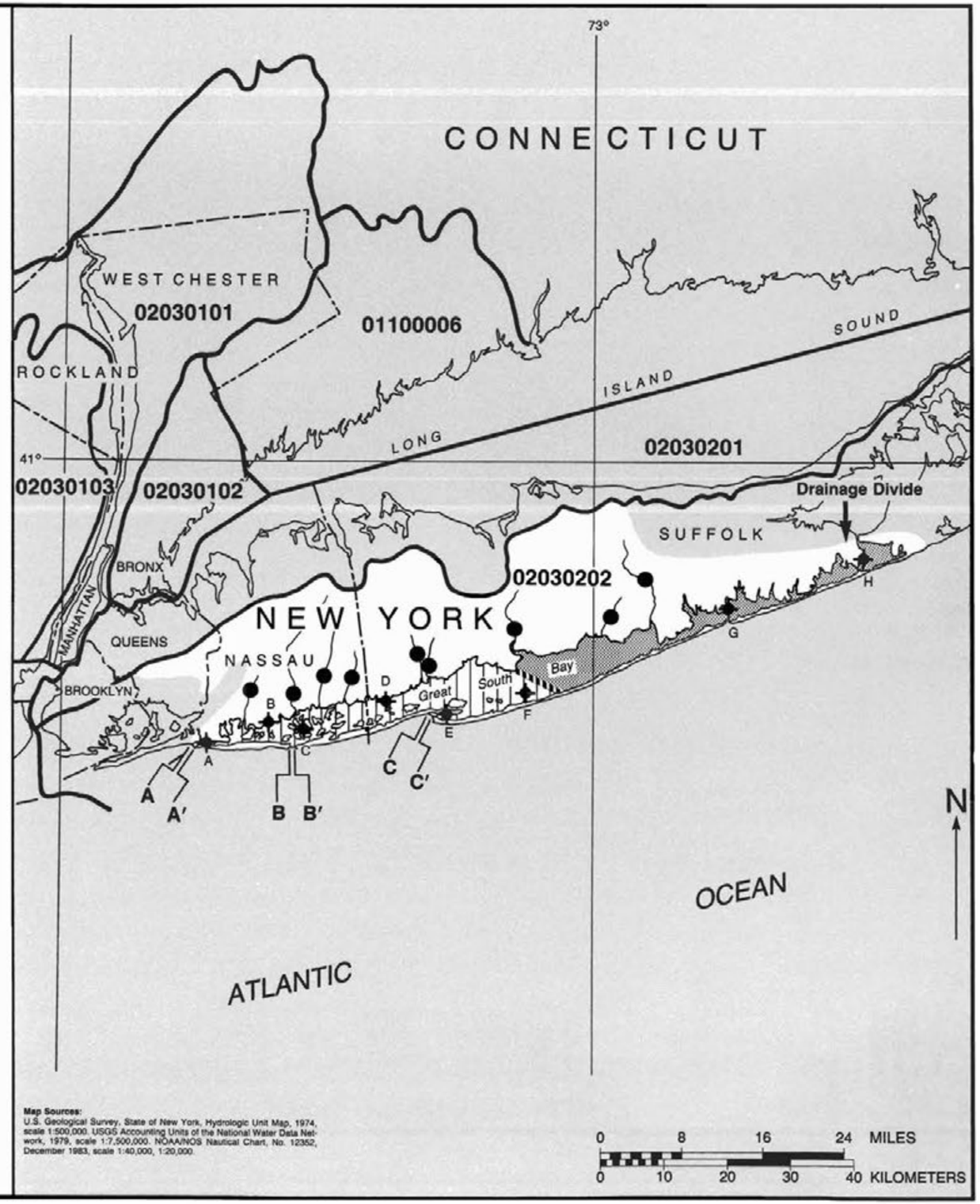
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi²)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record		1924-1983		Tidal Prism (cf)		2.64x10⁹
Estuarine Drainage	845							
Estuarine Zones		Long Term Average Daily		0.7		***Phase Range of Tide (ft.)***		
Tidal Fresh	0					Map Key	Station	Range
Mixing Zone	78	Long Term Average Monthly	J	0.6	J 0.6	A	1473	4.0
Seawater	73		F	0.6	A 0.7	B	1463	2.5
Total	151		M	0.7	S 0.7	C	1455	1.6
Dimensions			A	0.7	O 0.6	D	1445	0.2
Length (mi.)	72.0		M	0.7	N 0.7	E	1421	2.6
Width (mi.): Average	2.2		J	0.6	D 0.7	F	1427	0.2
Minimum	0.2	7-Day, 10-Year Low Flow		0.1		G	1415	2.8
Maximum	5.6					H	1411	2.1
Average Depth (ft.)	7.2	50-Year Flood		1.5				
Average Depth to Width Ratio	6.2x10⁻⁴	100-Year Flood		1.7				
		Flow Ratios						
Stratification Classification		Average Annual		0.011				
3-Month High Flow	VH	High Flow Period		0.012				
3-Month Low Flow	VH	Low Flow Period		0.011				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS. Not Applicable, NA (see notes).



Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area. Flows include freshwater input from precipitation.

References:
Blackey, et al., 1983. Spinello, et al., 1983. Swift, et al., 1979. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of New York, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12352, December 1983, scale 1:40,000, 1:20,000.

- Tide Gage
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- Head of Tide
- Estuarine Drainage Area (EDA)
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National Ocean Service/NOAA

National Estuarine Atlas

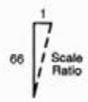
Hudson River/Raritan Bay
NY, NJ, MA, CT

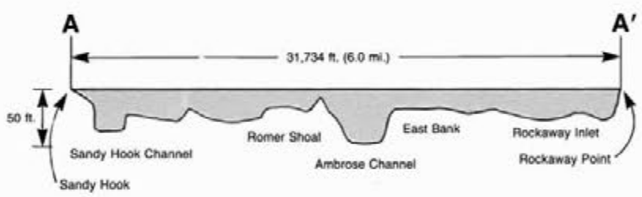
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

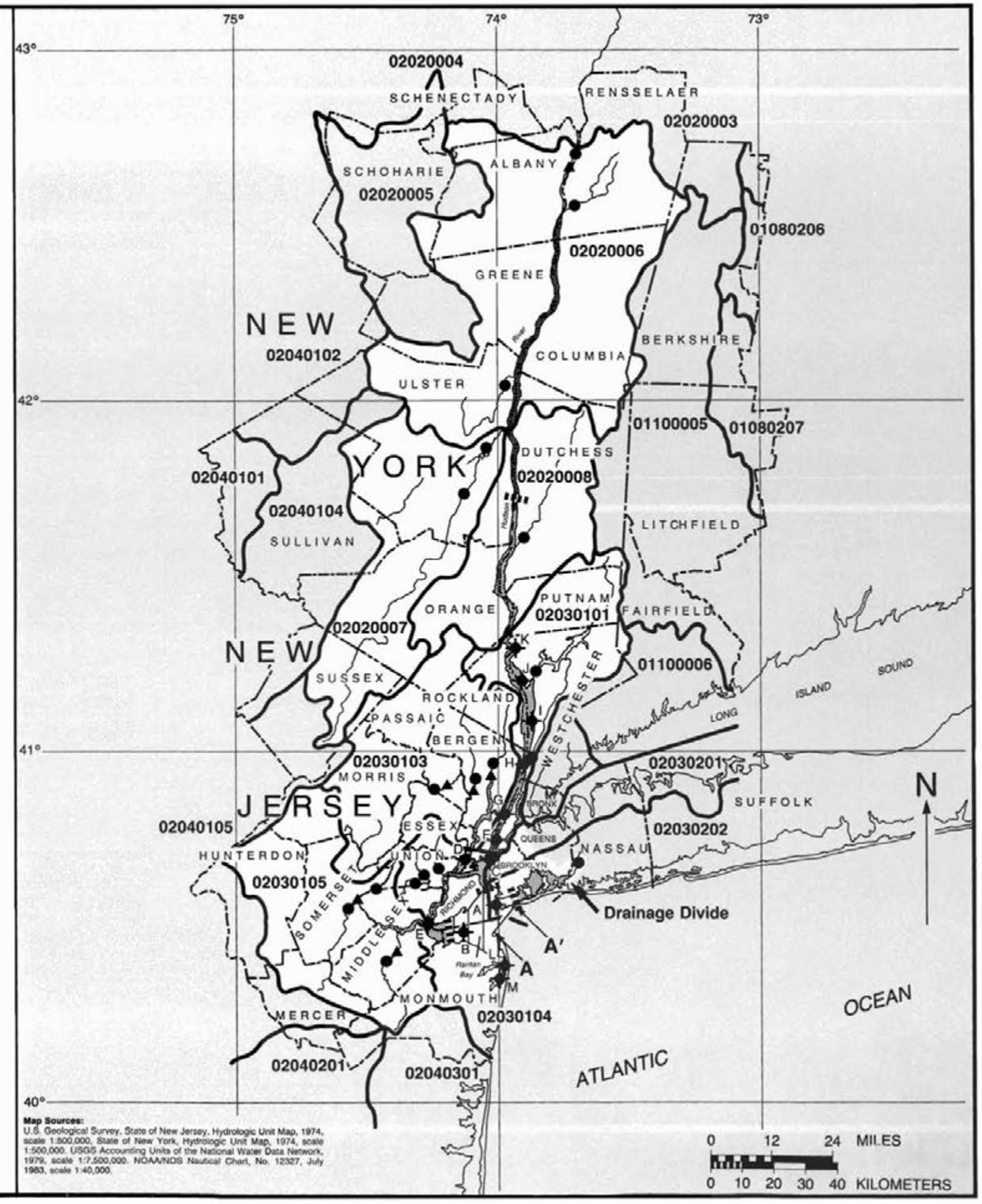
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	8,037	Period of Record		1946-1982		Tidal Prism (cf)		2.60×10^{10}
Estuarine Drainage	8,467					*Phase Range of Tide (ft.)*		
Estuarine Zones		Long Term Average Daily		26.7		Map Key	Station	Range
Tidal Fresh	37	Long Term Average Monthly	J 29.8	J 13.1		A	1493	4.7
Mixing Zone	168		F 32.5	A 11.1		B	1619	4.9
Seawater	93		M 47.8	S 12.2		C	1519	4.4
Total	298		A 54.1	O 16.0		D	1581	4.8
Dimensions			M 33.2	N 23.0		E	1601	5.2
Length (mi.)	160		J 19.7	D 29.3		F	1519	4.0
Width (mi.): Average	1.7	7-Day, 10-Year Low Flow		2.9		G	1525	3.5
Minimum	0.1					H	1531	2.7
Maximum	11.2							
Average Depth (ft.)	15.0	50-Year Flood		191.2		I	1535	1.7
Average Depth to Width Ratio	1.7×10^{-3}	100-Year Flood		203.4		J	1539	0.9
		Flow Ratios				K	1541	0.2
Stratification Classification		Average Annual		0.046		L	1631	2.5
3-Month High Flow	MS	High Flow Period		0.077		M	1633	0.6
3-Month Low Flow	VH	Low Flow Period		0.021				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.

Cross Section
(at mean high water)







- Tide Gage
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Notes:
One hundred percent of Estuarine Drainage Area is shown on map.

Map Sources:
U.S. Geological Survey, State of New Jersey, Hydrologic Unit Map, 1974, scale 1:500,000. State of New York, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12327, July 1983, scale 1:40,000.

References:
Abood and Bourodimos, 1976. Bauersfield, et al., 1983. Brackley and Thomas, 1978. Cerivone, 1982. Cooper, et al., 1984. Eissler, 1979. Haag and Bedford, 1974. Leendertse, 1970. Mann, 1980. O'Conner and Mueller, 1984. Stankowski, 1974. U.S. Department of Commerce, 1983a. Weiss, 1983. Zembruski, et al., 1979. Zembruski, et al., 1982.

Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service/NOAA

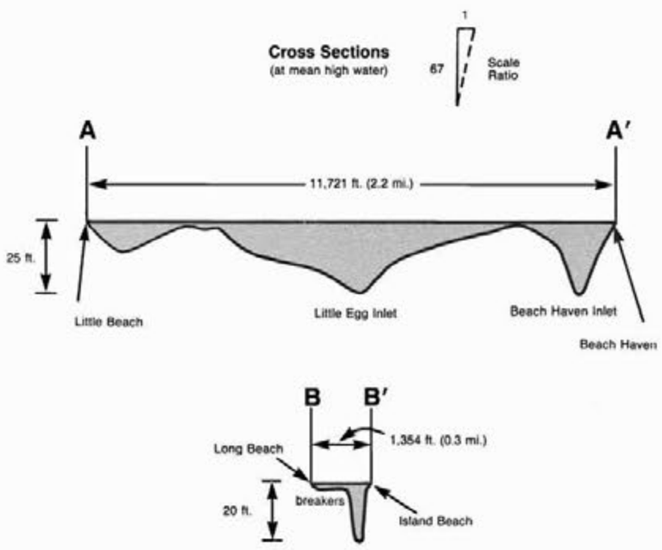
National Estuarine Atlas

Barnegat Bay
NJ

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

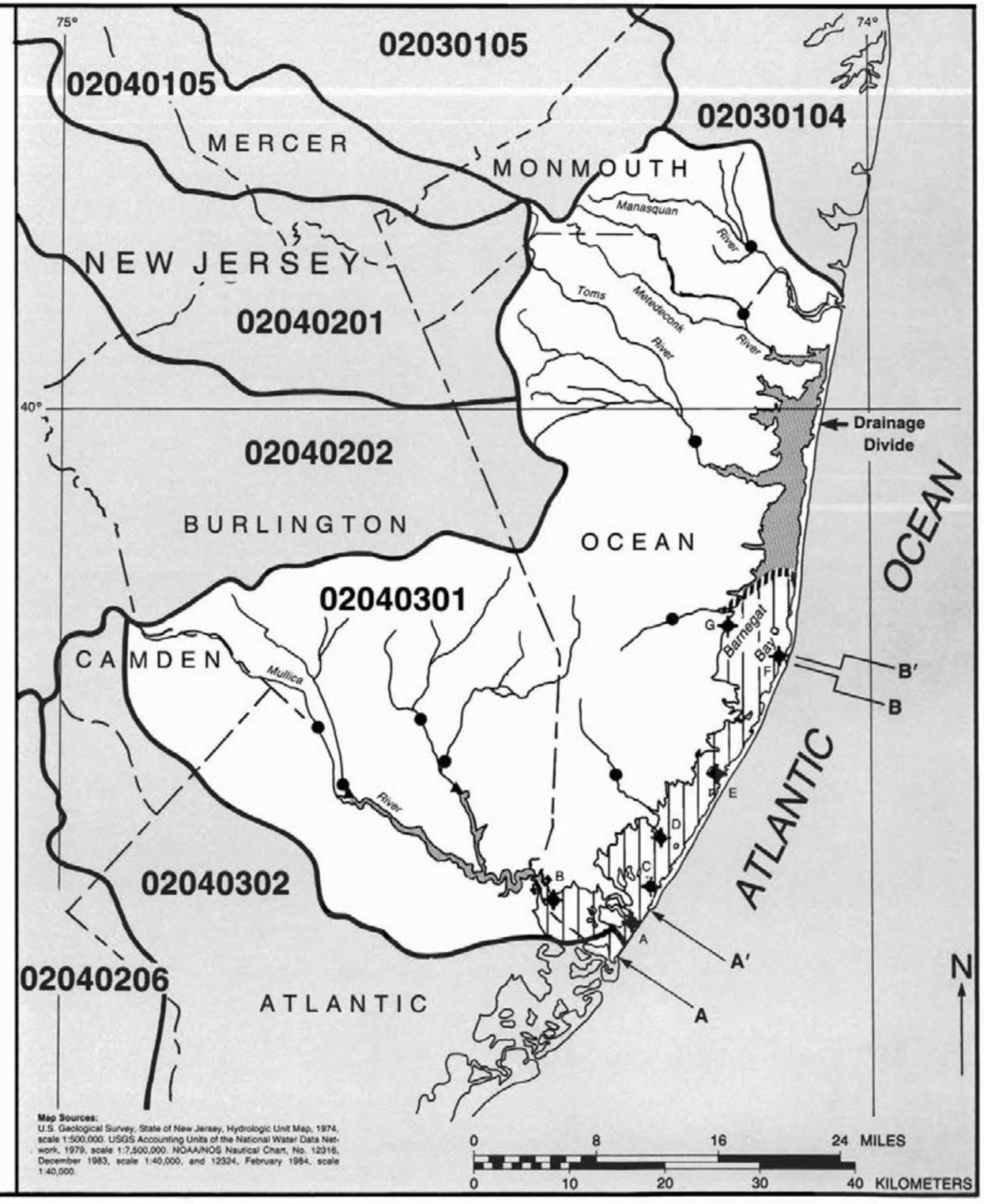
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			1928-1982	Tidal Prism (cf)		3.02×10^9
Estuarine Drainage	1,350							
Estuarine Zones		Long Term Average Daily			2.3	*Phase Range of Tide (ft.)*		
Tidal Fresh	0					Map Key	Station	Range
Mixing Zone	30	Long Term Average Monthly	J	2.8	J 1.6	A	1681	3.7
Seawater	72		F	2.8	A 1.7	B	1685	3.0
Total	102		M	3.2	S 1.5	C	1679	2.3
Dimensions			A	3.0	O 1.6	D	1673	1.4
Length (mi.)	40.0		M	2.6	N 2.1	E	1671	0.4
Width (mi.): Average	2.8		J	1.9	D 2.3	F	1667	3.1
Minimum	0.3	7-Day, 10-Year Low Flow			0.6	G	1663	0.2
Maximum	6.6							
Average Depth (ft.)	4.6	50-Year Flood			35.4			
Average Depth to Width Ratio	3.1×10^{-4}	100-Year Flood			42.6			
		Flow Ratios						
Stratification Classification		Average Annual			0.033			
3-Month High Flow	VH	High Flow Period			0.044			
3-Month Low Flow	VH	Low Flow Period			0.024			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS. Not Applicable, NA (see notes).

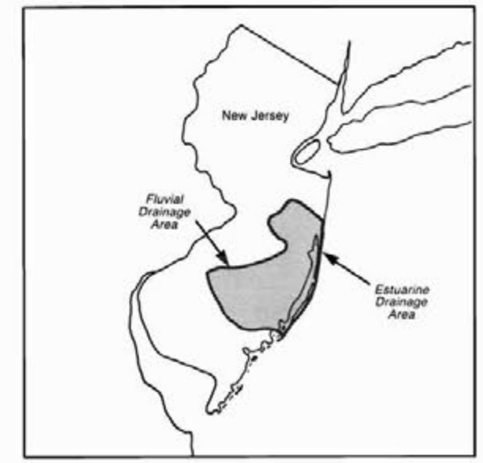


Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area.

References:
Bauersfield, et al., 1983. Chizmadia, 1984. Daiber, et al., 1976. Gillespie and Schopp, 1982. New Jersey Department of Environmental Protection, 1980. U.S. Department of Commerce, 1983a.



Map Sources:
U.S. Geological Survey, State of New Jersey, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12316, December 1983, scale 1:40,000, and 12324, February 1984, scale 1:40,000.



- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
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Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service/NOAA

National Estuarine Atlas

Delaware Bay
DE, NJ, PA, MD

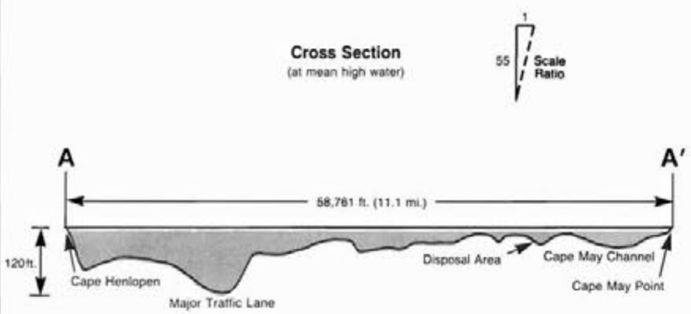
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL	
Surface Areas (mi²)	
Fluvial Drainage	8,700
Estuarine Drainage	4,750
Estuarine Zones	
Tidal Fresh	23
Mixing Zone	200
Seawater	545
Total	768
Dimensions	
Length (mi.)	138
Width (mi.): Average	15.0
Minimum	4.2
Maximum	28.4
Average Depth (ft.)	24.2
Average Depth to Width Ratio	3.1×10^{-4}
Stratification Classification	
3-Month High Flow	VH
3-Month Low Flow	VH

FRESHWATER INFLOW				
Flow Rates (1000 cfs)				
Period of Record				1963-1982
Long Term Average Daily				19.8
Long Term Average Monthly	J	23.1	J	13.2
	F	24.3	A	10.3
	M	30.9	S	10.1
	A	32.4	O	12.2
	M	23.9	N	15.7
	J	18.4	D	22.1
7-Day, 10-Year Low Flow				2.3
50-Year Flood				262.7
100-Year Flood				293.2
Flow Ratios				
Average Annual				0.009
High Flow Period				0.013
Low Flow Period				0.005

TIDAL DATA		
Prevailing Tide: Semidiurnal		
Tidal Prism (cf)	1.02×10^{11}	
Phase Range of Tide (ft.)		
Map Key	Station	Range
A	1809	4.2
B	1793	4.8
C	1769	5.0
D	1779	7.0
E	1791	6.0
F	1823	4.5
G	1827	2.6
H	1841	0.9

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.



Map Sources:
U.S. Geological Survey, State of Pennsylvania, Hydrologic Unit Map, 1974, scale 1:500,000; State of New Jersey, Hydrologic Unit Map, 1974, scale 1:500,000; State of Delaware, Hydrologic Unit Map, 1974, scale 1:500,000; USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000; NOAA/NOS Nautical Chart, No. 12304, October 1983, scale 1:80,000.

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- Flow Gage
- Head of Tide
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- Tidal Fresh Zone
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Notes:
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References:
Albert, 1982. Ambrose and Roesch, 1982. Buchanan, 1983. Delaware River Basin Commission, 1980. Flippo, 1982. Hatcher and Harleman, 1981. James, et al., 1982. New Jersey Department of Environmental Protection, 1978. Schaefer, et al., 1982. Simmons, 1967. Simmons and Carpenter, 1978. Thatcher and Harleman, 1978. U.S. Department of Commerce, 1983a. Voytik, et al., 1982.

Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service/NOAA

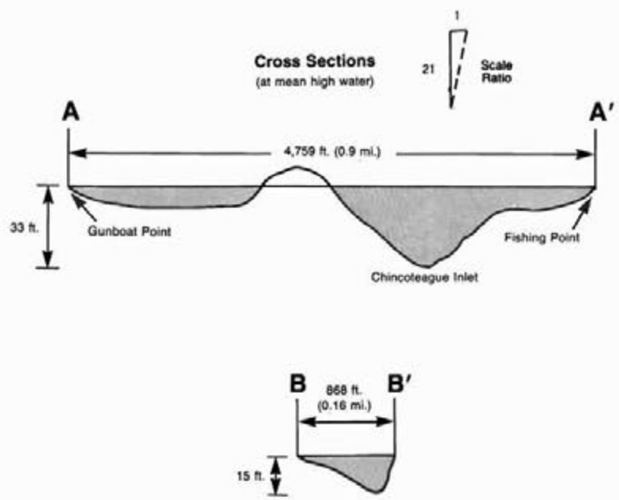
National Estuarine Atlas

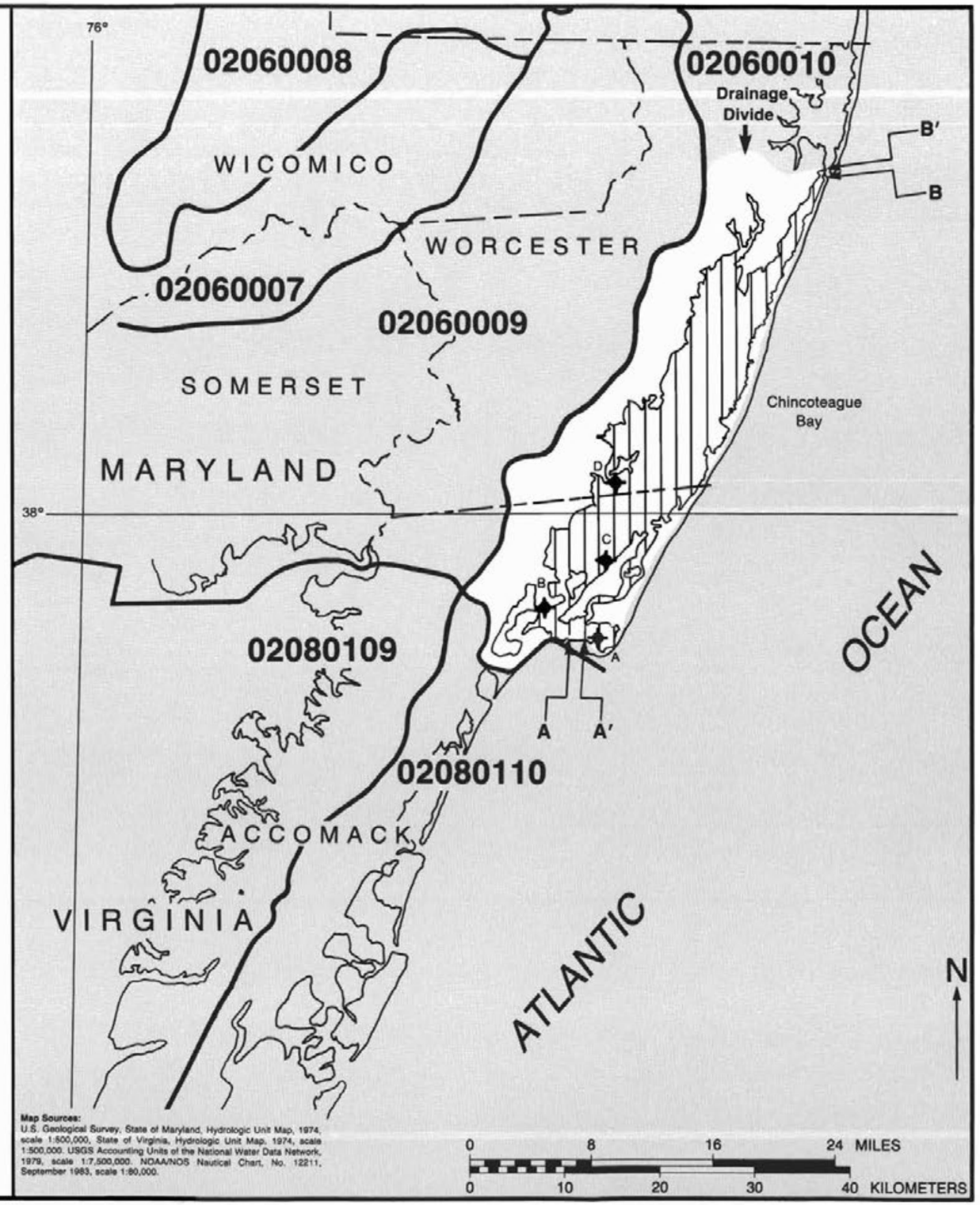
Chincoteague Bay
MD, VA

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

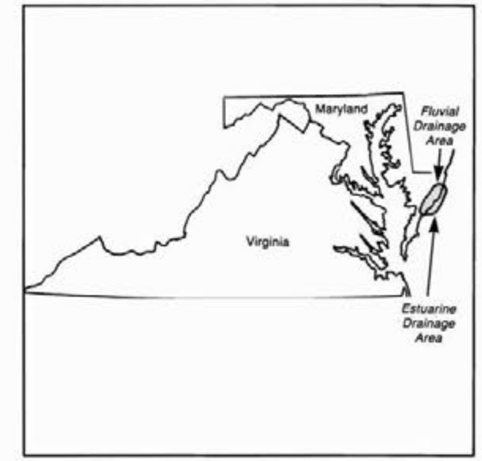
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			No Gages	Tidal Prism (cf)		1.65×10^9
Estuarine Drainage	300							
Estuarine Zones		Long Term Average Daily			0.4	***Phase Range of Tide (ft.)***		
Tidal Fresh	0					Map Key	Station	Range
Mixing Zone	0	Long Term Average Monthly	J	0.4	J 0.4	A	1913	3.6
Seawater	137		F	0.4	A 0.5	B	1918	2.6
Total	137		M	0.4	S 0.4	C	1919	1.7
Dimensions			A	0.4	O 0.3	D	1925	0.2
Length (mi.)	32.0		M	0.3	N 0.4			
Width (mi.): Average	4.5		J	0.4	D 0.3			
Minimum	1.0	7-Day, 10-Year Low Flow			ND			
Maximum	6.6							
Average Depth (ft.)	4.4	50-Year Flood			ND			
Average Depth to Width Ratio	1.9×10^{-4}	100-Year Flood			ND			
		Flow Ratios						
Stratification Classification		Average Annual			0.012			
3-Month High Flow	VH	High Flow Period			0.015			
3-Month Low Flow	VH	Low Flow Period			0.011			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS; Not Applicable, NA (see notes); Not Determined, ND (see notes).





Map Sources:
U.S. Geological Survey, State of Maryland, Hydrologic Unit Map, 1974, scale 1:500,000. State of Virginia, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12211, September 1983, scale 1:80,000.



- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

Notes:
One hundred percent of Estuarine Drainage Area is shown on map. Drainage Divide represents portion of Estuarine Drainage Area boundary not coinciding with U.S. Geological Survey cataloging unit boundary. NA: Fluvial Drainage Area equals Estuarine Drainage Area. ND: These statistics were not calculated because flood and low flow estimating equations have not been developed for this area. Flows include freshwater input from precipitation.

References:
Carpenter, 1983. College of William and Mary, 1984. James, et al., 1982. U.S. Department of Commerce, 1981. U.S. Department of Commerce, 1983a.

Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service/NOAA

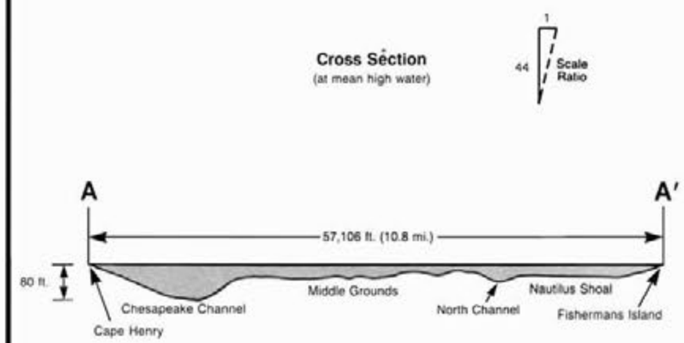
National Estuarine Atlas

Chesapeake Bay
VA, MD, DE, PA, DC

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

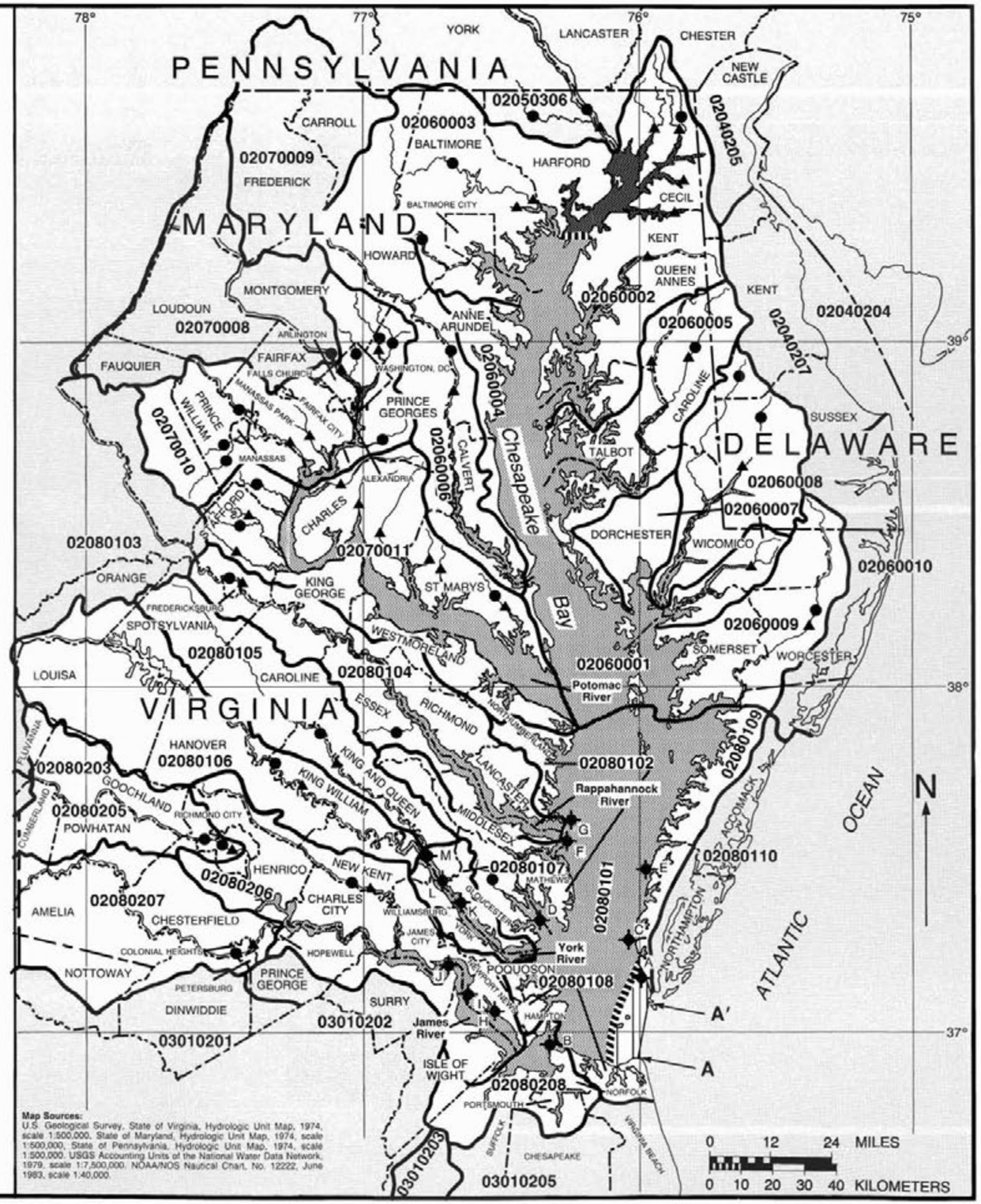
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	47,329	Period of Record			1968-1982	Tidal Prism (cf)		6.06×10^{10}
Estuarine Drainage	21,955	Long Term Average Daily			85.8	*Phase Range of Tide (ft.)*		
Estuarine Zones						Map Key	Station	Range
Tidal Fresh	153	Long Term Average Monthly	J	101.6	J 42.6	A	1951	2.7
Mixing Zone	3,562		F	140.4	A 33.7	B	2367	2.3
Seawater	115		M	149.4	S 43.6	C	1955	2.3
Total	3,830		A	118.7	O 60.6	D	2305	2.3
Dimensions			M	93.2	N 68.9	E	1957	1.2
Length (mi.)	198.0		J	82.6	D 96.1	F	2269	0.8
Width (mi.): Average	15.4	7-Day, 10-Year Low Flow			4.1	G	2270	0.4
Minimum	3.2					H	2379	1.8
Maximum	34.8					I	2385	0.6
Average Depth (ft.)	27.8	50-Year Flood			2,073.8	J	2387	0.1
Average Depth to Width Ratio	3.4×10^{-4}	100-Year Flood			2,652.7	K	2329	2.0
Stratification Classification		*Flow Ratios*				L	2330	1.0
3-Month High Flow	MS	Average Annual			0.063	M	2331	0.4
3-Month Low Flow	MS	High Flow Period			0.100			
		Low Flow Period			0.029			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.



Notes:
Approximately 95% of Estuarine Drainage Area is shown on map.

References:
Blumberg, 1977. Buchanan, 1983. Carpenter, 1983. Chesapeake Bay Commission, 1983. Flippo, 1982. James, et al., 1982. Jordan, 1984. Miller, 1975. Prugh, et al., 1983. U.S. Department of Commerce, 1982. U.S. Department of Commerce, 1983a. Voytik, et al., 1982. Wang, 1979. Wang, 1983. Yarbro, 1983.



Map Sources:
U.S. Geological Survey, State of Virginia, Hydrologic Unit Map, 1974, scale 1:500,000. State of Maryland, Hydrologic Unit Map, 1974, scale 1:500,000. State of Pennsylvania, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12222, June 1983, scale 1:40,000.

- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
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- County Boundary
- Salinity Zone Boundary - Low Variability
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National Estuarine Atlas

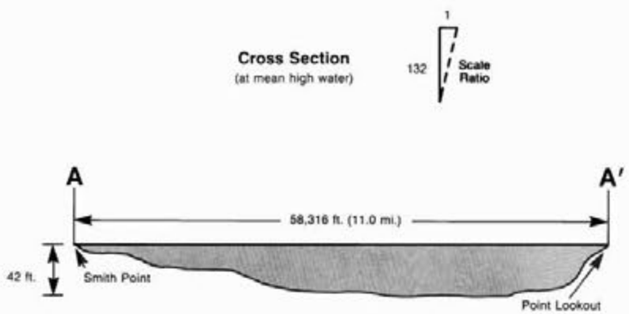
Potomac River
VA, MD, DC

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	11,520	Period of Record		1964-1982		Tidal Prism (cf)		1.2×10^{10}
Estuarine Drainage	3,080	Long Term Average Daily		15.9		*Phase Range of Tide (ft.)*		
Estuarine Zones						Map Key	Station	Range
Tidal Fresh	5	Long Term Average Monthly	J 20.4	J 7.0		A	2171	1.3
Mixing Zone	489		F 24.2	A 6.1		B	2182	1.4
Seawater	0		M 29.0	S 8.8		C	2193	1.6
Total	494		A 23.4	O 11.7		D	2201	0.9
Dimensions			M 18.1	N 10.7		E	2207	0.1
Length (mi.)	117.0		J 14.4	D 17.9				
Width (mi.): Average	6.4	7-Day, 10-Year Low Flow		0.5				
Minimum	1.6							
Maximum	11.1							
Average Depth (ft.)	25.2	50-Year Flood		324.5				
Average Depth to Width Ratio	7.5×10^{-4}	100-Year Flood		379.6				
		Flow Ratios						
Stratification Classification		Average Annual		0.059				
3-Month High Flow	MS	High Flow Period		0.095				
3-Month Low Flow	MS	Low Flow Period		0.027				

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS. Not Applicable, NA (see notes).

Cross Section
(at mean high water)



- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
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- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

Notes:
One hundred percent of Estuarine Drainage Area is shown on map.

References:
Ambrose and Roesch, 1982. Blumberg, 1977. Miller, 1978. U.S. Department of Commerce, 1983a.

Map Sources:
U.S. Geological Survey, State of Virginia, Hydrologic Unit Map, 1974, scale 1:500,000. State of Maryland, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12233, February 1983, scale 1:40,000.

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National Estuarine Atlas

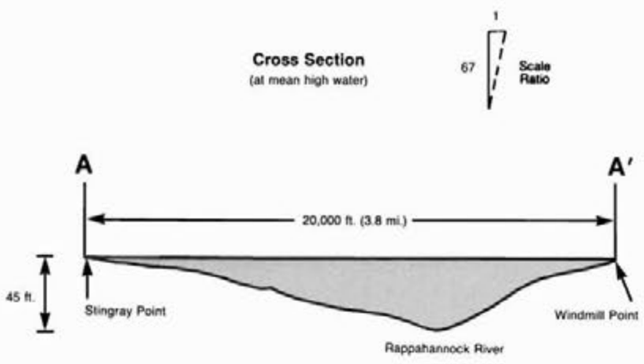
Rappahannock River VA

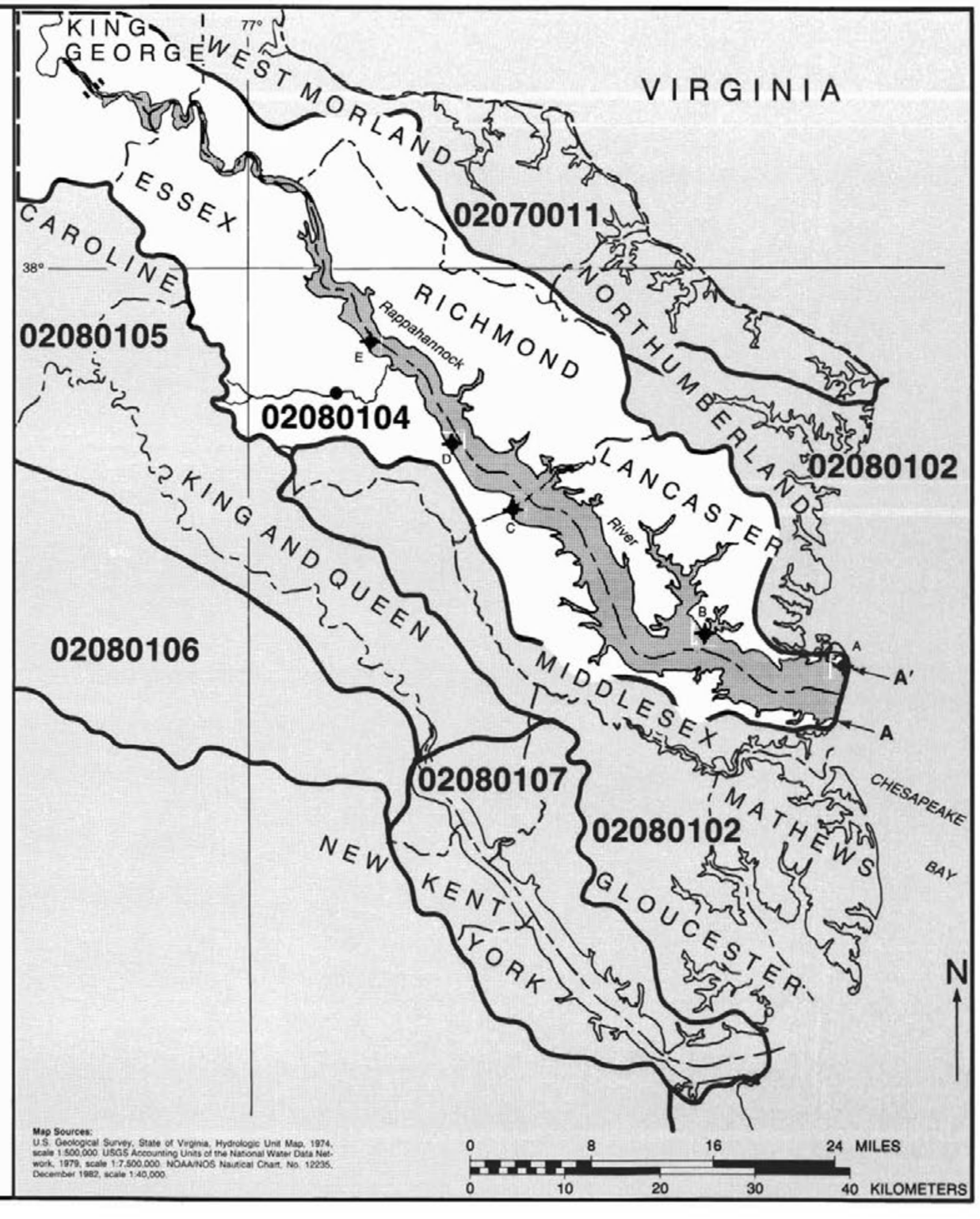
PHYSICAL AND HYDROLOGIC CHARACTERISTICS

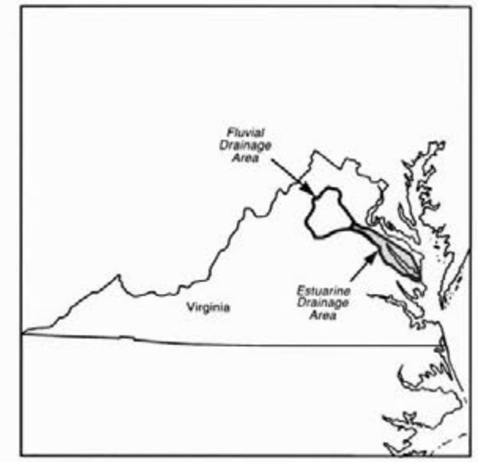
PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi²)		***Flow Rates (1000 cfs)***				Prevailing Tide: Semidiurnal		
Fluvial Drainage	1,530	Period of Record			1971-1982	Tidal Prism (cf)		4.12×10^9
Estuarine Drainage	1,160							
Estuarine Zones		Long Term Average Daily			2.9	***Phase Range of Tide (ft.)***		
Tidal Fresh	3					Map Key	Station	Range
Mixing Zone	142	Long Term Average Monthly	J	4.0	J 1.4	A	2270	1.2
Seawater	0		F	4.2	A 1.4	B	2273	1.3
Total	145		M	4.7	S 2.0	C	2278	1.3
Dimensions			A	4.4	O 2.4	D	2279	1.0
Length (mi.)	98.6		M	3.0	N 2.1	E	2281	0.4
Width (mi.): Average	2.3		J	2.4	D 3.0			
Minimum	0.4	7-Day, 10-Year Low Flow			< 0.1			
Maximum	3.2							
Average Depth (ft.)	18.0	50-Year Flood			68.4			
Average Depth to Width Ratio	1.5×10^{-3}	100-Year Flood			75.2			
Stratification Classification		***Flow Ratios***						
3-Month High Flow	MS	Average Annual			0.032			
3-Month Low Flow	MS	High Flow Period			0.048			
		Low Flow Period			0.017			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.

Cross Section
(at mean high water)







- Tide Gage
- Flow Gage
- Head of Tide
- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
- Mixing Zone
- Seawater Zone
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- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

Notes:
Approximately 90% of Estuarine Drainage Area is shown on map.

References:
Miller, 1978. Prugh, 1983. Thomas, et al., 1974. U.S. Department of Commerce, 1983a.

Map Sources:
U.S. Geological Survey, State of Virginia, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12235, December 1982, scale 1:40,000.

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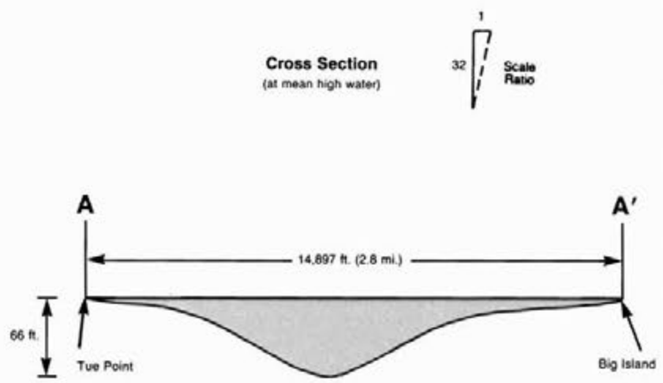
National Estuarine Atlas

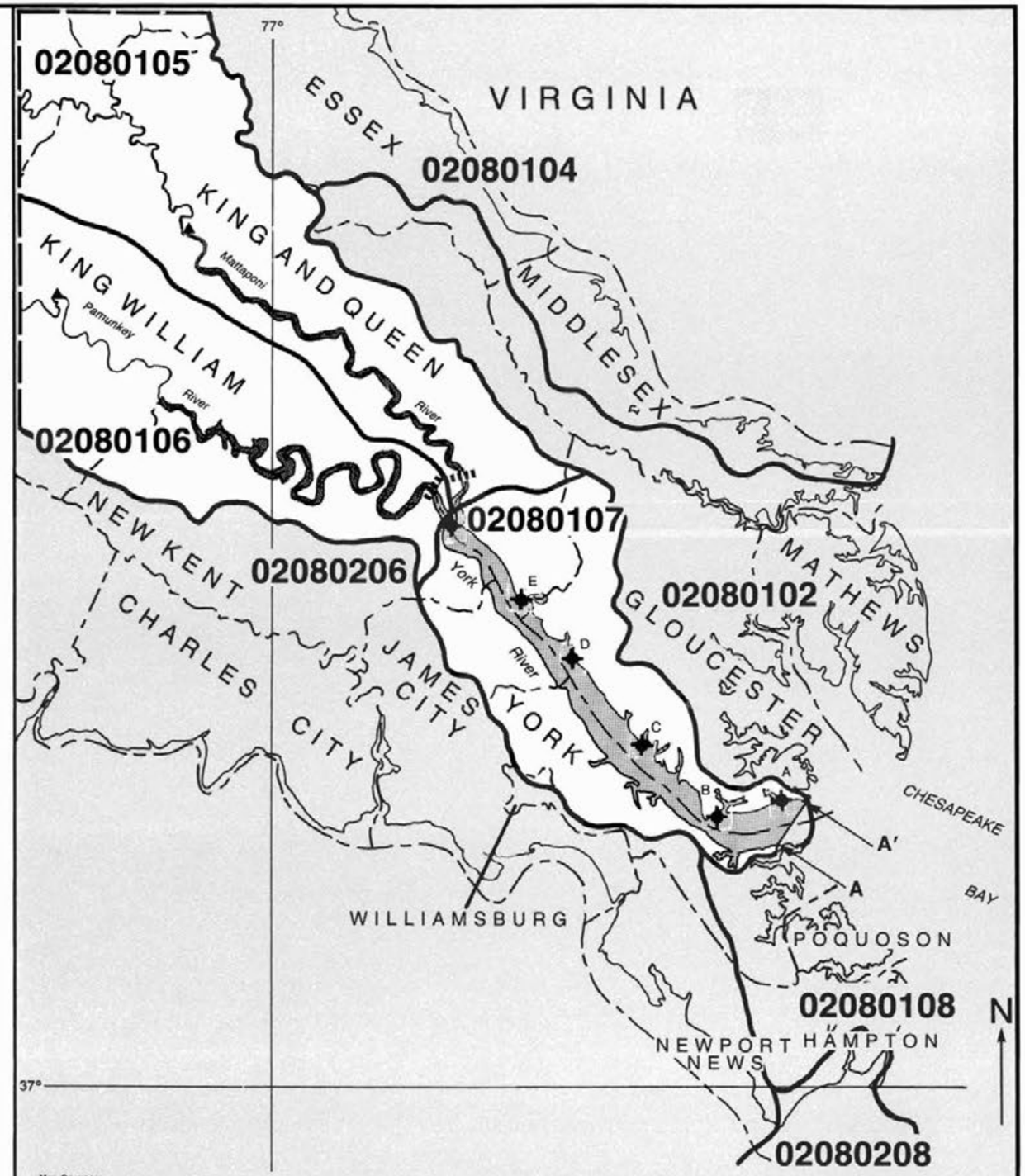
York River
VA

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	NA	Period of Record			1971-1982	Tidal Prism (cf)		3.75×10^9
Estuarine Drainage	2,626							
Estuarine Zones		Long Term Average Daily			2.5	*Phase Range of Tide (ft.)*		
						Map Key	Station	Range
Tidal Fresh	7.4	Long Term Average Monthly	J	4.0	J 1.3	A	2313	2.1
Mixing Zone	66.6		F	3.8	A 1.4	B	2317	2.2
Seawater	0		M	3.7	S 1.3	C	2324	2.4
Total	74		A	3.6	O 1.8	D	2330	1.9
Dimensions			M	2.5	N 1.8	E	2331	1.5
Length (mi.)	49		J	1.7	D 2.8			
Width (mi.): Average	2.1	7-Day, 10-Year Low Flow			< 0.1			
Minimum	0.4							
Maximum	4.1							
Average Depth (ft.)	21.6	50-Year Flood			97.3			
Average Depth to Width Ratio	1.9×10^{-3}	100-Year Flood			130.0			
Stratification Classification		*Flow Ratios*						
3-Month High Flow	MS	Average Annual			0.030			
3-Month Low Flow	MS	High Flow Period			0.046			
		Low Flow Period			0.016			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS. Not Applicable, NA (see notes).





Notes:
Approximately 45% of Estuarine Drainage Area is shown on map. NA: Fluvial Drainage Area equals Estuarine Drainage Area.

References:
Miller, 1978. Prugh, 1983. U.S. Department of Commerce, 1983a.

Map Sources:
U.S. Geological Survey, State of Virginia, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12238, June 1984, scale 1:40,000.

- Tide Gage
- Flow Gage
- Head of Tide
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Strategic Assessment Branch
Ocean Assessments Division
Office of Oceanography and Marine Assessment
National Ocean Service/NOAA

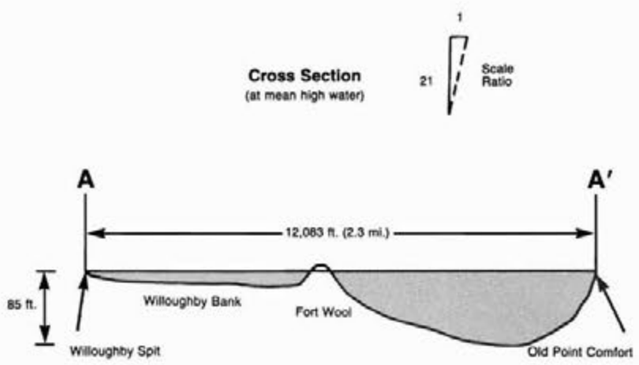
National Estuarine Atlas

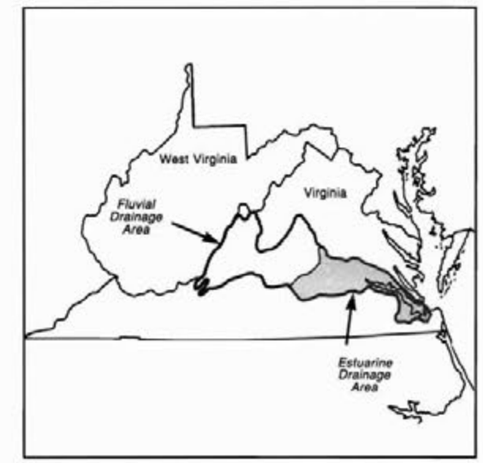
James River
VA

PHYSICAL AND HYDROLOGIC CHARACTERISTICS

PHYSICAL		FRESHWATER INFLOW				TIDAL DATA		
Surface Areas (mi^2)		*Flow Rates (1000 cfs)*				Prevailing Tide: Semidiurnal		
Fluvial Drainage	5,776	Period of Record			1971-1982	Tidal Prism (cf)		9.99×10^9
Estuarine Drainage	4,403	Long Term Average Daily			12.5	*Phase Range of Tide (ft.)*		
Estuarine Zones						Map Key	Station	Range
Tidal Fresh	32	Long Term Average Monthly	J	17.6	J 6.5	A	2353	2.5
Mixing Zone	204		F	17.7	A 5.3	B	2367	2.6
Seawater	0		M	21.1	S 6.7	C	2379	2.3
Total	236		A	16.3	O 11.1	D	2385	1.1
Dimensions			M	12.7	N 9.6	E	2387	0.8
Length (mi.)	100.8		J	12.4	D 12.7	F	2389	0.1
Width (mi.): Average	3.2	7-Day, 10-Year Low Flow			0.5			
Minimum	0.3							
Maximum	6.0							
Average Depth (ft.)	18.9	50-Year Flood			360.8			
Average Depth to Width Ratio	1.1×10^{-3}	100-Year Flood			416.7			
		Flow Ratios						
Stratification Classification		Average Annual			0.060			
3-Month High Flow	MS	High Flow Period			0.084			
3-Month Low Flow	MS	Low Flow Period			0.028			

Abbreviations: Vertically Homogeneous, VH; Moderately Stratified, MS; Highly Stratified, HS.





- Tide Gage
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- Estuarine Drainage Area (EDA)
- Tidal Fresh Zone
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- Hydrologic Cataloging Unit Boundary
- County Boundary
- Salinity Zone Boundary - Low Variability
- Salinity Zone Boundary - Moderate Variability
- Salinity Zone Boundary - High Variability

Notes:
Approximately 48% of Estuarine Drainage Area is shown on map.

References:
Dionner, et al., 1983. Hyer, 1972. Lung and O'Conner, 1984. Miller, 1978. Prugh, 1983. U.S. Department of Commerce, 1983a.

Map Sources:
U.S. Geological Survey, State of Virginia, Hydrologic Unit Map, 1974, scale 1:500,000. USGS Accounting Units of the National Water Data Network, 1979, scale 1:7,500,000. NOAA/NOS Nautical Chart, No. 12256, June 1982, scale 1:20,000.

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Ocean Assessments Division
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National Ocean Service / NOAA

Errata

Page or Map	
Contents Page	Savannah Sound should be listed as Savannah River
1.02	Total of estuarine zones is 76, not 78
1.11	Cataloging unit 01070005 should not be included in the estuarine drainage area
1.16	The B-B[1] cross-section on the map should be drawn between E. Plain Point to Culloden Point, not Shagwong Point
1.17	Tides Stations I, J, K, L are not shown on map
1.23	Average depth should be 23.1, not 27.8 feet
2.01	Cataloging units 03010204, 03010201, 03010202 should not be in the estuarine drainage area
2.02b	Point "A" cross-section should be Maw Point, not Man Point
2.04	Average depth should be 6.8, not 2.0 feet
2.16	Cataloging unit 03080101 boundary line was excluded, it should not be included in Cataloging unit 03080201
3.02	The Caloosahatchee River and its estuarine drainage area should be included in the Charlotte Harbor inset map
3.06	Gladsen County should be Gadsen County
3.07	Average depth should be 11.6, not 26.8 feet
3.08	Average depth should be 14.8, not 21.7 feet
3.12a	Length of estuary should be 41.2, not 97.2 miles
3.14	Average depth should be 7.0, not 36.0 miles
3.17	Surface area of estuarine zones should be Tidal Fresh - 13; Mixing - 461; Seawater - 51; total 525 square miles
4.05	Estuarine drainage area should be 6830, not 3230 square miles
4.07	"Humbolt County" should be "Humboldt"