

**SEA LEVEL RISE IMPLICATIONS:  
AN ACTION PLAN  
FOR BUZZARDS BAY**

Prepared for:

NEW ENGLAND INTERSTATE  
WATER POLLUTION CONTROL COMMISSION

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# SEA LEVEL RISE IMPLICATIONS: ACTION PLAN FOR BUZZARDS BAY

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## SEA LEVEL RISE IMPLICATIONS: AN ACTION PLAN FOR BUZZARDS BAY

### 1.0 PROBLEM STATEMENT

Increased rates of sea level rise will impact the immediate protected and open coast shoreline of Buzzards Bay. The 11 communities on the Bay are presently losing about 19 acres of upland each year due to passive submergence, without taking coastal erosion and ground water table changes into account (Geise et al., 1987). Based on a "mid-range high" global sea level rise rate (Hoffman et al., 1983) or Case 3 (Geise et al., 1987) in Massachusetts, a vertical rise of 1.57 feet by the year 2025 will account for a total loss of 2,953 acres. Effects of an increase in sea level will include increased flood occurrences at higher elevations, loss and erosion of wetland resource areas, elevated ground water levels, and salt water intrusion.

### 2.0 BACKGROUND

#### 2.1 RELATIVE SEA LEVEL RISE

Global warming caused by increased atmospheric concentrations of carbon dioxide, methane, chlorofluorocarbons, and other gases is contributing to acceleration in the rate of sea level rise within our lifetime. That warming, by thermally expanding the oceans and by causing the transfer of ice and snow resting on land to the oceans, should raise sea level substantially faster than the rise that has taken place during the past century (Hoffman et al., 1983). By the year 2100, global sea level rises are projected to range from 1.8 feet ("low scenario") to 11.3 feet ("high scenario") in absolute terms. To better assess the impact of sea level rise on a particular area of the earth, one must also account for any changes in the position of the landform which is being acted upon (i.e., subsidence or emergence). Over the past 60 years, Massachusetts has been sinking at a rate of 0.0062 ft./yr. (1.9 mm/yr.), while the ocean has been rising at 0.003 ft./hr. (1 mm/yr.) on average (Geise et al., 1987).

Three specified projections of future relative sea level rise for the period 1980-2025 have been presented in an effort to quantify the passive retreat of upland within the coastal communities of Massachusetts (Geise et al., 1987). These projections over the 45-year period are:

- Case 1: 0.45 feet (historical mean relative sea level rise, 0.01 ft./yr.)
- Case 2: 1.14 feet (Hoffman's "mid-range low" scenario plus local subsidence)
- Case 3: 1.57 feet (Hoffman's "mid-range high" scenario plus local subsidence)

These scenarios established for Massachusetts are not necessarily the most probable sea level rise scenarios because of scientific uncertainties; however, they are commonly cited scenarios widely thought to approximate the range of possible impacts (Geise et al., 1987).

Use of these scenarios for a specified time frame (by 2025) provides an acceptable basis upon which to examine the major impacts of sea level rise, to consider a range of management options, and to recommend an action plan for the 11 communities within the Buzzards Bay region (Figure 1). Additional background information concerning the hydrology and geology of Buzzards Bay is presented below for purposes of characterizing the regional environment and, perhaps more importantly, providing more site-specific information for each individual community to consider in the planning process.

## 2.2 GEOLOGIC SETTING

The surficial and shallow subsurface geology in the region encompassing Buzzards Bay has been significantly affected by Pleistocene glacial activity. Distinct differences in geology exist from the northwestern to the southeastern shores of the Bay. The northwestern shore of Buzzards Bay is part of the proterozoic southeast New England platform (Barosh and Hermes, 1981). During the late cretaceous and early tertiary, an exposed bedrock surface was eroded and subsequently unconformably overlain by coastal plain and continental shelf sediments (Kaye, 1983). During the late tertiary these sediments were eroded, resulting in a series of southerly flowing

drainage systems. This geomorphologic pattern persisted to the Pleistocene when the area was significantly affected by glacial activity.

The underlying structural and erosional grain of the area had a pronounced influence on the development and distribution of glacial sediments. Not only is it responsible for the north-south trending ridge and valley topography, but it also controlled the distribution of glacial deposits by confining glaciofluvial sedimentation to the existing valley systems (FitzGerald et al., 1987). The overall morphology of the northwestern Buzzards Bay area is primarily a product of the size of the drowned valleys and the amount of sediment available for transport and redistribution. Figure 2 illustrates the sedimentological development typical of the northwestern Buzzards Bay shoreline.

In contrast, the southeastern shoreline of Buzzards Bay has experienced a relatively abbreviated geologic history. Cape Cod and the Islands owe their existence to the glaciers of the Pleistocene. There was no previous expression, bedrock or otherwise, of the landforms southeast of the Bay prior to the Pleistocene. Cape Cod and associated islands consist of outwash plain and moraine sediments deposited during the recessional phase of Pleistocene glacial episodes. Figure 3 illustrates the distribution of moraine deposits that comprise the vast majority of unconsolidated sediments in the region around Buzzards Bay.

Note that with the exception of the small deposits of the great Quittaca Pond and Ellisville moraines, the upland area adjacent to the northwestern Bay shoreline is virtually void of significant moraine sediments. Conversely, the southeastern Bay shoreline is everywhere rimmed by the thick deposits of the Buzzards Bay end moraine.

### **2.2.1 Coastal Sediments**

The present morphology of the Buzzards Bay shoreline is the result of the interaction between bedrock, availability and distribution of unconsolidated sediments, both on-shore and off-shore, and oceanographic processes (tides, winds,

currents, etc.). These factors have remained relatively stable through time with the exception of the availability of unconsolidated sediment. It is these sediments that are transported to the coastal zone and are deposited as barriers, beaches, tidal flats, and other landforms at the land/water interface along the Buzzards Bay shoreline. It is precisely these features that comprise the "buffer zone" between upland areas and the erosive activities of the waters in Buzzards Bay.

As physical processes continue to erode upland areas, sediments are stripped from the land and transported to the Bay via the fluvial systems. The combination of relatively large river systems and a relative paucity of glacial deposits, the northwestern shoreline of Buzzards Bay is rapidly becoming a sediment starved area in comparison to the southeastern shoreline (Figures 3 & 4). The ten major drainage systems between the Cape Cod Canal and the Rhode Island Border have efficiently transported much of the available upland glacial sediments to the coastal areas of the northwestern bay shoreline. In contrast, the seven relatively small fluvial systems along the Cape Cod shoreline continue to transport sediment from extensive moraine and outwash plain deposits in this area to the southeastern shoreline of Buzzards Bay. The net result is a dramatic difference in the amount of sediment being supplied to opposite shorelines of the Bay, with greater quantities continuing to be supplied along the coastline of Cape Cod and the Elizabeth Islands. As a result, there exists a much greater amount within and consistent supply of sediments to the coastal zone along the southeastern shoreline. The presence and constant redistribution of these sediments act to mitigate the long-term effects of sea level rise and provide a buffer to the shorter-term erosive action of storms.

### **2.2.2 Net Shoreline Change Analysis**

The Massachusetts shoreline change summary map, produced under the direction of the Office of Massachusetts Coastal Zone Management, provides detailed information which may be utilized to assess historical shifts in shoreline position since the mid 19th century. In the Buzzards Bay region, this map contains over 70 site-specific measurements quantifying relative change in shoreline location. The numbers presented represent the horizontal shift in shoreline location based upon a



database consisting of maps, charts, and aerial photography. In order to summarize and compare these data, all net change values have been mathematically computed to their 100-year equivalents. All data, with the exception of three locations, exhibit measurements over a time span of 73 to 137 years. These three locations have been measured for only 34 years and were believed to be statistically invalid when adjusted to a 100-year average net change value. In addition, one data point located in South Fairhaven has been omitted. The net accretion measured in this location is unusually high due to an extensive man-made structure in the vicinity.

An initial inspection reveals no apparent pattern of accretional vs. erosional areas. Upon further inspection of local U.S. Geological Survey Quadrants, it was ascertained that of the 19 locations exhibiting accretion, ten can be at least partially attributed to adjacent man-made structures such as groins and dikes.

In order to more easily understand and compare these data, the Buzzards Bay shoreline has been subdivided into compartments (Figure 5). The odd-numbered compartments contain measurements indicating net retreat of shoreline (erosion) and the even-numbered compartments, those figures indicating net advancement (accretion). As designed, the compartments alternate between advancement and retreat of the shoreline resulting in 12 and 13 compartments, respectively. However, analysis reveals that the average retreat of the shoreline in those coastal compartments of Buzzards Bay to be an average of 59.6 feet/100 years, while the average advancement of shoreline in the remaining sections is only 31.2 feet/100 years. These figures yield an overall net change of approximately -14 feet/100 years. As expected, the combination of storm activity and rise in sea level has resulted in a retreat of shoreline position.

Further investigation reveals a greater net retreat of shoreline position along the northwestern shore compared to the southeastern shore. An average of measurements along the southeastern shore (compartments 1-15) reveal a net retreat of the shoreline to be approximately 10.4 feet/100 years. The average figure along the northwestern shore (compartments 16-25) indicates a net retreat of approximately 19.4 feet/100 years.

This significant difference in average rate of shoreline retreat reflects two fundamental differences evident between the opposing Buzzards Bay shorelines. First is the distinct difference in surficial glacial deposits. The relative lack of unconsolidated sediment available for transport to the northwestern shore has resulted in significantly reduced rates of accretion. In addition, eroding areas are retreating at a faster rate due to a lack of sediment available for replenishment. Conversely, the southeastern coastline has a much greater supply of sediments entering the coastal compartments from the nearby Buzzards Bay moraine deposits. This sediment supply acts to mitigate the effects of erosive processes.

The second main difference is the orientation of the shorelines with respect to the impacts of hurricanes and lesser storms. Along the eastern seaboard, as a consequence of the counterclockwise rotation around low pressure cells, the areas to the east and north of these storm centers experience the most severe conditions. A review of the storm tracks of several major storms affecting the southern New England Region (Figure 6) indicate that the Buzzards Bay area is located to the east of many of these storms. This results in the Bay area being subjected to strong winds from the south and southeast. During these storms, the northwestern shore of Buzzards Bay is being impacted by strong winds, waves, and storm surge approaching head-on to the coast. Conversely, the southeastern shore would be experiencing off-shore winds resulting in much less severe wave action and storm surge heights. The cumulative effect over time is one of much greater erosion along the northwestern shore of Buzzards Bay. The repeated activity of erosive storms, coupled with sea level rise, would be expected to produce a continuation of the differential shoreline retreat values measured over the past 100 years. In addition, in areas exhibiting a negative sediment budget, such as the northwestern coast of Buzzards Bay, shoreline retreat rates may illustrate an increase.

## 2.3 WATER BODY CHARACTERISTICS

### 2.3.1 Tidal Hydrology

Buzzards Bay is a body of water approximately 35 statute miles long and 8 statute miles wide on the average. It has a southwest-northeast orientation along its axis and narrows gradually from Rhode Island Sound to the Cape Cod Canal. The mean tidal range increases from Westport Harbor (3.0 feet) to the Canal (4.2 feet), thereby classifying the Bay as microtidal (0 - 2.0 m). Mean low water elevation remains constant throughout the Bay at 1.7 feet NGVD, while mean high water varies from 1.3 feet to 2.5 feet NGVD (Figure 7). Mean spring high water elevation also varies above NGVD ranging from 1.7 feet to 3.2 feet between Westport and Bourne, respectively. These elevations are important to recognize because they serve as controls on boundaries of wetland resource areas throughout the individual communities and establish jurisdictions for planning, regulatory, and enforcement activities.

### 2.3.2 Wetland Resource Areas

Valuable vegetated and unvegetated wetlands lie within the tidal influence of Buzzards Bay that each community should recognize. Salt marshes, tidal flats, and barrier beaches serve important functions of erosion and flood control, storm damage prevention, pollution attenuation, and marine productivity (e.g., food source and habitat for finfish and shellfish). An inventory of these resource areas reveals that 10.7% (11,671.9 acres) of the Commonwealth's resources lie within Buzzards Bay (Table 1). Approximately 80% (9,276.1 acres) of the resources in Buzzards Bay are located within the Towns of Westport, Dartmouth, Wareham, Fairhaven, and Falmouth. Although salt marshes, tidal flats, and barrier beaches represent a mere 5% of the total community area, opportunities for expansion (i.e., wetland migration) may occur with the rise of sea level.

**TABLE 1**  
**Existing Resource Area Acreage (saltmarsh, tidal flat, and barrier beach)**  
**for Buzzards Bay Communities**  
**(Hankin et al., 1985)**  
**(listed in descending order)**

<u>Town</u>	<u>Total Area</u>	<u>Salt Marsh</u>	<u>Tidal Flat (Marine/Estuarine)</u>	<u>Barrier Beach</u>	<u>Total Resource Area</u>
Westport	35,353.6	1,116.6	2,032.8 (0.0/2,032.8)	729.4	3,878.8
Dartmouth	39,558.4	1,143.1	281.7 (14.7/267.0)	154.4	1,579.2
Wareham	24,339.2	917.0	451.2 (256.3/194.9)	58.7	1,426.9
Fairhaven	7,936.0	607.5	582.1 (442.0/140.1)	86.3	1,275.9
Falmouth*	29,260.8	529.4	307.5 (127.3/180.2)	278.4	1,115.3
Mattapoisett	11,187.2	349.9	453.6 (439.5/14.1)	83.5	887.0
Bourne	26,585.6	297.7	201.8 (35.8/166.0)	75.0	574.5
Marion	9,152.0	305.8	93.6 (46.7/46.9)	36.9	436.3
Gosnold	8,288.0	89.7	34.1 (25.4/8.7)	186.3	309.8
New Bedford	12,691.2	0.0	107.7 (0.0/107.7)	0.0	107.7
Acushnet	12,038.4	30.4	49.8 (0.0/49.8)	0.0	80.2
<b>TOTALS:</b>	<b>216,390.4</b>	<b>5,387.1</b>	<b>4,595.9 (1,387.7/3,208.2)</b>	<b>1,688.9</b>	<b>11,671.9</b>

\*Includes Buzzards Bay and Vineyard Sound shorelines

No site-specific research that addresses the effects of sea level rise on wetlands has been undertaken in New England (U.S. EPA, 1988). A general projection of vegetated wetland loss and potential gain in the Northeast (ME, NH, MA, and RI) shows a 4,000-7,000 acre loss from a total of 120,900 acres for low and high scenarios, respectively (Alexander et al., 1986). This loss refers to wetlands inundated. No gain is projected, meaning that there is no potential increase in wetland acreage if upland areas are not developed or if development is removed. Historically, marsh loss has not been a problem since measured accretion rates exceed the locally determined relative rates of sea level rise (NRC, 1987). In other words, most marshes do receive an adequate sediment supply to compensate for current sea level rise. Consequently, if sedimentation rates cannot keep pace with sea level rise, wetlands will be lost.

Global warming, specifically sea level change, could affect recreational and commercial fishing industries (Bigford, 1989). Specifically regarding fishing industries, Sharp (1987) and Sherman (1988) correlated the effects of climate change to marine productivity. Predicted warming trends will affect aquatic species and

habitats worldwide (Brooke and Boyden, 1989). As rainfall patterns shift, as temperatures creep upward, and as freshwater flows decrease, environmental conditions on coastal lands and in rivers, lakes, estuaries, and near-shore waters will also change. New hydrologic regimes will thrust plant and animal communities into an era of transition that could be more disruptive than existing pressures from pollution and overfishing. Fish and shellfish may relocate elsewhere and might survive the slowly mounting stress of higher waters. Habitats like salt marshes, mud flats, and eelgrass beds may persist but in new locations prescribed by higher waters (EPA, 1988).

### 2.3.3. Coastal Flooding

The Bay is extremely vulnerable to storm surges, as previously described, resulting from hurricanes and nor'easters (Figure 6). There are 16 expected hurricanes per 100 years with an 80% probability of at least one hurricane occurring during a ten-year period (Figure 8).

A damaging hurricane has not struck the Buzzards Bay area since 1954 (35 years ago), and not since 1938 (51 years ago) has a 100-year frequency storm occurred. It was the '38 Hurricane that established the 100-year elevations throughout the Bay (Figure 7), ranging from 12.1 feet to 14.4 feet NGVD between Westport and Bourne, respectively. The "100-year flood" does not suggest that a flood is expected to occur once in 100 years. It is more accurate to state that a flood larger than the above-noted magnitudes has a 1% chance of occurring or being exceeded each year. With each succeeding year the probability of occurrence increases (Table 2). Hence, there is about a 40% probability that a hurricane as damaging as the '38 Hurricane will occur in 1990.

**TABLE 2**  
**Probability of Various Flood Events (White et al., 1976)**

Event (Annual Probability)	Probability of Occurring at Least Once in		
	<u>10 yrs.</u>	<u>25 yrs.</u>	<u>50 yrs.</u>
10-year (.10)	.65	.93	.99
25-year (.04)	.34	.64	.87
50-year (.02)	.18	.40	.64
100-year (.01)	.10	.22	.39

Still water surge elevations for the 10-, 50-, 100-, and 500-year floods are published by the Federal Emergency Management Agency (Table 3). With all of the 11 Buzzards Bay communities participating in the regular phase of the National Flood Insurance Program (NFIP), Flood Insurance Rate Maps (FIRMs) provide even more specific information that accounts for breaking waves and wave runup. Although the FIRMs are published for insurance purposes, they are useful tools for floodplain management.

## 2.4 COASTAL VULNERABILITY

A global assessment of shoreline vulnerability to coastal hazards relative to sea level rise is now being conducted through the U.S. Department of Energy (Gornitz and Kanciruk, 1989). On a gross assessment of shorelines within the U.S., several high-risk areas have been tentatively identified and include the central Gulf Coast, South Florida, North Carolina Outer Banks, southern Delmarva Peninsula, and the San Francisco Bay area. These findings have been determined by use of a Coastal Vulnerability Index (CVI), which ranks seven basic geologic and hydrographic variables. Most of these have been summarized for Buzzards Bay in the previous sections. The CVI was used for this region, and a ranking of moderate risk was determined (Table 4).

**TABLE 3**  
**Summary of Still Water Surge Elevations for**  
**Buzzard's Bay Communities (In Feet above NGVD)**

	10-Year	50-Year	100-Year	500-Year
Westport	7.9	10.9	12.3	15.4
Dartmouth	8.2	11.2	12.5	15.5
New Bedford	8.4	11.4	12.8	16.0
Acushnet	5.2	5.5	5.7	16.0
Fairhaven	8.4	11.4	12.8	16.0
Mattapoisett				
• Nasketuckett	7.3	11.2	13.1	18.3
• Mattapoisett Harbor	7.7	11.6	13.6	19.0
• Aucoot	8.0	12.2	14.2	19.8
Marion	9.6	12.9	14.5	17.7
Wareham				
• Weweantic	8.3	12.5	14.5	19.9
• Jacob's Neck	8.4	12.6	14.6	19.9
Bourne				
• Buttermilk Bay	9.6	13.2	14.7	17.9
• Cape Cod Canal to	9.6	13.2	14.7	17.9
Wings Neck				
• Wings Neck to	9.5	13.0	14.5	17.6
Scraggy Neck				
• Scraggy Neck to	9.1	12.6	14.0	17.2
N. Falmouth				
Falmouth				
• W. Falmouth Harbor to	8.5	11.7	13.0	16.1
Megansett Harbor				
• Megansett Harbor to	9.2	12.6	14.0	17.2
the Knob				
• The Knob to Penzance	7.9	11.5	13.0	16.6
Gosnold				
• Woods Hole	7.9	11.6	13.0	16.6
• Kettle Cove - Naushon	7.4	10.9	12.3	15.7
• West End Naushon Island	7.1	10.5	11.9	15.2
• Pasque Island	7.0	10.3	11.6	15.0
• Nashawena Island	6.7	9.9	11.2	14.4
• Cuttyhunk Island	6.3	9.4	10.7	13.7

TABLE 4 COASTAL VULNERABILITY INDEX

RANK	Very low	Low	Moderate	High	Very high risk
VARIABLE	1	2	3	4	5
Relief (m)	> 10.1	20.1-30.0	10.1-20.0	5.1-10.0	0-5.0
Rock type (relative resistance to erosion)	Plutonic Volcanic (low) High-medium grade metamorphic	Low-grade metamorphic Sediments and conglomerate (well-sorted)	Most sedimentary rocks	Coarse and/or poorly-sorted unconsolidated sediments	Fine unconsolidated sediment Volcanic ash
Landform	Rocky, cliffed Coasts Fjords Flats	Medium cliffs Inland coasts	Low cliffs Glacial drift Salt marsh Coral Reefs Mangrove	Beaches (public) Estuary Lagoon Alluvial plains	Barrier beaches Beaches (semi) Mudflats Deltas
Vertical movement (Relative Sea Level change) (mm/yr)	< -1.1 Land rising	-1.0 - 0.99	1.0 - 2.0 within range of eustatic rise	2.1 - 3.0	> 3.1 Land sinking
Shoreline displacement (m/yr)	> 2.1 Accretion	1.0 - 2.0	-1.0 - +1.0 Stable	-1.1 - -2.0	< -2.0 Erosion
Tidal Range, m (mean)	< 0.99 Microtidal	1.0 - 1.9	2.0 - 4.0 Macrotidal	4.1 - 6.0	> 6.1 Macrotidal
Wave height, m (maximum)	0 - 2.9	3.0 - 4.9	5.0 - 5.9	6.0 - 7.9	> 7.0

High and very high risks are cited for the region because of the coarse and poorly-sorted unconsolidated sediments found within low-lying relief (0-5 meters elevation within the first 10 m of MSL). It seems appropriate that these factors be of primary concern in the identification of major issues that an action plan addresses. Additional attention must be given to adjacent natural and altered shoreline characteristics that differ in form (e.g., rocky shorelines, coastal engineering structures). Despite the moderate to very low ranking of other vulnerability characteristics, the Buzzards Bay region has experienced the worst damages from coastal storms in Massachusetts because of its exposure to both hurricanes and nor'easters. Therefore, management actions that focus on future flood-related changes associated with sea level rise affecting this region of low-lying relief are prudent.



## 2.5 MANAGEMENT AND REGULATORY CONTROLS

In Massachusetts the issue of sea level rise is recent enough that no existing environmental laws or regulations address it directly. As a result of hurricane Gloria in 1985 and as a requirement for receiving federal disaster loans from FEMA, a hazard mitigation plan was developed that identified actions which could be taken to reduce future damages from similar storm events (EOEA, 1987). One of the 18 recommendations identified the need to establish state policy regarding sea level rise by the end of 1988. MCZM was identified as the lead state agency, and no local action was requested.

At this time, Coastal Zone Management is working on the adoption of a policy for the Commonwealth and, therefore, no management strategy is currently being implemented. Several federal, state, and local government agencies are involved with making regulatory decisions that address environmental impacts in the coastal zone and therefore can have some role in addressing the ramification of sea level rise. A list of key agencies, their legal and regulatory jurisdiction, and the area of control is contained in Table 5.

Non-regulatory authorities and controls may also have value in management program that addresses the impacts of sea level rise. In fact they may be more important at this stage in terms of guiding the long-term planning process, providing technical and financial assistance, and adopting policies which regulatory agencies can use to improve legal and regulatory measures. A list of the key non-regulatory agencies, their program, and area of service is contained in Table 6.

There is a substantial base of regulatory and non-regulatory management controls available in Massachusetts upon which to build an effective strategy of addressing sea level rise problems. Through the Buzzards bay Management Plan, each of the 11 communities can assess their specific vulnerability to sea level rise, identify the major impacts that will affect them, and act to better manage the growth and development in an environmentally and economically sound manner.

TABLE 5

## Key Regulatory Agencies in Massachusetts

AGENCY	LAW	REGULATION	CONTROL
<b>Federal:</b>			
U.S. Environmental Protection Agency	Clean Water Act (1977)	Section 401	Wetlands
U.S. Army Corps of Engineers	Clean Water Act (1977)	Section 404	Wetlands
	Rivers and Harbors Act (1899)	Section 10	Navigation
Federal Emergency Management Agency	National Flood Insurance Act (1968)	44 CFR Parts 59-77	Floodplain
<b>State:</b>			
Department of Environmental Protection	Wetland Protection Act (1965)	310 CMR 10.00	Wetlands and Floodplain
	Coastal Wetlands Restriction Act (1963)	None	Wetlands
	Title 5 (1975)	310 CMR 15.00	Sanitary Code
	Waterways Licensing	310 CMR 9.00	Waterways
Executive Office of Environmental Affairs	Massachusetts Environmental Policy Act	301 CMR 11.00	Coastal Zone
Department of Public Safety	State Building Code	780 CMR Section 744	Floodplain
Coastal Zone Management Office	Federal Consistency Review	301 CMR 21.00	Coastal Zone
<b>Local:</b>			
Zoning Board of Appeals			Floodplain, Coastal Zone,
Planning Board			Development and Sub-
Conservation Commission			division Approval, and
			Wetlands and Floodplains
Health Department			Sanitary Code
Building Inspector			Floodplain

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TABLE 6

## Key Non-Regulatory Agencies in Massachusetts

AGENCY	PROGRAM	SERVICE
<u>Federal:</u>		
U.S. Environmental Protection Agency	The National Bays Program	Financial
Federal Emergency Management Agency	Executive Order 11990 on Wetlands	Policy
	Executive Order 11988 on Floodplain Management	Technical
U.S. Army Corps of Engineers	Hurricane Preparedness	Financial
	Disaster Relief	Financial
	Hazard Mitigation Assistance	Technical and Financial
	Beach Erosion Control	Technical and Financial
U.S. Soil and Conservation Service	Flood Control Works	Technical
	Floodplain Management Services	Technical and Financial
U.S. Department of Agriculture, Farmers, and Home Administration	Watershed Protection and Flood Prevention	Technical
U.S. Geologic Survey	River Basin Surveys and Investigations	Financial
	Watershed Protection and Flood Prevention	Financial
	Topographic Survey and Mapping	Technical
	Water Resources Investigations	Technical and Financial
<u>State:</u>		
Executive Office of Environmental Affairs	Coastal Zone Management	Technical/Financial/Policy
Department of Environmental Management	Executive Order 181 on Barrier Beaches	Policy
	Conservation Services	Financial
	Flood Hazard Management Project	Technical
	River and Harbors	Financial
Massachusetts Civil Defense Agency	Waterways	Financial
	Executive Order 149 on Floodplains	Policy
	Disaster Planning	Technical
Department of Community Affairs	Land Use	Technical
<u>Regional:</u>		
Southeast Regional Planning and Economic Development Commission	Land Use	Technical
Cape Cod Planning and Economic Development Commission	Land Use	Technical

Sea Level Rise Implications: An Action Plan for Buzzards Bay

### 3.0 MAJOR ISSUES

Potential impacts from sea level rise can be numerous and diverse depending on the wide range of natural and man-made shoreline characteristics. In general, however, the major issues are a function of what changes will occur within three hydraulic regions: flood-prone areas, surface water areas, and ground water areas. For purposes of discussion six major issues are: loss of upland area, increased flooding impacts, loss of wetlands, accelerated shoreline changes, salt water intrusion, and elevated ground water levels.

#### 3.1 LOSS OF UPLAND AREA

The rate of upland loss due to passive submergence varies widely from town to town, and depends upon the geology of the region in which the town lies (Geise et al., 1987). Based on any scenario, potential loss of upland is greatest in the Towns of Wareham, Marion, Dartmouth, Falmouth and Bourne (Figure 9 and Table 7). Once the tax- assessed land value per acre in each town is documented, an eventual loss to the town's tax base can be calculated by multiplying that value by the lost acreage. This figure can then be used in the economic analysis for selecting a management option to address sea level rise. Protecting the existing infrastructure, planning and regulating new facilities or relocating others will be decisions that must be made during the accelerated sea level rise period. Aside from the construction materials and their costs is the consideration of environmental effects that are associated with the following issues.

**TABLE 7**  
**Range of Projected Upland Losses (in acres)**  
**1980-2025 (Geise et al., 1987)**

<u>Town</u>	<u>Case 1</u> (0.45 ft. rise)		<u>Case 3</u> (1.57 ft. rise)
Wareham	211.4	to	737.6
Falmouth*	172.0	to	600.0
Marion	96.0	to	335.0
Dartmouth	92.4	to	322.2
Bourne	68.9	to	240.5
Fairhaven	60.9	to	212.4
Westport	50.4	to	176.0
Mattapoisett	31.3	to	109.0
New Bedford	27.2	to	94.8
Gosnold	26.1	to	91.0
Acushnet	9.8	to	34.4
<b>TOTAL</b>	<b>846.4</b>		<b>2,952.9</b>

\*Includes Buzzards Bay and Vineyard Sound shorelines

### 3.2 INCREASED FLOODING IMPACTS

Existing flood elevations (Table 3) will continue to rise with any increase in sea level, and unless flood insurance or some other studies continue on a regular basis, the return frequencies will be misleading.

In general the difference in elevation between the 10- and 50-year floods and between the 100- and 500-year floods is on the order of 3-3.5 feet. Note, however, that the difference in elevation between the 50- and 100-year floods is 1-1.5 feet. This range falls within the projected range of sea level rise scenarios. As a result, the currently published elevations for each flood event will be reached with greater frequency, and if Case 3 (1.57 feet by the year 2025) occurs, the 50-year flood event will be equivalent to the 100-year flood event within 35 years. Based on the limited information provided (Table 3), Mattapoisett and Wareham are the most hazard-prone shorelines as reflected by the extreme difference of 5.2-5.4 feet between the 100- and 500-year floods (Figure 10).

Another consideration is the effect of an increase in sea level within the A-zone versus the V-zones. In areas where the storm surge is not affected by waves (i.e., A-zone), the increased flood elevations will be proportional to that of an increase in sea level. However, in areas where breaking waves and runup occur (i.e., V-zones), the increased flood elevations will exceed that of an increase in sea level. Using the standard equation  $\frac{H_w}{D} = .78$  where  $H_w$  is the wave height and  $D$  is the depth of

water, the flood elevation is derived by adding  $H_w$  to the surge elevation. Therefore, a 1-foot rise in sea level will result in the following:

Existing Condition

Given: Surge elevation = 11'  
Depth (D) = 4'

Then:  $\frac{H_w}{4} = .78$   
 $H_w = 4 \times .78$   
 $= 3.12'$

So:  $11 + 3.12' = 14.12'$

Future Condition

Surge elevation = 12'  
Depth (D) = 5'

$\frac{H_w}{5} = .78$   
 $H_w = 5 \times .78$   
 $= 3.90'$

$12 + 3.90' = 15.90'$

As a result, there is a 1.78' increase in total wave and surge elevation that will result from a 1-foot increase in sea level.

### 3.3 LOSS OF WETLANDS

The potential loss of salt marsh is a concern if adjacent uplands or sediment supply are not available for the migration of the wetland community to occur. Over half of the total salt marsh acreage in Buzzards Bay lies within the Towns of Westport, Dartmouth, and Wareham, so the concern is greatest there (Table 8). This is not to say that the gains in other towns might not exceed those lost elsewhere, thereby resulting in a net increase for the region. Attention to those towns having high projected upland losses may prove to benefit the wetland migration interest. Measures that could mitigate the loss of wetlands are wetland banking and creation.

Land use practices that include filling of the upland edge, bulkheading, and damming creeks and streams will contribute to the lost opportunity for wetlands to migrate. Regulation of the buffer zone to salt marshes within an area affected by a 1- to 2-foot rise in sea level may be adequate within the planning period 1980-2025.

**TABLE 8**  
**Existing Salt Marsh Acreage**  
**for Buzzard's Bay Communities**  
**(Hankin et al., 1985)**

TOWN	Total Area	Salt Marsh Area	%
Dartmouth	39,558.4	1143.1	2.9
Westport	35,353.6	1116.6	3.1
Wareham	24,339.2	917.0	3.8
Fairhaven	7,936.0	607.5	7.7
Falmouth	29,260.8	529.4	1.8
Mattapoisett	11,187.2	349.9	3.1
Marion	9,152.0	305.8	3.3
Bourne	26,585.6	297.7	1.1
Gosnold	8,288.0	89.7	1.1
Acushnet	12,038.4	30.4	0.3
New Bedford	12,691.2	0.0	0
		<hr/> 5387.1	

### 3.4 ACCELERATED SHORELINE CHANGES

Increased erosion rates may result from sea level rise for four primary reasons: 1) based on the Bruun rule, a rising sea level encountering a steep beach profile results in the reconfiguration of the profile to a more stable profile (Barth and Titus, 1984). This process results in a shoreward movement of the shoreline much greater than expected by only inundation; 2) rising sea level may cause some of the estuarine shoreline to lose the tidal mud flats and wetlands that presently buffer the shoreline from the erosive force from boat wakes and storm action (Weaver and Hayes, 1989);

3) narrowing of barrier beaches from the ocean and Bay sides, thereby lessening the protection of estuarine shorelines; and 4) larger wave heights in the surf zone will result in greater amounts of sediment movement (NRC, 1987).

The lack of sediment supply and storm-exposed shoreline along the northwestern side of Buzzards Bay places some concern within the communities of Dartmouth, Mattapoisett, Marion, and Wareham, in particular. However, erosion rates, on the average, have not been excessive in the historical context. More site-specific information is necessary.

### 3.5 SALT WATER INTRUSION

When fresh ground water meets sea water, the salt water/fresh water interface tends to be wedge shaped, with the fresh water floating above the denser sea water according to the Ghyben-Herzberg Principle. As a result, salt water lies at a depth below the coastal margin of fresh water aquifers. The depth to salt water is roughly 40 feet for each foot the water table lies above mean sea level. The implication for water supply is that a rise in mean sea level may produce a relatively minor lateral encroachment of salt water yet significantly reduce the depth to the salt water/fresh water boundary. Salt water may then be drawn more easily into water supply wells located in coastal aquifers due to upwelling, which is induced during pumping.

Where rivers discharge into the Bay, high tides carry sea water up the river mouth forming a series of brackish estuaries along Buzzards Bay. The upstream distance of the tidal effect is controlled by the height of the tide and the flow of fresh water in the river. An increase in sea level would cause the brackish estuaries to extend further upstream. Since municipal wells located near rivers can induce large seepage losses, the increased salinity of river waters could degrade these water supplies.

Figure 11 shows the location of municipal water supply wells in the Towns surrounding Buzzards Bay. Currently there is a narrow zone of salt water intrusion which raises salinity levels in some coastal wells under heavy pumping conditions



or during storm flooding (Williams and Tasker, 1978). This includes municipal wells at Fairhaven's Mattapoissett River station. The Mattapoissett River valley is characteristic of the type of coastal/riverine aquifer systems which have formed along the northwest shore of Buzzards Bay and which are particularly susceptible to saltwater intrusion. They lie within low-lying river valleys where the sand and gravel deposits provide an adequate saturated thickness and hydraulic conductivity for municipal water supply wells. Pumping within these aquifers lowers ground water levels, inducing recharge from the rivers. As saltwater moves up the lower reaches of these rivers in response to rising sea levels, the existing salinity problems will be aggravated and could potentially extend to wells further upstream.

Municipal wells on the southeast side of Buzzards Bay are located further inland and are consequently much less susceptible to salt water intrusion. The extensive stratified drift deposits on Cape Cod make alternative well sites easier to locate than in the river valley aquifers on the northwest shore. However, where the stratified drift deposits come in contact with the Bay, such as in Bourne, there is potential for saltwater intrusion problems.

### 3.6 ELEVATED GROUND WATER LEVELS

Another serious implication of sea level rise is the potential for water quality degradation as a consequence of a rise in ground water levels. A rise in the water table will accompany an increase in mean sea level as ground water flow responds to the change in base level. In addition, ground water levels along the coast may be subject to more pronounced tidal effects. Ground water levels fluctuate in response to diurnal tidal fluctuations, which gradually decrease inland. As sea level rises and the shoreline advances inland, the observed tidal flux at a given site may increase.

One effect will be a reduction in the unsaturated zone beneath septic systems. The unsaturated zone plays an important role in both the biodegradation, filtering and adsorption of pathogenic contaminants, and in the adsorption and precipitation of phosphorus (Cantor and Knox, 1986). In areas that currently meet only the minimum separation for adequate septic treatment, further reduction may cause a

significant decrease in the treatment of wastewater. Problems with ground water degradation due to septic effluent have been documented around Buttermilk Bay where residential development is concentrated along the shorelines, and ground water lies at very shallow depths (Valiella and Costa, 1988). Sea level rise could potentially aggravate these water quality problems, resulting in further degradation to the water quality of the coastal ponds and Bay.

#### 4.0 MANAGEMENT OPTIONS

Measures that can be taken to better understand or characterize the geographic area of sea level rise impact (i.e., research), to identify and classify those areas (i.e., mapping), to determine priorities with respect to costs and enumerate regulatory and non-regulatory measures (i.e., planning), to inform the public and decision-makers about realistic implications (i.e., education), and finally, to take action in implementing and enforcing those efforts (i.e., implementation) are all considered management options.

The time frame within which to select the appropriate management options is not as critical as the process which is used. Sea level rise is occurring at a rate which can be addressed by a balance of short- and long-term actions, while providing enough time to establish a better technical and scientific base, obtain political support, and fit within a capital planning budget.

There are also two basic strategies within which these management options should be considered, namely: retreat or entrench. There are varying degrees of each and even the combination of both. Political, legal, and economic considerations probably override the scientific issue because we know sea level rise is occurring now, and it cannot be reversed. Conversely, politics, law, and the economy can be controlled by actions or inactions of the private landowners as well as the government.

In this section, specific management techniques or measures are presented within the previously listed areas of research, mapping, planning, education, and

implementation. The major issue(s) and lead authority which is related to the management technique better defines the management option. From this information preferred options can be identified, and a management strategy recommended later in the report.

## Activities For Sea Level Rise Preparation

4.1 RESEARCH	Priority	Major Issues	Lead Authority
1.1 Compile existing information and sources of information. A database library should be developed and maintained somewhere in the Town Hall.	High	All	Town
1.2 Inventory the natural and man-made shoreline characteristics (e.g., soils, vegetation, flood elevations, ground water elevations, and fluctuation; coastal engineering structures; residential, commercial, and recreational facilities)	Moderate	All	Town
1.3 Conduct scientific and engineering studies of risk and vulnerability (i.e. determine what is getting flooded). This will become the basis for a prioritized work schedule.	Moderate	All	State
1.4 Monitor coastal processes (e.g., erosion rates; tidal and ground water fluctuations; storm elevations; ground water flow directions and rates). This could be made a requirement of permittees.	Moderate	Flooding, shoreline changes, ground water levels	Town-data; State-modeling & assessment
1.5 Establish salinity monitoring and modeling of rivers to evaluate the effects of river discharge and sea level elevation on the extent of the tidally influenced reach.	Low	Wetlands, salt water intrusion	State

1.6 Survey private and municipal wells for water quality. This sampling is routinely done by Towns and should be simple to access.	Moderate	Salt water intrusion	Town
1.7 Inventory the extent of existing and potential development. A Developable Lot Study can determine the potential for future development based upon current zoning requirements.	High	Flooding, wetlands, upland area	Town
1.8 Project costs of tax loss, acquisition, maintenance of public facilities, and research. This is essential information for budgeting and prioritizing future activities.	High	All	Town
<b>4.2 RESPONSIBILITIES</b>	<b>Priority</b>	<b>Major Issues</b>	<b>Lead Authority</b>
2.1 Identify groups or persons responsible for research & planning. Establish ad hoc committee or subcommittee of existing groups.	High	All	Town
2.2 Develop organizational chart of responsibilities and flow chart of actions. It is important to develop a system in order to carry out the action plan.	High	All	Town
2.3 Establish which groups in Town will have authority to carry out the action plan. The work will divide in revenue generation, regulation and permitting.	Moderate	All	Town

<b>4.3 MAPPING</b>	<b>Priority</b>	<b>Major Issues</b>	<b>Lead Authority</b>
3.1 Produce topographic base maps at a large scale (i.e., 1-foot contours). These will become the base maps for monitoring shoreline change.	Moderate	Flooding, wetlands, upland area	Town
3.2 Re-map flood plain by adding selected sea level rise factor. This can be done onto the topographic maps.	Moderate	Flooding upland area	Town
3.3 Establish critical zones for environmental resource protection. This will become an important planning tool. Local boards can begin to scrutinize projects more carefully that fall within these zones.	High	Wetlands, shoreline change, salt water intrusion	Town
3.4 Obtain oblique and ground photos at regularly scheduled times (e.g., every 2-5 years) of shoreline features, both natural and man-made. While it is expensive to do this at frequent intervals, it is worth considering at least once as a baseline. The visual record holds a tremendous amount of information.	Low	Upland area, shoreline change	Town
<b>4.4 PLANNING</b>	<b>Priority</b>	<b>Major Issues</b>	<b>Lead Authority</b>
4.1 Identify key issues to be resolved for the community. Prioritize these issues into a timetable for implementation. Much of this is based upon the research proposed in the first section.	High	All	Town

4.2 Consider corrective measures applied to existing, on-going, and proposed development (e.g., acquisition; relocation; redevelopment and renewal; site and building modifications).	High	All	Town
4.3 Consider regulatory measures that would guide growth and development (e.g., environmental, zoning; subdivision; housing and sanitary; building and construction; land use; moratoria).	High	All	Town
4.4 Consider non-regulatory measures that supplement other efforts (e.g., comprehensive and open space plans; transfer of development rights; post-disaster and hazard mitigation plans).	Moderate	All	Town
4.5 Consider shoreline stabilization measures (e.g., beach nourishment; revegetation; coastal engineering structures). Develop a database of appropriate methodologies.	Moderate	All	Town
<b>4.5 EDUCATION</b>	<b>Priority</b>	<b>Major Issues</b>	<b>Lead Authority</b>
5.1 Pursue community/public awareness through a programmed or casual approach for providing general information or establishing public consensus.	High	All	Town
5.2 Disseminate information about the implications of sea level rise through the public media.	Moderate	All	Region

5.3 Conduct presentations at public hearings, town meetings, workshops, seminars, lecture series, and classrooms to promote a wider understanding relative to a particular hazard.	Moderate	All	Town
5.4 Systematically gather views of the public or a segment of the public on potential or proposed actions.	Moderate	All	Town
<b>4.6 IMPLEMENTATION</b>	<b>Priority</b>	<b>Major Issues</b>	<b>Lead Authority</b>
6.1 Provide cost estimates for actions to be taken and devise a system of revenue generation.	High	All	Town
6.2 Coordinate government agencies that have financial, technical, and administrative responsibilities for specific actions. Prepare applications and permits.	Moderate	All	Region
6.3 Define a time frame in which specific actions should occur (e.g., immediate - within the year; short-term = 1-3 years; long-term = 4-10 years; and, specific event - major flood disaster).	Moderate	All	Region



## 5.0 PREFERRED ACTIONS

Limited information has been obtained and provided in this report; therefore, limited actions can be recommended until each community has adequately defined the impacts with which they may be faced. The process of data collection, analysis, and mapping is recommended for each community so that a sound technical basis is established. Improved quantification of resource areas can assist the local, regional, and state agencies charged with developing broader-scale planning, resource protection, and enforcement activities in setting priorities for their work (Hankin et al., 1985). Then specific measures can be defined, brought to the public, and implemented in a legally defensible manner. Greater opportunities to influence local action may arise, not through attempts to create new programs, but through efforts to incorporate management objectives into local programs and responsibilities (FEMA, 1986). However, once sea level rise is established as a legitimate issue for public action, there need to be ways to link knowledge about sea level rise to establish new ones where appropriate.

In general, strategic retreat from the shoreline is preferred to entrenchment. There needs to be developed a comprehensive package of regulations and programs designed to, over time, move structures and activities higher and further from the coast. The planning horizon for sea level rise - 20 to 50 years - is a good one for dealing with most coastal activities. Within this time frame many, if not most of the activities and structures, will come before town and state regulatory bodies seeking permits. Regulations can be designed to catch and correct potential problems at this stage, and no increase in administrative capacity will be required. Resistance from the landowners immediately affected (i.e., waterfront properties) can be expected. Alternatively, community-wide resistance would be greater with a strategy of entrenchment since the public would bear the cost of structural measures, disaster assistance, and environmental loss.

Specific actions can be recommended which would accomplish the following: 1) use existing knowledge and regulations as an acceptable basis; 2) avoid public versus private property arguments; 3) avoid high costs to the public; and 4) be flexible enough to change with updated information. The primary actions are listed below for each of the six major issues.

#### Loss of Upland Area

1. Communities should have 1-foot contour interval maps compiled for the immediate shoreline, below elevation 10' MSL.
2. Communities should have a developable lot study conducted within the existing 100-year floodplain.

#### Increased Flooding Impacts

1. The Department of Environmental Protection should adopt performance standards for the resource area Land Subject to Coastal Storm Flowage and better define Coastal Bank.
2. Communities should establish higher flood elevations that exceed the minimum flood elevations mapped by FEMA. A 1-foot increase in all A-zones and a 2-foot increase in all V-zones will address the documented historical rate of sea level rise for a 100-year period.

#### Loss of Wetlands

1. Strict regulation of activities within that portion of the 100-foot buffer zone from a vegetated resource area that would be affected by a 2-foot rise in sea level.
2. Identify and acquire adjacent uplands suitable for marsh creation and wetland banking.

### Accelerated Shoreline Changes

1. The Coastal Zone Management office should provide technical and financial assistance for beach nourishment projects.
2. Construction setbacks should be established by each community that incorporates erosion and sea level rise data.

### Salt Water Intrusion

1. Modify pumping patterns of existing wells to shift pumping away from critical zones, once they have been identified.
2. Maximize recharge areas on parcels (i.e., reduce impervious cover) by establishing lot coverage requirements for all parcels within the critical areas.

### Elevated Ground Water Levels

1. Require site-specific information on tidal fluctuations of ground water for all newly proposed, maintained, or renovated sewage disposal systems within 300 feet of the shoreline. Use information to require greater separation than 4 feet between the system and maximum ground water elevation (as presently required by Title 5).
2. Increase setback of disposal systems from waterbodies and vegetated wetlands to account for the retreat of the coastline and migration of wetlands further inland.

## 6.0 IMPLEMENTATION STRATEGY

The goal of an implementation strategy for Buzzards Bay is two-fold. One, the major issues should be prioritized for each community within the region, and two, the preferred options for the priority issues should be acted upon by a specific agency department within a specified time frame.

Use and expansion of the background information (Section 2.0) can be helpful in identifying the major issues and establishing priorities. Because of unique characteristics of each community, recommending an appropriate lead authority for all communities is difficult. However, a majority of the issues can be addressed within a wetland protection or floodplain management program. Therefore, the Conservation Commission or Planning Board may be the most appropriate departments. The time frames in which the actions are taken do not necessarily have to be the same for each community; however, a regional plan may be more unified if they can be.

Preferred options that are recommended for the state agencies should occur immediately (i.e., within a year). These include actions that address flooding impacts (#1); loss of wetlands (#2); and accelerated shoreline changes (#1). An additional option that the Coastal Zone Management Office should address immediately is adopting a sea level rise policy that was part of the state's 406 Hazard Mitigation Plan.

The preferred options of data collection, analysis, and mapping for all communities should be accomplished on a short-term basis (i.e., 1-4 years). These include actions that address the loss of upland (#1 & #2), increased flooding impacts (#2), accelerated shoreline changes (#2), and salt water intrusion (#1). For those communities that prioritize the option addressing the loss of wetlands (#1), the time frame should be immediate.

A long-term schedule (i.e., 1-10 years) can be used to adequately address salt water intrusion (#1) and elevated ground water levels (#1 & #2) since ground water changes are likely to be the slowest of any changes relating to sea level rise.

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**APPENDIX**  
**LIST OF FIGURES**

MASSACHUSETTS

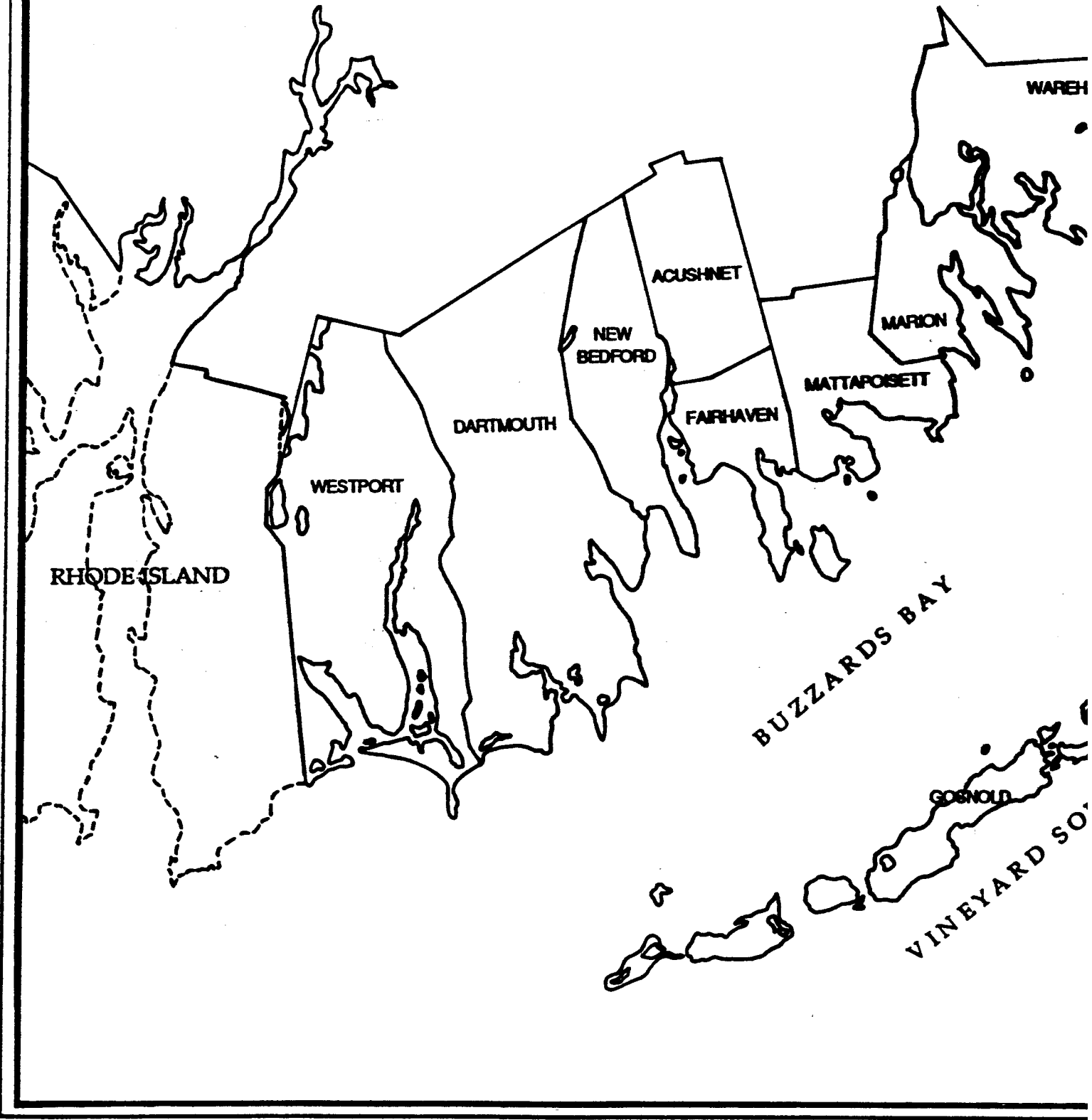
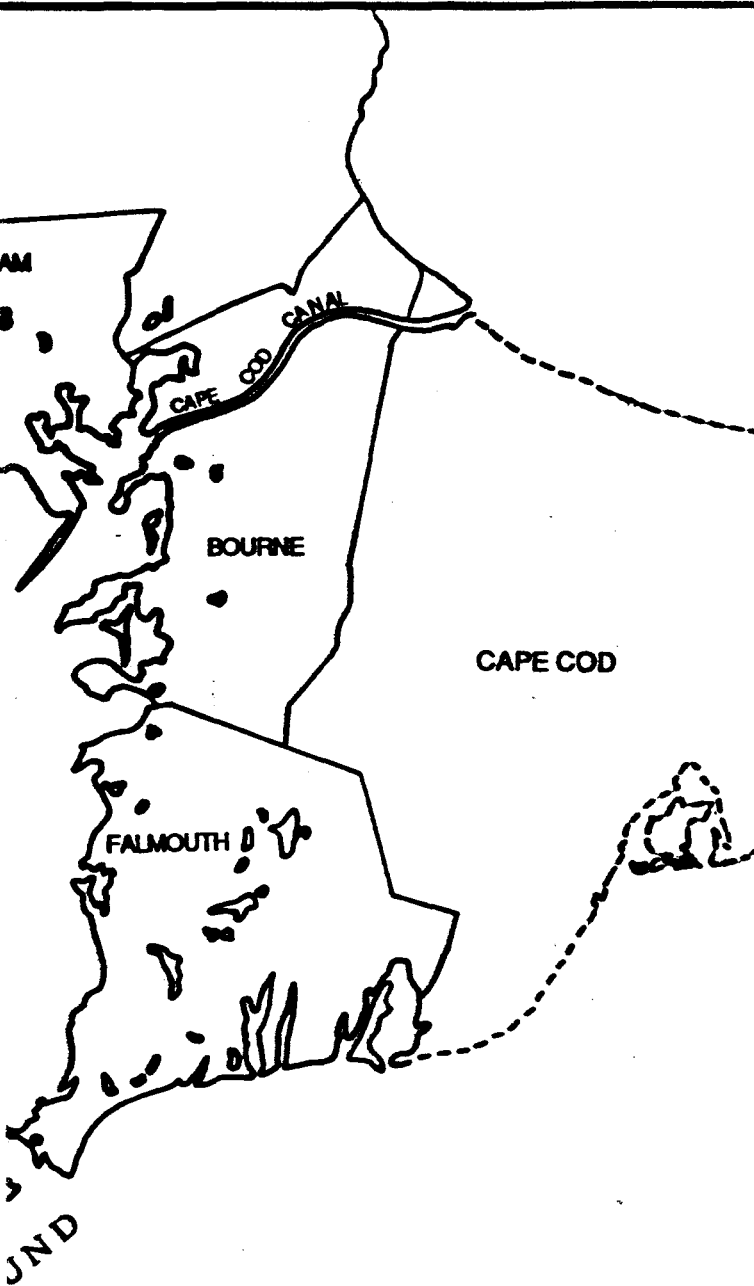
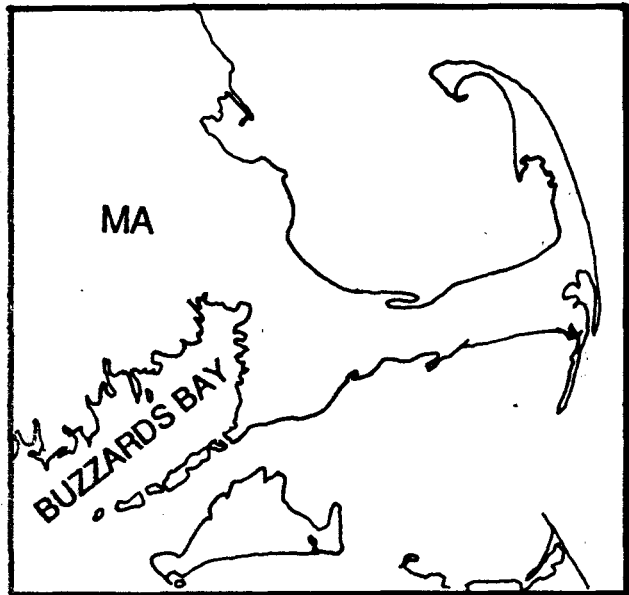


FIGURE 1: BUZZARDS BAY PLANNING AREA



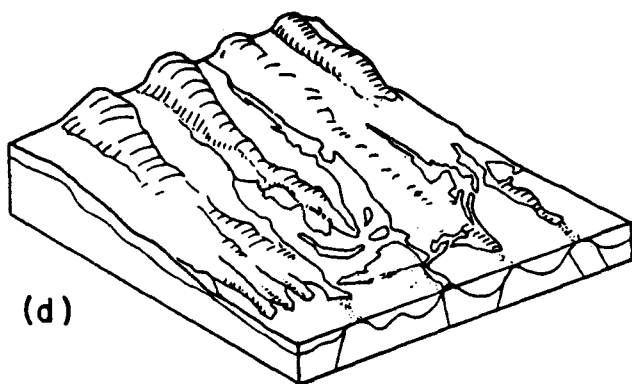
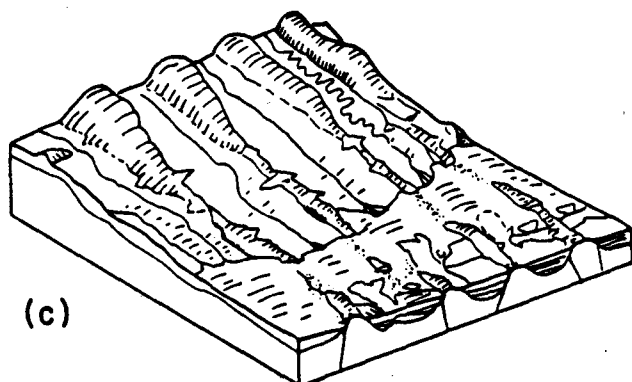
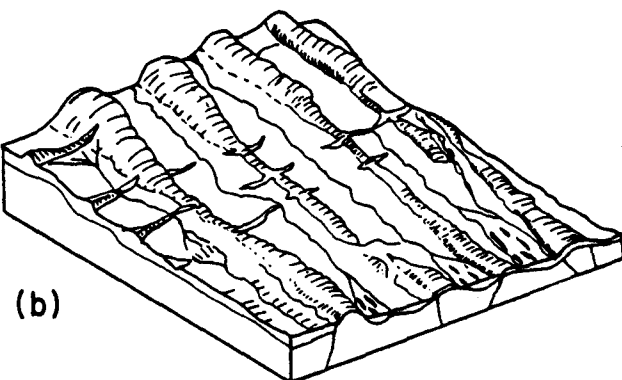
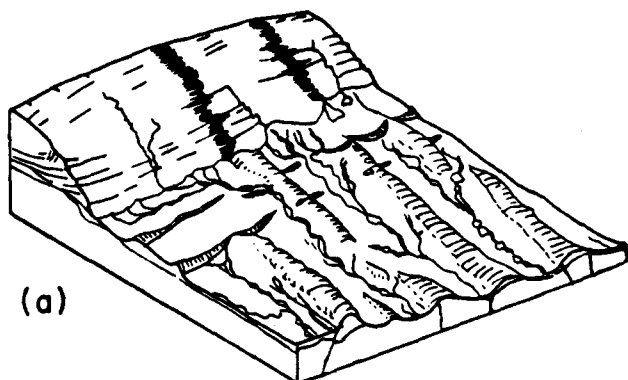
LOCUS



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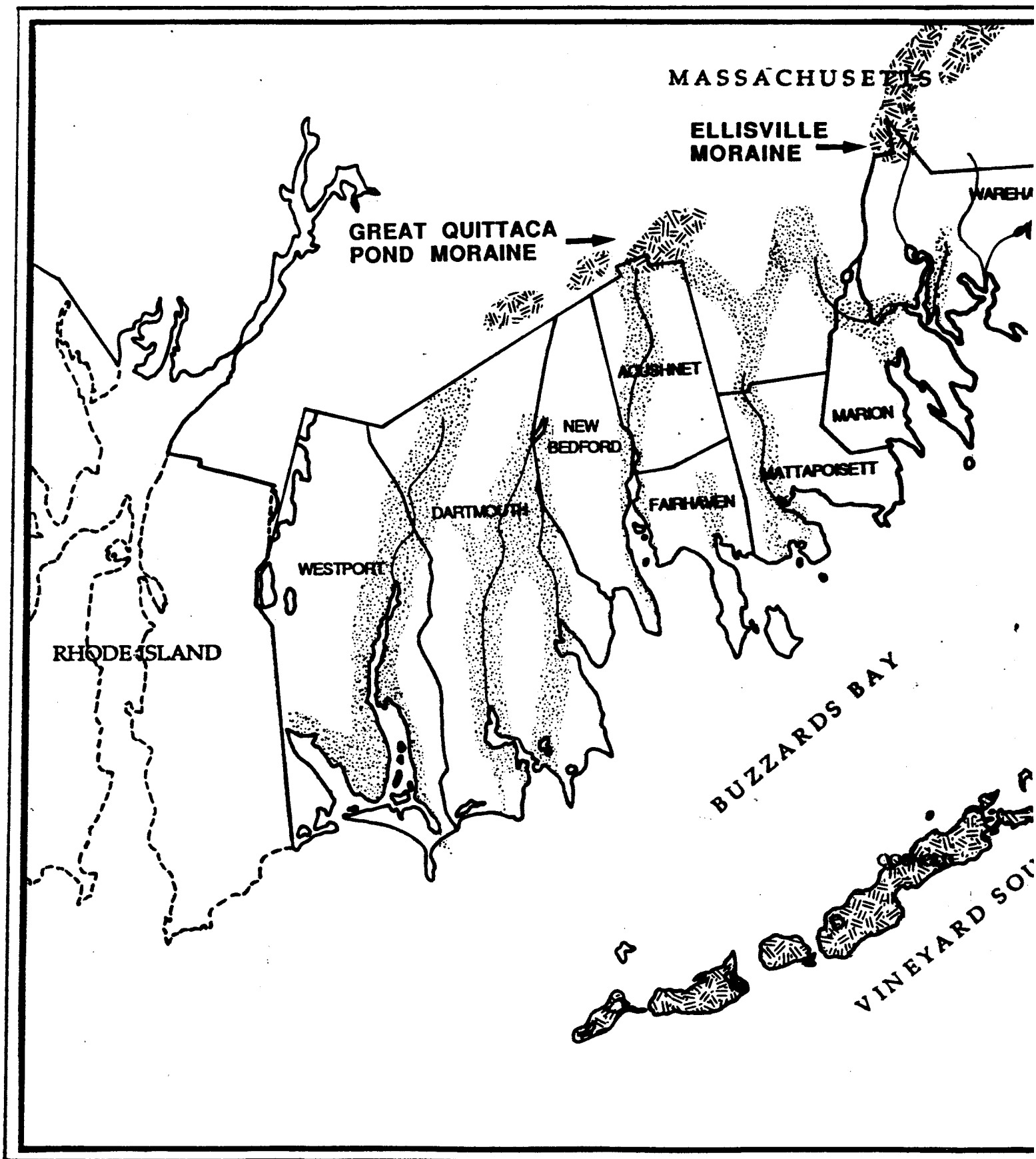


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**FIGURE 2: Model of sedimentological development of the Northwestern Buzzards Bay Region. Approximate time periods represent :**

- a) Stage 1, 15,000 yr. B.P., deglaciation of the region with glaciofluvial sedimentation focused within existing drainage basins
  - b) Stage 2, 14,00-7,000 yr. B.P., fluvial reworking
  - c) Stage 3, 7000-2800 yr. B.P., estuarine sedimentation and transgressive phase of marine reworking
  - d) Stage 4, 2800 yr. B.P. - present period of localized regression and beach building and regional shoreline retreat associated with sea level rise.
- Modified from FitzGerald, et al., 1987.



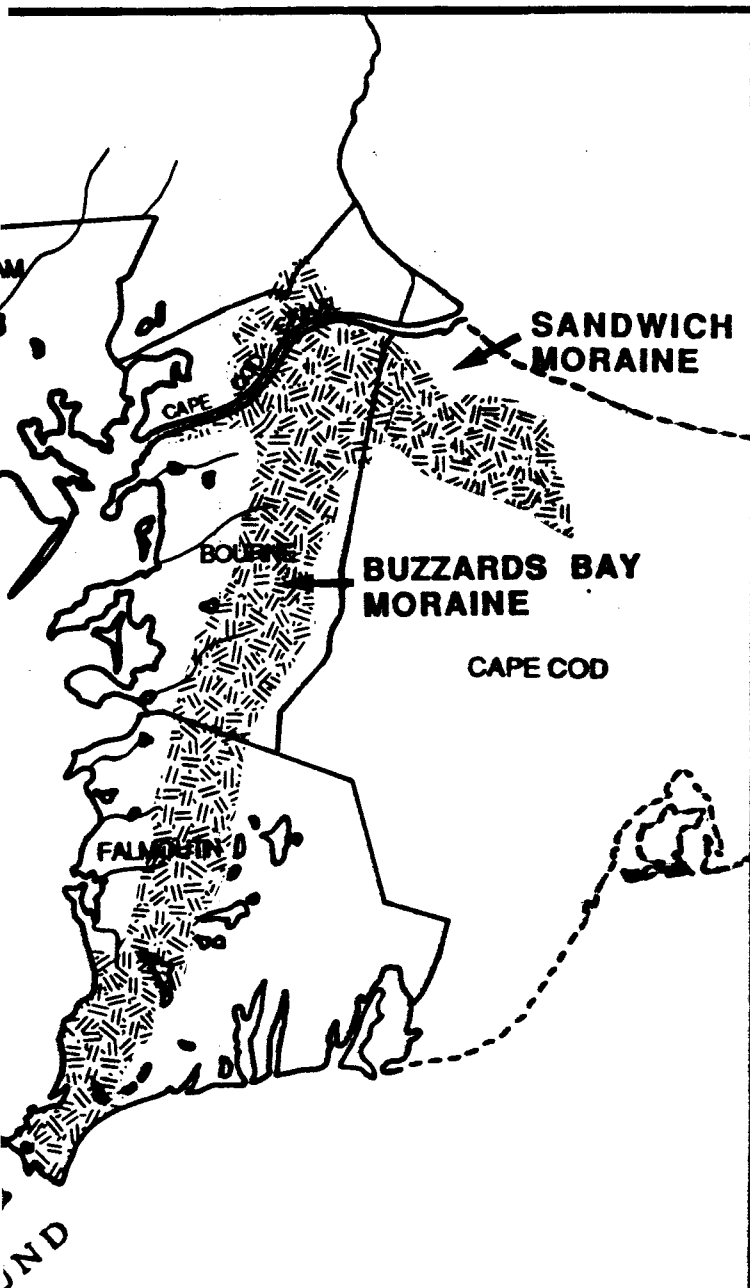


FIGURE 3: GEOLOGIC  
CHARACTERISTICS OF THE  
BUZZARDS BAY REGION

#### LEGEND



GLACIAL END  
MORaine DEPOSITS

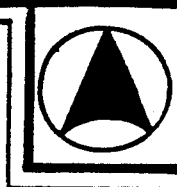
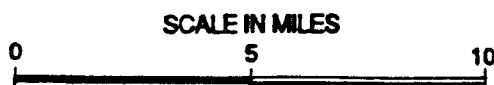


GLACIOFLUVIAL DEPOSITS  
( EXHIBITING SIGNIFICANT THICKNESS  
GREATER THAN APPROXIMATELY 25 FEET )

#### REFERENCES:

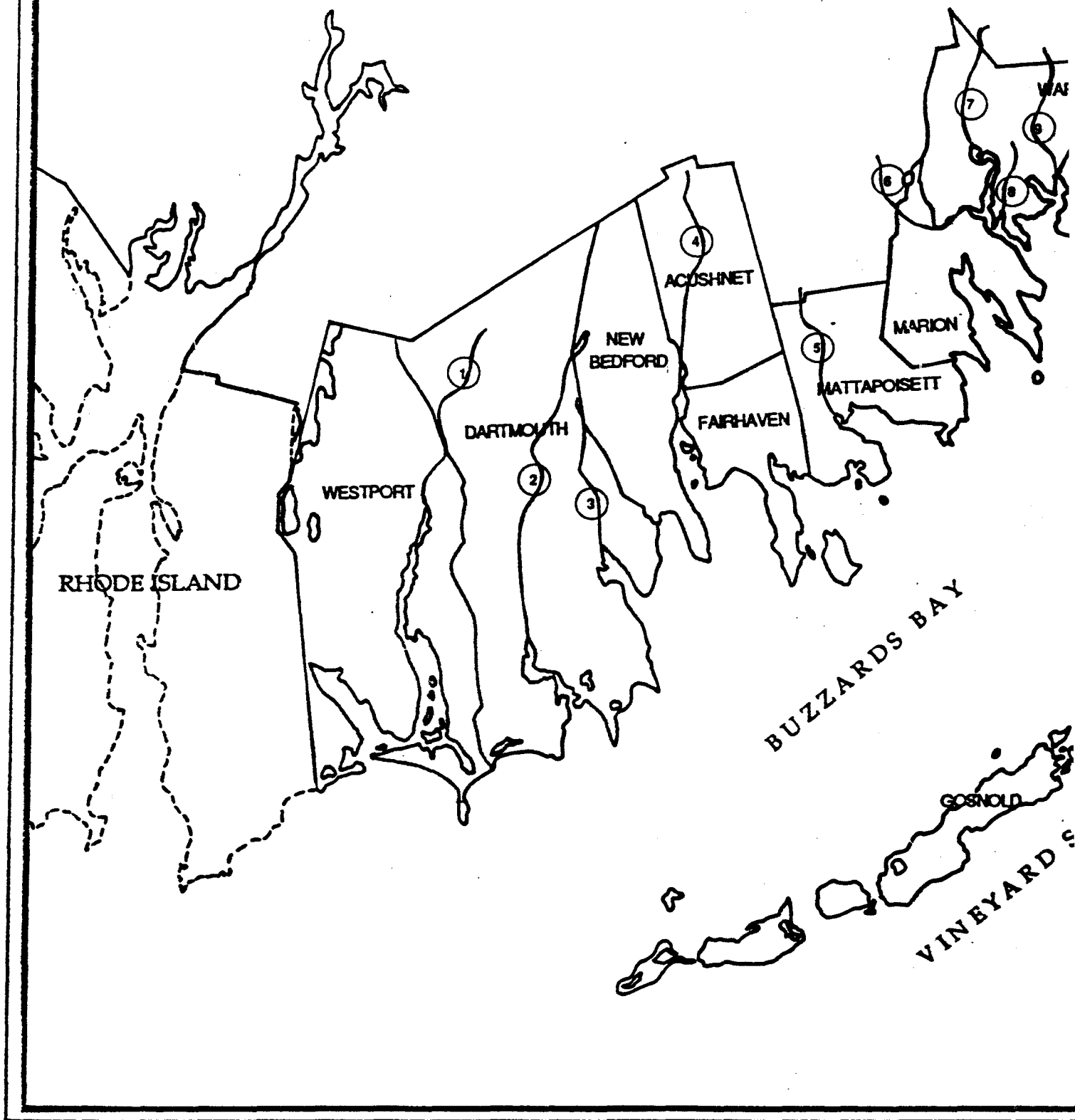
Fitzgerald, et. al., 1987, Koteff and Pessl Jr., 1981,  
and Williams and Tasker, 1974 and 1978.

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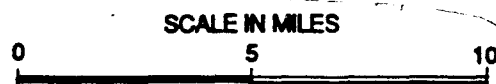


**FIGURE 4: FRESHWATER SYSTEMS  
WITHIN THE BUZZARDS BAY  
BASIN WITH WATER  
QUALITY CLASSIFICATIONS  
(DWPC, 1988)**

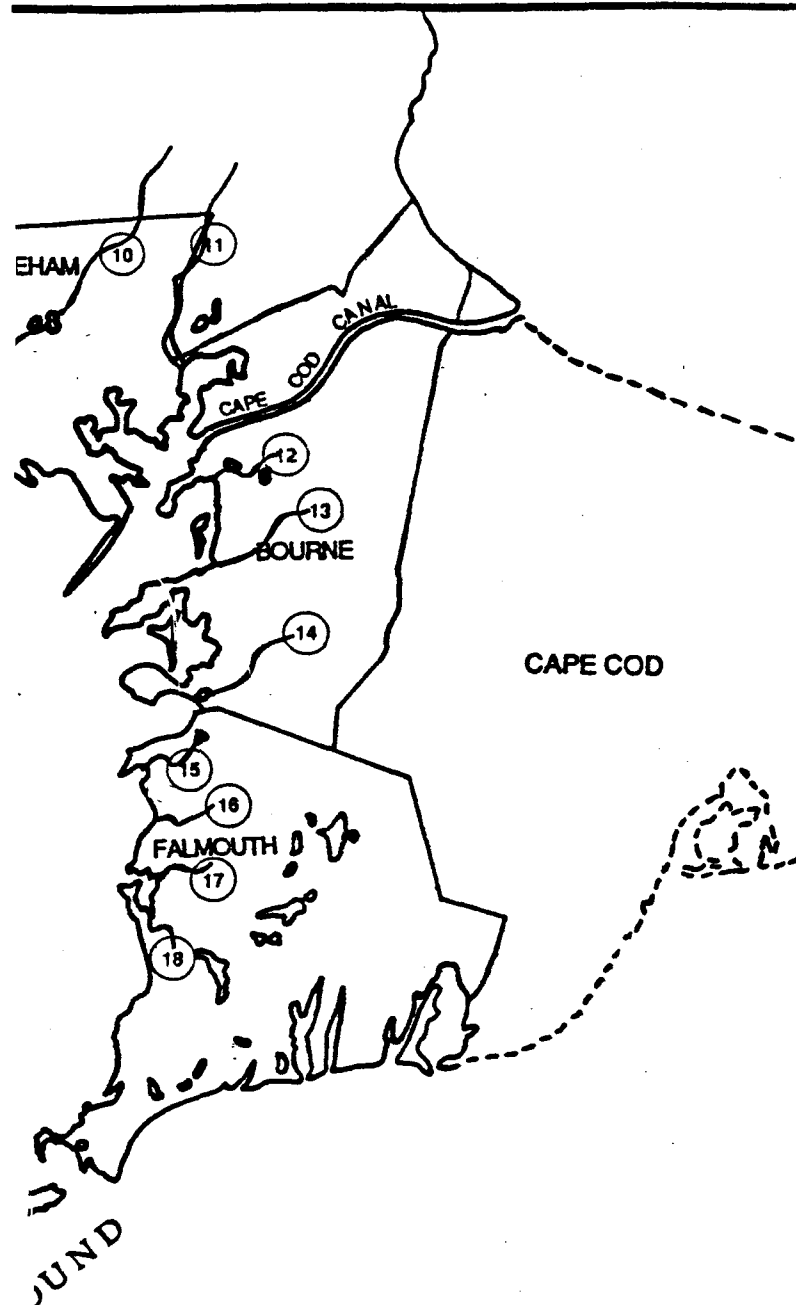
**LEGEND**

- ① WESTPORT RIVER, EAST BRANCH FROM  
OUTLET OF LAKE NOQUOCHOK TO MOUTH
- ② PASKAMANSET RIVER
- ③ SLOCUMS RIVER
- ④ ACUSHNET RIVER
- ⑤ MATTAPOISETT RIVER
- ⑥ SIPPICAN RIVER
- ⑦ WEWEANTIC RIVER
- ⑧ WAREHAM RIVER
- ⑨ WANKINCO RIVER
- ⑩ AGAWAM RIVER
- ⑪ RED BROOK
- ⑫ BACK RIVER
- ⑬ POCASSET RIVER
- ⑭ MEGANSETT HARBOR
- ⑮ HERRING CREEK
- ⑯ WILD HARBOR RIVER
- ⑰ GREAT SIPPEWISSET CREEK
- ⑱ LITTLE SIPPEWISSET CREEK
- AREAS OF CRITICAL ENVIRONMENTAL  
CONCERN
- MAJOR RIVER BASIN

NEIWP-1

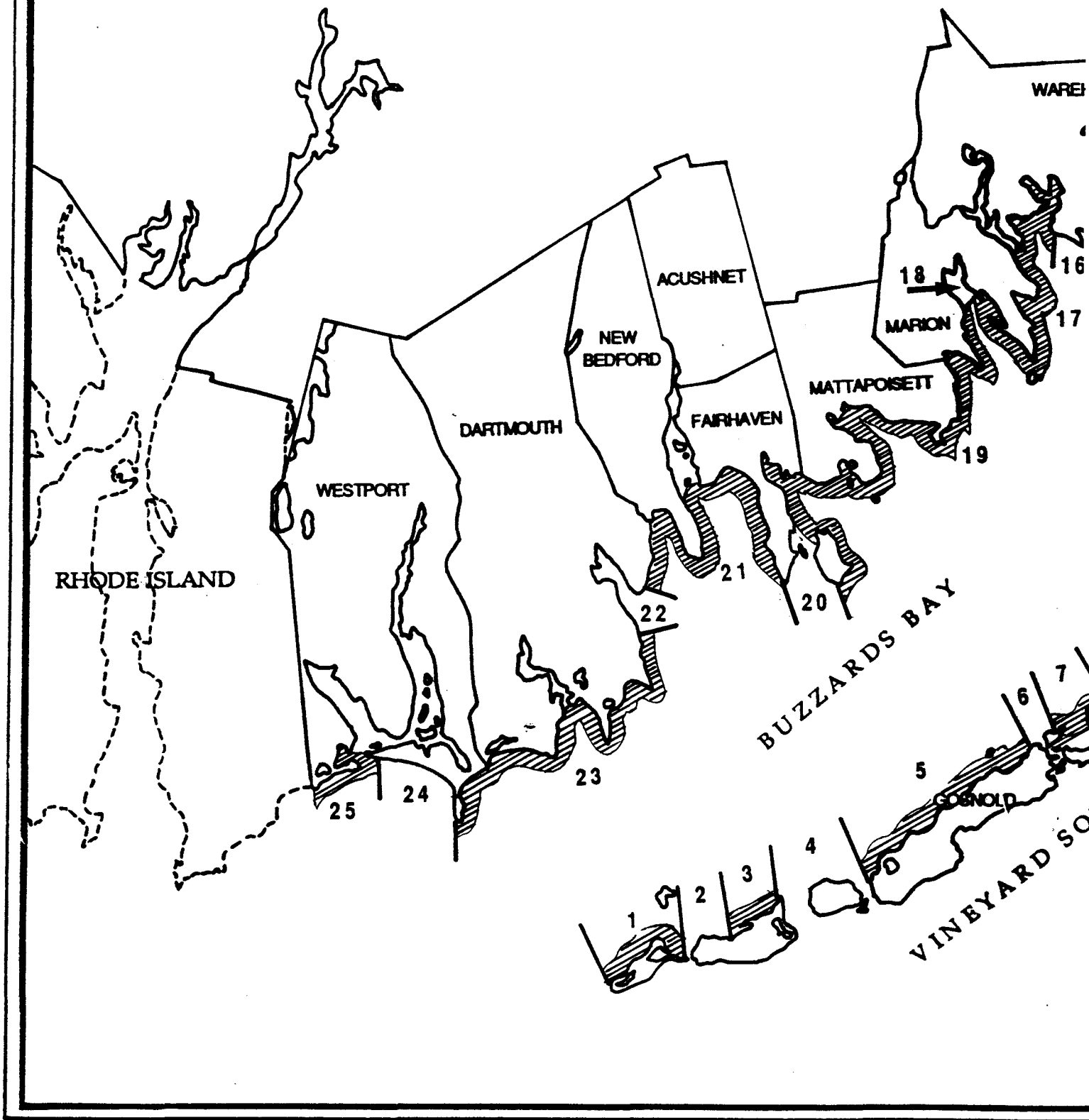


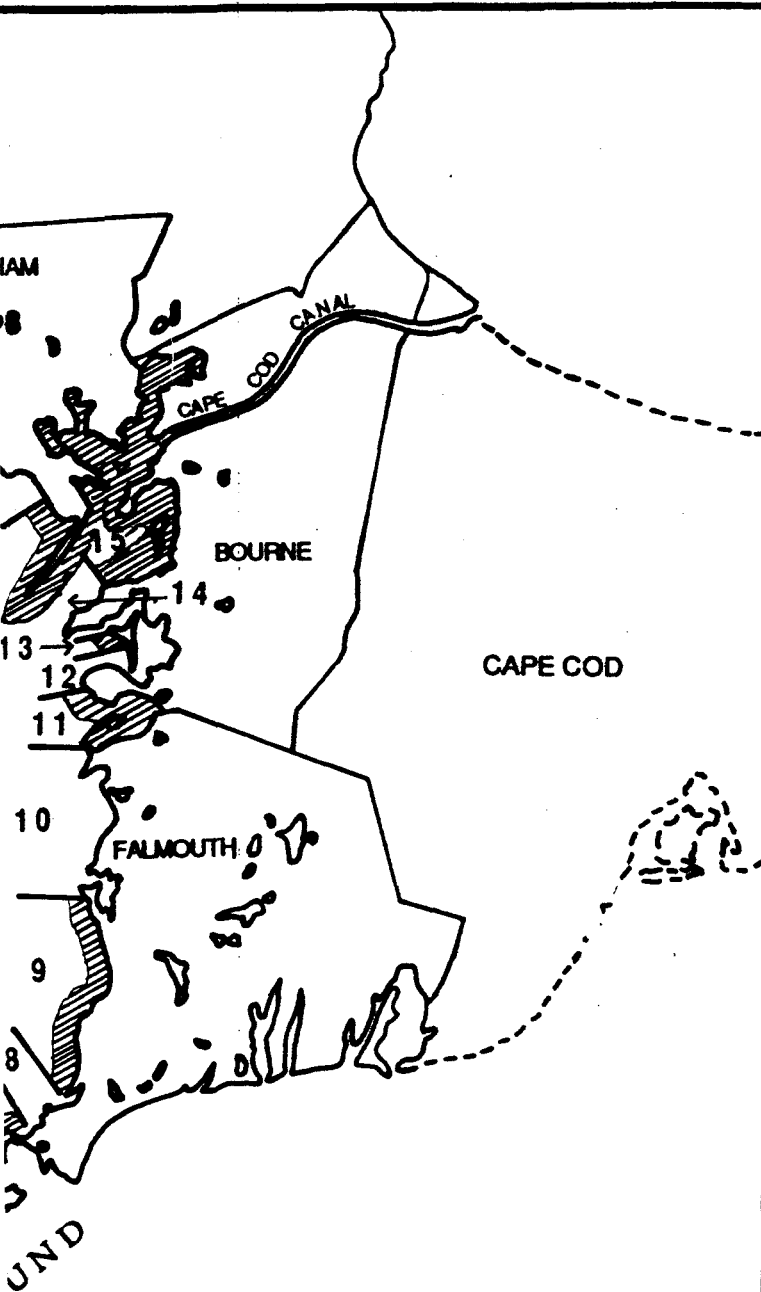
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**FIGURE 5: COASTAL COMPARTMENTS SHOWING NET RETREAT (LOSS) AND ADVANCE (GAIN) OF THE BUZZARDS BAY SHORELINE**

**LEGEND**

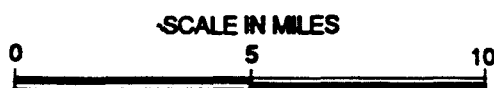
(Ft. per 100 yrs.)

COMPARTMENT	LOSS	GAIN
		
1	48.8	
2		50.5
3	26.2	
4		37.1
5	59.3	
6		15.2
7	38.9	
8		21.3
9	28.4	
10		30.1
11	26.7	
12		40.9
13	109.1	
14		13.6
15	27.3*	
16		56.4
17	87.6	
18		75.6
19	73.0	
20		32.8
21	91.2	
22		36.2
23	79.3	
24		15.5
25	79.2	

**REFERENCE:**

Based on Massachusetts Shoreline Summary Map, 1989.

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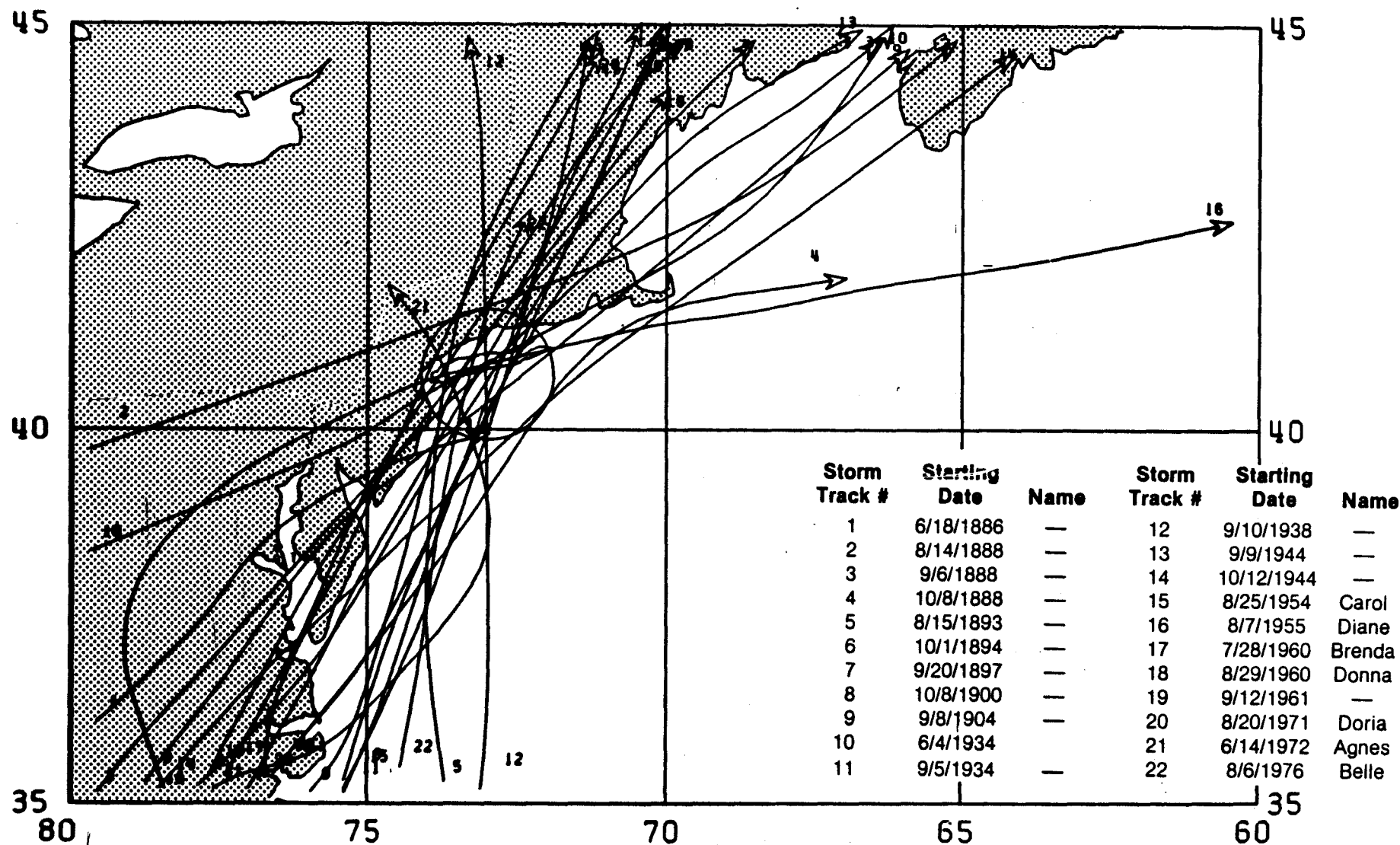
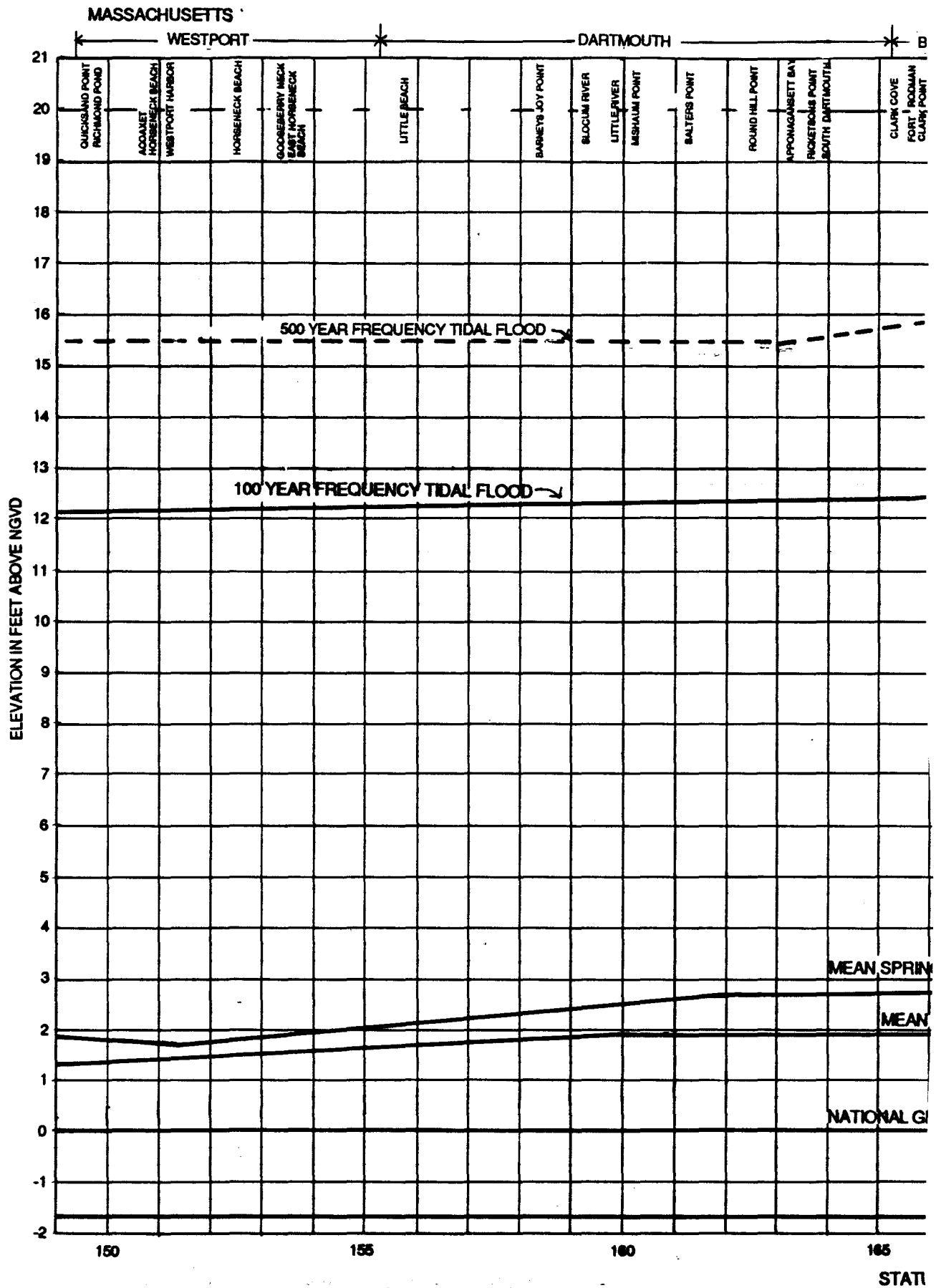


FIGURE 6 Tropical storms and hurricanes passing within 50 nautical miles of Long Island, N.Y. 40.7° N 73° W 1886-1982. Note that the majority of these storms have tracked west of the Buzzards Bay Region, thus imparting major storm winds on the Northwestern shoreline of the bay. (From Koppelman and Davis, 1984)



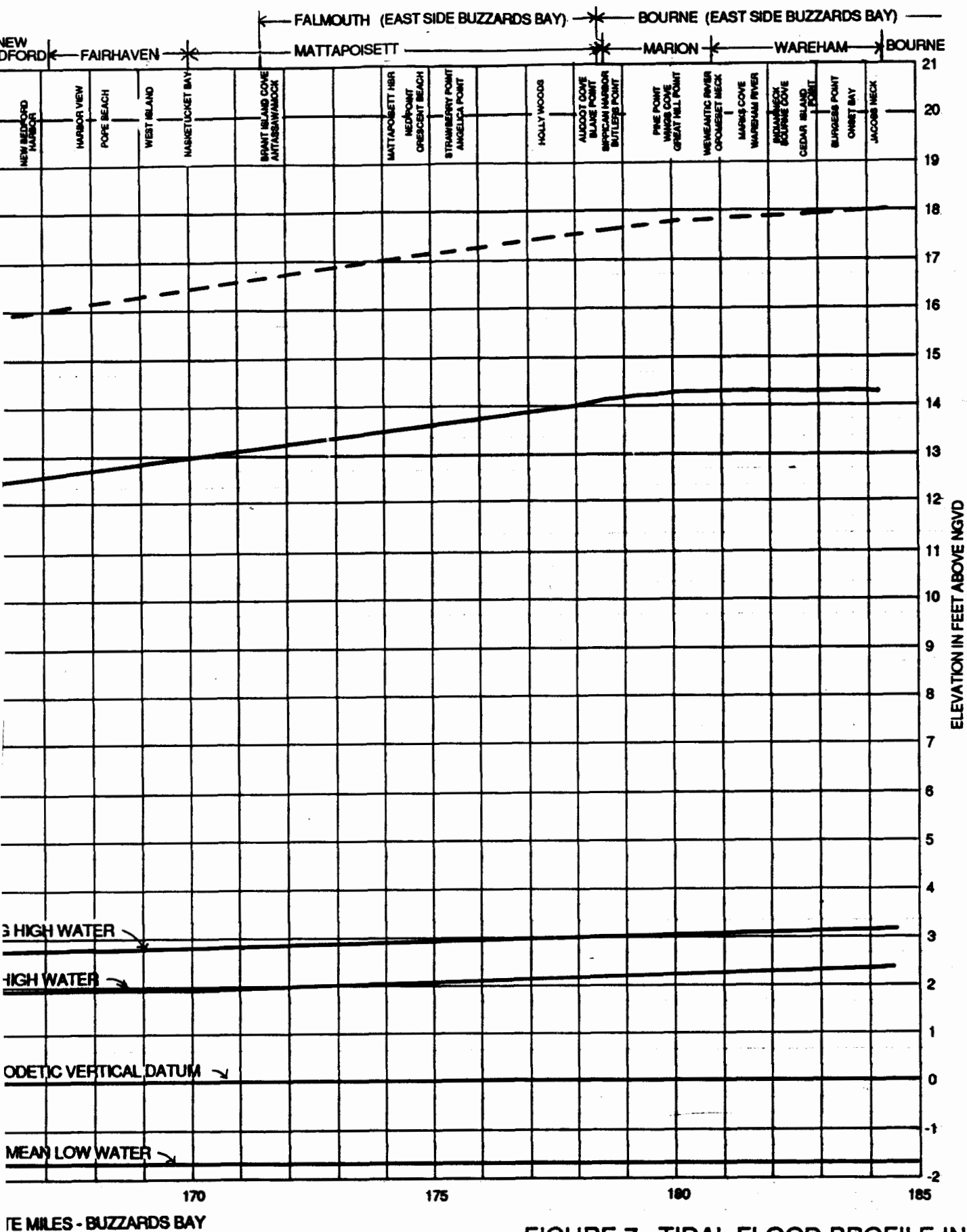


FIGURE 7: TIDAL FLOOD PROFILE IN BUZZARDS BAY (from COE, 1980)

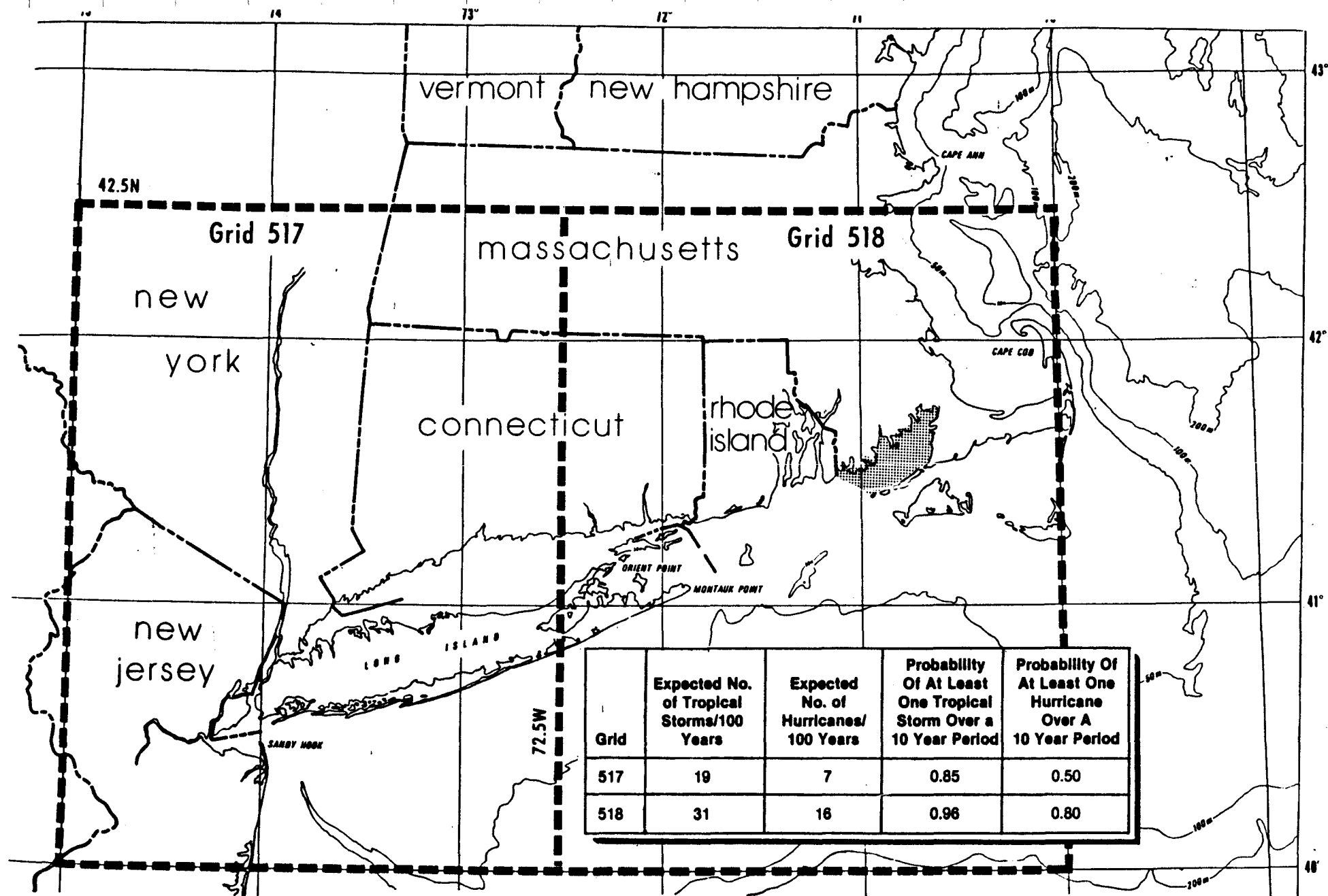


FIGURE 8, Expected number of tropical storms and hurricanes per 100 years impacting the Long Island region (From Koppelman and Davies, 1984)

# MASSACHUSETTS

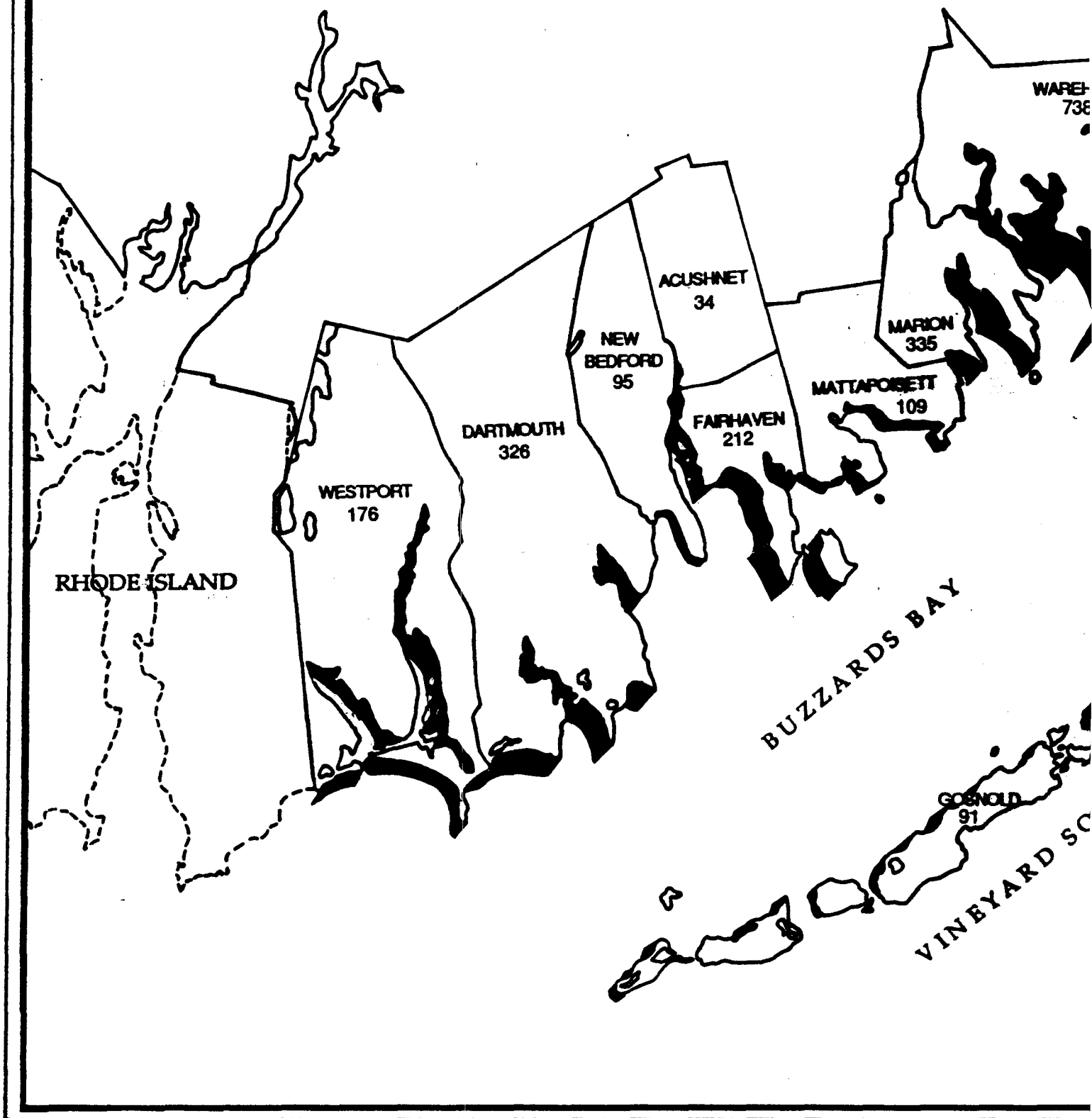
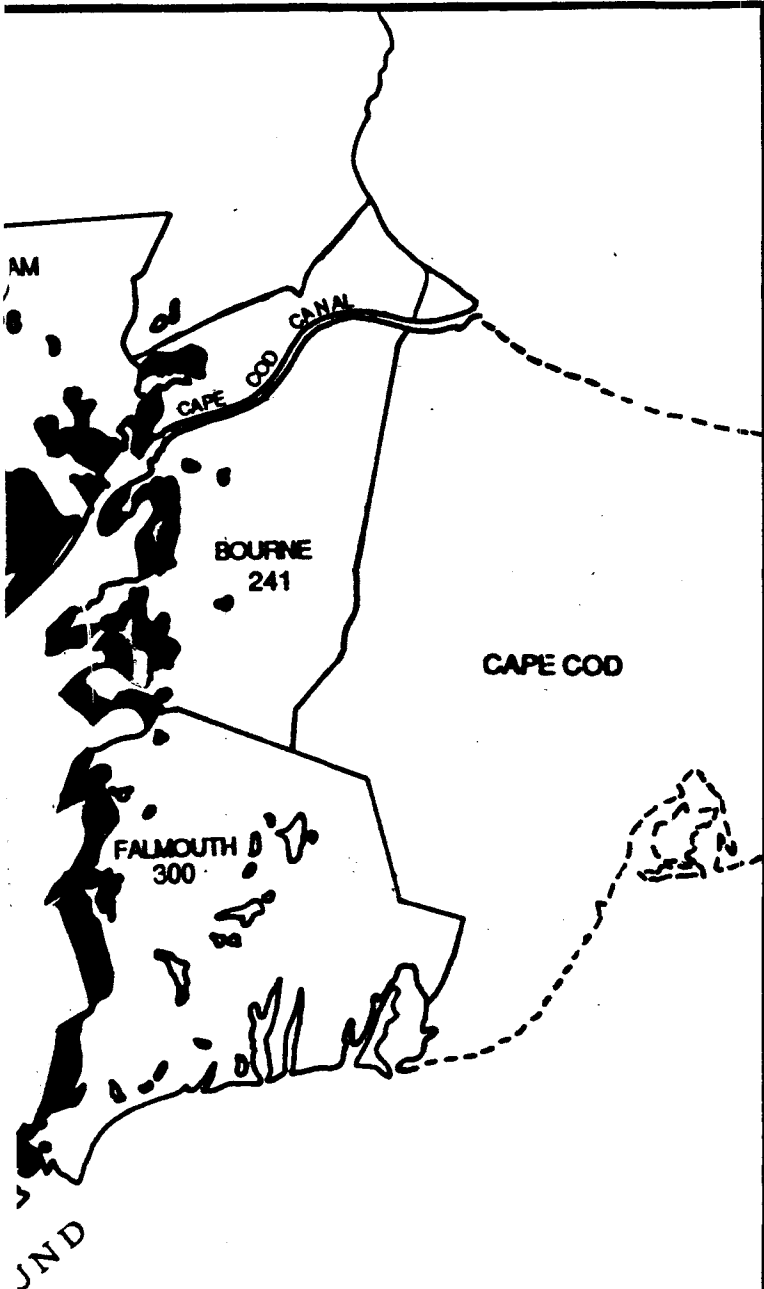


FIGURE 9: PROJECTED UPLAND  
LOSSES FROM 1980-2025  
ASSUMING 0.035 ft./yr. RISE IN  
SEA LEVEL



## LEGEND

APPROXIMATE NUMBER OF ACRES SHOWN  
FOR EACH COMMUNITY.

THE TOTAL ACREAGE FOR FALMOUTH IS  
600, BUT THAT INCLUDES THE VINEYARD  
SOUND SHORELINE

GRAPHIC REPRESENTATION PROVIDED TO  
SHOW RANGE IN VALUES FROM ONE  
COMMUNITY TO THE NEXT. USE 120 SCALE



0-99



100-199

REFERENCE: Geise et al., 1987.

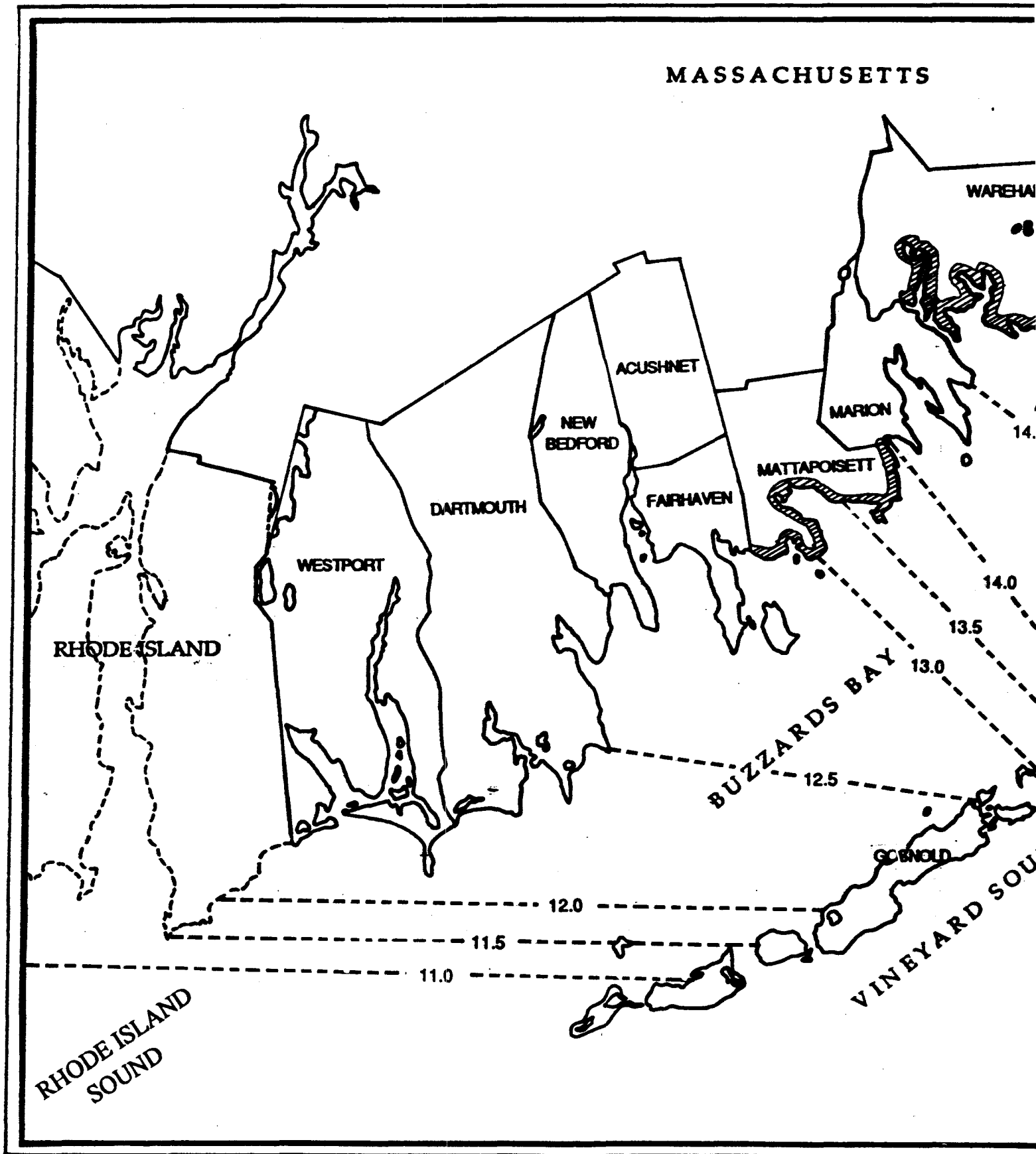
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SCALE IN MILES

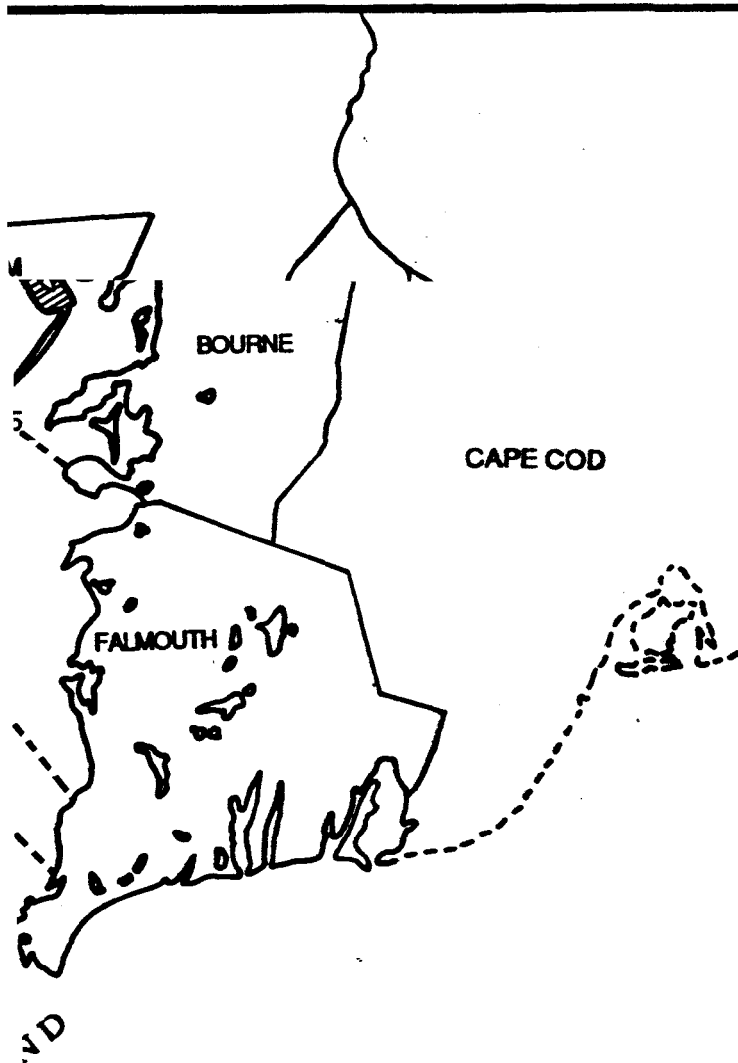


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**FIGURE 10: STILL WATER SURGE  
ELEVATIONS FOR CERTAIN  
COASTAL STORM EVENTS**

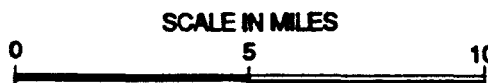


-13.0- APPROXIMATE CLOSURE LINE FOR SURGE  
ELEVATIONS ASSOCIATED WITH THE 100-  
YEAR COASTAL STORM (IN FEET ABOVE  
NGVD).

 AREAS WHERE THE 500-YEAR COASTAL  
STORM IS GREATER THAN FIVE FEET ABOVE  
THE 100-YEAR ELEVATIONS. ALL OTHER  
AREAS DIFFER BY 3-3.5 FEET.

REFERENCE: FEMA FLOOD INSURANCE  
STUDIES 1981-1986

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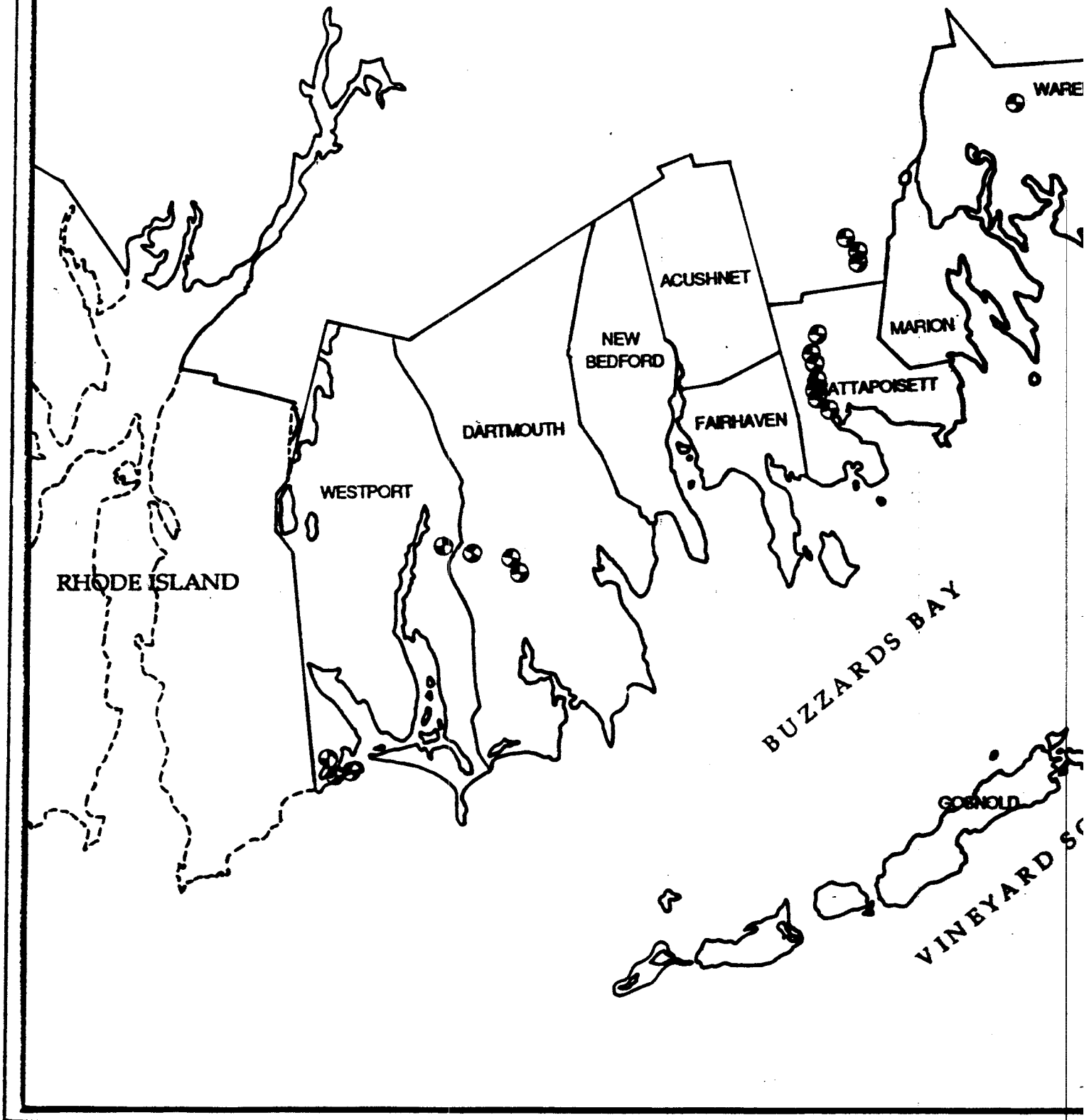
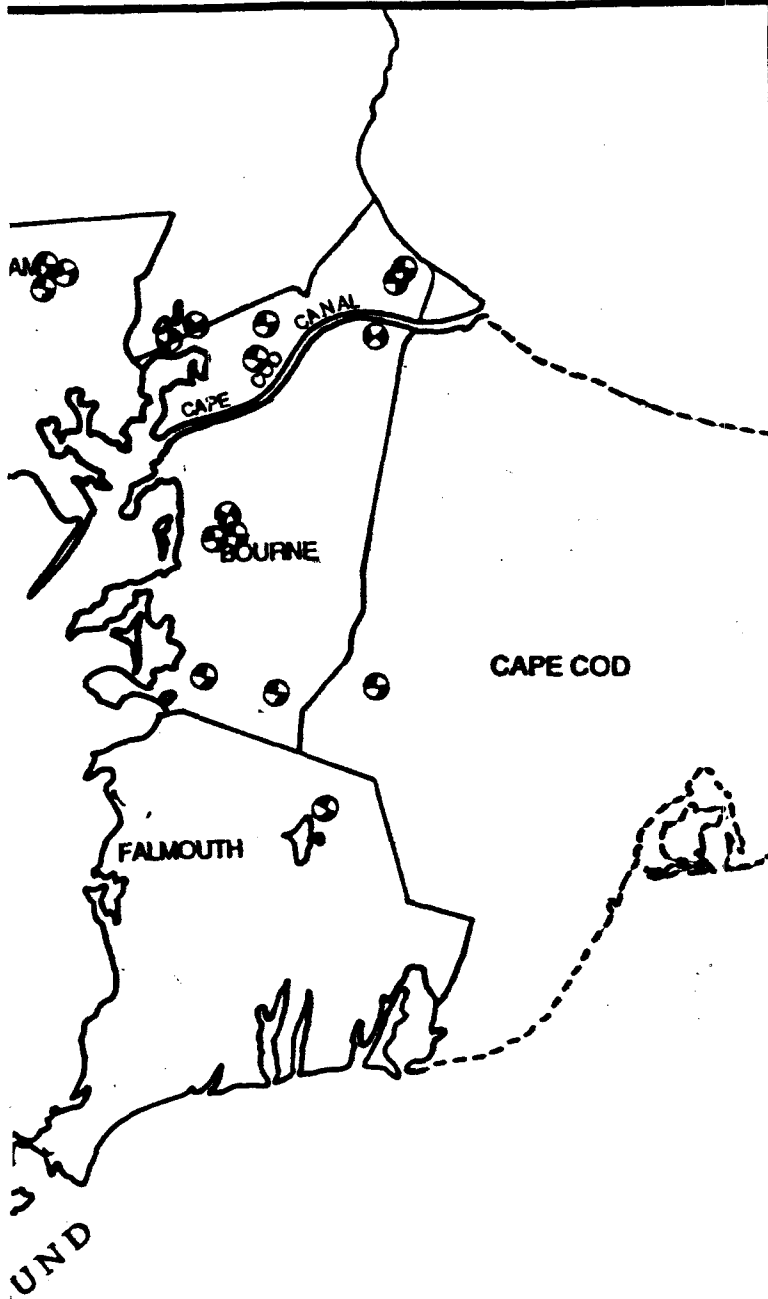


FIGURE 11: LOCATION OF MUNICIPAL  
WELLS ALONG BUZZARDS  
BAY

LEGEND

● PUBLIC WATER SUPPLY WELL



REFERENCES:

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of Southeastern Mass. Northwest Shore of  
Buzzards Bay, John R. Williams & Gary D. Tasker  
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Ground Water Resources of Cape Cod, Mass.  
Denis R. Le Blanc, John H. Guswa, Michael H.  
Frimpter & Clark J. Londquist  
ATLAS HA-692 1986

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River, Wareham  
Williams & Tasker HA-507 1974

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