Atlas of

Stormwater Discharges

in the Buzzards Bay Watershed

August 2003

Commonwealth of Massachusetts
Mitt Romney, Governor
Kerry Healey, Lieutenant Governor

Executive Office of Environmental Affairs
Ellen Roy Herzfelder, Secretary

Massachusetts Office of Coastal Zone Management
Tom Skinner, Director

Buzzards Bay Project National Estuary Program
Joseph E. Costa PhD., Executive Director

Atlas of

Stormwater Discharges

in the Buzzards Bay Watershed

Produced by:

Buzzards Bay Project National Estuary Program
Massachusetts Office of Coastal Zone Management
2870 Cranberry Highway
East Wareham, Massachusetts 02538
(508) 291-3625
www.buzzardsbay.org

Joseph E. Costa, *Executive Director*
Aria Brissette, *Natural Resource Analyst*

Funded by

Massachusetts Highway Department

Massachusetts Environmental Trust

Massachusetts Department of Environmental Protection

August 2003

Dear Friend of the Environment:

Over the years, many stormwater drainage systems from roads and parking lots have been built that discharge untreated stormwater to our wetlands, rivers, ponds, and coastal waters. These stormwater discharges pose many threats to the environment. Runoff from rain carries pollutants into wetlands, lakes, streams, and groundwater, which can affect water quality, habitat, and living resources. Excess stormwater pollutants can lead to conspicuous impacts like beach and shellfish bed closures, and more subtle changes such as loss of habitat and changes in the abundance of certain species.

The threat of stormwater discharge to human health and the environment has become an issue of national importance. The US Environmental Protection Agency is now requiring all urbanized municipalities to inventory stormwater discharges, and to develop strategies to manage stormwater to protect and restore water quality and wetland habitat. The importance of stormwater is why the Executive Office of Environmental Affairs has been making efforts to work with Massachusetts' municipalities to remediate stormwater discharges. It is also why this *Atlas of Stormwater Discharges in the Buzzards Bay Watershed* was created by the Buzzards Bay Project National Estuary Program.

This Atlas documents more than 2,600 known stormwater discharges along the Buzzards Bay coast and nearby streams, along with more than 12,000 contributing catch basins. The Atlas also helps to establish priority sites for remediation, which will help guide state and municipal officials to target limited resources toward the identification of stormwater discharge sites that, if remediated, may result in improved water quality.

The Atlas is the result of a multi-agency cooperative study, together with Buzzards Bay watershed municipalities, to inventory stormwater discharges near the coast of Buzzards Bay in southeastern Massachusetts. I applaud this collaborative effort and the team that developed this Atlas. It is my hope that it will serve as a catalyst for municipalities to develop comprehensive municipal stormwater management plans. Many communities have initiated efforts to map all stormwater discharges and catchbasins within their municipal boundaries and develop stormwater management plans. These efforts show the commitment of state and local government to protect water quality, habitat, and living resources most cherished by the residents of the Commonwealth.

Ellen Roy Herzfelder
Secretary of Environmental Affairs
Commonwealth of Massachusetts

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

The *Atlas of Stormwater Discharges in the Buzzards Bay Watershed* is the result of a multi-agency cooperative study of stormwater discharges along the coast of Buzzards Bay in southeastern Massachusetts. The original inventory of information was funded by the Massachusetts Highway Department, with a grant from the Intermodal Surface Transportation Efficiency Act (ISTEA) program. Additional funding was provided by the Massachusetts Department of Environmental Protection (DEP 00-03/319) to refine and publish the Atlas in a form more directly usable by local and state officials. The Massachusetts Environmental Trust provided funding for outreach and publication of the Atlas and for a student intern. Site locations, maps, and data summaries published in this Atlas were developed and produced by the Buzzards Bay Project National Estuary Program, a unit of the Massachusetts Office of Coastal Zone Management.

BBP staff participating in the development and production of this Atlas included Joseph Costa, Aria Brissette, John Rockwell, Tracy Warncke, Sarah Wilkes, and Mark Borrelli. Bernadette Taber of the USDA Natural Resources Conservation Service contributed appreciably to this effort. The staff of the Massachusetts Division of Marine Fisheries was of considerable assistance in providing water quality data and helping to identify priority sites. These individuals included Frank Germano, Michael Hickey, Thomas Hoops, John Mendes, Greg Sawyer, and David Whittaker.

ABOUT THIS ATLAS

Study Purpose

Similar to most coastal areas, stormdrain discharge pipes dot the coast of Buzzards Bay. Some discharges, like the one in Figure 1, are easy to find because they are marked or highly visible; others are hidden from view or forgotten. Some discharges are via pipes; others are merely "roadcuts." The *Atlas of Stormwater Discharges in the Buzzards Bay Watershed* attempts to document all known stormwater discharges and contributing catchbasins along the shores of the eight municipalities shown in Figure 2[1]. The stormwater discharges included in this study were limited to stormdrain pipes and major roadcuts. A roadcut is defined as any cut in a berm, curb, or bank that discharges stormwater runoff from a paved surface directly to a wetland, waterbody, or upland area.

Figure 1. A submerged stormdrain in Wareham.

This Atlas also establishes priorities for the remediation of the mapped stormwater discharges, utilizing information on water quality, shellfish bed closures, drainage network size, water supply zones, and lists of impaired waters. This information is provided in the Atlas in summary tables with scored ranks. Although the discharge database represents thousands of mapped sites that could not be effectively labeled in the maps in this report, the entire GIS database file is included on the CD-ROM that accompanies this report and can also be downloaded from the Buzzards Bay Project's website at *www.buzzardsbay.org/gisdata.htm*. The ArcView® program is needed to view the GIS shapefiles.

The main purpose of this Atlas is to help state and municipal officials target limited resources by identifying stormwater discharge sites that, if remediated, may result in improved water quality. Such a listing will assist government officials in identifying restoration opportunities, especially when road and bridge work is being contemplated. The information in this Atlas will provide the towns with justification for acquiring grant funds for stormwater projects, such as projects under consideration as part of the Regional Transportation Plan and those eligible for state and federal funding. In addition, information in the Atlas can assist local communities in implementing the goals established in their Phase II stormwater management plans. These stormwater management plans and complete stormwater discharge inventories must be completed by 2008 as part of the

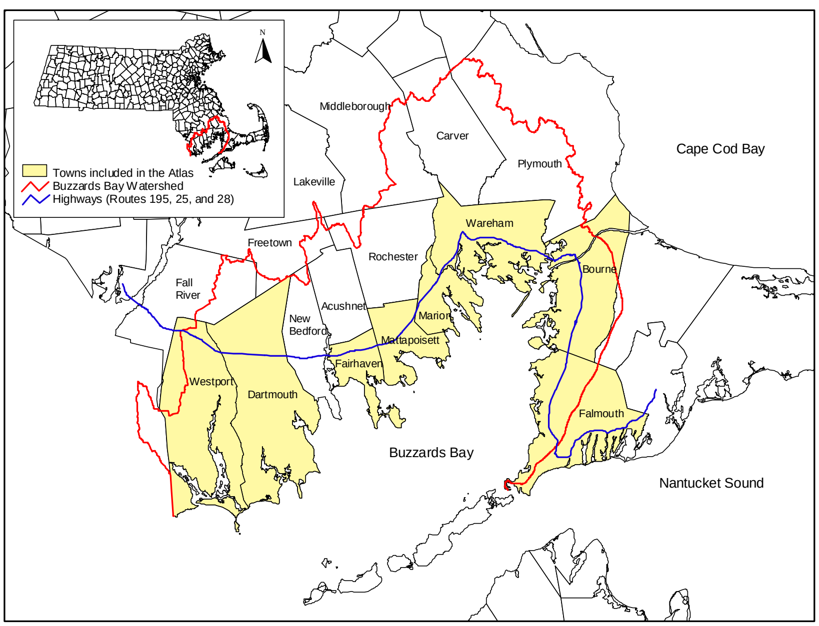


Figure 2. Municipalities included in this study.

[1] The City of New Bedford was not included in this study because the city's combined sewer-overflow system and many separate stormwater discharges could not be addressed within the scope and funding of the original grants.

US EPA's Small Municipal Separate Storm Sewer System (MS4) National Pollution Discharge Elimination System (NPDES) Program (Phase II) for those towns within "urbanized areas" as defined by the 2000 US Census. These urbanized areas are shown in Figure 3. Finally, the Atlas is of great interest to fire chiefs, who will now have documentation as to the likely discharge of contaminants from road spills and accidents.

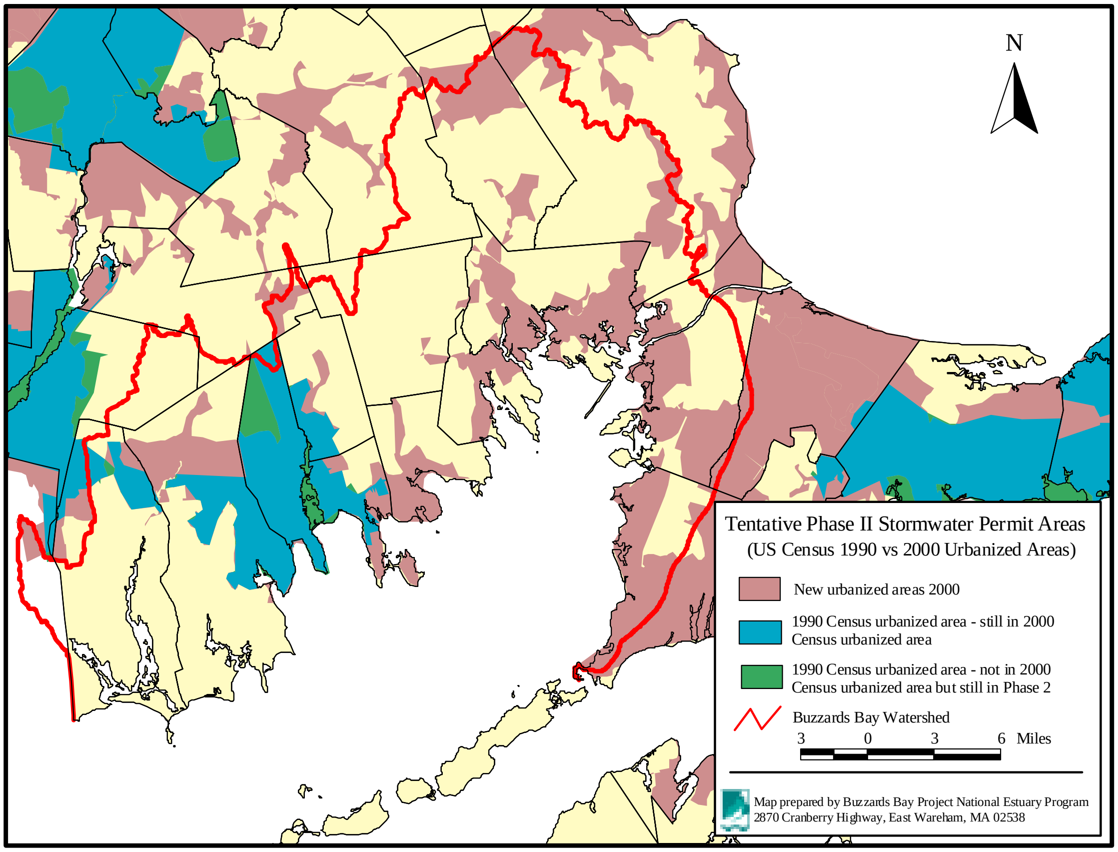


Figure 3. Newly defined urbanized areas from the 2000 US Census. All urbanized areas shown are included in the EPA NPDES Phase II Program for Municipal Small Storm Sewer Systems (MS4s).

Study Limitations

Although the Buzzards Bay Project made considerable efforts to identify all nearshore stormwater discharges in Buzzards Bay, we recognize some areas may have been overlooked. Therefore, our list should not be considered definitive and should only be used for planning purposes. Moreover, the scoring of priorities was biased towards identifying sites that would most likely result in changes in shellfish bed classification. In other words, we attempted to find remediation sites that might give "the biggest bang for the buck." However, the remediation of sites that do not rank high in our evaluation may still be justifiable and appropriate for numerous reasons.

Our estimate of the cost of remediation was derived from a simplified costing model based on completed local projects and best professional judgment. The costs should be considered approximate for the purposes of establishing a prioritization ranking. Actual costs will depend on many variables particular to each site.

Information in the Atlas

The study area for this project encompassed the southeastern coast of Massachusetts, extending from the border of Rhode Island to the southwestern tip of Cape Cod at Woods Hole (see Figure 2). The following eight Buzzards Bay municipalities were included: Westport, Dartmouth, Fairhaven, Mattapoisett, Marion, Wareham, Bourne, and Falmouth. The study area was generally limited to portions of these towns lying south of Interstate 195. In the Towns of Bourne and Falmouth, Route 28 served as the eastern boundary of the study area. The City of New Bedford was excluded due to reasons previously explained.

This *Atlas of Stormwater Discharges in the Buzzards Bay Watershed* contains the following information:

- Background information on stormwater and stormwater remediation solutions.
- A detailed methodology section.
- A series of five single page maps that together show all mapped stormwater discharges ranked in High, Medium, and Low Priority (Appendix A).
- A series of thirty single page maps that together show all mapped stormwater discharges, catchbasins, and assumed lines of flow along Buzzards Bay (Appendix B).
- Supplemental large format maps.
- A CD including a PDF version of this report, a spreadsheet that includes all sites, digital maps, and GIS data.

BACKGROUND

Stormwater poses many threats to the environment. Runoff from rain or snowmelt carries natural and manmade pollutants into wetlands, lakes, streams, and groundwater, which can affect water quality, habitat, and living resources. Pollutants associated with stormwater runoff may include bacteria, nutrients, pesticides, and hydrocarbons. Stormwater also conveys sediments that cause siltation of aquatic and wetland habitats, and contributes floatable debris, resulting in increased turbidity and declining water clarity. Excess stormwater pollutants can lead to swimming beach closures, loss of habitat and resources, and changes in species composition and diversity. In coastal areas, excessive stormwater pollutants (primarily bacteria) can also result in shellfish bed closures. Chronic stormwater pollution to sensitive resources can result in aesthetic impacts, as well as economic impacts such as those associated with the loss of commercial and recreational fisheries.

Although stormwater is associated with many of the environmental impacts described above, the principal focus of this Atlas was to evaluate stormwater impacts with respect to actual and potential pathogen contamination. The Atlas identifies stormwater discharges contributing to shellfish or bathing beach closures, or representing a threat to those resources. This focus was selected because the closure of shellfish beds in Buzzards Bay was identified as a priority in the Buzzards Bay Comprehensive Conservation and Management Plan (CCMP) adopted by the Commonwealth of Massachusetts and the US Environmental Protection Agency in 1991.

Investigations by the Massachusetts Division of Marine Fisheries and the Buzzards Bay Project have identified stormwater runoff as the primary factor contributing to most closures of shellfish beds around Buzzards Bay (Figure 4). Although the areas of shellfish bed closures represent a small portion of the overall area of Buzzards Bay, these closures are located along the fringes, in harbors and embayments, where they have the greatest impact. These areas are important because popular species such as soft-shell clams, bay scallops, and oysters are

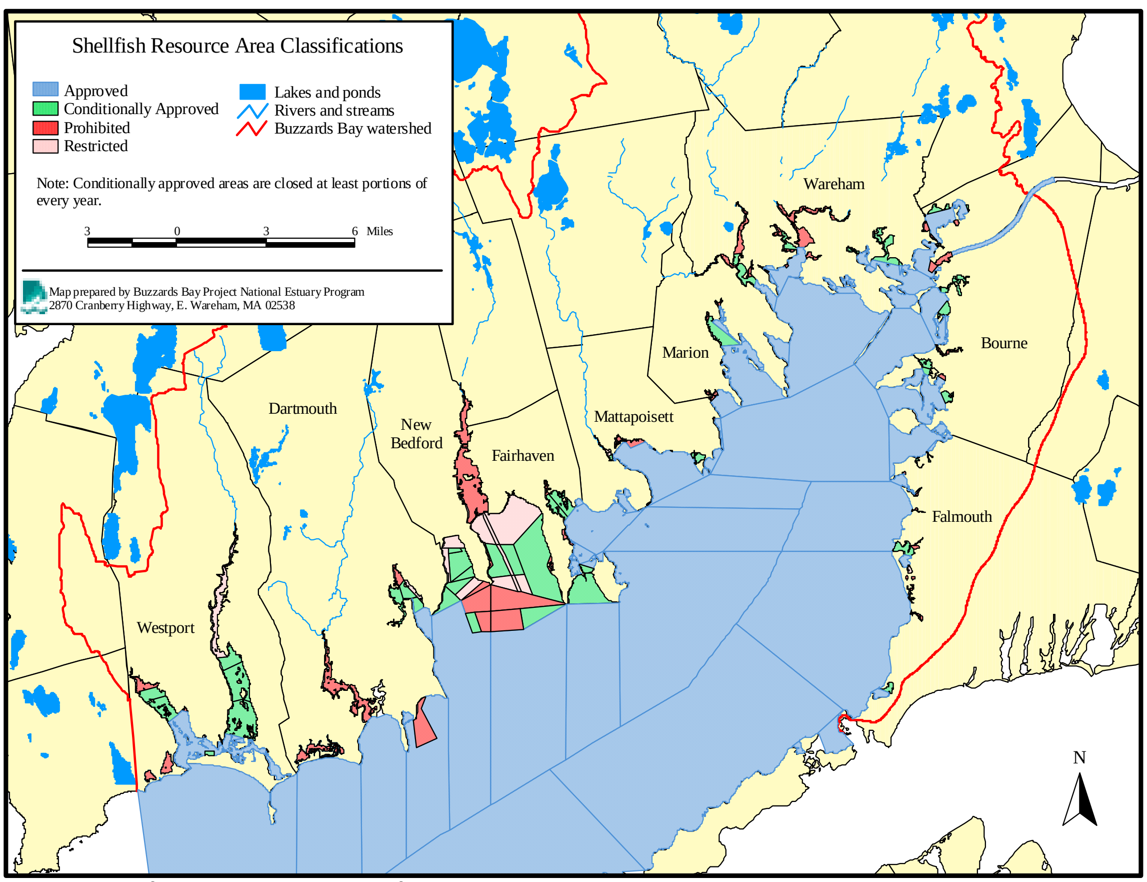


Figure 4. Shellfish Resource Area Classification in Buzzards Bay, circa July 1, 2000.

harvested nearly exclusively from these near shore areas. Even somewhat deeper water species like the quahog are most abundant in the coastal bays. For both commercial and recreational fisherman, large portions of easily accessed areas are closed during the summer because of elevated fecal coliform bacteria levels.

Stormwater is both a pollution source and a conveyance mechanism for inland sources of pollution. In practical terms, stormwater can convey pollutants from numerous sources (pet and wildlife feces, failed septic systems, farm management practices, etc.) to the coast, where the pollutants may have a greater impact on public health and the environment.

The principal pollutants of concern used to evaluate stormwater discharges are various types of fecal bacteria. Residents, municipal officials, and coastal managers alike identified fecal bacteria contamination as a priority management issue because of the widespread closure of shellfish resource areas along shore, and the occasional closure of swimming beaches. Shellfish bed closures have exceeded 15,000 acres (Figure 5, see also the closure definitions in Table 1). Moreover, because stormwater discharges and rainfall are highly linked to fecal coliform concentrations, the management and control of untreated stormwater discharges has remained a top priority in Buzzards Bay. Due to the geometry of the Buzzards Bay coastline, restoration of bay water quality is highly dependent on localized remediation of stormwater runoff.

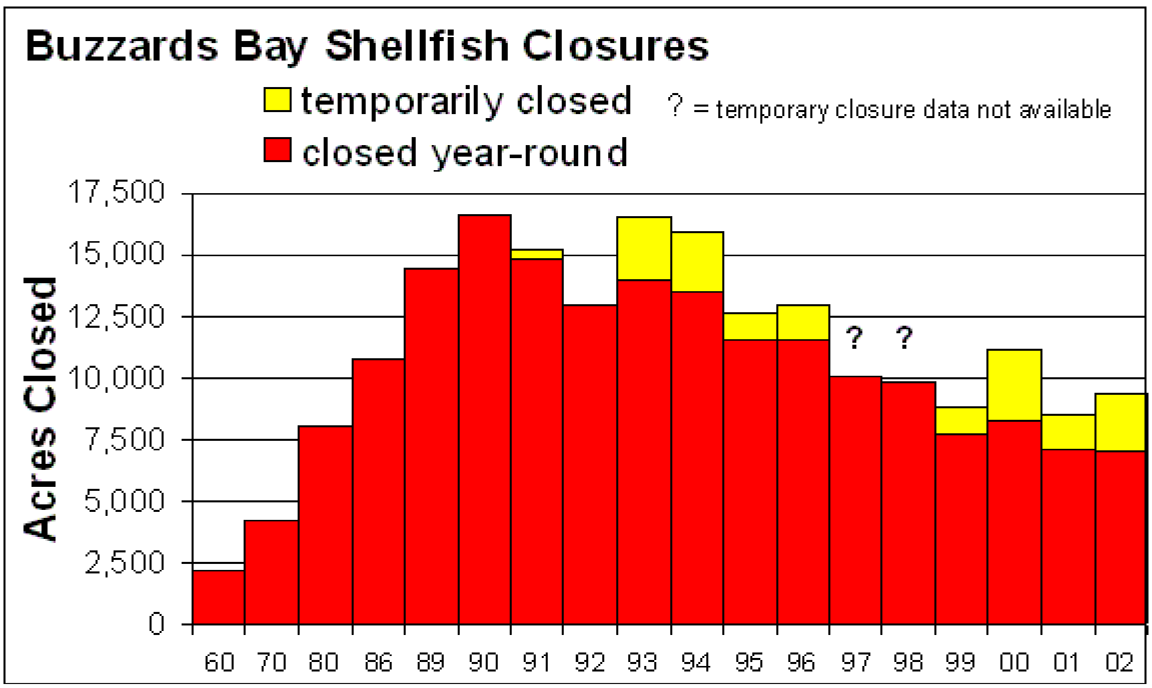


Figure 5. Number of acres of permanently and temporarily closed (rainfall or seasonal conditional) shellfish beds in Buzzards Bay on or about July 1. Note: Closed year round = “prohibited” + “restricted” + “management” closures. Whether the conditional beds were open or closed on July 1 depended on recent rainfall and other conditions.

In the CCMP, rainwater flowing off impervious and pervious land surfaces from both urbanized and agricultural areas was identified as the primary source of pathogens in many parts of Buzzards Bay and the cause of these shellfish bed closures. Consequently, in the Buzzards Bay CCMP, two goals were identified:

1. Prevent new or increased untreated stormwater flows to Buzzards Bay that would adversely affect shellfish harvesting areas, swimming beaches, water quality, and wetlands, and
2. Correct existing stormwater runoff problems that are causing or contributing to water quality degradation or shellfish bed closures in Buzzard Bay.

The CCMP also recognized that Best Management Practices (BMPs) implemented to reduce and treat stormwater fecal bacteria also contribute to the attenuation of other pollutants.

While these goals seem straightforward and simple, the Buzzards Bay Project has estimated that the cost of remediating all existing major stormwater discharges in Buzzards Bay (excluding CSOs in New Bedford) will exceed twenty million dollars. The management and permitting of new discharges to minimize water quality impacts is considered a piecemeal approach among many municipal departments and state agencies. At present, most new stormdrains are regulated entirely at the local level through wetland regulations, subdivision by-laws, and road-drainage regulations.

Table 1. Shellfish resource area classification definitions

Classification	Definition
Approved	Open for harvest of shellfish for direct human consumption subject to local rules and state regulations.
Conditionally Approved	During the time area is approved it is open for harvest of shellfish for direct human consumption subject to local rules and state regulations.
Conditionally Restricted	During the time area is restricted it is only open for the harvest of shellfish with depuration subject to local rules and state regulations.
Restricted	Open for harvest of shellfish with depuration subject to local rules and state regulations for the relay of shellfish.
Management Closure	Closed for harvest of shellfish. Not enough testing has been done in the area to determine whether it is fit for shellfish harvest or not.
Prohibited	Closed for harvest of shellfish.

These types of local regulations are often inconsistent from one community to the next. In addition, both local public works departments (DPWs) and the Massachusetts Highway Department (MHD) have, as their primary mission, the construction of safe roads. This includes the removal of stormwater from these roads as quickly as possible. Historically, resource protection and water quality considerations had been secondary to this mission. Often these kinds of projects have been exempt from wetland permit filing, and in some instances, filing requirements have been ignored. Furthermore, existing problematic stormwater discharges are rarely systematically remediated in any community. Exacerbating the problem is the fact that requirements within a single town's boards are not always consistent and sometimes even contradictory. Even more complex are situations where stormwater from more than one town contributes to water quality degradation or shellfish bed closures in a specific embayment. Each contributing town must enact similar and equitable stormwater controls in order for the affected resource to be fully protected.

Many changes have occurred during the past decade to help address these problems. Most significantly, the Buzzards Bay Project, Massachusetts Coastal Zone Management, and the Massachusetts Department of Environmental Protection have directed millions of dollars to remediate stormwater and other nonpoint pollution sources. Municipalities appear to have spent at least an equivalent amount on their own. Equally important have been changes in local and state regulations. In 1996, the Buzzards Bay Project began promoting a set of unified stormwater management regulations for Boards of Health, Conservation Commissions, and Planning Boards. Already, many of these boards have adopted regulations or policies that address stormwater discharges. Additionally, in 1999, the Commonwealth of Massachusetts issued stormwater policies to assist state regulators and municipal conservation commissions in reviewing new proposed stormwater discharges in order to meet the goals of the state's Wetland Protection Act. Both the Buzzards Bay Project's unified regulations and the state Stormwater Policy Guidance document have common goals and standards to address stormwater discharges.

The state stormwater policies and the Buzzards Bay Project's model local regulations include performance standards for stormwater flow rate, volume, and quality. In the case of the Buzzards Bay Project's model regulations, two goals are to be met with regard to pollution: 1) no new construction, whether public or private, should create any new direct untreated stormwater discharges that degrade water quality or living resources, and

2) stormwater must be treated onsite rather than be discharged to other public or private conveyance systems (that often discharge to surface waters). The Buzzards Bay Project and other agencies have also been promoting a variety of low-impact development techniques for new development and for retrofitting existing lots. These include rain gardens, swales, minimizing impervious surfaces, and other techniques for minimizing offsite transport of stormwater.

Together, all these actions have helped improve water quality in Buzzards Bay. One of the greatest successes that the Buzzards Bay Project, DMF, and the municipalities of Buzzards Bay can point to is the decline of permanently closed shellfish beds in Buzzards Bay since the early 1990s (see Figure 5). However, much more can be done, and this report will help direct future efforts.

Regulatory Framework for Managing Stormwater Discharges

Pathogen contaminated waters are regulated under two key state regulatory programs and one local regulatory program. The oldest of these is the DMF Shellfish Program, which seeks to protect public health and manage the Commonwealth's molluscan shellfish resources. Public health protection is achieved through the sanitary classification of all Massachusetts overlying waters in accordance with the provisions of the National Shellfish Sanitation Program (NSSP). The NSSP is the federal/state cooperative program recognized by the U.S. Food and Drug Administration (FDA) and the Interstate Shellfish Sanitation Conference (ISSC) for the sanitary control of shellfish produced and sold for human consumption. Table 2 identifies all major embayments in Buzzards Bay and identifies those embayments that have shellfish bed closures under the DMF Shellfish Program.

Areas where shellfish beds and swimming beaches have a history of closures due to pathogen contamination (or other environmental impacts) also have special designations under Massachusetts Department of Environmental Protection regulations. These sites are designated as impaired waters, or “303(d) list” waters. The 303(d) list includes waters impaired by other pollutants in addition to pathogens. The 1998 303(d) list (DEP, 1998) is currently under revision, but the most recent proposed list of impaired waters can be found in the document “Massachusetts Year 2002 Integrated List of Waters” October 2002, issued by the Massachusetts Department of Environmental Protection (DEP, 2002). As noted in the report:

> *Section 303(d) of the CWA and the implementing regulations at 40 CFR 130.7 require states to identify those waterbodies that are not expected to meet surface water quality standards after the implementation of technology-based controls [on existing permitted discharges] and to prioritize and schedule each of them for the development of a total maximum daily load (TMDL). A TMDL establishes the maximum amount of a pollutant that may be introduced into a waterbody and still ensure attainment and maintenance of water quality standards. Furthermore, a TMDL must also allocate that acceptable pollutant load among all potential sources. The sum total of all pollutant load allocations, including those for point and nonpoint pollution sources as well as an allowance for natural background loads and a margin of safety, cannot exceed the total maximum allowable pollutant load calculated for the receiving water.*

As a result of these regulatory requirements, 303(d) listed waters from the 2002 list are now included in this report under the heading “Massachusetts Category 5 Waters, Waters requiring a TMDL." The 303(d) listed coastal waters in Buzzards Bay are shown in Figure 6. The list of all Buzzards Bay 303(d) list waters (including freshwaters) and their impairment is shown in Table 3. Stormwater discharges were not mapped to all sites listed in this table. As shown, 26 of the 33 major Buzzards Bay embayments are listed as impaired on the 303(d) list because of bacterial pathogen contamination.

Table 2. Major Buzzards Bay embayments with corresponding DMF DSGA identification codes and their status pursuant to the "Final Massachusetts Section 303(d) List of Waters"

Embayment	Town(s)	303(d) list pathogens	DSGA Codes[1]
Westport West Branch	Westport	Yes	BB3
Westport East Branch	Westport	Yes	BB4
Allens Pond	Westport, Dartmouth	Yes	BB6
Slocums River	Dartmouth	Yes	BB8
Little River	Dartmouth	No	BB9
Apponagsett Bay	Dartmouth	Yes	BB12
Clarks Cove	Dartmouth, New Bedford	Yes	BB13
New Bedford Harbor	New Bedford, Acushnet, Fairhaven	Yes	BB15
Outer New Bedford Harbor	New Bedford, Fairhaven	Yes	BB15
Little Bay	Fairhaven	No	BB22
Nasketucket Bay	Fairhaven, Mattapoisett	No	BB21
Brant Island Cove	Mattapoisett	No	BB23
Mattapoisett Harbor	Mattapoisett	Yes	BB25
Eel Pond (Mattapoisett)	Mattapoisett	Yes	BB27
Hiller Cove	Mattapoisett	Yes	BB30
Aucoot Cove	Mattapoisett, Marion	Yes	BB31
Sippican Harbor	Marion	Yes	BB32
Wings Cove	Marion	Yes	BB34
Weweantic River	Marion, Wareham	Yes	BB35
Wareham River	Wareham	Yes	BB36
Little Harbor-Bourne Cove	Wareham	No	BB37
Onset Bay	Wareham	Yes	BB40
Buttermilk Bay	Wareham, Bourne	Yes	BB39
Little Buttermilk Bay	Bourne	Yes	BB40
Eel Pond -Pocasset River	Bourne	Yes	BB41
Phinneys Harbor	Bourne	Yes	BB42
Pocasset Harbor	Bourne	Yes	BB43
Hen Cove	Bourne	Yes	BB44
Red Brook Harbor	Bourne	Yes	BB45
Squeteague Harbor	Bourne	Yes	BB46
Megansett Harbor	Bourne, Falmouth	No	BB47
Wild Harbor	Falmouth	No	BB47
West Falmouth Harbor	Falmouth	Yes	BB48
Quissett Harbor	Falmouth	Yes	BB49

1. Designated Shellfish Growing Area (DSGA) codes do not match precisely to conventional embayment boundaries or 303(d) list boundaries.

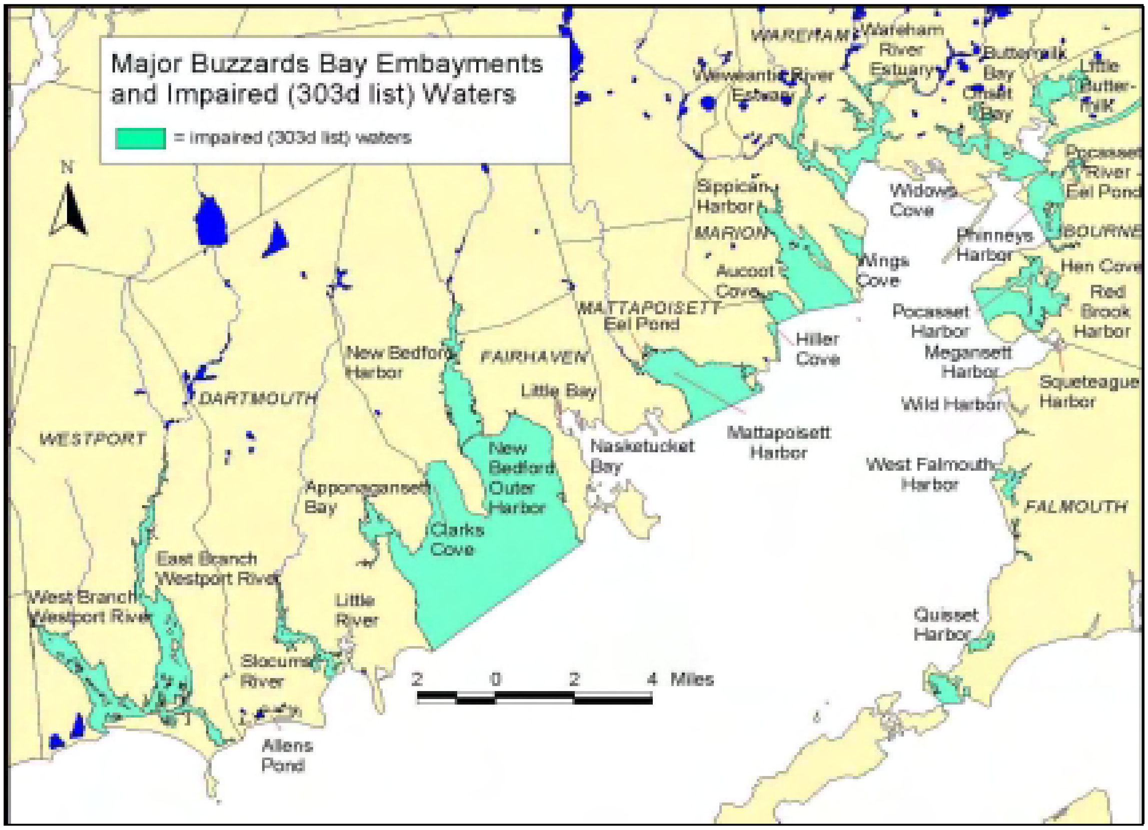


Figure 6. Waters of Buzzards Bay on the Massachusetts Section 303(d) list for waters impaired or threatened by pathogens. Note: West Pond and Cuttyhunk Pond on Cuttyhunk Island are not shown. Boundaries are approximate based on published verbal descriptions.

Table 3. Freshwater, marine, and estuarine waters identified for the Buzzards Bay Watershed in the DEP proposed 2002 "Massachusetts Year 2002 Integrated List of Waters," Category 5 waters, requiring a TMDL

Name	Description	Size	Assess. Date	Pollutant(s) Needing TMDL
Cornell Pond	Dartmouth	16 acres	Sep-97	Priority organics, Metals
Long Pond	Rochester	33 acres	Sep-97	Metals
Noquochoke Lake	(Main Basin) Dartmouth	110 acres	Apr-97	Priority organics, Metals, Noxious aquatic plants, Turbidity, Exotic species
Noquochoke Lake	(South Basin) Dartmouth	19 acres	Apr-97	Priority organics, Metals, Noxious aquatic plants, Turbidity, Exotic species
Noquochoke Lake	(North Basin) Dartmouth	17 acres	Apr-97	Priority organics, Metals, Noxious aquatic plants, Turbidity, Exotic species
Snipatuit Pond	Rochester	710 acres	Sep-97	Metals
Tihonet Pond	Wareham	89 acres	Apr-97	Organic enrichment/ Low DO
Turner Pond	New Bedford/ Dartmouth	55 acres	Apr-97	Metals, Turbidity
White Island Pond	(East Basin) Plymouth	159 acres	Sep-97	Nutrients, Organic enrichment/ Low DO, Noxious aquatic plants
White Island Pond	(West Basin) Plymouth	125 acres	Apr-97	Nutrients, Organic enrichment/ Low DO, Noxious aquatic plants, Exotic species
Acushnet River	Outlet New Bedford Reservoir to Hamlin Street culvert, Acushnet	2.7 miles	Sep-96	Nutrients, Siltation, Organic enrichment/ Low DO, Pathogens
Acushnet River	Hamlin Street to culvert at Main Street, Acushnet	1 mile	Sep-96	Nutrients, Organic enrichment/ Low DO, Pathogens

Name	Description	Size	Assess. Date	Pollutant(s) Needing TMDL
Acushnet River	Outlet Main street culvert to Coggeshall Street bridge	0.32 sq mi	Dec-99	Priority organics, Metals, Nutrients, Organic enrichment/ Low DO, Pathogens
Agawam River	Wareham WWTP to confluence with Wankinco River, Wareham	0.16 sq mi	Sep-97	Nutrients, Other habitat alterations, Pathogens, Noxious aquatic plants
Apponagansett Bay	Dartmouth	0.91 sq mi	Sep-97	Priority organics, Pathogens
Aucoot Cove	Aucoot Cove, Marion, Mattapoisett	0.47 sq mi	Sep-97	Pathogens
Buttermilk Bay	Bourne/ Wareham	0.77 sq mi	Sep-97	Pathogens
Buttonwood Brook	Headwaters, southwest of 195/140 interchange, New Bedford to Apponagansett Bay, Dartmouth	3.8 miles	Sep-97	Pathogens
Cape Cod Canal	Cape Cod Canal, Bourne	0.82 sq mi	Sep-97	Pathogens
Clark Cove	Clarks Cove, New Bedford, Dartmouth	1.15 sq mi	Sep-97	Priority organics, Pathogens
Copicut River	Outlet of Copicut Reservoir, Dartmouth/ Fall River to the inlet of Cornell Pond, Dartmouth	1.4 miles	Sep-97	Priority organics, Metals
East Branch Westport River	Outlet Noquochoke Lake, Dartmouth to Old County Road bridge, Westport	2 miles	Sep-97	Pathogens
East Branch Westport River	From Rhode Island border to mouth at Westport Harbor, Westport	1.55 sq mi	Sep-97	Pathogens
Great Sippewisset Creek	Great Sippewisset Marsh, Falmouth	0.09 sq mi	Nov 01	Pathogens
Herring Brook	Falmouth	0.01 sq mi	Sep-97	Pathogens
Hiller Cove	Marion	0.04 sq mi	Sep-97	Pathogens
Little Sippewisset Marsh	Falmouth	0.04 sq mi	Sep-97	Pathogens
Mattapoisett Harbor	Mattapoisett	1.1 sq mi	Sep-97	Pathogens
New Bedford Harbor	Coggeshall Street Bridge to Hurricane Barrier, Fairhaven/New Bedford	1.17 sq mi	Sep-97	Priority organics, Metals, Nutrients, Organic enrichment/ Low DO, Pathogens
Onset Bay	Wareham	0.79 sq mi	Jun-97	Pathogens, non Pollutant
Outer New Bedford Harbor	(Buzzards Bay) Waters landward of a line drawn from Ricketson Point to Wilbur Point	4.1 sq mi	Sep-97	Priority organics, Non-priority organics, Metals, Organic enrichment/ Low DO, Pathogens
Phinneys Harbor	Bourne	1.47 sq mi	Sep-97	Pathogens
Pocasset Harbor	Bourne	1 sq mi	Sep-97	Pathogens
Pocasset River	Outlet of Mill Pond to mouth at Buzzards Bay, Bourne	0.04 sq mi	Sep-97	Pathogens
Quissett Harbor	Falmouth	0.15 sq mi	Sep-97	Pathogens
Red Brook Harbor	Red Brook Harbor, Bourne	2.18 sq mi	Sep-97	Pathogens
Sippican Harbor	Sippican Harbor, Marion	2 sq mi	Sep-97	Pathogens
Sippican River	County Road to confluence with Weweantic River, Marion/Wareham	0.09 sq mi	Sep-97	Pathogens
Slocums River	Rock O'Dundee Road to mouth at Buzzards Bay, Dartmouth	2.6 sq mi	Sep-96	Pathogens
Snell Creek	Drift Road to confluence with East Branch Westport River	0.67 miles	Dec-99	Pathogens
Wareham River	Route 6 bridge to mouth at Buzzards Bay	0.79 sq mi	Sep-97	Pathogens
West Branch Westport River	Outlet Grays Mill Pond, Adamsville, Rhode Island to mouth at Westport Harbor, Westport	1.7 sq mi	Sep-97	Pathogens
West Falmouth Harbor	Falmouth	0.28 sq mi	Sep-97	Pathogens
Weweantic River	Outlet Horseshoe Pond, Wareham to mouth at Buzzards Bay, Marion/ Wareham	0.77 sq mi	Sep-97	Pathogens

The 303(d) listed waters have special relevance in this report because as of July 31, 2002, all Buzzards Bay municipalities should have submitted an application for a general permit for their municipal separate storm sewer systems (MS4s) within Urbanized Areas (as defined by the 2000 US Census – see Figure 3), under the US EPA's NPDES Phase II Stormwater Program. In municipal Stormwater Management Plans developed to comply with this permit program, municipalities must give special consideration to remediating stormwater discharges that result in water quality impairments to 303(d) listed waters.

When evaluating stormwater discharges, another concern and interest of coastal managers and the public is the fact that 22,000 acres (Figure 6) of Buzzards Bay were included on the 2002 proposed Massachusetts Section 303(d) list of impaired waters affected by pathogen contamination. Section 303(d) of the Federal Clean Water Act (CWA) requires states to identify those water bodies that are not expected to meet surface water quality standards after the implementation of technology-based controls and, as such, require the development of TMDLs.

States are required to submit an updated list of those waters to the US EPA on or before April 1 of even-numbered years. The 303(d) regulations require that states consider all "existing and readily available water quality-related data and information" when compiling their lists. Furthermore, states must include on their lists the specific pollutant(s) or stressor(s) causing impairment (if known), and a priority ranking for completing each TMDL. This stormwater Atlas may assist in the 303(d) process.

Finally, in 2000, the Massachusetts Department of Public Health imposed new beach testing standards on Massachusetts' municipalities. Instead of a limit of 200 fecal coliform per 100 ml or 1,000 total coliform per 100 ml standard, an *Enteroccocci* bacteria standard (one time limit of 104 bacteria per 100 ml or a geometric mean of 35) was adopted for marine waters. While the change in standard alone will not result in many new beach closures, requirements to use 24 hour rapid assays, publicly post the results, and immediately close beaches that show E*nterococcus* levels above new safe swimming standards will result in some first-time beach closures.

In 2001, there were already certain state beaches on Cape Cod and elsewhere that had beach closings after heavy rains for the first time ever. It is unclear if these closings were due to more stringent water quality standards, more stringent required management actions, or more frequent testing. Such new closings at municipal beaches in the future will, more than ever, initiate action to remediate stormwater discharges.

Stormwater Remediation Solutions

No single stormwater remediation technique solves all runoff problems. First, managers must determine whether it is more cost effective to reduce sources of pollution (failed septic systems, farm animal manure, bird and pet waste, parking lots) or to simply treat stormwater contaminated by these sources. Often the sources of pollution causing elevated contaminant levels in stormwater are not easily discerned or identified, so management strategies to improve surface water quality generally focus around treating stormwater in some fashion. Because the "first flush" of discharge from a stormwater system typically contains the highest contaminant load, this volume of water is treated. Typically the first inch of rain is considered the first flush volume.

A proper mix of stormwater control techniques can satisfy four major concerns: flooding, erosion, water quality, and groundwater recharge. Individual site conditions, type and use of receiving waters, and cost will determine the most appropriate design. The following best management practices (BMPs) have been accepted for treating stormwater:

- Infiltration devices provide filtering of pollutants through the soil and thus decrease overland runoff volume. Infiltration systems provide pollution control through soil filtration, volume control through reduction of stormwater to downstream surface waters, and runoff control because infiltration provides groundwater recharge. Infiltration systems used in Buzzards Bay include dry wells, infiltration trenches and basins, and grassy swales.

- Wet basins, ponds, and constructed wetlands (Figure 7) detain runoff and allow for settling of pollutants associated with sediments and reduction of nutrients through biological processes.
- Municipal maintenance practices remove potential pollutants from streets and storm sewers, and include street and catchbasin cleaning.

Figure 7. Settling basin and constructed wetland at Spragues Cove, Marion, MA.

The greatest potential for utilizing the full range of BMPs for stormwater control is in undeveloped areas where the reduction of future pollutant loadings can be realized for the least cost. In such areas, the opportunity exists to employ land-use planning to reduce a) potential pollution sources, thereby reducing the volume of stormwater to be treated, and b) mimic pre-construction hydraulic conditions, thereby reducing pollutant loads, increasing groundwater recharge, and reducing flooding. This strategy will also control erosion.

In areas that have already been developed, options for remediation of stormwater discharges are usually limited. Site conditions, land availability, and purchase cost of such land becomes an issue when large, end of the pipe solutions are proposed. If land is available, however, the Buzzards Bay Project encourages municipalities to construct “above-the-ground” remediation structures, such as infiltration basins and wetland systems. An example of this type of solution is a constructed wetland system that was installed in the Town of Marion to treat stormwater from a downtown residential area (Figure 7). In this particular case, the town owned a large parcel of land at the end of the pipe. Since no other land in the watershed was available, and site conditions within the watershed (poorly drained soils and high water table) limited design options, the constructed wetland was selected as the management practice.

The primary justification for above-the-ground solutions is the visual aspect of inspecting the management practice. If the system is underground, as in the cases of infiltration chambers and galleys, a high degree of maintenance is usually required. Unfortunately, these underground systems generally receive less maintenance (out of sight, out of mind). Historically, reported failure rates of infiltration systems due to lack of maintenance has been high and the cost of replacing all or part of the system prohibitive.

In some cases, however, the use of underground infiltration systems has been the only option. Parcels of land needed to install above ground solutions are not always readily available. In areas where the site conditions are amenable (good soils and adequate separation from groundwater), underground infiltration in the form of chambers and galleys is commonly used. Aside from the future maintenance and replacement costs, the installation costs of such systems are dictated by local site conditions. Factors such as the amount of impervious surface, the amount of roadway impacted, and the presence or absence of utilities, all affect the construction costs.

As discussed above, the construction of stormwater treatment facilities can be costly. Any town that is contemplating such an effort must consider all facets of the issue, including land acquisition, installation techniques, cost, treatment effectiveness, and maintenance requirements. Sampling data may be needed to determine the relative impact of each stormdrain on water quality degradation. Before targeting a particular stormdrain for action, the town should ensure that the problem is not emanating from septic systems that are "cross-connecting" with the drain. Most stormwater drains in Buzzards Bay are primarily wet weather discharges only. Those that have continuous, dry weather flows may be an indication of illegal cross connections with sewer lines or septic systems. Alternatively, dry weather flows could merely indicate groundwater infiltration or streams that have been channeled underground through the stormdrain system. This channelization of streams is most often found on the western shores of Buzzards Bay.

METHODS

Mapping Methodologies

The maps in this report were developed by extensive field surveys, evaluation of engineering plans on file with town and state highway departments, and discussions with town engineers and DPWs. For field investigations, a Global Positioning System (GPS) unit was occasionally used, but mostly sites were inventoried on paper copies of digital half-meter orthophotograph base maps enlarged to about 1:2500. The digital orthophotographs were obtained from MassGIS. Typically, each street near shore was walked to locate catchbasins (Figure 8) and these features were recorded on the orthophotographs. Sometimes previously prepared engineering plans, topographic sheets or other reference maps were also used. Catchbasins, discharge pipes, and roadcuts were marked on the maps using homes, intersections, and other features on the orthophotograph maps as guides. This process was preferred because of occasional problems with GPS performance or satellite reception, and the inventory was fast and expedient. All maps were submitted to municipal public works departments for review.

In addition to the town data, the Buzzards Bay Project also utilized data from the DMF Sanitary Surveys. To protect public health, DMF conducts these "sanitary surveys" of DSGAs and monitors overlying waters to determine their suitability as shellfish sources for human consumption. These sanitary surveys include: an evaluation of pollution sources that may affect an area, an evaluation of hydrographic and meteorological characteristics that may affect distribution of pollutants, and an assessment of water quality based on the sampling of overlying waters. DMF conducts a complete sanitary survey of each DSGA every twelve years, with a triennial evaluation every three years and an annual review to evaluate the existing classification. Many field observations made by DMF about specific discharges were included in the comment field of our ArcView® Shapefile database.

Stormdrain connections were determined by examining available engineering plans and inspecting stormdrains to identify, as best as possible, the direction of stormdrain flow. Presumed flow directions were determined from apparent land surface elevations in the field or review of state 10-meter orthophotographs with 3-meter elevation contours and USGS topographic maps with 10-foot contours.

No attempt was made to precisely measure discharge flow because of the time, cost, and access constraints on collecting such data. Pipe diameter data was not collected because many times there is little relationship between actual stormwater flows and pipe diameter. In addition to stormwater, many "stormwater" pipes intercept groundwater or collect dry weather flows from sources such as washing machines and sewage pipes.

Although we did not attempt to quantify flow in this study, we reviewed DMF sanitary survey reports to help identify the more problematic discharges. These reports contain valuable information, including documented or anecdotal information about stormwater discharges and dry weather flows for individual pipes spanning many years. These reports sometimes include fecal concentrations of discharges immediately along shore near shellfish resource areas.

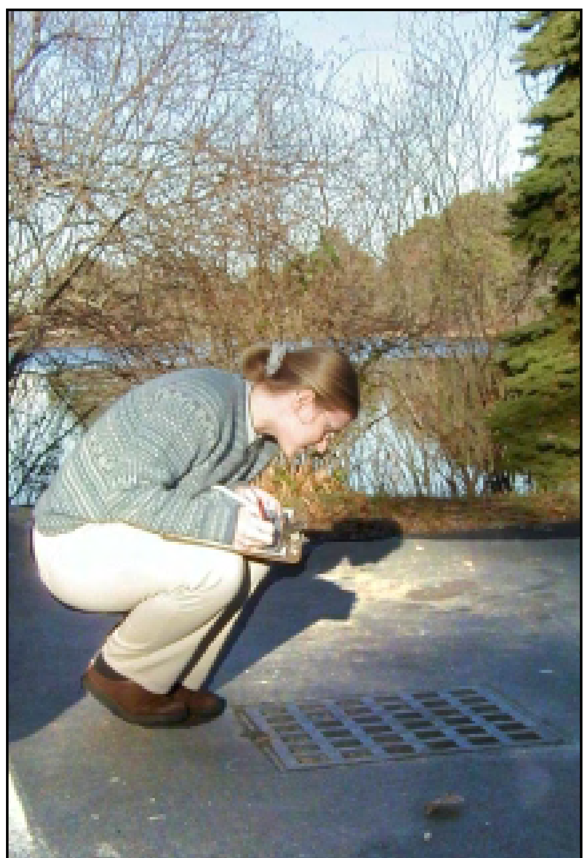


Figure 8. Inspecting and mapping stormdrains in the field.

Stormdrain positions recorded on paper maps in the field were transferred to ArcView® using the same MassGIS one half-meter orthophotographs as a base map. The final field survey and GIS data layer creation was conducted by the same individual to ensure maximum accuracy. The base map used was 1:5000 digital orthophotographs with half-meter resolution provided by MassGIS. Positional accuracy of the stormdrain pipe and catchbasin coverage is estimated to be generally within 30 feet based on features in the photograph. Data layers were coded so that each stormwater discharge had a unique identifier in the format TTBBSSDP-###, where TT is a two letter town mnemonic, BB a two letter embayment mnemonic, SS a two letter street mnemonic, DP an abbreviation for discharge pipe and ### a number. A similar coding system was used for catchbasins. Within the ARCView® database, each catchbasin had a stormwater discharge ID number associated with it where known.

Embayment Land Use Evaluations

In an attempt to estimate pathogen loading, land use was evaluated for each major embayment in the Buzzards Bay Watershed. The Buzzards Bay Project has undertaken a similar land use evaluation for nitrogen loading in these watersheds (e.g., Costa et. al, 1999), but for nitrogen loading analyses, the entire hydraulic subwatershed drainage basin is employed (Figure 9, red lines). These drainage delineations are not appropriate to evaluate stormwater discharges because only land very close to shore, or land connected to surface water by stormwater drainage networks, is likely to impair coastal water quality. The distance that stormwater may travel before it reaches surface water varies from watershed to watershed.

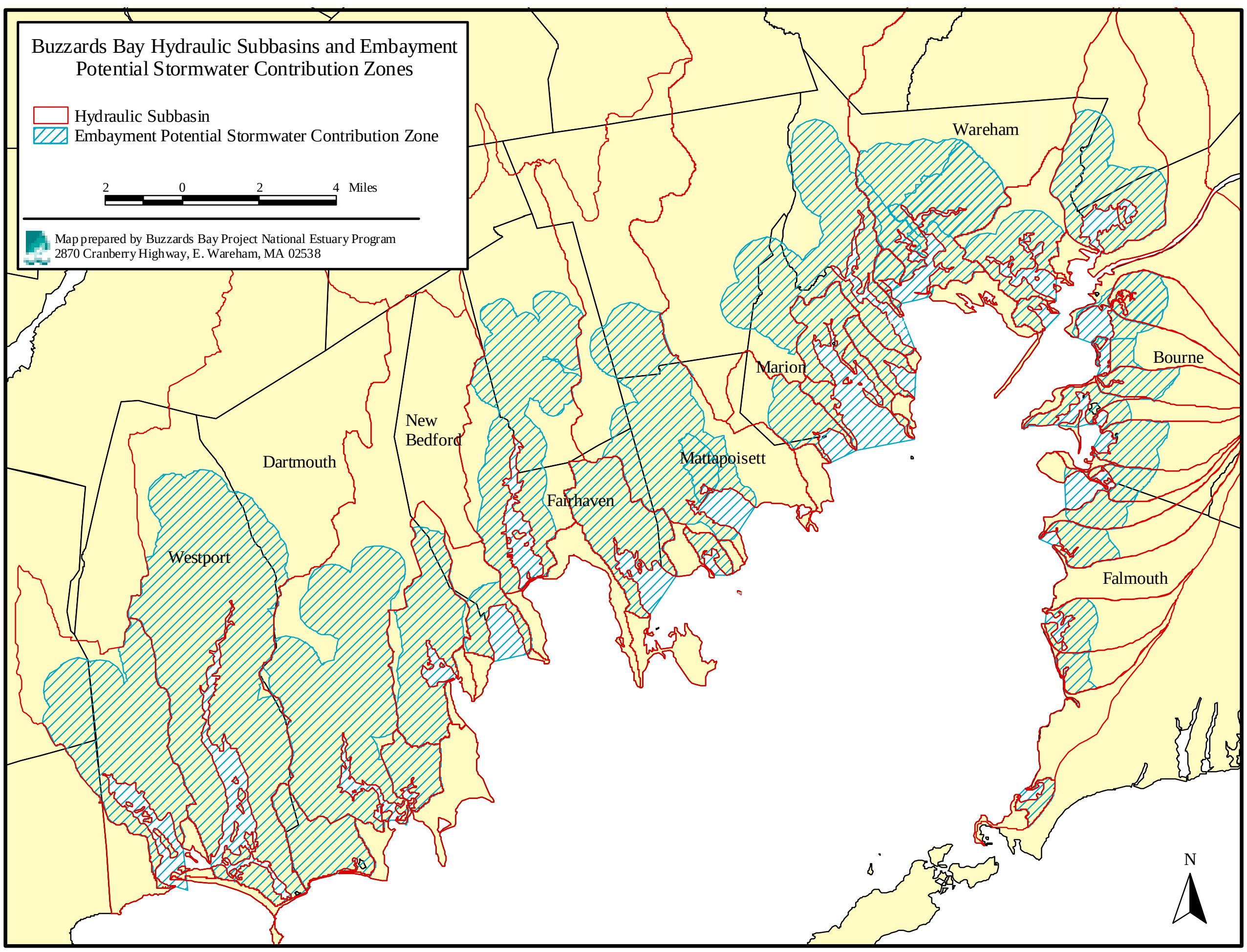


Figure 9. Hydraulic basins and presumed potential stormwater contribution zones for all major Buzzards Bay embayments.

Based on best professional judgment, only land use within one kilometer of shore or direct stream flow (but not exceeding watershed boundaries) was considered to contain pollution sources that may reach coastal water. This one-kilometer distance was labeled the "potential stormwater contribution zone" (Figure 9) and was selected because stormdrain networks typically do not exceed this zone. For defining "direct stream flow," the length of the stream to the first major pond or reservoir up to a distance of ten kilometers was included (Figure 10). The 10-kilometer upstream boundary was selected because this represented at least one day of travel, which has bearing on fecal bacteria survival and persistence and impact on coastal waters. However, the only non-dammed stream long enough to meet this criteria was the Mattapoisett River.

Table 4 shows an overview of Buzzards Bay embayment characteristics based on BBP analyses of GIS data and previous studies, and thus provides some insights into pollution problems and development in each subbasin. For this study, only drainage networks within the potential stormwater contribution zone were characterized. Information on land use was not used in the prioritization of stormwater discharges, described in the methods section, because it proved impossible to delineate "micro" drainage basins for all 2,600 mapped discharges in a consistent way.

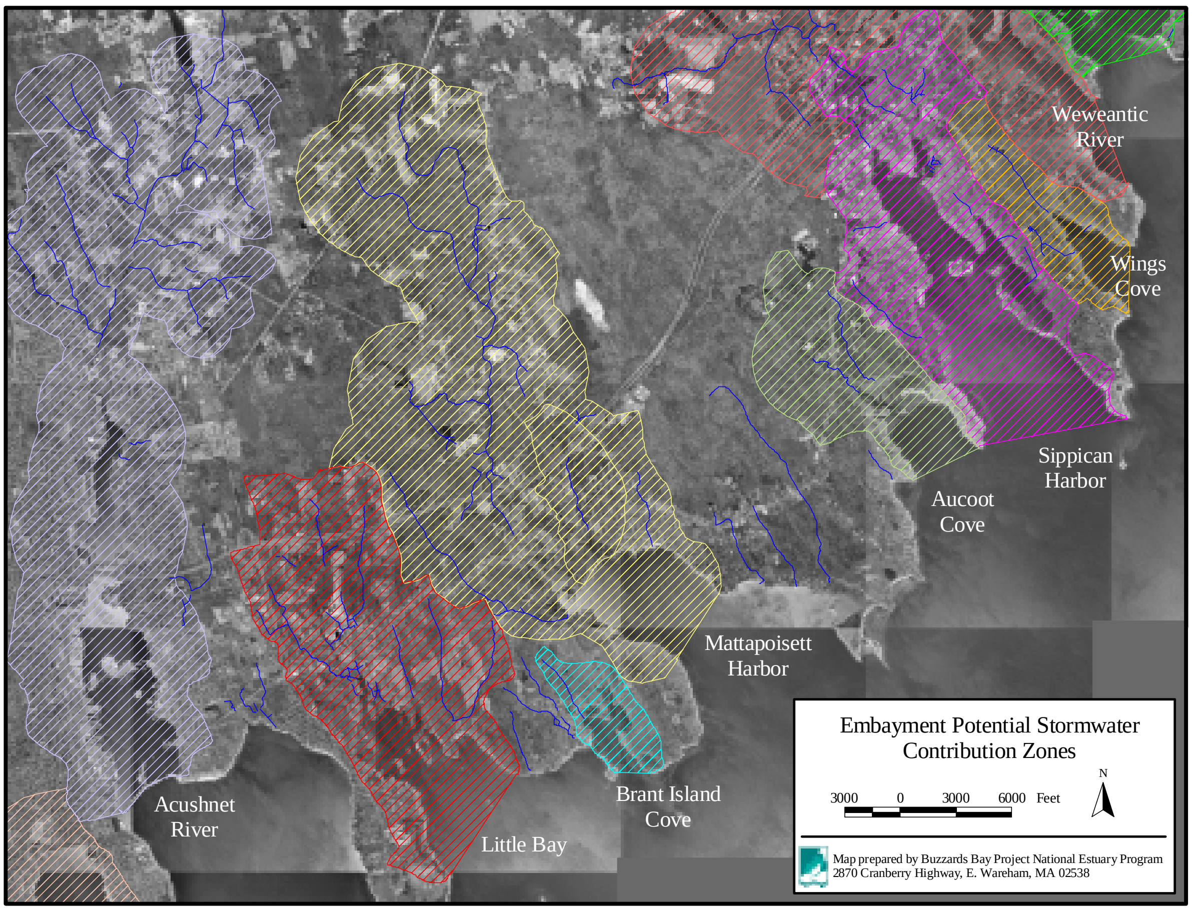


Figure 10. One-kilometer presumed potential stormwater contribution zones of several Buzzards Bay embayments. Note upstream extent of Mattapoisett River as compared to naturally smaller drainage basins like Sippican Harbor, or small basins like Aucoot Cove.

The argument can be made that during exceptionally heavy storms, larger zones of stormwater contribution exist beyond the assumed potential stormwater contribution zones shown, but overall this process was deemed adequate for establishing relative impacts, threats and priorities among Buzzards Bay embayments for environmental planning purposes.

Because the primary focus of the stormwater discharge prioritization effort was to target reclassification of DMF shellfish management areas, the boundaries of the potential stormwater contribution zones were further refined to define approximate drainage areas for these shellfish management areas. The subbasin boundaries of designated shellfish growing areas, which are essentially a subset of the potential stormwater contribution zones, are shown in Figure 11. It was the drainage characteristics of these areas that were used to establish remediation rankings.

Table 4. Key features of principal Buzzards Bay embayments

EMBAYMENT	Water area km2	Mean depth at MLW (m)	Vol. at MLW m3x10^6	Basin land area (km2)	Lower basin land area (km2)	Predicted units	Predicted Population	Lower basin 1990 census units	Lower basin 1990 sewered census units	Lower basin 1990 Census pop	Subbasin occupancy	Lower basin road area (ha)	Impervious per unit (ft2)	Residential unit impervious surface (ha)	Total impervious (ha)	Annual stormflow to MLW volume ratio
Agawam River	0.47	0.5	0.233	35.1	10.4	1610	3702	1261	272	2703	2.3	55.7	1000	11.72	67.40	3.18
Allens Pond	0.77	0.5	0.385	8.2	8.2	70	153	68	0	147	2.7	16.0	1275	0.81	16.81	0.48
Apponaganset, Inner	1.34	0.6	0.804	19.9	17.2	3866	8428	3274	2966	8544	3.0	69.9	1275	38.78	108.73	1.49
Aucoot Cove	1.29	2.2	2.86	10.5	5.6	231	505	276	8	568	2.6	23.2	1275	3.27	26.47	0.10
Back River-Eel Pond, Bourne	0.08	0.7	0.059	9.7	4.1	928	2024	491	0	867	2.2	13.7	1275	5.82	19.50	3.65
Brant Island Cove	0.34	0.8	0.274	1.7	1.7	42	92	67	0	155	2.9	2.1	1275	0.79	2.87	0.12
Broad Marsh River	0.40	0.3	0.12	3.4	3.4	745	1625	1129	861	1602	2.1	2.3	1000	10.49	12.80	1.17
Buttermilk Bay	2.14	1.2	2.55	25.7	15.6	2996	6532	2449	55	4466	2.1	67.4	1000	22.75	90.18	0.39
Clarks Cove	2.86	3.6	10.2	7.5	4.0	4389	9568	5578	5578	13143	2.5	41.4	1000	51.82	93.26	0.10
Eel Pond, Mattapoisett	0.10	0.7	0.068	2.7	2.1	308	672	458	148	1091	3.0	12.6	1275	5.43	18.05	2.92
Hen Cove	0.26	0.8	0.217	4.3	1.0	594	1295	335	0	317	2.0	5.4	1000	3.11	8.47	0.43
Little Bay, Fairhaven	0.74	1.1	0.814	14.2	14.2	1178	2567	1317	461	3193	3.0	45.6	1000	12.24	57.84	0.78
Little River	0.50	0.4	0.2	5.3	5.3	63	138	87	0	229	3.3	7.4	1275	1.03	8.39	0.46
Mattapoisett Upper Harbor	1.59	2.8	4.52	69.5	32.1	2035	4436	1699	411	4134	3.0	85.4	1275	20.13	105.50	0.26
Megansett Harbor	1.70	4.6	7.772	11.6	5.2	1993	4345	899	0	1461	2.5	28.0	1275	10.65	38.65	0.05
Marks Cove	0.46	0.8	0.361	1.5	1.5	11186	24386	21429	272	49767	2.8	203.1	1275	253.83	456.97	13.92
Little Bay-Inner, Nasketucket Bay	2.05	1.6	3.25	14.2	14.2	1178	2567	1317	461	3193	3.0	45.6	1275	15.60	61.20	0.21
New Bedford Harbor (Acushnet River)	3.85	3.5	13.6	67.8	32.4	11186	24386	21429	272	49767	2.8	203.1	1275	253.83	456.97	0.37
Onset Bay	2.39	1.3	3.09	12.5	8.1	2009	4379	2522	1625	3242	1.9	44.3	1000	23.43	67.75	0.24
Phinneys Harbor	2.17	2.0	4.35	12.6	5.7	1727	3766	992	0	1604	2.4	24.2	1275	11.75	35.99	0.09
Pocasset Harbor	1.00	2.2	2	2.8	2.8	646	1408	613	0	560	1.4	15.9	1275	7.26	23.18	0.13
Pocasset River	0.80	0.9	0.742	115.8	24.1	936	2041	689	0	1144	2.5	18.6	1000	6.40	25.02	0.37
Quisset Harbor	0.47	1.6	0.738	1.3	1.3	149	324	138	0	179	1.6	7.0	1275	1.63	8.59	0.13
Red Brook Harbor	0.61	1.7	1.06	10.3	4.3	491	1070	287	0	518	2.4	15.8	1275	3.40	19.24	0.20
Sippican Harbor Upper Harbor	1.70	1.4	2.45	9.9	9.9	1196	2607	1159	452	2465	2.7	46.4	1275	13.73	60.08	0.27
Slocums River	1.97	0.7	1.45	94.8	44.7	5606	12221	1562	547	5989	3.0	71.9	1275	18.50	90.42	0.69
Squeteague Harbor	0.30	0.8	0.243	5.2	2.5	863	1882	341	0	584	2.3	11.4	1275	4.04	15.39	0.70
Wareham River	2.49	1.0	2.4	115.8	24.1	4150	9048	3550	1408	6230	2.3	126.5	1000	32.98	159.50	0.73
Weweantic River	2.38	1.1	2.72	214.4	31.1	10132	22087	1908	27.5	4276	2.8	107.7	1275	22.60	130.30	0.53
West Falmouth Harbor	0.80	0.6	0.466	9.0	3.1	749	1633	543	0	809	2.0	18.2	1275	6.43	24.62	0.58
Widows Cove	0.54	0.9	0.507	5.2	5.2	20	44	26	0	37	2.1	6.4	1275	0.31	6.71	0.15
Wild Harbor	0.49	1.2	0.573	10.4	3.7	1540	3358	977	0	894	1.6	21.7	1275	11.57	33.24	0.64
Wings Cove	0.88	1.4	1.22	3.3	3.3	134	292	143	0	306	2.7	8.5	1275	1.69	10.17	0.09
Westport River, East Branch	8.02	0.8	6.21	154.2	72.9	5277	11503	3239	0	7889	2.9	164.8	1275	38.37	203.20	0.36
Westport River, West Branch	5.32	0.8	4.17	24.5	23.3	502	1094	693	0	1540	2.8	41.8	1275	8.21	49.99	0.13

Finally, the state has not adopted criteria for coastal embayment boundaries, particularly within the context of 303(d) lists. The defined boundary of an embayment can have great bearing on assumed contributing land use and stormwater discharges (note that the boundaries of Mattapoisett Harbor in Figure 10 excludes discharge of sources east of the harbor). In the absence of state criteria, the Buzzards Bay Project employed those embayment boundaries adopted in the 1991 US EPA and state approved Comprehensive Conservation and Management Plan (CCMP) for the Buzzards Bay Watershed. Based on these watershed boundaries, the road surface area, the number of discharges, catchbasins, and residential units, and other parameters were quantified.

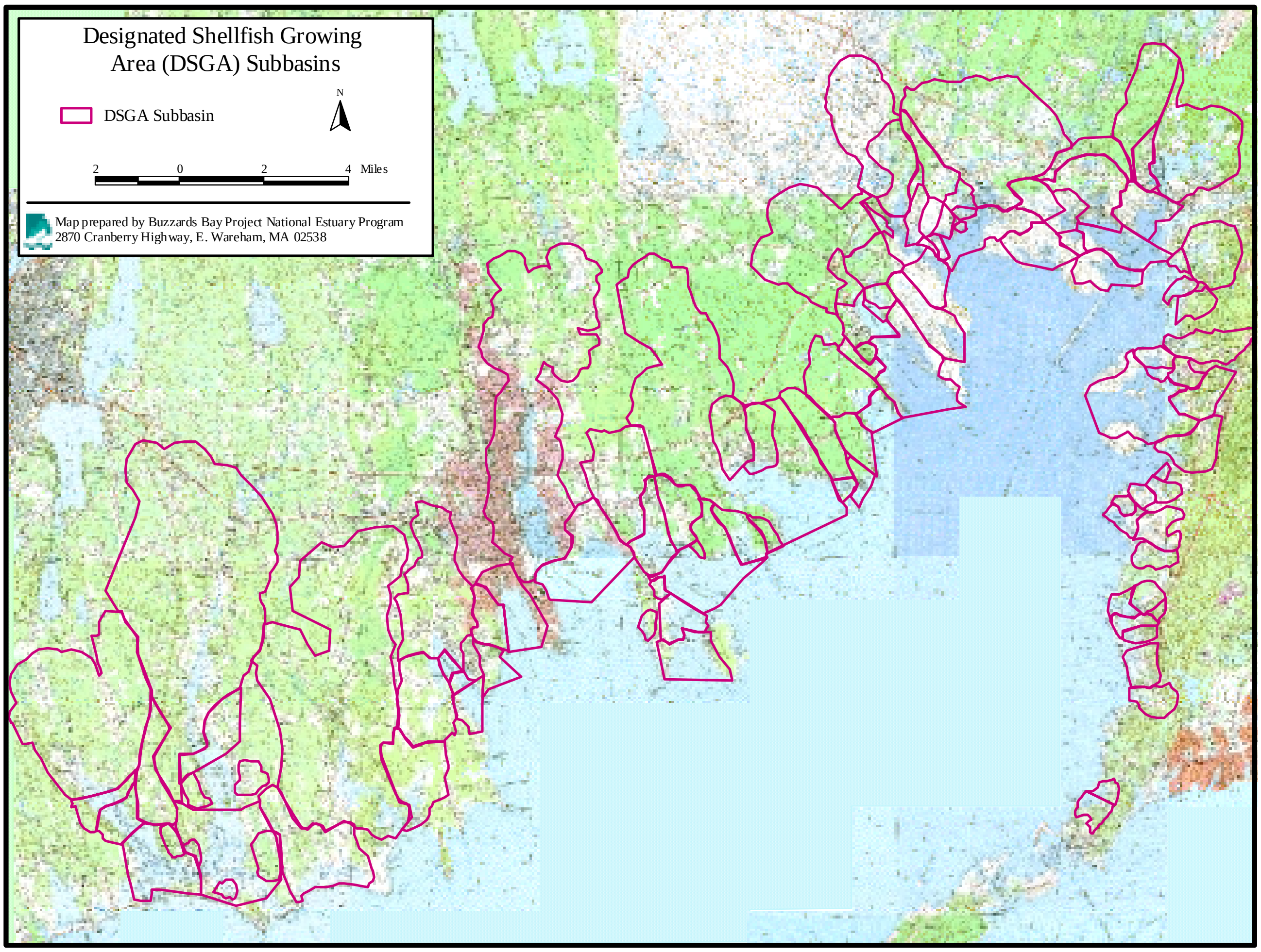


Figure 11. Designated shellfish growing area subbasins.
Note that the DSGAs were simplified and small management units were omitted.

Water Quality Data Analysis

Data provided by DMF from the period 1985 to 2001 for all regularly monitored stations within Buzzards Bay was evaluated (data courtesy of Tom Hoopes, DMF). This data, which represented more than 37,000 fecal coliform measurements, is coded with station name, "Designated Shellfish Growing Area," and sub-area identification numbers (Figure 12). Typically, offshore areas, such as BB19 ("West Island East Coastal") consist of a single management unit, whereas embayments such as Apponagansett Bay (BB12) are broken into smaller management units (BB12.1, BB12.2, etc.) for the purposes of monitoring and water quality closures. Only data collected after 1996 was used to evaluate water quality to account for more recent management actions or new designation. One of the most important criteria for closing shellfish growing areas occurs when 10% of recent samples exceed 28 fecal coliform per 100 ml. Closures may also occur if the geometric mean of fecal coliform exceeds 14 fecal coliform per 100 ml.

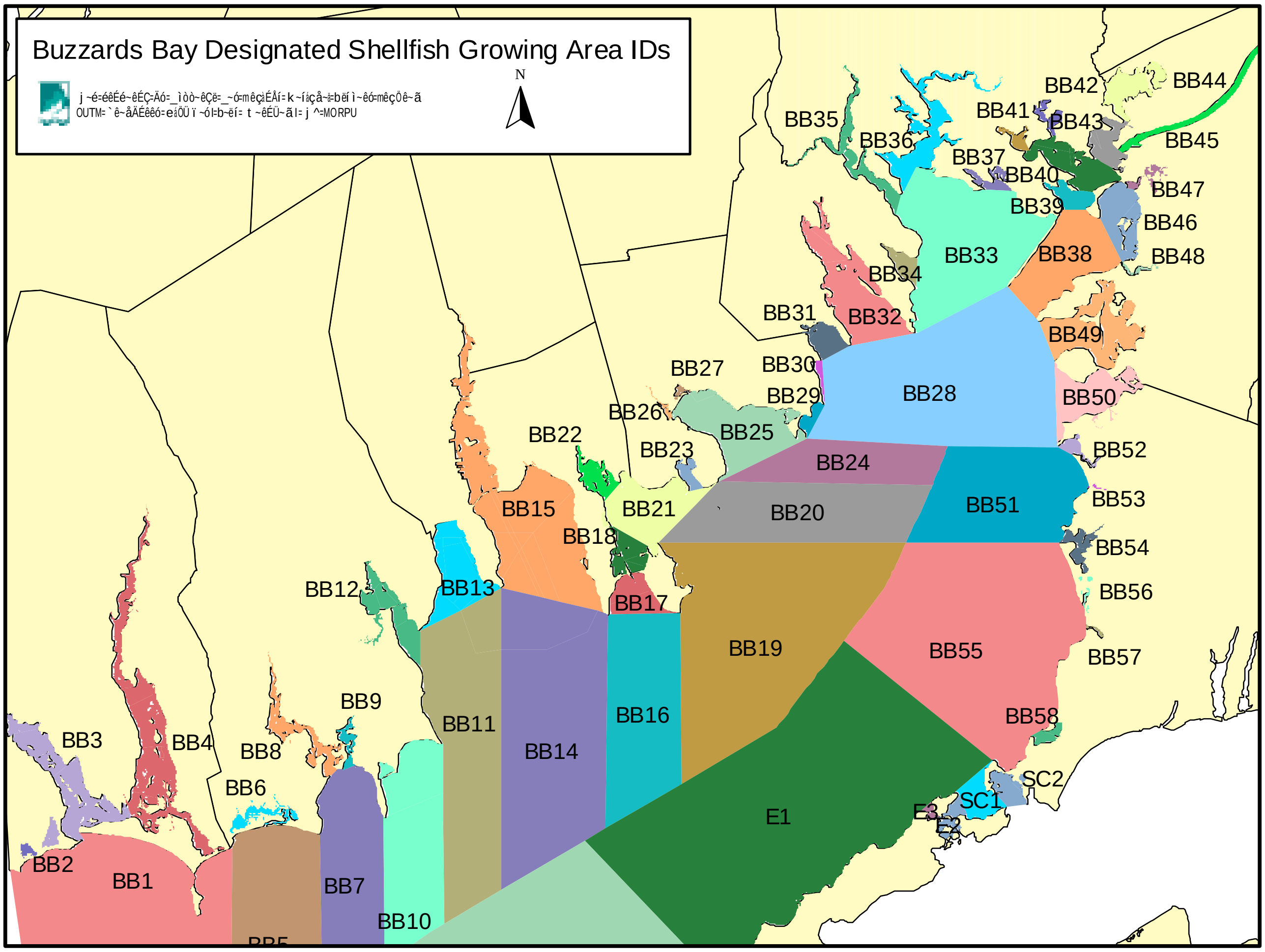


Figure 12. Massachusetts Division of Marine Fisheries (DMF) Designated Shellfish Growing Area (DSGA) identification codes.

In this evaluation, the geometric mean of fecal bacteria between 1996 and 2001 was used in the point scoring system described in detail below. In general, geometric means just above or below 14 received additional points in the priority scoring. For evaluating stormwater discharges and water quality data, Buzzards Bay and the data sets were geographically divided in accordance with these DMF DSGA management units.

Prioritization Methodology for Individual Discharges

The primary purpose of this report is to inventory stormwater discharges to Buzzards Bay and their contributing drainage area. These mapped drainage networks will have great utility to coastal managers, town officials, and regulators. Mapped discharges and contributing drainage areas are shown in the detailed maps in Appendix B, and in the large format maps inset in the pockets at the back of this report.

A secondary purpose of this report was to help establish remediation priorities for discharges based upon specific criteria for water quality, drainage network characterizations, existing water quality and shellfish resource area classifications, estimated cost of remediation, and a variety of other factors.

This report documents more than 2,600 discharges near the coast of Buzzards Bay. During the past decade, the Buzzards Bay Project has reviewed dozens of grant applications and stormwater projects. When reviewing these projects, often the same questions are asked: How much does the project cost? Will the proposed work open any shellfish beds or prevent their closing? Are the existing shellfish bed resources worth the expense of remediation or is there a more cost effective project within the embayment?

In this report and supporting databases, the BBP generated or estimated much of the information considered when evaluating individual stormwater remediation projects. This data was then evaluated against very specific scoring criteria that are described below. Clearly, any such prioritization will reflect the numerous assumptions and relative importance assigned to such scoring criteria. The limitations and utility of this approach are discussed in detail at the end of this report.

Due to the complex and voluminous nature of data collected in this study, a simplified approach was necessary to establish priorities for remediation. For example, it proved too difficult to evaluate certain parameters individually for 2,600 discharges. Among the parameters not evaluated were impervious surface area and number of homes surrounding the drainage network. Unfortunately, the GIS data layers for these parameters do not exist for most of the Buzzards Bay watershed. Moreover, it is impossible to identify all drainage connections in any watershed without detailed fieldwork that is beyond what was employed in this study.

For the prioritization, drainage network characterizations were based on the total drainage basin characterized within the contributing area shown in the designated shellfish growing area subbasin map (Figure 11). These designated shellfish growing area subbasins are derived from the potential stormwater contribution zones and based on land surface topography. The Designated Shellfish Growing Areas (DSGAs) employed by the Massachusetts Division of Marine Fisheries (DMF) boundaries were used as the management unit for evaluating and scoring many of the parameters in this study.

To evaluate stormwater remediation sites, the following information was gathered for each discharge (the maximum number of points in each respective category are also shown):

Table 5. Scoring for stormwater discharges

Parameter	**Maximum Possible Points Awarded**
DMF DSGA Recommended Ranking	30
Existing DSGA Classification of receiving waters	15
Existing fecal coliform concentrations of receiving waters (DMF data)	20
Projected cost	10
Sewering	5
Number of discharges and catchbasins in DSGA drainage area	30
“Percent of the Problem” discharge drainage characteristics	30
Proximity to public or private swimming beaches	10
Discharge within 303(d) listed pathogen impaired area	10
Discharge from Phase II MS4 area	10
Total Possible Points	**170**

The enumeration of features used in the prioritization of discharges was principally conducted in ArcView®, with data exported into Microsoft Excel® spreadsheets for calculation of scores. For example, stormdrain networks were connected “polyline” features and linear length of the network was automatically calculated in ArcView®.

To determine whether drainage areas were sewered, a 150-foot buffer was created around the GIS sewer coverage. If a stormwater discharge pipe fell within the sewered area or the 150-foot buffer, it was assumed that its corresponding drainage area was sewered. Review of sewage and stormwater drainage maps showed that this was a reasonable assumption for the prioritization.

As noted previously, the scoring system used to score parameters was subjective, and based on weighting schemes that relied on best professional judgment. Different prioritization schemes can result in different recommended priorities. The ranking database is included on the companion CD to allow the user to experiment with different scoring schemes and scoring weights. Scoring of these parameters to evaluate stormwater discharges is described below.

Division of Marine Fisheries DSGA Recommended Ranking (30 points):

The first-hand working knowledge of DMF staff and Area Biologists was given paramount importance in the ranking of DSGAs. Each DSGA subunit was given a High, Medium, or Low ranking for existing shellfish abundance based on DMF's knowledge of the shellfish resources (Figure 13). This ranking was not meant to be an absolute evaluation of the DSGA, but a draft evaluation for the purposes of this watershed evaluation.

Scoring was as follows:

- DMF High shellfish value resource: 30 points
- DMF Medium shellfish value resource: 15 points
- DMF Low shellfish value resource: 0 points

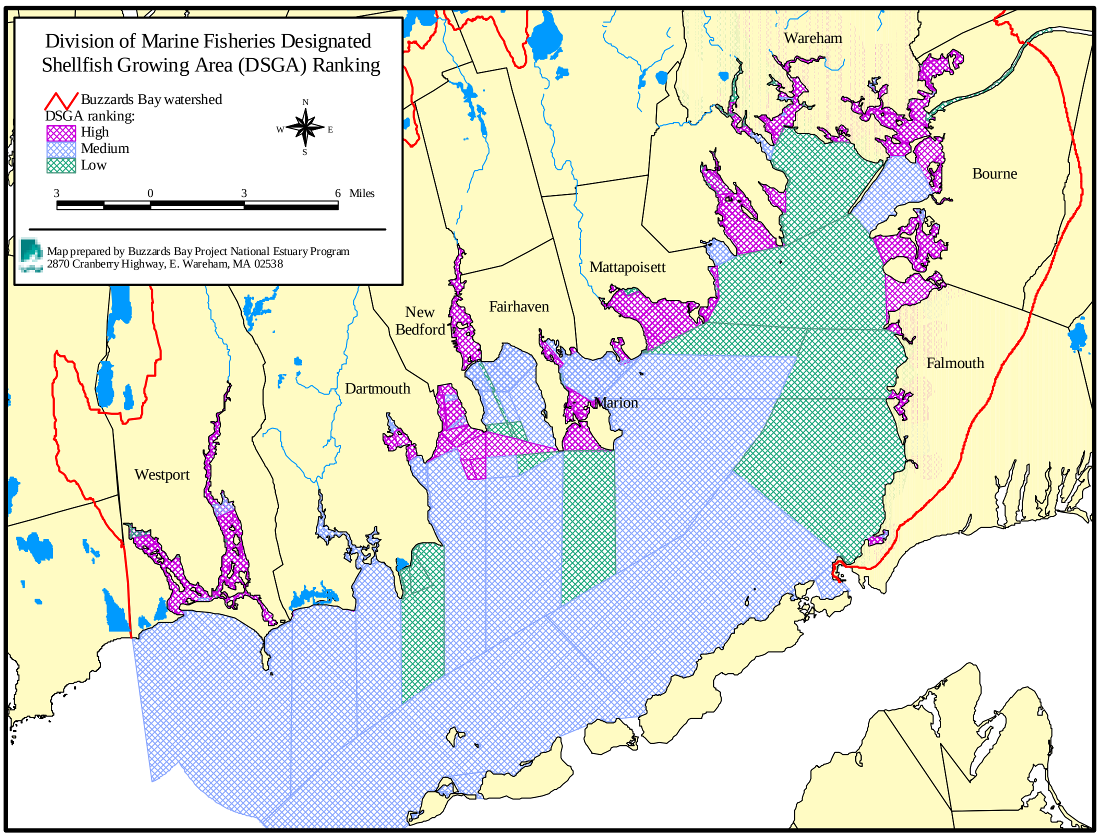


Figure 13. DMF DSGA subunit ranking.

Existing DSGA Classification of Receiving Waters (15 points):

Depending on the location of a stormwater discharge, it was awarded a certain number of points based on the management classification of adjoining shellfish resource areas (see Figure 4). If the discharge was to a freshwater stream, it was awarded points based on the closest receiving DSGA. Existing DSGA classifications bear on the appropriateness of any initiative to treat stormwater. For example, areas classified as "Prohibited" as a result of a required closure in the proximity of a sewage treatment facility discharges received 0 points. Other points were as follows:

- Prohibited 0 points
- Restricted: 5 Points
- Management Closure: 5 Points
- Conditionally Restricted: (none in Buzzards Bay) 10 Points
- Conditionally Approved: 15 Points
- Approved: 7 Points

This point system was developed based on best professional judgment. For example, it was reasoned that remediation of stormwater discharges in an area closed due to its proximity to a wastewater discharge should be a very low priority and receive 0 points. That is due to the fact that, even if stormwater discharges were eliminated, an automatic closure is required around outfalls. Similarly, it was felt that areas that were always open or occasionally closed should receive a higher number than polluted areas classified as prohibited because it is typically easier to protect a clean area, or restore a slightly polluted area, than it is to restore areas with high coliform levels, especially if they have many pollution sources. Finally, conditional areas received the highest number of points because it has been the experience of the Buzzards Bay Project that stormwater remediation projects in these areas are most likely to result in a classification change that will benefit the public.

Existing Fecal Coliform Concentrations of Receiving Waters (20 points):

To help rank and prioritize areas for restoration, DMF data for routine shellfish monitoring stations was summarized by calculating the 5-year geometric mean of data collected between 1997 and 2001. This data, representing more than 37,000 fecal coliform data points for Buzzards Bay, is summarized by the means of individual sampling stations (Figure 14) and means for all stations within a DSGA (Figure 15). It is worth noting that, although a geometric mean exceeding 14 fecal per 100 ml in a single season can be a basis for shellfish bed closures, the data does not represent worst case or wet weather conditions, nor are the geometric means alone the sole basis of shellfish bed closures. There are other factors taken into consideration, such as

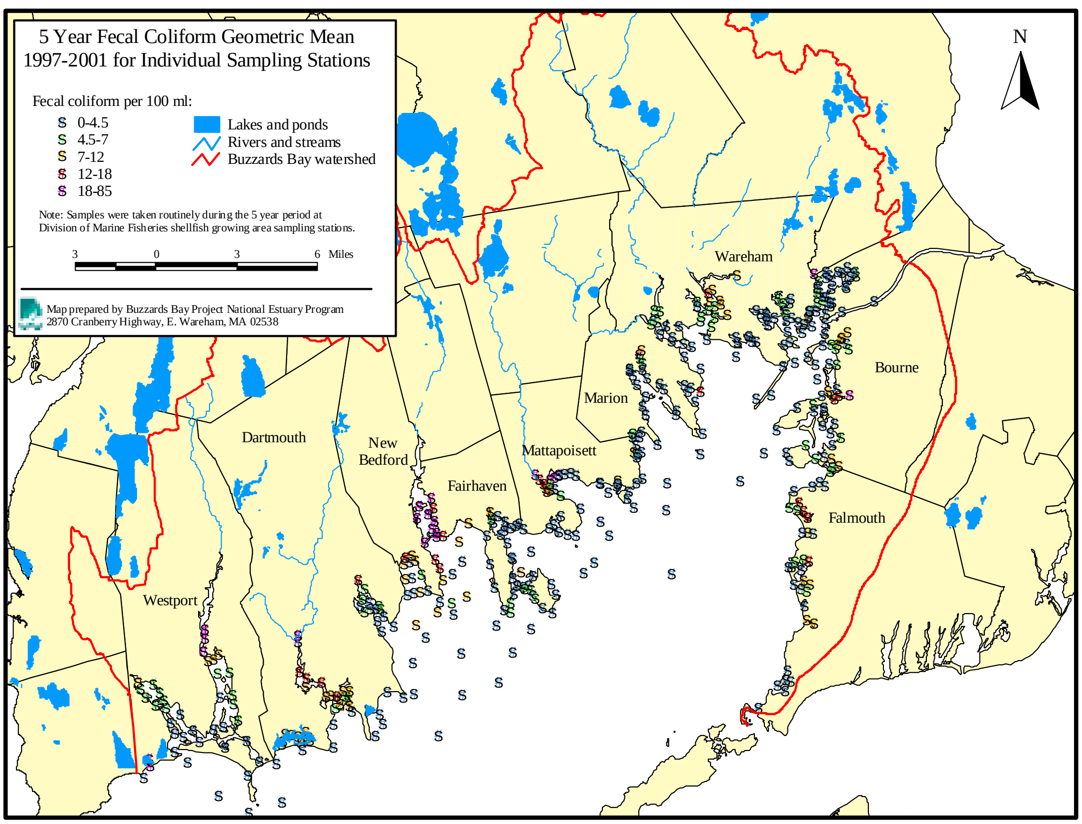


Figure 14. Five-year mean of samples taken routinely from DMF shellfish growing area sampling stations (1997-2001). The grouping of means reflect the scoring criteria used in the ranking of discharge methods.

typical high values after rainfall, presence of boats, and known pollution sources.

In addition, Figures 14 and 15 do not communicate trends. In some bays, the means shown are typical over the evaluation period whereas in other embayments, contaminants have been increasing or decreasing. Despite these obstacles, for the purpose of ranking shellfish growing areas for remediation, the DSGA geometric mean fecal coliform criteria were applied for determining scores for "sensitivity of receiving waters" as described above.

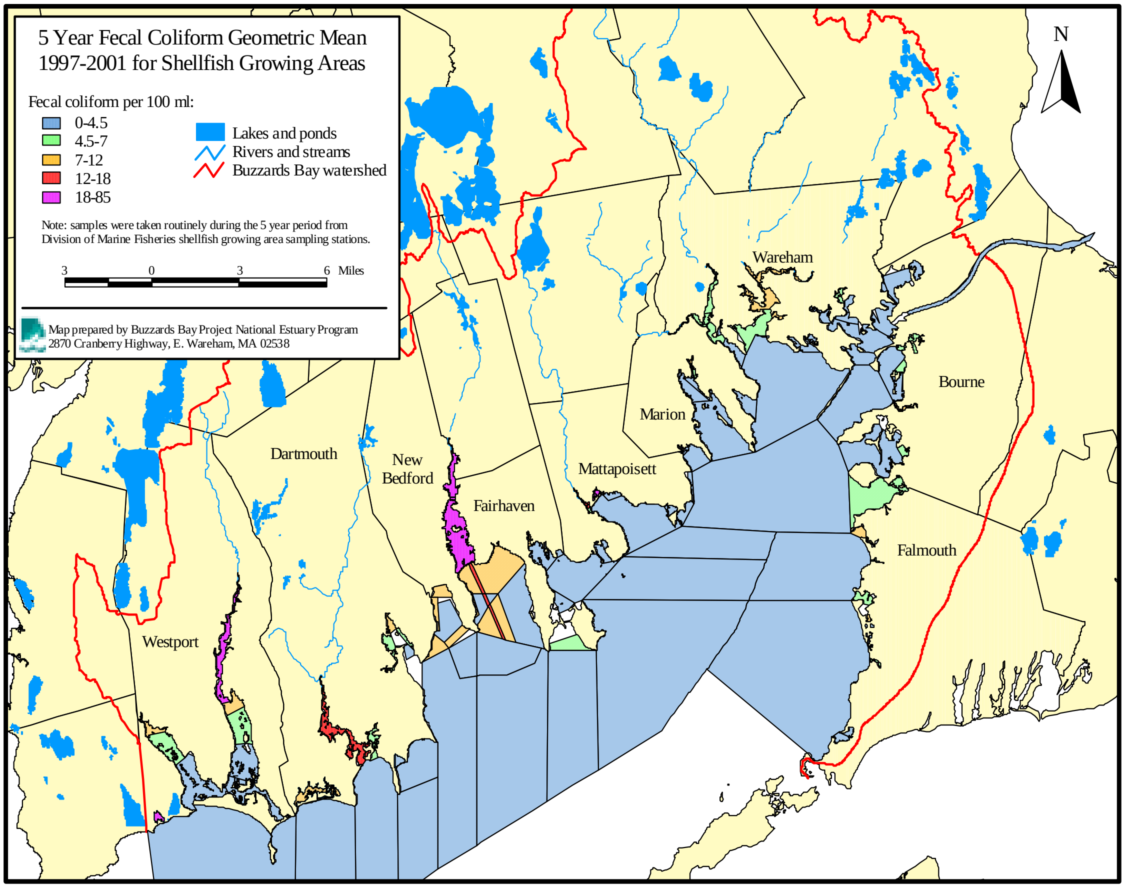


Figure 15. Five-year mean of all samples taken routinely from DMF stations within shellfish growing area boundaries (1997-2001).

Shellfish resource areas with fecal coliform levels (geometric mean) close to the regulatory standard of 14 fecal coliform per 100 ml are more sensitive to changes in water quality than pristine areas or areas exceptionally polluted. Based upon the 1996-2001 geometric means of fecal coliform concentrations in each DSGA, together with the best professional judgment of DMF area biologists, restoration efforts in an area were characterized as follows:

- <u>Negligible restoration or protection benefits perceived (0 points):</u> If receiving waters were grossly polluted, which in this study we selected to mean a DSGA geometric 5-year mean of 18 or higher fecal coliform per 100 ml (fc/100 ml), or exceptionally clean and well flushed with no water quality problems, which we established to be a DSGA 5-year geometric mean of less than 4.5 fc/100 ml.
- <u>Modest restoration or protection benefits (10 points):</u> If fecal coliform concentrations are often well above, or generally well below concentrations that would result in a change in closure classification. We selected a DSGA 5-year fecal geometric mean of 4.5-7 fc/100 ml or between 11-18 fc/100 ml as the criteria
- <u>Appreciable restoration or protection benefits (20 points):</u> If receiving waters are near a change in classification. In this study we selected the criteria to be a DSGA 5-year mean between 7 and 11 (or equal) fecal coliform per 100 ml (fc/100 ml).

Projected Cost (10 points):

Approximate costs of remediation were determined using the following formulation:

The sum of $5,000 base costs + $4,000 per catchbasin + $20 per linear foot of drainage network

This formula is highly simplistic, and does not account for many factors affecting cost such as depth to groundwater, types of soils, presence of underground utilities, street width, and availability of municipal lands, etc. Treating discharge from roadcuts is variable and site specific but, for the purpose of the ranking, remediation costs were assumed to be $12,000. For a small percentage of discharge pipes we were unable to document any associated catchbasins. These pipes received 0 points in this category.

None of these estimated costs included engineering costs. While this approach is crude, and probably accurate only to within an order of magnitude for most situations, for this study it created a relative distribution of costs for each discharge that could be assigned a score. These projected costs could receive up to 10 points based on the criteria below.

Dollar cost	Points
<=9,000	10
9,001-15,000	8
15,001-50,000	6
50,001-75,000	4
75,001-100,000	2
>100,000	0

Sewering (5 points):

Discharges within sewered areas (Figure 16) received 5 bonus points under the assumption that remediating nonpoint sources in sewered areas would be more successful in improving water quality. Comparable unsewered areas are also more likely to have stormwater contaminated by illegal cross connections or overflow from failing septic systems or cesspools. The Buzzards Bay Project made a policy decision to give more weight to sewered areas because it was believed that stormwater BMPs alone in unsewered areas would not reduce pollution discharges (without sewering).

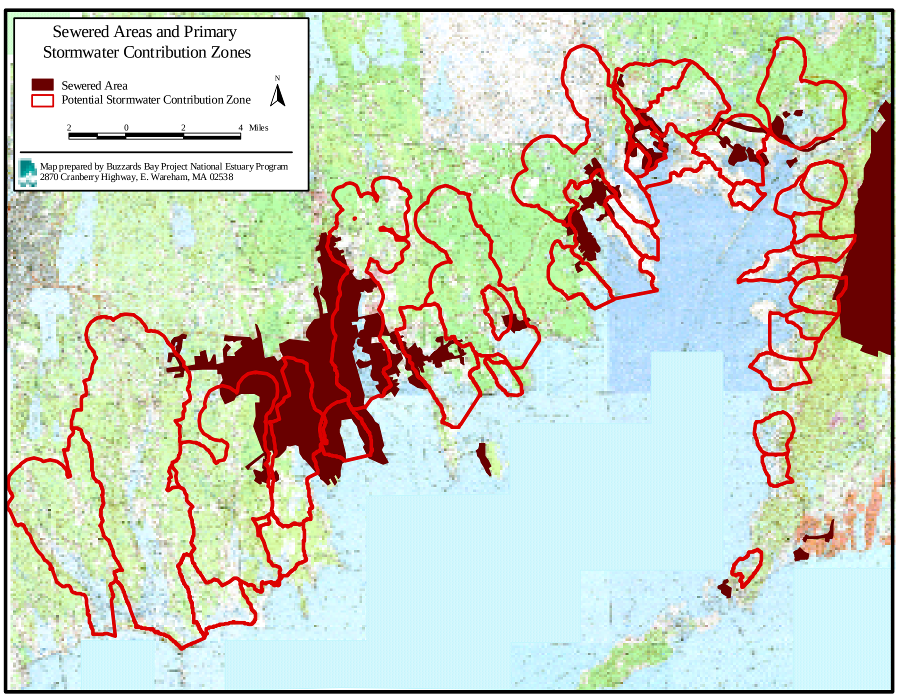
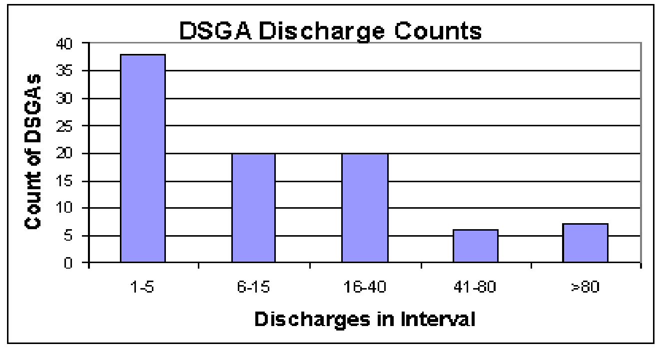


Figure 16. Sewered areas and potential stormwater contribution zones of Buzzards Bay.

Number of Discharges and Catchbasins in DSGA Drainage Basin (30 points):

The principal of this scoring was that the fewer the number of discharge pipes and catchbasins in a drainage area, the easier it is to achieve water quality goals (more results for less expenditure). Figure 17 shows the frequency of catchbasins and discharges in each DSGA drainage area. Only catchbasins defined in the database as having no treatment were counted in this calculation. Points were awarded as follows:



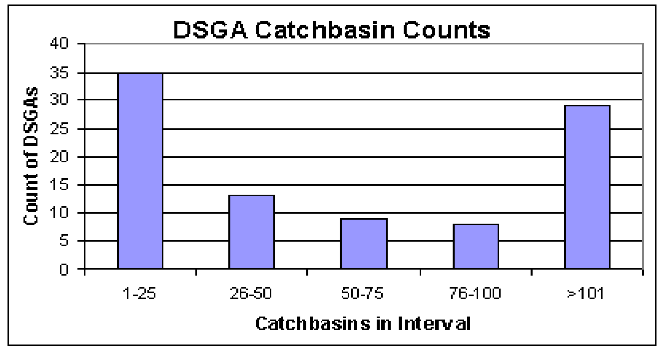


Figure 17. Frequency histograms of counts of discharges (top) and catchbasins (bottom) in each DSGA.

<u>Number of stormwater discharges (20 points):</u>

- 1-5: 20 points
- 6-15: 15 points
- 16-40: 10 points
- 41-80: 5 points
- >80: 0 points

<u>Number of catchbasins (10 points):</u>

- 1-25: 10 points
- 26-50: 8 points
- 51-75: 6 points
- 76-100: 3 points
- >101: 0 points

Percent of the Problem (30 points):

Even for drainage areas with a large number of catchbasins, if a single discharge pipe is connected to a large drainage system with many catchbasins, it could represent a large "percent of the problem," and warrants additional points in this category. Only catchbasins defined in the database as having no treatment were counted in this calculation.

Scoring in this category employed the following rules with respect to catchbasins and drainage lengths:

<u>Catchbasin connected to discharge as a percent of total catchbasins in the drainage basin:</u>

- 90% - 100% of total: 20 points
- 80% - 89% of total: 18 points
- 70% - 79% of total: 16 points
- 60% - 69% of total: 14 points
- 50% - 59% of total: 12 points
- 40% - 49% of total: 10 points
- 30% - 39% of total: 8 points
- 20% - 29% of total: 6 points
- 10% - 19% of total: 4 points
- 0% - 10% of total: 0 points

<u>Drainage length connected to discharge as a percent of total drainage system length in the drainage basin:</u>

- 90% - 100% of total: 10 points
- 80% - 89% of total: 9 points
- 70% - 79% of total: 8 points
- 60% - 69% of total: 7 points
- 50% - 59% of total: 6 points
- 40% - 49% of total: 5 points
- 30% - 39% of total: 4 points
- 20% - 29% of total: 3 points
- 10% - 19% of total: 2 points
- 0% - 10% of total: 0 points

Proximity to Public or Private Swimming Beaches (10 points):
If the discharge was within 200 feet of a private beach, 5 points was received. Ten points was received if the discharge was within 200 feet of a public beach (Figure 18).

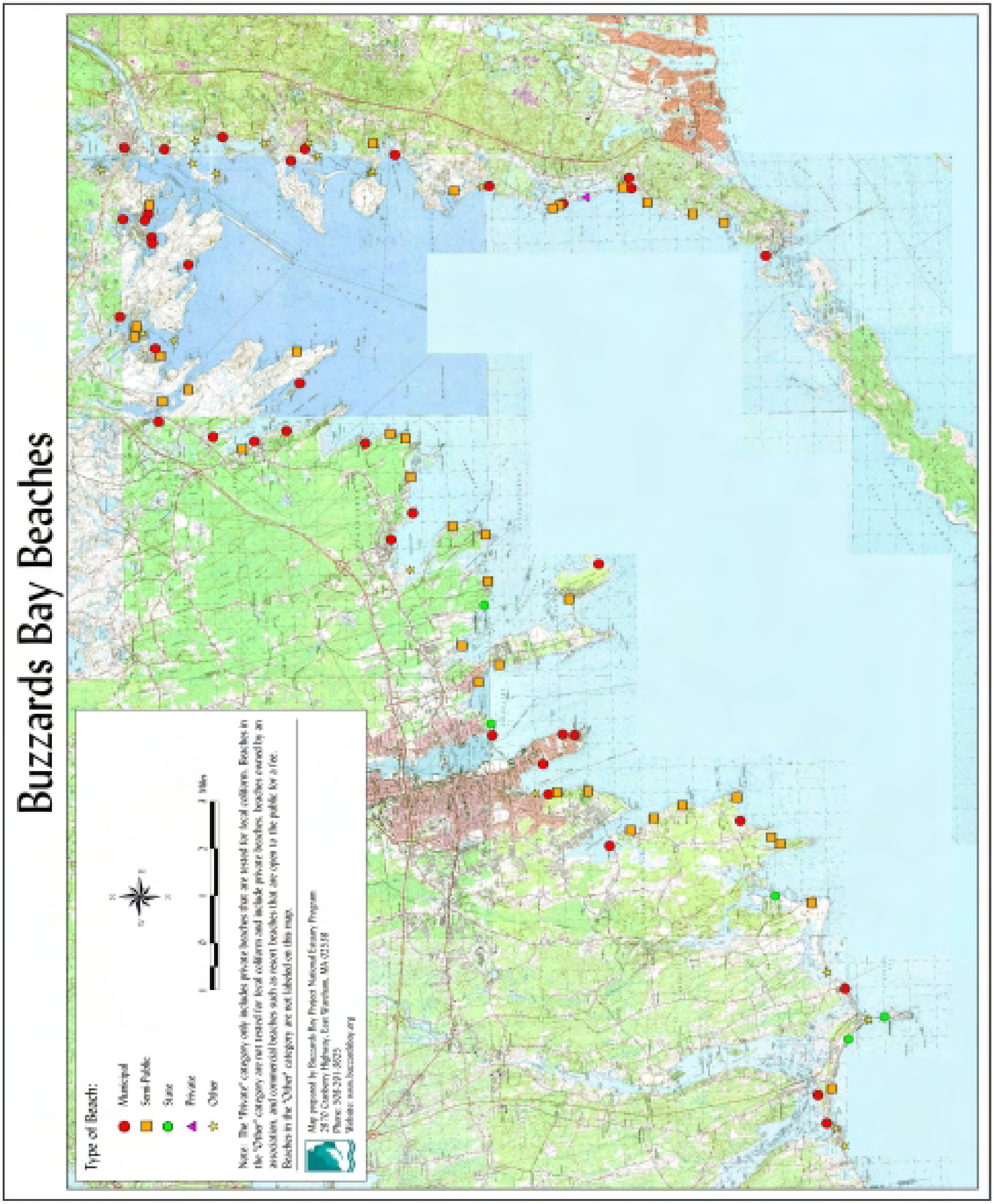


Figure 18. State, public, and private beaches.

Discharge Within 303(d) Listed Pathogen Impaired Area (10 points):

If the discharge was within a pathogen impaired water body (DEP, 2002; see Tables 2 and 3 and Figure 6), or the contributing potential stormwater contribution zone, as shown in Figure 9, the discharge received 10 points in the priority ranking. The awarding of these points was meant to reflect the important role remediating 303(d) listed sites has in achieving the Commonwealth's goals of improving surface water quality.

Discharge From Phase II MS4 Area (10 points):

If the discharge was within a Phase II MS4 designated urbanized area (Figure 3), the discharge received an additional 10 points in the priority ranking. The awarding of these points was meant to reflect how important it is for municipalities to remediate these discharges in order to meet local goals under municipal Phase II NPDES permit stormwater management plans.

High, Medium, and Low Prioritization

Each stormwater discharge was assigned a "High" "Medium" or "Low" priority ranking for remediation based on the combined scores generated by the criteria described above. In assigning the combined scores to each category, breakpoints in the total score were selected so that roughly one third of the sites received a grade of "low," one third received a score of "medium," and one third received a score of "high."

RESULTS

Inventory Results

More than 2,600 drainage pipes and roadcut discharges and more than 12,700 catchbasins were inventoried during this survey, and entered into a GIS database. Nearly 23% of the mapped discharges were roadcuts. The drainage system mapped to the discharge pipes covered a linear distance of 374.6 miles. The estimated cost for remediation using the formula adopted equaled nearly 45 million dollars. A map showing all mapped discharge sites is shown in Figure 19. This map is too large a scale to show individual discharge pipes and basins and is provided here to give the reader a sense of the scope of the stormwater discharge inventory. More detailed maps of subareas are contained in Appendix B, and in the individual plates for each town in the body of the report.

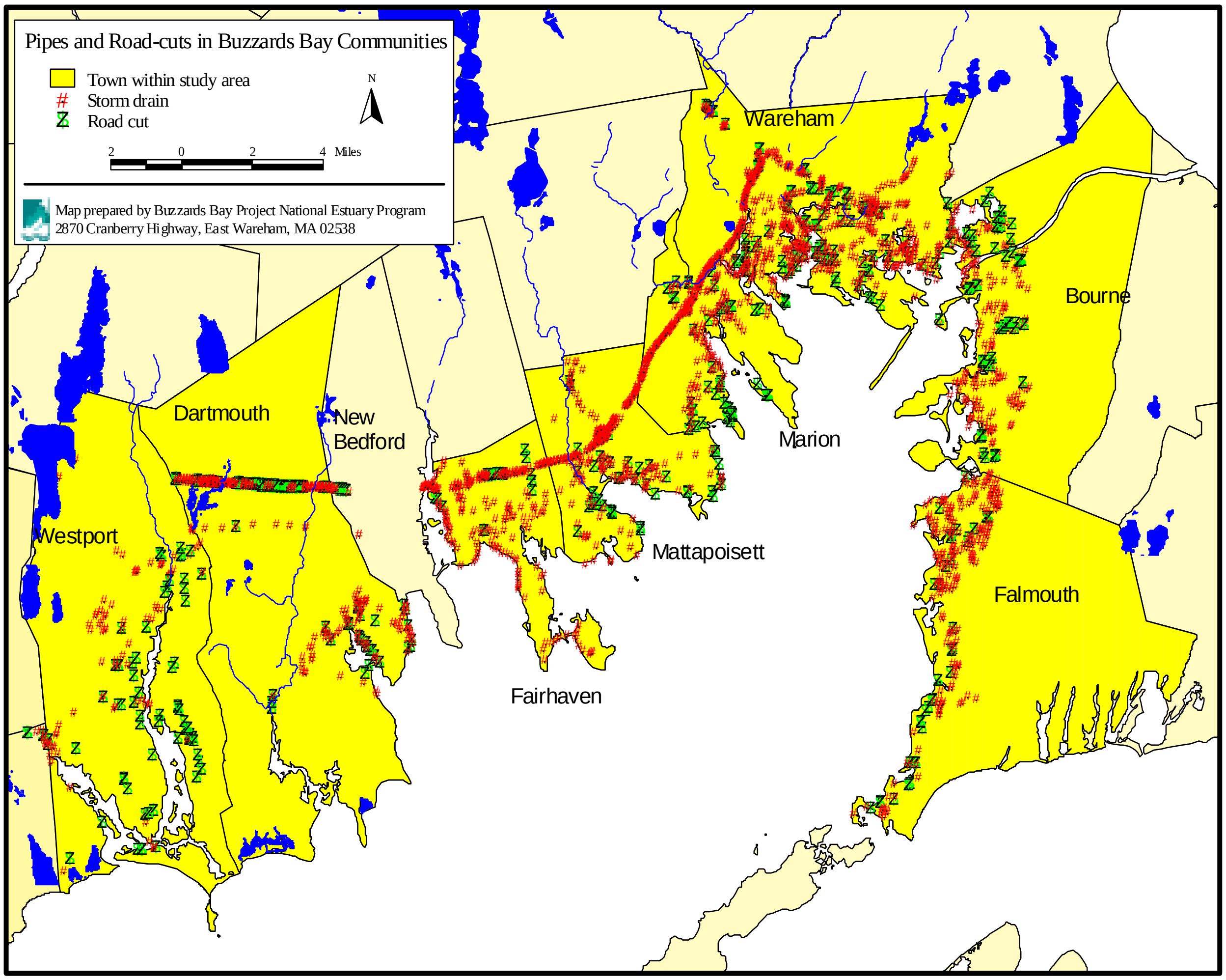


Figure 19. Overview map of all stormdrains and roadcuts in Buzzards Bay watershed communities.

There was considerable variation in the number of stormwater discharge pipes and contributing catchbasins in each of the municipalities surveyed in this study. These variations were due to the area of the town surveyed, density of development, percent of land as wetlands, age of development, proximity of highways to the coast, and other factors. Also contributing to differences was the fact that the limit of the land area surveyed was not an equal distance from shore in all towns. Part of this was because all of state-owned Interstate 195 and Route 6 were included in the study for all towns except Westport (because Routes 6 and 195 were so far north of the coast). Table 6 shows the total number of stormwater discharges (stormdrain pipes and roadcuts) inventoried in each municipality surveyed. Table 7 shows the total number of catchbasins inventoried in each municipality, including those catchbasins flowing into a stormwater treatment system. Several of the "treated" catchbasins were remediation projects and involve underground infiltration. Infiltration is widely believed to minimize fecal bacteria discharges to coastal waters. Table 8 shows the length of the mapped stormwater network in each community.

Table 6. Summary of stormwater discharges by town

Municipality	Miles
Bourne	33.4
Dartmouth	59.4
Fairhaven	61.4
Falmouth	10.6
Marion	38.0
Mattapoisett	40.4
Wareham	63.6
Westport	49.9
Total	366.7

Table 7. Summary of catchbasins by town, showing numbers of basins tied to treatment systems

Municipality	Pipe	Road cut	Total	UA Total[1]
Bourne	169	62	231	220
Dartmouth	255	168	423	412
Fairhaven	224	25	249	185
Falmouth	202	40	242	242
Marion	227	53	280	167
Mattapoisett	276	42	318	172
Wareham	592	118	710	513
Westport	88	85	173	12
Grand Total	2,033	593	2,626	1,923

1. "UA Total" equals number of discharges mapped in the Phase II urbanized areas.

Table 8. Summary of mapped stormwater system length contributing to mapped discharge pipes

Municipality	Untreated	Treated	Total
Bourne	1,303	136	1,439
Dartmouth	1,203	105	1,308
Fairhaven	2,214	11	2,225
Falmouth	1,567	0	1,567
Marion	789	75	864
Mattapoisett	1,171	19	1,190
Wareham	2,405	265	2,670
Westport	662	115	777
Grand Total	11,314	726	12,040

With respect to designated Phase II areas based on the 1990 Census, 392 of the 2,600 (15%) discharges mapped near coastal areas were located in the Phase II area. With the newly expanded urbanized area definition adopted by the US Census Bureau, the Phase II designated area is expected to increase dramatically based on Census 2000 data as shown in Figure 3. The expected new Phase II area includes 1,802 of the 2,600 (69%) discharges mapped in this study.

Based on data for 4 of 8 towns, the average number of catchbasins connected to a drainage pipe in the study was 8.1, with a median of 2.0. Many drainage pipes had 20 or more catchbasins attached. The actual number varied widely, and a frequency histogram summarizing the catchbasin data set is shown in Figure 20.

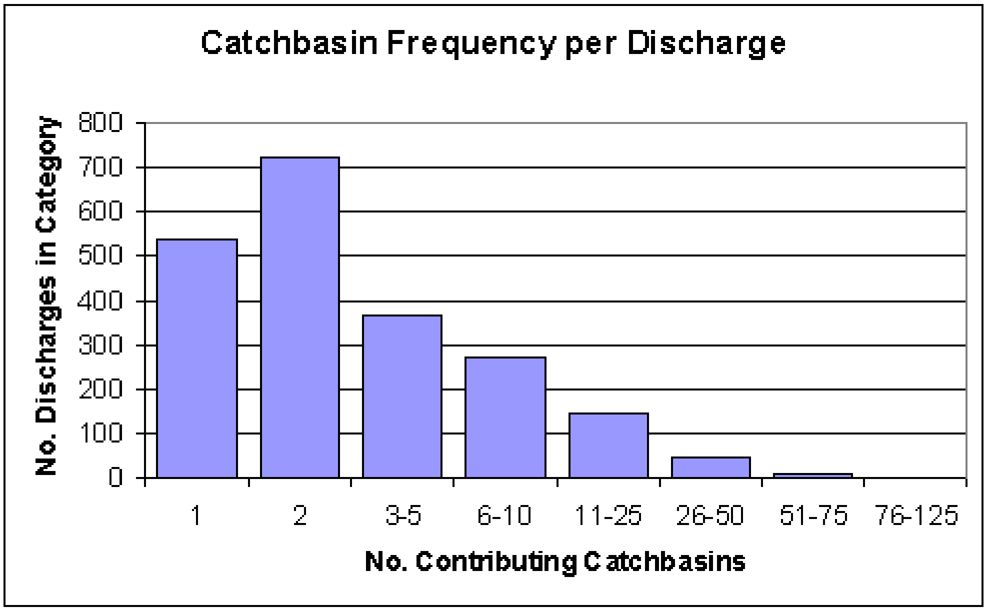


Figure 20. Frequency histogram of number of catchbasins per stormwater discharge pipe for all known and mapped connections.

The catchbasin data were also characterized and summarized by 1 km potential stormwater contribution zones (Table 9), and DSGA drainage basins (Table 10). Similarly, stormwater discharges were characterized and summarized by embayment nitrogen drainage basins (Table 11), potential stormwater contribution zones (Table 12), and DSGA drainage areas (Table 13).

Table 9. Number of catchbasins within the "potential stormwater contribution zone," summarized by embayment[1]

Potential Stormwater Contr. Zone	Untreated	Treated	Total
Acushnet River	736	0	736
Agawam River	415	24	439
Allens Pond	1	0	1
Apponagansett Bay	382	43	425
Aucoot Cove	64	0	64
Back River-Eel Pond	125	22	147
Brant Island Cove	9	0	9
Buttermilk Bay	270	187	457
Clarks Cove	126	47	173
East Branch Westport River	481	103	584
Great Sippewisset	103	0	103
Hen Cove	39	19	58
Little Bay	609	11	620
Mattapoisett River	795	19	814
Megansett Harbor	286	0	286
Onset Bay	395	76	471
Phinneys Harbor	68	7	75
Pocasset Harbor	55	12	67
Pocasset River	184	7	191
Quissett Harbor	11	0	11
Red Brook Harbor	98	0	98
Sippican Harbor	426	48	474
Slocums River	107	0	107
Toby Island Cove	59	0	59
Wareham River	667	47	714
West Branch Westport River	146	12	158
West Falmouth Harbor	109	0	109
Weweantic River	615	12	627
Widows Cove	4	0	4
Wild Harbor	241	0	241
Wings Cove	2	15	17
(blank)[2]	3,800	15	3,815
Grand Total	11,428	726	12,154

1. The "potential stormwater contribution zone" includes those discharges within 1 km of shore and direct stream discharges below ponds and reservoirs.

2. 'Blank' indicates catchbasins are not in a potential stormwater contribution zone.

Table 10. Number of catchbasins summarized by DSGA drainage basins[1]

DSGA	Untreated	Treated	Total
BB1.0	2	0	2
BB12.1	129	0	129
BB12.3	31	11	42
BB12.4	363	40	403
BB12.5	6	0	6
BB13.20	51	6	57
BB13.3	117	46	163
BB15.1	792	0	792
BB15.4	120	0	120
BB15.7	338	0	338
BB17.0	82	0	82
BB18.0	1	0	1
BB19.0	1	0	1
BB2.0	7	0	7
BB21.0	98	0	98
BB21.20	3	0	3
BB21.3	2	0	2
BB21.4	66	0	66
BB22.1	395	0	395
BB22.3	97	11	108
BB23.0	8	0	8
BB25.0	173	0	173
BB25.11	126	0	126
BB25.2	47	0	47
BB25.4	12	0	12
BB26.2	306	17	323
BB27.0	311	2	313
BB3.0	4	0	4
BB3.3	144	6	150
BB3.7	3	0	3
BB3.8	2	0	2
BB30.0	13	0	13
BB30.1	1	0	1
BB31.0	1	0	1
BB31.1	64	0	64
BB32.0	16	0	16
BB32.1	150	2	152
BB32.13	178	0	178
BB32.3	71	11	82
BB32.4	12	0	12
BB32.5	9	35	44
BB33.0	1	0	1
BB34.0	1	13	14
BB35.0	17	0	17
BB35.1	73	0	73
BB35.2	204	0	204
BB35.4	253	12	265
BB35.5	34	0	34
BB36.0	35	2	37
BB36.1	52	0	52
BB36.11	15	16	31
BB36.20	7	0	7
BB36.21	45	0	45
BB36.3	686	25	711
BB36.4	13	0	13
BB36.5	17	0	17
BB36.6	1	0	1
BB36.7	43	0	43
BB36.8	31	26	57
BB36.9	134	2	136

DSGA	Untreated	Treated	Total
BB37.0	38	0	38
BB38.0	11	0	11
BB39.0	7	0	7
BB4.0	20	0	20
BB4.1	5	0	5
BB4.5	10	0	10
BB4.6	1	0	1
BB4.8	5	4	9
BB4.9	447	105	552
BB40.0	4	0	4
BB40.3	172	68	240
BB41.0	98	0	98
BB41.2	53	8	61
BB42.3	190	0	190
BB43.0	164	0	164
BB44.0	167	185	352
BB44.5	86	2	88
BB45.1	37	0	37
BB45.2	162	0	162
BB46.0	27	0	27
BB46.1	30	0	30
BB46.21	64	0	64
BB47.2	111	29	140
BB47.20	8	0	8
BB48.0	136	0	136
BB49.0	15	11	26
BB49.1	104	0	104
BB49.20	22	19	41
BB49.5	57	6	63
BB50.0	121	0	121
BB50.1	27	0	27
BB50.2	60	0	60
BB50.20	20	0	20
BB51.0	34	0	34
BB52.0	179	0	179
BB52.3	2	0	2
BB53.0	115	0	115
BB54.0	100	0	100
BB54.1	6	0	6
BB54.2	3	0	3
BB54.20	1	0	1
BB55.0	76	0	76
BB56.0	97	0	97
BB57.0	37	0	37
BB58.0	6	0	6
BB58.2	5	0	5
BB8.0	127	0	127
SC1.0	4	0	4
blank[2]	2,143	6	2,149
Grand Total	11,428	726	12,154

1. DSGA drainage basin boundaries are shown in Figure 12.
2. 'Blank' indicates catchbasins that are not in a DSGA drainage area.

Table 11. Number of discharges summarized by embayment nitrogen drainage basin

Subbasin	Pipe	Roadcut	Total
Agawam River	73	30	103
Aucoot Cove	57	12	69
Brant Island Cove	2	0	2
Buttermilk Bay	42	18	60
Buzzards Bay	22	17	39
Clark's Cove	24	4	28
East Branch Westport River	181	151	332
Hen's Cove	19	0	19
Inner Apponagansett	2	0	2
Inner Apponagansett Bay	46	25	71
Inner Naskatucket	84	18	102
Inner New Bedford Harbor	91	5	96
Inner Sippican Harbor	99	14	113
Mark's Cove	13	2	15
Mattapoisett River	245	34	279
Onset Bay	98	10	108
Outer Apponagansett Bay	2	1	3
Outer New Bedford Harbor	30	2	32
Outer Sippican Harbor	4	16	20
Phinneys Harbor	26	13	39
Pocasset River	32	8	40
Quissett Harbor	3	7	10
Red Brook Harbor	17	4	21
Slocum's River	73	63	136
Squeteague Harbor	10	5	15
Taunton River	3	0	3
Wareham River	209	40	249
West Branch Westport River	23	20	43
West Falmouth Harbor	11	0	11
Weweantic River	248	30	278
Widow's Cove	1	0	1
Wild Harbor	27	4	31
Wings Cove	4	0	4
Coastal, and other areas	237	55	292
Grand Total	2,058	608	2,666

Table 12. Number of discharges within the "potential stormwater contribution zone"[1], summarized by embayment

Subbasin	Pipe	Roadcut	Total
Acushnet River	61	5	66
Agawam River	79	36	115
Apponagansett Bay	42	23	65
Aucoot Cove	15	12	27
Back River-Eel Pond	19	0	19
Brant Island Cove	1	0	1
Buttermilk Bay	41	17	58
Clarks Cove	23	4	27
East Branch Westport River	68	69	137
Great Sippewisset	9	3	12
Hen Cove	11	0	11
Little Bay	83	18	101
Mattapoisett River	215	26	241
Megansett Harbor	44	2	46
Onset Bay	67	7	74
Phinneys Harbor	6	5	11
Pocasset Harbor	10	0	10
Pocasset River	24	8	32
Quissett Harbor	4	7	11
Red Brook Harbor	22	7	29
Sippican Harbor	92	28	120
Slocums River	11	5	16
Toby Island Cove	6	0	6
Wareham River	206	35	241
West Branch Westport River	23	14	37
West Falmouth Harbor	17	1	18
Weweantic River	210	25	235
Widows Cove	1	0	1
Wild Harbor	41	8	49
Wings Cove	4	0	4
(blank)[2]	603	243	846
Grand Total	2,058	608	2,666

1. The "potential stormwater contribution zone" includes those discharges within 1 km of shore and direct stream discharges below ponds and reservoirs.
2. "Blanks" represent discharges within 1 km of shore but not within one of the named drainage basins.

Table 13. Number of discharges summarized by DSGA boundaries[1]

DSGA	Pipe	Road cut	Total
BB12.1	6	6	12
BB12.3	2	1	3
BB12.4	39	18	57
BB12.5	2	0	2
BB12.7	0	1	1
BB13.20	1	2	3
BB13.3	23	4	27
BB15.1	70	5	75
BB15.4	7	0	7
BB15.7	24	2	26
BB17.0	15	0	15
BB18.0	1	0	1
BB2.0	1	2	3
BB21.0	11	1	12
BB21.3	1	0	1
BB21.4	4	0	4
BB22.1	69	18	87
BB22.3	6	0	6
BB23.0	2	0	2
BB25.0	25	15	40
BB25.11	12	5	17
BB25.2	2	2	4
BB25.4	4	0	4
BB26.2	91	6	97
BB27.0	100	6	106
BB29.0	0	2	2
BB3.0	4	3	7
BB3.3	22	10	32
BB3.5	0	3	3
BB3.6	0	3	3
BB30.0	5	3	8
BB30.1	1	2	3
BB31.0	0	3	3
BB31.1	15	9	24
BB32.0	1	11	12
BB32.1	53	2	55
BB32.13	18	1	19
BB32.3	25	11	36
BB32.4	2	2	4
BB32.5	2	3	5
BB33.0	0	1	1
BB34.0	4	0	4
BB35.0	3	2	5
BB35.1	13	2	15
BB35.2	76	5	81
BB35.4	92	9	101
BB35.5	15	5	20
BB36.0	6	7	13
BB36.1	11	7	18
BB36.11	6	4	10
BB36.20	1	0	1
BB36.21	0	2	2
BB36.3	183	53	236
BB36.4	3	0	3
BB36.5	5	1	6
BB36.6	2	0	2

DSGA	Pipe	Road cut	Total
BB36.7	9	0	9
BB36.8	20	0	20
BB36.9	39	1	40
BB37.0	9	9	18
BB39.0	2	1	3
BB4.0	1	4	5
BB4.1	1	0	1
BB4.6	0	3	3
BB4.8	0	3	3
BB4.9	68	63	131
BB40.0	3	0	3
BB40.3	35	3	38
BB41.0	13	2	15
BB41.2	7	1	8
BB42.3	38	2	40
BB43.0	24	11	35
BB43.3	1	0	1
BB44.0	35	17	52
BB44.5	3	0	3
BB45.1	9	0	9
BB45.2	12	9	21
BB46.0	3	2	5
BB46.1	3	0	3
BB46.21	7	2	9
BB47.2	16	0	16
BB47.20	1	0	1
BB48.0	18	3	21
BB49.0	6	4	10
BB49.1	24	0	24
BB49.20	9	0	9
BB49.5	7	0	7
BB50.0	19	5	24
BB50.1	11	1	12
BB50.2	9	0	9
BB50.20	3	1	4
BB51.0	7	2	9
BB52.0	27	5	32
BB52.3	0	1	1
BB53.0	21	2	23
BB54.0	14	1	15
BB54.1	2	0	2
BB54.20	1	0	1
BB55.0	4	10	14
BB56.0	11	3	14
BB57.0	5	1	6
BB58.0	1	3	4
BB58.2	3	4	7
BB8.0	11	5	16
SC1.0	1	0	1
(blank)	399	164	563
Grand Total	2,058	608	2,666

1. DSGA drainage area boundaries are shown in Figure 12.
2. ‘Blank’ indicates discharges that are not in a DSGA drainage area.

Prioritization Results

Each stormwater discharge was assigned a “High” “Medium” or “Low” priority for remediation based on the methods described. If all of the known connecting catchbasins had some form of stormwater treatment system installed, a discharge was labeled “remediated” (96 discharges met this criteria). These prioritization ranks are summarized in the tables below and the maps shown in Appendix A. Some interesting patterns emerge using the scoring criteria adopted. Most notably, certain bays had a greater percentage of high priority sites than others. Another obvious trend is that discharges near the central to lower portions of embayments often tended to have higher rankings than upper watershed discharges. Table 14 shows the breakdown of priorities by town. Table 15 shows priorities summarized by hydraulic subbasin.

Whether the discharge was a roadcut or a discharge pipe appeared not to affect the prioritization. For example, nearly 23% of all discharges were roadcuts, whereas 26% of the discharges ranking high were roadcuts, and 21% ranked low were roadcuts.

Table 14. Summary of prioritization rankings by municipality and discharge type.

		Rank				
Municipality	**Type**	**Low**	**Medium**	**High**	**Remediated**	**Total**
Bourne	pipe	18	47	86	18	169
	roadcut	14	10	38	0	62
Bourne Total		**32**	**57**	**124**	**18**	**231**
Dartmouth	pipe	164	42	36	13	255
	roadcut	125	11	32	0	168
Dartmouth Total		**289**	**53**	**68**	**13**	**423**
Fairhaven	pipe	38	81	105	0	224
	roadcut	0	9	16	0	25
Fairhaven Total		**38**	**90**	**121**	**0**	**249**
Falmouth	pipe	69	36	97	0	202
	roadcut	6	15	19	0	40
Falmouth Total		**75**	**51**	**116**	**0**	**242**
Marion	pipe	141	47	26	13	227
	roadcut	1	30	22	0	53
Marion Total		**142**	**77**	**48**	**13**	**280**
Mattapoisett	pipe	110	141	23	2	276
	roadcut	1	19	22	0	42
Mattapoisett Total		**111**	**160**	**45**	**2**	**318**
Wareham	pipe	124	220	216	32	592
	roadcut	7	23	88	0	118
Wareham Total		**131**	**243**	**304**	**32**	**710**
Westport	pipe	20	45	5	18	88
	roadcut	9	64	12	0	85
Westport Total		**29**	**109**	**17**	**18**	**173**
Grand Total		**847**	**840**	**843**	**96**	**2,626**

Table 15. Summary of prioritization rankings by hydraulic subbasin (see boundaries in Figure 9)

Subbasin	Type	Rank Low	Medium	High	Remediated	Total
Agawam River	pipe	7	14	52	0	73
	roadcut	0	5	25	0	30
Agawam River Total		**7**	**19**	**77**	**0**	**103**
Aucoot Cove	pipe	42	15	0	0	57
	roadcut	0	9	3	0	12
Aucoot Cove Total		**42**	**24**	**3**	**0**	**69**
Brant Island Cove	pipe	0	0	2	0	2
Brant Island Cove Total		**0**	**0**	**2**	**0**	**2**
Buttermilk Bay	pipe	0	10	18	14	42
	roadcut	0	1	17	0	18
Buttermilk Bay Total		**0**	**11**	**35**	**14**	**60**
Clark's Cove	pipe	0	0	21	3	24
	roadcut	0	0	4	0	4
Clark's Cove Total		**0**	**0**	**25**	**3**	**28**
East Branch Westport River	pipe	108	53	3	17	181
	roadcut	81	64	6	0	151
East Branch Westport River Total		**189**	**117**	**9**	**17**	**332**
Hen's Cove	pipe	2	4	9	4	19
Hen's Cove Total		**2**	**4**	**9**	**4**	**19**
Inner Apponagansett Bay	pipe	1	22	13	10	46
	roadcut	0	0	25	0	25
Inner Apponagansett Bay Total		**1**	**22**	**38**	**10**	**71**
Inner Nasketucket	pipe	1	51	32	0	84
	roadcut	0	9	9	0	18
Inner Nasketucket Total		**1**	**60**	**41**	**0**	**102**
Inner New Bedford Harbor	pipe	21	25	45	0	91
	roadcut	0	0	5	0	5
Inner New Bedford Harbor Total		21	25	50	0	96
Inner Sippican Harbor	pipe	51	24	18	6	99
	roadcut	1	12	1	0	14
Inner Sippican Harbor Total		**52**	**36**	**19**	**6**	**113**
Mark's Cove	pipe	0	10	3	0	13
	roadcut	0	0	2	0	2
Mark's Cove Total		**0**	**10**	**5**	**0**	**15**
Mattapoisett River	pipe	100	132	11	2	245
	roadcut	1	18	15	0	34
Mattapoisett River Total		**101**	**150**	**26**	**2**	**279**
Onset Bay	pipe	5	38	46	9	98
	roadcut	0	2	8	0	10
Onset Bay Total		**5**	**40**	**54**	**9**	**108**
Outer Apponagansett Bay	pipe	0	0	2	0	2
	roadcut	0	0	1	0	1
Outer Apponagansett Bay Total		**0**	**0**	**3**	**0**	**3**
Outer New Bedford Harbor	pipe	0	5	25	0	30
	roadcut	0	0	2	0	2
Outer New Bedford Harbor Total		**0**	**5**	**27**	**0**	**32**
Outer Sippican Harbor	pipe	0	0	3	1	4
	roadcut	0	0	16	0	16
Outer Sippican Harbor Total		**0**	**0**	**19**	**1**	**20**

Subbasin	Type	Low	Rank Medium	High	Remediated	Total
Phinneys Harbor	pipe	6	0	16	4	26
	roadcut	11	0	2	0	13
Phinneys Harbor Total		**17**	**0**	**18**	**4**	**39**
Pocasset River	pipe	4	1	27	0	32
	roadcut	3	0	5	0	8
Pocasset River Total		**7**	**1**	**32**	**0**	**40**
Quissett Harbor	pipe	0	1	2	0	3
	roadcut	0	0	7	0	7
Quissett Harbor Total		**0**	**1**	**9**	**0**	**10**
Red Brook Harbor	pipe	1	1	15	0	17
	roadcut	0	0	4	0	4
Red Brook Harbor Total		**1**	**1**	**19**	**0**	**21**
Slocum's River	pipe	62	11	0	0	73
	roadcut	58	5	0	0	63
Slocum's River Total		**120**	**16**	**0**	**0**	**136**
Squeteague Harbor	pipe	0	1	9	0	10
	roadcut	0	0	5	0	5
Squeteague Harbor Total		**0**	**1**	**14**	**0**	**15**
Wareham River	pipe	2	107	82	18	209
	roadcut	0	8	32	0	40
Wareham River Total		**2**	**115**	**114**	**18**	**249**
West Branch Westport River	pipe	19	1	2	1	23
	roadcut	10	4	6	0	20
West Branch Westport River Total		**29**	**5**	**8**	**1**	**43**
West Falmouth Harbor	pipe	3	0	8	0	11
West Falmouth Harbor Total		**3**	**0**	**8**	**0**	**11**
Weweantic River	pipe	185	45	16	2	248
	roadcut	7	16	7	0	30
Weweantic River Total		**192**	**61**	**23**	**2**	**278**
Widow's Cove	pipe	0	0	1	0	1
Widow's Cove Total		**0**	**0**	**1**	**0**	**1**
Wild Harbor	pipe	0	1	26	0	27
	roadcut	0	0	4	0	4
Wild Harbor Total		**0**	**1**	**30**	**0**	**31**
Wings Cove	pipe	0	0	0	4	4
Wings Cove Total		**0**	**0**	**0**	**4**	**4**
Grand Total		**792**	**725**	**718**	**95**	**2,330**

DISCUSSION

In 1991, the Buzzards Bay Project estimated that it would cost ten million dollars to remediate the major stormwater discharges in Buzzards Bay that contribute to shellfish bed closures[2]. This estimate was based on the assumption that 400 discharges needed to be remediated at a cost of $25,000 each. In this report, we identified more than 2,600 discharges with a minimum remediation cost of more than $60 million. The cost of remediating the sites ranked medium and high totals approximately $45 million. The 852 sites ranked high are estimated to cost nearly $23 million to remediate. These costs are conservative estimates. Moreover, while this survey of discharges in Buzzards Bay was comprehensive, we believe some coastal discharges were overlooked.

When reviewing the prioritization tables and maps shown in Appendix A, it is important to recognize that a very different remediation prioritization could have been achieved using different assumptions, criteria, or scoring weights. For example, where roadcuts fell within the prioritization distribution could have been affected somewhat by remediation costs, or the weighting associated with the number of connected catchbasins to pipes. Few discharges in the Westport Rivers received a "high" ranking because of the very elevated fecal coliform concentrations, and the large number of stormwater discharges reduced scores for many sites. The high-medium-low categories themselves are arbitrary, and meant only to discriminate sites in order to look for regional, municipal, or embayment level patterns and priority areas. Scoring criteria are not the only factors controlling the prioritization results because in a database composed of tens of thousands of pieces of information, potential errors or omissions could have affected the priority ranking of any single discharge. Given more time and money, more or different information could have been included in the prioritization process.

For these reasons, this Atlas should not be used alone to evaluate the feasibility or suitability of remediating any particular discharge. In a practical sense, both town officials and granting agencies should rely on very site-specific information in determining whether a stormwater discharge should be remediated. For example, the Buzzards Bay Project encourages municipalities, as a matter of policy, to remediate stormwater discharges whenever major roadwork is planned. This is because many embayments are impaired by the cumulative impact of dozens of discrete discharges, and water quality and living resources will be restored only when the majority of these discharges are treated or eliminated. Restoration of all discharges should proceed whenever opportunities arise, irrespective of whether a discharge is listed as high, medium, or low in this report.

On the other hand, this Atlas gives an indication of where stormwater remediation efforts are needed at the watershed, municipal, and embayment levels. It has provided a synthesis and evaluation of stormwater discharges never before attempted in an area the size of the Buzzards Bay Watershed. This prioritization, together with the detailed maps shown in Appendix B, GIS data produced, and spreadsheet ranking database, as well as the DMF Sanitary Surveys, should help municipal officials, regulators, and granting agencies begin to identify and target sites for stormwater treatment or elimination. The data, maps, and GIS files produced through this undertaking (available on CD-ROM and through the internet at www.buzzardsbay.org) will help Buzzards Bay municipalities identify and treat those stormwater discharges contributing most to the loss of water quality or living resources. This information will also help scientists and managers better understand the relationship between land use, stormwater, and water quality. It is hoped that these efforts will result in the continued reopening and reclassification of Buzzards Bay shellfish beds, and the continued improvement in water quality, as documented in Figure 5 of this report.

[2] Testimony presented to the U.S. House of Representatives Merchant Marine and Fisheries Subcommittee on Fisheries and Wildlife Conservation and the Environment, and The Subcommittee on Oceanography, Great Lakes and the Outer Continental Shelf by Joseph E. Costa, Ph.D., Project Manager, Buzzards Bay Project, May 15, 1991.

SUMMARY

More than 2,600 stormwater discharges were mapped during field surveys conducted within the coastal areas of eight Buzzards Bay municipalities. These discharges consisted of more than 2,000 pipes and 600 roadcuts. To the extent practical, drainage systems associated with these discharges were mapped, totaling 375 miles. Twelve thousand catchbasins were also mapped during these surveys, most contributing to the discharges. Based on this information, comprehensive GIS data layers, spreadsheet databases, and detailed maps were provided to Buzzards Bay municipalities. This information is also available on CD-ROM, and on the Internet at www.buzzardsbay.org.

These stormwater discharges were prioritized for remediation based upon specific criteria for water quality, drainage network characterizations, existing water quality, shellfish resource area classifications, estimated cost of remediation, and a variety of other factors. The top third scoring sites were classified as high priority, and the preliminary estimate for remediating these sites was $23 million. While this ranking is not suitable for evaluating site-specific proposals, this ranking provides environmental managers and municipal officials with a guide for targeting specific areas for remediation. The database and maps generated can also be widely used by municipalities for compliance with Phase II Stormwater NPDES permits, implementation of stormwater planning programs, and general municipal planning. This report will hopefully contribute to the continued reopening and reclassification of shellfish beds in Buzzards Bay that has been observed during the past decade.

REFERENCES CITED

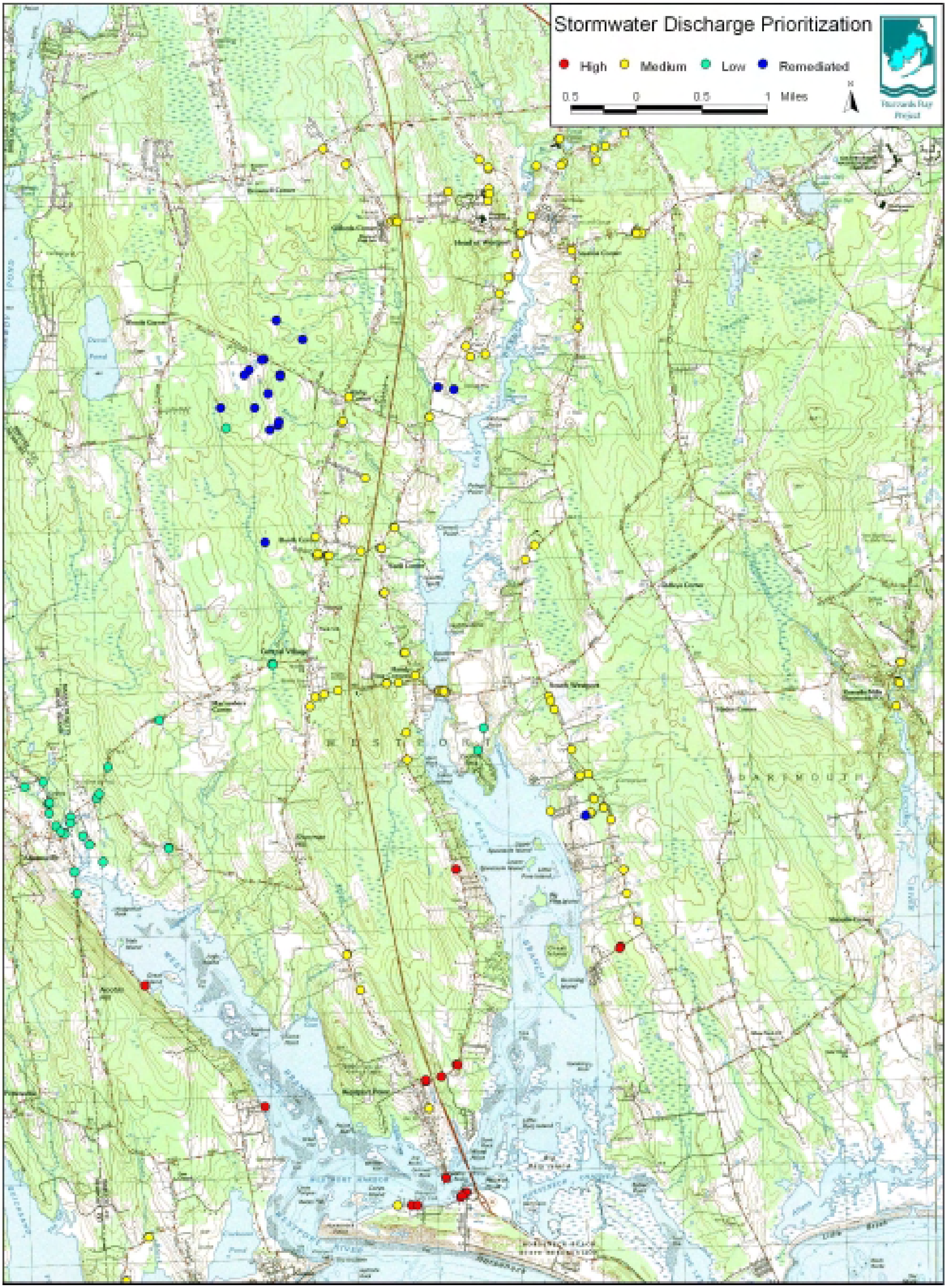
Buzzards Bay Project (U. S. Environmental Protection Agency and Massachusetts Executive Office of Environmental Affairs). 1991. Buzzards Bay Comprehensive Conservation and Management Plan, 8/91 Final. 246p.

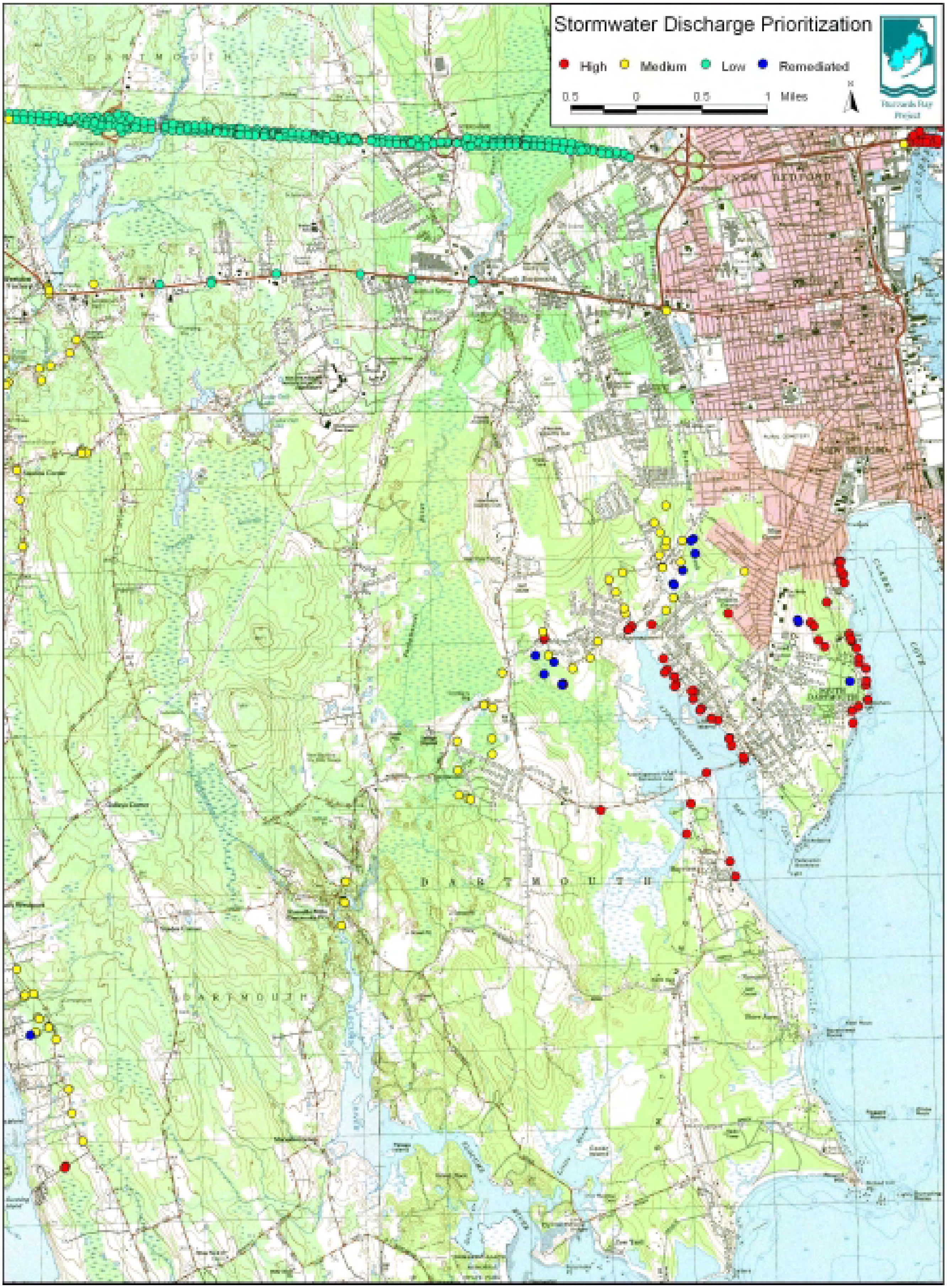
DEP (Massachusetts Department of Environmental Protection). 1998. FINAL MASSACHUSETTS SECTION 303(d) LIST of WATERS - 1998. 131 pp.

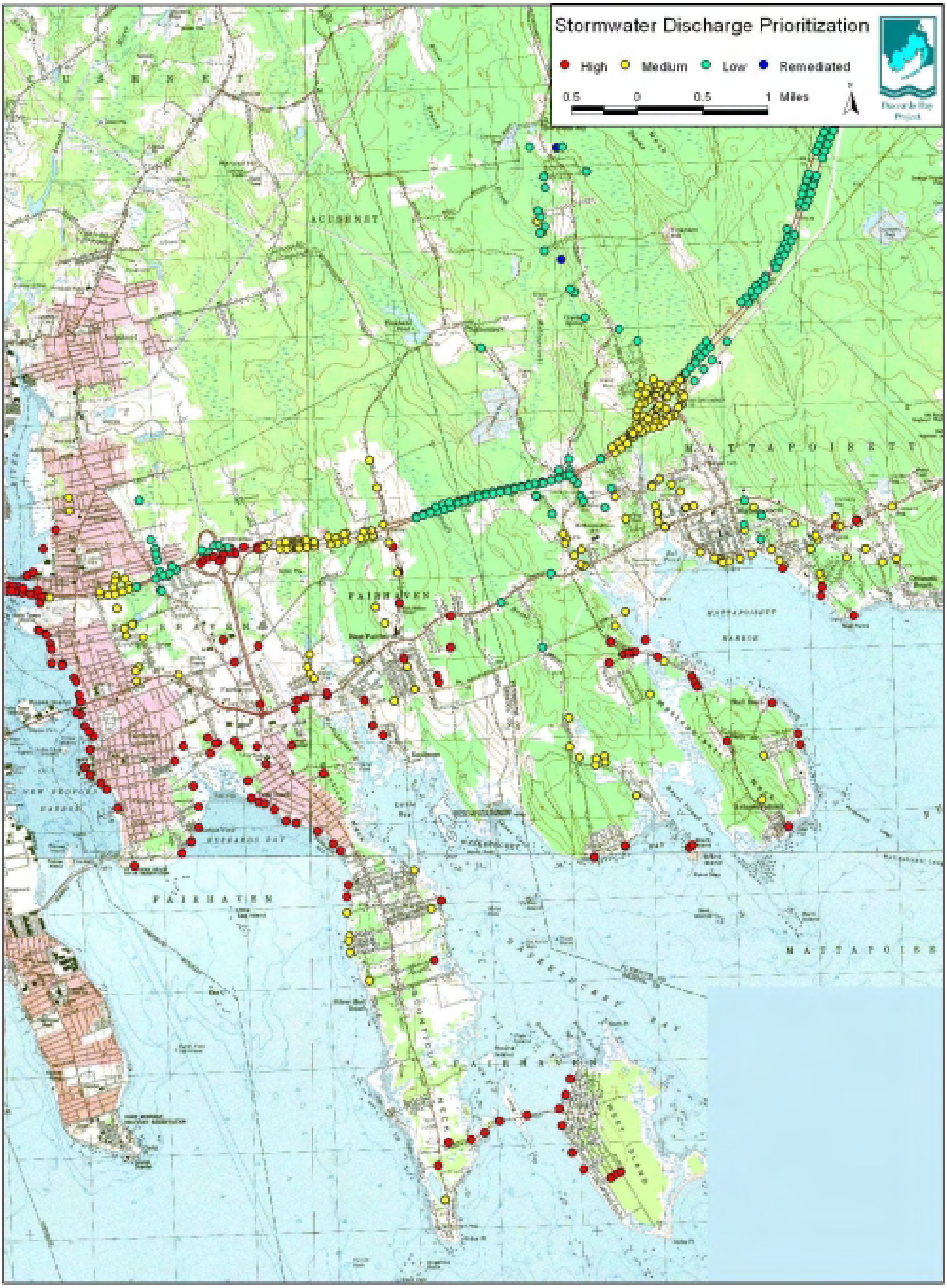
DEP (Massachusetts Department of Environmental Protection). 2002. Massachusetts Year 2002 Integrated List of Waters. Part 2 – Proposed Listing of Individual Categories of Waters. October 2002. 137 pp.

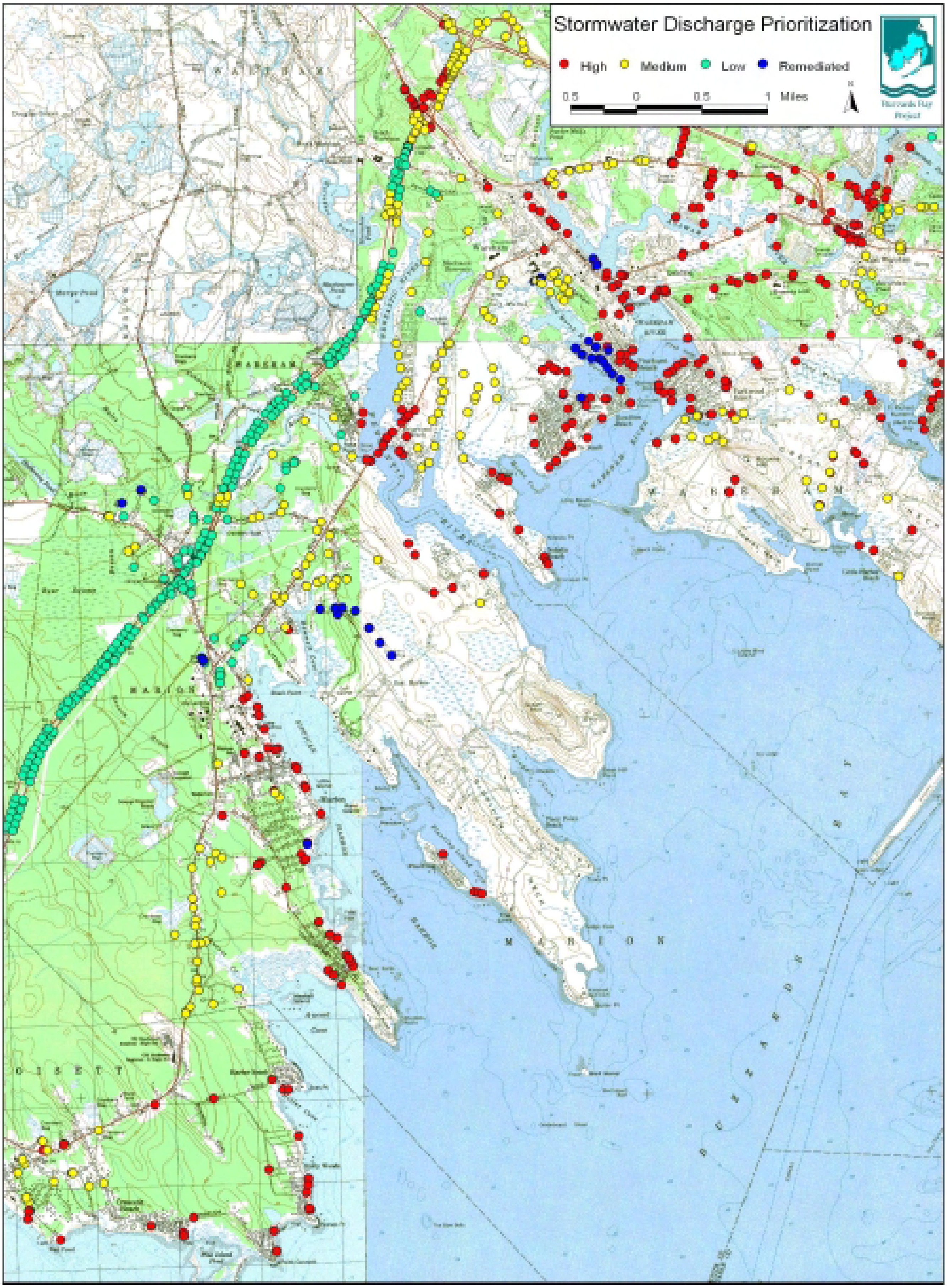
J. E. Costa, B. L. Howes, D. Janik, D. Aubrey, E. Gunn, A. E. Giblin. 1999. Managing anthropogenic nitrogen inputs to coastal embayments: Technical basis of a management strategy adopted for Buzzards Bay. Buzzards Bay Project Technical Report. 56 pages. Draft Final, September 24, 1999.

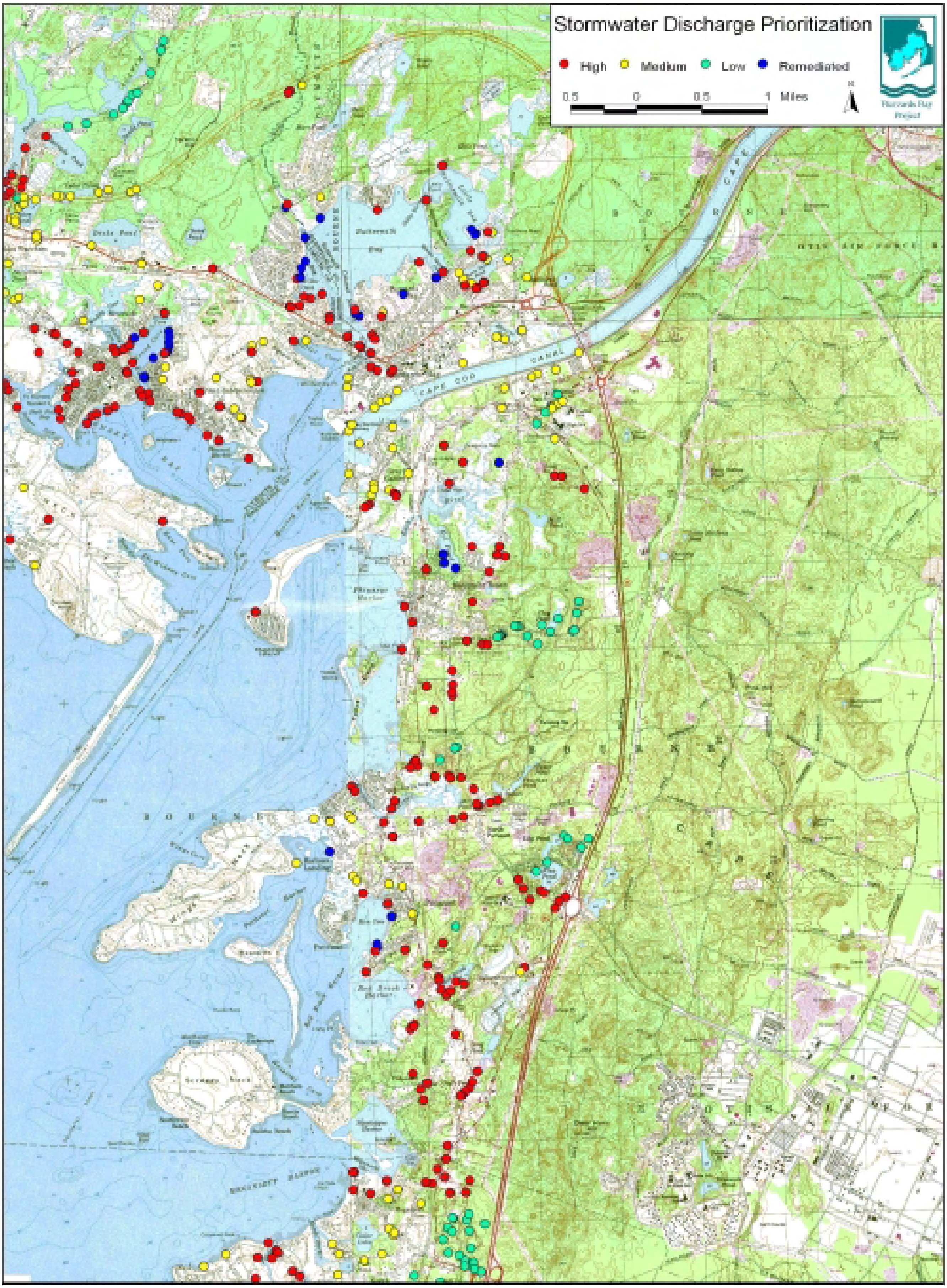
APPENDIX A: STORMWATER DISCHARGE PRIORITIZATION

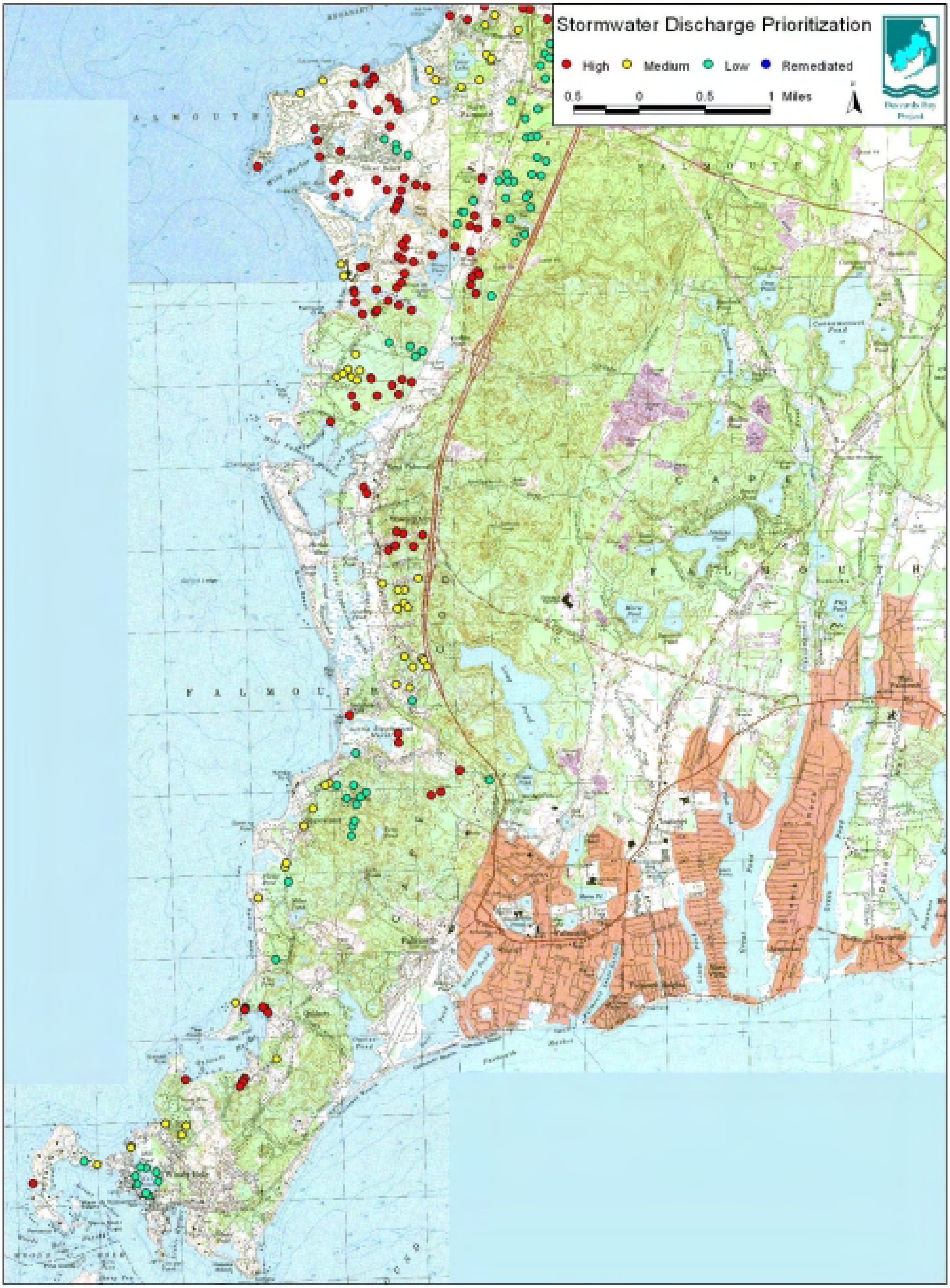

Stormwater Discharge Prioritization
High
Medium
Low
Remediated
0.5
0
0.5
1
Miles
N
Buzzards Bay Project


Stormwater Discharge Prioritization
High
Medium
Low
Remediated
0.5 0 0.5 1 Miles
N
Buzzards Bay Project
D A R T M O U T H


Stormwater Discharge Prioritization
High
Medium
Low
Remediated
0.5
0
0.5
1 Miles
ACUSHNET
MATTAPOISETT
FAIRHAVEN
NEW BEDFORD HARBOR
FAIRHAVEN

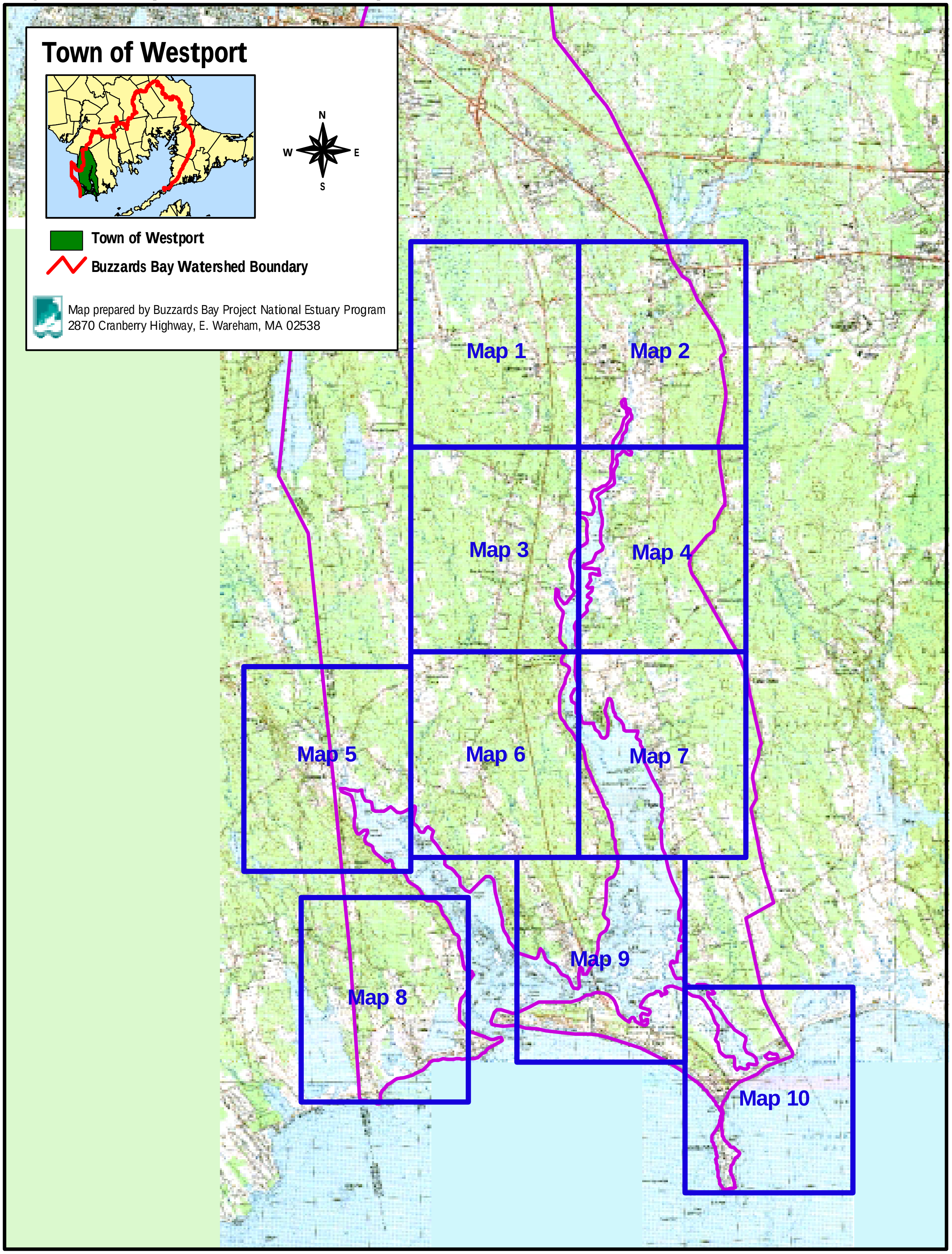

Stormwater Discharge Prioritization
High
Medium
Low
Remediated
0.5
0
0.5
1 Miles
N
Buzzards Bay Project


Stormwater Discharge Prioritization
High
Medium
Low
Remediated
0.5
0
0.5
1
Miles
N
CAPE COD CANAL
Buzzards Bay Project

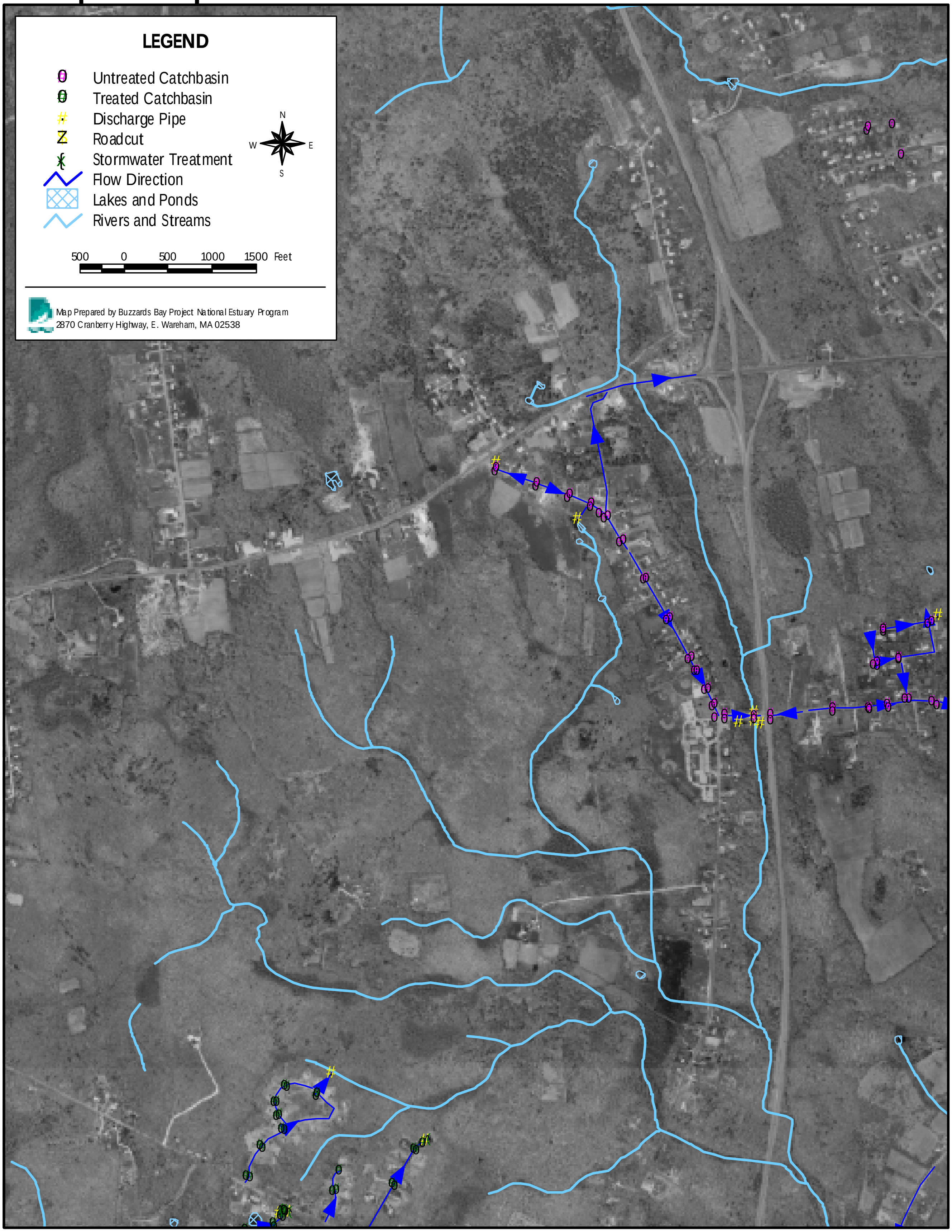

Stormwater Discharge Prioritization
High
Medium
Low
Remediated
0.5
0
0.5
1 Miles
F A L M O U T H
C A P E

APPENDIX B: STORMWATER DISCHARGE INVENTORY

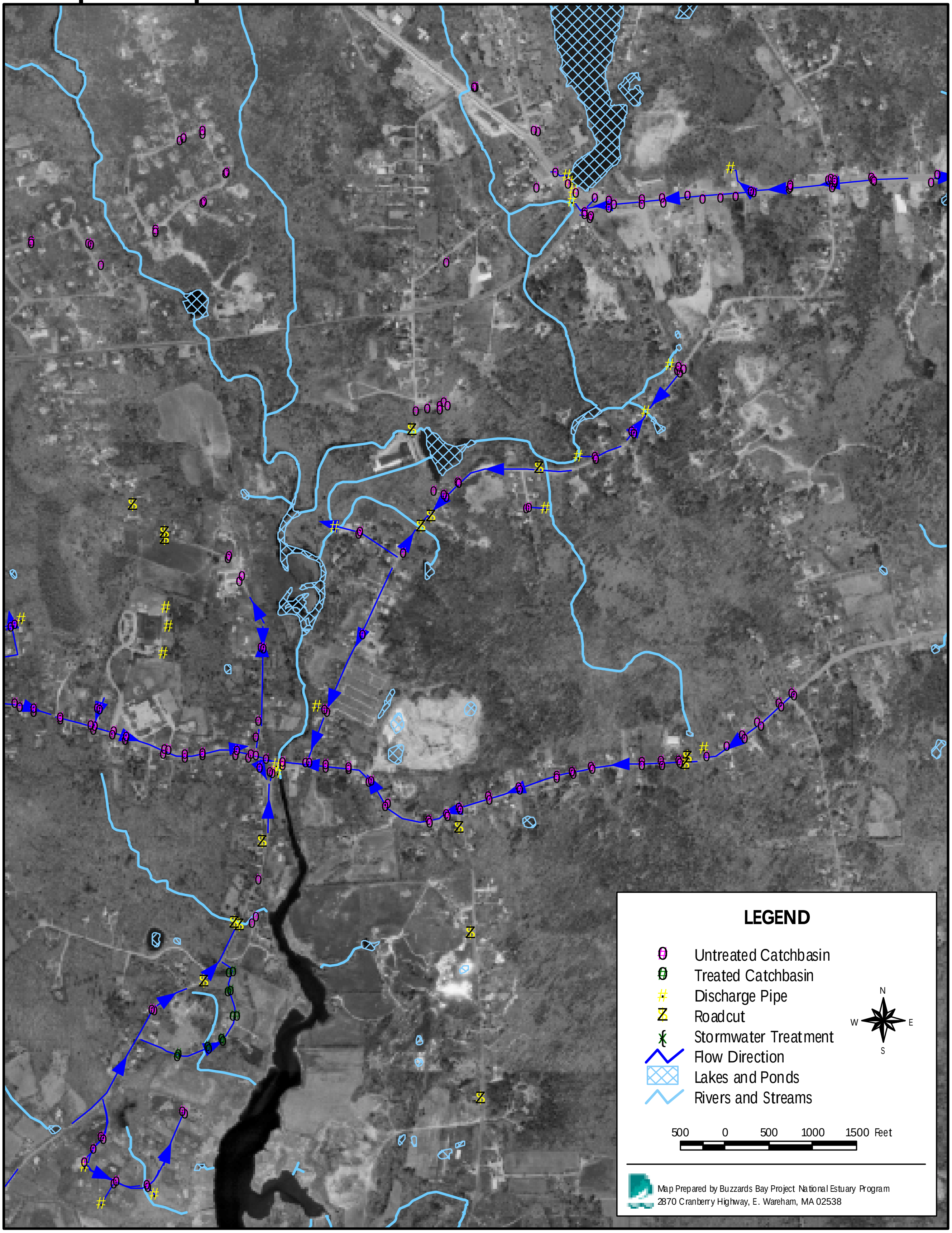
Key for Westport Stormdrain Maps



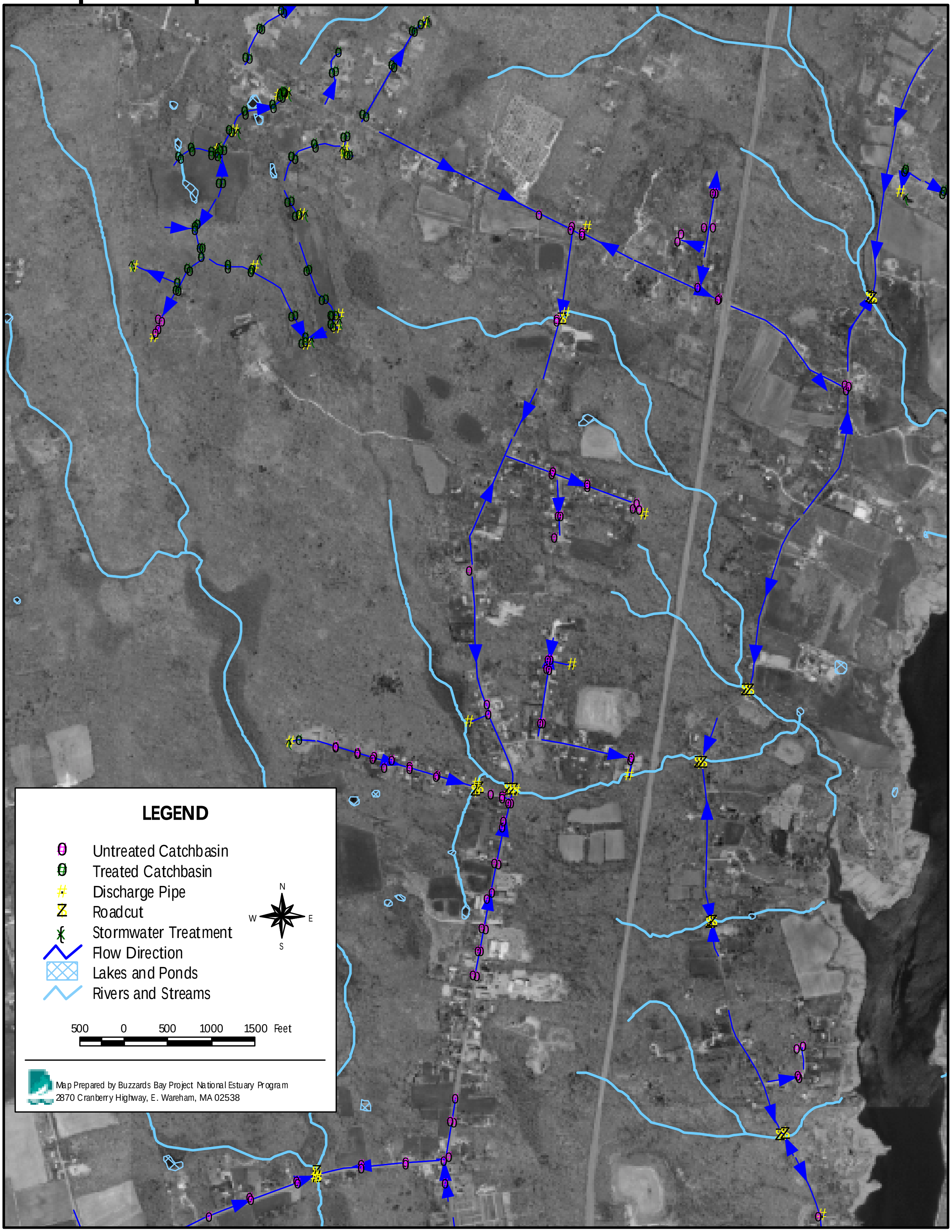
Westport: Map 1



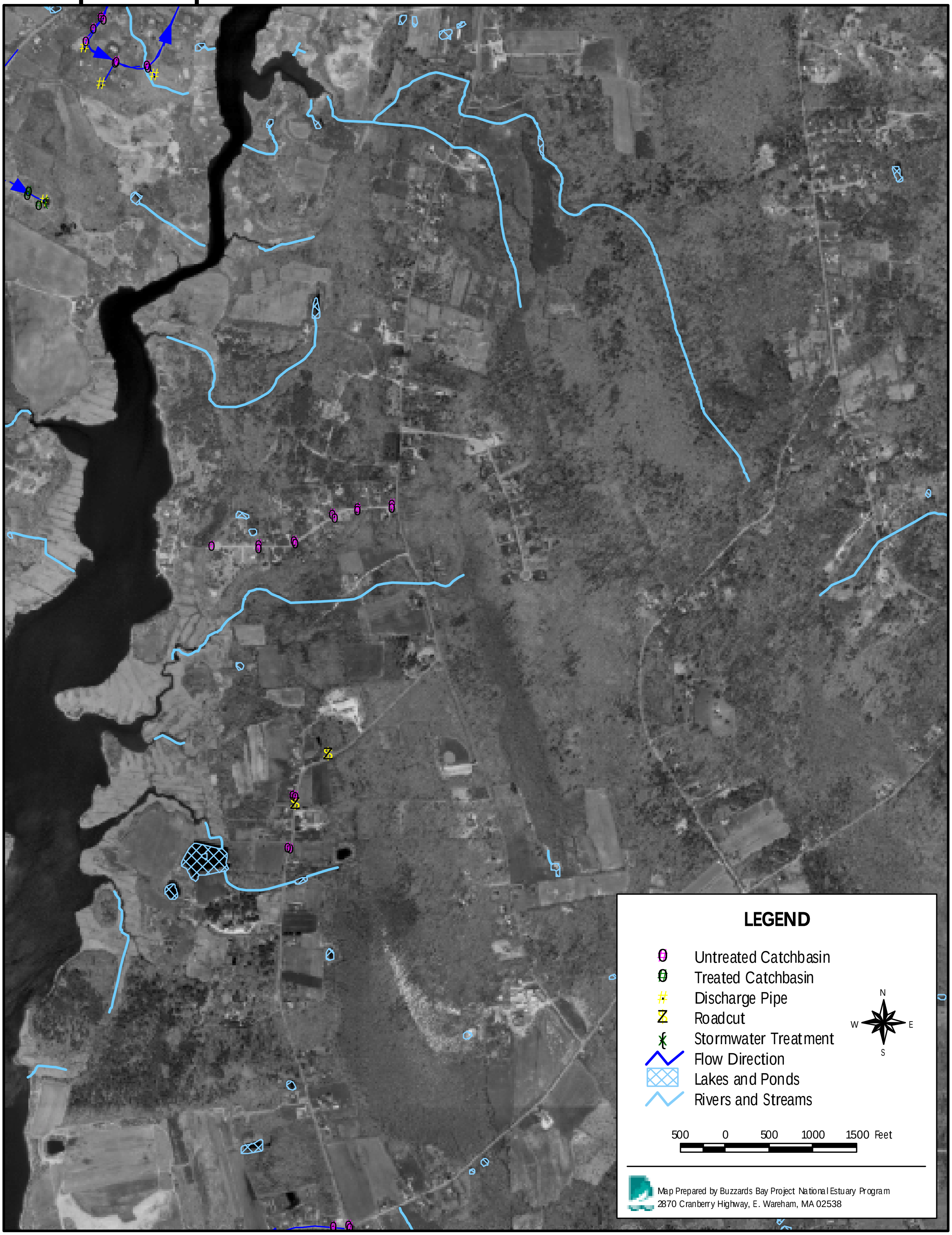
Westport: Map 2



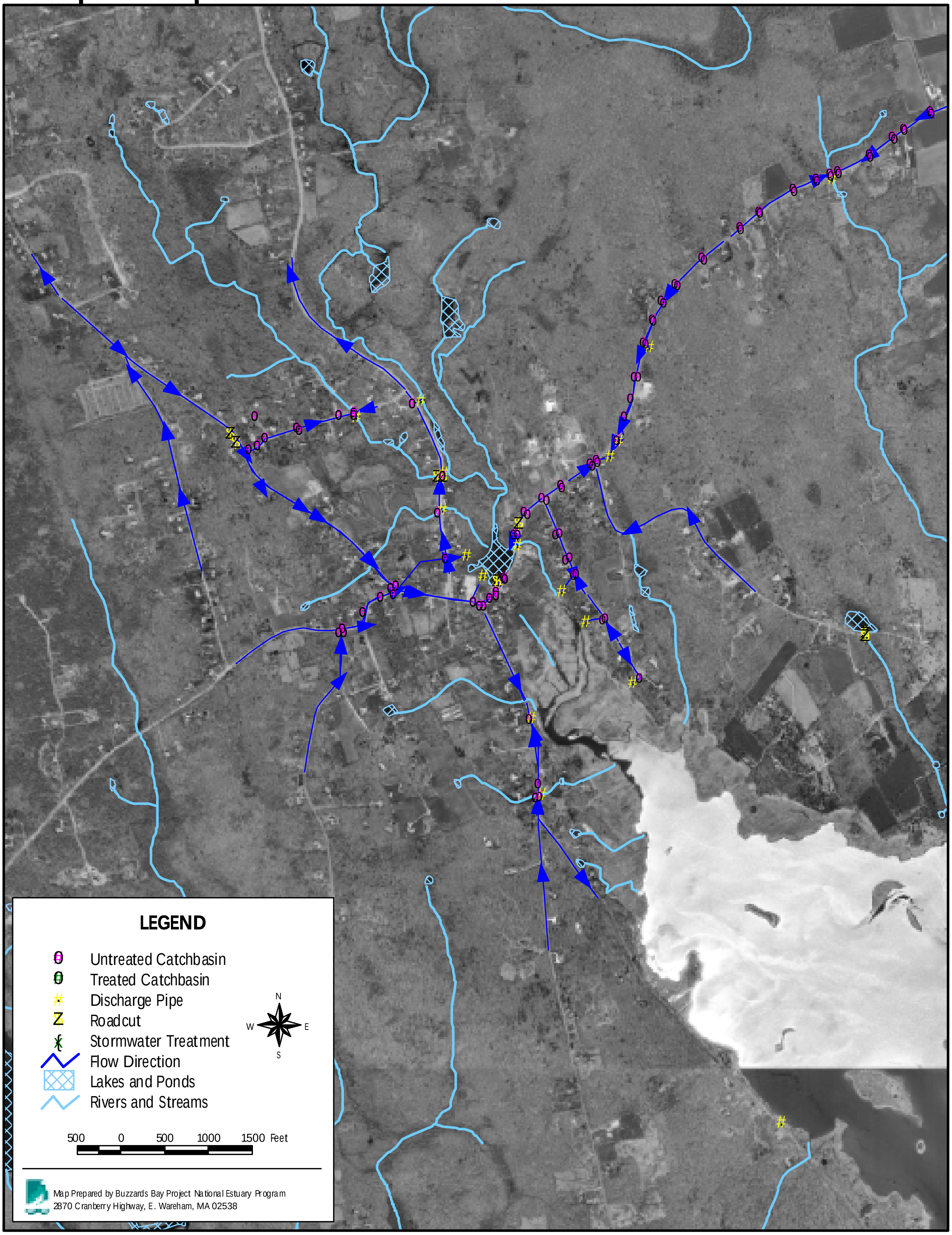
Westport: Map 3



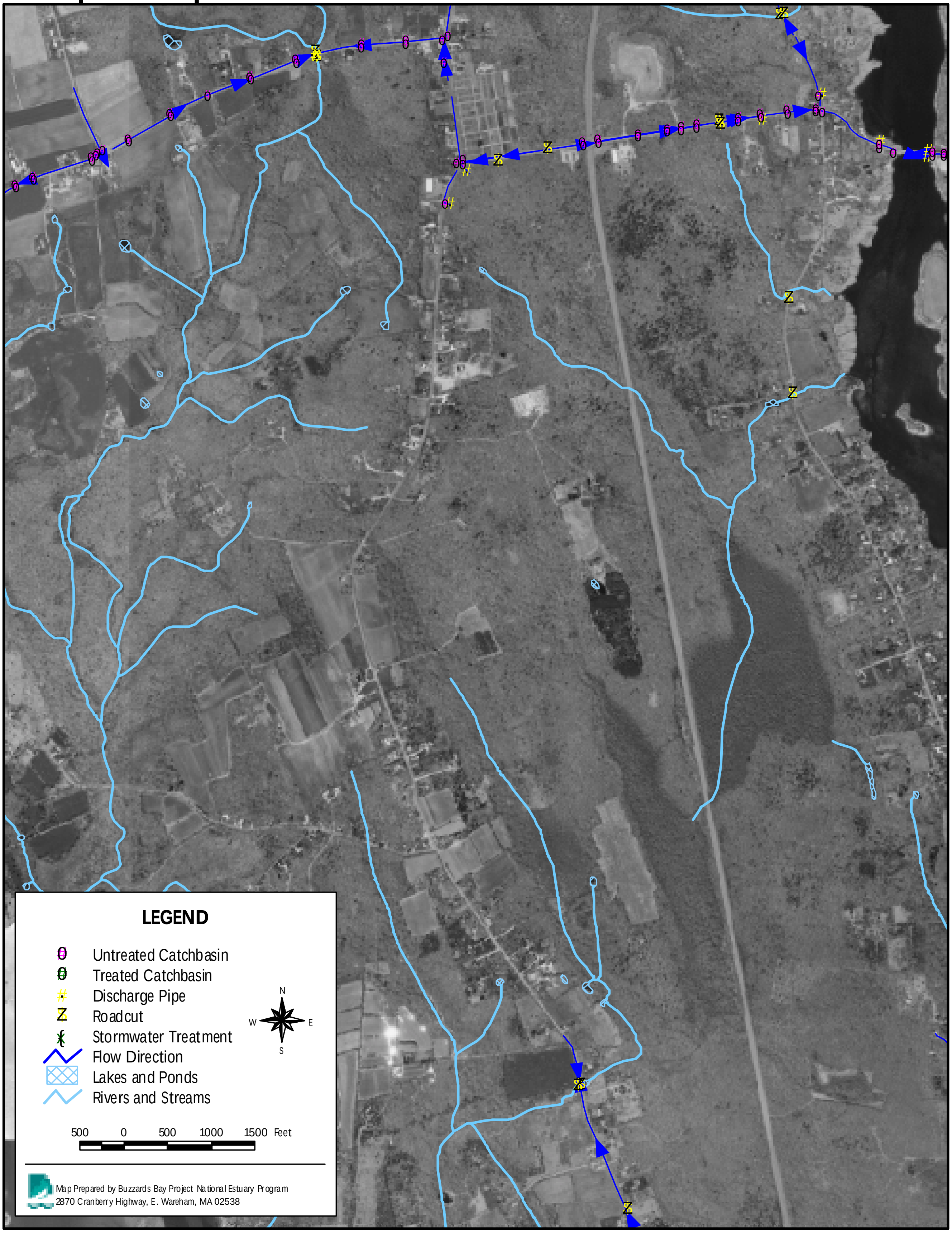
Westport: Map 4



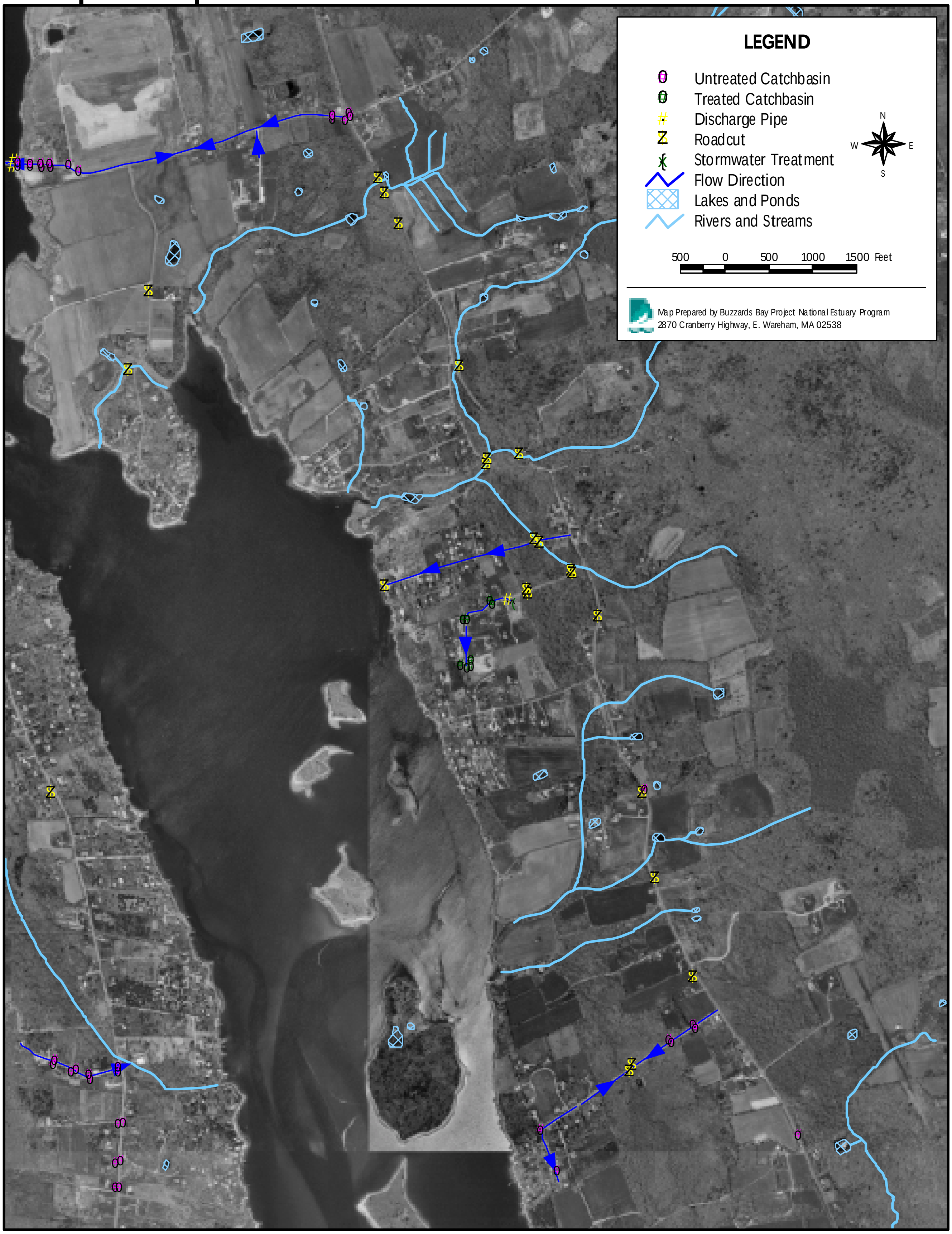
Westport: Map 5



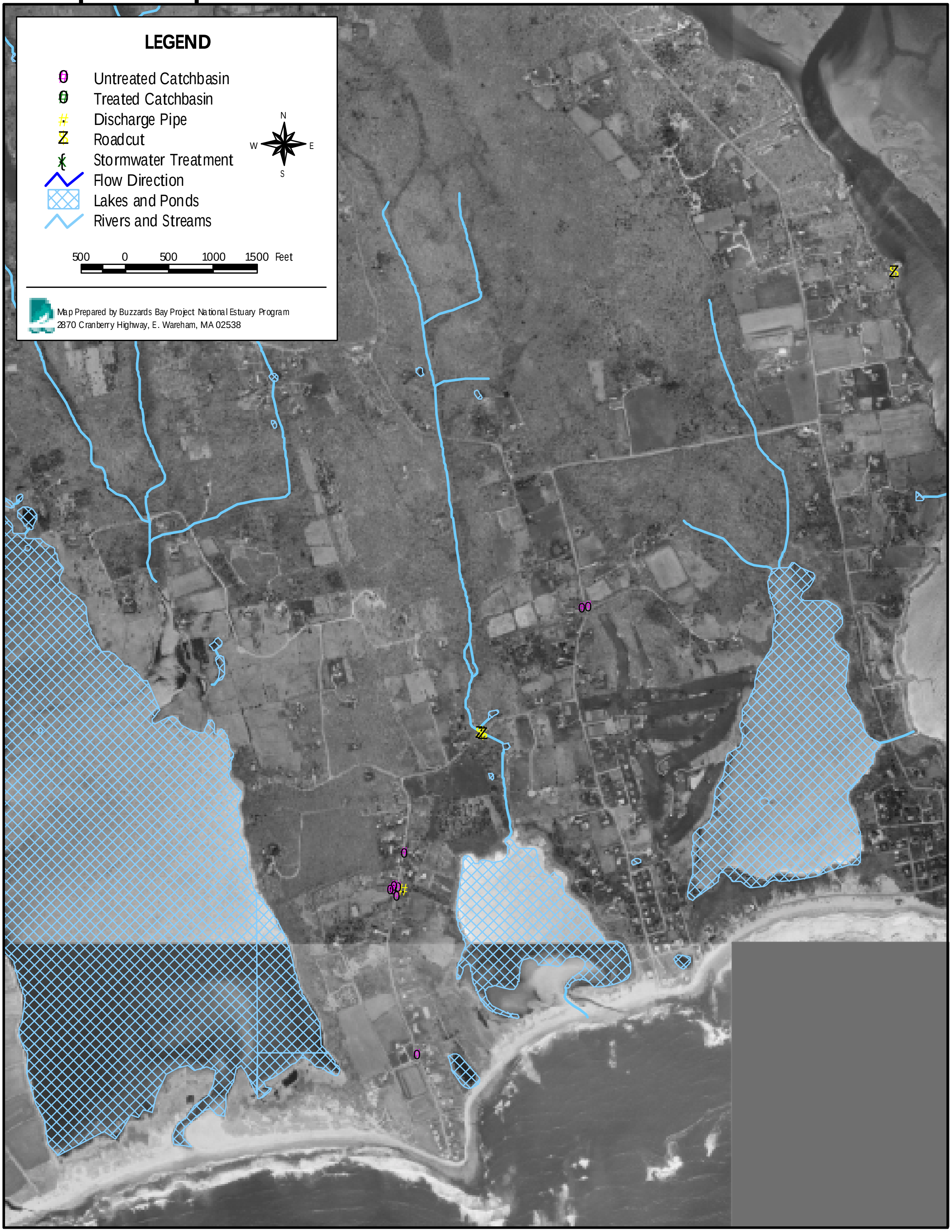
Westport: Map 6



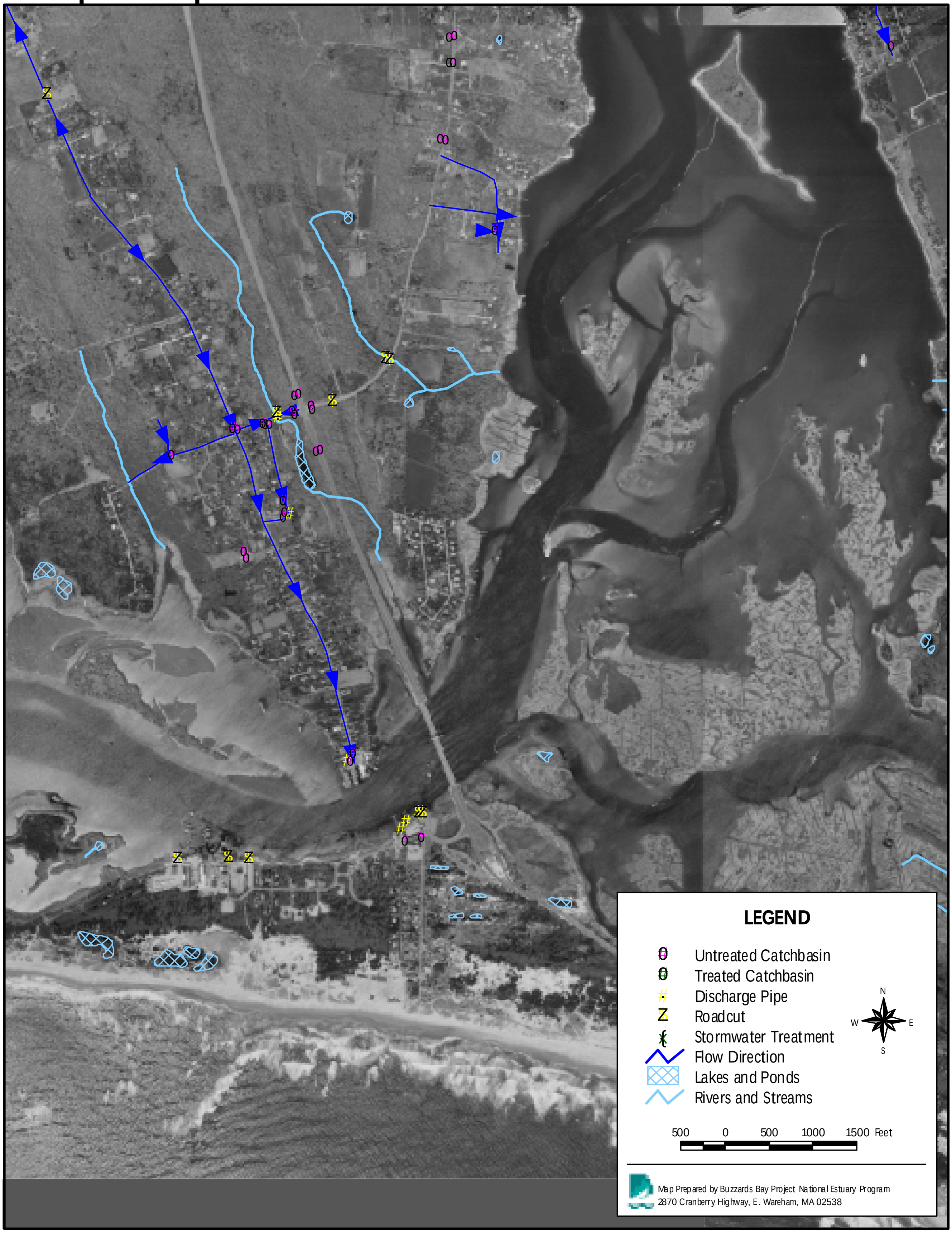
Westport: Map 7



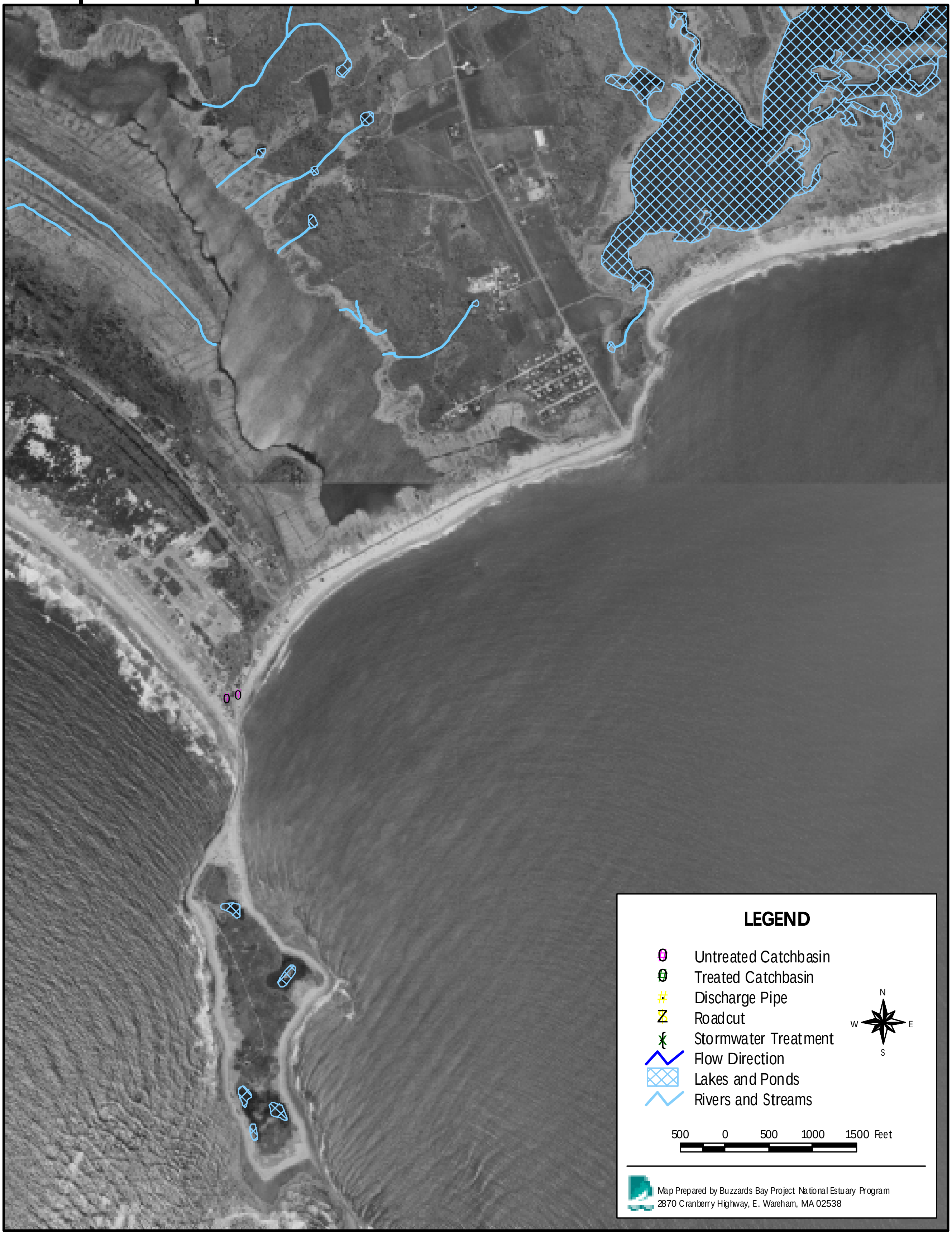
Westport: Map 8



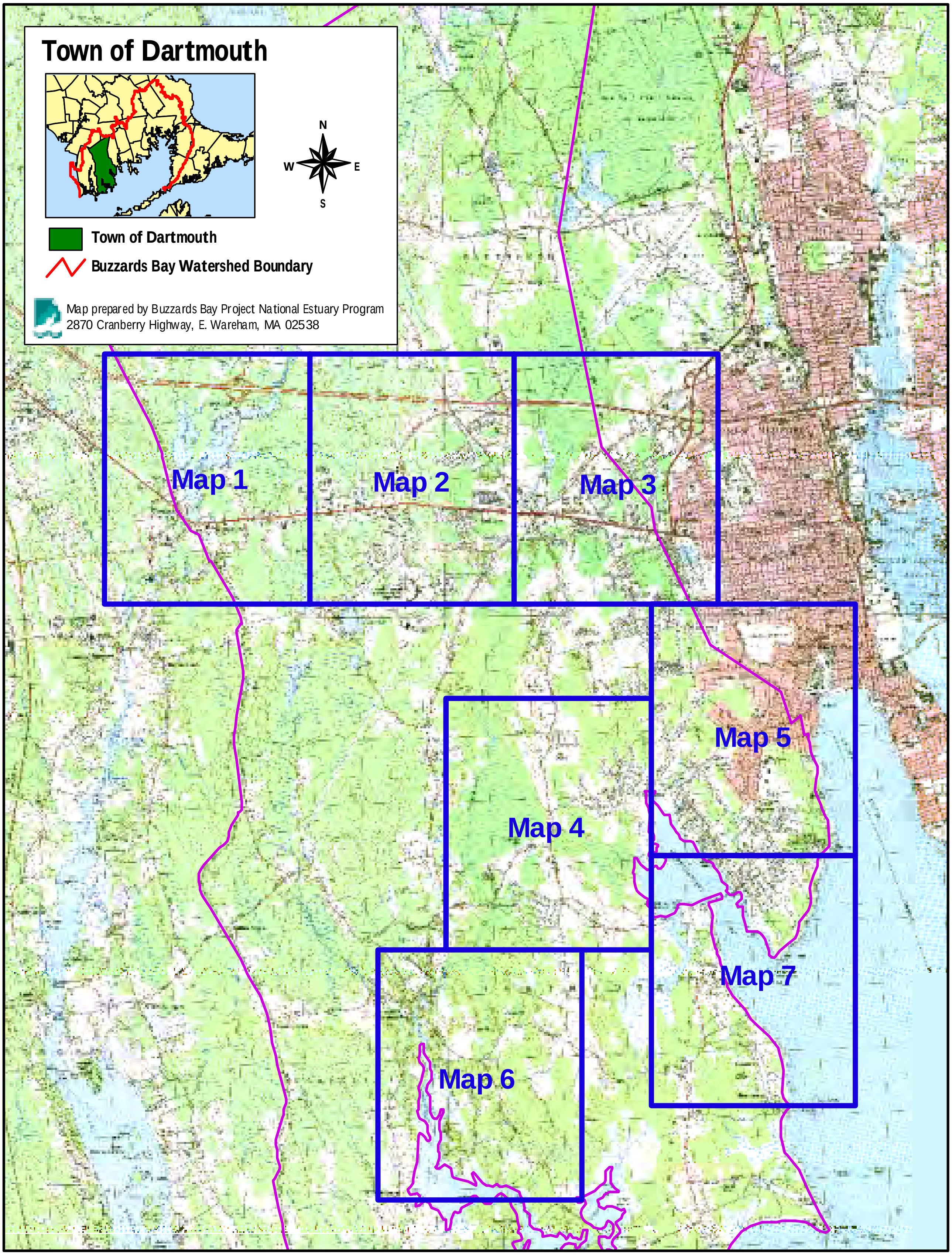
Westport: Map 9



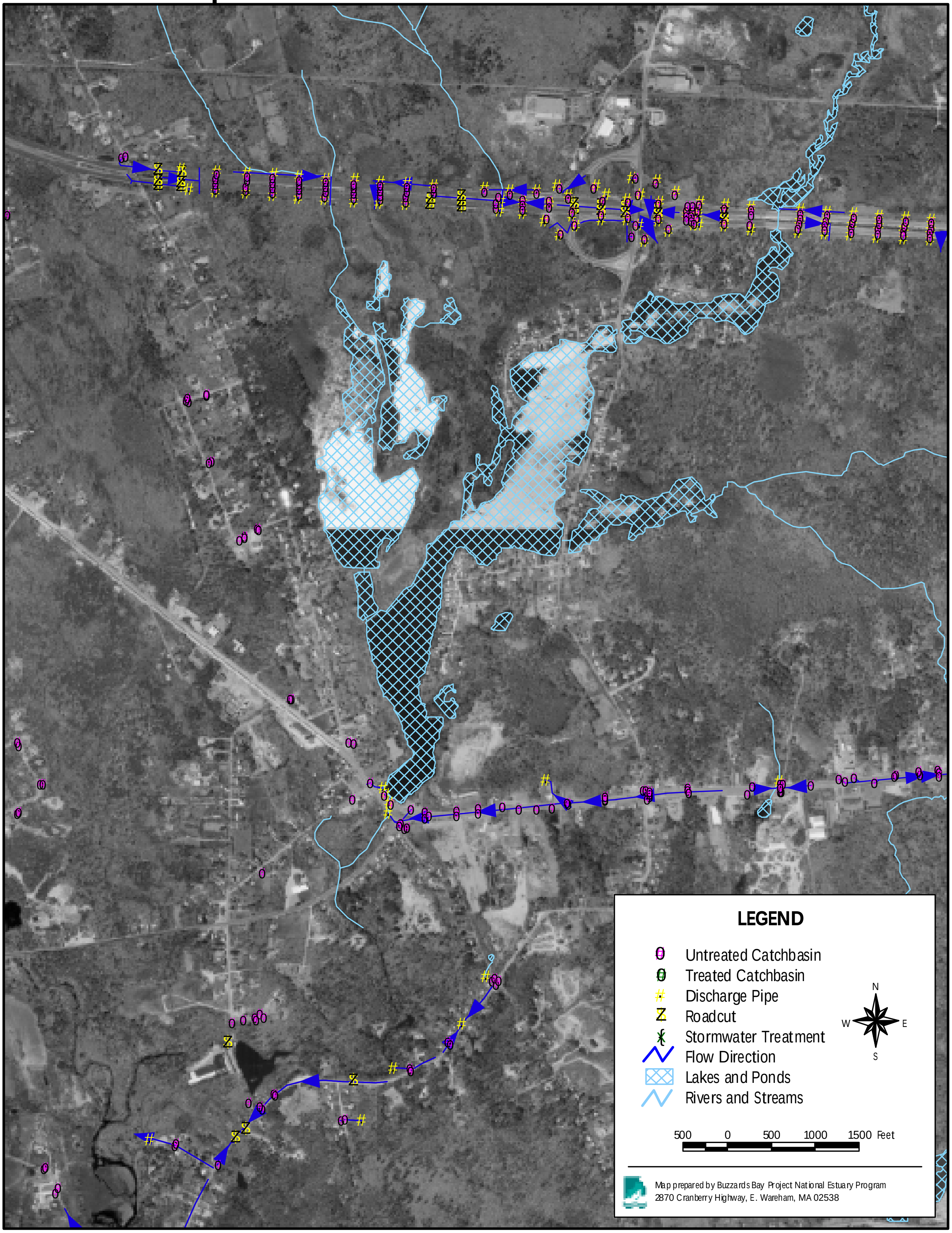
Westport: Map 10



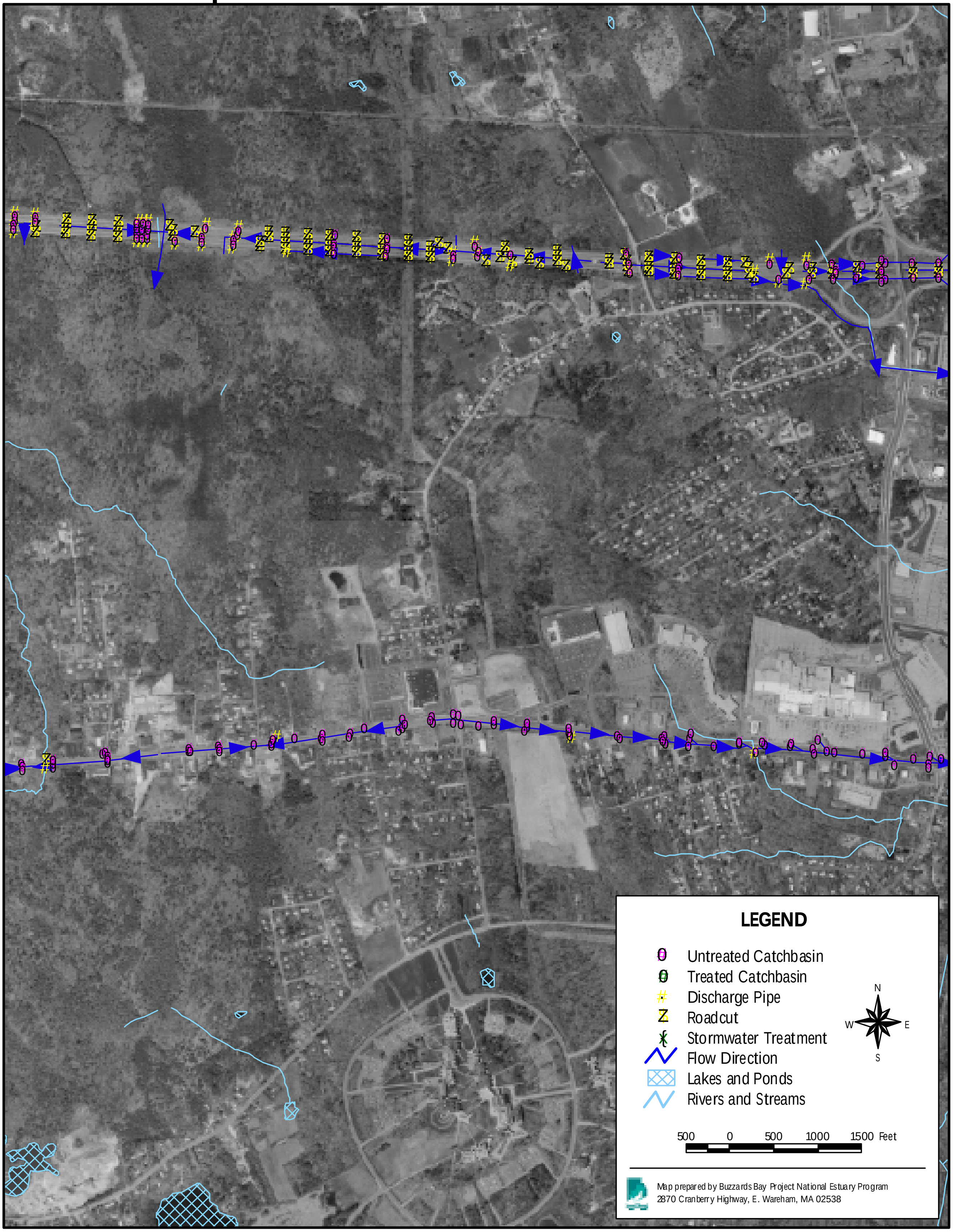
Key for Dartmouth Stormdrain Maps



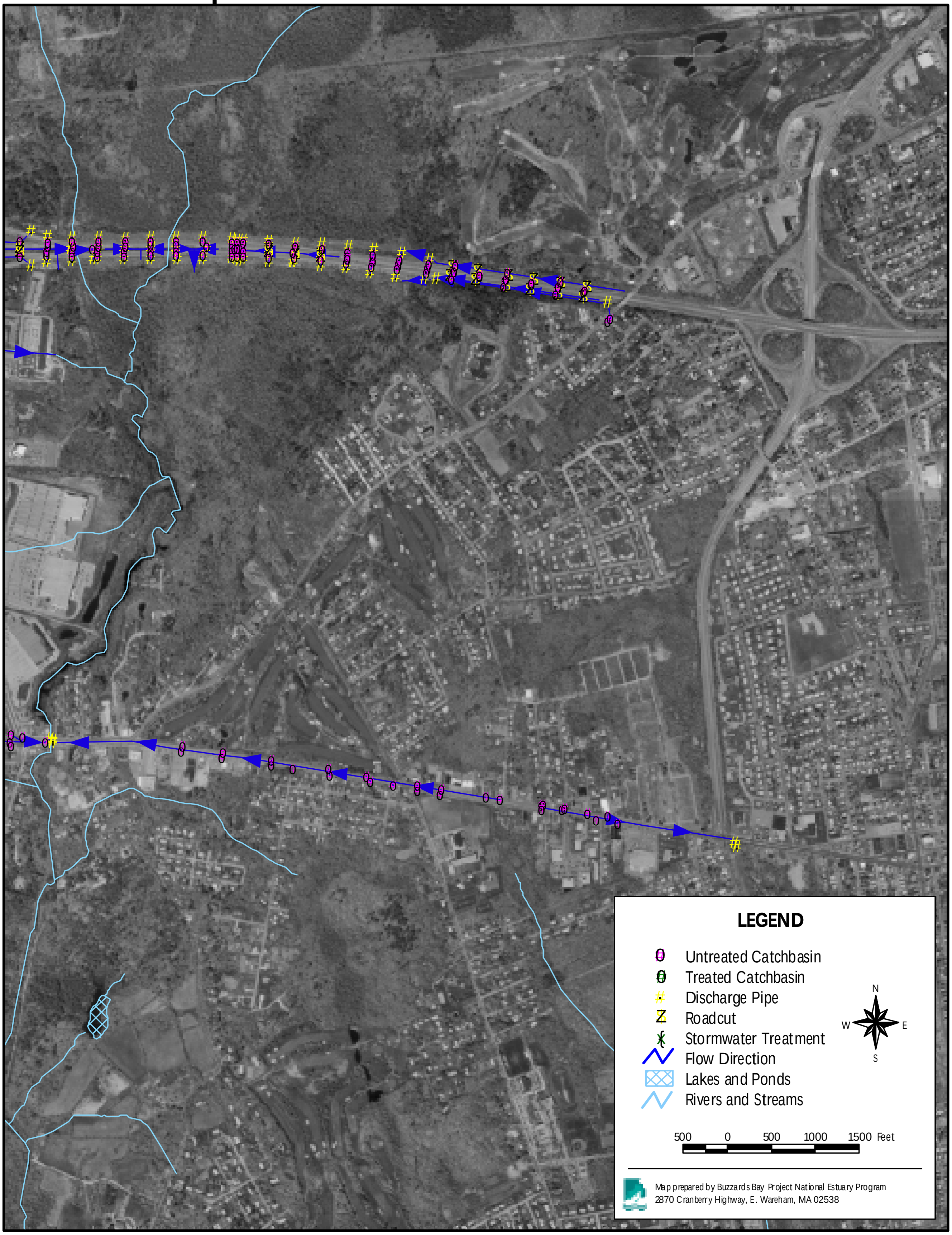
Dartmouth: Map 1



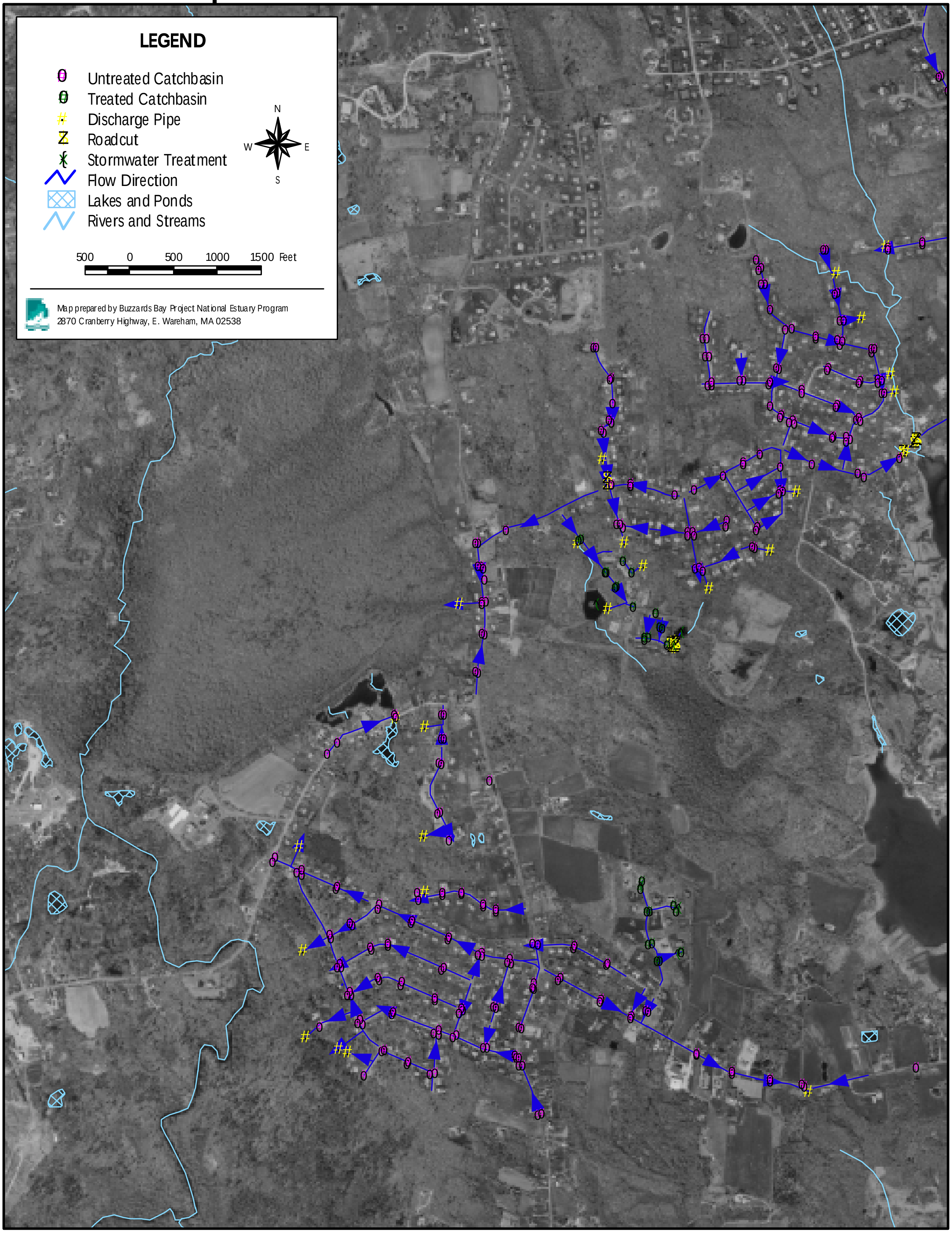
Dartmouth: Map 2



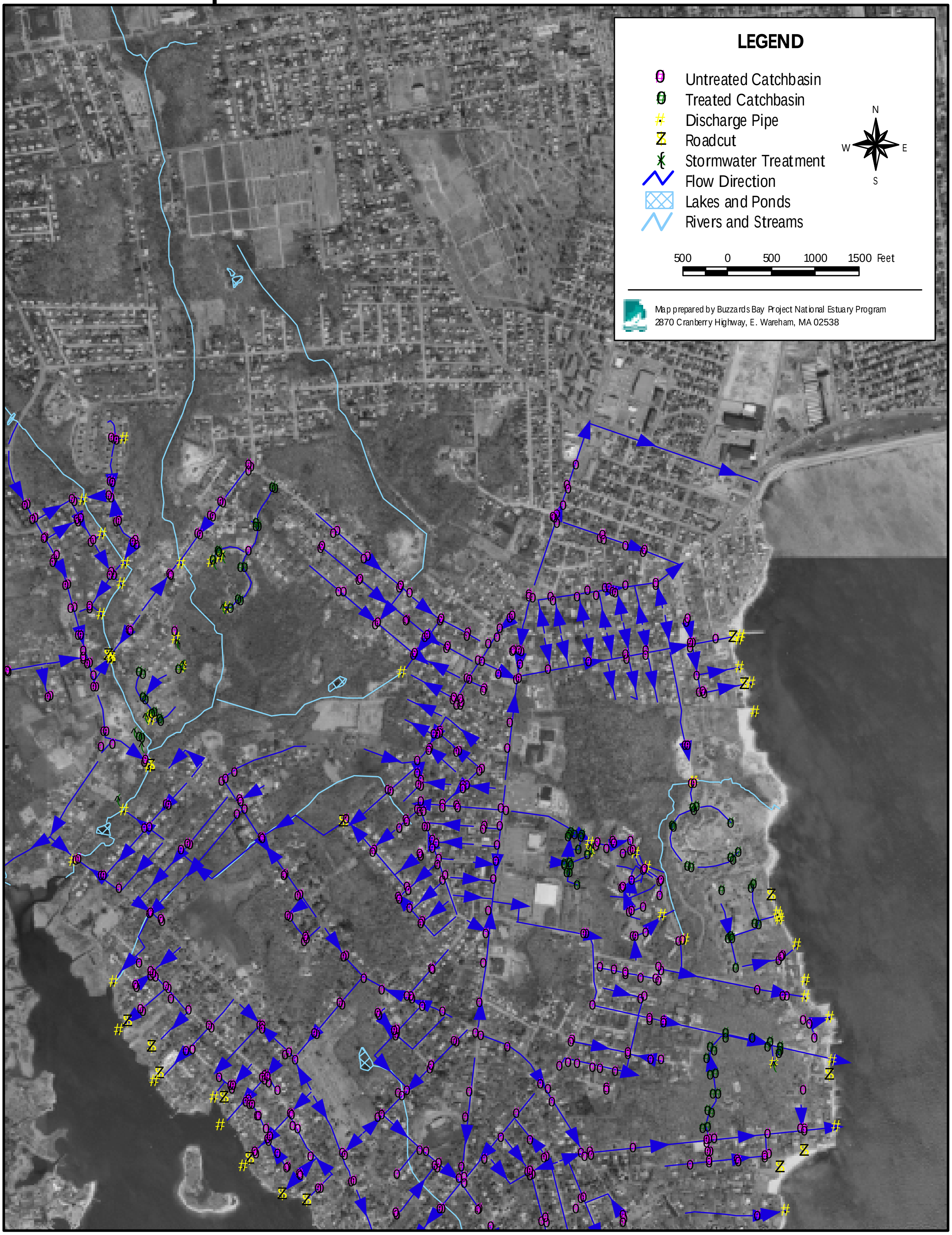
Dartmouth: Map 3



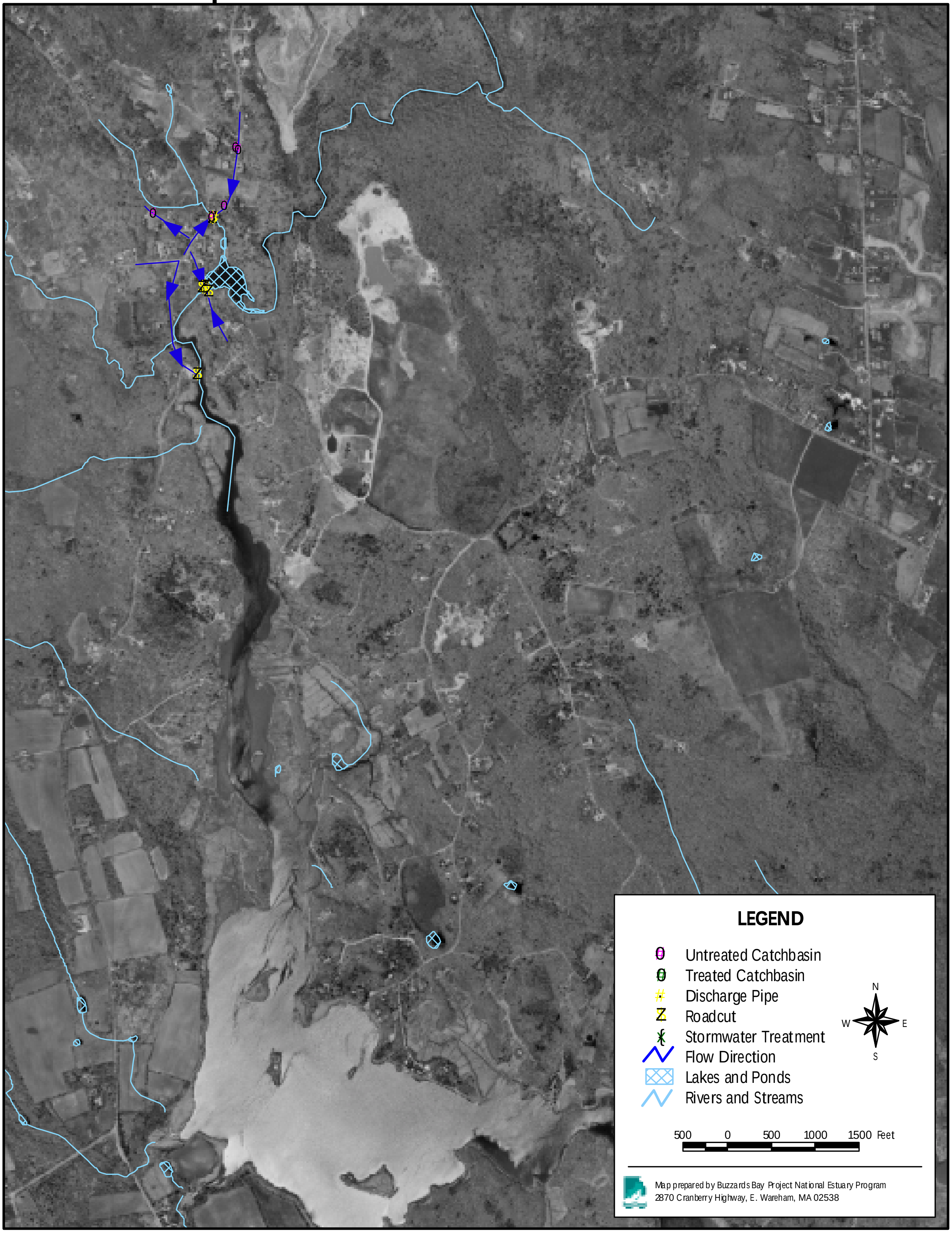
Dartmouth: Map 4



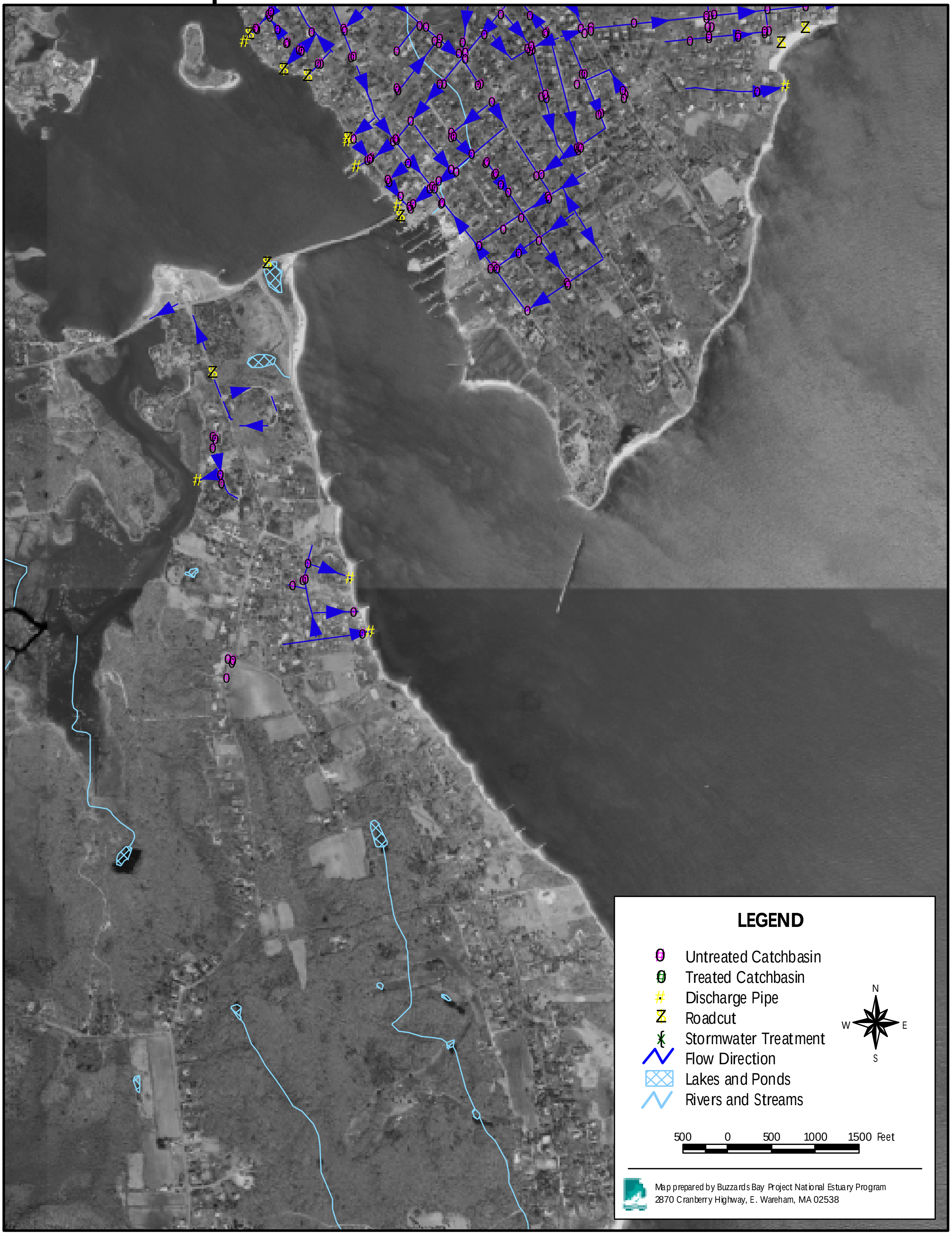
Dartmouth: Map 5



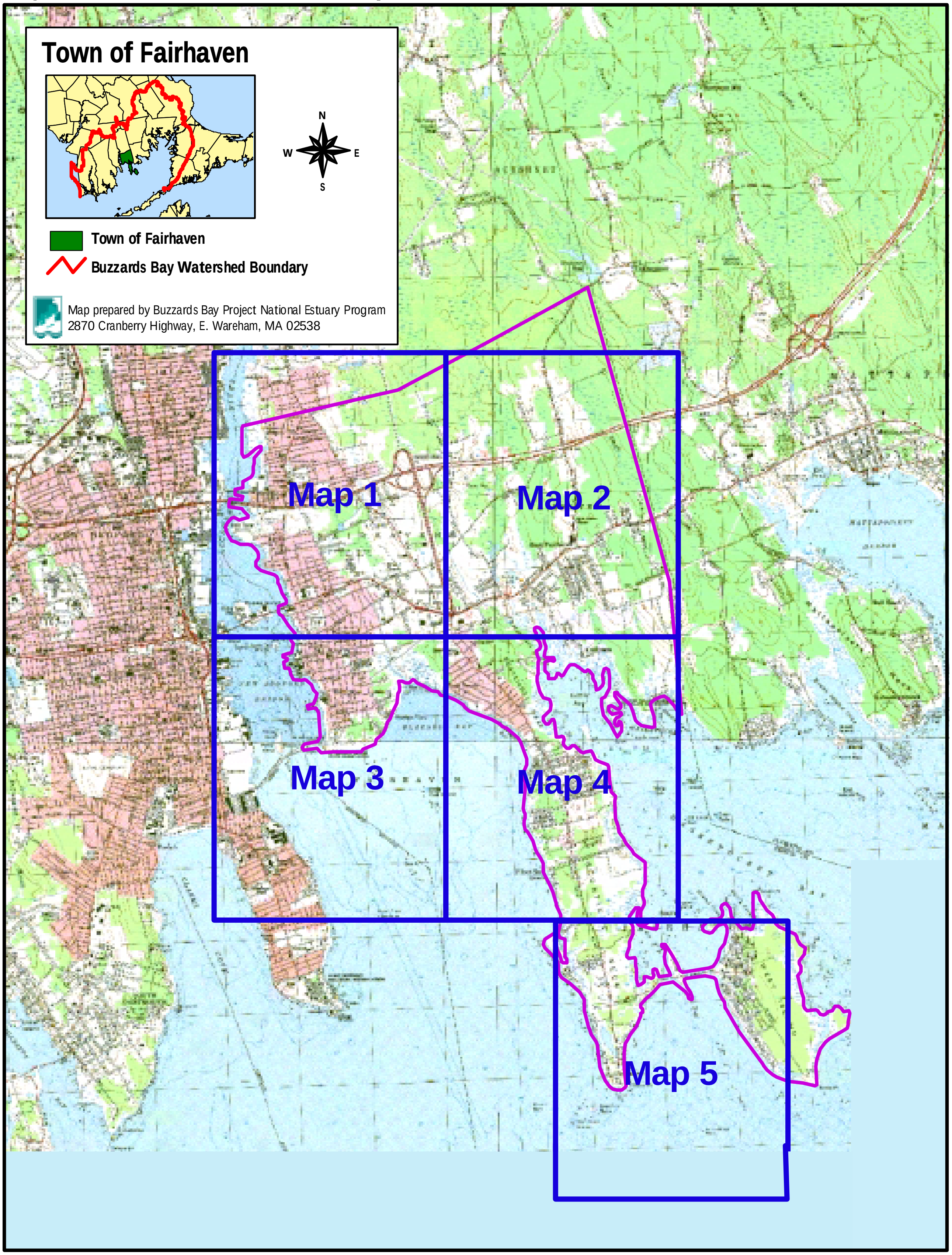
Dartmouth: Map 6



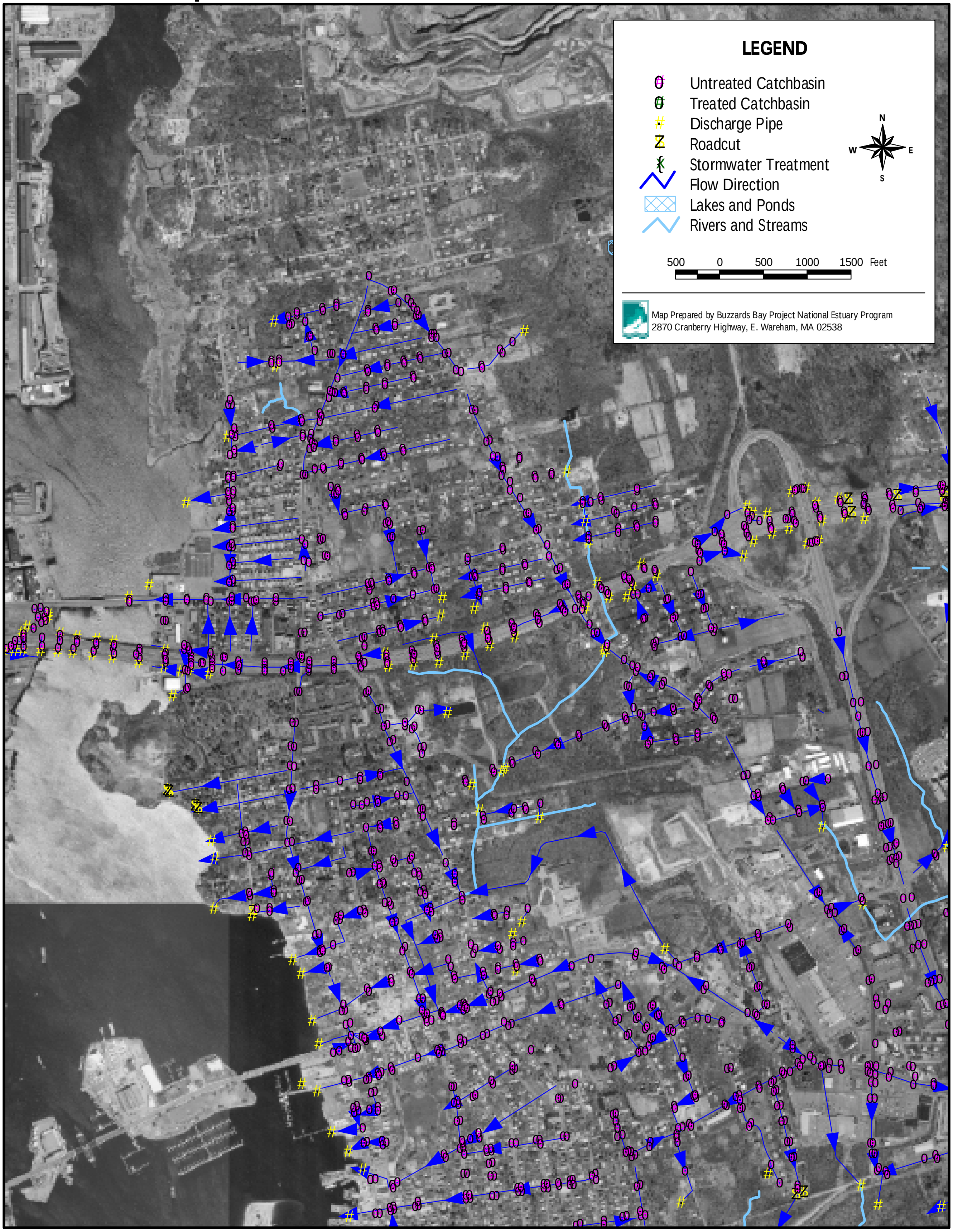
Dartmouth: Map 7



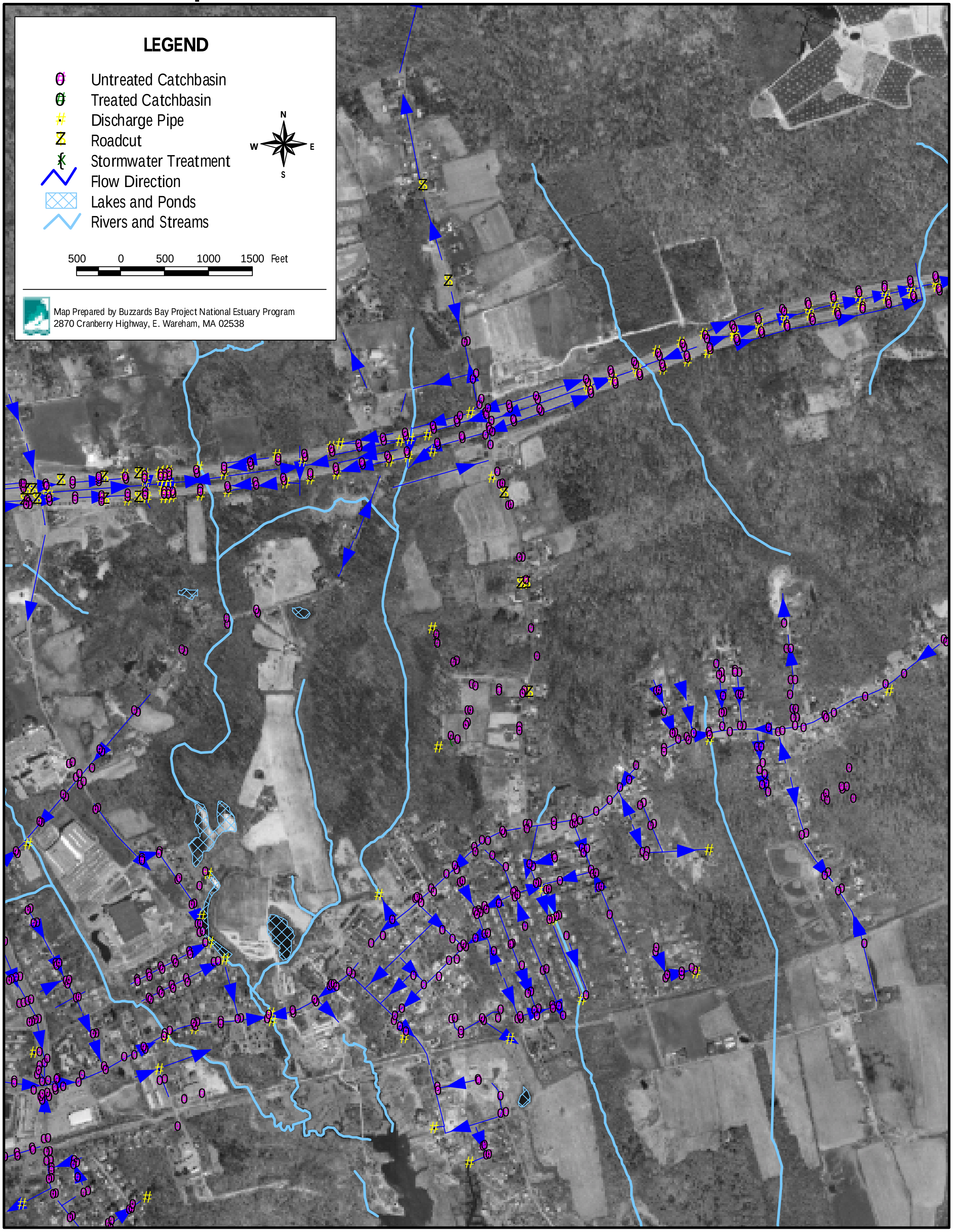
Key for Fairhaven Stormdrain Maps



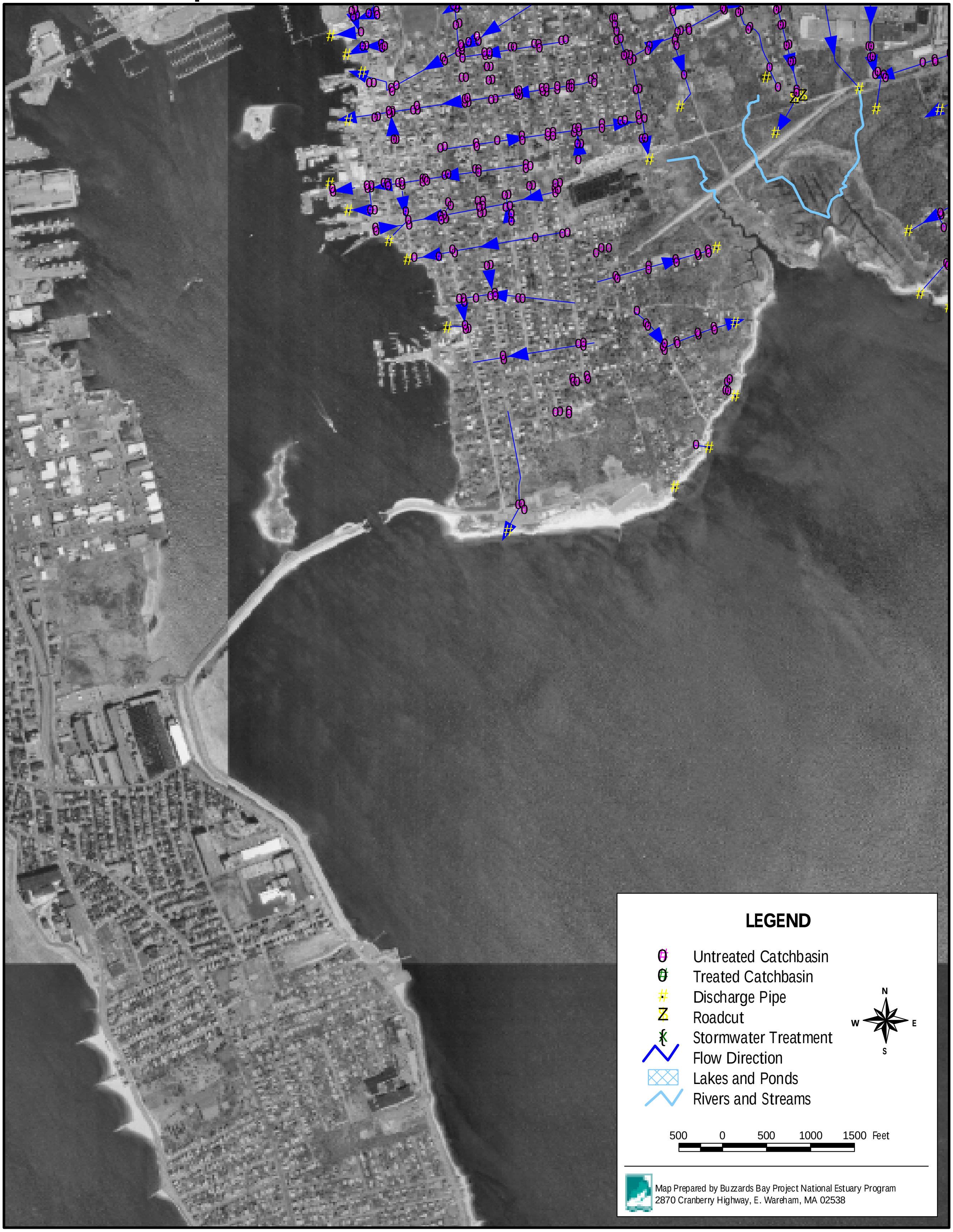
Fairhaven: Map 1



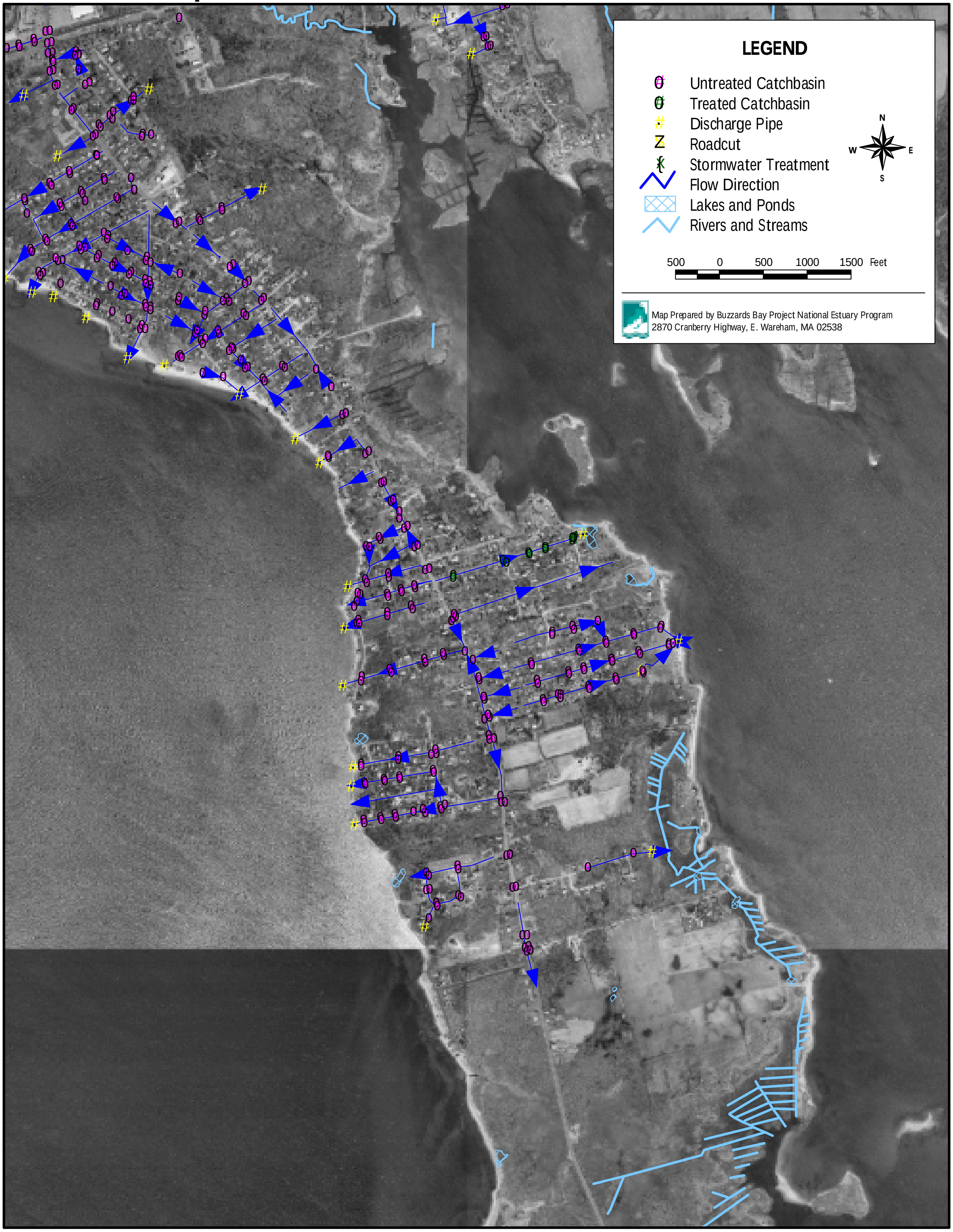
Fairhaven: Map 2



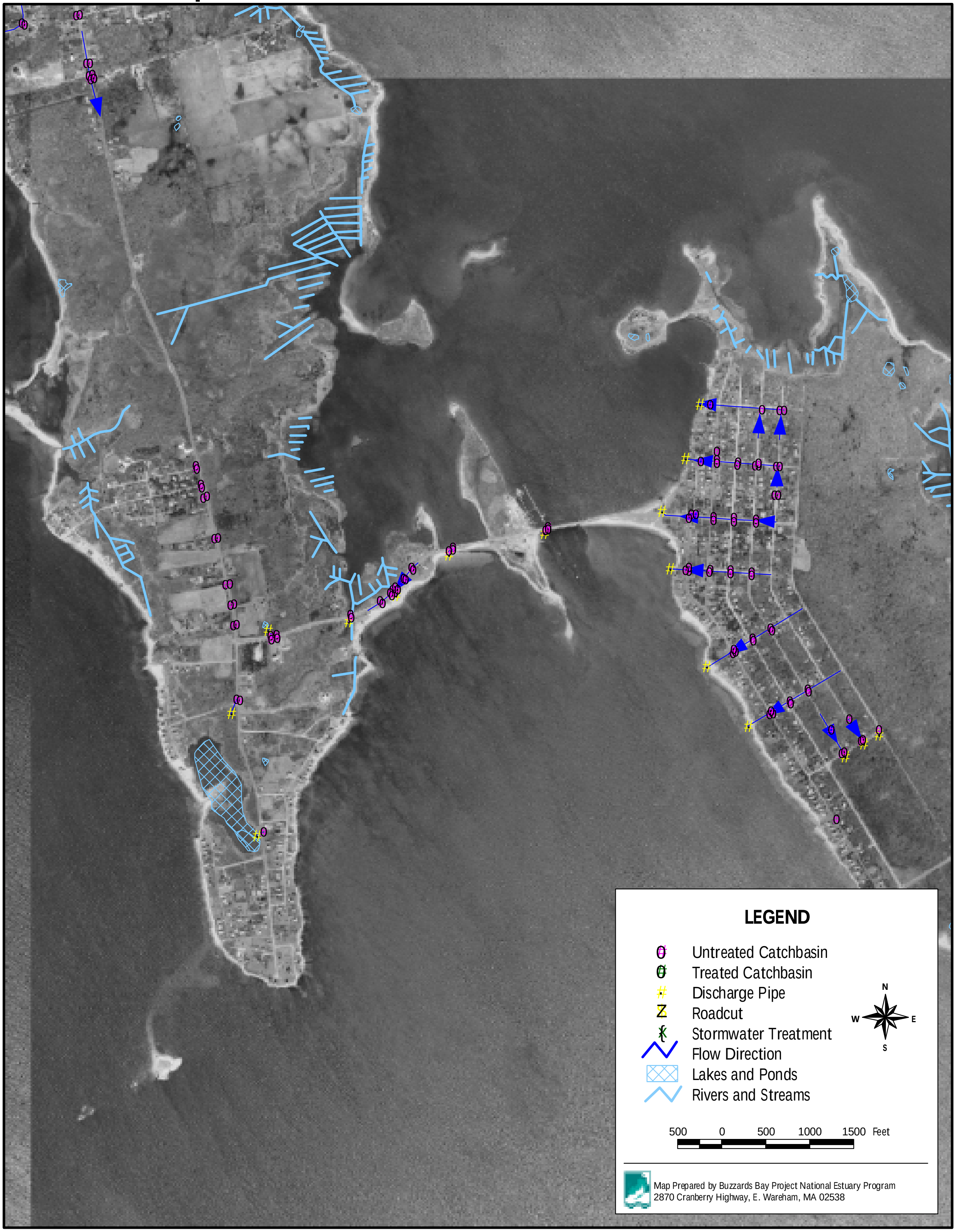
Fairhaven: Map 3



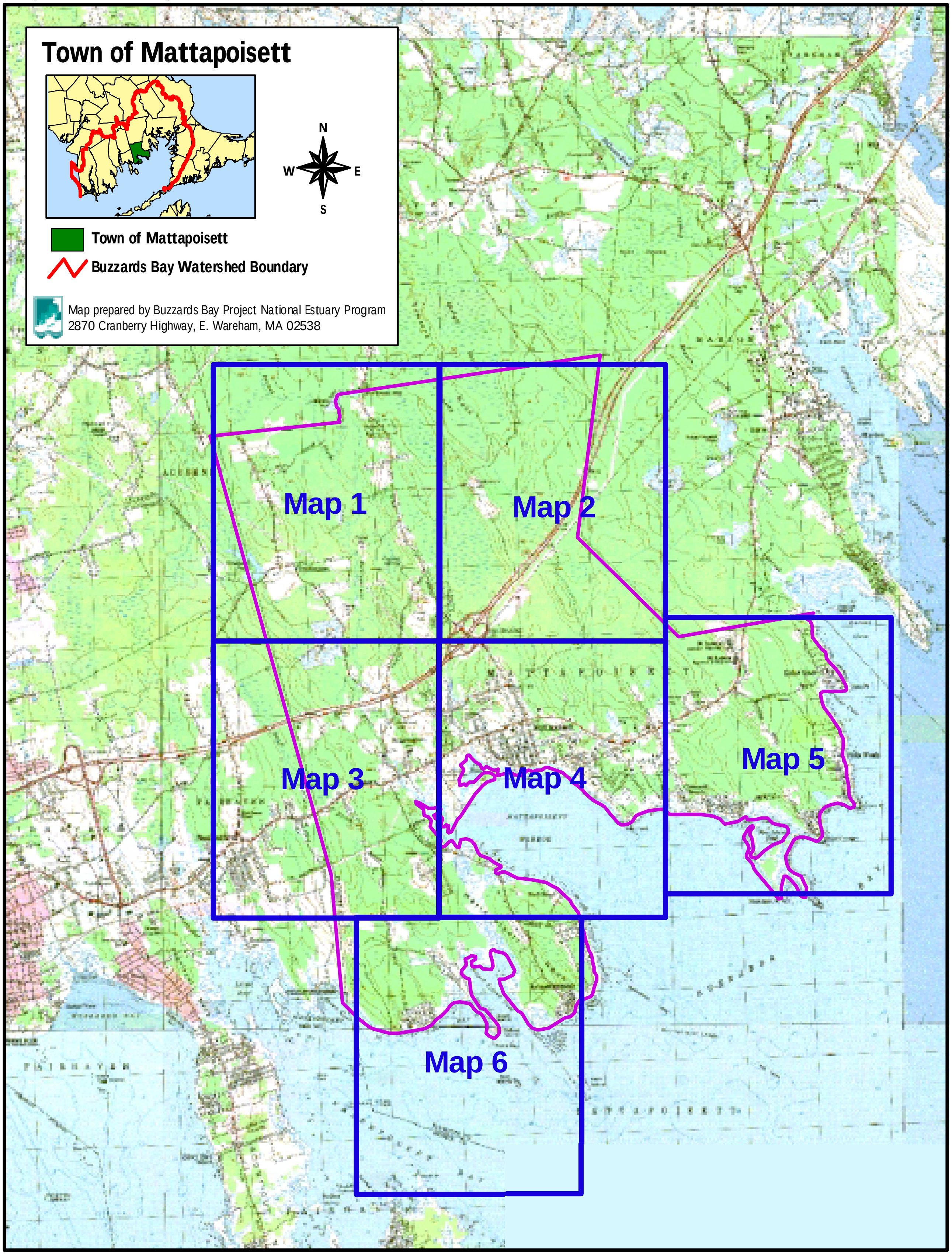
Fairhaven: Map 4



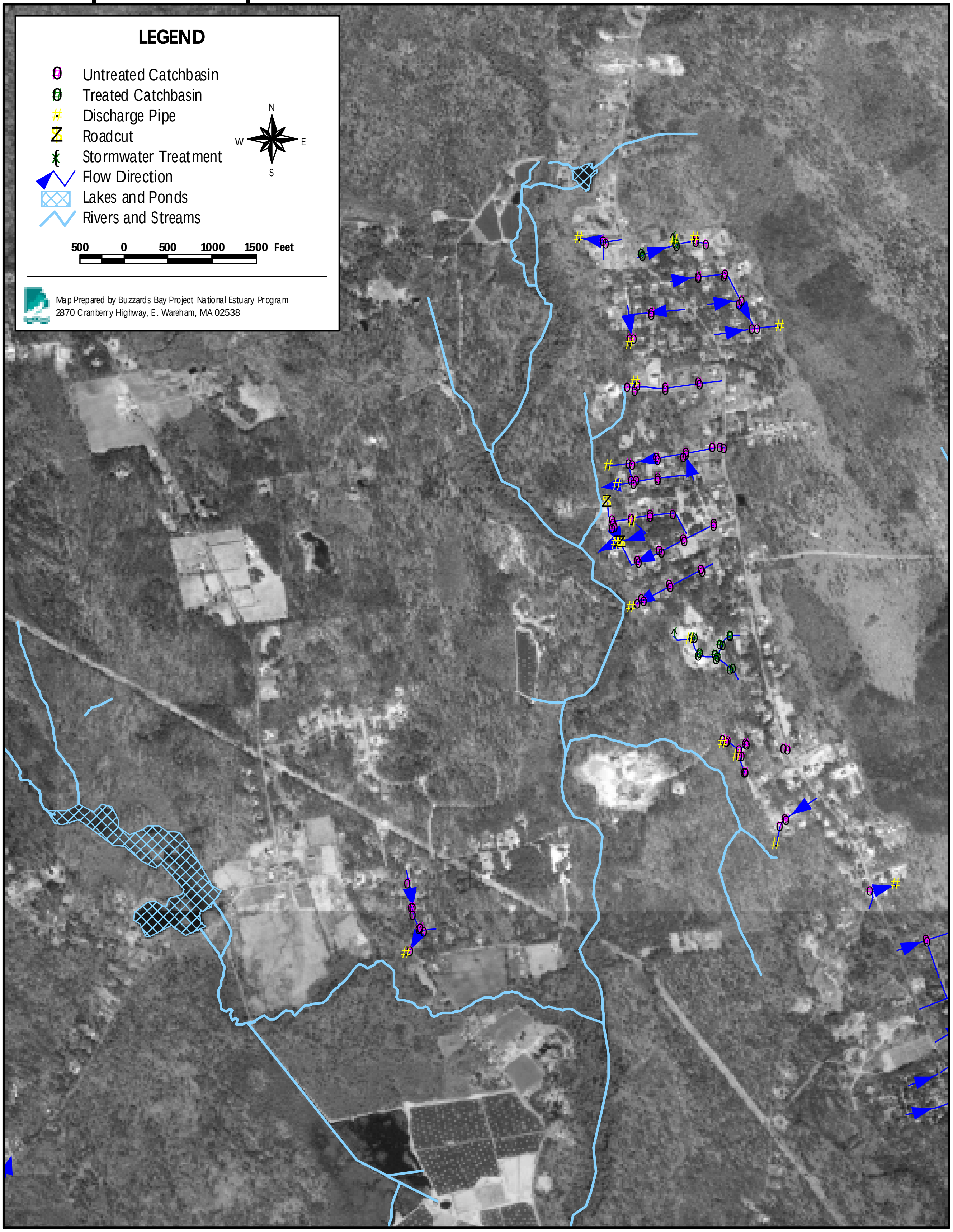
Fairhaven: Map 5



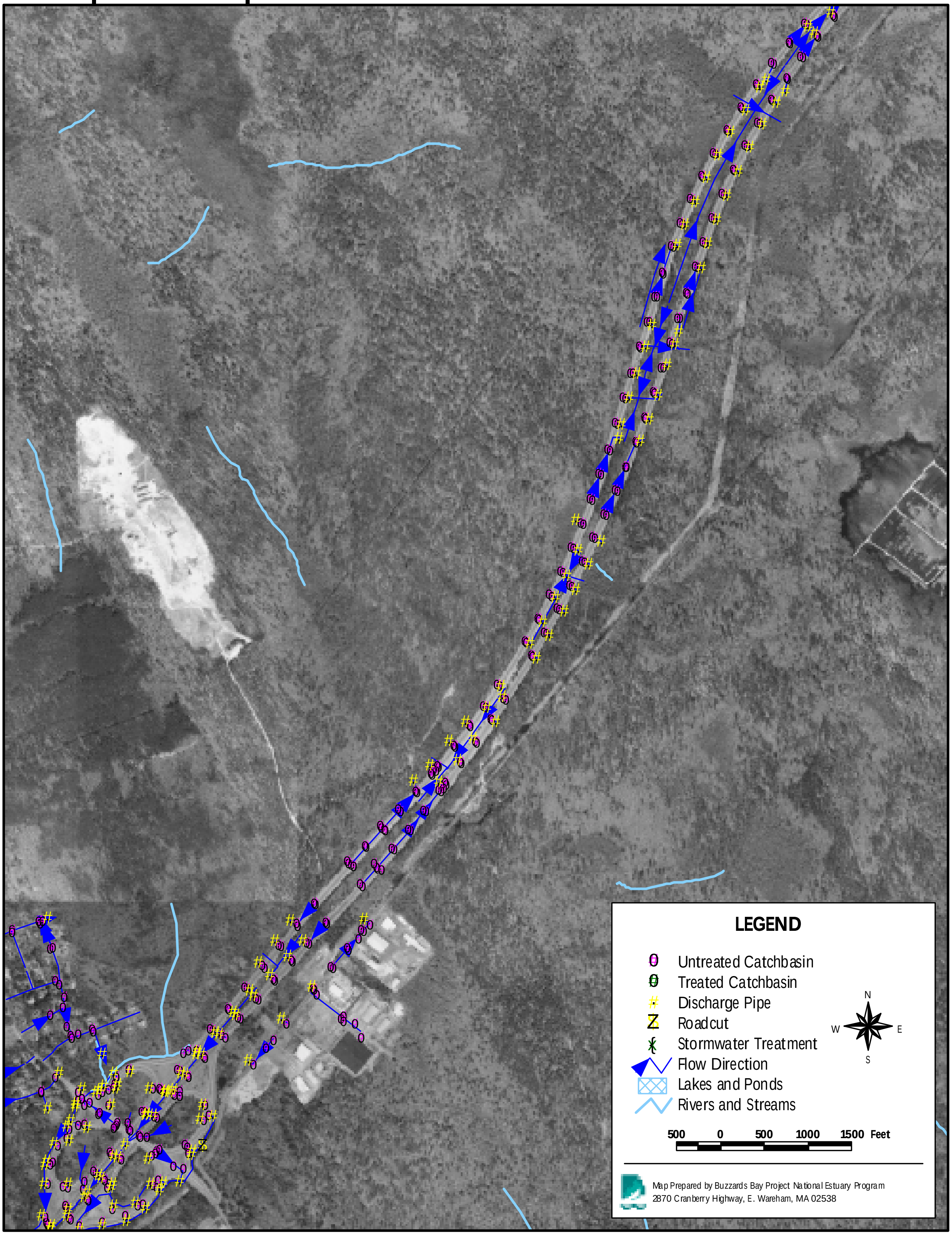
Key for Mattapoisett Stormdrain Maps



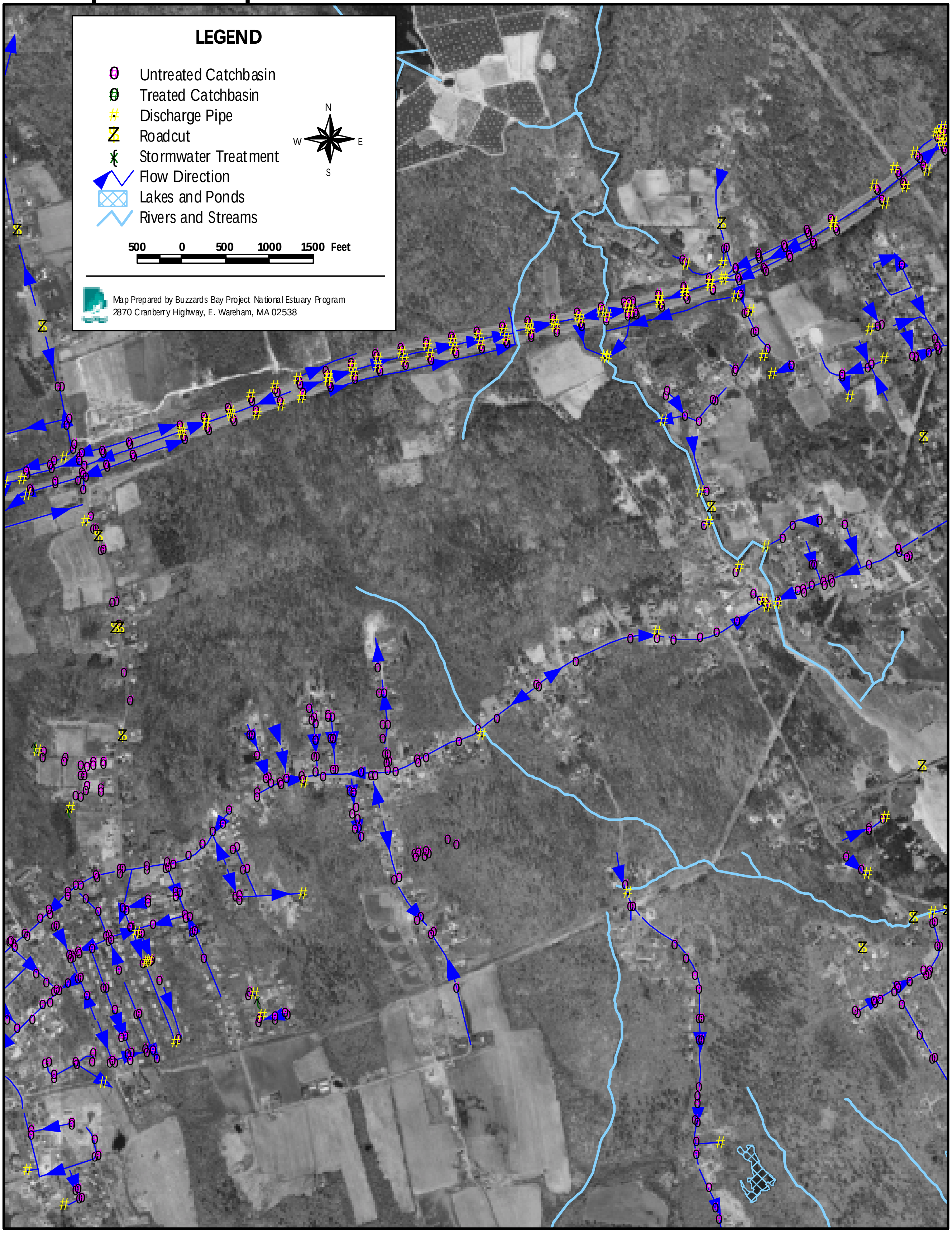
Mattapoisett: Map 1



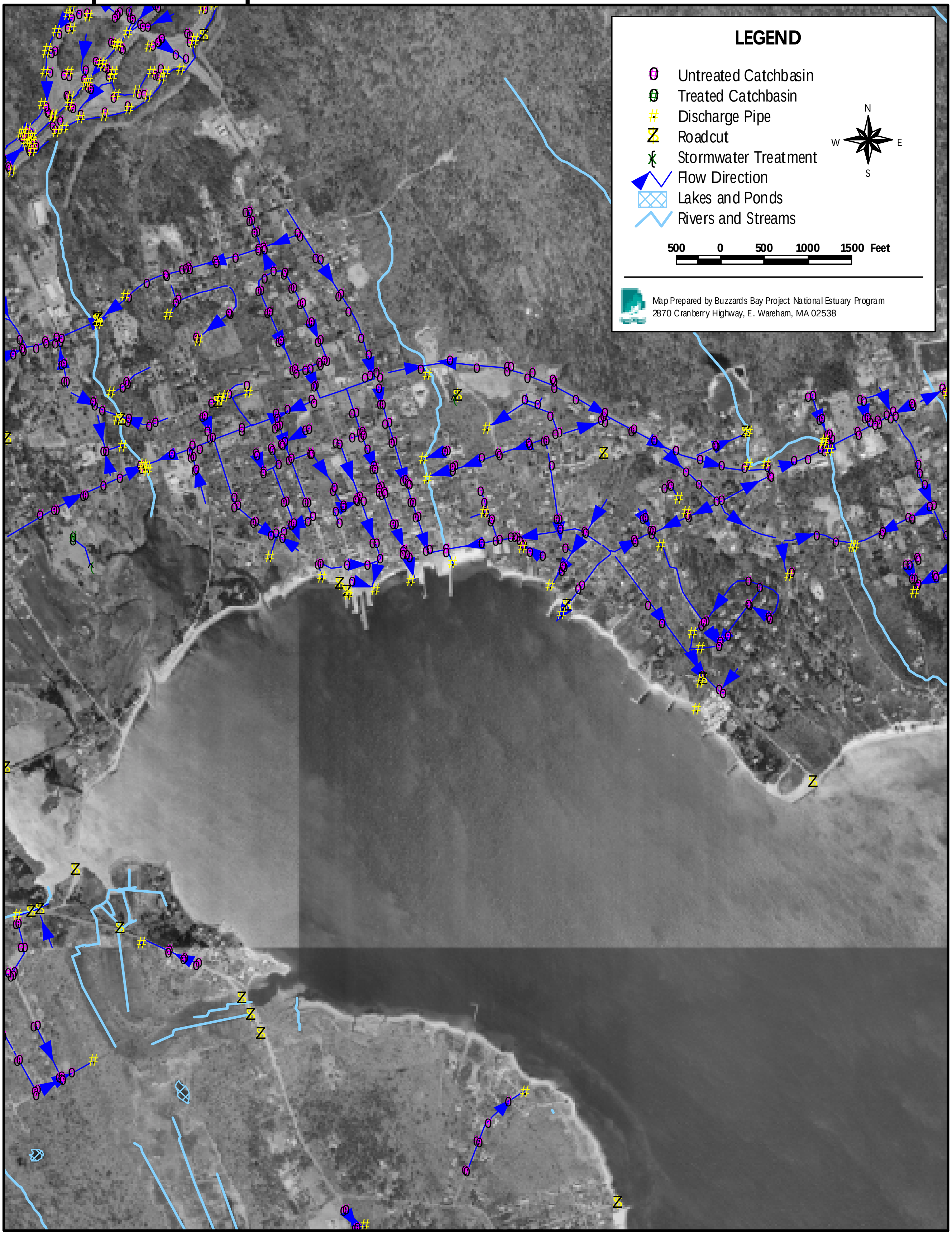
Mattapoisett: Map 2



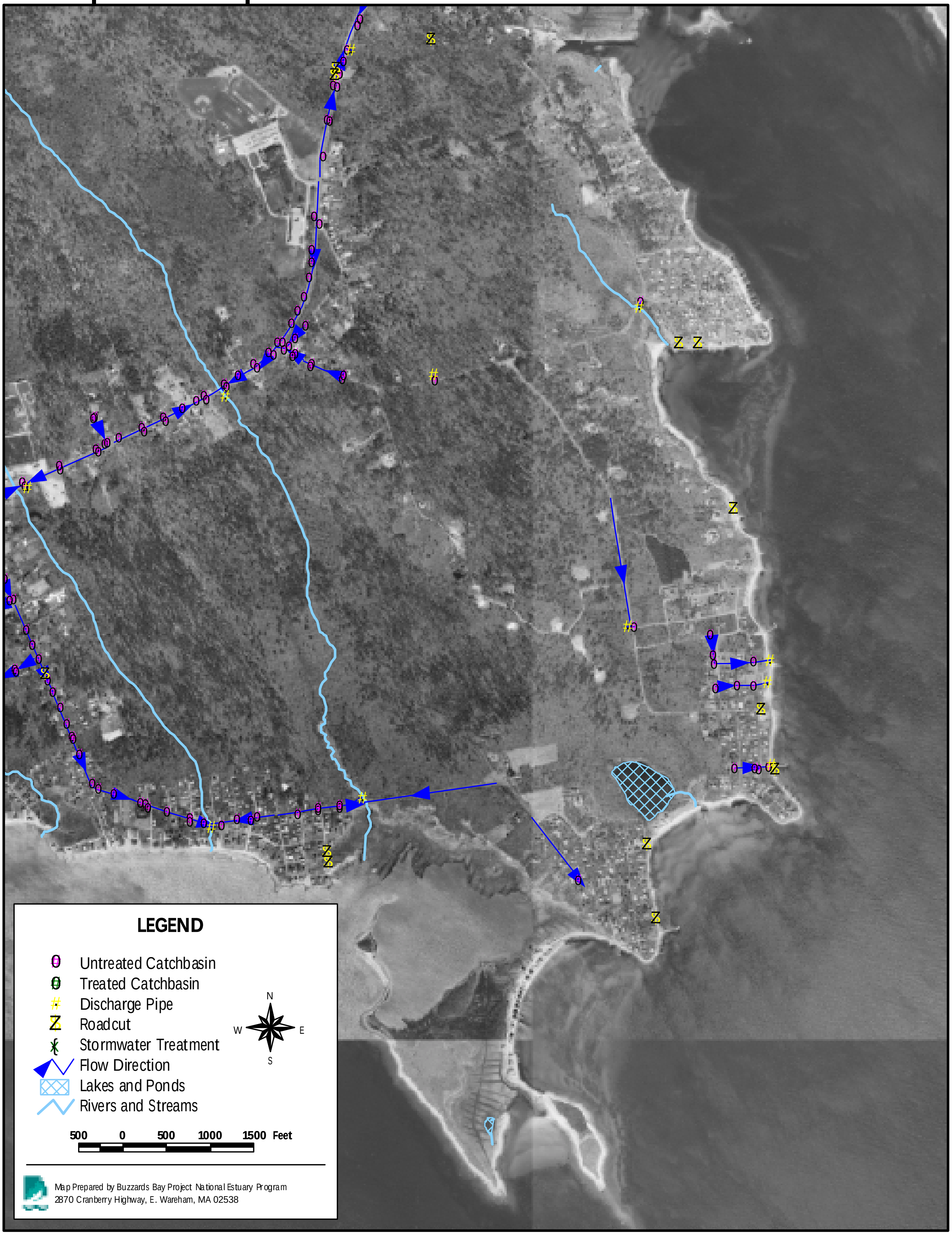
Mattapoisett: Map 3



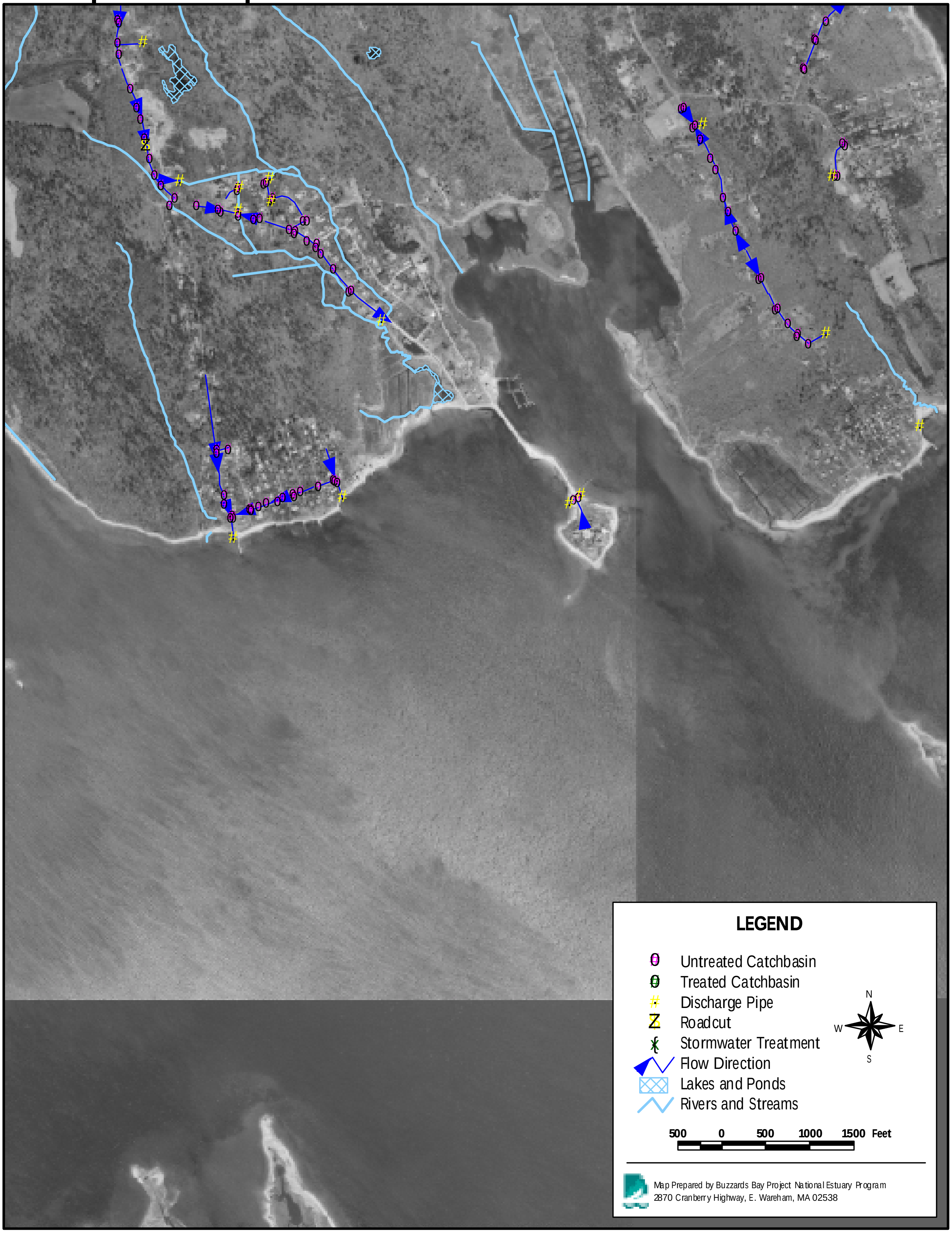
Mattapoisett: Map 4



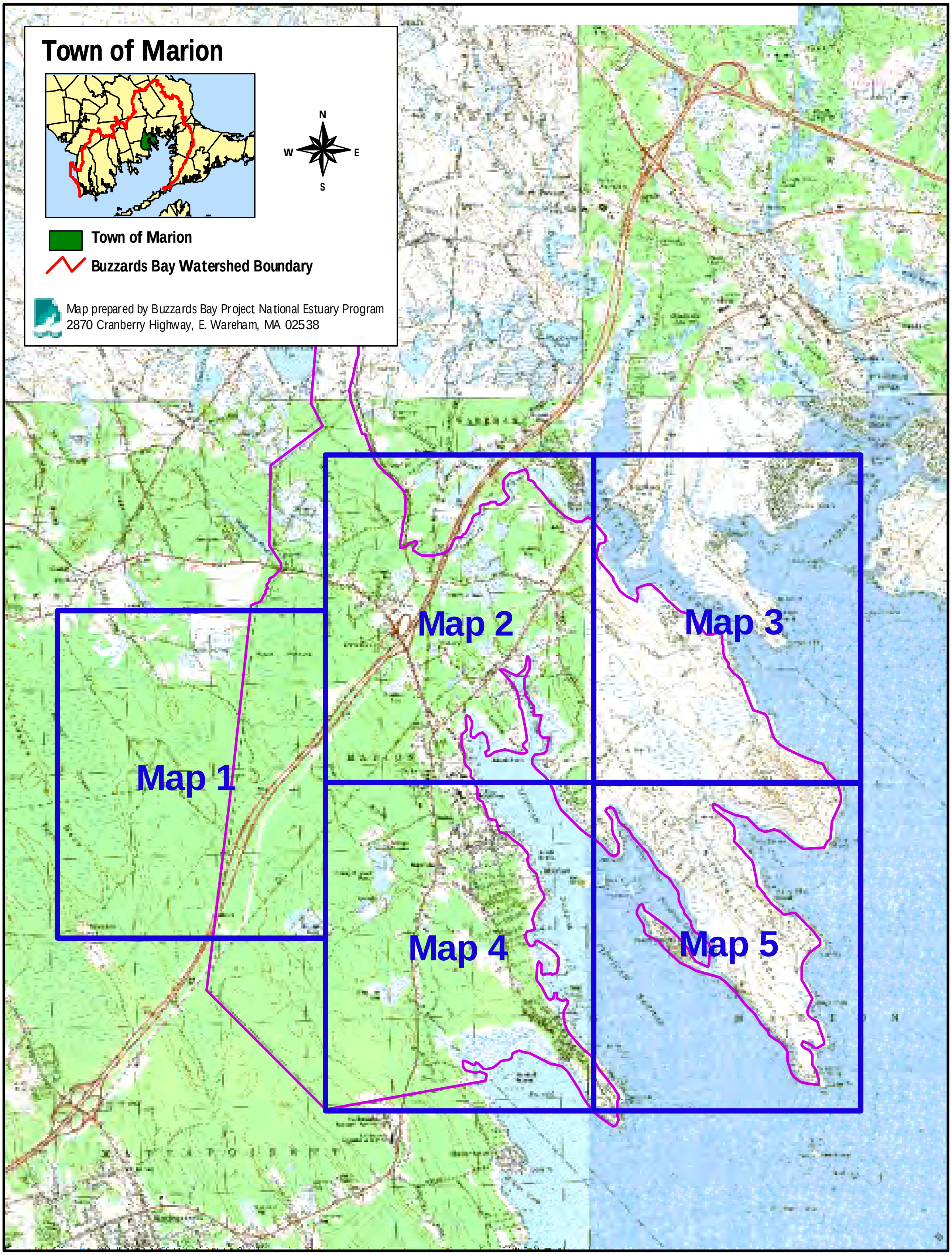
Mattapoisett: Map 5



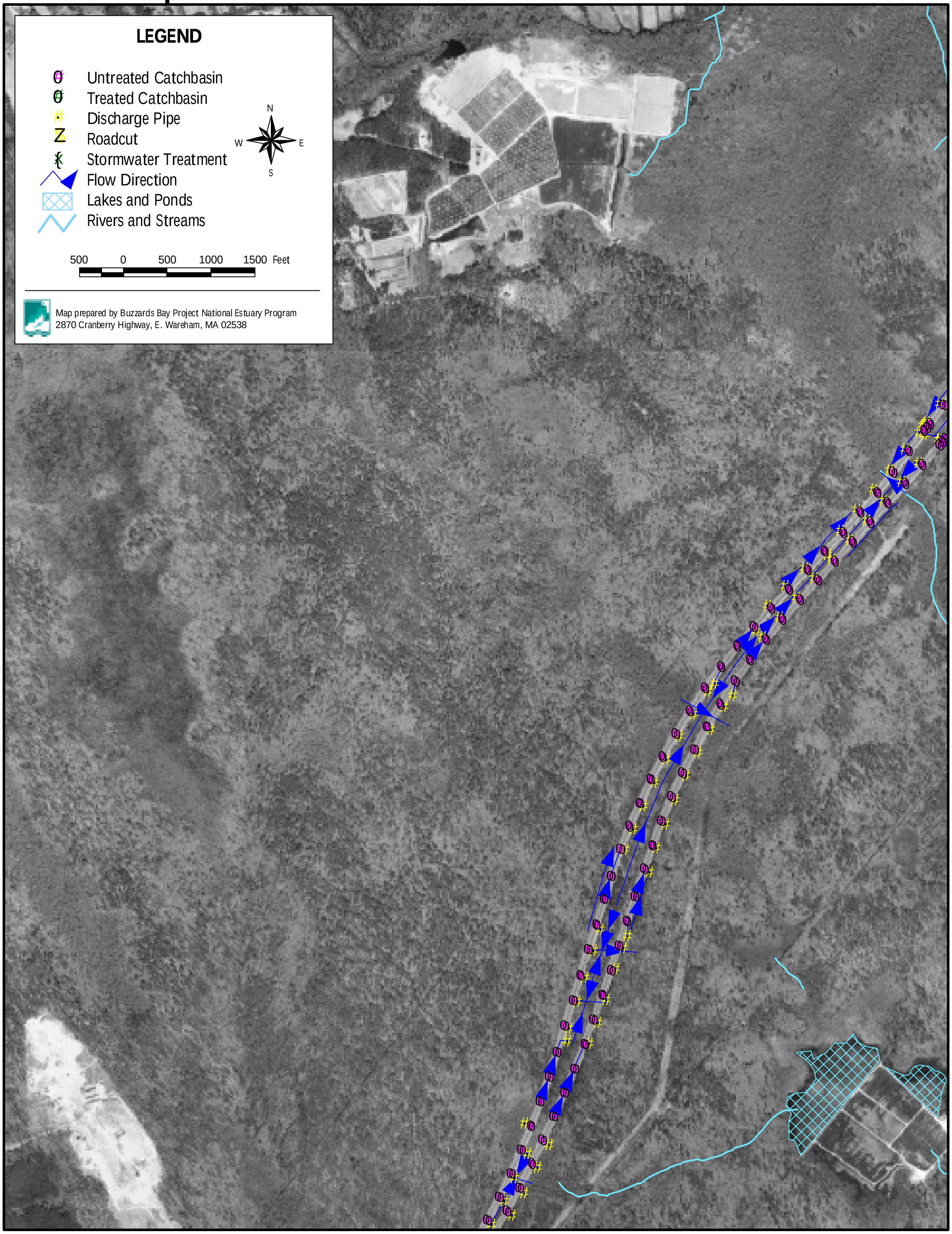
Mattapoisett: Map 6



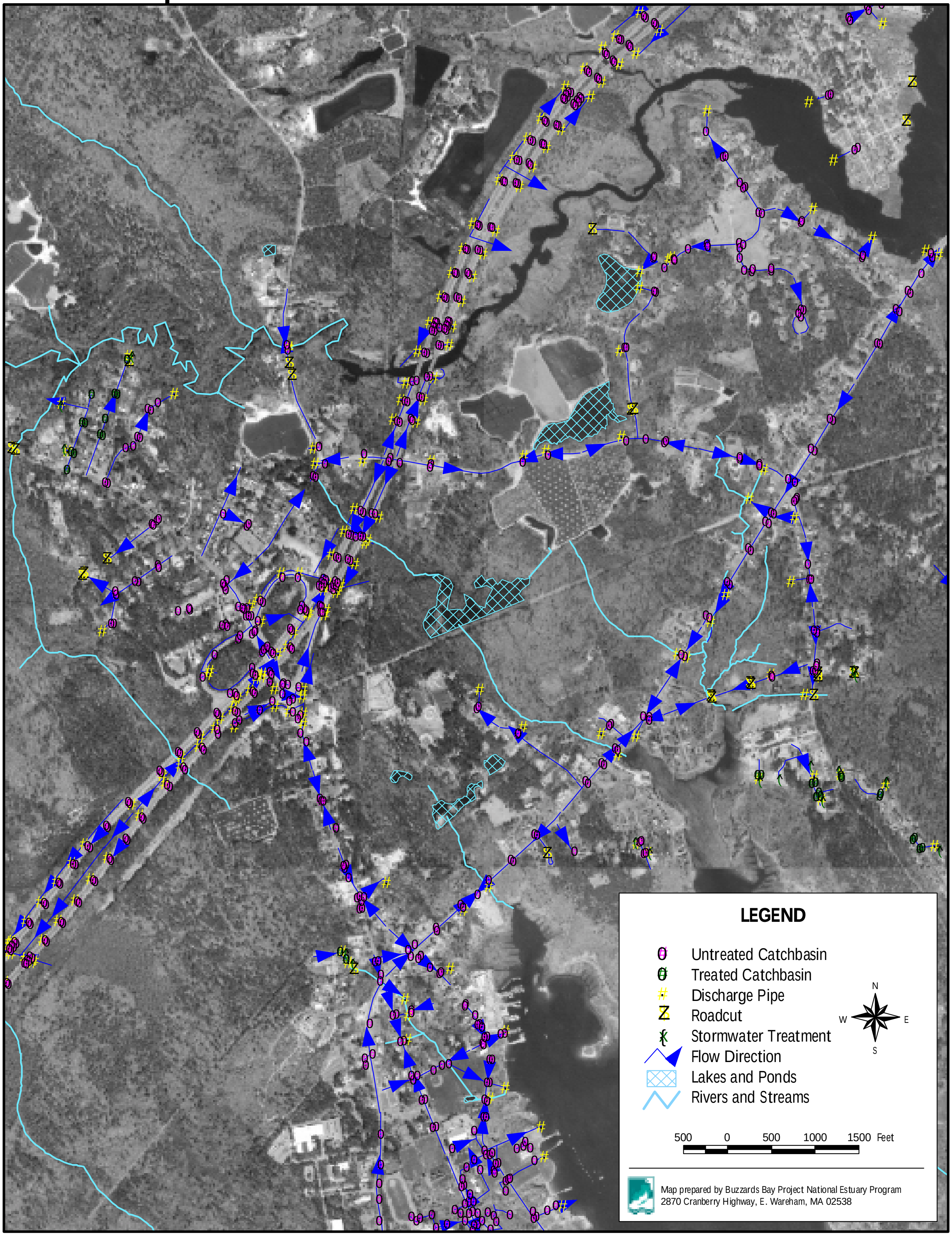
Key for Marion Stormdrain Maps



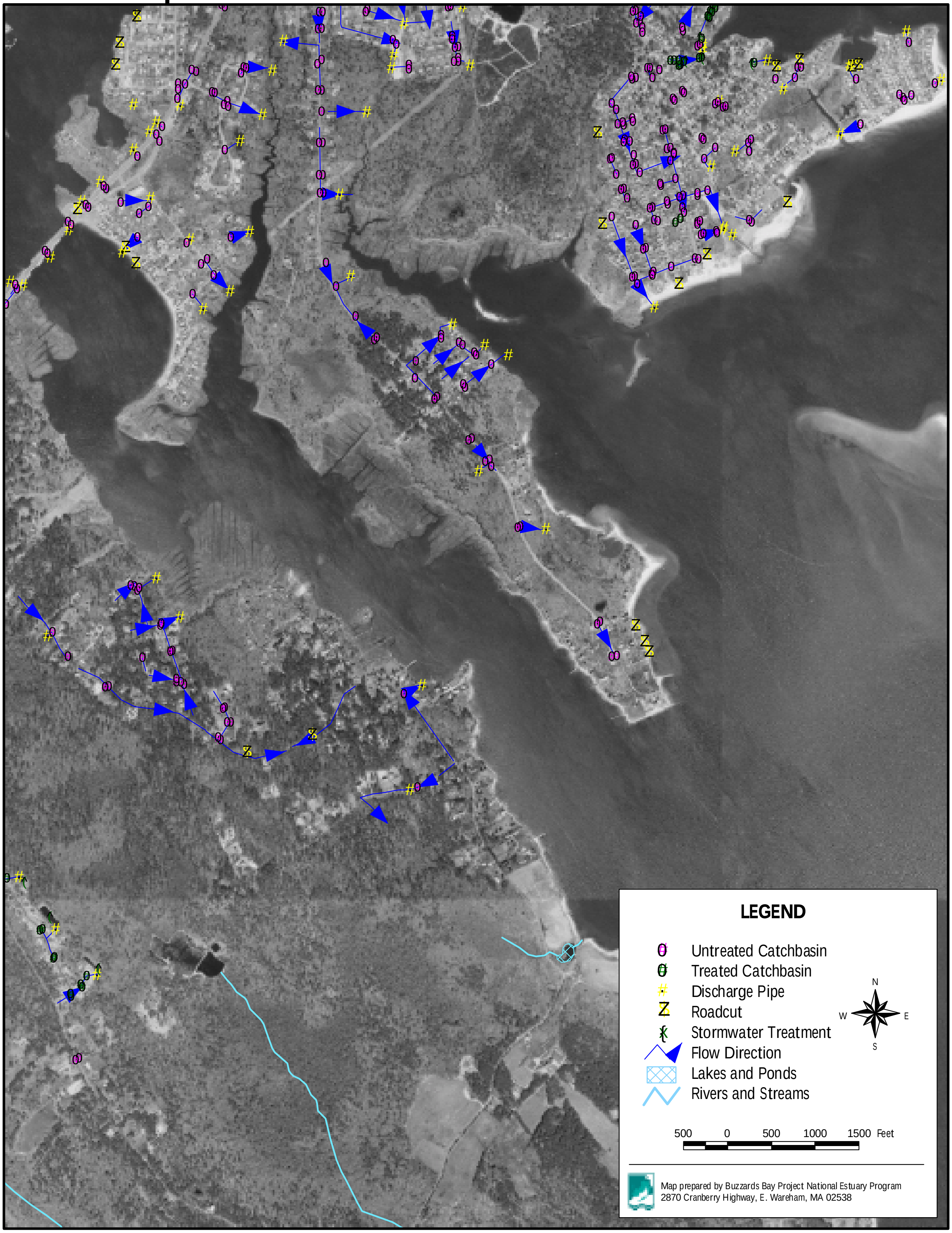
Marion: Map 1


LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

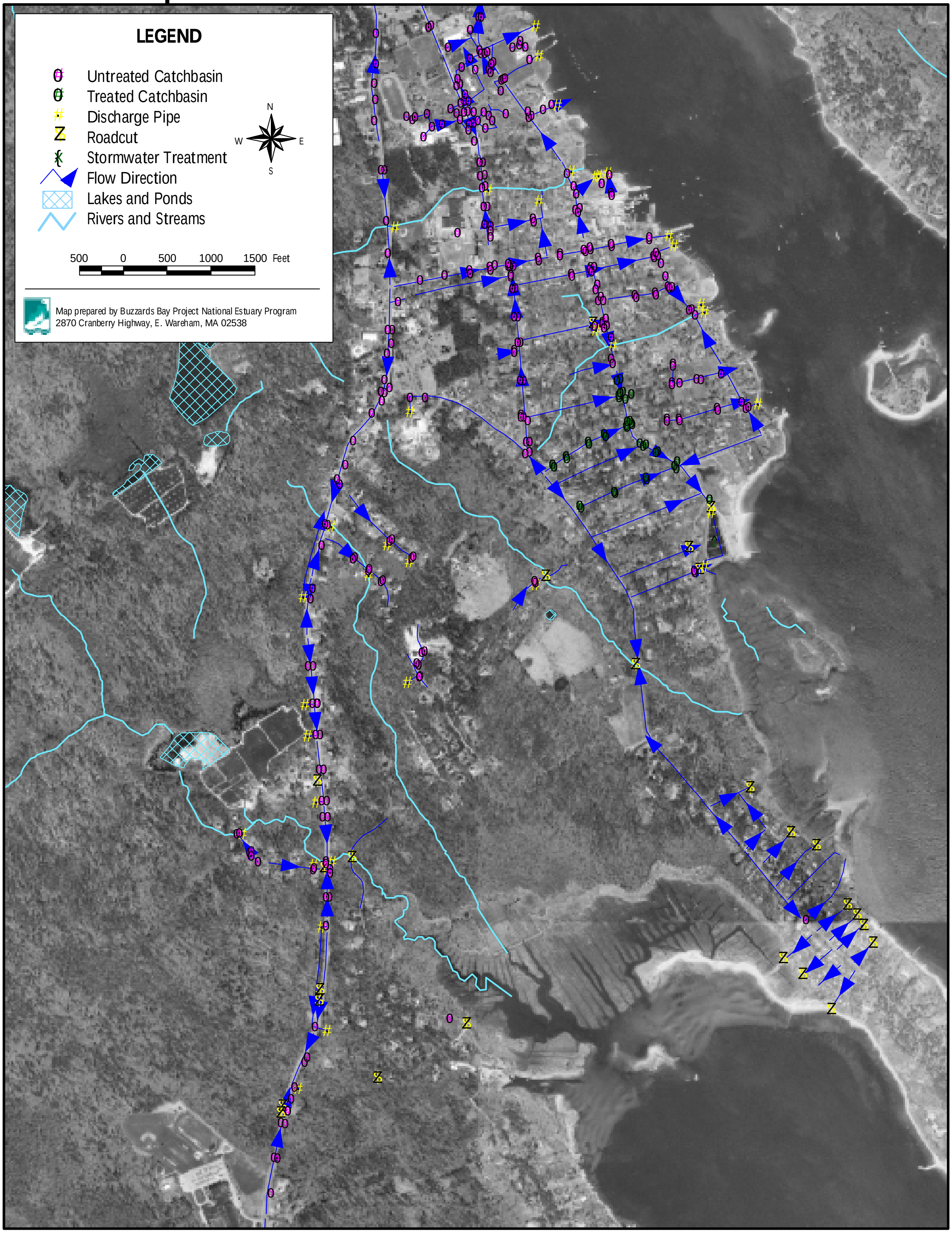
Marion: Map 2


LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

Marion: Map 3

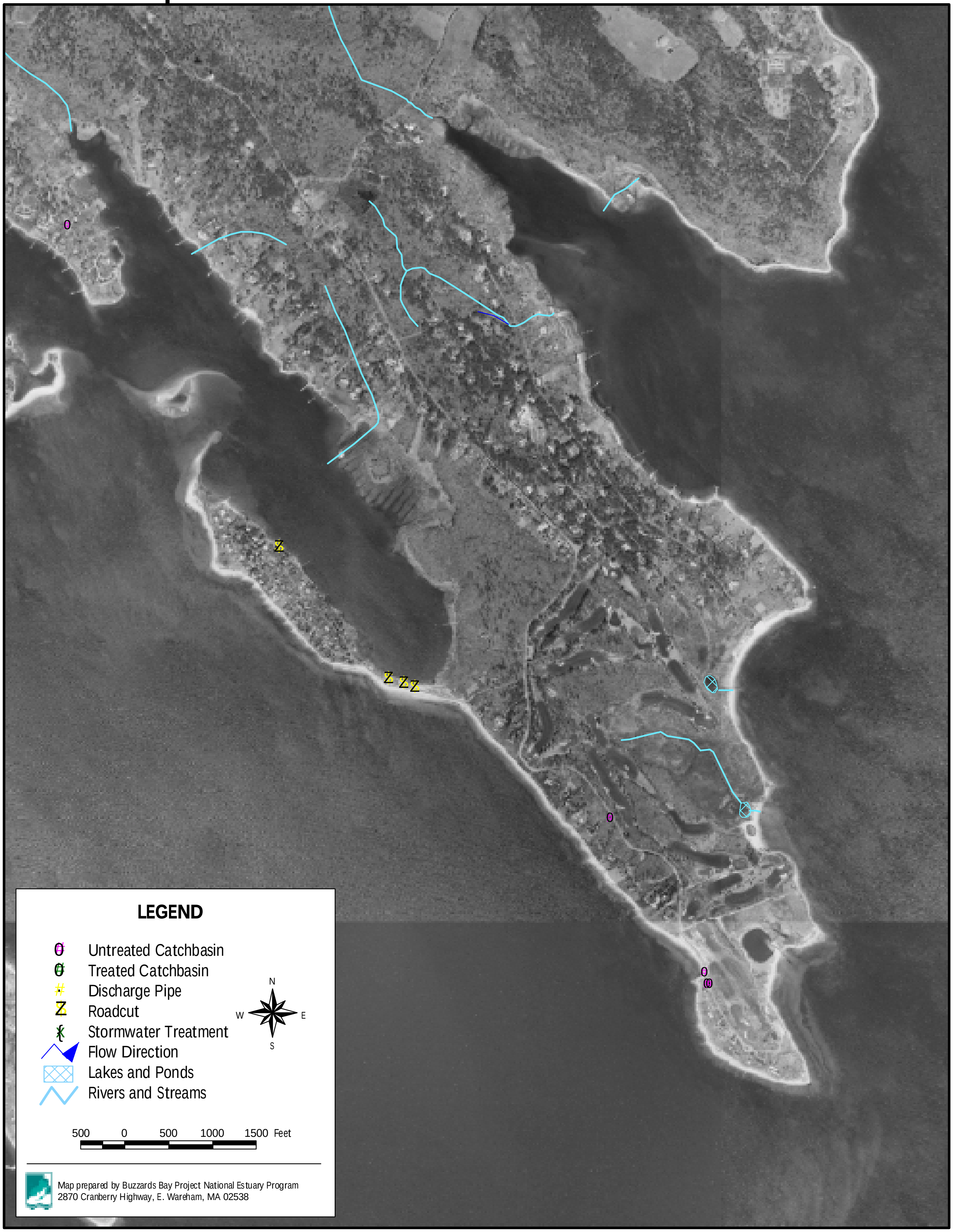

LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

Marion: Map 4



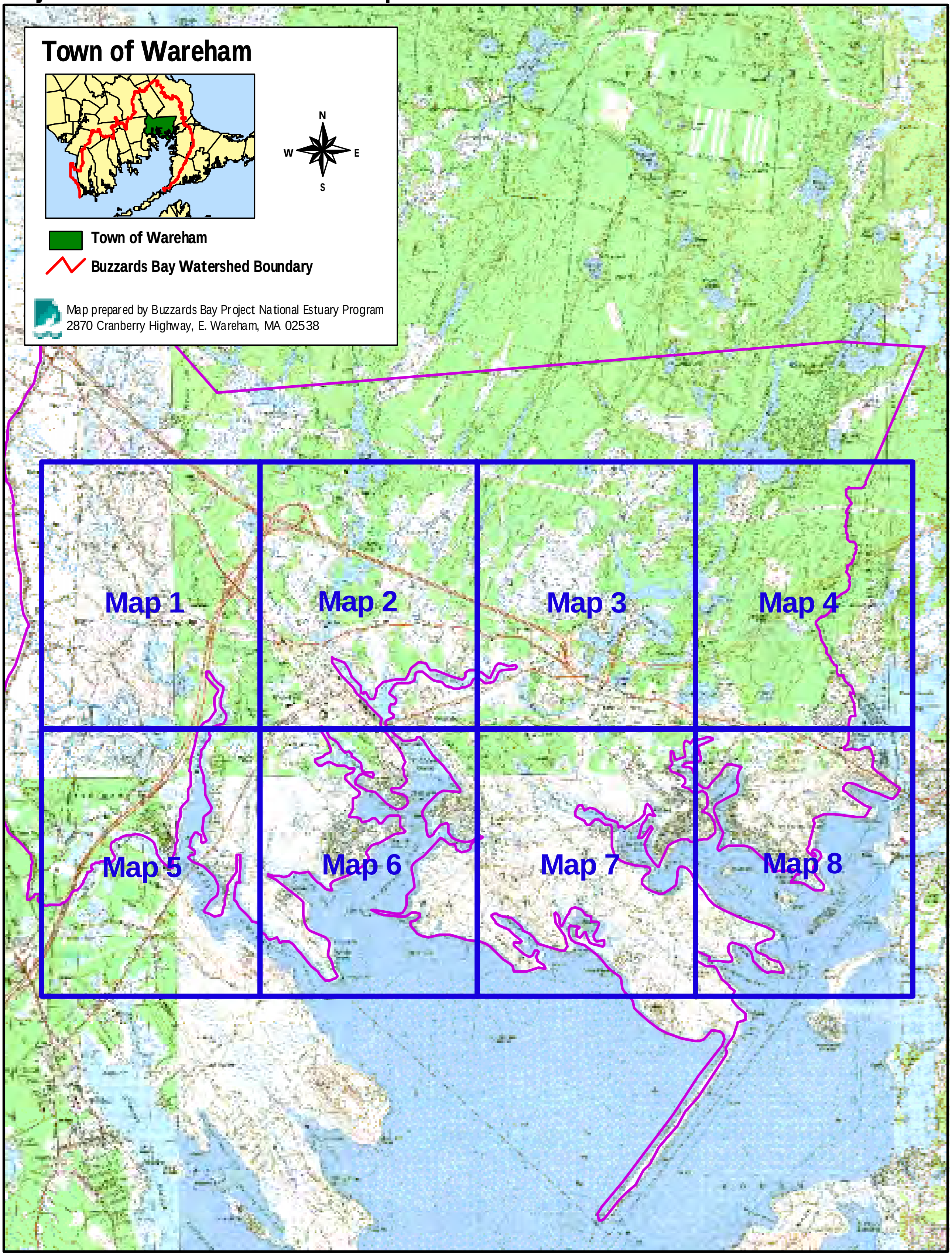
LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

Marion: Map 5

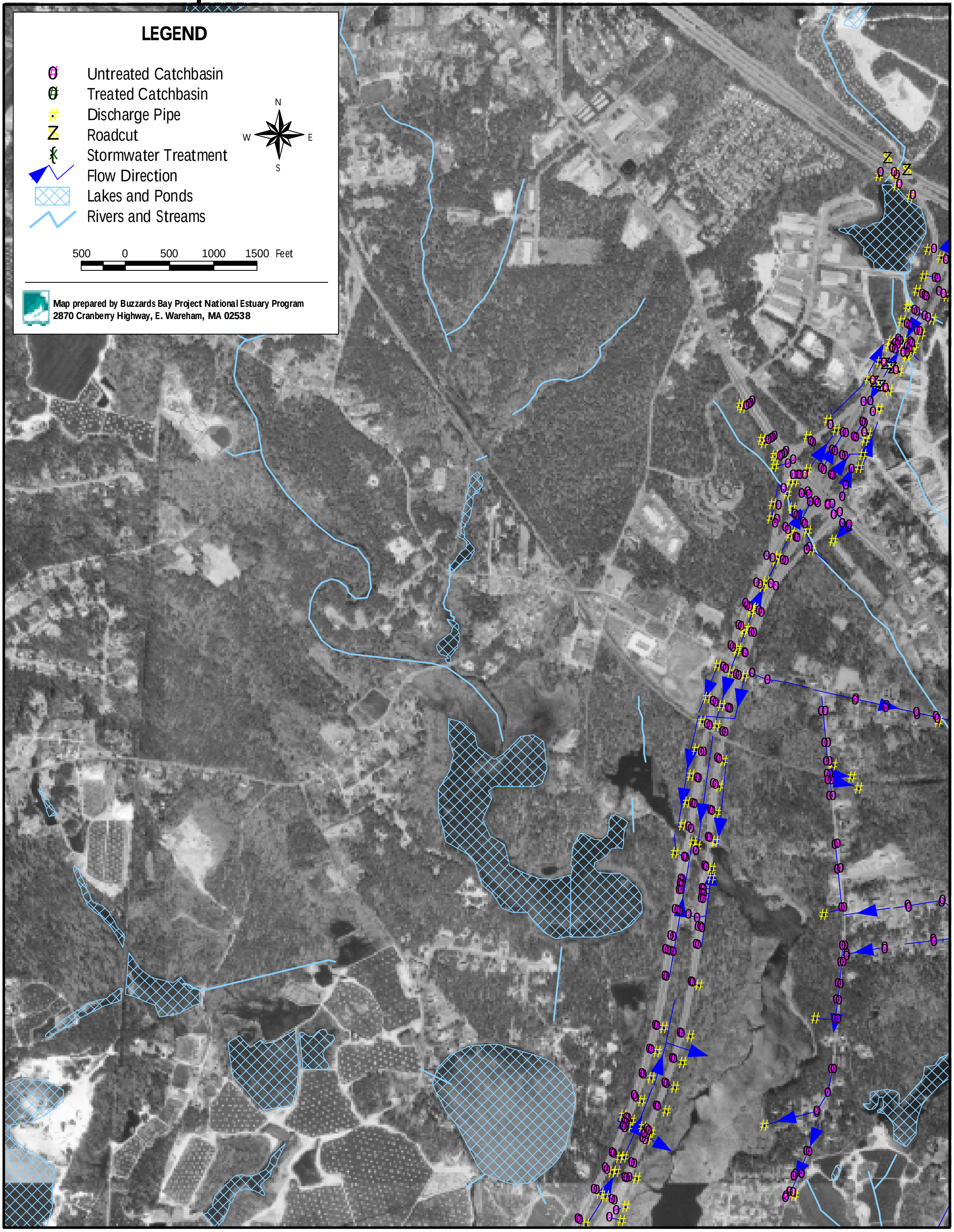


LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

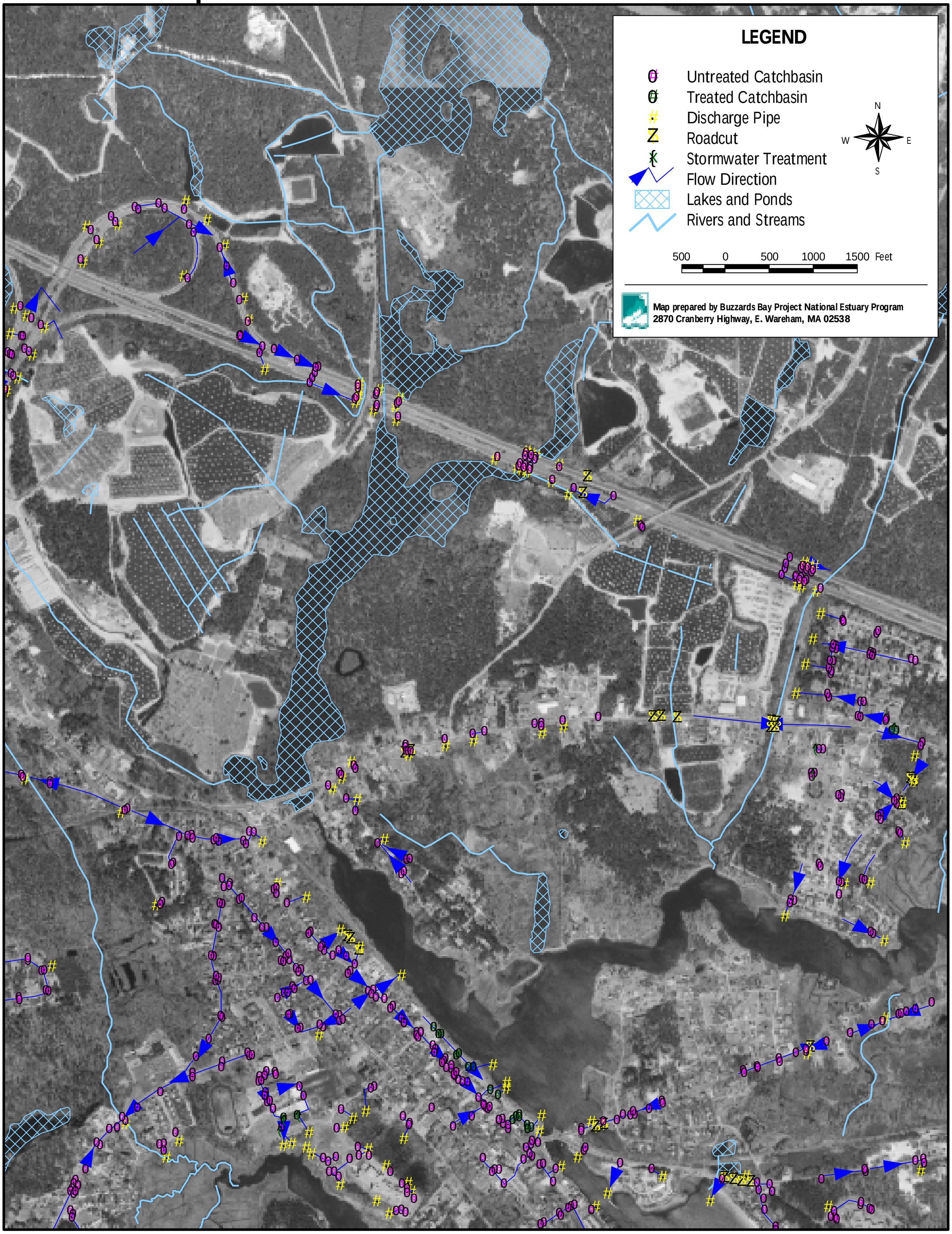
Key for Wareham Stormdrain Maps



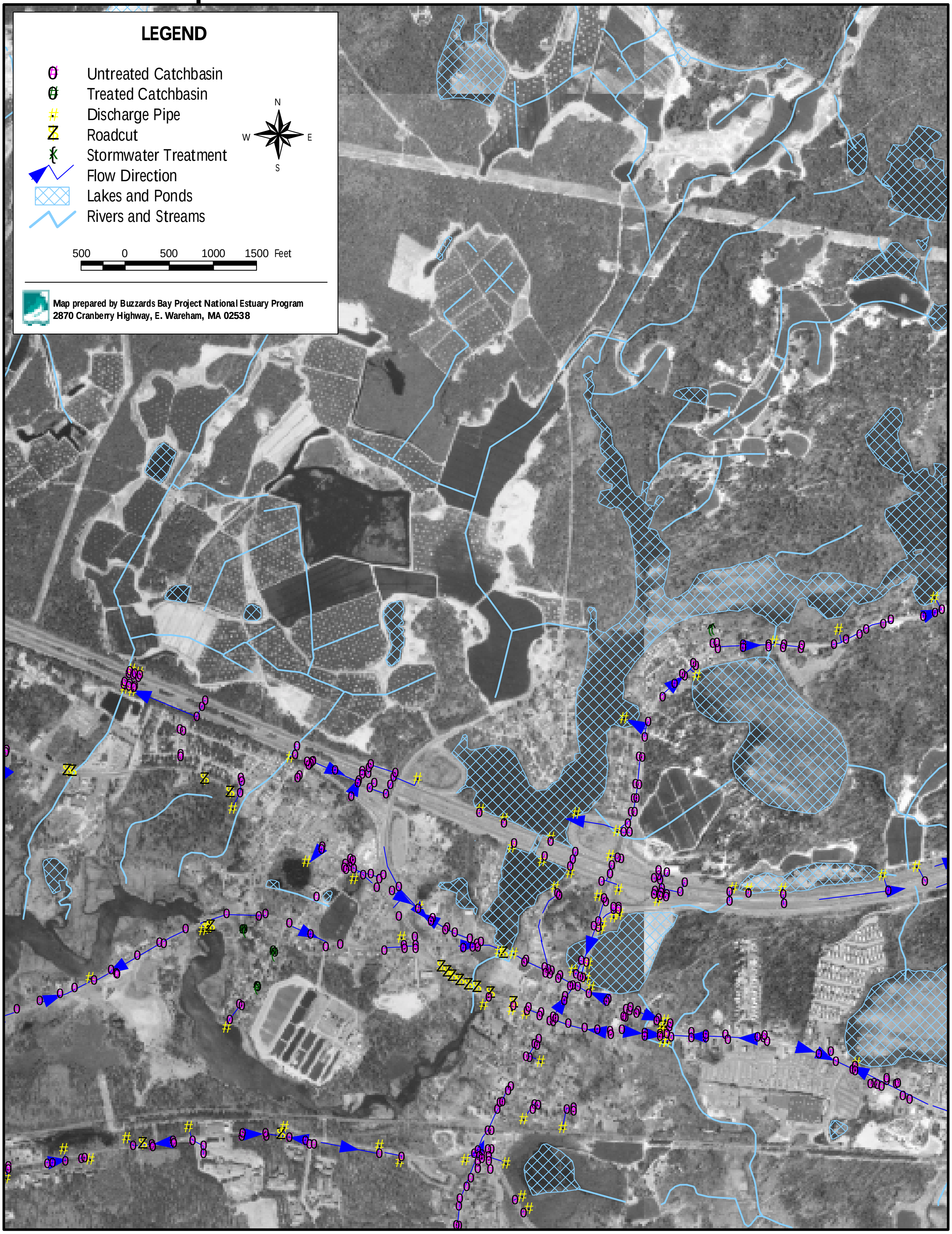
Wareham: Map 1



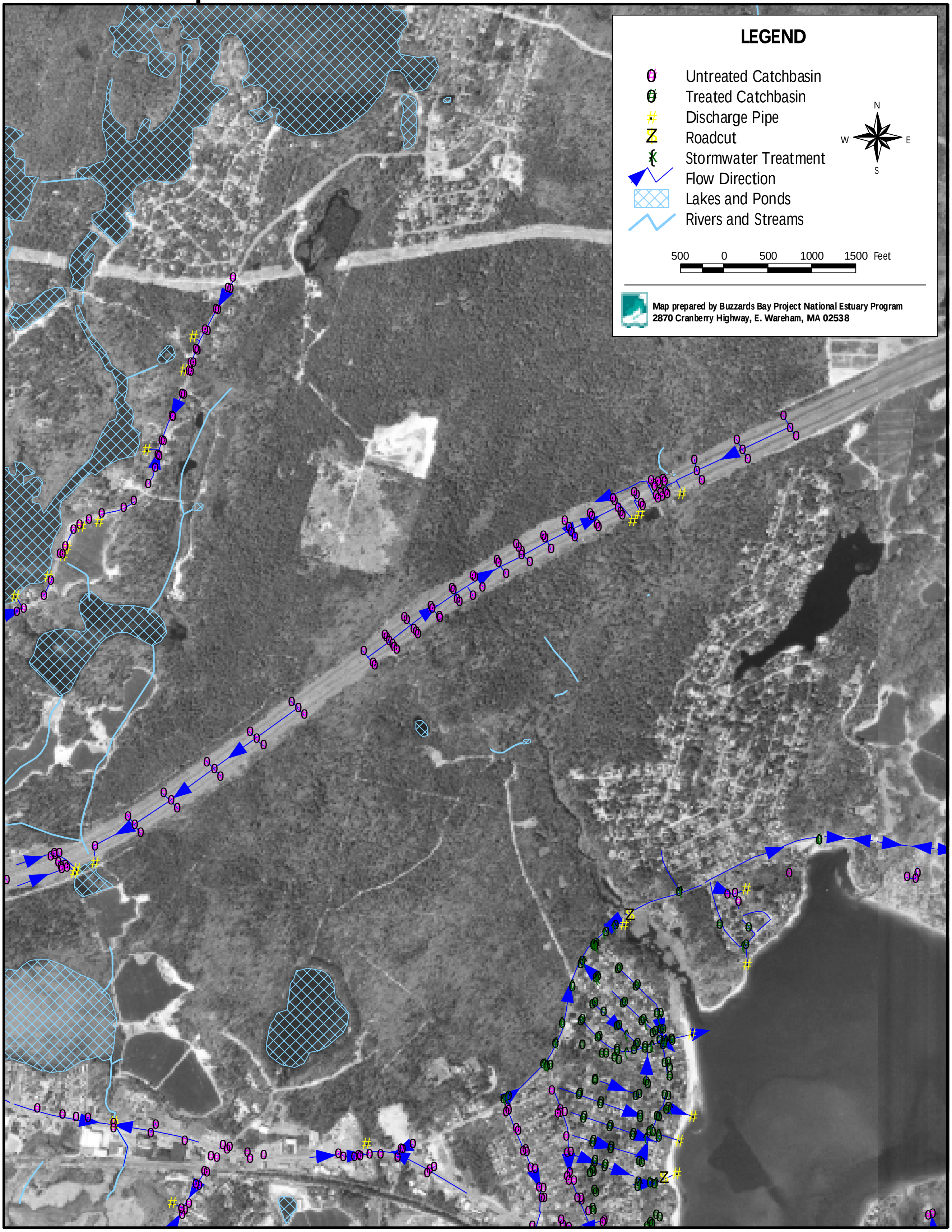
Wareham: Map 2



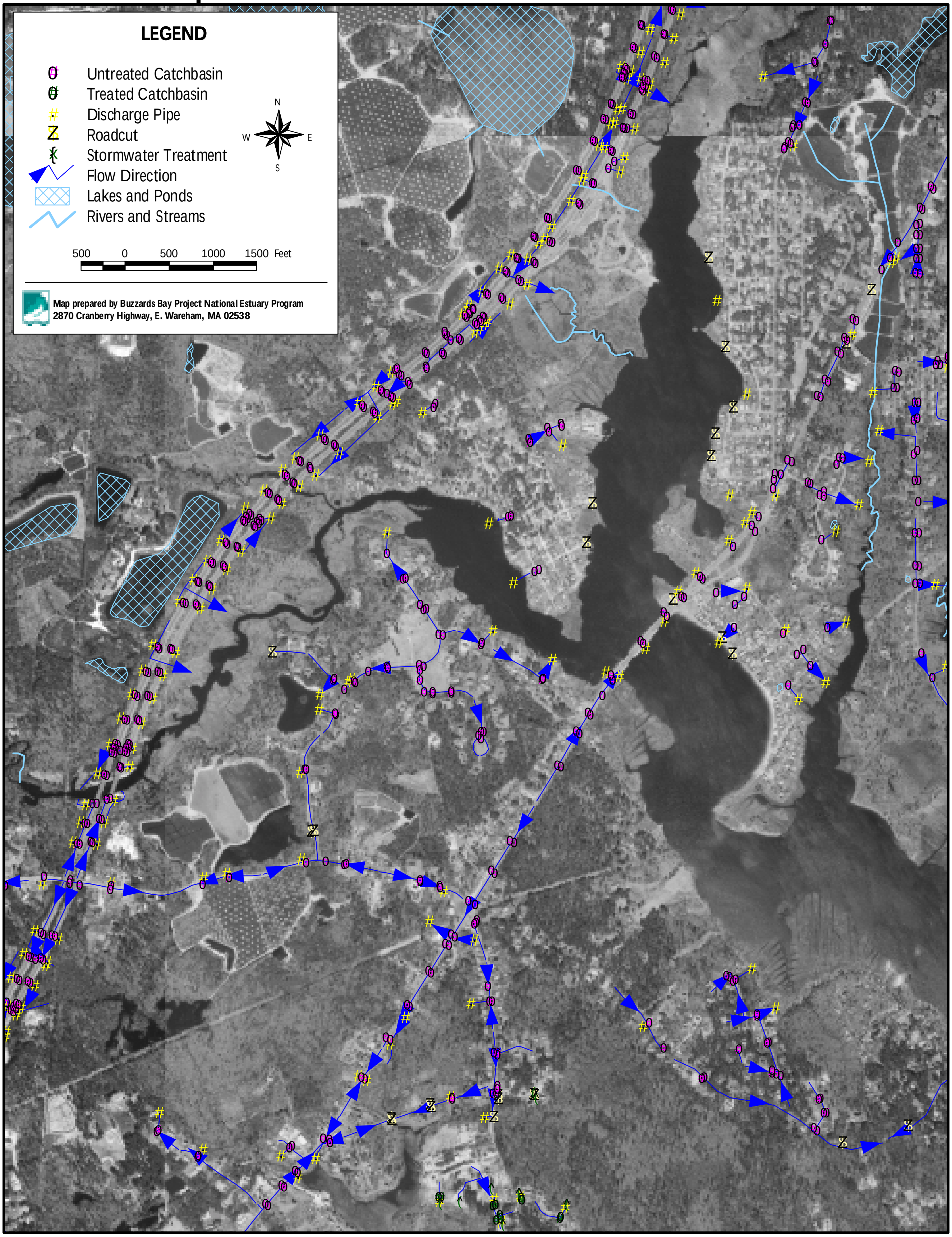
Wareham: Map 3



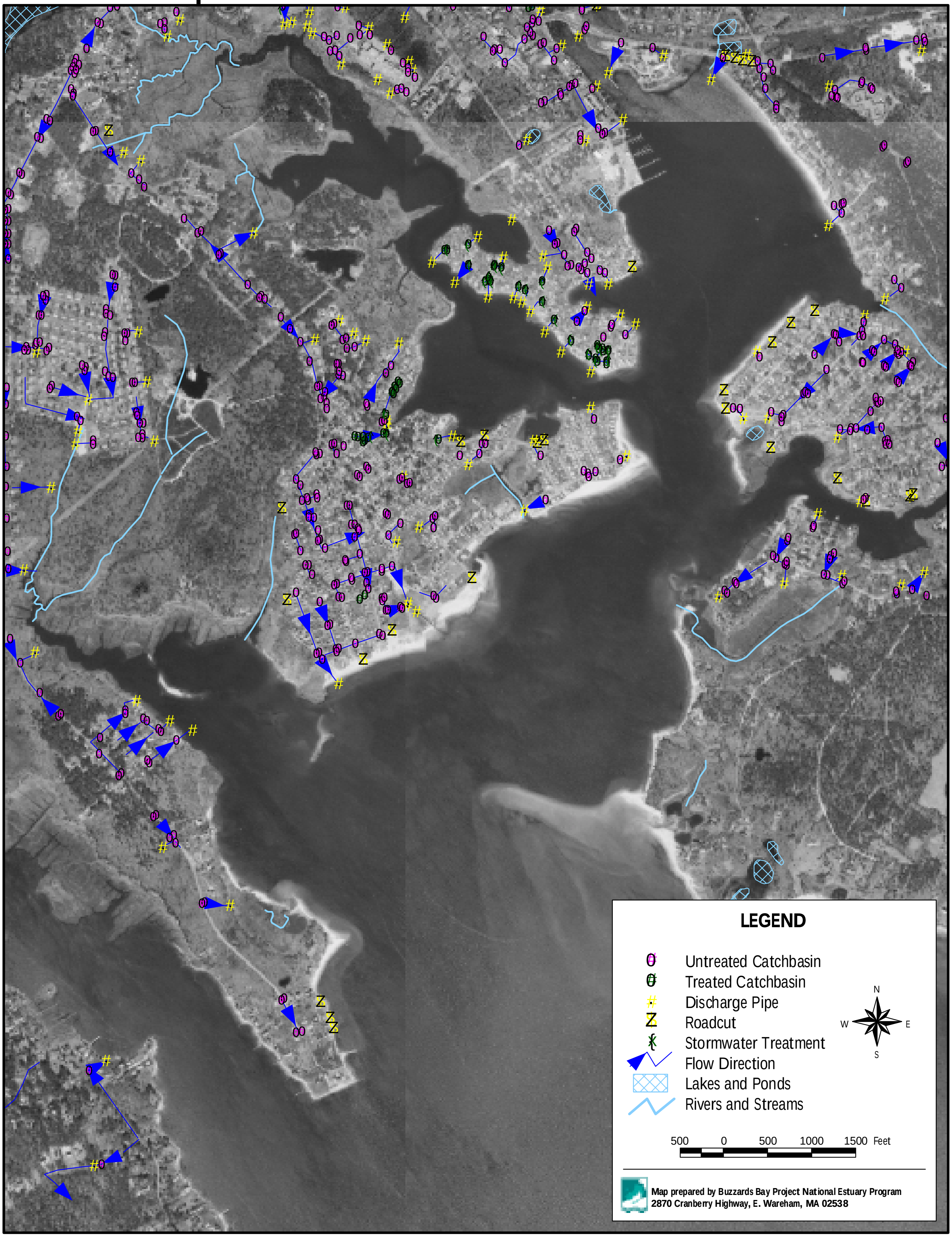
Wareham: Map 4



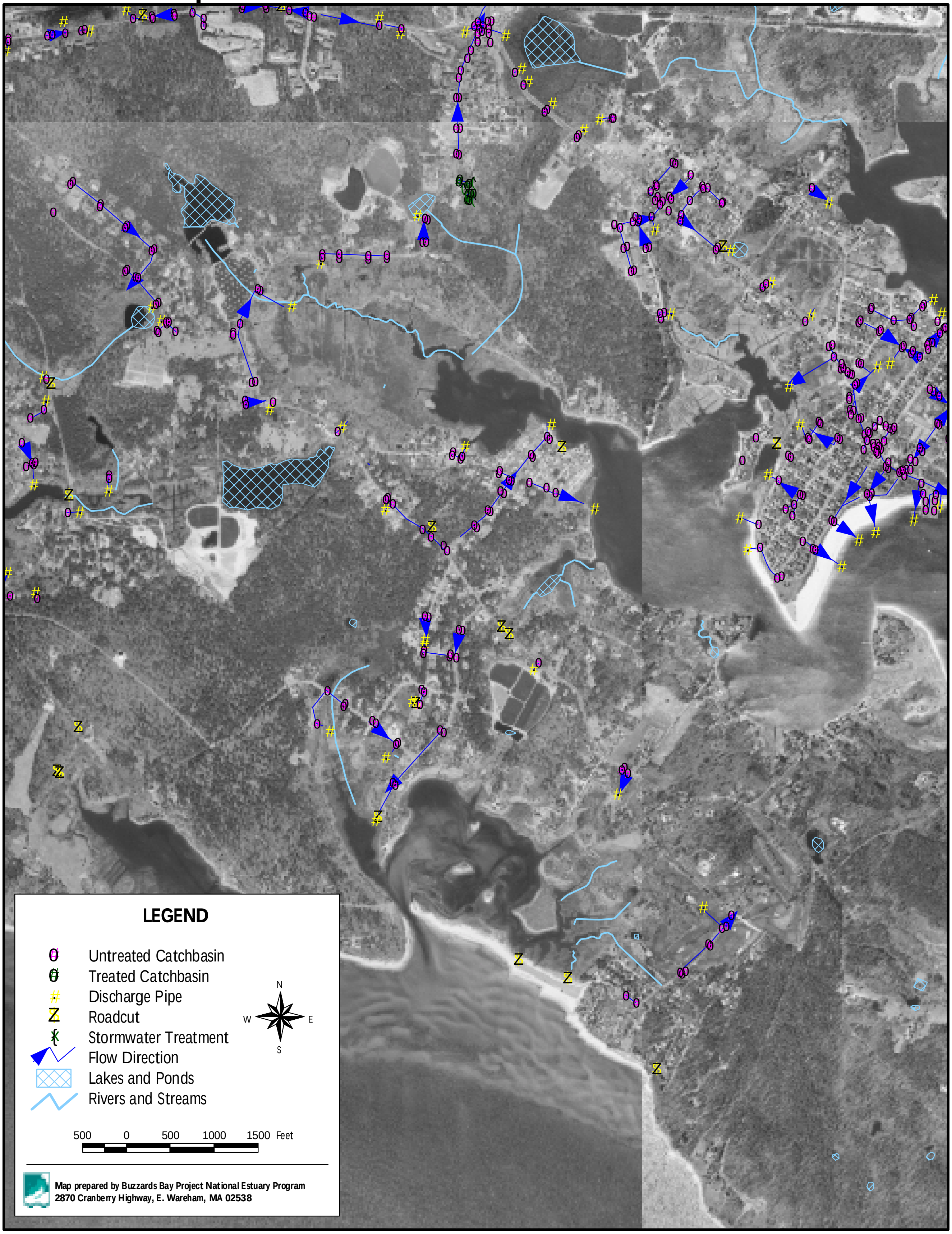
Wareham: Map 5



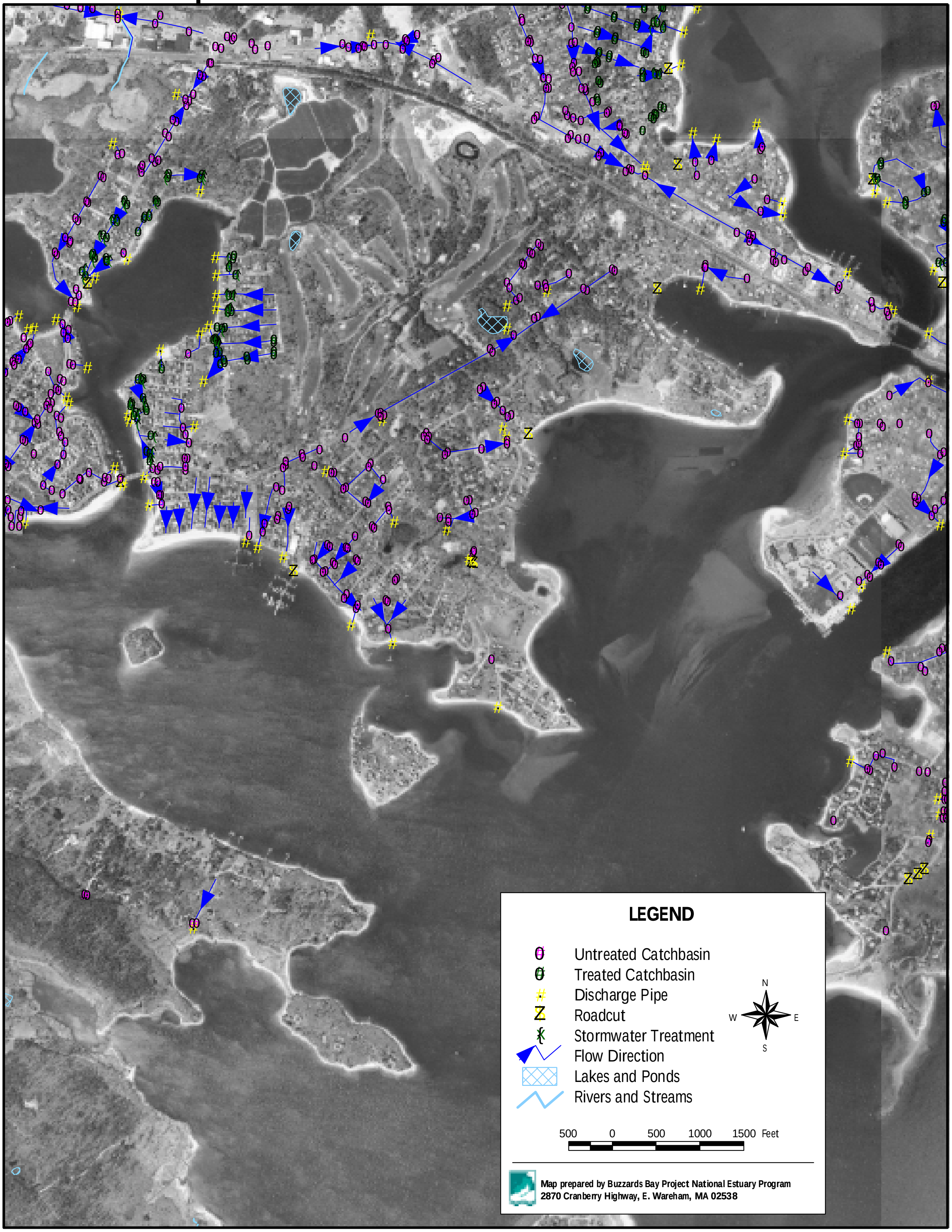
Wareham: Map 6



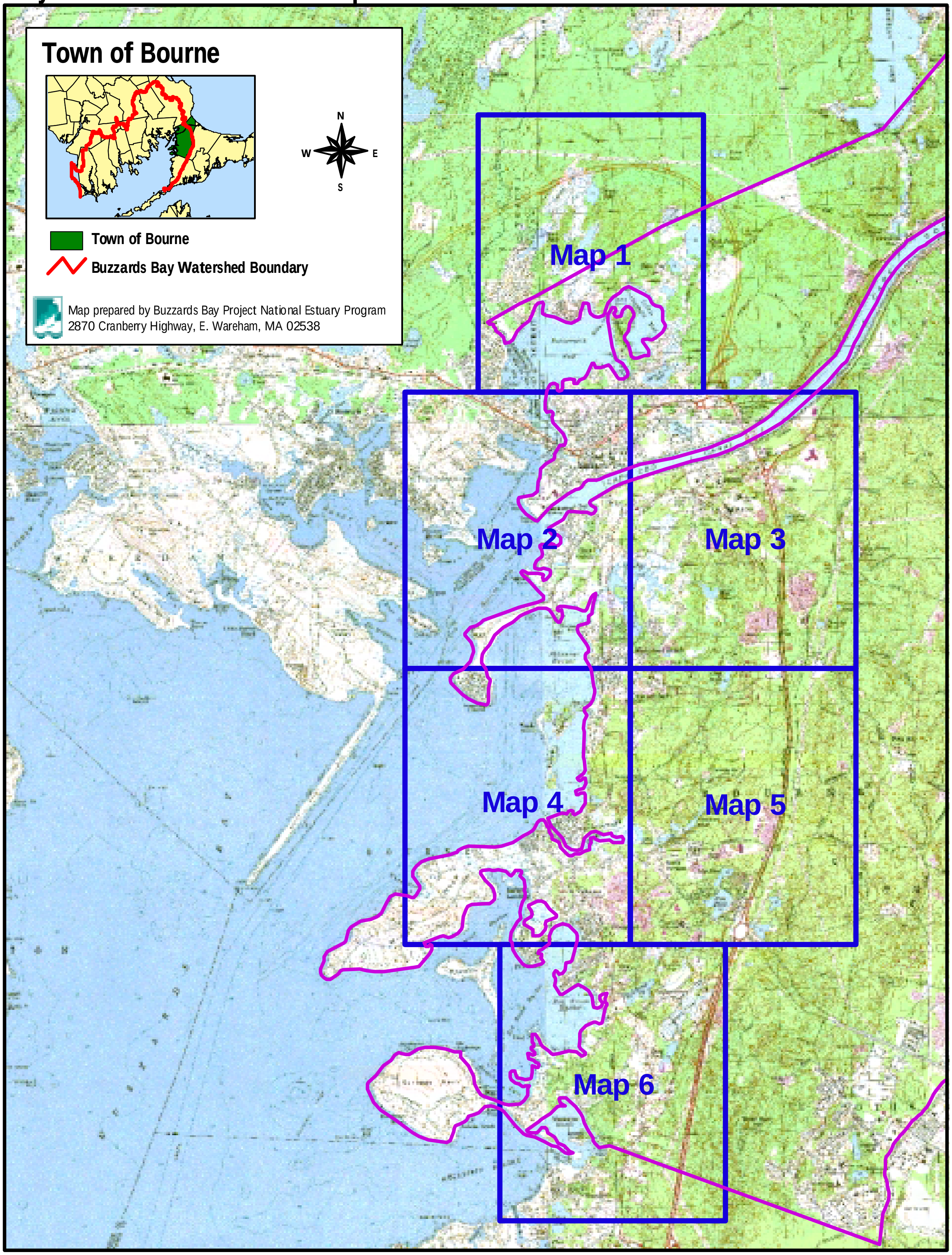
Wareham: Map 7



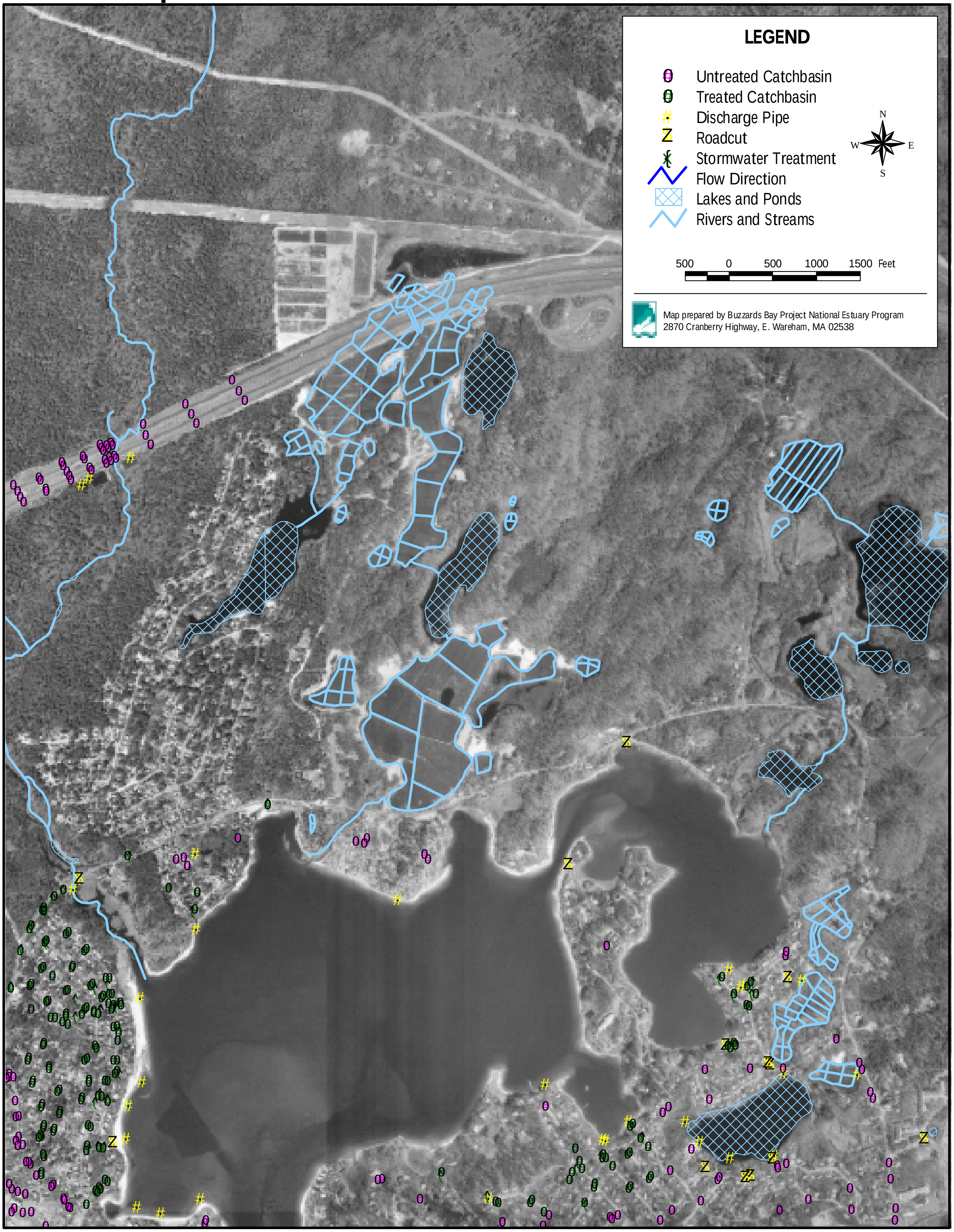
Wareham: Map 8



Key for Bourne Stormdrain Maps

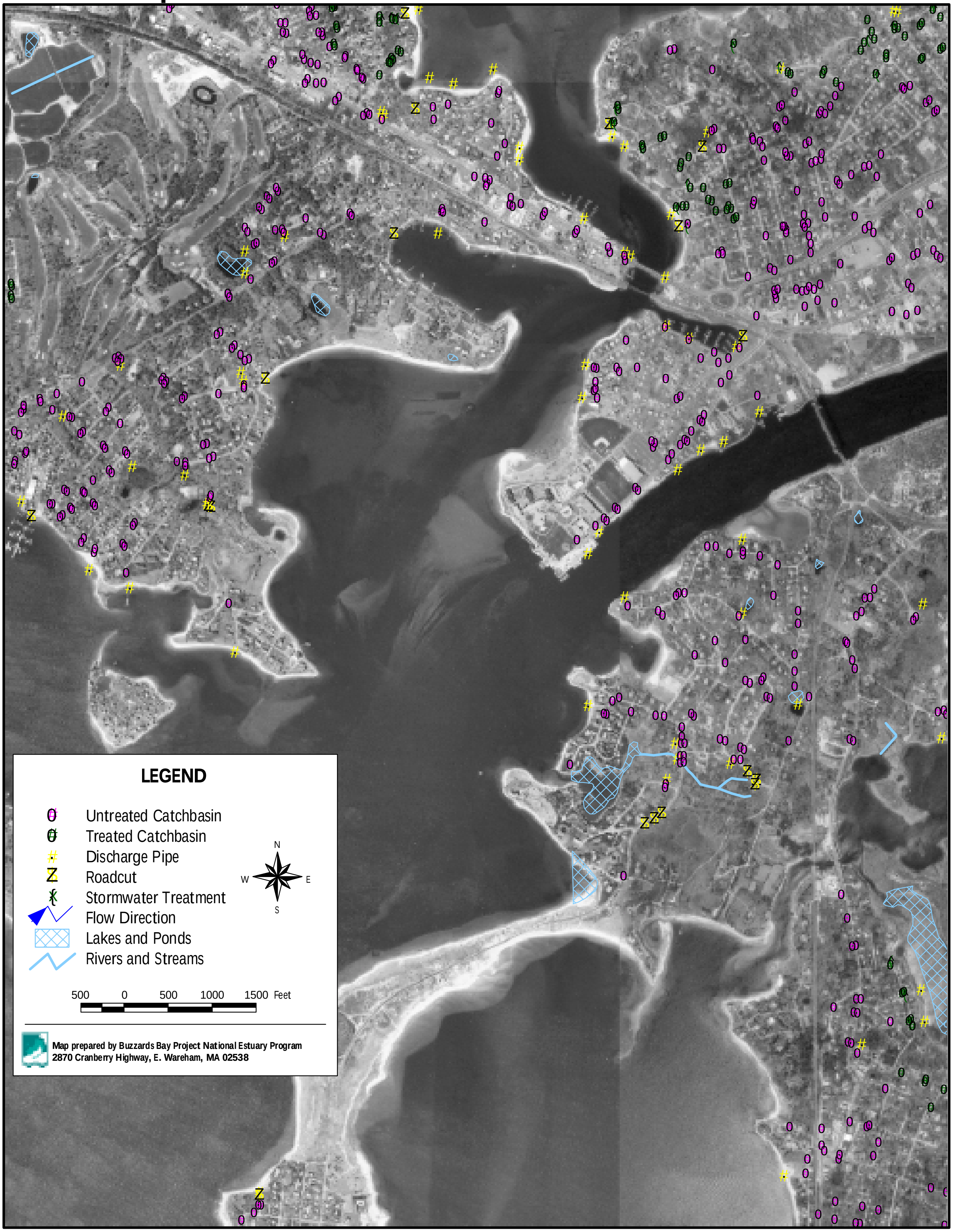


Bourne: Map 1

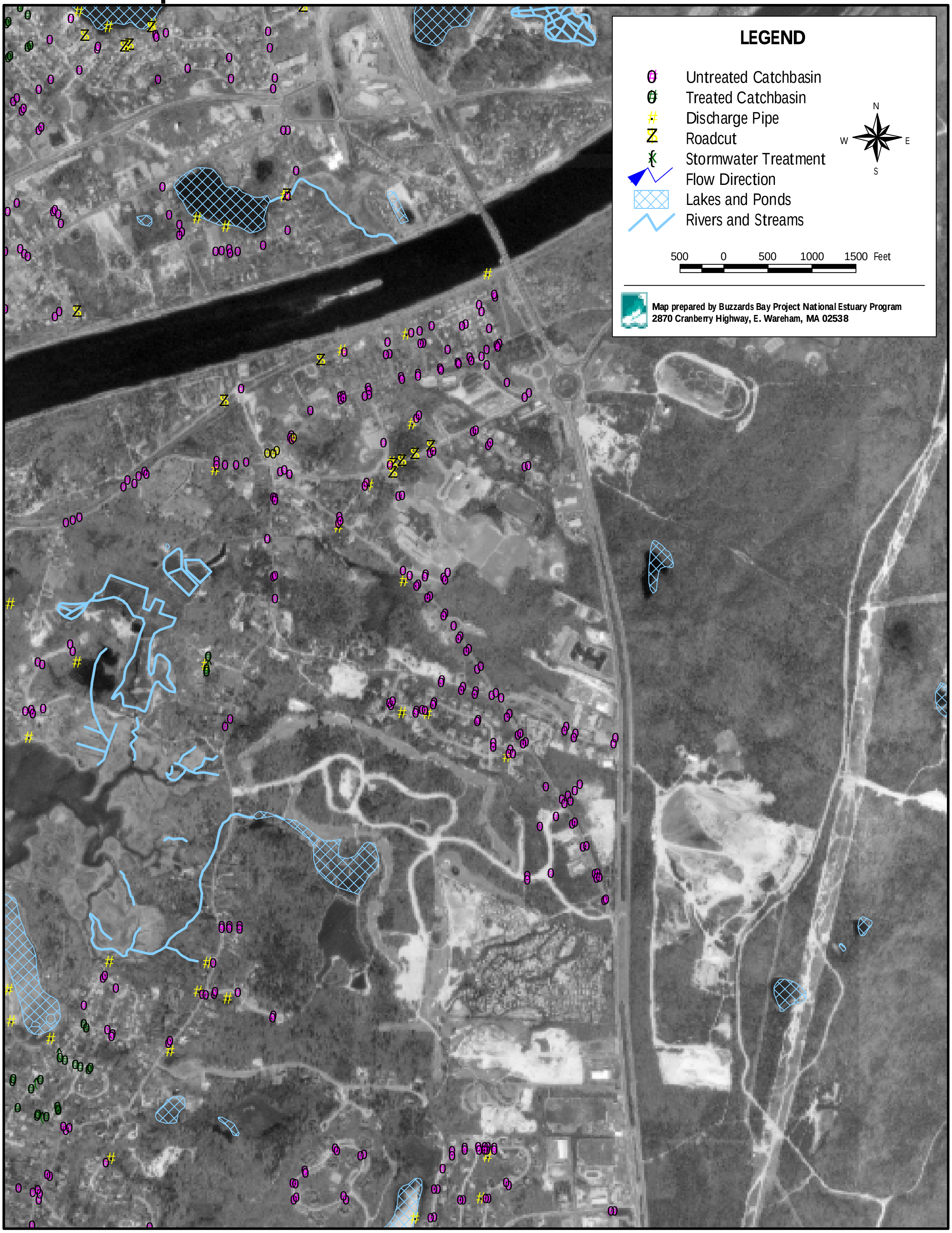


LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

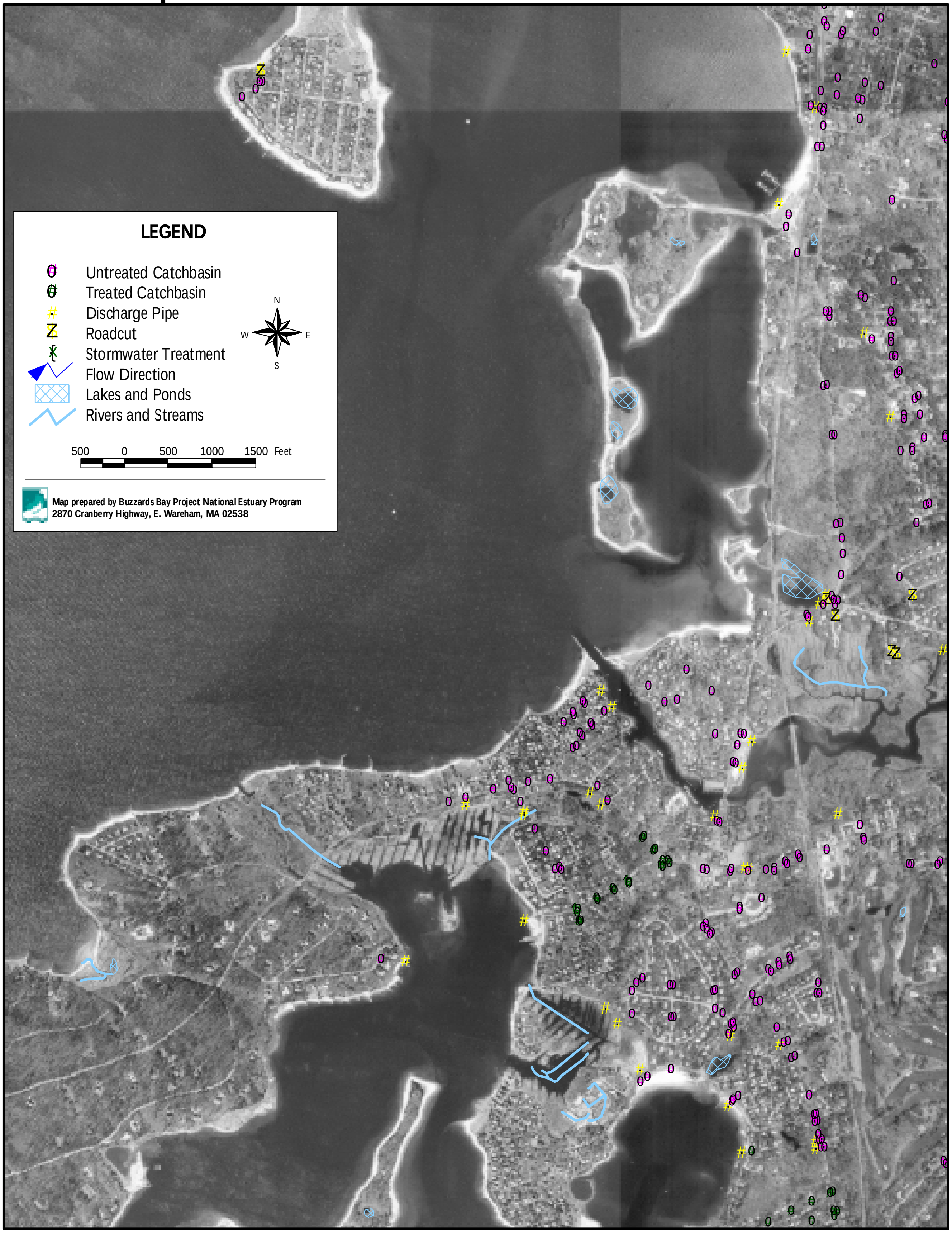
Bourne: Map 2


LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

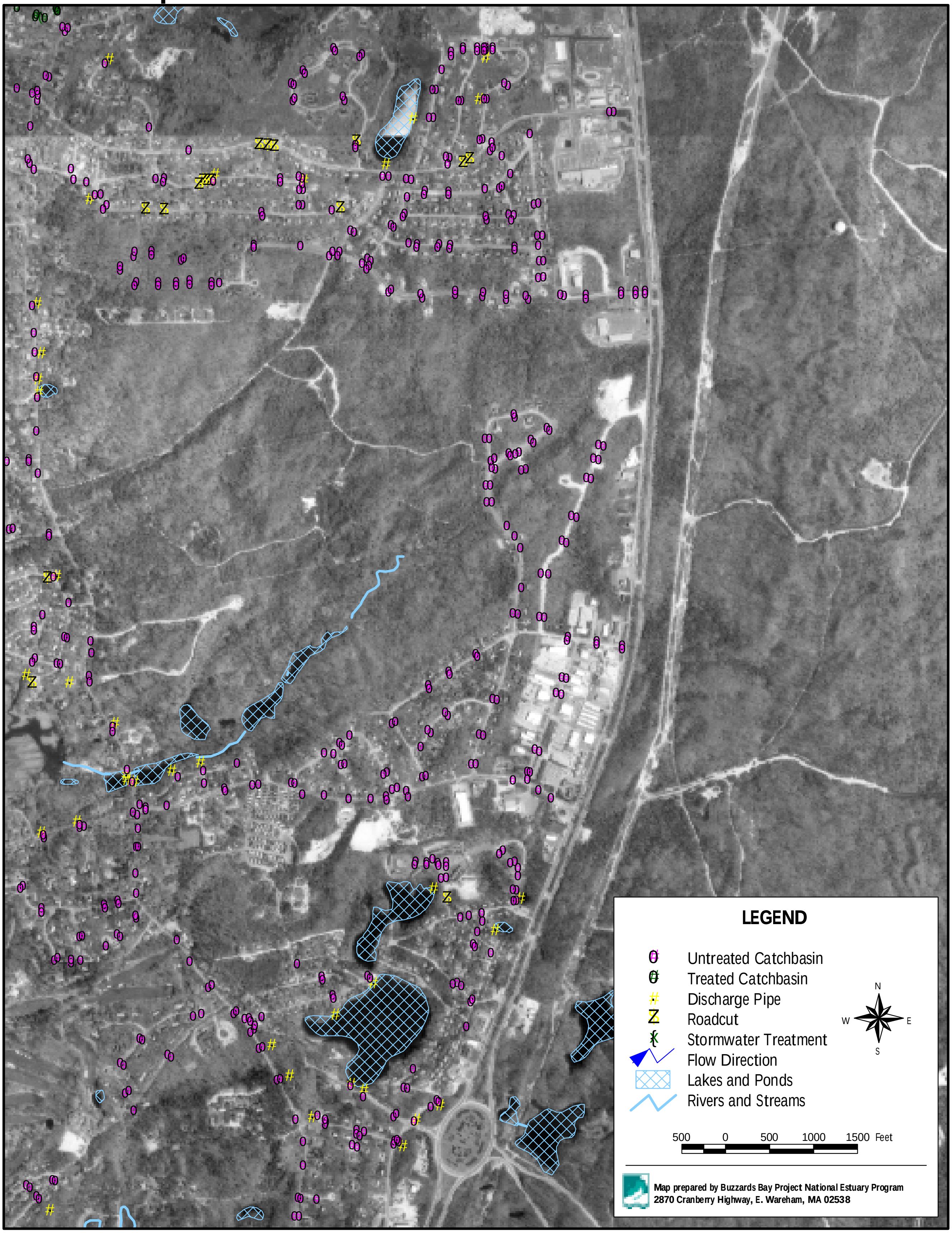
Bourne: Map 3


LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

Bourne: Map 4

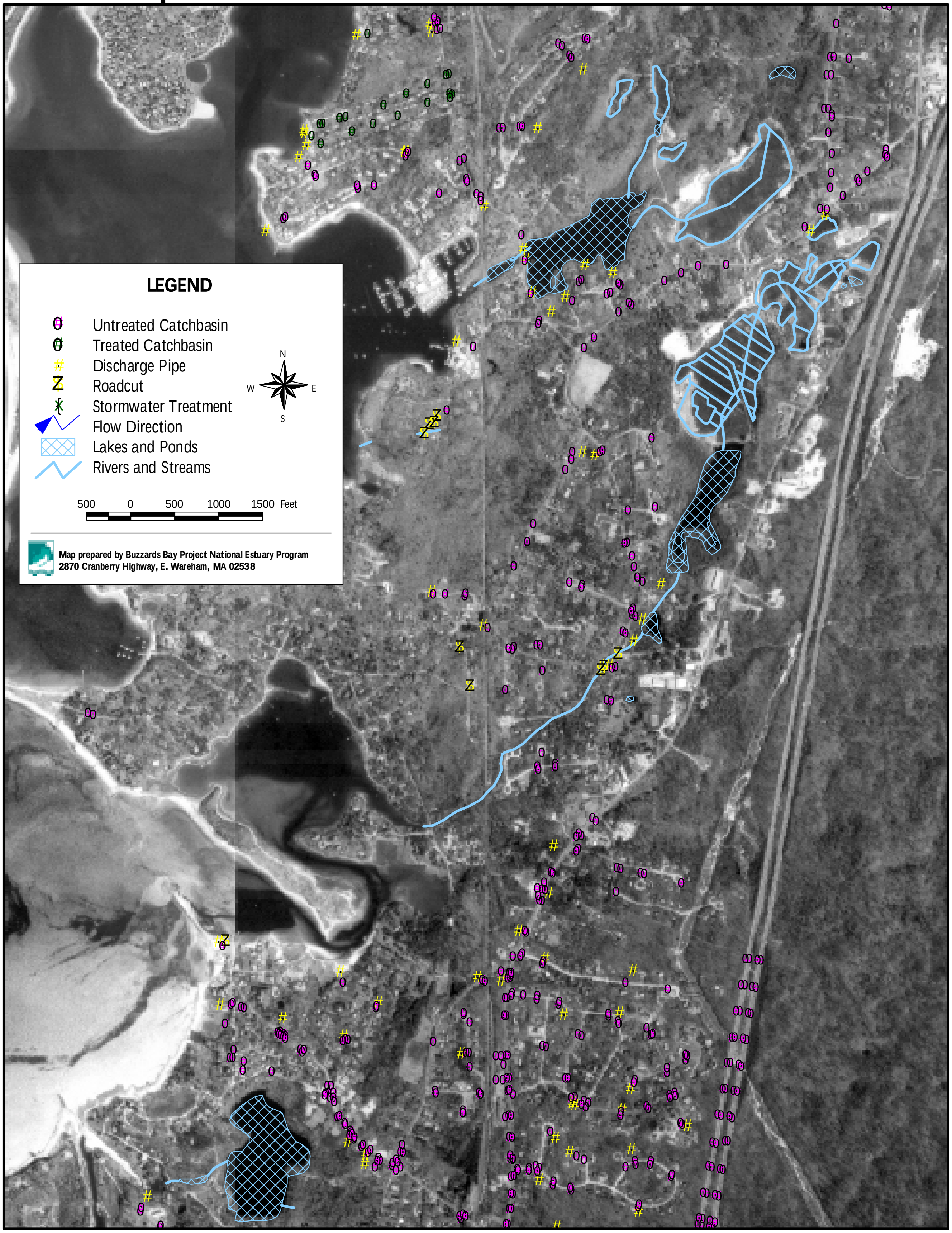

LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

Bourne: Map 5

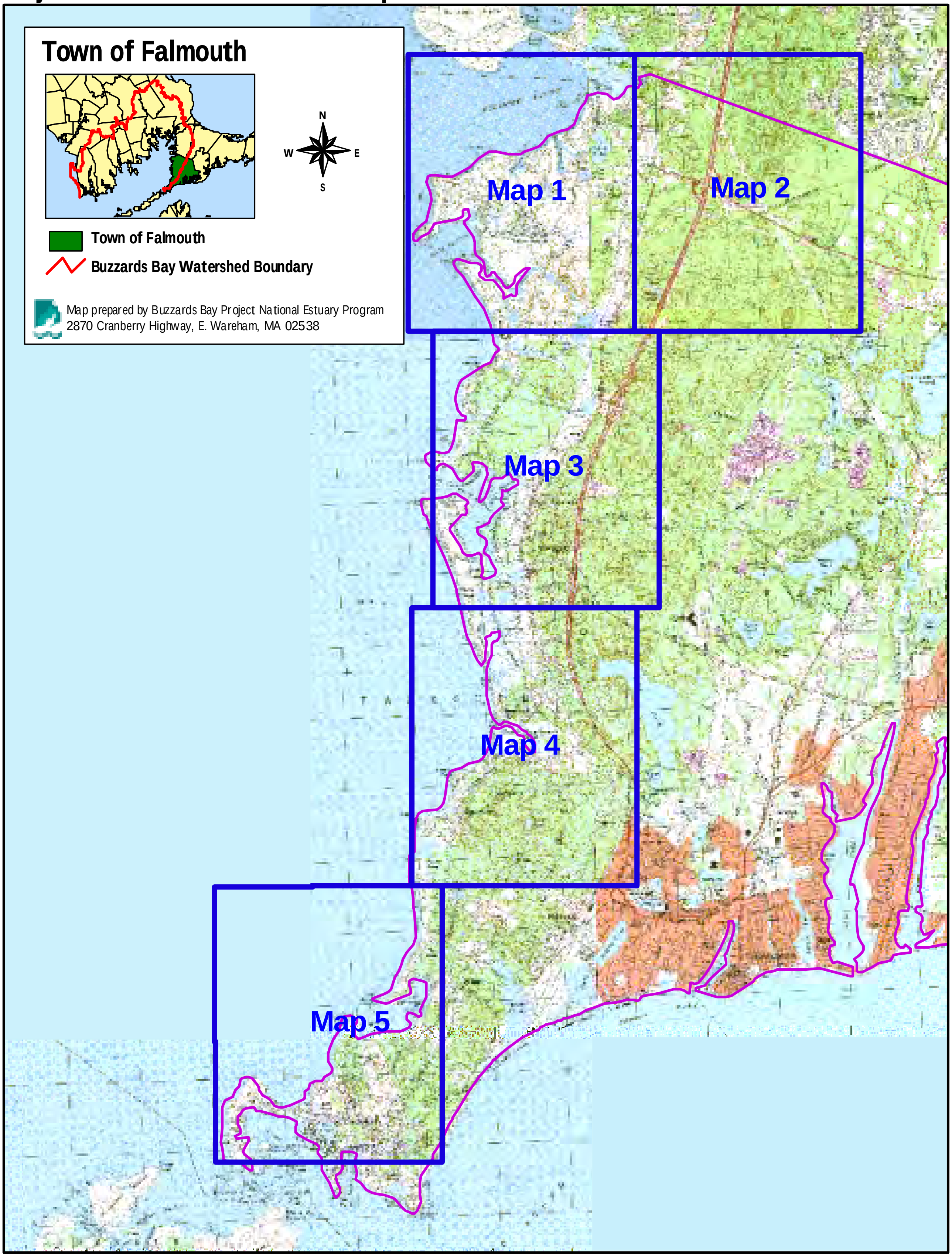


LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500
0
500
1000
1500
Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

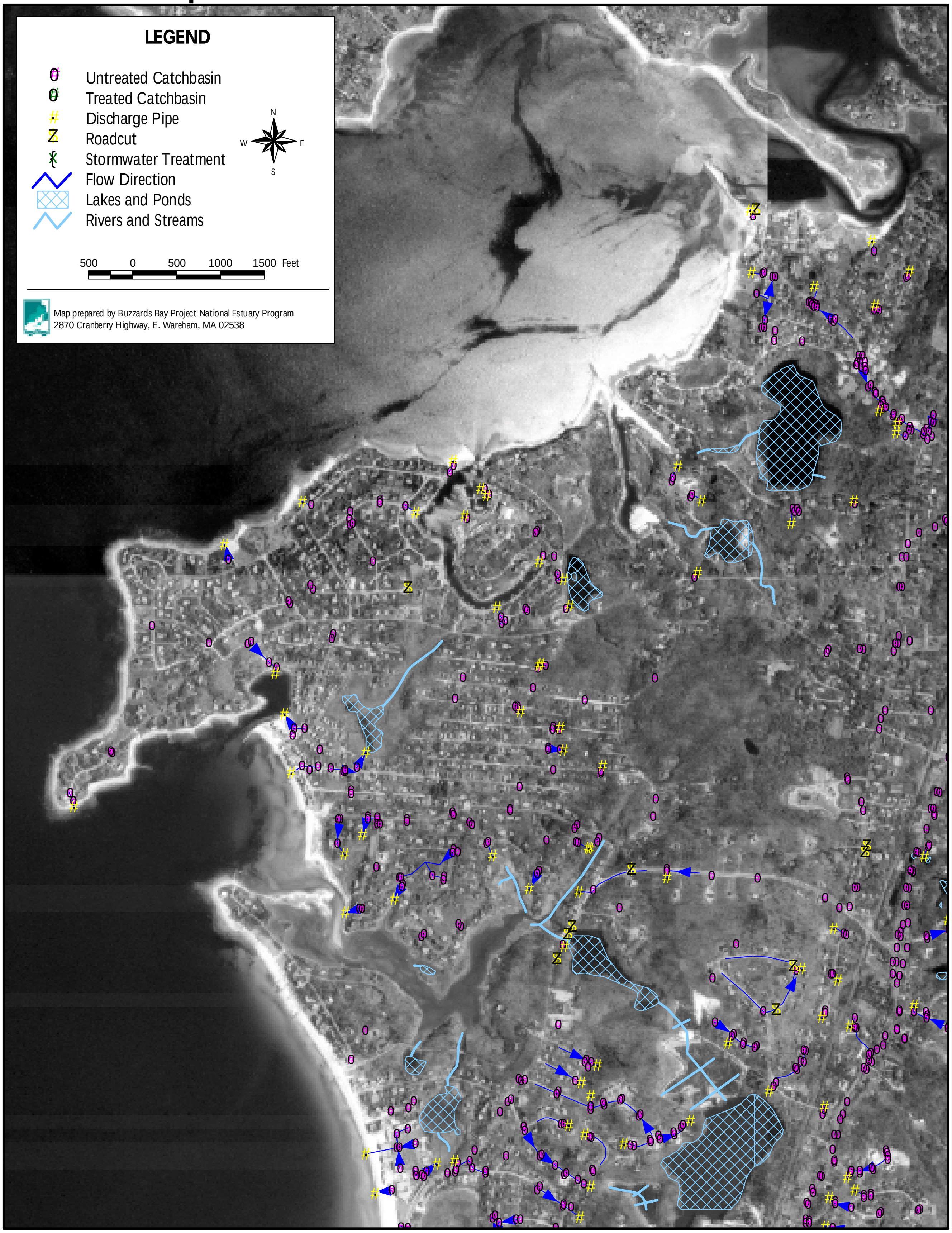
Bourne: Map 6


LEGEND
Untreated Catchbasin
Treated Catchbasin
Discharge Pipe
Roadcut
Stormwater Treatment
Flow Direction
Lakes and Ponds
Rivers and Streams
N
W
E
S
500 0 500 1000 1500 Feet
Map prepared by Buzzards Bay Project National Estuary Program
2870 Cranberry Highway, E. Wareham, MA 02538

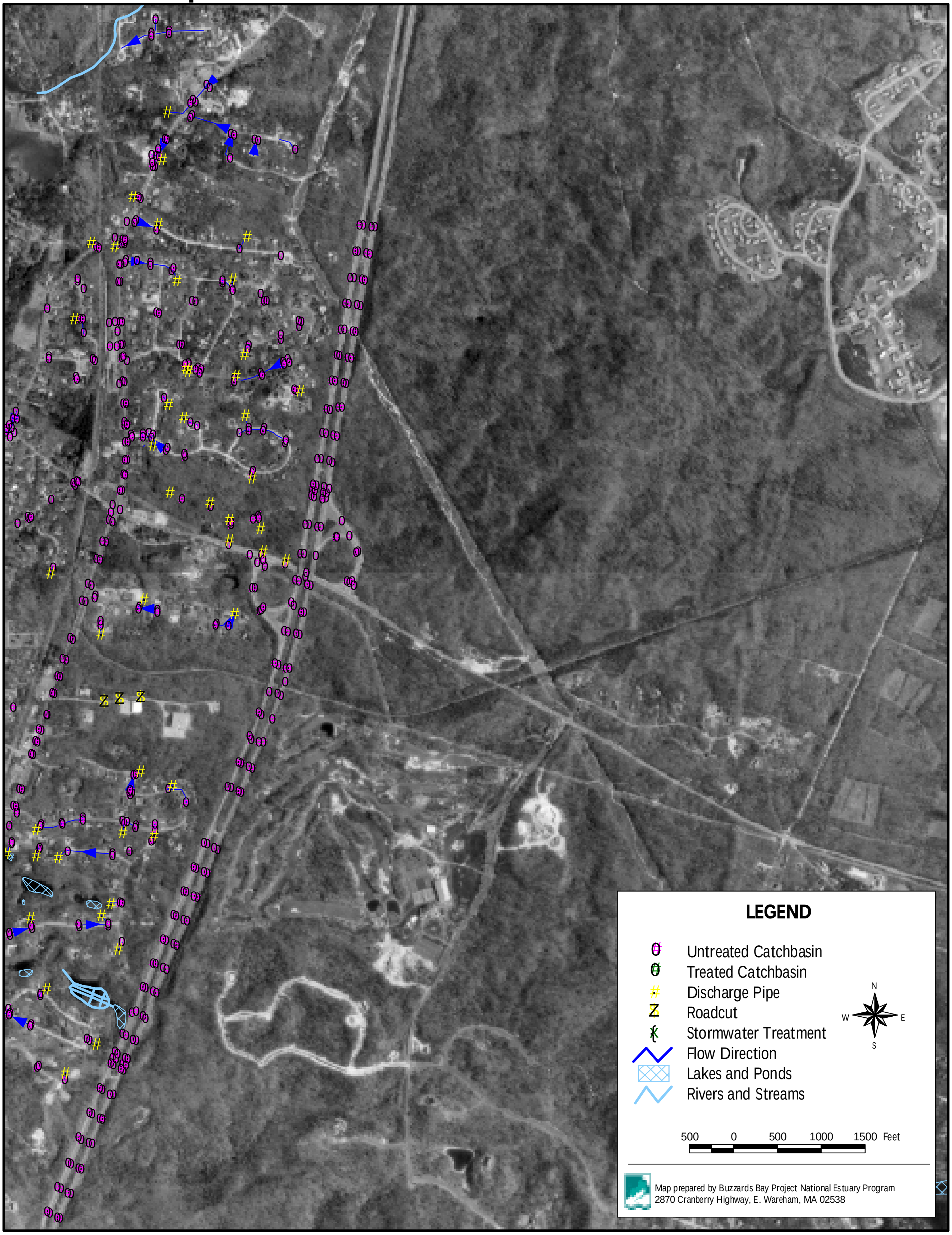
Key for Falmouth Stormdrain Maps



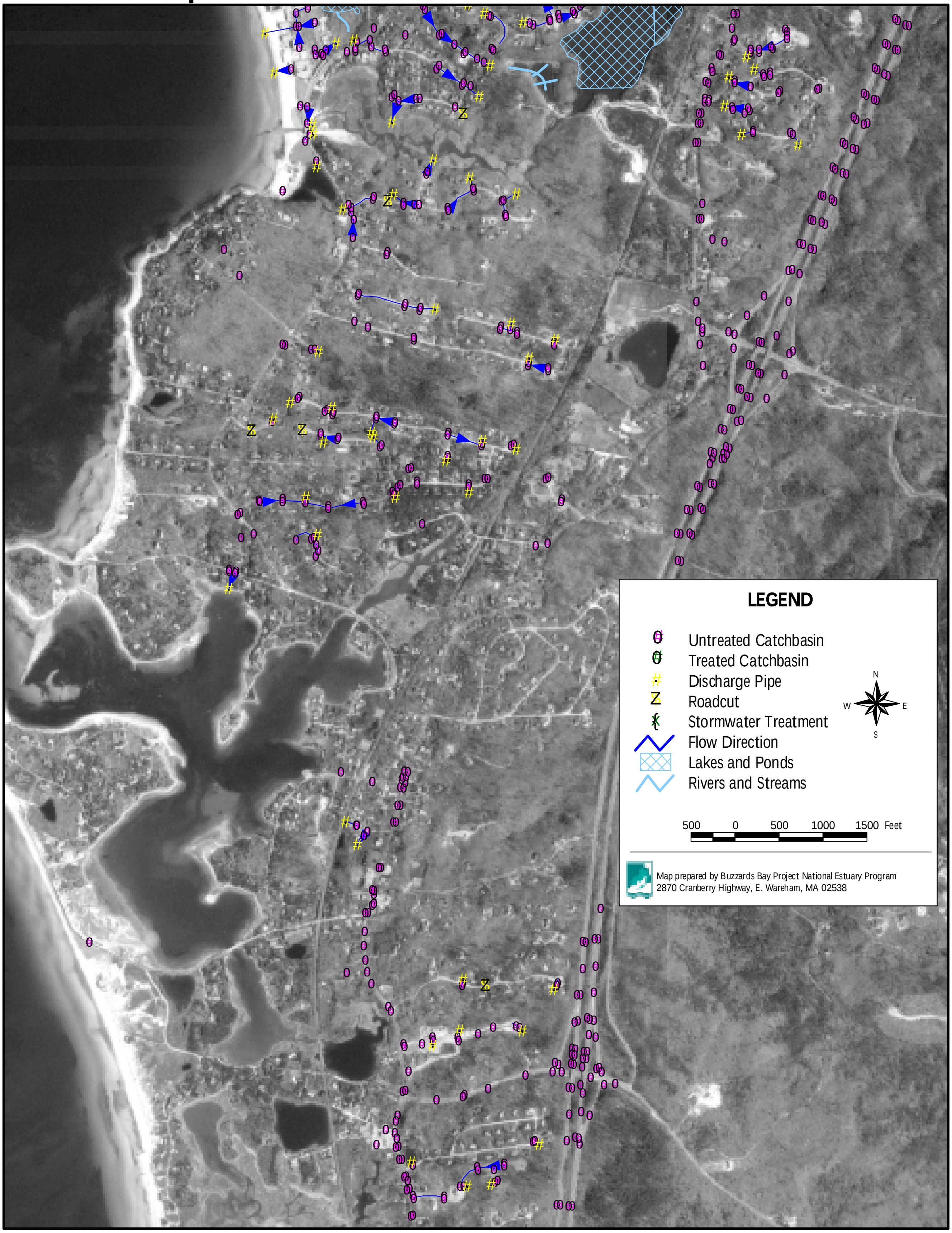
Falmouth: Map 1



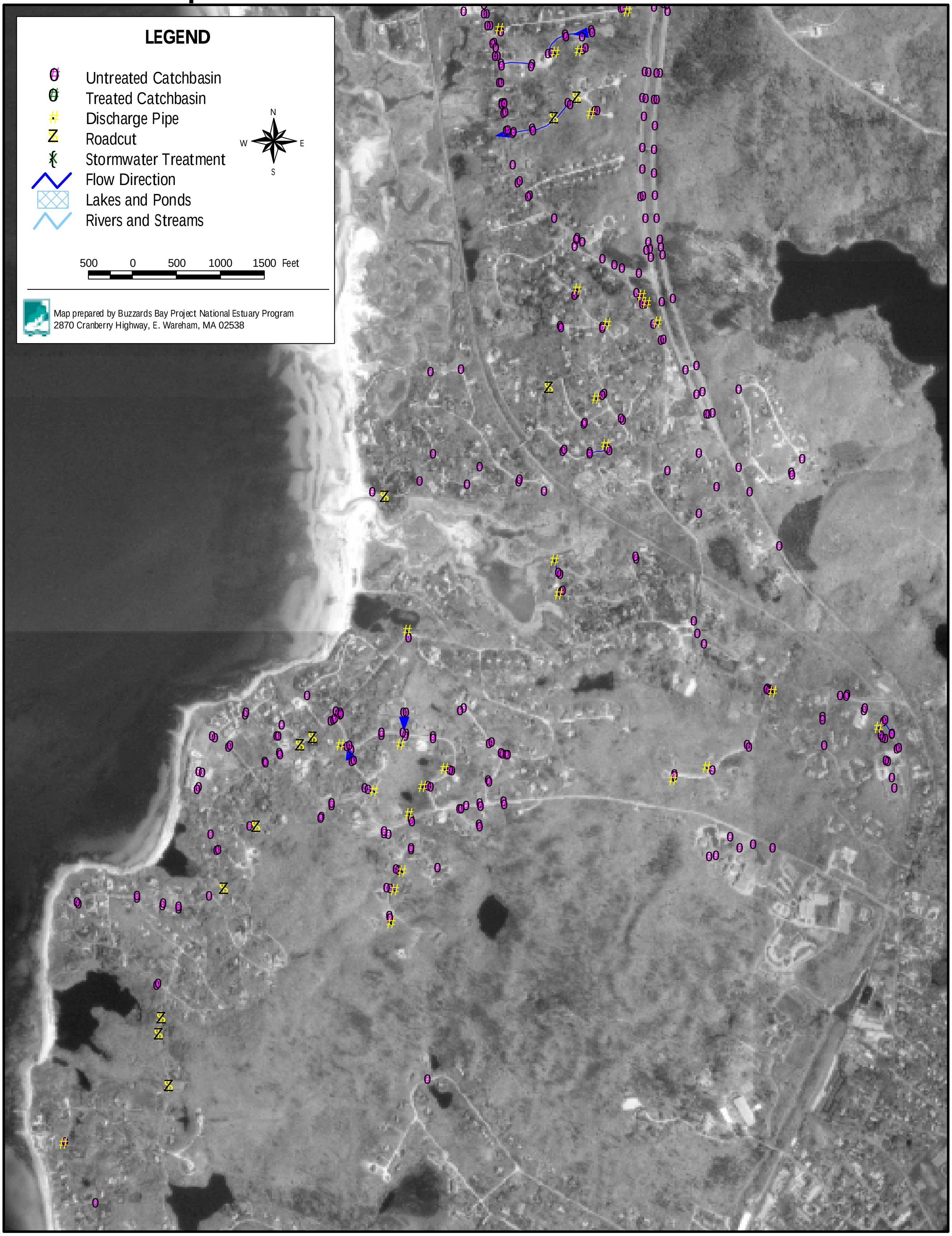
Falmouth: Map 2



Falmouth: Map 3



Falmouth: Map 4



Falmouth: Map 5