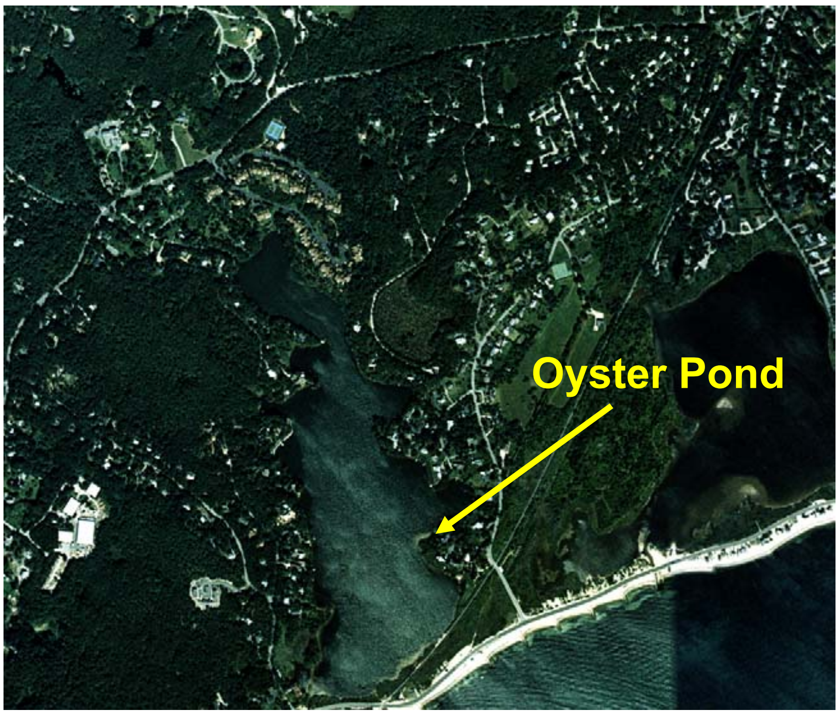
SMAST University of Massachusetts Dartmouth
The School for Marine Science and Technology

Massachusetts Department of Environmental Protection

THE MASSACHUSETTS ESTUARIES PROJECT

Basis for Development of Total Maximum Daily Load of Bacteria



Oyster Pond Watershed
Town of Falmouth, Massachusetts

Prepared for:

The Massachusetts Department of Environmental Protection

Submitted:

July 2005 (FINAL)

NOTICE OF AVAILABILITY

Copies of this Technical Report will be available through the MADEP website at:

http://www.mass.gov/dep/smerp/esttmdls.htm

Massachusetts Department of Environmental Protection
Division of Watershed Management
627 Main Street
Worcester, MA 01608

DISCLAIMER

References to trade names, commercial products, manufacturers, or distributors in this report constituted neither endorsement nor recommendations by the Division of Watershed Management for use.

Table of Contents

List of Figures

List of Tables

Acknowledgements

The Massachusetts Estuaries Project would like to express its gratitude to the Massachusetts Division of Marine Fisheries (DMF) for its valuable bacterial data and shellfish growing area maps. Additionally, the DMF has been very generous with its staff time for interviews and discussions regarding interpretation of its historical bacterial data records. The Division of Marine Fisheries exemplifies the spirit of collaboration in science to meet the greater good of the coastal environment we serve.

The Massachusetts Estuaries Project would also like to thank the Town of Falmouth Department of Public Works for maps depicting locations of catch basins and leaching basins as supplied by the Town Engineer, Gaetano Calise. MEP working with Engineering Department, Oyster Pond Environmental Trust volunteers in concert with PondWatch conducted bacterial sampling of 5 rain events from stormwater pipes discharging directly to Oyster Pond. Special thanks go to Wendi Buessler (OPET) who organized the volunteer effort for MEP and to the Coastal Systems Program at SMAST for supporting the bacterial analyses. These data provide important point source information for management of this system and underscore the ability to leverage resources for the management of this system.

Additionally, the Estuaries Project would like to express its appreciation to Dave Carigan of the Town of Falmouth Board of Health for his generosity with time spent discussing septic systems in the vicinity of Oyster Pond and incidents of failure. Site-specific knowledge such as that shared by the Town DPW and BOH help to make these technical reports more complete and accurate. Similarly, the efforts of the Falmouth PondWatch Program and the Oyster Pond Environmental Trust (OPET) were helpful in providing historical information on changes in tidal exchange and salinity within Oyster Pond and for keeping a focus on the management of this brackish coastal pond.

Authors

This TMDL technical report was written and prepared by B.L. Howes, R.I. Samimy and D.W. White of the Coastal System Program SMAST-UMD, with data contributions provided by S. Kelley of Applied Coastal Research and Engineering and B. Dupont of the Cape Cod Commission. All are members of the Massachusetts Estuaries Project Technical Team.

Recommended Citation

B.L. Howes, R.I. Samimy and D.S. White. 2005. Technical Basis for Development of Bacterial TMDL for Muddy Creek, Chatham, MA. DEP/SMAST Massachusetts Estuaries Project Technical Report.

Executive Summary

The Massachusetts Department of Environmental Protection (MA DEP) is responsible for monitoring and protection of the water resources of the Commonwealth, identifying those water resources that are impaired, and developing plans for restoration of any impaired water resources such that they achieve compliance with the Massachusetts Water Quality Standards (310 CMR 4.00). The Massachusetts Year 2002 Integrated List of Waters (http://www.mass.gov/dep/brp/wm/tmdls.htm), Category 5 ("Section 303(d) List") identifies river, lake, and coastal waters that exhibit degradation and the reason for the impairment.

The DEP is required by the Federal Clean Water Act to develop a pollution budget for a water resource once it is identified as impaired and subsequently listed in Category 5 of the Massachusetts Integrated List of Waters. The pollution budget associated plan is designed to restore the health of the impaired water resource. The process of developing the pollution budget, generally referred to as a Total Maximum Daily Load (TMDL), includes identifying the source(s) of the pollutant from direct discharges (point sources) and indirect discharges (non-point sources), determining the maximum amount of the pollutant that can be discharged to a specific water resource thus enabling it to meet water quality standards, and developing a plan for meeting the restoration goal.

This report provides the technical basis for reducing bacterial pollutant loads in Oyster Pond, Town of Falmouth, Cape Cod, Massachusetts. The recommendations contained within this report should be integrated with the MA DEP's watershed-wide Pathogen TMDL Report for the Cape Cod watershed (August 2005 draft) http://www.mass.gov/dep/brp/wm/tmdls.htm. Though limited data exists for both *E. coli* and Enterococci in this report, the goal is *to meet state water quality standards for aquatic life, shellfishing and recreational uses*. Fecal Coliform bacteria are indicators of contamination of a water resource with sewage and/or the feces of warm-blooded wildlife (mammals and birds). This type of bacterial contamination may pose risks to human health as well as limit the use of natural resources such as shellfish beds. The present effort was undertaken as the first step to prevent further degradation in water quality and to ensure that the water resource (Oyster Pond) will meet state water quality standards. This Technical Report will use the data provided herein in order to establish the bacterial limits for the water resource and will outline corrective actions to achieve the restoration goal.

Based on previous discussions with the DEP, this report is not meant to direct the reader to specific bacterial sources (point or non-point), nor was it intended to produce Fecal Coliform Waste Load Allocations (WLAs) or Load Allocations by bacteria source for the Oyster Pond system. This report aims to point to likely geographic sections of the overall Oyster Pond system that is/are the most likely source of the highest bacterial concentrations recorded to date. However, at the request of the Town of Falmouth, measurements of some specific stormwater discharges to Oyster Pond were undertaken by MEP. In addition, historical data was compiled from multiple agencies and synthesized in the context of more recent weekly bacterial data collected by the

Massachusetts Estuaries Project (MEP) at one location in Quivett Creek discharging to the head of Oyster Pond in addition to completing wet and dry weather sampling at seven sampling stations in Oyster Pond. In order to identify likely sections of Oyster Pond responsible for highest bacterial contamination, geometric means and percent exceedances of water quality standards were developed for current and historical data obtained for this report.

While specific sections of Oyster Pond have been identified as not meeting relevant bacterial standards, recommendations presented herein support the need for further bacterial source tracking investigations, similar in detail as a sanitary survey. The recommendations aim to focus such intense efforts to most contaminated sections of Oyster Pond as a starting point for sanitary survey level investigation of bacterial sources. While the MEP did not undertake a detailed sanitary survey of the Oyster Pond watershed, it did collect information on Quivett Creek and 4 stormwater discharges to Pond waters. Estimates of the inputs of bacterial indicators through 4 stormwater discharges (Oyster Pond Rd: OPR1, OPR2; Quonset Rd., Tree Tops) were undertaken by the MEP as part of the Oyster Pond evaluation. Bacterial contamination most likely attributable to wildlife should be considered a natural condition unless some form of human inducement (feeding or improper trash disposal) is causing congregation of wildlife.

Authority to regulate sources of bacterial pollution and thus the successful implementation of a bacterial TMDL for Oyster Pond generally rests with local government and will therefore require cooperation from local volunteers, watershed associations, municipal government, and other entities as necessary. These cooperative activities may include but not be limited to the following:

- Expanded education
- Obtaining and/or providing funding
- Bacterial source tracking and remediation
- Local enforcement

Federal and state funds to help implement the bacterial TMDL for Oyster Pond are available on a competitive basis and include the Non Point Source Control Grants (Section 319), Water Quality Grants (Section 604(b)), and the State Revolving (Loan) Fund Program (SRF). Financial aid to municipalities will typically involve some degree of local match as well. These funding programs are administered through the Massachusetts Department of Environmental Protection, the Massachusetts Coastal Zone Management Coastal Pollutant Remediation Grant Program and the Division of Municipal Services.

I. Introduction

The State of Massachusetts is responsible under section 303 (d) of the federal and state adopted Clean Waters Act to evaluate the quality of waters in the state, identify those that exhibit water quality problems and to develop a plan with municipalities to return the waters to compliance with acceptable standards.

This report concerning bacterial water quality in Oyster Pond in Falmouth has been submitted to the MA Department of Environmental Protection (MA DEP) by the UMASS Dartmouth School of Marine Science and Technology (SMAST) as a component of the ongoing MA Estuaries Project (MEP). Although the Estuaries Project focuses primarily on estuarine health as related to nutrient inputs it was deemed cost effective by Project membership to simultaneously evaluate those estuaries in the Project study area that are, or should be, listed on the state's revised (2002) 303(d) impaired waters list. This multi-step process involves a comprehensive researching of available bacterial water quality information for estuaries under review, submittal of a status report to the MA DEP regarding historical water quality and a determination as to whether a more detailed bacterial report such as this one, for conversion into a TMDL will be undertaken. Seven systems of the Estuaries Project first tier group of twenty estuaries were selected for preparation of a Bacterial TMDL report. Five of those had been previously 303d listed and two were added because of historically poor bacterial water quality.

This technical report synthesizes, presents, and discusses existing and new bacteriological water quality data on Oyster Pond waters and major surface inflows (Quivett Creek and 4 stormwater inflows). It includes recommendations for future action in areas of the Oyster Pond, based on comprehensive water quality and land use evaluation. Fecal Coliform bacteria are indicators of potential contamination of a water resource with sewage and/or the feces of warm-blooded wildlife (mammals and birds). While fecal coliform bacteria are not generally a direct public health risk, they are typically associated with pathogenic organisms in fecal waste and wastewater. Given that this type of bacterial contamination indicates risk to human health via primary and/or secondary contact recreation (i.e. swimming/fishing) as well as through ingestion of shellfish from contaminated areas, both of these risk pathways impair the use of the aquatic resource and are called out in the State's Water Quality Classifications. As such, in order to prevent further degradation of water quality in Oyster Pond and to restore its beneficial state designated use as an open shellfishing resource (SA water class), fecal coliform data has been assembled to characterize the bacterial conditions in the pond. In addition, although local corrective actions have been outlined in order to achieve the highest possible shellfishing restoration goal, it is important to note that the present salinity of Oyster Pond (2 ppt) is not presently supporting shellfish resources. The present management plan for Oyster Pond aims to maintain the pond at this low salinity into the foreseeable future with the goal of establishing a stable and healthy brackish water ecosystem. Therefore, it must be considered that Oyster Pond bacterial levels may appropriately increase the emphasis on standards for primary contact recreation, which does occur in this system. However, for the purposes of the present technical report, the MEP Technical Team included analysis relative to shellfishing, as it is presently designated as a shellfishing resource.

Based on the process established by DEP, this technical report is not meant to direct the reader to specific bacterial sources (point or non-point), nor is it intended to produce Fecal Coliform Waste Load Allocations (WLA's) or Load Allocations by bacteria source for the Oyster Pond System. Though ambient water quality data are available for comparison to state bacterial standards, and data were collected that allow for the identification of some of the point sources of contamination. The overall, goal is to point to geographic sections of the overall Oyster Pond system that are the most likely sites of bacterial entry, and that may require additional targeted source identification efforts over and above those presented herein. This focusing of potential future effort is primarily based upon spatial and temporal analysis of bacterial levels within Oyster Pond waters and how they respond to rainfall. However, as some discharges have been measured as part of the MEP effort, some specific remediation steps may also be supported.

This technical report, integrated with regulatory input from the MA DEP, will be submitted to EPA Region 1 as a completed Massachusetts Estuaries Project workplan deliverable. This Technical Report and the MA DEP watershed-wide Pathogen TMDL for the Cape Cod watershed will include recommended corrective actions that will be used to direct the process and activities deemed necessary to reduce bacterial loadings, minimize the human health risk and restore the historical beneficial uses of the water body. A TMDL is a pollution budget or pollution allocation that accounts for the multitude of variables that influence water quality and that establishes the acceptable limits of pollution based on the combined influence of these variables and the sensitivity and use of the water body. As described, a TMDL also includes an outline of a generalized cleanup plan for restoring the designated water quality use. This restoration plan is developed with the communities associated with the specific water resource and involves public input.

II. Oyster Pond

Oyster Pond (Massachusetts Category 5 Water, Segment Id. MA96-62_2002, east of Fells Road, Falmouth) is located in the Town of Falmouth, Massachusetts, approximately 1.5 miles northeast of Woods Hole. Oyster Pond exchanges tidal waters with Vineyard Sound through a tidal control structure placed between the Pond and the Lagoon at the upper end of the Trunk River (Figure II-1). Due to the tidal control structure, the Pond has held a salinity of ~2 ppt in recent years. Oyster Pond is a drowned coastal kettle pond comprised of three basins with a maximum depth of 6.5 meters. The pond qualifies as a "great pond", having a surface area is 63 acres (25.5 hectares). The pond is approximately 1050 meters long and is oriented north-northwest almost perpendicular to the shore of Vineyard Sound. The maximum width of the pond is 400 meters with an irregular shore that makes for an average width of approximately 200 meters.

Freshwater inflow to Oyster Pond is predominantly through groundwater (~2300 m^3 d^{-1}) with a small stream, Quivett Creek entering the headwaters (<100 m^3 d^{-1}). Oyster Pond has effectively become a brackish oligohaline (0.5 ppt – 3 ppt) system as a result of the restriction of its outlet to Vineyard Sound. The south end of the pond was formerly a sand and gravel bar, which separated it from Vineyard sound. In the 1880's a railroad embankment was constructed and more recently a roadway built along the north side of the bar and atop an adjoining marsh now limits the ponds tidal exchange with Vineyard Sound. At present the railroad bed is preserved as a bikeway. The tombollo fronting Oyster Pond on the Sound is Quissett Beach.

Tidal exchange with Vineyard Sound waters is through the Trunk River (Figure II-2). The Trunk River inlet is presently fixed with jetties, which have been recently repaired. The lower reach of the channel is armored with rip-rap from the inlet, under the bikeway, up to the branch leading to a salt marsh lagoon on the way to the inlet to Oyster Pond proper. The tidal flow to Oyster Pond is presently controlled by a weir structure, designed to allow fish passage and control of the water level and salinity of the Pond. When the Trunk River channel is properly maintained, the primary restriction to tidal flows to Oyster Pond is the weir, rather than the channel or conduits under the roadway. The primary channel maintenance task is to clear sand deposited during storms. The small salt marsh lagoon is shallow (0.5 meter deep) and extends approximately 350 meters southwest of the pond and hosts a variety of avian wildlife. Given its position in the tidal river and its morphology, the lagoon acts as a depositional basin for fine particulates and macrophytes detritus entering from either the Sound or Pond. As a result the lagoon supports organic rich and sulfidic sediments. Current management of the Trunk River-Oyster Pond System includes maintaining some tidal water within the lagoon at low tide both as habitat and to prevent nuisance odors (hydrogen sulfide and organo-sulfur compounds) during summer months. The Town's management of Oyster Pond has resulted in stable salinities and the restoration of key fish populations (e.g. white perch and herring).

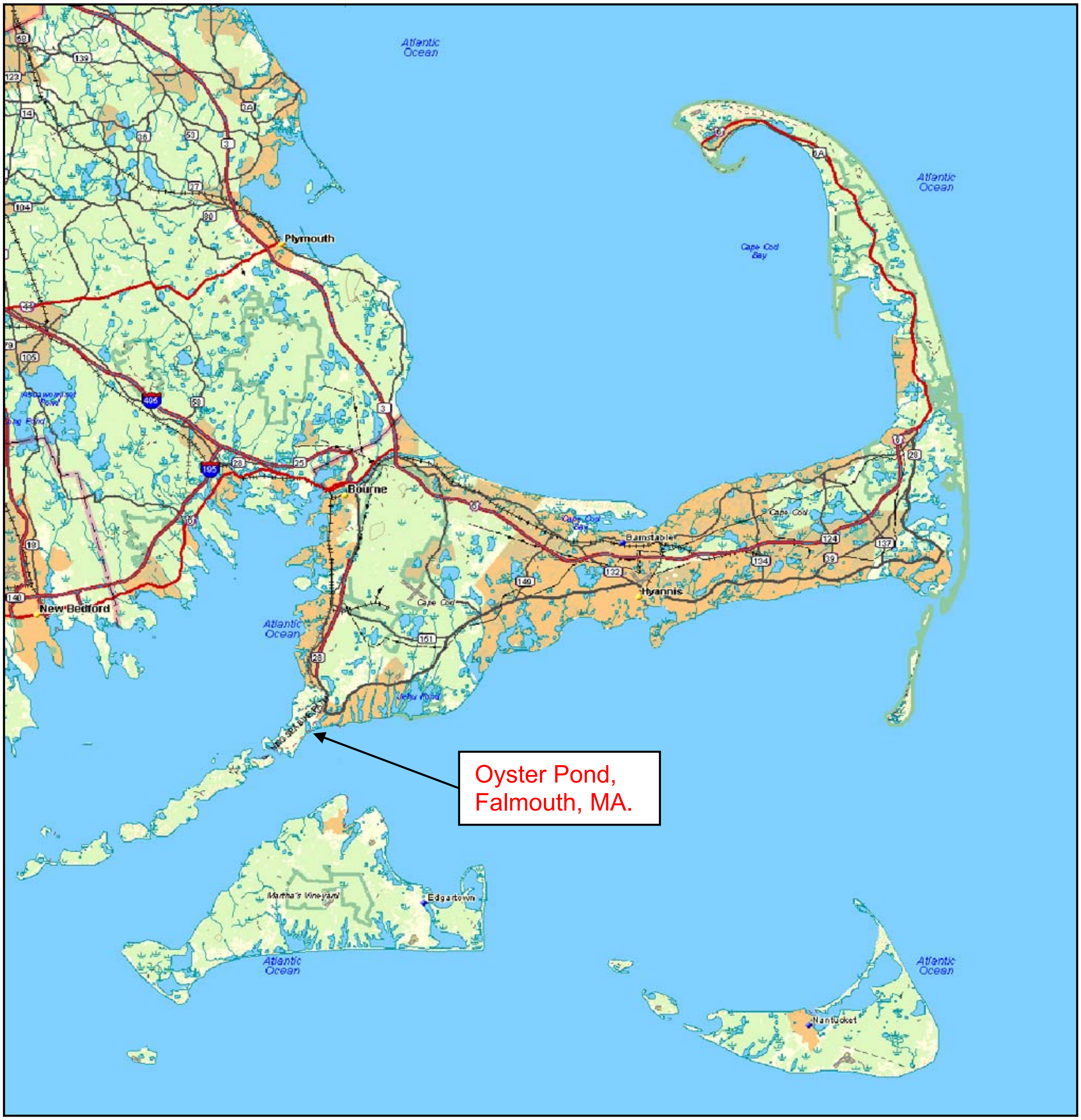


Figure II-1. Location of the Oyster Pond system, Cape Cod, Town of Falmouth, Massachusetts.

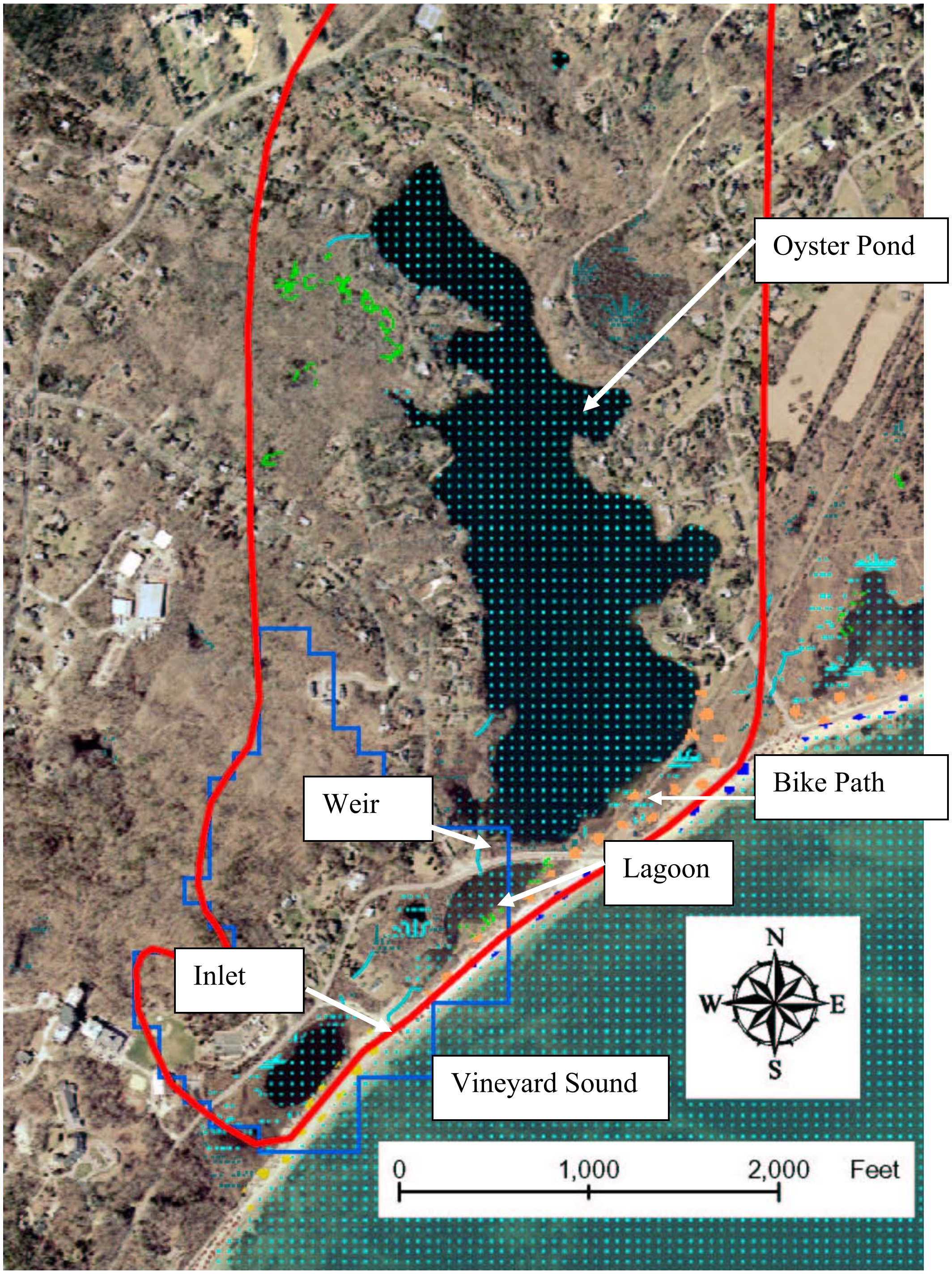


Figure II-2. The Oyster Pond System, Cape Cod, Town of Falmouth, Massachusetts.

II.1 Land Use Analysis

For the purpose of this technical report in support of bacterial TMDL development to be completed by the MA DEP, the MassGIS Land Use database was utilized to conduct the land use analysis of the Oyster Pond watershed as delineated by the USGS for MEP (Figure II-3). A more detailed parcel by parcel analysis of the Oyster Pond watershed land use characteristics is nearing completion under the Massachusetts Estuaries Project, but was not available for completion of this technical report. Although the more detailed analysis has a higher overall accuracy, relative to the pathways of bacterial input and land-uses adjacent the waters of Oyster Pond there is no discernable difference between the methods. In addition, the direct measurement of surface water inflows provides a major refinement to the land-use data. The MassGIS data-layer has land use classifications interpreted from 1:25,000 aerial photography. The LU37_CODE land use classification was used for the purpose of this land use analysis. In 1990 the Cape Cod Commission updated the land use data layers for all of Cape Cod, including the watershed to Oyster Pond. The land use data used in this technical report are based upon 1999 surveys. Given the minimal construction in this watershed, these data accurately represent present conditions. The data are categorized into 26 land use classifications, expanding the original MassGIS codes to include 23,26,29 and 30. These additional codes, along with the original 21, are listed in LU37_CODE. The original 21category classification aggregates the categories in the LU37_CODE data layer and the 15 additional categories are described below:

CODE	ABBREV	CATEGORY	DEFINITION
1	AC	Cropland	Intensive agriculture
2	AP	Pasture	Extensive agriculture
3	F	Forest	Forest
4	FW	Wetland	Nonforested freshwater wetland
5	M	Mining	Sand; gravel & rock
6	O	Open Land	Abandoned agriculture; power lines; areas of no vegetation
7	RP	Participation Recreation	Golf; tennis; Playgrounds; skiing
8	RS	Spectator Recreation	Stadiums; racetracks; Fairgrounds; drive-ins
9	RW	Water Based Recreation	Beaches; marinas; Swimming pools
10	R0	Residential	Multi-family
11	R1	Residential	Smaller than 1/4 acre lots
12	R2	Residential	1/4 - 1/2 acre lots

13	R3	Residential	Larger than 1/2 acre lots
14	SW	Salt Wetland	Salt marsh
15	UC	Commercial	General urban; shopping center
16	UI	Industrial	Light & heavy industry
17	UO	Urban Open	Parks; cemeteries; public & institutional greenspace; also vacant undeveloped land
18	UT	Transportation	Airports; docks; divided highway; freight; storage; railroads
19	UW	Waste Disposal	Landfills; sewage lagoons
20	W	Water	Fresh water; coastal embayment
21	WP	Woody Perennial	Orchard; nursery; cranberry bog
22	-	No Change	Code used by MassGIS only during quality checking

The additional categories in LU37_CODE are:

CODE	**ABBREV**	**CATEGORY**
23	CB	Cranberry bog (part of #21)
24	PL	Powerlines (part of #6)
25	RSB	Salwater sandy beach (part of #9; no longer used)
26	RG	Golf (part of #7)
27	TSM	Tidal salt marshes (part of #14; no longer used)
28	ISM	Irregulary flooded salt marshes (part of #14; no longer used)
29	RM	Marina (part of #9)
30	-	New ocean (areas of accretion; part of #20)
31	UP	Urban public (part of #17)
32	TF	Transportation facilities (part of #18)
33	H	Heath (part of #17)
34	CM	Cemeteries (part of #17)
35	OR	Orchard (part of #21)
36	N	Nursery (part of #21)
37	-	Forested wetland (part of #3; no longer used)

For the Oyster Pond watershed land use analysis, the watershed land use was divided into several general categories that were further subdivided to refine land use descriptions. For example, the residential land use grouping includes single family, two, three and multiple family dwellings, apartments and boarding houses to name a few. In this report the primary groupings will be employed (Table II-1).

Generally the most common sources of fecal coliform bacteria to coastal water bodies are “failing” septic systems, stormwater runoff from impermeable surfaces, combined sewer overflows, congregation of waterfowl, wildlife in wetlands and sometimes boat discharges.

It is interesting to note that the predominant land use types in the Oyster Pond watershed are forest land and residential. Almost half (46.37 percent) of the watershed is currently classified as forested land and 17.27 percent of the watershed is medium density residential (1/4 to ½ acre lots). Both the eastern and western shores of Oyster Pond are classified as medium density residential and the upper portions of the watershed as forested land (Figures II-3, II-4). A small portion (3.97 acres) of the Oyster Pond watershed abutting the head of Oyster Pond is comprised of town house type residences (e.g. Treetops condominium development) that utilize individual septic systems, classified as multi-family residential. Discussions with the Town of Falmouth Board of Health in January 2003 indicated that the:

- East shore of Oyster Pond is on town sewer
- North shore of Oyster Pond is dependent on individual septic systems with no knowledge of failures.
- Northwest shore of Oyster Pond is very lightly populated with no structures near pond, therefore there are no direct discharges to the pond in this area.
- No sanitary surveys have been undertaken since 1984

A watershed comprised of approximately ½ forest land is unusual in southeastern MA and combined with the fact that there are very few septic systems located near the Pond suggest that the cause of most bacterial contaminants are very likely the observed congregating birds and the stormwater runoff both of which are exacerbated by the lack of circulation and tidal flushing discussed previously. Boat waste is not an issue in Oyster Pond as there is no navigable entrance or boat ramp on Oyster Pond and therefore the only boats are small non-motorized craft.

To address the potential importance of stormwater the MEP met with George Calise, Falmouth Town Engineer. Discussions with and data provided by the Town Engineer in 2004 indicated the potential importance of 4 stormwater discharges to the surface waters of Oyster Pond. These were addressed with an initial round of direct measurements (see below).

OYSTER POND WATERSHED LANDUSE AREA BY FREQUENCY AND AREA					
CODE DESCRIPTION	**CLASSIFICATION DESCRIPTION**	**CLASSIFICATION CODES**	**AREA_FT2**	**AREA_Acres**	**PERCENT OF WATERSHED**
Cropland	*intensive agriculture*	1	146553	3.36	0.78%
Pasture	*extensive agriculture*	2	4011	0.09	0.02%
Forest	*forest*	3	8756863	201.03	46.37%
Wetland	*nonforested freshwater wetland*	4	467238	10.73	2.47%
Open Land	*abandoned agriculture; areas of no vegetation*	6	398219	9.14	2.11%
Participation Recreation	*golf; tennis; playgrounds; skiing*	7	39533	0.91	0.21%
Water Based Recreation	*beaches; marinas; swimming pools*	9	8096	0.19	0.04%
Residential	*multi-family*	10	749165	17.20	3.97%
Residential	*1/4 to 1/2 acre lots*	12	3260703	74.86	17.27%
Residential	*larger than 1/2 acre lots*	13	1549876	35.58	8.21%
Salt Wetland	*salt marsh*	14	272924	6.27	1.45%
Waste Disposal	*landfills; sewage lagoons*	19	211111	4.85	1.12%
Water	*fresh water*	20	3000092	68.87	15.89%
Urban Public	*parks, cemeteries, public and institutional greenspace, also vacant undeveloped land*	31	21765	0.50	0.12%
	Total Parcel Area		18886149	433.57	100.00%

Table II-1 Land use distribution for the Oyster Pond Watershed

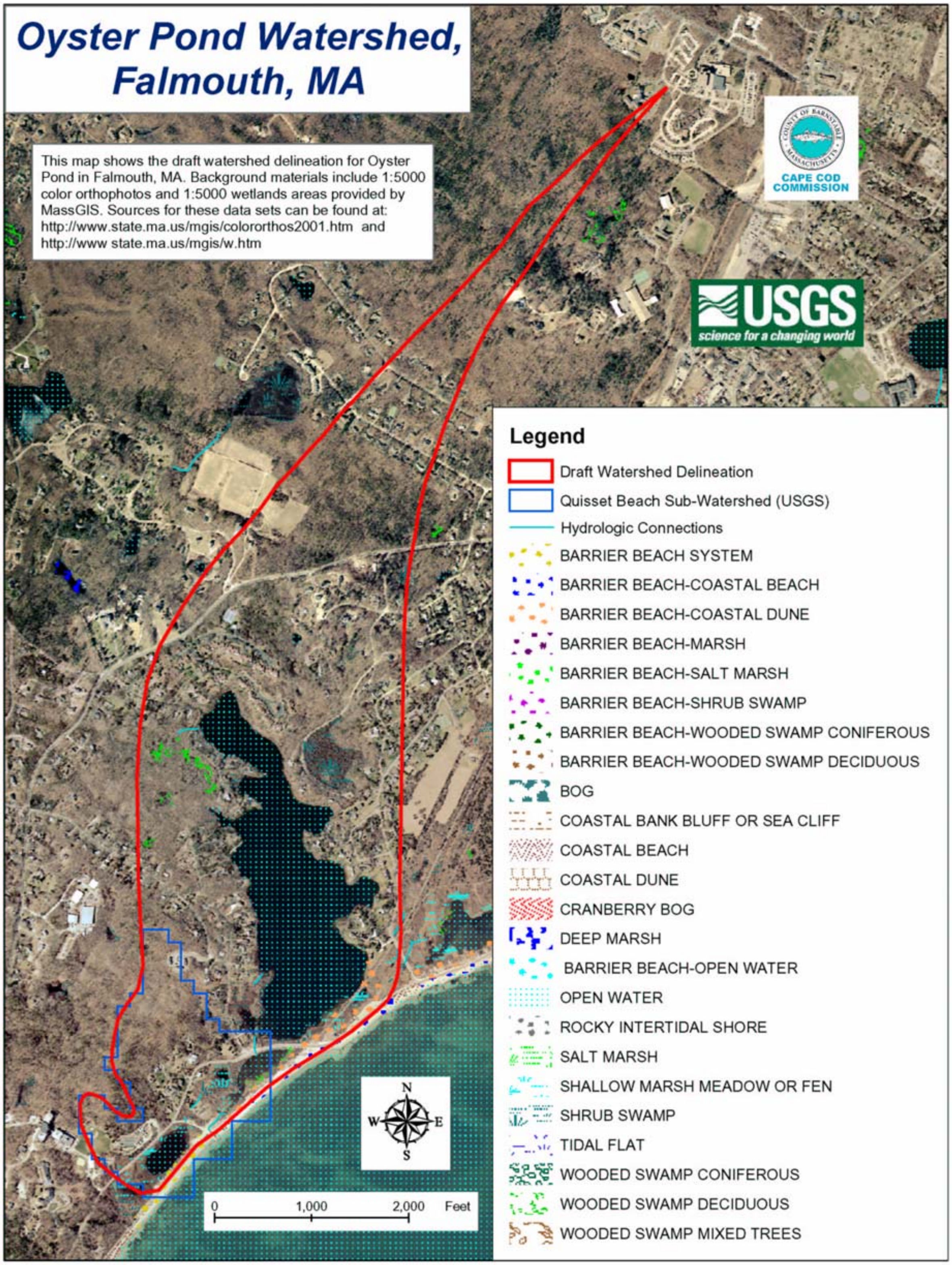


Figure II-3. Ecological and geologic characteristics of the watershed to the Oyster Pond System, Town of Falmouth, Massachusetts.

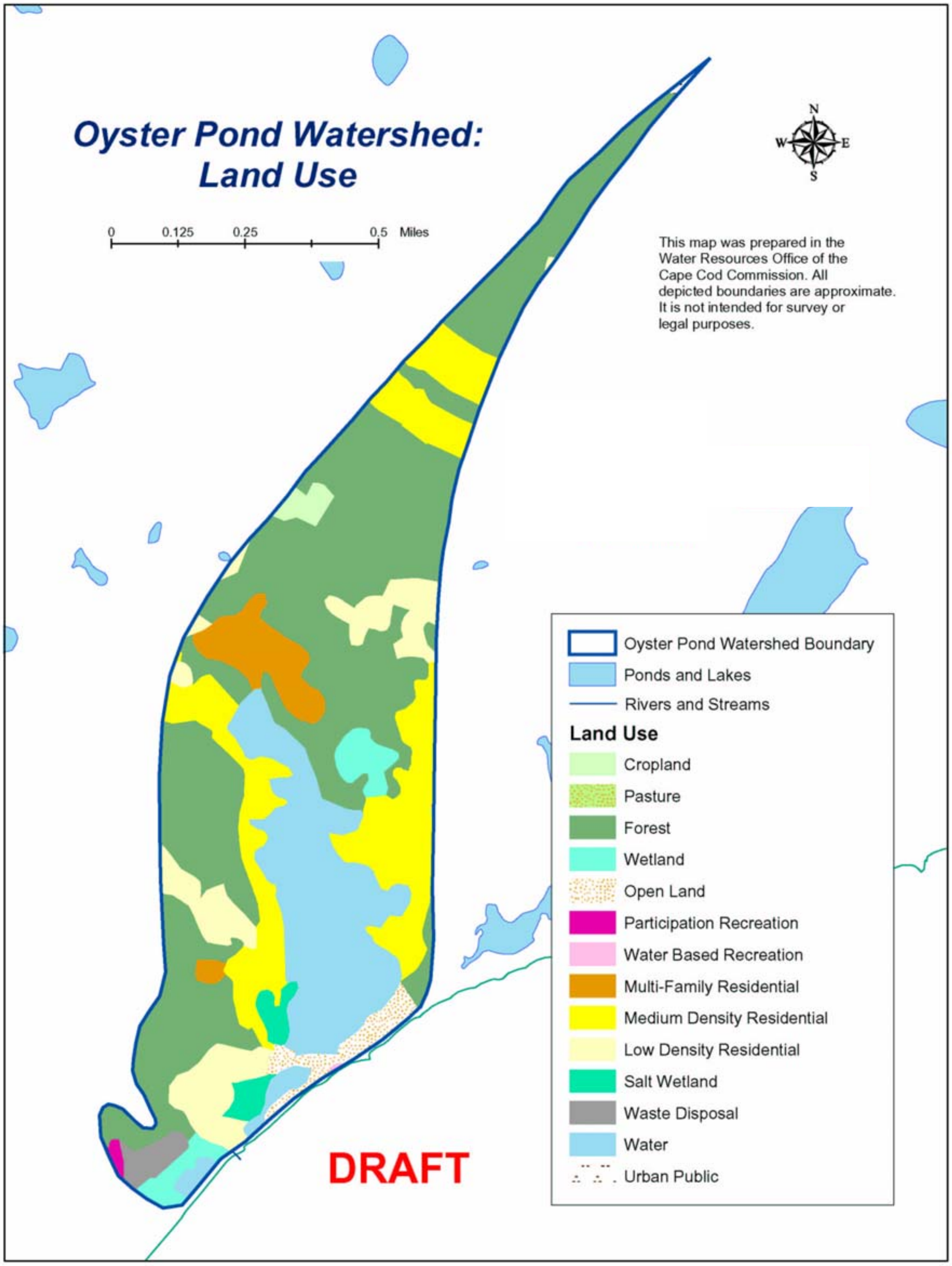


Figure II-4. Land-use characteristics of the watershed to the Oyster Pond System, Town of Falmouth, Massachusetts.

III. Problem Assessment

Oyster Pond was one of seven embayments selected to undergo further bacterial evaluation from the original list of 20 estuaries prioritized under the Massachusetts Estuaries Project. It was selected because the waters exceeded the state's Water Quality Standards for bacterial pathogens in historical samplings and analyses. As a result, Oyster Pond has been closed as a shell fishing resource since 1984. However, in setting the management target in this system, the MEP concludes that the shellfishing threshold for bacterial indicators is no longer appropriate. Due to the restoration of historical (20^{th} century) salinities (~2ppt) in Oyster Pond in the 1990's, it no longer is able to support harvestable shellfish. The Town of Falmouth's management plan for the Pond is based upon maintaining the salinity at its current level based upon habitat stability and health, community interests and restoration of the herring run. To the Town's credit, the fish populations have been restored (e.g. white perch, herring) over the past decade.

There were five active sampling stations monitored by DMF from 1986-88 and seven active stations monitored from 1989-97 generating almost 90 data points for the years 1986-97. No sanitary surveys have been conducted since 1984 when the Pond was permanently closed to shell fishing

At present, the most likely sources of fecal coliform bacteria are waterfowl and storm water runoff from the discharges. The Pond hosts a variety of waterfowl and there are several storm drains and leaching catch basins discharging into or proximal to the Pond. There are also culverts/pipes transferring water from abutting marshy areas into the pond. Five surface water inflows (Quivett Creek and 4 storm discharges) were identified and assayed as part of the MEP effort. However, the northern and western sides of the Pond support limited development and none directly abutting the Pond. There have been no reported failures of septic systems in this area (1999-2003). There are no CSO inputs and the residences on the eastern side of the Pond are connected to town sewer. The limited flushing of the pond restricts the transport of bacterial indicators and pathogens from the system, almost certainly making "die-off" the major loss factor in this system.

The State utilizes a fecal coliform standard of 14 colonies /100ml for maintaining open and fishable shellfish resource areas. This standard has been exceeded frequently since the Ponds closure in 1984. The Pond does not support any public beaches.

III.1 Freshwater Inflow to Oyster Pond From Surface Water Inflows

In order to address the importance of known surface water discharges to the waters of Oyster Pond as pathways of entry of indicator bacteria, the MEP monitored the only stream, Quivett Creek (Mosquito Ditch) , and conducted wet weather sampling on 4 stormwater discharges. Quivett Creek was a MEP stream gauge site and sampling of the stormwater discharges was in partnership with the Town of Falmouth Engineering Department and the Oyster Pond Environmental Trust (OPET). Estimates of the levels of bacterial indicators and the volumentric discharges were determined at all sites to determine bacterial loads. These loads were then compared to records of bacterial levels within the various Pond basins to assess their relative importance to the observed levels of contamination.

Quivett Creek: In consideration of potential sources of bacterial contamination to the northern upper basin at the head of Oyster Pond, stream flow data generated under the Massachusetts Estuaries Project nutrient analysis efforts was referenced and combined with periodic MEP bacterial sampling conducted in Quivett Creek for the purpose of this technical report (Figure III-1). A bacterial sampling site was selected in Quivett Creek (station QC), to assess the potential instantaneous point source bacteria load (cfu d^{-1}) associated with Quivett Creek discharge.

During previous field reconnaissance, Quivett Creek was found to drain a forested area currently owned by the Oyster Pond Environmental Trust. The Environmental Trust owns four lots that constitute the Mary Zinn Park. The approximate drainage area to Quivett Creek appears to include these four lots (254, 255, 256, and 257) as well as a fifth parcel (parcel 9) that is owned by the Woods Hole Oceanographic Institution. Quivett Creek upgradient of Ransom Road has very little flow and resembles a mosquito ditch with stagnant water and large amounts of decomposing organic matter. The forested Park area likely supports populations of wildlife and waterfowl that may use Quivett Creek as a source of water and may contribute to bacterial contamination in the creek flowing into Oyster Pond. Additionally, there are a handful of homes that are likely on septic systems with leach fields that may drain to this forested area and therefore, potentially discharge to Oyster Pond via Quivett Creek. As such, estimates of daily flow from Quivett Creek were obtained from the estuaries Project and combined with bacterial concentration data to quantify the potential instantaneous point load of bacteria to the north basin at the head of Oyster Pond.

As required by the Massachusetts Estuaries Project (MEP), a stream gage was deployed in Quivett Creek in July of 2002. The stream gage was installed in the creek bed immediately down gradient of the culvert that passes under Ransom Road, which separates the forested land (Mary Zinn Park) from Oyster Pond.

The stream gage has collected stage data in Quivett Creek for 18 months at a 10-minute interval, at the time of this writing. In conjunction with the automated collection of stage measurements within Quivett Creek, the MEP has also been responsible for conducting periodic measurements of volumetric discharge at the stream gage site. The discharge and stage data were integrated to develop a stage-discharge relationship (rating curve) for Quivett Creek. Observed flows were obtained as the sum of measured cross sectional velocities multiplied by stream cross sectional areas. The rating curve developed for Quivett Creek and the continuous stage record, collected from August 1, 2002 to July 31, 2003, allowed the determination of daily discharge volumes. Over the year of sampling, discharge from Quivett Creek ranged from a maximum of 299 m^3/day to a minimum of 35 m^3/day. The average daily discharge was determined to be 95 m^3/day. Quivett Creek discharged approximately 35,000 m^3 of freshwater to Oyster Pond between August 2002 and August 2003.

As an independent confirmation of the annual stream flow to the north basin of Oyster Pond from Quivett Creek, the recharge area to Quivett Creek was back calculated from annual recharge for this area of Cape Cod and the predicted annual stream flow. Based on a recharge rate of 26 inches per year and the MEP measured annual stream flow of 34,700 m^3, the contributing land area would be approximately 13 acres. The Town of Falmouth Tax Assessors Department was contacted for confirmation of the size of the land area generally thought to be the contributing area to Quivett Creek (the forested land up-gradient of Ransom Road as well as some of the adjacent residential properties) in order to compare to the calculated contributing area to Quivett Creek based on annual flow and recharge rate. Discussion with the assessors office revealed that the forested area, which is a large portion of the contributing area to Quivett Creek, is comprised of 4 lots owned by the Oyster Pond Environmental Trust and represents a total of 7.5 acres and 2 parcels owned by the Woods Hole Oceanographic Institution. The first of these latter parcels is 2.54 acres, which appears to be fully within the sub-watershed. The second is 17.52 acres, which is only partially within the sub-watershed. Based upon topographic analysis it appears that as much as 40% of this parcel may contribute to Quivett Creek (values are being refined in the MEP nutrient report). Based upon these approximations the contributing area generating flow to Quivett Creek is on the order of 17 acres, ~30% higher than the estimate from measured discharge. Given the uncertainties determining the contributing area for the recharge analyses and the small areas involved, it appears that the measured discharge of Quivett Creek is sufficiently supported to be acceptable for calculating instantaneous bacterial loads to Oyster Pond based on bacterial sampling results. Note that the recharge analysis is only used to confirm that the measured flows are reasonable. The values used are still the actual flows and loads that were directly measured.

The loading analysis for Quivett Creek and for the point source stormwater discharges was conducted to determine the relative importance of different sources to the overall load in the pond or to help set priorities for future source identification work. Based on measured daily flows and periodic bacterial sampling (station QC) at the MEP gauge site, it is possible to calculate instantaneous point loads of bacteria from Quivett Creek to the north basin of Oyster Pond. Table III-1 summarizes flow rates, bacterial levels (colony forming units per 100 mL, CFU/100 mL) and associated loads (CFU/day). As would be expected, bacterial load to the north basin of Oyster Pond varies significantly with the magnitude of discharge from Quivett Creek as well as the bacterial concentration of the samples. Loads to Oyster Pond ranged from a maximum of 10^9 colony forming units per day to a minimum of 10^6 (Table III-2). However, Fecal Coliform levels in Quivett Creek waters were relatively stable over the 29 samplings, with a geometric mean of 49 CFU $100mL^{-1}$. While this exceeds the threshold for shellfishing (see Section IV, below), it is well below 200 CFU $100mL^{-1}$, which was exceeded on 5 of 29 dates (17%).

In order to further gage the significance of the indicator bacteria loading from Quivett Creek to Oyster Pond, the number of potential bacteria present in the volume of north basin from the surface to 1.0 meter below the surface was calculated. A 1 meter surface layer was selected for calculations as (1) watercolumn bacterial samples are collected from 6" (15 cm) depths, (2) it provided for some degree of dilution upon mixing into pond waters, and (3) it represents a conservative estimate of mixing/dilution. The calculation was based on an average observed bacterial levels (geometric mean) determined for the north basin of Oyster Pond based on three monitoring stations (OP1, OP2 and OP7, see Figure V-2 below). Average bacterial levels were determined under the various conditions depicted in Figures V-3 (summer / winter 2003 – 2003) and V-4 (summer wet/dry, winter wet/dry 1994 – 2003). The surface area of north basin was obtained by GIS and was determined to be 14.46 acres (58,518 m^2). Table III-3 summarizes the number of CFU per the volume of the surface layer (surface of pond to 1.0 meter below surface) in comparison to the maximum and minimum instantaneous point load discharging from Quivett Creek (CFU d^{-1}). The average point load from Quivett Creek (3.35×10^7 CFU d^{-1}) is (summer 1.29×10^{10} CFU/basin ; winter 3.71×10^9 CFU/basin) 2-3 orders of magnitude less than the number of CFU represented in the surface volume of the north Basin of Oyster Pond. Given die-off and flushing of bacteria out of the basin, it appears that in general Quivett Creek is a small contributor to the present bacterial inputs to the North Basin. However, the single highest input from Quivett Creek (2.02×10^9 CFU d^{-1}, Table III-1) would indicate that Quivett Creek can be an important source, but this event was 5 times higher than the next highest record of 21 samplings. The geometric mean of the 21 Fecal Coliform load samplings at the MEP gauge site on Quivett Creek was 3.35×10^7 CFU d^{-1}. The mean daily load accounts of only 0.3% and 0.9% of the total north basin average summer and winter surface water FC pool, respectively. However, to the extent that there is less dilution (5000 m2 area is 3% and 10% respectively) or that the populations persist for several days before die-off or being flushed out (e.g. at 3 days, 1% and 2.7%, respectively) the contribution from Quivett Creek becomes relatively more important. However, overall it appears that while Quivett Creek may under rare events contribute significant bacterial loads to the north basin, in general it explains only a small portion of the bacterial pool observed. In addition, it is likely that the source of bacteria to Quivett Creek is through wildlife, given its watershed land-use (see below).

Stormwater Inflows: Estimates of the inputs of bacterial indicators through stormwater discharge were undertaken by the MEP as part of the Oyster Pond evaluation. Discussions with the Falmouth Town Engineer, indicated that the Town was working on stormwater remediation and needed field sampling data to guide remediation in this system. The Engineering Department provided information on potential stormwater inflows to Oyster Pond to the MEP. MEP working with volunteers from OPET collected data on 4 potential stormwater discharges distributed throughout the Pond (Figure III-1); 1 to the North Basin (Tree Tops), 1 to the Mid Basin (Quonset Rd), 2 to the Lower Basin (Oyster Pond Rd). At each site there was either a discharge pipe or a discernable channeled discharge that could be sampled for flow volume and bacterial levels. Bacterial samples and discharge were measured at first flush and after the first 0.25 inches of precipitation had fallen. A total of 5 rain events were sampled from September 2004 to December 2004. All bacterial samples were processed within 6 hr of collection at the Barnstable County Department of Health and the Environment Laboratory.

The storm event sampling was used to determine the relative importance of each of the stormwater discharges to the immediate region of the pond, defined as 5000 m^2 (0-1m) and the larger sub-basin (0-1m). These values were compared to average wet weather bacterial levels collected in the Pond waters by SMAST (V-4). The concept is to screen the stormwater discharges, not to determine their quantitative contribution to Oyster Pond bacterial levels. Each of the 4 discharge sites appeared to have flow related to storm events and showed little to no flow during dry weather. In fact, each discharge site did not show flow on all 5 sampling events, only the Oyster Pond Rd. sites (OPR1, OPR2) flowed in each event and generally showed higher discharge rates that the other 2 sites (Table III-4). Similarly, the fecal coliform levels were significantly higher in the Oyster Pond Rd. discharges (OPR1, OPR2, Table III-4), than in the other discharges sampled, including Quivett Creek. Relative to levels of indicator bacteria (CFU mL^{-1}), the discharges ranked OPR1>OPR2>>Quonset R>Tree Tops. However, it is the transported bacterial loads (CFU d^{-1}) that primarily affect bacterial levels within the receiving waters.

Comparisons were made of the load of bacterial indicators from each discharge relative to the “pool” of bacteria within the receiving waters. Similar to the analysis for Quivett Creek, the specific volume of receiving pond water serving to dilute the inputs has not been quantified. Therefore, the analysis of the Pond pool of bacteria is based upon an initial volume (5000 m^3, 5000 m^2 in the 0-1m layer, Table III-5) and a greater basin volume based upon the specific Pond basin that the discharge enters (0-1m layer, Table III-6). The concept is to constrain the assessment of the importance of a source to both nearfield and whole system bacterial levels. The nearfield volume (5000 m^3) was based upon the size of coves around the pond. The bacteria levels in this analysis are based upon summer wet weather samples. The discharges were assumed to flow for 8 hours, which is consistent with observations. However, the actual duration at each site varies with the rain event and quantification of flow duration would require additional sampling. Based upon this screening analysis the relative importance of the measured stormwater discharges is OPR1>>OPR2, Quonset>Tree Tops (Table III-5). These rankings generally hold in the analysis using the greater pond basins (Table III-6). This latter analysis is aimed at explaining the bacterial contamination consistently measured throughout the basins, not just along the shoreline. It appears that only OPR1 can discharge sufficient bacterial loads to impact both the initial region of discharge <u>and</u> the greater basin, while the other sites are only locally important in some events (OPR2, Quonset Rd.>Tree Tops).

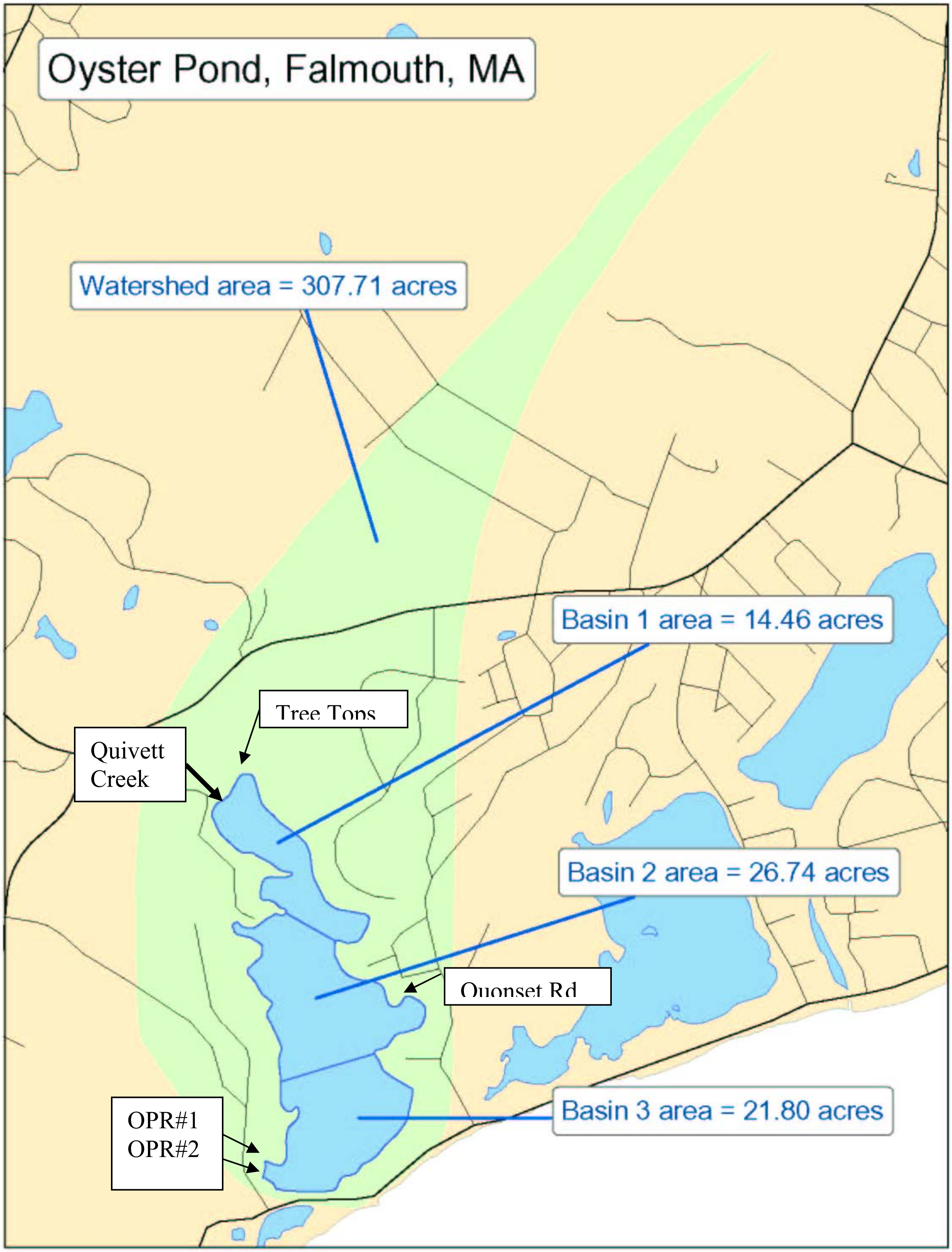


Figure III-1. Surface areas to the 3 sub-basins of Oyster Pond, Town of Falmouth, Massachusetts and locations of the stream inflow from Quivett Creek and 4 stormwater discharges sampled under MEP.

Dates of Measured Flow	Calculated Flows m3/sec based on Measured Velocity	Calculated Flows m3/day based on Measured Velocity	Flow m3/day based on Rating Curve 4	Date of Bacterial Sampling	E. Coli CFU/100mL	E. Coli Instantaneous Point Load	Enterococcus CFU/100mL	Enterococcus Instantaneous Point Load	Fecal CFU/100mL	Fecal Instantaneous Point Load
7/1/2002	0.00000	No measurable flow *								
7/24/2002	0.00000	No measurable flow *								
				8/7/2002	156		400		580	
9/10/2002	0.00000	No measurable flow *								
10/22/2002	0.00000	No measurable flow *								
				10/30/2002	36		30		50	
				11/7/2002	24		32		20	
				11/13/2002	462		4		1450	
				11/20/2002	10		10		100	
				12/4/2002	4		2		10	
				12/10/2002	4		12		10	
12/17/2002	0.00300	259		12/17/2002	4	10368000	14	36288000	10	25920000
			94	2/10/2003	4		2		10	
2/13/2003	0.00090	78								
			126	4/3/2003	4	5040000	2	2520000	10	12600000
			117	4/7/2003	4	4680000	2	2340000	10	11700000
			114	4/17/2003	4	4560000	2	2280000	10	11400000
4/24/2003	0.00160	138								
			106	5/1/2003	4	4240000	28	29680000	10	10600000
			112	5/5/2003	4	4480000	68	76160000	10	11200000
			101	5/19/2003	800	808000000	16	16160000	2000	2020000000
			104	5/29/2003	10	10400000	10	10400000	100	104000000
			134	6/2/2003	288	385920000	6	8040000	330	442200000
			111	6/12/2003	34	37740000	12	13320000	40	44400000
6/13/2003	0.00120	104								
			81	6/16/2003	48	38880000	64	51840000	100	81000000
			71	6/26/2003	16	11360000	14	9940000	20	14200000
			54	6/30/2003	44	23760000	28	15120000	30	16200000
			52	7/10/2003	24	12480000	46	23920000	30	15600000
			46	7/14/2003	48	22080000	50	23000000	10	4600000
7/18/2003	0.00070	60								
			66	7/21/2003	56	36960000	20	13200000	40	26400000
			45	7/28/2003	88	39600000	208	93600000	140	63000000
			73	8/6/2003	152	110960000	108	78840000	300	219000000
			40	8/12/2003	16	6400000	36	14400000	80	32000000
			51	8/20/2003	28	14280000	8	4080000	130	66300000
			35	8/26/2003	120	42000000	158	55300000	140	49000000
8/27/2003	0.00050	43								
10/3/2003	0.00049	43								

* Stagnant standing water in Quivett Creek. Samples were taken by syringe.
NOTE: In cases where the bacteria concentration was listed as less or greater (</>), changed to the actual number in order to calculate a load.

Table III-1 Summary of discharge from Quivett Creek and associated instantaneous point load of bacteria (cfu/day).

	E. Coli CFU/day	Enterococci CFU/day	Fecal Coliform CFU/day
MAX	808000000	93600000	2020000000
MIN	4240000	2280000	4600000

Table III-2 Maximum and Minimum point load through Quivett Creek to north basin of Oyster Pond

STATION	Fecal (summer) cfu/100ml	Fecal (winter) cfu/100ml	Fecal summer-wet cfu/100ml	Fecal summer-dry cfu/100ml	Fecal winter-wet cfu/100ml	Fecal winter-dry cfu/100ml
OP 1	17	7	17	nd	10	5
OP 2	13	5	13	nd	5	5
OP 7	36	7	36	nd	10	5
avg north basin	22	6	22		8	5
avg (cfu/m3)	220000	63333	220000	0	83333	50000
approx vol. North basin (surface to 1 meter)	58519	58519	58519	0	58519	58519
average cfu in north basin (surface to 1 meter)	**1.29E+10**	**3.71E+09**	**1.29E+10**		**4.88E+09**	**2.93E+09**
Max Fecal (sta. QC)	2.02E+09	2.02E+09	2.02E+09	2.02E+09	2.02E+09	2.02E+09
Min Fecal (sta. QC)	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06	4.60E+06

Table III-3 Comparison of maximum and minimum instantaneous point load from Quivett Creek to average number of CFU per the surface 1 meter layer (volume in cubic meters) of basin 1 (north basin) of Oyster Pond, as represented by sampling stations OP1, 2, 7. Geometric mean Fecal Coliform load was 3.35×10^7.

Site	Rainfall	Bacterial Indicator			Flow (m3/min)
		E. Coli CFU/100 mL	Fecal Coliform CFU/100 mL	Enterococcus CFU/100 mL	
Rain Event: September 27, 2004					
Quonset Rd.	First Flush	--	--	--	0.008
	0.25 inches	--	--	--	
OPR 1	First Flush	21000	20800	12800	0.208
	0.25 inches	--	--	--	0.182
OPR 2	First Flush	5700	8200	22000	0.023
	0.25 inches	--	--	--	0.019
Rain Event: October 14, 2004					
Quonset Rd.	First Flush	No Flow	No Flow	No Flow	0
	0.25 inches	No Flow	No Flow	No Flow	0
OPR 1	First Flush	1200	1300	23000	0.004
	0.25 inches	No Flow	No Flow	No Flow	
OPR 2	First Flush	<100	400	8000	0.002
	0.25 inches	No Flow	No Flow	No Flow	0
Rain Event: October 19, 2004					
Quonset Rd.	First Flush	2200	5500	8300	0.049
	0.25 inches	900	2200	10700	0.076
OPR 1	First Flush	800	1500	3600	0.114
	0.25 inches	2800	3500	5600	0.171
OPR 2	First Flush	700	1300	17000	0.019
	0.25 inches	800	900	10700	0.023
Tree Tops	First Flush	300	1100	12400	0.045
	0.25 inches	500	1100	15600	0.015
Rain Event: December 1, 2004					
Quonset Rd.	First Flush	36	164	2200	0.003
	0.25 inches	310	164	3900	0.076
OPR 1	First Flush	36	63	6400	0.004
	0.25 inches	1727	3000	35000	0.379
OPR 2	First Flush	64	127	2300	0.005
	0.25 inches	73	36	3400	0.045
Tree Tops	First Flush	18	<10	22400	0.057
	0.25 inches	--	--	--	--
Rain Event: December 7, 2004					
Quonset Rd.	First Flush	--	--	--	--
	0.25 inches	--	--	--	--
OPR 1	First Flush	--	73	1700	0.015
	0.25 inches	--	760	6100	0.045
OPR 2	First Flush	--	64	740	0.006
	0.25 inches	--	120	4400	0.005
Tree Tops	First Flush	No Flow	No Flow	No Flow	0
	0.25 inches	No Flow	No Flow	No Flow	0

Table III-4 Bacterial concentrations and outflows from stormwater discharges during 5 rain events sampled in 2004 under MEP, assays by Barnstable County Health Laboratory. The 2 samples where counts of E. coli > Fecal coliform, likely result from variations in assays.

Site	Rain	"Basin" Area m2	Pond Layer m	Calculated FC Load CFU/8 hr	In Pond FC Level CFU/100mL	In Pond Pool: 0-1 m CFU	Ratio Load/Pool %
Rain Event: September 27, 2004							
Quonset Rd.	First Flush	5000	1	--	--	--	--
	0.25 inches	5000	1	--	--	--	--
OPR 1	First Flush	5000	1	2.08E+10	64	3.20E+09	650%
	0.25 inches	5000	1	9.08E+09	64	3.20E+09	**284%**
OPR 2	First Flush	5000	1	8.95E+08	64	3.20E+09	28%
	0.25 inches	5000	1	3.73E+08	64	3.20E+09	**12%**
Rain Event: October 14, 2004							
Quonset Rd.	First Flush	5000	1	0.00E+00	81	4.05E+09	0%
	0.25 inches	5000	1	0.00E+00	81	4.05E+09	**0%**
OPR 1	First Flush	5000	1	2.36E+07	64	3.20E+09	1%
	0.25 inches	5000	1	0.00E+00	64	3.20E+09	**0%**
OPR 2	First Flush	5000	1	3.64E+06	64	3.20E+09	**0%**
	0.25 inches	5000	1	0.00E+00	64	3.20E+09	**0%**
Rain Event: October 19, 2004							
Quonset Rd.	First Flush	5000	1	1.31E+09	81	4.05E+09	32%
	0.25 inches	5000	1	8.00E+08	81	4.05E+09	**20%**
OPR 1	First Flush	5000	1	8.19E+08	64	3.20E+09	26%
	0.25 inches	5000	1	2.87E+09	64	3.20E+09	**90%**
OPR 2	First Flush	5000	1	1.18E+08	64	3.20E+09	4%
	0.25 inches	5000	1	9.82E+07	64	3.20E+09	**3%**
Tree Tops	First Flush	5000	1	2.40E+08	17	8.50E+08	28%
	0.25 inches	5000	1	8.00E+07	17	8.50E+08	**9%**
Rain Event: December 1, 2004							
Quonset Rd.	First Flush	5000	1	2.75E+06	81	4.05E+09	0%
	0.25 inches	5000	1	5.97E+07	81	4.05E+09	**1%**
OPR 1	First Flush	5000	1	1.15E+06	64	3.20E+09	0%
	0.25 inches	5000	1	5.46E+09	64	3.20E+09	**171%**
OPR 2	First Flush	5000	1	2.77E+06	64	3.20E+09	0%
	0.25 inches	5000	1	7.86E+06	64	3.20E+09	**0%**
Tree Tops	First Flush	5000	1	1.36E+06	17	8.50E+08	0%
	0.25 inches	5000	1	--	--	--	--
Rain Event: December 7, 2004							
Quonset Rd.	First Flush	5000	1	--	--	--	--
	0.25 inches	5000	1	--	--	--	--
OPR 1	First Flush	5000	1	5.31E+06	64	3.20E+09	**0%**
	0.25 inches	5000	1	1.66E+08	64	3.20E+09	**5%**
OPR 2	First Flush	5000	1	1.75E+06	64	3.20E+09	**0%**
	0.25 inches	5000	1	2.62E+06	64	3.20E+09	**0%**
Tree Tops	First Flush	5000	1	0.00E+00	17	8.50E+08	**0%**
	0.25 inches	5000	1	0.00E+00	17	8.50E+08	**0%**

Table III-5 Comparisons of Fecal Coliform (FC) inputs from 4 stormwater inflows to the levels of FC within the immediate basin during 5 rain events sampled in 2004 (see also Table III-4).

Site	Rain	"Basin" Area m2	Pond Layer m	Calculated FC Load CFU/8 hr	In Pond FC Level CFU/100mL	In Pond Pool: 0-1 m CFU	Ratio Load/Pool %
Rain Event: September 27, 2004							
Quonset Rd.	First Flush	108214	1	--	--	--	--
	0.25 inches	108214	1	--	--	--	--
OPR 1	First Flush	88222	1	2.08E+10	64	5.65E+10	37%
	0.25 inches	88222	1	9.08E+09	64	5.65E+10	**16%**
OPR 2	First Flush	88222	1	8.95E+08	64	5.65E+10	2%
	0.25 inches	88222	1	3.73E+08	64	5.65E+10	**1%**
Rain Event: October 14, 2004							
Quonset Rd.	First Flush	108214	1	0.00E+00	81	8.77E+10	0%
	0.25 inches	108214	1	0.00E+00	81	8.77E+10	**0%**
OPR 1	First Flush	88222	1	2.36E+07	64	5.65E+10	0%
	0.25 inches	88222	1	0.00E+00	64	5.65E+10	**0%**
OPR 2	First Flush	88222	1	3.64E+06	64	5.65E+10	**0%**
	0.25 inches	88222	1	0.00E+00	64	5.65E+10	**0%**
Rain Event: October 19, 2004							
Quonset Rd.	First Flush	108214	1	1.31E+09	81	8.77E+10	1%
	0.25 inches	108214	1	8.00E+08	81	8.77E+10	**1%**
OPR 1	First Flush	88222	1	8.19E+08	64	5.65E+10	1%
	0.25 inches	88222	1	2.87E+09	64	5.65E+10	**5%**
OPR 2	First Flush	88222	1	1.18E+08	64	5.65E+10	0%
	0.25 inches	88222	1	9.82E+07	64	5.65E+10	**0%**
Tree Tops	First Flush	58518	1	2.40E+08	17	9.95E+09	2%
	0.25 inches	58518	1	8.00E+07	17	9.95E+09	**1%**
Rain Event: December 1, 2004							
Quonset Rd.	First Flush	108214	1	2.75E+06	81	8.77E+10	0%
	0.25 inches	108214	1	5.97E+07	81	8.77E+10	**0%**
OPR 1	First Flush	88222	1	1.15E+06	64	5.65E+10	0%
	0.25 inches	88222	1	5.46E+09	64	5.65E+10	**10%**
OPR 2	First Flush	88222	1	2.77E+06	64	5.65E+10	0%
	0.25 inches	88222	1	7.86E+06	64	5.65E+10	**0%**
Tree Tops	First Flush	58518	1	1.36E+06	17	9.95E+09	0%
	0.25 inches	58518	1	--	--	--	--
Rain Event: December 7, 2004							
Quonset Rd.	First Flush	108214	1	--	--	--	--
	0.25 inches	108214	1	--	--	--	--
OPR 1	First Flush	88222	1	5.31E+06	64	5.65E+10	**0%**
	0.25 inches	88222	1	1.66E+08	64	5.65E+10	**0%**
OPR 2	First Flush	88222	1	1.75E+06	64	5.65E+10	**0%**
	0.25 inches	88222	1	2.62E+06	64	5.65E+10	**0%**
Tree Tops	First Flush	58518	1	0.00E+00	17	9.95E+09	**0%**
	0.25 inches	58518	1	0.00E+00	17	9.95E+09	**0%**

Table III-6 Comparisons of Fecal Coliform (FC) inputs from 4 stormwater inflows to the levels of FC within the greater Oyster Pond basins during 5 rain events sampled in 2004 (see also Tables III-4, III-5). Highlighted values after 0.25" of rain and assumed 8 hr flow, indicate a potentially important source load relative to average Pond FC levels.

IV. Water Quality Standards

Oyster Pond (Segment ID MA96-62_2002) is in the coastal and marine Class and has been classified by the Massachusetts State Water Quality Standard as a Class SB (restricted shellfishing areas) water. From the Massachusetts Year 2002 Integrated List of Waters (Massachusetts Category 5 Waters), Oyster Pond is considered those waters east of Fells Road, Falmouth, MA. Oyster Pond is also classified by the Massachusetts Division of Marine Fisheries (DMF) as shellfish growing area SC:6.0 which encompasses Oyster Pond and the up-gradient small tidal basin between Oyster Pond and Quissett Beach prior to discharge to Vineyard Sound. (Figure II-3).

At a regulatory level, two bacterial contamination standards must be met in order to safe guard the quality and value of the water resource and public health. The first regulatory standard (Massachusetts Surface Water Quality Standards 314 CMR 4.05(4)(a)4) is intended to protect the water resource and its shellfish habitat using fecal coliform as the indicator organism . The second is a minimum standard for bathing beaches (105 CMR 445.000) and is commonly regarded as a swimming standard aimed at protecting public health using Enterococci as the indicator organism in marine waters.

Though Oyster Pond is classified as Class SB waters, for the purpose of this study it was decided to base the analysis of the historical bacterial data on a comparison of the data to more stringent fecal coliform criteria for Class SA (open shellfishing areas) waters. The intent being to bring potential restoration of Oyster Pond to the highest level possible.

Based on the Surface Water Quality Standard (SWQS), fecal coliform criteria for coastal and marine Class SA waters specify that: a) waters approved for open shell fishing shall not exceed a geometric mean MPN of 14 organisms per 100 mL, nor shall more than 10 percent of the samples exceed a MPN of 43 per 100 mL and, b) waters not designated for shell fishing shall not exceed a geometric mean of 200 organisms in any representative set of samples, nor shall more than 10 percent of the samples exceed 400 organisms per 100 ml. With regard to safe guarding public health relative to primary and secondary contact recreation, as specified in 105 CMR 445.031(A)(1), for marine water, the indicator organism shall be Enterococci and no single Enterococci sample shall exceed 104 colonies per 100 mL and the geometric mean of the most recent five (5) Enterococci levels within the same bathing season shall not exceed 35 colonies per 100 mL.

From the point of view of protecting shellfish resources, currently, fecal coliform bacteria is the pathogenic indicator utilized by the State of Massachusetts as the measure for whether a coastal marine water body is in compliance with bacteria based Water Quality Standards. The State anticipates replacing fecal coliform with enterococci as recommended by EPA for the indicator organism in bathing waters. Fecal coliform will remain the standard for shellfish waters. The goal of the TMDL that will evolve from this technical report will be to decrease or eliminate fecal coliform bacterial contamination or determine that it is not human related (i.e. not linked to pathogens) in order to protect human health and return these waters to their most beneficial use as a shellfish resource.

V. Fecal Contamination of the Oyster Pond System

The history of bacterial contamination in Oyster Pond is briefly reviewed in, The Massachusetts Estuary Project Embayment Water Quality Assessment Interim Report: Priority Embayments 1-20 (2002). All of Oyster Pond has been classified as Prohibited since 1984. There have been no sanitary surveys conducted since that time and only the surface water inflow data from the recent MEP Quivett Creek and stormwater study (see Section III.1). For the past decade, Oyster Pond has been managed as a brackish water system (1-3 ppt.). The management system was finalized with the installation of a weir at the Pond outlet (2000), which allows fish migration, but limits tidal inflow. The structure is set to maintain the salinity of the Pond and was the result of a management plan developed over many years through PondWatch, OPET and the Town of Falmouth (Engineering Department).

Data on Fecal coliform bacteria is available from The Massachusetts Department of Marine Fisheries (DMF) at its designated stations 1, 2, 3, 4 and 5. Stations 2, 3 and 5 were dropped from the sampling program in 1994 and data from Stations 1 and 4 are available through 1997 (Figure V-1). SMAST has been taking samples at its designated stations (OP1-OP7 and QC) since 2002 for Fecal Coliforms, E. coli and Enterococcus (Figure V-2).

Seven (7) stations were selected for wet/dry weather sampling in Oyster Pond by SMAST (see Figure V-2) and to date five wet weather sampling events and two dry sampling events have been completed at the following stations.

- Station #OP1: Representative sample
- Station #OP2: Representative sample (same location as DMF station # 4).
- Station #OP3: Near outlet of 10" VC pipes
- Station #OP4: Near outlet of 8" pipe
- Station #OP5: Oyster pond south (near Sakonet Road, close to DMF station #5).
- Station #OP6: End of Ransom Rd. (same location as DMF station #3).
- Station #OP7: Just north of Station #6 (same location as DMF station # 4A).

Fecal coliform is a general classification of bacteria that are typically associated with animal and human waste. E coli are typically found in the intestines of animals and humans. Some strains are known to be toxic to humans. Enterococcus, a bacterium of potential health concern to humans, is thought to be a better tracer of human pathogenic contamination than fecal coliforms, due to its persistence in the environment.

Data from both DMF and SMAST have been compiled and analyzed for this technical TMDL report. Data was grouped by year (1985-1997 and 2002-2003), by season (November through April for winter and May through October for summer) and by wet weather or dry weather status (1994-2003 data only, based upon available rainfall data). Wet/Dry samplings were based on the total rainfall amount at the site over the three days prior to sampling. Less than 0.25 inches was considered to be a dry weather event and 0.25 inches or greater was designated as wet weather sampling.

For each sampling station, the geometric mean, standard deviation (SD) and number of samples taken (N) were computed for winter and summer for each time interval (1985-1995 and 1996-2003) and are presented in Tables V-1. Geometric means that exceeded the water quality standard for Class A Waters of 14 CFU/100 mL for Fecal Coliforms and E. coli, and 35 colonies/100mL for Enterococcus are highlighted. In addition, when more than 10% of the samples exceeded the water quality standard of 43 CFU/100 mL for Fecal Coliforms and E. coli, or where any sample exceeded the water quality standard of 104 colonies/100mL for Enterococcus, these data were also highlighted. The ratio of the summer to winter geometric means was also determined for each sampling station as indicators of the degree of summer versus winter contamination levels.

Wet and Dry data were compiled in the same manner for each station where rainfall data were available and are presented in Tables V-2 and V-3. Geometric means and standard deviations were calculated seasonally for wet and dry data from each station during the years 1994-2003. Means that exceeded the water quality standards were highlighted. Data were highlighted when more than 10% of the samples exceeded the water quality standard of 43 CFU/100 mL for Fecal Coliforms and E. coli or where any sample exceeded the water quality standard of 104 colonies/100mL for Enterococcus. The ratio of wet to dry geometric means for summer and winter data were also determined for each sampling station as indicators of the degree of summer versus winter contamination levels.

From 1985-1997 DMF sampling, there were a total of 43 summer sampling events (Figure V-1). Summer geometric means of fecal coliform counts ranged from 22 CFU/100 mL at Station 1, south of the Surf Drive culvert and closest to Vineyard Sound, to 81 CFU/100 mL at Station 2 located north of the Surf Drive culvert (Figure V-1, Table V-1). Means at all stations exceeded the water quality standard of 14 CFU/100 mL. At all stations, more than 10% of the samples exceeded 43 CFU/100 mL (Table V-1). Even before the present managed restriction of tidal flow to the Pond (i.e. during the collection of these DMF data), tidal exchange between Oyster Pond and Vineyard Sound was very restricted. As a result, Oyster Pond circulation is driven by wind and distribution of contamination is much like other kettle ponds on Cape Cod, which show only slight horizontal gradients. Similarly, in Oyster Pond there is no down-stream trend of decreasing coliform counts (North Basin to Inlet), which could indicate a dilution of contamination as it moves away from its likely source (Figure V-5a).

During the winter months DMF conducted 47 sampling events (Figure V-1). Winter geometric means for fecal coliform bacteria were lower than summer means at all stations except and were less than the water quality standard of 14 CFU/100 mL except for Station 1 (Figure V-1, Table V-1a). Three of the stations had greater than 10% sample exceedences of the water quality standard of 43 CFU/100 mL (Table V-1a). The ratio of the summer to winter geometric means ranged from 1.0 at Station 1 to 19.7 at Station 5 (Table V-1a), indicating that summer inputs of fecal coliforms were approximately 1-20 times winter inputs. This summer to winter trend has also been observed in other Cape Cod embayments, for example Muddy Creek and Frost Fish Creek (Chatham, MA).

From 2002-2003 there were a combined total of 49 summer fecal coliform, E. coli and Enterococcus samples taken by SMAST (Figure V-3). Summer geometric means for Fecal Coliforms (all in wet weather) ranged from 13 CFU/100 mL at Station OP-2 to 81 CFU/100 mL at Station OP-4 (Figure V-3a, Table V-1a). All summer means except the one at Station OP-2 exceeded the water quality standard of 14 CFU/100 mL . At all stations except OP-1 and OP-2, more than 10% of the samples were greater than 43 CFU/100 mL (Table V-1a). *E. coli* is a subset of fecal coliform and typically is about 60-80% of the fecal coliform value. As noted elsewhere, the water quality standard for shellfishing is based upon fecal coliform levels. Keeping these points in mind, it is still useful as a confirmatory check to evaluate the E. coli data. Summer geometric means for E. coli ranged from 16 CFU/100 mL at Station OP-5 to 66 at OP-4 (Figure V-3, Table V-1b). All summer means exceeded the water quality standard of 14 CFU/100 mL and more than 10% of all samples exceeded the water quality standard of 43 CFU/100 mL at all stations except OP-1 and OP-2 (Table V-1b). For Enterococcus summer geometric means ranged from 11 colonies/100 mL at Station OP-5 to 82 at Station OP-4 (Figure V-3, Table V-1c). Summer means exceeded 35 colonies/100 mL at Stations OP-4 and OP-6. Samples exceeded 104 colonies/100 mL at stations OP-3, OP-4, OP-6 and QC (Table V-1c).

A total of 36 fecal coliform, E. coli and Enterococcus samples were taken at all stations during the winter (Figure V-3). All geometric means at all stations were lower than the water quality standards and were significantly lower than summer means (Figures V-3, Table V-1a, b, c). For Fecal coliforms and E. coli, less than 10% of the samples taken at all stations exceeded the water quality standard of 43 CFU/100 mL at all stations (Table V-1a, b). None of the Enterococcus samples exceeded the water quality standard of 104 colonies/100mL (Table V-1c).

The ratio of summer to winter geometric means for Fecal coliforms ranged from 2.4 to 12.9, indicating that fecal contamination in the summer was approximately 2-13 times higher than the winter. This is similar to the seasonal pattern found in the DMF data. For E. coli, the ratios ranged from 3.9 to 25.7 and for Enterococcus, they varied from 5.3 to 58.1.

During the years 1994-2003, samplings were separated into wet and dry events based on the total rainfall for the 3 days prior to sampling. A total of 38 wet samples and 17 dry samples were taken during the summer for fecal coliforms. A total of 20 wet and 20 dry samples were taken during the winter (Figure V-4, Table V-2a). For the summer, wet geometric means ranged from 13 CFU/100 mL at Station OP-2 to 131 CFU/100 mL at Station QC at Quivett Creek. Dry means were available only for Station 1 (4 CFU/100 mL) and Station QC at Quivett Creek (44 CFU/100 mL) (Figures V-4 and Table V-2a). Wet means exceeded the water quality standard of 14 CFU/100 mL at all stations except OP-2. Dry weather geometric means exceeded the standard only at Station QC (Table V-2a). More than 10% of samples at all stations except OP-1 and OP-2 were above the water quality standard of 43 CFU/100 mL for wet sampling (Table V-2a). Only Station QC had more than 10% of its dry samplings above 43 CFU/100 mL (Table V-2a). The ratio of wet to dry geometric means ranged from 3 at Station QC to 12.6 at Station 1. Wet inputs were approximately 3-13 times dry inputs at Stations 1 and QC.

For winter samplings, wet geometric means of Fecal Coliforms ranged from 5 CFU/100 mL at Stations OP-2, OP-3, OP-4 and OP-6 to 65 CFU/100 mL at Stations 1and 4. Dry geometric means ranged from 5 CFU/100 mL at Stations OP-1, OP-2, OP-3, OP-5, OP-6, and OP-7 to 65 CFU/100 mL at Stations 1 and 4 (Figures V-4, Table V-2a). The geometric means for wet or dry samples exceeded the water quality standard of 14 CFU/100 mL only at Stations 1 and 4 and more than 10% of samples taken exceeded the water quality standard of 43 CFU/100 mL at Stations 1, 4 and QC for wet samples and at Stations 1 and 4 for dry samplings (Table V-2a). Ratios of wet to dry means ranged from 0.5 at Station OP-4 to 2.3 at Station QC, indicating that wet bacterial inputs during the winter were no higher than approximately 2 times dry inputs (Table V-2a).

For E. coli, total of 34 wet samples and 15 dry samples were taken during the summer and 18 wet and 18 dry samples were taken during the winter (Table V-2b). Summer wet geometric means ranged from 16 CFU/100 mL at Stations OP-2 and OP-5 to 66 CFU/100 mL at Station OP-4. Dry means were available only for Station QC at 36 CFU/100 mL (Table V-2b). Wet means exceeded the water quality standard of 14 CFU/100 mL at all stations. Dry means exceeded the standard at Station QC (Table V-2b). More than 10% of samples at all stations except OP-2 were above the water quality standard of 43 CFU/100 mL for wet sampling (Table V-2b). Station QC had more than 10% of its dry samplings above 43 CFU/100 mL (Table V-2b). The ratio of wet to dry geometric means at Station QC 1.1 (no data were available for the other stations). Wet inputs were approximately the same as dry inputs.

For winter samplings, wet and dry geometric means of E. coli ranged from 2 to 12 CFU/100 mL at all stations. None of the geometric means for wet or dry samples exceeded the water quality standard and less than 10% of samples taken exceeded the water quality standard of 43 CFU/100 mL at all stations. Ratios of wet to dry means ranged from 0.5 to 6, indicating that wet bacterial inputs during the winter were as high as approximately 6 times dry inputs (Table V-2b).

For Enterococcus, total of 34 wet samples and 15 dry samples were taken during the summer and 18 wet and 18 dry samples were taken during the winter (Table V-3).

Summer wet geometric means ranged from 11 colonies/100 mL at Station OP-5 to 82 colonies/100 mL at Station OP-4. Dry means were available only for Station QC at 40 colonies/100 mL (Table V-3). Wet means exceeded the water quality standard of 35 colonies/100 mL at stations OP-4 and OP-6. Dry means exceeded the standard at Station QC (Table V-3). Samples at stations OP-3, OP-4, OP-6 and QC were above the water quality standard of 104 colonies/100 mL for wet sampling, and at Station QC for dry sampling (Table V-3). The ratio of wet to dry geometric means at Station QC was 0.5 (no data were available for the other stations). Wet inputs were approximately one half dry inputs at Quivett Creek. This is consistent with the forested nature of the Quivett Creek sub-watershed, with little runoff.

For winter samplings, none of the wet and dry geometric means for Enterococcus were above the water quality standard of 35 colonies/100mL. Means ranged from 2 to 5 colonies/100 mL at all stations. None of the samples exceeded the water quality standard of 104 colonies/100 mL. Ratios of wet to dry means ranged from 1 to 10, indicating that bacterial inputs during the winter wet weather versus dry weather showed a similar trend to the summer (Table V-3). These data suggest that terrestrial inputs of bacteria from wildlife, stormwater, etc are important to the level of bacterial indicators within the Pond year round.

Salinities in Oyster Pond during the years from 1985 to 1997 varied from approximately 2 to 33 ppt. with most of the readings in the range of 2-15 ppt (Figure V-10a). Salinities from 1997 to 2003 were 1-3 ppt. There was no clear relationship between fecal coliform counts and salinity. In the 1985-1997 interval fecal coliform levels in Pond surface waters varied from approximately 2 to 125 CFU/100 mL at all salinities between 2 and 15 ppt. Oyster Pond is a drowned kettle pond whose surface waters are relatively well mixed horizontally such that there is no discernible downstream dilution effect as might be expected in a drowned river valley estuary. In 2000 a water control structure was put into effect at the entrance to the channel to Vineyard Sound. Since then the pond has been managed as a brackish water environment and salinities have stayed within a narrow range of approximately 1-3 ppt. (Figure V-10b). During the period from 2002-2003, individual fecal coliform levels from all Pond surface water sites have varied from approximately 1-300 CFU/100 mL with Quivett Creek showing several counts as high as 600-2000 CFU/100 mL. In Figure V-10, samples with <0.5ppt are from Quivett Creek. As was the case with the data set from 1985-1997, there is no discernible relationship of fecal coliform counts to salinity.

The fecal coliform and entrococcus data in Pond waters suggests a source in the region of OP4, near the Quonset Rd. stormwater site and in the region of OP3 and DMF station 1, near the Oyster Pond sites. There is little evidence for a strong bacterial source from Quivett Creek or the Tree Tops discharge, as the North Basin (OP1) station were generally lower than other pond stations for all bacterial indicators (Figure V-3).

The per cent exceedences of the water quality standard of 14 CFU/100mL at various salinity ranges is shown in Figure V-11. From 1985-1997 the % exceedence varied from 40% in the 15-20 ppt. salinity range up to 74% in the 5-10 ppt. salinity range.

There was no consistent pattern of relationship between salinity range and exceedence of the standard. From 2002-2003 all data fell within the 0-5 ppt salinity range (Figure V-11) and exceedences were comparable to the 1985-1997 data.

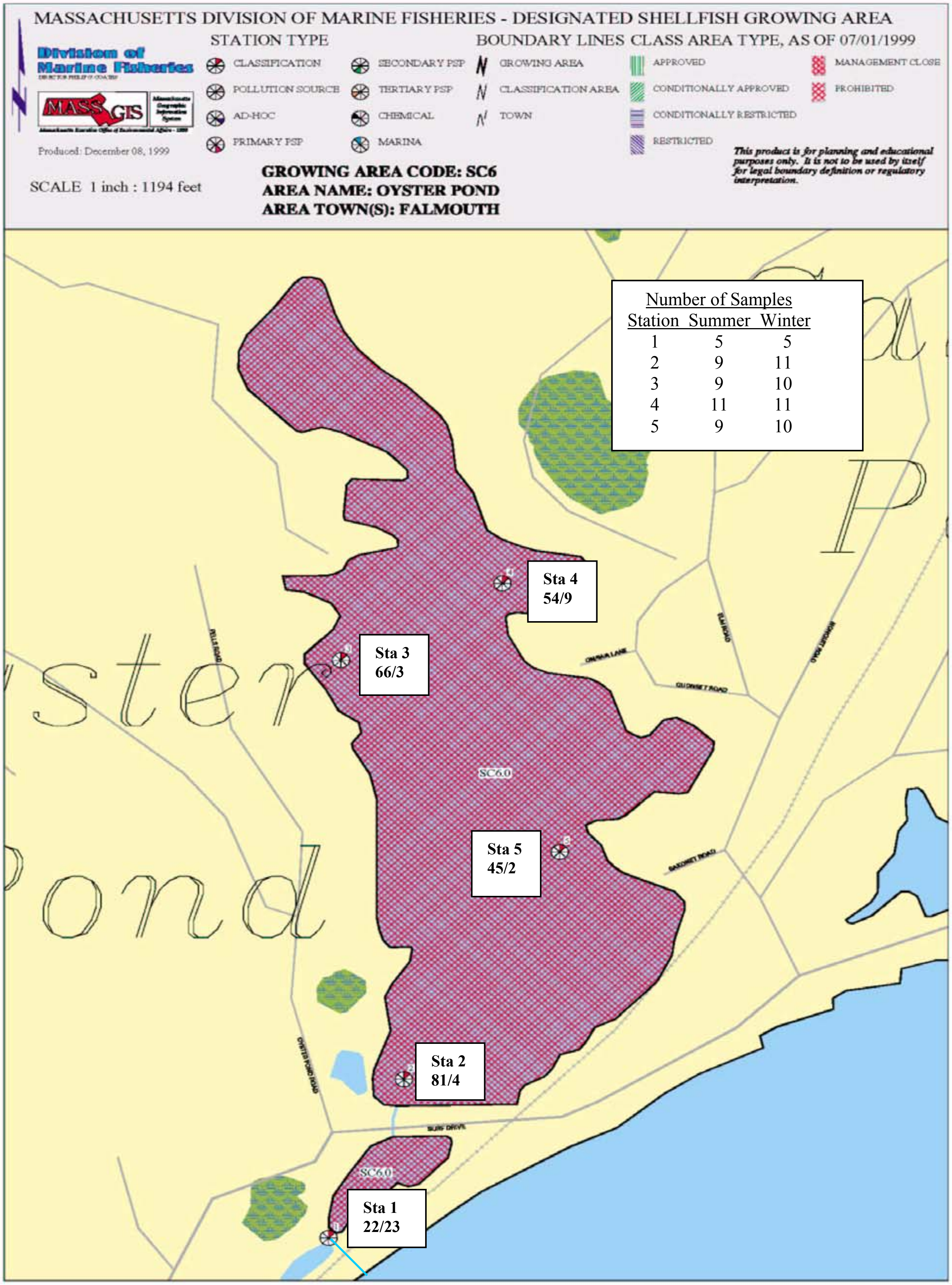


Figure V-1 Summer and winter fecal coliform bacteria counts (number of cells/100 mls), 1985-1997. Numbers indicate geometric means for summer/winter DMF samplings.

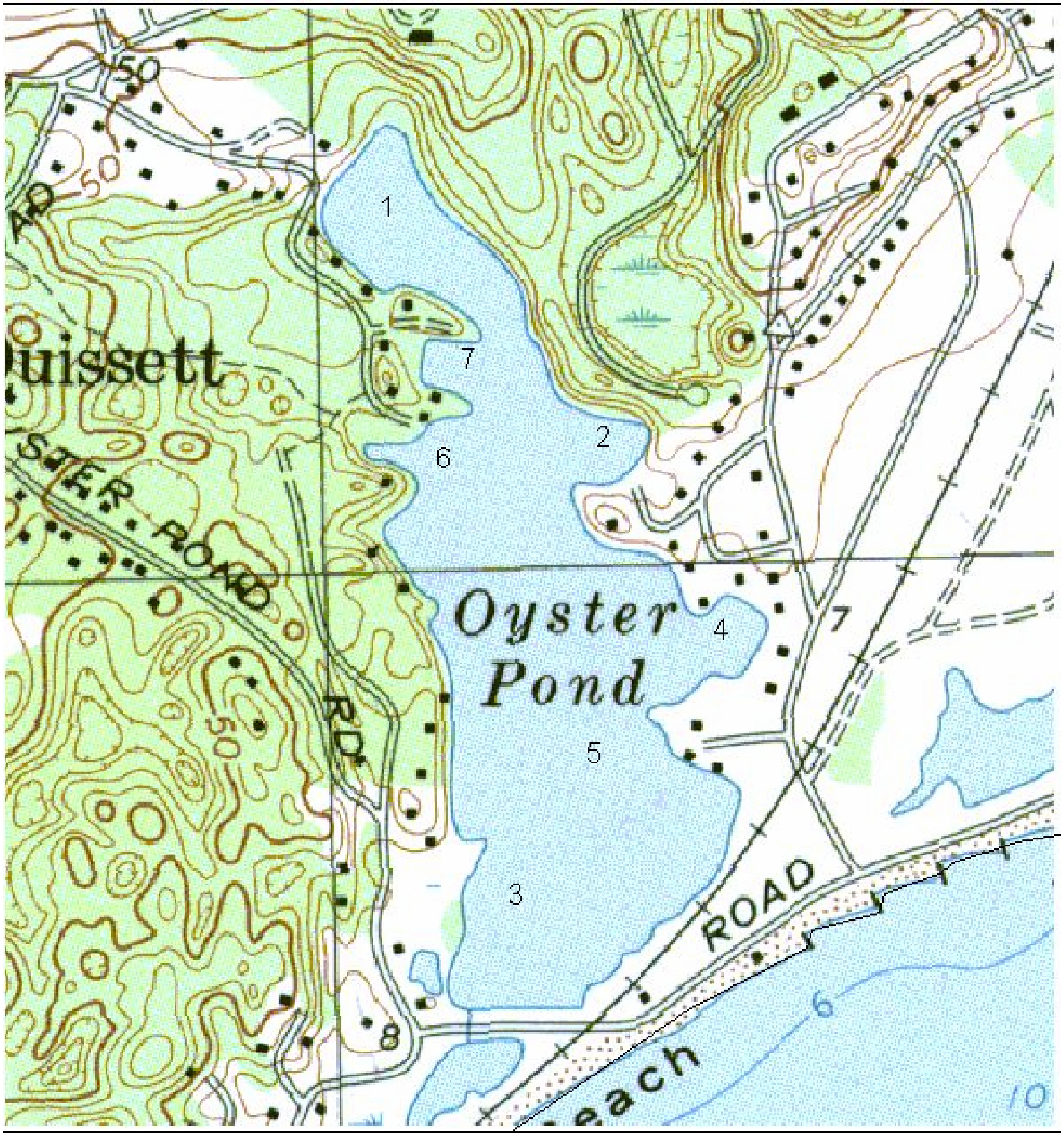


Figure V-2 Oyster Pond Wet / Dry weather sampling locations sampled by SMAST, 2002-2003. Stations are identified as OP1 – OP7 throughout this report.

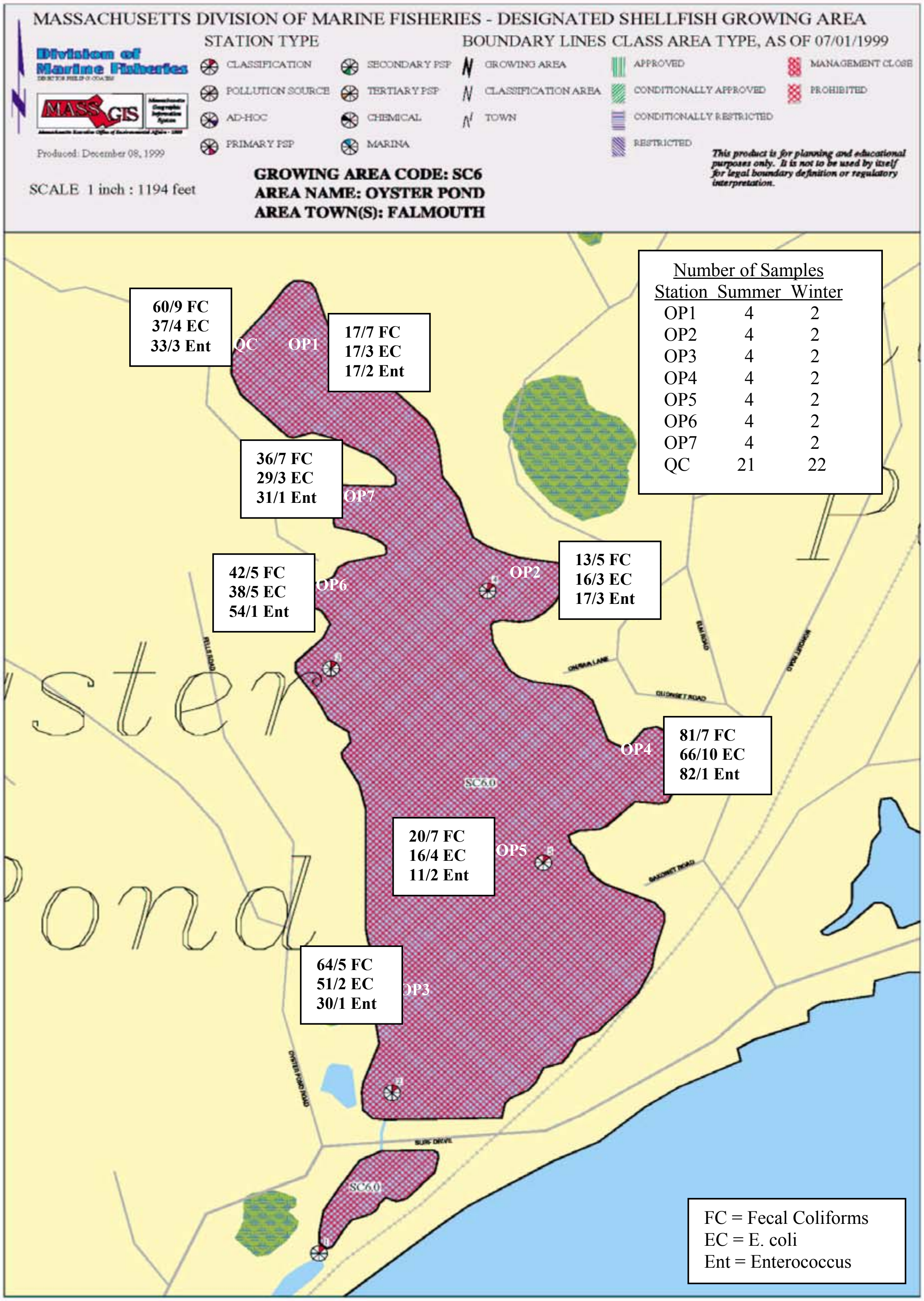


Figure V-3 Summer and winter fecal coliform bacteria counts (number of cells/100 mls), 2002-2003. Numbers indicate geometric means for summer/winter SMAST samplings.

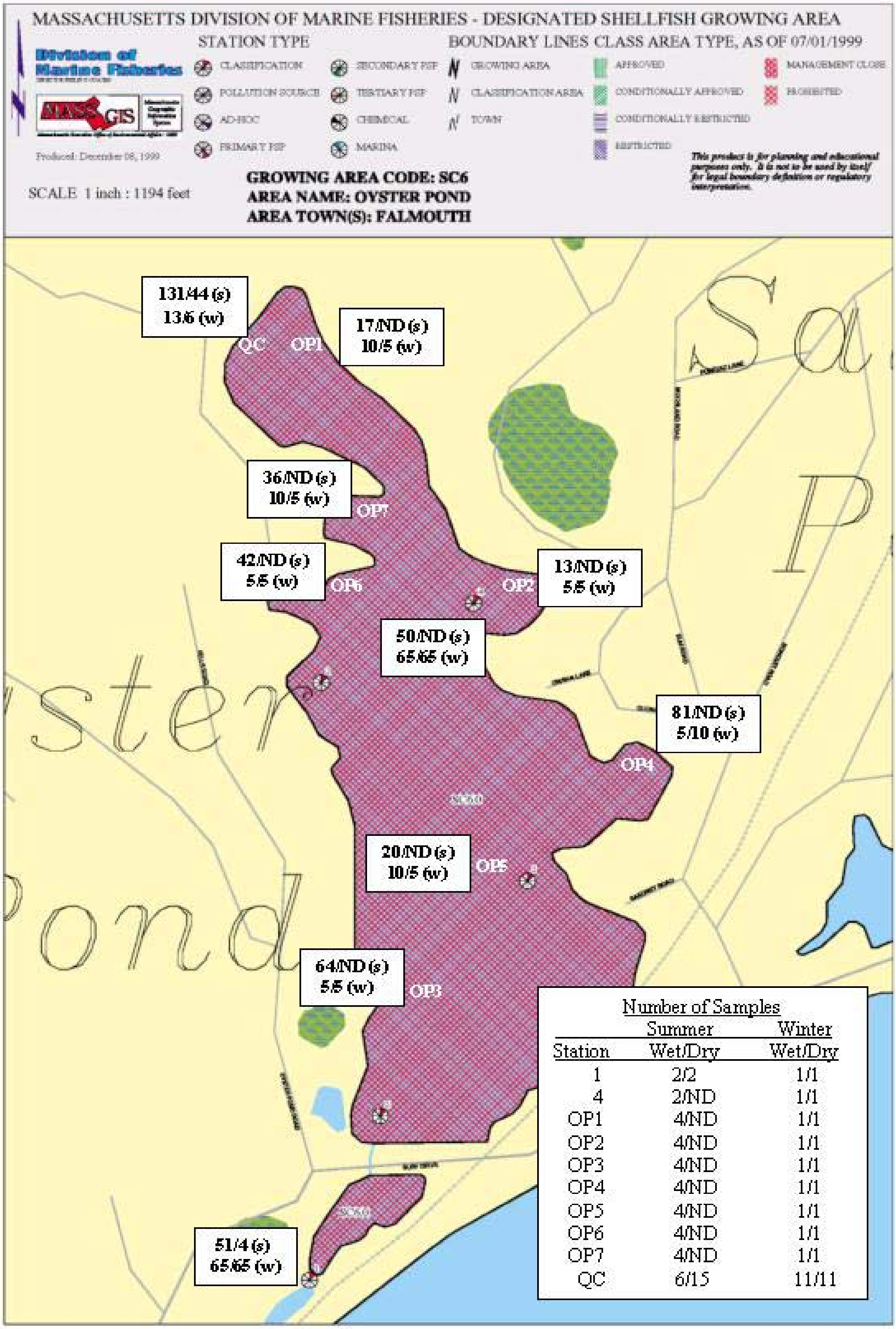
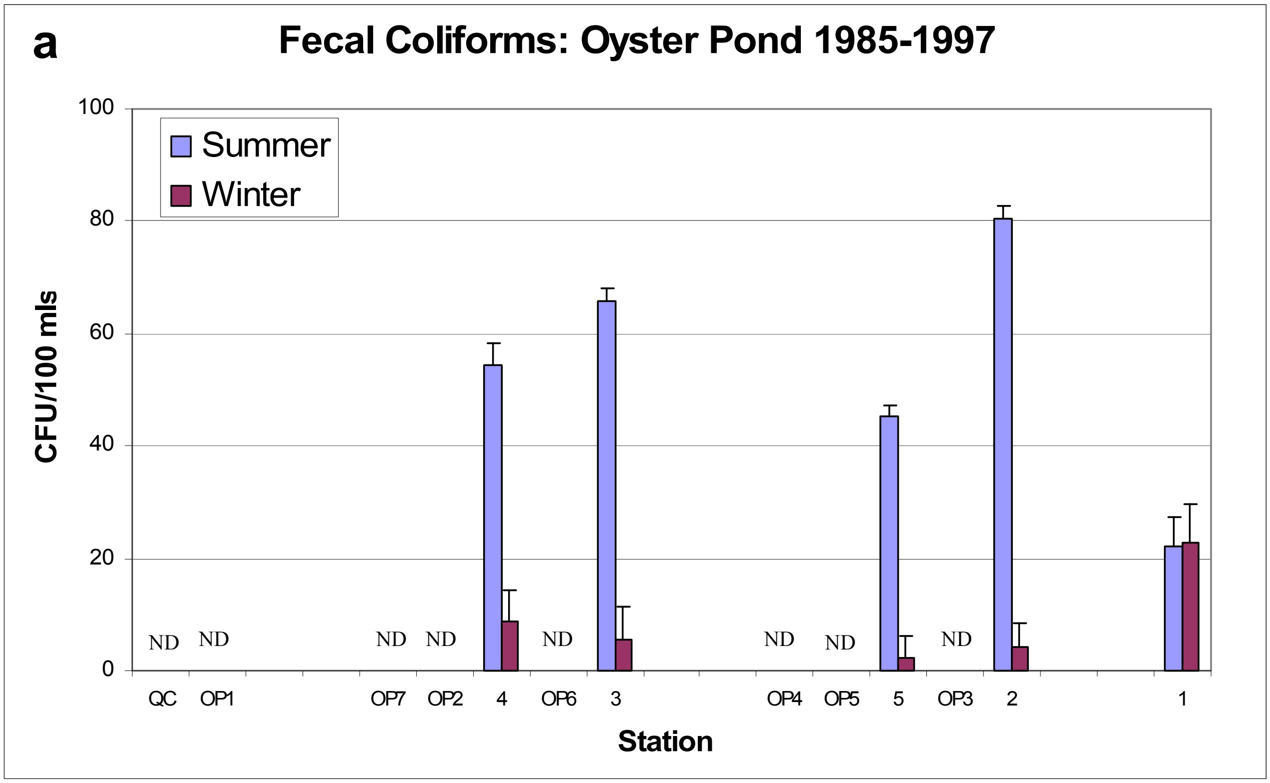
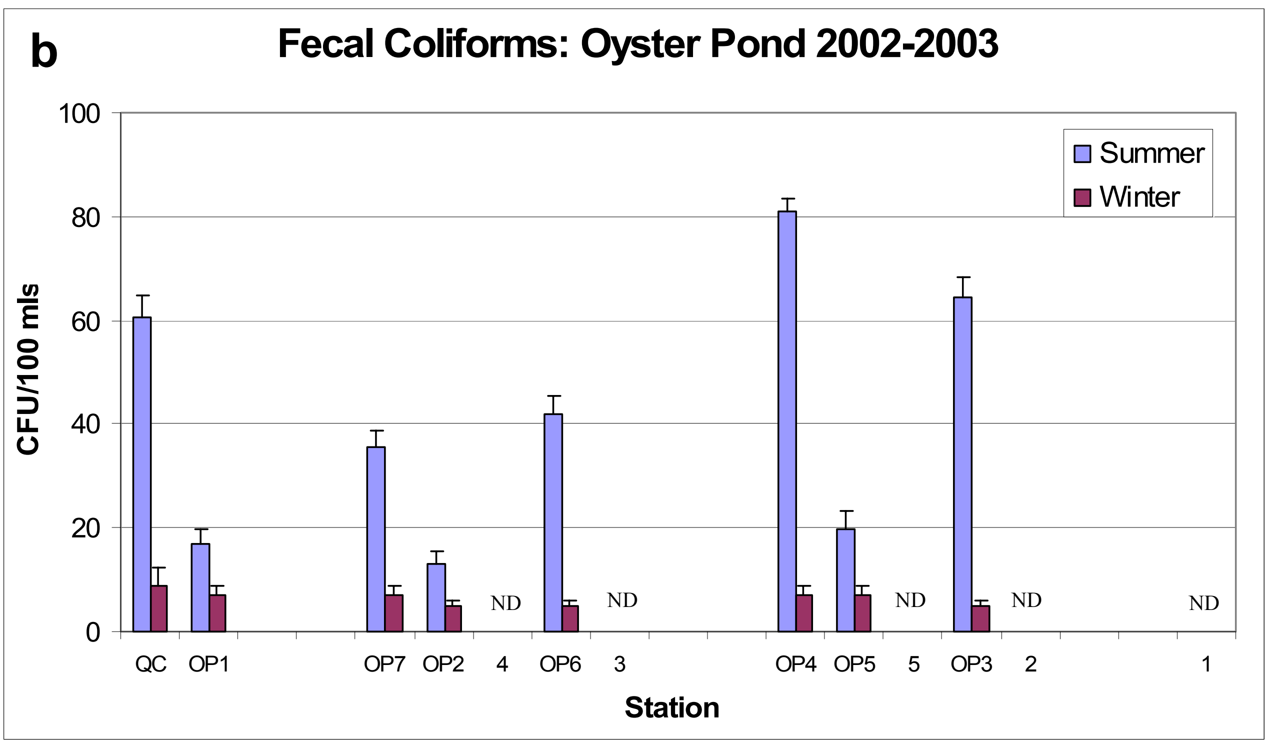


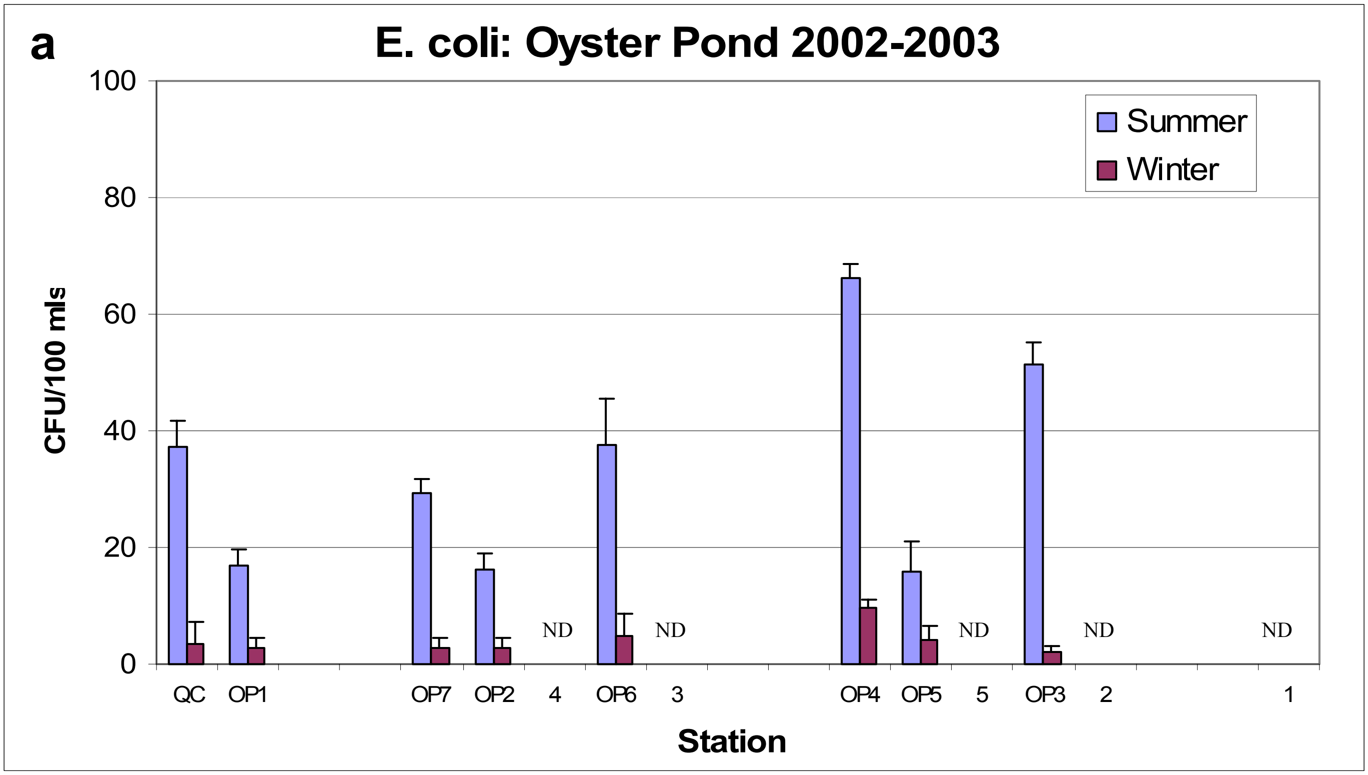
Figure V-4 Wet and Dry fecal coliform bacteria counts (number of cells/100 mls), 1994-2003. Numbers indicate geometric means of wet/dry data from all winter (w) and all summer (s) samplings by the Massachusetts Department of Marine Fisheries and SMAST.

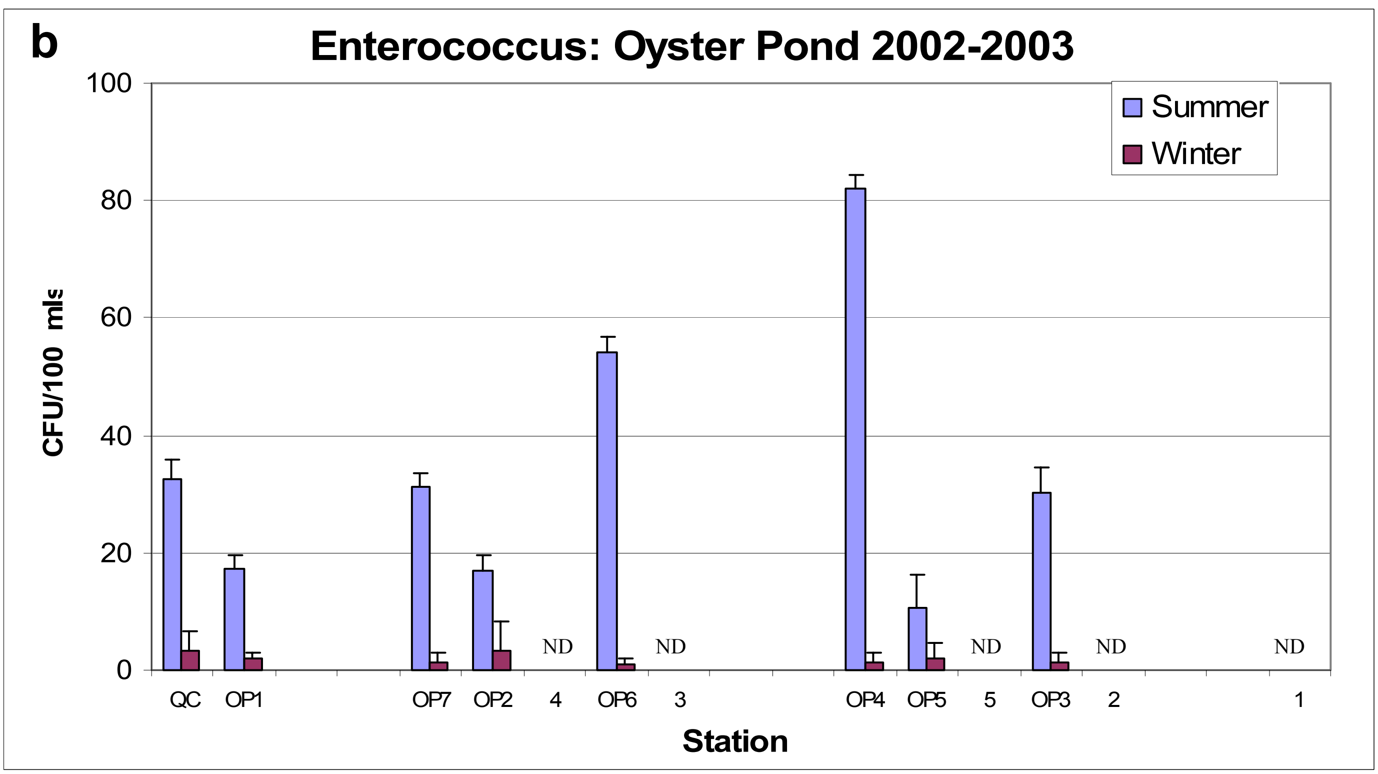




ND = No Data Available

Figure V-5 Summer and winter Fecal Coliform bacteria counts (CFU/100 mls) in Oyster Pond during the years (a) 1985-1997 and (b) 2002-2003. Numbers indicate geometric means for summer/winter samplings by Massachusetts Department of Marine Fisheries and SMAST (QC, OP1-OP7).





ND = No Data Available

Figure V-6. Summer and winter E. coli (a) and Enterococcus (b) bacteria counts (CFU/100 mls) in Oyster Pond during the years 2002-2003. Numbers indicate geometric means for summer/winter samplings by SMAST (SM).

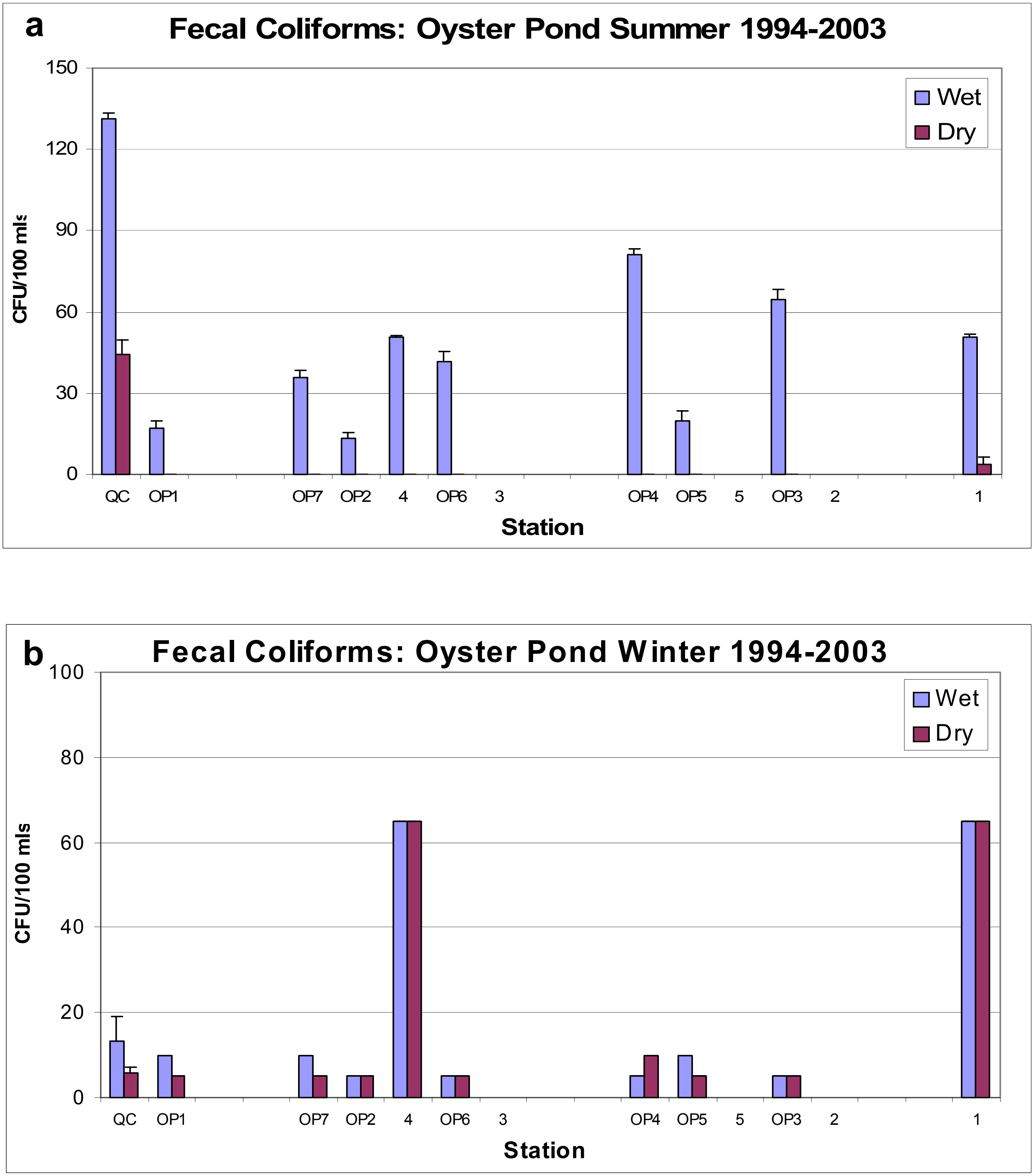
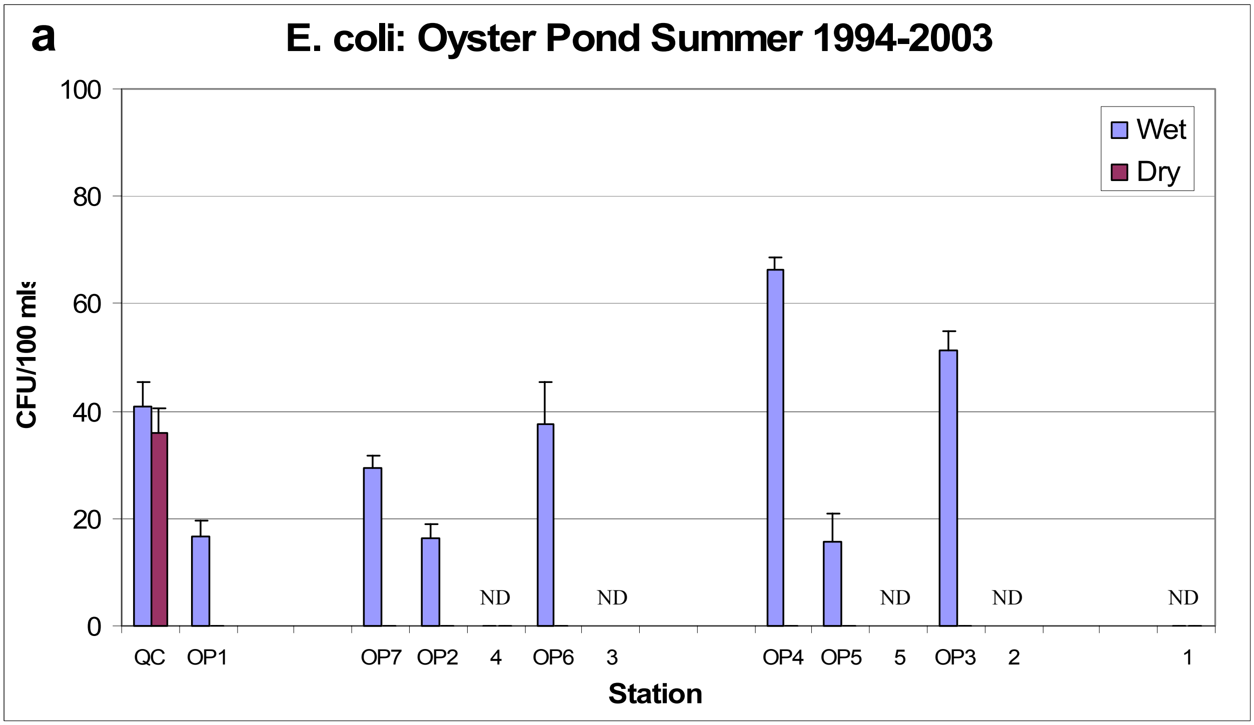
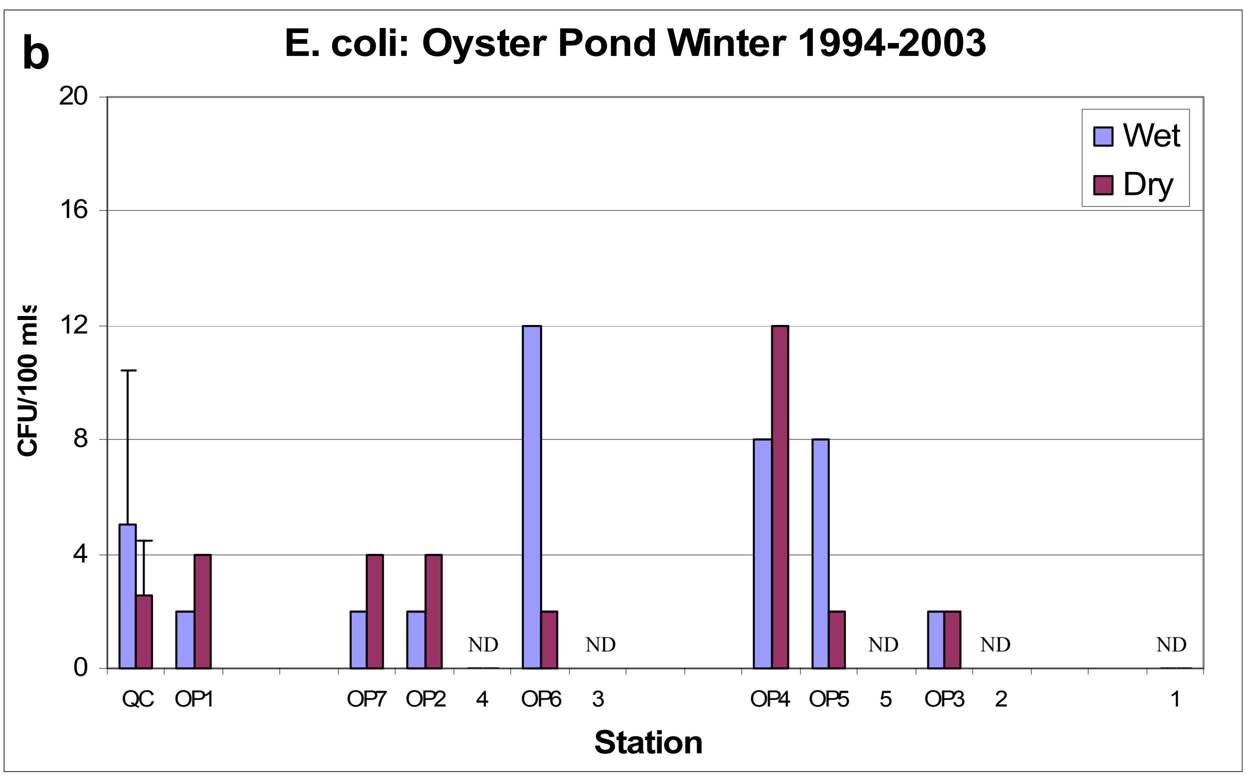


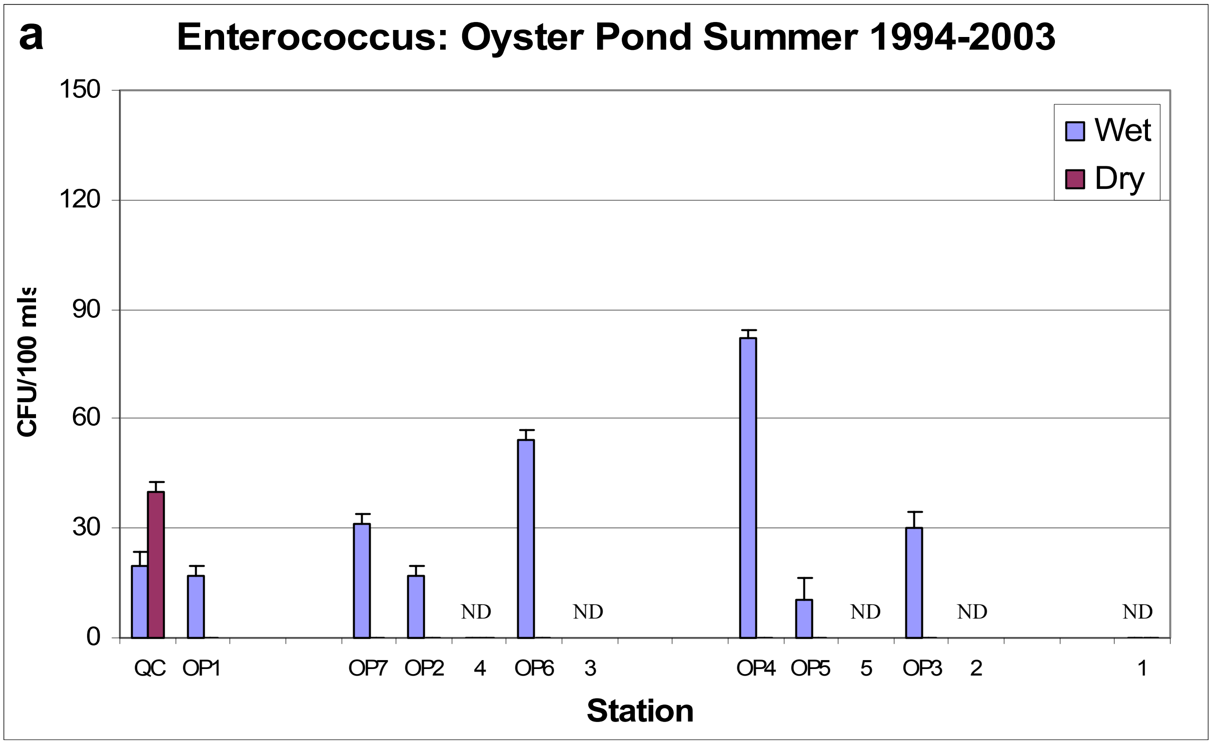
Figure V-7 Wet and Dry Fecal Coliform bacteria counts (CFU/100 mls) in Oyster Pond during the years 1994-2003. Numbers indicate geometric means of wet/dry data for (a) summer and (b) winter samplings by The Massachusetts Department of Marine Fisheries and SMAST.

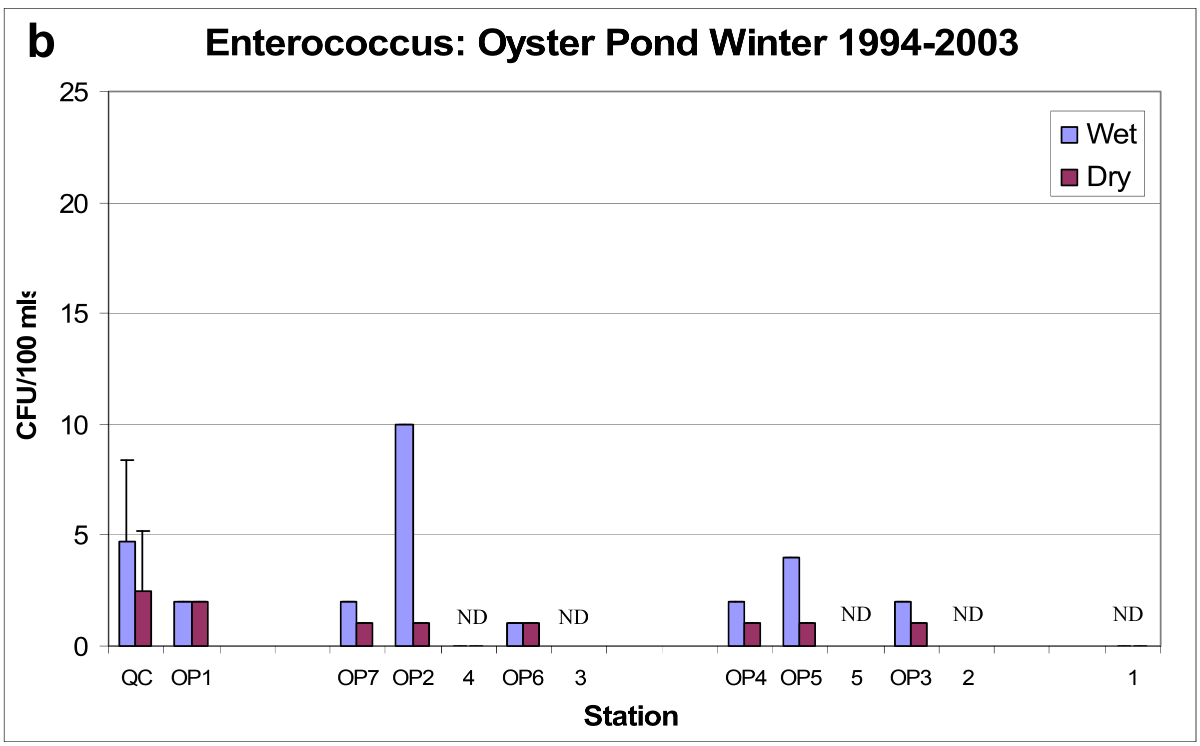




ND = No Data

Figure V-8 Wet and Dry E. coli bacteria counts (CFU/100 mls) in Oyster Pond during the years 1994-2003. Numbers indicate geometric means of wet/dry data for (a) summer and (b) winter samplings by SMAST.





ND = No Data

Figure V-9 Wet and Dry Enterococcus bacteria counts (CFU/100 mls) in Oyster Pond during the years 1994-2003. Numbers indicate geometric means of wet/dry data for (a) summer and (b) winter samplings by SMAST.

a

Fecal Coliforms Year	Station	Summer Geomean	SD	N	% Samples >14	% Samples >43	Winter Geomean	SD	N	% Samples >14	% Samples >43	Geomean Ratio: Summer:Winter
1985-1997	1	22	5	5	60%	60%	23	7	5	80%	60%	1.0
1985-1997	2	81	2	9	100%	78%	4	4	11	18%	9%	18.8
1985-1997	3	66	2	9	89%	78%	6	6	10	20%	20%	11.6
1985-1997	4	54	4	11	73%	73%	9	6	11	45%	27%	6.2
1985-1997	5	45	2	9	100%	22%	2	4	10	10%	0%	19.7
2002-2003	OP-1	17	3	4	50%	0%	7	2	2	0%	0%	2.4
2002-2003	OP-2	13	2	4	50%	0%	5	1	2	0%	0%	2.6
2002-2003	OP-3	64	4	4	75%	75%	5	1	2	0%	0%	12.9
2002-2003	OP-4	81	2	4	100%	75%	7	2	2	0%	0%	11.5
2002-2003	OP-5	20	4	4	50%	25%	7	2	2	0%	0%	2.8
2002-2003	OP-6	42	4	4	75%	50%	5	1	2	0%	0%	8.4
2002-2003	OP-7	36	3	4	75%	50%	7	2	2	0%	0%	5.0
2002-2003	QC	60	4	21	86%	52%	9	4	22	18%	9%	7.0

b

E. coli Year	Station	Summer Geomean	SD	N	% Samples >14	% Samples >43	Winter Geomean	SD	N	% Samples >14	% Samples >43	Geomean Ratio: Summer:Winter
2002-2003	OP-1	17	3	4	75%	25%	3	2	2	0%	0%	5.9
2002-2003	OP-2	16	3	4	75%	0%	3	2	2	0%	0%	5.8
2002-2003	OP-3	51	4	4	75%	75%	2	1	2	0%	0%	25.7
2002-2003	OP-4	66	2	4	100%	50%	10	1	2	0%	0%	6.8
2002-2003	OP-5	16	5	4	50%	50%	4	3	2	0%	0%	3.9
2002-2003	OP-6	38	8	4	75%	75%	5	4	2	0%	0%	7.7
2002-2003	OP-7	29	2	4	75%	50%	3	2	2	0%	0%	10.4
2002-2003	QC	37	4	21	86%	52%	4	4	22	14%	5%	10.3

c

Enterococcus Year	Station	Summer Geomean	SD	N	% Samples >104	Winter Geomean	SD	N	% Samples >104	Geomean Ratio: Summer:Winter
2002-2003	OP-1	17	3	4	0%	2	1	2	0%	8.6
2002-2003	OP-2	17	3	4	0%	3	5	2	0%	5.4
2002-2003	OP-3	30	4	4	25%	1	2	2	0%	21.4
2002-2003	OP-4	82	2	4	25%	1	2	2	0%	58.1
2002-2003	OP-5	11	6	4	0%	2	3	2	0%	5.3
2002-2003	OP-6	54	3	4	25%	1	1	2	0%	54.1
2002-2003	OP-7	31	3	4	0%	1	2	2	0%	22.0
2002-2003	QC	33	3	21	19%	3	3	22	0%	9.6

Table V-1 Comparison of geometric means (CFU/100 mls) of summer and winter samplings for (a) Fecal Coliforms, (b) E. coli and (c) Enterococcus bacteria in Oyster Pond by Massachusetts Department of Marine Fisheries and SMAST during the years 1985-1997 and 2002-2003.

a

Fecal Coliforms Summer Year	Station	Wet Geomean	SD	N	% Samples >14	% Samples >43	Dry Geomean	SD	N	% Samples >14	% Samples >43	Geomean Ratio: Wet:Dry
1994-2003	1	51	1	2	100%	100%	4	3	2	0%	0%	12.6
1994-2003	4	50	1	2	100%	100%	ND	ND	ND	ND	ND	ND
1994-2003	OP-1	17	3	4	50%	0%	ND	ND	ND	ND	ND	ND
1994-2003	OP-2	13	2	4	50%	0%	ND	ND	ND	ND	ND	ND
1994-2003	OP-3	64	4	4	75%	75%	ND	ND	ND	ND	ND	ND
1994-2003	OP-4	81	2	4	100%	75%	ND	ND	ND	ND	ND	ND
1994-2003	OP-5	20	4	4	50%	25%	ND	ND	ND	ND	ND	ND
1994-2003	OP-6	42	4	4	75%	50%	ND	ND	ND	ND	ND	ND
1994-2003	OP-7	36	3	4	75%	50%	ND	ND	ND	ND	ND	ND
1994-2003	QC	131	2	6	100%	100%	44	5	15	80%	33%	3.0
Fecal Coliforms Winter Year	**Station**	**Wet Geomean**	**SD**	**N**	**% Samples >14**	**% Samples >43**	**Dry Geomean**	**SD**	**N**	**% Samples >14**	**% Samples >43**	**Geomean Ratio: Wet:Dry**
1994-2003	1	65	0	1	100%	100%	65	0	1	100%	100%	1.0
1994-2003	4	65	0	1	100%	100%	65	0	1	100%	100%	1.0
1994-2003	OP-1	10	0	1	0%	0%	5	0	1	0%	0%	2.0
1994-2003	OP-2	5	0	1	0%	0%	5	0	1	0%	0%	1.0
1994-2003	OP-3	5	0	1	0%	0%	5	0	1	0%	0%	1.0
1994-2003	OP-4	5	0	1	0%	0%	10	0	1	0%	0%	0.5
1994-2003	OP-5	10	0	1	0%	0%	5	0	1	0%	0%	2.0
1994-2003	OP-6	5	0	1	0%	0%	5	0	1	0%	0%	1.0
1994-2003	OP-7	10	0	1	0%	0%	5	0	1	0%	0%	2.0
1994-2003	QC	13	6	11	27%	18%	6	2	11	9%	0%	2.3

b

E. coli Summer Year	Station	Wet Geomean	SD	N	% Samples >14	% Samples >43	Dry Geomean	SD	N	% Samples >14	% Samples >43	Geomean Ratio: Wet:Dry
1994-2003	OP-1	17	3	4	75%	25%	ND	ND	ND	ND	ND	ND
1994-2003	OP-2	16	3	4	75%	0%	ND	ND	ND	ND	ND	ND
1994-2003	OP-3	51	4	4	75%	75%	ND	ND	ND	ND	ND	ND
1994-2003	OP-4	66	2	4	100%	50%	ND	ND	ND	ND	ND	ND
1994-2003	OP-5	16	5	4	50%	50%	ND	ND	ND	ND	ND	ND
1994-2003	OP-6	38	8	4	75%	75%	ND	ND	ND	ND	ND	ND
1994-2003	OP-7	29	2	4	75%	50%	ND	ND	ND	ND	ND	ND
1994-2003	QC	41	4	6	83%	50%	36	5	15	87%	53%	1.1
E. coli Winter Year	**Station**	**Wet Geomean**	**SD**	**N**	**% Samples >14**	**% Samples >43**	**Dry Geomean**	**SD**	**N**	**% Samples >14**	**% Samples >43**	**Geomean Ratio: Wet:Dry**
1994-2003	OP-1	2	0	1	0%	0%	4	0	1	0%	0%	0.5
1994-2003	OP-2	2	0	1	0%	0%	4	0	1	0%	0%	0.5
1994-2003	OP-3	2	0	1	0%	0%	2	0	1	0%	0%	1.0
1994-2003	OP-4	8	0	1	0%	0%	12	0	1	0%	0%	0.7
1994-2003	OP-5	8	0	1	0%	0%	2	0	1	0%	0%	4.0
1994-2003	OP-6	12	0	1	0%	0%	2	0	1	0%	0%	6.0
1994-2003	OP-7	2	0	1	0%	0%	4	0	1	0%	0%	0.5
1994-2003	QC	5	5	11	18%	9%	3	2	11	9%	0%	2.0

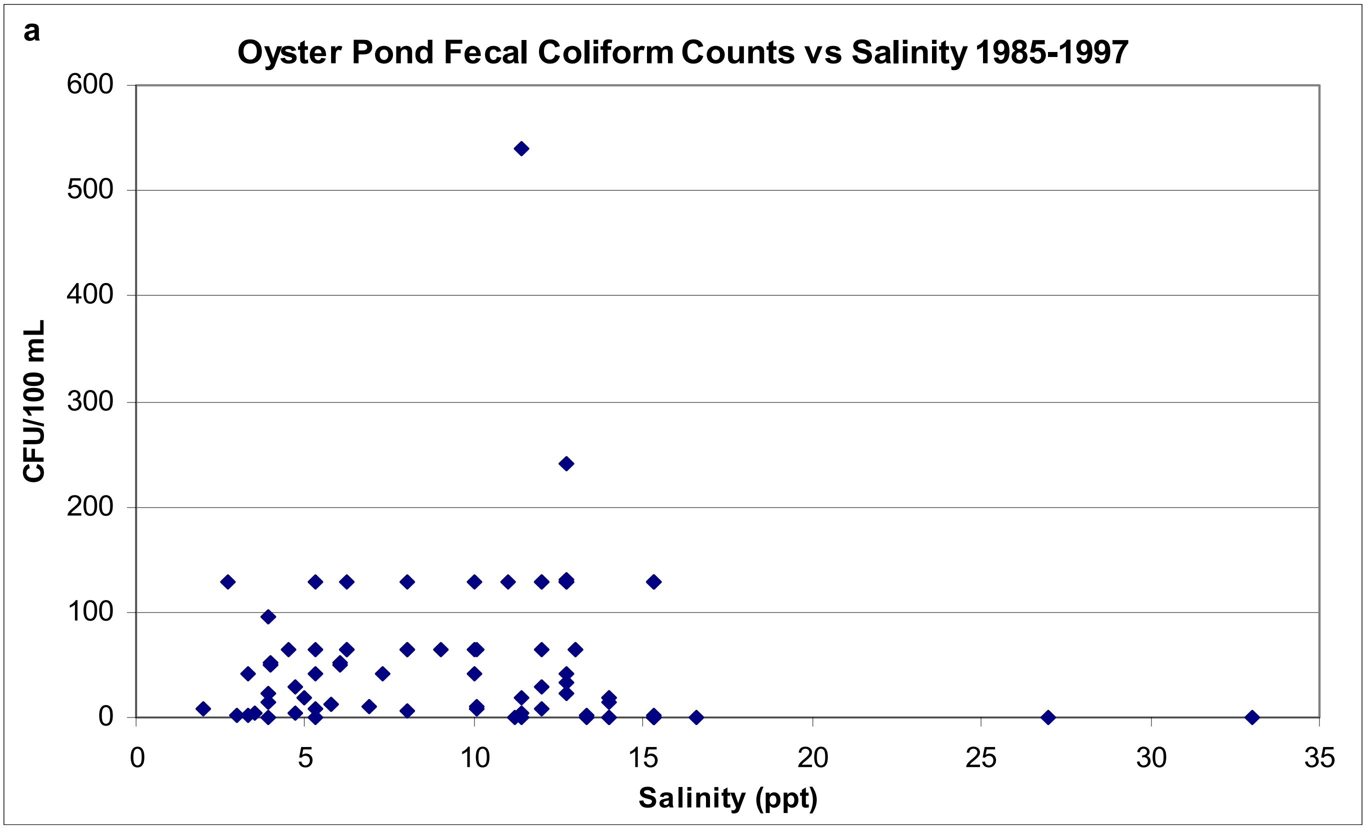
ND = No Data Available

Table V-2 Wet and Dry fecal coliform (a) and E. coli (b) bacteria counts (CFU/100 mls) during the years 1994-2003 in Oyster Pond. Numbers indicate geometric means of wet/dry data for summer and winter samplings by The Department of Marine Fisheries and SMAST.

Enterococcus Summer Year	Station	Wet Geomean	SD	N	% Samples >104	Dry Geomean	SD	N	% Samples >104	Geomean Ratio: Wet:Dry
1994-2003	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1994-2003	4	ND	ND	ND	ND	ND	ND	ND	ND	ND
1994-2003	OP-1	17	3	4	0%	ND	ND	ND	ND	ND
1994-2003	OP-2	17	3	4	0%	ND	ND	ND	ND	ND
1994-2003	OP-3	30	4	4	25%	ND	ND	ND	ND	ND
1994-2003	OP-4	82	2	4	25%	ND	ND	ND	ND	ND
1994-2003	OP-5	11	6	4	0%	ND	ND	ND	ND	ND
1994-2003	OP-6	54	3	4	25%	ND	ND	ND	ND	ND
1994-2003	OP-7	31	3	4	0%	ND	ND	ND	ND	ND
1994-2003	QC	20	4	6	17%	40	3	15	20%	0.5
Enterococcus Winter Year	**Station**	**Wet Geomean**	**SD**	**N**	**% Samples >104**	**Dry Geomean**	**SD**	**N**	**% Samples >104**	**Geomean Ratio: Wet:Dry**
1994-2003	1	ND	ND	ND	ND	ND	ND	ND	ND	ND
1994-2003	4	ND	ND	ND	ND	ND	ND	ND	ND	ND
1994-2003	OP-1	2	0	1	0%	2	0	1	0%	1.0
1994-2003	OP-2	10	0	1	0%	1	0	1	0%	10.0
1994-2003	OP-3	2	0	1	0%	1	0	1	0%	2.0
1994-2003	OP-4	2	0	1	0%	1	0	1	0%	2.0
1994-2003	OP-5	4	0	1	0%	1	0	1	0%	4.0
1994-2003	OP-6	1	0	1	0%	1	0	1	0%	1.0
1994-2003	OP-7	2	0	1	0%	1	0	1	0%	2.0
1994-2003	QC	5	4	11	0%	2	3	11	0%	1.9

ND = No Data Available

Table V-3 Wet and Dry Enterococcus bacteria counts (CFU/100 mls) during the years 1994-2003 in Oyster Pond. Numbers indicate geometric means of wet/dry data for summer and winter samplings by SMAST.



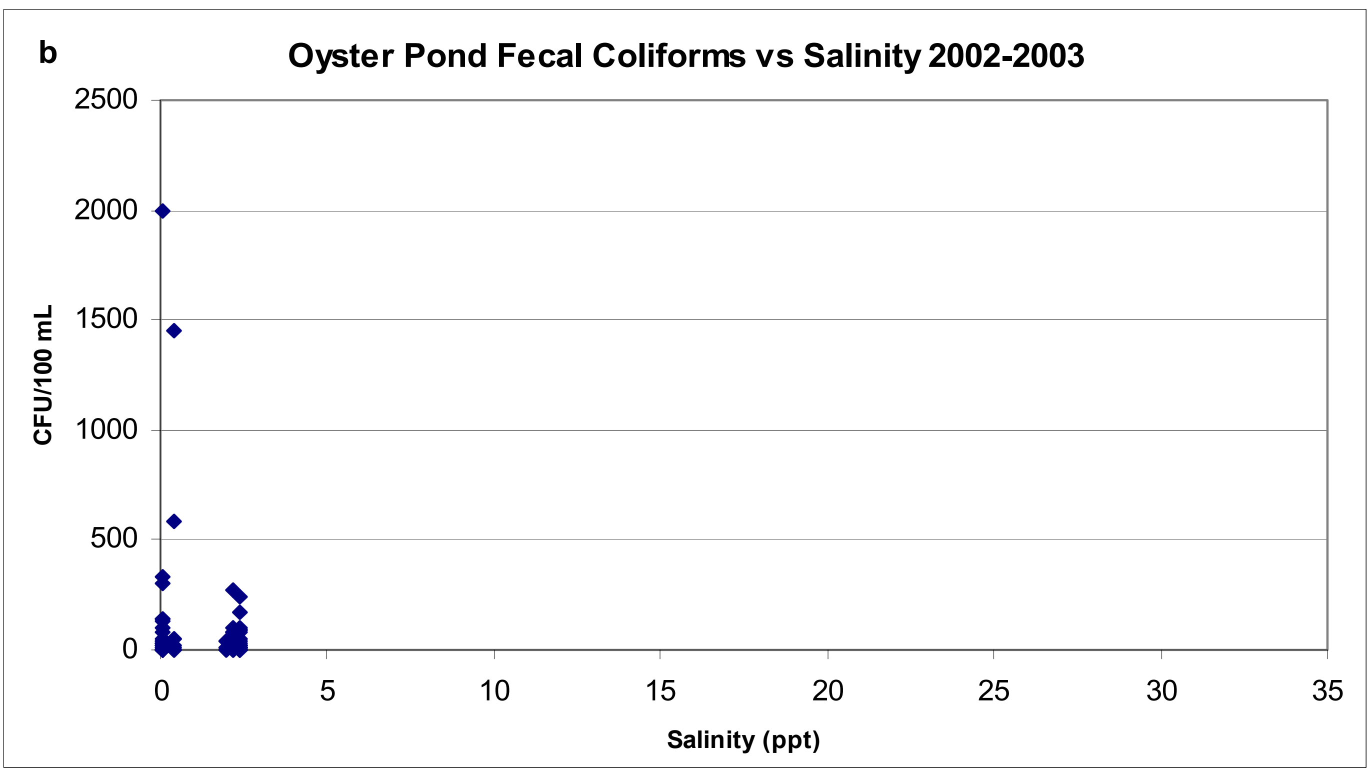


Figure V-10 Fecal Coliform bacteria counts (CFU/100 mls) vs salinity in Oyster Pond during the years 1985-1997 (a) and 2002-2003 (b). The 0-0.5ppt values are from Quivett Creek.

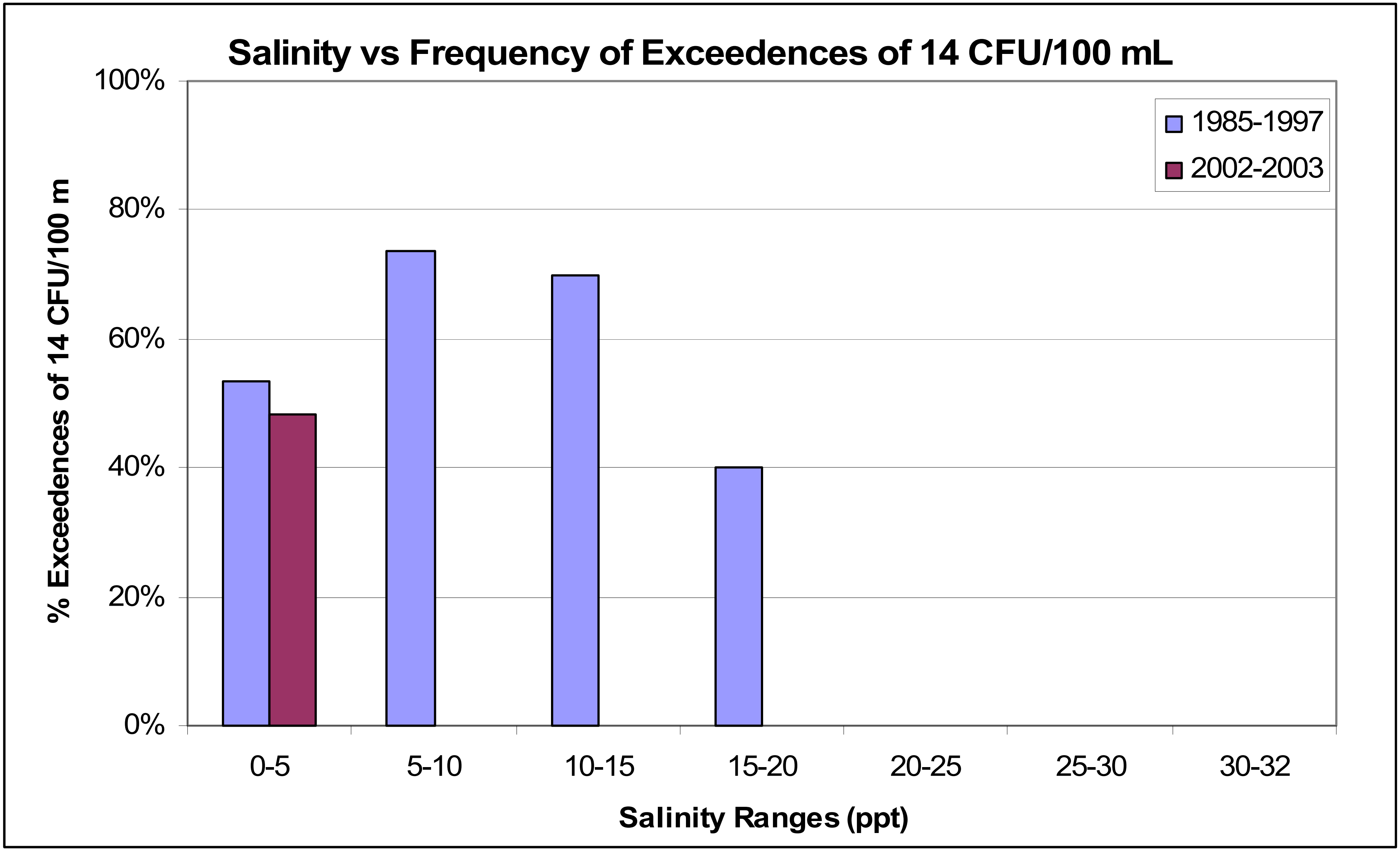


Figure V-11 Frequency of exceedences of 14 CFU/100 mL for samples for Fecal Coliform bacteria in Oyster Pond at different salinity ranges during the years 1985-1997 and 2002-2003. Frequencies are expressed as per cent of the total samples taken.

V.1 Bacterial Contamination Relative to Watershed Land-use

In order to refine the direction of future bacterial investigations that may be undertaken as a result of the TMDL for Oyster Pond or the need for more specific identification of sources of bacterial contamination, bacterial data were presented relative to land-use distribution in areas proximal to Oyster Pond. As shown in Figure V-12, based on bacterial data obtained from the DMF for the period 1985 to 1997, it is evident that there is definite bacterial contamination in the summer versus the winter and that the highest bacterial counts are at DMF stations 1, 2, and 4 located relatively close to forested and wetland land use areas. These land uses likely support populations of waterfowl and wildlife that would be more prevalent during the summer months when higher bacterial contamination is evident. Additional information provided by the Town of Falmouth Department of Public Works indicates that there are stormwater discharges to Oyster Pond (OPR 1, OPR 2, see above) that may one source contributing to the high summer bacterial levels seen at Station 2. Two 10-inch PVC pipes from Oyster Pond to the marsh area proximal to Station 2 were also identified by the DPW. Stormwater discharges from Oyster Pond Road was found to be a potentially important source of indicator bacteria to Oyster Pond waters, particularly at site OPR1 (Section III.1). The Oyster Pond Road stormwater discharges should be considered in any future investigations of potential bacterial sources.

DMF stations 3 and 5 are both proximal to pond shoreline that has been classified as medium density residential which may suggest that there is bacterial contamination associated with failed septic systems, however, in verbal discussion (January 2003) with the Falmouth Board of Health, the residential area on the east side of the pond is on town sewer and the residential area adjacent to the northwest shore of the pond is lightly developed with no structures near the pond and no apparent direct discharges. The residential area (multi-family) on the north side of the pond is on septic, however, the Board of Health reported no current knowledge of septic system failures.

Considering more recent summer and winter bacterial sampling (2002 – 2003) undertaken by SMAST for the MEP, bacterial contamination still appears more prevalent under summer rather than winter conditions (Figure V-13). A total of eight stations were sampled (OP1-7 and QC), one of which was a stream sample taken from Quivett Creek (QC) within which a stream gage was placed to quantify flows for the nutrient objectives of the Estuaries Project. Several stations were similar to previously sampled DMF stations such that a longer term record could be pieced together. SMAST station OP2 was in a similar location as DMF station 4 and SMAST station OP5 was similar to DMF station 5. Other stations were added to give more spatial coverage and to allow comparisons to the stormwater sampling (section III.1).

As depicted in Figure V-13, the greatest exceedances occur at SMAST stations QC located at the MEP gauge site on Quivett Creek, which drains a forested conservation area as well as OP4 and OP3. OP4 is proximal to the eastern shore of Oyster Pond which is classified as medium density residential and, according to the Board of Health, is on town sewer. OP4 is in the cove receiving stormwater discharge from the Quonset Rd. site (section III.1). Station OP3 is located proximal to an area of the pond shore that has been classified as wetland area and shows clear bacterial contamination during the summer months. This may be attributable to waterfowl or wildlife populations supported by the open space. As noted above, this site also receives potentially high inputs of stormwater from Oyster Pond Road. Other stations such as OP5 (eastern shore), OP6 and OP7 (western shore), and OP1 (northern shore) are all proximal to pond shore line classified as residential (either multi-family or medium density) and show moderate bacterial impairment in the summer and none under winter conditions. As such, it may be necessary for the town to further investigate potential for failing septic systems with the exception of the area in the vicinity of station OP5 which is theoretically on town sewer.

Based on the historical data (1994 – 2003) obtained from the DMF (stations 1 and 4) in addition to bacterial data collected by SMAST (stations OP1-7 and QC), an evaluation of wet and dry bacterial contamination under both summer and winter conditions and relative to land use was undertaken and is represented in Figures V-14 and V-15. As might be expected, the greatest bacterial exceedances occur under wet summer conditions and this is uniformly the case across all the sampling stations with the exception of station OP2 located most proximal to the eastern shore of Oyster Pond approximately mid way up from the mouth of the pond. DMF station 1 and SMAST stations QC and OP3 are all proximal to either wetland or forested areas and may be affected by stormwater discharges, which may be the cause for the high contamination during summer storm events. Stations OP6 and OP7 are both adjacent to the western shore of the pond, which is classified as medium density residential, and show moderate impairment during summer storm events. This area is not sewered and does not support known stormwater discharges. There have been no reports or septic system failures to the Board of Health. However, the bacterial levels in this region of the pond may indicate a local terrestrial source or a congregation area for wildlife. At present the source of contamination in this region is unknown. A sanitary survey should be considered in this area.

Figure V-15 shows bacterial contamination relative to land use for both wet and dry conditions during winter months. In general, bacterial contamination is minimal, however two stations (DMF stations 1 and 4) show significant exceedances at both stations under both wet and dry conditions. Both these stations are close to wetland areas, however, station 4 is also potentially influenced by either road run-off from the residential area on the adjacent shore and station 1 potentially affected by stormwater discharges from Oyster Pond Road.

Given that a sanitary survey has not been conducted in Oyster Pond since 1984 the Town may want to consider either a system-wide or targeted sanitary survey. Key elements of concern are the stormwater discharges, particulary Oyster Pond Road and Quonset Road and identifying sources of contamination at OP2/DMF4, OP6/DMF3 and OP4. The significant increase in bacterial levels in wet versus dry weather suggests that stormwater discharges and runoff are important to the contamination of this system. The data further support the concept that much of the non-stormwater inputs may be related to wildlife/wetlands.

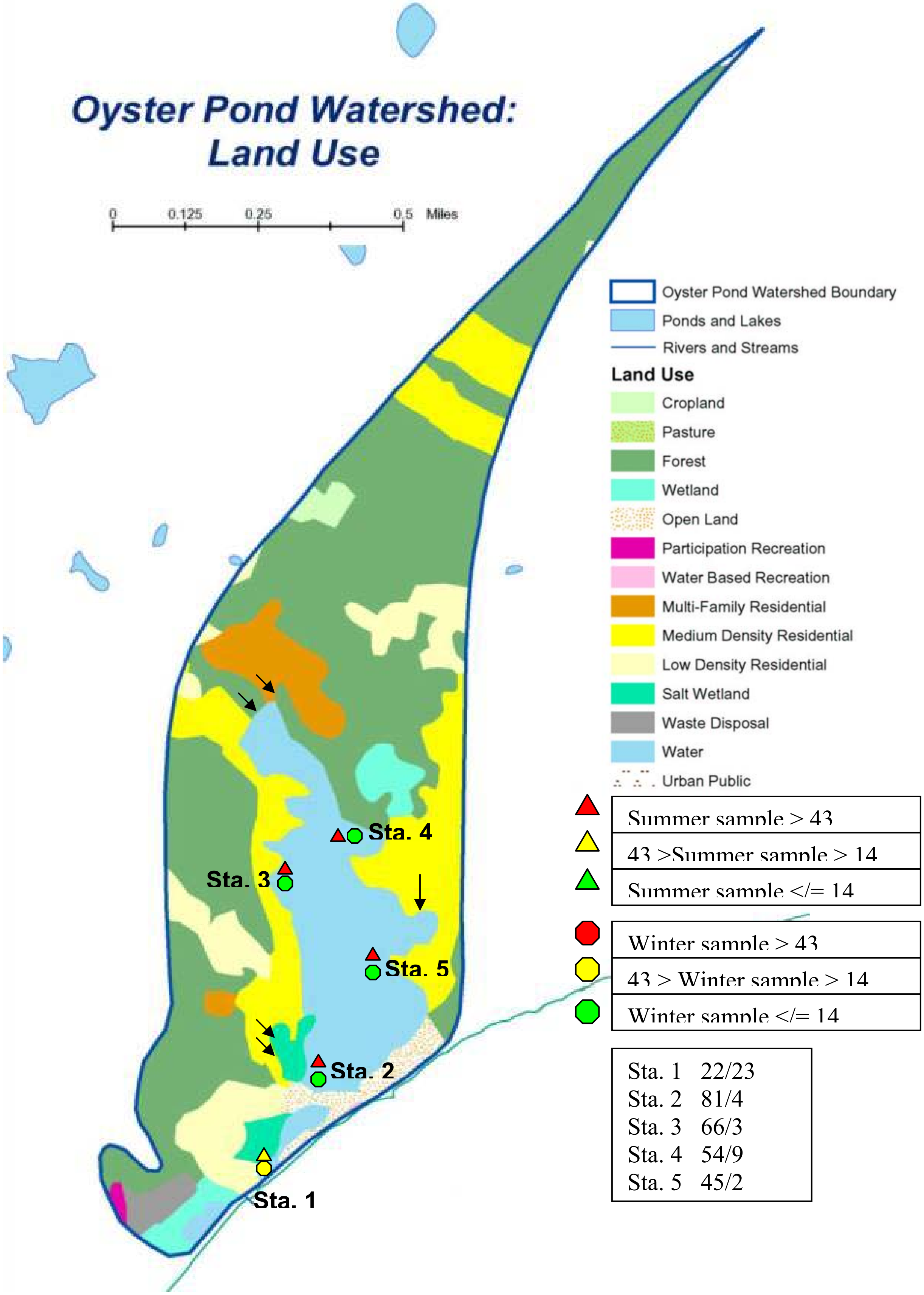


Figure V-12 Summer and Winter fecal coliform counts (cells/100ml) as geometric means relative to land use. Division of Marine Fisheries sampling 1985 – 1997. Arrows show approximate locations of stream and stormwater discharges.

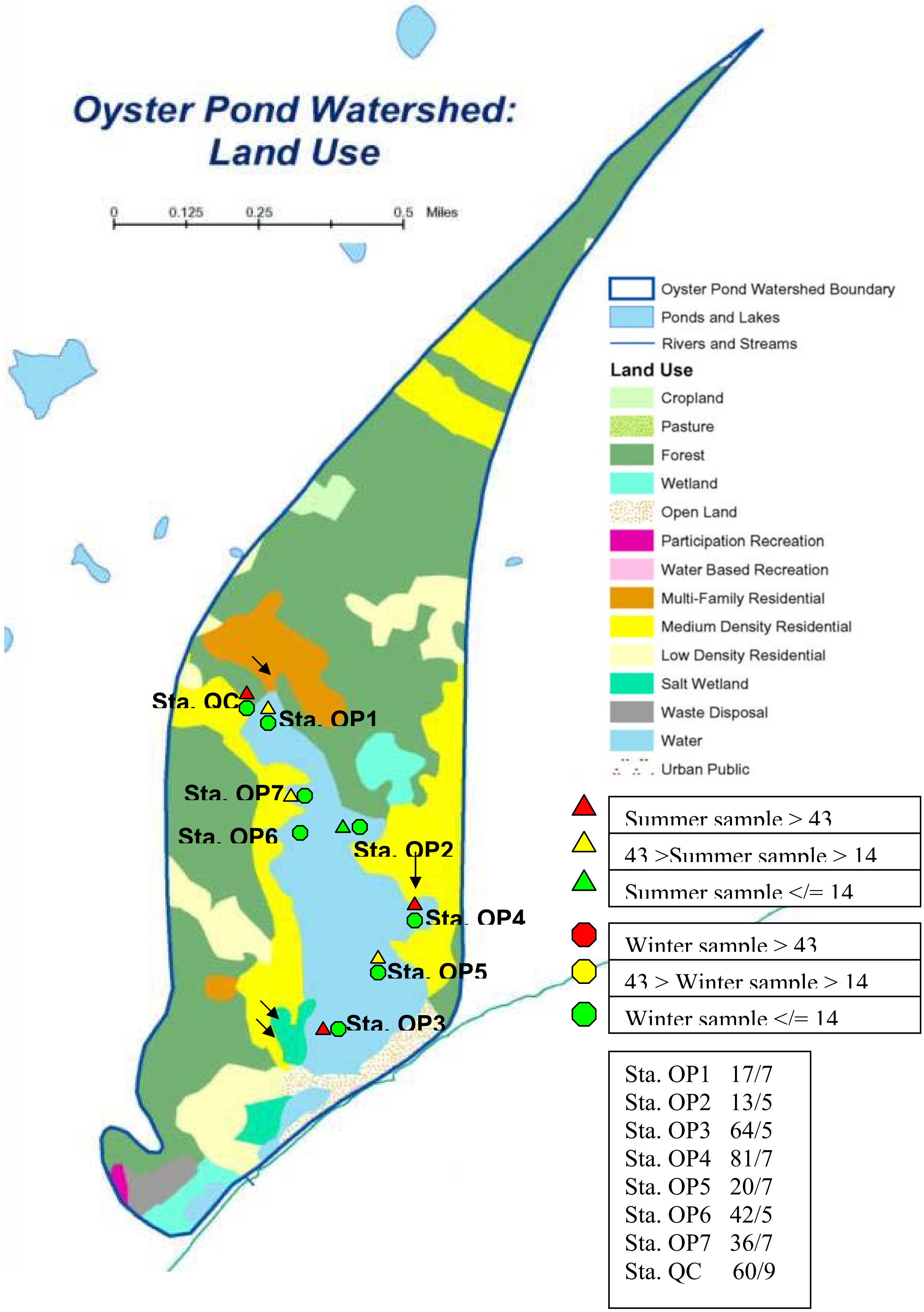
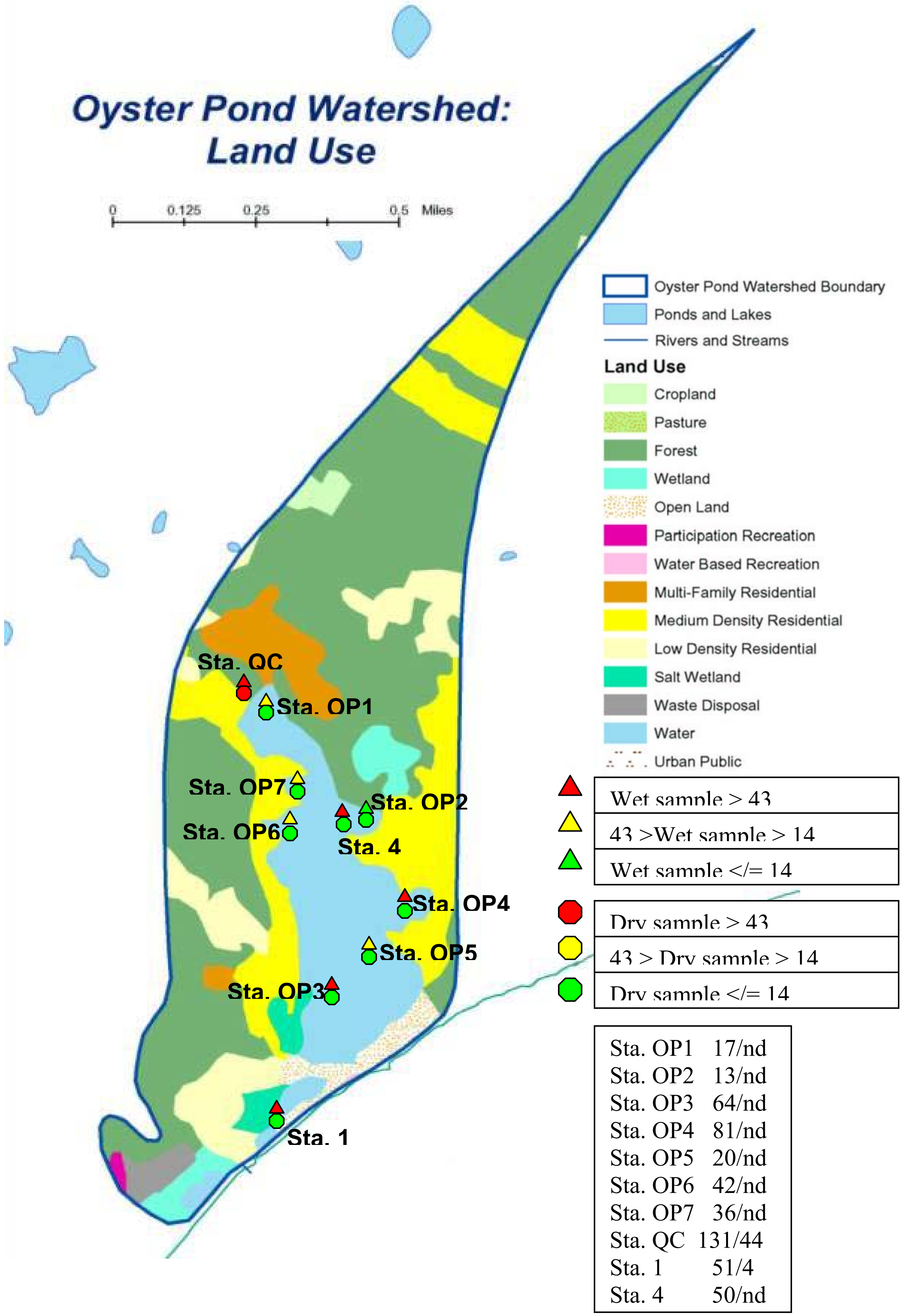


Figure V-13 Summer and Winter fecal coliform counts (cells/100ml) as geometric means relative to land use. SMAST sampling 2002 – 2003. Arrows are approx. locations of stormwater discharge sites.



Sta. OP1	17/nd
Sta. OP2	13/nd
Sta. OP3	64/nd
Sta. OP4	81/nd
Sta. OP5	20/nd
Sta. OP6	42/nd
Sta. OP7	36/nd
Sta. QC	131/44
Sta. 1	51/4
Sta. 4	50/nd

Figure V-14 Wet and Dry (summer) fecal coliform counts (cells/100ml) as geometric means relative to land use. Division of Marine Fisheries and SMAST sampling 1994 - 2003

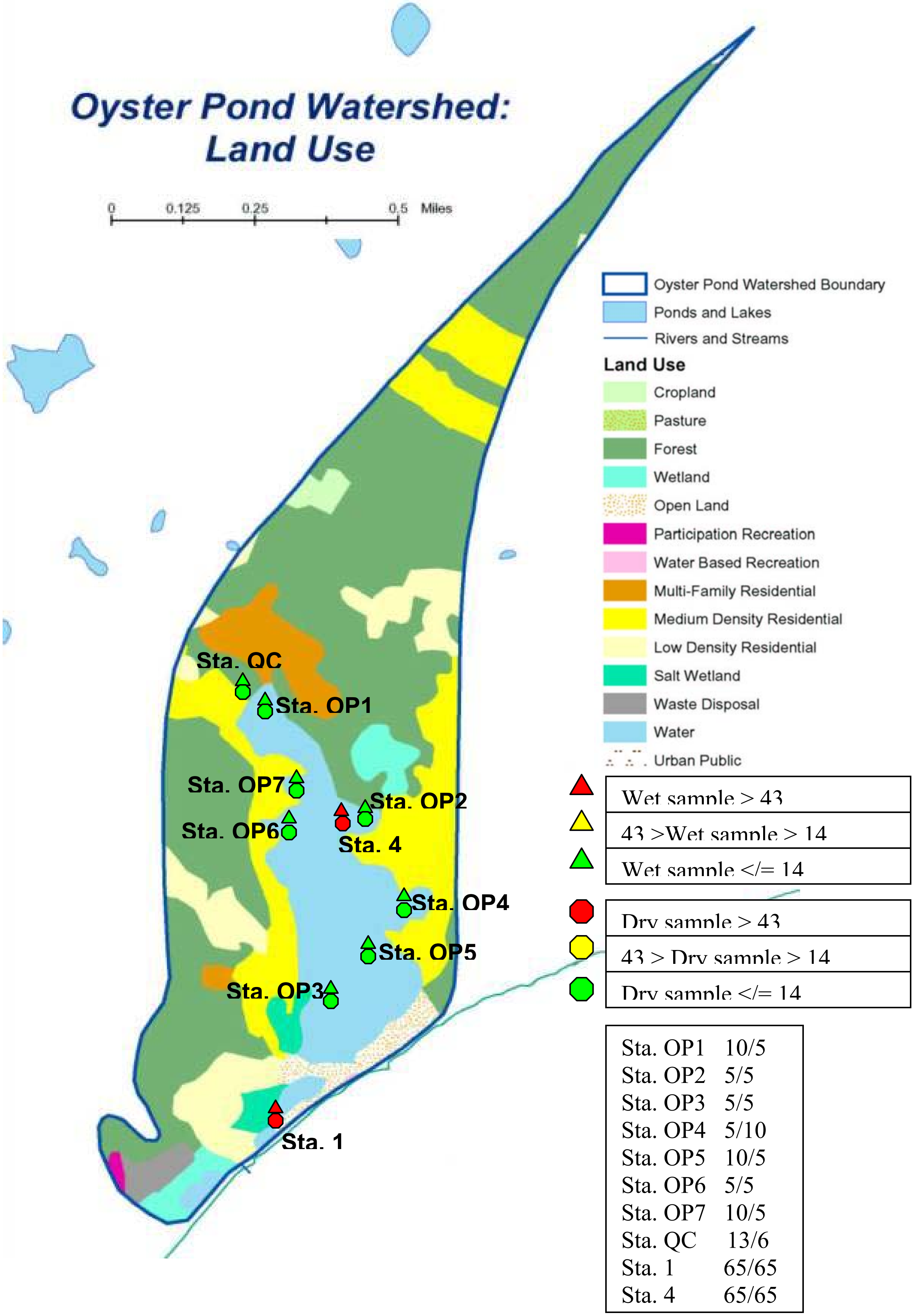


Figure V-15 Wet and Dry (winter) fecal coliform counts (cells/100ml) as geometric means relative to land use. Division of Marine Fisheries and SMAST sampling 1994 - 2003

VI. Conclusions and Recommendations

The Estuaries Project recommendations are for the Town of Falmouth to undertake future sampling as a component of the TMDL in the known areas of waterfowl congregation and to perform stormwater sampling on street drains draining into the Pond to better pinpoint specific bacterial sources. MEP also recommends that the DEP and DMF contemplate and discuss the lack of shellfish viability in this pond as a result of factors that are not directly related to pathogens and consider whether 303d listing is therefore necessary. Oyster Pond has been managed as a brackish water basin for over a decade and with the construction of a weir at the Pond outlet for salinity control and fish passage, it is likely to continue to be brackish (1-3ppt) into the foreseeable future. Aligning the current resource with the appropriate bacterial management criteria, would still require a judgment on the sources of current bacterial contamination and likely some remediation as the levels currently exceed even those for primary contact recreation (at some stations for part of the year).

From the available data, it is clear that Oyster Pond has summer inputs of fecal coliforms that are substantially higher than winter inputs throughout the pond. Summer geometric means exceed the water quality standard of 14 CFU/100mL consistently at all stations from 1985 to present. In addition more than 10% of the samples exceed the water quality standard of 43 CFU/100 mL at most of the stations. More recent (2002-2003) data show that summer inputs of E. coli and Enterococcus are higher than winter inputs. Summer geometric means for E. coli consistently exceed 14 CFU/100mL, while those for Enterococcus exceed 35 colonies/100mL at only 2 stations. At most of the stations more than 10% of the E. coli samples exceed the water quality standard of 43 CFU/100mL. For Enterococcus, samples exceed the water quality standard of 104 colonies/100mL at 5 stations.

There is clearly an enhancement of bacterial inputs after rain events in the summer. Wet geometric means are consistently above the 14 CFU/100 mL standard while most dry geometric means are below the standard where sufficient data are available. In winter the pattern is not consistent and many of the geometric means for both wet and dry data are below the water quality standard.

Storm event sampling of 4 stormwater discharge sites was consistent with the response of bacterial levels after rain events. Each of the 4 discharge sites appeared to have flow related to storm events and showed little to no flow during dry weather. Based upon this screening analysis the relative importance of the measured stormwater discharges is Oyster Pond Rd. 1>>Oyster Pond Rd. 2, Quonset Rd.>Tree Tops. In addition, it appears that the Oyster Pond Rd. discharges and Quonset Road discharge may play an important role in the increase in bacterial levels in the receiving waters after a rain event. Further analysis relative to remediation of these surface water discharges should be conducted as pertains to reducing bacterial contamination within Oyster Pond.

Potential problems in Oyster Pond seem to occur primarily during the summer. The most likely sources of fecal coliform bacteria are waterfowl and other wildlife in the summer. Although Tree Tops Condominiums abuts the pond, there are no reported failures of any of the septic systems. Residences on the east side of the pond are sewered. Quivett Creek may also be a source of contamination.

The greatest bacterial exceedances occur under wet summer conditions and is uniformly the case across all the sampling stations with the exception of station OP2 located most proximal to the eastern shore of Oyster Pond approximately mid way up from the mouth of the pond. Many of the pond sites showing elevated bacterial levels are proximal to either wetland or forested areas and/or are apparently affected by known stormwater discharges. Along the western shore of the pond, which is classified as medium density residential, shows moderate impairment during summer storm events. This area is not sewered and does not support known stormwater discharges. There have been no reports or septic system failures to the Board of Health. However, the bacterial levels in this region of the pond may indicate a local terrestrial source or a congregation area for wildlife. At present the source of contamination in this region is unknown. A sanitary survey should be considered in this area.

The Massachusetts Estuaries Project (MEP) recommends that Oyster Pond be considered for removal from the list of shellfish growing areas since it is now being managed as a brackish/freshwater habitat, and there are presently no known shellfishing resources within the Pond.

References

Code of Massachusetts Regulations, 105 CMR 445.031(A)(1), Minimum Standards for Bathing Beaches, State Sanitary Code, Chapter VII.

Code of Massachusetts Regulations, Massachusetts Surface Water Quality Standards 314 CMR 4.05(4)(a)4.

Howes, B.L. and S.R. Hart. 1996. Oyster Pond - Three Decades of Change. pp. 79-106, In: K.O. Emery, A Coastal Pond: Studied by Oceanographic Methods. OPET, Inc.

K.O. Emery. 1996. A Coastal Pond: Studied by Oceanographic Methods. OPET, Inc.

Millham, N.P. and B.L. Howes, (1994). Freshwater flow into a coastal embayment: groundwater and surface water inputs. Limnology and Oceanography 39: 1928-1944.

Massachusetts Estuaries Project (MEP), 2002. The Massachusetts Estuaries Project Embayment Water Quality Assessment Interim Report: Priority Embayments 1 – 20.

Town of Falmouth Department of Public Works, Coastal Drainage Program. Summary of Direct Stormwater Discharges, 1999.