FINAL DRAFT

Fecal Coliform Total Maximum Daily Load Study Plan For Sinclair and Dyes Inlets

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Draft Quality Assurance Project Plan

Prepared by

PSNS Project ENVVEST Regulatory Working Group

For

Washington State Department of Ecology

Watershed Assessments Sections

October 4, 2002

Water Body Numbers

WA-15-0040 Sinclair Inlet
WA-15-0050 Dyes Inlet

Approvals:

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Mike Hendrick, Ecology 10/7/02

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Puget Sound Naval Shipyard: *G.M. Sherrell, V.S. Whitney, and J.M Wright*
Space and Naval Warfare Systems Center: *R.K. Johnston, K.E. Richter, H. Halkola, and P.F. Wang*
U.S. EPA Region X: *M. Rylko and M. Turvey*
Washington State Department of Ecology: *Will Kendra, M. Roberts, D. Garland, and S. Sweet*
Applied Physics Laboratory of the University of Washington: *C.W. May*
City of Bremerton: *M. Mecham, C. Berthiaume, K. Cahall, and D. Adams*
Kitsap County Surface and Storm Water Management: *S. Olsen and M. Hein*
Washington State Department of Health: *F. Meriwether*
U.S. Army Corps of Engineers Environmental Research and Development Center: *B. Skahill*
Suquamish Tribe: *Tom Ostrom and Paul Williams*
Kitsap County Health District: *J. Zimny*
Kitsap Public Utilities District: *M. Morgan and M. Sebren*
Battelle Marine Sciences Laboratory: *M. Miller and E. Crecelius*
Concurrent Technologies Corporation: *J. Baker and Z. Zhang*

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ACRONYMS

CWA	Clean Water Act
BKCHD	Bremerton Kitsap County Health District
BMSL	Batelle Marine Science Laboratory, Sequim, WA
CEAM	Center for Exposure Assessment Modeling
CH3D	Curvilinear hydrodynamics in 3 dimensions, a numerical modeling system
CFS	Cubic feet per second
CSO	Combined Sewer Outfall
CTC	Concurrent Technologies Corporation
DOH	Department of Health
ENVVEST	ENVironmental ReinVEStment
ERDC	Environmental Research and Development Center, Vicksburg, MS
FC	Fecal Coliform
HSPF	Hydrological Simulation Program Fortran
KPUD	Kitsap Public Utilities Department
LA	Load Allocation
MPN	Most Probable Number
NPS	National Pollution System
NSB	Naval Station Bremerton
PSNS	Puget Sound Naval Shipyard
QA/QC	Quality Control/Quality Assurance
RPD	Relative Percent Difference
RSD	Relative Standard Deviation
SSC	Space and Naval Warfare Systems Center, San Diego, CA
SSWM	Kitsap County Surface and Stormwater Management
SWMM	Storm Water Management Model
TMDL	Total Maximum Daily Load
WAC	Washington Administrative Code
WAL	Waste Allocation Load
WASP	Water Analysis Simulation Program
WES	Army Corps of Engineers Waterways Experiment Station, Vicksburg, MS
WDOE	Washington Department of Ecology
WDOH	Washington Department of Health

1. INTRODUCTION

The Washington State Department of Ecology (Ecology) is responsible for administering the state's water quality management program under the authority of state law and under the direction of the federal Clean Water Act and the U.S. Environmental Protection Agency (EPA). To that end, Ecology has established surface water quality standards to protect the beneficial water uses of the state such as swimming, fish and shellfish harvesting, aquatic life habitat, and domestic water supply (Chapter 173-201A WAC, Water Quality Standards). The water quality standards establish goals for lakes, rivers, and marine waters by assigning appropriate combinations of beneficial uses to each water body, and by setting criteria to ensure those uses are protected. These criteria are often quantitative limits on how much of a particular toxic chemical or other pollutant can exist in a water body without harming the various beneficial uses. Contaminants in fish and shellfish (either measured or extrapolated from EPA bioaccumulation factors) that pose a human risk via consumption can also result in a Section 303(d) listing.

Section 303(d) of the Federal Clean Water Act and EPA's implementing regulations (40 CFR Part 130) require that states prepare a list of water body segments that do not attain state water quality standards. For each impaired water body on the 303(d) list, Ecology is required to determine the maximum pollutant load the water body can accept and still meet the Water Quality Standards. This Total Maximum Daily Load (TMDL) is then used to develop a Water Cleanup Plan - a strategy to improve water quality in the water body and achieve state standards. The TMDL is a tool for implementing water quality standards and is based on the relationship between in-stream water quality conditions and pollution sources. The allowable pollutant loadings or other quantifiable parameters for a water body are established by TMDLs and thereby provide the basis for establishing water quality-based pollution controls (WDOE 1996, WDOE 2001a)

This work plan has been prepared under the Puget Sound Naval Shipyard Project ENVVEST Final Project Agreement (US Navy, EPA and Ecology 2000) as a cooperative project among the Navy, EPA, Ecology, and technical stakeholders to help improve the environmental quality of the Sinclair and Dyes Inlet Watershed (US Navy, EPA and Ecology 2002).

2. PROBLEM STATEMENT

Sinclair and Dyes Inlets and contributing tributaries are listed on the Section 303(d) list for high fecal coliform concentrations in the water column (Table 1). Sinclair and Dyes Inlets are classified as *Class A* excellent (WAC 173-201A-140) and their beneficial uses include; salmonid migration, rearing, spawning, and harvesting; fish and shellfish harvesting, excellent wildlife habitat, and primary human recreational contact (WAC 173-201A-030). The surface streams that drain into Sinclair and Dyes Inlet are also designated *Class A* excellent (WAC 173-201A-120). All waters designated *Class A* must meet the following standards for fecal coliform:

> Fecal coliform organisms:
>
> (A) Freshwater - fecal coliform organism levels shall both not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100 mL.
>
> (B) Marine water - fecal coliform organism levels shall both not exceed a geometric mean value of 14 colonies/100 mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 43 colonies/100 mL. (WAC 173-201A-030)

The purpose of this study plan is to address listings for fecal coliform in the water column within the Sinclair and Dyes Inlet system (Table 1).

3. STUDY AREA

The Sinclair and Dyes Inlet Watershed is located in Kitsap County Washington, Water Resource Inventory Area 15 (Figure 1). The boundaries of the watershed include the receiving waters of Sinclair and Dyes Inlets extending out from the Inlets into the passages that connect them with the main reaches of the Puget Sound and the surrounding landscape that drains into the Inlets. The watershed area that drains into Sinclair and Dyes Inlets consists of 62,348 acres (25,231 hectares) of which about 35% of the watershed is classified as having impervious surfaces. Most of the impervious surfaces are located in the urban centers of Bremerton, Silverdale, the Naval Station and Shipyard, and areas around Port Orchard. The stream network drains about 80% of the watershed, but about one third of the impervious surfaces (11% of the watershed) are located in areas not drained by streams (Figure 2). The impervious surfaces that are not drained by streams are urban areas predominantly located in West Bremerton, portions of East Bremerton, and along the shoreline of Dyes Inlet.

4. HYDRODYNAMICS

Flows in Sinclair Inlet are governed primarily by tides that propagate from the Pacific Ocean into Puget Sound and then into the Inlet through two narrow passages, Port Orchard in the north and Rich Passage in the southeast. Tides in the Puget Sound region are semi-diurnal and diurnal mixed modes with two high and two low tides every diurnal cycle (24.8 hours). Once reaching the entrances to the two passages and into the Inlet, the tides are further modulated in a nonlinear fashion by a number of forcing mechanisms, including freshwater inflows, wind, water depth variations and waterbody geometry. Tidal flows in the Inlet are modulated both spatially and temporally, with maximum tidal ranges (from low tide to high tide) reaching 5.5 meters during spring tides (Wang and Richter 1999).

Freshwater enters Sinclair and Dyes Inlet from major streams and many smaller creeks (Figure 1). The Bremerton, Port Orchard, and Brainbridge Island POTWs discharge treated sewage effluent into Sinclair Inlet. Storm drains distributed around the shores of the Inlet also discharge untreated storm water into the Inlet during rainy seasons.

5. PROJECT OBJECTIVES

The purpose of this project is to provide a comprehensive assessment of fecal coliform bacteria from all identifiable sources in the study area. This study will include quantification of sources of fecal coliform, levels of contamination, pollutant transport mechanisms, and die-off within the Sinclair/Dyes Inlet system. The major objectives of the study are to:

- Determine the contribution of all significant source of fecal coliform loading to the system by measuring or predicting flow and average concentration of fecal coliform from these sources.
- Determine the effects of storm events and other upset conditions on loading to the system.
- Model the distribution of fecal coliform within the Sinclair/Dyes Inlet system as it is affected by loads from point and non-point sources, tidal circulation and transport, and the natural process of die-off of bacteria.
- Predict the effect of pollution events on water quality at various locations in the Inlets.
- Compare the levels of fecal coliform contamination to the Ecology and DOH water quality standards for the protection of shellfish and other beneficial uses.

- Provide information required to determine the pollution reductions that are needed so that local communities, agencies, and other affected parties can develop and implement appropriate cleanup strategies. This will also provide information for establishing waste load allocations (WLAs) for point sources and load allocations (LAs) for non-point sources, for establishing a TMDL as required under section 303(d) of the federal Clean Water Act.

6. GENERAL METHODOLOGY

Loading terms for fecal coliform from the streams, storm water, point sources, and non-point sources and boundary conditions within the watershed will be determined using a combination of:

- Available historical data

- Ongoing studies being conducted by the Department of Health, Bremerton Kitsap Health District, Kitsap County, the Suquamish Tribe, the City of Bremerton, Puget Sound Naval Shipyard, the Washington Department of Ecology and other technical stakeholders within the study area.

- New sampling and analysis efforts conducted as part of this study. (New sampling efforts will be conduced to fill in data gaps not covered by historical or ongoing studies and to validate data sets as appropriate).

Modeling studies will be conducted to assess:

- The distribution of fecal coliform within the Sinclair/Dyes Inlet system as it is affected by loads from point and non-point sources, tidal circulation and transport, and the natural process of die-off of bacteria as well as to assess the assimilative capacity of the receiving waters.

7. SOURCE ASSESSEMENT

7.1 General Discussion:

Degradation of water quality due to contamination by pathogens represents a serious health risk and economic loss to many parts of Puget Sound. The pathogens associated with sanitary waste disposal that are of primary concern to humans are disease- causing bacteria and viruses. Some bacteria are free-living organisms able to survive on their own and grow in an aquatic habitat; viruses, on the other hand, can grow only inside of a suitable host. Of the many different viruses associated with human

wastes, most are responsible for causing gastrointestinal illness, but some cause significant illnesses such as hepatitis and polio. Pathogenic bacteria found in waste material are responsible for a variety of diseases.

Because public health agencies are not able to measure the entire host of human pathogens directly, they have relied on "indicator" organisms to assess the probability of the presence of pathogens. The indicator organisms presently used to evaluate the status of overlying waters are a group of bacteria called fecal coliform. This fecal coliform indicator test has been in use since the early 1980s. Formerly 'total coliforms' a superset of fecal coliform, had been used as the basis of regulatory action back to the 1920s.

Large numbers of fecal coliform bacteria are present in the fecal material of mammals and birds. Fecal coliforms themselves are not usually pathogenic, but are often found associated with other organisms that do cause disease in humans. When predetermined concentrations of fecal coliforms are reached, the area is considered unsafe for certain uses.

Human development and land-use activities in the near shore environment have the potential to significantly alter the aquatic ecosystems of estuaries and coastal marine areas. In addition, land-cover alterations and land-use activities in upland watersheds can also significantly influence natural conditions within estuaries and near shore areas where these upland watersheds drain. Among the cumulative impacts of human activities on the near shore are the following:

- Non-Point Source (NPS) Pollution
- Point-Source Industrial Discharges
- Wastewater Treatment Plant Outfalls
- Nutrient Eutrophication
- Physical Modification of Shoreline Habitat
- Over-harvest of Nearshore Biota

Beneficial uses of estuarine, near shore, and coastal marine water resources are diverse and generally very highly valued. These beneficial uses include passive recreation, swimming, boating, fishing, and shellfish harvesting (Scott et al., 1998). As human population and development within the near shore area and in adjacent watersheds has increased, there has generally been an increase in the number and extent of “beach closures” for fishing, contact recreation, and shellfish harvest. This trend is common to coastal areas such as the North Carolina coast (Maiolo, 1981), major estuaries such as the Chesapeake Bay (McConnell, 1995), and to Puget Sound (Washington DOH, 2001).

Pathogenic enteric bacteria enter the freshwater and near shore environment from human and animal waste products (Dadswell, 1993). Direct contact with contaminated water or consumption of contaminated shellfish or finfish can lead to human health problems. Public health organizations, state environmental agencies, and the US-EPA have developed several water quality criteria to protect human health. The most commonly utilized measure of fecal pathogenic bacteria is fecal coliform (FC) abundance (Dadswell, 1993). Typically, the geometric mean of all FC samples must be less than a specified level and no more than 10% of all FC samples must be below a higher level (43

FC/100 ml for shellfish consumption) based on the beneficial uses of the waters in question. In addition to the ecological impacts, fecal bacterial contamination of near shore areas has a direct economic impact to coastal and estuarine communities through the loss of shellfish revenues and the restrictions placed on recreational uses.

Recent studies indicate that levels of FC contamination in near shore areas is strongly correlated with human population, the level of watershed development, and the quantity of impervious surfaces within a drainage area (Weiskel et al., 1996; Young and Thackston, 1999; Mallin et al., 2000). These studies also show that FC is often highly correlated with water column turbidity and nutrient concentration as well as being inversely correlated with salinity (Mallin et al., 2000).

Sources of fecal bacterial contamination include humans, domestic animals, and wild animals. Fecal bacteria can enter near shore waters directly from waterfowl or marine mammal excretion. Although the annual loading of FC into coastal and estuarine waters from waterfowl and other wildlife can be significant, the effects are generally mitigated by the often seasonal nature of these inputs, their wide distribution across the marine surface area, and the apparent limited dispersal from their fecal pellets (Weiskel et al., 1996). The elution of fecal bacteria from shoreline deposits of decaying vegetation (so-called "wrack") also contributes to FC loading. In addition, release of FC bacteria during the re-suspension of nutrient-rich, sub-tidal sediments was found to be a minor source of FC contamination (Weiskel et al., 1996). Direct inputs from human sources include boat discharges, sewage conveyance spills, and sewage treatment plant outfalls.

In general, on-site sewage treatment (septic) systems are often the largest single FC source in a watershed-near shore area (Young and Thackston, 1999), but due to attenuation and filtering during subsurface transport very little fecal bacterial contamination reaches receiving waters from these widely dispersed sources. The exception to this is when septic systems have failed, are improperly designed or installed, or in areas where septic system density has overwhelmed the assimilative capacity of the native soils. Another human-related source of fecal bacterial contamination is agricultural runoff from livestock wastes. This can be a significant source in watersheds where farming or livestock production is a major land use. However, in most developed areas, the most significant source of FC input to the near shore environment is from stormwater runoff or NPS pollution. This surface runoff can flow directly into estuaries or near shore waters from developed shoreline areas via storm drain outfalls or as overland flow. In addition, fecal bacteria contamination and other NPS pollution can indirectly enter the near shore via streams that drain developed upland watersheds. Recent studies have shown that stormwater runoff from impervious surfaces (roads, parking lots, etc.) and from stormwater drainage networks (drain-inlets, stormwater piping, and outfalls) are the most significant sources of FC contamination in urbanizing watersheds and near shore drainages (Weiskel et al., 1996; Young and Thackston, 1999; Mallin et al., 2000). As a result, streams that drain urbanizing watersheds can be significant sources of fecal bacterial contamination to the near shore environment.

The transport pathway of FC contamination in developed watersheds is generally quite simple. When fecal material is deposited on or near an impervious surface, such as

a road or driveway, the fecal contamination and other NPS pollutants (litter, sediment, nutrients, metals, organics, etc.) are provided with a means of concentration and rapid conveyance to downstream water bodies. During "dry" periods, fecal material accumulates on impervious areas, with little decline in FC density for up to 30 days and possibly longer, depending on ambient conditions (Weiskel et al., 1996). When storm events occur, these pollutants are washed off the impervious surfaces and transported downstream with stormwater runoff. The conveyance network may be in the form of roadside ditches or vegetated swales in rural watersheds. In suburban and urban watersheds, the stormwater conveyance system is often much more "efficient", including curbs and gutters, drain-inlets or catch basins, and a storm-drain piping network that routes runoff directly to streams, rivers, and lakes, as well as into near shore marine waters. Therefore, it is not just the intensity or level of development that is important to downstream pollutant loading, but the type of land-use activity, the location of that development, the amount of impervious surface area, and the type of stormwater infrastructure present (White et al., 2000). In a study of a shallow embayment near Buzzards Bay MA, it was found that FC bacterial yields were 2-3 orders of magnitude greater from impervious areas served by stormwater drainage piping networks than from areas of rural or low-intensity residential land-use that were served by "unimproved" stormwater conveyance systems (Weiskel et al., 1996).

It has also been shown that fecal bacteria counts are generally higher in urbanized watersheds that are served by sanitary sewers than in non-sewered basins (Young and Thackston, 1999). In these situations, FC densities are typically related to human population level, the density of development, the percentage of total impervious area (%TIA), and the domestic animal population. As has been discussed, this fecal material deposited on and near impervious surfaces, such as roads and driveways, as well as residential lawns and park areas, is transported by stormwater runoff into natural streams and stormwater systems. From there, it is transported downstream to estuaries or near shore waters. If the conveyance route includes vegetated drainage swales, vegetated filter strips, or wetland areas, the level of bacterial contamination can be significantly reduced (Weiskel et al., 1996; Young and Thackston, 1999; Mallin et al., 2000). In addition, if the runoff can be infiltrated and allowed to flow through the shallow groundwater layer prior to reaching downstream receiving waters (much as septic systems are designed to do), the level of FC contamination can typically be reduced even further (Weiskel et al., 1996; Young and Thackston, 1999; Mallin et al., 2000).

7.2 Assessment of Existing Sources: Bacteriological Contamination in Sinclair-Dyes Inlet Watershed

Currently there are several agencies and jurisdictions collecting data on bacterial contamination in Sinclair and Dyes Inlets. The majority of this data is based on periodic fecal coliform (FC) sampling in the near shore, marine waters and freshwater streams draining to the Sinclair-Dyes watershed. Very little data is available from stormwater outfalls or runoff from developed areas within the watershed. The data from periodic sampling covers wet-weather (storm) events and dry weather periods, but this is mainly a

matter of what the weather was during a scheduled sampling event rather than a sampling scheme that specifically targeted a storm event. Nevertheless, there is a wealth of data available that provides a good foundation for developing an effective FC sampling plan to support the TMDL process.

The agencies or groups that have jurisdiction within the Sinclair-Dyes Inlet watershed include:

- Washington Department of Health (DOH)
- Washington Department of Ecology (DOE)
- Kitsap County Surface and Stormwater Management (SSWM)
- Bremerton-Kitsap County Health Department (BKCHD)
- City of Bremerton
- City of Port Orchard
- Puget Sound Naval Shipyard (PSNS)

The available data from DOH and BKCHD were obtained and analyzed to identify known sources of bacterial contamination, quantify those sources based on the most current existing data, and to identify "data-gaps" that will need to be addressed in the TMDL sampling plan.

7.3 Washington Department of Health Data

Washington DOH has numerous near shore marine sampling sites within southern and northern Dyes Inlet and Port Orchard Passage (Figure 3, Figure 4, and Figure 5, respectively). The main objective of DOH monitoring is to assess FC contamination of historic shellfish growing areas within the inlet. Currently DOH has no active sampling stations in Sinclair Inlet, but has sites in Port Orchard Passage. An analysis of DOH FC data (using the geometric mean of all available data) from 2000-2001 indicates that, in general, the levels of bacterial contamination are relatively low (Appendix A).

However, based on the Washington State Water Quality Criteria at least one site does not meet the standard for *Class A* (Part 1) waters (Geo-Mean <= 14 FC/100ml). This is the sampling site at the mouth of Clear Creek (DOH Site #466) near Silverdale. The lower reaches of this creek are highly developed and the upper watershed contains extensive suburban development. There are also several stormwater outfalls that drain into this portion of Dyes Inlet that may be contributing FC pollution. In addition, Strawberry creek empties into the inlet nearby. The watershed of this creek is also largely developed and may be contributing to the bacterial contamination of the near shore around Silverdale. The *Class A* (Part 2) water quality criteria also require that less than 10% of all FC samples from a given site are < 43 FC/100ml. Several sites do not meet this criterion, most of which are located at or close to stream mouths within Dyes Inlet. These sites include several in Chico Bay (near the mouth of Chico Creek) and in Silverdale Bay near the mouths of Clear, Strawberry, and Barker Creeks.

Based on the available DOH FC data, it can be concluded that the near shore areas at the mouth of streams draining developed watersheds and highly developed shoreline

areas, such as Silverdale are likely to violate bacterial water quality criteria, resulting in restrictions on shellfish harvesting and/or contact recreation. In addition, analysis of DOH data in relation to storm events indicates that high FC levels in near shore marine samples are more likely immediately following a major storm event. Only limited rainfall data was available to run this analysis and other factors, such as storm intensity and duration, tidal conditions, or sample site location, are likely to also influence FC levels, so no significant correlation was noted in the data. However, in a many of cases, higher FC levels were found when sampling was done within one day of a major storm event.

7.4 Bremerton Kitsap County Health District Data:

The BKCHD has the most extensive FC database for Sinclair and Dyes Inlet. Both marine and freshwater samples are taken on a regular basis (generally monthly). Data extends back to 1996 for most sample sites. The BKCHD publishes an annual summary report of water quality data. These reports contain a wealth of data on Dyes and Sinclair Inlets, as well as contributing stream watersheds. The BKCHD data also provides the foundation for watershed planning efforts and water quality improvement projects. There have been several projects initiated within the Sinclair-Dyes watershed to address FC contamination problems identified by BKCHD. These projects have improved conditions in several sub-basins and near shore areas and could well result in the removal of already "listed' water bodies (see 303d list).

Analysis of BKCHD marine, near shore FC data indicates much the same as the DOH data discussed previously (Appendix B). In general, there are only a few sites that do not meet state water quality (FC Parts 1 & 2) criteria in Sinclair (Figure 6) and Dyes (Figure 7) Inlets. For this analysis, only the 2000 & 2001 FC data was used. This was done to try and account for any water quality improvements made in the recent past and to keep the analysis as current as possible. In addition, rainfall data was also available with the BKCHD FC data. As with the DOH FC data, there was no significant correlation between rainfall and FC levels, but in general, samples taken within 48 hours of a major storm event resulted in relatively higher FC levels, especially for sites located at creek outlets.

The following sites did not meet state FC (Parts 2) water quality criteria:

- Mouth of Clear Creek near Silverdale (DY27)
- Near the mouth of Olney/Annapolis Creeks (SN13)
- At the mouth of Gorst creek near Gorst (SN05)
- Mouth of Blackjack Creek in Port Orchard (SN12)

Analysis of BKCHD freshwater, stream FC samples indicates that these are major sources of bacterial contamination into the near shore environment of Sinclair (Figure 8) and Dyes (Figure 9) Inlets. The state FC water quality for *Class A* freshwater sites requires that the geometric mean of all samples be <= 50 FC/100ml (Part 1) and that <10% of all samples be less than 200 FC/100 ml (Part 2). The following freshwater

sample sites do not meet Part 1 of the criteria (seeFigure 8 and Figure 9):

- Barker Creek @ mouth (BK01)
- Barker Creek @ Nels Nelson Rd (BK02)
- Barker Creek @ Bucklin Hill Rd (BK03)
- Clear Creek @ Ridgetop Blvd (CC01)
- Clear Creek East Fork Ridgetop Tributary(RT01)
- Ostrich Bay Creek @ mouth (OB01)
- Annapolis Creek @ mouth (AP01)
- Olney/Karcher Creek @ mouth (KA01)
- Sacco Creek @ mouth (SC01)

Based on the most current BKCHD FC data, it can be concluded that streams draining developed watersheds are likely to violate bacterial water quality criteria and are significant sources of FC loading to near shore marine waters (Figure 10). In addition, analysis of BKCHD data in relation to storm events indicates that higher FC levels in stream samples are more likely following a major storm event that produces stormwater runoff. In addition, more developed watersheds have generally higher "wet-weather" FC concentrations.

7.5 Storm Sewer Outfall Sampling:

There is almost no FC data from stormwater outfalls in the Sinclair and Dyes Inlet watershed. The Kitsap County SSWM completed an outfall inventory in 2001 and sampled a majority of the outfalls for FC and various other water quality parameters. These samples were "grab" samples taken during dry and wet weather conditions (Figure 11). Several SSWM stormwater outfalls had very high FC levels, some exceeding 1000 FC/100 ml (Appendix C). These levels are typical of stormwater runoff from developed areas (see Section 7.1).

The City of Bremerton is currently sampling Combined Sewer Overflows (CSOs) that discharge into Dyes and Sinclair Inlets (Figure 12) as part of its (CSO) program to reduce and eliminate CSO discharges (City of Bremerton 2000), but they do not monitor specifically for stormwater (Chance Berthiaume, City of Bremerton, Personal Communication). Storm water from industrial areas, roof tops, and fleet support areas is also discharged by the Puget Sound Naval Shipyard and Naval Station Bremerton (Figure 13). The City of Port Orchard has no stormwater monitoring program and no FC data.

During the recent Dye Release Study in the Port Washington Narrows, six storm water outfalls, tributary streams, and marine stations in Sinclair and Dyes Inlets were monitored for FC from March 10-14, 2002 (Figure 14, Appendix D). This sampling period included a wet-weather period followed by dryer weather with little runoff. The preliminary results indicate that storm water outfalls were more significant sources of FC loading than streams by an order of magnitude in most cases. These levels decreased significantly as rainfall decreased and runoff tapered off (Figure 15). Note that the samples collected from SW2 (Pacific Ave Outfall) on March 13 and 14 were influenced

by chlorinated potable water draining into the storm water outfall from an emergency main break (Chance Berthiaume, City of Bremerton, personal communication). Based on the limited storm water outfall data available, it can be concluded that storm water outfalls are significant FC loading sources, especially during wet-weather conditions.

7.6 Hydrologic and Meteorological Monitoring

A network of stream monitoring and precipitation stations has been established which includes existing stations maintained by the KPUD, SSWM, City of Bremerton, and others to support the PSNS Project ENVVEST (Navy, EPA, Ecology 2002). Currently, the Kitsap Public Utilities District is monitoring precipitation gages in the watershed and stream gages on the major streams and tributaries draining into Sinclair and Dyes Inlets (Table 2, Appendix E. Hydrological Stations). Stream gauge monitoring will be conducted according to the Kitsap Public Utilities District protocols (KPUD 2000). The protocol includes stream gauge maintenance and calibration, data processing procedures, quality control requirements, data reporting specifications, and other actions that are necessary to assure high quality data are obtained.

New stream gauging stations were installed (Dec 2000) and monitoring was initiated (Feb 2001) for Barker Creek (BC), Clear Creek East (CE), Clear Creek West (CW), Steel Creek (ST), Gorst Creek (GC), and Blackjack Creek (BC). A gauging station on Strawberry Creek (SC) was added in Oct 2001. Following the unusually high stream flows that occurred during the storm of January 8-9, 2002, the gages on Gorst and the Chico tributary on Taylor Rd were washed out. These have been refurbished and were re-established in March 2002 (J. LeCuyer, KPUD, personal communication). In addition, stream gage stations were established on Parish and Heinz Creeks just above where they join with Gorst Creek (M. Morgan, KPUD, personal communication). These stations will allow more accurate determination of how much water is coming from pristine areas of the Gorst watershed (Gold and Green Mountain) and from developed areas along Parish Creek (Sunnyslope). The gage at Steel Creek was disestablished in June 2002, because scheduled roadwork in the area would have made the station unusable.

7.7 Source Assessment Gap Analysis

Analysis of current sampling efforts within the study area indicates the need for additional sampling in order to fill in spatial and event driven data gaps. Major gaps in order, according to their potential to contribute fecal material include:

- Storm event fecal data and flow from urban storm water systems including: Bremerton, Port Orchard, Silverdale, Gorst, and Puget Sound Naval Shipyard.
- Storm event fecal data from major streams.
- Flow rates for storm water discharge from Bremerton, Kitsap County, Port Orchard, and PSNS outfalls.
- Ambient FC marine data from areas near PSNS, Port Orchard, and local marinas.
- FC data in marine sediments.

8. DATA QUALITY OBJECTIVES

The data quality objectives for this study are to produce data that can be used to estimate the temporal and spatial variability of fecal coliforms, ancillary data (temperature, specific conductance, pH, and turbidity), and flow in streams, storm water outfalls, and marine waters of the study area. The objective is to sample base and storm condition during a period of relatively high discharge conditions (the onset of fall and winter rainfall), which typically occurs between October and December of the year (KPUD 2000). Representative samples of streams, storm water outfalls, and ambient marine and nearshore conditions will be sampled during storm and nonstorm conditions. Storm events are defined as at least 0.2 in of precipitation in a 24 hr period following an antecedent dry period of 24 hours (< 0.02 in of precipitation in the previous 24 hours) (City of Tacoma 2001).

Because a high degree of variability is expected for the measurement parameters a relatively large number of samples will be required. Quality Assurance (QA) activities will be conducted to ensure that the collected data are of sufficient quality to support the goals of the project. Table 3 provides the field and laboratory measurements and the precision and detection limits established for the study. The following indicators of data quality will be used to assess the quality and integrity of the analytical and operational data: accuracy, completeness, representativeness, precision, and comparability.

Accuracy (Bias). Accuracy is the agreement between an analytical result and the true value. The difference between a measured value and the true or expected value represents an estimate of systematic error or net bias of the method (Johnston and Valenti 2001, Lombard an Kirchmer 2001). All phases of sample collection, transportation, storage, and analysis will be performed in accordance with accepted protocols and procedures to minimize bias in the sample results. Accuracy for this project will be checked with field blanks, field replicates, and laboratory duplicates (split samples).

Completeness. Completeness refers to the total amount of valid data collected, expressed as a percentage of the amount of data collection planned. The completeness goal for this project is 95%. Sample data loss due to poor handling or mislabeling will be minimized to the extent possible.

Representativeness. Representativeness is the degree to which the data accurately and precisely represent the population being measured and is a function of sampling strategy. The representativeness objectives for this project are to ensure that all samples represent the media from which they are collected such that the water quality and biological diversity in the study area may be assessed. This objective will be accomplished by carefully choosing sites throughout the watershed to yield balanced samples from both natural and anthropogenically influenced sites.

Precision. Precision is the variability of replicate measurements due to random

error and can be estimated by calculating the relative standard deviation (RSD) of replicate measures or the relative percent difference of duplicate measurements (RPD) (Johnston and Valenti 2001, Lombard an Kirchmer 2001). Precision will be estimated by calculating the RPD of laboratory/field duplicates and the RSD of field replicates.

Comparability. Comparability of the project data with data from similar watershed studies will be ensured by adhering to standard methods, where available, and by presenting results in appropriate standard units, according to industry conventions.

8.1 Sample Control

Sample control will be maintained by accurately labeling samples and by tracking sample location and handling with chain-of-custody forms. Procedures for each are detailed below.

8.1.1 Sample Labels

Each sample will be assigned a unique identification number. All samples will be clearly labeled using waterproof and solvent-proof black or blue ink on a pre-printed adhesive label. Incorrect information will be marked and corrected. Corrections will be initialed, dated, and incorrect information marked out with a single line. An example of a sample label is presented below:

ENVVEST FC TMDL STUDY

Collection Organization _____

Sample Identification Number _____

Media _____

Station _____

Date _____

Time _____

Storm Beginning / Middle / End / None_____

Tide Low Slack / Rising / High Slack / Falling

Sampler(s) _____

_____

8.2 Chain of Custody

To ensure sample integrity, all samples will be collected, handled, preserved, and transported for laboratory analysis in accordance with standard procedures published by Ecology or the U.S. EPA. Chain-of custody-records will be used to document the movement of samples. Sample custody will be initiated at the time of sample collection by placing the labeled sample into an iced cooler in the possession of the sampler. A line item on the Chain-of-Custody Record will be immediately filled out and initialed by the sampler. Upon completion of all line items, or upon sample pickup, the sampler will sign, date, and enter the time on the Chain-of-Custody Record, and will confirm the completeness of all descriptive information on the form. Each individual who subsequently assumes responsibility for the samples will sign the Chain-of-Custody Record. Chain-of -Custody Records will be used to document each sample's history, including sampling location, date of collection, laboratory receipt, and final disposition. Complete Chain-of-Custody Records will be maintained within project documentation.

9. SAMPLING DESIGN

9.1 Technical Approach

On average, the onset of fall/winter storm events occurs between October and December. The highest precipitation and higher stream flows are generally recorded during that period (Table 4, Figure 16, KPUD 2000). Therefore the bulk of fecal coliform sampling will occur during that period. As discussed in Section 7.1, the vast majority of fecal loading to surface waters from all sources is contributed as a result of storm events. Additionally the major data gaps identified in Section 7.7 are also associated with storm water sampling. In the interest of collecting the most relevant data in the most efficient manner possible, sampling activities will be concentrated over a six-week period extending from approximately Nov. 5, 2002 through Dec. 24, 2002. This sampling period covers the historical onset of winter precipitation, the rise of the water table, increased stream flows, and has a high likelihood of capturing multiple storm events (J. LeCuyer, KPUD, personal communication). Sampling sites, frequencies, parameters and participating agencies are listed in (Table 5, Figure 17, Figure 18, and Figure 19). Details on the proposed sampling stations and a preliminary cost estimate are provided in Appendix F. Sampling Plan and Cost Estimate. The sampling team working group will finalize the list of stations and sampling schedule prior to sample collection.

Two types of grab samples will be collected – periodic samples and event samples. Periodic samples will be collected on all stream and storm water outfalls that have continuous flow – i.e. there is always enough water flowing in the stream or outfall to collect a viable sample. Because of the logistics involved in collecting the marine and nearshore samples, they will also be collected periodically (weather permitting). Periodic grab samples will be taken three times a week (Monday, Wednesday, and Thursday) at the stream and storm water stations and once a week at the marine and nearshore stations. To the extent practical, sampling will be timed to occur at low tide (i.e. low slack during daylight hours) for the marine, nearshore, and storm water stations that may be tidally influenced. Measurement of conductivity (salinity) will help determine the contribution of tidal waters to the sample (e.g. high salinity in a sample collected from a storm water outfall will indicate that the samples is essentially a “nearshore” sample rather than a “storm water” sample. The stage of the tide (high slack, falling, low slack, or rising) will be recorded on the sample log for any station that is tidally influenced.

Event samples will be collected at the storm water outfalls that will lack sufficient flow to sample unless it is raining. An event sampling interval will consist of a grab sample collected at the beginning, middle, and end of an “event,” where an event is defined as > 0.2 in of rain in a 24 hr period, preceded by a 24 hr dry period. The stage of the storm (beginning, middle, or end) will be recorded on the sample log for all event samples. If no storm occurs, the sample bottles for that week will be held until the next event occurs. Sampling will continue until six events are sampled. In addition, event

Sampling Plan Addendum (10/18/2002)

The objective of the sampling is to obtain data from streams and storm water outfalls during storm conditions. Event grab samples will be collected at the storm water outfalls that will lack sufficient flow to sample unless it is raining. The event sampling will occur on the same schedule as the continuous samples. If it is raining and there is flow, event samples will be taken. If it is not raining and no flow is present in some of the outfalls, then only the periodic samples in the streams and outfalls with continuous flow will be collected. Sampling will not be initiated until the onset of rainy weather. In the case of extended dry periods (>1 week), all sampling will be suspended until it begins to rain again. Rainfall data collected during the study will be used to assign whether the samples were collected at the beginning, middle, or end of an "event," where an event is defined as > 0.2 in of rain in a 24 hr period, preceded by a 24 hr dry period. Sampling will continue until about six weeks of data are collected. In addition, event samples will be collected in conjunction with the stream storm event sampling being conducted by The Environmental Company for the ENVVEST Watershed Monitoring Program. In that program, flow-proportional samples at 11 streams will be collected for three storms (TEC 2002). Grab samples for fecal coliform analysis will be collected at the beginning, middle, and end of the storm events sampled.

Station Locations, Sampling Teams, Chain of Custody Forms, and Field Sampling Procedures

Appendices F, G, and H

samples will be collected in conjunction with the stream storm event sampling being conducted by The Environmental Company for the ENVVEST Watershed Monitoring Program. In that program, flow-proportional samples at 11 streams will be collected for three storms (TEC 2002). Grab samples for fecal coliform analysis will be collected at the beginning, middle, and end of the storm events sampled.

Quality assurance samples will be collected from each sampling station during the course of the sampling. The quality assurance samples will be very important in reducing sampling error and bias and assuring the comparability among samples collected by the different stakeholder groups participating in the study. Each jurisdiction participating in the sample collection will prepare a sampling team-specific field sampling check list, procedures, and protocol that will be followed during sampling (e.g. similar to Ecology's stream sampling protocols Ward, W. (ed) 2001. Stream Sampling Protocols for the Environmental Monitoring and Trends Section. October 2001, Washington State Department of Ecology. Publication No. 01-03-036. http://www.ecy.wa.gov/biblio/0103036.html). See Appendix H. Project Specific SOPs.

For the *in situ* measurements, manufacturer recommended calibration procedures will be followed prior to field sampling and decontamination procedures will be followed between sampling stations. For the fecal coliform samples one field duplicate for every nine samples (10%) will be collected during the course of the sampling. The field duplicates will be labeled and processed by the laboratory in the same manner as the other field samples. Electronic spreadsheets will be used to document chain of custody information. Each jurisdiction will be responsible for accurately filling out the chain of custody information, transcribing the information onto the electronic spreadsheets, and posting the COC information on the project web site (see envvest_coc.xls for an example COC form).

Laboratory QA/QC procedures will also be followed according to the laboratory specific SOPs in effect for the project (Appendix H. Project Specific SOPs). For each batch of 20 samples, the laboratory will include at least one method blank and one laboratory duplicate to be analyzed along with the field samples.

Sampling in urban areas will be conducted by representatives from the City of Bremerton, Kitsap County Surface and Storm Water Management, Puget Sound Naval Shipyard, Bremeton-Kitsap County Health District(?), and the City of Port Orchard(?). Sampling in streams will be conducted by representatives of the Bremerton-Kitsap County Health District, Kitsap Public Utilities District No 1, Washington State Department of Ecology, and contractors designated by Puget Sound Naval Shipyard. Ambient marine sampling will be conducted by representatives of the Washington State Department of Health, The Suquamish Tribe and Puget Sound Naval Shipyard.

In addition to the sampling to be conducted in accordance with this plan, water quality trend monitoring being conducted by the Bremerton-Kitsap County Health District (BKHD) and the Washington State Department of Health (WDOH) will also be used to support development of the TDML. Currently, BKCHD is conducting monthly sampling at stream and nearshore locations in Sinclair and Dyes Inlets (Figure 6 to Figure

9) as part of a cooperative program with Kitsap County SSWM to evaluate water quality trends in streams and marine waters http://www.wa.gov/kitsaphealth/EH/WQ/wq.htm (Appendix H. Bremerton Kitsap County Health District). Also, WDOH, in cooperation with the Suquamish Tribe, is conducting bimonthly fecal coliform monitoring at station in Dyes Inlet, Port Orchard Passage, and Rich Passage (Figure 3 to Figure 5) as part of the States' shellfish monitoring program. The shellfish program monitors and classifies shellfish growing areas (http://www.doh.wa.gov/ehp/sf/default.htm) (WDOH 2001) and "…provides timely information to recreational harvesters regarding where and when it is safe to harvest shellfish" (http://ww4.doh.wa.gov/scripts/esrimap.dll?name=bioview&Cmd=Map&Step=1, Appendix H. Washington State Department of Health). These data sets will be very useful for evaluating long-term trends and assessing beneficial uses of shellfish harvesting areas within the study area.

As discussed in Section 7.7 marine sediments and beach wracks are a potential source of fecal coliform. However, due to limited resources and the predicted relatively low contribution to total fecal loading, no sediment samples will be collected for fecal analysis. Uncertainty introduced by this omission will be discussed in the TMDL Technical Report.

9.2 Water Quality Field Measurements

In Situ Measurements

Some water quality parameters will be measured in the field at the time of surface-water grab-sample collection. Each parameter will be measured and recorded for each sample collected. The following measurements will be obtained using the portable sensors and recorded on the Field Data Form:

- Temperature.
- pH.
- Specific Conductance/Salinity
- Turbidity

The manufacturer's operating and calibration procedures for the portable sensors will be followed to ensure data quality. Calibration will occur per the manufacturer's instructions and a pre-sampling checklist will be developed to assure the sampling unit is in proper working order before making field measurements (Ward 2001). The repeatability and range of the field measurements are listed in Table 3.

Water Grab Samples

Surface water grab samples will be obtained for fecal coliform analysis according to the detailed field sampling plan (Appendix F. Sampling Plan and Cost Estimate). Samples will be collected in accordance with accepted sampling protocols (Ward 2001, Caltrans 2000, Lombard and Kirchmer, 2001). Chain-of-custody records will be obtained from the analytical laboratory and completed by the field team for each sample collected. A subset of grab samples from selected stations will also be collected for analysis of total suspended solids (TTS) and grain size. These data will be very useful for developing a relationship between TTS and turbidity and modeling particulate transport within the watershed.

9.3 Flow Measurement for Storm Water Outfalls

A flow measurement-sampling plan will be developed in concert with the participating stakeholders for the storm water monitoring stations (Table 5(A)). For accurate TMDL calculations it is imperative that reliable flow estimates are obtained for the storm water outfalls. To accomplish this objective, flow monitoring equipment and data loggers must be obtained and installed in selected outfalls. Once installed the flow monitors will be maintained by each jurisdiction to assure that the instruments are functioning properly, that batteries are fully charged, and that the data are periodically downloaded. Example equipment needed, the outfalls to be monitored, and an estimate of cost for procurement and installation is included in Appendix G. Flow Measurement Sampling Plan and Cost Estimate. If practical, flow-monitoring equipment will be moved from one outfall to another to capture representative storms. If necessary, manual flow monitoring methods (Caltrans 2000) will be used to estimate flow for the outfalls for which flow-monitoring equipment is not available. The long term goal will be to develop data on the relationships between rainfall and flow that will be used to support model development as well as future TMDL studies (Ecology 2002). Eventually enough data from gauged streams and outfalls will be obtained so that estimates of flow from ungauged streams and outfalls can be developed (the storm drains and streams not being monitored).

9.4 Station Location

Basic manufacturer recommend procedures will be followed for recording sampling station position information with portable GPS units. Where possible, station markers will be installed to facilitate repeat sampling of the same location.

9.5 Field Personnel Training Requirements

All field technicians who work on this project will receive appropriate training to

ensure competent performance. Field technicians who collect field data or environmental samples will have a background in environmental science. Field methods will be followed at all times to maintain consistency in sampling for all sites. Examples of procedures for which field technicians will be trained are:

- Installation, calibration, operation, and maintenance of field equipment.
- Collection and field preparation of samples.
- Documentation of field data.

9.6 Sample Handling and Preservation

The Washington State Department of Ecology Manchester Laboratory will analyze the surface water grab samples. The laboratory's QA/QC Plan will be available for review (WDOE 2002) to ensure that proper techniques will be used. Additional QA/QC checks will be completed upon receipt of laboratory data to ensure that laboratory protocols were followed. After collection, sample bottles will be placed on ice and transported to the laboratory so that the laboratory can begin processing the sample within 24 hrs. Samples with holding times longer than 24 hr will be flagged and noted on the case narrative.

All field technicians will be appropriately trained in applicable procedures. Subcontractors will be required to comply with all regulatory requirements pertaining to training.

10. LABORATORY MEASUREMENTS

The Washington State Department of Ecology Manchester Laboratory will perform the fecal coliform analysis using a Membrane Filter Technique. In addition, a sub set of samples will be analyzed for total suspended solids and grain size for modeling purposes.

The analytical laboratory is responsible for calibration and maintenance of analytical laboratory equipment and instruments and the maintenance of laboratory personnel qualifications. The laboratory supervisor is responsible for timely completion of calibration and maintenance. Records of these activities will be made available upon request.

The laboratory's standard data quality acceptance criteria will be used. Acceptance criteria will focus on ensuring an appropriate level of data quality to meet the project objectives. Method blanks and laboratory duplicate samples will be analyzed to evaluate and monitor analytical results. Throughout this study, acceptance criteria will be periodically reviewed for appropriateness and adequacy in meeting the study goals and objectives. Acceptance criteria will be modified if conditions warrant. The laboratory SOPs to be used for this study are provided in Appendix H. Project Specific SOPs.

11. MODELING

Mathematical computer models are critical tools that can be used to develop TMDLs. Models enable scientists to trace pollutants from their source to their environmental fate (dispersion, decay, sedimentation). Once this linkage is established and verified with monitoring data, models can be used to simulate more critical environmental conditions. For example, to predict what water quality might look like in the future when wastewater treatment plants have reached their design capacity, or forested lands have been converted to farms and urban areas. Equally important, models can be used to explore various waste load reduction strategies in order to determine if pollution controls proposed under a TMDL will bring the water back into compliance with state water quality standards.

11.1 Model Selection.

Watershed Runoff

The model selected for this portion of the project is the Hydrological Simulation Program Fortran (HSPF). Although HSPF is a lumped parameter model, it is the only public-domain model currently available that can simulate both hydrological and water quality parameters at the watershed scale. The HSPF model has been widely used, it has a large user group, and it is a commonly accepted regulatory tool (http://www.epa.gov/OST/BASINS/basinsv2.htm). Run off from streams and urban areas will be simulated using a unified HSPF model that has been developed to incorporate stream flow and storm water flow from the watershed into the receiving waters of the Inlets (Skahill 2002, Skahill in prep).

Receiving Water Hydrodynamics:

Originally developed by the Army Corps of Engineers for the Chesapeake Bay estuarine system, CH3D calculates time-varying 3-dimensional numerical flow fields for water surface, velocity, salinity, and temperature to simulate vertical and horizontal mixing (Johnson et al. 1991, Brown 2001). CH3D uses curvilinear boundary-fitted numerical grids in the horizontal plane. The grids in the vertical direction (z-grid) divides the water column into many layers of equal thickness, with number of layers varying from several layers for deeper regions to one layer for extremely shallow regions (< 3m). CH3D is capable of handling a variety of external forcing, including tides, winds, tributary flows, point and non-point sources, as well as baroclinic effects due to density differences between freshwater inflows and saline Inlet water (Wang and Richter 1999).

11.2 Status Of Modeling

As part of PSNS Project ENVVEST a CH3D model has been calibrated and verified for Sinclair and Dyes Inlets, individual HSPF models have been developed and calibrated to simulate stream flow (hydrology) for the major streams (Barker, Clear, Strawberry, Chico, Gorst, Anderson, and Blackjack Creeks, Figure 1) within the watershed (Johnson et al. 2001), and a WASP box model has been setup to run long-term simulations (years to decades) of the estuary (Choi et al. 2002). Presently, the grid for CH3D had been refined, a Lagrangian particle tracking model within CH3D has been used to calibrate the model with data from the drogue study (see below), and a module to simulate fecal coliform growth and die off in the marine environment based on the Mancini Equation has been added to the model code — CH3D-FC (P.F. Wang, SSC, personal communication). The CH3D grid has been refined to provide higher resolution of the hydrodynamics in Dyes Inlet and has been verified with measured current data (Richter 2002a). A PC-based user-friendly graphics software to animate CH3D modeling results is also under development (click here to launch CH3D-FC demo animation). Addenda and updates for the CH3D manual will be developed to document additions and revisions to the software code (Brown 2001).

The set up and calibration of the Water Analysis Simulation Program (WASP) for conducting contaminant transport modeling in Sinclair and Dyes has been completed. Both Sinclair Inlet and Dyes Inlet were divided into "boxes", which are assigned the same characteristics and properties. Each box contains multiple surface water and sediment segments. The boundaries of the boxes were designed to coalesce with sub-gridlines for CH3D so that future modifications can be made conveniently. The WASP modeling structure was designed to conduct simulations over long periods (years-decades) for use in calculating Total Maximum Daily Loadings (TMDLs) for the Inlets and provide the linkage to couple the WASP with CH3D. The WASP model will be calibrated to address the modeling questions defined in the TMDL study plan and ecorisk risk exposure assessment modeling questions.

The CH3D (Curvilinear Hydrodynamics in 3 Dimensions) and WASP (Water Quality Analysis Simulation Program) model have been developed to simulate the effects of the loads, generated by the surrounding areas, on Sinclair and Dyes Inlets. A number of HSPF (Hydrological Simulation Program – Fortran) models are being used to simulate the hydrology and water quality of individual streams (Johnson et al. 2002). If necessary, these models could be used to model specific in-stream processes. Currently, a unified HSPF model is being developed for the complete study area that will include flow and fecal loading from higher order streams as well as run off associated with urban and non-stream areas (Skahill et al. in prep). The unified model can be used to specify inputs into the receiving water system.

Sinclair and Dyes Inlets also receive urban runoff from the City of Bremerton and urbanized areas of Kitsap County and Port Orchard. Since the effects of urbanization is often the single biggest contributor to impaired water quality, altered habitats, and reduced bio-diversity these effects must be taken into account in order to make good use

of the integrated modeling effort. Currently, the unified HSPF model is being implemented to incorporate storm water and runoff flows from urban areas that do not drain into the stream system. When fully developed, this effort will result in a comprehensive, dynamic, hydrograph-based computer model of stream and storm water flow from urban and nonurban areas of the watershed (Skahill, in prep).

Modeling Fecal Coliform Transport in Sinclair and Dyes Inlets

In June 2000 a Modeling Sub-Working Group of Stakeholders was established to address the issue of fecal coliform contamination of shellfish beds in Dyes Inlet from combined sewer overflows (CSOs) in the Port Washington Narrows. Participants in the working group included the Suquamish Tribe, Washington State Department of Health, City of Bremerton, Kitsap County, CTC, PSNS, and SSC. The working group determined that shellfish beds in upper Dyes Inlet remain closed in part due to uncertainty about CSO overflows in the Port Washington Narrows. A modeling study was proposed to model "typical" CSO overflow events on incoming tide. Key issues were the lack of knowledge on current and transport patterns in upper Dyes Inlet, the need for data on CSO events and discharge parameters, and other data needed to support the modeling approach. The Navy and Stakeholder Team planned and cooperatively executed a drogue and current meter study for Dyes Inlet in the fall of 2000 The CSO sub-working group also identified the need to conduct a dye-release study to confirm and validate the model. In partnership with the City of Bremerton, Washington State Department of Health, Suquamish Tribe, Kitsap County SSWM, and the Bremerton-Kitsap Health District a dye-release study was conducted on March 12, 2002.

Drogue and Current Meter Study

During the CSO working group meetings the lack of knowledge on current and transport patterns in Upper Dyes Inlet were identified as key issues that would have to be addressed before any decision could be made to open shellfish beds in Dyes Inlet. Therefore, the participants cooperatively executed a drogue and current meter study to provided data to address key issues for the CSO modeling study. A drogue study was a very effective means of determining discharge trajectories and dispersion dynamics of simulated CSO event(s). Moreover, improvements and refinements to the model obtained from such data will result in an improved modeling capability for Sinclair Inlet as well.

The drogue and current meter study was completed in fall 2000. (https://swdata.spawar.navy.mil/envvest/Reports/CSO%20Modeling%20Subworking%20Group_March_1_2001.htm).Data from current meter and drogues were used to calibrate the CH3D model for Dyes Inlet (click here to launch CH3D-FC demo animation).

Model confirmation with Dye Release Study

The CSO sub-working group also identified the need to conduct a dye-release study to confirm and validate the model. In partnership with the City of Bremerton, Washington State Department of Health, Suquamish Tribe, Kitsap County SSWM, and the Bremerton-Kitsap Health District a dye-release study was conducted on March 12,

2002 to address this need (Dye Release Study in Port Washington Narrows, Draft Sampling Plan). The objectives of the dye study were to:

(1) Simulate a CSO discharge event in the Port Washington Narrows on the incoming tide.

(2) Provide physical and chemical data sets for validating model performance.

(3) Develop data on ambient concentrations of fecal coliform and selected contaminants in the estuary.

The dye release study was conducted on March 12, 2002. The dye was injected into the East Side Treatment Facility Outfall by metering a specified flow of concentrated dye into the outfall and flushing it through the pipe with water from a hydrant. The injection began just after low slack (+15 min) and continued until just before high tide (15 min before high slack). At the start of the injection Vessel A (Suquamish Shellfish Patrol Boat), stationed over the discharge point, released a self-tracking drogue to mark the "head" of the plume. Vessel A, outfitted with SSC's mini-MESC system, was equipped with real time sensors to continuously monitor temperature, salinity, dissolved oxygen, pH, turbidity, dye concentration, sensor probe depth, and GPS position at one second intervals. Vessel A remained on station until the dye was detected and then proceed to track the dye plume up the Port Washington Narrows. Vessel B (Suquamish Pakman Boat), stationed at Rocky Point, conducted transects across the mouth of Dyes Inlet to continuously to monitor the movement of the plume out of the narrows into Dyes Inlet. Vessel B was equipped with a flow-through bench-top fluorometer programmed to continuously monitor surface (about 8 inches depth) dye concentration every second and a hydrolab which recorded surface temperature, salinity, dissolved oxygen, and pH every 10 seconds. Vessel C (DOH Shellfish Boat) released drogues at the injection point every forty minutes during the injection, monitored drogue trajectories, and collected discrete dye samples for post survey analysis.

In addition to monitoring the dye release in the Port Washington Narrows, discrete samples were be collected at 8 stations within the estuary to characterize ambient conditions for fecal coliforms, conventional parameters, metals, and toxic organics. Replicate samples were taken (at or near low tide) at each station during the shakedown cruises (T-48 h, T-24 h), during (T0) and after the dye study (T+24). Temperature, conductivity, sechi disk depth, etc. were measured on site, and bottle samples will be collected for laboratory analysis. Bacterial samples were analyzed by WDOH; metals, toxic organics, and other parameters were measured by BMSL.

Based on the preliminary model runs, it was apparent that a flood tide of 3-5 ft was sufficient for model confirmation and validation. Because the model simulates the whole Sinclair-Port Washington Narrows-Dyes Inlet system, the plume movement both up the Port Washington Narrows to Dyes Inlet and down the Narrows to Sinclair Inlet is equally valid for obtaining scientifically defensible data for model confirmation and validation (Wang 2002, Richter 2002b).

11.3 Modeling gap Analysis:

A capability to model urban storm water is needed to accurately simulate fecal coliform loading into the receiving water. This gap will be addressed by developing the unified HSPF model with line segments specifically developed to incorporate storm water catch basins and discharge points into the estuary (Aqua Terra 2001). The land use and land cover GIS layers for the study area will be incorporated into sub-watershed boundaries associated with the storm water catch basins. Partnering with the City of Bremerton, Kitsap County Surface and Storm Water Management and other stakeholders will be crucial for modeling storm water runoff. The data for setting up the model must be identified, the storm water conveyance systems must be mapped and incorporated into the model, and data on flow rates and volume must be obtained. Drawings and "as built" diagrams will need to be verified, existing data on storm water flow and contaminant levels will need to be processed, and data to fill in missing data gaps must also be obtained.

The unified HSPF model will used to simulate storm events and base flow conditions for the streams and storm water outfalls. Data from the gauged streams and storm water outfalls will be use to estimate flows and loading from ungauged streams and outfalls (Skahill 2002, Skahill et al. in prep).

11.4 Modeling Plan

The ongoing modeling efforts within the study area will be used to the greatest extent possible for the fecal coliform study. Individual models will be used to address system-wide issues relating to total maximum daily load (TMDL) development.

The current bacterial load entering the water bodies will be based, in part, on modeled stream and storm water flows multiplied by the measured concentration of fecal coliform bacteria (primarily *E. coli*) in those flows. The flows, modeled by HSPF for streams and storm water, will be calibrated by flow measurements for the largest expected bacterial loads. Flows from relatively small urban catch basins will be modeled only. Similarly, bacterial concentrations will be measured in the flows introducing the largest loads, but will be estimated for the many smaller storm drain discharges. Estimates will be based bacterial loads versus land use in the larger catch basins that are measured.

The hydrodynamic model coupled with a fecal coliform module CH3D-FC will be used to predict the passive dispersal of bacteria loads by advective diffusion, tidal and wind-driven currents. Buoyancy and momentum effects of fresh water flows entering the marine inlets will be modeled using CoreMix. The hydrodynamic portion of CH3D has been calibrated (model parameter values selected) and validated (model predictions compared to data) with large independent data sets of water currents collected from 1997 to the present (Richter 2002a, Richter et al. in prep). In addition, results from the recent CSO dye release and drogue studies will be used to further validate CH3D-FC (Wang

2002, Richter 2002b). The dye, introduced in fresh water into the Port Washington Narrows, is particularly relevant to bacterial dispersal predictions. The loss of viable bacteria due to inlet water temperatures, salinity and light will be based on Mancini's algorithm (Mancini, J.L. 1978). Temperature and salinity will be both modeled and measured. Diurnal surface light levels will be modeled; light attenuation with depth will be measured with a Secchi disk to derive the extinction coefficient. Subsequent predictions of bacterial concentrations in the water column will be validated with field samples. Differences between predicted and measured concentrations will be used to refine the sampling plan used to measure bacterial loading, particularly if predicted concentrations are too low. The high model spatial and temporal resolution used in this effort may make it possible to 'back-calculate' locations of likely bacterial sources.$$$

Exercise of the validated model with hypothetical loadings of fecal coliform bacteria is central to TMDL development (e.g. Pelletier and Seiders, 2000). Simulations that vary the load, location of bacterial input into the inlets, and timing (e.g., simultaneous CSO overflows on an incoming tide) can be compared the water quality standard. Margin of safety values should be constrained to (1) watershed and hydrodynamic model accuracy revealed in the validation studies, and (2) accuracy and statistical variability in the measured loading data. The error in CH3D hydrodynamic predictions is well known because of the size of measured water current data set. The greatest uncertainty in TMDL development is expected to stem from incomplete loading data.

11.5 Modeling Bacterial Contamination in Sinclair and Dyes Inlets

The fully verified and confirmed fecal coliform model will be used to support TMDL development. The model will be used to conduct simulations of CSO releases in the Port Washington Narrows, other sewage upsets in the study area, and assess loading from stream and storm water sources. In addition, the model will be used to assess the assimilative capacity of marine systems for fecal coliform loading from all sources. A sensitivity analysis will be conducted to evaluate the relative importance of loading from all sources and define critical sources for future monitoring. If the sensitivity analysis shows that specific streams or storm water outfalls are a major source of fecal contamination in the estuary, more detailed model of those areas will be developed to model bacterial loading into the receiving waters. The objective of the model studies will be to address the following objectives:

- model the distribution of fecal coliform within Sinclair and Dyes Inlets
- predict the effect of coliform discharges on water quality in areas of the Inlets containing shellfish beds
- and provide information for establishing waste load (WLAs) for point sources and load allocations (LAs) for non-point sources for establishing a TMDL as required under section 303(d) of the Federal Clean Water Act.

A key component of this effort is to fully report and document the results of the modeling study and supporting data. This will be critical in providing the scientific and technical basis for developing policy and management decisions, documenting advances

in modeling and monitoring technology, and obtaining scientific acceptance of new and emerging technology through publication in the open literature.

The modeling study will be used to estimate the distribution of fecal coliform bacteria within Sinclair and Dyes Inlets following pollution events. Fecal coliform will be modeled using a first order die-off rate (Mancini 1978) in marine waters. A matrix of measured or estimated loading from point and non-point sources (including stream and storm water runoff) will be developed to represent seasonal variability and simulate reasonably anticipated “worst-case” pollution events.

TABLES

Table 1. Water body grid cells and stream segments included on the 1998 303(d) list in Sinclair and Dyes Inlets and contributing streams for exceeding fecal coliform water quality criteria.

GRID	SEGMENT	PARAMETER	96list?	WBID	Water Body
47122F6E4		Fecal Coliform	No	WA-15-0040	SINCLAIR INLET
47122G7A0		Fecal Coliform	Yes	WA-15-0050	DYES INLET
47122G6A9		Fecal Coliform	Yes	WA-15-0050	DYES INLET
TF15AC	1047	Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
TF15AC	1048	Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
TF15AC	1049	Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
TF15AC	1050	Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
TF15AC		Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
TF15AC		Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
JH59OI	1066	Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
MV26EP	1067	Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
DT92SL	1068	Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
DT92SL		Fecal Coliform	Yes	WA-15-5000	CLEAR CREEK
IQ67FF	1032	Fecal Coliform	Yes	WA-15-5100	BARKER CREEK
IQ67FF	1033	Fecal Coliform	Yes	WA-15-5100	BARKER CREEK
IQ67FF		Fecal Coliform	Yes	WA-15-5100	BARKER CREEK
IQ67FF		Fecal Coliform	Yes	WA-15-5100	BARKER CREEK
LK41ZU	1036	Fecal Coliform	Yes	WA-15-4200	BLACKJACK CREEK
LK41ZU	1037	Fecal Coliform	Yes	WA-15-4200	BLACKJACK CREEK
LK41ZU	1038	Fecal Coliform	Yes	WA-15-4200	BLACKJACK CREEK
LK41ZU	1039	Fecal Coliform	Yes	WA-15-4200	BLACKJACK CREEK
WT04RS	1051	Fecal Coliform	Yes	WA-15-4000	GORST CREEK
CS87QP	1077	Fecal Coliform	Yes	WA-15-4400	ANNAPOLIS CREEK
LS41EH	1034	Fecal Coliform	Yes	WA-15-4900	BEAVER CREEK
LS41EH	1035	Fecal Coliform	Yes	WA-15-4900	BEAVER CREEK

Table 2. Stream gage stations in Kitsap County currently being monitored by the Kitsap Public Utilities District. Streams listed in **boldface** are located within the study area.

KPUD SURFACE WATER MEASUREMENT				
KITSAP COUNTY, WASHINGTON				
	NAME	**PREFIX**	**STREAM #**	**PERIOD OF RECORD**
1	HANSVILLE CREEK	HC	166	10/1996 - Present
2	GAMBLE CREEK	GA	158	94-96 USGS, 1996 - Present KPUD
3	DOGFISH CREEK	DC	207	10/1990 - Present
4	JOHNSON CREEK	LJ	208	94-96 USGS, 1996 - Present KPUD
5	**CLEAR CREEK**	**CC**	**246**	**10/1990 - Present**
6	**ANDERSON CREEK - BREM.**	**AC**	**272**	**1/1991 - Present**
7	STAVIS CREEK	ST	113	9/1994
8	ANDERSON CREEK - HOLLY	AN	096	10/1994 - Present
9	OLALLA CREEK	OL	313	1993
10	BURLEY CREEK	BC	356	10/1990 - Present
11	**KARCHER CREEK**	**OC**	**282**	**4/1997 - Present**
12	BOYCE CREEK	BO	111	1999 - 2000
13	ANDERSON CREEK - SEABECK	AS	124	6/1999 - Present
14	GOLD CREEK	GO	655	2/2000 - Present
15	SEABECK CREEK	SE	117	5/1999 - Present
16	**CHICO CREEK**	**CH**	**259**	**3/1991 - 4/1996, 7/1999 - Present**
	SSWM - CHICO BASIN PROJECT			
17	**DICKERSON CREEK**	**DI**	**259A**	**10/2000 - Present**
18	**WILDCAT CREEK at LAKE OUTLET**	**WC**	**259B**	**10/2000 - Present**
19	**KITSAP LAKE at CONTROL**	**KL**	**259C**	**10/2000 - Present**
20	**KITSAP CREEK at LAKE OUTLET**	**KC**	**259D**	**10/2000 - Present**
21	**CHICO TRIB. at TAYLOR ROAD**	**CT**	**259E**	**10/2000 - Present**
	PSNS - ENVVEST PROJECT			
22	**CLEAR CREEK - EAST**	**CE**	**246B**	**1/2001 - Present**
23	**CLEAR CREEK - WEST**	**CW**	**246C**	**1/2001 - Present**
24	**BARKER CREEK**	**BA**	**245**	**1/1991 - 11/1996, 1/2001 - Present**
25	STEEL CREEK	SL	223	1/2001 - 6/2002
26	**STRAWBERRY CREEK**	**SC**	**248**	**1/1991 - 4/2000, 10/2001 - Present**
27	**GORST CREEK**	**GC**	**268**	**10/1990 - 9/1996, 1/2001 Present**
28	**PARISH CREEK**	**PA**	**268-3**	**2/28/2002 - Present**
29	**BLACKJACK CREEK**	**BL**	**279**	**1/1993 - 12/1997, 1/2001 - Present**
30	**HEINS CREEK**	**HE**	**268-4**	**6/2002 - Present**
Jim LeCuyer, R.S.				
Manager - Hydrologic Services & Water Quality				
360/779-7592 x 710 ; jlecuyer@ kpud.org				

Table 3. Summary of the field and laboratory measurements and the precision and detection limits established for the study.

Analysis	Precision	Detection Limit
Field Measurements	**Repeatability**	**Range**
Flow[1]	±0.1 ft./s (±0.03 m/s)	-5 to +20 ft/s (-1.5 to +6.1 m/s)
pH[2]	±0.05 pH units	0 – 14 pH
Temperature[2]	±0.3 °C	0 - 50 °C
Specific conductance[2]	±1% of full scale	0-100 mS/cm
Salinity[2]	±0.1%	0-4%
Turbidity[2]	±3% of full scale	0-800 NTU
Dissolved Oxygen[2] (Optional)	±0.1 mg/L	0-19.9 mg/L
Laboratory Analysis		
Fecal Coliform (MPN)	< 25% RSD (log transformed data)	1 cfu/100 ml
Lab Duplicates	< 25% RPD	

[1] Isco Inc. Products - 2150 Area Velocity Module (http://www.isco.com/aspscripts/products3.asp?PDG=2021010) or Isco Inc. Products - 750 Area Velocity Flow Module (http://www.isco.com/aspscripts/products3.asp?PDG=2016050), or Isco 4110 ultra sonic flow meter meets requirements.
[2] Horiba Water Quality Checker/U-10 (http://global.horiba.com/analy_e/u-10/) meets requirements

Table 4. (A) Monthly average precipitation (in) and (B) monthly average of mean daily discharge (CFS) recorded at selected stations within the study area. Data from KPUD 2000.

A. Precipitation Station	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	total
[a]Bremerton Airport	5.11	9.35	8.99	9.47	6.62	7.09	4.64	2.66	1.53	1.14	0.09	1.91	58.6
[b]Port Orchard-Private	4.65	9.71	9.38	8.43	7.19	5.91	4.53	2.31	2.04	0.96	1.00	1.70	57.8
[c]Bremerton Water Dept	4.14	8.23	8.70	7.79	6.27	5.20	4.13	1.98	1.57	1.02	1.20	1.30	51.5
[d]Silverdale - Dawn Park	3.77	6.98	8.04	8.08	6.61	4.79	3.88	2.02	1.83	1.11	1.32	1.08	49.5

[a]1983-1998
[b]1973-1999
[c]1991-1999
[d]1990-1999

B. Stream Station	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	total
Clear Creek 1997-98	17.3	15.5	14.3	22.1	21.0	14.7	8.7	6.9	6.1	5.6		5.6	137.8
Clear Creek 1998-99	6.6	25.9	34.5	32.1	59.1	24.7	11.4	8.3	8.2	6.7	6.1	5.8	229.3
Barker 1996-97	4.5	8.1	8.1	10.9	17.8	7.7	10.5	5.0	3.5	3.3	3.3	4.6	87.1
Strawberry 1998-99	1.7	24.8	36.6	28.2	106.0	42.8	3.0	2.6	4.3	1.6	1.5	1.4	254.6
Chico 1993-94	8.4	10.7	46.3	41.1	67.8	49.5	24.1	12.2	9.4	5.9	6.5	3.7	285.6
Anderson 1997-98	6.9	7.3	9.1	16.7	11.0	7.9	5.9	4.7	3.5	3.3	3.3	3.3	82.9
Karcher (Olny) 1998-99	3.7	8.6	9.7	12.0	12.5	5.8	5.1	4.7	4.3	4.2	3.7	3.1	77.5

Table 5. Proposed storm water (A), stream and nearshore (B), and marine and storm event sampling stations (C), the Jurisdiction responsible for collecting the samples, the outfall or station id, sampling frequency, and type of sample to be collected.

(A). Storm water sampling stations	Jurisdiction	OUTFALL ID	Station Lable	Sampling Frequency	Type of Sample
City of Bremerton Storm Water Outfalls					
Callow Ave	City of Bremerton	ST 28	SW1	3/Week	EVENT
Pacific Ave	City of Bremerton	ST/CSO 16	SW2	3/Week	EVENT
Pine Rd	City of Bremerton	ST 1	SW3	3/Week	Mon/Wed/Thr
Trenton Ave	City of Bremerton	ST 12	SW4	3/Week	Mon/Wed/Thr
Stephenson Creek	City of Bremerton	ST 3	SW5	3/Week	Mon/Wed/Thr
Oyster Bay Ave	City of Bremerton	ST 26	B-ST26	3/Week	Mon/Wed/Thr
Campbell Way	City of Bremerton	ST 4	B-ST04	3/Week	Mon/Wed/Thr
Evergreen Park	City of Bremerton	ST 27	B-ST27	3/Week	EVENT
Kitsap County Storm Water Outfalls					
Silverdale at Sandpiper	Kitsap SSWM	LMK002	SW6	3/Week	Mon/Wed/Thr
Silverdale West Bucklin Hill Road	Kitsap SSWM	LMK001	SW6	3/Week	Mon/Wed/Thr
Silverdale at Bayshore	Kitsap SSWM	LMK004	LMK004	3/Week	Mon/Wed/Thr
Phinney Bay	Kitsap SSWM	LMK020	LMK020	3/Week	EVENT
Silverdale East Bucklin Hill Road	Kitsap SSWM	LMK026	LMK026	3/Week	Mon/Wed/Thr
Tracyton Boat Dock 055	Kitsap SSWM	LMK055	LMK055	3/Week	EVENT
Tracyton 060	Kitsap SSWM	LMK060	LMK060	3/Week	EVENT
Gorst Subaru	Kitsap SSWM	LMK128	LMK128	3/Week	Mon/Wed/Thr
Port Orchard 155	Kitsap SSWM	LMK155	LMK155	3/Week	EVENT
Gorst Navy City Metals	Kitsap SSWM	LMK122	SW7	3/Week	EVENT
Port Orchard 136	Kitsap SSWM	LMK136	LMK136	3/Week	Mon/Wed/Thr
National Ave. 164	Kitsap SSWM	LMK164	LMK164	3/Week	Mon/Wed/Thr
Manchester 038	Kitsap SSWM	LMK038	LMK038	3/Week	Mon/Wed/Thr
PSNS Storm Water Outfalls					
PSNS CIA	PSNS	PSNS003	PSNS003	3/Week	EVENT
PSNS Dry Dock	PSNS	PSNS006	PSNS006	3/Week	EVENT
PSNS Motor Pool	PSNS	PSNS056	PSNS056	3/Week	EVENT
PSNS Industrial Nondrydock	PSNS	PSNS030	PSNS030	3/Week	EVENT
Naval Station Coml/Res/Rec	PSNS	PSNS014	PSNS014	3/Week	EVENT
Naval Station Industrial	PSNS	PSNS008	PSNS008	3/Week	Mon/Wed/Thr
PSNS Downstream of CSO 16	PSNS	PSNS126	PSNS126	3/Week	Mon/Wed/Thr
Port Orchard Storm Water Outfalls					
Port Orchard Bay St	Port Orchard	PO1	TBD	3/Week	EVENT
Port Orchard Bethal Rd	Port Orchard	PO2	TBD	3/Week	EVENT
Port Orchard Wilkens Rd	Port Orchard	PO3	TBD	3/Week	Mon/Wed/Thr
Port Orchard Blvd	Port Orchard	PO4	TBD	3/Week	Mon/Wed/Thr

B. Stream, nearshore, and marine sampling stations	Jurisdiction	STATION ID	Station Lable	Sampling Frequency	Type of Sample
Major Streams					
BARKER CREEK	KPUD	BA	BA	3/Week	Mon/Wed/Thr
BLACKJACK CREEK	KPUD	BL	BL	3/Week	Mon/Wed/Thr
CLEAR CREEK	KPUD	CC	CC	3/Week	Mon/Wed/Thr
CHICO CREEK (Main Stem)	KPUD	CH	CH	3/Week	Mon/Wed/Thr
GORST CREEK (Jarsted Park)	KPUD	GC	GC	3/Week	Mon/Wed/Thr
STRAWBERRY CREEK	KPUD	SC	SC	3/Week	Mon/Wed/Thr
ANDERSON CREEK - BREM.	KPUD	AC	AC	3/Week	Mon/Wed/Thr
OLNEY CREEK (KARCHER CREEK)	KPUD	OC	OC	3/Week	Mon/Wed/Thr
Tributary Streams					
Clear Creek East	PSNS	CE	CE	3/Week	Mon/Wed/Thr
Clear Creek West	PSNS	CW	CW	3/Week	Mon/Wed/Thr
Bangor Trident Lake	PSNS	BTL	BTL	3/Week	Mon/Wed/Thr
Bangor Storm Water Ponds	PSNS	BSWP	BSWP	3/Week	Mon/Wed/Thr
BARKER CREEK Upstream 1	ECOLOGY	BA-1	BA-1	3/Week	Mon/Wed/Thr
BARKER CREEK Upstream 2	ECOLOGY	BA-2	BA-2	3/Week	Mon/Wed/Thr
BLACKJACK CREEK (KFC)	ECOLOGY	BL-1	BL-1	3/Week	Mon/Wed/Thr
GORST CREEK below Sam Christopherson	ECOLOGY	GC-1	GC-1	3/Week	Mon/Wed/Thr
ANNAPOLIS CREEK	ECOLOGY	AN-1	AN-1	3/Week	Mon/Wed/Thr
BEAVER CREEK Lower segment	ECOLOGY	BE-1	BE-1	3/Week	Mon/Wed/Thr
BEAVER CREEK Upper segment	ECOLOGY	BE-2	BE-2	3/Week	Mon/Wed/Thr
Chico @ Taylor Rd	Kitsap NR	CT	CT	3/Week	Mon/Wed/Thr
Dickerson	Kitsap NR	DI	DI	3/Week	Mon/Wed/Thr
Lost (or Wildcat lake)	Kitsap NR	CL	CL	3/Week	Mon/Wed/Thr
Kitsap Creek	Kitsap NR	KC	KC	3/Week	Mon/Wed/Thr
Kitsap Lake	Kitsap NR	KL	KL	3/Week	Mon/Wed/Thr
Nearshore Stations					
Clam Bay	BKHD	N1	N1	Weekly	PERIODIC
Sinclair Inlet	BKHD	N2	N2	Weekly	PERIODIC
Sinclair Inlet	BKHD	N3	N3	Weekly	PERIODIC
Sinclair Inlet	BKHD	N4	N4	Weekly	PERIODIC
Sinclair Inlet	BKHD	N5	N5	Weekly	PERIODIC
Sinclair Inlet	BKHD	N6	N6	Weekly	PERIODIC
Sinclair Inlet	BKHD	N7	N7	Weekly	PERIODIC
Port Washington Narrows	BKHD	N8	N8	Weekly	PERIODIC
Port Washington Narrows	BKHD	N9	N9	Weekly	PERIODIC
Port Washington Narrows	BKHD	N10	N10	Weekly	PERIODIC
Finney Bay	BKHD	N11	N11	Weekly	PERIODIC
Dye's Inlet - Ostrich	BKHD	N12	N12	Weekly	PERIODIC
Dye's Inlet - Ostrich	BKHD	N13	N13	Weekly	PERIODIC
Dyes Inlet - Chico Bay	BKHD	N14	N14	Weekly	PERIODIC
Dyes Inlet - Chico Bay	BKHD	N15	N15	Weekly	PERIODIC
Dyes Inlet - Chico Bay	BKHD	N16	N16	Weekly	PERIODIC
Dyes Inlet - North	BKHD	N17	N17	Weekly	PERIODIC
Dyes Inlet - North	BKHD	N18	N18	Weekly	PERIODIC
Dyes Inlet - North	BKHD	N19	N19	Weekly	PERIODIC
Dyes Inlet - Barker Creek	BKHD	N20	N20	Weekly	PERIODIC

C. Marine and stream event Sampling Stations	Jurisdiction	STATION ID	Station Lable	Sampling Frequency	Type of Sample
Marine Stations					
Port Orchard Passage	DOH/Suquamish Tribe	M1	M1	Weekly	PERIODIC
Rich Passage	DOH/Suquamish Tribe	M2	M2	Weekly	PERIODIC
Sinclair Outer	DOH/Suquamish Tribe	M3	M3	Weekly	PERIODIC
Sinclair Inner	DOH/Suquamish Tribe	M4	M4	Weekly	PERIODIC
Rocky Point	DOH/Suquamish Tribe	M5	M5	Weekly	PERIODIC
Erlands Point	DOH/Suquamish Tribe	M6	M6	Weekly	PERIODIC
Windy Point	DOH/Suquamish Tribe	M7	M7	Weekly	PERIODIC
Oyster Bay	DOH/Suquamish Tribe	M8	M8	Weekly	PERIODIC
Stream Event Samples					
BARKER CREEK	PSNS/TEC	BA		3	EVENT
BLACKJACK CREEK	PSNS/TEC	BL		3	EVENT
CLEAR CREEK	PSNS/TEC	CC		3	EVENT
CHICO CREEK (Main Stem)	PSNS/TEC	CH		3	EVENT
GORST CREEK (Jarsted Park)	PSNS/TEC	GC		3	EVENT
STRAWBERRY CREEK	PSNS/TEC	SC		3	EVENT
ANDERSON CREEK - BREM.	PSNS/TEC	AC		3	EVENT
OLNEY CREEK (KARCHER CREEK)	PSNS/TEC	OC		3	EVENT
Clear Creek East	PSNS/TEC	CE		3	EVENT
Clear Creek West	PSNS/TEC	CW		3	EVENT
CHICO @ Taylor Rd	PSNS/TEC	CT		3	EVENT
Bainbridge Island					
Lynwood Center Stream	Bainbridge Island	BI1	3/Week		Mon/Wed/Thr
Lynwood Center SW	Bainbridge Island	BI2	3/Week		EVENT
Pleasant Beach	Bainbridge Island	BI3	3/Week		Mon/Wed/Thr

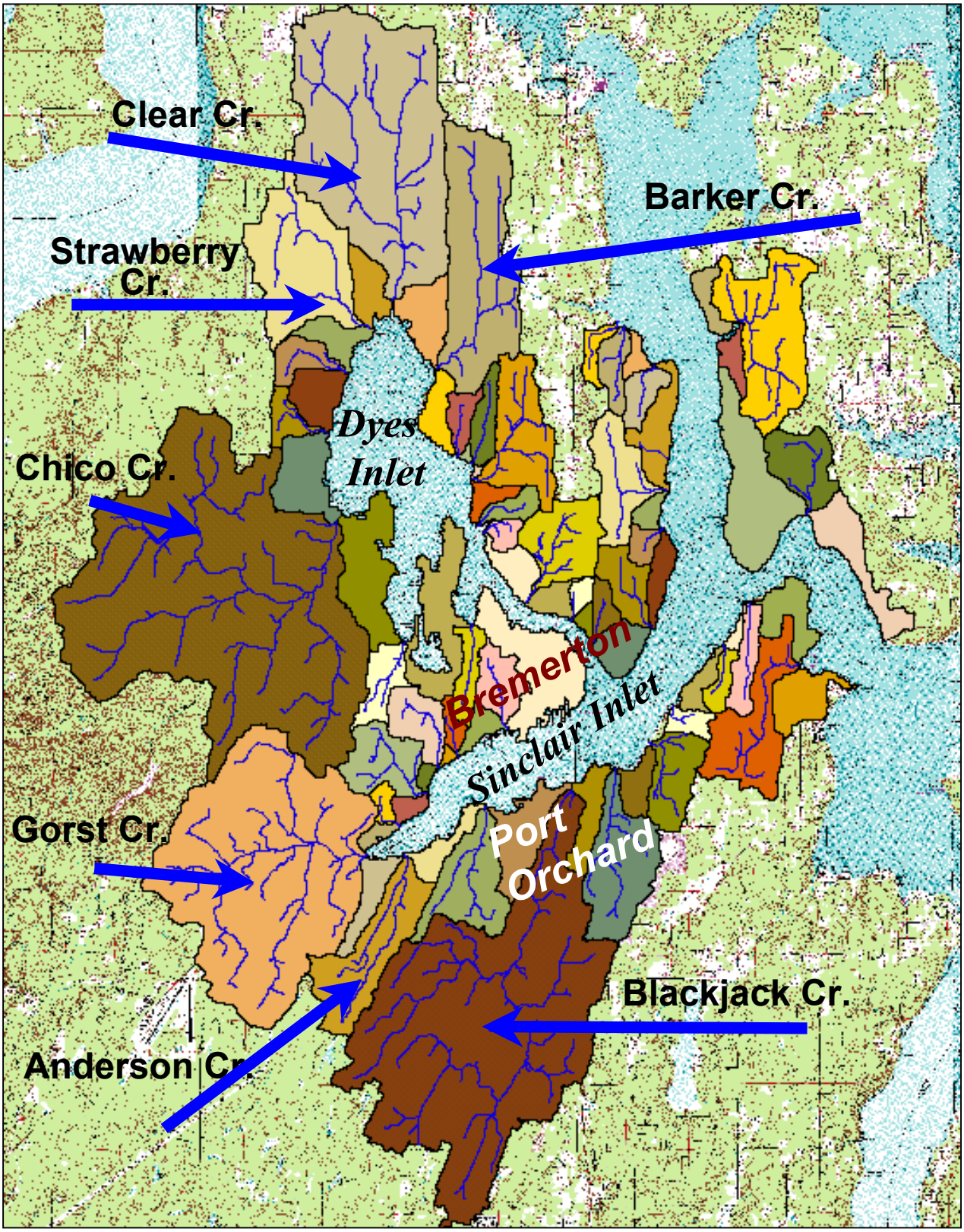


Figure 1. Study area consisting of the marine waters of Sinclair and Dyes Inlets and the surrounding watershed.

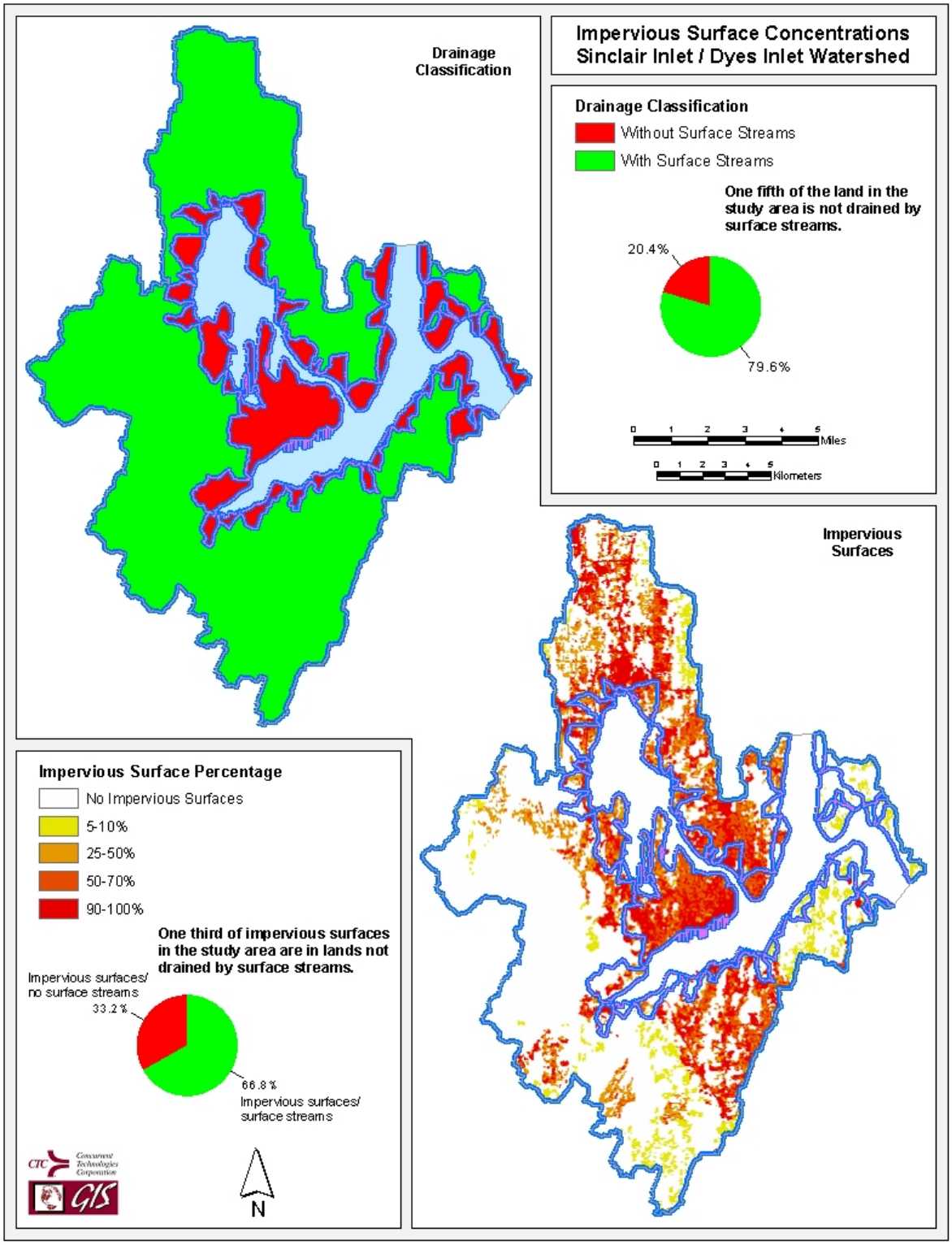


Figure 2. The amount of the study area that is drained by stream networks (upper figure) and the location of impervious surfaces within the study area (lower figure) (from Vandervoort 2001).

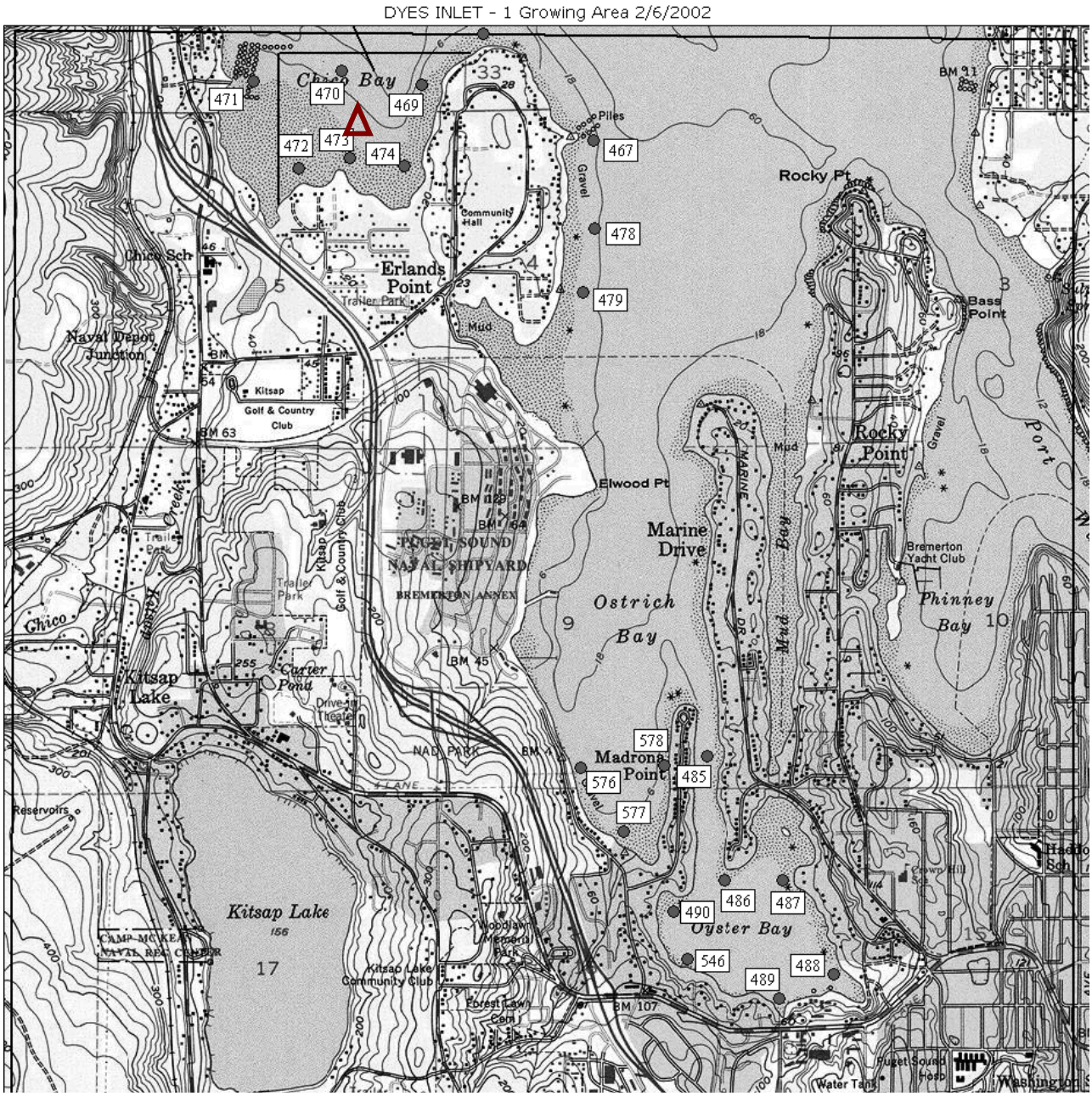


Figure 3. Stations in southern Dyes Inlet sampled for fecal coliform bacteria by the Washington State Department of Health and Suquamish Tribe.

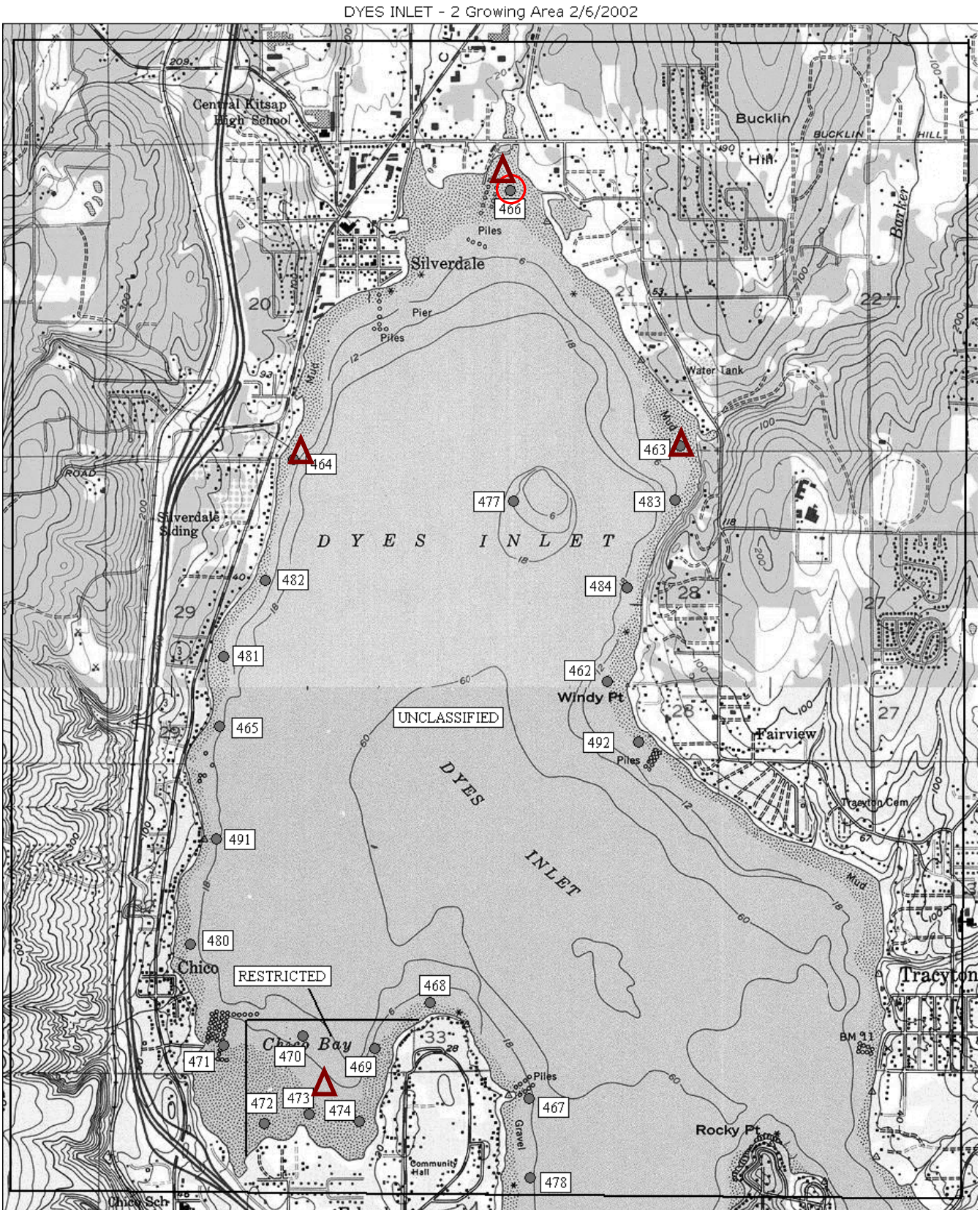


Figure 4. Stations in northern Dyes Inlet sampled for fecal coliform bacteria by the Washington State Department of Health and Suquamish Tribe. Circle indicates areas that exceeded Part 1 and triangles indicate areas that exceeded Part 2 of the Water Quality Criteria.

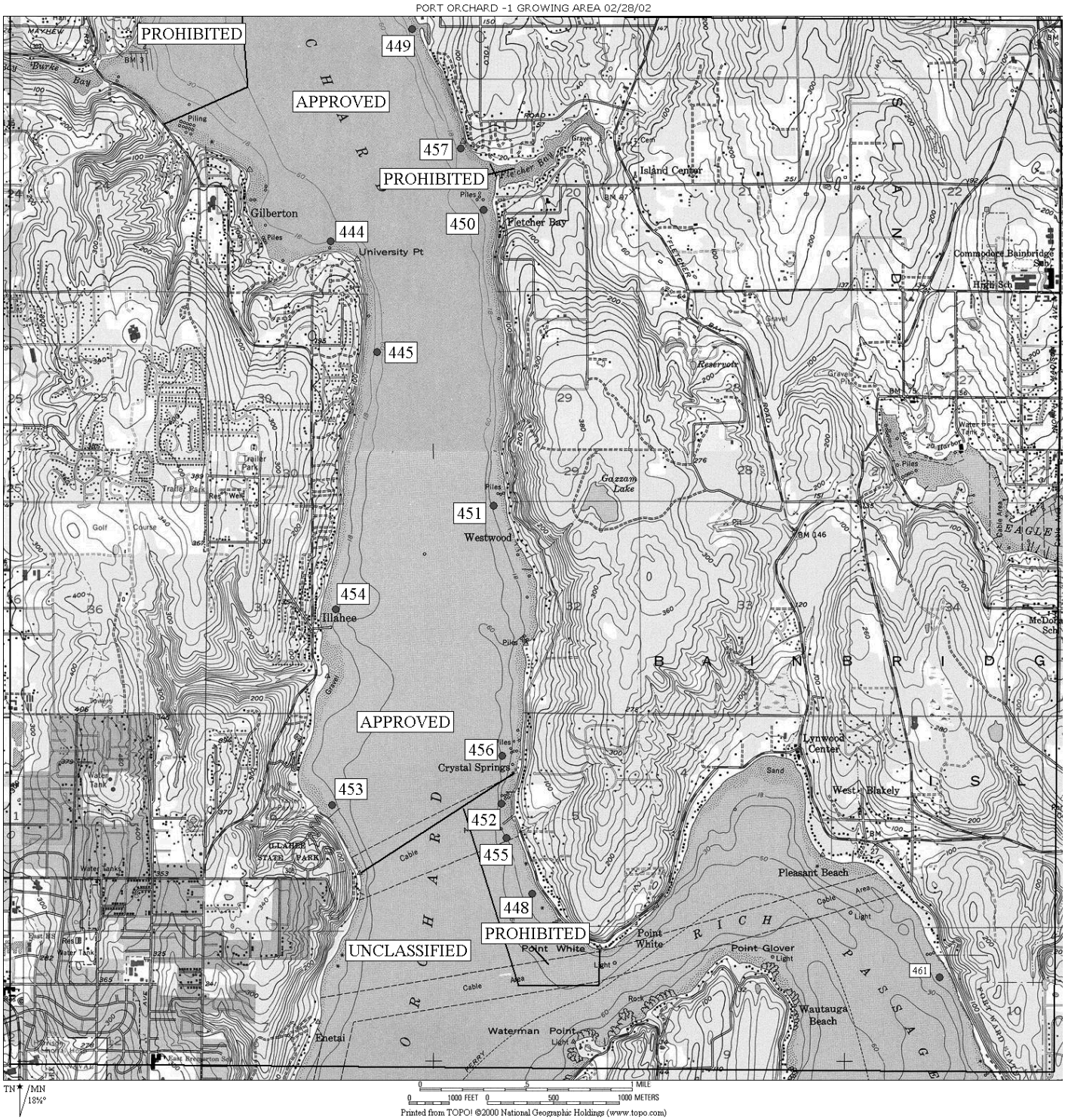
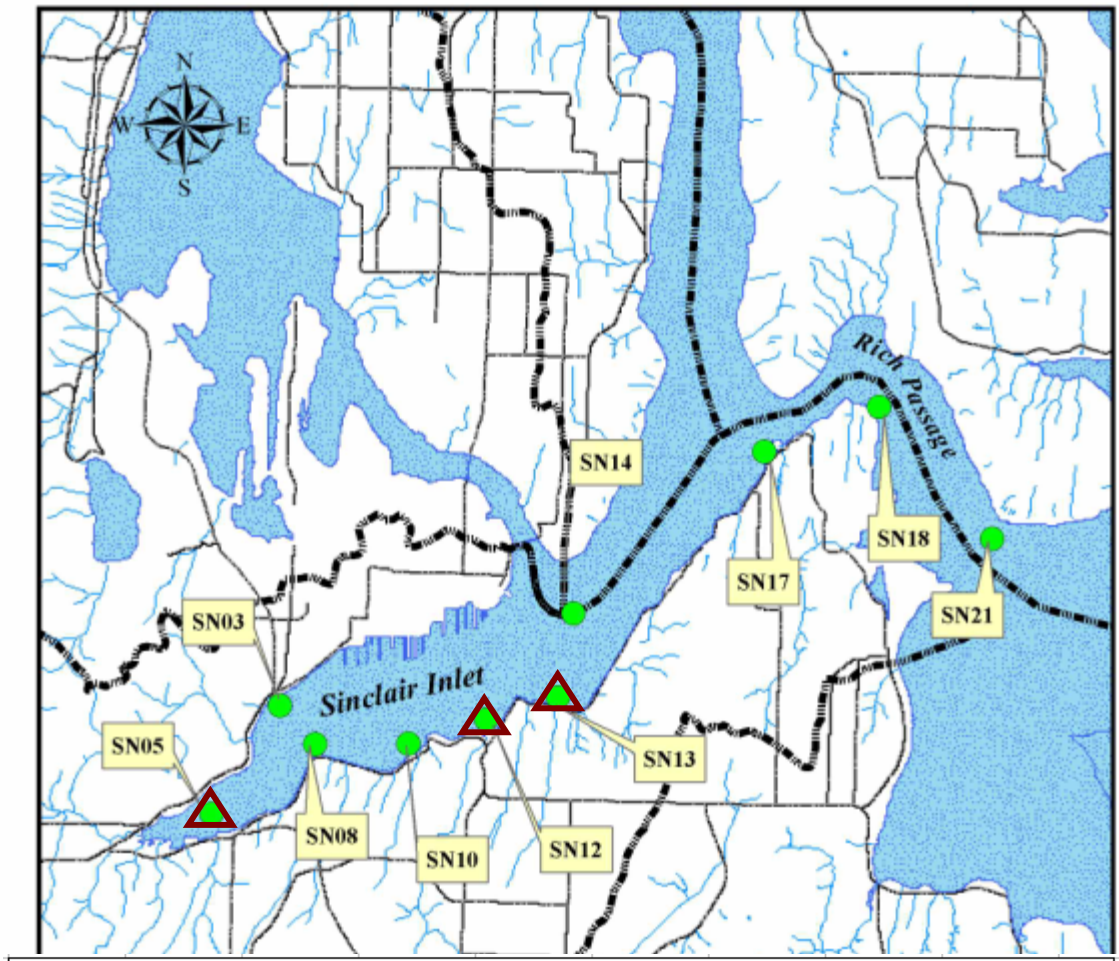


Figure 5. Marine Stations in Port Orchard Passage sampled for fecal coliform bacteria by the Washington State Department of Health and Suquamish Tribe.



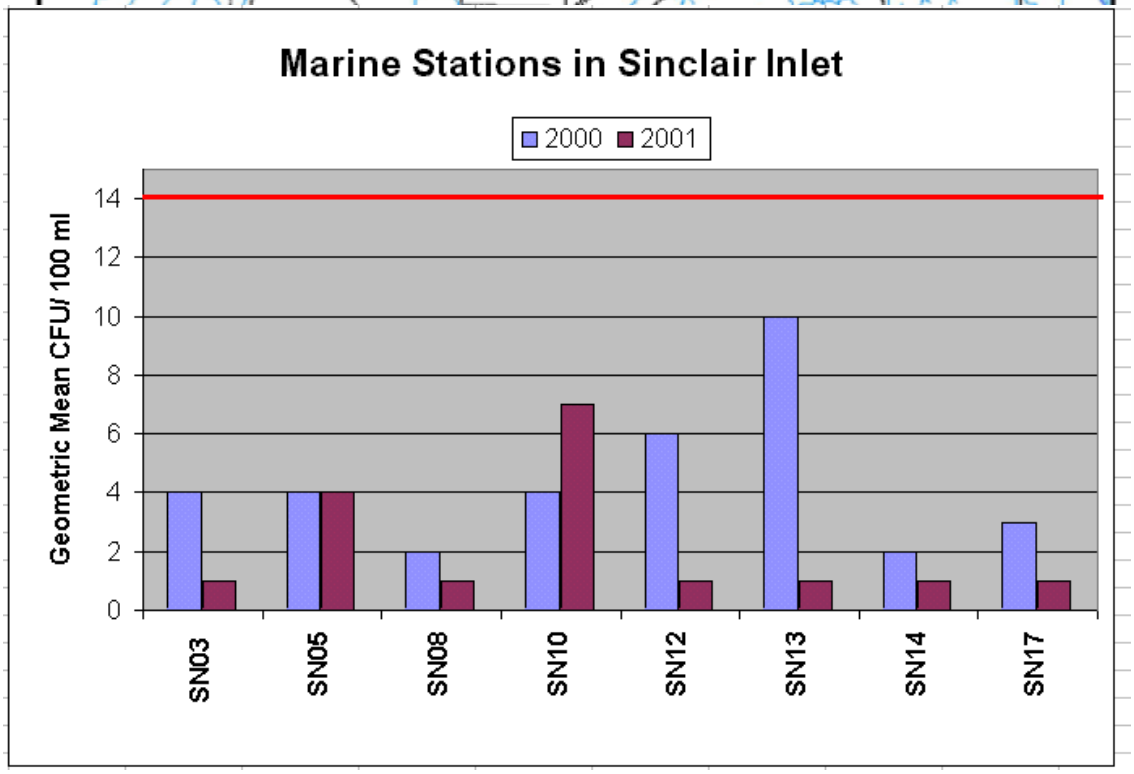


Figure 6. Fecal coliform stations sampled in Sinclair Inlet by the Bremerton Kitsap Health District. Triangles indicate areas that exceeded Part 2 of the Water Quality Criteria.

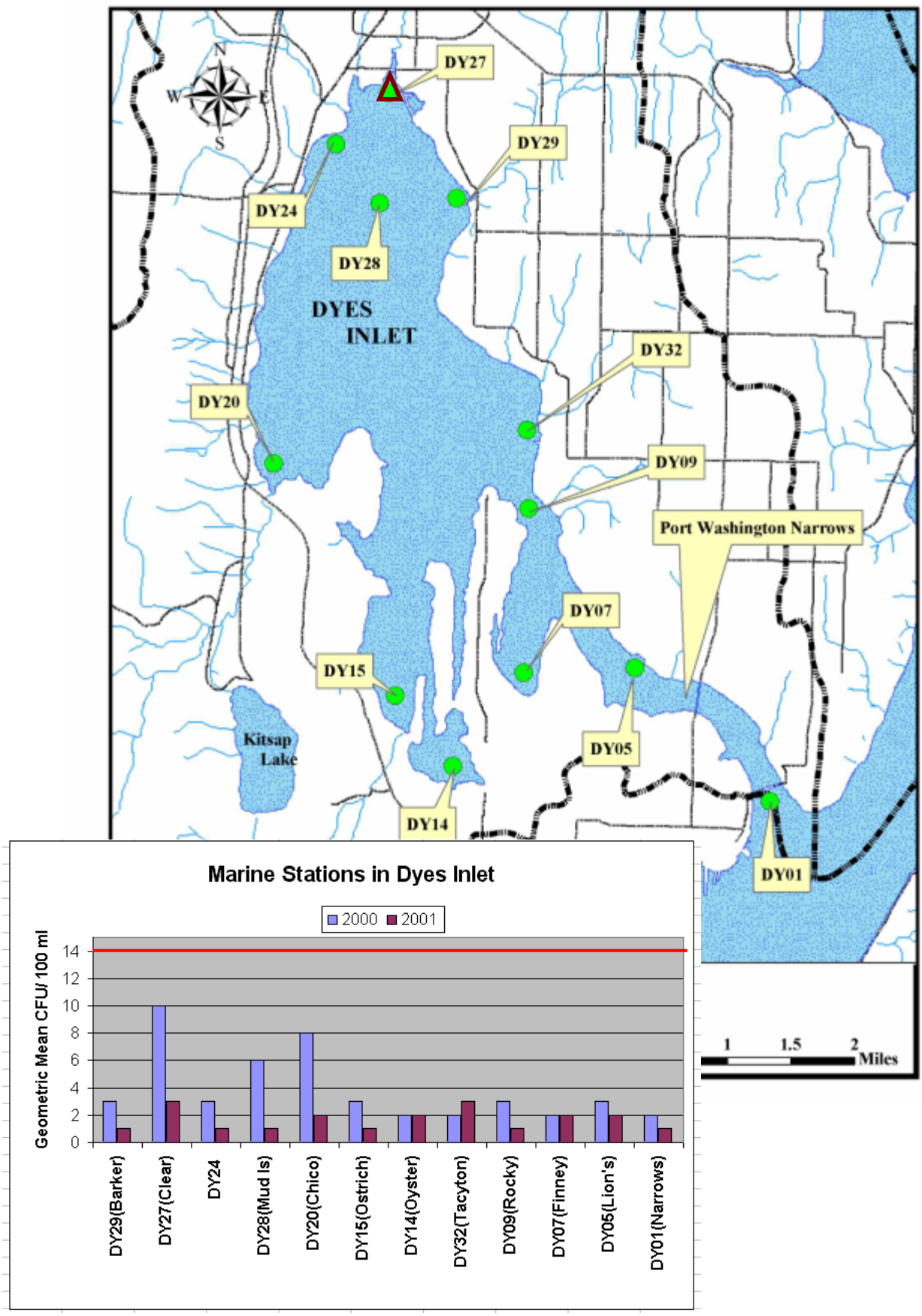
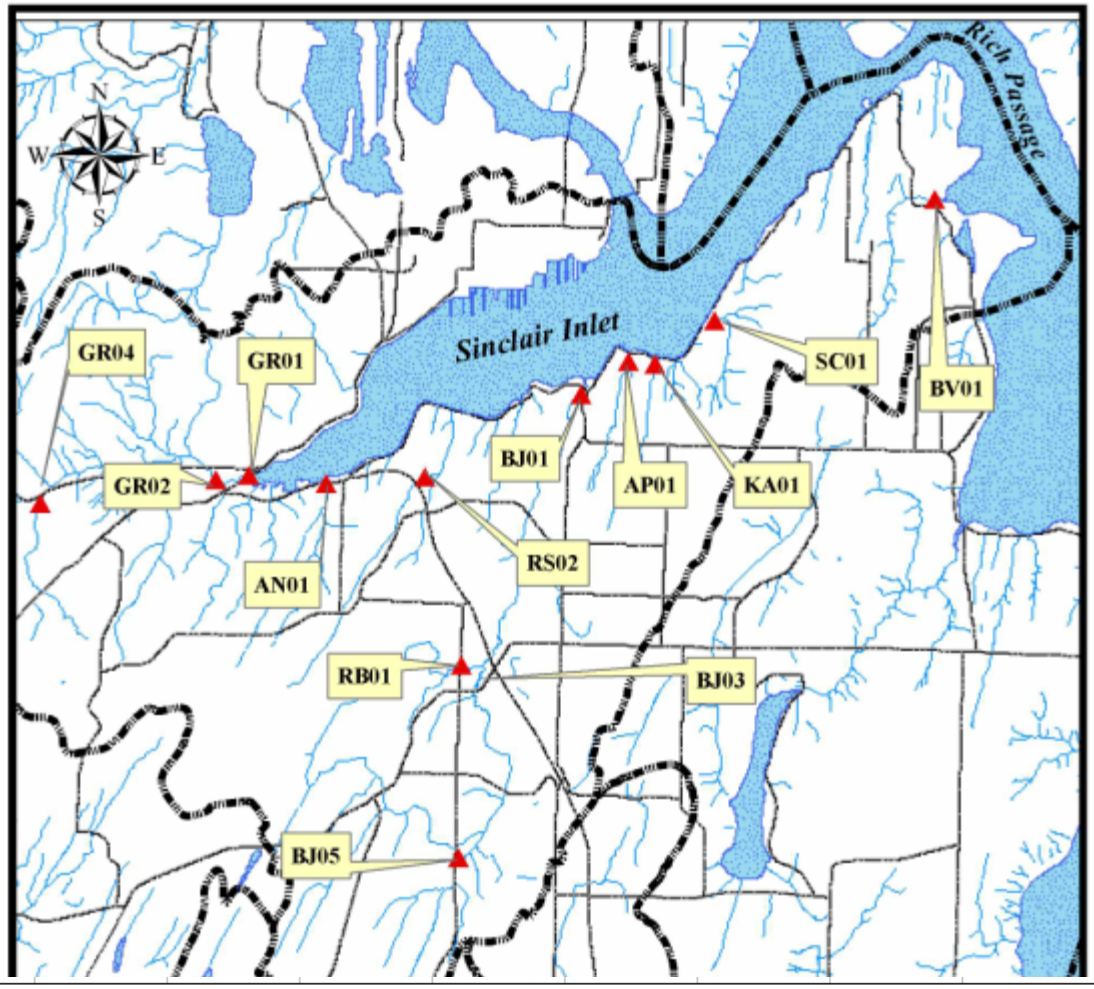


Figure 7. Fecal coliform stations sampled in Dyes Inlet by the Bremerton Kitsap Health District. Triangle indicate areas that exceeded Part 2 of the Water Quality Criteria.



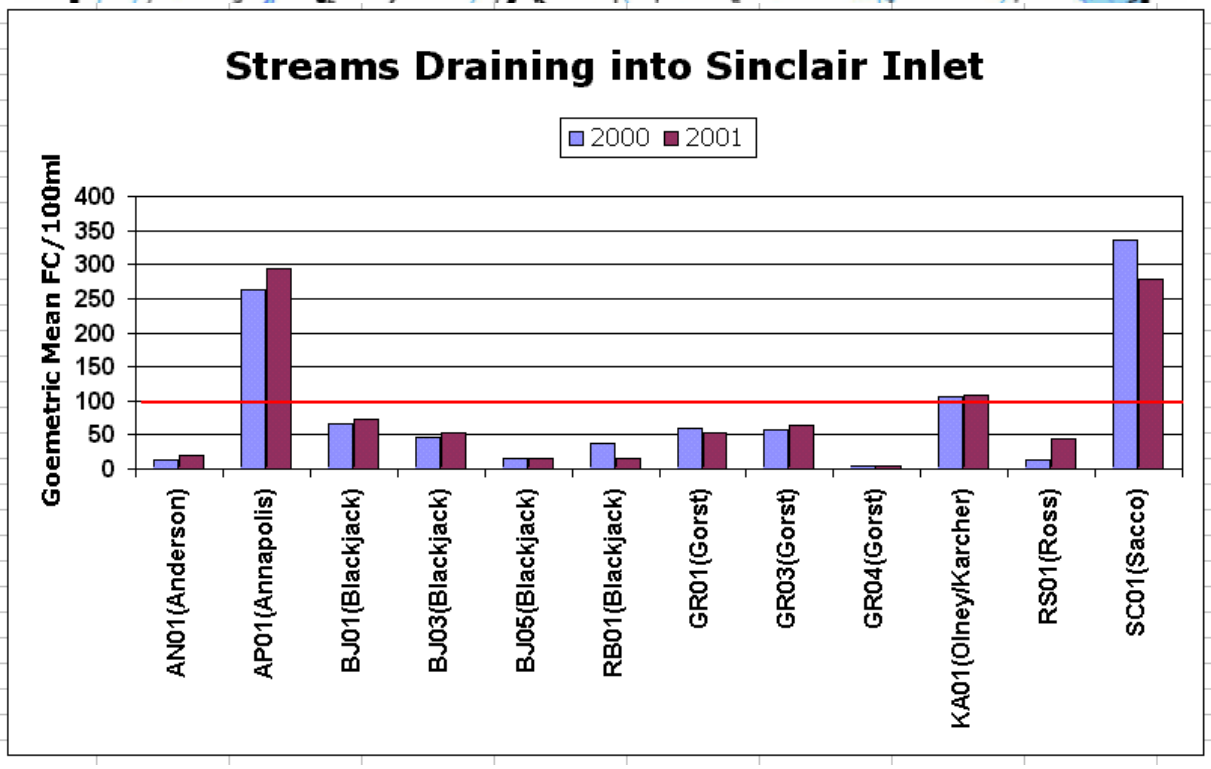


Figure 8. Fecal coliform stations sampled in streams that drain into Sinclair Inlet by the Bremerton Kitsap Health District.

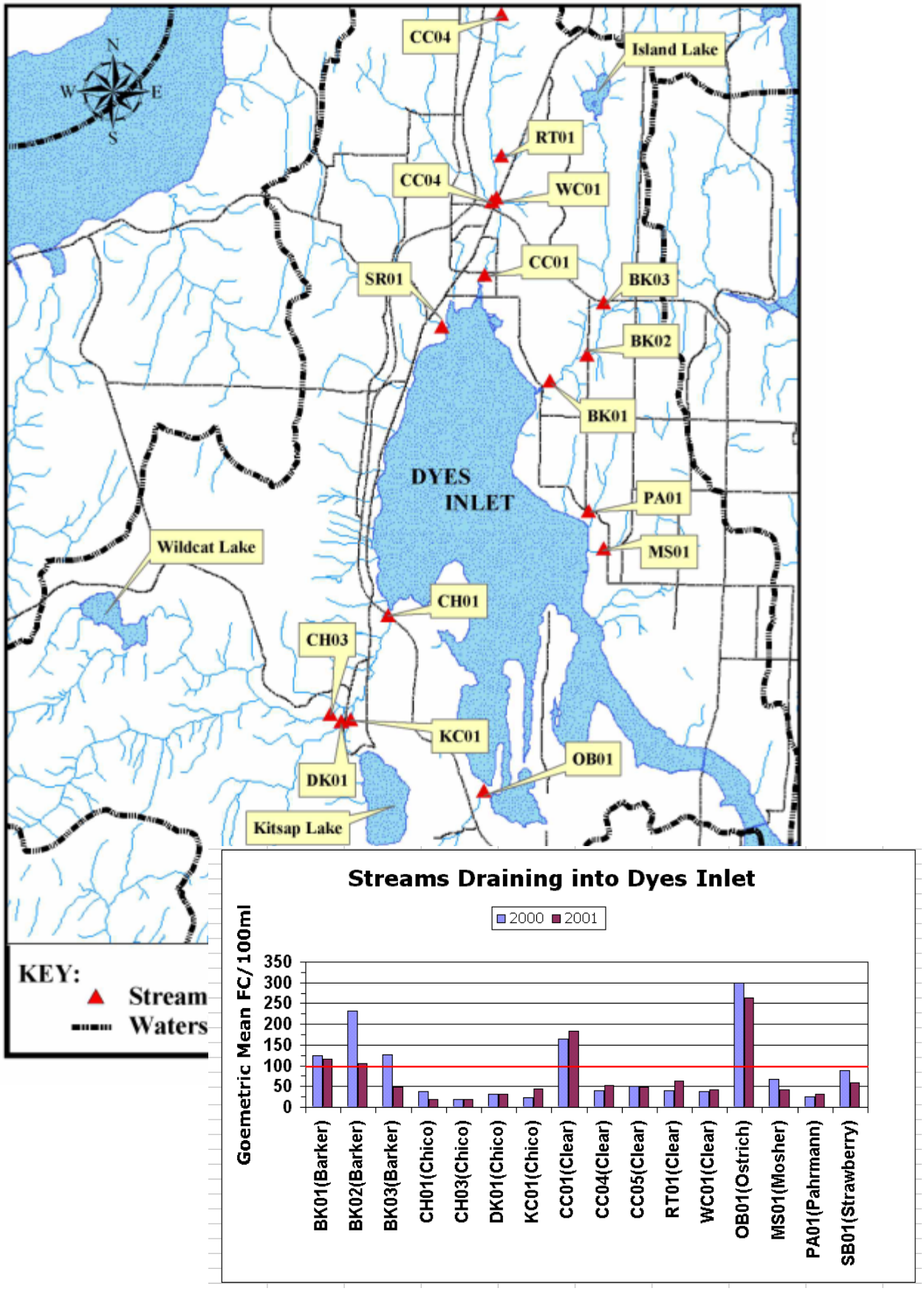


Figure 9. Fecal coliform stations sampled in streams that drain into Dyes Inlet by the Bremerton Kitsap Health District.

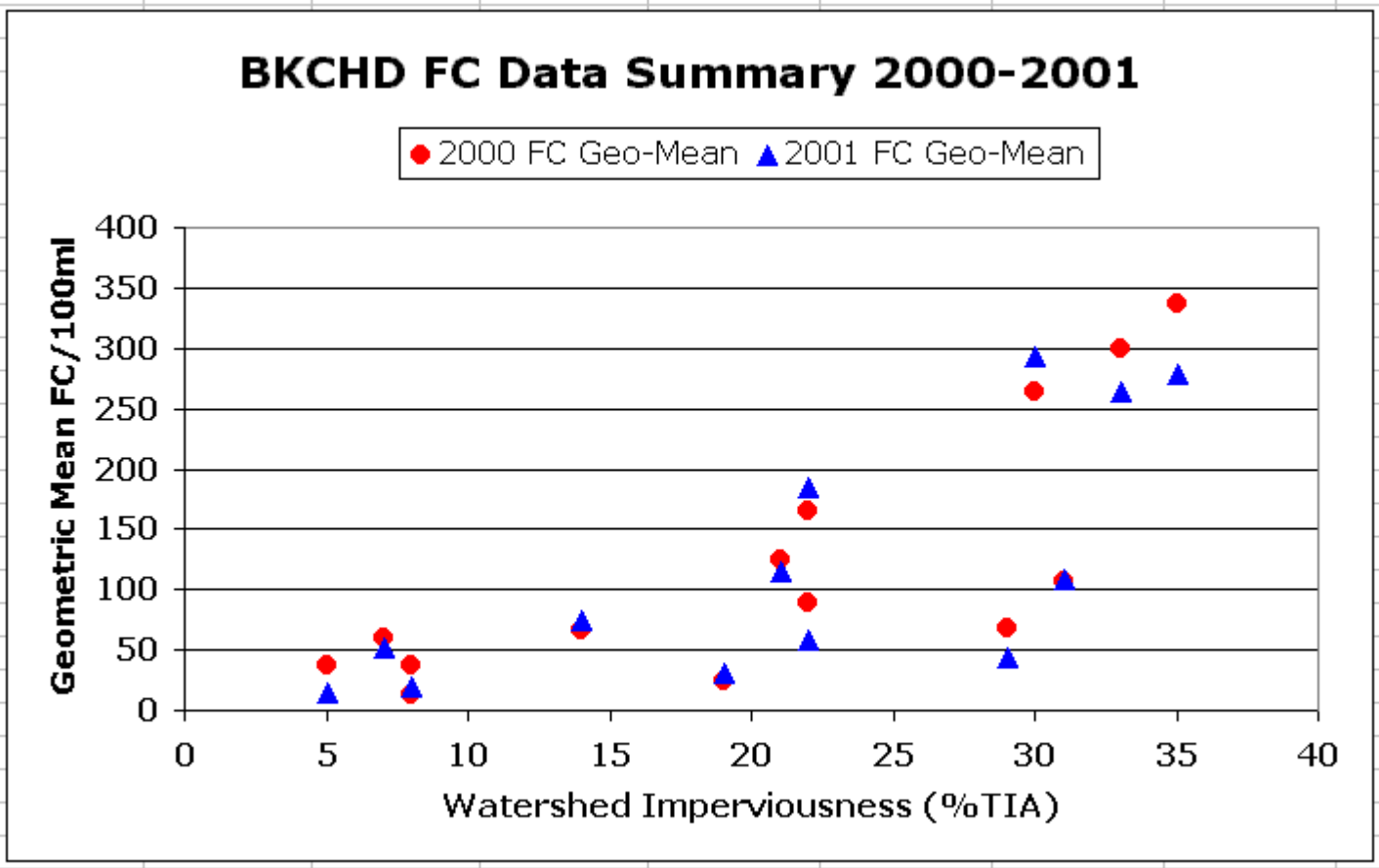


Figure 10. Relationship between fecal coliform and percent Total Impervious Surface (%TIA) determined from the BKCHD FC data.

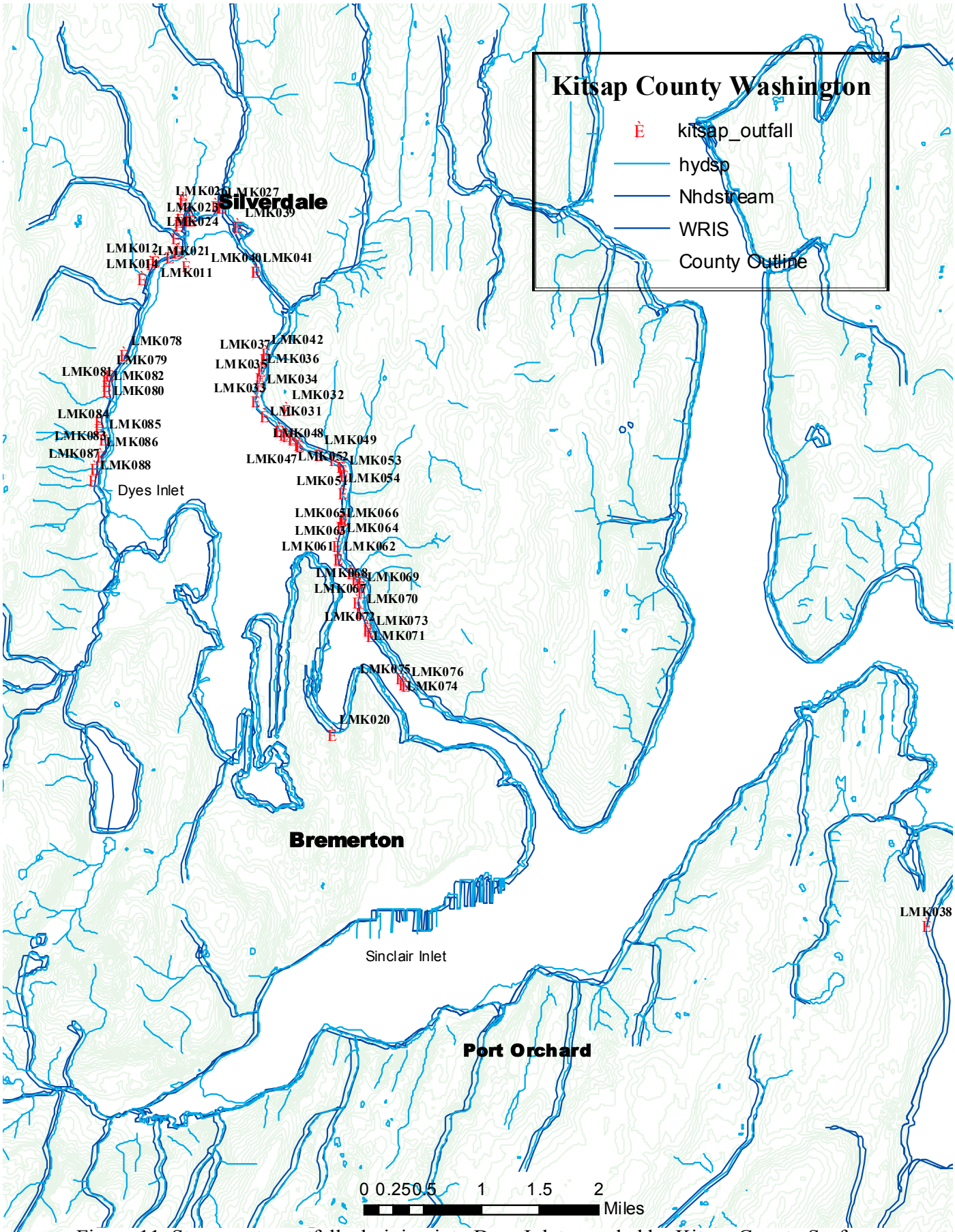


Figure 11. Storm water outfalls draining into Dyes Inlet sampled by Kitsap County Surface and Storm Water Management. (Outfalls draining into Sinclair Inlet is under construction).

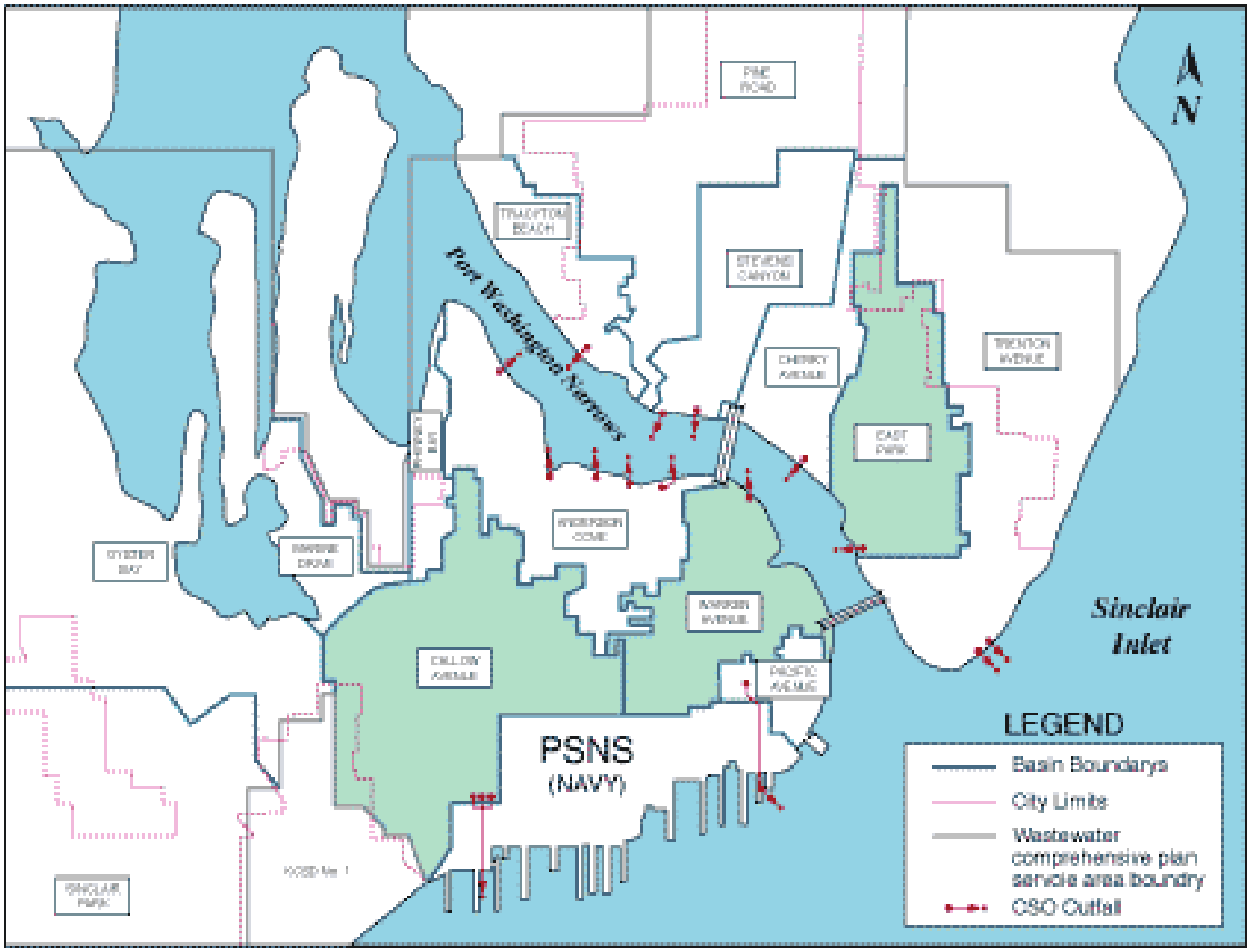


Figure 12. Drainage basin boundaries within the City of Bremerton.

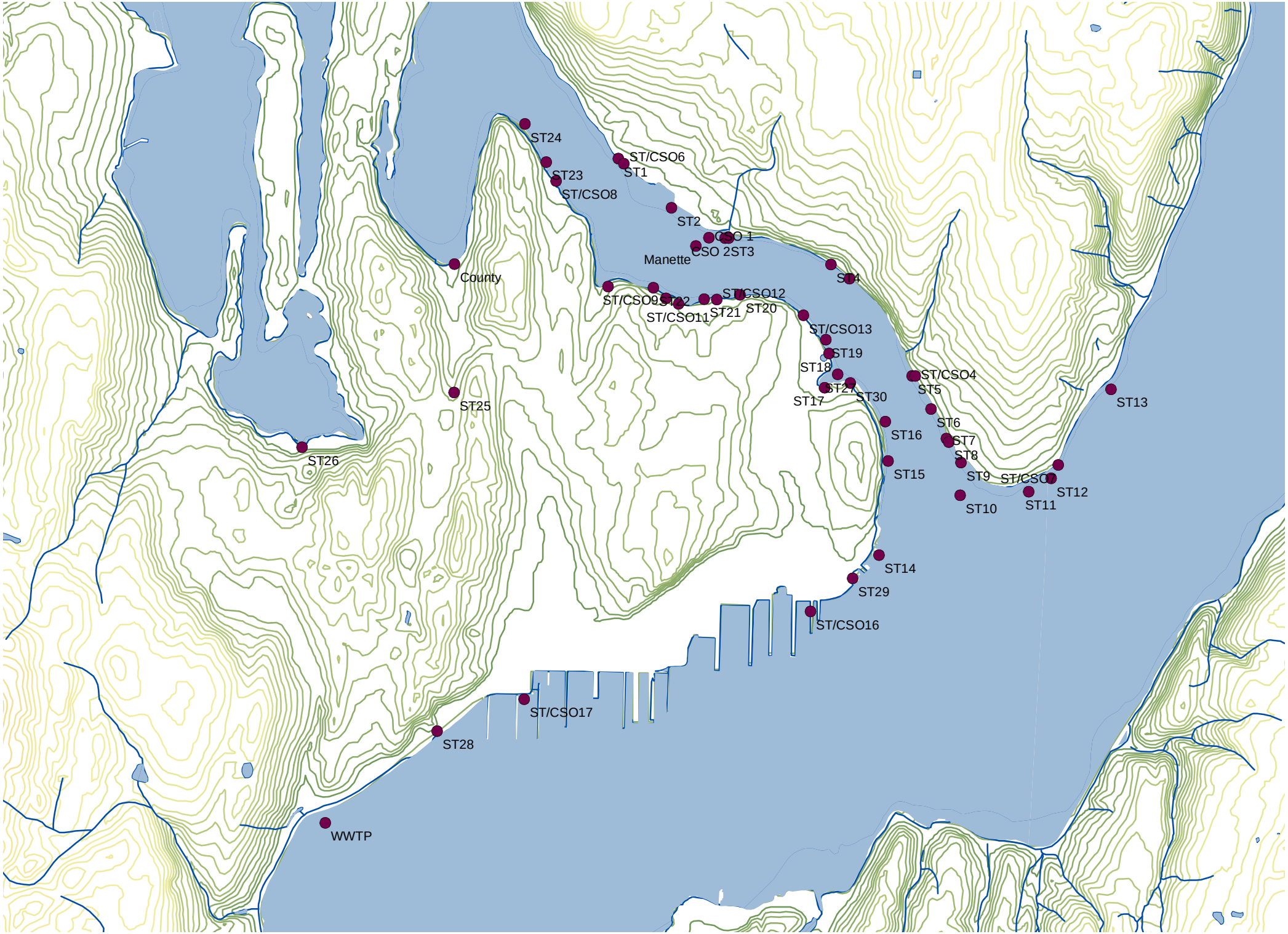


Figure 12a Storm water outfalls and combined sewer overflows in the City of Bremerton.

Puget Sound Naval Shipyard

Figure 13. Buildings, catch basins, and major storm water outfalls within Bremerton Naval Complex.

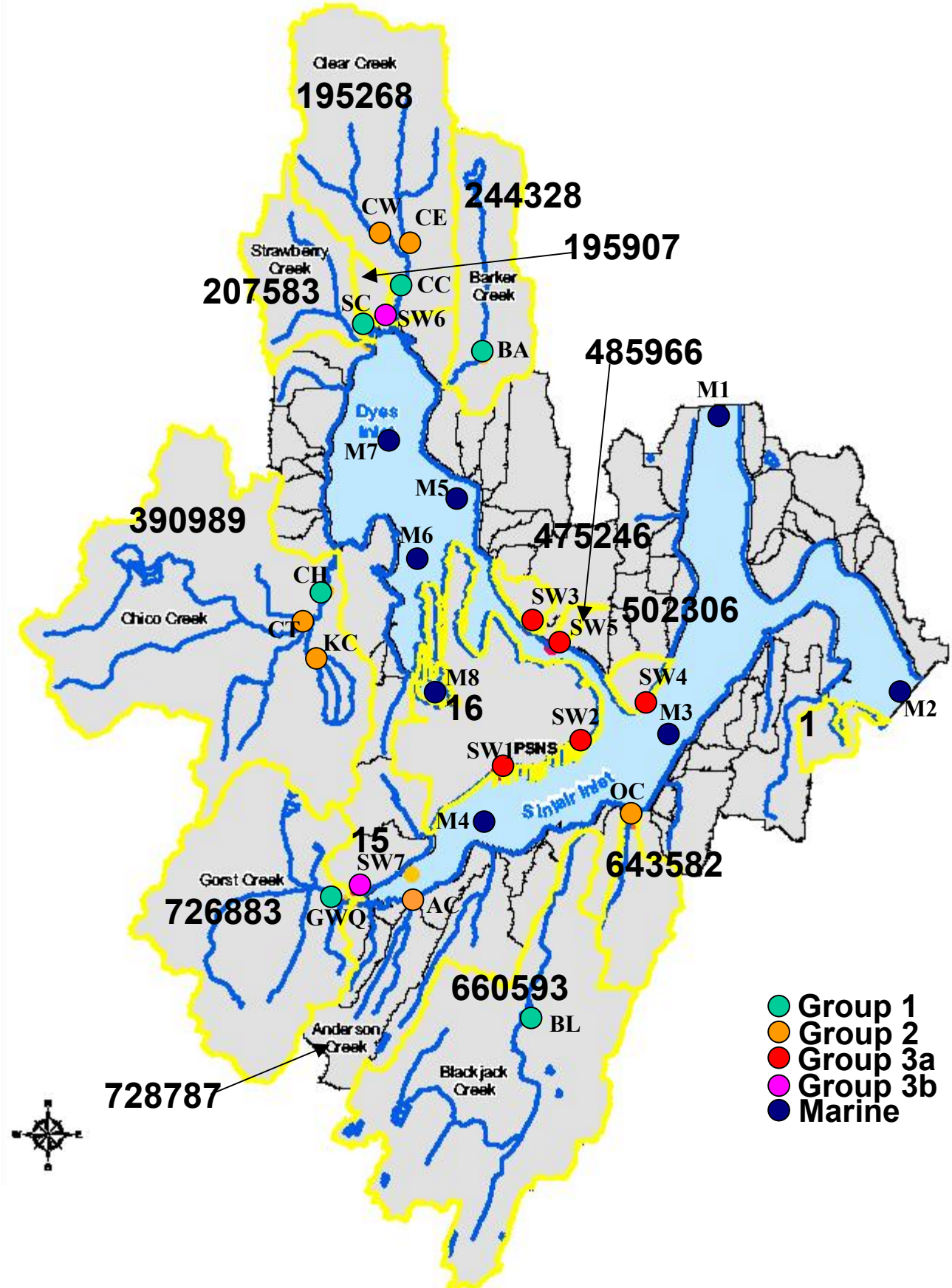


Figure 14. Station locations for streams (Groups 1 and 2), storm water outfalls (Groups 3a and 3b), marine stations and the watershed id (numbers) sampled from March 10-14, 2002.

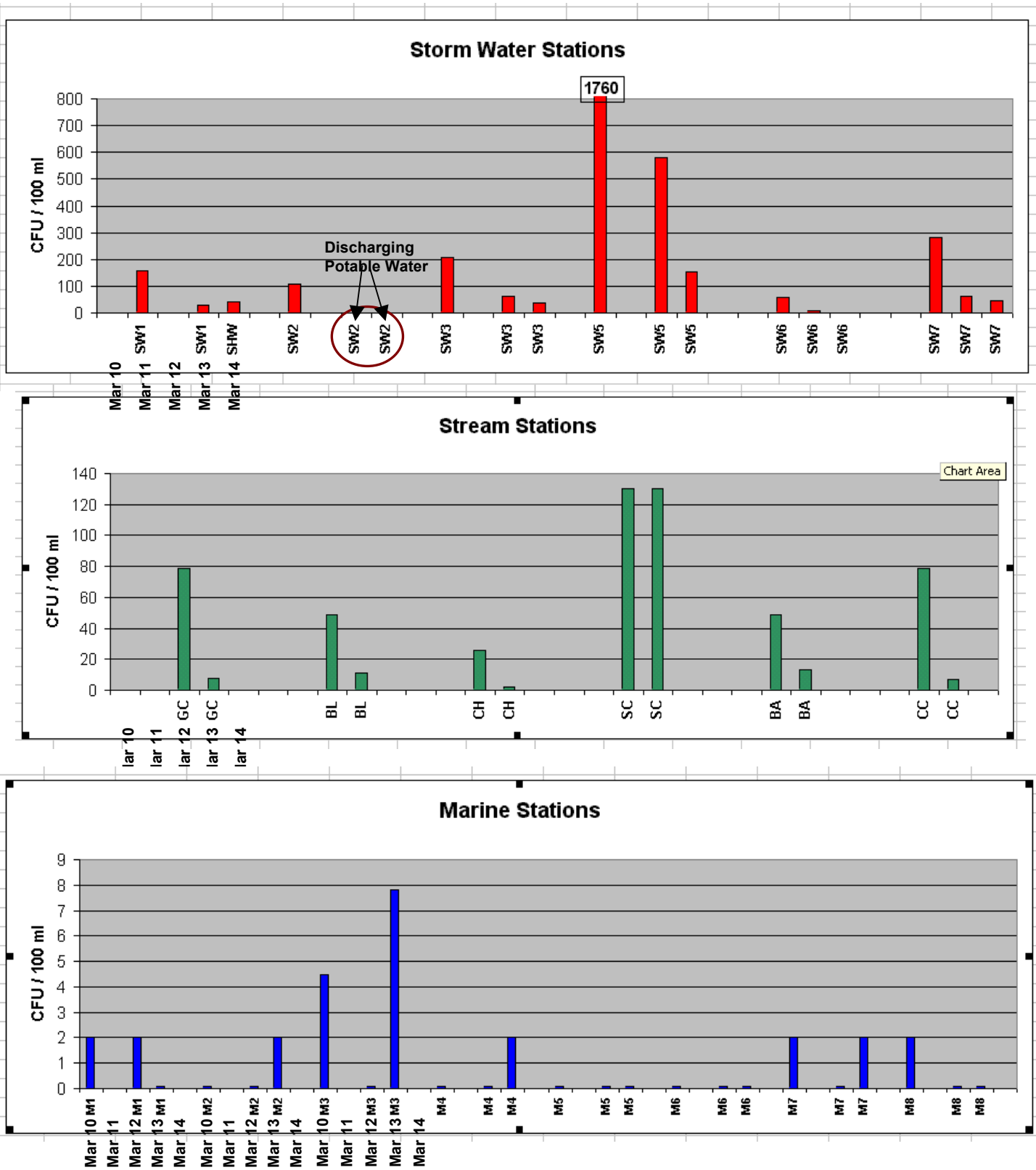
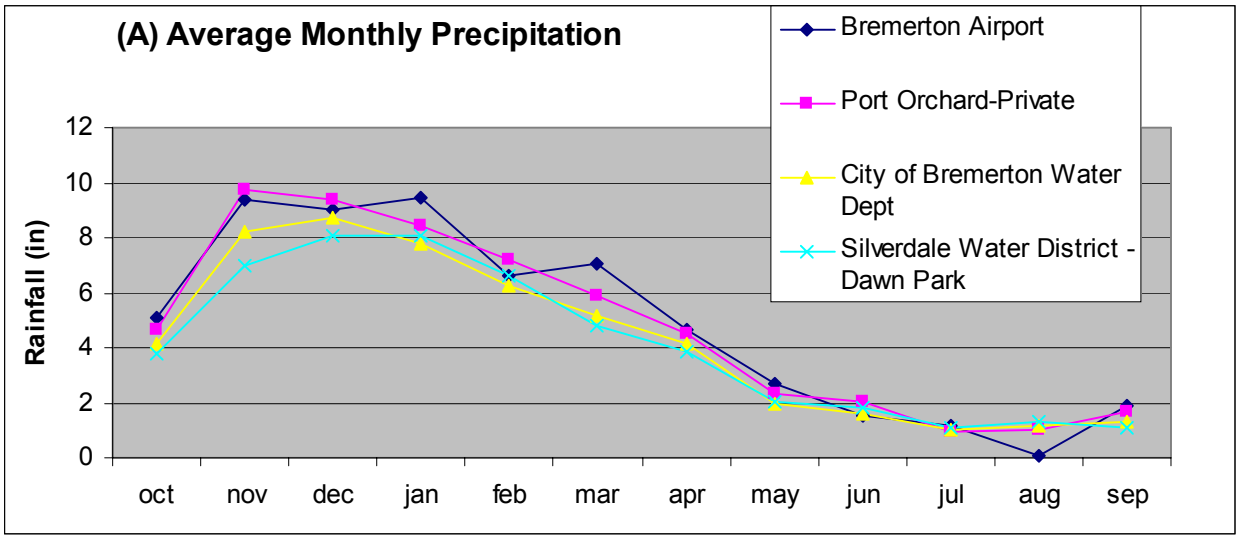


Figure 15. Results of winter base flow sampling for fecal coliform bacteria collected at storm water, stream, and marine stations from March 10-14, 2002. Note samples are plotted by date for each station from March 10-14, 2002.



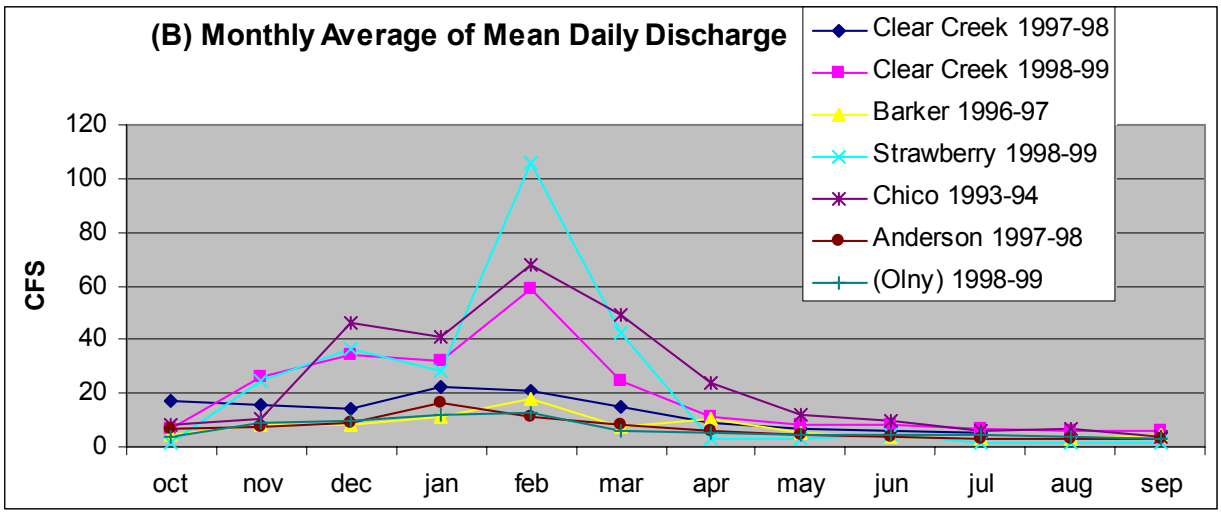


Figure 16. (A) Monthly average precipitation (in, ten year average) and (B) monthly average of mean daily discharge (CFS) recorded at selected stations within the study area. Data from KPUD 2000.

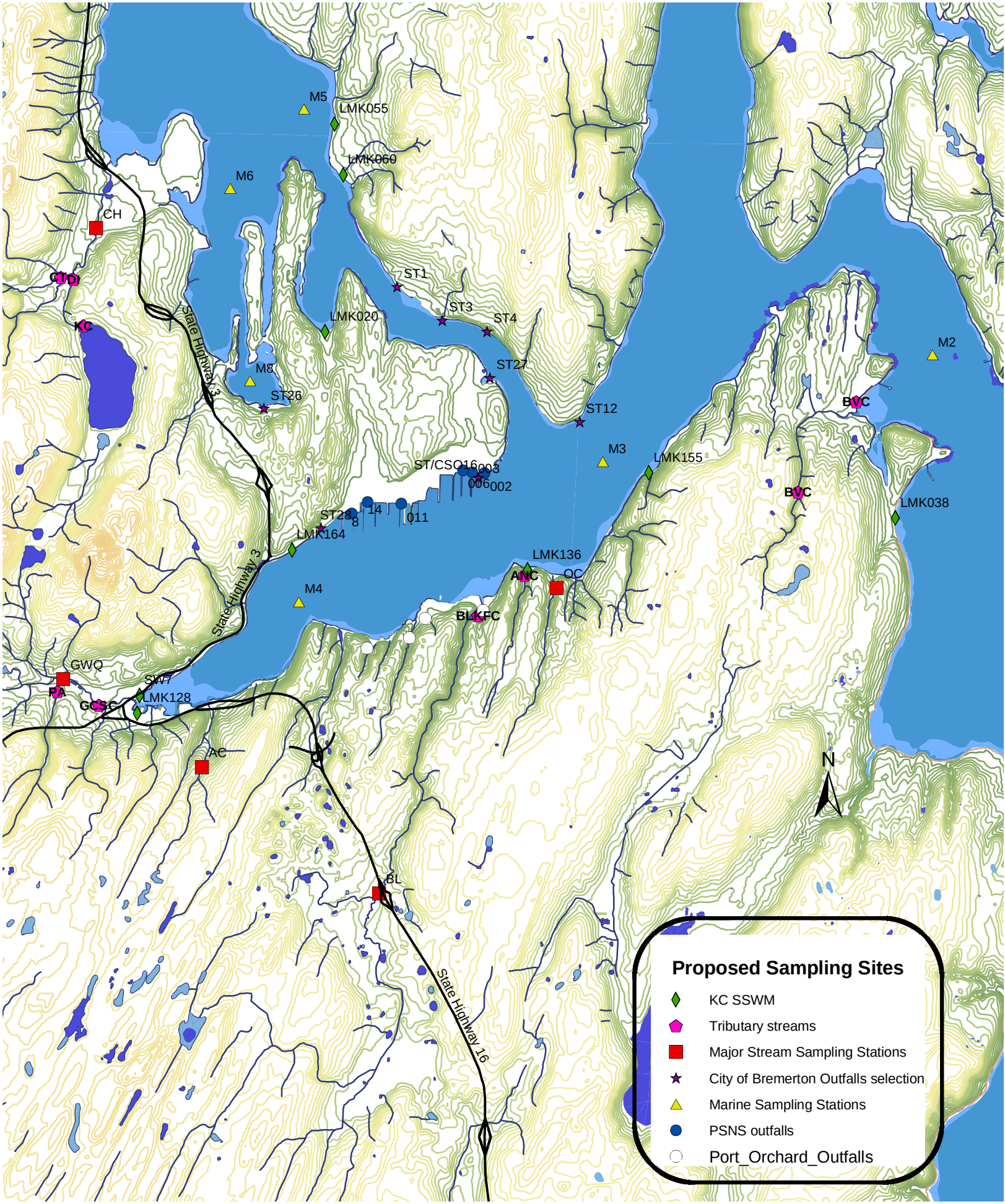


Figure 17 Proposed sampling stations in Sinclair Inlet * Nearshore stations shown on Figure 19.

Text

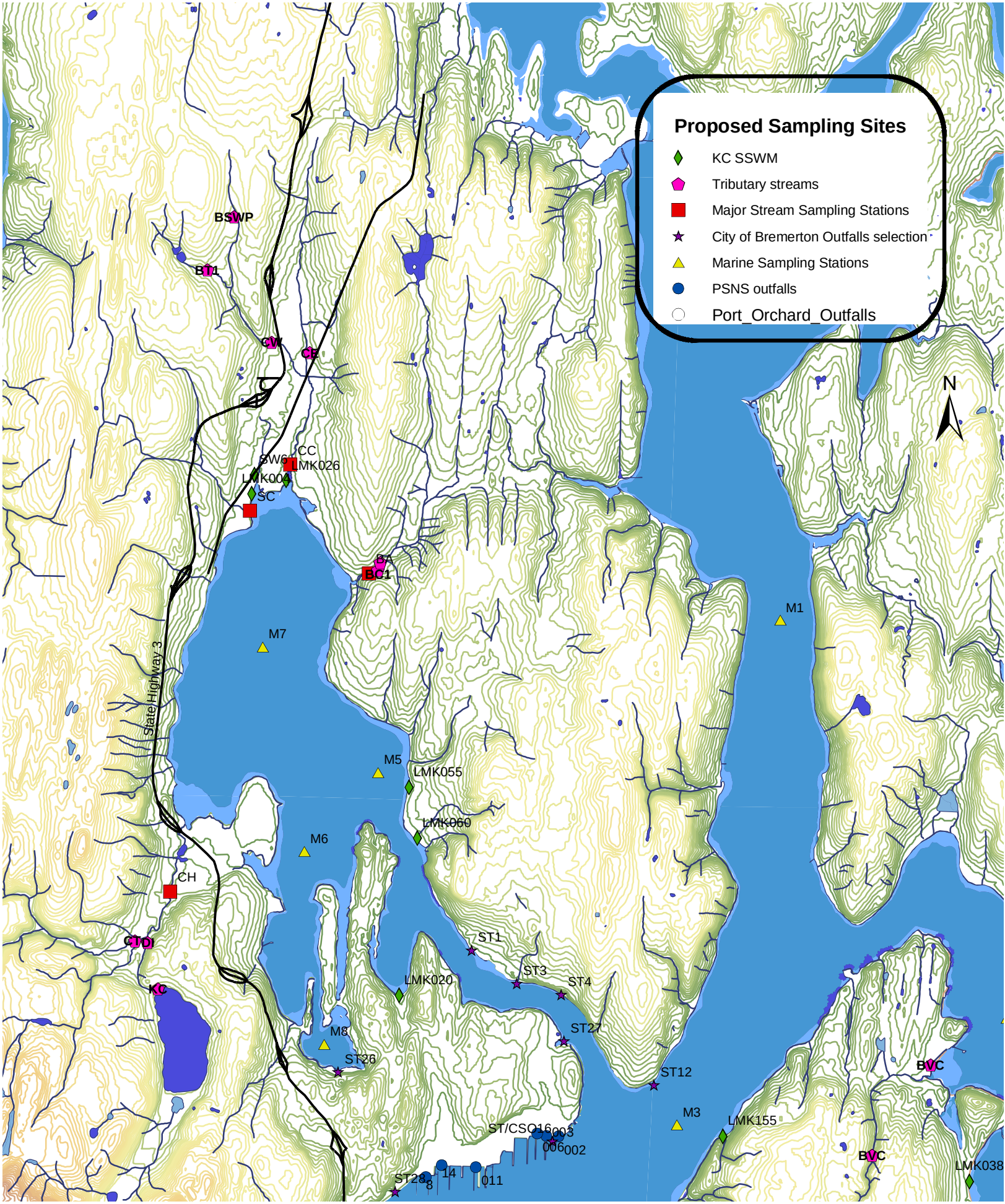


Figure 18 Proposed sampling stations in Dyes Inlet * Nearshore stations shown on Figure 19.

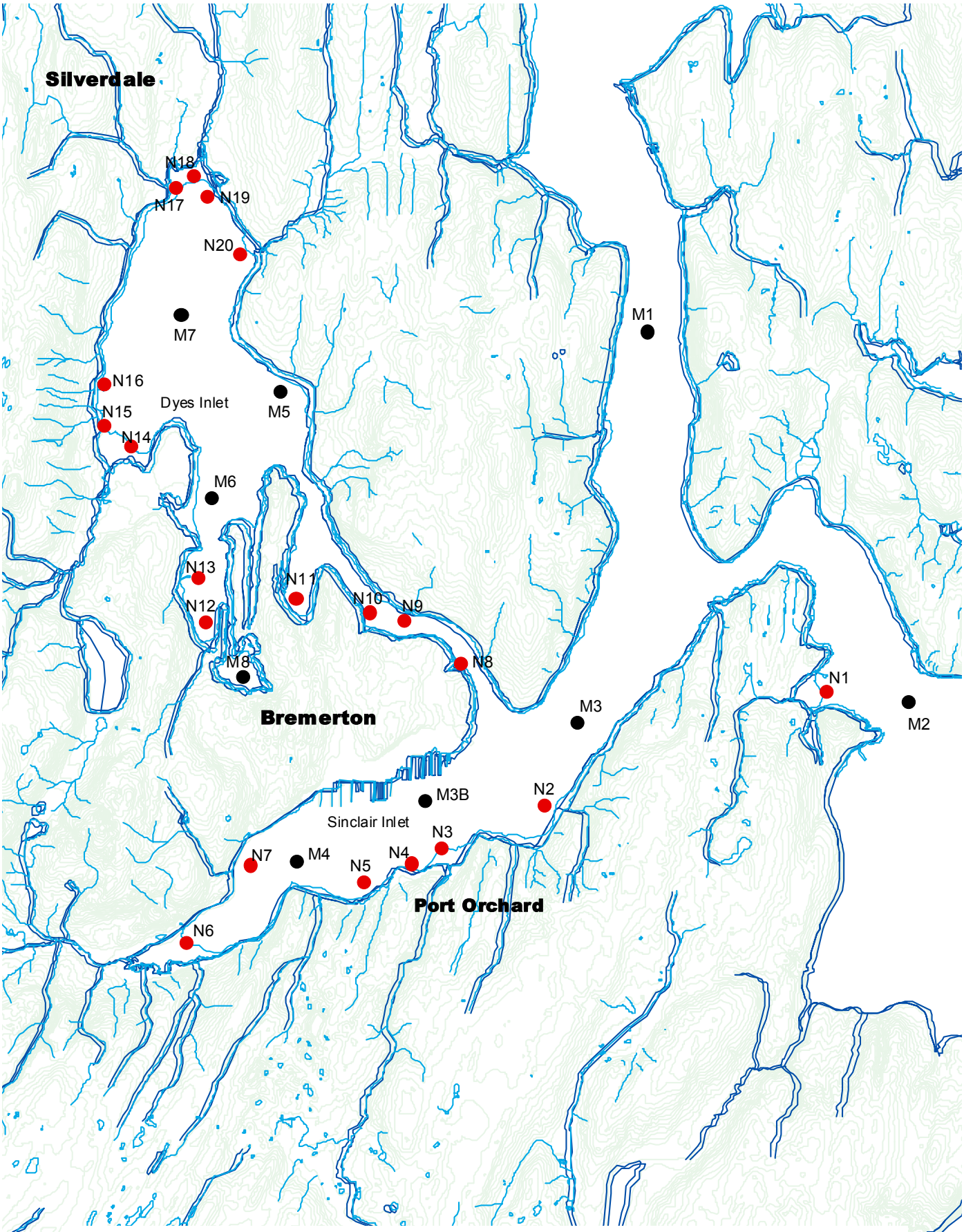


Figure 19. Proposed nearshore and marine sampling stations in Sinclair and Dyes Inlet.

REFERENCES

Aqua Tera 2001. Conceptual Design of Multipurpose Detention Facilities for Flood Protection and Nonpoint Source Pollution Control" prepared by Aqua Terra Consultants for the Santa Clara Valley Water District.

Brown, J. 2001 (ed). User's Guide For A Three-Dimensional Numerical Hydrodynamic, Salinity, and Temperature Model of Sinclair Inlet. July 2001.

Caltrans 2000. Guidance: Stormwater Monitoring Protocols (Revised). California Department of Transportation, CTSW-RT-00-005, Sacramento, CA. http://www.dot.ca.gov/hq/env/stormwater/special/

City of Bremerton, 2000. Cooperative Approach to CSO Reduction. http://www.cityofbremerton.com/index1.html

City of Tacoma, 2001. Thea Foss and Wheller –Osgood Waterways stormwater monitoring sampling and analysis plan. Prepared for Washington State Department of Ecology, Sept. 2001.

Choi, Woo-Hee, P.F. Wang, B.E. Skahill, R.K. Johnston, and Robert Ambrose, 2002.CH3D-WASP-A Linked Hydrodynamic and Water Quality Model. Paper to be presented American Water Resources Association (AWRA) 2002 Spring Specialty Conference, Coastal Water Resources, New Orleans, Louisiana, May 13-15, 2002

Dadswell, J.V. 1993. Microbiological Quality of Coastal Waters and its Health Effects. International Journal of Environmental Health Research 3: 32-46.

Johnson, B. H., Kim, K. W., Heath, R. H., Butler, H. L., and Hsieh, B. B. 1991. "User's Guide for a Three-Dimensional Numerical Hydrodynamic, Salinity, and Temperature Model of Chesapeake Bay," Technical Report HL-91-20, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Johnson, B.E., Z. Zhang, B.E. Skahill, H. Samaitis, J.D. Jorgeson, and P.N. Deliman, 2001. Hydrologic Simulation Program - FORTRAN (HSPF) Development, Calibration, and Verification Plan for the Sinclair/Dyes Inlet Watershed. July 31, 2001, Prepared For: Puget Sound Naval Shipyard Project ENVVEST.

Johnson, B.E., B.E. Skahill,, H. Halkola, Z. Zhang, 2002. Draft Anderson Creek Intercalibration Report. , Prepared For: Puget Sound Naval Shipyard Project ENVVEST. https://swdata.spawar.navy.mil/envvest/Reports/AndersonIntercalibration_5_7_2002.ZIP

Kendra, Will 2002. Strategy for Developing TMDLs for WRIA 15. Presentation at the PSNS Project ENVVEST Regulatory Working Group Meeting, June 20, 2002, Bremerton, WA 98312.

Lombard, S. and C. Kirchmer, 2001. Guidelines for Preparing Quality Assurance Project Plans for Environmental Studies. Ecology, Environmental Assessment Program, Manchester, WA. Publication No. 01-03-003. http://www.ecy.wa.gov/biblio/0103003.html

Maiolo, J.R. 1981. Relating Population Growth to Shellfish Bed Closures: A Case Study for North Carolina. *Coastal Zone Management Journal* 9(1): 1-18.

Mallin, M.A, K.E. Williams, E.C. Esham, and R.P. Lowe. 2000. Effect of Human Development on Bacteriological Water Quality in Coastal Watersheds. *Ecological Applications* 10(4): 1047-1056.

Mancini, J.L. 1978. Numerical Estimates of Coliform Mortality Rates Under Various Conditions. Journal WPCF (November), pp. 2477-2484.

McConnell, R.L. 1995. Human Population Carrying Capacity of Chesapeake Bay Watershed. *Journal of Population and Environment* 16(4): 339-352.

OSU 2001. EPA Storm Water Management Model (SWMM), Versions 4.31 and 4.4. Department of Civil, Construction, and Environmental Engineering, Oregon State University http://www.ccee.orst.edu/swmm/

Pelletier and Seiders, 2000. Grays Harbor Fecal Coliform Total Maximum Daily Load Study. Washington State Department of Ecology, 00-030-20, 110pp. http://www.ecy.wa.gov/biblio/0003020.html

Richter, K.E., 2002a. Verification of Hydrodynamics from CH3D Presentation at the PSNS Project ENVVEST Regulatory Working Group Meeting, June 20, 2002, Bremerton, WA 98312. https://swdata.spawar.navy.mil/envvest/Meetings/2002_06_20/KRichter_9196grid_vs_9183grid.ppt

Richter, K.E. 2002b. Dye Study Dye Dispersion. Presentation at the PSNS Project ENVVEST Regulatory Working Group Meeting, June 20, 2002, Bremerton, WA 98312. https://swdata.spawar.navy.mil/envvest/Meetings/2002_06_20/KRichter_dye_study.ppt

Scott, G.I. 1998. The Impacts of Urbanization on Shellfish Harvesting Waters: Development of Techniques to Identify Coliform Pollution Sources. Abstracts of Technical Papers from the International Conference on Shellfish Restoration, 1998, Hilton Head SC. Journal of Shellfish Research 17(4): 1312-1313.

Skahill, B.E. 2002. HSPF - Unified Model for Loading into Receiving Waters. Presentation at the PSNS Project ENVVEST Regulatory Working Group Meeting, June 20, 2002, Bremerton, WA 98312. https://swdata.spawar.navy.mil/envvest/Meetings/2002_06_20/Skahill_june_20_2002_.ppt

Shakill, B.E et al. in prep. A unified HSPF model to estimate loading from streams and storm water discharges into the receiving waters of Sinclair and Dyes Inlets. US Army Environmental Research and Development Center, Waterways Experiment Station, Vicksburg, MS.

US Navy, US EPA, and Washington State Department of Ecology 2000. Project ENVVEST: Phase I Final Project Agreement for the Puget Sound Naval Shipyard, September 25, 2000 [Federal Register: October 23, 2000 (Volume 65, Number 205)]. http://www.epa.gov/ProjectXL/puget2/fpasigned.pdf.

US Navy, US EPA, and Washington State Department of Ecology 2002. Puget Sound Naval Shipyard Project ENVVEST Technical Work Master Plan (Review Draft) May 10, 2002. https://swdata.spawar.navy.mil/envvest/tech_master_plan_06_f2_web2b.pdf

Vandervoort, D. 2001. GIS analysis for watershed assessment. Presentation for the PSNS ENVVEST Modeling Technical Working Group Meeting, Aug 29-30, 2001, Naval Subase Bangor, Wa. https://swdata.spawar.navy.mil/envvest/Meetings/2001_08_29/Vandervoort_8-30.ppt

Ward, W. (ed) 2001. Stream Sampling Protocols for the Environmental Monitoring and Trends Section. October 2001, Washington State Department of Ecology. Publication No. 01-03-036. http://www.ecy.wa.gov/biblio/0103036.html

Wang, P.F and K.E. Richter 1999. A Hydrodynamic Modeling Study Using CH3D for Sinclair Inlet, Draft Report. Space and Naval Warfare Systems Center, San Diego, CA, November 3, 1999.

Wang, PF 2002. CH3D-FC Model Calibration and Verification from Dye Study Presentation at the PSNS Project ENVVEST Regulatory Working Group Meeting, June 20, 2002, Bremerton, WA 98312. https://swdata.spawar.navy.mil/envvest/Meetings/2002_06_20/PF_Wang_dye_study_drogues.ppt

Washington Department of Health (DOH). 2001. 2000 Annual Inventory of Commercial and Recreational Shellfish Areas of Puget Sound.

Weiskel, P. K., B.L. Howes, and G.R. Heufelder. 1996. *Environmental Science and Technology* 30(6): 1872-1881.

White, N.M., D.E. Line, J.D. Potts, W.K. Smith, B.B. Doll, and W.F. Hunt. 2000. Jump Run Creek Shellfish Restoration Project. *Journal of Shellfish Research* 19(1); 473-476.

Young, K.D. and E.L. Thackston. 1999. Housing Density and bacterial Loading in Urban Streams. *Journal of Environmental Engineering* 1177-1180.

Washington State 1997a. Chapter 173-201A WAC, Water Quality Standards For Surface Waters Of The State Of Washington. http://www.ecy.wa.gov/biblio/wac173201a.html see also: http://search.leg.wa.gov/wslwac/WAC%20173%20%20TITLE/WAC%20173%20-201A%20CHAPTER/WAC%20173%20-201A%20Chapter.htm

Washington State 1997. WAC 173-201A-030 General water use and criteria classes. http://search.leg.wa.gov/wslwac/WAC%20173%20%20TITLE/WAC%20173%20-201A%20CHAPTER/WAC%20173%20-201A-030.htm

Washington State 1997. WAC 173-201A-140 Specific classifications -- Marine water. http://search.leg.wa.gov/wslwac/WAC%20173%20%20TITLE/WAC%20173%20-201A%20CHAPTER/WAC%20173%20-201A-140.htm

Washington State Department of Ecology (WDOE) 1996. Total Maximum Daily Load Development Guidelines. TMDL Workgroup, Ecology 97-315. http://www.ecy.wa.gov/biblio/97315.html

WDOE 1998. Final 1998 Section 303(d) List -WRIA 15. http://www.ecy.wa.gov/programs/wq/303d/1998/wrias/wria15.pdf

WDOE 1999a. Guidance Document for Developing Total Maximum Daily Loads (TMDLs) -- Water Cleanup Plans. http://www.ecy.wa.gov/biblio/9923.html

WDOE 2001a. Water Quality Program Responsiveness Summary Fiscal Year 2001 TMDL Priority List. http://www.ecy.wa.gov/pubs/0110053.pdf

WDOE 2001b. Focus: Priority Water Cleanup Plans for Fiscal Year 2001. http://www.ecy.wa.gov/pubs/0010052.pdf

WDOE 2001c. 2002 Section 303(d) List Issue Papers. http://www.ecy.wa.gov/programs/wq/303d/2002/issuepprs.html

WDOE 2002. 303d Scoping Summary for Sinclair and Dyes Inlets and Watershed. Prepared by Washington State Department of Ecology.

WDOE 2002. Manchester Environmental Laboratory Quality Assurance Manual.

Washing State Department of Health 2001. Status and Trends in Fecal Coliform Pollution in Puget Sound Year 2000. Office of Food Safety and Shellfish Programs. A Report for the Puget Sound Ambient

Monitoring Program http://www.doh.wa.gov/ehp/sf/Pubs/fecalreport00.pdf

Appendices

Appendix A. Analysis of DOH Data

Marine Data: Appendices\DOH_FC_DataSummary

Appendix B. Analysis of BKCHD Data

Marine Data: Appendices\BKCHD_FC_NearshoreSummary
Stream Data: Appendices\BKCHD_FC_StreamSummary

Appendix C. Analysis of SSWM Data

SSWM Fecal Data Report: Appendices\SSWM_fecal_Data.PDF

Appendix D. Fecal Coliform data from winter base flow sampling March 10-14, 2002.

Raw Data: Appendices\BaseflowFecal\Fecal_data_raw

Appendix E. Hydrological Stations

Precipitation Stations: Appendices\PrecipStations2000

Stream Stations: Appendices\SGSPSNSb

Appendix F. Fecal Coliform Sampling Plan and Cost Estimate

Stations and FC Samples: Appendices\FC_sampling_plan_09_03

Appendix G. Flow Measurement Sampling Plan and Cost Estimate

Equipment and Cost Estimate: Appendices\FC_sampling_plan_09_03

Appendix H. Project Specific SOPs

2. Washington State Department of Ecology, Manchester Laboratory

Standard Operating Procedure for Fecal Coliforms Membrane Filter Technique, Standard Method 9222 D, Modified, 20th Edition

3. Appendix Bremerton Kitsap County Health District

Bremerton-Kitsap County Health District On-Site Sewage / Water Quality Program: WATER QUALITY TREND MONITORING PLAN, STREAMS AND MARINE WATERS

Analysis Methods, Detection Limits, and Accuracy

Parameter	Method of Analysis	Method Detection Limits	Accuracy
Fecal Coliform Bacteria	APHA Procedure 9221-E, MPN Fecal Coliform Direct Test (A-1 Medium)	2 to 1,600 col/100 mL (without dilution)	1 col/100 mL
Temperature	Field Meter: Hydrolab Model #H20, Temperature sensor	-5 to 50° C	$\pm$ 0.1^{o} C
PH	Field Meter: Hydrolab Model #H20, pH probe / redox sensor	0 to 14 units	$\pm$ 0.1 units
Dissolved oxygen	Field Meter: Hydrolab Model #H20, Clark cell w/standard flow membrane	0 to 20 mg/L	$\pm$ 0.01 mg/L
Specific Conductance	Field Meter: Hydrolab Model #H20, six electrode sensor	0 to 100 µmho/cm	$\pm$ 1 µmho/cm
Turbidity	Field Meter: Hydrolab Model #H20, nephelometric and ratio	0 to 1000 NTU	$\pm$ 5 NTU
Salinity	Field Meter: Hydrolab Model #H20, six electrode sensor	0 to 70 ppt	0.2 ppt

4. Kitsap County Surface and Storm Water Monitoring (SSWM)

SSWM WQ Laboratory Test Procedures

Samples for Microbiological Examination

5. **Appendix H.3 Washington State Department of Health**

Modified A-1 Fermentation Test for Fecal Coliforms (A-1 Procedure) MPN

Appendix H.4 City of Bremerton

Appendix I. Response to Comments

Response to Comments Received on draft of 19 June 2002 from Mindy Roberts, Ecology: Appendices\ResponesMindyRoberts_____

Response to comments on revised draft received on September 11, 2002 from Will Kendra: Appendices\ResponesWill_Kendra_____