Henderson Inlet Fecal Coliform Total Maximum Daily Load

Water Quality Effectiveness Monitoring Report

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Henderson Inlet
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Water Quality
Effectiveness Monitoring Report

by

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Water Resource Inventory Area (WRIA) and 12-digit Hydrologic Unit Code (HUC) number for the study area:

- WRIA: 13-Deschutes River
- HUC number: 171100190502-Puget Sound

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Abstract

Results of a 2013-2014 TMDL effectiveness monitoring study in the Henderson Inlet watershed indicate that fecal coliform bacteria (FC) levels are declining at the watershed and sites level, although FC standards were met only at 1 of the 20 sampling locations. This FC reduction occurred despite an increase in human population in the watershed and an increase in parcel density within the urban growth areas. Of the 6 waterbodies with sufficient data to evaluate long-term FC trends, only Dobbs and Fleming Creeks showed increasing FC trends over time. Sleepy, Goose, Woodland, and Woodard Creeks all indicated declining FC trends.

An assessment of two state funding programs indicates that between 1990 and 2014 a total of $22 million in state and federal grants and loans were given to recipients to implement 42 water cleanup, restoration, or protection projects in the watershed. Of the 11 recipients, Thurston County and the Washington State Department of Natural Resources implemented the most projects and accounted for 63% of the total funds invested.

All these projects likely benefit surface waters to some degree. But a comparison of projects implemented in the watershed and water quality trend data suggests that stormwater retrofits, septic-to-sewer projects, and land acquisition projects are likely responsible for the majority of the FC declines. Nonpoint source issues in non-urban areas and stormwater in the upper watershed are still problematic in certain areas.

Many of the improvements outlined in this report are the result of coordination between Thurston County, the City of Lacey, and the City of Olympia. The successful implementation of the water quality improvement plan and subsequent assessment of effectiveness can be attributed to up-front investments in planning and Thurston County's long-term monitoring programs.

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Background

Henderson Inlet and several streams in the Henderson basin are on the 2012 303(d) list of impaired waterbodies that are not meeting one or more Washington State water quality bacteria standards (Figure 1). To address the listings, the Washington State Department of Ecology (Ecology) conducted a total maximum daily load (TMDL) study in the basin from 2003 to 2005 (Sargeant et al., 2003). The 2006 TMDL study found high fecal coliform bacteria (FC) concentrations throughout the watershed (Sargeant, 2006). The TMDL wet-season load estimates suggested 80% of the FC load to Henderson Inlet was Dobbs and Woodland Creeks while 77% of the dry-season load was from Woodland Creek.

The Henderson Inlet TMDL implementation strategy set load allocations for reducing FC at several locations and identified priority actions to reduce FC loads to the basin (Ecology, 2008). Many of the pollution control methods included in the recommendations for FC were also suggested to help reduce nutrient inputs into the watershed. Since completion of the original TMDL study, both local governments, together with local citizen groups, have been actively involved in water quality protection and cleanup actions. Cleanup actions have included a combination of:

- Improved management of stormwater discharges.
- Implementation of an onsite sewage system (OSS) operations and maintenance program.
- Source investigation including OSS surveys, water quality monitoring, and visual surveys of land use and management practices.
- Conversion from OSSs to sanitary sewer systems.
- Technical assistance to landowners.
- Informational workshops and other outreach.
- Protection and restoration of shoreline areas.
- Improved agricultural practices.

In 2013, Ecology's Water Quality Program determined that most of the priority actions outlined the TMDL implementation plan had been completed (Ecology, 2008). Overall, 24 of the 33 actions identified have been implemented 14 of which were identified as high priority (Table B-1). Based on this information, Ecology began an effectiveness monitoring study in 2014 to determine if FC target reductions and water quality standards were being meet (Collyard and Anderson, 2014). As part of this study, a list of water cleanup, restoration and protection projects was compiled and compared with water quality data. The overall intent of this assessment was to contribute to the adaptive management process by attempting to provide:

- Measures of progress toward implementation of recommendations, i.e., level of watershed restoration achieved and level of effort still required.
- More efficient allocation of funding and optimization in planning and decision-making.
- Identification of restoration activities that worked well and those that were most cost-effective.
- Technical feedback to refine the initial TMDL model, best management practices, nonpoint source plans, and permits.

Because assessing effectiveness is difficult for large scale cleanup or restoration efforts, a weight-of-evidence approach was used to develop conclusions and future recommendations (Collyard and Onwumere, 2013). A weight-of-evidence approach relies on correlative data to suggest causation (Diefenderder et al., 2011). While evaluating the data, we addressed the following questions to determine causation:

Did the landscape change over time?

- Evaluate changes in land uses and human population between years using Geographical Information System (GIS) data.

Did FC concentrations change over time?

- Determine if water quality standards are being meet.
- Evaluate percent change relative to FC water quality standards between years.
- Evaluate target FC reductions relative to observed reductions.
- Evaluate seasonal trends in water quality data over time at basin, subbasin, and site scale using all available data.
- Evaluate trends at long-term monitoring stations using data collected by stakeholders.

Did other changes in water quality occur over time?

- Measure seasonal and long-term trends in nutrient concentrations over time.

Was improvement in water quality tied to water cleanup effort in the watershed?

- Compare the timing of changes in water quality with the timing of changes in land use and implementation efforts over the project history.
- Use biological assessment above and below known projects and compare results.

Although many of these comparisons are correlative they still can provide meaningful data for informing the adaptive management process. In addition, by identifying areas of overlap between water cleanup and restoration efforts, we may employ a more holistic approach to restoring and protecting ecosystem function at a watershed scale.

Study Area

Henderson Inlet, located in Thurston County, is one of five inlets that form the southern terminus of Puget Sound. It is located between Budd Inlet on the west and Nisqually Reach on the east (Figure 1). The five-mile-long inlet ranges from 0.25 to 0.75 miles in width, averaging about 25 feet in depth. A large portion of the lower inlet is exposed mudflats at low tide. Since the 1980s, commercial shellfish harvesting in the lower third of Henderson Inlet has been prohibited or restricted due to high FC concentrations in the water. Tidal elevations in this area (South Puget Sound) range from +16 to -4 feet from the 0 foot level (Cleland, 2000).

The 30,000-acre Henderson Inlet hydrological unit code (HUC) 12 is the second largest basin in Water Resource Inventory Area (WRIA) 13. Woodland and Woodard Creeks are the largest of the five main tributaries to Henderson Inlet, draining 80% of the basin. The other three streams in the watershed−Dobbs Creek (East Creek), Meyer Creek (Snug Creek), and Sleepy Creek−drain small areas of the Dickerson Point and Johnson Point peninsulas.

Woodland Creek, draining an area of approximately 29.7 square miles (76.8 square kilometers), is the largest creek draining to Henderson Inlet. The creek flows through the City of Lacey urban growth area (UGA) and unincorporated Thurston County before emptying into Henderson Inlet (Figure 1). Three lakes connected by extensive wetlands make up the headwaters of Woodland Creek. From Lake Lois to Martin Way, Woodland Creek is an intermittent channel that often dries up during the summer. Downstream of Martin Way, several springs provide perennial flow to lower Woodland Creek. Woodland Creek tributaries include College, Eagle, Palm, Fox, Jorgenson, and Quail Creeks (Figure 1).

Woodard Creek (Figure 1), the second largest creek in the Henderson basin, is 7.5 miles in length and drains a 5,090-acre basin (Thurston County PHSS and WWM, 2000). Groundwater feeds a large wetland at the headwaters of Woodard Creek just south of Interstate-5 at the Pacific Avenue interchange. Industrial and commercial development on Fones Road surrounds the wetland at the creek's headwaters. Stormwater from large portions of high-density commercial areas in Lacey and Olympia, including South Sound Mall and Olympia Square, is directed through two stormwater facilities before discharging into the Taylor Wetlands through the Fones Road ditch. The mouth of Woodard Creek is an estuarine wetland that is currently protected as a natural area by the Washington State Department of Natural Resources.

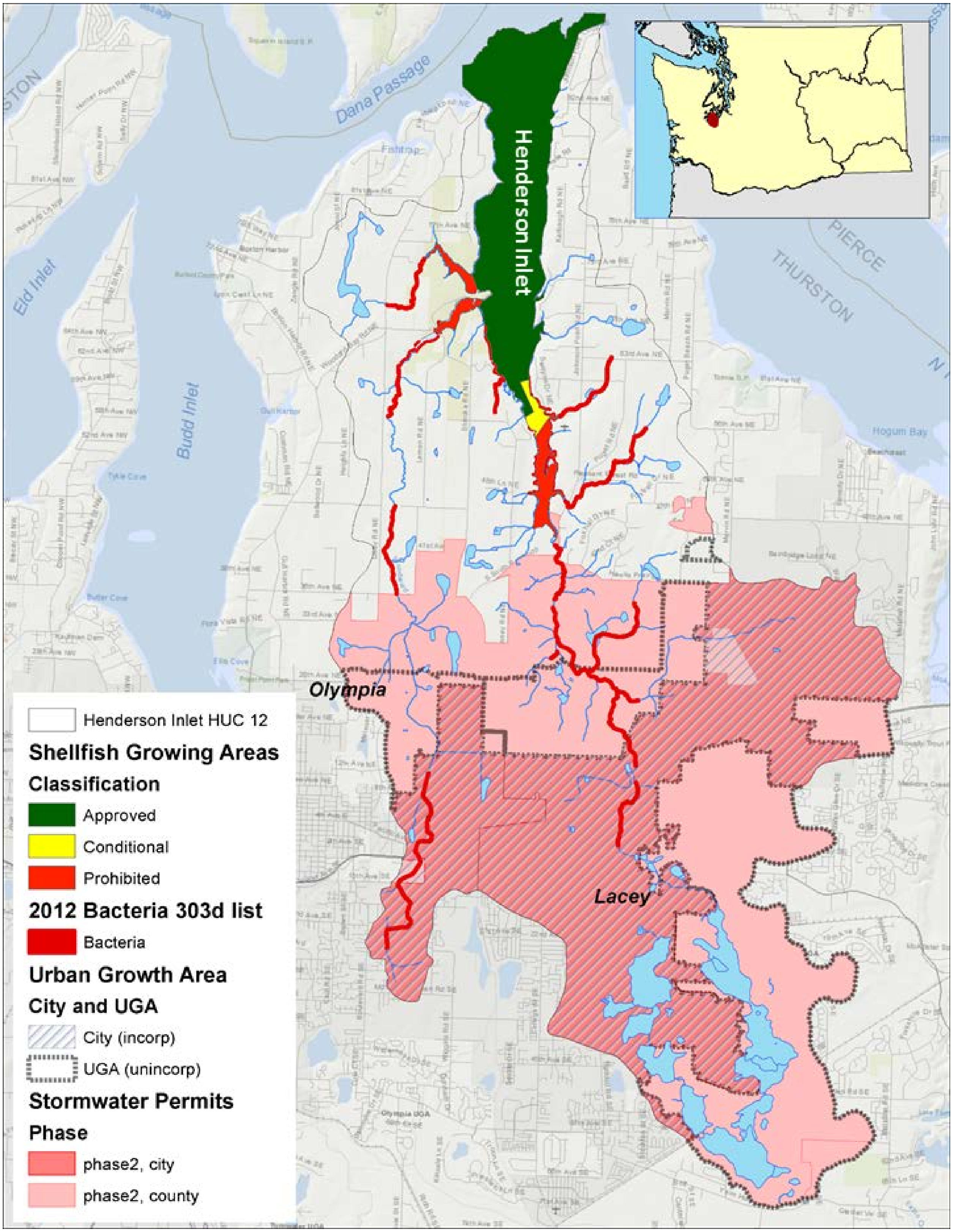

Figure 1. Henderson Inlet study area and Washington State Department of Health shellfish growing areas.

Much of the Woodland Creek subbasin lies within the City of Lacey, and to a lesser degree, in the Olympia urban growth area (Thurston County, 2007a). The basin still contains substantial areas of undeveloped forests, although the dominant land use is residential development. Residential subdivisions have expanded rapidly in the area around the headwater lakes and near the mouth of the stream basin. Residential development is most dense in the southern (upper) portion of the basin. Population in the Henderson Inlet watershed steadily increased between 1999 and 2010 and is expected to continue growing (Figure 2).

A complete description of Woodland Creek and Woodard Creek subbasin geology, soils, hydrology, vegetation, fish habitat, and critical areas can be found in the *Woodland and Woodard Creek Comprehensive Drainage Basin Plan* (Thurston County, 1995) and the *Current Conditions Report Woodland Creek Pollutant Load Reduction Project* (Pacific Groundwater Group and Brown and Caldwell, 2007a).

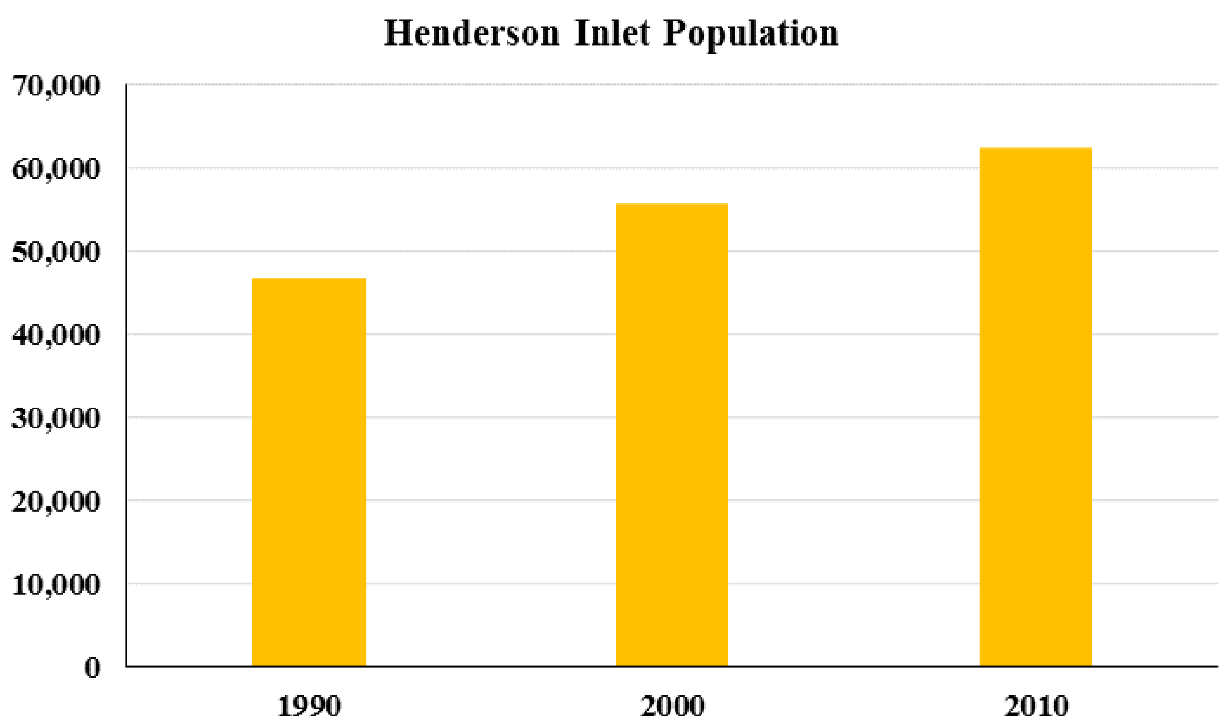

Figure 2. Population in the Henderson Inlet watershed from 1990 to 2010 based on census data.

Stormwater

Local governments and other public entities that collect and discharge stormwater runoff from municipal storm sewer systems are required to have a permit under the National Pollutant Discharge Elimination System (NPDES) program of the federal Clean Water Act. The overall intent of the permit program is to reduce water pollution caused by stormwater runoff.

The permits were established in two phases: Phase I permits apply to the most-populated cities and counties in Washington, while the Phase II permit covers small and medium-sized jurisdictions. The Cities of Lacey and Olympia, and the most urbanized portions of Thurston County, are covered under the Phase II Western Washington Municipal Stormwater Permit (Ecology, 2014a).

Under the Permit, each jurisdiction is required to develop and implement a Stormwater Management Program (SWMP) Plan. The SWMP Plan outlines the actions permittees will take to reduce the discharge of pollutants from stormwater in order to protect water quality. The plans include the following main components:

- Public Education & Outreach
- Public Involvement and Participation
- Illicit Discharge Detection & Elimination (IDDE)
- Construction Site Erosion and Sediment Control
- Controlling Runoff from Development Sites
- Municipal Operations and Maintenance
- Monitoring
- Planned actions to meet applicable Total Maximum Daily Load (TMDL) requirements

Thurston County and the cities of Lacey and Olympia all manage nonpoint sources of pollution in the Henderson Inlet watershed.

Many of the programmatic components outlined under the SWMP Plans are consistent with implementation objective of the Henderson Inlet TMDL. Phase II permits contain additional requirements for TMDLs within the geographic scope of the permit (Figure 1). A list of required actions outlined in the Phase II permit specific to the Henderson Inlet TMDL are presented in Appendix B.

Land Use

Land and water resources are essential for sustaining local economies as well as ecological function. Land use planning is a tool allowing local governments to regulate and manage the use and development of land within their jurisdictions.

Changes in land uses over time may have a measurable effect on water quality that should be considered when assessing the effectiveness of pollution prevention and watershed restoration actions. Classifying land uses by parcel based on the type of activity that occurs on the parcel provides planners with a consistent model for classifying and regulating land uses. This in turn allows watershed planners, regulators, and landowners to apply appropriate regulations to land use activities in order to protect water quality and resources as well as other natural resources. Land use planning is essential not only for maintaining and protecting surrounding natural resources but also for economic growth and development.

Parcel counts and land use for 2014 in the Henderson Inlet watershed (HUC 12) were summarized based on 2014 Thurston County tax parcel layers (Figure 3). Parcel counts and classified land use as a percentage of the total watershed are listed below:

- Total parcels: 20,022
- Parcel size range: < 0.5 – 221 acres
- Residential: 46%
- Undeveloped: 22%
- Trade & services: 7.3%
- Agricultural: 3.2%

Changes in land use between 2006 and 2014 were estimated by subtracting total parcel area in acres for each land use group between years. Land use data from 2006 and 2014 were obtained from digital county tax parcel codes (WAC 458-53-030). Parcel attribute data was stratified into 10 major land use groups. Total area for each land use group was estimated for both years using Geographical Information System (GIS) analysis (Table D-1). It is important to note that in some cases differences in land-use classification may not represent actual change in land use. Classification may change based on reporting errors or other reasons.

Between 2006 and 2014 major land use categories which increased in land coverage (acres) within the watershed included *culture-recreation, undeveloped, residential, and manufacturing*. Major land categories that decreased in size over time included *open space*, *wholesale-retail trade*, *private forest*, *agriculture*, *parks* and *services* (Figure 4). The total number of parcels in the watershed increased by 1515 between 2006 and 2014 and indicates an overall increase in parcel density.

A detailed assessment of land use change within tributary subbasins between 2006 and 2014 is provided in Appendix E of this report.

Results of a parcel hot spots analysis indicates parcel density is highest within the urban growth area (UGA) and indicates the majority of residential growth has been confined within the boundary of the UGA (Figure 5). To assess where residential development is occurring within the basin, a hotspot analysis was performed with GIS and 2014 parcel area data within the watershed. The resulting analysis produces a map identifying locations of statistically significant hot (red) and cold (yellow) spots based on parcel density (Figure 5). A high Z score (>1.64) for a feature indicates parcel density is significantly different when compared to surrounding parcel sizes. A low negative Z score (<1.64) value indicates a significant cold spot. The higher the Z score, the more intense the clustering or parcel density. Areas in this figure without Z scores indicate large parcels and were not included in the analysis.

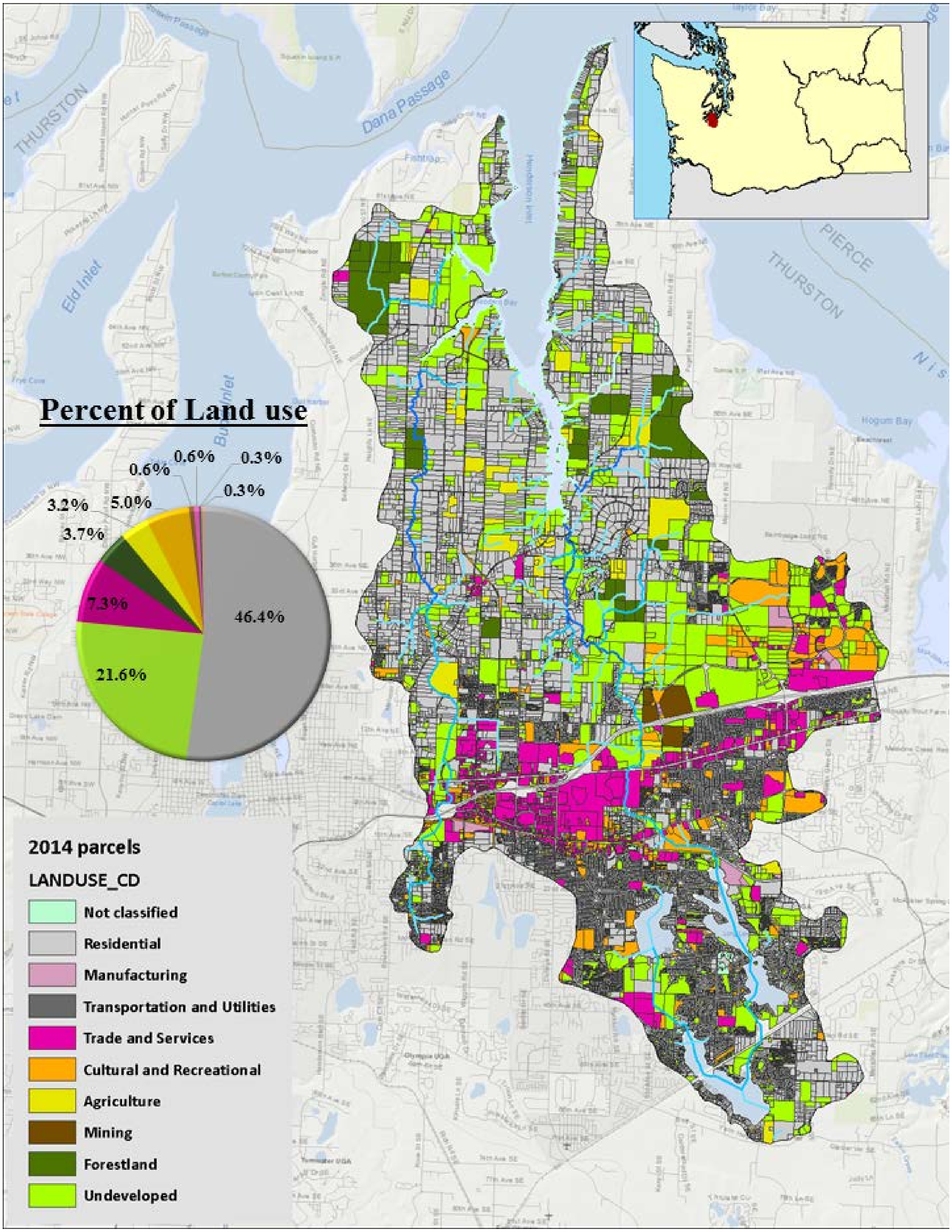

Figure 3. Land uses in the Henderson Inlet (HUC 12) watershed based on 2014 data.

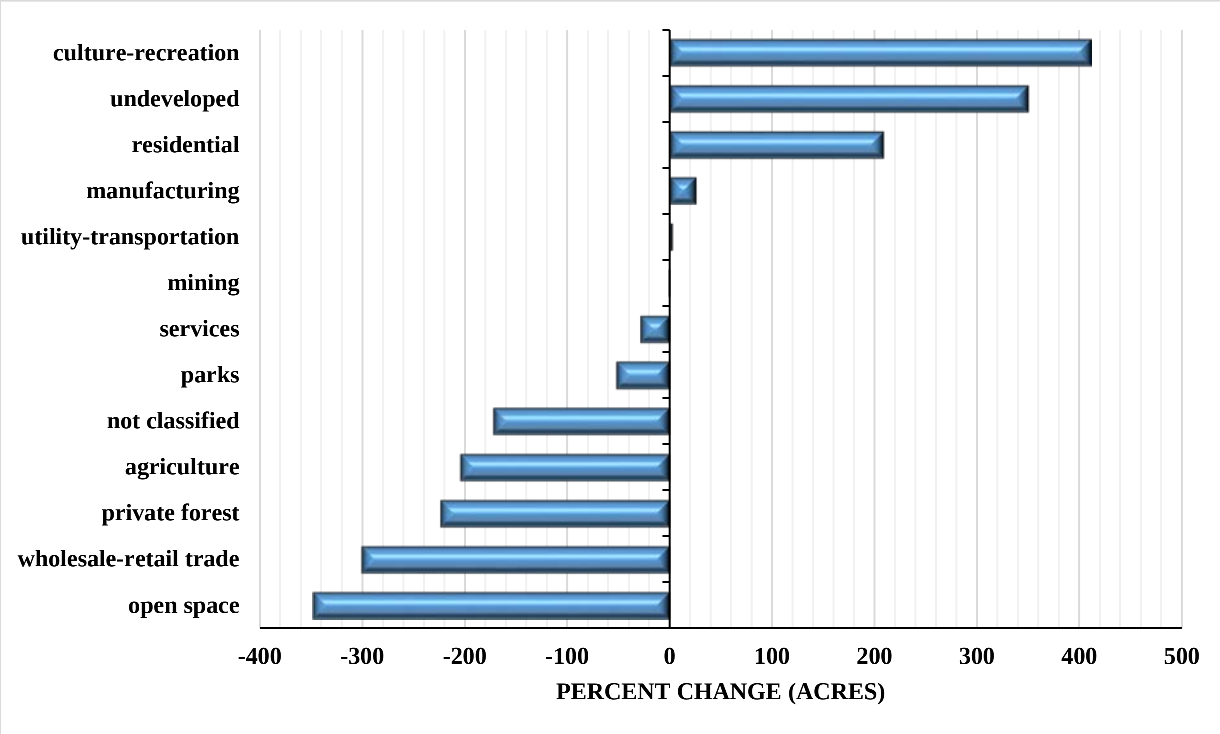

Figure 4. Percent change in acres of land use types, 2006-2014.

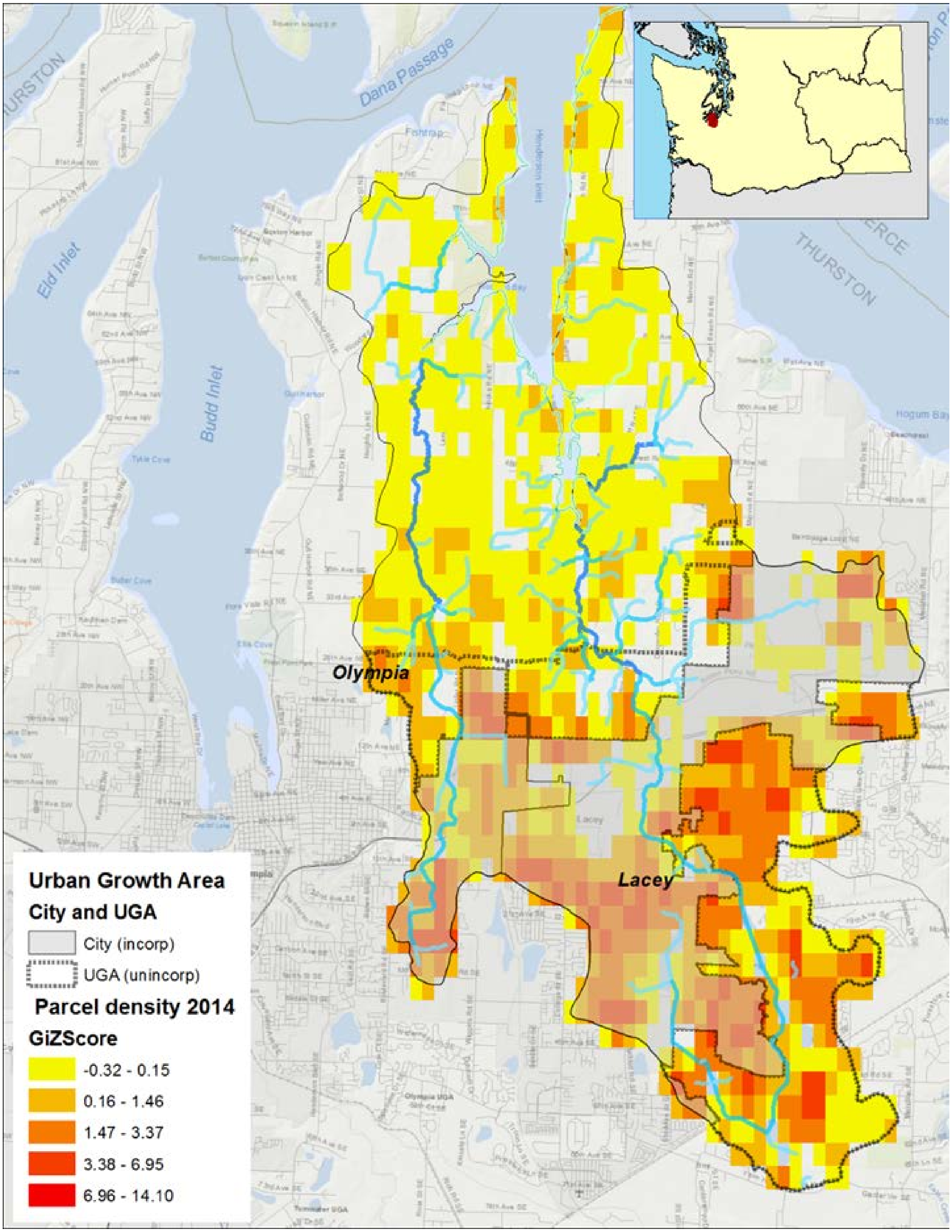

Figure 5. Results of GIS hotspot analysis of parcel size in the Henderson Inlet (HUC 12) watershed.

Water Quality Classifications

Henderson Inlet is designated *Extraordinary* quality marine water. Its beneficial uses include Extraordinary aquatic life use and primary contact recreation, including shellfish harvest. The *Extraordinary Primary Contact* designation in both fresh and marine waters means these waters are to provide extraordinary protection against waterborne disease or serve as tributaries to extraordinary quality shellfish harvesting.

Tributaries to Henderson Inlet are considered *Extraordinary* quality water and in addition to primary contact recreation are protected for the designated uses of salmon and trout spawning, core rearing, and migration.

Table 1 shows the Category 4A, and 2 FC listings on the state Water Quality Assessment for FC in the Henderson Inlet watershed, approved by EPA in 2012 (Ecology, 2014b). See Figure 1 for locations of Category 4A 303(d) listed streams. A full list of water quality impairments is available in Washington's Water Quality Assessment (WQA) 303(d)/305(b) Integrated Report Viewer: https://fortress.wa.gov/ecy/approvedwqa/ApprovedSearch.aspx.

The WQA tells a more complete story about the condition of Washington's water. This list divides waterbodies into five categories:

Category 1 – Meets standards for the parameter (or parameters) for which it has been tested
Category 2 – Waters of concern
Category 3 – Waters with no data available
Category 4 – Polluted waters that do not require a TMDL because:
- 4a. – Has an approved TMDL and it is being implemented
- 4b. – Has a pollution control plan in place that should solve the problem
- 4c. – Is impaired by a non-pollutant such as low water flow, dams, culverts

Category 5 – Polluted waters that require a TMDL – the 303(d) list.

The uses will be protected by ensuring that the waterbodies in Table 1 meet applicable water quality standards.

Table 1. Henderson Inlet and tributaries on the 2012 303(d) list and impaired waterbodies that do not meet FC water quality standards.

Waterbody Name	Category	WBID Code	Town/Range/ Section	Assessment Listing ID
College Creek	4A	17110019021476	18N-1W-9	45296
College Creek	4A	17110019021475	18N-1W-15	45297
Eagle Creek	4A	17110019007953	18N-1W-4	45287
Fleming Creek	4A	17110019007538	19N-1W-21	45124
Fox Creek	4A	17110019007897	18N-1W-4	45286
Jorgenson Creek	4A	17110019007870	18N-1W-4	45288
Myer Creek	4A	17110019007518	19N-1W-20	45546
Palm Creek	4A	17110019007929	18N-1W-4	45295
Quail Creek	4A	*	18N-1W-4	74813
Sleepy Creek	4A	17110019007953	19N-2W-18	40614
Woodard Creek	4A	17110019007870	19N-1W-19	3772
Woodard Creek	4A	17110019015362	18N-1W-18	45125
Woodard Creek	4A	17110019000236	19N-1W-31	45127
Woodland Creek	4A	17110019013161	18N-1W-16	6657
Woodland Creek	4A	17110019013153	18N-1W-9	45027
Woodland Creek	4A	17110019013148	18N-1W-4	45082
Woodland Creek	4A	17110019013141	18N-1W-4	45292
Woodland Creek	4A	17110019013145	18N-1W-4	46176
Woodland Creek	2	17110019013174	18N-1W-22	74723
Woodland Creek	2	17110019013179	18N-1W-22	74724

WBID: Waterbody Identification

*WBID not assigned

Regulatory Criteria

The FC criteria have two statistical components: a geometric mean (GM) and an upper limit value that 10% of the samples cannot exceed. In Washington State, the upper limit statistic (i.e., not more than 10% of the samples shall exceed) has been interpreted as a 90th percentile value of the log-normalized values. Freshwater and Marine FC criteria for the Henderson Inlet watershed are presented in Table 2.

Henderson Inlet and its tributaries are available to the public for *Primary* (e.g., swimming) and *Secondary* (e.g., wading) *Contact Recreation*. Recreational and tribal/commercial shellfish harvestings occur on Washington beaches that the Washington State Department of Health has approved for shellfishing.

Table 2. Freshwater and marine FC criteria for the Henderson Inlet watershed

Water	Criteria	Geometric Mean	Not more than 10% (90th Percentile)
Freshwater	Extraordinary Primary Contact Recreation	50 cfu/100 mL	100 cfu/100 mL
Marine	Extraordinary Primary Contact Recreation	14 cfu/100 mL	43 cfu/100 mL

cfu: colony-forming units

Goals and Objectives

Project Goals

The goal of this study is to measure the effect of FC pollution control measures implemented in the Henderson Inlet watershed.

Study Objectives

- Collect twice a week FC samples at a fixed network of TMDL target locations.
- Collect FC samples from five stormwater outfalls identified in TMDLs.
- Collect biological and habitat data at five locations in Woodland and Woodard Creeks.
- Compare data collected in this study with TMDL targets.
- Use current and historic data to detect (or test for) trends in FC concentrations in fresh and marine waters over time.
- Catalog and map implementation activities in the watershed with available data.
- Evaluate timing and location of changes in water quality data with implementation of best management practices (BMPs).
- Make recommendations for future actions.

Methods

Data Analysis

A list of studies and data used for the data analysis are presented in Table 3. There were two primary sets of water quality data used in this assessment. All data used to assess compliance with water quality standards and to determine seasonal trends were obtained from Ecology's Environmental Information Management (EIM) system (www.ecy.wa.gov/eim/). Water quality data to assess long-term trends in Woodland Creek (WL1.6) and Woodard Creek (WD2.6) were obtained from Thurston County (http://www.co.thurston.wa.us/monitoring/) and EIM.

Table 3. Sources of data used to determine compliance with water quality standard, target reductions, and trends analysis.

Study Name or Site	Years	Data Source	Study/ Station ID
Water quality compliance, bacteria reductions			
Henderson Inlet TMDL study	2002-2004	EIM	DSAR2
Henderson Inlet effectiveness monitoring study	2014-2015	EIM	PAND0004
Long-term trend analysis			
Sleepy Creek river mile 0.8 (SL0.8)	1988-2014	TC	HENSL0000
Fleming Creek (FCRM1.3)	1993-2013	TC	HENDO0000
Goose Creek (GC0.1)	2001-2014	TC	HENGS0010
Dobbs Creek (DB0.1)	2003-2014	TC	HENDO000
Dobbs Creek (DB0.1)	2002-2004	EIM	DSAR2
Dobbs Creek (DB0.1)	2007-2008	EIM	BEDI0011
Woodard Creek (WD2.6)	1986-2014	TC	HENWO0000
Woodland Creek (WD1.6)	1983-2014	TC	HENWL0000
Woodland Creek Tanglewilde outfall (WL3.7SW)	2005-2014	TC	HENWL0800

TC: Thurston County
EIM: Environmental Information Management

Water Quality Standards and TMDL Target Reductions

In order to measure effectiveness FC control strategies, the effectiveness monitoring study collected samples at the same 20 locations previously monitored in the 2006 TMDL study (Collyard and Anderson, 2014).

These stations included:

- 5 locations on 5 small tributaries draining directly into Henderson Inlet.
- 2 locations on the mainstem of Woodland Creek.
- 6 tributary locations of Woodland Creek.
- 4 stormwater outfalls discharging to or near Woodland Creek.
- 2 locations on Woodard Creek mainstem.
- 1 stormwater outfall location discharging into Woodard Creek.

Locations and descriptive information of sampling locations are provided in Figure 6 and Table 4.

The data collected in 2014-15 were used to determine if 303(d)-listed waters within the Henderson Inlet (HUC 12) watershed met (i.e., did not exceed) water quality standards for FC. To determine compliance, data were first separated by wet and dry seasons (dry: June-Sept, wet: Oct-May) based on recommendations in the TMDL study (Sargeant, 2006).

FC geometric means were calculated by back-transforming the mean of log-transformed concentration values. FC 90th percentiles were calculated as the 90th percentile of a log-normal distribution, where the mean and standard deviation are estimated from the log-transformed data (Swanson, 2008).

Although FC criteria were calculated and included in this assessment from stormwater outfalls, compliance with water quality standards, by definition, only applies to receiving waters above and below outfalls. For the purposes of this study, water quality results from stormwater outfalls are only applied for the purpose of assessing reductions of pollutants.

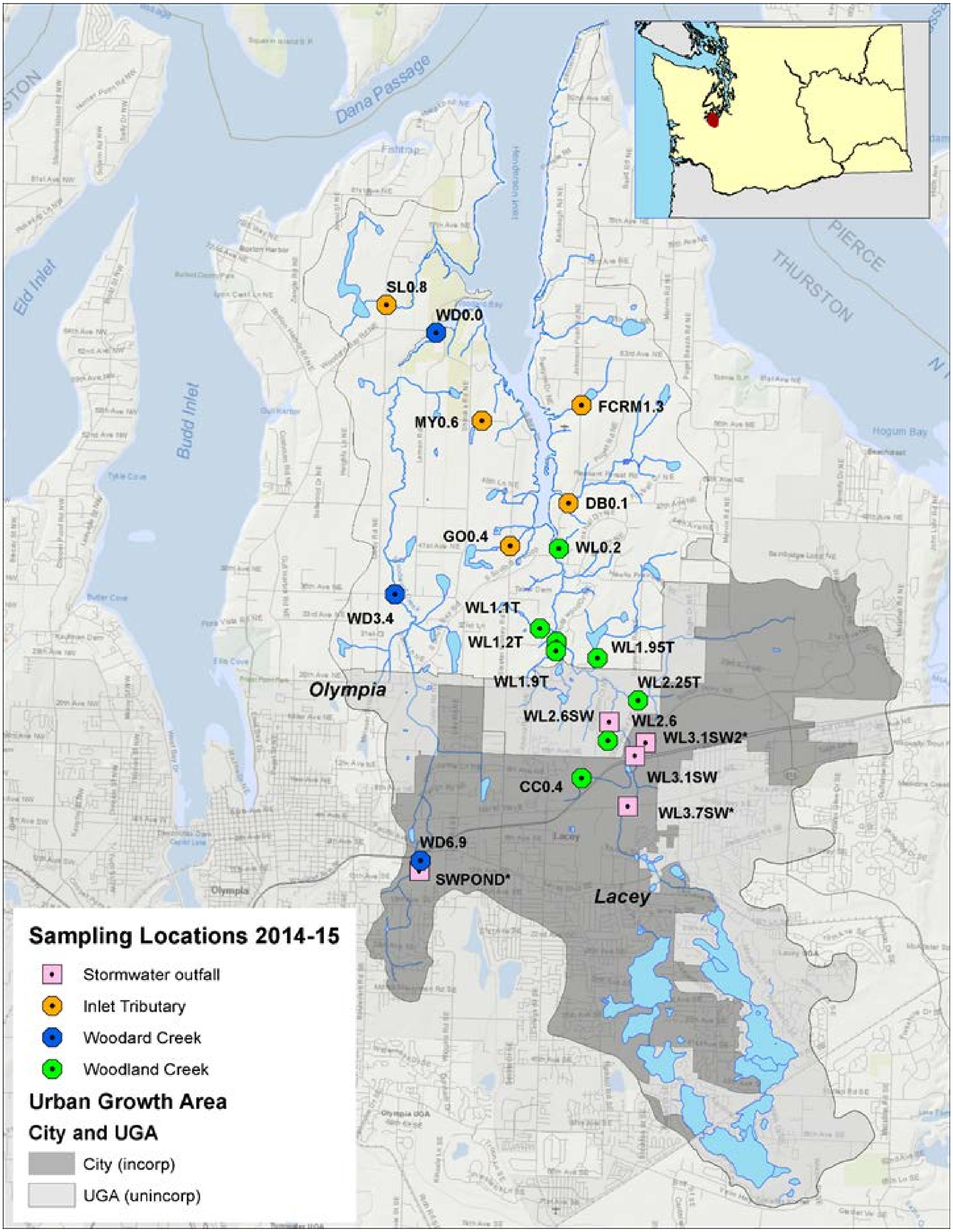

Figure 6. Henderson Inlet 2014 TMDL effectiveness monitoring sampling stations.

Table 4. Henderson Inlet TMDL effectiveness monitoring sampling locations, 2014-2015.

Site ID	Description	Latitude	Longitude	Limiting Criterion	Critical Season
Henderson Inlet					
SL0.8	Sleepy Creek	47.11236	-122.841	90th	Wet
FCRM1.3[2]	Fleming Creek	47.11533	-122.8176	na	na
MY0.6	Myer Creek	47.13093	-122.865	90th	Wet
DB0.1	Dobbs Creek	47.1338	-122.858	90th	Wet
GO0.4	Goose Creek	47.09188	-122.834	90th	Wet
Woodard Creek					
WD0.0	Woodard Creek at river mile (RM) 0.0	47.12648577	-122.8529	90th	Wet
WD3.4	Woodard Creek at RM 3.4	47.0832175	-122.86038	90th	Wet
WD6.9	Woodard Creek at bike path, Taylor wetland outlet	47.03992085	-122.85310	90th	Wet
SWPOND[1]	Stormwater discharge near Fones Road	47.03815	-122.853	90th	Wet
Woodland Creek					
WL0.2	Woodland Creek at RM 0.2	47.09027	-122.823	GM/90th	Dry/Wet
WL1.1T	Quail Creek	47.08029	-122.823	90th	Wet
WL1.2T	Jorgensen Creek	47.07655	-122.822	90th	Dry
WL1.9T	Fox Creek	47.07655	-122.822	90th	Wet
WL1.95T	Palm Creek	47.07041	-122.812	90th	Wet
WL2.25T	Eagle Creek	47.06841	-122.806	90th	Dry
WL2.6	Woodland Creek at RM 2.6	47.06351	-122.809	GM/90th	Dry/Wet
WL2.6SW[1]	Stormwater pipe at Woodland RM 2.6	47.06351	-122.809	90th	Wet
WL3.1SW[1]	Stormwater to Woodland from WSDOT vault	47.05787	-122.802	90th	Wet
WL3.1SW2[1]	Tributary from WSDOT vault, north Interstate-5 culvert, right bank	47.05808	-122.802	GM	Wet
CC0.4	College Creek at RM 0.4	47.04791	-122.819	90th	Wet
WL3.7SW[1]	Stormwater discharge from pipe south side Martin Way	47.0498	-122.804	90th	Wet

[1] Stormwater outfall
[2] Location not included in the original TMDL study.
GM: Geometric mean
90^{th}: 90^{th} percentile

Trend Monitoring

Testing for trends in long-term monitoring data collected from different studies and organizations can be problematic. Such data sets often violate the assumptions necessary to use traditional statistical approaches when assessing for the presence of trends. For the purposes of this report, it is acknowledged that many outside variables can affect results.

Linear regression and nonparametric trend tests were used as a diagnostic tool for assessing water quality trends for this study (Helsel and Hirsch, 2002). In addition to FC, total phosphorus

(TP) and nitrate+nitrite (NO_x) data collected by Thurston County were assessed for trends. While the information is useful for interpreting potential relationships between water quality and time, caution should be used when using the results for other purposes such as predicting future concentrations.

To determine if the linear regression test was appropriate, data sets where log transformed and tested for normal distribution using a Shapiro-Wilk test for normality (Shapiro et al., 1968). All statistical tests were performed using Systat® version 13.0.

Seasonal Kendall

Trends analysis for all parameters was conducted using the Seasonal Kendall test (Helsel and Hirsch, 2002). The test accounts for seasonal (month) variations in data over time and is resistant to outliers in data sets. Both of these conditions are common in water quality data sets and can significantly influence regression results. This approach was used to assess for trends in pooled FC and nutrient data. The Seasonal Kendall test calculates the probability (p-value) of a relationship occurring between the variable (water quality) and time (year). A $p<0.05$ means there are significant differences at the 95% confidence level in concentration over time. A separate test (Sen) calculates the slope of the trend. A negative slope indicates a decreasing trend while a positive slope indicates an increasing trend. The greater the slope the higher the rate of change over time.

Ordinary least square regression

Ordinary least squares (OLS) regression was used to test for trends in FC and nutrient data. The OLS regression analysis is based on linear regression of the water quality parameter against time. Variability of the data was removed by accounting for external variables such as flow and precipitation on the same day as water quality samples were collected. The resulting FC residual data were then averaged by month and plotted over time. This approach was used for long-term data collected by Thurston County's ambient monitoring stations. All FC, total phosphorus, and nitrate data were log normalized before regression analysis was performed. P values of <0.05 indicate if the relationship between the variables is significant. The coefficient indicates the direction of the trend (negative or positive) as well as the rate of change over time.

Implementation Assessment

Each year in Washington State, several federal, state, and local agencies award millions of dollars in grants and loans to protect, restore, or enhance degraded waterbodies. Although many of these projects are not implemented as the result of the TMDL process, many still contribute to net improvements in water quality and watershed health. When effectiveness assessments are made at a watershed scale, all such actions should be taken into account in order to provide a comprehensive assessment. With a more holistic view of actions, stakeholders from various groups may more easily become aligned with similar goals and make informed decisions regarding future projects.

For purposes of this assessment, grant, loan, and project data for activities implemented within the Henderson Inlet study area were obtained from two state agencies. Ecology's Water Quality Program (WQP) and the Washington Department of Recreation and Conservation Office (RCO) provide grants and loans to recipients in excess of $20 million dollars to implement numerous pollution prevention and restoration projects in the watershed since 1990 (Table F-1). Each agency provides approximately half of the funding for the projects that will be presented in this assessment.

Ecology's WQP administers four major funding programs under the Integrated Water Quality Financial Assistance Program through an annual funding cycle. Ecology awards grants and loans on a competitive basis to eligible applicants for high priority water quality projects throughout Washington. Grant data such as project descriptions, project costs, recipient name and start and end dates are tracked at a Water Resource Inventory Area (WRIA) scale. Specific types and locations of projects implemented within the Henderson Inlet TMDL were determined through review of project descriptions, web searches, and follow-up with the grant recipients.

Using these data, Ecology identified these three general groups of grant types: (1) grants that included remedial actions carried out at identified locations, (2) grants that provided funds for projects that are subjective such as prioritization studies, and (3) grants that fund multiple project types without specific locations, including projects in neighboring watersheds.

RCO provides funding for building community recreational opportunities and for protecting and restoring wild areas. Grants and projects implemented within this framework are tracked via two databases. RCO's Project Information System (PRISM) tracks both recreational and restoration grants. Habitat Work Schedule system is a mapping and project tracking tool that allows community-based salmon recovery programs (Lead Entity Program) to share habitat protection and restoration projects with funders and the public. Both databases provided summaries and outcomes of grant projects at a site scale.

Once all grant data were obtained, projects were categorized by date, grant recipient, location, cost and activity. A list and definition used to determine activity types is provided in Table 5. A selection of projects provided enough information to estimate the total acres treated by action (Table F-1).

Although this list includes a majority of the implementation work in the watershed, it does not account for all projects. Thurston County, and the Cities of Olympia and Lacey all use storm and surface water utility fees to support capital improvement projects as well as ongoing stormwater and OSS management, inspection, and enforcement programs. In addition, implementation and periodic updates of local land use ordinances can also affect water quality over time. Likewise, the Thurston Conservation District together with the Natural Resources Conservation Services and other state and federal agencies provide assistance to agricultural operations to protect water quality, and these are not factored into this assessment. See Appendix B for an overview of additional projects and programs, implemented by stakeholders, that were not captured in the grant and loan data.

Table 5. Implementation activity and definitions used to evaluate and summarize water cleanup and restoration activities.

Activity	Definition
Land Acquisition	The purchase or protection (easement) of private lands for the purposes of conserving unique or sensitive natural and cultural resources.
Onsite Sewage	Activities which consist of remedial and preventative activities to correct nonpoint contamination from failing onsite sewage disposal systems.
Planning	The process of regulating land use and development of a geographic area through drafting, adopting, and implementing long term plans designed to achieve desired outcomes.
Stormwater	Activities or structural improvements that help reduce stormwater runoff and improve its quality.
Agricultural	Activities or improvements that help reduce the amount of pollutants entering surface waters.
Fish Passage	Activities that enable or enhance fish migration in streams.
Wetland Restoration	Restoring or protecting a land area that is saturated with water, either permanently or seasonally.
Education and Outreach	Activities that provide the general public or landowners with educational experiences about preventing pollution of surface waters.
Public Access	Activities that provide, enhance, or increase public access to recreational activities.
Riparian Restoration	Restoring or protecting the area between land and a waterway.
Monitoring	The collection of water quality sampling over a period of time.

Results and Discussion

Water Quality Standards

The 2013-2014 wet-season and dry-season FC geometric means (GMs) and 90th percentiles are presented in Table 6 and Figures 7 and 8. The marine primary contact recreation standard was applied to the 2 sites nearest to Henderson Inlet: Woodard Creek at river mile 0.0 (WD0.0) and Woodland Creek at river mile 0.2 (WL0.2). The freshwater extraordinary primary contact recreation standard was applied to all other locations. Supporting GIS and field summary assessments for individual sampling locations are provided in Appendix E.

Henderson Inlet tributaries (Dobbs, Goose, Fleming, Meyer, and Sleepy Creeks)

None of the Henderson Inlet tributary sites met either the dry-season GM or 90th percentile criteria for FC (Table 6, Figure 7). Meyer and Goose Creeks have seasonal flows and were not sampled during the dry season. During the wet season, only Meyer and Goose Creeks met the wet-season FC GM criteria (Table 6, Figure 8). None of the sites met the wet-season 90th percentile criteria.

Dry-season FC GM and 90th percentile ranged between 115-16677 cfu while wet-season values ranged between 10-617 cfu. Overall, elevated dry-season FC levels suggests sources are related to the direct input of organic waste from domestic animals, humans, wildlife, or sources related to leaching of sanitary waste from OSS. Low dry-season flows in these tributaries make them particularly sensitive to any input of the above mentioned sources.

Woodard Creek

During the dry season, none of the sites sampled in Woodard Creek met water quality criteria for FC (Table 6, Figure 7). Woodard Creek below Taylor wetlands (WD6.9) and a stormwater outfall discharging Taylor wetlands (SWPOND) were not sampled during the dry season because of lack of flow. During the wet-season sampling, WD6.9 was the only site sampled meeting both GM and 90th percentile standards (Table 6, Figure 8).

Dry-season FC GM and 90th percentiles ranged between 90 and 265 cfu, while wet-season values ranged between 24 and 539. FC GM and 90th percentiles decreased from upstream (WD3.4) to downstream (WD0.0) during dry-season sampling and increased during wet-season sampling.

Woodland Creek

During the dry-season sampling, none of the sites sampled met water quality criteria for FC (Table 6, Figure 7). Wet-season FC GM criterion was met on Fox, Palm, College, and Woodland Creeks at river mile 2.6 (WL2.6). None of the stations sampled met the 90th percentile criterion during the wet season (Table 6, Figure 8).

Of the four stormwater outfalls sampled, only the outfall discharging from the Washington State Department of Transportation (WSDOT) vault (WL3.1SW) was flowing during dry-season sampling. Dry-season FC GM and 90th percentile ranged from 45 to 1370 cfu, and wet-season values ranged from 32 to 1674 cfu. Although reported, water quality criterion for stormwater outfalls WL2.6SW, WL3.1SW and WL3.7SW were calculated with three or fewer samples. This was due to the lack of discharge during sampling events.

Table 6. Critical season FC geometric means and 90th percentiles in the Henderson Inlet watershed based on 2013-2014 results.

Site ID	Station Description	Dry			Wet		
		N	GM	90th %tile	N	GM	90th %tile
Henderson Inlet							
SL0.8	Sleepy Creek at Libby Road	12	115	789	15	80	502
FCRM1.3	Fleming Creek at Johnson Point Road	12	1555	16677	15	78	405
MY0.6	Meyer Creek	0	NA	NA	10	10*	116
DB0.1	Dobbs Creek at Johnson Creek Road	12	213	513	15	116	617
GO0.4	Goose Creek at Sleater Kinney Road	0	NA	NA	9	11*	137
Woodard Creek							
WD0.0	Woodard Creek at Woodard Bay Road[2]	6	90	149	7	89	539
WD3.4	Woodard Creek at 36th Avenue	11	121	265	15	61	260
WD6.9	Woodard Creek at bike path, Taylor wetland outlet	0	NA	NA	15	24*	90*
SWPOND[1]	Stormwater discharge near Fones Road	0	NA	NA	2	214	326
Woodland Creek							
WL0.2	Woodland Creek at Hawks Prairie Road[2]	11	166	433	15	89	404
WL1.1T	Quail Creek (just upstream from mouth)	12	111	326	13	111	378
WL1.2T	Jorgenson Creek (mouth), left bank tributary	11	213	824	15	82	359
WL1.9T	Fox Creek at Pleasant Glade Road	11	84	299	15	45*	132
WL1.95T	Palm Creek, Upstream from mouth, left bank tributary	11	98	215	15	43*	175
WL2.25T	Eagle Creek, right bank tributary	12	465	1370	15	100	391
WL2.6	Woodland Creek at 21 Court	11	89	186	15	45*	232
WL2.6SW[1]	Stormwater pipe at Woodland RM 2.6	0	NA	NA	2	340	619
WL3.1SW[1]	Stormwater to Woodland from WSDOT vault	4	77	1127	2	322	1674
WL3.1SW2[1]	Tributary from WSDOT vault, north Interstate-5 culvert	0	NA	NA		656	1072
CC0.4	College Creek at RM 0.4	3	87	160	12	32*	221
WL3.7SW[1]	Stormwater discharge from pipe south side Martin Way	0	NA	NA	3	812	1407

[1] Wet season samples with three or fewer samples
[2] Marine criteria for FC apply (see Table 2)
* Meets water quality standards
NA: Not applicable

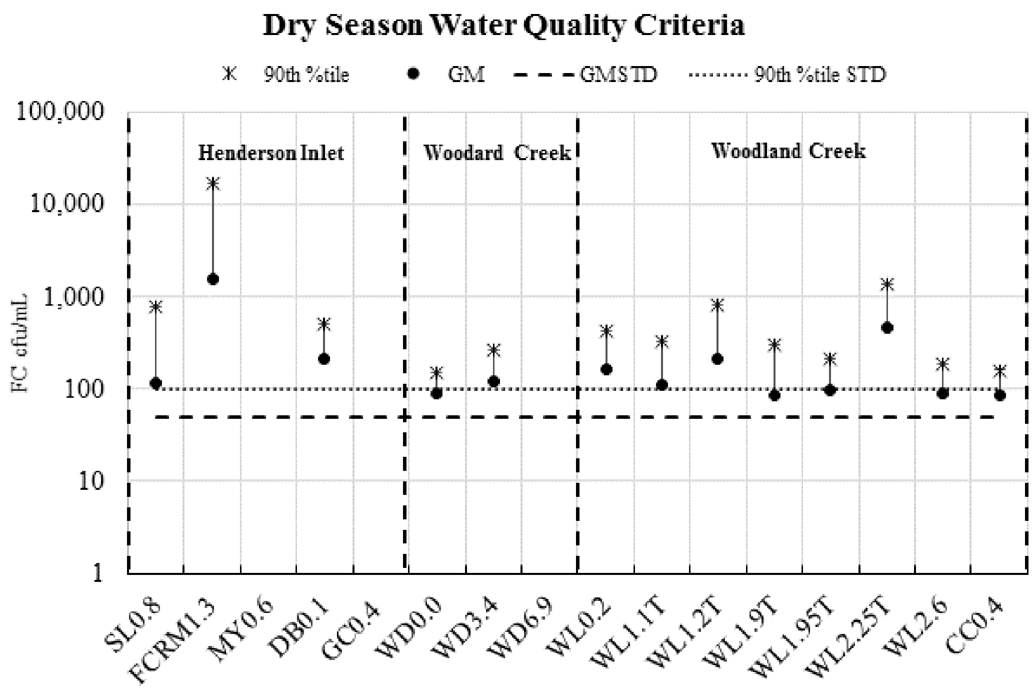

Figure 7. Dry-season FC levels, June-September 2014.

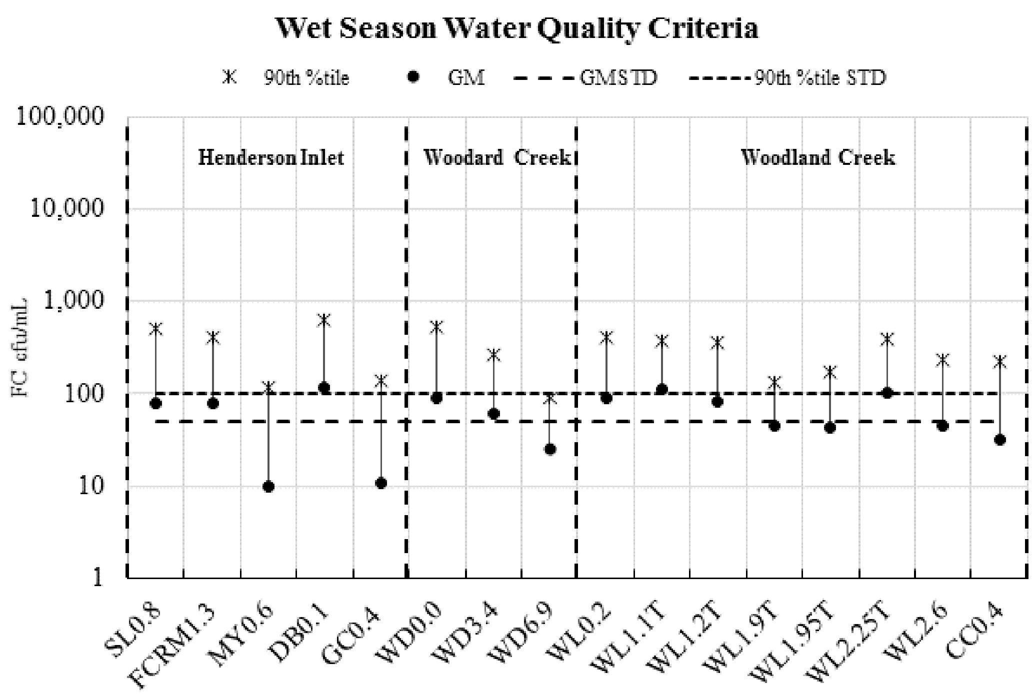

Figure 8. Wet-season FC levels, September 2014 – May 2015.

TMDL Target Reductions

Although compliance is measured as meeting water quality standards, FC targets are routinely established to assist water quality managers in assessing the progress toward compliance with established criteria. The 2003-04 TMDL water quality study set target goals for reducing FC at key locations in the Henderson Inlet watershed. These targets, or load allocations, are determined using the rollback methods (Ott, 1997) to calculate reductions necessary to meet both parts of the water quality standard for bacteria. Application of this method is applied to the water quality criterion that is most limiting (geometric mean or 90th percentile).

Percent change between limiting criteria identified in the original TMDL study (Sargent, 2006) and 2014-2015 study are presented in Table 7 and Figure 9.

Henderson Inlet tributaries (Dobbs, Goose, Fleming, Meyer, and Sleepy Creeks)

FC reductions were observed in Myer, Dobbs, and Goose Creeks (Table 7, Figure 9). Reductions observed in Goose Creek met the reduction needed to meet water quality standards outlined in the TMDL. This result was consistent with the FC GM criterion but not the 90th percentile criterion reported in Table 6. In Sleepy Creek, the limiting criterion (90th percentile) increased by 43% between the studies. Fleming Creek was not sampled as part of the original TMDL study, thus no targets were applied.

Woodard Creek

FC reductions in Woodard Creek were observed at all sampling stations and ranged between 9 and 93% (Table 7, Figure 9). Reductions observed in Woodard Creek below Taylor wetland (WD6.9) met the target outlined in the TMDL and was consistent with reported water quality standards attainment presented in Table 6. The highest reduction was observed from SWPOND, a stormwater outfall discharging into Taylor wetland. However, only three wet-season samples were collected because of lack of discharge.

Woodland Creek

FC reductions were observed at all sampling locations in the Woodland Creek subbasin with the exception of WL3.1SW (Table 7, Figure 9). The 90th percentile increased at this stormwater outfall 66% between studies. FC reductions ranged from 14% (WL0.2) to 84% (WL1.1). Reductions observed in Palm Creek (WL1.95) met the wet-season 90th percentile target outlined in the TMDL and was consistent with reported GM criteria but not the 90th percentile water quality criterion presented in Table 6.

Table 7. Percent change in FC between TMDL targets and effectiveness monitoring study.

Site ID	Description	Critical Season	Limiting Criterion	% Reduction Needed	% Reduction Observed
Henderson Inlet					
SL0.8	Sleepy Creek	Wet	Wet	88	-43 (increase)
FMRM1.3	Fleming Creek	NA	Wet	NA	NA
MY0.6	Myer Creek	Wet	Wet	87	89[2]
DB0.1	Dobbs Creek	Wet	Wet	96	82
GO0.4	Goose Creek	Wet	Wet	87	87[2]
Woodard Creek					
WD0.0	Woodard Creek at RM 0.0	Wet	Wet	90	9
WD3.4	Woodard Creek at RM 3.4	Wet	Wet	64	53
WD6.9	Woodard Creek at bike path, Taylor wetland outlet	Wet	Wet	76	78[2]
SWPOND[1]	Stormwater discharge near Fones Road	Wet	Wet	98	93
Woodland Creek					
WL0.2	Woodland Creek at RM 0.2	Dry/Wet	Dry/Wet	93/92	14/20
WL1.1T	Quail Creek	Wet	Wet	96	89
WL1.2T	Jorgensen Creek	Dry	Dry	89	74
WL1.9T	Fox Creek	Wet	Wet	78	75
WL1.95T	Palm Creek	Wet	Wet	59	79[2]
WL2.25T	Eagle Creek	Dry	Dry	95	59
WL2.6	Woodland Creek at RM 2.6	Dry	Dry	43	29
WL2.6SW[1]	Stormwater pipe at Woodland RM 2.6	Wet	Wet	95	31
WL3.1SW[1]	Stormwater to Woodland from WSDOT vault	Wet	Wet	84	-66 (increase)
WL3.1SW2	Tributary from WSDOT vault, north Interstate-5 culvert, right bank	Wet	Wet	91	67
CC0.4	College Creek at RM 2.6	Wet	Wet	86	68
WL3.7SW[1]	Stormwater discharge from pipe south side Martin Way	Wet	Wet	99	83

[1] Wet season samples with three or fewer samples
[2] Meets or exceeds required reduction
RM: river mile
WSDOT: Washington State Department of Transportation
NA: Not applicable

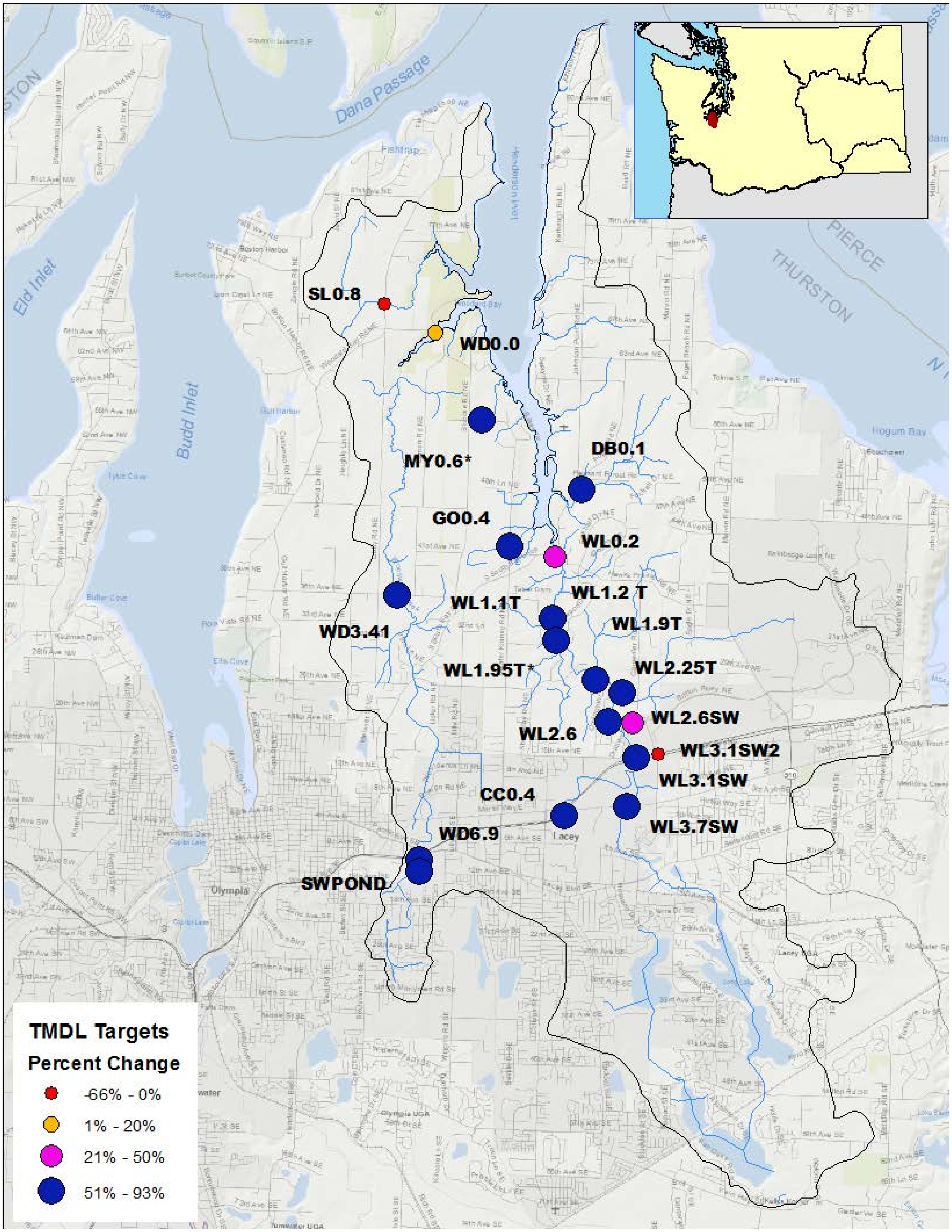

Figure 9. Comparison of TMDL targets and effectiveness monitoring FC changes over time.

Water Quality Trends

Calculating percent reductions between two time periods can be useful for assessing change over time using small data sets. However, if sufficient data exists, long-term trends analysis should be performed. Trends analysis can account for variability of data not related to implementation of best management practices (BMPs). Variability in the parameter(s) of interest is often tied to variability in other measurable parameters that directly reflect the drivers of water quality change. Covariate data can be used to "sort out" natural variability versus variability attributed to implementation of BMPs. Therefore, the inclusion of explanatory variables in TMDL effectiveness monitoring can greatly improve the power of the statistical methods applied to detect differences between sites or change over time. In the case of FC and nutrient concentrations, common covariates include precipitation, seasons (months), and streamflow.

Seasonal Kendall and OLS regression were used to test for trends in data at three spatial scales; watershed (WS_All), basin (Inlet_All, WD_All, WL_All), and site (Table 8). Additional descriptive information for data included in these assessments is provided above in Table 4. FC data for watershed and basin sites were pooled using all available FC data without consideration of distribution of data over time and space.

FC and nutrient data for Woodard Creek at river mile 2.6 (WD2.6) and Woodland Creek at river mile 1.6 (WL1.6) were obtained from the Thurston County Ambient Monitoring Program. Data are available on the County's web site: http://www.co.thurston.wa.us/monitoring/. All other data were obtained from Ecology EIM system: https://fortress.wa.gov/ecy/eimreporting/.

Table 8. Description of spatial scales and data used for trend analysis.

ID	Scale	Description	Stream Miles	Number of Sites	# of Samples	Date Range
WS_All	Watershed	All available FC data for watershed	52	27	1201	2002-2015
Inlet_All	Subbasin	All available FC data for Henderson Inlet tributaries streams	11	4	555	1983-2015
WD_All	Subbasin	All available FC data for Woodard Creek subbasin	16	4	317	1986-2015
WL_All	Subbasin	All available FC data for Woodland Creek subbasin	24	13	671	1983-2015
FCRM1.3	Site	Fleming Creek	2.0	1	95	1983-2015
DB0.1	Site	Dobbs Creek	4.3	1	153	1983-2015
SL0.8	Site	Sleepy Creek	2	1	249	1987-2015
GC0.4	Site	Goose Creek	0.8	1	58	2001-2015
WD2.6	Site	Woodard Creek	11	1	236	1986-2013
WL1.6	Site	Woodland Creek	14.6	1	254	1986-2013
WL3.7SW*	Site	Stormwater outfall near Woodland Creek at river mile 3.7	NA	1	134	2003-2015

Seasonal Kendall

Results for two-sided (no trend vs two-sided trend) Seasonal Kendall test for trends for FC and nutrient samples are presented in Table 9 and Figure 10. The critical Z score indicates the direction of the trend (negative or positive) and the magnitude of the trend (the higher or lower the Z score, the more abrupt the slope), and if the trend is significant ($Z \geq \pm 1.64$). The results of the Seasonal Kendall test shows that FC has decreased at both the watershed and subwatershed scale, although the decrease was only modest in the Woodard Creek subwatershed (Table 9, Figure 10). These decreases were significant overall within the watershed (WS_All) and in the Woodland Creek (WL_All) subwatershed. The greatest decrease in FC was observed in the Woodland Creek subwatershed as indicated by the magnitude of the Z score in comparison with other stations (Table 9, Figure 10).

FC concentrations decreased in Sleepy (SL0.8), Goose (GC0.4), Woodard (WD2.6), and Woodland (WL1.6 and WL3.7SW) Creeks. FC concentrations increased in Fleming (FCRM1.3), Dobbs Creek (DB0.1) (Table 9, Figure 10). These changes were significant in Sleepy, Dobbs, Woodard, and Woodland Creeks as indicated by the Z scores.

Nitrate samples collected from WL1.6 and WD2.6 from 1993-2013 showed declining trends. However, the decline was only significant in Woodland Creek (WL1.6) (Table 9). Total phosphorus (TP) concentrations increased at these locations during the same time period. This increase was significant at WD2.6 (Table 9). Summary statistics for Seasonal Kendall analysis are presented in Table G-1.

Table 9. Results from Seasonal Kendall Trend analysis of FC data.

Station	Parameter	Z	Slope	Tau Stat	Trend
Pooled Data					
WS_All	FC	**-1.777**	-0.102	-0.102	Decreasing
Inlet_all	FC	-1.375	-0.006	-0.064	Decreasing
WD_All	FC	-0.243	0.01	-0.022	Decreasing/None
WL_All	FC	**-4.67**	-0.019	-0.238	Decreasing
Henderson Inlet					
SL0.8	FC	**-1.815**	-0.008	-0.075	Decreasing
GC0.4	FC	-1.259	-0.051	-0.046	Decreasing
FCRM1.3	FC	1.004	0.013	0.156	Increasing
DB0.1	FC	**4.315**	0.023	0.314	Increasing
Woodard Creek					
WD2.6	FC	-0.606	-0.002	-0.041	Decreasing
WD2.6	NO_x	-1.347	-0.002	-0.065	Decreasing
WD2.6	TP	**3.128**	0.005	0.203	Increasing
Woodland Creek					
WL1.6	FC	**-2.209**	-0.006	-0.14	Decreasing
WL1.6	NO_x	**-3.831**	-0.004	-0.245	Decreasing
WL1.6	TP	0.13	0	0.004	Decreasing/none
WL3.7SW	FC	**-4.84**	-0.133	-0.332	Decreasing

Items in **bold** represent significant Z^{crit} values of 1.64.

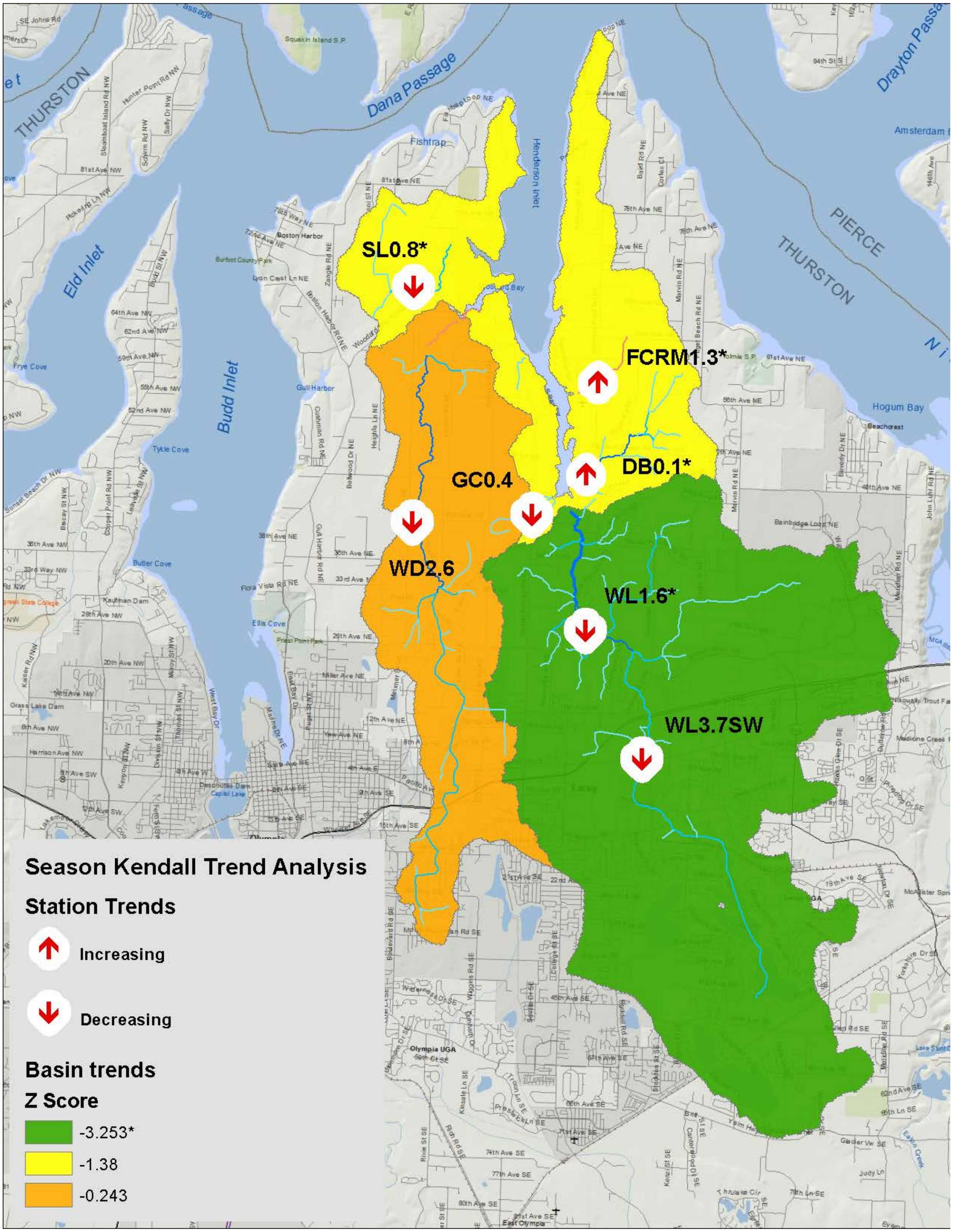

Figure 10. Result of FC Seasonal Kendall trends analysis (Z score) by subwatershed and Thurston County's long-term ambient monitoring stations.

** The decrease in FC over time was statistically significant.*

OLS Regression

To assess patterns in FC concentrations over time an ordinary least squares (OLS) regression analysis was used to test for trends using long-term ambient data from Thurston County. Variability in the data was reduced by including the variables month, year, $year^2$, $flow^2$ and precipitation in the OLS regression analysis. The resulting residual values for FC and nutrients were averaged by year and plotted over time. These are presented in Figures 11 and 12. OLS regression statistics are presented in Appendix G.

Results of OLS regression are consistent with Seasonal Kendall trend results. Decreasing FC trends were observed in Sleepy (WL0.8), Goose (GC0.4), Woodland (WL1.6), and Woodard (WD2.6) Creeks (Figure 10). Decreasing FC trends SL0.8 and GC0.4 were strong, based on p-values ($p=<0.05$). FC concentrations in both Dobbs and Fleming Creeks showed strong, increasing FC trends over time based on p-values ($p=<0.05$). Although OLS regressions for WD2.6 and WL1.6 demonstrated declining FC trends over time, the results were not significant for WD2.6. The general shape of the OLS, regression suggests the trends are non-linear even after accounting for outside variability (Figures 13E and F).

Nitrate-nitrite (NO_x) samples collected in Woodard (WD2.6) and Woodland Creek (WL1.6) from 1993-2013 also showed declining trends (Figure 10A). The decline in NO_x was significant at WL1.6 based on p-values ($p=<0.05$). By comparison, concentration and pattern of the declining trend lines for NO_x between Woodard and Woodland Creeks were different. NO_x concentrations in Woodard Creek were 40% lower than samples collected during the same time period in Woodland Creek. In addition, NO_x concentrations decreased steadily over time while NOx concentrations in Woodland Creek were similar to FC−an increase in NO_x followed by a decrease (Figure 13 E). Possible explanations for dissimilar behaviors between declining trend lines include different NO_x sources, type of action implemented or differences in basin sizes and hydrological processes.

In contrast, total phosphors (TP) concentrations increased at both locations during the same time period (Figure 12B). This increase was significant ($p=<0.05$) at WD2.6 (Table G-2). Trend lines behaved similarly between stations and, like NO_x, TP was approximately 40% lower in Woodard Creek.

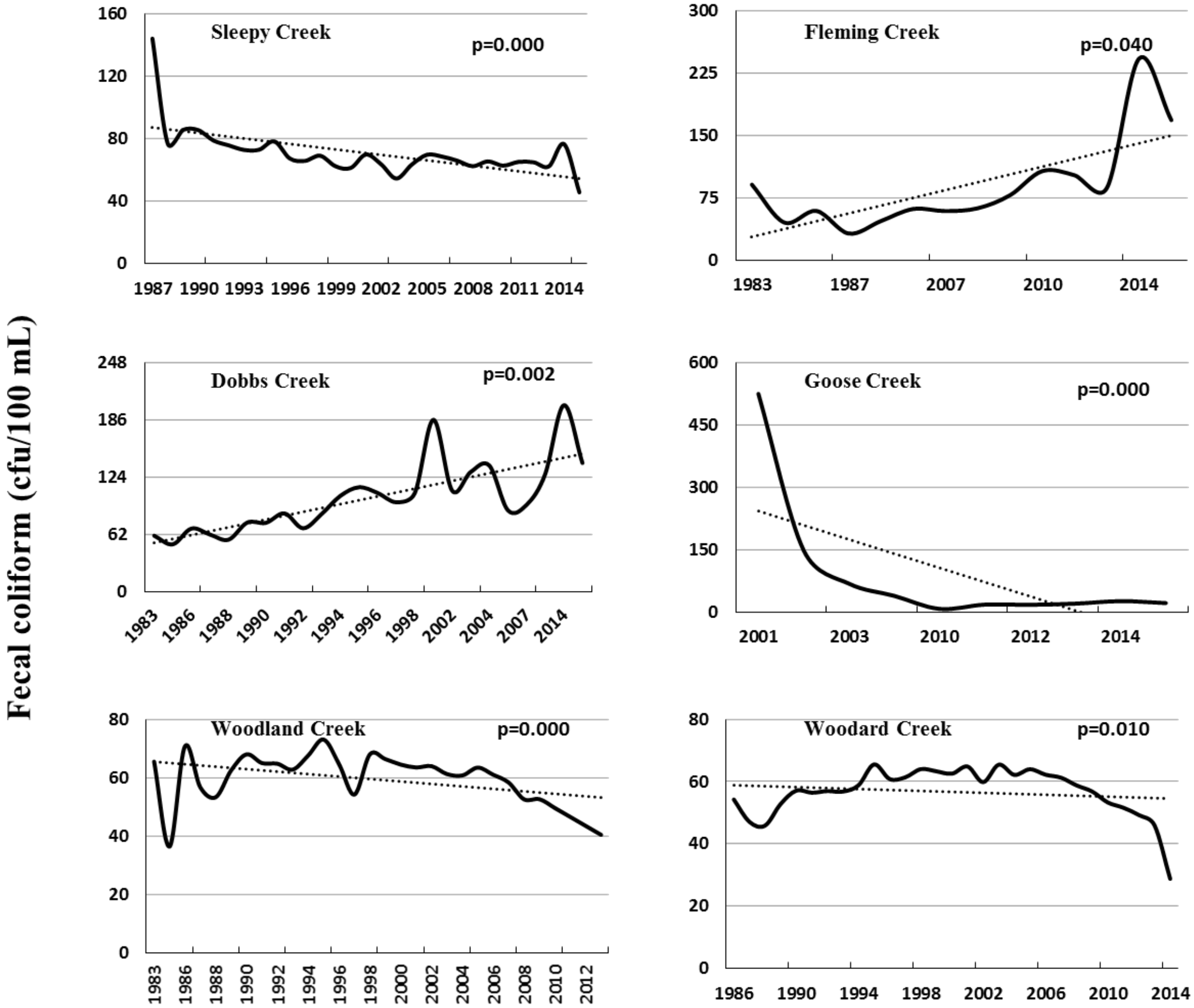

Figure 11. Yearly average of residual values from OLS regression analysis values plotted over time using Thurston County's long-term ambient monitoring stations in Sleepy Creek (A), Fleming Creek (B), Dobbs Creek (C), Goose Creek (D), Woodland Creek (E), and Woodard Creek (F).

FC concentrations represent yearly averages of residual values from resulting OLS regression analysis and are not reflective of water quality standards.

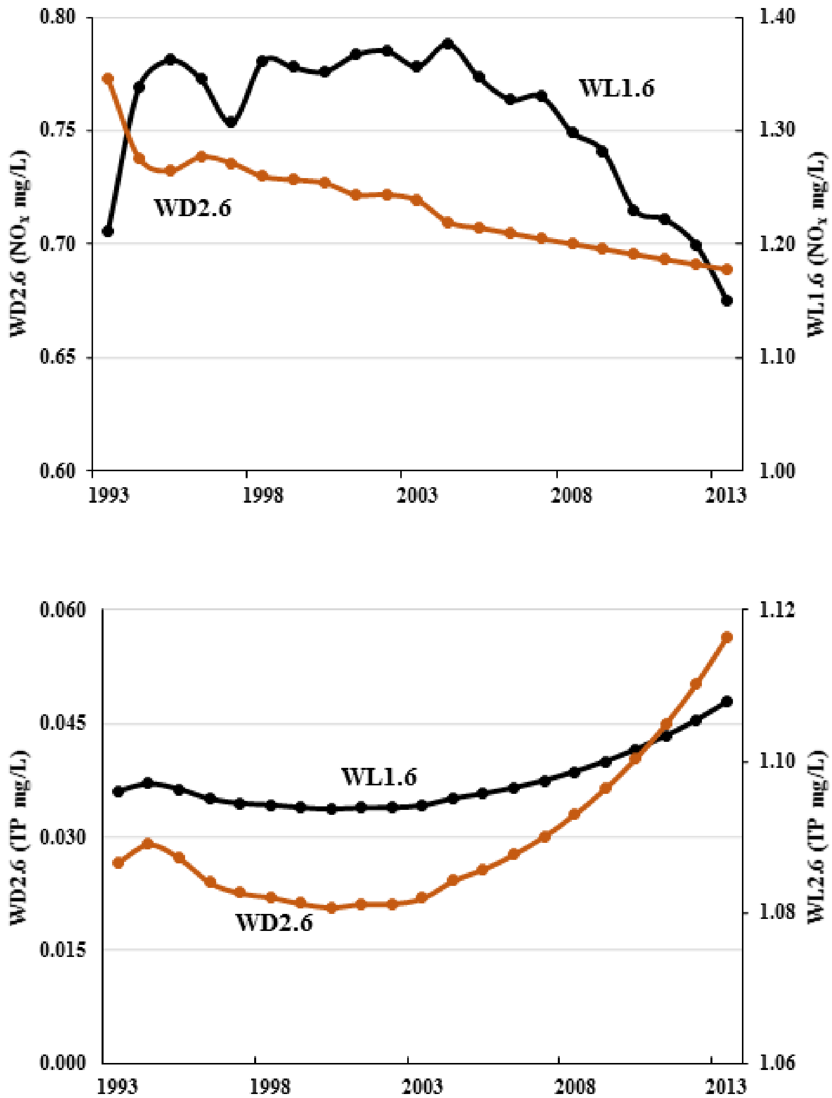

Figure 12. Results of nitrate (A) and total phosphorus (B) OLS regression analysis using data from Thurston County's long-term (1983-2013) ambient monitoring stations on Woodland (WL1.6) and Woodard Creeks.

Range of y Axis are not consistent between variables and sites.

Implementation Assessment

Grant and loans overview

A review of grant and loan investments in the Henderson Inlet watershed (HUC 12) identified 42 funded projects between 1989 and 2014 totaling approximately $22 million. This estimate does not include other non-grant investments implemented by local governments. Figure 13 presents cumulative investments in dollars over time plotted in relation to activities associated with the TMDL. Investments in projects increased steadily from 1989 through 2009 then increased sharply from 2010 to 2014 (Figure 13A). In general, projects related to planning were the first to be funded, followed by implementation of stormwater and agricultural projects (Figure 13B).

Much of the increase in cumulative funding occurred in response to activities associated with the TMDL planning process and publication of the detailed implementation plan. This increase is evident in Figure 13B which shows increased funding for onsite sewage system (OSS) and stormwater projects beginning in 2010. Acquisition projects were primarily funded through RCO for protection and restoration of critical habitat and were not related to the TMDL.

Figure 14A displays a summary of water cleanup and recreational investments by grant recipient. Thurston County and the Washington Department of Natural Resources (WDNR) were the primary recipients of funding in the watershed investing 35 and 28% respectively, of the total grant funds. The City of Lacey Parks and Recreation Department, the Thurston Conservation District, and the Capitol Land Trust followed behind each invested 9% of the total funds in restoration or cleanup actions (Figure 14A). The greatest investment made in the watershed was for land acquisition projects making up 43% of total investments (Figure 14B). This was followed by onsite sewage (OSS) projects, planning, and stormwater projects.

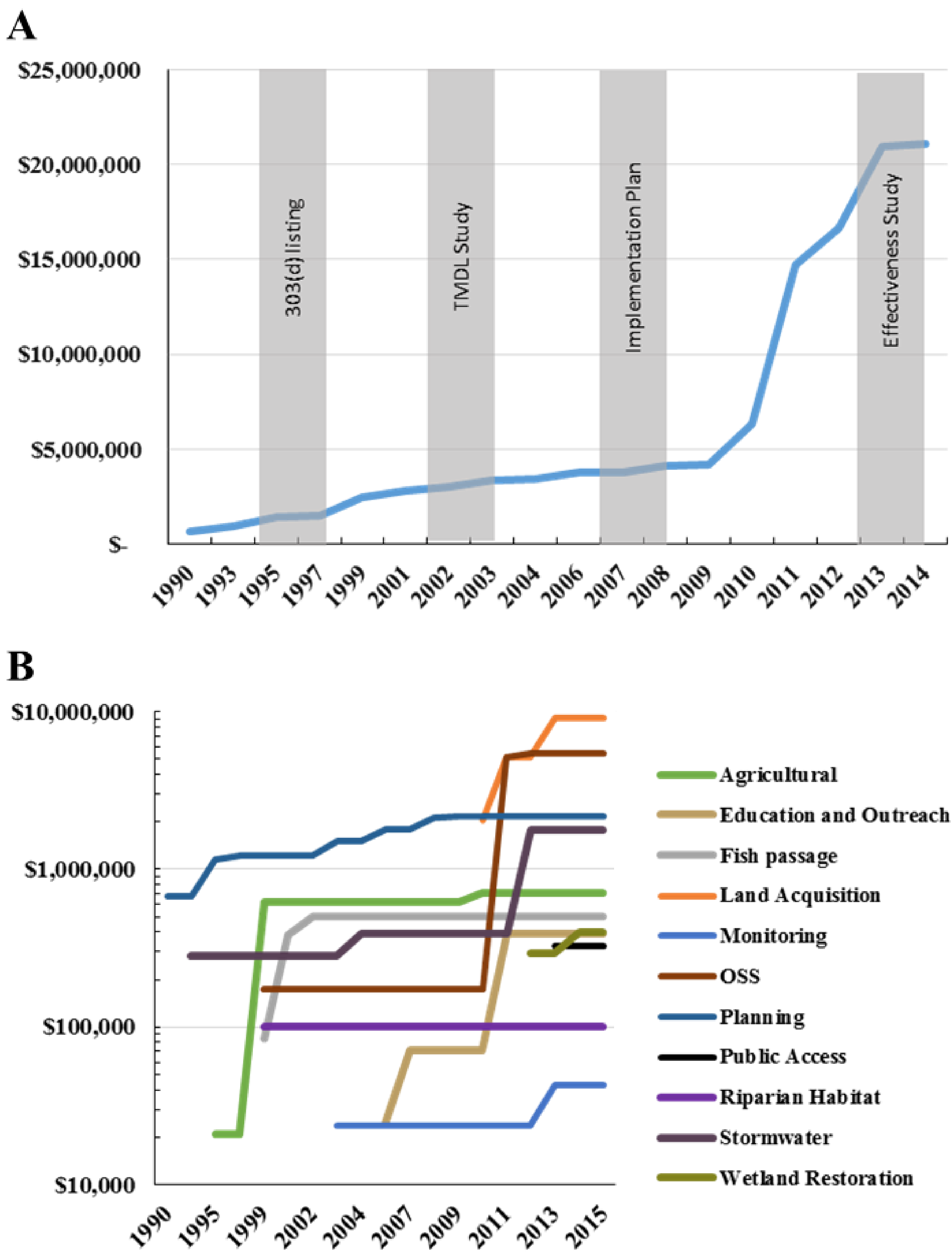

Figure 13. Cumulative grant funding for water cleanup and recreational projects (A) and cumulative grant funding by project type over time (B) in the Henderson Inlet watershed (1990-2014).

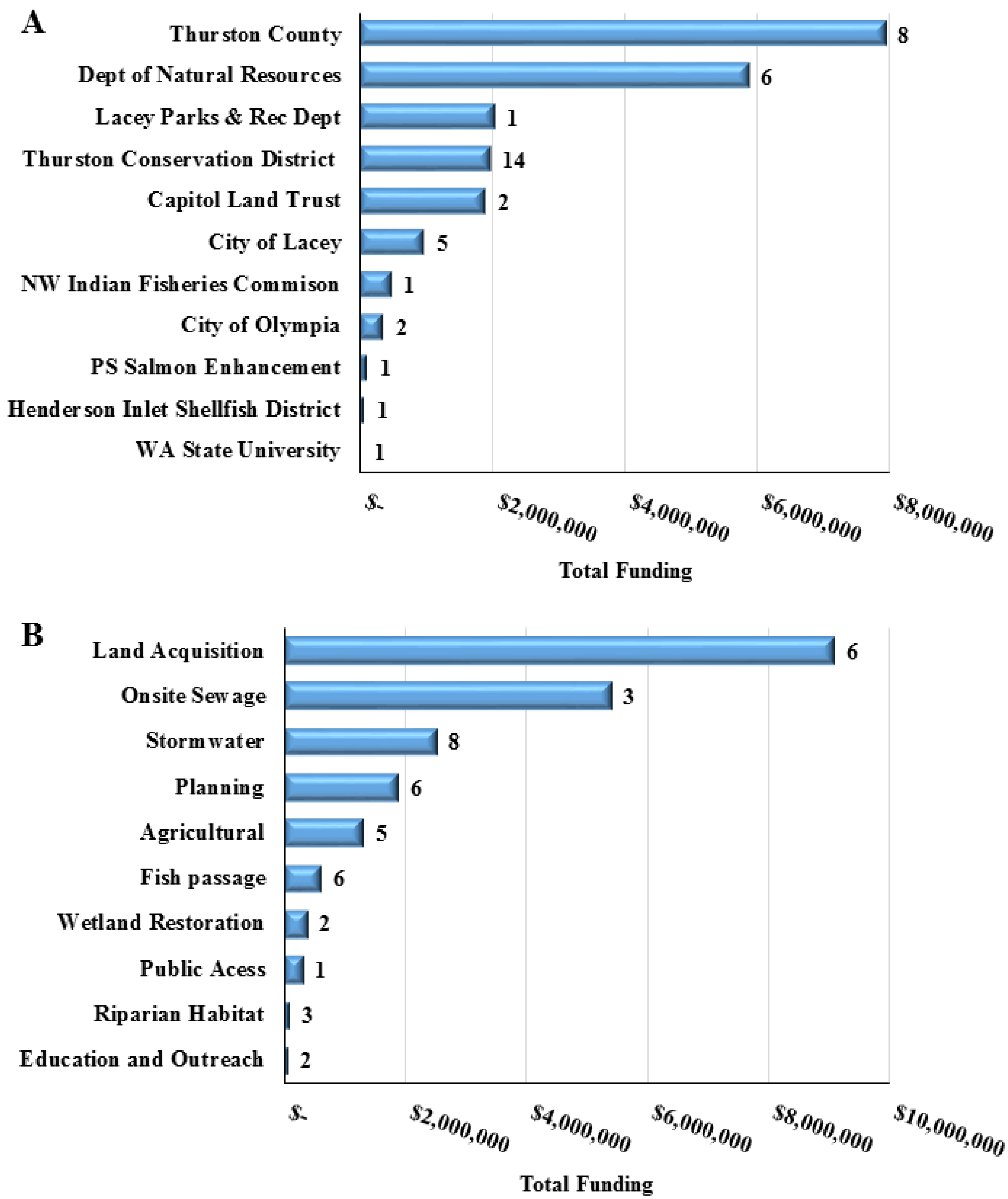

Figure 14. Total grant funding for water cleanup and recreation projects in Henderson Inlet by grant recipient (A) and by project type (B).

Values to the right of each bar indicate the number of projects funded.

The average cost per acre of a select number of grant-funded projects was estimated based on reporting metrics provided in annual reports or grant applications. See Appendix F for a list of projects used for this assessment. Cost per acre was estimated by dividing the project footprint in acres by the total cost of the project. Funding for planning and other non-grant-funded expenses was not included in the assessment. Fish passage and public access were the most costly projects, followed by onsite sewage (septic to sewer conversion), land acquisition, and implementation of agricultural projects (Figure 15). Stormwater projects were the least costly per acre of the projects assessed.

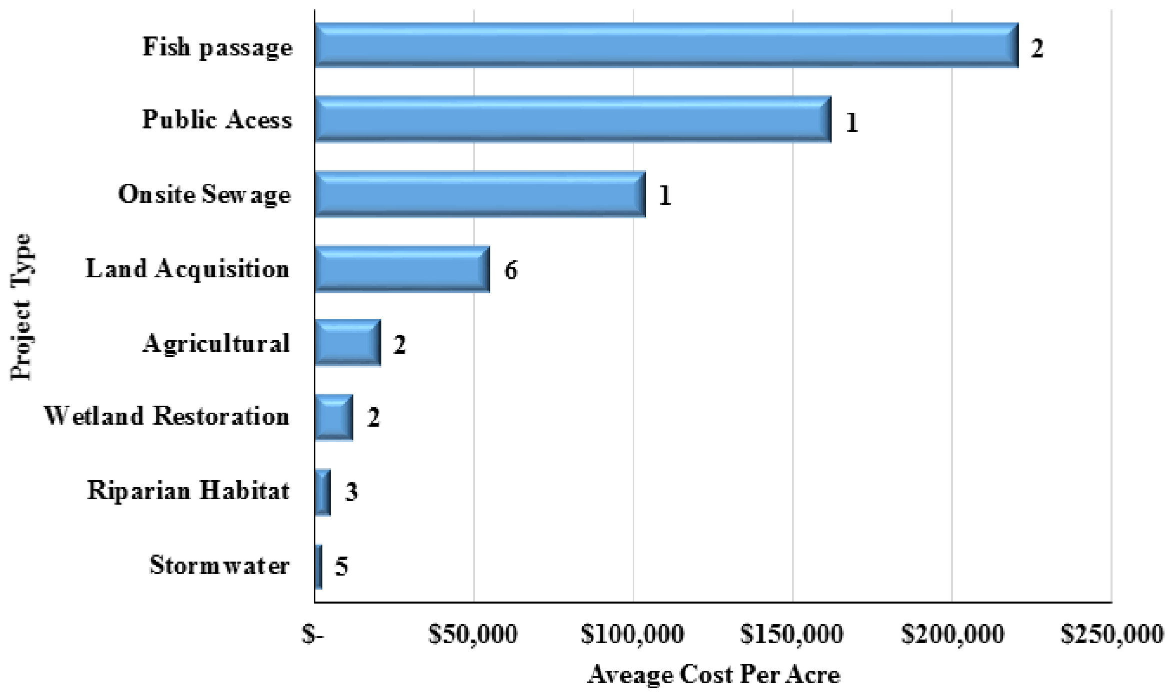

Figure 15. Average cost per acre of land treated by project types.

Values to the right of each bar indicate the number of projects funded.

Linking Implementation to Water Quality Changes

For purposes of this assessment, project data were limited to on-the-ground projects where year when project was installed, area of project (footprint), and location could be determined. Using these criteria, the specific locations of 21 of the 42 grant-funded projects were determined. These projects accounted for 81% of the total grant funds spent in the watershed (Figure 16 and Table F-1). Areas for four non-grant-funded stormwater projects were included in the assessment and were not included in funding estimates. While additional locations of many smaller stormwater projects (i.e., ponds and catch basins) were obtained from the City of Lacey, City of Olympia, and Thurston County, these location data were not included in this assessment. These projects represent a substantial investment by the municipalities; however, assessment of their effectiveness is beyond the scope of this study.

Implementation actions were compared with water quality trends at two spatial scales: (1) by comparing results of Seasonal Kendall FC Z scores and the size of the implementation footprint in acres between basins, and (2) by comparing OLS regression results from specific sampling locations with timing of specific projects upstream of sampling locations.

Basin scale assessment

Table 10 presents an overview of the basin data used in this assessment. Based on Z scores, the greatest reductions in FC occurred in Woodland Creek, followed by Henderson Inlet tributaries and Woodard Creek (the more negative the Z score, the greater the magnitude of FC change over time). These results are consistent with the cumulative implementation footprint and the percent of total grant funds by basin (Table 10). In general terms, the more grant dollars spent in a basin and the greater the cumulative footprint, the greater the FC decrease was over time.

Table 10. Henderson Inlet basins used for basin-scale FC assessment.

Basin	Area (miles)	Miles of Streams	Projects (acres)	% of Total Grant Funds	FC Z score
Henderson Inlet watershed	9.6	11.7	361	35	-1.38
Woodard Creek subbasin	9.2	16.2	117	1	-0.243
Woodland Creek subbasin	24.3	22.5	2628	45	-4.67

A map of projects implemented in Henderson Inlet watershed overlaid with results of FC trends is presented in Figure 16. Land acquisition projects were located predominantly in the Henderson Inlet basin. Stormwater projects were located predominantly in the Woodard and Woodland Creek subbasins. Agricultural lands were included in the project layer of this map; however, they were not included in this assessment. Agricultural lands are meant to represent possible locations of farm plans and other agricultural BMPs that were implemented by the Thurston County Conservation District (CD) over the study period (Figure 16).

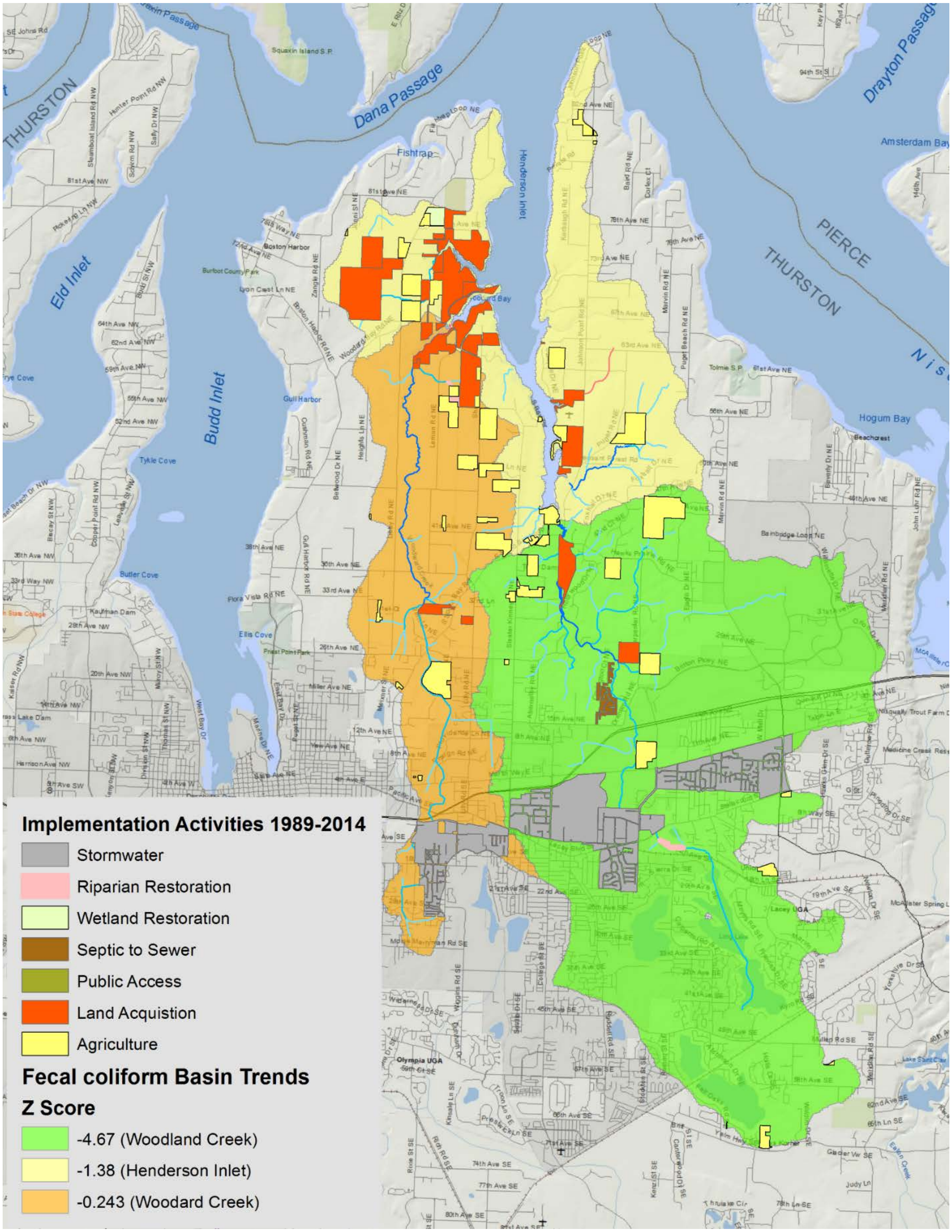

Figure 16. Overview of projects implemented in the Henderson Inlet and FC trends over time by subbasin.

Site-Scale Assessment

Figures 17-18 present results of OLS regression analysis of FC data over time and start dates of grant projects above long-term ambient monitoring stations on Sleepy, Woodard, and Woodland Creeks. No implementation information was available for other long-term FC data sets from Goose and Dobbs Creeks. Note that FC concentrations represent yearly averages of residual values from resulting OLS regression analysis and are not reflective of water quality standards.

Sleepy Creek

FC concentrations for Sleepy Creek at river mile 0.1 have been decreasing steadily over time, based on OLS regressions. An initial drop in FC concentrations between 1987 and 1988 coincided with the establishment of the Woodard Bay Natural Resources Conservation Area (NRCA) in 1987 (Figure 17). Much of Sleepy Creek flows through the Woodard Bay NRCA, an 870-acre site protecting upland and marine habitat. Since 1987, WDNR and its partners have been actively working on protecting and restoring upland and marine habitat for endangered, threatened, and sensitive plants and animals, and scenic landscapes (WDNR, 2010). To date, over 172 acres of uplands surrounding Sleepy Creek is part of the Woodard Bay NRCA (Appendix E-1). All grant data available for Sleepy Creek was associated with development of the NRCA.

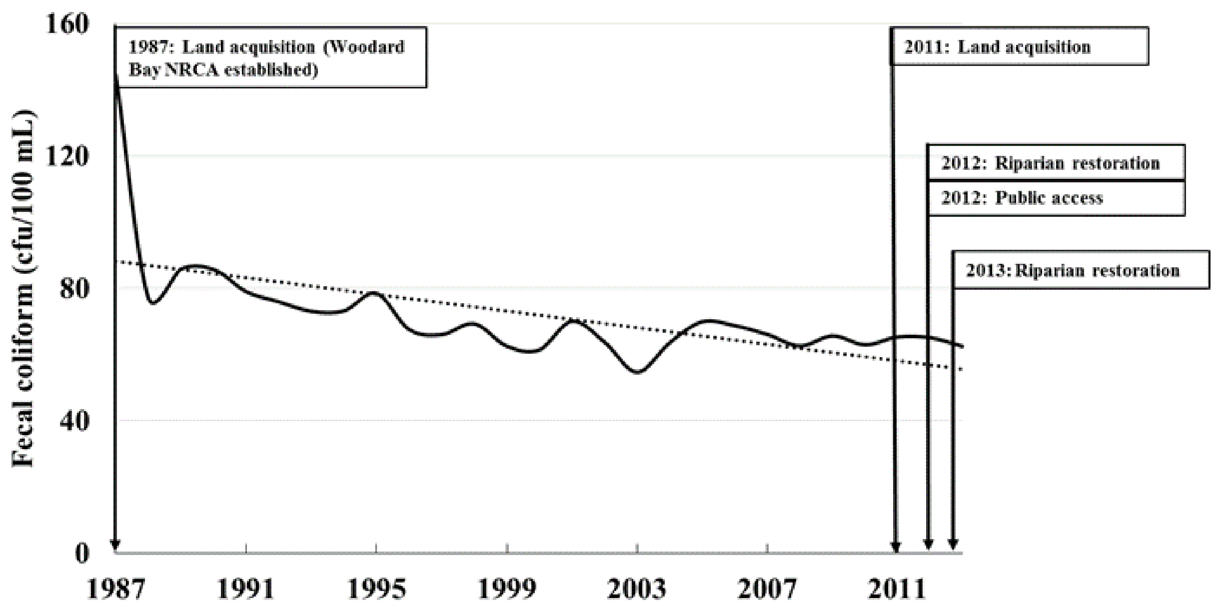

Figure 17. A comparison of results of FC trends and projects by type from 1987 through 2014 at Sleepy Creek river mile 0.1 (SL0.8).

Woodard Creek

Based on OLS regression results, FC concentrations in Woodard Creek at river mile 2.6 (WD2.6) increased from 1986 through 1997 before declining steadily through 2013 (Figure 18). Two projects were identified upstream of this sampling location. In 2002 approximately 22 acres of land adjacent to Woodard Creek was donated to Capitol Land Trust to establish a preserve (CLT, 2015). Additionally, a stormwater treatment facility was installed in 2004 on the Fones Rd ditch. This ditch was identified as a major source of FC to Woodard Creek in the original TMDL study (Sargent, 2006).

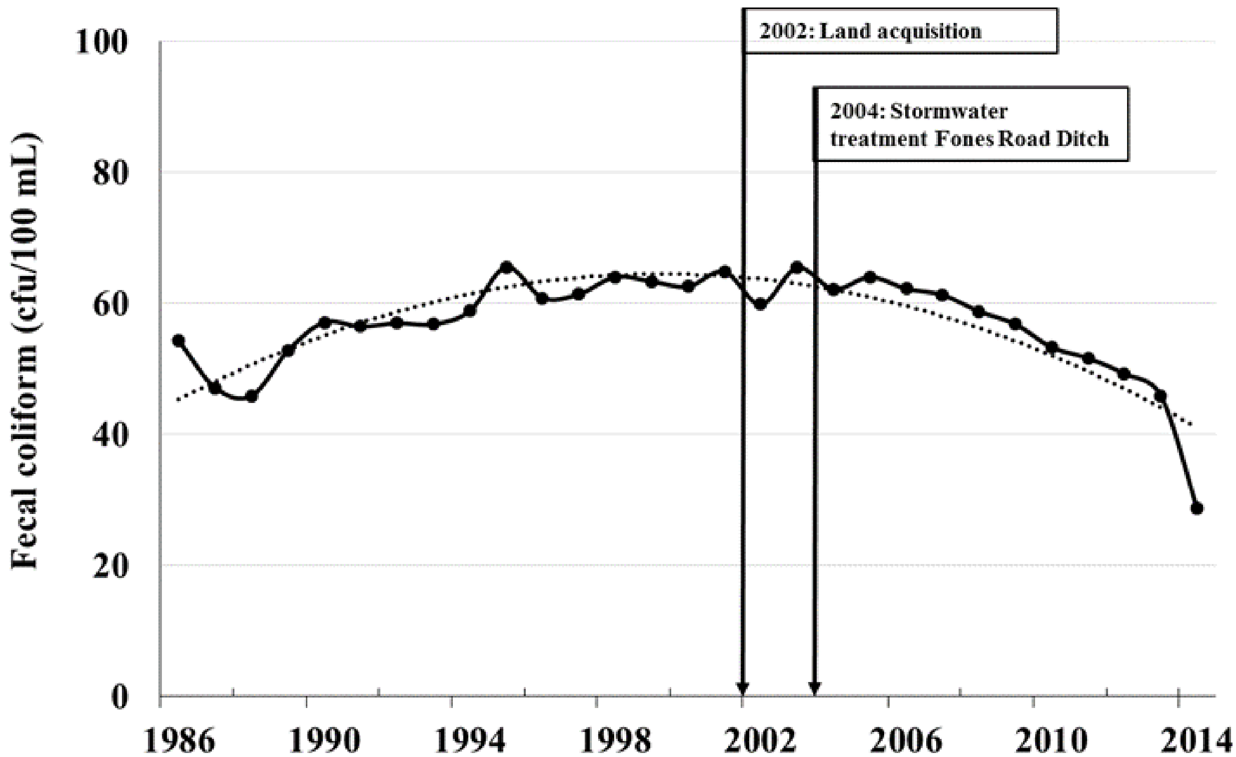

Figure 18. A comparison of results of FC trends and projects by type from 1986 through 2015 on Woodard Creek above river mile 2.6 (WD2.6).

Woodland Creek

A total of eight projects were identified as being completed upstream of WL1.6 between 1983 and 2013 (Figure 19A). The Woodland Creek Estates onsite to sanitary sewer project and the Tanglewilde stormwater retrofit projects were identified as being the two most significant projects for reducing FC and nutrient loads to Woodland Creek (Ecology, 2008). These projects were started in 2011 and 2012 respectively and both were completed in 2013.

Based on OLS trend results, FC reductions occurred before initiation of these projects, although the decline appeared to be more pronounced between 2010 and 2013 (Figure 19A). This decreasing trend was consistent with reductions in NO_x observed in Figure 10. Results of FC and NO_x results from the stormwater discharge at WL3.7SW suggest a significant decrease from 2005 through 2010 (Figure 19B). This is consistent with observations at WL1.6 and suggests reductions are likely linked to decreasing FC and NO_x trends observed at WL3.7SW. However, FC and NO_x reductions were observed at WL3.7SW before the start of the Tanglewilde retrofit project (19B).

Results of flow data collected from this outfall during 2009-2015 by Thurston County are consistent with the timing of the Tanglewilde retrofit project start and completion dates. Daily discharge data presented Figure 20 suggest a significant net decrease in the volume of stormwater discharged from the outfall over this time period. This also represents a potential significant decrease in pollutant loading to Woodland Creek.

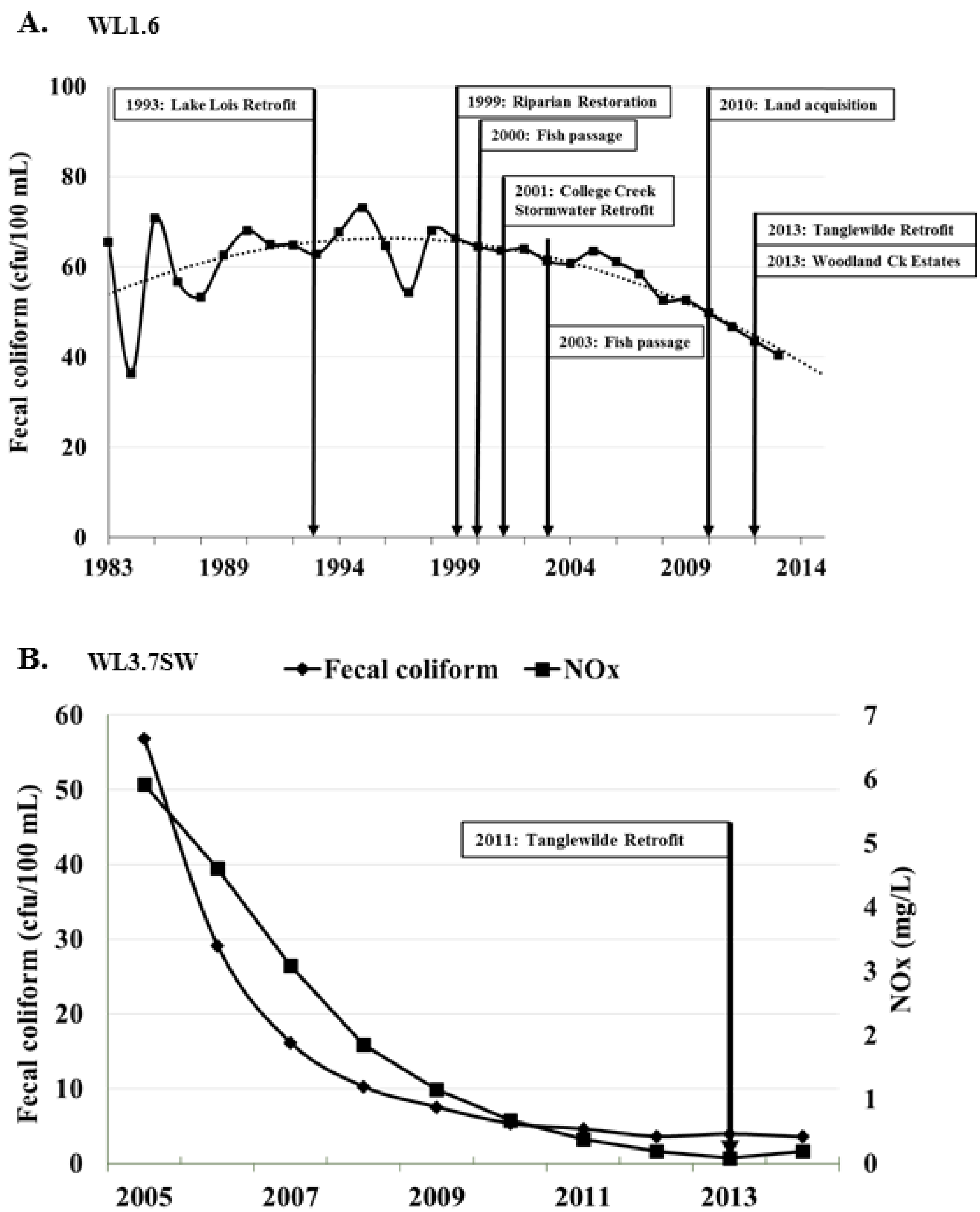

Figure 19. A comparison of results of FC trends and projects by type from 1983 through 2015 on (A) Woodland Creek river mile 1.6 (WL1.6) and the (B) Martin Way stormwater outfall at river mile 3.76 (WL3.76SW).

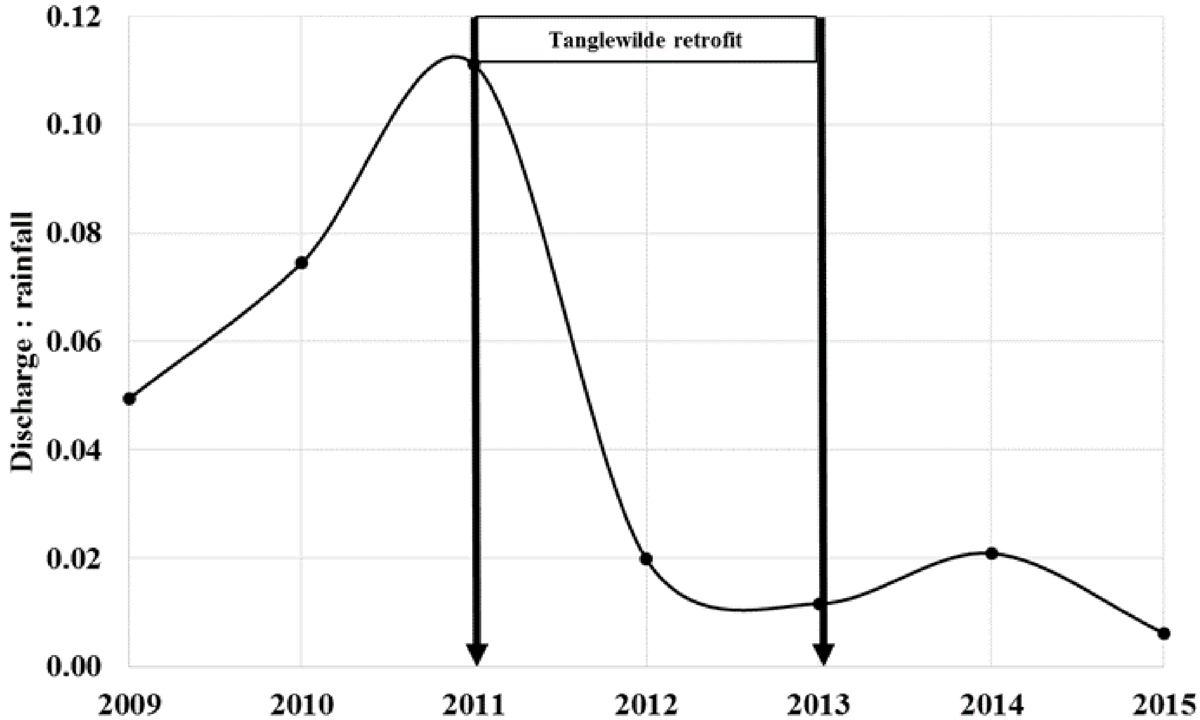

Figure 20. Ratio of cumulative yearly discharge from stormwater outfall WL3.7 to cumulative yearly rainfall from 2009 through 2015.

To account for effects of precipitation, rainfall was converted to gallons per year based on area of Tanglewilde catchment area.

Supporting Data

Additional information used to support the conclusions and recommendations is provided in the appendices of this report. This includes:

- Updates of specific actions and responsibilities outlined in the TMDL implementation plan (Appendix B).
- Phase II municipal stormwater permit requirements for the Henderson Inlet watershed (Appendix C).
- A site-scale land use and water quality assessment for tributary streams in the Henderson Inlet watershed (Appendix E).
- Results of periphyton metals sampling in Woodland and Woodard Creeks (Appendix H).
- Overview of selected grant projects implemented in the Henderson Inlet watershed (Appendix I).

Summary

Did the landscape change over time?

Land-use activities in the Henderson Inlet watershed have changed since the original TMDL study. Increases in the residential population and development of residential properties have occurred in the upper watershed within the urban growth areas (UGAs). Based on these land-use classifications, open space, trade, private forestland, and agriculture land uses have been decreasing, while cultural & recreational, undeveloped, residential, and manufacturing land uses have been increasing. Much of the decrease in open space was due to a reclassification of state lands to culture and recreation. Increases in undeveloped land uses is largely the result of land acquisition of residential parcels and reclassification of larger parcels to undeveloped prior to development.

Did FC concentrations change over time?

Results of 2014-2015 TMDL effectiveness monitoring sampling indicate that although FC water quality standards were met only at one sampling station (WD6.9), 18 of the 20 assessed stations showed reductions when compared to TMDL target reductions. When compared with TMDL targets, only FC in Sleepy Creek at river mile 0.8 (SL0.8) and a stormwater discharge from Interstate-5 to Woodland Creek (WL3.1SW2) did not improve.

Based on trend analysis, significant declines of FC were observed at watershed, subbasin, and sampling-location scales. FC results in the Woodard Creek subbasin suggest only a slight decline (improvement) in FC over time.

Did other water quality changes occur over time?

FC trends assessed using data from Thurston County's long-term ambient stations show significant decreasing trends at SL0.8, WL1.6, and WL3.76SW. Similar declines were observed in nitrate-nitrite (NO_x) concentrations at WL1.6, WL3.7SW, and WD2.6. Also, total phosphorus (TP) concentrations significantly decreased from the Martin Way stormwater outfall (WL3.7SW); however, TP concentrations increased in receiving waters during the same time period. Both Dobbs Creek (DB0.1) and Fleming Creek (FCRM1.3) demonstrated significant increasing trends in FC over time.

Were water quality improvements tied to water-cleanup efforts in the watershed?

An assessment of water-cleanup and recreational-supported projects implemented in the watershed suggests stormwater retrofits and OSS-to-sewer projects are likely the major reason for declining FC and NOx in Woodard and Woodland Creeks. Figure 21 presents the polynomial regression (lines developed in Excel) of FC and NO_x results generated with OLS regression analysis to help estimate when water quality variables began trending downwards. Based on the points of inflection of regression lines, FC reduction in Woodland and Woodard Creeks began in 1996, while reductions of NO_x began in 2001. These reductions occurred before the TMDL was developed, but they are consistent with development of new stormwater treatment facilities in the watershed (Table B-2). Note that this analysis is subjective, and estimates of years are meant only to provide approximate times.

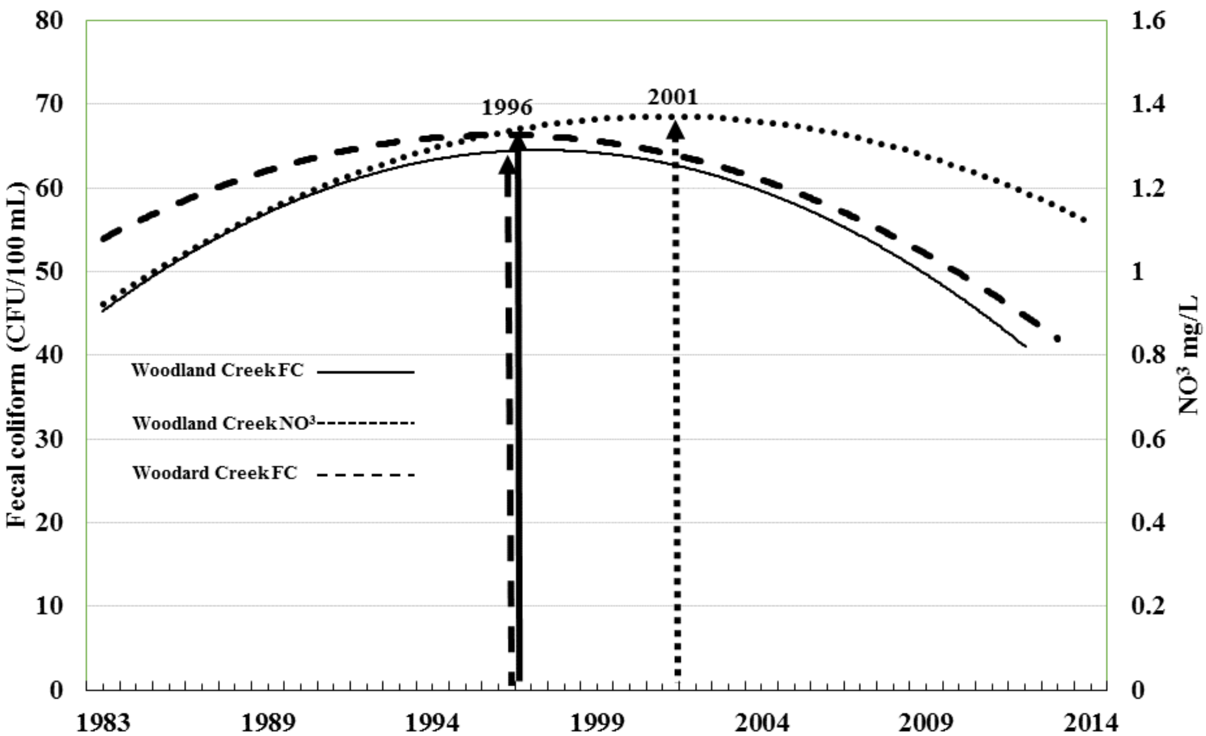

Figure 21. Non-linear regression results of FC and nitrate-nitrite (NO_x) samples from Woodland and Woodard Creeks.

Year indicates when the point of inflection occurred.

Declining TP trends observed from WL3.7SW also suggest stormwater projects were successful at reducing TP entering Woodland Creek. However, TP in both Woodard and Woodland Creeks continue to increase. Additional investigation is required to assess why TP is increasing in the watershed while NO_x is decreasing. Since many of the water cleanup actions were assumed to reduce all nutrients from waterways, an additional pathway for phosphorus input may be present.

Results of a recent nationwide study of lakes and streams indicate TP has been increasing nationwide, most notably in undisturbed catchments (Stoddard et al., 2016). The study attributes much of this increase to increased atmospheric deposition overtime. Other processes which might contribute to increases in TP in surface waters include: increases in runoff over time and loss of riparian habitat (Stoddard et al., 2016). In addition, studies have shown that stormwater retention ponds may lose capacity to treat stormwater runoff, particularly for TP, if not properly maintained over time (Gulliver et al., 2010).

In reviewing the detailed assessment, the water quality improvements observed in Sleepy Creek are likely in response to development of the Woodard Bay Natural Resource Conservation Area and changes in land use. Reductions of FC concentrations in Goose Creek indicate FC sharply decreased over a short period of time, suggesting removal of a significant pollution source. Although no records of implementation actions were available for Goose Creek, a review of land uses in this area suggests cleanup actions likely involved improved/repaired onsite sewage systems (OSSs) or correction of domestic animal access.

Results of metal analysis in periphyton, collected instream on artificial substrates during the wet season in 2014, indicate that metal concentrations (1) decrease from upstream to downstream in Woodland and Woodard Creeks, and (2) are much lower below the Martin Way stormwater outfall (WL3.7SW) than above. This may indicate stormwater treatment is more effective at removing metals below river mile 4.4 and could be reflective of the age of the treatment facility (Table H-1).

Conclusions and Recommendations

Based on the information provided above, the following conclusions and recommendations have been developed:

- Successful TMDL implementation was the result of coordination between Thurston County, City of Lacey, City of Olympia, and the other partners involved in implementation actions. Up-front grants investments made in planning were worthwhile for prioritizing implementation actions. This conclusion is partially based on the results of the *Woodland Creek Pollution Load Reduction Project* (Appendix I) which was the basis for much of the work implemented within the UGA of Woodland Creek.
    - Recommend continued support of future planning efforts in the watershed, especially for prioritizing larger infrastructure projects.
- Long-term monthly ambient water quality data collected by Thurston County's monitoring programs were essential for supporting conclusions made in this assessment. Before and after analysis of water quality data over 10 years or more has limited value for assessing effectiveness compared to assessing trends over time. This conclusion is based on the inconsistences between FC percent reduction and trend results from Sleepy and Dobbs Creeks. Only percent change results from one instream sampling station, Goose Creek, were consistent with long-term trend data.
    - Recommend continuing Thurston County's long-term ambient water quality and flow monitoring at key locations within the Henderson Inlet watershed to assess effectiveness of future actions. At a minimum, ambient monitoring and flow stations should be reestablished on Woodland (WL1.6) and Woodard (WD2.6) Creeks, with sampling monthly for nutrients and FC. Monitoring locations on Sleepy (SL0.8), Dobbs (0.1), and Fleming (FCRM1.3) Creeks should be sampled monthly for FC.
- Reductions of instream FC and NOx concentrations below stormwater outfalls were likely the result of reduction of discharge from outfalls during the wet season. Of the 15 wet-season sampling events, most outfalls were observed discharging three or fewer times during the study period (2014-2015). The exception was a stormwater outfall discharging from Interstate-5 (WL3.1SW) which was observed discharging during both wet and dry seasons, suggesting subsurface groundwater is supplementing flows from this outfall.

- Recommend future water quality monitoring locations be established in receiving waters, above and below mixing zones of outfalls, to assess water quality compliance.
- Recommend improvements to stormwater facilities at Interstate-5 which limit or reduce flow from this outfall.

- Metal concentrations from wet-season periphyton sampling suggest total metal concentrations were on average 90% higher in Woodland Creek between river mile 4.4 and 4.5 than samples collected elsewhere in the watershed (Table H-1).
  - Recommend Ecology conduct a follow-up assessment in Woodland Creek above Martin Way to assess potential sources of metals in this area.

- Dry-season FC loads continue to be problematic throughout the Henderson Inlet watershed. Windshield surveys of the watershed during the sampling period indicate small hobby farms are common in this area and could be a potential source of FC pollution. Additionally, there are more than 6600 OSSs in the watershed; approximately 1,500 are within 200 meters of a waterbody (Figure I-1). Although Thurston County requires homeowners to submit OSS inspection reports every 3 years, many of the homeowners are certificated to conduct self-inspections (Appendix I).
  - Recommend working with the Thurston Conservation District to provide targeted education and outreach to small hobby farms within the watershed.
  - Recommend working with the Conservation District to limit domestic animal access to waterways throughout the watershed.
  - Recommend Thurston County expand randomized follow ups of OSS self-inspection reports on parcels that border all waterways in the watershed.

- High FC concentrations in Fleming Creek were believed to be from wildlife, based on visual observations of raccoon waste in and near the creek upstream of the sampling location; however, contributions from an upstream residential OSS could not be ruled out.
  - Recommend Thurston County follow up with upstream landowners to rule out OSSs as a source of FC to Fleming Creek and require corrections when necessary.
  - Recommend education and outreach be conducted throughout the watershed to inform residents of the potential water quality problems associated with attracting wildlife to residential areas.

- Dobbs Creek continues to be a significant contributor to FC in Henderson Inlet. Specifically, a residential not-for-profit campground was identified in this and past studies as being a possible significant source for FC contamination to Dobbs Creek. Although livestock and hobby farms are upstream of the campground, no observable violations were identified in this study. This possible campground source is also supported by bracketed FC and optical brightener data collected during the effectiveness monitoring study.
  - Recommend Ecology continue to follow up with Thurston County regarding sanitary waste and pet waste management issues at the campground.

- Recommend Ecology provide monitoring support to Thurston County for FC source identification and follow-up monitoring once remedial actions are completed in Dobbs Creek.

- Domestic animal access to Eagle Creek was identified as a potential dry-season source of FC in the current study (Table E-6). Elevated FC concentrations during the wet season are anecdotal correlations with beaver activity at the culvert crossing upstream of Carpenter Road. Also, in 2014, a failing large (multi-resident) OSS in the upper Eagle Creek subbasin was identified and corrected (personal communication, City of Lacey). Upper Eagle Creek has been extensively developed since 2006, and stormwater, in addition to OSSs, could be potential FC sources during the wet season.
  - Recommend limiting domestic animal access to Eagle Creek.
  - Recommend assessing potential wet-season FC loading below residential areas in the upper Eagle Creek subbasin.

- Although FC and NO_X declined in response to TMDL implementation actions in the Henderson Inlet watershed, TP increased in both Woodard and Woodland Creeks during the implementation period (1993-2013). Although increases in the frequency of high run-off events and or loss of riparian areas can increase TP levels in streams, many of the water cleanup actions implemented in the watershed were meant to mitigate these processes. Decreases in the efficiency of older stormwater infiltration ponds and increases in atmospheric deposition of TP may also contribute to higher TP levels.
  - Recommend Ecology work with Thurston County, City of Lacey, and City of Olympia to identify and evaluate all TP data from the watershed.
  - Recommend evaluating TP trends from nearby waterbodies with sufficient data within the Water Resource Inventory Area (WRIA).
  - Recommend evaluating changes in stream discharge over time where data are available.
  - Recommend assessing operation and maintenance records of some of the older stormwater retrofits, particularly above Martin Way within the City of Lacey.

- In assessing stormwater management-related programs (including retrofits) at a watershed scale, continuous flow monitoring at downgradient stormwater outfalls is an inexpensive and informative way to evaluate effectiveness. Flow data collected from the Martin Way stormwater outfall over the course of the Tanglewilde stormwater retrofit project was key to showing effectiveness.
  - Recommend supporting continuous flow monitoring of outfalls in future retrofit projects to assist with assessing effectiveness.

- Difficulty in acquiring land for developing new stormwater treatment infrastructure and protection of sensitive areas was a common theme while reviewing many of the reports associated with this document.
  - Recommend expanding, or including, grants and loans that support land acquisition for stormwater retrofits in the watershed.

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Appendices

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Appendix A: Glossary and Acronyms

Glossary

Anthropogenic: Human-caused.

Best management practices (BMPs): Physical, structural, and/or operational practices that, when used singularly or in combination, prevent or reduce pollutant discharges.

Clean Water Act: Federal Act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

Designated uses: Those uses specified in Chapter 173-201A WAC (Water Quality Standards for Surface Waters of the State of Washington) for each waterbody or segment, regardless of whether or not the uses are currently attained.

Effectiveness monitoring: Monitoring to determine whether the recommended *Detailed Implementation Plan*, after a significant portion of the recommendations or prescriptions have been implemented, is adequate in meeting (1) the goals and objectives for the TMDL project or (2) other desired outcomes over long temporal scales.

Existing uses: Those uses actually attained in fresh and marine waters on or after November 28, 1975, whether or not they are designated uses. Introduced species that are not native to Washington, and put-and-take fisheries comprised of nonself-replicating introduced native species, do not need to receive full support as an existing use.

Extraordinary primary contact: Waters providing extraordinary protection against waterborne disease or that serve as tributaries to extraordinary quality shellfish harvesting areas.

Fecal coliform bacteria (FC): That portion of the coliform group of bacteria which is present in intestinal tracts and feces of warm-blooded animals as detected by the product of acid or gas from lactose in a suitable culture medium within 24 hours at 44.5 + or - 0.2 ° Celsius. FC are "indicator" organisms that suggest the possible presence of disease-causing organisms. Concentrations are measured in colony forming units per 100 milliliters of water (cfu/100mL).

Geometric mean: A mathematical expression of the central tendency (an average) of multiple sample values. A geometric mean, unlike an arithmetic mean, tends to dampen the effect of very high or low values, which might bias the mean if a straight average (arithmetic mean) were calculated. This is helpful when analyzing bacteria concentrations, because levels may vary anywhere from ten to 10,000 fold over a given period. The calculation is performed by either: (1) taking the nth root of a product of n factors, or (2) taking the antilogarithm of the arithmetic mean of the logarithms of the individual values.

Load allocation: The portion of a receiving waters' loading capacity attributed to one or more of its existing or future sources of nonpoint pollution or to natural background sources.

Loading capacity: The greatest amount of a substance that a waterbody can receive and still meet water quality standards.

Margin of safety: Required component of TMDLs that accounts for uncertainty about the relationship between pollutant loads and quality of the receiving waterbody.

Nonpoint source: Source of pollution that enters any waters of the state from any dispersed land-based or water-based activities. This includes, but is not limited to, atmospheric deposition, surface-water runoff from agricultural lands, urban areas, or forestlands, subsurface or underground sources, or discharges from boats or marine vessels not otherwise regulated under the National Pollutant Discharge Elimination System Program. Generally, any unconfined and diffuse source of contamination. Legally, any source of water pollution that does not meet the legal definition of "point source" in section 502(14) of the Clean Water Act.

Nutrient: Substances such as carbon, nitrogen, and phosphorus used by organisms to live and grow. Too many nutrients in the water can promote algal blooms and rob the water of oxygen vital to aquatic organisms.

Phase I Stormwater Permit: The first phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to medium and large municipal separate storm sewer systems (MS4s) and construction sites of five or more acres.

Phase II Stormwater Permit: The second phase of stormwater regulation required under the federal Clean Water Act. The permit is issued to smaller municipal separate storm sewer systems (MS4s) and construction sites over one acre.

Point source: Source of pollution that discharges at a specific location from pipes, outfalls, and conveyance channels to a surface water. Examples of point source discharges include municipal wastewater treatment plants, municipal stormwater systems, industrial waste treatment facilities, and construction sites where more than 5 acres of land have been cleared.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Primary contact recreation**:** Activities where a person would have direct contact with water to the point of complete submergence including, but not limited to, skin diving, swimming, and water skiing.

Riparian: Relating to the banks along a natural course of water.

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snow melt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Total Maximum Daily Load (TMDL): Water cleanup plan. A distribution of a substance in a waterbody designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual wasteload allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a Margin of Safety to allow for uncertainty in the wasteload determination. A reserve for future growth is also generally provided.

Wasteload allocation: The portion of a receiving water's loading capacity allocated to existing or future point sources of pollution. Wasteload allocation constitutes one type of water quality-based effluent limitation.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

303(d) List: Section 303(d) of the federal Clean Water Act requires Washington State periodically to prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited waterbodies (ocean waters, estuaries, lakes, and streams) that fall short of state surface water quality standards and are not expected to improve within the next two years.

90th percentile: A statistical number obtained from a distribution of a data set, above which 10% of the data exists and below which 90% of the data exists.

Acronyms and Abbreviations

BMP	Best management practice
Ecology	Washington State Department of Ecology
EPA	U.S. Environmental Protection Agency
FC	Fecal coliform bacteria
GIS	Geographic Information System software
GM	Geometric mean
HUC	Hydrologic unit code
LOTT	Lacey Olympia Tumwater Thurston Clean Water Alliance
NOx	Nitrate-nitrite
NHD	National Hydrography Dataset
NRCA	Natural Resources Conservation Area
OLS	Ordinary least squares
OSS	Onsite sewage system
RCO	Washington Department of Recreation and Conservation Office
RCW	Revised Code of Washington

RM	River mile
TMDL	(See Glossary above)
TP	Total phosphorus
WAC	Washington Administrative Code
WDNR	Washington Department of Natural Resources
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation

Units of Measurement

°C	degrees centigrade
cfs	cubic feet per second
cfu	colony forming unit
dw	dry weight
ft	feet
kg	kilograms, a unit of mass equal to 1,000 grams.
mg/Kg	milligrams per kilogram (parts per million)
mmol	millimole or one-thousandth of a mole.
mole	an International System of Units (IS) unit of matter
ug/Kg	micrograms per kilogram (parts per billion)
uM	micromolar, a chemistry unit

Appendix B: Authorities and Responsibilities for TMDL Implementation

This section describes the regulatory authorities, responsibilities, and programs of the groups that participate in reporting and protecting waterways within the Henderson Inlet watershed. Table B-1 shows specific actions and responsibilities for restoring water quality from the 2008 implementation plan (Ecology, 2008).

The Henderson Inlet technical advisory group determined Priority 1 actions that are most important for reducing bacteria, based on information from the water quality study. Priority 2 and 3 items either address smaller bacteria sources or are actions that will be undertaken only if higher priority actions fail to achieve anticipated results. An “R” in the Priority column means “recommended action” and refers to actions for parameters other than bacteria (i.e., dissolved oxygen, pH, and temperature). Some analysis was done for these parameters during the TMDL water quality study, and their management is important (especially in the case of dissolved oxygen and related nutrients). But reductions are not a mandated part of the TMDL project. Most of the actions in Table B-1 that address bacteria issues would also help improve or protect other water quality parameters.

Table B-1. Actions and responsibilities for restoring water quality in the Henderson Inlet watershed.

Source area	Action	Priority*	Lead Authority	Implementation status
Henderson Inlet watershed	Henderson Inlet Watershed Septic System Operations and Maintenance Program.	1	Thurston County	Program development; ongoing implementation
	Support low impact development (LID) area-wide.	1	Thurston County, City of Lacey, City of Olympia	Local jurisdictions to complete the most recent update to stormwater manuals in by 12/13/16.
	Watershed characterization to help prioritize stormwater projects for greatest benefit.	1	Thurston County	Completed.
	Investigate potential for homeless camps in wooded areas to contribute to bacteria pollution.	3	Thurston County and the cites of Lacey and Olympia.	NA
	Investigate human activities that may be encouraging unnatural concentrations of wildlife (i.e., unintentional food supplies such as garbage, intentional feeding of ducks and geese).	3	Thurston County and the cites of Lacey and Olympia.	NA
	Continue to encourage watershed residents to use water wisely.	R	City of Lacey, Thurston County, Thurston CD	Ongoing
	Offer technical and cost share assistance and outreach to agricultural, shoreline, and riparian landowners to help them implement Best Management Practices (BMPs) that address water quality issues.	1	Thurston CD	Ongoing
Woodland Creek	Protect springs and tributaries in lower Woodland Creek from further degradation, offering measures to protect streamside vegetation and groundwater in hydraulic continuity.	R	City of Lacey, Thurston County	Ongoing. Covered under Thurston County's Critical Area Ordinance, and Phase II stormwater permit.
	Implement effective shade recommendations to improve dissolved oxygen levels.	R	Thurston CD	Ongoing
	Include nutrient attenuation or removal in stormwater treatment to limit algal growth in Woodland Creek.	R	Thurston County, City of Lacey	Ongoing. Covered under Phase II stormwater permit requirements.
	Prohibit exempt wells within Lacey city limits where city water is available.	R	City of Lacey	Complete
	Investigate possible widespread changes in groundwater nitrate concentrations in the Woodland Creek subbasin.	R	Thurston County	Ongoing. Monitoring conducted under an inter-local agreement between Thurston County, City of Lacey, and City of Olympia.

Source area	Action	Priority*	Lead Authority	Implementation status
Lake Lois to mouth of Jorgensen Ck (approximately RM 4.3 to 1.4)	Pollutant Load Reduction Project: Analyze sources of pollution, including groundwater, to stormwater and to Woodland Creek from the Long Lake outlet to RM 1.6. Resulting information will be used to determine improvement options, which may include facility designs, pursuit of funding, and/or policy or regulation changes.	1	Thurston County, City of Lacey	Completed final report. Restoration of drywells, new infiltration facility, and Carpenter Road improvements runoff treatment and infiltration projects were constructed in 2010-2013.
Stormwater discharge at Martin Way (RM 3.7)	Pollutant Load Reduction Project and Watershed Characterization project will determine appropriate actions for this discharge. Follow-up monitoring will be conducted to confirm effectiveness.	1	Thurston County	Completed final report.
College Ck and discharge to Woodland Ck	At College Regional Stormwater Facility, monitor discharge, if any, for bacteria.	1	City of Lacey	Construction completed October 2007.
RM 3.4	Set biological oxygen diamond limits for Fish Farm.	R	Ecology	
WSDOT discharges (2) at Woodland Ck and Interstate-5 RM 3.1	Implement pollution-prevention measures in Storm Water Management Plan to address bacteria concentrations at these state highway storm drains.	2	Washington State Department of Transportation	Construction completed in 2010. Water quality monitoring occurred in 2014-15.
Woodland Ck RM 2.6 to 0.2 including Eagle, Fox, Quail, Jorgenson, Palm, and Fox Creeks	Evaluate agricultural operations affecting this reach. Provide technical assistance as needed.	1	Thurston CD	Completed
	At Fox Creek, investigate low dissolved oxygen and possible sources of biochemical oxygen demand (BOD).	R	Thurston County, Thurston CD	Sources of nonpoint pollution are limited to onsite sewage systems (OSSs).
	Investigate possible FC sources during storm events, including stormwater ponds.	1	Thurston County	Completed
	Investigate sources (onsite and stormwater) on Jorgenson Creek especially above Pleasant Glade Rd.	1	Thurston County	79% reduction was observed between 2006 and 2014 studies. No sources of stormwater have been identified.
	Sample water quality on Quail Creek to determine if changes in agricultural practices have accomplished needed reductions.	2	Ecology	Monitoring conducted in 2014-2015. Water quality standards not met; however, an 89% reduction of critical season target water observed.
Woodard Creek	Control phosphorus sources to protect or improve dissolved oxygen levels.	R	City of Olympia, Thurston CD, Thurston County	Partially addressed by the Septic System Operations and Maintenance Program and the work of Thurston CD. NPDES Phase II Municipal Stormwater Phosphorous Treatment for new project in Woodard basin.

Source area	Action	Priority*	Lead Authority	Implementation status
	Provide stewardship education to residents in the Woodard Creek area.		Thurston CD, Thurston County	This program has been active in the watershed since 2003 and is currently being expanded.
	Stormwater treatment facility for Taylor wetland stormwater discharge. Monitor discharge, if any, for bacteria.	1	City of Olympia	Completed. Facility appears to be well-sized to handle volume of stormwater received.
	Continue investigation of sources.	1	City of Olympia, Thurston County	Ongoing. Covered under Phase II stormwater permits.
Meyer Creek	Provide technical assistance on livestock management.	1	Thurston CD	Completed. Meyer Creek at RM 0.6 meeting geometric mean criteria and nearly meeting wet-season criteria.
Sleepy Creek	Provide technical assistance on livestock management.	1	Thurston CD	Ongoing
Dobbs Creek	Investigate possible sources at RV park.	1	Thurston County	Ongoing
	Conduct segment monitoring to identify source areas.	1	Ecology	Completed. 2014-2015 monitoring by Ecology and Dickes, 2009.
Henderson Inlet	Long-term trend monitoring of ammonia, nitrogen, and total nitrogen in Woodland Creek.	R	Thurston County	Ongoing. Thurston County monitoring program.
	Periodically review the operation and planned expansion of Hawks Prairie Water Reclamation Facility, including monitoring data.	R	Ecology	Ongoing
	Evaluate factors contributing to low dissolved oxygen levels and determine load and wasteload allocations so that the inlet meets water quality standards in the future.	R	Ecology	Completed. South Puget Sound Dissolved Oxygen Study completed in 2014 (Ahmed et al., 2014)

RM: river mile
CD: Conservation District

City of Lacey

The City of Lacey implements a variety of programs, activities, and regulations related to controlling runoff as required under the Phase II Permit (City of Lacey, 2016). In addition, Lacey's Stormwater Utility manages an extensive system of public stormwater facilities located throughout the city (Table B-2) and maintains a drainage system of more than 5,000 catch basins and more than 90 miles of storm drain pipe. The storm system drains to more than 50 regional stormwater ponds, which also require regular maintenance and periodic renovation (City of Lacey, 2016).

The city also actively investigates the sources of pollutants entering streams and stormwater through their Illicit Discharge Detection and Elimination Program and conducts outreach to businesses and residents. They have a storm-pond education program and a stormwater facility inspection program for privately owned stormwater facilities. Lacey's Stream Team volunteer program includes storm drain stenciling and other pollution prevention education. The Stream Team is also part of the region-wide pet waste pollution prevention program and offers brochures, signs, and pet waste stations to homeowners associations and also places these at city-owned facilities (City of Lacey, 2016).

Lacey is installing stream buffers to protect the entire Woodland Creek corridor within the city limits. In addition, Lacey acquired several parcels in the Woodland Creek corridor and has provided grants to private landowner to establish native, riparian buffers within the city limits. The result is that the entire creek within the city limits is now protected with 200-foot riparian buffers that are mandated by city ordinance (City of Lacey, 2016).

Table B-2. City of Lacey managed stormwater facilities.

Ruddell Road Stormwater Treatment Facility ("Ruddell & 32nd")	
Location:	3411 Ruddell Road, west of Hicks Lake
Facility Type:	Pre-treatment Pond and Wetland
Discharge to:	Hicks Lake
Constructed:	1999
Contributing Drainage Basin Area	436 acres
College Regional Stormwater Facility	
Location:	St. Martin's University, north of 6th Avenue SE
Facility Type:	Settling Pond and two Retention Ponds
Discharge to:	College Creek, a tributary to Woodland Creek
Constructed:	2007
Contributing Drainage Basin Area:	424 acres
Woodland Creek Stormwater Treatment Facility	
Location:	North of 7th Avenue SE at Lacey Avenue SE
Facility Type:	Constructed Wetland and Infiltration Basin
Discharge to:	Groundwater, with overflow to Woodland Creek
Constructed:	1991
Contributing Drainage Basin Area:	299
Ruddell Road SE Stormwater Treatment Facility	
Location:	4701 Ruddell Road, SE corner of Rainier Vista Park
Facility Type:	Wet Pond and Infiltration Basin
Discharge to:	Groundwater, with overflow to Southwick Lake
Constructed:	1993
Contributing Drainage Basin Area:	114 acres
Upper Fones Road Stormwater Facility	
Location:	East of Fones Road, south of Pacific Avenue SE
Facility Type:	Wetpond and Infiltration Basin
Discharge to:	Lower Fones Facility, Taylor Wetlands, Woodard Creek
Constructed:	2004
Contributing Drainage Basin Area:	97 acres
College & 53rd Avenue SE Stormwater Facility	
Location:	East of College Street on 53rd Avenue SE
Facility Type:	Wetpond and Infiltration Basin
Discharge to:	Groundwater
Constructed:	1991
Contributing Drainage Basin Area:	51 acres

City of Olympia

Approximately 2,130 acres of the Woodard Creek and Woodland Creek subbasins are within the City of Olympia's jurisdiction and its urban growth area. Olympia's Storm and Surface Water Utility is responsible for stormwater management, water quality, and aquatic habitat in the city. This program includes many services, including development review; technical assistance/code enforcement; public education and involvement; environmental planning and policy development; capital facilities planning; and monitoring, research, and evaluation. Olympia also works closely with Lacey to reduce FC discharges from Fones/Taylor wetland treatment facilities and to monitor water quality adjacent to these facilities (City of Olympia, 2016).

Henderson Inlet Shellfish Protection District citizen advisory group

In December 2001, the Board of Thurston County Commissioners created shellfish protection districts for Henderson Inlet and the Nisqually Reach because shellfish resources were declining there. The following spring, the commissioners appointed a stakeholder group for each shellfish protection district. The groups developed recommendations to restore water quality in Henderson Inlet and Nisqually Reach. Their recommendations submitted to the county commissioners in 2003 included: improving management of onsite sewage systems (OSSs) and stormwater, agricultural practices, land use, and wildlife.

The Henderson and Nisqually Shellfish Protection District stakeholders groups recommended that the two groups be combined and they began work on an implementation work plan. That plan is available at http://www.co.thurston.wa.us/shellfish/.

In December 2003, the combined shellfish protection district stakeholder group became the core members of a larger citizen advisory committee to help develop a risk-based operation and maintenance program for OSSs in the Henderson Inlet watershed. The program was started in response to degrading water quality in Henderson Inlet and to the results of a Henderson Inlet DNA-typing study which showed that human waste is contributing to the problem. In the fall of 2005, the Thurston County Board of Health passed the *Septic System Operation and Maintenance Proposal for Henderson Inlet Watershed.*

The group continues to meet and oversee implementation of their work plan and issues affecting bacteria in Henderson Inlet. Their work, along with the *Henderson Watershed Total Maximum Daily Load Study*, will provide the foundation of the detailed cleanup plan for Henderson Inlet.

Thurston Conservation District

The Thurston Conservation District – under authority of Ch. 89.08 RCW, *Conservation Districts* – provides education and technical assistance to residents, develops conservation plans for farms, and assists with design and installation of best management practices. When developing conservation plans, the district uses guidance and specifications from the U.S. Natural Resources Conservation Service. Farmers who receive a Notice of Correction from Ecology will normally be referred to the Thurston Conservation District for assistance.

The Thurston Conservation District is funded by a county-wide district assessment, in accordance with Chapter 89.08.400 RCW. The district assessment excludes properties within the city limits of Yelm, Tenino, and Rainier, as those cities were formed before 1948 and chose to be excluded, per the RCW. Currently, 28% of the district's tax assessment is dedicated to project work in the Shellfish Protection District. The district regularly receives funding from the Conservation Commission and grants from Ecology, the Salmon Recovery Funding Board, and others.

The Thurston Conservation District serves the county in many ways. It offers conservation planning, technical and cost-share assistance to landowners, a yearly native plant sale, and most of the funding for South Sound GREEN − a student-based volunteer monitoring and education program. It also coordinates the Shellfish Pledge Program, an incentive-based program that is geared toward both urban and rural landowners.

Thurston County

In addition to implementing Phase II permit requirements (Thurston County, 2015), Thurston County manages nonpoint sources of pollution in Henderson Inlet through regulating land uses and onsite sewage systems (OSSs), animal waste, and other nonpoint sources through Article VI (http://www.co.thurston.wa.us/health/ehadm/pdf/Article_VI.pdf).

The county regulates land use in unincorporated areas, including urban growth areas (UGAs), within the Henderson Inlet watershed through Thurston County development codes (Titles 17,18,20-23) and a Critical Areas Ordinance (TCC Title 24), in accordance with Washington State's Growth Management Act, Ch. 36.70A.

The Growth Management Act requires local governments to protect five types of critical areas: important fish and wildlife habitat areas, wetlands, critical aquifer recharge areas, frequently flooded areas, and geologically hazardous areas such as bluffs. Thurston County adopted and updated the Critical Areas Ordinance in 2013 (TCC Title 24). The purpose of the changes are to modify the critical areas regulations for agricultural activities.

Thurston County has jurisdiction over OSSs within the Henderson Inlet watershed, both within and outside of Olympia city limits. Regulation of OSSs is covered under the county's OSS management plan that was updated in 2016 (Thurston County, 2016).

Washington State Department of Transportation (WSDOT)

WSDOT is responsible for managing stormwater from state highways. It implements their Storm Water Management Plan which describes a range of best management practices. These practices are applied to new development and are retrofitted to existing facilities as needed.

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Appendix C: Phase II TMDL Requirements.

Total Maximum Daily Load (TMDL) Requirements
Western Washington Phase II Municipal Stormwater Permit –
August 1, 2013, Modified January 16, 2015

Thurston County

1. Annually implement the following best management practices in areas discharging to the Henderson Inlet via the MS4 in accordance with S5.C.4 of the Western Washington Phase II Permit:
    a. Require phosphorus control for new and redevelopment projects that discharge via the MS4 to Woodard Creek and meet the project thresholds in Appendix 1, Minimum Requirement #6: Runoff Treatment of the Western Washington Phase II permit.
2. Annually implement the following best management practices for reducing fecal coliform bacteria (FC) in areas discharging to the Henderson Inlet via the MS4 in accordance with S5.C.3 of the Western Washington Phase II Permit:
    a. Designate areas discharging via the MS4 to Woodland Creek from river mile 1.6 to 0.2 and Jorgenson Creek upstream of Pleasant Glade Road as high priority areas for illicit discharge detection and elimination field screening. Implement the schedules and activities identified in S5.C.3 of the Western Washington Phase II permit. Investigation shall include stormwater ponds and onsite sewage systems (OSSs) as potential FC sources, and sampling of wet-weather discharges (November through April).
3. Annually implement the following best management practices for reducing FC in areas discharging to the Henderson Inlet via the MS4 in accordance with S5.C.1 of the Western Washington Phase II Permit.
    a. Continue supporting the *Watershed Septic System Operations and Maintenance Program.* Develop a targeted educational plan delivering:
        i. Technical assistance to landowners through at least one presentation or workshop annually.
        ii. Technical assistance to landowners through one publication or targeted letter annually.
        iii. A resource webpage on the city's website.
    b. Continue offering public education and outreach efforts for FC reduction such as brochures, signage, and pet waste stations to homeowner associations.

City of Lacey

1. Annually implement the following best management practices in areas discharging to the Henderson Inlet via the MS4 in accordance with S5.C.1 of the Western Washington Phase II Permit:
    a. Continue the Private Stormwater Facilities Maintenance Program, providing commercial and residential stormwater facility/BMP owners educational resources for facility function and maintenance requirements.

b. Offer bacteria pollution reduction brochures, signage, and pet waste stations to homeowners associations.
c. Maintain pet waste bag dispenser units in City parks.
d. Install educational signage at City facilities/property.
e. Develop a targeted educational plan for OSS owners that includes goals, target audiences, messages, format, distribution, and evaluation methods by December 31, 2016. Permittees may meet requirement individually or through regional efforts.

2. Continue developing and implementing a FC wet weather sampling program for the College Regional Stormwater Facility by December 31, 2013 in accordance with the illicit discharge detection and elimination efforts and activities identified in S5.C.3 of the Western Washington Phase II permit.
   a. Submit a plan to Ecology for approval by November 1, 2013. The sampling program shall establish a regularly scheduled sampling schedule (at least two times per year, as feasible and consistent with the city's Wet Weather Discharge Plan) during the wet season (November through April), specific sampling locations, sampling protocols, parameters, analytical methods, and timelines for implementation.
   b. If sampling results indicate potential illicit discharges, conduct an investigation in accordance with S5.C.3 of the Western Washington Phase II permit.
   c. Submit a summary of sampling and investigations with each annual report.

3. Develop and implement a coordinated plan with the City of Olympia to monitor and reduce FC discharges from the Fones/Taylor wetland treatment facilities by December 31, 2014 in accordance with S5.C.3 of the Western Washington Phase II permit.
   a. Submit a program plan to Ecology that includes a timeline for implementation, sampling frequencies, and identifies, at the minimum, who will be responsible for sampling, investigations, and enforcement by December 31, 2013.
   b. If sampling results indicate potential illicit discharges, conduct an investigation in accordance with S5.C.3 of the Western Washington Phase II permit.
   c. Submit a summary of the coordinated efforts with sampling, investigation, and enforcement actions taken with the annual reports.

4. Annually implement the following best management practices in areas discharging to the Henderson Inlet via the MS4 in accordance with S5.C.5 of the Western Washington Phase II Permit:
   - Continue re-vegetation and nuisance vegetation management along Woodland Creek and its tributaries.

City of Olympia

1. Annually implement the following BMPs in areas discharging to Henderson Inlet via the MS4 in accordance with S5.C.4 of the Western Washington Phase II permit:
   - Require phosphorus control for new and redevelopment projects that discharge via MS4 to Woodard Creek and meet the project thresholds in Appendix 1, Minimum Requirement #6: Runoff Treatment of the Western Washington Phase II permit.

2. Develop and implement a coordinated plan with the City of Lacey to monitor and reduce FC discharges from the Fones/Taylor wetland treatment facilities by December 31, 2014 in accordance with S5.C.3 Illicit Discharge Detection and Elimination of the Western Washington Phase II permit.
   a. Submit a program plan to Ecology that includes a timeline for implementation, sampling frequencies, and identifies, at the minimum, who will be responsible for sampling, investigations, and enforcement by December 31, 2013.
   b. If sampling results indicate potential illicit discharges, conduct an investigation in accordance with S5.C.3 of the Western Washington Phase II permit.
   c. Submit a summary of the coordinated efforts with sampling, investigation, and enforcement actions taken with each annual report.

Appendix D: Land-Use Classifications

Table D-1. Stratification of real property and assessment roles.

Land Use Classification	Code	Description
Not Classified	1	No classification
Residential	11	Household, single family units
	12	Household, 2-4 units
	13	Household, multi-units (5 or more)
	14	Residential condominiums
	15	Mobile home parks or courts
	16	Hotels/motels
	17	Institutional lodging
	18	All other residential not elsewhere coded
	19	Vacation homes and cabins
Manufacturing	21	Food and kindred products
	22	Textile mill products
	23	Apparel and other finished products made from fabrics, leather, and similar materials
	24	Lumber and wood products (except furniture)
	25	Furniture and fixtures
	26	Paper and allied products
	27	Printing and publishing
	28	Chemicals
	29	Petroleum refining and related industries
	30	Rubber and miscellaneous plastic products
	31	Leather and leather products
	32	Stone, clay, and glass products
	33	Primary metal industries
	34	Fabricated metal products
	35	Professional, scientific, and controlling instruments
	36	Not presently assigned
	37	Not presently assigned
	38	Not presently assigned
	39	Miscellaneous manufacturing
Transportation and Utilities	41	Railroad/transit transportation
	42	Motor vehicle transportation
	43	Aircraft transportation
	44	Marine craft transportation
	45	Highway and street right of way
	46	Automobile parking
	47	Communication
	48	Utilities
	49	Other transportation, communication, and utilities not classified elsewhere
Retail Trade	50	Condominiums - other than residential condominiums
	51	Wholesale trade
	52	Retail trade - building materials, hardware, and farm equipment

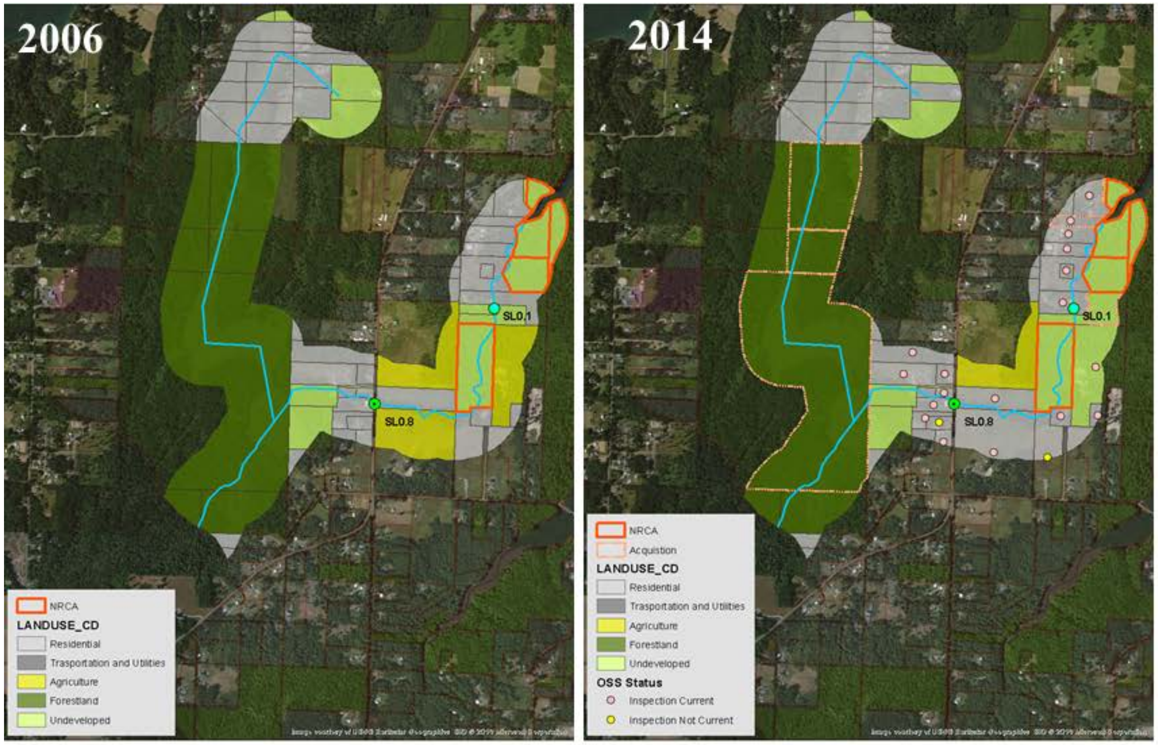
Land Use Classification	Code	Description
	53	Retail trade - general merchandise
	54	Retail trade - food
	55	Retail trade - automotive, marine craft, aircraft, and accessories
	56	Retail trade - apparel and accessories
	57	Retail trade - furniture, home furnishings, and equipment
	58	Retail trade - eating and drinking
	59	Other retail trade
	61	Finance, insurance, and real estate services
	62	Personal services
	63	Business services
	64	Repair services
	65	Professional services
	66	Contract construction services
	67	Governmental services
	68	Educational services
	69	Miscellaneous services
Cultural and Recreational	71	Cultural activities and nature exhibitions
	72	Public assembly
	73	Amusements
	74	Recreational activities
	75	Resorts and group camps
	76	Parks
	77	Not presently assigned
	78	Not presently assigned
	79	Other cultural, entertainment, and recreational
Agriculture	81	Agriculture (not classified under current use law)
	82	Agriculture related activities
	83	Agriculture classified under current use chapter 84.34 RCW
Resource Production	84	Fishing activities and related services
	85	Mining activities and related services
	86	Not presently assigned
	87	Not presently assigned
	88	Designated forestland under chapter 84.33 RCW
	89	Other resource production
Open Space	92	Noncommercial forest
	94	Open space land classified under chapter 84.34 RCW
Undeveloped	91	Undeveloped land
	93	Water areas
	95	Timberland classified under chapter 84.34 RCW
	96	Not presently assigned
	97	Not presently assigned
	98	Not presently assigned
	99	Other undeveloped land

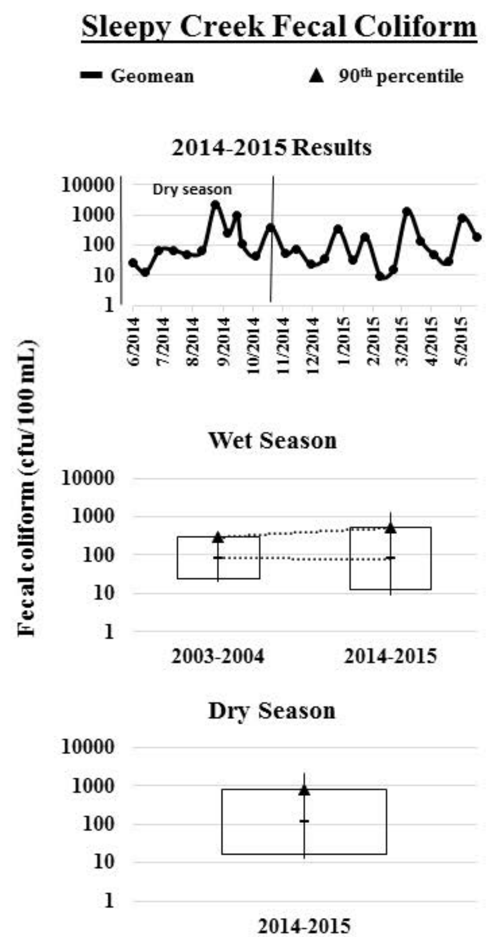
Appendix E: Site-Scale, Land-Use Assessment and Water Quality Results

Figures E-1 through E-11 present fecal coliform bacteria (FC) results, land-use changes between 2006 and 2014, septic system locations, and locations of stormwater infrastructure in selected tributaries sampled within the Henderson Inlet watershed.

Information in this assessment was limited data within 200 meters on either side of the waterbody as delineated by the National Hydrography Dataset (NHD) at a 1:24,000/1:12,000 scale. Geographical Information System (GIS) was used to create 200-meter buffers around NHD input features, and resulting output feature class was used to clip land-use features within the buffer. The resulting features were used to summarize changes and present infrastructure within the buffer area.

For purposes of data visualization in relation to land uses, diffusion interpolation using the 200-meter buffer feature class as a barrier was used to predict upstream and downstream FC concentrations between sampling points. Analyses were perform using GIS.

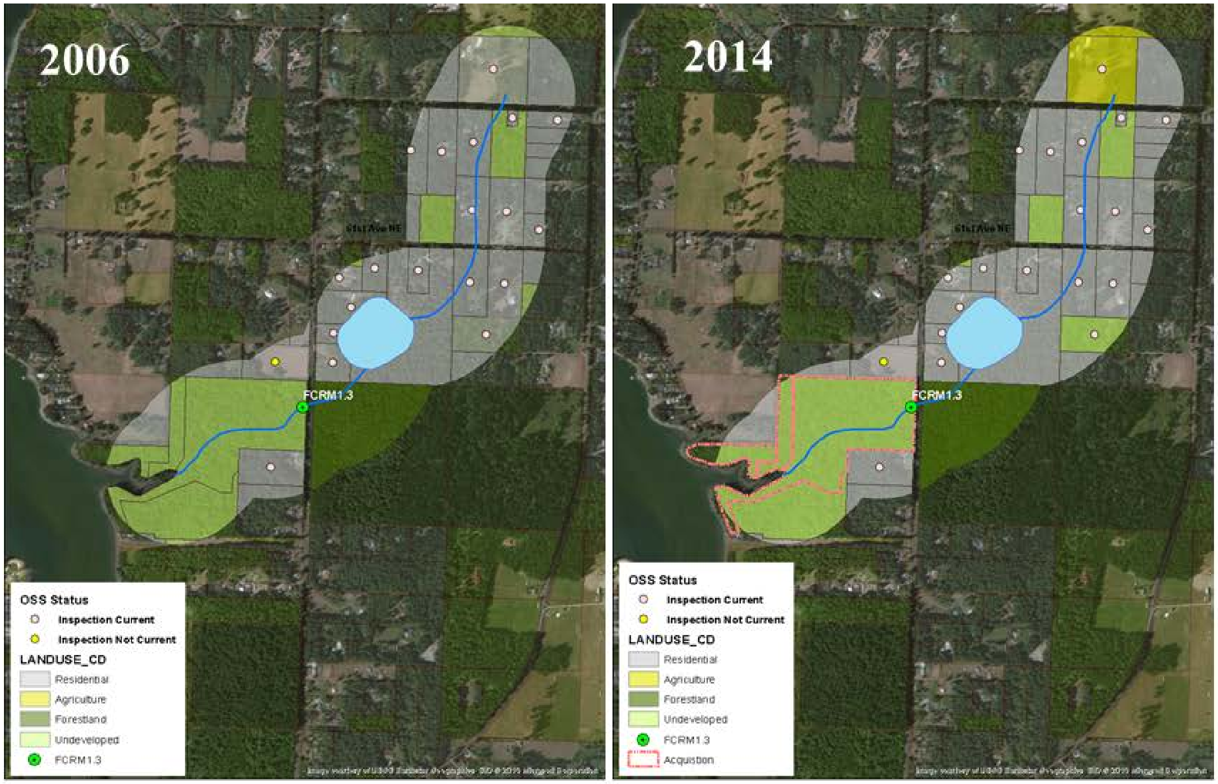


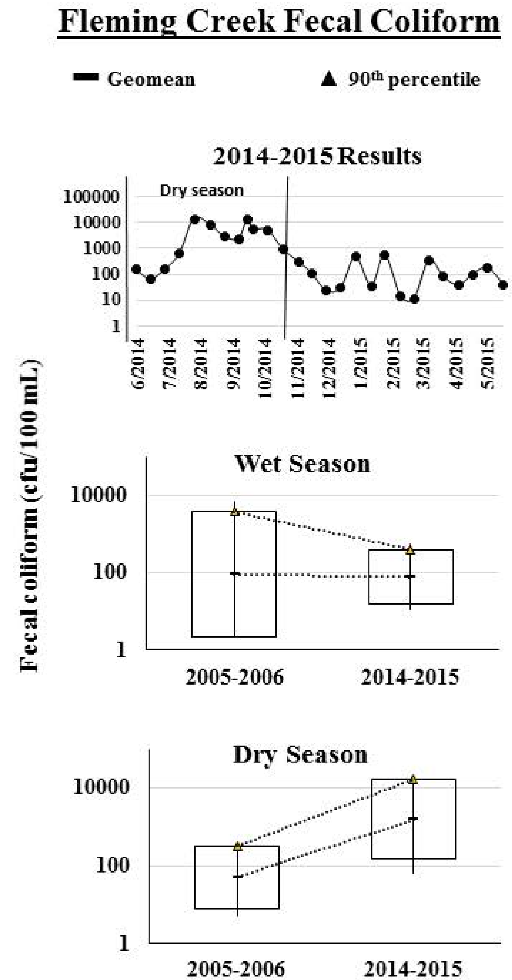


Sleepy Creek Land Use Statistics

Year	Agriculture		Residential		Forestland		Transportation		Undeveloped		Sum	
	N	Sum	N	Sum	N	Sum	N	Sum	N	Sum	N	Sum
2006	3	52	51	157	7	196	1	1	16	81	78	487
2014	1	16	54	181	7	196	1	1	16	94	79	487
Difference	-2	-36	3	24	0	0	0	0	0	13	1	0

Figure E-1. The primary land use in the Sleepy Creek subbasin is classified as forestland. The remaining land uses are low-density residential, undeveloped, and agriculture. Changes in land use between 2006 and 2014 include conversion of agricultural lands to residential and undeveloped. There are 20 OSSs within this area and 2 were identified as not being current. Land acquisition between 2006 and 2014 occurred to expand the Woodard Bay Natural Resources Conservation Area (NRCA). Since 1987, the Washington Department of Natural Resources (WDNR) and its partners have actively worked on protect and restore upland and marine habitat for endangered, threatened, and sensitive plants and animals, as well as scenic landscapes (WDNR, 2010).

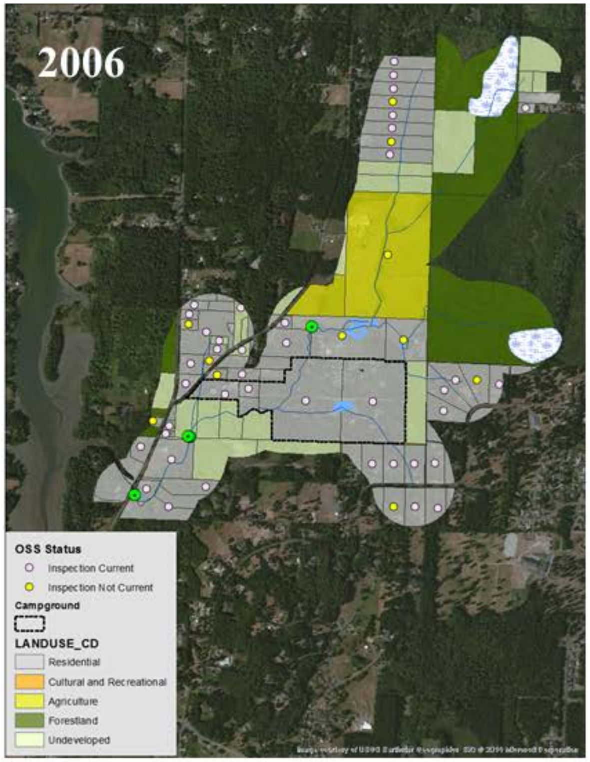


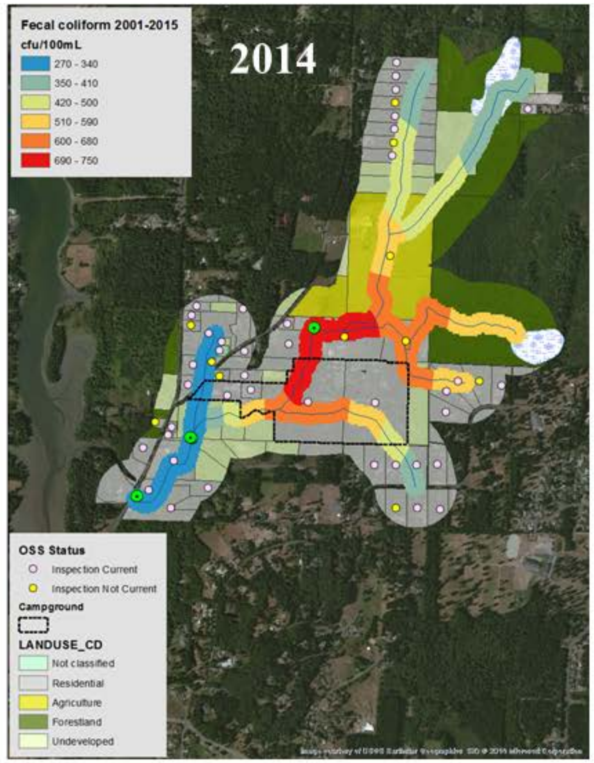


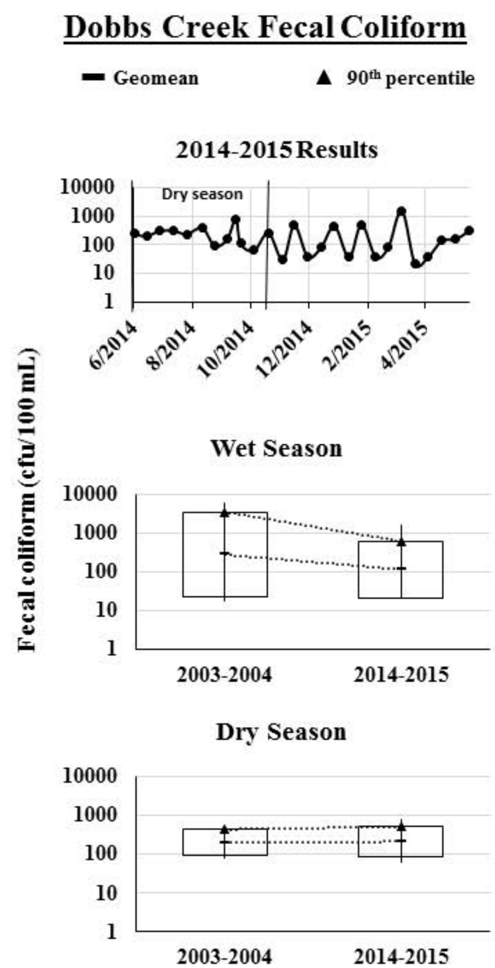
Fleming Creek Land Use Statistics

Year	Agriculture		Residential		Forestland		Undeveloped		Sum	
	N	Acres	N	Acres	N	Acres	N	Acres	N	Acres
2006			36	117	1	16	9	23	46	183
2014	2	11	36	105	1	16	7	25	46	183
Difference	2	11	0	-13	0	0	-2	2	0	0

Figure E-2. Based on 2014 GIS data, the primary land use in the Fleming Creek subbasin is classified as residential. The remaining land uses include undeveloped and forestland. Changes in land use between 2006 and 2014 include conversion of residential land to undeveloped and to agriculture. There are 18 OSS within this area, and 100% have been identified as having current inspection reports (Thurston County, 2014). Field leads indicated the presence of raccoon latrine along banks of the creek immediately upstream of the sampling location. Other anthropogenic FC sources above the sampling site are limited; however, FC sources from OSSs above the sampling location could not be ruled out. Fleming Creek is dry above 36th Street during the dry season and drains into a large wetland complex above the sampling location during the wet season.







Dobbs Creek Land Use Statistics

	Agriculture		Residential		Forestland		Undeveloped		Sum	
Year	N	Acres	N	Acres	N	Acres	N	Acres	N	Acres
2006	2	69	71	288	5	130	21	97	99	584
2014	2	69	69	290	7	138	24	88	102	584
Difference	0	0	-2	2	2	7	3	-8	2	0

Figure E-3. Based on 2014 GIS data, the primary land use in the Dobbs Creek subbasin is classified as residential. The remaining land uses include forestland, agriculture, and undeveloped. Changes in land use between 2006 and 2014 include the conversion of undeveloped to residential and the division of undeveloped parcels. There are 51 OSSs, of which 11 have been identified as not being current on inspection. Approximately 0.5 mile upstream of DB0.1, a private camping club operates a campground for recreational vehicles. There are approximately 348 lots within this 70-acre parcel for both RV and tent camping; many of the residents live on site year-round. Sanitary waste within the campground is disposed of in a central holding tank. At the time of this assessment, the campground was working with the Thurston County Health Department to address waste storage on the premises. Using GIS FC data from 2001-2014, concentrations were interpolated between sampling locations within a 50-meter buffer along Dobbs Creek and tributary NHD lines in order to help visualize FC hot spots.

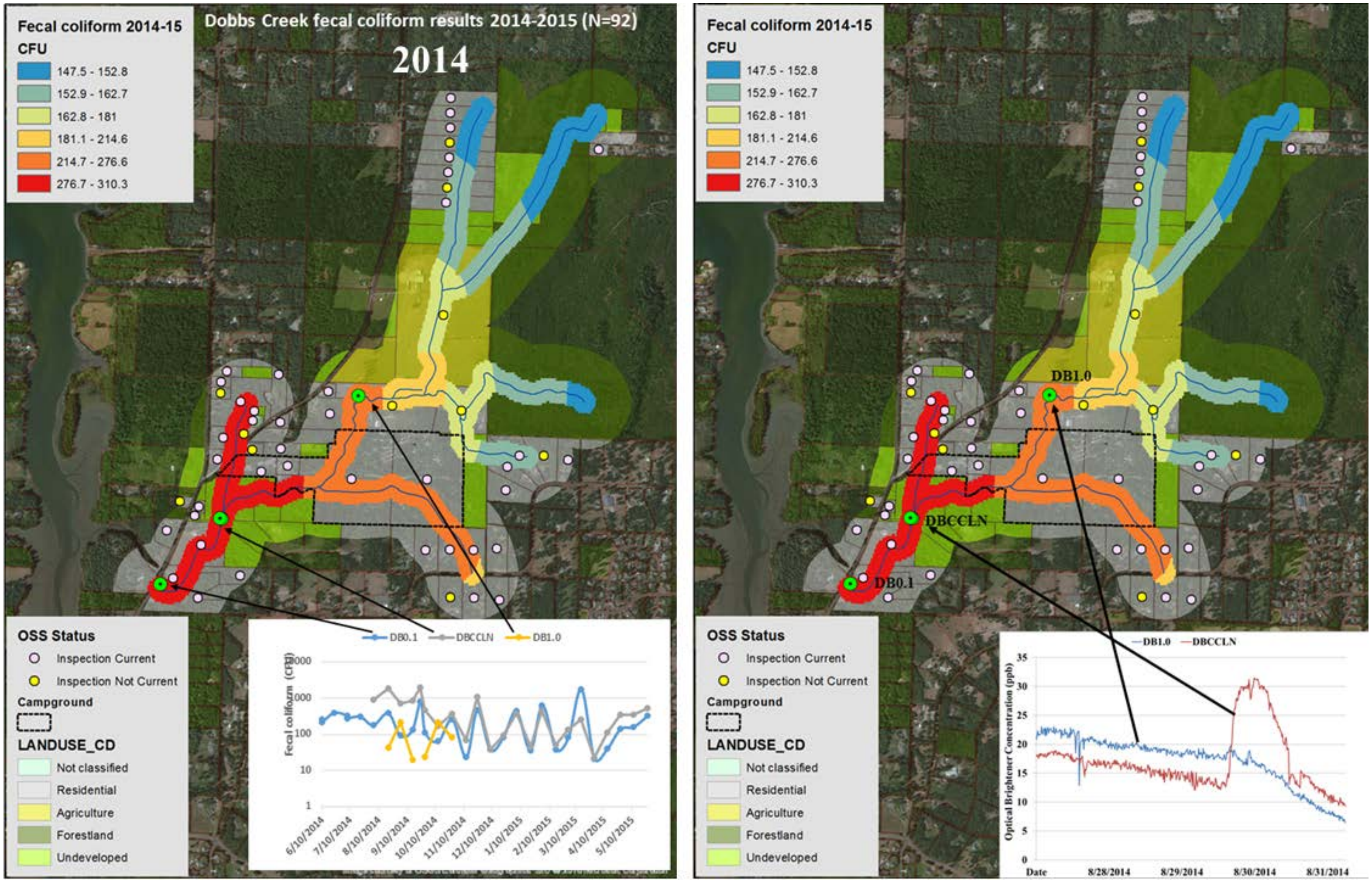
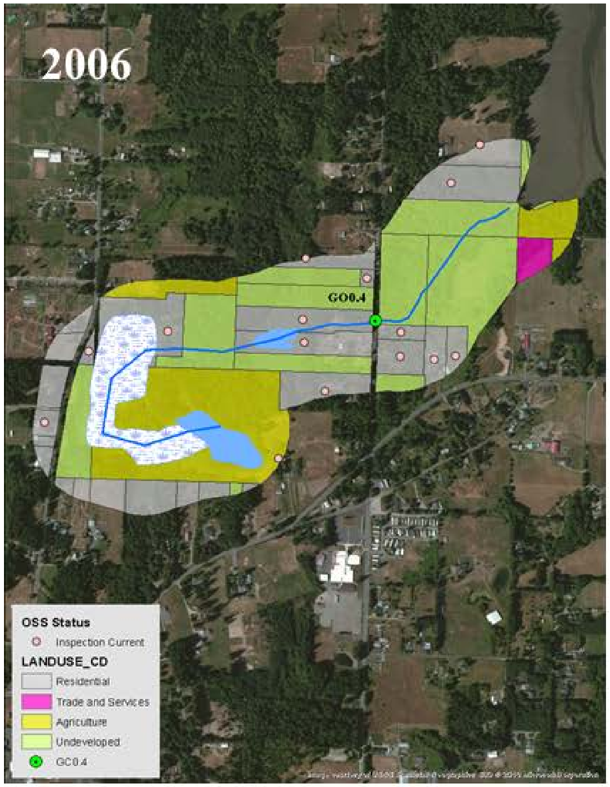
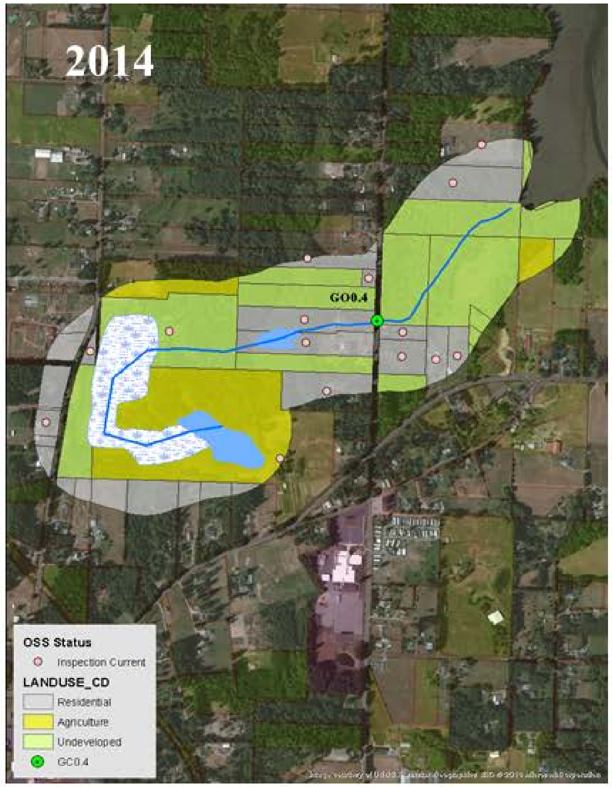
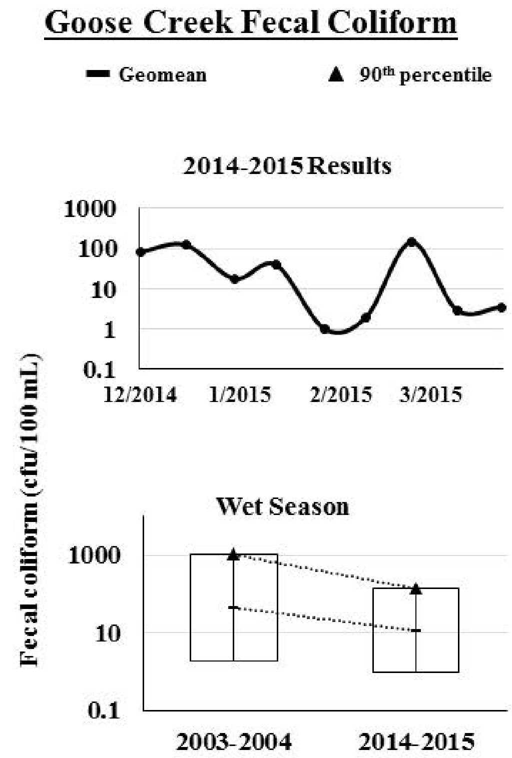


Figure E-4. Results of bracketed FC sampling upstream of DB0.1 indicate dry-season FC sources are primarily located above Clear Creek Lane (DBCCLN). Results of samples collected at DB1.0 from August through October indicate FC sources are primarily located below this station. Field staff indicated the unnamed tributary entering Dobbs Creek above DBCCLN was dry below Pleasant Forest Road from July to October 2014. In August 2014, optical brightener probes were concurrently deployed to bracket the area between DBCCLN and DB1.0. A spike in the optical brightener was detected during a rain event on August 30 at the downstream location. This spike was not observed at the upstream location. Although not a conclusive test, the presence of optical brightener in surface waters may suggest FC contribution from sanitary sewer waste. Using GIS FC data from 2014-2015, concentrations were interpolated between sampling locations within a 50-meter buffer along Dobbs Creek and tributary NHD lines in order to help visualize FC hot spots.





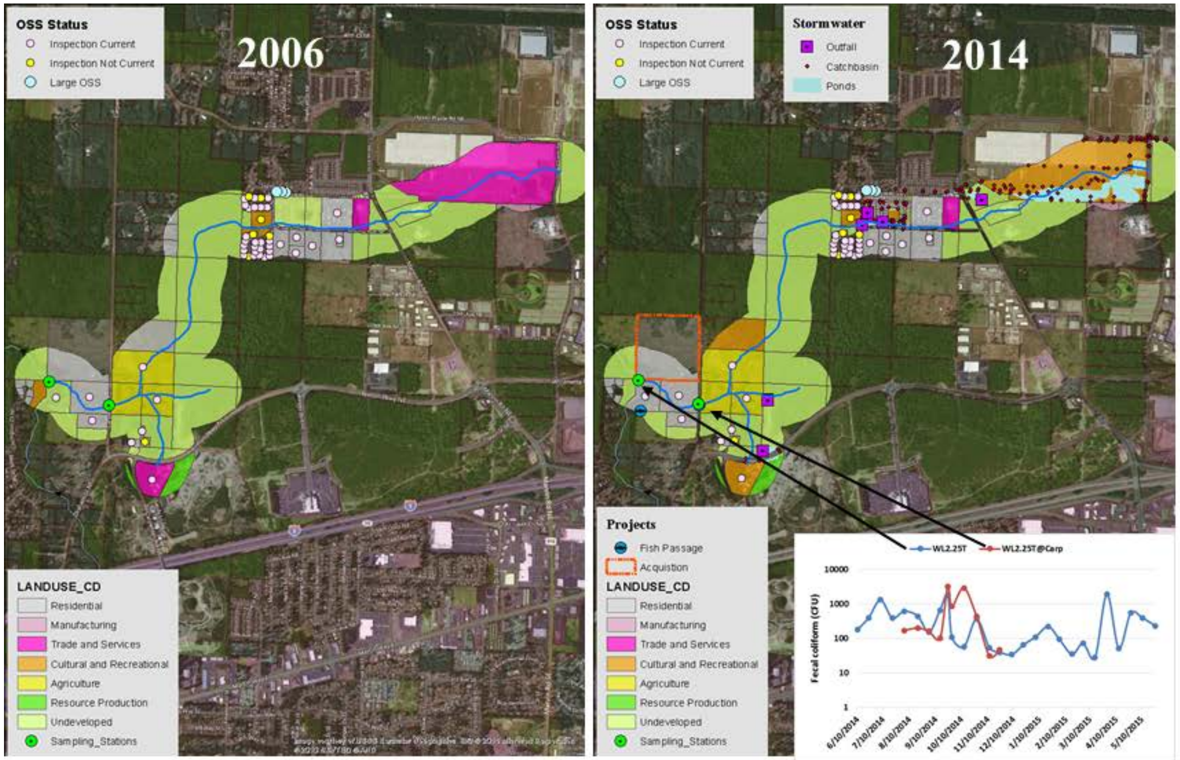


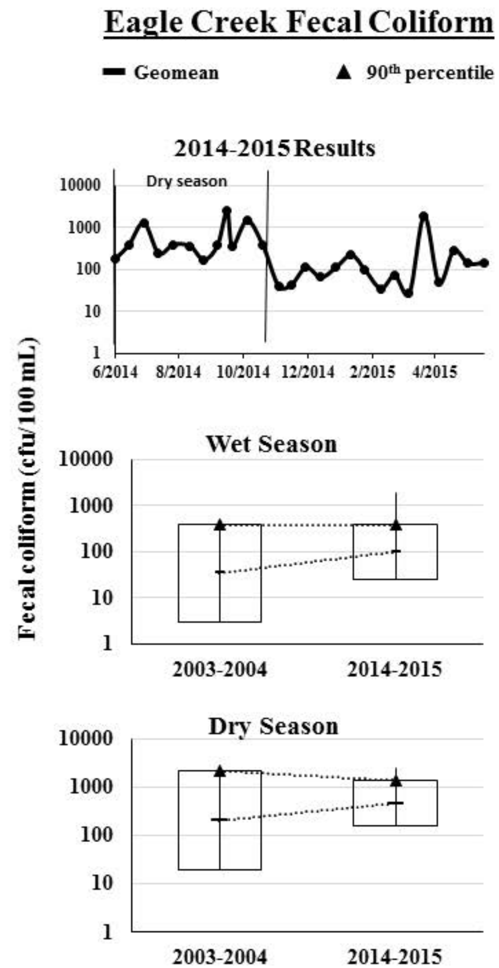
Dry season (No flow)

Goose Creek Land Use Statistics

Year	Agriculture		Residential		Retail Trade		Undeveloped		Sum	
	N	Acres	N	Acres	N	Acres	N	Acres	N	Acres
2006	4	52	28	69	1	3	12	66	45	189
2014	3	50	27	58			16	81	46	189
Difference	-1	-2	-1	-11	-1	-3	2	11	1	0

Figure E-5. Based on 2014 GIS data, the primary land use in the Goose Creek subbasin is classified as residential. The remaining land uses include agriculture and undeveloped. The majority of the agricultural lands are located in the upper watershed above and surrounding a large wetland complex. Changes in land use between 2006 and 2014 include the conversion of agriculture to undeveloped near the mouth of Goose Creek and the conversion of residential lands to undeveloped. There are 15 OSSs and all have been identified as being current on inspection. Although no projects were identified in the subbasin, it is assumed that agricultural parcels at the headwaters have farm plans that have been implemented.

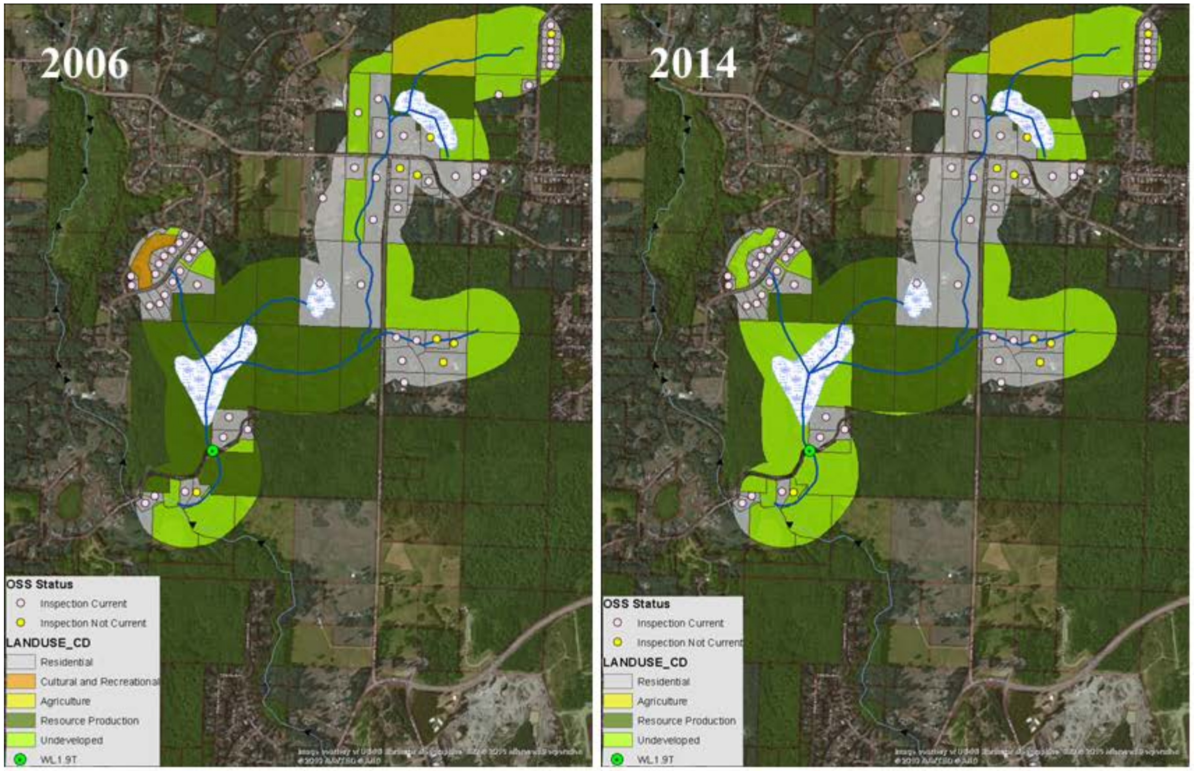


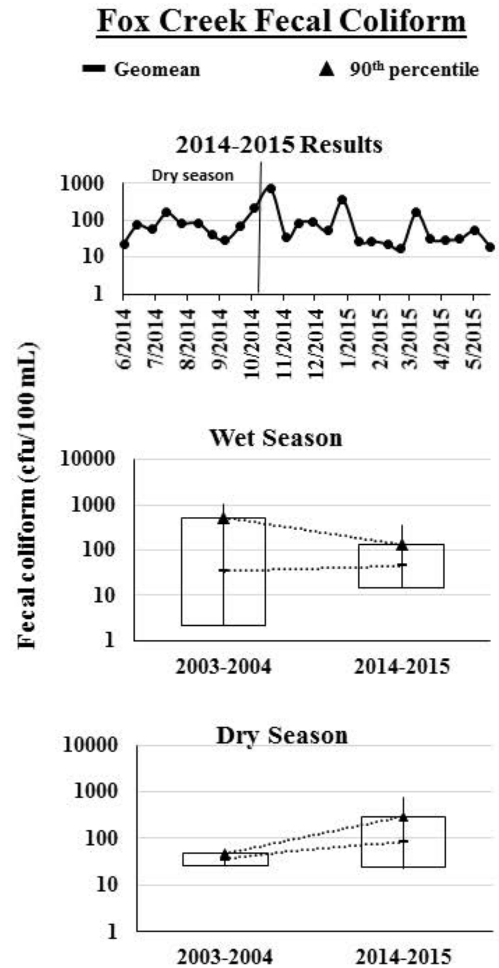


Eagle Creek Land Use Statistics

Year	Agriculture N	Agriculture Acres	Cultural and Recreational N	Cultural and Recreational Acres	Manufacturing N	Manufacturing Acres	Residential N	Residential Acres	Mining N	Mining Acres	Trade N	Trade Acres	Undeveloped N	Undeveloped Acres
2006	3	39	7	9	2	3	69	99	2	7	3	87	52	273
2014	3	39	11	102	2	3	153	101	2	7	1	5	53	254
Difference	0	0	4	94	0	0	84	2	0	0	-2	-83	1	-19

Figure E-6. Based on 2014 GIS data, the primary land use in the Eagle Creek subbasin is classified as undeveloped. The remaining land uses include residential, cultural & recreation, and agriculture. Major changes in land use between 2006 and 2014 include the conversion of retail & trade and residential to culture & recreation as well as the division of undeveloped parcels to residential. There are 57 OSSs, of which 7 have been identified as not being current on inspection. The majority of residential parcels are located in a subdivision 1.5 miles upstream of Carpenter Road. This area also has the highest density of OSS, stormwater catch basins and outfalls in relation to Eagle Creek. Dry-season samples collected upstream of WL2.25T off of Carpenter Road suggest there are FC sources below Carpenter Road. Field leads noted the presence of livestock (4-6 cattle) with access to Eagle Creek. Similar observations were made in 2003, and recommendations were made to limit animal access to Eagle Creek (Sargent, 2006). One land-acquisition and two fish-passage projects were identified as being implemented in this subbasin.

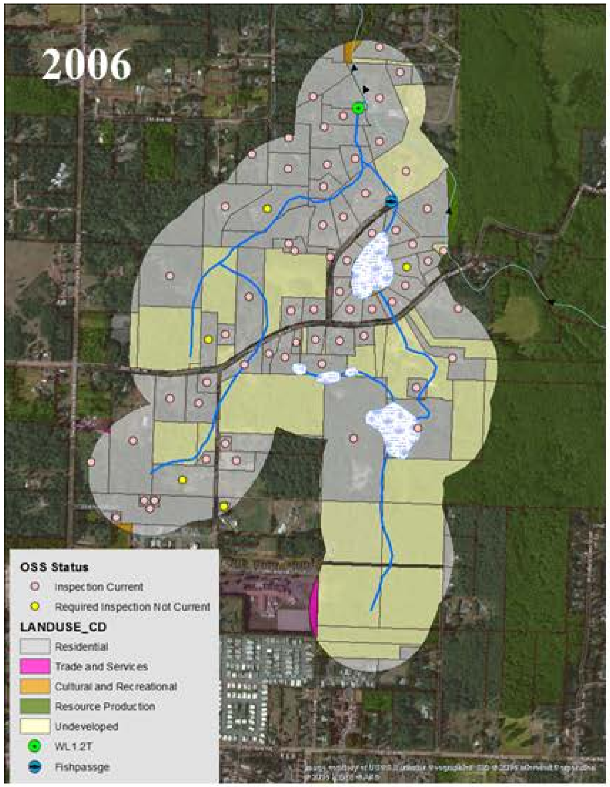


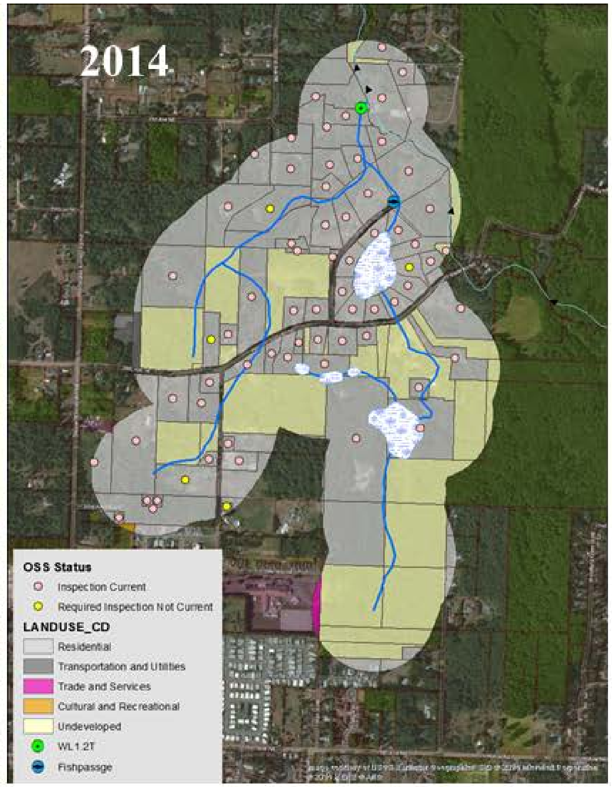


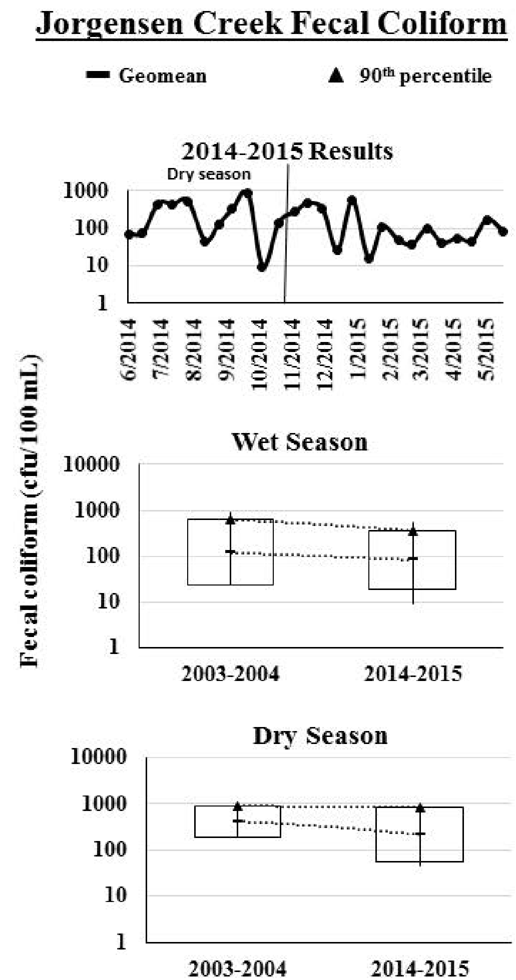
Fox Creek Land Use Statistics

	Agriculture		Culture and Recreation		Residential		Forestland		Undeveloped		Sum	
Year	**N**	**Acres**	**N**	**Acres**	**N**	**Acres**	**N**	**Acres**	**N**	**Acres**	**N**	**Acres**
2006	1	24	2	6	73	169	10	193	25	136	111	528
2014	1	24			76	191	7	112	24	202	108	528
Difference	0	0	-2	-6	3	21	-3	-81	-1	65	-3	0

Figure E-7. Based on 2014 GIS data, the primary land use in the Fox Creek subbasin is classified as residential. The remaining land uses include forestland, undeveloped, and agriculture. Major changes in land use between 2006 and 2014 include the conversion of forestland to undeveloped and residential parcels and conversion of recreation & culture to undeveloped. There are 58 OSSs, of which 8 have been identified as being current on inspection. No projects were identified as being implemented in the subbasin.



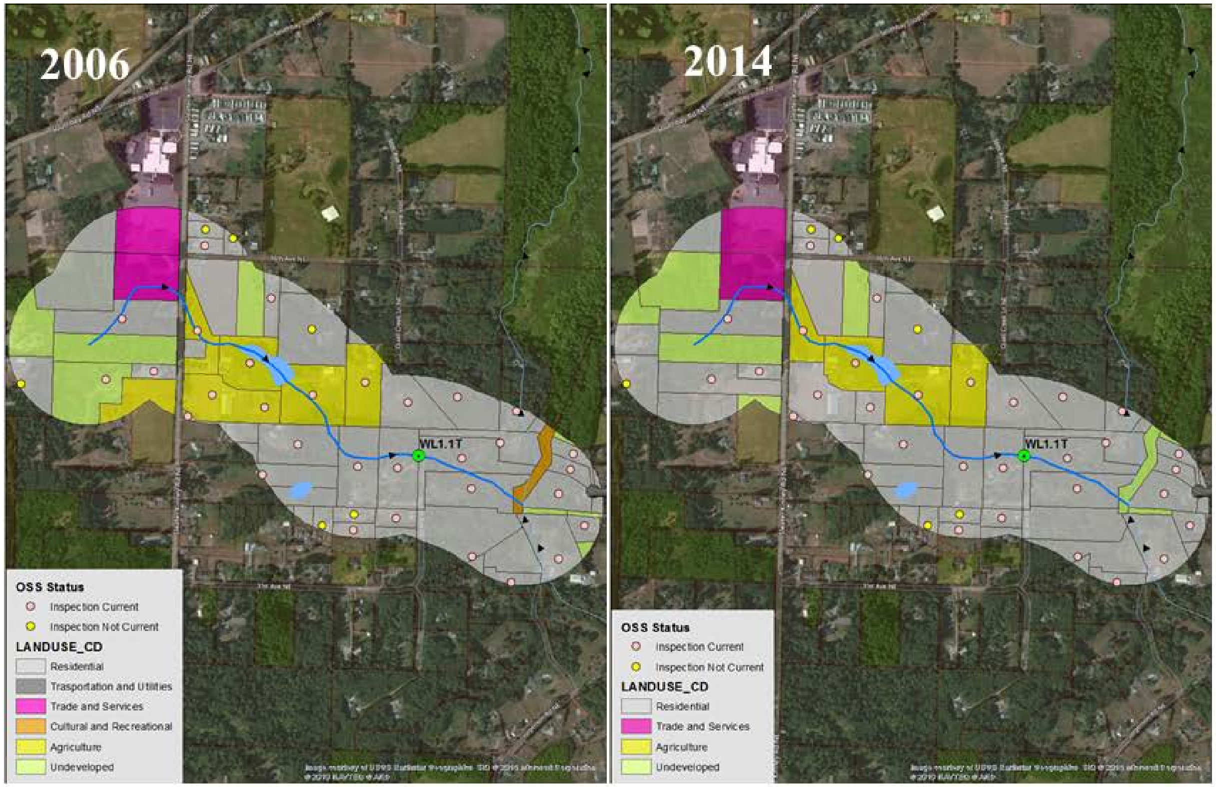


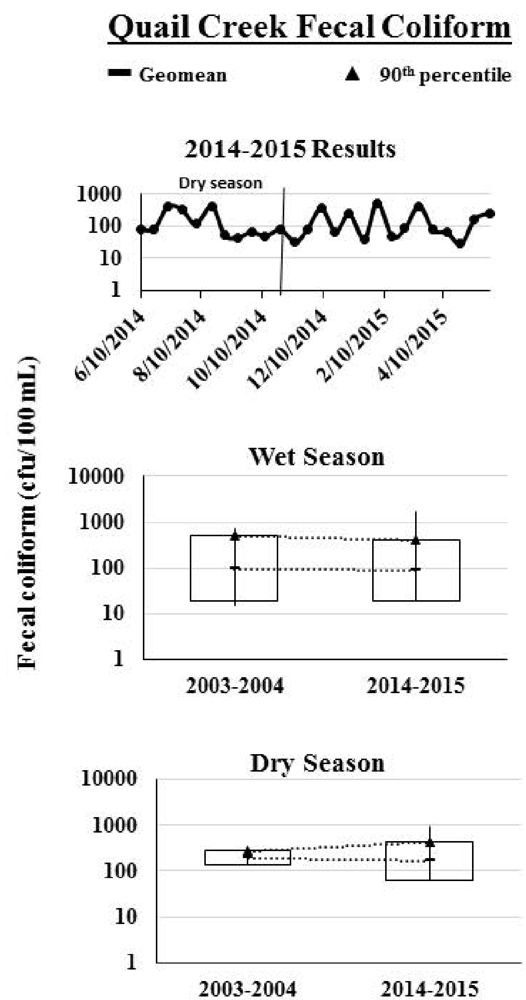


Jorgensen Creek Land Use Statistics

Year	Culture and Recreation		Residential		Resource Production		Retail Trade		Undeveloped		Sum	
	N	Acres	N	Acres	N	Acres	N	Acres	N	Acres	N	Acres
2006	3	5	89	220	1	2	2	1	30	139	125	367
2014	1	0	95	241			2	1	28	124	125	367
Difference	-2	-5	6	21	-1	-2	0	0	-2	-15	2	1

Figure E-8. Based on 2014 GIS data, the primary land use in the Jorgensen Creek subbasin is classified as residential. The remaining land uses include undeveloped, trade & services, and culture & recreation. Major changes in land use between 2006 and 2014 include the conversion of undeveloped to residential. There are 58 OSSs, of which 8 have been identified as being current on inspection. One fish-passage project was identified as being implemented in this subbasin.

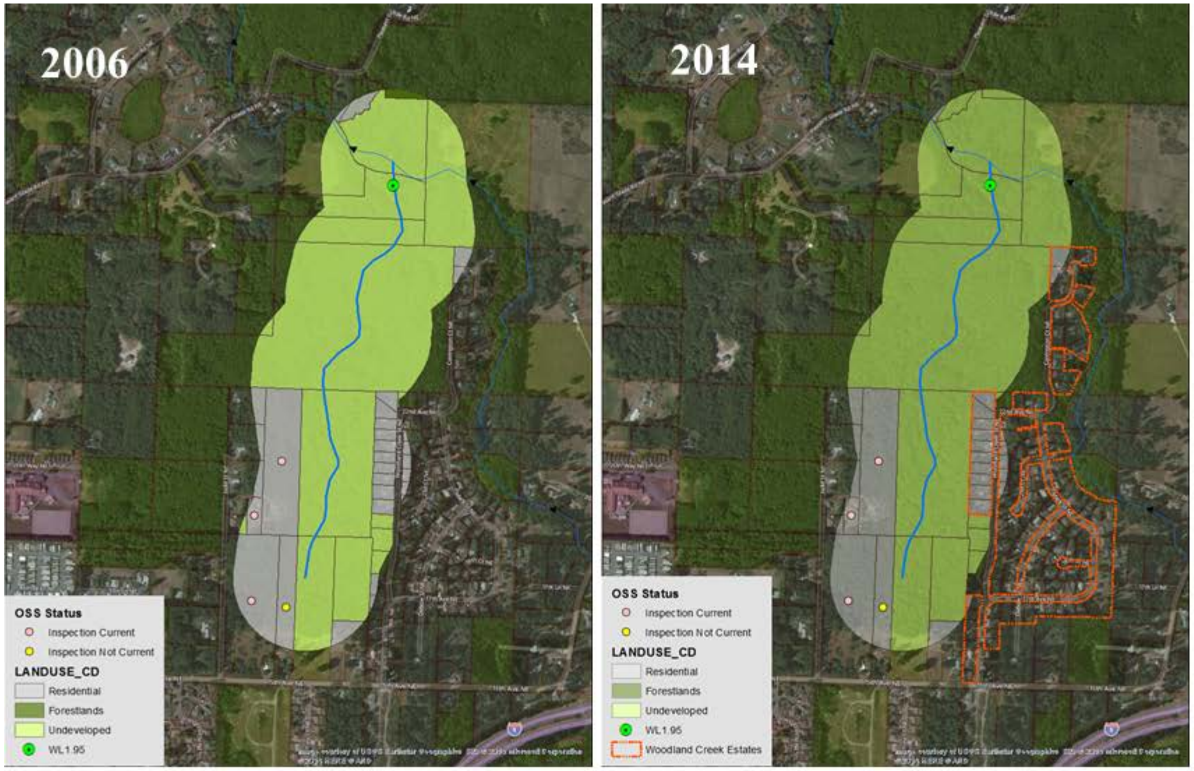


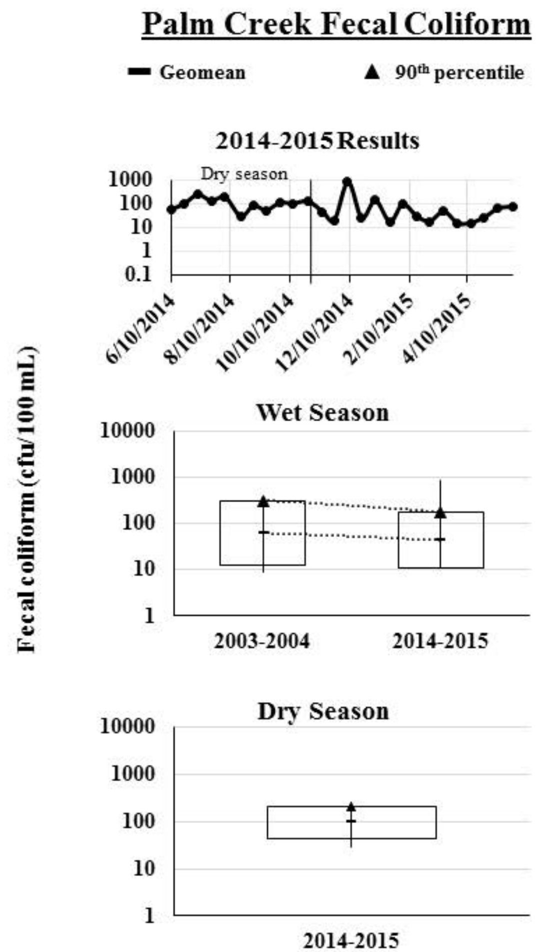


Quail Creek Land Use Statistics

Year	Agriculture		Culture and Recreation		Residential		Retail Trade		Undeveloped		Sum	
	N	Acres	N	Acres	N	Acres	N	Acres	N	Acres	N	Acres
2006	6	27	1	2	52	106	2	9	8	19	69	163
2014	4	18			58	116	2	9	8	19	72	163
Diff.	-2	-9	-1	-2	6	11	0	0	0	0	2	0

Figure E-9. Based on 2014 GIS data, the primary land use in the Quail Creek subbasin is classified as residential. The remaining land uses include agriculture, undeveloped, and trade & services. Major changes in land use between 2006 and 2014 include the conversion of agriculture to residential and of undeveloped to residential. There are 37 OSSs, of which 6 have been identified as being current on inspection. Farm plans on two agriculture parcels were identified as being implemented during this assessment (Ecology, 2008).

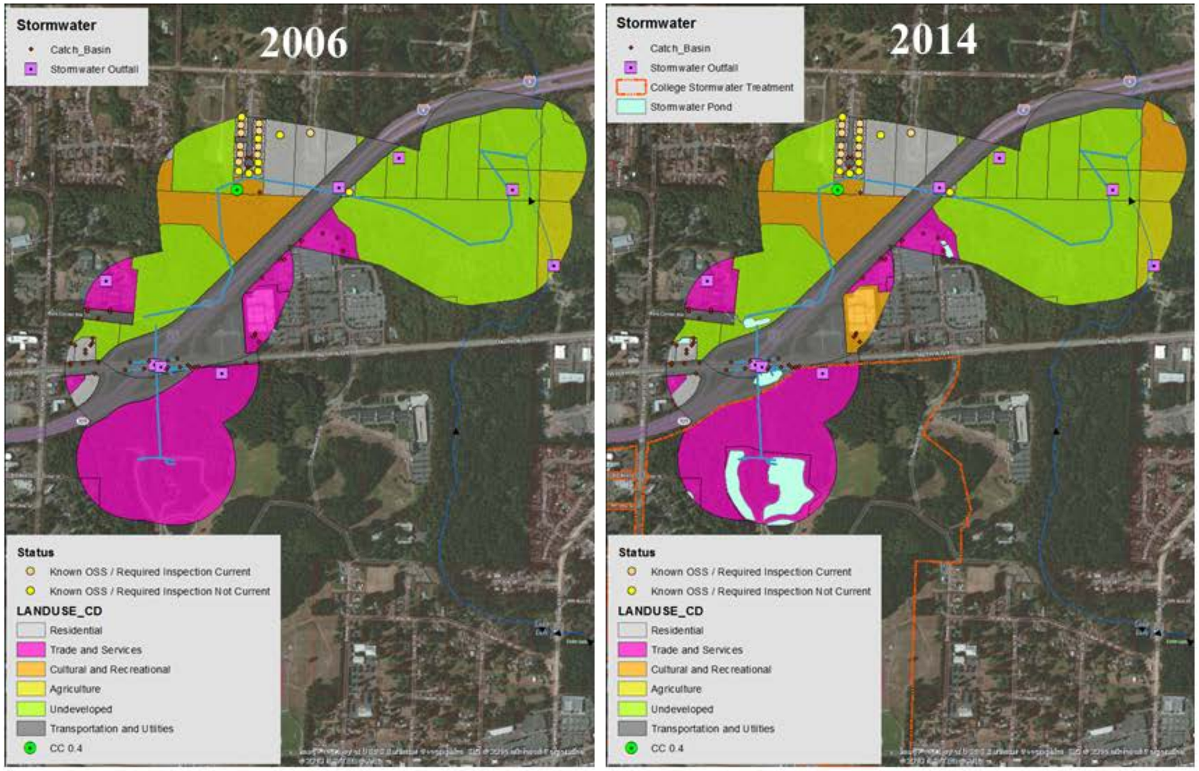


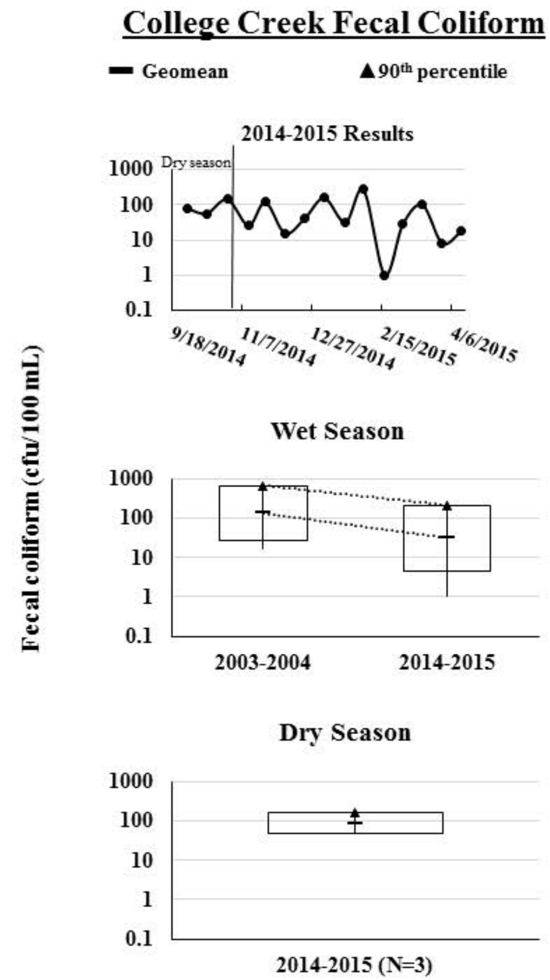


Palm Creek Land Use Statistics

Year	Residential		Forestland		Undeveloped		Sum	
	N	Acres	N	Acres	N	Acres	N	Acres
2006	34	33	1	1	15	119	50	153
2014	33	32			16	120	49	153
Difference	-1.0	-1.0	-1.	-1	1.0	1.0	0	0

Figure E-10. Based on 2014 GIS data, the primary land use in the Palm Creek subbasin is classified as undeveloped. The remaining land uses include residential and forestlands. Changes in land use between 2006 and 2014 include the reclassification of residential properties to undeveloped, resulting in a net loss of 1 parcel. There are 4 OSSs, of which 1 has been identified as being current on inspection. Although no projects were identified in this subbasin, several parcels within the Woodland Creek Estates Septic to Sanitary Sewer project footprint overlap the boundary area.





College Creek Land Use Statistics

Year	Agriculture N	Agriculture Acres	Culture and Recreation N	Culture and Recreation Acres	Residential N	Residential Acres	Retail Trade N	Retail Trade Acres	Undeveloped N	Undeveloped Acres	Sum N	Sum Acres
2006	2	9	3	17	24	21	7	71	14	119	50	238
2014	2	9	5	29	24	21	8	66	13	112	52	238
Difference	0	0	2	12	0	0	1	-5	-1	-7	-2	0

Figure E-11. Based on 2014 GIS data, the primary land use in the College Creek subbasin is classified as undeveloped. The remaining land uses include trade & services, residential, culture & recreation, and agriculture. Changes in land use between 2006 and 2014 include the reclassification of undeveloped and trade & services to culture & recreation. There are 18 OSSs, of which 8 have been identified not being current. One major project was identified in this subbasin: the College Creek Regional Stormwater Facility was completed in 2007 and now treats stormwater draining from a 424-acre area before discharging to College Creek.

Appendix F: Grant and Loan Data

Table F-1. Grant and loan data.

Grant #	Data Source	Project Name	Primary Activity	Start Year	End Year	Project Area (acres)	Cost/ Area	Total Funds	Web Link
04-02-99-02	RCO	Lemon Rd Riparian Enhancement	Riparian Habitat	1999	2001	2.4	$1.67	$4,777	http://waconnect.paladinpanoramic.com/project/150/11955
14-1429 P	RCO	Harmony Farms Restoration Design	Land Acquisition	2015	2016	55.7	$538.60	$30,000	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=14-1429
12-1119 R	RCO	Woodard Bay NRCA Wetland and Shoreline Restoration	Wetland Restoration	2014	2016	26.0	$4,026.92	$104,700	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=12-1119
04-03-00-06	RCO	Woodland Creek Revegetation	Riparian Habitat	1999	2000	7.3	$5,467.41	$39,912	http://waconnect.paladinpanoramic.com/project/150/11954
04-03-99-07	RCO	Woodland Creek Revegetation Project	Riparian Habitat	1999	2000	6.4	$8,846.19	$56,616	http://waconnect.paladinpanoramic.com/project/150/11947
04-02-99-01	RCO	Lemon Rd Culvert Replacement	Fish passage	1999	2000	3.6	$9,116.13	$33,231	http://waconnect.paladinpanoramic.com/project/150/11952
10-1198 A	RCO	Budd to Henderson Conservation Initiative Phase 3	Land Acquisition	2011	2016	150.0	$12,506.00	$1,875,900	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=10-1198
10-1353 R	RCO	Woodard Bay NRCA-Weyer Point Restoration	Wetland Restoration	2012	2016	14.0	$21,048.43	$294,678	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=10-1353
12-1185 A	RCO	Woodard Bay NRCA 2012	Land Acquisition	2013	2016	92.1	$23,276.71	$2,143,785	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=12-1185
10-1690 A	RCO	Greg J. Cuoio Community Park	Land Acquisition	2010	2014	67.1	$30,474.62	$2,044,542	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=10-1690
10-1116 AR	RCO	Woodard Bay NRCA Nearshore Restoration/ Protection	Land Acquisition	2011	2016	26.7	$45,596.51	$1,216,059	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=10-1116

Grant #	Data Source	Project Name	Primary Activity	Start Year	End Year	Project Area (acres)	Cost/ Area	Total Funds	Web Link
12-1121 D	RCO	Woodard Bay NRCA Access Development	Public Access	2013	2015	2.0	$162,500.00	$325,000	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=12-1121
12-1120 ADR	RCO	Woodard Bay NRCA Public Access and Education	Land Acquisition	2013	2016	8.2	$220,208.33	$1,796,900	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=12-1120
04-03-99-01	RCO	Carpenter Rd Culvert Replacement	Fish passage	1999	2000	0.1	$432,485.79	$27,145	http://waconnect.paladinpanoramic.com/project/150/11950
04-03-99-02	RCO	Jorgenson Creek Fish Passage	Fish passage	1999	2002			$25,000	http://waconnect.paladinpanoramic.com/project/150/11951
04-03-01-03	RCO	Pleasant Glade Road Salmon Barrier	Fish passage	2001	2003			$300,000	http://waconnect.paladinpanoramic.com/project/150/11925
04-03-02-04	RCO	Salazar Culvert Replacement 01	Fish passage	2002	2003			$118,369	http://waconnect.paladinpanoramic.com/project/150/11929
01-1239 R	RCO	Salazar Culvert Replacement 01	Fish passage	2002	2007			$118,369	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=01-1239
TAX900064	ECY	Woodland Creek Stormwater Treatment	Stormwater	1993	2000	260.0	$1,089.87	$283,365	
TAX90098	ECY	Fones Road Stormwater Treatment Facility	Stormwater	2004	2004	97.0	$1,137.78	$110,365	
L9900036	ECY	Ruddell Road and 32nd Facility	Stormwater	1999	2001	114.0	$2,077.00	$399,208	
G0800374	ECY	Henderson/ Nisqually Water Quality Improvement	Agricultural	2011	2013	122.0	$2,645.81	$322,789	http://iaspub.epa.gov/apex/grts/f?p=110:700:::NO:RP,700:P700_PRJ_SEQ:32962
G0800626	ECY	Woodland Creek Pollutant Load Reduction-Tanglewilde	Stormwater	2012	2013	405.0	$3,441.64	$1,393,865	http://www.co.thurston.wa.us/waterresources/woodland/woodland-home.html
G1000530	ECY	TMDL Response to Fecal Coliform	Agricultural	2010	2013	2.0	$39,557.23	$79,510	http://iaspub.epa.gov/apex/grts/f?p=110:700:::NO:RP,700:P700_PRJ_SEQ:53985

Grant #	Data Source	Project Name	Primary Activity	Start Year	End Year	Project Area (acres)	Cost/ Area	Total Funds	Web Link
G1100203_ L1100004	ECY	Woodland Creek Estates Sanitary Sewer Project	Onsite Sewage	2011	2013	48.0	$103,958.33	$4,990,000	http://woodlandcreekproject.blogspot.com/
G9700134	ECY	Septic System Education and Correction	Onsite Sewage	1999	2000			$175,000	
TAX91030	ECY	Lake Lois Phase 1 Restoration and Woodland Creek Study	Stormwater	1990	1995			$160,191	
G0200279	ECY	Stormwater Pond Maintenance Outreach	Stormwater	2004	2004			$103,033	
C0700093	ECY	Rain Gardens and Non Point Projects for High School Seniors	Stormwater	2006	2008			$24,231	http://iaspub.epa.gov/apex/grts/f?p=110:700:::NO:RP,700:P700_PRJ_SEQ:23885
C0800254	ECY	Bivalves for Clean Water - SeaGrant	Education and Outreach	2007	2010			$46,752	http://iaspub.epa.gov/apex/grts/f?p=110:700:::NO:RP,700:P700_PRJ_SEQ:29625
G9200337	ECY	Install Agricultural BMPs	Agricultural	1995	1996			$21,000	
G9400080	ECY	North Thurston Clean Ground Water Farms	Agricultural	1999	2000			$603,312	
G0000146	ECY	Henderson Inlet Watershed Implementation Program	Agricultural	2003	2004			$294,833	
G0300138	ECY	Henderson Shellfish Response & TMDL Project	Planning	2006	2006			$282,960	http://www.co.thurston.wa.us/health/ehrp/henderson.html
L0800011	ECY	Septic Connection Assistance Loan Program	Onsite Sewage	2012	2013			$250,000	
TAX88002	ECY	Thurston Watershed Ranking & Planning.	Planning	1990	1995			$674,670	http://www.co.thurston.wa.us/waterresources/woodland/woodland-home.html
TAX91066	ECY	Tribal Participation Project	Planning	1995	1995			$479,998	

Grant #	Data Source	Project Name	Primary Activity	Start Year	End Year	Project Area (acres)	Cost/ Area	Total Funds	Web Link
G9300032	ECY	Martin Way/ Woodland Cr. Stormwater Treatment Facility Engineering Report	Stormwater	1993	1995			$54,136	
TAX90209	ECY	Drainage Management System Initiation	Stormwater	1997	1997			$57,879	
TAX91174	ECY	College Street/ Woodland Cr. Stormwater Outfall Engineering Report	Stormwater	1993	1997			$33,938	
G0600191	ECY	Woodland Creek Pollutant Load Reduction	Planning	2008	2008			$320,000	www.co.thurston.wa.us/health/ehrp/woodland.html
G0800147	ECY	Henderson Inlet LGSG	Planning	2009	2009			$75,000	http://www.co.thurston.wa.us/planning/natural-res/shellfish-home.htm
04-02-99-02	RCO	Lemon Rd Riparian Enhancement	Riparian Habitat	1999	2001	2.4	$1.67	$4,777	http://waconnect.paladinpanoramic.com/project/150/11955
14-1429 P	RCO	Harmony Farms Restoration Design	Land Acquisition	2015	2016	55.7	$538.60	$30,000	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=14-1429
12-1119 R	RCO	Woodard Bay NRCA Wetland and Shoreline Restoration	Wetland Restoration	2014	2016	26.0	$4,026.92	$104,700	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=12-1119
04-03-00-06	RCO	Woodland Creek Revegetation	Riparian Habitat	1999	2000	7.3	$5,467.41	$39,912	http://waconnect.paladinpanoramic.com/project/150/11954
04-03-99-07	RCO	Woodland Creek Revegetation Project	Riparian Habitat	1999	2000	6.4	$8,846.19	$56,616	http://waconnect.paladinpanoramic.com/project/150/11947
04-02-99-01	RCO	Lemon Rd Culvert Replacement	Fish passage	1999	2000	3.6	$9,116.13	$33,231	http://waconnect.paladinpanoramic.com/project/150/11952
10-1198 A	RCO	Budd to Henderson Conservation Initiative Phase 3	Land Acquisition	2011	2016	150.0	$12,506.00	$1,875,900	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=10-1198
10-1353 R	RCO	Woodard Bay NRCA-Weyer Point Restoration	Wetland Restoration	2012	2016	14.0	$21,048.43	$294,678	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=10-1353

Grant #	Data Source	Project Name	Primary Activity	Start Year	End Year	Project Area (acres)	Cost/ Area	Total Funds	Web Link
12-1185 A	RCO	Woodard Bay NRCA 2012	Land Acquisition	2013	2016	92.1	$23,276.71	$2,143,785	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=12-1185
10-1690 A	RCO	Greg J. Cuoio Community Park	Land Acquisition	2010	2014	67.1	$30,474.62	$2,044,542	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=10-1690
10-1116 AR	RCO	Woodard Bay NRCA Nearshore Restoration/ Protection	Land Acquisition	2011	2016	26.7	$45,596.51	$1,216,059	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=10-1116
12-1121 D	RCO	Woodard Bay NRCA Access Development	Public Access	2013	2015	2.0	$162,500.00	$325,000	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=12-1121
12-1120 ADR	RCO	Woodard Bay NRCA Public Access and Education	Land Acquisition	2013	2016	8.2	$220,208.33	$1,796,900	https://secure.rco.wa.gov/prism/search/ProjectSnapshot.aspx?ProjectNumber=12-1120
04-03-99-01	RCO	Carpenter Rd Culvert Replacement	Fish passage	1999	2000	0.1	$432,485.79	$27,145	http://waconnect.paladinpanoramic.com/project/150/11950

LGSG: Local Government Stormwater Grant
NRCA: Natural Resources Conservation Area
RCO: Washington Department of Recreation and Conservation Office
SPD: Shellfish Protection District

Appendix G: Supporting information

Table G-1. Results of Seasonal Kendall test for trends from long-term water quality monitoring data from the Henderson Inlet watershed.

Station	Parameter	Statistic	ASE	Z	p-Value	Slope	Tau Stat	Trend
Woodland Creek								
WL1.6	FC	-256	115.876	**-2.209**	**0.014**	-0.006	-0.14	-
WL1.6	NO_x	-296	77.011	-3.831	0.000	-0.004	-0.245	-
WL1.6	TP	11	76.792	0.13	0.896	0	0.004	None
WL3.7SW	FC	-179	36.774	-4.84	0.000	-0.133	-0.332	-
Woodard Creek								
WD2.6	FC	-69	112.171	-0.606	0.544	-0.002	-0.041	-
WD2.6	NO_x	-106	77.932	-1.347	0.089	-0.002	-0.065	-
WD2.6	TP	244	77.675	3.128	0.002	0.005	0.203	+
Henderson Inlet Tributaries								
SL0.8	FC	-204	112.395	-1.815	0.07	-0.008	-0.075	-
DB0.1	FC	221	50.98	4.315	0.000	0.023	0.314	+
GC0.4	FC	-19	14.295	-1.259	0.208	-0.051	-0.046	-
FCRM	FC	20	18.921	1.004	0.315	0.013	0.156	+
Pooled Data								
WSALL	FC	-93	52.329	-1.777	0.038	-0.017	-0.102	-
INLETALL	FC	-175	127.315	-1.375	0.169	-0.006	-0.064	-
WDAll	FC	-29	119.559	-0.243	0.404	0	-0.022	None
WLALL	FC	-595	127.422	-4.67	0.00	-0.019	-0.238	-

ASE: Asymptotic Standard Error.

Table G-2. Results of ordinary least squared (OLS) regression test from long-term water quality monitoring data from the Henderson Inlet watershed.

Station	Parameter	SS	Df	Mean Squares	F-Ratio	Trend	**p-Value**
SL0.8	FC	8.61	6	1.437	5.140	-	**0.000**
FCRM1.3	FC	2.847	6	1.807	2.182	+	**0.050**
DB0.1	FC	7.861	6	1.310	3.772	+	**0.002**
GO0.8	FC	12.854	3	4.285	10.424	-	**0.000**
WL1.6	FC	1.2863	7	1.838	8.977	-	**0.000**
WL1.6	NO_x	0.247	6	0.041	3.420	-	**0.003**
WL1.6	TP	0.147	6	0.024	2.644	+	**0.018**
WD2.6	FC	4.534	6	0.756	2.868	-	**0.010**
WD2.6	NO_x	0.164	6	0.027	2.025	-	**0.065**
WD2.6	TP	0.526	6	0.088	4.236	+	**0.001**
WL3.7SW	FC	42.130	6	7.022	10.574	-	**0.000**
WL3.7SW	NO_x	49.248	6	8.208	8.827	-	**0.000**
WL3.7SW	TP	25.431	6	4.239	9.218	+	**0.000**

SS: Sum of squares. **Bold** text indicates p-Value for regression model is <0.05.

Table G-3. Systat results for OLS regression analysis.

Site	Parameter	N	Multiple R	Multiple R2	ASMR	SEE
SL0.8	FC	221	0.355	0.126	0.101	0.529
FCRM1.3	FC	95	0.36	0.129	0.070	0.910
DB0.1	FC	153	0.367	0.135	0.099	0.589
GO0.8	FC	58	0.657	0.431	0.364	0.625
WL1.6	FC	226	0.473	0.224	0.199	0.452
WL1.6	NO_x	177	0.328	0.108	0.076	0.110
WL1.6	TP	176	0.293	0.086	0.053	0.096
WD2.6	FC	235	0.265	0.070	0.046	0.513
WD2.6	NO_x	178	0.258	0.066	0.034	0.116
WD2.6	TP	177	0.361	0.130	0.099	0.144

ASMR: Adjusted squared multiple R.
SEE: Standard error of estimate.

Table G-4. Results of OLS regression analysis for SL0.8.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-3848.765	2798.272	0.000	.	-1.375	0.170
MONTH	0.046	0.010	0.308	0.984	4.775	**0.000**
YEAR	3.857	2.797	52.380	0.000	1.379	0.169
$YEAR^2$	-0.001	0.001	-52.489	0.000	-1.382	0.169
P1	0.202	0.101	0.133	0.939	2.010	**0.046**
P2	0.031	0.086	0.024	0.905	0.362	0.718
P3	-0.049	0.101	-0.032	0.916	-0.482	0.631

SE: Standard Error.
P1: Precipitation day of sampling.
P2: Precipitation 24 hrs prior to sampling.
P3: Precipitation 48 hrs prior to sampling.
Precipitation data collected at the Olympia Airport were obtained from Office of the Washington State Climatologist.

Table G-5. Results of OLS regression analysis for FCRM1.3.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-3848.765	2798.272	0.000	.	-1.375	0.170
MONTH	0.046	0.010	0.308	0.984	4.775	**0.000**
YEAR	3.857	2.797	52.380	0.000	1.379	0.169
$YEAR^2$	-0.001	0.001	-52.489	0.000	-1.382	0.169
P1	0.202	0.101	0.133	0.939	2.010	**0.046**
P2	0.031	0.086	0.024	0.905	0.362	0.718
P3	-0.049	0.101	-0.032	0.916	-0.482	0.631

Table G-6. Results of OLS regression analysis for DB0.1.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-1975.361	2048.704	0.000	.	-0.964	0.337
MONTH	0.026	0.013	0.160	0.948	2.014	**0.046**
YEAR	1.962	2.050	34.030	0.000	0.957	0.340
$YEAR^2$	0.000	0.001	-33.747	0.000	-0.949	0.344
P1	-0.002	0.110	-0.002	0.879	-0.019	0.985
P2	0.135	0.177	0.062	0.906	0.760	0.448
P3	-0.540	0.226	-0.194	0.908	-2.391	**0.018**

Table G-7. Results of OLS regression analysis for GO0.8.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	70114.836	24344.952	0.000	.	2.880	**0.006**
MONTH	0.065	0.024	0.301	0.922	2.739	**0.008**
YEAR	-69.753	24.249	-414.651	0.000	-2.877	**0.006**
$YEAR^2$	0.017	0.006	414.134	0.000	2.873	**0.006**
P1	-0.561	0.341	-0.183	0.897	-1.643	0.107
P2	0.323	0.204	0.172	0.941	1.583	0.120
P3	0.163	0.394	0.045	0.946	0.413	0.681

Table G-8. Results of FC OLS regression analysis for WL1.6.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-4033.678	1683.512	0.000	.	-2.396	**0.017**
MONTH	0.027	0.009	0.196	0.771	2.889	**0.004**
YEAR	4.036	1.685	74.703	0.000	2.396	**0.017**
$YEAR^2$	-0.001	0.000	-74.650	0.000	-2.394	**0.018**
Flow (log)	-0.559	0.134	-0.288	0.754	-4.187	**0.000**
P1	0.080	0.074	0.067	0.932	1.076	0.283
P2	0.193	0.071	0.170	0.914	2.722	**0.007**
P3	-0.174	0.087	-0.125	0.922	-2.016	**0.045**

Table G-9. Results of nitrate-nitrite OLS regression analysis for WL1.6.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-1775.328	1083.439	0.000	.	-1.639	0.103
MONTH	0.007	0.002	0.231	0.973	3.149	**0.002**
YEAR	1.776	1.081	86.679	0.000	1.642	0.102
$YEAR^2$	0.000	0.000	-86.852	0.000	-1.645	0.102
Flow (log)	-0.016	0.022	-0.053	0.951	-0.710	0.479
P1	0.009	0.019	0.035	0.892	0.459	0.647
P2	-0.026	0.022	-0.089	0.923	-1.185	0.238
P3	-1775.328	1083.439	0.000	.	-1.639	0.103

Table G-10. Results of total phosphorus OLS regression analysis for WL1.6.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-1190.749	955.056	0.000	.	-1.247	0.214
MONTH	0.006	0.002	0.239	0.970	3.196	**0.002**
YEAR	1.186	0.953	66.521	0.000	1.245	0.215
$YEAR^2$	0.000	0.000	-66.482	0.000	-1.244	0.215
Flow (log)	0.027	0.020	0.103	0.950	1.364	0.174
P1	0.012	0.017	0.056	0.893	0.725	0.470
P2	0.008	0.019	0.034	0.923	0.440	0.660
P3	-1190.749	955.056	0.000	.	-1.247	0.214

Table G-11. Results of FC OLS regression analysis for WD2.6.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-4018.171	2478.337	0.000	.	-1.621	0.106
MONTH	0.034	0.009	0.244	0.984	3.788	**0.000**
YEAR	4.019	2.478	58.497	0.000	1.622	0.106
$YEAR^2$	-0.001	0.001	-58.505	0.000	-1.622	0.106
P1	0.090	0.092	0.065	0.934	0.980	0.328
P2	0.019	0.084	0.015	0.898	0.223	0.823
P3	-0.035	0.098	-0.024	0.908	-0.361	0.718

Table G-12. Results nitrate-nitrite OLS regression analysis for WD2.6.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	308.655	1144.334	0.000	.	0.270	0.788
MONTH	-0.005	0.002	-0.153	0.975	-2.044	**0.042**
YEAR	-0.307	1.142	-14.545	0.000	-0.269	0.788
$YEAR^2$	0.000	0.000	14.486	0.000	0.268	0.789
P1	-0.015	0.024	-0.048	0.960	-0.640	0.523
P2	0.023	0.020	0.088	0.894	1.127	0.261
P3	-0.060	0.023	-0.203	0.914	-2.624	**0.009**

Table G-13. Results of total phosphorus OLS regression analysis for WD2.6.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	3520.126	1427.856	0.000	.	2.465	**0.015**
MONTH	0.006	0.003	0.149	0.973	2.058	**0.041**
YEAR	-3.521	1.425	-129.122	0.000	-2.471	**0.014**
$YEAR^2$	0.001	0.000	129.360	0.000	2.476	**0.014**
P1	0.051	0.030	0.124	0.960	1.702	0.091
P2	-0.002	0.025	-0.007	0.895	-0.092	0.927
P3	0.012	0.028	0.030	0.915	0.407	0.685

Table G-14. Results of FC OLS regression analysis for WL3.7SW.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	77620.933	24252.209	0.000	.	3.201	0.002
MONTH	-0.010	0.021	-0.037	0.921	-0.484	0.630
YEAR	-77.112	24.139	-280.948	0.000	-3.194	**0.002**
$YEAR^2$	0.019	0.006	280.410	0.000	3.188	**0.002**
P1	0.434	0.270	0.124	0.886	1.606	0.111
P2	0.179	0.194	0.070	0.910	0.920	0.359
P3	-0.166	0.244	-0.053	0.865	-0.682	0.497

Table G-15. Results of nitrate-nitrite OLS regression analysis for WL3.7SW.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-62683.559	68986.840	0.000	.	-0.909	0.366
MONTH	-0.120	0.029	-0.356	0.985	-4.196	**0.000**
YEAR	62.614	68.672	132.661	0.000	0.912	0.364
$YEAR^2$	-0.016	0.017	-133.113	0.000	-0.915	0.363
P1	0.065	0.270	0.021	0.907	0.240	0.811
P2	0.182	0.184	0.087	0.924	0.993	0.323
P3	-0.046	0.233	-0.017	0.949	-0.198	0.844

Table G-16. Results of total phosphorus OLS regression analysis for WL3.7SW.

Effect	Coefficient	SE	Std. Coefficient	Tolerance	t	p-value
CONSTANT	-49690.806	48506.605	0.000	.	-1.024	0.308
MONTH	-0.090	0.020	-0.381	0.984	-4.555	**0.000**
YEAR	49.610	48.285	148.471	0.000	1.027	0.307
$YEAR^2$	-0.012	0.012	-148.906	0.000	-1.030	0.306
P1	0.135	0.190	0.062	0.909	0.712	0.478
P2	0.116	0.129	0.077	0.924	0.896	0.373
P3	-0.006	0.164	-0.003	0.947	-0.037	0.970

Appendix H: Periphyton Metal Sampling Results

Periphyton Spring Metals Sampling

In February-April of 2014, artificial substrates were deployed *in-situ* at several locations (Figure H-1) in upper Woodland and Woodard Creeks as well as in Moxlie Creek located in Watershed Park in Olympia. Moxlie Creek originates as a spring within the 153-acre park and served as the City of Olympia's water supply until the 1950s. Periphyton collected in Moxlie Creek was meant to represent a control in which no stormwater outfalls are discharging. Methods used for this assessment are outlined in Anderson and Collyard (2016).

After 3 months, substrates were taken out of streams, and periphyton was removed from substrates and processed for metal analysis. The goal of this assessment was to measure metal concentrations in periphyton during the wet season in relation to several stormwater outfalls which discharge into Woodard and Woodland Creeks.

Metal concentrations in Table H-1 and Figure H-1 represent total moles of metals (Cu, Cd, Pb, Ni, Zn) in periphyton that propagated or attached on substrates between February and April of 2014. Total metal concentrations in periphyton decreased from upstream to downstream in Woodland Creek and ranged from 0.43 to 27.8 M/kg periphyton. Metal concentrations were highest in Woodland Creek at river miles 4.4 (WL4.4) and 4.5 (WL4.5), averaging 25.2 M/kg periphyton (Figure H-1). Total moles of metals in periphyton at river mile 3.7 (WL3.7) were 75% lower than concentrations observed upstream (WL3.1). The lowest concentrations of metals were observed in Woodland Creek at river mile 3.1 (below Durham Road). Metal concentrations in Moxlie Creek were the third highest sampled, although concentrations were 76% less than concentrations observed at WL4.4.

Total metals in periphyton in Woodard Creek ranged from 2.3 to 1.6 M/kg (Figure H-1). The highest concentrations were observed at WD6.9, below the Taylor Wetland complex; however, the concentrations were less that observed in Moxlie Creek (MC1.3).

An assessment of individual metal concentrations suggests Zn was the highest of the metals at all stations, although concentrations varied between sites (Figures H-2A & B). On average Cu, was the second highest metal at all sites and was followed by Ni, Pb and Cd (Figures H-2A & B).

Table H-1. Metal concentrations in periphyton collected during the wet season on Woodland and Woodard Creeks.

Station	Mg/kg periphyton					Moles/kg periphyton
	Cd	Cu	Ni	Pb	Zn	Total Metals
WD3.4	ND	7.49	11.5	6.22	188	1.61
WD6.9	ND	25.4	11.4	12.1	267	2.37
WL3.1	0.485	7.65	4.7	11.1	39.3	0.43
WL3.7	ND	9.26	5.07	5.88	241	1.97
WL4.4	2.09	72.15	31	22.65	2945	23.41
WL4.5	4.28	60.4	24.4	40.7	3510	27.64
MC1.3	1.18	23.1	63.1	11	683	5.97

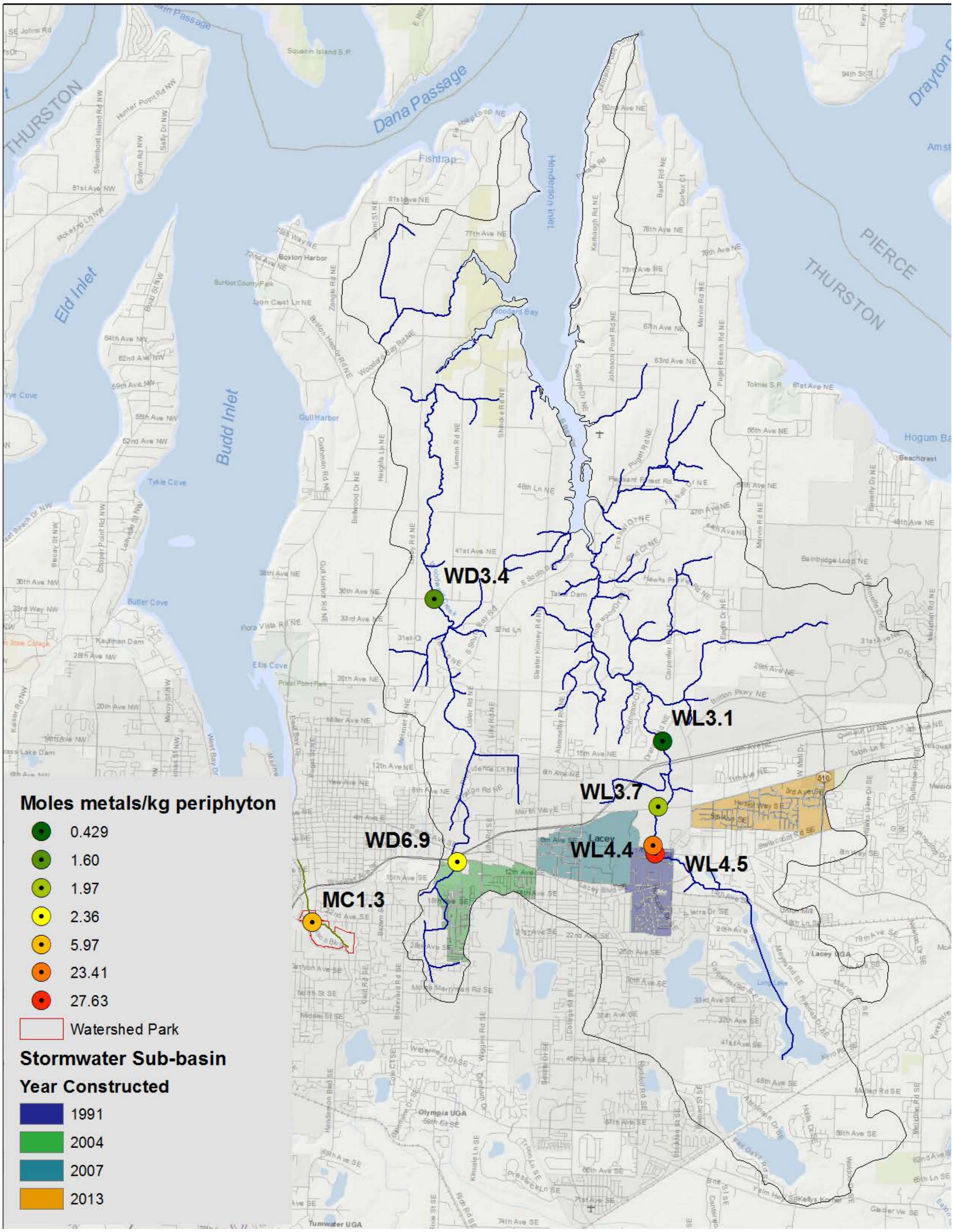


Figure H-1. Total moles of metals (Cu, Cd, Pb, Ni, Zn) in periphyton collected on artificial substrates during the wet season (February-April) in relation to major stormwater catch basins and year constructed.

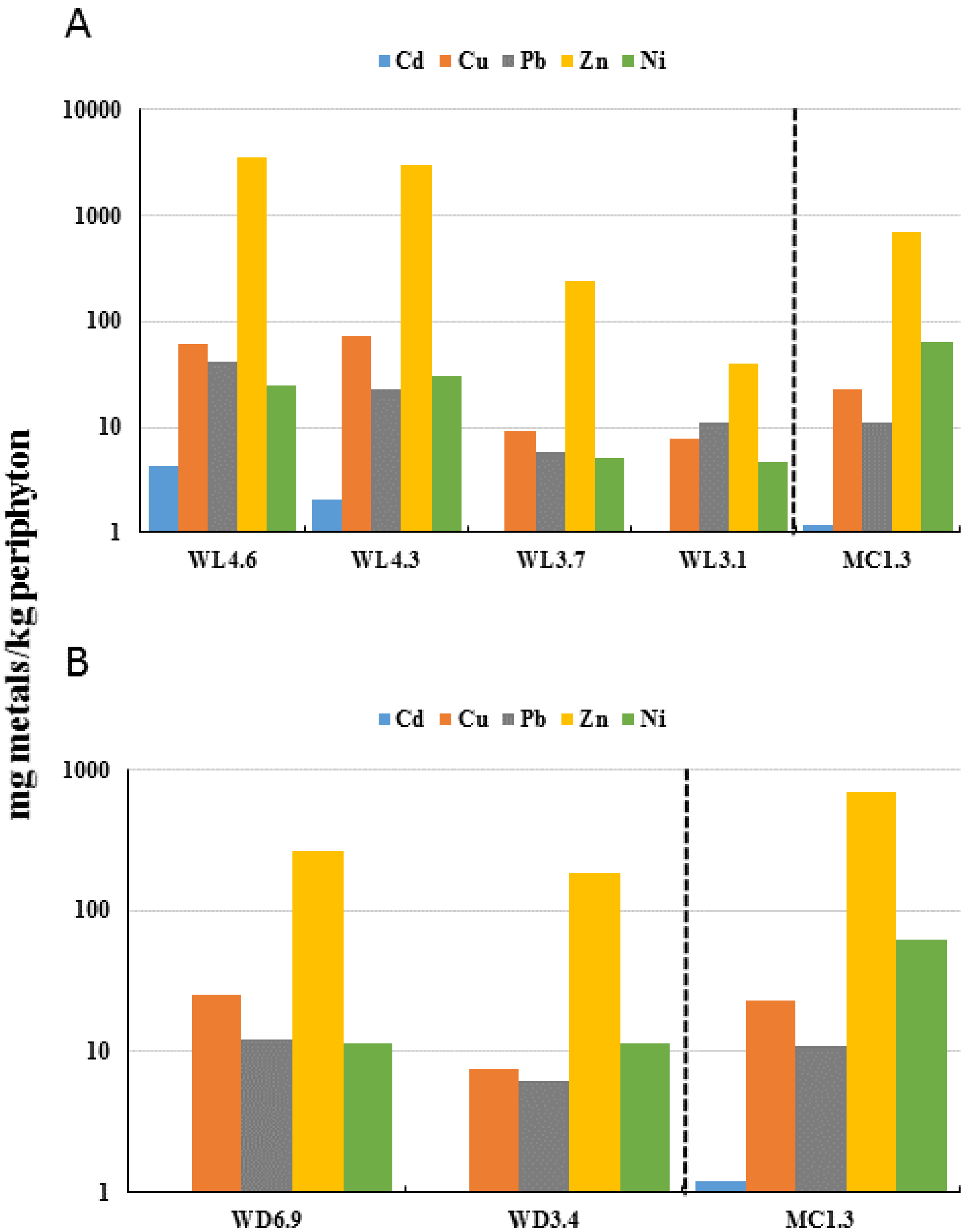


Figure H-2. Concentrations of Cd, Cu, Pb, Zn and Ni in periphyton collected on artificial substrates from Woodland Creek (A) and Woodard Creek (B) compared with Moxlie Creek (MC1.3).

Reference for Appendix H

Anderson, P. and S. Collyard, 2016. Standard Operating Procedure for Collection and Processing of Periphyton Samples for TMDL and Effectiveness Monitoring Studies. SOP # EAP085. Version 2. Washington State Department of Ecology, Olympia, WA.

Appendix I: Examples of Grant Project Categories

Planning

Thurston County Current and Future Conditions Report

To address these contamination problems and comply with regulatory requirements, Thurston County, with support from the City of Lacey and the Lacey Olympia Tumwater Thurston Clean Water Alliance (LOTT) initiated the *Woodland Creek Pollution Load Reduction Project* in January 2006. The County retained a consultant team of Pacific Groundwater Group (PGG) and Brown and Caldwell (BC) to provide technical support.

The project was funded by Thurston County, the City of Lacey, and Washington State Centennial Clean Water Fund Grant G0600191. It consisted of three major tasks:

- Evaluate Current Conditions and Estimate Pollutant Loads from Land Uses
- Develop Options for Reducing Pollutant Loads
- Public Involvement

The first task involved an evaluation of the current water quality and pollutant sources in the study area. The results of that task are described in the *Current Conditions Report, Woodland Creek Pollution Load Reduction Project* (Pacific Groundwater Group and Brown and Caldwell, 2007a). After completing the Current Conditions Report, the project team defined environmental goals, developed and screened a list of possible actions to reduce pollution, combined actions into three management options, predicted future pollution loads under a "no action" option and the three management options, and compared predicted future conditions to the environmental goals. That work is documented in the *Future Conditions Report, Woodland Creek Pollutant Load Reduction Project* (Pacific Groundwater Group, 2008).

This Woodland Creek Pollutant Reduction Plan summarizes the previous work and adds the following information:

- Conceptual designs and cost estimates for the capital improvement actions (built items) and management options.
- A recommended plan to reduce pollution consisting of capital improvements, programs, priorities, monitoring, and possible funding sources.

The document recommended pursuing the "medium" option which calls for providing public sewer service to certain densely built neighborhoods that have high rates of onsite sewage system (OSS) failures. The neighborhoods were prioritized to reduce fecal coliform bacteria (FC) loads to Woodland Creek first, followed by reductions of nitrate discharges to groundwater.

The results of these planning assessments ultimately allowed the County to pursue the most cost-effective options for reducing bacteria and nutrient loading in high-priority areas in the watershed. These included:

- Woodland Creek Estates Sanitary Sewer Project (Woodland Creek Estates and Covington Place).
- Tanglewilde/Martin Way Stormwater Improvement Project.

Infrastructure

Thurston County Onsite Septic program

There are approximately 6,684 OSSs in the Henderson Inlet watershed, of which approximately 1,500 are within 200 meters of a waterbody (Figure I-1). In January 2007, Thurston County implemented a Septic System Operations and Maintenance Program for watersheds that drain to Henderson Inlet. This risk-based program requires that homeowners properly maintain OSSs with a potential to affect water quality in Henderson Inlet.

Some of the elements of this program include:

- All onsite sewage systems (OSSs) must have an operational certificate (OPC) which is based on an inspection report demonstrating that the system functions properly and must be renewed every 3 years.
- Training and certification of property owners to conduct their own inspections.
- Dye testing of systems identified as high-risk every six years. (High risk is based on proximity to surface waters and soil permeability.)
- Development of a database for tracking inspection compliance and testing results.
- Procedures and policies for dealing with non-conforming systems.
- Other strategies for reducing bacteria from OSSs, including outreach to homeowners, providing low-interest loans to homeowners who need to repair or replace their tanks, sewering of appropriate areas, and additional investigation to identify sources and source areas.

In 2013, Thurston County published a five-year evaluation to assess elements and effectiveness of the program (Thurston County, 2013). The report indicates the number of permits for OSS repairs has been decreasing over time. The report concludes that the success of the program has contributed to measurable improvements in the marine water of Henderson Inlet, although correlations are difficult to establish. More information on specific locations of failing systems, repairs, and related details is needed to support this conclusion.

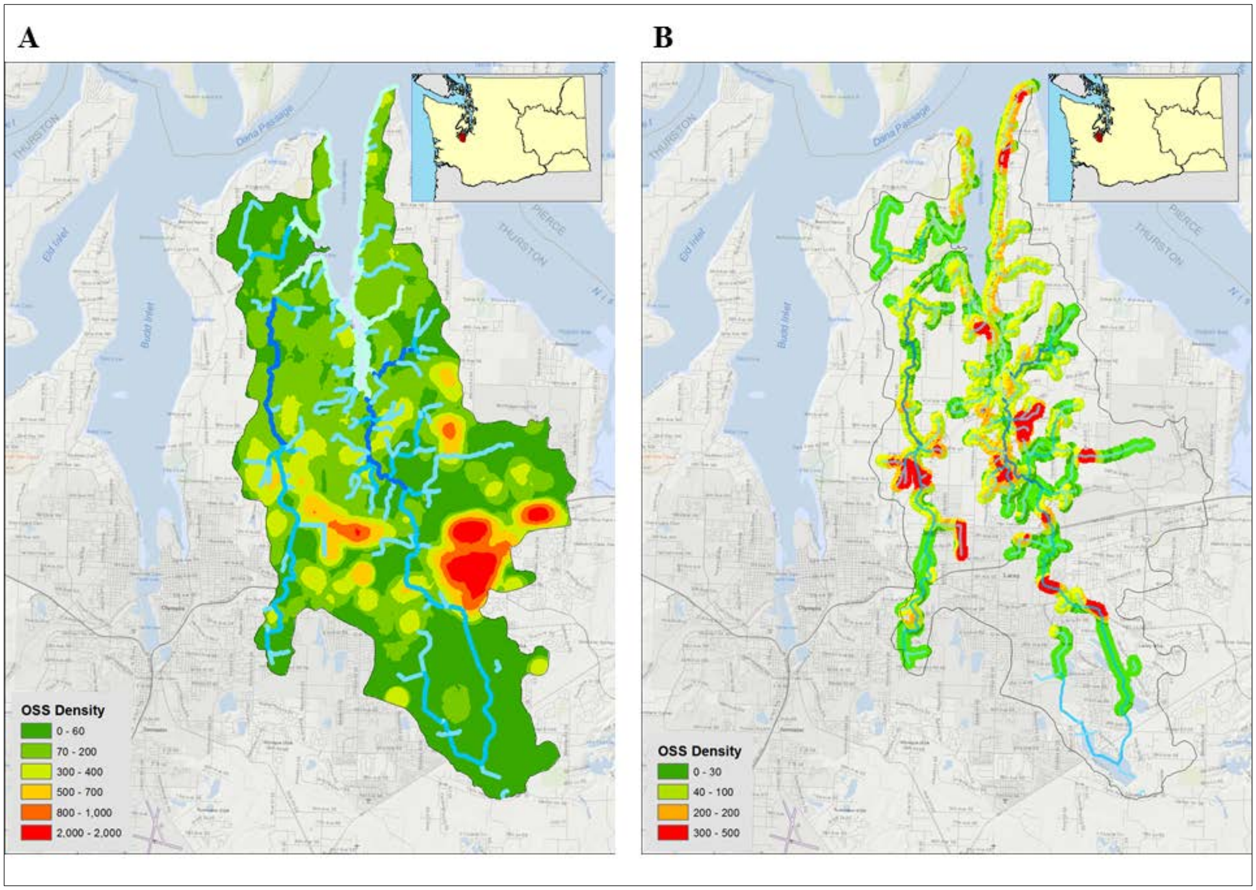


Figure I-1. Onsite sewage system (OSS) density map for Henderson Inlet HUC 12 (A) and within a 200-meter buffer of water way (B).

Woodland Creek Estates and Covington Place

Failing onsite sewage systems (OSSs) in the Woodland Creek Estates and Covington neighborhoods, located adjacent to Woodland Creek, were identified as a significant source of FC to Woodland Creek. In 2011, Thurston County Public Works began a project to covert 128 homes in these neighborhoods from OSS to public sewer (Thurston County, 2009). The project was completed in 2013. An estimated 30,000 gallons of sewage is being removed from this basin per day and sent to LOTT for treatment.

In September 2014, Ecology conducted instream sampling of periphyton along 150-meter stream reaches upstream (WL3.1), within (WL2.6), and downstream (WL1.9) of the project's footprint (based on residential parcel areas of converted systems). Figure I-2 presents periphyton total % nitrogen and nitrogen stable isotope (D15N) results from this assessment. Stable nitrogen isotope analysis has revealed elevated D15N in periphyton collected in streams below non-sewered (septic tanks) neighborhoods when compared to sewered neighborhoods (Cabana and Rasmussen, 1996; DeBruyn and Rasmussen, 2002).

For visualization purposes, a diffusion interpolation with barriers analysis was performed using GIS to estimate % nitrogen and nitrogen isotopes between stations (D-1). Results suggest both % nitrogen and D15N (Figures I-2A & B) increased from above to within the project footprint before decreasing again at the downstream station (WL1.9).

Although the relationship is correlative, results may indicate either sources of anthropogenic nitrogen still exist within the project footprint or legacy nitrogen from groundwater is entering the stream during the dry season. Long-term water quality data collected between 1983 and 2013 from WL1.6 downstream of the project suggest a lag between when NO_x and FC began trending downward (I-3). Assuming the sources of NO_x and FC are the same (i.e., Woodland Creek Estates OSS), results may be indicative of legacy nitrogen inputs from groundwater.

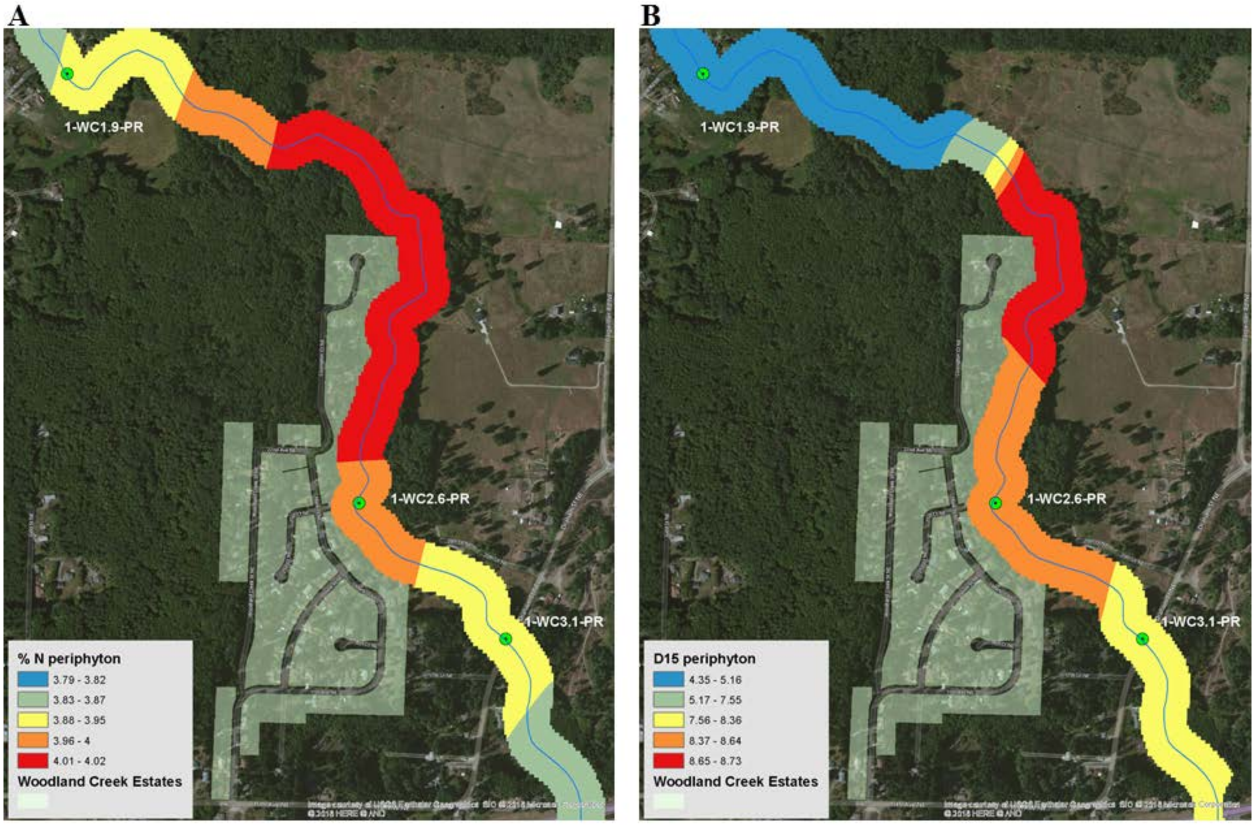


Figure I-2. Percent nitrogen (A) and D15N (B) in periphyton collected during the dry-season watershed health assessment (August 2014).

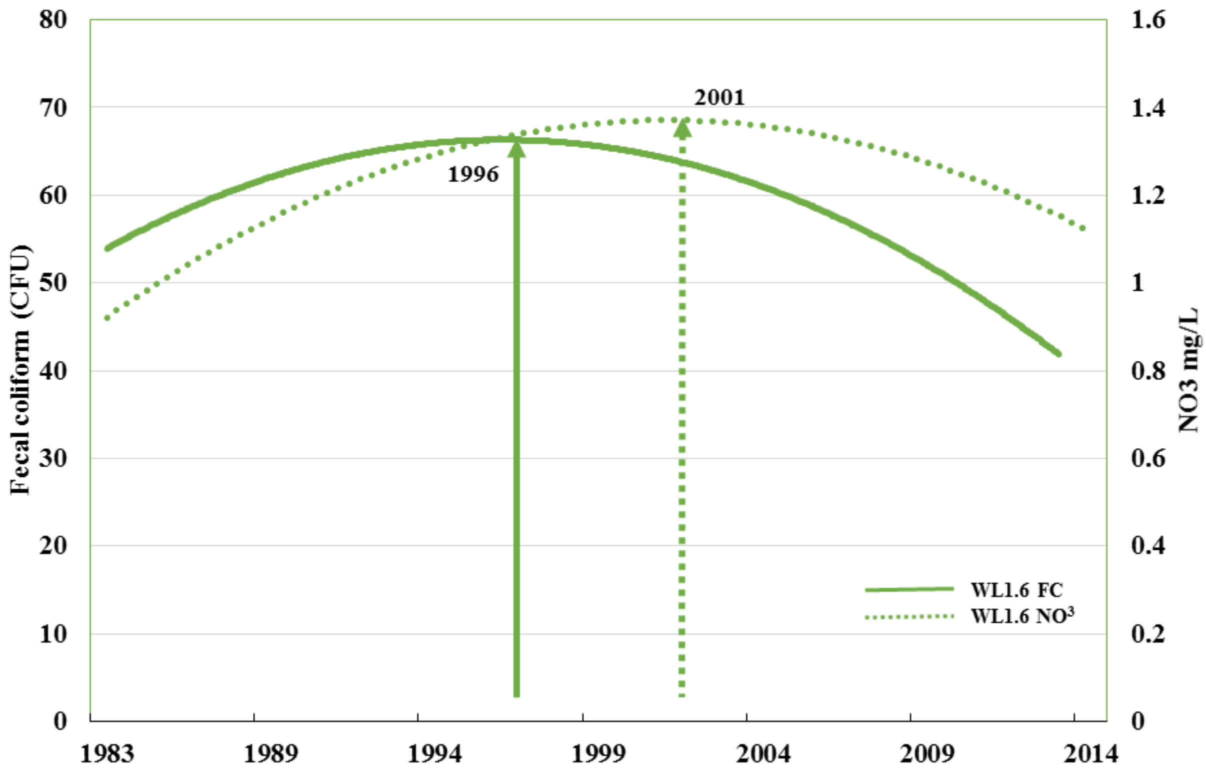


Figure I-3. Non-linear regression results of FC and nitrate samples collected from WL1.6 downstream of Woodland Creek Estates Sanitary Sewer project. Year indicates when the point of inflection occurred.

Tanglewilde stormwater retrofit (2011-2013)

The 2003 TMDL study identified significant FC pollution in Woodland Creek downstream of Martin Way (Sargent, 2006). The study found that the greatest FC load to the creek comes from a stormwater outfall draining the Tanglewilde neighborhood. Bacteria is flushed into Woodland Creek from stormwater runoff that comes from roads, roofs, driveways, lawns, and other impervious surfaces in the Tanglewilde neighborhood. The FC-contaminated runoff flowed to a low point and was conveyed to an outfall on Martin Way (WL3.7SW), which discharges the water directly into Woodland Creek. Also, FC-contaminated groundwater in the Tanglewilde area was believed to be primarily recharged from local OSSs. Groundwater was exfiltrating into the stormwater system which discharges into Woodland Creek.

Beginning in 2011, Thurston County installed a series of new drywells with interconnecting infiltration galleries and repaired more than 50 existing drywells in the Tanglewilde neighborhood. Combined, these improvements were expected to greatly reduce the volume of contaminated stormwater runoff that enters Woodland Creek.

Figure I-4 presents an overview of historic water quality sampling results and periphyton metals results collected in 2015 by Thurston County and Ecology.

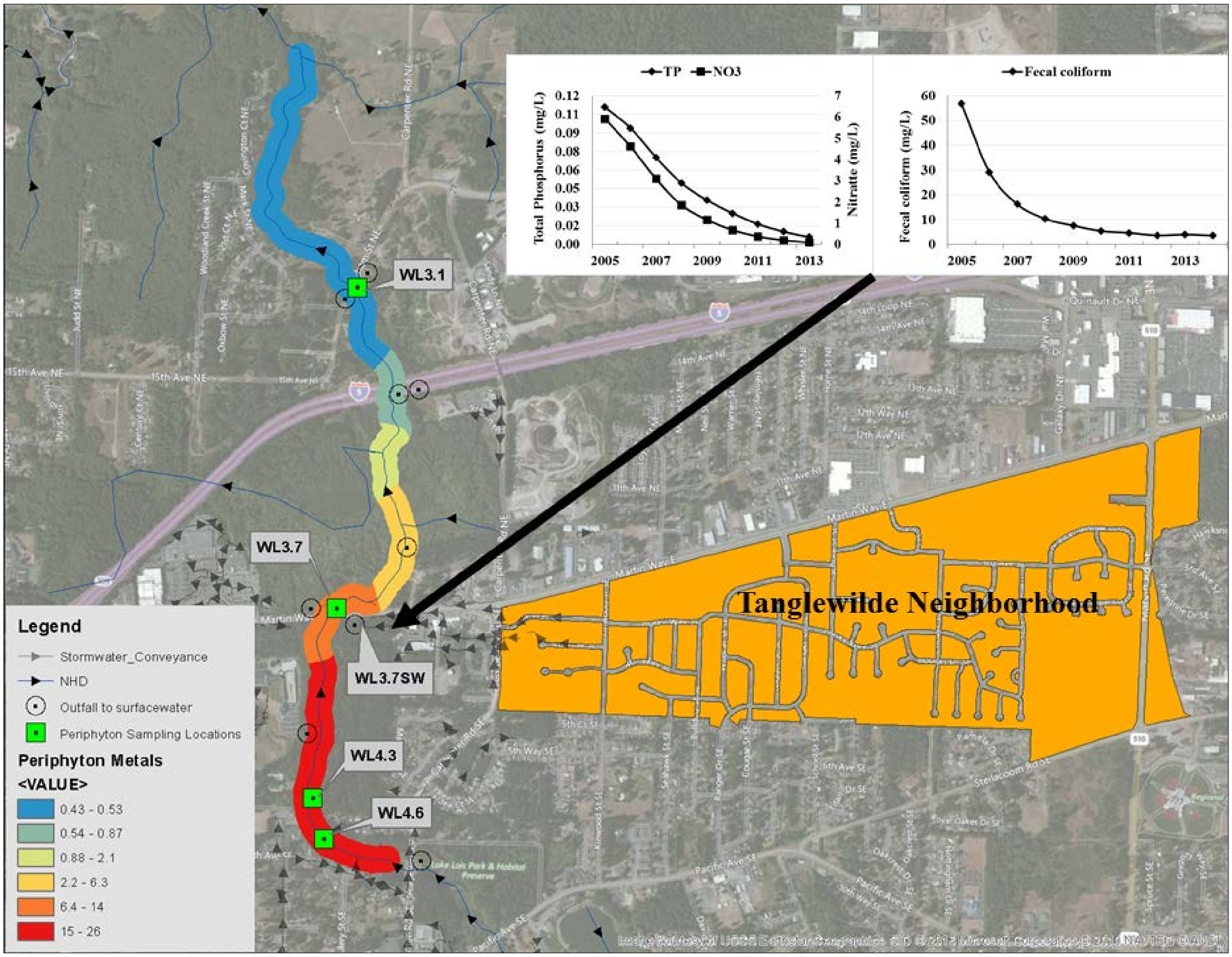


Figure I-4. Metals results from Woodland Creek wet-season periphyton sampling at locations above and below the stormwater outfall at river mile 3.7 (WL3.7SW) and Thurston County's water quality results from stormwater outfall (WL3.7SW),

Agricultural

Thurston Conservation District

The Thurston Conservation District (TCD) – under authority of Chapter 89.08 RCW, *Conservation Districts* – provides education and technical assistance to residents, develops conservation plans for farms, and assists with design and installation of best management practices (BMPs).

In addition to conservation planning, and technical and cost-share assistance to landowners, the TCD has a yearly native plant sale and provides most of the funding for South Sound GREEN, a student-based volunteer monitoring and education program. The TCD also coordinates the Shellfish Pledge Program, an incentive-based program for both urban and rural landowners.

Figure I-5 displays agricultural areas within the Henderson Inlet watershed based on Thurston County land use data for 2014. Areas do not represent individual projects but rather the possible locations where agricultural best management practices (BMPs) or farm planning would likely have been implemented.

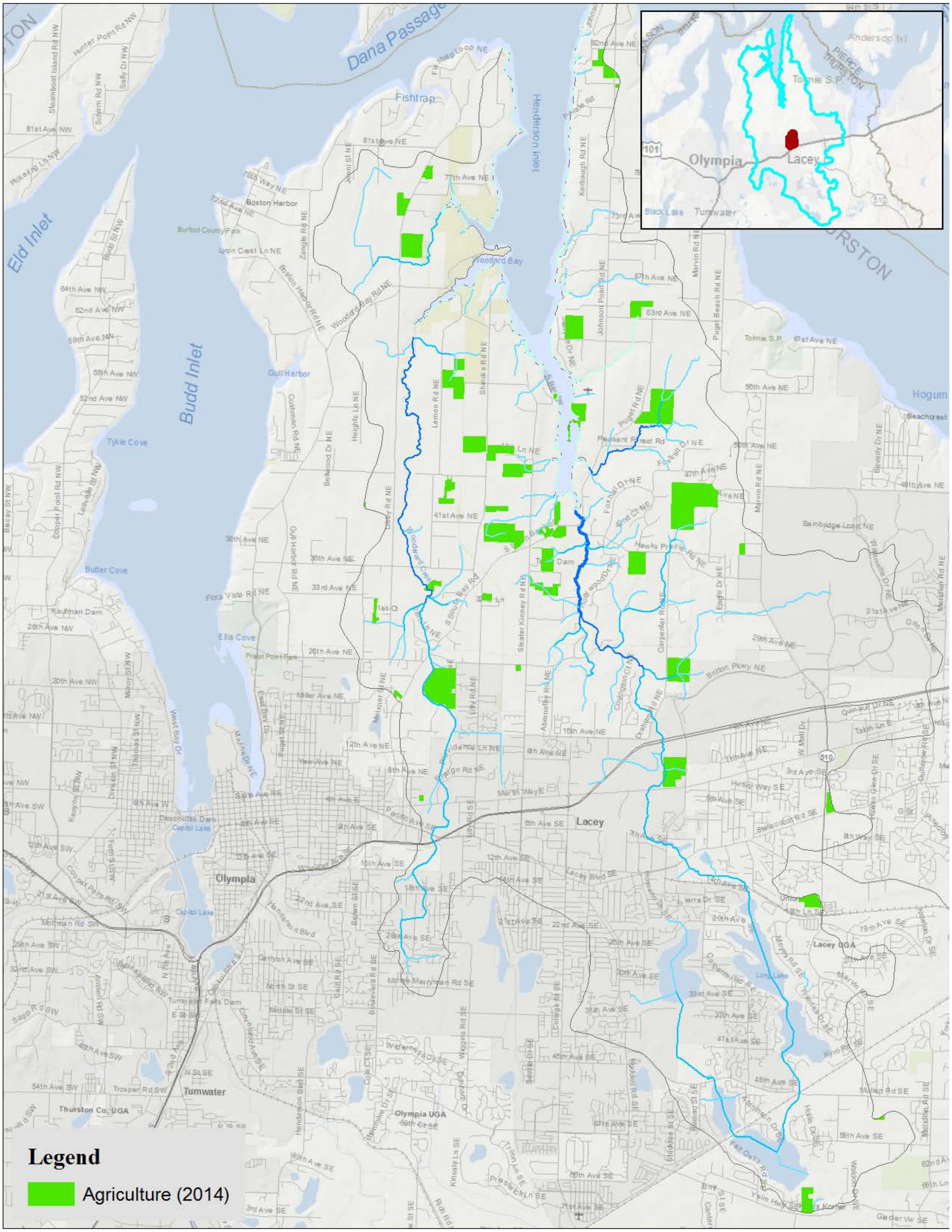


Figure I-5. Agricultural parcels in the Henderson Inlet watershed, 2014.

Education and outreach

Scoop it to win it

In 2012, the Pacific Shellfish Institute (PSI) initiated the pet waste education campaign, a survey of dog waste in the Henderson and Nisqually Inlet Shellfish Protection Districts, to identify problem areas (PSI, 2012). Staff flagged and scooped over 1200 piles of dog waste from neighborhood parks and pinpointed locations in need of bag dispensers, signage, and further outreach. Volunteers flagged individual poop piles, weighed and removed feces, and distributed raffle tickets to responsible dog owners. The survey detected significant quantities of dog waste at various locations within the more urbanized portions of the Henderson Inlet. Figure I-6 presents the amount of dog waste in parks surveyed in the Henderson Inlet watershed in lbs/acre. The results also suggested that dog feces are concentrated at specific locations throughout the watershed and that many dog owners are not cleaning up after their pets.

The report made specific recommendations based on the survey:

- Install pet waste stations in parks and natural areas.
- Conduct outreach to neighborhoods and schools in the vicinity of Homann Park and Woodland Creek.
- Increase code enforcement at Homann Park and Woodland Creek.
- Increase the number of properly-sited off-leash parks throughout the watersheds.

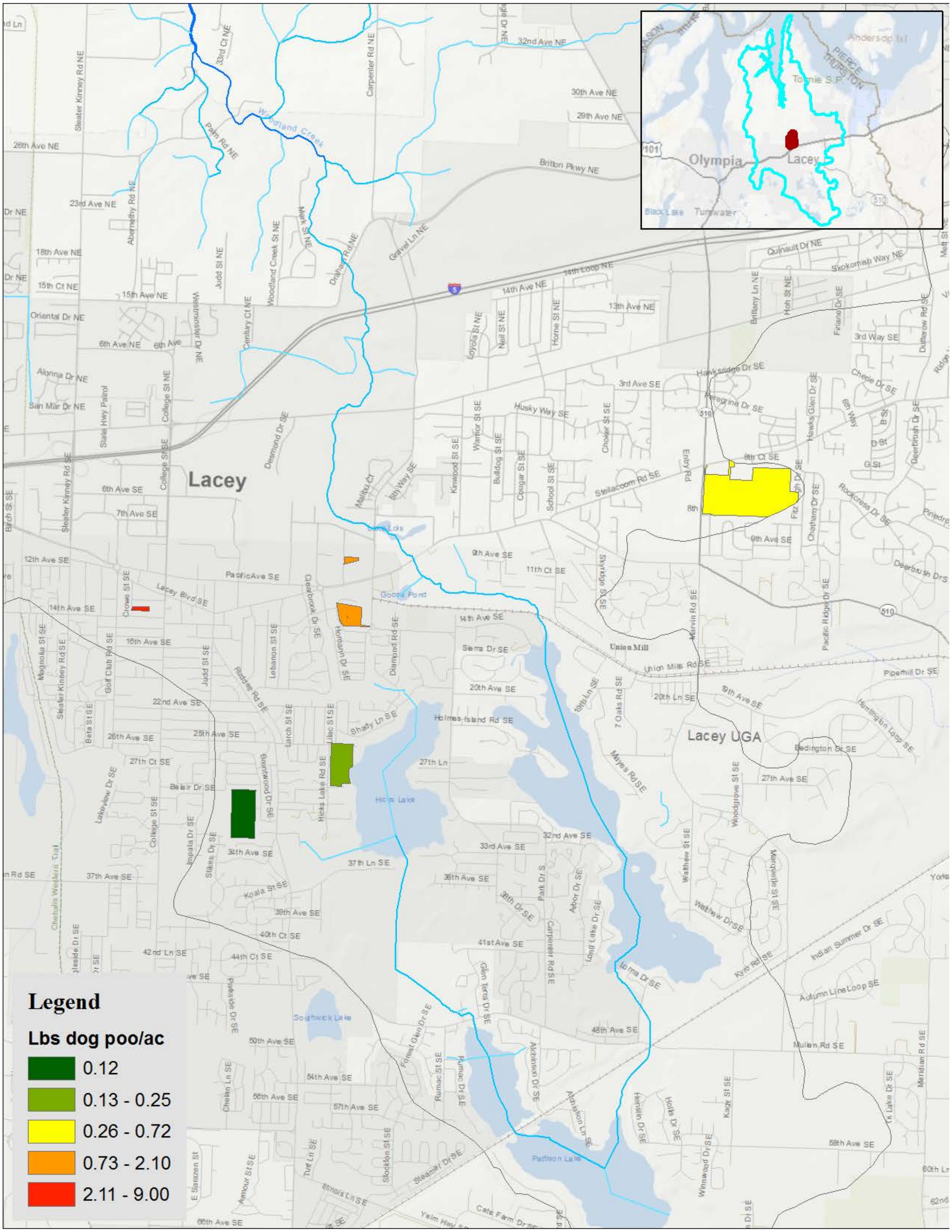


Figure I-6. Results of 2011 pet waste assessment in Henderson Inlet watershed parks.

References for Appendix I

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