

FINAL SPANAWAY LAKE WATERSHED-SCALE STORMWATER MANAGEMENT PLAN

AUGUST 2017

Prepared in compliance with NPDES Phase I Municipal Stormwater Permit (effective date August 1, 2013), S5C5c Watershed-scale Stormwater Planning Requirements by Pierce County, Washington, with assistance from Brown and Caldwell.



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EXECUTIVE SUMMARY

Stormwater discharges in unincorporated Pierce County (County) are covered by the Washington State (State) Phase I Municipal Stormwater Permit (Permit), which became effective on August 1, 2013. Special Condition S5.C.5.c of the Permit requires watershed-scale stormwater planning. The Permit requires that the County submit a watershed-scale stormwater plan to the Washington State Department of Ecology (Ecology) by September 6, 2017. The watershed-scale stormwater management plan (WSP) should include a summary of results of the modeling and planning process, results of the evaluation of strategies under S5.C.5.c.iv.(5).a, and an implementation plan and schedule developed pursuant to S5.C.5.c.iv.(6).

The Permit requires the County to conduct watershed-scale stormwater planning in the Clover Creek watershed or an alternative watershed that meets criteria specified in the Permit. The County selected the Spanaway Lake watershed, which is a tributary to Clover Creek. Ecology approved the County's selection on March 11, 2014. On April 1, 2014, the County sent Ecology a draft scope of work (SOW) and schedule for developing a WSP for the Spanaway Lake watershed. The County revised the SOW in response to Ecology comments on the draft. Ecology approved the County's revised SOW in a letter dated August 8, 2014.

The Permit requires watershed modeling to predict whether Benthic Index of Biotic Integrity (B-IBI) benchmarks and water quality standards for temperature, copper, zinc, or fecal coliform bacteria will be met under existing and future conditions. If the modeling results indicate that these benchmarks or water quality standards may not be met, the Permit requires evaluation of potential stormwater management strategies to meet the water quality standards or B-IBI.

This Spanaway Lake WSP focuses on the potential stormwater management strategies that must be evaluated per S5.C.5.iv.(5).a.

Data collection included monitoring of streamflow, surface water quality, and groundwater quality at the locations shown on Figure ES-1. As required by the Permit, the WSP monitoring included water temperature, dissolved copper and zinc, fecal coliform bacteria, and B-IBI.

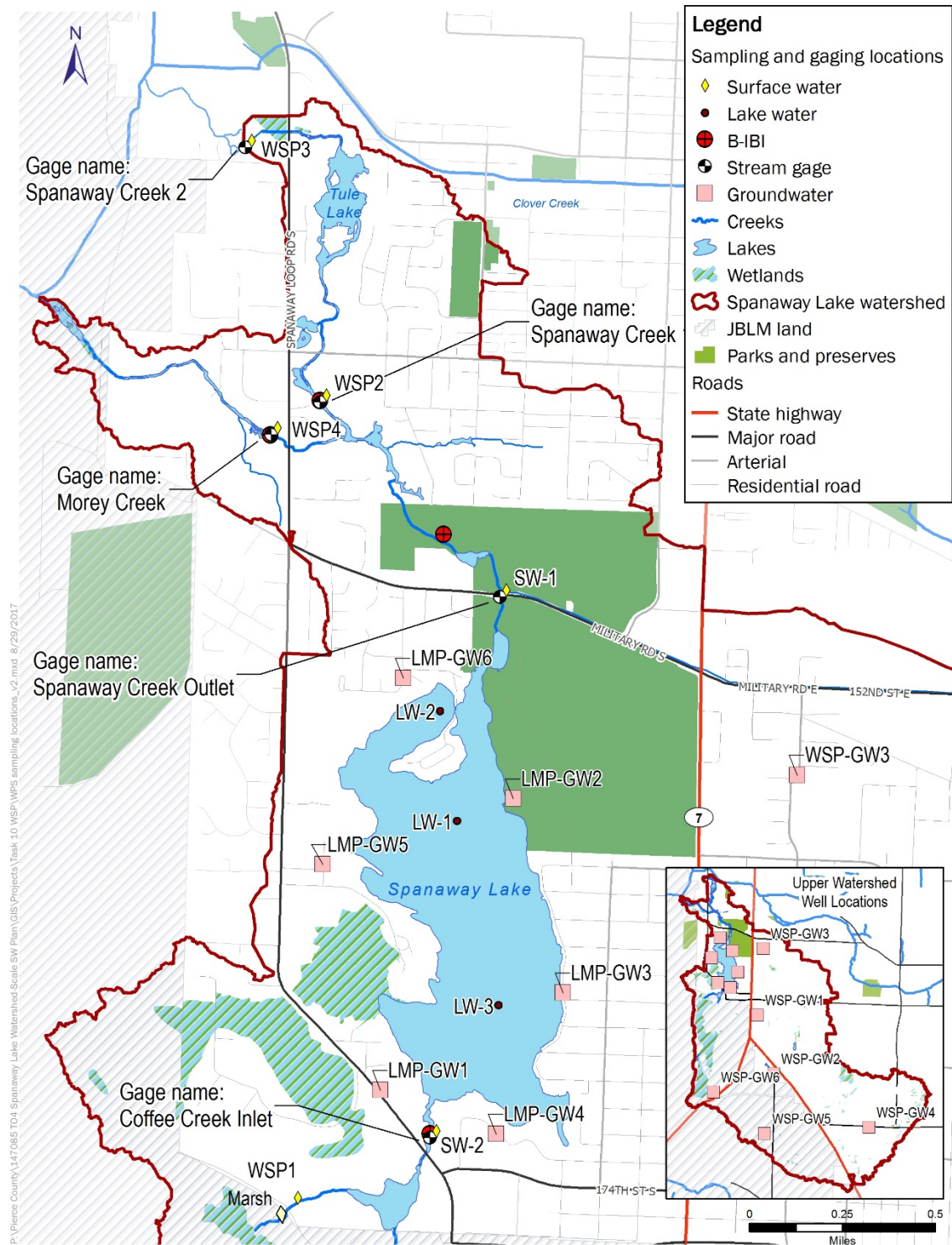


Figure ES-1. Spanaway Lake WSP sampling locations

The monitoring results were used to calibrate a Hydrological Simulation Program-Fortran (HSPF) watershed model and a MODFLOW groundwater model for the Spanaway Lake WSP area. The watershed model was used to simulate streamflow, water temperature, dissolved copper and zinc, and fecal coliform bacteria under existing, historical, and future (full-buildout) conditions. The model was also used to calculate hydrologic metrics, which were then used to estimate B-IBI scores using the regression equations cited in Ecology's 2016 WSP guidance document. The following paragraphs summarize the key findings from Spanaway Lake WSP monitoring and modeling:

- **Water temperature:** Water temperatures exceeded the numeric criterion (7-day average of daily maximum temperature [7-DADMax] of 17.5 degrees Celsius [°C]) in Spanaway Lake and in Spanaway and Morey creeks downstream of the lake during much of summer 2015. The monitoring results show that warming in Spanaway Lake was the primary cause for the elevated water temperatures observed in Spanaway and Morey creeks downstream of the lake. 7-DADMax values in Spanaway Lake exceeded 27.5°C in July 2015. The warmest water temperatures were observed at SW-1 just downstream of the lake. Water temperatures were slightly lower at WSP2 and WSP4, potentially because of groundwater inflows and a thick riparian canopy along Spanaway Creek just downstream of SW-1. Warming in Tule Lake could contribute to elevated temperatures in Spanaway Creek downstream of the lake.

For lakes and other water bodies that exceed 17.5°C 7-DADMax because of natural conditions, human actions considered cumulatively may not increase the 7-DADMax by more than 0.3°C. The HSPF simulations indicate that existing 7-DADMax values are within 0.3°C of historical conditions near the Spanaway Lake outlet (SW-1). These model results indicate that SW-1 meets the temperature criterion. The temperature model results for Spanaway Creek and Morey Creek downstream of SW-1 indicate that the current conditions are more than 0.3°C warmer than simulated historical conditions. The simulated increase in temperatures is likely due to less riparian shade compared to historical conditions, rather than the limited direct stormwater discharges to surface water bodies.

- **Dissolved copper and zinc:** The monitoring and modeling results indicate that the Spanaway Lake WSP water bodies currently meet the water quality criteria for copper and zinc (see Appendix C). The lack of exceedances may be due at least in part to the lack of direct stormwater discharges to surface water bodies. Pervious areas in the watershed generate little surface runoff because of the highly permeable soils. Nearly all stormwater from impervious areas is infiltrated through low-impact development (LID) measures (e.g., dispersion onto adjacent pervious areas) or through infiltration facilities. Future-conditions

modeling assuming full buildout per current zoning indicates future copper and zinc exceedances are unlikely.

- **Fecal coliform bacteria:** The WSP found that fecal coliform concentrations exceeded the criteria at most monitoring locations during the WSP monitoring period (October 2014 through March 2016), including the Joint Base Lewis-McChord (JBLM) marsh upstream of Coffee Creek. Ecology's 2013–14 study, however, found that most of the sites within the Spanaway Lake WSP met the criteria (Ecology 2016b). Both the WSP and Ecology monitoring found that fecal coliform concentrations in the creeks were higher during the dry season than during the wet season. Riparian wildlife appears to be an important source. Other potential sources include stormwater discharges from the Military Road outfall, shoreline area septic systems, shoreline area stormwater infiltration systems, and domestic animals with direct access to the creeks.
- **B-IBI:** B-IBI scores were below Ecology's target (38 on the 10–50 scale, or 90 percent of pre-development scores) at all WSP monitoring sites. The highest B-IBI score, measured at SW-2 (Coffee Creek), was in the "fair" range even though only about 1.2 percent of its watershed area is urbanized. B-IBI scores for sites downstream of Spanaway Lake were much lower. Stressor analysis indicated that elevated water temperatures and lack of habitat complexity are the primary factors limiting B-IBI scores downstream of the lake. Low dissolved oxygen (DO) and poor substrate were also identified as limiting factors. Altered hydrology and physical channel disturbance were not indicated as limiting factors.

The HSPF model simulations indicate that hydrologic metrics for the existing Spanaway Lake watershed conditions are close to model-simulated historical conditions. These results are consistent with the highly permeable soils and lack of connected stormwater conveyance systems in the WSP area. Nearly all runoff from impervious areas is either infiltrated through adjacent pervious areas or the more than 1,400 infiltration facilities in the WSP area. Because of the permeable soils, the pervious areas produce little runoff. The watershed model indicates that groundwater is the source of about 99 percent of the creek flow leaving the watershed. Infiltration greatly limits direct surface runoff and peak flows, while groundwater discharges provide ample baseflow. Spanaway and Tule lakes provide additional flow attenuation.

Table ES-1 lists the B-IBI scores estimated based on the model-simulated hydrologic metrics and the regression equations developed by DeGasperi et al. (2009) and Horner (2012). The regression equations predict average B-IBI scores that are 43 to 90 percent higher than the observed 2015 B-IBI scores. The B-IBI scores predicted based on simulated historical

hydrologic conditions are only slightly higher (1-3 points) than the B-IBI scores predicted based on existing conditions. These results are consistent with the B-IBI stressor evaluation (Appendix C), which indicates that altered hydrology is not an important limiting factor for benthic macroinvertebrates in the Spanaway Lake WSP area. This result is not surprising considering that nearly all stormwater runoff in the WSP area is infiltrated and groundwater accounts for 99 percent of the flow in Coffee, Spanaway, and Morey creeks, according to the HSPF model.

Table ES-1. Predicted and Observed B-IBI Scores in the Spanaway Lake Watershed (10-50 Scale)

B-IBI Scores from Regression Equations	Basis of B-IBI Score	Existing-Conditions Model				Historical-Conditions Model			
		SW-1	SW-2	WSP2	WSP4	SW-1	SW-2	WSP2	WSP4
	Low pulse count	32	36	31	35	29	39	30	34
	Low pulse duration	27	34	27	25	24	36	28	23
	High pulse count	40	41	39	39	41	43	41	42
	High pulse duration	39	44	37	37	42	49	44	42
	High pulse range	32	32	31	31	36	35	35	37
	Flow reversals	24	37	22	21	25	47	32	29
	TQ _{mean}	42	37	45	34	40	37	42	42
	Richards-Baker flashiness index	37	37	37	35	37	38	37	37
	Average B-IBI (all hydrologic metrics)	34	37	34	32	34	41	36	36
	Observed (2015)	18	26	18	22	--	--	--	--

The future-conditions model predicts small declines in the hydrologic metrics and B-IBI scores. However, the future-conditions model likely overestimates surface runoff because it assumes no LID or flow control for new development.

Table ES-2 lists the model-predicted excursions for the WSP parameters and the likely sources or causes of the excursions based on the monitoring and modeling results. The table shows that dissolved copper and zinc are predicted to meet water quality criteria at full buildout, while water temperature, fecal coliform bacteria, and B-IBI scores may not.

Table ES-2. Summary of Predicted Excursions and Causes in the Spanaway Lake Watershed

WSP Parameter	Meets Criteria?		Causes or Sources for Excursions	
	Existing	Buildout	Primary	Secondary
Water temperature	No	No	Natural warming in Spanaway Lake	Reduced shade on some creek reaches
Fecal coliform	No	No	Waterfowl and other riparian wildlife	Stormwater runoff from Military Road sub-basin; runoff from shoreline areas with wildlife and domestic animals; shoreline septic systems; shoreline stormwater infiltration systems
Dissolved copper and zinc	Yes	Yes	Meets criteria	Meets criteria
B-IBI	No	No	Elevated water temperature, lack of habitat complexity	Low DO, fine sediments in creek beds, embeddedness

The monitoring and modeling results suggest that elevated water temperature and lack of habitat complexity, rather than altered hydrology, are the main factors limiting B-IBI scores in the Spanaway Lake WSP area. Low DO and fine or embedded substrate appear to be moderate limiting factors at several sites.

Comparison of existing and historical model simulations indicates that warming in Spanaway Lake is the main cause of the elevated water temperatures in Spanaway and Morey creeks, although sparse riparian canopy is likely a contributing factor in some reaches (e.g., WSP2). Elevated water temperatures can also contribute to reduced DO, which could adversely affect benthic organisms.

The objective of the watershed-scale stormwater planning requirement of the Permit is “...to identify a stormwater management strategy or strategies that would result in hydrologic and water quality conditions that fully support ‘existing uses,’ and ‘designated uses,’ as those terms are defined in WAC 173-201A-020, throughout the stream system.” Our evaluation suggests that in the Spanaway Watershed no stormwater management strategy or strategies are available to achieve the Permit objective.

However, Pierce County has identified the following four potential stormwater management strategies to help avoid the predicted excursions for water temperature and fecal coliform and improve B-IBI scores:

- Construct facility in Military Road sub-basin to treat and infiltrate stormwater, thereby reducing discharge volume and fecal coliform loads to Spanaway Creek
- Retrofit drywells in shoreline areas to reduce potential for fecal coliform to reach receiving water bodies via the subsurface



- Retrofit shoreline-area infiltration ponds to reduce potential for fecal coliform to reach receiving water bodies via pond overflow or subsurface transport
- Require 100 percent onsite retention for new development and redevelopment in the Military Road sub-basin and other WSP areas where there is potential for direct stormwater discharge to surface waters

These potential stormwater management strategies should help to improve water temperature, fecal coliform, and benthic conditions in the Spanaway Lake WSP. The improvements are likely to be modest, however, for the reasons listed below:

- The County has already installed more than 1,400 infiltration and LID facilities in the WSP area; consequently, there is little direct stormwater runoff to receiving water bodies.
- Because of widespread use of LID and infiltration practices, municipal stormwater runoff is a relatively minor source of fecal coliform to receiving waters in the Spanaway Lake WSP. Riparian sources appear to be the primary cause for the fecal coliform excursions.
- Natural warming in Spanaway Lake is the primary cause for elevated water temperatures, while sparse riparian canopy is a contributing factor. Current stormwater management practices result in ample groundwater recharge and cool baseflow to Spanaway Lake and Coffee, Spanaway, and Morey creeks.
- Elevated water temperature and lack of habitat complexity appear to be the main factors limiting B-IBI scores in the Spanaway Lake WSP. Altered hydrology does not appear to be a significant limiting factor for B-IBI in the Spanaway Lake WSP area because of its unique hydrogeology and the extensive use of infiltration and LID practices.

Because of the extensive use of infiltration and LID practices, municipal stormwater discharges do not appear to be a major cause or source of the predicted temperature, fecal coliform, and B-IBI excursions. Moreover, there is limited opportunity for additional flow control because the vast majority of stormwater is infiltrated. Therefore, the potential stormwater management strategies described in this WSP are expected to provide incremental water quality improvements rather than full attainment of temperature or fecal coliform criteria, or Ecology's proposed B-IBI target score of 38.

The WSP monitoring and modeling evaluations identified several potential limiting factors unrelated to municipal stormwater discharges. Stormwater management strategies would not address these factors. Potential non-stormwater management strategies are addressed separately from this WSP.

The County involved stakeholders in the development of the Spanaway WSP. Stakeholder outreach activities included:

- Communications and briefings with Washington State Department of Transportation (WSDOT), JBLM, and City of Tacoma

- Posting of information about the WSP on the County website
- Briefings for the Chambers-Clover Watershed Council and Pierce County Surface Water Advisory Board
- Public review of the draft WSP document

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List of Abbreviations

°C	degree(s) Celsius	LID	low-impact development
°F	degree(s) Fahrenheit	LMD	Lake Management District
7-DAD _{Max}	7-day average of daily maximum temperature	LMP	Lake Management Plan
µg	microgram(s)	mg	milligram(s)
AACE	Advancement of Cost Engineering International	mi ²	square mile(s)
BC	Brown and Caldwell	mL	milliliter(s)
BCG	Biological Condition Gradient	MS4	municipal separate storm sewer system
B-IBI	Benthic Index of Biotic Integrity	NA	not applicable
cfs	cubic foot/feet per second	ND	non-detect
cfu	colony-forming unit(s)	NPDES	National Pollutant Discharge Elimination System
County	Pierce County	NRCS	Natural Resources Conservation Service
CWSRF	Clean Water State Revolving Fund	O&M	operations and maintenance
DO	dissolved oxygen	OSDS	onsite sewage disposal system
Ecology	Washington State Department of Ecology	PALS	(Pierce County) Planning and Land Services
EPA	U.S. Environmental Protection Agency	PCC	Pierce County Code
EPT	Ephemeroptera-Trichoptera-Plecoptera	Permit	Phase I Municipal Stormwater Permit for Western Washington
FCZD	Flood Control Zone District	PSRC	Puget Sound Regional Council
FEMA	Federal Emergency Management Agency	PSSB	Puget Sound Stream Benthos
GIS	geographic information system	QAPP	Quality Assurance Project Plan
GROSS	Grants of Regional or Statewide Significance	RCW	Revised Code of Washington
HRU	hydrologic response unit	RMSE	root mean square error
HSPF	Hydrological Simulation Program-Fortran	RPD	relative percent difference
ID	identifier	RSMP	Regional Stormwater Monitoring Program
JBLM	Joint Base Lewis-McChord	SFAP	Stormwater Financial Assistance Program
L	liter(s)	SRF	State Revolving Fund
		SOW	scope of work

SSURGO	Soil Survey Geographic (database)
State	Washington State
STI	straight-to-implementation
SWGP	State Waste Discharge General Permit
SWM	(Pierce County) Surface Water Management
SWMMWW	Stormwater Management Manual for Western Washington
TMDL	total maximum daily load
TPCHD	Tacoma-Pierce County Health Department
TSS	total suspended solids
UGA	urban growth area
ULID	Utility Local Improvement District
USGS	U.S. Geological Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WQI	water quality improvement
WRIA	Water Resource Inventory Area
WSDOT	Washington State Department of Transportation
WSP	Watershed-scale Stormwater Management Plan

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SECTION 1: INTRODUCTION

Stormwater discharges in unincorporated Pierce County (County) are covered by the Washington State (State) Phase I Municipal Stormwater Permit (Permit), which became effective on August 1, 2013. Special Condition S5.C.5.c of the Permit requires a watershed-scale stormwater planning process to identify a stormwater management strategy or strategies that would result in hydrologic and water quality conditions that fully support “existing uses” and “designated uses,” as defined in Washington Administrative Code (WAC) 173-201A-020. The watershed-scale stormwater management plan (WSP) should include a summary of results of the modeling and planning process, results of the evaluation of strategies under S5.C.5.c.iv.(5).a, and an implementation plan and schedule developed pursuant to S5.C.5.c.iv.(6).

The Permit specifies that the County conduct watershed-scale stormwater planning in the Clover Creek watershed or an alternative watershed that meets criteria specified in the Permit. The County selected the Spanaway Lake watershed, which is a tributary to Clover Creek. On March 11, 2014, the County received the Washington State Department of Ecology’s (Ecology’s) formal approval to develop a watershed-scale stormwater management plan (WSP) for the Spanaway Lake watershed. Ecology approved the County’s WSP scope of work (SOW) on August 8, 2014.

The Spanaway Lake watershed encompasses approximately 23 square miles (mi²) within the Clover Creek watershed (see Figure 1-1). About one third of the watershed is within Joint Base Lewis-McChord (JBLM) and the remainder is in unincorporated Pierce County. Residential and commercial land uses cover about 64 percent and 4 percent, respectively, of the watershed area outside JBLM. The JBLM portion of the watershed is covered with forest, wetlands, and prairie with very little infrastructure aside from unpaved roads. The current population of the WSP area is approximately 44,200 (PSRC 2017).

The surface water bodies in the WSP planning area include Coffee Creek, Spanaway Lake, Spanaway Creek, Morey Creek, and Tule Lake. Coffee Creek is formed by springs and wetland areas within JBLM. From JBLM it flows north into Spanaway Lake. Spanaway Lake discharges into Spanaway Creek, which splits into two channels, Spanaway and Morey creeks, about 1 mile downstream of the lake. The main channel (Spanaway Creek) flows north into Tule Lake. Outflow from Tule Lake discharges into Clover Creek. Morey Creek flows west and enters Clover Creek about 1 mile downstream of Spanaway Creek.

Most of the WSP area is covered by very permeable soils. The surface water drainage network is relatively small. A large portion of the watershed has no direct surface connection (via natural or man-made conveyance) to receiving water bodies. Consequently, groundwater is the main

source of flow to Coffee Creek, Spanaway Lake, and Spanaway Creek. Spanaway Lake is the largest lake in the watershed. The lake supports a variety of beneficial uses including boating, fishing, swimming, and wildlife habitat. More than 170 single-family homes and 160 multifamily residences are located along the lake shoreline. Spanaway Lake Park has swimming beaches, a fishing pier, a boat ramp, and other amenities that attract visitors from throughout the region.

Spanaway Lake has a history of water quality problems associated with excess cyanobacteria growth and elevated fecal coliform concentrations. The County recently developed a Lake Management Plan (LMP) to address these water quality issues.

1.1 Document Purpose

The County prepared this WSP to meet the requirements of Special Condition S5.C.5.c of the Permit. The WSP describes the County's monitoring and modeling activities, evaluation of potential stormwater management strategies, and other potential strategies to address water quality issues. The WSP also includes a potential implementation plan and schedule. The County prepared this WSP in accordance with an SOW approved by Ecology in August 2014 (Appendix A).

1.2 Document Organization

Following the preceding executive summary and this introductory section, this WSP is organized as follows:

- **Section 2** provides background information on the WSP, including the relevant Municipal Separate Storm Sewer System (MS4) Permit requirements, and describes the tasks involved in WSP development
- **Section 3** provides a summary description of the WSP study area and includes maps showing watershed land use, soils, and hydrology
- **Section 4** provides a summary of the WSP development methods, including the monitoring methods detailed in Appendix B, the *Quality Assurance Project Plan* (QAPP), and the Hydrological Simulation Program-Fortran (HSPF) and groundwater modeling methods detailed in the *Model Development and Calibration* reports (Appendices E and F)
- **Section 5** provides a summary of the flow, water quality, and benthic monitoring results
- **Section 6** provides a summary of the modeling results and includes discussions on model accuracy from calibration report and benchmark scenario simulation results
- **Section 7** provides a summary of the stormwater management scenarios, including the identification of potential strategies to address excursions, model simulation results for potential strategies, cost-effectiveness of potential strategies, and recommendations

- **Section 8** contains the WSP implementation plan, which describes the potential stormwater management actions, responsible parties, estimated costs, potential, funding sources, schedule, and limitations
- **Section 9** presents report limitations to this WSP
- **Section 10** lists references cited in this WSP

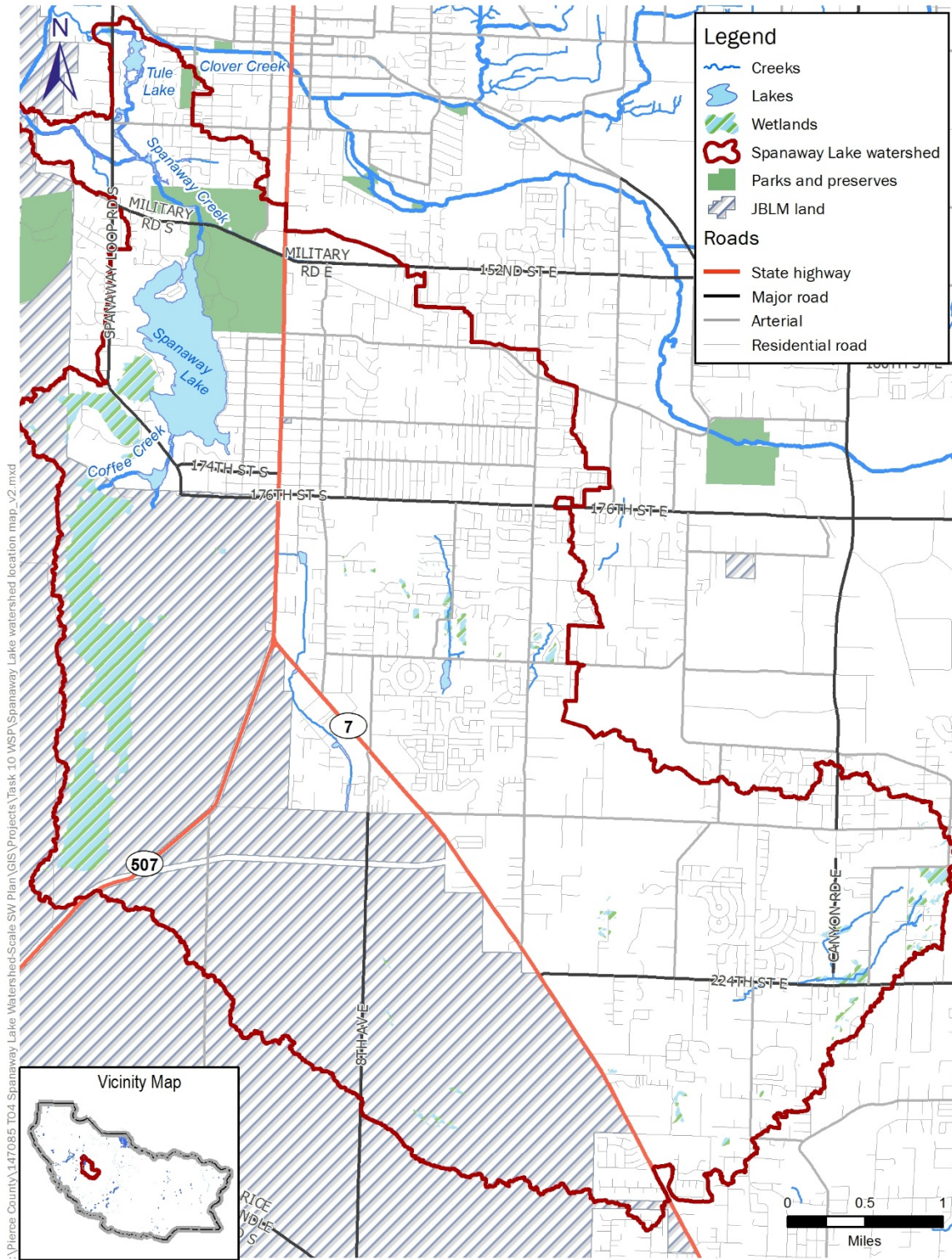


Figure 1-1. Spanaway Lake watershed

SECTION 2: BACKGROUND

This section provides background information on the WSP requirements in the Permit.

2.1 MS4 Permit

The Permit is a National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit (SWGP) for discharges from large and medium MS4s. Ecology developed the Permit in accordance with the provisions of the State of Washington Water Pollution Control Law, Revised Code of Washington (RCW) Chapter 90.48 and the Federal Water Pollution Control Act (Clean Water Act), United States Code Title 33 Section 1251 *et seq.* The current MS4 permit took effect on August 1, 2013, and is due to expire on July 31, 2018. The Permit was modified in January 16, 2015, and August 19, 2016 (Ecology 2016a). Ecology recently announced that it plans to extend the current Permit term by 1 year, so that it may expire on July 31, 2019.

Special Condition S5.C.5.c of the Permit requires watershed-scale stormwater planning to identify a stormwater management strategy or strategies that would result in hydrologic and water quality conditions that fully support “existing uses” and “designated uses,” as those terms are defined in WAC 173-201A-020. For the County, the Permit requires watershed-scale stormwater planning in the Clover Creek watershed or an alternative watershed that meets criteria specified in the Permit. The County selected the Spanaway Lake watershed, which is a tributary to Clover Creek. Ecology approved the County’s selection on March 11, 2014 (Letter from Chris Montague-Breakwell dated March 11, 2014).

2.2 Development of This WSP

Special Condition S5.C.5.c.iv of the Permit required that each permittee submit an SOW and schedule for WSP development. On April 1, 2014, the County sent Ecology a draft SOW and schedule for developing a WSP for the Spanaway Lake watershed. The draft SOW included an existing-conditions assessment; hydrologic, biologic, and water quality modeling to assess changes between existing, historical, and future conditions; an evaluation of stormwater management strategies; implementation planning; and a public review process. The County revised the SOW based on Ecology’s comments. Ecology approved the County’s SOW in a letter dated August 8, 2014. Appendix A contains a copy of Ecology’s approved SOW.

The County developed the Spanaway Lake WSP following the tasks described in the SOW. The following paragraphs summarize the tasks involved in preparing this WSP.

Task 1: Assessment of Existing Conditions [S5.C.5.c.iv(1)]

In accordance with the Permit (S5.C.5.c.iv(1)) and SOW, the County assessed the current hydrologic, biologic, and water quality conditions and the status of the aquatic community within the Spanaway Lake watershed. The County reviewed available monitoring data (streamflow, water quality, macro-invertebrate) and mapping data to assess whether those data were adequate to meet requirements in Special Condition S5.C.5.c.iv of the Permit and adequate to support continuous runoff modeling.

The County collected new data as needed to complete the assessment. The assessment was intended to characterize current conditions in the Spanaway Lake watershed including flow, water quality, benthic macroinvertebrates, land cover and land use, and the salmonid community using observed local and regional data. The results served as input data for hydrologic model calibration described in Special Condition S5.C.5.c.iv.(3).

The County began the assessment of existing conditions by reviewing existing data and reports relevant to the Spanaway Lake watershed, including the documents listed below:

- Mastin, M.C., 1996, *Surface-water hydrology and runoff simulations for three basins in Pierce County, Washington*, U.S. Geological Survey Water-Resources Investigations Report 95-4068, 148 p.
- McCarthy, Kathleen A., 1996, *Surface-Water Quality Assessment of the Clover Creek Basin, Pierce County, Washington 1991–92*, U.S. Geological Survey Water-Resources Investigations Report 95-4181, 113 p.
- Pierce Conservation District, 2003, *Salmonid Habitat Limiting Factors Analysis—Chambers-Clover Creek Watershed, Water Resource Inventory Area 12*, 130 p.
- Pierce County, 2007, *Buildable Lands Report: A Monitoring and Evaluation Analysis of Urban Growth and Development Capacity for Pierce County and its Cities and Towns*, 360 p.
- Pierce County, 2008, *Frederickson Community Plan: A Component of the Pierce County Comprehensive Plan*, Ordinance 2003-93s2, amended by Ordinance 2007-86s, 155 p.
- Pierce County, 2008, *Graham Community Plan: A Component of the Pierce County Comprehensive Plan*, Ordinance 2010-87, 238 p.
- Pierce County, 2010, *Parkland-Spanaway-Midland Communities Plan: A Component of the Pierce County Comprehensive Plan*, Ordinance 2002-21s, amended by Ordinance 2009-71s, 230 p.
- Pierce County Public Works and Utilities Water Programs Division, 2005. *Clover Creek Basin Plan*, 2005.
- Pierce County Public Works and Utilities Water Programs Division, 2013, 2013 Report Card: Surface Water Health.
- U.S. Department of Transportation Federal Highway Administration, Washington State Department of Transportation, and Pierce County, 2003, *Cross-Base Highway (State Route*

704) I-5 to SR 7 Final Environmental Impact Statement Appendix K: Vegetation, Wildlife, and Fisheries Discipline Report, Lakewood and Pierce County, Washington.

- U.S. Geological Survey, 2010, *Hydrogeologic Framework, Groundwater Movement, and Water Budget in the Chambers-Clover Creek Watershed and Vicinity, Pierce County, Washington*, Scientific Investigations Report 2010-5055, 46 p.
- U.S. Geological Survey, 2011, *Numerical Simulation of the Groundwater-Flow System in Chamber-Clover Creek Watershed and Vicinity, Pierce County, Washington*, Scientific Investigations Report 2011-5086, 108 p.
- Washington State Department of Ecology, 2013, *Clover Creek Dissolved Oxygen, Fecal Coliform, and Temperature Total Maximum Daily Load Water Quality Study Design (Quality Assurance Project Plan)*, Publication 13-03-109, 92 p.

The County also evaluated the results Ecology's October 2016 *Clover Creek Watershed Fecal Coliform Bacteria, Dissolved Oxygen, and Temperature Source Assessment Report*, Ecology's Clover Creek assessment included monitoring in Spanaway and Morey Creeks in the northern portion of the Spanaway Lake WSP area (Ecology 2016b).

Task 1a: Water Quality [S5.C.5.c.iv(1).a]

The Permit requires that the WSP evaluate dissolved copper, dissolved zinc, temperature, and fecal coliform bacteria. The County reviewed previous studies to look for potentially relevant data. The review encompassed the following information:

- Pierce County ambient water quality monitoring results
- Ecology water quality data collected from Spanaway Creek at Spanaway Park (Ecology site identifier [ID] MS006)
- Clover Creek Basin Plan (Pierce County 2005)
- Long Term Groundwater Monitoring Program (Tacoma-Pierce County Health Department [TPCHD])

Based on this review, the County determined that additional data collection was needed to support development of the Spanaway Lake WSP. The County developed a QAPP to guide the monitoring activities. Appendix B contains the QAPP, which called for surface water monitoring under baseflow and storm flow conditions at key locations. The QAPP also included groundwater monitoring at various locations in the watershed.

In addition to the WSP, the County developed an LMP to improve water quality and protect beneficial uses in Spanaway Lake. The primary focus of the LMP is to reduce cyanobacteria; fecal coliform is the secondary concern. To support development of the LMP the County monitored surface water and groundwater around the lake in accordance with an Ecology-approved QAPP for the LMP. The LMP monitoring included fecal coliform and temperature. The

County analyzed the LMP surface water and groundwater samples for copper and zinc to provide data for the WSP effort.

Section 4 of this WSP summarizes the WSP monitoring program and the relevant portions of the LMP monitoring program. Section 5 describes the key monitoring results. Appendix C contains a detailed discussion of the WSP monitoring results. Section 5 also summarizes relevant monitoring results from Ecology's October 2016 Clover Creek Watershed Assessment report (Ecology 2016b).

Task 1b: Flow [S5.C.5.c.iv(1).b]

The Permit requires an assessment of flow within the watershed. Continuous flow data are needed for hydrologic modeling. Prior to the WSP, little flow monitoring had been conducted in the Spanaway Lake WSP area. The County therefore installed flow gages at key locations to provide the data necessary to calibrate a continuous runoff model. Section 4 provides a detailed discussion on the flow monitoring program.

Task 1c: Macroinvertebrate Data [S5.C.5.c.iv(1).c]

The Permit requires benthic macroinvertebrate data to evaluate existing Benthic Index of Biotic Integrity (B-IBI) scores, predict historical and future B-IBI scores based on hydrologic modeling, and compare existing and predicted B-IBI scores to Ecology's benchmarks. Prior to the WSP, benthic samples were collected by the County and Pierce Conservation District from Coffee Creek (2014) and the Spanaway Lake outlet (2013 and 2014). These samples were collected from 3 square feet of creek substrate and analyzed at a coarse level of taxonomic resolution.

The County determined that additional benthic macroinvertebrate data were needed to support the WSP. To that end, the County evaluated the previously sampled locations, methods, and results. The sample collection methods were revised to include more sample area and collect metadata about the sample site, and the analytical methods were revised to improve taxonomic resolution. These improvements also served to enhance comparability of the WSP benthic macroinvertebrate data with regional data hosted at the Puget Sound Stream Benthos (PSSB) website. The County also searched for additional benthic monitoring locations and found that local channel conditions and legal access limit the potential benthic sampling sites in the WSP area.

The WSP QAPP identified four locations for benthic macroinvertebrate sampling. At each location samples were collected from 8 square feet of substrate and analyzed at a fine level of taxonomic resolution. The results were used to calculate B-IBI scores for comparison with scores predicted by hydrologic metrics as in S5.C.5.c.iv.(4), using the correlations described in DeGasperi et al. (2009) or others approved by Ecology. Section 4 describes the benthic monitoring methods and Section 5 summarizes the results. Appendix C contains more detailed information about the benthic monitoring locations, methods, and results.

Task 1d: Aquatic Community [S5.C.5.c.iv(1).d]

Fish community monitoring conducted in the Spanaway Lake watershed by the Washington Department of Fish and Wildlife (WDFW) in 2000, fish removal data from County fish biologists in 2016, historical accounts, Water Resource Inventory Area (WRIA) reports, fish blockage assessment, and WDFW geospatial reports were used to determine extent of fish use of the watershed. Section 3.7 describes the information on the salmonid community in the Spanaway Lake WSP.

Task 2: Mapping [S5.C.5.c.iv(2)]

The Permit requires mapping to delineate general soil types, vegetative land cover, impervious land cover, MS4s, and non-regulated public stormwater systems (if applicable). The maps must also identify areas that appear especially vulnerable to hydrologic and water quality impacts. These maps focus on the types of information necessary for construction of a rainfall/runoff model representation of the watershed. Section 3 and Appendix E contain the Permit-required maps.

Task 3: Watershed Model Calibration [S5.C.5.c.iv(3)]

The Permit requires development and calibration of a hydrologic model to simulate flow, water temperature, dissolved copper and zinc, and fecal coliform bacteria. After reviewing the results of Tasks 1 and 2, the County selected the HSPF modeling platform because it can simulate current and future conditions and assess stormwater management strategies related to flow control and pollutant load reduction. The County used flow and water quality data collected during the watershed assessment (Task 1), together with long-term meteorological data (precipitation, air temperature, etc.) to build and calibrate an HSPF model of the Spanaway Lake watershed. The County also refined a regional MODFLOW model developed by the United States Geological Survey (USGS) with Pierce County and stakeholder participation to simulate groundwater flow in the WSP area. Section 4 provides a detailed discussion of the watershed model development and calibration task. Section 6 provides a detailed discussion of the model results.

Task 4: Historical- and Future-Conditions Modeling [S5.C.5.c.iv(4)]

The Permit requires simulation of flow and water quality for historical and future conditions as well as existing conditions. The County used the calibrated HSPF model to simulate historical and future land use scenarios in the Spanaway Lake watershed. Historical flows were modeled by revising the land use/land cover to prairie and forested conditions as appropriate based on the available data regarding land use and land cover prior to development. The future-conditions scenario was based on full buildout in accordance with the County's current comprehensive land use management plans and applicable development regulations. Future

land use scenarios at full buildout were used to simulate the future hydrologic and water quality conditions. Future hydrologic conditions were then used to estimate the B-IBI scores based on the hydrologic metrics and regression equations developed by DeGasperi et al. (2009) and Horner (2012). Future water quality conditions were described through estimation of concentrations of dissolved copper, dissolved zinc, temperature, and fecal coliform. Section 4 describes the watershed model development and calibration. Section 6 discusses the model results.

Task 5: Evaluation of Stormwater Management Strategies [S5.C.5.c.iv.(5)]

If the monitoring and modeling results indicate that the B-IBI benchmarks or the water quality standards for temperature, copper, zinc, or fecal coliform bacteria will not be met, the Permit requires that the County to evaluate stormwater management strategies to meet the standards throughout the watershed. According to S5.C.5.c.iv.(5).a, stormwater management strategies to be evaluated by the County must include the following information:

- Changes to development-related codes, rules, standards, and plans; and
- Potential future structural stormwater control projects consistent with Permit condition S5.C.6.a.

S5.C.5.c.iv.(5).b states that stormwater management strategies to be evaluated may also include the following information:

- Basin-specific stormwater control requirements for new development and redevelopment as allowed by Section 7 of Appendix 1 in the Permit; and/or
- Strategies to encourage redevelopment and infill, and an assessment of options for efficient, effective runoff controls for redevelopment projects, such as a regional facility, in lieu of individual site requirements.

The County compared the existing- and future-conditions modeling results to the applicable State water quality standards for copper, zinc, fecal coliform, and temperature. The County used the calibrated watershed model to calculate the hydrologic metrics and estimate current, historical, and future B-IBI scores based on the studies cited in the Permit.

The County evaluated the watershed assessment and modeling results to identify stormwater management strategies with the potential to address the causes of the observed or predicted water quality standards excursions for copper, zinc, fecal coliform, and temperature, and for improving B-IBI scores. The County then used the calibrated watershed model to evaluate the potential stormwater management strategies that must be evaluated per S5.C.5.c.iv.(5).a. Section 7 describes the stormwater management strategies evaluated for the Spanaway Lake WSP.

Task 6: Implementation Plan and Schedule [S5.C.5.c.iv.(6)]

The Permit requires preparation of a WSP implementation plan and schedule. The County developed an implementation plan and schedule based on the evaluation of potential stormwater management strategies described in Section 7 of this WSP. Section 8 contains the implementation plan and schedule, which identify potential future actions to implement the identified stormwater management strategies, responsible parties, estimated costs, and potential funding mechanisms.

Task 7: Public Process [S5.C.5.c.iv.(7)]

The Permit requires a public review and comment process that at a minimum allows for public comment from all governmental entities with jurisdiction in the watershed. To that end, the County published a draft version of this WSP to provide an opportunity for the public to review and comment. The County coordinated with JBLM to obtain information on land use/land cover and management activities on the JBLM portion of the watershed. The County coordinated with WSDOT to obtain information on stormwater management activities associated with SR 7 in the Spanaway Watershed. The County also communicated with the City of Tacoma regarding future land use in the portion of the WSP area within the City's Urban Growth Area (UGA).

In addition, County staff briefed the Chambers-Clover Watershed Council and other interest groups about the WSP process and draft WSP. County staff also provided briefing materials to the Surface Water Advisory Board. The County periodically posted material about the WSP on the County website.

Task 8: Evaluation of Other Strategies [S5.C.5.c.v]

S5.C.5.c.v. in the Permit states that in addition to the stormwater management strategies listed above, the watershed-scale stormwater planning process may include an evaluation of other strategies to preserve or improve other factors that influence maintenance of the existing and designated uses of stream, such as:

- Channel restoration
- In-stream culvert replacement
- Quality of the riparian zone
- Gravel disturbance regime
- Presence and distribution of large woody debris

This WSP is limited to the stormwater management strategies that must be evaluated for all jurisdictions as required by S5.C.5.c.iv.(5).a. Non-stormwater management strategies are discussed in a separate document.

Task 9: Final Watershed-Scale Stormwater Plan [S5.C.5.c.vi]

The Permit requires that the final WSP be submitted to Ecology by September 6, 2017. This WSP meets Permit requirements for summarizing the results of the monitoring, modeling, and planning process; describing the results of the evaluation of strategies under Task 5; and inclusion of the implementation plan and schedule developed under Task 6.

SECTION 3: WSP PLANNING AREA DESCRIPTION

This section describes the salient Spanaway Lake WSP planning relevant to the four Permit criteria:

- Has a drainage area of at least 10 square miles [S5.C.5.c.i(1)]
- Is partially or wholly within the County's existing MS4 service area with discharges to the stream [S5.C.5.c.i(2)]
- Has a stream system that has been impacted by development but retains some anadromous fish resources [S5.C.5.c.i(3)]
- Is targeted to accept significant population growth and associated development, and is partially, if not fully, within the urban growth area (UGA) established under Revised Code of Washington (RCW) Chapter 36.70A, or a potential future expansion of the UGA [S5.C.5.c.i(4)]

Additionally, watershed maps were prepared to identify the existing distribution and totals of general soil types, vegetative land cover, impervious land covers, MS4s, stormwater systems, and non-regulated public stormwater systems (if applicable). The maps also identify areas that appear especially vulnerable to hydrologic and water quality impacts. These maps focus on the types of information necessary for construction of a rainfall/runoff model representation of the watershed. The following specific figures were developed to comply with Permit SOW Task 2 [S5.C.5.c.iv.(2)]: Spanaway Lake watershed-scale stormwater planning area, existing land use/land cover, soils, hydrologic response units (HRUs), sub-basins and reaches, historical land use/land cover, and future land use/land cover. These figures are provided in the *Model Development and Calibration* report (Appendix E).

3.1 Geology, Soils, and Hydrology

The Spanaway WSP area is underlain by northwest-thickening, unconsolidated, highly permeable glacial (till and outwash) deposits that overlie sedimentary and volcanic bedrock deposits (USGS 2011). Most surficial deposits in the Spanaway Lake WSP area are referred to as the Steilacoom gravel, Qgo(sq) (Figure 3-1). The Steilacoom gravel is a porous gravel/cobble deposit 30 to 50 feet thick that offers little resistance to infiltration or rainwater (Troost 2014). The gravel/cobble unconsolidated deposits in the county and the Spanaway Lake WSP area are the result of repeated jökulhlaups, which is an Icelandic term used to describe any large and abrupt release of water from a subglacial or proglacial lake/reservoir (Troost 2014).

Roughly 80 percent of the Spanaway Lake WSP area is covered with deep, highly permeable glacial outwash soils that produce little runoff (Figure 3-2). Prior to development, much of the WSP area was covered with prairie vegetation (Figure 3-3).

Surface water bodies in the WSP area include Spanaway Lake, Coffee Creek, Spanaway Creek, Morey Creek, Tule Lake, and a large wetland system on JBLM property south (upstream) of Coffee Creek (Figure 1-1).

Most of the WSP planning area is underlain by a very transmissive unconfined aquifer. Groundwater discharge appears to be the main source of inflow to Spanaway Lake as well as Coffee Creek, which flows into Spanaway Lake. The reach of Spanaway Creek just downstream of the lake has also been observed to gain flow from groundwater (Ecology 2016b). Spanaway Creek has substantial baseflow throughout the year, with flow rates rising and falling in response to groundwater and lake elevations.

Spanaway and Tule lakes provide substantial detention, further attenuating wet weather flows in the creeks downstream. Consequently, the creeks in the watershed tend to respond slowly to precipitation.

The creeks in the Spanaway Lake watershed are characterized by low gradients, with slopes less than 1 percent. Approximately 1 mile downstream of Spanaway Lake, Morey Creek branches off the mainstem of Spanaway Creek and flows west about 1 mile before discharging into Clover Creek. Most of the flow remains in the Spanaway Creek channel, which flows north through Tule Lake before discharging into Clover Creek about 1 mile upstream of its confluence with Morey Creek (nhc 2002; nhc 2005a; nhc 2005b; Pierce County 2005).

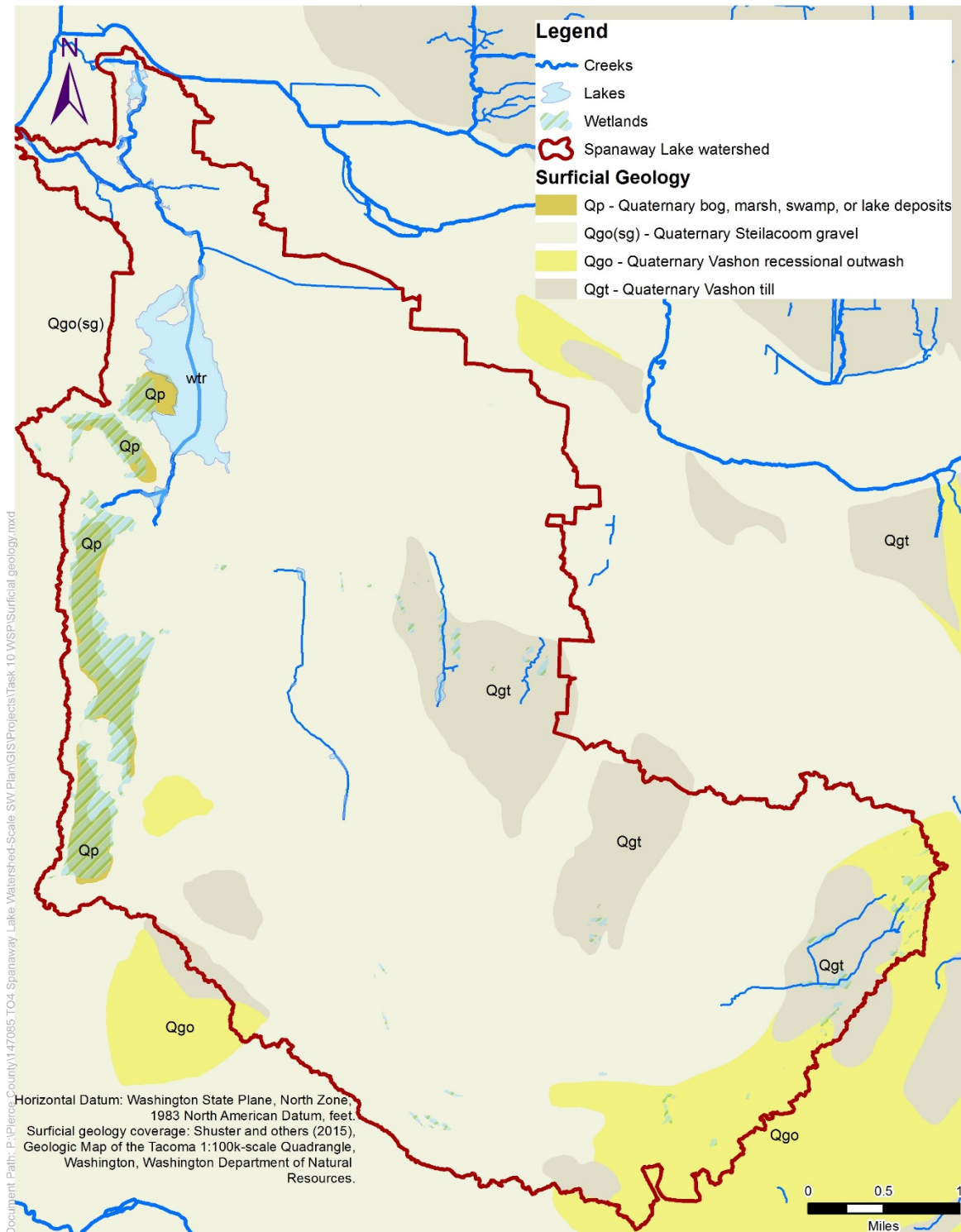


Figure 3-1. Surficial geology of Spanaway Lake WSP area

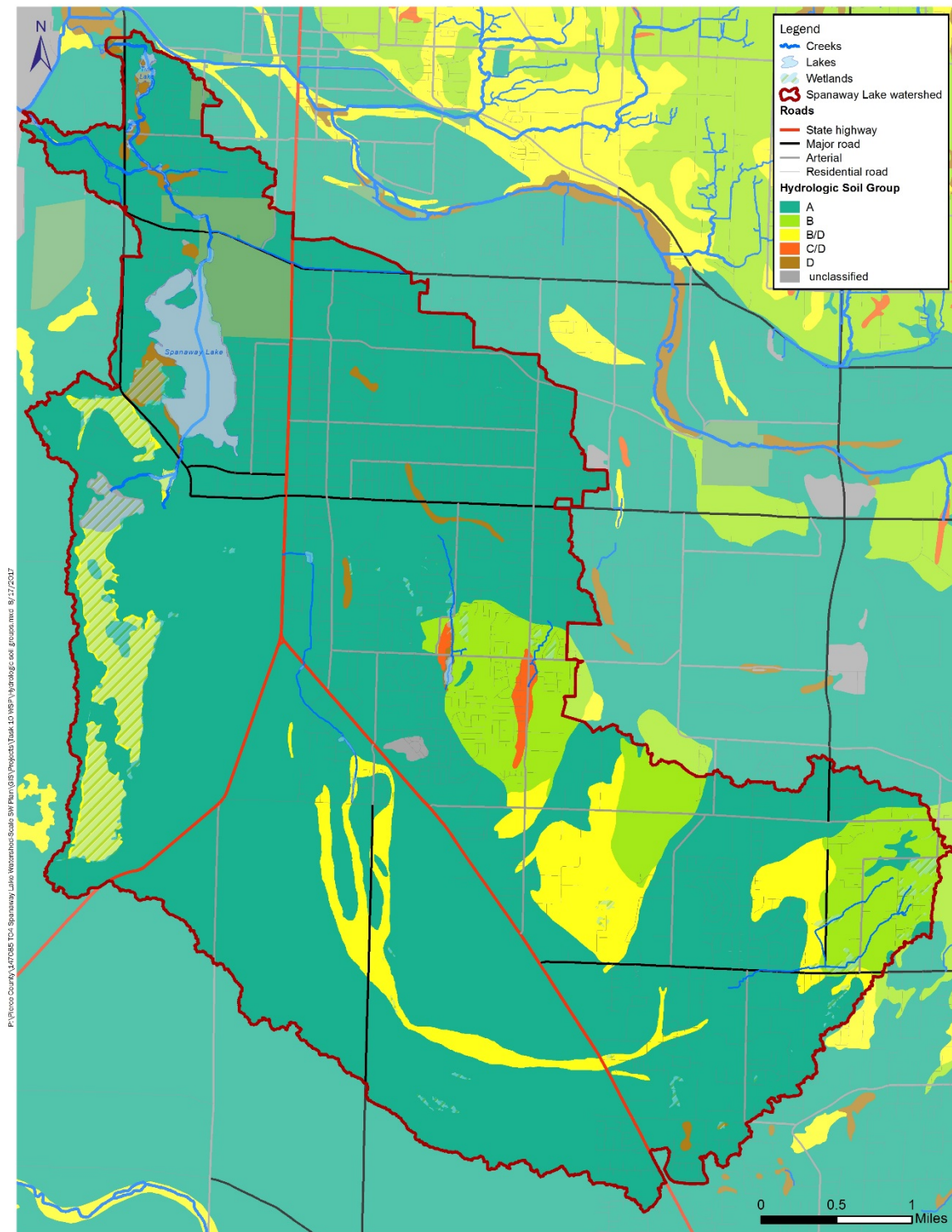


Figure 3-2. Hydrologic soil groups in Spanaway Lake watershed

Source: NRCS 2001.

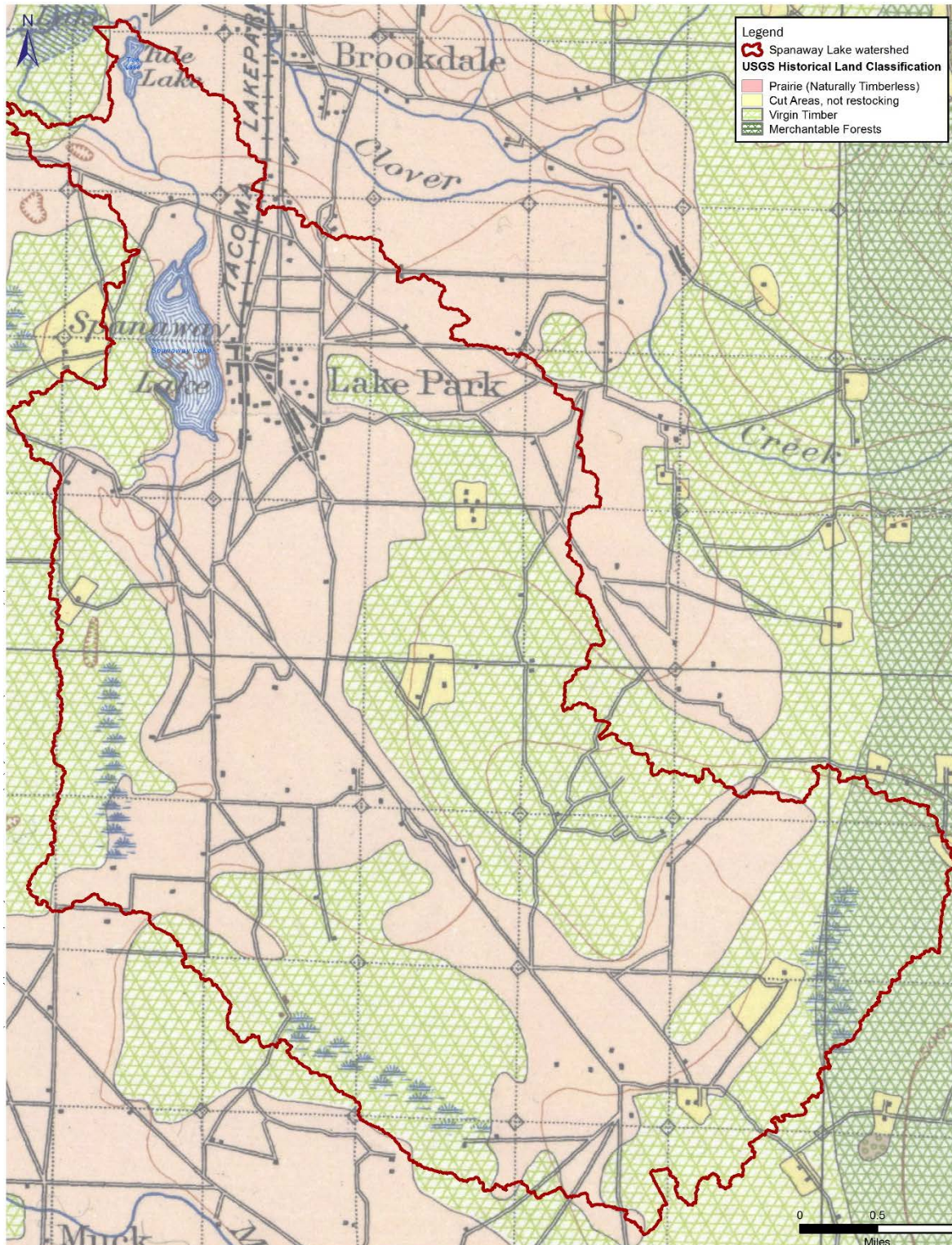


Figure 3-3. Historical land cover in Spanaway Lake watershed

Source: Gannett, USGS 1897.

3.2 Stormwater Drainage System

Nearly all stormwater runoff from impervious cover in the WSP area is infiltrated or dispersed onto adjacent pervious areas. The WSP area encompasses more than 1,400 infiltration facilities including drywells, infiltration basins, and infiltration trenches (Figure 3-4). Because of the highly permeable soils and ubiquitous infiltration facilities, the WSP area has only one significant MS4 conveyance system that discharges directly into a surface water body. This system receives stormwater runoff from approximately 176 acres and discharges into Spanaway Creek on the north side of Military Road. Numerous infiltration facilities have been installed in the catchment area for this outfall to reduce wet weather flows. The County recently installed a media filter just upstream of the outfall to treat the remaining flow prior to discharge. In addition, infiltration where feasible is the preferred option for WSDOT stormwater facilities in the watershed.

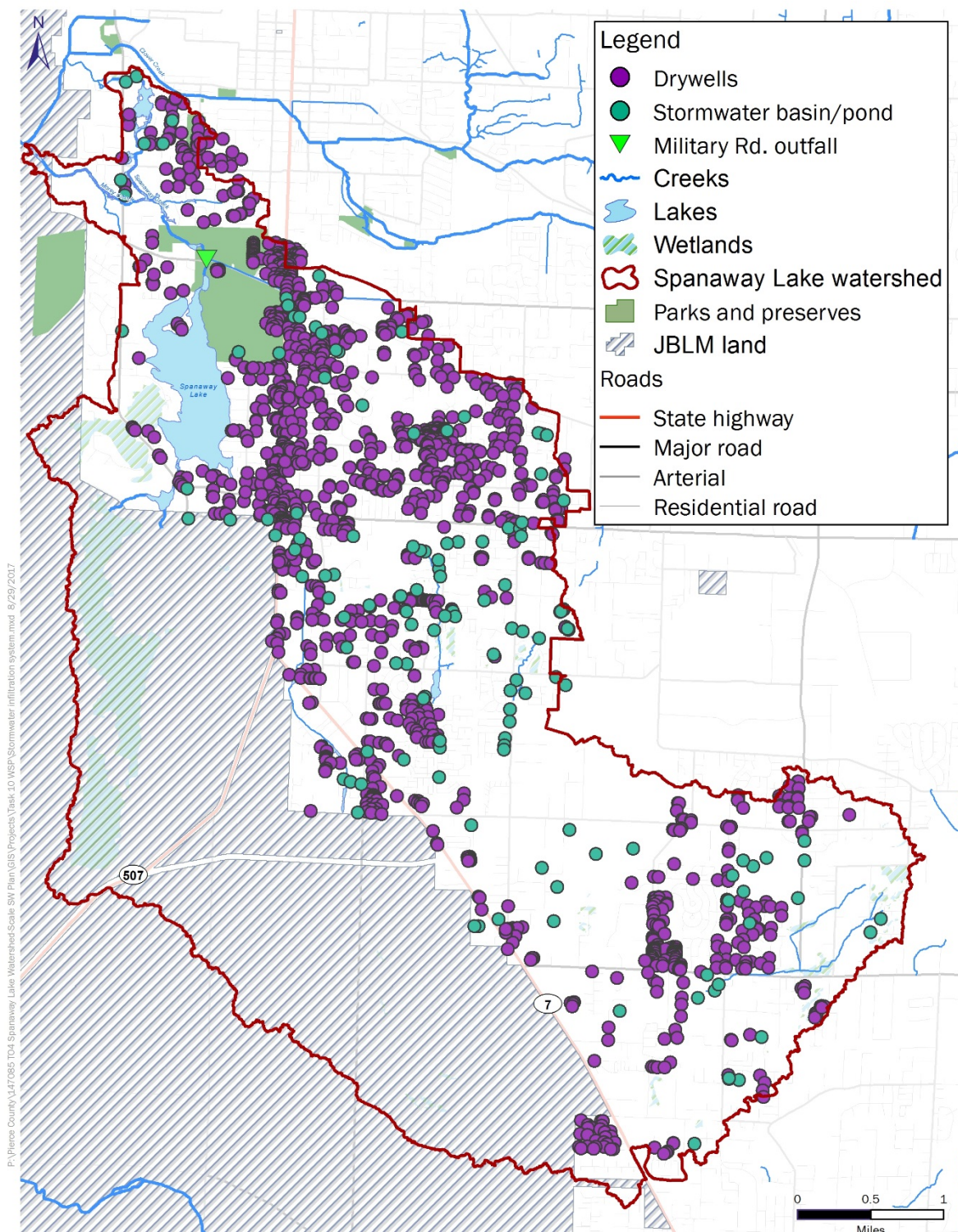


Figure 3-4. Stormwater infiltration systems and drywells in Spanaway Lake watershed

3.3 Land Use

Approximately 44,000 people currently live in Spanaway Lake watershed (PSRC 2017). Residential and commercial land uses cover approximately 10,000 acres, parks and golf course cover approximately 70,000 acres, and public facilities cover approximately 3,000 acres (see Figure 3-5). Most of the WSP area is served by onsite wastewater treatment systems (Figure 3-6).

About 67 percent of the watershed is under County jurisdiction and the remainder is within JBLM. Municipal stormwater discharges in the County portion of the watershed are regulated by the Phase I Permits issued by Ecology to the County and to the Washington State Department of Transportation (WSDOT). Coffee Creek, Spanaway Lake, Spanaway Creek, and Morey Creek are within the County's MS4 service area.

The JBLM portion of the Spanaway Lake watershed is undeveloped. Stormwater discharges within the developed portions of JBLM are regulated under a municipal NPDES permit issued by the U.S. Environmental Protection Agency (EPA) Region 10 since Washington lacks NPDES delegation for discharges from federal facilities and on Tribal lands. The northern portion of JBLM contains a large marsh and other wetlands that are managed as wildlife habitat.

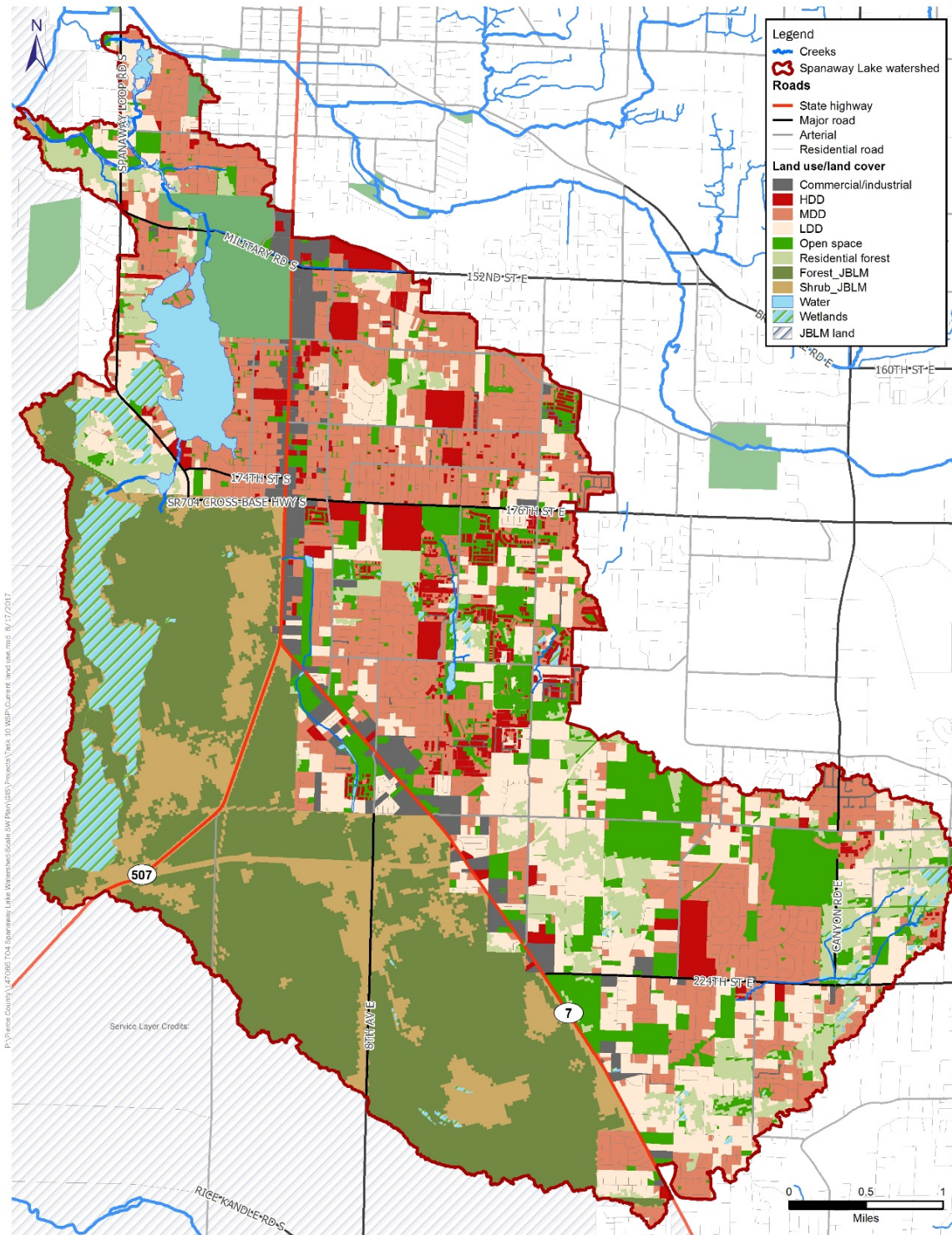


Figure 3-5. Current land use in Spanaway Lake watershed

Source: BC 2017 and Pierce County GIS data 2014.

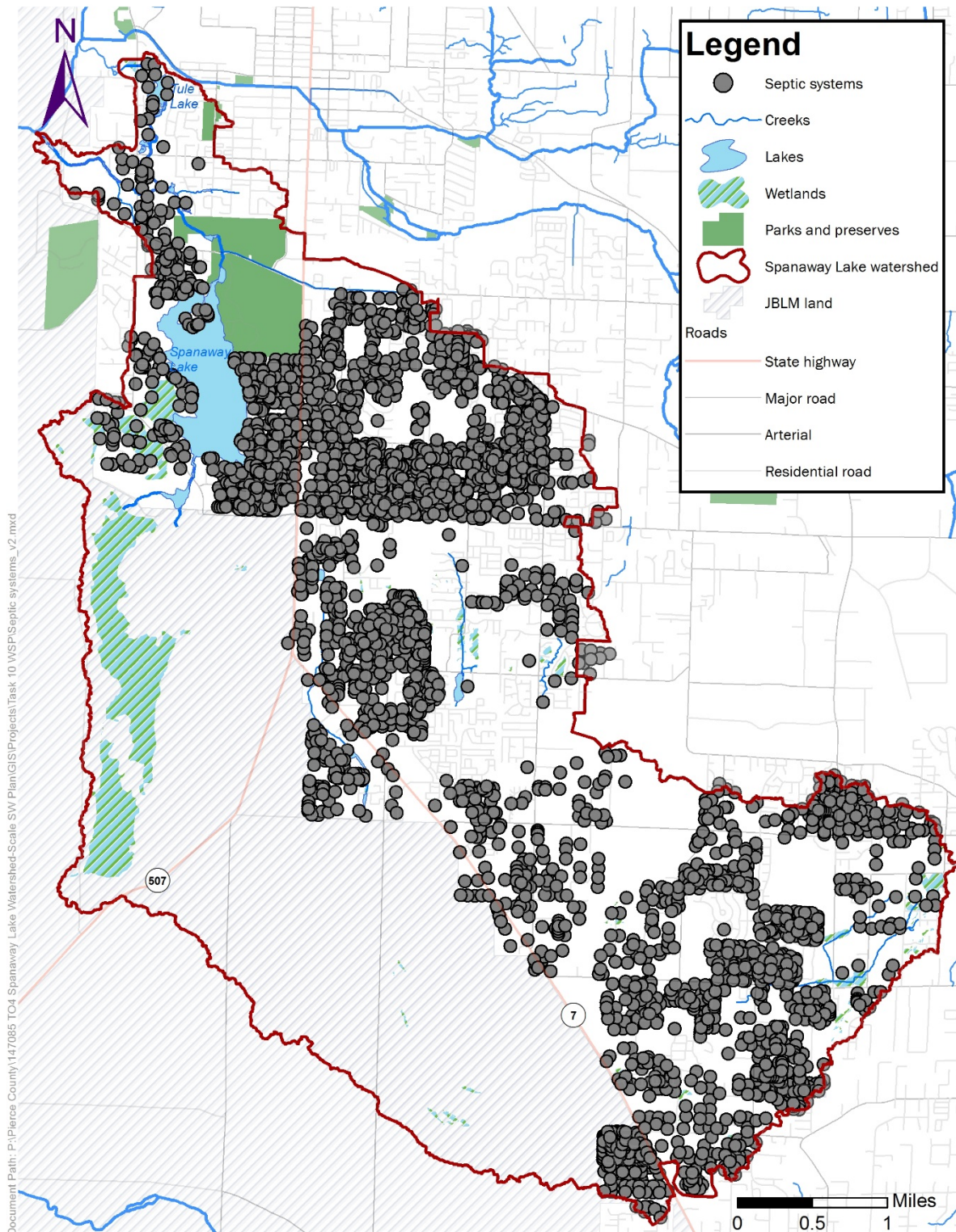


Figure 3-6. Septic systems in Spanaway Lake watershed

3.4 Future Growth

The northern portion of the watershed is in the Parkland/Spanaway/Midland unincorporated area, which is part of the UGA for the City of Tacoma. The southeast portion of the Spanaway Lake watershed, about 5.4 mi² (23 percent of the area), is outside of the Tacoma UGA, but within the Pierce County Comprehensive UGA. The southeast region of the watershed includes portions of the Frederickson and Graham communities. The WSP area population is expected to increase to about 50,000 by 2030 and 50,500 by 2040 (PSRC 2017).

3.5 Designated Uses and Water Quality Criteria

WAC 173-201A-600 provides use designations for freshwater bodies in Washington State. Spanaway and Morey creeks have the following designated uses:

- Salmonid spawning, rearing, and migration
- Primary contact recreation
- Domestic, industrial, agricultural, and stock water supply
- Wildlife habitat, harvesting, commerce/navigation, boating and aesthetics

Spanaway Lake and Coffee Creek have the designated uses listed above, except that they are designated for Extraordinary Primary Contact Recreation rather than Primary Contact Recreation.

According to Special Condition S5.C.5.c in the Permit, the WSP must evaluate water temperature, dissolved copper, dissolved zinc, fecal coliform bacteria, and benthic macroinvertebrates. The following sections summarize the applicable water quality criteria for water temperature, dissolved copper and zinc, fecal coliform bacteria, and benthic macroinvertebrates.

Water Temperature Criteria

The WSP water bodies are designated for salmonid spawning, rearing, and migration. To protect these uses, the 7-day average of the daily maximum temperatures (7-DADMax) shall not exceed 17.5 degrees Celsius (°C) (63.5 degrees Fahrenheit [°F]) more than once every 10 years on average. For lakes and other water bodies that exceed 17.5°C 7-DADMax because of natural conditions, human actions considered cumulatively may not increase the 7-DADMax by more than 0.3°C (0.54°F).

Copper and Zinc Criteria

To protect aquatic life, all water bodies in the WSP area have the same criteria for copper and zinc (Ecology 2016c). Copper and zinc toxicity generally increases as water hardness decreases. Therefore, the copper and zinc criteria depend on hardness and must be calculated for each

sample using the formulas listed below. The criteria apply to the dissolved form of these metals. These criteria may not be exceeded more than once every 3 years on the average.

- **Acute criterion for copper:** The 1-hour average concentration of dissolved copper may not exceed the value calculated using this formula: $(0.960) (e^{(0.9422[\ln(\text{hardness})] - 1.464)})$
- **Chronic criterion for copper:** The 4-day average concentration of dissolved copper may not exceed the value calculated using this formula: $(0.960) (e^{(0.8545[\ln(\text{hardness})] - 1.465)})$
- **Acute criterion for zinc:** The 1-hour average concentration of dissolved zinc may not exceed the value calculated using this formula: $(0.978) (e^{(0.8473[\ln(\text{hardness})] + 0.8604)})$
- **Chronic criterion for zinc:** The 4-day average concentration of dissolved zinc may not exceed the value calculated using this formula: $(0.986) (e^{(0.8473[\ln(\text{hardness})] + 0.7614)})$

Fecal Coliform Bacteria Criteria

Spanaway Lake and Coffee Creek are designated for Extraordinary Primary Contact Recreation use. To protect these uses, the geometric mean fecal coliform concentration may not exceed 50 colony-forming units (cfu) per 100 milliliters (mL), and no more than 10 percent of samples may exceed 100 cfu/100 mL.

The water bodies downstream of Spanaway Lake are designated for Primary Contact Recreation. In these water bodies, the geometric mean fecal coliform concentration may not exceed 100 cfu/100 mL, and no more than 10 percent can exceed 200 cfu/100 mL.

Table 3-1 below provides a summary of the numerical water quality standards applicable to the water bodies within the Spanaway Lake watershed.

Benthic Macroinvertebrate Criteria

The State water quality standards do not include numeric criteria for benthic macroinvertebrates. Under Ecology's current Water Quality Policy 1-11, an informal guidance document, water bodies with B-IBI scores of 38 or higher on the 10–50 scale are placed in Category 1 (meets criteria), while water bodies with B-IBI scores less than 27 are placed in Category 5 (impaired). Water bodies with B-IBI scores between 38 and 27 are placed in Category 2 (waters of concern) (Ecology 2012). Ecology is now updating Water Quality Policy 1-11; consequently, the B-IBI assessment criteria may change. It is unknown if Ecology will formalize B-IBI scores in the context of adopted state water quality standards. Ecology's WSP guidance suggests that for water bodies where B-IBI scores are limited by natural conditions, 90 percent of the pre-development B-IBI score would be an appropriate target (Ecology 2016e).

Table 3-1. Water Quality Standards for Permit-Mandated Constituents in the Spanaway Lake Watershed

Parameter	Numeric Criteria
Temperature ^a	<ul style="list-style-type: none"> Salmonid rearing and migration only. “7-DADMax” or “7-day average of the daily maximum temperatures” is the arithmetic average of seven consecutive measures of daily maximum temperatures. For this location, the criterion is 7-DADMax of 17.5°C (63.5°F).
Dissolved copper	<ul style="list-style-type: none"> Acute^b: (0.960) ($e^{(0.9422[\ln(\text{hardness})] - 1.464)}$) Chronic^c: (0.960) ($e^{(0.8545[\ln(\text{hardness})] - 1.465)}$)
Dissolved zinc	<ul style="list-style-type: none"> Acute^b: (0.978) ($e^{(0.8473[\ln(\text{hardness})] + 0.8604)}$) Chronic^c: (0.986) ($e^{(0.8473[\ln(\text{hardness})] + 0.7614)}$)
Fecal coliform bacteria	<ul style="list-style-type: none"> Locations upstream of Spanaway Lake and within Spanaway Lake (WSP1, SW-2, LW-1, LW-2, and LW-3): Extraordinary Contact—geometric mean value < 50 colonies/100 mL, with < 10% exceeding 100 colonies/100 mL Locations downstream of Spanaway Lake (SW-1, WSP2, WSP3, and WSP4): Primary Contact—geometric mean value < 100 colonies/100 mL, with < 10% exceeding 200 colonies/100 mL

- a. Temperature (7-DADMax) not to exceed the criteria more than once every 10 years on average.
- b. Acute criteria, 1-hour average concentration not to be exceeded more than once every 3 years on the average.
- c. Chronic criteria, 4-day average concentration not to be exceeded more than once every 3 years on the average.

3.6 Current Water Quality Assessment

Every 2 years, Ecology performs a water quality assessment to identify water bodies that are not meeting their applicable water quality standards. Ecology’s 2016 Water Quality Assessment lists Spanaway Lake as impaired (Category 5) for fecal coliform bacteria and a water of concern (Category 2) for phosphorus. Spanaway Creek, immediately downstream of the lake, is listed as impaired (Category 5) for temperature and a water of concern (Category 2) for pH. Morey Creek is listed as impaired (Category 5) for dissolved oxygen (DO). Tule Lake is listed as a water of concern (Category 2) for temperature.

Category 5 water bodies typically require development and implementation of total maximum daily loads (TMDLs) or equivalent water quality improvement (WQI) plans.

3.7 Fish Populations

Limited information is available regarding fish populations in the Spanaway Lake WSP area. In May 2000, WDFW surveyed the Spanaway Lake fish population. WDFW used electrofishing, gill nets, and trap nets to capture 1,702 fish in 11 different taxa: yellow perch (*Perca flavescens*) and rock bass (*Ambloplites rupestris*) were the most abundant species. Largemouth bass (*Micropterus salmoides*), rainbow trout (*Onchorynchus mykiss*), common carp (*Cyprinus carpio*), smallmouth bass (*M. dolomieu*), coho salmon (*O. kisutch*), pumpkinseed (*Lepomis gibbosus*), sculpin (family Cottidae), brown bullhead (*Ameiurus nebulosus*), and cutthroat trout

(*O. clarki*) were also found. The WDFW analysis of the Spanaway Lake fish population was limited by the single sample and low sample counts of many of the key species such as largemouth bass and smallmouth bass. Relative weights of most species were high or average, possibly indicating low competition, an adequate food supply, low-density population, or a combination of these factors (Caromile 2002).

In August 2016, fish were removed from a section of Spanaway Creek downstream of 138th Street S, near the intersection with Spanaway Loop Road S. The fish were removed prior to pilot testing of the “Sand Wand” water jet and suction sediment removal system. Seine and dip nets were used to remove fish from the creek so they would not be harmed during sediment removal. Lamprey, cutthroat trout, rainbow trout, bass, perch, dace, and sculpin were identified during the fish removal portion of the pilot testing, but numbers of each species were not recorded (Winecka 2016). Figure 3-7 shows a few of the fish collected from Spanaway Creek in August 2016 prior to the “Sand Wand” pilot testing program.

Other sources of data consulted were the WDFW geographic information system (GIS) data set for salmonid distribution (“SalmonScape”), fish species and populations identified in the Chambers-Clover Creek Watershed 1995 and 2003 WRIA 12 limiting-factors reports, and historical accounts.



Figure 3-7. Fish collected from Spanaway Creek in August 2016

Historical accounts indicate that salmon (probably coho and chum), steelhead, rainbow trout, and large cutthroat trout were observed and caught from Spanaway Creek during the 1940s through the 1960s (Tobiason 2003). Ecology’s 1995 WRIA 12 report said that coho and chum salmon were the primary anadromous species present in the Chambers-Clover Creek system (Ecology 1995). The 2003 WRIA 12 Salmonid Habitat limiting-factors report noted that coho

were present throughout the entire length of Morey Creek, and coho were potentially present in Spanaway Creek (Runge et al. 2003). Current distribution as indicated by the WDFW fish presence GIS indicates that coho salmon spawning has been documented in Morey Creek, and coho presence has been documented in the Tule Lake area. A 1996 study reported that Spanaway Lake, Spanaway Creek, and Morey Creek contained trout (Pierce County 2005).

In 2007, Pierce County Surface Water Management (SWM) built a bypass channel to encourage anadromous fish passage around Bresemann Dam, which is located about 2,200 feet downstream of Spanaway Lake. In 2010, the County and JBLM completed a bypass channel around the 12-foot-high Morey Creek Dam, allowing fish access to Morey Creek, Spanaway Creek, and Spanaway Lake. This project, as well the Bresemann Dam bypass, was one of several fish passage projects conducted by SWM as part of the Clover Creek Basin Plan and intended to protect and enhance anadromous fish passage throughout the watershed.

The Clover Creek watershed downstream of the Spanaway Lake WSP area contains several barriers to fish passage. A dam built in 1852 at the mouth of Chambers Creek was a complete barrier to all migrating fish until the recent construction of a fish ladder. Several sections of Clover Creek have been confined to culverts, most notably under the JBLM runways. Railroad crossings and small private dams also impede fish passage (Runge et al. 2003).

Table 3-2 summarizes the fish species reported to be present in the Spanaway Lake WSP area.

Table 3-2. Summary of Reported Fish Species and Sources in Spanaway Lake Watershed	
Fish Species	Source
Yellow perch	Caromile 2002; Winecka 2016
Rock bass	Caromile 2002; Winecka 2016
Largemouth bass	Caromile 2002; Winecka 2016
Rainbow trout	Caromile 2002; Winecka 2016; Tobiason 2003
Common carp	Caromile 2002
Smallmouth bass	Caromile 2002; Winecka 2016
Coho salmon	Caromile 2002; Tobiason 2003; Ecology 1995; Runge et al. 2003; Pierce County 2005
Chum salmon	Tobiason 2003; Ecology 1995
Pumpkinseed	Caromile 2002
Sculpin	Caromile 2002; Winecka 2016
Brown bullhead	Caromile 2002
Cutthroat trout	Caromile 2002; Winecka 2016; Tobiason 2003
Lamprey	Winecka 2016
Dace	Winecka 2016
Steelhead	Tobiason 2003

3.8 Recent Water Quality Studies

The sections below provide a summary of two recent water quality studies pertinent to the Spanaway Lake WSP project: the Spanaway LMP and the Clover Creek Watershed Assessment.

3.8.1 Spanaway Lake Management Plan

Spanaway Lake has a long history of health advisories triggered by cyanobacteria (blue-green algae) blooms. The lake is on Ecology's current 303(d) list because of elevated fecal indicator bacteria (*E. coli*) concentrations near swimming areas.

In 2013, the County received a budget allocation from the Washington State Legislature to develop an LMP for Spanaway Lake. The LMP focused on cyanobacteria and fecal indicator bacteria. The first phase of LMP development involved monitoring surface water discharge into and out of the lake, lake and groundwater elevations, lake water quality, creek water quality, groundwater quality, and lakebed sediment. The LMP monitoring was conducted in accordance with an Ecology-approved QAPP. The LMP monitoring results were used to develop a nutrient budget for the lake, identify key nutrient sources, and support evaluation of lake management measures.

The County used the LMP monitoring results for streamflow, water temperature, and fecal coliform bacteria to support WSP development. In addition, the County expanded the LMP parameter list to include copper and zinc analyses for use in WSP development. Section 5 of this WSP discusses the LMP monitoring results relevant to this WSP.

3.8.2 Clover Creek Watershed Assessment

In October 2016, Ecology published the *Clover Creek Watershed Fecal Coliform, Dissolved Oxygen, and Temperature Source Assessment Report* (Ecology 2016b). Ecology conducted the study because water quality data showed that some water bodies in the Clover Creek watershed do not meet State criteria (WAC 173-201A) for fecal coliform, DO, and/or temperature. The assessment was originally intended as a TMDL study. However, Ecology subsequently decided to adopt a "TMDL Alternative" approach with the County playing a key role.

The Clover Creek assessment included monitoring five sites within the Spanaway Lake WSP area between March 2013 and February 2014. The sites were located on Spanaway and Morey creeks downstream of Spanaway Lake. Ecology's monitoring included fecal coliform, temperature, and benthic macroinvertebrates. Section 5.6 discusses the Clover Creek assessment monitoring results that are relevant to the Spanaway Lake WSP.

SECTION 4: MONITORING LOCATIONS AND METHODS

Pierce County Water Quality Section's Monitoring and Assessment staff performed a variety of monitoring activities to support development of the Spanaway Lake WSP, including the following:

- Installation of streamflow gages at five locations
- 20 rounds of instantaneous flow measurements from October 2014 to May 2016
- 19 rounds of routine monthly sampling and 3x6 rounds of storm event sampling at key surface water locations
- Installation of six groundwater monitoring wells in the watershed upgradient of the lake
- Collections of soil samples during well drilling to evaluate major anions and cations in aquifer material
- 5 rounds of quarterly groundwater sampling and 14 rounds of monthly groundwater level monitoring
- One round of benthic macroinvertebrate sampling at four locations
- Analysis of creek and groundwater samples for copper, zinc, fecal coliform bacteria, hardness, and temperature

The County also analyzed groundwater samples from six LMP wells installed near Spanaway Lake for copper, zinc, and temperature, in addition to the LMP parameters. In addition, the County analyzed LMP lake water samples for copper, zinc, and hardness to provide data for the WSP.

This section summarizes the Spanaway Lake WSP monitoring activities. The Spanaway Lake WSP QAPP (Appendix B) contains more detailed information on the monitoring program.

4.1 Creek Monitoring

Monthly grab samples were collected at the six creek locations (including two LMP sites and four WSP sites) shown on Figure 4-1. All six locations were also sampled during six wet weather events. Three grab samples were collected at each location during each wet weather event. Samples were analyzed for total and dissolved copper and zinc, fecal coliform bacteria, total suspended solids (TSS), hardness, and other parameters. Because WSP1 was sometimes dry, the County also collected samples from the JBLM Marsh just upstream of WSP1. Appendix B contains detailed descriptions of the monitoring locations and methods.

Continuous temperature and level measurements were collected at five surface water monitoring locations. The County installed level/flow gages at SW-1, SW-2, WSP2, WSP3, and WSP4. County staff performed instantaneous depth and velocity measurements over a range of

flows at each of the gaged sites to develop stage-discharge relationships. The measurements were then used to calculate streamflow based on the rating curves developed by the County. However, the County was unable to obtain useful flow data at WSP3 (Spanaway Creek below Tule Lake). WSP3 is located in a brushy wetland area with persistent beaver activity, so it was not possible to develop a meaningful stage-discharge relationship for this site. The County was unable to find a more conducive location for flow monitoring in this reach.

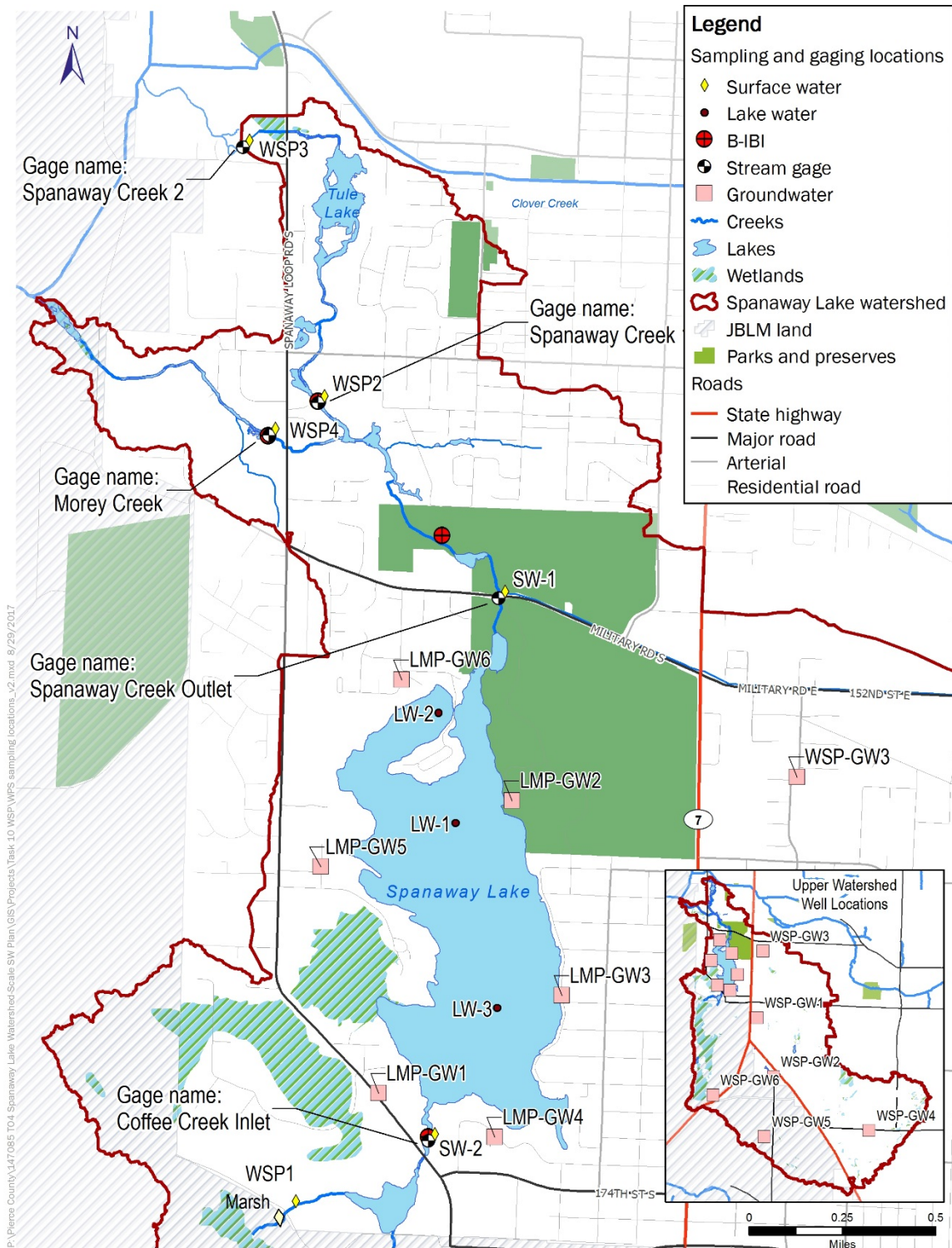


Figure 4-1. Spanaway Lake WSP monitoring locations

4.2 Lake Monitoring

Three locations were monitored in Spanaway Lake (LW-1, LW-2, and LW-3), as shown on Figure 4-1. Location LW-1 was in the deepest portion of the lake, LW-2 was in the northern portion of the lake, and LW-3 was near the middle of the southern portion of the lake. Grab samples were collected at each location using a Kemmerer sampler. The samples were analyzed for copper, zinc, hardness, and fecal coliform bacteria, in addition to nutrients and other parameters relevant to the LMP. The County also performed water quality profiling in the deepest part of the lake (LW-1) once or twice per month, using a datasonde to measure pH, DO, conductivity, and temperature at 1.5-foot depth intervals throughout the water column. The County also installed a pressure transducer and data logger to measure lake water levels and a thermistor to measure lake water temperature throughout the study period.

4.3 Groundwater Monitoring

The County installed six groundwater monitoring wells to support the WSP. The County selected the locations of the WSP wells based on review of regional groundwater data and field investigations. The WSP wells were sited to complement the six shoreline-area monitoring wells installed for the LMP. All WSP and LMP wells were completed in the surficial unconfined aquifer. Figure 4-1 shows the WSP and LMP monitoring well locations. Appendix C, Attachment A contains the borehole logs and well construction details.

WSP-GW1 through WSP-GW4 are located on County property adjacent to County stormwater facilities upgradient (south and southeast) of Spanaway Lake. WSP-GW5 and WSP-GW6 are located on JBLM upgradient of the large wetland complex that feeds Coffee Creek.

The WSP wells were installed using sonic drilling technology by a licensed drilling contractor under the direction of a licensed hydrogeologist. After well installation, the ground surface and top-of-casing measuring points were surveyed by a licensed surveyor. The wells were developed to remove any fines entrained during construction.

Groundwater levels were measured in the WSP and LMP monitoring wells monthly for 1 year. All 12 wells were sampled quarterly for 1 year and analyzed for the following water quality parameters: copper, zinc, hardness, and fecal coliform bacteria. Groundwater temperature was measured in the field.

4.4 Benthic Macroinvertebrate Sampling

The County collected and analyzed benthic macroinvertebrate samples as required by the Permit. County staff collected the benthic macroinvertebrate samples in late July through late August 2015 at the locations identified in the 2015 project QAPP (Brown and Caldwell [BC] 2015). Figure 4-2 shows the benthic sampling locations.

County staff followed Ecology guidelines for the collection of freshwater macroinvertebrate data in streams (Adams 2012). County staff used a Surber Sampler net to collect stream invertebrates from 8 square feet of area of the stream bottom. The goal was to collect at least 500 organisms for each sample. All sites achieved their goal for minimum number of organisms collected (number of organisms collected: SW-1 = 531; SW-2 = 557; WSP2 = 544; and WSP4 = 543). The B-IBI sample for SW-1 was collected in Spanaway Creek several hundred feet downstream of the Military Road crossing where the flow gage was located (see Figures 4-1 and 4-2). Rhithron Associates Inc. analyzed the samples to the lowest practicable level of taxa resolution, the “fine” level.

To aid in interpreting the benthic sample results, County staff collected creek bed sediment samples for particle size analysis. Pebble counts were also performed.

Two changes from the QAPP were related to benthic invertebrate sampling. Because of unfavorable channel conditions at the SW-1 sampling location (logjams and debris), benthic sampling was performed slightly further downstream, below the Bresemann Dam, to represent conditions downstream of the lake outlet. The sample was referenced as site code SW-1 on the chain of custody and maintains this reference in this report. An additional benthic sampling site (WSP2) was added on Spanaway Creek just downstream of the split with Morey Creek to represent this reach. The Morey Creek sample (WSP4) was collected over 2 days (August 19 and 20, 2015) and then composited from two sample jars to one composite sample when analyzed (Carla Vincent, personal communication to Laura Reed, April 2017).

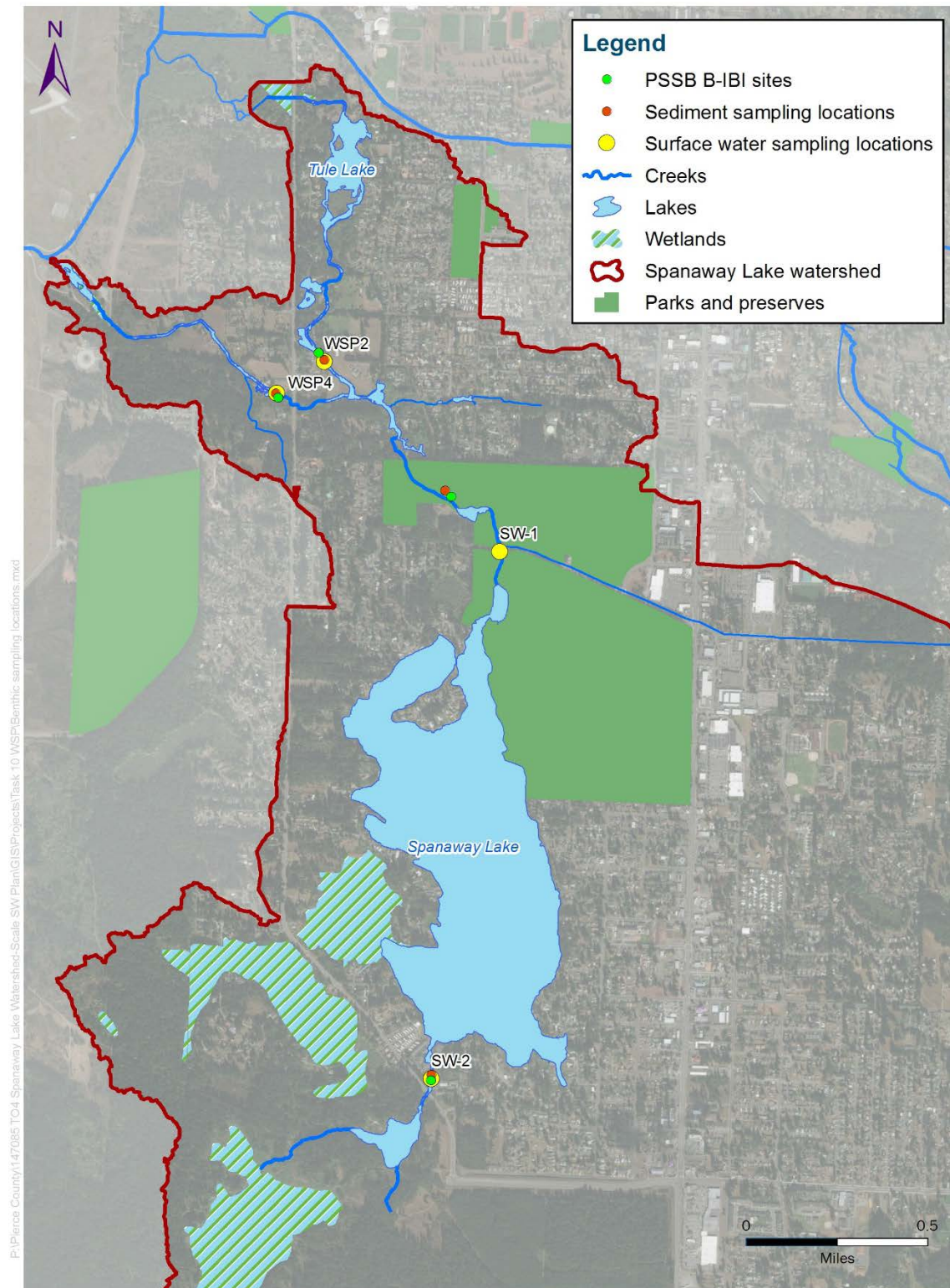


Figure 4-2. Spanaway Lake WSP benthic sampling locations

4.5 Modeling Methods Summary

The Spanaway Lake watershed-scale planning process required development of a continuous-simulation hydrologic model (Spanaway Lake WSP model) to simulate flow and selected water quality parameters within the watershed planning area. The Spanaway Lake WSP model was calibrated to observed data and then modified to simulate historical conditions and future conditions. The Spanaway Lake WSP model output was used to calculate hydrologic metrics, such as high pulse counts, that was used to estimate future B-IBI scores using the correlations developed by DeGasperi et al. (2009) and Horner (2012).

The *Model Development and Calibration* report (Appendix E) documents the development of the hydrologic and water quality Spanaway Lake WSP model. It describes the HSPF modeling platform, the sub-modules used, and the model development data requirements, as well as final model parameters. The report includes a description of the data that County staff collected to support model calibration, model calibration approach, and results

The Spanaway Lake WSP model development was informed by an existing HSPF model developed by the USGS, and based on recent land use/land cover, streamflow and water quality monitoring data. The HSPF modeling approach described in the *Model Development and Calibration* report (Appendix E) incorporates the key lessons learned from other recent HSPF modeling efforts in the Puget Sound lowlands. For example, many of the initial parameter values for the Spanaway Lake WSP model were selected based on review of calibrated HSPF models for locations in the Pacific Northwest.

The Spanaway Lake WSP model considers surface water-groundwater interactions because the watershed contains numerous stormwater infiltration facilities, and creeks and lakes are mainly groundwater-fed. BC modified an existing USGS groundwater model to refine some HSPF model parameters for simulating subsurface flow in the Spanaway Lake watershed.

BC used the monitoring results from the surface water flow, and surface water and groundwater quality from both the Spanaway Lake WSP and LMP monitoring programs to develop and calibrate the Spanaway Lake WSP model using the process and criteria described in the *Model Development and Calibration* report (Appendix E).

4.5.1 Modeling Objectives

The Permit requires development and calibration of a watershed model to support development of the Spanaway Lake Watershed-Scale Plan. The specific objectives for the model are listed below:

- Develop an existing-conditions hydrologic and water quality model that simulates streamflow; water temperature; and in-stream concentrations of fecal coliform, dissolved copper, and dissolved zinc in the Spanaway Lake Watershed.

- Calibrate the existing-conditions model using recent measured data, consisting of streamflow and water quality monitoring data, collected by the County for this modeling effort.
- Use the existing-conditions model to generate long-term time series for streamflow, temperature, fecal coliform, dissolved copper, and dissolved zinc at the gaging locations on Coffee, Spanaway, and Morey creeks.
- Modify the existing-conditions model by converting developed land surfaces to pervious/vegetated land surfaces to create a model scenario that represents historical conditions.
- Use the historical-conditions model to generate long-term time series for streamflow at the gaging locations on Coffee, Spanaway, and Morey creeks to evaluate the hydrologic changes between historical and existing conditions.
- Modify the existing-conditions model by changing land use/land cover to create a model scenario that represents future conditions based on current and zoned land uses and development regulations.
- Use the future-conditions model to generate long-term time series for streamflow, temperature, fecal coliform, dissolved copper, and dissolved zinc at the gaging locations on Coffee, Spanaway, and Morey creeks. Use the time series to calculate hydrologic metrics, B-IBI scores (based on regional correlations with hydrologic metrics), water temperature, fecal coliform concentration, dissolved copper concentration, and dissolved zinc concentrations that can be compared with relevant criteria to evaluate if the criteria are met.
- If the future-conditions model predicts that water quality criteria will be exceeded or B-IBI scores are below levels associated with viable salmonid habitat conditions¹, create a management strategy model(s) by modifying the future-conditions model to incorporate alternative strategies for stormwater management.
- Generate long-term time series for streamflow, temperature, fecal coliform, dissolved copper, and dissolved zinc at the gaging locations on Coffee, Spanaway, and Morey creeks for each stormwater management strategy model to calculate hydrologic metrics, B-IBI scores (based on regional correlations with hydrologic metrics), water temperature, fecal coliform concentration, dissolved copper concentration, and dissolved zinc concentrations that can be compared with relevant criteria to evaluate if the stormwater management strategy improves hydrologic conditions or water quality.

¹ Ecology's WSP guidance specifies a target B-IBI score of 38 (10–50 scale) or 90 percent of pre-development score (Ecology 2016e).

4.5.2 Hydrologic Response Unit Representation

HSPF is a lumped-parameter model where similar components of the land surface are simulated on a unit-area basis, and the unit-area results are then multiplied by the applicable area to estimate the outflow from a sub-basin to a stream reach. These land surface components should be defined in a way that facilitates both parameter identification and evaluation of stormwater management alternatives.

This is accomplished by using an HRU approach, in which model areas are defined based on a unique combination of land use/land cover, soil characteristics, and slope. Hydrologic processes simulated at the HRU level include rainfall-runoff, groundwater recharge, and baseflow discharge to streams. Direct runoff, interflow, and baseflow rates from HRUs are multiplied by respective drainage areas within a sub-basin to obtain total outflow rates to the stream network. See Appendices E and F for additional details.

4.5.3 Surface Drainage Segmentation

Sub-basin outflows are routed into a network of stream reaches that represent Coffee Creek, Spanaway Lake, Spanaway Creek, Morey Creek, and Tule Lake. Reach flow is simulated with a RCHRES depth-volume-discharge relationship. Because a large portion of the watershed is not connected directly to the creeks and lakes via surface drainage features (i.e., creeks, pipes, or ditches), sub-basin outflows are also routed to RCHRES representing infiltration basins or drywells, and then to one of three RCHRES representing groundwater flow to the lake and creeks. Sub-basin outflow from areas with no infiltration facilities are routed directly to the groundwater RCHRES.

Surface drainage segmentation consists of delineated sub-basin areas tributary to each reach. The upper watershed area, which has no direct surface connection to the stream network, was further subdivided into areas that predominantly drain to infiltration basins/ponds, areas that infiltrate via drywells, and areas with little stormwater infrastructure that likely infiltrate. When the upper watershed was segmented, the watershed boundary was revised to include areas that infiltrate to groundwater that flows to the Spanaway stream network and lakes. Figure 4-3 shows the model outflow routing.

The watershed includes approximately 40 infiltration ponds managed by the County, 2 ponds managed by WSDOT, and 60 private infiltration basins. Two infiltration ponds located near Spanaway Creek appear to be able to discharge directly to the creek (RCHRES 2). The remaining infiltration ponds have no direct surface connection to the stream network and likely infiltrate into the groundwater. Some infiltration basins in the lower watershed are modeled explicitly, where the infiltration basin is represented with a RCHRES and a sub-basin discharges to the RCHRES. The groundwater RCHRESs were set up in a manner similar to the USGS model and then modified during calibration. See Appendix E for details.

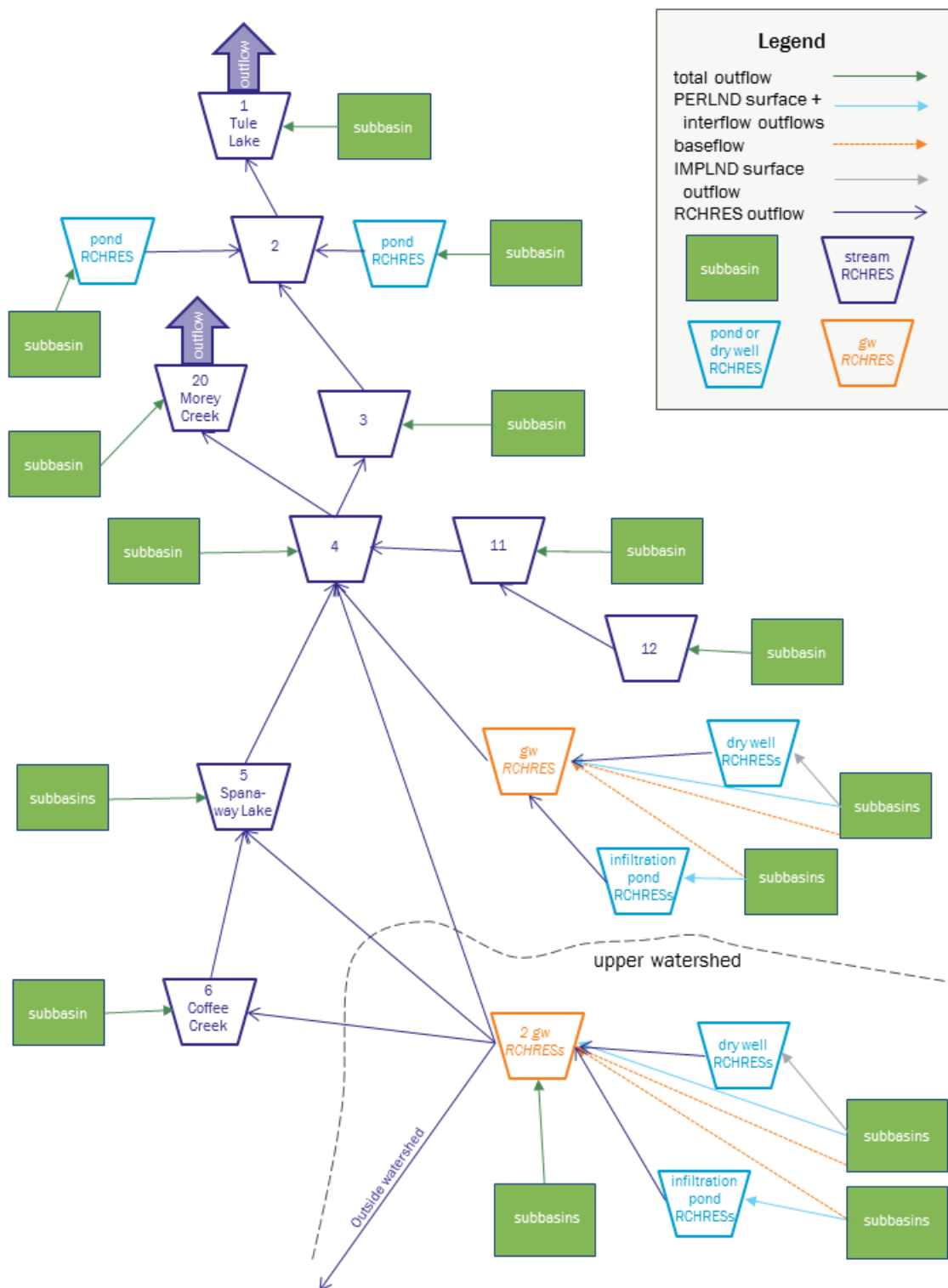


Figure 4-3. Spanaway Lake watershed model segmentation schematic

SECTION 5: MONITORING RESULTS

This section summarizes the results from the Spanaway Lake watershed monitoring program conducted from October 2014 to March 2016. As discussed in Section 4, monitoring was conducted for streamflow, water temperature, copper and zinc, fecal coliform bacteria, and benthic macroinvertebrates at the monitoring locations shown in Figure 4-1. This section also discusses water quality and other relevant data collected by Ecology for the Clover Creek Assessment study (Ecology 2016b). Appendix C contains a detailed discussion of the monitoring results.

5.1 Streamflow

The County collected streamflow data from summer 2014 through spring 2016 at the Spanaway Creek Outlet (SW-1), Coffee Creek Inlet (SW-2), Spanaway Creek 1 (WSP2), and Morey Creek (WSP4), as shown in Figure 4-1. USGS flow data were also collected at the SW-1 site between September 2014 and November 2015. Ecology collected biweekly instantaneous flow measurements on Spanaway and Morey creeks from March 2013 to February 2014 to estimate flow gains and losses (Ecology 2016b).

Coffee Creek (SW-2) showed a muted response to rain events, which is expected for a stream that is predominantly groundwater-fed with substantial upstream storage in wetland areas. Spanaway Creek at Military Road (SW-1) showed a substantial increase in winter baseflow due to groundwater discharge into Spanaway Lake.

Spanaway Creek appeared to gain groundwater flow between the lake and the split with Morey Creek. Unfortunately, the flow data collected from WSP3, the site downstream of Tule Lake on Spanaway Creek, proved to be unusable for model calibration because of equipment issues and impounded water conditions in the area around the gage. Flow data from the other four flow gages were used to calibrate the Spanaway Lake WSP model.

5.2 Water Temperature

The WSP water bodies are designated for salmonid spawning, rearing, and migration (Ecology 2016c). To protect these uses, the 7-DADMax shall not exceed 17.5°C more than once every 10 years on average. For lakes and other water bodies that exceed 17.5°C 7-DADMax because of natural conditions, human actions considered cumulatively may not increase the 7-DADMax by more than 0.3°C (0.54°F).

Instantaneous readings of temperature measured during the routine surface water monitoring events ranged from 4.5°C to 31.3°C between the five creek sites (SW-1, SW-2, WSP2, WSP3, and WSP4). Table 5-1 provides a summary of the 7-DADMax water temperatures at each monitoring

location during the monitoring period. Figure 5-1 shows the 7-DADMax temperature for each monitoring location, including the water quality criteria limit (red line).

WSP Site ID	Location	Monitoring Period	Number of Days > 17.5°C
SW-1	Spanaway Creek at lake outlet	October 2014–May 2016	161
SW-2	Coffee Creek at lake inlet	July 2014–May 2016	29
WSP2	Spanaway Creek at 141st St. S	October 2014–May 2016	126
WSP3	Spanaway Creek below Tule Lake outlet	December 2014–May 2016	122
WSP4	Morey Creek	October 2014–May 2016	110

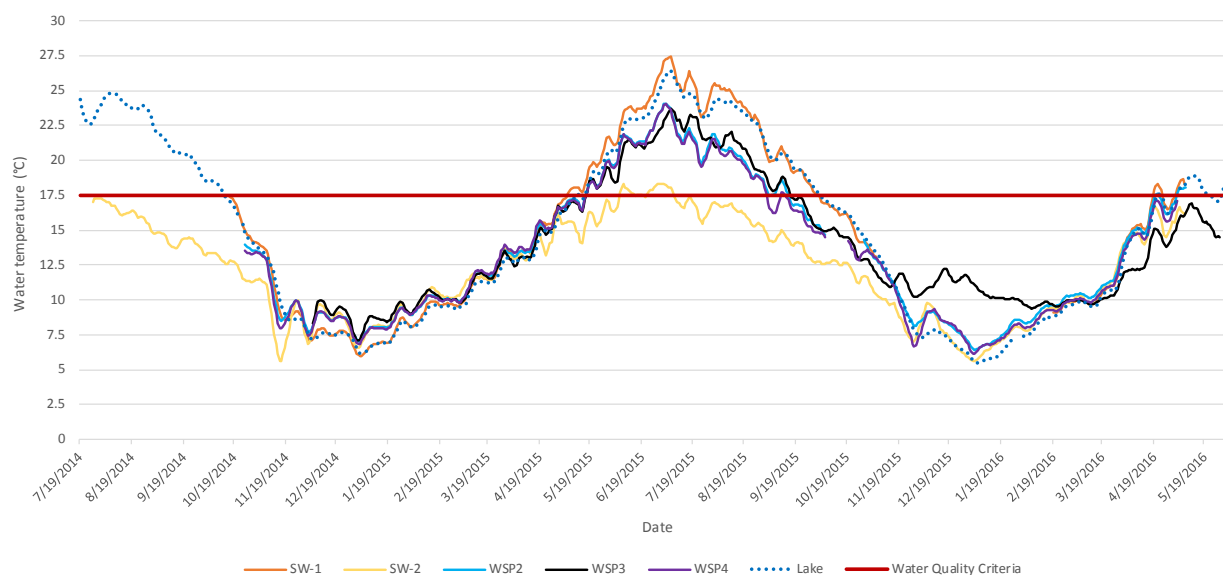


Figure 5-1. 7-day averages of daily maximum water temperatures in Spanaway Lake watershed

Warming in Spanaway Lake is the primary cause of higher water temperatures at SW-1, WSP2, WSP3, and WSP4 during the summer. Warmer temperatures in Spanaway Lake are due to the long hydraulic residence time and large open water area. Warming in Tule Lake may also contribute to the elevated temperatures at WSP3.

Spanaway Lake is a natural lake with no man-made control structures. (Bresemann Dam, located on Spanaway Creek in the park downstream of the lake and Military Road, is too low in elevation to affect lake levels [BC 2016]). Groundwater is the main source of water to the lake. HSPF model simulations indicate that existing 7-DADMax values at SW-1 are within 0.3°C of

historical (pre-developed) conditions. This suggests that the elevated water temperatures at SW-1 are primarily due to natural warming in the lake.

While natural lake warming is probably the main contributor to the elevated water temperatures observed at WSP2, WSP3, and WSP4, decreased riparian shade is probably a contributing factor. Ecology's Clover Creek Assessment found that only about 20 percent of the channel near WSP2 was effectively shaded (Ecology 2016b). The HSPF model simulations indicate that existing 7-DADMax values at WSP2, WSP3, and WSP4 are often more than 0.3°C higher than historical conditions.

As shown in Figure 5-1 above, the 7-DADMax at Coffee Creek (SW-2) was slightly above 17.5°C for about 29 days during the WSP monitoring period. Groundwater is the main source of flow in Coffee Creek during the summer months. It is possible that limited riparian shade contributed to the exceedances. Historical maps (Figure 3-3), however, indicate that prairie (rather than forest) covered the Coffee Creek area, so it is likely that riparian shade was limited under pre-developed conditions as well.

5.3 Copper and Zinc

This section summarizes the results for dissolved and total recoverable metals in creek, lake water, and groundwater samples. Appendix C contains a detailed discussion of the sample results.

5.3.1 Dissolved Copper and Zinc

Dissolved copper and zinc can be toxic to aquatic life. Potential toxicity depends on dissolved metal concentrations, water hardness, and other factors.

Tables 5-2 and 5-3, respectively, summarize the dissolved copper and zinc concentrations observed in the creek, lake, and groundwater samples collected during the monitoring period.

As shown in the tables, none of the routine or storm event samples from the creeks exceeded the acute or chronic criteria for dissolved copper or dissolved zinc. None of the lake water samples exceeded the acute or chronic criteria for dissolved zinc. None of the lake samples exceeded the acute criteria for dissolved copper, but one sample exceeded the chronic (4-day) criterion (see Table 5-4). This sample was collected about 3 meters below the surface from location LW-3 near the middle of the lake. The sample was a grab sample so it is not directly comparable to the chronic criterion, which is a 4-day average concentration. Ecology's WQP 1-11 error analysis found that individual daily observations have a much greater chance of exceeding the chronic criteria than 4-day averages (Ecology 2016d).

Dissolved zinc concentrations of 106 micrograms per liter (µg/L) and 116 µg/L were observed in two groundwater samples collected from monitoring well LMP-GW2. This well is located near

the boat ramp and a public washroom in Spanaway County Park. There are no stormwater infiltration facilities or MS4 outfalls near this monitoring well. Surface water samples collected in Spanaway Lake and at SW-1 just downstream of the lake contained low zinc concentrations. Therefore, the two LMP-GW2 samples with elevated zinc concentrations do not appear to be representative of groundwater discharges into the lake.

Table 5-2. Dissolved Copper (µg/L) in Creek, Lake and Groundwater Samples in Spanaway Lake Watershed							
Media Type	Sample Location	Minimum	Average	Median	Maximum	Number of Samples	Percent Exceeding Criteria
Routine water sampling from creeks	Marsh	<0.50 U	<0.50 U	<0.50 U	<0.50 U	16	0
	SW-1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18	0
	SW-2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18	0
	WSP1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	13	0
	WSP2	<0.50 U	0.33	0.25	1.70	18	0
	WSP3	<0.50 U	0.34	0.25	1.70	17	0
	WSP4	<0.50 U	0.33	0.25	1.70	18	0
Storm event water sampling from creeks	Marsh	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18 (6 storms)	0
	SW-1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18 (6 storms)	0
	SW-2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18 (6 storms)	0
	WSP1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	6 (2 storms)	0
	WSP2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18 (6 storms)	0
	WSP3	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18 (6 storms)	0
	WSP4	<0.50 U	0.31	0.25	1.30	18 (6 storms)	0
Lake water samples	LW-1	<0.50 U	0.54	0.25	2.30	7	0
	LW-1E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	12	0
	LW-1H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	12	0
	LW-2	<0.50 U	0.94	0.25	5.10	7	0
	LW-2E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	10	0
	LW-2H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	2	0
	LW-3	<0.50 U	1.30	0.25	7.50	7	14
	LW-3E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	10	0
	LW-3H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	2	0

Table 5-2. Dissolved Copper (µg/L) in Creek, Lake and Groundwater Samples in Spanaway Lake Watershed							
Media Type	Sample Location	Minimum	Average	Median	Maximum	Number of Samples	Percent Exceeding Criteria
Groundwater samples	LMP-GW1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	LMP-GW2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4	NA
	LMP-GW3	<0.50 U	<0.50 U	<0.50 U	<0.50 U	7	NA
	LMP-GW4	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	LMP-GW5	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	LMP-GW6	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4	NA
	WSP-GW1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	WSP-GW2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	WSP-GW3	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	WSP-GW4	<0.50 U	<0.50 U	<0.50 U	<0.50 U	6	NA
	WSP-GW5	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4	NA
	WSP-GW6	<0.50 U	<0.50 U	<0.50 U	<0.50 U	6	NA

U = compound was analyzed and not detected.

Statistics calculated using half the detection limit (0.5 µg/L).

Percent exceedance calculated based on the hardness of that sample.

A lower detection limit of 0.2 µg/L instead of 0.5 µg/L was used for some of the analytes in March 2016.

NA = not applicable; water quality criteria for aquatic life do not apply to groundwater.

Table 5-3. Dissolved Zinc ($\mu\text{g/L}$) in Creek, Lake and Groundwater Samples in Spanaway Lake Watershed

Media Type	Sample Location	Minimum	Average	Median	Maximum	Number of Samples	Percent Exceeding Criteria
Routine water sampling from creeks	Marsh	<0.50 U	0.28	0.25	0.25	16	0
	SW-1	<0.50 U	0.30	0.25	0.80	18	0
	SW-2	<0.50 U	0.35	0.25	2.0	18	0
	WSP1	<0.50 U	0.35	0.25	1.5	13	0
	WSP2	<0.50 U	0.28	0.25	0.80	18	0
	WSP3	<0.50 U	0.25	0.25	0.25	17	0
	WSP4	<0.50 U	0.27	0.25	0.60	18	0
Storm event water sampling from creeks	Marsh	<0.50 U	0.41	0.25	2.1	18 (6 storms)	0
	SW-1	<0.50 U	0.39	0.25	2.5	18 (6 storms)	0
	SW-2	<0.50 U	0.30	0.25	1.1	18 (6 storms)	0
	WSP1	<0.50 U	0.53	0.25	1.9	6 (2 storms)	0
	WSP2	<0.50 U	0.55	0.25	2.2	18 (6 storms)	0
	WSP3	<0.50 U	0.38	0.25	1.2	18 (6 storms)	0
	WSP4	<0.50 U	0.52	0.25	2.1	18 (6 storms)	0
Lake water samples	LW-1	<0.50 U	0.99	1.1	2.0	7	0
	LW-1E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	12	0
	LW-1H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	12	0
	LW-2	<0.50 U	0.96	0.50	2.0	7	0
	LW-2E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	10	0
	LW-2H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	2	0
	LW-3	0.50	0.80	0.60	1.5	7	0
	LW-3E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	10	0
	LW-3H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	2	0

Table 5-3. Dissolved Zinc ($\mu\text{g/L}$) in Creek, Lake and Groundwater Samples in Spanaway Lake Watershed

Media Type	Sample Location	Minimum	Average	Median	Maximum	Number of Samples	Percent Exceeding Criteria
Groundwater samples	LMP-GW1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	LMP-GW2	<0.50 U	56.00	53.00	116.0	4	NA
	LMP-GW3	<0.50 U	0.53	0.25	2.20	7	NA
	LMP-GW4	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	LMP-GW5	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	LMP-GW6	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4	NA
	WSP-GW1	<0.50 U	0.50	0.25	1.50	5	NA
	WSP-GW2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5	NA
	WSP-GW3	<0.50 U	0.38	0.25	0.90	5	NA
	WSP-GW4	<0.50 U	<0.50 U	<0.50 U	<0.50 U	6	NA
	WSP-GW5	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4	NA
	WSP-GW6	<0.50 U	<0.50 U	<0.50 U	<0.50 U	6	NA

U = compound was analyzed and not detected.

Statistics calculated using half the detection limit (0.5 $\mu\text{g/L}$).

Percent exceedance calculated based on the hardness of that sample.

Dissolved zinc concentrations for sample result WSP-GW1 and its duplicate, WSP-GW1_dup during the 3/25/2015 sample event was 1.5 $\mu\text{g/L}$ and 1.1 $\mu\text{g/L}$, respectively. The statistical results listed in this summary table do not include results from the duplicate sample.

NA = not applicable; water quality criteria for aquatic life do not apply to groundwater.

Table 5-4. Sample Result with Potential Exceedance of Dissolved Metal Concentrations

Sample Location	Sample Date	Total Hardness (mg/L)	Dissolved Copper ($\mu\text{g/L}$)	Chronic Criterion ($\mu\text{g/L}$, 4-day average)	Acute Criterion ($\mu\text{g/L}$, 1 hr average)
Lake Water Samples					
LW-3	11/20/2014	47.1	7.5 ^a	6.0	8.4

a. Grab sample concentration. Sample result may not be an exceedance because chronic criterion applies to a 4-day average concentration rather than a grab sample concentration.

5.3.2 Total Recoverable Copper and Zinc

Tables 5-5 and 5-6 summarize the results for total copper and total zinc in creek, lake, and groundwater samples collected during the WSP monitoring period. A comparison of the total metal concentrations to the dissolved metal concentrations shows that average and maximum

concentrations are much greater than the average and maximum dissolved concentrations, which are expected. Appendix C contains more detailed information on the sample results.

The highest average total copper concentration in the routine creek water samples was 1.2 µg/L, at WSP4. The highest concentrations were from locations WSP2, WSP3, and WSP4, with concentrations of 11.2, 11.9, and 15.9 µg/L, respectively. The highest average total zinc concentration in the routine surface water samples was 0.7 µg/L, at WSP4. The highest concentration was from location WSP4 with 3.8 µg/L.

The highest average total copper concentrations of the storm event water sampling from creeks was 0.31 µg/L, at WSP1. The highest concentration was from location WSP4 with 4.2 µg/L. The highest average total zinc concentrations of the storm event water sampling from creeks was 2.8 µg/L. The highest concentrations were from locations WSP1 and WSP4 with 11.4 and 11.8 µg/L, respectively.

The highest average total copper concentration of the lake water samples was 1.4 µg/L, at LW-1. The highest concentration was from location LW-1 with 8.1 µg/L. The highest average total zinc concentration of the lake water samples was 3.5 µg/L, at LW-1. The highest concentration was from location LW-1 with 9.4 µg/L.

The highest average total copper concentration of the groundwater samples was 0.5 µg/L, at LMP-GW3. The highest concentration was from location LMP-GW3 with 2.2 µg/L. The highest average total zinc concentration of the groundwater samples was 64 µg/L, observed at LMP-GW2. The highest concentration was from location LMP-GW2 with 141 µg/L.

Table 5-5. Total Copper (µg/L) in Creek, Lake and Groundwater Samples in Spanaway Lake Watershed

Media Type	Sample Location	Minimum	Average	Median	Maximum	Number of Samples
Routine water sampling from creeks	Marsh	<0.50 U	0.85	0.25	8.7	16
	SW-1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18
	SW-2	<0.50 U	0.30	0.25	1.1	18
	WSP1	<0.50 U	0.28	0.25	0.60	13
	WSP2	<0.50 U	0.86	0.25	11.2	18
	WSP3	<0.50 U	0.94	0.25	11.9	17
	WSP4	<0.50 U	1.21	0.25	15.9	18

Table 5-5. Total Copper (µg/L) in Creek, Lake and Groundwater Samples in Spanaway Lake Watershed						
Media Type	Sample Location	Minimum	Average	Median	Maximum	Number of Samples
Storm event water sampling from creeks	Marsh	<0.50 U	0.29	0.25	1.0	18 (6 storms)
	SW-1	<0.50 U	0.30	0.25	1.1	18 (6 storms)
	SW-2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18 (6 storms)
	WSP1	<0.50 U	0.31	0.25	0.6	6 (2 storms)
	WSP2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18 (6 storms)
	WSP3	<0.50 U	<0.50 U	<0.50 U	<0.50 U	18 (6 storms)
	WSP4	<0.50 U	0.47	0.25	4.2	18 (6 storms)
Lake water samples	LW-1	<0.50 U	1.37	0.25	8.1	7
	LW-1E	<0.50 U	0.25	0.25	0.25	12
	LW-1H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	12
	LW-2	<0.50 U	1.26	0.25	7.3	7
	LW-2E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	10
	LW-2H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	2
	LW-3	<0.50 U	1.33	0.25	7.8	7
	LW-3E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	10
	LW-3H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	2
Groundwater samples	LMP-GW1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5
	LMP-GW2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4
	LMP-GW3	<0.50 U	0.53	0.25	2.20	7
	LMP-GW4	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5
	LMP-GW5	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5
	LMP-GW6	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4
	WSP-GW1	<0.50 U	0.44	0.25	1.40	6
	WSP-GW2	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5
	WSP-GW3	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5
	WSP-GW4	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5
	WSP-GW5	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4
	WSP-GW6	<0.50 U	0.53	0.25	2.20	7

Table 5-6. Total Zinc (µg/L) in Creek, Lake and Groundwater Samples in Spanaway Lake Watershed

Media Type	Sample Location	Minimum	Average	Median	Maximum	Number of Samples
Routine water sampling from creeks	Marsh	<0.50 U	0.37	0.25	1.3	16
	SW-1	<0.50 U	0.51	0.25	1.5	18
	SW-2	<0.50 U	0.37	0.25	2.4	18
	WSP1	<0.50 U	0.86	0.25	4.6	13
	WSP2	<0.50 U	0.39	0.25	1.3	18
	WSP3	<0.50 U	0.53	0.25	1.8	17
	WSP4	<0.50 U	0.70	0.25	3.8	18
Storm event water sampling from creeks	Marsh	<0.50 U	1.39	0.25	10.4	18 (6 storms)
	SW-1	<0.50 U	0.99	0.65	2.6	18 (6 storms)
	SW-2	<0.50 U	0.38	0.25	1.3	18 (6 storms)
	WSP1	<0.50 U	2.82	0.70	11.4	6 (2 storms)
	WSP2	<0.50 U	1.22	0.65	5.0	18 (6 storms)
	WSP3	<0.50 U	0.77	0.25	3.1	18 (6 storms)
	WSP4	<0.50 U	1.60	0.25	11.8	18 (6 storms)
Lake water samples	LW-1	<0.50 U	3.52	2.8	9.4	7
	LW-1E	<0.50 U	0.31	0.25	1.0	12
	LW-1H	<0.50 U	0.30	0.25	0.8	12
	LW-2	<0.50 U	1.44	1.7	2.4	7
	LW-2E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	10
	LW-2H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	2
	LW-3	<0.50 U	1.48	1.0	4.3	7
	LW-3E	<0.50 U	<0.50 U	<0.50 U	<0.50 U	10
	LW-3H	<0.50 U	<0.50 U	<0.50 U	<0.50 U	2
Groundwater samples	LMP-GW1	<0.50 U	<0.50 U	<0.50 U	<0.50 U	5
	LMP-GW2	<0.50 U	64	57	141	4
	LMP-GW3	<0.50 U	1.0	0.25	4.1	7
	LMP-GW4	<0.50 U	0.42	0.25	1.1	5
	LMP-GW5	<0.50 U	0.72	0.25	2.6	5
	LMP-GW6	<0.50 U	0.49	0.25	1.2	4
	WSP-GW1	<0.50 U	0.70	0.25	1.7	6
	WSP-GW2	<0.50 U	0.38	0.25	0.90	5
	WSP-GW3	<0.50 U	0.46	0.25	1.3	5
	WSP-GW4	<0.50 U	<0.50 U	<0.50 U	<0.50 U	6
	WSP-GW5	<0.50 U	<0.50 U	<0.50 U	<0.50 U	4
	WSP-GW6	<0.50 U	<0.50 U	<0.50 U	<0.50 U	6

5.3.3 Copper and Zinc Sources in the Lake Spanaway Lake WSP Area

As noted above, only one of the creek or lake samples collected for the WSP exceeded the acute or chronic criteria for dissolved copper. One sample collected near the middle of Spanaway Lake (sampling location LW-3) contained 7.5 µg/L of dissolved copper, which is slightly above the chronic criterion (4-day average concentration of 6.0 µg/L). As stated above, single grab samples have a much greater chance of exceeding chronic criteria than 4-day averages (Ecology 2016c).

MS4 discharges do not appear to be a likely source for the elevated copper concentration in the LW-3 sample because nearly all stormwater runoff from impervious areas in the watershed is infiltrated, and none of the groundwater samples upgradient of the lake contained dissolved copper above the detection limit (0.5 µg/L). Samples collected from Coffee Creek upstream of the lake had considerably lower dissolved copper concentrations than the LW-3 sample.

Domestic septic system effluent typically contains low concentrations of copper and zinc. Copper and zinc in the subsurface are subject to specific adsorption on ferric, aluminum, and manganese hydroxides. None of the monitoring wells around the lake contained detectable dissolved copper concentrations. Thus, septic systems do not appear to be a likely source.

It is possible that the elevated dissolved copper concentration in the mid-lake sample could be related to historical use of copper sulfate for algae control. Copper sulfate was reportedly used as an algicide in Spanaway Lake (Longfellow and Holt 2004).

Dissolved zinc concentrations in all the creek and lake samples were far below the acute and chronic criteria. Two groundwater samples collected from the monitoring well near the Spanaway Park boat ramp (LMP-GW2) contained elevated zinc concentrations. It is possible that runoff from the boat ramp is affecting this shallow monitoring well. Potential zinc sources associated with boat ramps include sacrificial anodes on hulls and motors, motor oil, galvanized metal trailers, and tires. Another possible source is runoff generated during cleaning of a public restroom near the well. This bathroom and the rest of the park is connected to the sanitary sewer system rather than onsite septic systems. There are no MS4 outfalls or stormwater infiltration facilities near LMP-GW2.

5.4 Fecal Coliform

Fecal coliform bacteria are commonly used as an indicator of possible fecal contamination because they originate in human and animal feces. Although they are generally not harmful themselves, they indicate the potential presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming in or eating shellfish from these waters might be a health risk.

The State water quality standards for fecal coliform vary depending on the designated uses of the water body (Ecology 2016c). Spanaway Lake (sample locations LW-1, LW-2, and LW-3) and Coffee Creek upstream of the lake (sample locations WSP1 and SW-2) are designated for extraordinary contact. For water bodies with this designated use, the geometric mean fecal coliform concentration should not exceed 50 cfu/100 mL and no more than 10 percent of samples can have concentrations exceeding 100 cfu/100 mL. The water bodies downstream of the lake (sample locations SW-1, WSP2, WSP3, and WSP4) are designated for primary contact. For these water bodies, the geometric mean fecal coliform concentration must not exceed 100 cfu/100 mL and less than 10 percent of samples should have concentrations exceeding 200 cfu/100 mL.

A summary of the fecal coliform monitoring results from creek, lake, and groundwater samples is provided below (refer to Appendix C for a detailed discussion on the results). Fecal coliform concentrations were evaluated under three periods: during the wet season (October 1 through April 31), dry season (May 1 to September 30), and full year. Tables 5-7 and 5-8 summarize the fecal coliform bacteria results for the routine and storm surface water sampling from creeks and the lake from October 2014 to March 2016. Table 5-9 summarizes the combined fecal coliform bacteria results for the routine and average storm surface water samples. Figure 5-2 summarizes fecal coliform concentrations in the lake, creek, and groundwater samples.

5.4.1 Fecal Coliform in Lake Samples

Fecal coliform concentrations in the lake water samples ranged from non-detect to 80 cfu/100 mL, with geometric means of 0.01 cfu/100 mL. The WSP and LMP lake water samples met both parts of the State's fecal coliform criteria, as shown in Table 5-7 below. However, some samples collected by TPCHD in summer 2015 from public swimming areas in the lake contained elevated concentrations of *E. coli*, a type of fecal coliform bacteria. For example, a sample collected near North Beach on June 9, 2015, contained 801 cfu/100 mL, while a sample collected from Main Beach on August 10, 2015, contained 540 cfu/100 mL. Waterfowl are often present in these areas of Spanaway Lake.

**Table 5-7. Fecal Coliform Bacteria (cfu/100 mL) Results:
Routine Surface Water Sampling from Creeks & Lake (10/2014–3/2016) in Spanaway Lake Watershed**

WSP Site ID	Water Body	Wet Season			Dry Season			Full Year		
		Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}	Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}	Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}
Marsh	JBLM marsh	11	3	36	5	51	40	16	7	38
WSP1	Coffee Creek below marsh	8	0.31	0	5	3	0	13	1	0
SW-2	Coffee Creek at Spanaway Loop Rd.	13	4	0	5	71	40	18	8	11
LW-3	Spanaway Lake: south	9	0.01	0	10	0.01	0	19	0.01	0
LW-2	Spanaway Lake: northwest	9	0	0	10	0.01	0	19	0	0
LW-1	Spanaway Lake: north	11	0.02	0	20	0.01	0	31	0.01	0
SW-1	Spanaway Creek at Military Rd.	13	12	0	5	74	20	18	20	6
WSP2	Spanaway Creek at 138th	13	6	8	5	166	40	18	15	17
WSP4	Morey Creek	13	12	0	5	373	80	18	32	22
WSP3	Tule Lake outlet	12	56	0	5	124	40	17	71	12

ND = non-detect. (Geomean calculations used a value of 0.001 for concentrations below detection limits.)

Values in bold exceed criteria.

Wet season is from October 1 through April 31. Dry season is from May 1 through September 30.

- For water bodies with extraordinary contact designated use (Marsh, SW-2, and WSP1), the geometric mean fecal coliform concentration should not exceed 50 cfu/100 mL and no more than 10% of samples can have concentrations exceeding 100 cfu/100 mL.
- The water bodies downstream of the lake (SW-1, WSP2, WSP3, and WSP4) are designated for primary contact; the geometric mean fecal coliform concentration must not exceed 100 cfu/100 mL and less than 10% of samples should have concentrations exceeding 200 cfu/100 mL.

5.4.2 Fecal Coliform in Creek Samples

The County collected creek samples monthly and during storm events. The following sections summarize the results.

5.4.2.1 Routine Samples

Routine surface water fecal coliform results were evaluated under three periods: during the wet season (October 1 through April 31), dry season (May 1 to September 30), and full year. Table 5-7 provides a summary of these results.

As summarized in Table 5-7, the fecal coliform concentrations in the marsh did not meet the Part 1 criterion, which states that the geometric mean fecal coliform concentration should not exceed 50 cfu/100 mL for the dry season. The marsh also did not meet the Part 2 criterion, which states that no more than 10 percent of samples can have concentrations exceeding 100 cfu/100 mL during the wet season, dry season, and full year.

Fecal coliform concentrations at WSP1 met all criteria for each evaluation period. Fecal coliform results for SW-2 (Coffee Creek) did not meet Part 1 criteria for the dry season and did not meet the Part 2 criteria for the dry season and full year evaluation periods. SW-2 is in Coffee Creek, upstream of the lake. Coffee Creek originates below a large wetland complex on JBLM and passes through more wetland areas between JBLM and Spanaway Loop Road. The wetland appears to be a groundwater discharge zone. Aside from the road and a few residences there is little development or infrastructure upstream of SW-2. Stormwater runoff composes a small fraction of the flow at SW-2.

Fecal coliform concentrations from the downstream locations included SW-1, WSP2, WSP3, and WSP4. During the wet season and full year evaluation period, each of these locations met Part 1 of the criteria. During the dry season, WSP2, WSP3, and WSP4 exceeded the Part 1 criteria. During the dry season, each location exceeded Part 2 of the criteria. For the full year evaluation period, WSP2, WSP3, and WSP4 exceeded the Part 2 criteria.

5.4.2.2 Storm Event Samples

Creek samples were collected during six storm runoff events. During each event, three samples were collected from each site. The fecal coliform results were evaluated under three periods: during the wet season (October 1 through April 31), dry season (May 1 to September 30), and full year. Table 5-8 provides a summary of these results.

As summarized in Table 5-8, the fecal coliform concentrations in the marsh did not meet the Part 1 criteria, which states that the geometric mean fecal coliform concentration should not exceed 50 cfu/100 mL for the dry season. The marsh also did not meet the Part 2 criteria, which

states that no more than 10 percent of samples can have concentrations exceeding 100 cfu/100 mL during the wet season, dry season, and full year. Waterfowl and other wildlife are the likely source of the fecal coliform measured in the samples from the marsh.

Fecal coliform concentrations at WSP1 and SW-2 met the Part 1 criteria for each evaluation period. However, WSP1 exceeded the Part 2 criteria during the wet season and full year period and SW-2 exceeded the Part 2 criteria during each evaluation period. There was no flow at WSP1 during some of the monitoring events. As stated above, the monitoring results and land use data indicate that wildlife are the most likely sources of fecal coliform bacteria to Coffee Creek at SW-2.

Fecal coliform concentrations from the downstream locations included SW-1, WSP2, WSP3, and WSP4. During the wet season, each location met the Part 1 criteria; however, Part 2 was exceeded. During the dry season, each location exceeded both Part 1 and Part 2 criteria. For the full year evaluation period, SW-1 and WSP3 met the Part 1 criteria and exceeded the Part 2 criteria, whereas WSP2 and WSP4 exceeded both Part 1 and Part 2 criteria.

Table 5-9 lists the geomeans and percentages of routine and storm event samples exceeding 100 cfu/100 mL or 200 cfu/100 mL at each location. The average concentration from the three samples collected during each storm event was used to represent the storm event. As shown in the table, during the wet season, none of the locations exceeded the geomean criteria and only the JBLM marsh site exceeded the Part 2 criterion (100 cfu/100 mL). During the dry season, all sites except WSP1 exceeded both parts of the criteria. However, fewer samples were collected at WSP1 because the channel was dry during many of the sampling events.

**Table 5-8. Fecal Coliform Bacteria (cfu/100 mL) Monitoring Results:
Stormwater Samples from Creeks (12/2014–10/2015) in Spanaway Lake Watershed**

Site ID	Water Body	Wet Season			Dry Season			Full Year		
		Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}	Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}	Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}
Marsh	JBLM marsh	12	2	33	6	205	50	18	8	39
WSP1	Coffee Creek below marsh	3	1	33	3	23	0	6	4	17
SW-2	Coffee Creek at Spanaway Loop Rd.	12	5	17	6	69	50	18	12	28
SW-1	Spanaway Creek at Military Rd.	12	22	25	6	484	100	18	62	50
WSP2	138th/Spanaway	12	66	25	6	289	67	18	108	39
WSP4	Morey Creek	12	26	25	6	241	50	18	55	33
WSP3	Tule Lake outlet	12	89	25	6	213	50	18	119	28

ND = non-detect. (Geomean calculations used a value of 0.001 for concentrations below detection limits.)

Values in bold exceed criteria.

Wet season is from October 1 through April 31. Dry season is from May 1 through September 30.

- For water bodies with extraordinary contact designated use (Marsh, SW-2, and WSP1), the geometric mean fecal coliform concentration should not exceed 50 cfu/100 mL and no more than 10% of samples can have concentrations exceeding 100 cfu/100 mL.
- The water bodies downstream of the lake (SW-1, WSP2, WSP3, and WSP4) are designated for primary contact; the geometric mean fecal coliform concentration must not exceed 100 cfu/100 mL and less than 10% of samples should have concentrations exceeding 200 cfu/100 mL.

**Table 5-9. Fecal Coliform Bacteria (cfu/100 mL) Monitoring Results:
Routine and Stormwater Samples from Creeks (10/2014–3/2016) in Spanaway Lake Watershed**

Site ID	Water Body	Wet Season			Dry Season			Full Year		
		Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}	Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}	Count	Geomean	Percent of Samples > 100 or 200 ^{a,b}
Marsh	JBLM marsh	15	5.4	33	7	77	43	22	13	36
WSP1	Coffee Creek below marsh	9	0.52	0	6	4.5	0	15	1.2	0
SW-2	Coffee Creek at Spanaway Loop Rd.	17	9.3	6	7	71	43	24	11	17
SW-1	Spanaway Creek at Military Rd.	17	17	6	7	134	43	24	32	17
WSP2	138th/Spanaway	17	11	6	7	205	43	24	26	17
WSP4	Morey Creek	17	18	6	7	349	71	24	43	25
WSP3	Tule Lake outlet	16	67	6	7	154	43	23	86	17

ND = non-detect. (Geomean calculations used a value of 0.001 for concentrations below detection limits.)

Values in bold exceed criteria.

Wet season is from October 1 through April 31. Dry season is from May 1 through September 30.

"Count" is the number of values used for calculating statistics. One grab sample was collected during each routine event, while three grab samples were collected during each storm event. Therefore, the average fecal coliform concentration each storm event was used for the criteria-related calculations in this table."

- For water bodies with extraordinary contact designated use (marsh, SW-2, and WSP1), the geometric mean fecal coliform concentration should not exceed 50 cfu/100 mL and no more than 10% of samples can have concentrations exceeding 100 cfu/100 mL.
- The water bodies downstream of the lake (SW-1, WSP2, WSP3, and WSP4) are designated for primary contact; the geometric mean fecal coliform concentration must not exceed 100 cfu/100 mL and less than 10% of samples should have concentrations exceeding 200 cfu/100 mL.

5.4.3 Fecal Coliform in Groundwater Samples

Fecal coliform concentrations in the groundwater samples ranged from non-detect to 120 cfu/100 mL (see Appendix C for a statistical summary of the results). As shown in Figure 5-2 below, the groundwater samples generally had lower fecal coliform concentrations than samples collected from the creeks. Samples collected from the monitoring wells near the lake (LMP-GW1, LMP-GW3, LMP-GW4, and LMP-GW6) had low fecal coliform concentrations except for one sample collected from the monitoring well located in the County park (LMP-GW2). MODFLOW particle tracking shows that most of the groundwater discharge to Spanaway Lake comes from the south, where monitoring wells LMP-GW1, LMP-GW4, and LMP-GW3 are located. LMP-GW1 and LMP-GW4 had no fecal coliform detections, while one result of 10 cfu/100 mL was found in one sample from LMP-GW3. The MODFLOW results indicate that LMP-GW5 is downgradient of the lake. The highest fecal coliform concentration was observed in a sample collected from WSP-GW6, which is in a portion of JBLM with no known human-related sources.

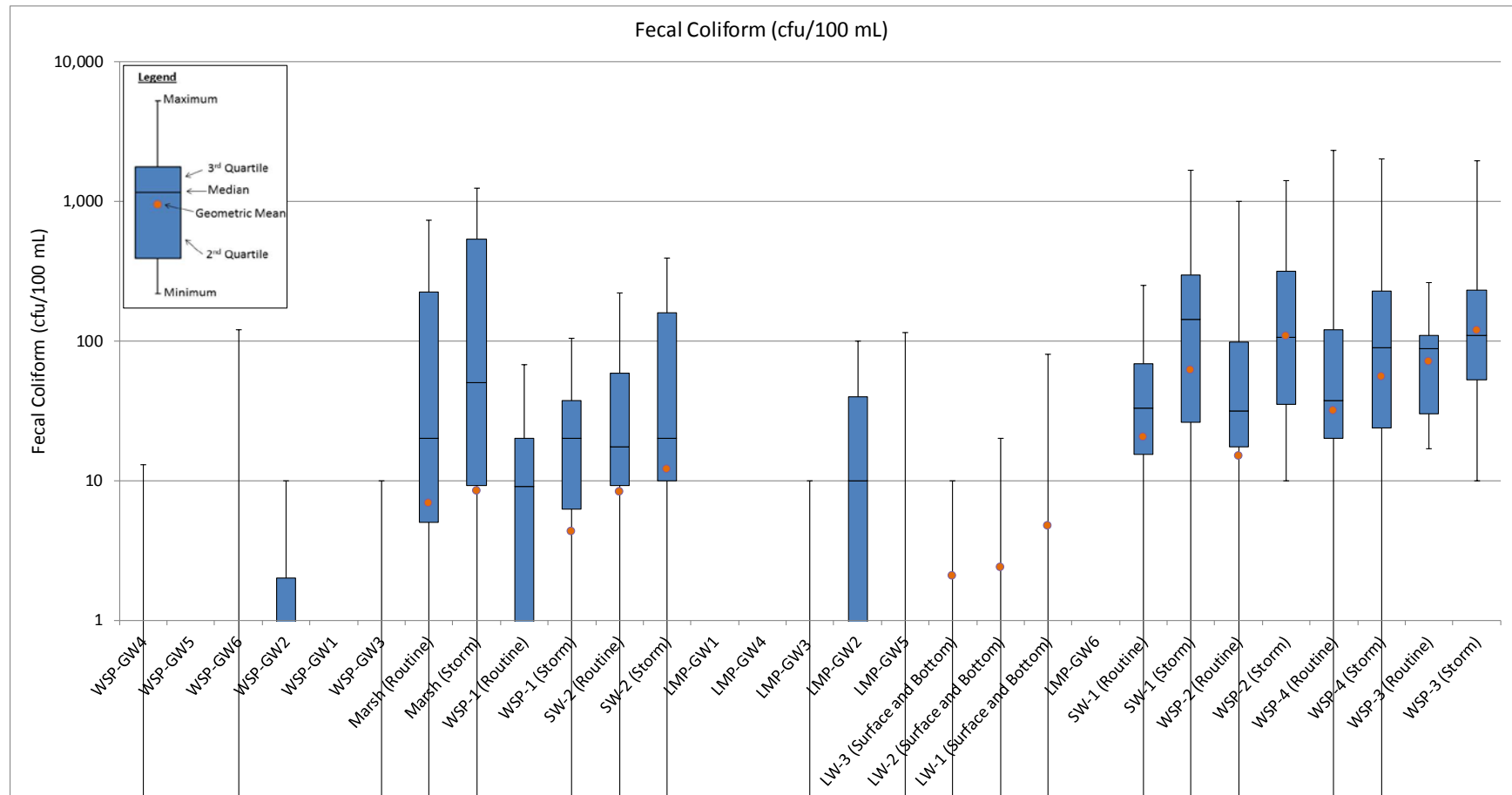


Figure 5-2. Fecal coliform concentrations in lake, creeks, and groundwater in Spanaway Lake watershed

5.4.4 Fecal Coliform Sources in the Lake Spanaway Lake WSP Area

Elevated fecal coliform concentrations were observed at most monitoring locations during the WSP monitoring period. Potential sources include septic systems, stormwater runoff, and wildlife. The following sections describe each potential source.

Coffee Creek (SW-2)

Coffee Creek concentrations were considerably higher than the lake water samples collected from LW-1, LW-2, and LW-3. The Coffee Creek sub-basin upstream of SW-2 has very little development (~1 percent urban land). Most of the sub-basin is in a portion of JBLM covered with forest, prairie, and a large marsh. Samples collected from the JBLM marsh, which is about 1/2 mile upstream of SW-2, contained higher fecal coliform concentrations than SW-2. The marsh supports a large wildlife population with more than 20 species of waterfowl and 110 other bird species (ebird.org 2017). Thus, the land use and monitoring data suggest that wildlife is the predominant source of fecal coliform bacteria in Coffee Creek upstream of Spanaway Loop Road. Coffee Creek may receive additional fecal coliform via stormwater runoff from the residential areas located along the creek downstream of Spanaway Loop Road.

Septic Systems

The WSP area includes more than 4,000 onsite sewage disposal systems (OSDSs) or septic systems. For the Spanaway LMP project, BC developed a model to estimate fecal coliform loads from septic systems in the watershed based on typical fecal coliform concentration in drainfield effluent, location/distance to lake, estimated depth to groundwater, and technical literature on subsurface transport and die-off rates. The technical literature and model results indicated that septic systems more than 350 feet from the lake are unlikely to contribute fecal bacteria to the lake because of filtering, adsorption, and die-off.

The calibrated MODFLOW model was used to delineate groundwater capture zones for the surface water reaches that gain flow from groundwater discharge. Flow monitoring data and modeling results showed that Coffee Creek and portions of Spanaway Lake, Spanaway Creek, and Morey Creek gain flow from groundwater. Approximately 60 septic systems are located in groundwater capture zones within 350 feet of the gaining reaches of Spanaway Lake, Spanaway Creek, or Morey Creek. Of these systems, approximately 48 have estimated depths to groundwater of less than 10 feet. These systems are likely to have fecal coliform removal efficiencies on the order of 1- to 4-log removals (99.00 to 99.99 percent). TPCHD reported a mean concentration of about 750,000 cfu/100 mL in drainfield effluent from new pressurized systems in the Spanaway, Tillicum, and Bethel areas (TPCHD 1994). 1-log removal would result in a concentration of 75,000 cfu/100 mL, while 4-log removal would result in 75 cfu/100 mL.

This suggests that fecal bacteria from these systems could reach the lake. However, these results do not account for mixing and dilution with groundwater or lake water (BC 2016).

Direct Stormwater Runoff

Urban stormwater runoff often contains elevated fecal coliform concentrations from pets and wildlife and sometimes from human sources such as failed septic systems, leaking sewer lines, and homeless encampments. Pets and livestock are also potential sources. Livestock have been observed near Spanaway Creek downstream of Morey Creek. Creek flooding could mobilize fecal material from domestic animals and wildlife.

Because of the very permeable soils and lack of surface conveyance systems, there is relatively little direct stormwater runoff to the receiving water bodies in the Spanaway Lake WSP. The HSPF model simulations indicate that groundwater provides 99 percent of the flow of the Spanaway Lake WSP lakes and creeks. The only significant stormwater discharge is from the Military Road drainage system, which enters Spanaway Creek downstream of Spanaway Lake. The calibrated HSPF watershed model indicates that stormwater from the Military Road outfall is less than 2 percent of the annual flow in Spanaway Creek.

Stormwater Infiltration Facilities

Infiltrated stormwater from impervious areas is another potential fecal coliform source. The WSP area contains more than 1,400 stormwater infiltration structures including drywells, trenches, and ponds. The septic system evaluation cited above found that septic systems more than 350 feet from the lake are unlikely to contribute appreciable fecal coliform to the lake. Fecal coliform concentrations in stormwater are typically several orders of magnitude lower than fecal coliform concentrations in septic tank effluent. Therefore, stormwater infiltration facilities more than 350 feet from receiving water bodies are not expected to be significant sources of fecal coliform. Two County infiltration ponds and approximately 20 drywells are located in groundwater capture zones within 350 feet upgradient of receiving water bodies in the WSP area. Five of these drywells have been retrofitted to improve water quality treatment and facilitate maintenance.

Wildlife

Waterfowl and other wildlife can be a significant source of fecal bacteria to lakes and creeks. Alderisio and DeLuca (1999) reported that Canada goose droppings had an average of 15,300 fecal coliforms per gram of wet feces. Hussong et al. (1979) estimated that a Canada goose generates about 36,000 fecal indicator bacteria per day. Moriarty et al. (2011) found that duck feces contained approximately 95 million *E. coli* bacteria per gram. In a 3-year study of Green Lake (Seattle), Scherer et al. (1995) estimated that 50 percent of the goose droppings and 80 percent of the duck droppings were deposited directly into the lake, but each duck

dropping generated about one fourth as much fecal material as the average goose dropping. A 2002–03 microbial source tracking study in the Clarks Creek watershed found that about two-thirds of the 680 fecal samples analyzed were from birds and rodents (Milne et al. 2004). A study conducted in the Tualatin watershed found similar results (Clean Water Services 2006).

More than 20 waterfowl species have been observed on Spanaway Lake (eBird 2017). Ecology and TPCHD have observed as many as 75 geese and 400 other waterfowl in the northern portion of Spanaway Lake. More than 130 bird species including 20 species of waterfowl have been observed at JBLM marsh. The land use data, limited direct stormwater runoff, and dry weather fecal coliform concentrations suggest that waterfowl and other riparian animals may be an important source in the Spanaway Lake WSP.

5.5 Benthic Macroinvertebrates

An evaluation of benthic habitat conditions in the Spanaway Lake watershed was conducted based on Puget Sound Lowlands B-IBI scores.

B-IBI scores are calculated using the benthic macroinvertebrate community found in undisturbed conditions as a benchmark. The Puget Sound Lowlands B-IBI is based primarily on targeted riffle samples from moderate to high-gradient streams with coarse sediments (Karr and Chu 1999, Fore et al. 1996, Morley and Karr 2002).

The MS4 Permit requires that the WSP predict future B-IBI scores in the Spanaway Lake watershed based on hydrologic modeling and regression equations developed for other creeks in the Puget Sound lowlands (DeGasperi et al. 2009). If the modeling results indicate that future B-IBI scores are likely to be less than 38 (the threshold for “good” benthic conditions under the 10–50 B-IBI scoring system), or less than 90 percent of the model-simulated historical B-IBI scores, then the WSP must include stormwater management strategies for achieving the B-IBI target scores. See Appendix C for additional details on the benthic evaluation.

Table 5-10 summarizes the monitoring results for benthic macroinvertebrate samples collected for the Spanaway Lake WSP with B-IBI scores based on the 10-50 scale. Table 5-11 summarizes the monitoring results for benthic macroinvertebrate samples collected for the Spanaway Lake WSP with B-IBI scores based on the 0-100 scale. For comparison, Ecology’s proposed Regional Stormwater Monitoring Program (RSMP) biological indicator threshold for B-IBI scores on the 0–100 scale is 60.8 (DeGasperi 2016). All the sites fell below this threshold. The highest B-IBI score (40) was observed in Coffee Creek just upstream of Spanaway Lake. The lowest score (11) was observed in Spanaway Creek just downstream of the lake outlet. Morey Creek and Spanaway Creek just downstream of the split with Morey Creek share an almost identical drainage area, yet their scores were significantly different (14.5 for lower Spanaway Creek versus 35.3 for Morey Creek). This suggests that the difference in B-IBI scores at WSP2 and WSP4 may be attributable to local conditions.

Table 5-10. Observed B-IBI Results for Spanaway Lake WSP Monitoring Sites (10-50 Scale)

Basis of B-IBI Score	Spanaway Creek Outlet (SW-1)	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)
Observed B-IBI 2015	18	26	18	22

Table 5-11. B-IBI Results for Spanaway Lake WSP Monitoring Sites (0-100 Scale)

Site Code	Site Name	Year	Scores: 0–100 Scale, 2012 Taxa List										
			Overall Score	Taxa Richness	Ephemeroptera Richness	Plecoptera Richness	Trichoptera Richness	Clinger Richness	Long-lived Richness	Intolerant Richness	Percent Dominant	Predator Percent	Tolerant Percent
SW-1	Spanaway Lake Outlet	2015	11	0.3	0.0	0.0	2.5	0.6	5.0	0.0	1.3	1.3	0.0
SW-2	Coffee Creek	2015	40	4.1	4.3	5.7	3.8	4.1	2.5	0.0	5.3	3.3	7.4
WSP2	Spanaway Creek	2015	14	2.4	0.0	0.0	2.5	0.0	3.8	0.0	1.7	4.2	0.0
WSP4	Morey Creek	2015	35	9.7	1.4	0.0	2.5	2.4	2.5	0.0	4.4	10	2.4

Excellent	Good	Fair	Poor	Very poor
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To compare the Spanaway Lake WSP area B-IBI scores with the scores of other sites in the Puget Sound lowlands, BC used methods and data described in Fore et al.'s 2013 paper, *Using Natural History Attributes of Stream Invertebrates to Measure Stream Health*. Fore et al. concluded that higher urbanization in the drainage area upstream of a benthic monitoring site is correlated with lower B-IBI scores (Fore et al. 2013).

This process allowed the Spanaway Lake WSP B-IBI scores and associated urbanization levels to be compared to the B-IBI scores and urbanization levels of other Puget Sound lowlands monitoring sites. Figure 5-3 shows how the Spanaway Lake WSP sites compare to the 784 sites included in the Fore et al. (2013) study. The 10–50 B-IBI scoring system was used for compatibility with Ecology's criteria for the WSP.

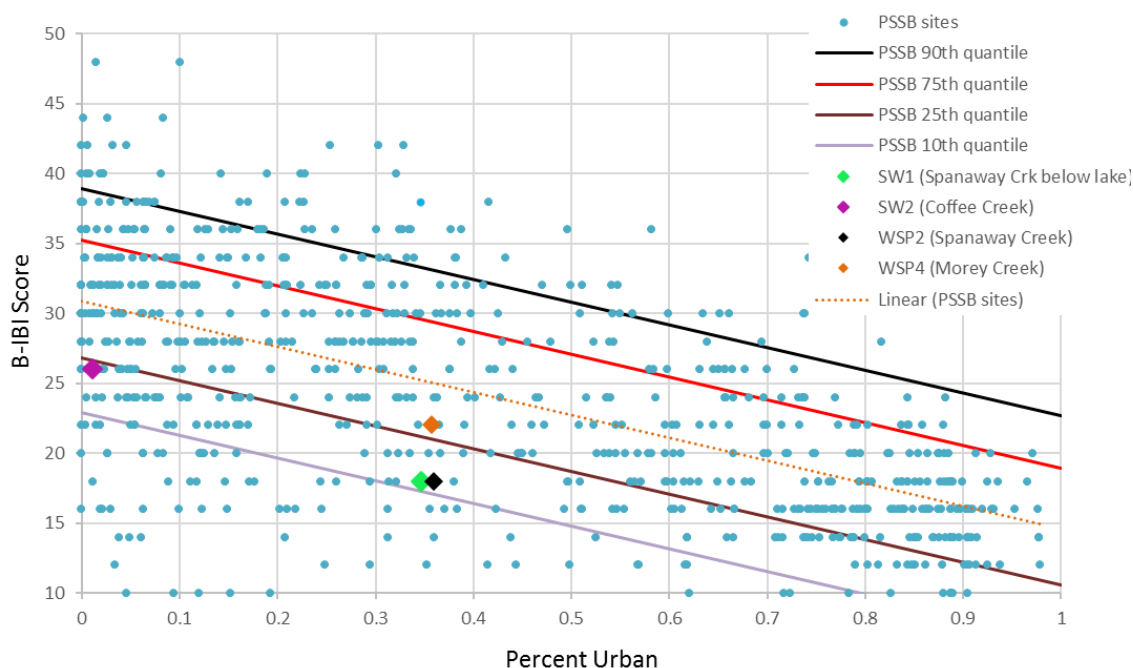


Figure 5-3. B-IBI score vs. percent urban in drainage area for Puget Sound Lowland sites

As indicated in Figure 5-3, the B-IBI scores for the Spanaway Lake WSP sites were relatively low compared to the Puget Sound Lowlands sites evaluated in the Fore et al. (2013) study. The B-IBI scores for SW-1 (Spanaway Creek below the lake) and WSP2 (Spanaway Creek below the split with Morey Creek) were both 18 under the 10–50 scoring system, putting them in the lower 15 percent of sites with similar levels of watershed urbanization. Site SW-2 (Coffee Creek) scored in the lower 25 percent of Puget Sound Lowlands sites with similar levels of urbanization. WSP4 (Morey Creek) was slightly above the 25th quantile for sites with similar urbanization levels.

WSP4 and WSP2 are located a short distance downstream of the point where Morey Creek splits off from Spanaway Creek; consequently, the upstream watershed area and percent urbanized are virtually identical for both sites. Nevertheless, the B-IBI score at WSP2 was considerably lower than the score at WSP4, indicating that factors other than the percent of urbanized area in the watershed exerted a strong influence.

The B-IBI score at SW-2 (Coffee Creek) site was in the “fair” range even though only about 1.2 percent of its watershed area is urbanized. However, this site is downstream of a major road, and is within a landscaped apartment complex, with lawn extending down to the edge of the creek. The relatively low B-IBI scores at this site and others could be due to local channel and riparian alterations (e.g., landscaped riparian area, sparse riparian tree canopy) as well as natural conditions (groundwater-dominated flow regime, low gradient).

Robert Wisseman (Aquatic Biology Associates) conducted on-site community assessments of the areas where the 2015 benthic samples were collected. Robert Wisseman conducted on-site community assessments of the benthic sampling sites (SW-1, SW-2, WSP2, and WSP4) in May 2017. He performed a stressor analysis based on his field assessment and detailed evaluation of the 2015 taxonomic data. Table 5-12 contains a summary of stressors based on this analysis. The categories of high, moderate, low, and not indicated indicate how much impact the stressor is considered to have on stream biotic integrity at the site, and are based on best professional judgment. Appendix C includes a detailed analysis of the benthic community at each WSP site.

Table 5-12. Benthic Invertebrate Community Assessment: Potential Stressors/Limiting Factors for Spanaway Creek				
Potential Stressor	SW-1 (Spanaway Creek near Spanaway Lake Outlet)	SW-2 (Coffee Creek)	WSP2 (Spanaway Creek: Lower)	WSP4 (Morey Creek)
Altered hydrology	Not indicated	Not indicated	Not indicated	Not indicated
Physical channel disturbance	Not indicated	Not indicated	Not indicated	Not indicated
Sand/fine substrate	Not indicated	Not indicated	Moderate	High
Low DO	Moderate	Not indicated	Moderate	Moderate
High water temperature	High	Not indicated	High	High
Acute toxicity	Not indicated	Not indicated	Not indicated	Not indicated
Nutrient enrichment	Not indicated	Not indicated	Low	Not indicated
Habitat simplification	Moderate	Moderate	High	Low
Substrate embeddedness	Low	Low	High	Moderate

The following bullets summarize each potential stressor identified in Table 5-12:

- **Altered hydrology:** Extreme “spikes” or intermittent/stagnant flow were not indicated by the taxa at any of the sites. The groundwater-fed flow is steady and not prone to the flashiness or low summer baseflow found in many other urbanizing Puget Sound watersheds. Hydrology does not appear to be a limitation at any of the Spanaway Lake WSP sites. This observation is supported by the results of the hydrologic model simulations for 1950–2015.
- **Physical channel disturbance:** Excessive scouring, bedload transport, or intermittent flows in summer are not indicated by the fauna or by physical evidence at any of the sample sites. A large amount of stream scour or flashy flows would be unusual for a low-gradient stream with this level of groundwater influence. Thus, physical channel disturbance does not appear to be a limitation at any of the Spanaway Lake WSP sites.

- **Sand/fine substrate:** Fauna ranges from a mix of erosional and depositional related taxa at SW-2 to a dominance of fine sediment-related taxa at SW-1, WSP2, and WSP4. The sample site substrate at WSP4 is mostly fine sediment, while WSP2 substrates are composed of mostly coarse sediment. At WSP2, the significant number of fine sediment-related taxa captured in the 2015 samples may indicate that these invertebrates have drifted downstream from depositional areas upstream. Depositional conditions dominated by fine sediment are typical of low-gradient stream reaches.
- **Low dissolved oxygen:** Despite the elevated water temperatures downstream of Spanaway Lake, DO was generally above the water quality standards even directly below the lake (upstream of SW-1). However, the taxa indicate that a combination of slightly lower DO and elevated water temperature may be a stressor at SW-1, WSP2, and WSP4.
- **High water temperatures:** The invertebrates present are tolerant of warmer water, with no or very few cold-water species. This is likely due to the large amount of marsh, pond, and lake area upstream of these locations. The SW-1 site just downstream of Spanaway Lake shows biological evidence of high temperatures and possibly low DO.
- **Acute toxicity** is not indicated at any of the Spanaway Lake WSP sites by the benthic fauna.
- **Nutrient enrichment** is indicated at slight to moderate levels at the Spanaway Lake WSP2 only. Sites downstream of larger lakes typically support large numbers of filtering benthic invertebrates; however, this is not the case at SW-1.
- **Habitat simplification and microhabitat complexity is variable:** This stressor is low in some areas, but higher in others. As indicated by the benthic community composition, habitat complexity is low at SW-2, SW-1, and WSP2, but higher at WSP4.
- **Substrate embeddedness was high at WSP2, moderate at WSP4, and low at the other sites:** Because the degree of embeddedness directly affects the habitat quality of benthic macroinvertebrates, and high embeddedness frequently correlates to low B-IBI scores, this variable may help to explain some of the score differential between WSP2 and WSP4.

In summary, excessive flow, intermittent flow, “flashy” flow, or stagnant flow are not indicated as stressors to the benthic macroinvertebrate fauna at any of the sites. The most important stressors for stream biota in the Spanaway Lake watershed appear to be elevated water temperature and low habitat complexity. Elevated water temperatures appear to limit benthic organisms in Spanaway and Morey creeks downstream of Spanaway Lake. The elevated creek temperatures are due primarily to warming that occurs within Spanaway Lake during the summer months because of the lake’s long hydraulic residence time and large open water area. Some creek reaches downstream of the lake, such as the Spanaway Creek reach containing site WSP2, have limited riparian canopy. The lack of riparian shade exacerbates the temperature impacts of the lake. Actions to increase riparian shade in these reaches would help to mitigate the impact of the lake on downstream water temperatures.

Low habitat complexity appears to be another important limiting factor for benthic organisms in the Spanaway Lake WSP area. Some reaches (such as Spanaway Creek just downstream of Morey Creek) have been straightened and armored, and contain little large woody debris.

Unlike many other watersheds in the Puget Sound area, altered hydrology does not appear to be a stressor for benthic organisms in the Spanaway Lake WSP area. The Spanaway Lake WSP area is covered by very permeable soils. Nearly all runoff from impervious areas is infiltrated, so there is very little direct stormwater runoff to the lake or creeks. Groundwater is the main source of flow for the Spanaway Lake WSP surface water bodies.

None of the creek samples collected during the Spanaway Lake WSP monitoring period exceeded water quality criteria for copper or zinc. These monitoring results are consistent with the findings of the benthic data evaluation, which indicated that acute toxicity is not an issue in the Spanaway Lake WSP creeks.

While excessive fine sediment has been identified as a key stressor for many Puget Sound lowland streams (Dorfmeier 2014), fine sediment was observed only at WSP4 (Morey Creek), and dominance of fine substrate is normal and expected in this low-gradient, depositional reach. Higher embeddedness at WSP2 on Spanaway Creek may be significant; other sites had only low or moderate embeddedness.

5.6 Ecology Clover Creek Watershed Assessment

Ecology published the *Clover Creek Watershed Fecal Coliform, Dissolved Oxygen, and Temperature Source Assessment Report* in October 2016 (Ecology 2016a). Ecology conducted the study because water quality data showed that some water bodies in the Clover Creek watershed did not meet State criteria (WAC 173-201A) for fecal coliform, DO, and temperature (Ecology 2016c). The project was originally intended to support development of a TMDL. However, Ecology subsequently decided to support the County's "TMDL Alternative" approach rather than a TMDL for the watershed.

Ecology's monitoring program included fecal coliform, temperature, benthic macroinvertebrates, and periphyton. The Ecology study also assessed streamflow gains and losses. The Clover Creek Assessment did not include copper or zinc analyses, however.

The Clover Creek Assessment included monitoring of Spanaway and Morey creeks between March 2013 and February 2014. Four of Ecology's sites were located near WSP monitoring locations, as shown on Figure 5-4. As noted in Table 5-13, Ecology monitored fecal coliform at fixed-network and stormwater sample locations, continuous temperature from thermistors, diurnal DO concentrations, discharge measurements, riparian shade estimates, and macroinvertebrate and periphyton (Bio) samples.

Table 5-13. WSP Site IDs, Clover Creek Site IDs and Monitored Parameters

Clover Creek Assessment Report Site ID	Corresponding WSP Site	Clover Creek Assessment Report Site Description	Fecal Coliform Fixed Site	Fecal Coliform Storm Site	Temperature	DO	Discharge	Shade	Bio
SPA1.8	~SW-1	Spanaway Creek at Spanaway Park	✓	✓	✓	✓	✓	✓	✓
SPA1.4	~WSP2	Spanaway Creek at 138th St S	✓	✓	✓	-	✓	✓	-
SPA0.5	~WSP3	Spanaway Creek at Spanaway Loop Rd. S	✓	✓	✓	-	-	-	-
MORO.9	~WSP4	Morey Creek at Spanaway Loop Rd. S	✓	✓	✓	-	✓	✓	-
MORO.1	None	Morey Pond outlet to bypass at JBLM	✓	✓	✓	-	✓	✓	-

NA = this site does not correspond to a WSP location.

- = no samples collected.

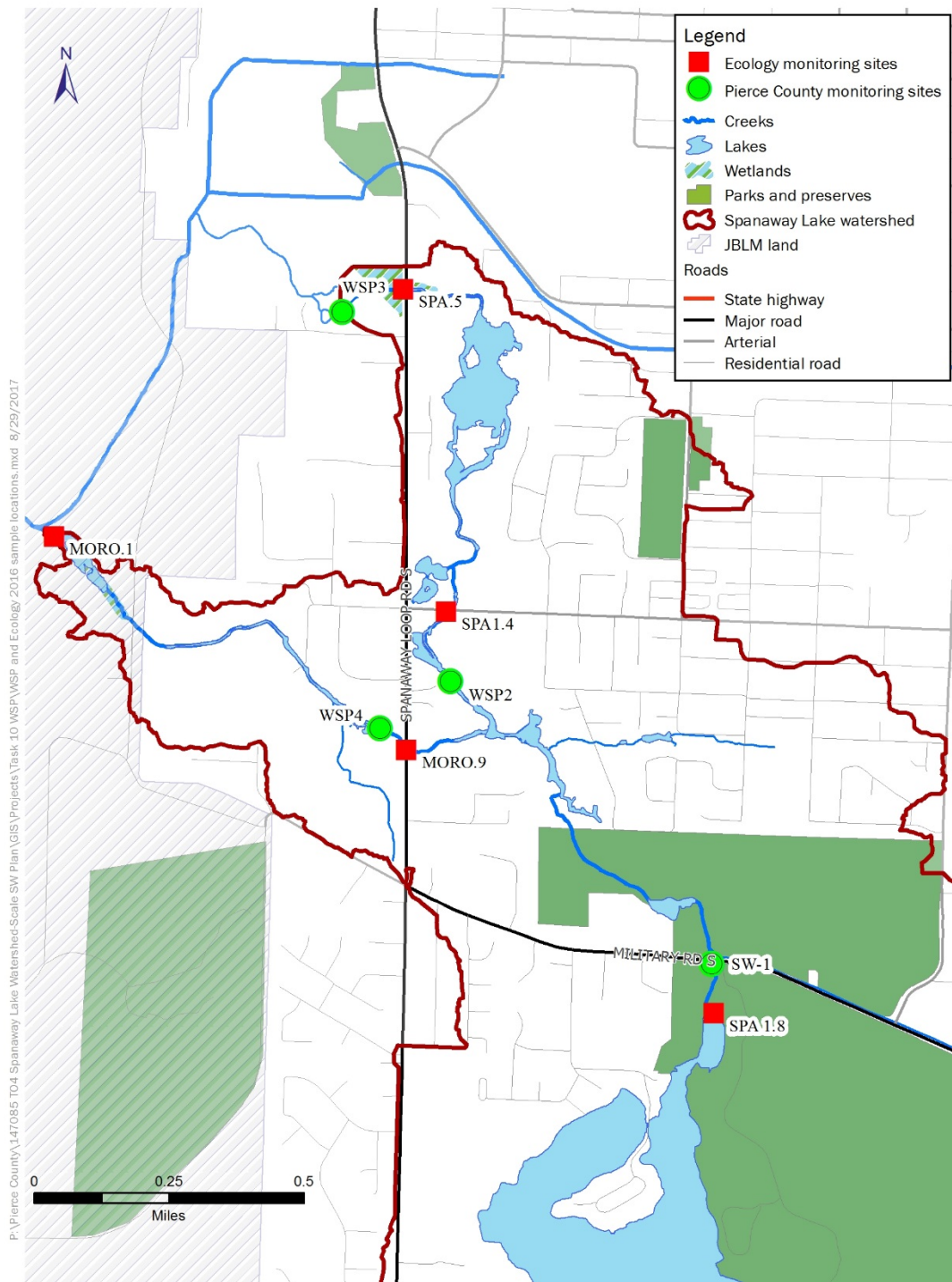


Figure 5-4. Spanaway Lake WSP and Ecology Clover Creek Assessment water quality monitoring locations

The amount of precipitation received within the Spanaway Lake watershed during the two monitoring periods was very different, which could be a reason for differing results in some of the parameters, such as fecal coliform bacteria. The monitoring period for Ecology's Clover Creek monitoring program occurred from March 2013 to February 2014, a total of 14 months. During this monitoring period, a total of 48.3 inches of precipitation was recorded at the Spanaway Golf Course weather station. The Spanaway Lake WSP monitoring program occurred from October 2014 to March 2016, a total of 18 months, with a total of 71.1 inches of precipitation recorded at the Spanaway Golf Course weather station. As can be seen on Figure 5-5, the total monthly precipitation values are significantly different from both monitoring programs. The wet season months (October–April) during Ecology's study totaled 27.3 inches. The Spanaway Lake WSP had wet seasons in 2015 and 2016, with totals of 28.4 and 38.8 inches, respectively. The dry season months (May–September) during Ecology's study totaled 14.7 inches, whereas the Spanaway Lake WSP's dry season months totaled 3.9 inches—an exceptionally dry season.

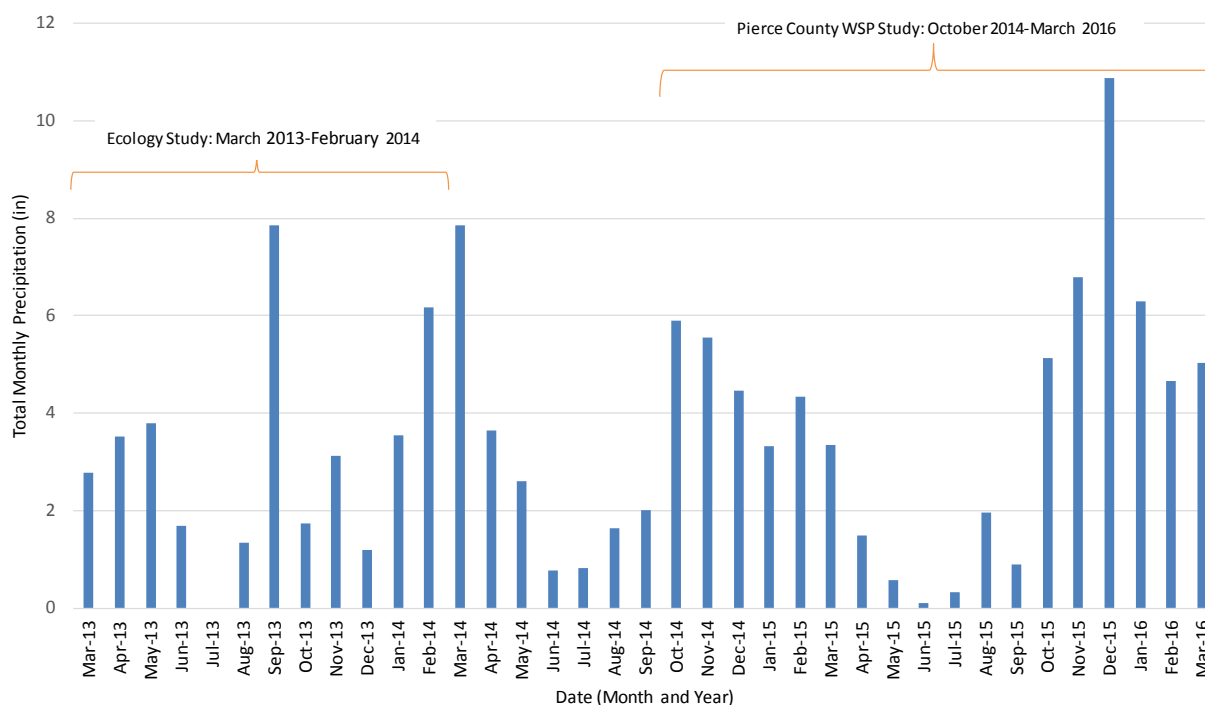


Figure 5-5. Total monthly precipitation during Ecology's and Pierce County's monitoring programs

5.6.1 Streamflow (Synoptic Gains/Losses)

Ecology measured instantaneous stream discharge biweekly at the study sites from March 2013 to February 2014, as summarized in Table 5-14.

Based on this study's findings, Spanaway Creek gained flow between the lake, SPA1.8 (~SW-1) and site below the split, SPA1.4 (~WSP2). The mean flow gain during this monitoring period ranged from 0.10 cubic foot per second (cfs) to 2.46 cfs. Flow was not measured at SPA0.5 (~WSP3) because the site was a wetland without discernible channel and flow direction (Ecology 2016b).

Spanaway Creek gained the most during average (almost 1.5 cfs) and maximum (approximately 1.0 cfs) flow conditions. A small amount was gained during minimum flow (approximately 0.3 cfs). Spanaway Creek flowed during the entire monitoring period (March 2013 and February 2014) and appeared less flashy than other parts of the Clover Creek watershed (Ecology 2016b).

From the 24 stream discharge measurements collected, the average flow for sites SPA1.8 (~SW-1) and SPA1.4 (~WSP2) were 18 cfs and 19 cfs, respectively. The minimum flows were 6.2 and 6.5 cfs and maximum flows were 33.0 and 34.0 cfs, respectively.

Morey Creek appeared to lose flow going downstream, between the split, MOR0.9 (~WSP4) and confluence with Clover Creek, MOR0.1. The mean flow loss during this monitoring period ranged from 4.77 to 0.00 cfs (Ecology 2016b).

Streamflow was higher at MOR0.9, near where it branched off from Spanaway Creek. Morey Creek lost at minimum (approximately 0.5 cfs), average (approximately 1.3 cfs), and maximum (approximately 3.5 cfs) flows. Morey Creek contributed an average of over 1.5 cfs (minimum approximately 0.5, maximum over 7.5 cfs) to Clover Creek.

Table 5-14. Instantaneous Stream Discharge Measurements in the Clover Creek Watershed

Ecology Site ID	SPA1.8 (~SW-1)	SPA1.4 (~WSP2)	MOR0.9 (~WSP4)	MOR0.1
Number of samples collected	24	24	23	24
Average daily flow (cfs)	18.0	19.0	2.9	1.6
Minimum daily flow (cfs)	6.2	6.5	1.0	0.5
Maximum daily flow (cfs)	33.0	34.0	11.0	7.7

5.6.2 Water Temperature

Ecology deployed temperature data loggers (thermistors) at each Spanaway Creek and Morey Creek monitoring location where there was streamflow from May to September 2013. Ecology staff downloaded loggers approximately every 4 weeks.

Each location exceeded the 7-DADMax of 17.5°C. The 7-DADMax temperature exceeded 17.5°C for more than 90 days at each location. A summary showing the 7-day average of daily maximum temperatures (°C) for each location is provided in Table 5-15.

Temperature measurements taken during site visits exceeded 17.5°C from June to September at SPA0.5 and SPA1.4. At SPA1.8, temperature exceeded the criterion from May to September.

Table 5-15. 7-Day Average of Daily Maximum Temperatures for Spanaway and Morey Creeks

Ecology Site ID	Date	7-DADMax (°C)
SPA1.8 (~SW-1)	7/1/2013 and 7/3/2013	25.3
SPA1.4 (~WSP2)	7/1/2013	22.6
SPA0.5 (~WSP3)	7/1/2013	25.4
MORO.9 (~WSP4)	7/1/2013	22.5
MORO.1	7/1/2013	24.8

The water temperature monitoring results from the WSP and Ecology study were comparable, with exceedances of the 7-DADMax water quality criterion of 17.5°C at each location. Although the temperature monitoring results were higher in the Spanaway Lake WSP study, the trends were the same in both studies.

5.6.3 Fecal Coliform Bacteria

Ecology collected creek samples within the vicinity of the WSP locations (SW-1, WSP2, WSP3 and WSP4) from March 2013 to February 2014, as summarized in Table 5-16, which shows that all the fecal coliform concentrations collected during the wet season (October through April) and the full year met the water quality criteria for *Primary Contact Recreation* at Spanaway and Morey creeks. During the dry season (May through September), SPA0.5 (~WSP3) did not meet the Part 2 criteria, which states that no more than 10 percent of samples can have concentrations exceeding 200 cfu/100 mL.

Ecology collected samples in the stream during one storm event, on June 13, 2013. Sample sites SPA1.8, SPA0.5, MORO.9, and MORO.1 exceeded the criterion for a single sample (200 cfu/100 mL), as shown in Table 5-16.

The Clover Creek assessment and the WSP fecal coliform results for the wet season were similar. The geomeans for SW-1 and SPA1.8 were 12 cfu/100 mL and 10 cfu/100 mL, respectively. The geomeans for WSP2 and SPA1.4 were 6 cfu/100 mL and 17 cfu/100 mL, respectively. The geomeans for WSP3 and SPA0.5 were 56 cfu/100 mL and 38 cfu/100 mL, respectively. The geomeans for WSP4 and MOR0.9 were 12 cfu/100 mL and 11 cfu/100 mL, respectively. All samples met Parts 1 and 2 of the water quality criteria during the wet season.

The WSP samples had higher geomeans than Ecology's samples collected during the dry season. The geomeans for SW-1 and SPA1.8 were 74 cfu/100 mL and 38 cfu/100 mL, respectively. Similarly, the geomeans for WSP2 and SPA1.4 were 166 cfu/100 mL and 74 cfu/100 mL, respectively. The geomeans for WSP3 and SPA0.5 were 124 cfu/100 mL and 71 cfu/100 mL, respectively. The geomeans for WSP4 and MOR0.9 were 373 cfu/100 mL and 49 cfu/100 mL, respectively. During the dry season, several WSP monitoring locations exceeded the water quality criteria, whereas only one Ecology location (SPA0.5) did not meet the Part 1 criteria. These differences could be due at least in part to differences in weather and streamflow conditions. The weather was unusually warm and dry when much of the Spanaway Lake WSP monitoring was conducted.

A general comparison for the full year results shows that the WSP sample locations did not meet the Part 2 criteria for locations WSP2, WSP3, and WSP4, whereas all of Ecology's sample locations did. Again, this could be attributable at least in part to the unusually warm and dry weather during the Spanaway Lake WSP monitoring period.

Table 5-16. Fecal Coliform Bacteria (cfu/100 mL) Results from the Ecology Clover Creek Assessment (3/2013-2/2014)

Ecology Site ID (~WSP Site ID)	Wet Season			Dry Season			Full Year			6/13/2013 Storm Event Sample
	Count	Geomean	Percent of Samples > 200	Count	Geomean	Percent of Samples > 200	Count	Geomean	Percent of Samples > 200	
SPA1.8 (~SW-1)	13	10	0	10	38	10	23	18	4	220
SPA1.4 (~WSP2)	13	17	0	10	74	0	23	33	0	190
SPA0.5 (~WSP3)	13	38	0	10	71	20	23	50	9	250
MORO.9 (~WSP4)	11	11	0	10	49	10	21	22	5	220
MORO.1 ^a (NA)	13	9	0	10	10	10	23	17	4	310

ND = non-detect. (Geomean calculations used a value of 0.001 for concentrations below detection limits.)

Values in bold exceed criteria.

Wet season is from October 1 through April 31. Dry season is from May 1 through September 30.

The water bodies downstream of the lake (SPA1.8 [~SW-1], SPA1.4 [~WSP2], SPA0.5 [~WSP3], MORO.9 [~WSP4], and MORO.1) are designated for primary contact; the geometric mean fecal coliform concentration must not exceed 100 cfu/100 mL, and less than 10% of samples should have concentrations exceeding 200 cfu/100 mL.

a. Distribution is not normally distributed based on Shapiro-Wilk Normality Test; difference between the seasons determined to be statistically significant.

5.6.4 Aquatic (B-IBI and Periphyton)

Ecology conducted a riparian assessment to determine percent of effective shade and canopy cover, diurnal surveys for DO in August and December 2013, and a collection of benthic macroinvertebrates and periphyton to conduct a bioassessment of the Clover Creek watershed, as summarized below.

5.6.4.1 Riparian Corridor

Ecology measured percent average canopy cover and effective shade using hemispherical photography. Hemispherical digital photographs were taken from July 22 to August 1, 2013. Photographs were taken looking upward from beneath the plant canopy, using a 180-degree fish-eye lens and digital camera. Images were generally taken in the middle of a stream channel (Ecology 2016b).

Canopy cover is the percentage of the sky that is blocked by vegetation or topography. Effective shade is the fraction of total possible solar radiation above the vegetation and topography that is blocked from reaching the surface of the stream and summed over a full day (Ecology 2016b).

Monitoring locations that had the highest effective shade were SPA1.8 (~SW-1) and MOR0.9 (~WSP4), both at slightly over 80 percent. The percent average effective shade was relatively low at SPA1.4 (~WSP2) at 21.6 percent. Monitoring results from Morey Creek showed that the percent average effective shade was higher at the upstream site (MOR0.9 at 82.1 percent) than at the downstream site (MOR0.1, 53.2 percent).

5.6.4.2 Diurnal Surveys for Dissolved Oxygen

Ecology conducted a diurnal survey for DO from August 26–29, 2013, at SPA1.8 (~SW-1). The DO criterion for Spanaway Creek is 8.0 milligrams per liter (mg/L). SPA1.8 fell below the daily minimum DO water quality criterion on August 27 and had a very pronounced diurnal fluctuation (Ecology 2016b).

Ecology deployed a multi-probe logging temperature, conductivity, pH, and DO at half-hour intervals from December 16–19, 2013, at SPA1.8. Results showed that the monitoring location met the water quality criteria.

Ecology collected DO measurements biweekly at the Spanaway and Morey creek monitoring sites from March 2013 to February 2014 (these DO measurements did not occur at the same time of day and do not account for diurnal fluctuations in DO). All DO measurements taken at the Spanaway Creek locations were above the 8.0 mg/L criterion (Ecology 2016b).

The minimum and 10th percentile of DO concentration collected at the Morey Creek site visits were below the criterion of 8.0 mg/L. DO at MOR0.1 was below 8.0 mg/L from July to September. DO at MOR0.9 (~WSP4) was below 8.0 mg/L from June to December (Ecology 2016b).

5.6.4.3 Bioassessment Sampling

Ecology collected benthic macroinvertebrate and periphyton samples during the first 2 weeks of October 2013 at SPA1.8 (~SW-1). The biological condition at SPA1.8 was classified as “very poor.” Taxa richness was reduced at SPA1.8 compared to the reference sites, as was richness of all *Ephemeroptera-Trichoptera-Plecoptera* (EPT) taxa. Clinger, long-lived, predator, dominant, and nitrogen autotroph taxa richness was also reduced. The proportion of dominant and tolerant species was higher at SPA1.8. No intolerant taxa were collected at SPA1.8 (Ecology 2016b).

Comparing the periphyton metrics for SPA1.8 to the reference sites, SPA1.8 had higher Shannon diversity and taxa richness values, had a higher percentage of two taxa groups that are indicators of elevated nutrient levels, a higher percentage of facultative nitrogen heterotroph taxa, higher percentages of eutraphentic taxa, higher percentages of low DO, higher percentages of motile and siltation taxa compared to the reference sites, and higher percentages of metals-tolerant and acidophilous taxa. The periphyton data indicate possible nutrient enrichment and low DO conditions.

The overall B-IBI scores from both studies are comparable, showing very poor quality near SW-1.

SECTION 6: MODELING RESULTS

This section summarizes the watershed model calibration and simulation results for the Spanaway Lake WSP. Appendices E and F contain detailed descriptions of the HSPF and MODFLOW models, respectively.

6.1 Spanaway Lake WSP Model Calibration for Flow

Calibration consists of the process of adjusting model parameters to produce results that match with observed data. Calibration was based on the approximately 18 months of monitoring data collected for the project. A weight-of-evidence approach was used where the calibration relied on graphical comparisons and statistical tests (Donigian 2002).

Calibration consisted of iteratively adjusting model parameters and groundwater RCHRES representation to produce results that match with observed data. Calibration was based on the approximately 18 months of monitoring data collected for the project. A weight-of-evidence approach was used where the calibration relied on graphical comparisons and statistical tests (Donigian 2002). In addition to comparisons of flow, volume, and hydrographs at each gage location for the entire calibration period, model performance was characterized with statistical evaluation of hourly, monthly, seasonal, low-flow, and peak flow data. The statistical comparisons of the hourly data are provided in Table 6-1 and Table 6-2.

Table 6-1 represents model performance based on continuous hourly simulations for the available period of record (regardless of data quality), per gage location.

Table 6-1. Calibration Summary Statistics of Hourly Flow Rates

Statistic	Spanaway Creek Outlet (SW-1)	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)
Mean error (cfs)	0.89	0.95	-0.46	-1.00
Mean absolute error (cfs)	4.49	2.47	4.09	2.75
Root mean square error (RMSE) (cfs)	5.46	3.77	6.00	4.02
Pearson coefficient (R)	0.97	0.90	0.93	0.93
r-square	0.94	0.81	0.86	0.86
Nash-Sutcliffe coefficient (E)	0.93	0.79	0.85	0.85
Skill score	0.74	0.55	0.61	0.61

For the first three statistics, a value of 0 would indicate an exact match between the model results and the observed data.

For the last four statistics, a value of 1 would indicate an exact match between the model results and the observed data. These statistics measure the following: Pearson coefficient: correlation, r-square: variance, Nash-Sutcliffe: correlation taking into account data variability and Skill score: predictive capability

Table 6-2 summarizes how well the model simulates a broader spectrum of flow rates grouped into five thresholds. The table represents model performance based on continuous hourly simulations for the available period of record (regardless of data quality), per gage location. The table shows that the model performs well for higher flows, and tends to over-predict lower flows (except for Spanaway Creek 1). Additional calibration results and discussion on quality of observed data are provided in Appendix E.

Table 6-2. Calibration Summary of Flow Rate Quantiles Characterizing Various Flow Rate Magnitudes

Statistic	Spanaway Creek Outlet (SW-1)	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)
Mean	3%	12%	-2%	-12%
90th percentile	-5%	<1%	-1%	-13%
75th percentile	-4%	24%	-2%	-21%
50th percentile	11%	32%	-1%	-9%
25th percentile	11%	25%	-27%	57%
10th percentile	80%	57%	21%	5%

6.2 Water Quality Calibration

The following sections summarize the HSPF model calibration for temperature, fecal coliform, dissolved copper, and dissolved zinc.

6.2.1 Temperature

Table 6-3 summarizes the Spanaway Lake WSP model calibration statistics for temperature at each site. The calibration statistics indicate that the model-simulated temperatures are close to observed temperatures for all WSP locations.

Statistic	Spanaway Lake (LW-1)^a	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)
Mean error (°F)	-0.06	-0.60	-0.56	-0.32
Root mean square error (RMSE) (°F)	2.04	1.97	2.61	2.44
Mean relative percent difference (RPD)	-0.1 %	-1.2 %	-1 %	-0.6 %
r-square	0.97	0.90	0.93	0.93

a. The simulated reach more closely resembles Spanaway Lake than Spanaway Creek in terms of temperature, so observed data from lake monitoring site LW-1 were used for calibration rather than creek monitoring data from SW-1.

6.2.2 Fecal Coliform

Fecal coliform concentrations are widely variable and difficult to measure and simulate in a hydrologic model. In particular, it is difficult to simulate short-term spikes unrelated to stormwater runoff, such as direct fecal contamination from waterfowl or riparian animals. The Spanaway HSPF model simulates fecal coliform loads that build up and wash off the land surface but the model does not simulate fecal coliform loads from waterfowl or other riparian wildlife that defecate directly into water bodies.

Figures 6-1 and 6-2 show the time series of observed and simulated fecal coliform, along with streamflow for each WSP location. The highest fecal coliform concentrations were observed during the dry season, which is indicative of a non-stormwater source. Also, because of the permeable soils and extensive use of infiltration and LID measures, there is relatively little runoff from the land surface. As a result, the model simulated very little wash-off of fecal coliform, except during storms in winter 2014, at the end of August 2015, at the end of October 2015, and during the winter of 2015-2016.

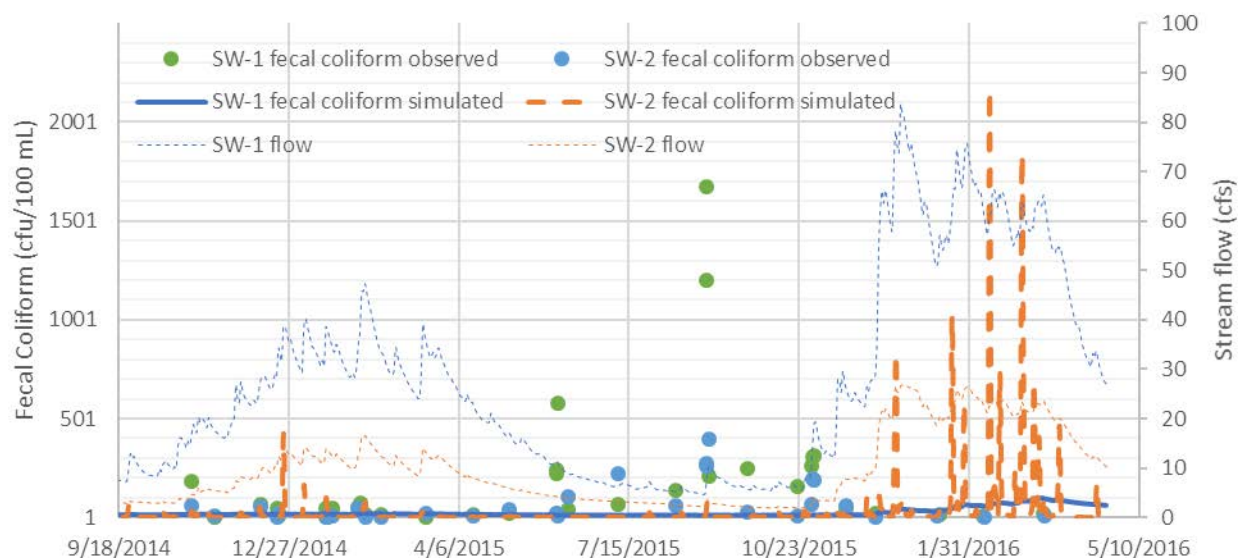


Figure 6-1. Time series of calibrated fecal coliform for Spanaway Creek Outlet (SW-1) and Coffee Creek Inlet (SW-2)

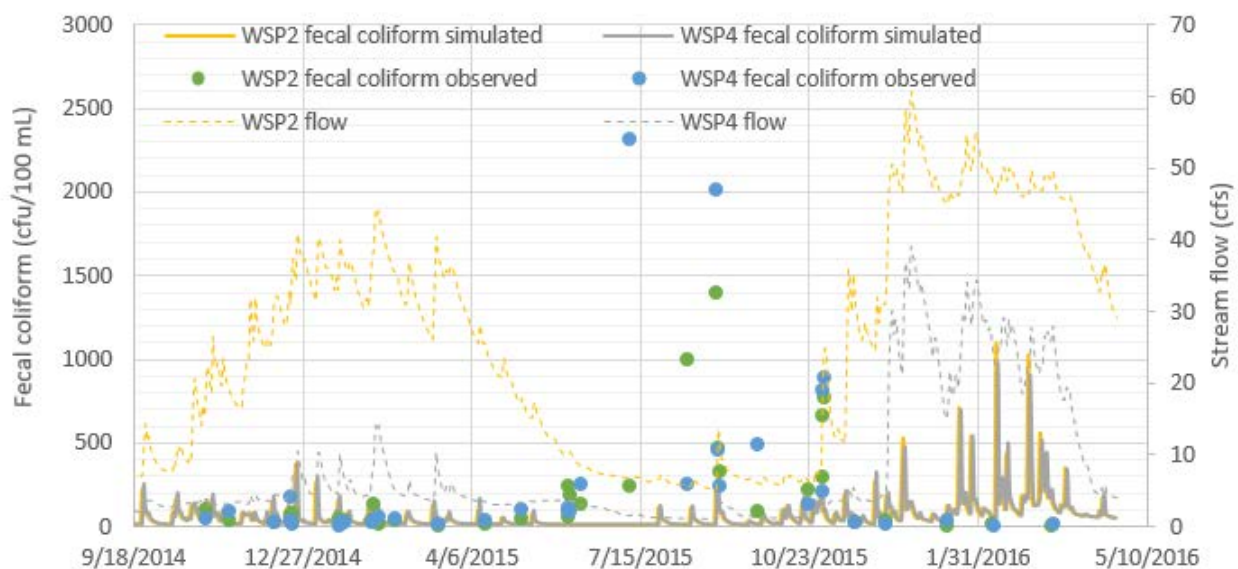


Figure 6-2. Time series of calibrated fecal coliform for Spanaway Creek 1 (WSP2) and Morey Creek (WSP4)

Because the model was not able to simulate short-term spikes of the non-storm inputs of fecal coliform, efforts were made to match the geometric mean of the observed data to the geometric mean of simulated data, in particular for the wet season when fecal coliform related

to stormwater runoff would be more prevalent. The model could not represent the full log-normal distribution of observed fecal coliform data, primarily representing a smaller distribution with values close to the geometric mean, with a smaller proportion of values in the high end of the distribution compared to the observed data. Statistical comparison of the observed and simulated data was done to provide context rather than presenting a threshold of acceptability. Table 6-4 provides a summary of the Spanaway Lake WSP model results for fecal coliform. Appendix E contains a detailed discussion of the water quality model.

Table 6-4. Summary Statistics for Calibration of Wet Season Fecal Coliform				
Statistic	SW-1 (Spanaway Creek Outlet)	SW-2 (Coffee Creek inlet)	WSP2 (Spanaway Creek 1)	WSP4 (Morey Creek)
Mean error (cfu/100 mL)	73	33	46	56
Geometric mean observed (cfu/100 mL)	39	17	49	48
Geometric mean simulated (cfu/100 mL)	17	12	46	48
Geometric mean observed: wet season (cfu/100 mL)	31	13	34	34
Geometric mean simulated: wet season (cfu/100 mL)	19	15	64	68

6.2.3 Dissolved Copper and Zinc

Dissolved copper concentrations were below detection limits ($<0.5 \mu\text{g/L}$) in most samples collected for the Spanaway Lake WSP. Because of the limited number of detects, the calibration was performed by visually matching the model dissolved concentrations to the detected data and non-detect levels rather than developing any statistical comparison. Plots of the graphical calibration are included in Appendix E, the *Model Development and Calibration* report, for each WSP location. The model was calibrated to reproduce approximately the non-detect level of dissolved copper as a background concentration, and represent the slight spikes in dissolved copper during several storms in the observation period.

The creek and lake samples contained low concentrations of dissolved zinc, with many samples below detection limits. Because of the limited number of detects, the zinc calibration was performed by visually matching the model dissolved concentrations to the detected data and non-detect levels rather than developing any statistical comparison. Plots of the graphical calibration are included in Appendix E, the *Model Development and Calibration* report, for each WSP location. The model was calibrated to reproduce approximately the non-detect level of dissolved zinc as a background concentration, and represent the slight spikes in dissolved copper during several storms in the observation period.

6.3 Modeling Scenario Results

This section provides summary water quality, hydrologic metric, and benthic results of the benchmark, historical, and full buildout scenarios.

The water quality model results were compared to the water quality criteria to identify potential excursions for water temperature, fecal coliform bacteria, dissolved copper, and dissolved zinc. The runoff model results were used to calculate hydrologic metrics and predict B-IBI scores, which were then compared to Ecology's benchmarks. The following sections describe the findings.

6.3.1 Water Temperature

Water temperatures exceeded the numerical criterion (7-DADMax of 17.5°C) in Spanaway Lake and in Spanaway and Morey creeks downstream of the lake during much of summer 2015. The monitoring results show that warming in Spanaway Lake was the primary cause for the elevated water temperatures observed in Spanaway and Morey creeks downstream of the lake. 7-DADMax values in Spanaway Lake exceeded 27.5°C in July 2015. The warmest temperatures were observed at SW-1 just downstream of the lake. Water temperatures were slightly lower at WSP2 and WSP4, potentially due to groundwater inflows and a thick riparian canopy along Spanaway Creek just downstream of SW-1. Warming in Tule Lake could contribute to elevated temperatures in Spanaway Creek downstream of the lake.

Table 6-5 summarizes the HSPF temperature modeling results for the existing, historical, and future scenarios. The table shows that 7-DADMax values are predicted to exceed 17.5°C in Spanaway Lake and the creeks downstream of the lake.

Table 6-5. Average Days/Year Simulated 7-DADMax Water Temperature Exceeds 17.5°C				
Model Scenario	SW-1 (Spanaway Creek Outlet)	SW-2 (Coffee Creek inlet)	WSP2 (Spanaway Creek 1)	WSP4 (Morey Creek)
Historical	141	0	112	109
Existing	142	2	119	134
Future (full buildout)	141	0	129	140

Spanaway Lake is a natural lake with no man-made control structures. The lake is fed primarily by groundwater. The lake has a long hydraulic residence time and a large open-water area. Its large open-water area means that shoreline shading has limited impact on water temperature. Thus, the observed warming in Spanaway Lake appears to be due to natural conditions.

For lakes and other water bodies that exceed 17.5°C 7-DADMax because of natural conditions, human actions considered cumulatively may not increase the 7-DADMax by more than 0.3°C (0.54°F). As shown in Table 6-6, the HSPF simulations indicate that future 7-DADMax values are within 0.3°C of historical conditions near the Spanaway Lake outlet (SW-1). These model results indicate that SW-1 would meet the temperature criterion, even though it often exceeds 17.5°C 7-DADMax. The temperature model results for Spanaway Creek and Morey Creek downstream of SW-1 indicate that simulated current and future conditions are more than 0.3°C warmer than simulated historical conditions. The simulated increase in temperatures is likely due to less riparian shade compared to historical conditions; the future (full buildout) scenario maintains the same assumptions for shade related to vegetated or unvegetated riparian buffer as the existing conditions.

Table 6-6. Average Days/Year Simulated 7-DADMax Water Temperature is >0.3°C above Historical

Model Scenario	SW-1 (Spanaway Creek Outlet)	WSP2 (Spanaway Creek 1)	WSP4 (Morey Creek)
Existing	1	178	266
Future (full buildout)	0	259	302

6.3.2 Fecal Coliform

Fecal coliform concentrations exceeded the criteria at most monitoring locations during the WSP monitoring period (October 2014–March 2016), as described in Section 5.4 above. In contrast, Ecology’s 2013–14 study found that the sites within the Spanaway Lake WSP area met the criteria (Ecology 2016b). Both the WSP and Ecology monitoring found that fecal coliform concentrations in the creeks were higher during the dry season than during the wet season. Potential fecal coliform sources include septic systems, direct stormwater runoff, stormwater infiltration facilities, and riparian wildlife. Regrowth in bottom sediment is another potential fecal coliform source.

The Spanaway Lake WSP model simulated geomean fecal coliform concentrations reasonably well, but underestimated the occasional high values or spikes and overestimated wet weather values during the winter of 2015-2016. Overall, the model results may underestimate the frequencies of exceedance of Part 2 of the fecal coliform criteria. The underestimation of fecal coliform spikes may be related to the “buildup/wash-off” method that HSPF uses to simulate fecal coliform. The model does not simulate direct fecal coliform loading from waterfowl or other riparian sources.

Because the model was not able to represent the distribution of fecal coliform in the observed data, calculations of geomean or 90th percentile exceedances for the simulated data showed no exceedances for historical, existing, or future conditions. The existing conditions results do not reflect the observed exceedances, probably because the HSPF model simulates a small amount of runoff-related fecal coliform but does not simulate direct inputs from riparian sources.

As noted above, potential fecal coliform sources in the Spanaway Lake WSP area include septic systems, direct stormwater runoff, stormwater infiltration facilities, and riparian wildlife. The following bullets discuss each potential source:

- **Septic systems:** Septic system surface failures are very rare in the Spanaway Lake WSP because of the very permeable soils and depth to groundwater. To evaluate the potential for subsurface impacts, BC developed a spreadsheet model to estimate fecal coliform loads from septic systems in the watershed based on typical fecal coliform concentrations in drainfield effluent, location/distance to lake, estimated depth to groundwater, and technical literature on subsurface transport and die-off rates (BC 2016). The evaluation indicated that septic systems more than 350 feet upgradient of surface waters are unlikely to contribute fecal bacteria because of filtering, adsorption, and die-off.

As shown in Figure 6-3, 60 septic systems are in groundwater capture zones within 350 feet upgradient of gaining lake and creek reaches. The groundwater capture zones were delineated using the calibrated MODFLOW model as described in Appendix F. About 48 of these septic systems are in areas where the estimated depth to groundwater is less than 10 feet.

The risk of fecal coliform reaching the water table depends on the type and age of the drainfield system and the depth to groundwater. The risk is highest for older systems with a thin vadose zone (unsaturated layer above the groundwater table) and non-pressurized drainfield. Shallow septic systems (<10 feet to groundwater) are likely to have fecal coliform removal efficiencies on the order of 2- to 4-log removals (99.00 to 99.99 percent) in the vadose zone before mixing with the groundwater.

TPCHD reported a mean concentration of about 750,000 cfu/100 mL in drainfield effluent from new pressurized systems in the Spanaway, Tillicum, and Bethel areas (TPCHD 1994). 1-log removal would result in a concentration of 75,000 cfu/100 mL, while 4-log removal would result in 75 cfu/100 mL. These estimates could be high because they do not account for mixing and dilution with groundwater (BC 2016). Nevertheless, these results indicate that fecal bacteria from shoreline septic systems could reach receiving water bodies.

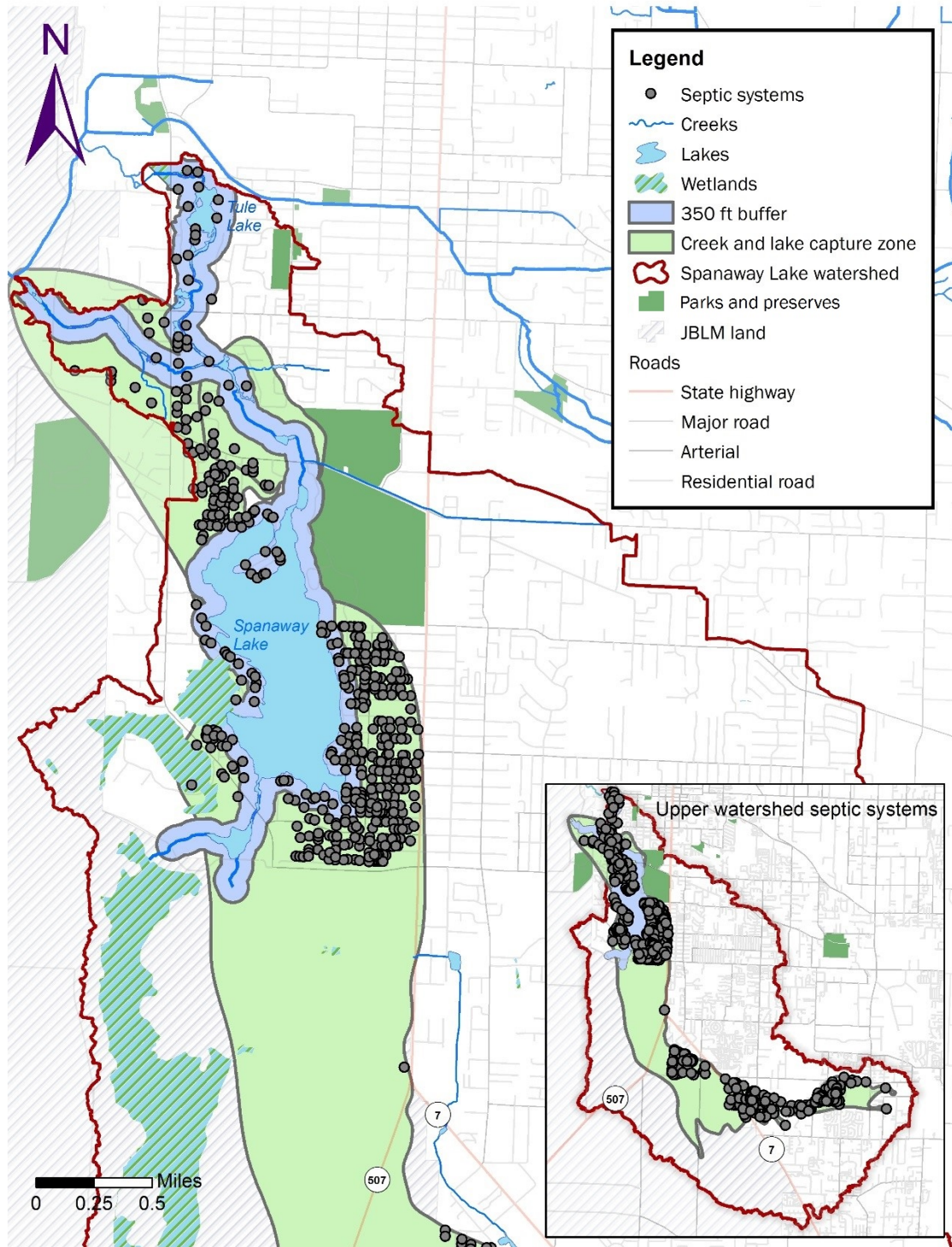


Figure 6-3. Septic systems located within groundwater capture zones for receiving water bodies

- **Direct stormwater runoff:** Stormwater runoff from developed areas often contains elevated fecal coliform concentrations from domestic animals and wildlife. Livestock have been observed in shoreline areas downstream of Morey Creek. Runoff can also contain bacteria from human sources such as failing septic systems and homeless camps.

Because of the very permeable soils and lack of surface conveyance systems, there is little direct stormwater runoff to the lakes or creeks in the Spanaway Lake WSP area. The Military Road outfall is the only MS4 outfall with an appreciable catchment area (see Figure 6-4). HSPF model results indicate that this outfall contributes less than 2 percent of the average annual flow volume and about 20% of the annual fecal coliform load in Spanaway Creek at Military Road. The County has retrofitted the catchment area with low-impact development (LID) and other infiltration facilities to reduce flow volume. In 2012, the County installed a hydrodynamic separator just above the outfall to treat stormwater prior to discharge.

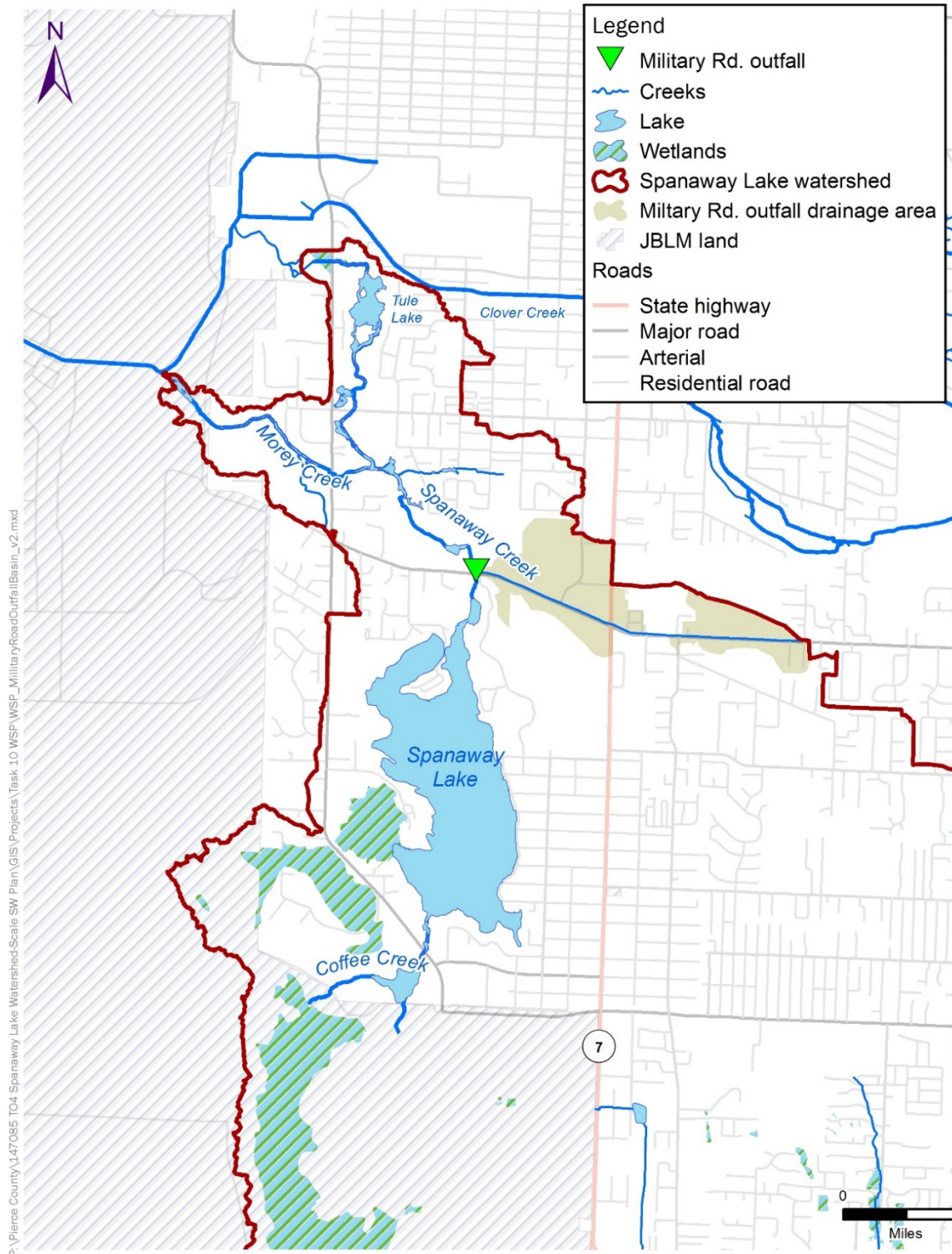


Figure 6-4. Military Road sub-basin

- **Stormwater infiltration:** The WSP area contains more than 1,400 stormwater infiltration facilities including drywells, infiltration trenches, and infiltration ponds or basins. TPCHD septic system records indicate that surface failures are very rare because of the very permeable soils and groundwater conditions. As discussed above, evaluation of local soil and groundwater data found that septic systems more than 350 feet upgradient are unlikely to contribute appreciable fecal coliform to the lakes or creeks in the Spanaway Lake WSP. Fecal coliform concentrations in stormwater are typically several orders of magnitude lower than fecal coliform concentrations in septic system drainfield effluent. Therefore, stormwater infiltration facilities more than 350 feet upgradient of receiving water bodies are not expected to be a significant source of fecal coliform in the Spanaway Lake WSP area. Moreover, stormwater facilities upgradient of “losing” surface water bodies (i.e., water bodies or reaches that do not receive groundwater discharge) are unlikely to be a source of fecal coliform to those water bodies.

Figures 6-5 and 6-6 show the stormwater drywells and infiltration ponds located in the groundwater capture zones within 350 feet of a receiving water body. As shown in Figure 6-5, approximately 20 drywells are located within 350 feet upgradient of receiving water bodies that gain groundwater inflow. Five of these have been retrofitted by replacing the old single-stage drywells with two-stage systems consisting of a treatment vault to remove sediment and floatables and an infiltration pipe.

As shown in Figure 6-6, two infiltration ponds are located in groundwater capture zones within 350 feet of receiving water bodies. One of these ponds was constructed before 1997, when the County began requiring water quality treatment prior to infiltration to be equivalent with *the Stormwater Management Manual for Western Washington* (SWMMWW).

Another pre-1997 infiltration pond is located within 350 feet of Spanaway Creek, just upstream of Tule Lake (Figure 6-6). This pond is not in a groundwater capture zone, which means that infiltrated stormwater from the pond does not enter the creek. The pond is so close to the creek that it might be possible for overflows to reach the creek on the ground surface. However, the pond was designed to infiltrate a 100-year event so overflows should be rare.

Ecology’s WSP guidelines suggest that infiltration facilities designed according to SWMMWW criteria should be assumed to remove 100 percent of fecal coliform (Ecology 2016e). Thus, the stormwater infiltration facilities in the Spanaway Lake WSP area are not expected to be a significant source of fecal coliform bacteria to surface water bodies.

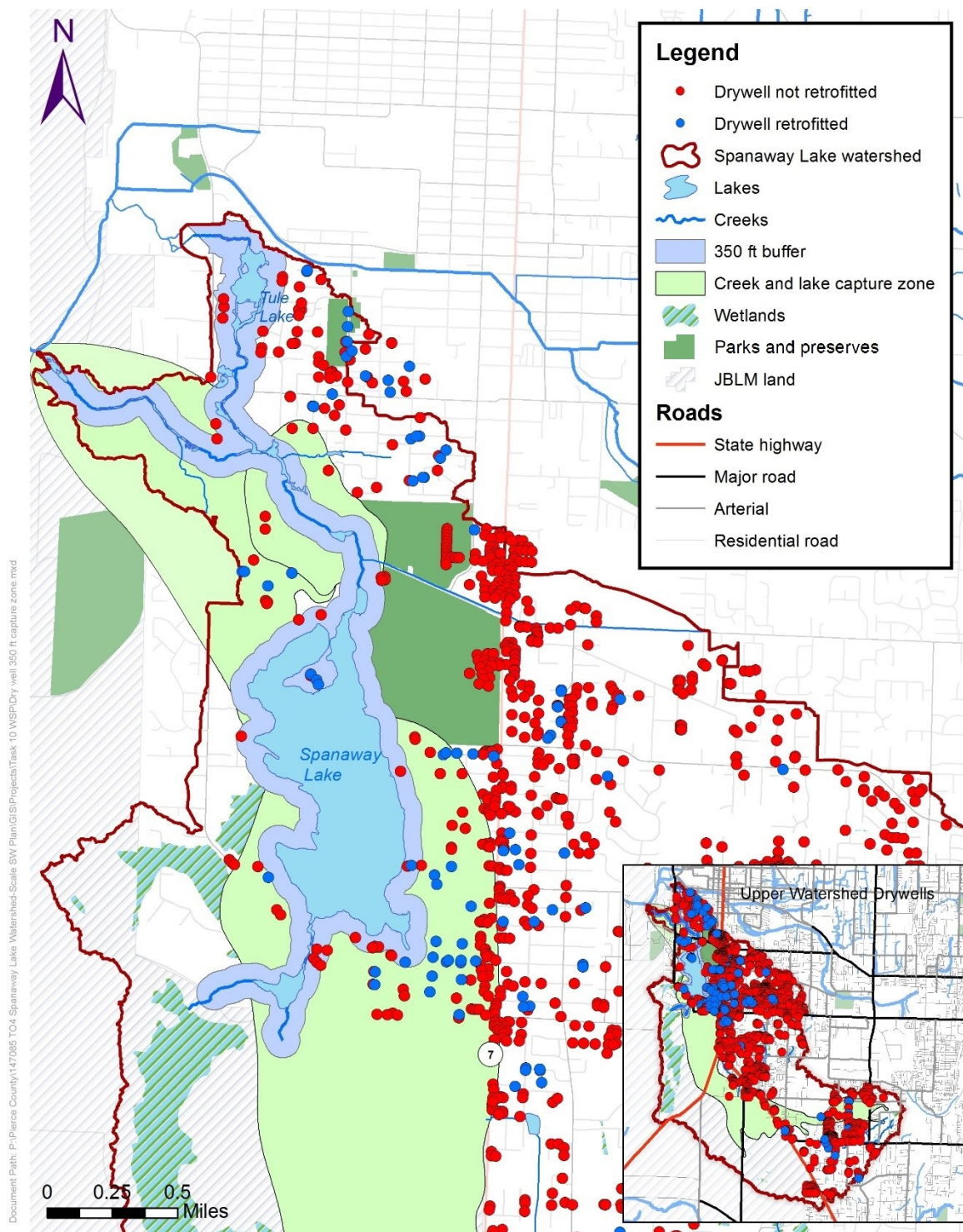


Figure 6-5. Stormwater drywells located within 350-foot capture zone of receiving water body

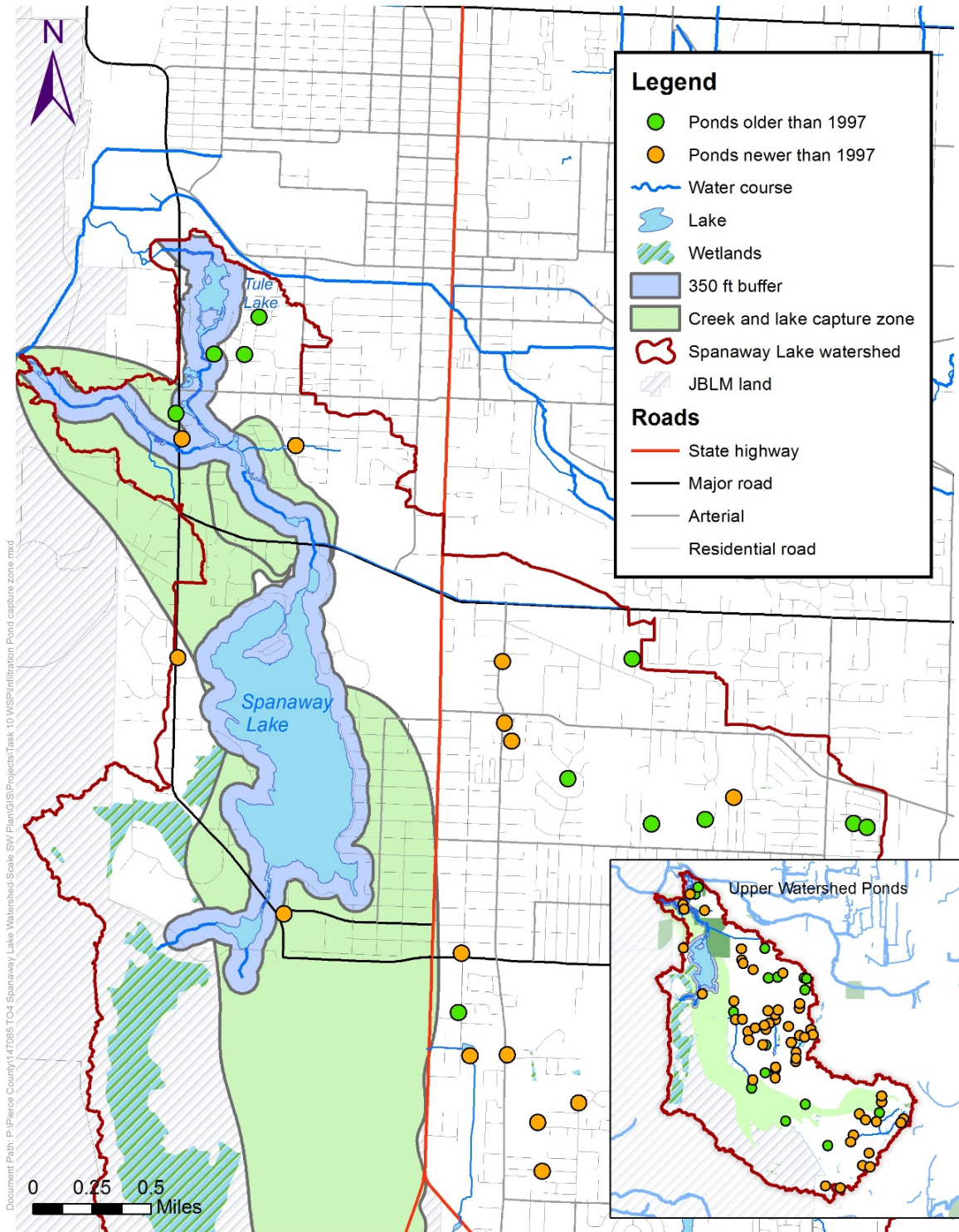


Figure 6-6. Infiltration ponds within 350 feet of receiving water body and groundwater capture zones

- **Waterfowl.** Waterfowl and other riparian wildlife appear to be an important source of fecal coliform bacteria in the Spanaway WSP area. The Spanaway LMP identified waterfowl as a potentially significant source of fecal coliform to Spanaway Lake based on reported waterfowl counts and technical literature on fecal production rates (BC 2016). Based on land use and other observed data, wildlife is the likely source of the elevated fecal coliform concentrations measured at the JBLM marsh. As noted above, the marsh provides habitat for more than 20 species of waterfowl and 110 other bird species (ebird.org 2017). Wildlife that defecate directly into the water can cause spikes in fecal coliform concentrations during dry weather when there is no runoff from shoreline areas. Fecal deposits on shoreline areas are also a potential source but, as noted above, surface runoff is limited by the very permeable soils.

6.3.3 Dissolved Copper and Zinc

The monitoring results indicate that the Spanaway Lake WSP water bodies currently meet the water quality criteria for copper and zinc (see Appendix C). The lack of exceedances may be due at least in part to the lack of direct stormwater discharges to surface water bodies. Pervious areas in the watershed generate little surface runoff because of the highly permeable soils. Nearly all stormwater from impervious areas is infiltrated through LID measures (e.g., dispersion onto adjacent pervious areas) or through infiltration facilities. Dissolved copper concentrations were below detection limits ($< 0.5 \mu\text{g/L}$) in all groundwater samples collected for this study. Dissolved zinc concentrations in groundwater were also low except for two anomalous samples collected at Spanaway Park. These low concentrations are consistent with Ecology's WSP guidelines, which suggest that infiltration facilities designed according to SWMMWW criteria should be assumed to remove 100 percent of copper and zinc (Ecology 2016e).

Tables 6-7 and 6-8 summarize the HSPF modeling results for dissolved copper and zinc under the historical, existing, and future (full buildout) scenarios. The table lists the highest 1-hour dissolved copper and zinc concentrations for the 65-year simulation period, together with the lowest measured hardness values and corresponding water quality criteria for each site. As shown in the table, the maximum simulated 1-hour copper and zinc concentrations for historical conditions are well below the acute and chronic criteria calculated based on the lowest observed hardness. Simulated existing-conditions concentrations show similar results—maximum concentrations well below water quality criteria. Thus, the model results indicate that copper and zinc exceedances are very unlikely under current full buildout conditions.

Most of the Spanaway Lake WSP area is well-suited to LID and infiltration practices and such practices are widely used today. New development and redevelopment will continue to rely on LID and other infiltration practices so direct stormwater discharge is not expected to increase over existing conditions.

Washington’s “Better Brakes Law,” enacted in 2010, should provide additional insurance against future exceedances for copper. Brake pads account for about 50 percent of copper loading in urban areas. The Better Brakes Law should effectively eliminate this source of copper by 2025 (Ecology 2017).

Table 6-7. Simulated Dissolved Copper Results under Existing, Historical and Future Scenarios

Water Quality Criteria/Spanaway Lake WSP Model Run	Unit	SW-1 (Spanaway Creek Outlet)	SW-2 (Coffee Creek Inlet)	WSP2 (Spanaway Creek 1)	WSP3	WSP4 (Morey Creek)
Minimum hardness ^a	mg/L	31	22.8	30.1	25.8	30.2
Copper acute life criteria: freshwater—acute	µg/L	5.6	4.2	5.5	4.7	5.5
Copper acute life criteria: freshwater—chronic	µg/L	4.2	3.2	4.1	3.6	4.1
Maximum Simulated Concentrations						
Existing condition	µg/L	0.4	2.4	0.8	0.9	0.8
Historical condition	µg/L	0.5	1.2	0.7	0.7	0.7
Future condition	µg/L	0.4	0.8	1.0	0.9	1.0

a. Minimum observed hardness from monitoring data

Table 6-8. Simulated Dissolved Zinc Results under Existing, Historical, and Future Scenarios

Water Quality Criteria/Spanaway Lake WSP Model Run	Unit	SW-1 (Spanaway Creek Outlet)	SW-2 (Coffee Creek Inlet)	WSP2 (Spanaway Creek 1)	WSP3	WSP4 (Morey Creek)
Minimum hardness ^a	mg/L	31	22.8	30.1	25.8	30.2
Zinc acute life criteria: freshwater—acute	µg/L	42.4	32.7	41.4	36.3	41.5
Zinc acute life criteria: freshwater—chronic	µg/L	38.7	29.9	37.8	33.2	37.9
Maximum Simulated Concentrations						
Existing condition	µg/L	0.6	1.5	0.8	0.7	0.8
Historical condition	µg/L	0.8	1.2	0.8	0.8	0.8
Future condition	µg/L	0.6	1.0	0.9	0.8	0.9

a. Minimum observed hardness from monitoring data.

6.3.4 Hydrologic Flashiness Metrics

Altered hydrology has been identified as a key factor limiting B-IBI scores in the Puget Sound lowlands (DeGasperi et al. 2009; Horner 2012). For this reason, the Permit requires calculation of metrics to assess the nature and extent of hydrologic alterations due to development.

Table 6-9 lists the hydrologic metrics calculated for the Spanaway Lake WSP sites based on the Spanaway Lake WSP model simulations for historical and current watershed land use/land cover conditions and 1960–2016 meteorological conditions. The metrics were calculated as defined by DeGasperi et al. (2009) and Horner (2012).

Table 6-9. Simulated Existing Hydrologic Flashiness Metrics

Hydrologic Flashiness Metric	SW-1 (Spanaway Creek Outlet)	SW-2 (Coffee Creek Inlet)	WSP2 (Spanaway Creek 1)	WSP4 (Morey Creek)	Mean (Range) from 16 streams in DeGasperi et al. (2009)
Low pulse count	4	3	5	3	10 (2–28)
Low pulse duration	25	48	25	20	26 (7–93)
High pulse count	2	1	2	2	10 (2–22)
High pulse duration	20	30	16	16	7 (2–31)
High pulse range	106	104	113	114	168 (34–306)
Flow reversals	56	39	58	60	55 (37–70)
TQ _{mean}	0.43	0.4	0.45	0.37	0.31 (0.25–0.38)
Richards-Baker flashiness index	0.04	0.03	0.04	0.07	0.27 (0.08–0.49)

With only one full year of observed flow data at each creek location, a statistical comparison of simulated and observed hydrologic flashiness metrics was not meaningful. Many of the WSP hydrologic metrics, including low pulse count, high pulse count, high pulse duration, TQ_{mean}, and Richards-Baker flashiness index, are near the end or outside of the ranges for the streams included in DeGasperi et al. (2009). This indicates that the Spanaway Creek watershed is different from most of the creeks in that study, such that the hydrologic metrics and B-IBI correlations may not be a good fit for the Spanaway WSP.

The metrics calculated based on the existing-conditions model show that the Spanaway Lake WSP is less “flashy” than most of the streams included in the DeGasperi et al. 2009 study. Moreover, the hydrologic metrics for the existing Spanaway Lake watershed conditions are close to model-simulated historical conditions. These results are consistent with the highly permeable soils and lack of connected stormwater conveyance systems in the WSP area. Nearly all runoff from impervious areas is either infiltrated through adjacent pervious areas or the more than 1,400 infiltration facilities in the WSP area. Because of the permeable soils, the pervious areas produce little runoff. The watershed model indicates that direct stormwater discharge composes less than 1 percent of the creek flow leaving the watershed. The model results show that infiltration greatly limits direct surface runoff and peak flows, while groundwater discharges provide ample baseflow. Spanaway and Tule lakes provide additional flow attenuation.

Table 6-10 lists the hydrologic metrics calculated based on the HSPF model simulations for the existing and future scenarios. The future-conditions model likely overestimates stormwater runoff because it does not account for Permit-required LID and flow control to mitigate the hydrologic impacts of new development and redevelopment. This is conservative because

County development regulations require implementation of LID measures wherever feasible, few (if any) sites in the Spanaway WSP would be deemed infeasible for LID. New development and redevelopment are expected to continue to rely on LID and infiltration because they are the most cost-effective stormwater management strategies in the Spanaway Lake WSP area. The lack of connected stormwater conveyance systems further reduces the potential for increased direct discharge to surface water bodies. Despite these conservative assumptions, the future-conditions model results indicate that the Spanaway WSP would be only slightly more flashy than historical conditions.

Table 6-10. Simulated Historical and Future Hydrologic Flashiness Metrics

Hydrologic Flashiness Metric	Spanaway Creek Outlet (SW-1)	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)	Spanaway Creek Outlet (SW-1)	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)
	Historical				Future			
Low pulse count	5	2	5	3	4	3	6	4
Low pulse duration	18	61	26	17	26	39	20	18
High pulse count	1	1	1	1	2	2	3	4
High pulse duration	24	48	31	26	18	23	10	10
High pulse range	81	88	86	76	105	126	138	140
Flow reversals	54	26	46	49	56	52	66	71
TQ _{mean}	0.42	0.4	0.43	0.43	0.43	0.4	0.46	0.36
Richards-Baker flashiness index	0.03	0.02	0.03	0.04	0.04	0.03	0.06	0.09

6.3.5 Simulated B-IBI

All four B-IBI sampling sites in the Spanaway Lake WSP area had B-IBI scores well below Ecology's target of 38 on the 10–50 scoring system. The highest score was observed in Coffee Creek upstream of Spanaway Lake. The 2015 samples collected from Coffee Creek had a B-IBI score of only 26, even though the creek is almost entirely groundwater-fed and there is little (~1 percent) urban development upstream of the site. B-IBI scores were even lower at the three sites downstream of Spanaway Lake.

The simulated existing hydrologic flashiness metrics were used to calculate B-IBI scores based on the relationships developed by DeGasperi et al. (2009) and Horner (2012). Observed and simulated existing B-IBI scores for each creek location are also shown in Table 6-11. The regression equations predict average B-IBI scores that are 43 percent to 90 percent higher than

the observed 2015 B-IBI scores. Some of the hydrologic metrics predict observed B-IBI scores at or above the Ecology's target of 38. The large disparity between the predicted and observed B-IBI scores indicates that B-IBI cores in the Spanaway WSP area are limited by factors other than hydrology.

Table 6-11. Observed and Simulated Existing B-IBI Scores Based on Hydrologic Metrics (10-50 Scale)

Basis of B-IBI Score	Spanaway Creek Outlet (SW-1)	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)
Observed B-IBI 2015	18	26	18	22
Low pulse count	32	36	31	35
Low pulse duration	27	34	27	25
High pulse count	40	41	39	39
High pulse duration	39	44	37	37
High pulse range	32	32	31	31
Flow reversals	24	37	22	21
TQ _{mean}	42	37	45	34
Richards-Baker flashiness index	37	37	37	35

Table 6-12 lists the B-IBI scores estimated based on the hydrologic metrics listed in Table 6-9 and the regression equations developed by DeGasperi et al. (2009) and Horner (2012). The B-IBI scores predicted based on historical hydrologic conditions are only slightly higher than the B-IBI scores predicted based on existing and future conditions. These results indicate that altered hydrology is not an important limiting factor for benthic macroinvertebrates in the Spanaway Lake WSP. The Biological Condition Gradient (BCG) evaluation of the benthic data reached a similar conclusion (see Appendix C). This is not surprising considering that nearly all stormwater runoff in the WSP area is infiltrated and groundwater accounts for 99 percent of the flow in Coffee, Spanaway, and Morey creeks, according to the calibrated HSPF model.



Table 6-12. Simulated Historical and Future B-IBI Scores (10-50 Scale)

Hydrologic Flashiness Metric	Spanaway Creek Outlet (SW-1)	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)	Spanaway Creek Outlet (SW-1)	Coffee Creek Inlet (SW-2)	Spanaway Creek 1 (WSP2)	Morey Creek (WSP4)
	Historical				Future			
Low pulse count	29	39	30	34	32	34	28	33
Low pulse duration	24	36	28	23	28	32	25	24
High pulse count	41	43	41	42	40	40	36	36
High pulse duration	42	49	44	42	39	41	32	33
High pulse range	36	35	35	37	32	29	27	27
Flow reversals	25	47	32	29	24	27	17	13
TQ _{mean}	40	37	42	42	42	37	46	32
Richards-Baker flashiness index	37	38	37	37	37	37	36	34
90% of average	31	36	33	32				
Average					34	35	31	29

Guidance from Ecology recommended including a target B-IBI score of 38, or 90 percent of the forested or historical-conditions B-IBI score. Table 6-12 shows the 90 percent historical B-IBI score based on an average of the scores from all hydrologic metrics. It also shows the average score based on all hydrologic metrics for the future condition. The future-conditions B-IBI score exceeds the 90 percent historical score for SW-1, and is estimated to be 1 to 3 points (on the 10–50 scale) less than the 90 percent historical score for the other WSP locations.

Unlike many other urbanized watersheds in the Puget Sound lowlands, altered hydrology does not appear to be a major limiting factor for B-IBI in the Spanaway Lake WSP. The monitoring and modeling results suggest that elevated water temperature and lack of habitat complexity, rather than altered hydrology, are the main factors limiting B-IBI scores in the Spanaway Lake WSP area. Low DO and fine or embedded substrate appear to be moderate limiting factors at several sites. Comparison of existing and historical model simulations indicates that warming in Spanaway Lake is the main cause of the elevated water temperatures in Spanaway and Morey creeks, although sparse riparian canopy is likely a contributing factor in some reaches (e.g., WSP2). Elevated water temperatures can also contribute to reduced DO, which could adversely affect benthic organisms.

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SECTION 7: MANAGEMENT STRATEGIES

This section describes the County's identification and evaluation of potential stormwater management strategies for the Spanaway Lake WSP. This WSP focuses on the stormwater management strategies that must be evaluated to comply with Special Condition S5.C.5.iv.(5).a of the Permit. The potential management strategies described here will be submitted for consideration by County decision makers in determining what actions might be effective, efficient, and appropriate for achieving Permit compliance within the Spanaway Lake WSP area. Optional management strategies or other actions not specifically required by the Permit are not addressed in this WSP document.

7.1 Permit Requirements

If the modeling results indicate that the B-IBI benchmarks or the water quality standards for temperature, copper, zinc, or fecal coliform bacteria will not be met, the Permit requires evaluation of stormwater management strategies to meet the water quality standards or B-IBI benchmarks. According to S5.C.5.iv.(5).a, stormwater management strategies to be evaluated for all jurisdictions must include:

- Changes to development-related codes, rules, standards, and plans
- Potential future structural stormwater control projects consistent with Permit condition S5.C.6.a

S5.C.5.iv.(5).b in the Permit states that stormwater management strategies evaluated may also include:

- Basin-specific stormwater control requirements for new development and redevelopment as allowed by Section 7 of Appendix 1 in the Permit
- Strategies to encourage redevelopment and infill, and an assessment of options for efficient, effective runoff controls for redevelopment projects, such as a regional facility in lieu of individual site requirements

In addition to the stormwater management strategies listed above, S5.C.5.v in the Permit notes that the watershed-scale stormwater planning process may include an evaluation of other strategies to preserve or improve other factors that influence maintenance of the existing and designated uses of stream, such as:

- Channel restoration
- In-stream culvert replacement
- Quality of the riparian zone
- Gravel disturbance regime
- Presence and distribution of large woody debris

This WSP focuses on the potential stormwater management strategies that must be evaluated per S5.C.5.iv.(5).a. Other strategies that could be used to address B-IBI, temperature, and fecal coliform bacteria will be addressed separately from this WSP.

7.2 Summary of Spanaway Lake WSP Excursions and Causes

Table 7-1 lists the model-predicted excursions for the WSP parameters and the likely sources or causes of the excursions based on the monitoring and modeling evaluations presented in Sections 5 and 6 above. The table shows that dissolved copper and zinc are predicted to meet water quality criteria at full buildout, while water temperature, fecal coliform bacteria, and B-IBI scores may not.

Table 7-1. Summary of Predicted Excursions and Causes				
WSP Parameter	Meets Criteria?		Causes or Sources for Excursions	
	Existing	Buildout	Primary	Secondary
Water temperature	No	No	Natural warming in Spanaway Lake	Reduced shade on some creek reaches
Fecal coliform	No	No	Waterfowl and other riparian wildlife	Stormwater runoff from Military Road sub-basin; runoff from shoreline areas with wildlife and domestic animals; shoreline septic systems; shoreline stormwater infiltration systems
Dissolved copper and zinc	Yes	Yes	Meets criteria	Meets criteria
B-IBI	No	No	Elevated water temperature, lack of habitat complexity	DO, fines, embeddedness

Hydrologic modification due to forest clearing and urban development has been identified as a key factor degrading water quality and physical channel conditions in Puget Sound lowland streams (DeGasperi et al. 2009; Horner 2012). Altered hydrology does not appear to be an important factor in the Spanaway Lake WSP area, however. The primary reason is that the County and private property owners have installed more than 1,400 infiltration facilities and LID measures such as full dispersion and permeable pavement in the WSP area. Only one large stormwater outfall is left in the watershed, and its tributary area has been retrofitted with LID and infiltration facilities to reduce flow volumes. Consequently, surface water bodies in the WSP area receive substantial groundwater baseflow but very little direct stormwater runoff. The flow monitoring and modeling results show that direct stormwater runoff contributes less than 1 percent of the creek outflow from the Spanaway Lake watershed. Groundwater discharge provides the vast majority of the flow in Spanaway Lake and Coffee, Spanaway, and Morey creeks.

Ecology has determined that LID is the most effective strategy for dealing with urban runoff impacts. Therefore, the Permit requires implementation of LID techniques for new development and redevelopment, wherever feasible. The Permit also requires flow control to ensure that surface runoff from new development and redevelopment matches undeveloped conditions (typically forest).

The Spanaway Lake WSP monitoring found little evidence of channel instability because of altered hydrology. This is consistent with the hydrologic metrics calculated based on HSPF modeling, which shows that the creeks in the Spanaway Lake WSP are much less “flashy” than most of the creek studies by DeGasperi et al. (2009). The model simulations indicate that the existing hydrologic metrics are similar to the historical conditions. The future-conditions model predicts hydrologic metrics that are slightly worse than existing conditions; however, the future-conditions model does not account for Permit-required LID and flow control to mitigate the hydrologic impacts of new development and redevelopment.

This WSP study confirms that LID and infiltration can be very effective at mitigating the hydrologic impacts of development—the Spanaway Lake WSP area hydrology is similar to historical pre-development conditions, despite now being home to 44,000 people. In addition, the Spanaway Lake WSP results support Ecology’s findings that LID and infiltration are effective strategies for removing fecal coliform, copper, and zinc.

7.3 Potential Stormwater Management Strategies

The Spanaway Lake WSP model simulations indicate that water temperature and fecal coliform bacteria are likely to exceed the State water quality criteria at full buildout. The model simulations and regression equations indicate that future B-IBI scores are likely to be below Ecology’s benchmark of 38 (10–50 scale). However, as shown in Table 6-12 above, the average simulated future scores are only 0 to 3 points less than 90 percent of the average simulated historical score. The Permit requires that Permittees evaluate potential stormwater management strategies to address these potential excursions. All jurisdictions must evaluate (1) changes to development-related codes, rules, standards, and plans, and (2) potential future structural stormwater control projects consistent with Permit condition S5.C.6.a.

The following sections discuss potential stormwater management strategies to help address model-predicted water temperature, fecal coliform bacteria, and B-IBI excursions in the Spanaway Lake WSP area. These potential stormwater management strategies complement the County’s recent and ongoing stormwater retrofits in the Spanaway Lake WSP area. For example, the County is in the final phase of the Spanaway Lake Park LID retrofit program, which includes installation of bioretention areas, permeable pavement and pavers, and stormwater filters. The County has retrofitted the Sprinker Recreation Center parking area with permeable pavement to reduce surface runoff to the Military Road outfall. In addition, County Roads has

replaced numerous single-stage drywells in the WSP area with two-stage systems that provide enhanced treatment and are easier to maintain.

7.3.1 Potential Stormwater Management Strategies to Reduce Water Temperature

Warming in Spanaway Lake is the primary reason that 7-DADMax temperatures frequently exceed the numerical criterion during the summer. The warming in Spanaway Lake appears to be due to natural conditions as described in Section 6.2.3 above. Lake warming is the primary cause for elevated water temperatures in Spanaway and Morey creeks.

In the Spanaway Lake WSP area, infiltration is the most effective stormwater management strategy to reduce receiving water temperatures. Stormwater infiltration reduces the discharge of warm runoff to lakes and creeks and preserves groundwater recharge. Groundwater discharge provides cool baseflow to receiving water bodies during the summer.

The County is already implementing this stormwater management strategy throughout the Spanaway Lake WSP. As a result of the numerous infiltration facilities and LID measures, direct stormwater discharge composes a very small fraction of the flow in the Spanaway Creek system. Groundwater is the main source of flow to the lakes and creeks in the Spanaway Lake WSP area.

Although lake warming is the primary reason for the temperature excursions in Spanaway Lake and the creeks downstream of the lake, watershed model results indicate that limited riparian shade contributes to higher water temperatures in lower Spanaway, Morey, and Coffee creeks. These areas were developed before the County's current development regulations took effect. Chapter 18E.40.060 in the development regulations requires that new development and redevelopment projects provide 150-foot-wide buffers on both sides of Spanaway, Morey, and Coffee creeks. The critical areas regulation allows the County to require native tree planting and other enhancements to ensure that the buffer areas provide the desired habitat functions. Thus, redevelopment under the County's current development regulations should protect riparian areas in good condition and improve riparian areas that have been degraded by tree removal, landscaping, domestic animal grazing, invasive plants, etc.

The future-conditions model indicates that there could be a small increase in direct stormwater discharge to Morey Creek and lower Spanaway Creek. This increase could cause a slight increase in water temperature. A potential stormwater management strategy to address this issue would be to revise the Pierce County Stormwater Management and Site Development manual to require onsite retention using LID practices and other infiltration measures in the areas where direct discharge could otherwise occur. This potential stormwater management strategy would provide limited benefits because direct discharge would have a small impact on water temperature relative to the natural warming that occurs in Spanaway Lake.

7.3.2 Potential Stormwater Management Strategies for Fecal Coliform

The Spanaway Lake WSP model predicts that fecal coliform bacteria concentrations will exceed the applicable water quality criteria under existing conditions and at full buildout. The monitoring and modeling results indicate that waterfowl and other riparian animals are an important fecal coliform source. Shoreline septic systems are another potential but likely smaller source.

Municipal stormwater appears to be a relatively minor source of fecal coliform in the Spanaway Lake WSP. Most stormwater from the MS4 is infiltrated and infiltration is generally quite effective at removing fecal coliform bacteria. Through its extensive use of infiltration and LID, the County is already implementing some of the best available stormwater management strategies to reduce fecal coliform loads from MS4 discharges in the Spanaway Lake WSP area.

Potential stormwater-related fecal coliform sources include shoreline-area infiltration facilities and stormwater discharges from the Military Road outfall. The County has identified the following potential stormwater management strategies to address these sources:

- **Retrofit shoreline area infiltration facilities:** As discussed in Section 6.2.3, stormwater infiltration facilities more than 350 feet upgradient of receiving water bodies are not expected to be a significant source of fecal coliform in the Spanaway Lake WSP area. Approximately 15 single-stage (i.e., not retrofitted) drywells are located within 350 feet upgradient of receiving water bodies in the WSP area (see Figure 7-1). Two pre-1997 infiltration ponds are located within 350 feet of Spanaway Creek. These ponds were built before the County began requiring water quality treatment prior to infiltration. One of the ponds is located in a groundwater capture zone where infiltrated stormwater could reach receiving water bodies via the subsurface. The other infiltration pond is not in a groundwater capture zone, but overflows (if any) from the pond could reach the creek via overland flow.

This potential stormwater management strategy would entail replacing the single-stage drywells with two-stage systems that include a pretreatment vault to trap sediments and floatables followed by an infiltration trench (see Appendix G for design details). The trench provides a much larger infiltration area than the typical single-stage drywell, resulting in lower hydraulic loading rates.

This strategy would also include installing water quality treatment devices such as cartridge filters to treat flows entering the two shoreline-area stormwater infiltration basins (SF 116 and SF 149). The systems would be sized to treat the water quality design flow (91 percent of total runoff).

As discussed in Section 6.2, shoreline-area stormwater facilities appear to be a relatively minor source of fecal coliform bacteria in the Spanaway Lake WSP. Thus, this potential stormwater management strategy is not expected to result in receiving water bodies achieving compliance with the State water quality criteria for fecal coliform.

- **Retrofit the Military Road drainage system:** This potential stormwater management strategy would involve constructing a sand-lined infiltration facility near the Military Road storm drain line. This is the only storm conveyance system of appreciable size that remains in the Spanaway Lake WSP. The infiltration facility would be designed to divert and infiltrate flow from the storm drain, thereby reducing discharges through the outfall to Spanaway Creek. The facility would be lined with sand to control infiltration rates and enhance treatment.

The County has already retrofitted the Military Road sub-basin with LID measures (e.g., permeable pavement, bioretention facilities) and other infiltration facilities to reduce surface flow volumes. In 2012, the County installed a hydrodynamic separator near the outfall to treat runoff prior to discharge. The HSPF model results indicate that this outfall currently contributes less than 2 percent of the annual flow volume and roughly 20 percent of the fecal coliform load in Spanaway Creek at Military Road. Constructing an infiltration facility above the Military Road outfall would further reduce storm flows and fecal coliform loads from this sub-basin.

This potential stormwater management strategy would be expected to provide modest reductions in fecal coliform loadings to Spanaway and Morey creeks.

- **Require 100 percent retention for new development and redevelopment in the Spanaway Lake Watershed:** This potential stormwater management strategy would involve revising the County's Stormwater Management and Site Development manual to require 100 percent infiltration for new development and redevelopment in the Military Road sub-basin and other WSP areas where direct stormwater discharge might be possible. The benefits of these stormwater management measures are expected to be modest because existing regulations require new development and redevelopment sites about thresholds would need to implement LID where feasible. LID is expected to be feasible throughout this sub-basin. The onsite retention requirement would provide additional assurance that storm flows to the Military Road outfall do not increase because of future development.

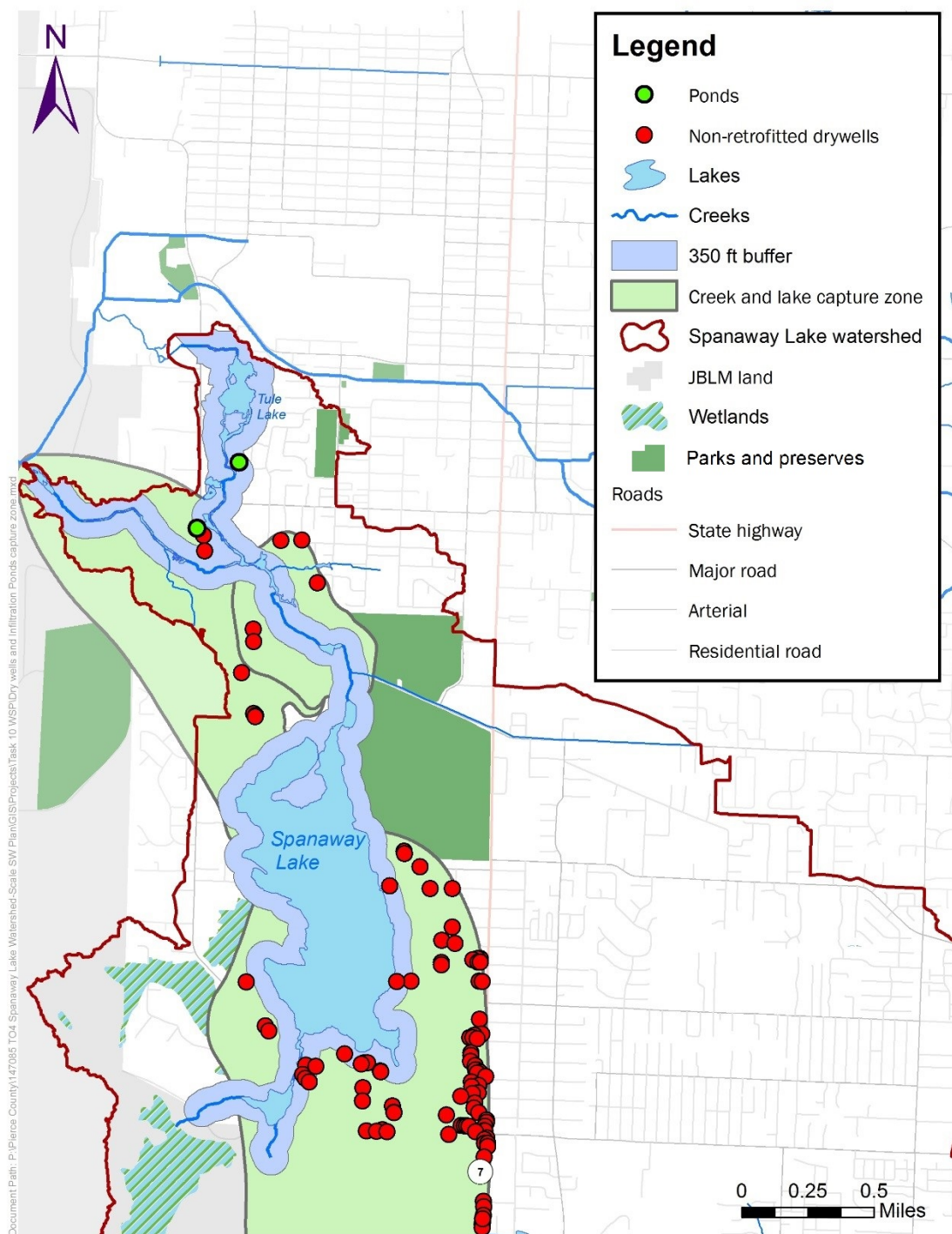


Figure 7-1. Stormwater drywells and infiltration ponds located within 350-foot capture zone of receiving water bodies

7.3.3 Potential Stormwater Management Strategies for B-IBI

Altered hydrology is often a key factor limiting B-IBI scores in urbanized watersheds in the Puget Sound lowlands. In the Spanaway Lake WSP area, however, extensive use of infiltration and LID practices has minimized the hydrologic impacts of development. The hydrologic metrics based on the existing-conditions modeling show that Spanaway Creek is less “flashy” than most other creeks in the region. The simulated hydrologic metrics for existing conditions are similar to historical conditions, with strong baseflow and only a few high pulses per year. However, despite the apparently stable hydrologic regime, B-IBI scores in the Spanaway Lake WSP area are relatively low. These findings show that, while a sound hydrologic regime is necessary to achieving good B-IBI scores, it does not by itself guarantee good B-IBI scores.

B-IBI scores predicted based on the model-generated hydrologic metrics are much higher than observed B-IBI scores (see Section 6.2.3 above). These results suggest that factors other than urban altered hydrologic impacts are limiting B-IBI in the Spanaway Lake WSP area. The B-IBI stressor evaluation found that relatively high seasonal water temperatures and lack of habitat complexity, rather than altered hydrology, are likely the main stressors limiting B-IBI scores. Stormwater runoff does not appear to contribute very much to either problem. The County’s extensive use of infiltration is an effective stormwater management strategy for avoiding water temperature problems. Infiltration minimizes direct discharge of seasonally warm stormwater in the warmer months and maximizes cool baseflow during summer.

Two of the potential stormwater management strategies for fecal coliform reduction could also provide some benefits for B-IBI. A new infiltration facility in the Military Road sub-basin and an onsite retention requirement for new development and redevelopment in that sub-basin would reduce surface runoff from the only remaining outfall in the WSP area. However, these potential stormwater management strategies would provide small incremental flow reduction benefits, given the numerous existing infiltration facilities in this sub-basin and elsewhere in the WSP area.

The potential stormwater management strategies described above are not expected to substantially increase B-IBI scores, for the reasons summarized below:

- The County is already implementing two of the best available stormwater management strategies—infiltration and LID practices—to protect benthic habitat. These strategies help to minimize hydrologic alteration, maintain cool water temperatures, and remove potential pollutants. The simulated hydrologic metrics for the existing and future conditions and the observed streamflows and channel conditions show that infiltration and LID can effectively mitigate the hydrologic impacts of development. Future development is expected to continue to rely on LID and infiltration.

- B-IBI scores are low despite the extensive use of LID and infiltration because:
 - Altered hydrology does not appear to be an important limiting factor in the Spanaway Lake watershed
 - Elevated water temperature appears to be an important limiting factor for benthic macroinvertebrates in the Spanaway Lake WSP area. Natural warming in Spanaway Lake is the main cause of the elevated water temperatures. Direct stormwater runoff contributes a small fraction of streamflow so it has little impact on water temperature.
 - Non-stormwater factors, such as lack of habitat complexity and sparse riparian canopy, appear to be limiting B-IBI scores in the Spanaway Lake WSP.

The potential stormwater management strategies are not expected to increase B-IBI scores sufficiently to attain Ecology's targets (minimum score of 38 or 90 percent of simulated pre-development scores). As noted above, the regression equations based on hydrologic metrics predict B-IBI scores that are 43 to 90 percent higher than the observed B-IBI scores. This indicates that the regression equations likely overestimate the historical B-IBI scores. The relative difference between the simulated existing and historical B-IBI scores may provide a more appropriate target for this WSP. The future-conditions B-IBI score exceeds the 90 percent historical score for SW-1, and is estimated to be 1 to 3 points (on the 10–50 scale) less than the 90 percent historical score for the other WSP locations.

7.4 Costs of Potential Stormwater Strategies

This section provides the planning-level cost estimates of the three main stormwater strategies selected for implementation of this WSP plan: drywell retrofits, infiltration pond retrofits, and construction of an infiltration facility to reduce storm flows and bacteria loads from the Military Road outfall.

The estimates were developed based on conceptual design schematics, including preliminary quantity take-offs and estimated unit costs. The concepts are at a level of design completion of less than 5 percent. The estimates are for construction costs and include percent increases for other project costs including design engineering, environmental review and permitting, and contingency. The estimate is in 2017 dollars and must be escalated to the midpoint of construction once that time frame has been identified.

A planning-level estimated cost to design and construct for each project has been developed based on unit prices available from public-works projects, previous project bids, and vendor quotes. All prices reflect construction in the Puget Sound region. Detailed cost estimates are included in Appendix G.

In accordance with Association for the Advancement of Cost Engineering International (AACE) criteria, the costs presented within this implementation plan are Class 4 estimates, which are defined as a Planning-Level or Design Technical Feasibility Estimate with engineering in the range of 1 to 15 percent complete. Class 4 estimates are used to prepare planning-level cost scopes or to evaluate alternatives in design conditions and form the base work for the Class 3 Project Budget or Funding Estimate. Expected accuracy for Class 4 estimates typically ranges from -30 to +50 percent, depending on the technological complexity of the project, appropriate reference information, and inclusion of an appropriate contingency determination. In unusual circumstances, ranges could exceed those shown.

Table 7-2 contains planning-level cost estimates for the potential structural stormwater management strategies. The table also lists the estimated 30-year life-cycle cost for each strategy. The following sections describe the potential strategies in more detail.

Table 7-2. Planning-Level Cost Estimate for Stormwater Strategies			
Stormwater Strategy Project	Total Direct Construction Cost (2017 dollars)	Cost Range (-30% to +50%)	30-year Life Cycle Cost ^a
Drywell retrofits (15)	\$105,000	\$73,500–\$157,500	\$120,000
SF 116 pond retrofit	\$240,000	\$168,000–\$359,000	\$313,000
SF 149 pond retrofit	\$177,000	\$124,000–\$265,000	\$212,000
Military Rd. infiltrating sand filter	\$1,259,000 ^b	\$881,000–\$1,889,000 ^b	\$1,355,000 ^b

a. Net present value based on a 2% discount rate. Includes total estimated capital costs. Drywell retrofit estimate assumes vacuoring catch basins every 5 years. Pond retrofits estimates assume filter cartridges will be replaced twice per 5 years, with minimal annual maintenance. Military Road estimates assumes complete replacement of sand filter at 30 years, thorough raking every 5 years, and minimal annual maintenance.

b. Includes rough estimate of land acquisition cost.

7.4.1 Drywell Retrofits

This potential stormwater management strategy would involve replacing approximately 15 single-stage drywells located within 350 feet upgradient of surface water bodies (lakes and creeks), based on the MODFLOW capture area and particle tracing evaluation (Figure 7-1). The single-stage drywells would be replaced with two-stage systems consisting of a treatment vault to remove sediments and floatables, followed by a lined infiltration trench. Table 7-2 contains the planning-level cost estimate.

The County has already replaced many single-stage drywells in the Spanaway Lake WSP area and elsewhere in the Clover Creek watershed using State grant funds. The County has installed multiple configurations of drywells depending on the site layout and restrictions. The cost estimate included here assumes 40-foot-long perforated pipe in an infiltration trench, in

accordance with the example County design drawing included in Appendix G. The planning-level cost estimate for drywell retrofits came directly from the County's many recent comparable project costs. Site-specific information is required to determine each trench configuration. The life-cycle cost estimate assumes vactoring the treatment vault every 5 years.

Appendix G contains additional information on this potential stormwater management strategy.

7.4.2 Infiltration Pond Retrofits

This potential strategy would involve retrofitting two infiltration ponds, one near Morey Creek and the other near Spanaway Creek (Figure 7-1). Infiltration ponds SF 116 and SF 149 are the only ponds within the Spanaway Lake WSP area that are close enough to surface water bodies to be potential sources of fecal coliform bacteria. The planning-level cost estimate in Table 7-2 assumes that cartridge media filters would be installed near the pond inlets, outside of the roadway, maintaining the existing piping and basin configuration and that the treatment systems would be sized to the water quality design flow rate (91 percent of total flow volume) based on HSPF model flows for their respective catchment areas. The water quality design flow rate for SF 116 is 0.15 cfs and for SF 149 it is 0.77 cfs. The vendor system used for estimating purposes was the CONTECH StormFilter®. SF 116 has two inlets into the pond so the system requires two cartridge filter systems, each in 60-inch manholes on each inlet pipe. SF 149 has one inlet that would require the cartridge system placed in an 8-by-11-foot vault. More data, such as existing pipe invert information and underground utility location, are required to fully determine the hydraulic design requirements and locations.

Based on regional experience, the life-cycle cost estimate (Table 7-2) assumes that each cartridge will need to be replaced every 2.5 years. The cost for full maintenance is \$250 per cartridge. The actual cartridge replacement frequency would depend on the sediment loads at each location as determined by inspections.

Appendix G contains additional information on this potential stormwater management strategy.

7.4.3 Military Road Infiltration Facility

The Military Road outfall is the only MS4 outfall with an appreciable catchment area. This potential stormwater management strategy would involve constructing an infiltration facility in the lower portion of the Military Road sub-basin to reduce fecal coliform bacteria loads to Spanaway Creek. This strategy could also help reduce creek water temperatures. Figure 7-2 shows a potential location near the Sprinker Recreation Center where an offline pond could be constructed to divert, treat, and infiltrate stormwater from the pipe on Military Road.

This potential strategy would complement recent retrofitting projects in the Military Road sub-basin. For example, the County replaced a portion of the Sprinker Recreation Center parking lot with permeable pavement and installed a hydrodynamic separator near the outfall.

The planning-level cost estimate for installing an infiltrating sand filter on Military Road is based on construction per the Pierce County Stormwater Management and Site Development Manual for Sand Filter Basins. The infiltrating sand filter would be an offline installation assumed to have a bottom width of 101 feet and a bottom length of 211 feet. These dimensions were estimated based on the available parcel size, access, and buffers. The filter side slopes are assumed to be 4:1. Using the minimum sand media depth of 18 inches and the required design infiltration rate of 1 inch per hour for the sand media, this facility infiltrates 1 cfs if it accumulates 2 feet of ponding. When flows exceed the facility design capacity, they would overtop the flow control weir and remain in the Military Road storm pipe, bypassing the facility.

The life-cycle cost estimate for the Military Road facility assumes full replacement of the sand layer at year 30 with basic annual maintenance and more thorough sand raking every 5 years.

The conceptual design and design flow for this facility are based on limited information and numerous assumptions. Additional data such as pipe invert elevations, existing utilities, and geotechnical information would be needed to support design and develop more accurate performance estimates.

Appendix G contains additional information on this potential stormwater management strategy.

7.5 Priorities

The Military Road infiltrating sand filter should be the first priority among the structural stormwater management strategies. This strategy would substantially reduce the current discharge volume and fecal coliform loads from the only appreciable stormwater outfall in the Spanaway Lake WSP. It would capture runoff from the commercial heart of the Spanaway Lake WSP area.

Retrofitting single-stage drywells in shoreline areas should be the second priority. The WSP analyses indicate that these facilities are probably minor sources of fecal coliform bacteria. Replacing the old drywells with two-stage systems (treatment vault and lined infiltration trench) would provide additional protection of the underlying aquifer and adjacent receiving water bodies.

Adding water quality treatment to the two existing shoreline-area infiltration ponds should be the third priority among the structural measures. One of these ponds is in a groundwater capture zone while the other is not. The WSP analysis indicates that these infiltration ponds are

probably minor sources of fecal coliform via subsurface transport. If the ponds were to overflow, surface runoff could reach the creeks. The ponds were designed to infiltrate the 100-year storm event so overflows should be rare.

The WSP includes only one non-structural stormwater management strategy: requiring full onsite retention for new development and redevelopment in areas such as the Military Road sub-basin where direct stormwater discharge is possible. This would require revising the Pierce County Stormwater Management and Site Development manual. Based on recent trends, Pierce County Planning and Land Services (PALS) does not expect much near-term development or redevelopment activity in the Spanaway Lake WSP area.

7.6 Summary

The four potential stormwater management strategies described above would help to improve water temperature, fecal coliform, and benthic conditions in the Spanaway Lake WSP area. The improvements are likely to be modest, however, for the reasons listed below:

- The County has already installed more than 1,400 infiltration and LID facilities in the WSP area. Consequently, direct stormwater runoff contributes less than 1 percent to the creek flow from the watershed.
- Because of widespread use of LID and infiltration practices, municipal stormwater runoff is a relatively minor source of fecal coliform to receiving waters in the Spanaway Lake WSP. Riparian sources appear to be the primary cause for the excursions.
- Natural warming in Spanaway Lake is the primary cause for elevated water temperatures, while sparse riparian canopy is a contributing factor. Current stormwater management practices result in ample groundwater recharge and cool baseflow to Spanaway Lake and Coffee, Spanaway, and Morey creeks.
- Elevated water temperature and lack of habitat complexity appear to be the main factors limiting B-IBI scores in the Spanaway Lake WSP. Altered hydrology does not appear to be a significant limiting factor for B-IBI in the Spanaway Lake WSP area because of its unique hydrogeology and the extensive use of infiltration and LID practices.

Municipal stormwater discharges do not appear to be a major cause for the predicted temperature, fecal coliform, and B-IBI excursions in the Spanaway WSP area because of the unique hydrogeology and extensive use of infiltration and LID practices. Moreover, since the vast majority of stormwater is infiltrated, there is limited opportunity for additional flow control. Therefore, the potential stormwater management strategies described in this WSP are expected to provide incremental water quality improvements rather than full attainment of temperature or fecal coliform criteria, or Ecology's proposed B-IBI target score of 38.

SECTION 8: IMPLEMENTATION PLAN

The Permit requires that the WSP include an implementation plan for the potential stormwater management strategies. The implementation plan must describe potential measures to implement the stormwater management strategies, responsible parties, estimated costs, potential funding mechanisms, and schedule.

As described in Section 7, the County evaluated potential stormwater management strategies to address model-predicted future excursions for water temperature and fecal coliform bacteria, and B-IBI scores below Ecology's proposed targets at full buildout. The evaluation considered changes to development-related codes, rules, standards, and plans, as well as potential future structural stormwater control projects consistent with S5.C.6.a in the Permit.

The County selected the following four potential stormwater management strategies for inclusion in this WSP implementation plan:

- Retrofit drywells in shoreline areas
- Retrofit infiltration ponds in shoreline areas
- Construct an infiltration facility in the Military Road sub-basin
- Require onsite retention for new development and redevelopment in areas with potential direct stormwater discharge to surface water bodies

These potential stormwater management strategies are expected to yield modest benefits because municipal stormwater appears to play a minor role in the observed and predicted temperature, fecal coliform, and B-IBI impairments. The WSP monitoring and modeling evaluations identified several potential limiting factors unrelated to municipal stormwater discharges. Stormwater strategies would not address these factors. Potential non-stormwater strategies are addressed separately from this WSP.

Section 8.1 describes the limitations of the implementation plan. Section 8.2 describes responsible parties. Section 8.3 describes planning-level cost estimates. Section 8.4 summarizes potential funding sources. Section 8.5 contains a general schedule. Section 8.6 describes the County's adaptive management strategy.

8.1 Implementation Constraints

The County's ability to implement the potential stormwater management strategies described in this WSP is contingent on several factors including:

- Approval by the Pierce County Surface Water Advisory Board, County Executive, and the County Council
- Securing necessary funds
- Acquiring land and access for retrofit projects
- Site conditions that could affect project feasibility, design, and costs

WSP implementation costs are not included in the County's current budget. It is likely that grant funding will be required to allow implementation. Because of the uncertainty of funding, feasibility, and effectiveness of the stormwater management strategies available in this watershed, this plan is intended to provide long-term guidance for meeting the Permit objectives, and is not directly suitable for implementing specific actions.

This WSP is limited to the potential stormwater management measures that must be evaluated per Special Condition S5.C.5.iv.(5).a of the Permit. Implementation of the potential stormwater measures described in this WSP is not expected to result in full attainment of water quality criteria and benchmarks because municipal stormwater discharges do not appear to be the main cause for the predicted water temperature, fecal coliform, or B-IBI excursions.

8.2 Responsible Parties

The County would be responsible for designing, constructing, and maintaining the potential structural stormwater measures described in Section 7. Developers and property owners would be responsible for complying with the potential requirement to retain/infiltrate all stormwater on site for new development and redevelopment in areas where direct stormwater discharge could occur. The County would be responsible for development plan review, inspection, and enforcement.

8.3 Planning-Level Cost Estimates

Table 8-1 provides planning-level cost estimates for the potential structural stormwater management strategies. Appendix G contains additional information on these potential measures.

Table 8-1. Planning-Level Cost Estimates for Potential Stormwater Strategies

Stormwater Strategy Project	Total Direct Construction Cost (2017 dollars)	Construction Cost Range (-30% to +50%)	30-year Life Cycle Cost ^a
Drywell retrofits (15)	\$105,000	\$73,500--\$157,500	\$120,000
SF 116 pond retrofit	\$240,000	\$168,000--\$359,000	\$313,000
SF 149 pond retrofit	\$177,000	\$124,000--\$265,000	\$212,000
Military Rd. infiltrating sand filter	\$1,259,000 ^b	\$881,000--\$1,889,000 ^b	\$1,355,000 ^b
Total	\$1,781,000	\$1,246,500-\$2,670,500	\$2,120,000

a. Net present value based on a 2% discount rate. Includes total estimated capital costs. Drywell retrofit estimate assumes vactoring catch basins every 5 years. Pond retrofits estimates assume filter cartridges will be replaced twice per 5 years, with minimal annual maintenance. Military Road estimates assumes complete replacement of sand filter at 30 years, thorough raking every 5 years, and minimal annual maintenance.

b. Includes rough estimate of land acquisition cost.

The potential stormwater management measures also include changing the County Stormwater and Site Development manual to require onsite infiltration in areas of the WSP where there is potential for direct stormwater discharge to surface waters. LID and infiltration are feasible throughout most of the WSP area and infiltration is typically a cost-effective strategy (as evidenced by the numerous existing LID and infiltration practices in the Spanaway area). Therefore, this potential stormwater management measure is not expected to increase development costs.

8.4 Potential Funding Sources

As noted in Table 8-1, the 30-year life-cycle cost for the potential structural stormwater measures is on the order of \$2,120,000. Given the County's other commitments and obligations, WSP implementation would probably require funding from sources outside of the County government. Implementation of the potential stormwater management measures could involve a variety of different funding mechanisms.

The County is responsible for stormwater quality and management for discharges from its MS4. WSDOT has responsibility for its stormwater discharges, facilities, and operations. JBLM is responsible for water quality management and environmental protection in its portion of the Spanaway Lake WSP area.

The County's SWM Utility Service Charge is one potential source of funding. This service charge is collected in accordance with Pierce County Code (PCC) Chapter 11.02. In 2017, the SWM utility charge is \$123.61 per single-family residence. PCC 11.02.050 allows reduced charges for parcels with stormwater facilities that retain runoff from large storm events (>10-year event recurrence interval). The revenues are used for a variety of purposes including stormwater

drainage and quality management, floodplain management, levee maintenance, inspections, and technical assistance.

Grant revenue is a significant source of funding for the County, and enables the County to leverage its resources with grant matches to increase the level of spending beyond what might otherwise be possible for stormwater programs and projects. State grants helped fund the County's recent LID retrofit projects, drywell retrofit projects, and fish passage projects in the Spanaway Lake WSP area. A State budget allocation provided much of the funding for the Spanaway LMP.

Pierce County grant revenue for stormwater and water quality projects and programs has included Ecology, EPA, Federal Emergency Management Agency (FEMA), regional government clearinghouses, and other sources.

Other entities with stormwater- and/or water quality-related jurisdiction, activities, or operations in the WSP area include WSDOT and JBLM. WSDOT has its own funding sources. The WSP does not identify any potential stormwater management strategies for the JBLM portion of the Spanaway Lake WSP because that portion of JBLM is covered with wetlands, prairie, and forest, with little infrastructure and no plans for future development. EPA has water quality-related jurisdiction over the JBLM portion of the WSP area.

The County intends to investigate and further evaluate potential funding options during the first phase of WSP implementation. Future County funding for the WSP study area is expected to be similar to current levels.

The two main funding sources for the stormwater projects identified in this implementation plan include the stormwater management service charge revenues and potentially the General Fund, particularly for road-related projects. These potential funding sources, as well as others, which the County intends to research for future funding, are summarized below.

Note that full implementation of the Spanaway Lake WSP may require funding from multiple sources. For example, capital costs could be funded by State grants, budget allocations, and/or a State Revolving Fund (SRF) loan, while long-term operation and maintenance costs and SRF loan payments could be funded by revenues from stormwater service charges.

8.4.1 Surface Water Rate Surcharge-Area of Special Benefit

Some local jurisdictions have successfully implemented surcharges on stormwater utility rates or service charges. Revenue generated from these surcharges can fund improvements and programs that provide services and benefits beyond those provided in the rest of the utility service area. Rate surcharges could potentially be applied to stormwater retrofits that are not provided across the general utility service area. Such a surcharge is implemented through

revisions to the surface water utility rate ordinance and revenue is collected through the utility billing process.

8.4.2 Stormwater Financial Assistance

Stormwater financial assistance funds come through various State grant programs including the Capacity Grants, Grants of Regional or Statewide Significance (GROSS), and capital construction grants whose funding comes from a combination of State bond and hazardous substance tax dollars. Stormwater financial assistance is available through several programs:

- **Capacity grants** are non-competitive and are awarded to holders of Phase I and Phase II NPDES municipal permits for activities and equipment necessary for permit implementation. These grants are generally applied to NPDES permit compliance activities. Funds are limited to availability per State budget and no match is required.
- **GROSS** are competitive grants that assist permittees in completing projects that will benefit multiple permittees and are generally applied to permit compliance efforts. No match is required and budgets are limited to \$300,000.
- **Stormwater Financial Assistance Program (SFAP)** grants are capital grants that have had several different names over the years including Low-Impact Development and State-wide Retrofit, Low-Impact Development grants, and Supplemental State-wide Stormwater grants. These funds could be applied to stormwater management improvements and retrofits in the Spanaway Lake watershed. A 25 percent match is required (15 percent for hardship communities) with a \$5 million limit per community.
- **SFAP Preconstruction grants** can be used to develop construction plans for stormwater capital projects. Preconstruction funding may be available as part of the combined program or may run as a standalone program. These funds are typically limited to a maximum of \$250,000.

8.4.3 Clean Water State Revolving Fund Loans

The Clean Water State Revolving Fund (CWSRF) program is funded via an annual EPA capitalization grant, State matching funds, and principal and interest repayments on past CWSRF loans. This program provides low-interest and forgivable principal loan funding for wastewater treatment construction projects, eligible nonpoint source pollution control projects, and eligible green projects. Local governments, special-purpose districts, and tribes can apply for these funds. No match is required and CWSRF loans can be used to match Centennial Clean Water and Section 319(h) grants. No more than 50 percent of the total available funds can go to any one applicant.

A reliable revenue source is needed for CWSRF loan repayment. Potential revenue sources include a potential Lake Management District (LMD), Flood Control Zone District (FCZD) funds,

general tax revenues, and utility service charge or surcharge revenue among others discussed here.

8.4.4 Public Works Trust Fund Loans

The Public Works Trust Fund Loan program provides low-interest loans for local governments to finance public infrastructure construction and rehabilitation. Eligible projects must improve public health and safety, respond to environmental issues, promote economic development, or upgrade system performance. Stormwater projects are eligible for these loans for which counties and other entities may apply.

8.4.5 Centennial Clean Water Grants

The Centennial Clean Water program is a State-funded grant program administered by Ecology. Local governments, special-purpose districts, conservation districts, and federally recognized tribes are eligible for these funds applicable to water quality infrastructure (e.g., wastewater treatment facilities) and nonpoint source pollution projects to improve and protect water quality. Nonpoint source pollution projects require a 25 percent match.

8.4.6 Local Improvement Districts

Local improvement districts are a means of financing needed capital improvements through the formation of a special assessment district. Special assessment districts allow improvements to be financed and paid for over a period through assessments on the benefiting properties. A variation of the Local Improvement District is the Utility Local Improvement District (ULID). The difference between ULIDs and Local Improvement Districts is that utility revenues are pledged to the repayment of the ULID debt, in addition to the assessments on the benefiting properties. State statutes provide that a Local Improvement District can be converted to a ULID after formation. The reverse is not possible.

The Local Improvement District financing mechanism is a process to finance infrastructure improvements and does not provide a mechanism to construct those improvements. Construction projects must be managed by the County. Local Improvement District project financing is based on the sale of bonds to investors and the retirement of those bonds via annual assessments to owners of property within a district. The assessment per parcel must not exceed the special benefit of the improvement to that parcel.

8.4.7 Lake Management District

An LMD is a form of special-service district that funds lake management activities through charges on lake-area properties. An LMD can finance a range of activities, and may be able to provide some funding for any needed lakeshore infiltration retrofits. Generally, LMDs are

established to implement measures other than those required of the WSP. LMD revenue is typically applied to the following types of activities or projects:

- Controlling aquatic vegetation
- Improving water quality, including control of stormwater and agricultural runoff
- Performing water quality studies to pinpoint problems and identify solutions
- Maintaining ditches or streams associated with the lake
- Maintaining lake levels
- Maintaining beaches

An LMD is formed with property owners from within the proposed district voting by mail, each granted one vote for each dollar they would be assessed under the proposed LMD. Both the County Council and affected property owners must approve the LMD formation, and revenues are then collected by the treasurer as a specific item on the annual property tax statement (RCW 36.61). An LMD is established for a specific time frame, up to 10 years. Both privately and publicly owned lakefront property and upland lots with access to community beach areas are commonly included. It may be possible to include the entire watershed in an LMD. For additional information on an LMD program, see the Spanaway LMP (Pierce County 2017).

8.4.8 Flood Control Zone District

An FCZD can be used to fund actions addressing a broad range of watershed issues from flood control and water quality improvement to watershed management.

An FCZD is governed by a board, which can be the local legislative authority. The board may initiate the creation of a zone or additional zones within the FCZD for undertaking, operating, or maintaining flood control projects or stormwater control projects or groups of projects that are of special benefit to specified areas within the FCZD. Formation of a zone may also be initiated by a petition signed by 25 percent of the electors within that proposed zone (based on the vote cast in the last County general election).

The County created an FCZD in 2012. The County FCZD is a special-purpose district governed by a board of supervisors and an executive committee. The County Council serves as board of supervisors. An advisory committee, with County participation, provides input and recommendations to the board to carry out the FCZD's approved projects and programs.

Funding for the County's FCZD comes from a countywide property levy of \$0.10 per \$1,000 of assessed value. The levy raises approximately \$8 million per year. Ten percent of the County's FCZD's levy proceeds are assigned to an Opportunity Fund, which is made available to jurisdictions throughout the County's FCZD on a proportional basis, based on assessed valuation.

The Opportunity Fund grants could potentially be used for actions called for in the Spanaway Lake WSP such as stormwater control improvements (whether extended, enlarged, acquired, or constructed).

Accessing allocations from the Opportunity Fund requires entering into an Interlocal Agreement with the County's FCZD, and the jurisdiction must prepare and submit a draft agreement (to the County's FCZD administrator and the Director of Pierce County Planning & Public Works Department). Given the County FCZD approval process and criteria, it would be prudent to discuss possible projects with the County's FCZD and Planning & Public Works Department well in advance of potential project funding need.

8.4.9 Special-Purpose Districts

Another option for the County to consider is the development of special-purpose districts. Special-purpose districts are generally created through the local legislative authority to meet a specific need of the local community. The needs may include new services or higher levels of existing services. Many types of special-purpose districts are authorized in Washington including diking, drainage, flood control, and environmental protection districts. Some WSP efforts may be appropriate to the financing available through creation of a special-purpose district, although one objection to some special-purpose districts is that they result in an additional layer of government.

Special-purpose districts can be political subdivisions of the State and can come into existence, acquire legal rights and duties, and be dissolved in accordance with statutory procedures. Enabling legislation sets forth the purpose of the district, procedures for formation, powers, functions and duties, composition of the governing body, methods of finance, and other provisions. The districts may be quasi-municipal corporations—though some districts can be statutorily defined as municipal corporations. Although the general provisions for some special-purpose district statutes have been consolidated, such as for diking and drainage districts, no set of uniform provisions covers all special-purpose districts in Washington as there is with cities and counties.

8.4.10 Non-traditional WSP Funding

Several private foundations and charitable trusts operating within the state of Washington provide grants for environmental works. Further research into these foundations as potential WSP funding sources may be worthwhile; it may be that partnering with nonprofit organizations may enhance access to various non-governmental entity grant funding opportunities.

8.5 General Schedule

The implementation plan assumes a 30-year time frame. Table 8-2 presents a possible implementation schedule. This general schedule may change depending on project approval by the County Council, availability of funding, property access/acquisition, and other factors.

Table 8-2. Potential Implementation Schedule					
Project Name	Description	Phase 1 (Years 1-5)	Phase 2 (Years 6-10)	Phase 3 (Years 11-15)	Phase 4 (Years 16-30)
Military Road Infiltrating Sand Filter	Construct facility to treat and infiltrate stormwater from Military Road sub-basin	Secure funds/Apply for grants	Design & Construct	O&M	O&M
Drywell Retrofits	Replace 15 single-stage drywells in shoreline areas with 2-stage systems (treatment vault and infiltration trench)	-	Secure funds/Apply for grants	Design & Construct	O&M
Infiltration Pond Retrofits	Install filter systems at inlets to 2 ponds in shoreline areas to treat stormwater prior to infiltration	-	Secure funds/Apply for grants	Design & Construct	O&M

8.6 Adaptive Management

If the WSP is implemented, the County will follow adaptive management principles to improve the effectiveness and efficiency of the WSP stormwater management strategies. Adaptive management is a process that promotes flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Figure 8-1 shows the typical adaptive management approach.

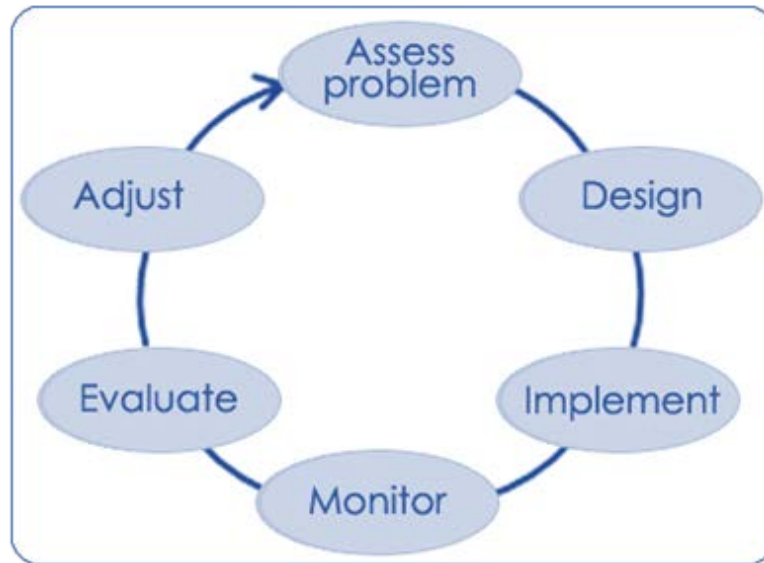


Figure 8-1. Diagram of adaptive management approach

The potential stormwater management measures described in this WSP are not expected to result in substantial changes in water quality or benthic habitat conditions because municipal stormwater does not appear to be a key limiting factor in the Spanaway Lake WSP area. The relatively small changes associated with WSP implementation would be difficult to discern based on monitoring data. Therefore, adaptive management for the Spanaway Lake WSP would focus on improving the efficiency and effectiveness of potential stormwater strategies based on new information on the effectiveness of the potential strategies, information on new methods or technologies, and “lessons learned” during design, construction, and maintenance of the measures as they are implemented.

SECTION 9: LIMITATIONS

The stated objective of the Permit is to “identify a stormwater management strategy or strategies that result in hydrologic and water quality conditions that fully support designated uses as defined by Chapter 173-201A Washington Administrative Code.” This Plan concludes no such stormwater management strategy or strategies exist to meet this objective due in large part to the significant infiltration already occurring in the watershed and because most impairments are not stormwater driven. Rather, this Plan is intended to meet Permit requirements for watershed-scale planning. Incremental improvements may occur through implementation of identified stormwater management strategies, yet even those are limited due to the great deal of uncertainty for success in the foreseeable future and the uncertain funding and feasibility of key projects in the near term.

This document was prepared solely for Pierce County in accordance with professional standards at the time the services were performed and in accordance with the contract between Pierce County and Brown and Caldwell dated October 27, 2014. This document is governed by the specific scope of work authorized by Pierce County; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Pierce County and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

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Appendix A: Ecology-Approved Scope of Work

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Appendix B: Quality Assurance Project Plan

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Appendix C: Watershed Characterization Memo

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Appendix D: Field and Lab Reports

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Appendix E: Model Development and Calibration Report

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Appendix F: Groundwater Model Report

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Appendix G: Potential Stormwater Strategies

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