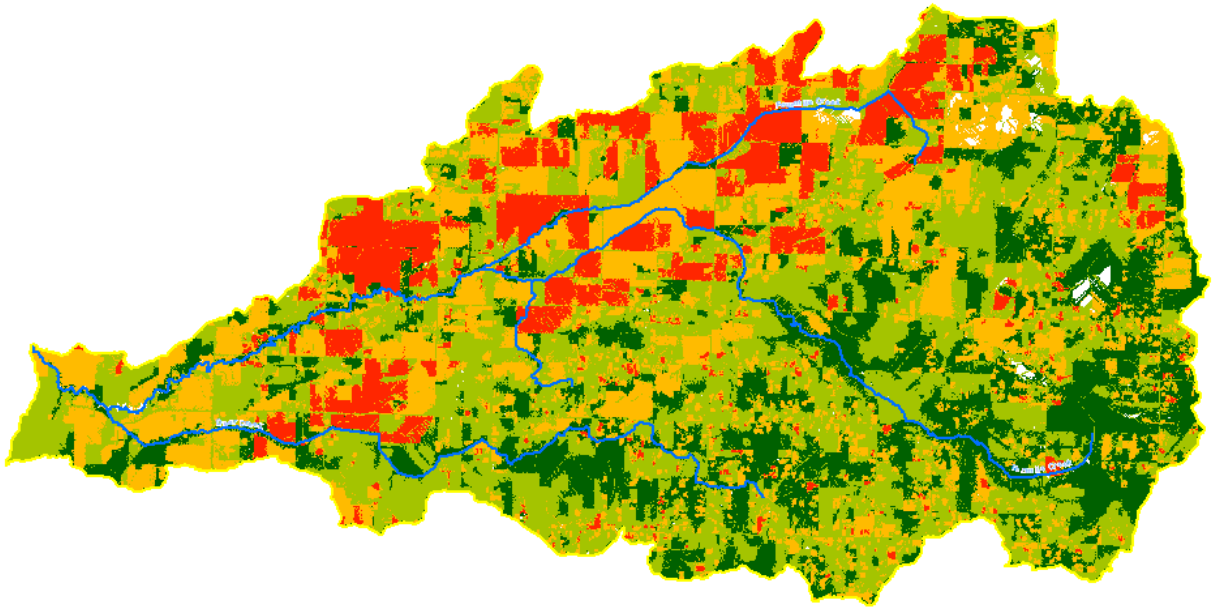
NRCS National Water Quality Initiative (NWQI) Pilot Watershed Assessment:

Tenmile Watershed



Prepared By:
Whatcom Conservation District
Lynden, WA

September, 2017
v.3

Whatcom CONSERVATION DISTRICT

NRCS Natural Resources Conservation Service

TABLE OF CONTENTS

TABLE OF MAPS

TABLES AND FIGURES

OVERVIEW

The following document contains a watershed assessment completed for the Tenmile Watershed located in Whatcom County, Washington and nested within the larger Nooksack Watershed. This watershed assessment was an exercise in characterizing and identifying the land uses, or "critical source areas", that have the greatest potential for nutrient (nitrogen and phosphorous), sediment, and/or pathogen impacts to water quality, while also identifying the outreach strategy and conservation management practices that can be implemented to reduce those impacts. The follow up activity to this assessment is implementation of the outreach strategy including a comprehensive survey of land users in the watershed, modeling of the impact of specific management practices by land use identified in the survey, and connection of those land users to NRCS practices, programs and planning as appropriate to achieve water quality goals.

The watershed assessment and outreach components follow the NRCS 9 Steps of Planning:

1. Identifying the pollutants of concern in the watershed
2. Determining the water quality objectives of the watershed
3. Inventory resources by collecting watershed data
4. Analyze the data via modeling to identify critical source areas
5. Formulate alternatives by suggesting various conservation practices
6. Evaluate/model the impact of different conservation practices on water quality pollutants
7. Work with partners on decision on plans of action for the watershed
8. Implement the Outreach and Implementation plan in the watershed
9. Evaluate the effectiveness of the plan and adapt as necessary to achieve water quality goals

This assessment addresses steps 1-5. The next phase of the project will address steps 6-8, with step 9 being a long-term objective of the project to be conducted by local partners indelibly.

For more detail on the general process for development of a watershed assessment plan, see the NRCS National Planning Procedures Handbook (NPPH), Subpart F: Area-wise Conservation Planning (NPPH Part 600.50 B. (2)).

For more information about this report, please contact authors:

- Nichole Embertson, Ph.D., Science and Planning Coordinator
- Meagan Harris, M.S., Water Quality Data Coordinator
- Aneka Sweeney, M.Ed., Education and Outreach Coordinator

Whatcom Conservation District
6975 Hannegan Rd,
Lynden, WA 98229
P: (360) 526-2381

Written in collaboration with Washington State NRCS.

USDA - Natural Resources Conservation Service
316 W. Boone Ave., Suite 450
Spokane, WA 99201-2348
P: (509) 323-2900

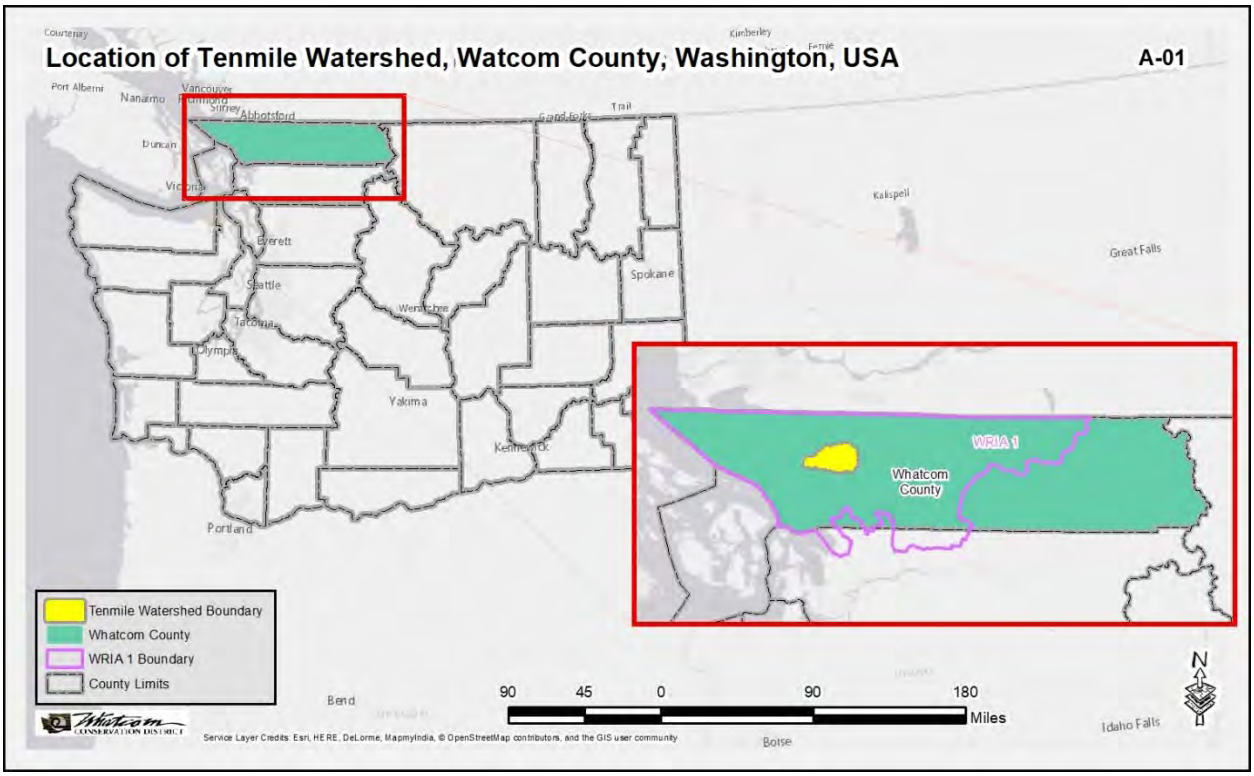
A. BACKGROUND AND PURPOSE

1. Background

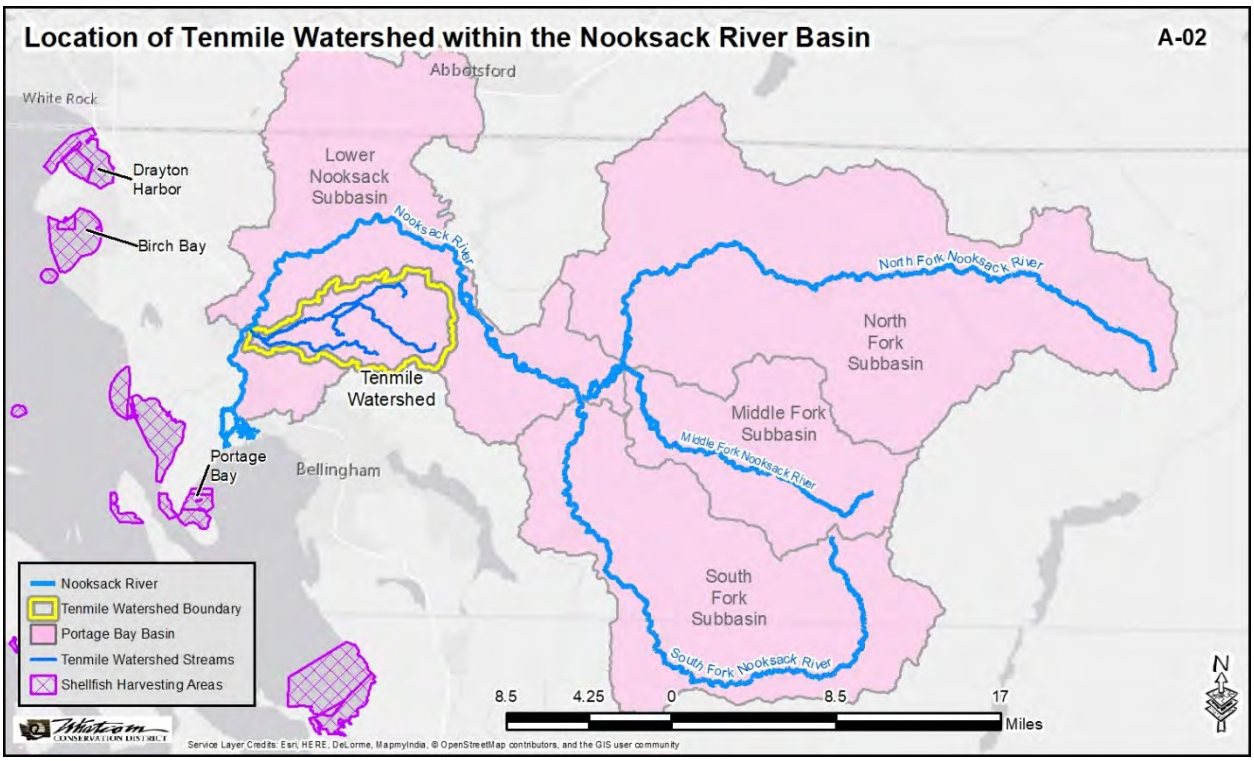
This watershed assessment plan was developed in collaboration with Washington NRCS to identify critical source areas for strategic implementation of land conservation practices for water quality. Past and current conservation practice and plan implementation has been based on landowner engagement, opportunity, and/or regulatory response. A critical, watershed level evaluation has not been performed to create a targeted and strategic outreach effort to focus on high risk land uses for water quality. This watershed assessment provided a means to identify all land uses on a HUC-12 watershed level, potential pollution from nitrogen, phosphorous, sediment, and pathogens to surface waters, and the relative effectiveness of different conservation practices to effect water quality improvement. The results of the watershed assessment will be used to implement a focused and engaged watershed outreach plan to connect land users to available programs, practices, and materials, and/or guide the adoption or revision of current programs to better reach end users.

The Nooksack Watershed in Whatcom County, Washington (Map A-01) is home to a strong agricultural economy, residential communities, rural landowners, commercial business, productive forest and natural habitats, and valuable natural resources. However, with so many diverse and demanding land uses, the watershed has also seen an impact in environmental resources such as water quality. The primary artery through this diverse land use is the Nooksack River which originates from mountain glaciers and natural headwater lands and meanders through the County on its 75 mile journey to Portage and Bellingham Bay in the Puget Sound (Map A-02). At its deposition point in Portage Bay is a recreational, commercial, and tribal shellfish industry that is dependent on clean waters for production. Unfortunately, the Nooksack River had a TMDL instated in 2000 for fecal coliform (pathogens), and has roughly 53 303(d) listed segments in the Nooksack watershed for pathogens, ammonia, low dissolved oxygen, and/or temperature, many of which have seasonal high pollutant levels. The persistent high levels of pollutants, particularly fecal coliform, is reflected in the on-going seasonal closures of the shellfish beds in Portage Bay. These closures impact not only the economics of the downstream aquafarmers, but also the tribal harvest that occurs year round for subsistence and ceremonial purposes. The loss in harvest and change in timing of collection, has greatly impacted the social structure and community dynamics of these populations.

The Nooksack Watershed TMDL (Joy, 2000) addresses potential impairments on 18 waterbodies in the Nooksack watershed that contribute to loading in the Nooksack River. The Tenmile Creek and Deer Creek, both part of the Tenmile Watershed, are two of those waterbodies listed for ammonia, low dissolved oxygen, pathogens, and temperature. The Tenmile Watershed also has six 303(d) listed segments identified. In addition to historic and current water quality degradation issues, the Tenmile watershed also has a very active stakeholder group working to make things better. For this reason, as well as its diverse and mixed land use and potential impact to the Nooksack River, the Tenmile Watershed was chosen for this assessment.



Map A-01. Location of the Tenmile Watershed, Whatcom County, WA, USA.



Map A-02. Location of the Tenmile Watershed within the Nooksack Basin and Portage Bay.

2. Location of Watershed Assessment Area

The Tenmile Watershed is located within the greater Nooksack River Basin (HUC 17110004) in Whatcom County Washington (Maps A-01 and A-02). It also falls within the Water Resource Inventory Area (WRIA) 01. A comprehensive description of the Nooksack watershed and WRIA 1 is included in the Puget Sound Partnership's *2014/2015 Action Agenda for Puget Sound, Section 4* (Puget Sound Partnership, 2014).

Tenmile Watershed

The Tenmile Watershed, which is 35.4 square miles, is comprised of four subwatersheds: Tenmile Creek, Fourmile Creek, Deer Creek, and Fazon (Map A-03). The Tenmile Watershed was chosen for this assessment due to its mixed land use, current level of stakeholder engagement, geographic location within the county, and water quality history. The HUC-12 unit of Tenmile Watershed is also referred to as Barret Lake Watershed in some agencies documents, though we will use the former in this report.

The westernmost portion of the Tenmile watershed falls within the City of Ferndale (Map A-04). Other nearby municipalities include Lynden and Everson to the north and Bellingham to the south. The Laurel Watershed Improvement District (Laurel WID) overlaps the watershed, as do five Drainage Improvement Districts (DID or CDID).

3. Water Quality Resource Concerns

Based on the Nooksack TMDL for pathogens, and Tenmile Watershed 303(d) pollutant listings for ammonia, low dissolved oxygen, pathogens, and temperature, the following pollutants were chosen for evaluation in this assessment: sediment, nutrients (nitrogen and phosphorous), and pathogens. Project-driven surface water quality monitoring of sediment and nutrients has taken place in the Nooksack Basin and Tenmile Watershed since 1997. Regular sampling of surface water quality pathogens (measured as fecal coliform and *Eschericia coli*) has been occurring since 2010. Land use would indicate that all four pollutants are potential threats to water quality within the watershed.

Washington State Surface Water Quality Criteria

Table 1 summarizes surface water quality criteria for Washington State for the pollutants of concern in this assessment. These criteria are established under WAC 173-201A-200 (fresh water designated uses and criteria). More information can be found at http://www.ecy.wa.gov/programs/wq/swqs/criteria.html. Full text of Chapter 173-201A WAC is available at http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201a&full=true.

Lower Nooksack River Basin Bacteria TMDL

Following the 2000 Nooksack River basin bacteria total maximum daily load (TMDL) evaluation, Ecology published specific water quality targets for bacteria in the mainstem Nooksack River and its lowland tributaries (Hood, 2002). These TMDL targets for Tenmile Watershed are 39 CFU/ 100 ml. The TMDL implementation plan also sets load allocation targets for Tenmile and Deer Creeks based on relative flow.

Table 1. Surface water quality criteria for Washington State for the pollutants (or parameters) of concern in this assessment.

Parameter	Measured as	Surface Water Criteria for Freshwater
Total Suspended Solids	Total Suspended Solids (mg/L) Turbidity (NTU)	No defined criteria for rivers and streams; A turbidity criteria is defined as percent saturation (percent increase over background)
Nitrogen	mg/L	No defined criteria for rivers and streams.
Phosphorus	mg/L	No defined criteria for rivers and streams.
Pathogens	Fecal coliform (CFU/ 100 ml)	**Two part criteria** Geomean: 100 CFU/100ml 90th percentile: 200 CFU/100 ml

4. Opportunities and Goals for Water Quality

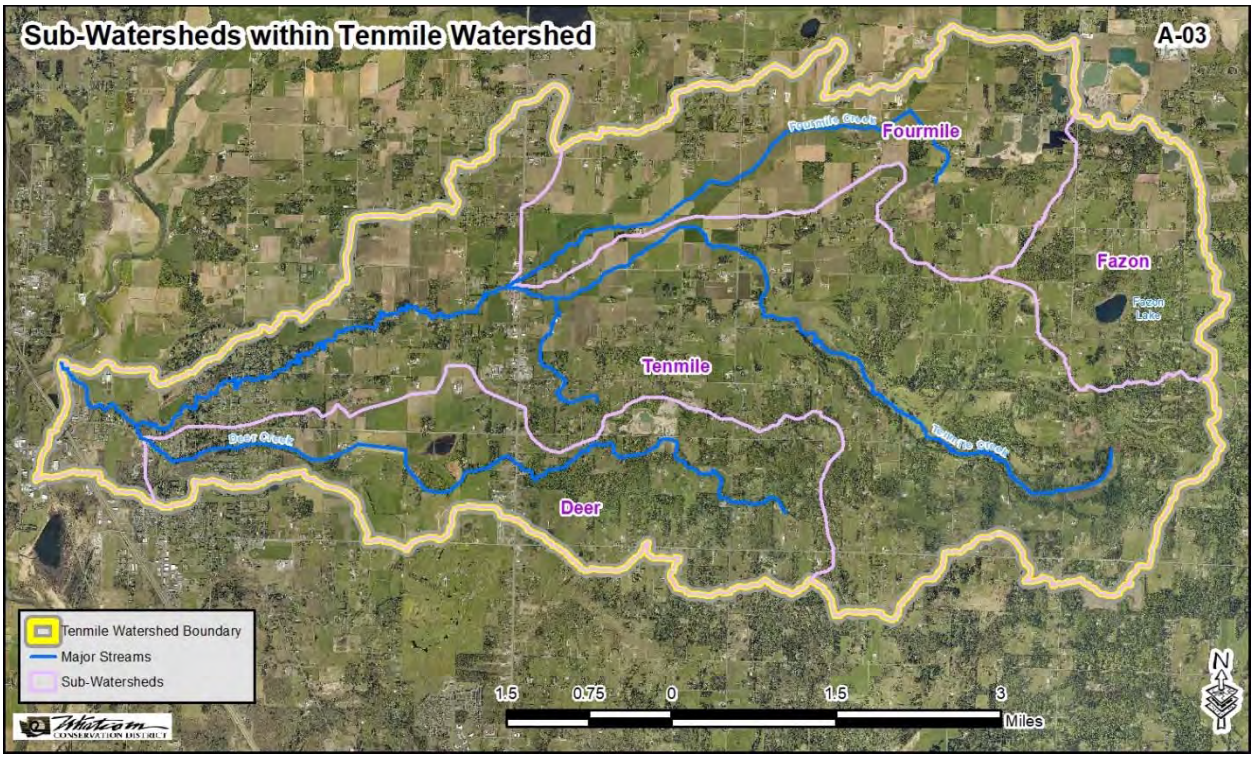
The Tenmile Watershed is reflective of the greater Whatcom County in its diverse land uses with agriculture being the primary land use (by acreage), residential second, and commercial and natural landscapes the remaining. The agricultural sector is serviced by a variety of agencies and organizations including the Whatcom Conservation District (WCD) and NRCS who provide non-regulatory technical assistance in conservation planning and practice implementation. Whatcom County Public Works (WCPW) provides outreach to agricultural and non-agricultural land users. Other agencies such as the Washington Department of Agriculture (WSDA), Ecology, and Whatcom County Planning Development and Services (PDS) are the primary regulators for the dairy (WSDA) and non-dairy agriculture sectors (Ecology, PDS). Whatcom County PDS, Washington Department of Health, and Ecology also interact in non-agricultural land use in a regulatory context. A variety of other groups interact with landowners around water quality issues for education, outreach, awareness, services, and more.

Local water quality groups - including the Tenmile Clean Water Project (TCWP) - support the goals of reducing fecal coliform in the Tenmile Watershed to meet the WA state water quality standards and Nooksack TMDL objectives. The TCWP engages community members with a primary focus on fecal coliform monitoring in Deer, Tenmile, and Fourmile Creeks.

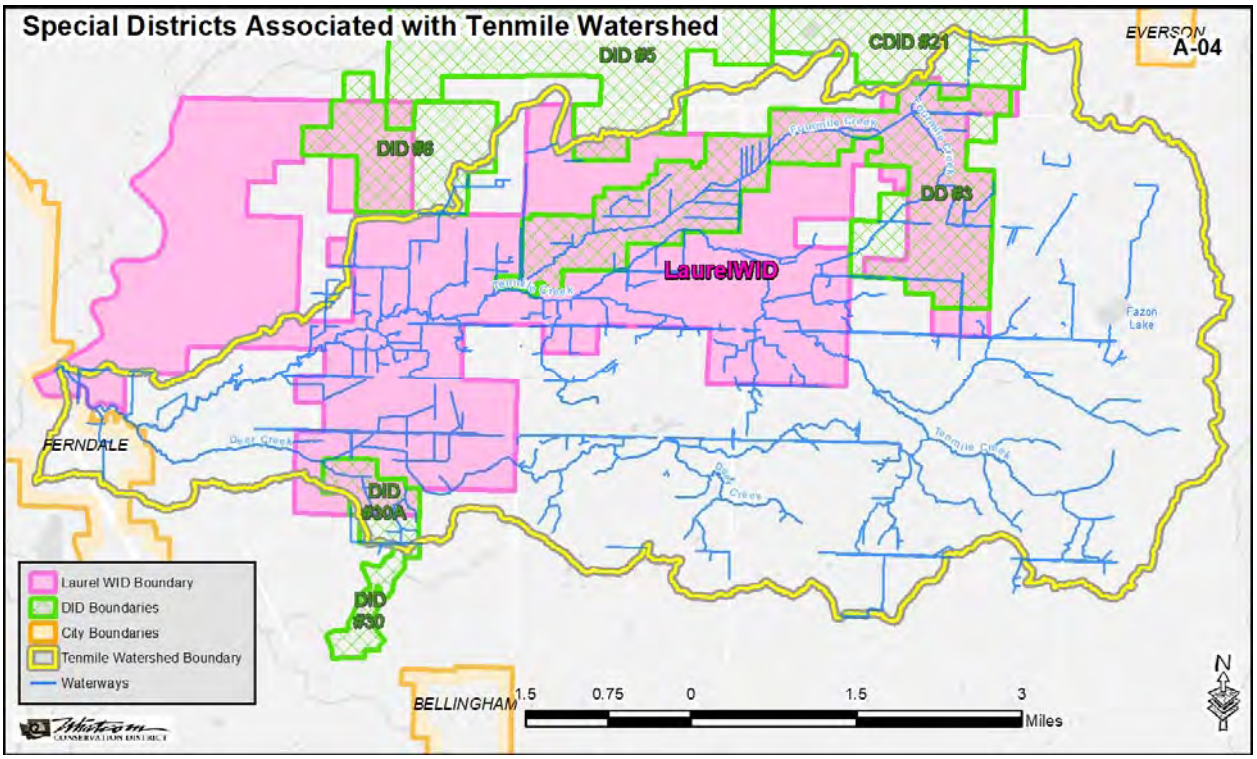
Other partners in Tenmile Watershed include Laurel Watershed Improvement District (WID) and a number of Drainage Improvement Districts (DID; Consolidated DID or CDID). WID and DID boundaries are shown on Map A-04.

5. NRCS's Partnership in Reaching Goals

Local NRCS is committed to helping the watershed meet its water quality goals. NRCS has active task orders with Whatcom Conservation District for engineering and biological assistance, and has provided assistance to farmers in the watershed via the EQIP program. There are currently two NRCS conservation planners in the office in the Everson Field Office to assist with landowner engagement in the Tenmile Watershed. To maintain current workload, and add additional workload, it would be ideal to have a field office engineer and a nutrient management specialist in the office.



Map A-03. Sub-watersheds within Tenmile Watershed.



Map A-04. Special Districts Associated with Tenmile Watershed.

B. WATERSHED CHARACTERIZATION

1. Watershed Location

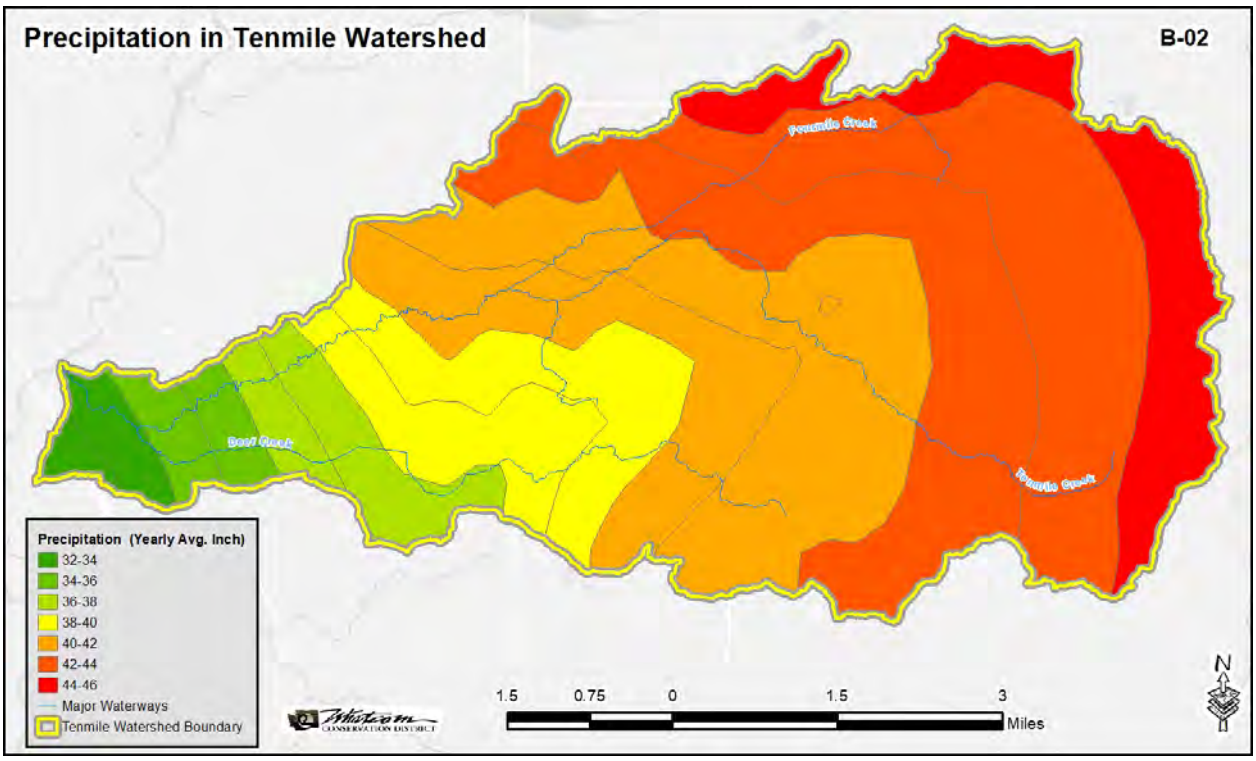
See section A.1 for more information about the watershed.

2. Local Climate Overview

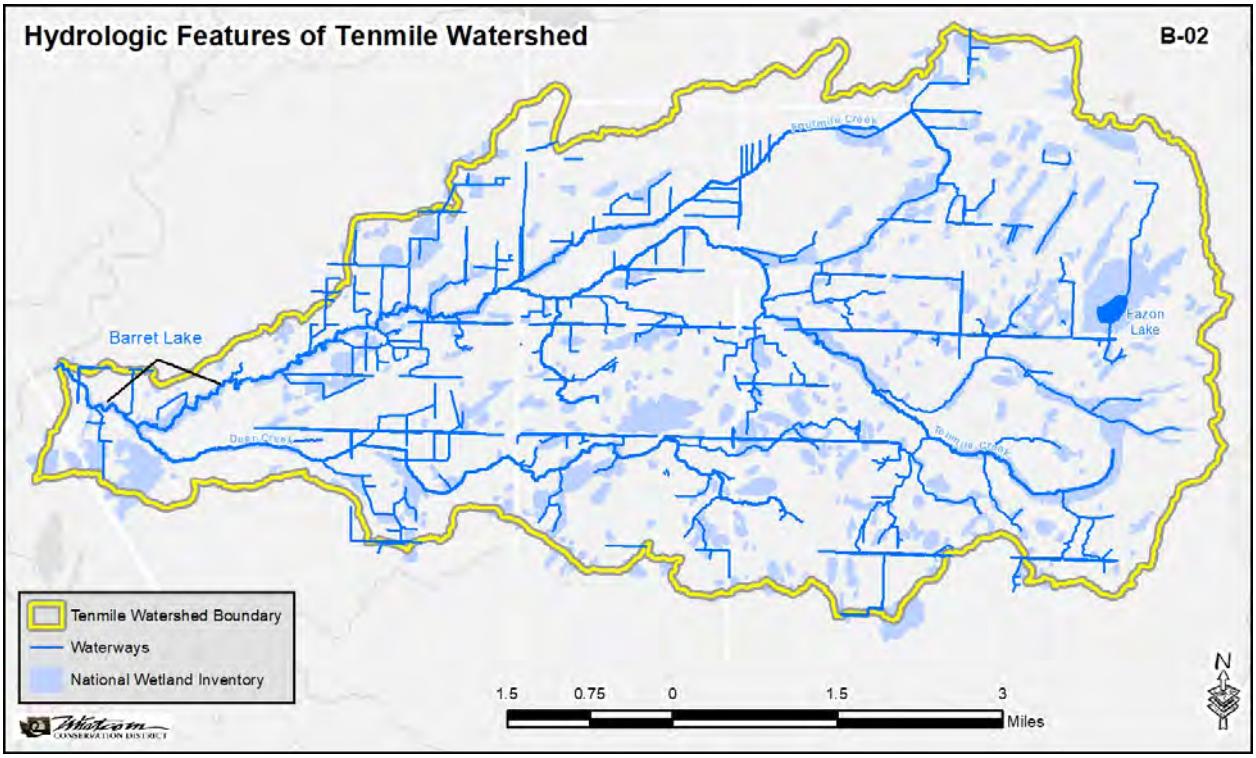
Located in northwest Washington, the Nooksack Basin and Tenmile Watershed receive large amounts of precipitation annually. On average, the Tenmile Watershed receives 40 inches of precipitation as rainfall annually, with a variation from west to east of 32-46 in. (Map B-01; data source: USDA and Texas A&M University). The majority of precipitation (86%) falls October-May; while the summer months, June-September, receive little (14%) rainfall. The Washington State University (WSU) weather station for this watershed, "Ten Mile", can be accessed at www.weather.wsu.edu.

Table 2. Annual climate summary (2008-2017) for ambient temperature and precipitation from the WSU Ten Mile weather station located in the Tenmile Watershed. Data accessed from: www.weather.wsu.edu (2017)

	Mean			**Mean**			**Mean**			**Total**		
	Min Temp (°F)			**Avg Temp (°F)**			**Max Temp (°F)**			**Precipitation (in)**		
Month	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**	**Min**	**Avg**	**Max**
January	27.8	32.8	39.1	34.2	38.6	44.8	41.1	45.3	51.2	1.87	4.75	8.10
February	30.5	34.2	39	36.7	40.8	46.6	42.3	48	54.5	1.50	3.2	6.10
March	31.5	36.9	39.7	39.3	44.3	47.7	47.1	52.2	58.3	3.29	4.99	7.05
April	36.2	39.4	42.6	44.2	48.7	53.0	51.6	58.1	64.3	1.95	3.42	5.48
May	41.6	43.9	46.6	51.2	54.5	57.4	59.3	64.9	69.4	0.57	2.71	4.41
June	46.6	48.7	50.2	56.3	59.4	64.4	64.5	69.7	78.4	0.17	1.34	3.21
July	48.4	50.6	53.2	60.5	63.5	66.9	71.1	75.6	80.0	0.01	0.8	1.98
August	48.3	50.5	53.4	61.4	63.3	65.1	72.5	76.4	79.3	0.04	1.01	3.07
September	41.3	46	50.1	55.2	57.6	59.9	67.4	70.2	73.7	0.13	2.19	4.75
October	38.3	41.8	48.2	48.1	50.4	55.3	57.3	59.5	63.0	1.91	4.47	8.02
November	31.4	36.5	42.7	39.5	43.2	48.8	45.7	50	54.5	3.24	5.98	8.51
December	27.5	31.9	35.7	33.1	37.1	41.2	37.8	42.3	47.3	2.27	4.18	6.11
Summary	**27.5**	**41.1**	**53.4**	**33.1**	**50.1**	**66.9**	**37.8**	**59.4**	**80**	**0.01**	**39.04**	**8.51**



Map B-01. Precipitation in Tenmile Watershed. Data source: USDA and Texas A&M University



Map B-02. Hydrologic Features of Tenmile Watershed.

3. Physical Characterization of Watershed Area

Hydrologic Features

Map B-02 shows the waterways and wetlands of the Tenmile Watershed. These waterways include the three major creeks identified previously (Tenmile, Fourmile, and Deer) and their associated tributaries and agricultural drainage ditches.

Tenmile Creek flows into the Lower Nooksack River at Ferndale, WA. The western most portion of Tenmile Creek is Barrett Lake, a seasonally flooded portion of Tenmile Creek. Fourmile creek enters Tenmile Creek upstream of Barret Lake and Deer Creek enters Tenmile Creek at Barrett Lake. Fazon Lake does not flow to Tenmile Creek but surface streams and irrigation ditches within the Fazon lake subwatersheds do flow to Tenmile Creek. Additional information on the hydrology of the Tenmile Watershed is found in Section C.

Soils

For the purposes of the Watershed Assessment Model, soils were defined by their Hydrologic Soil Group (Map B-03). Tenmile Watershed is comprised primarily of Group C or C/D soils.

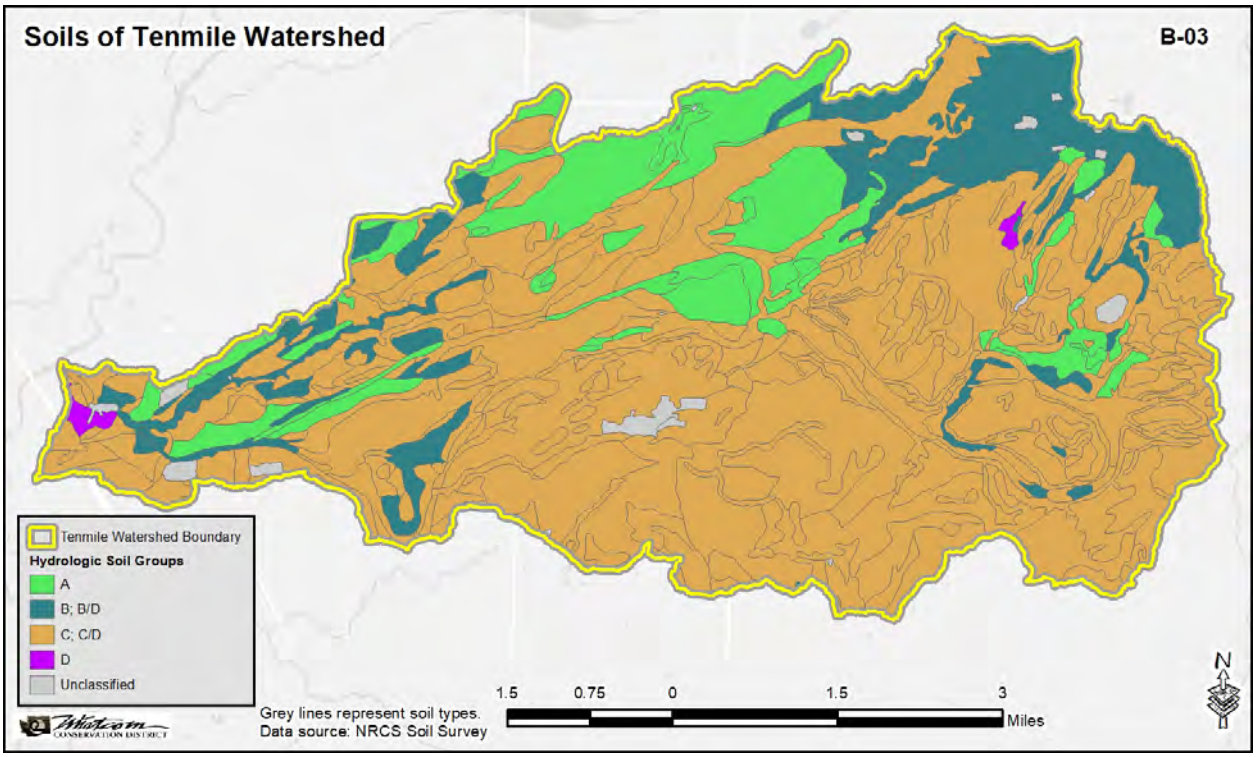
There are 36 unique soil types in the Tenmile Watershed, with the most common (by acreage) being Whatcom silt loam and Whatcom-Labounty silt loam soils. Soil types are represented in Map B-03 by grey lines between different soil types.

Digital Elevation Model

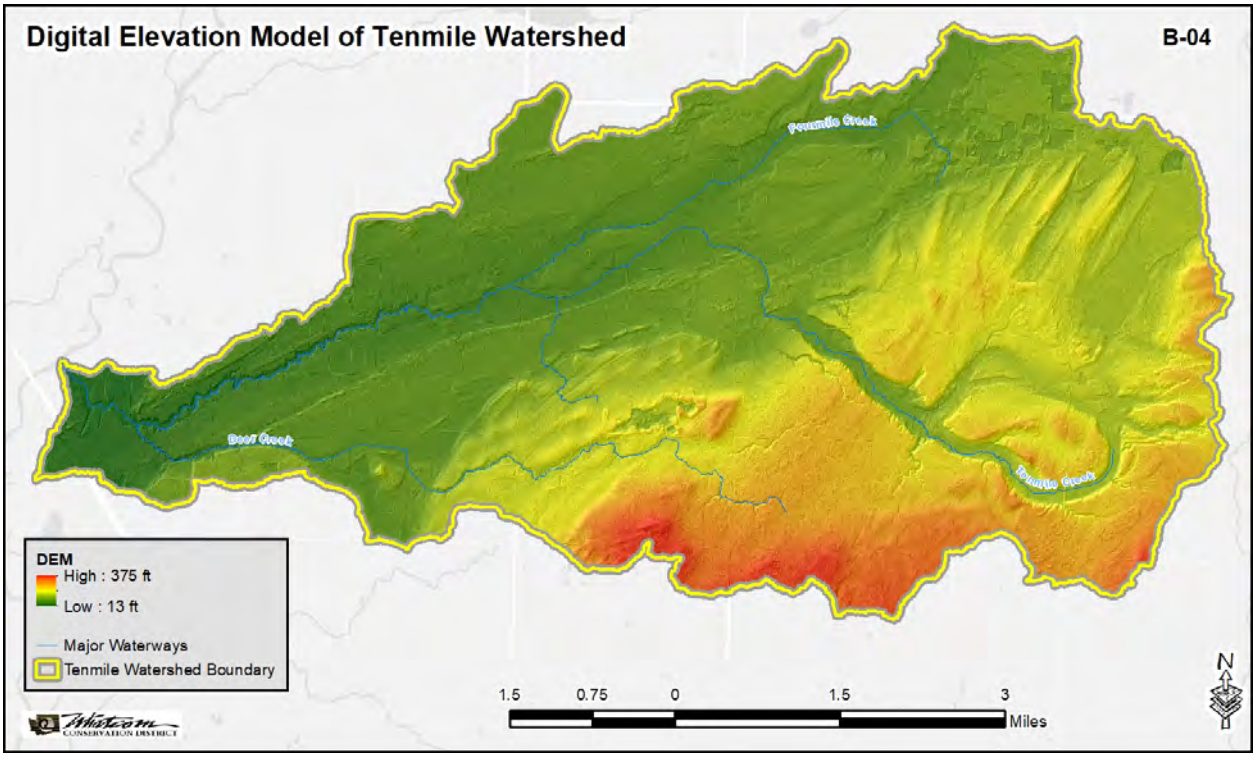
The digital elevation model (DEM) shows the elevation profile of the Tenmile Watershed, from 13 feet at its lowest point to 375 feet on the southernmost edge of the watershed (Map B-04).

Table 3. Soils of the Tenmile Watershed by Hydrologic Soil Group.

Hydrologic Soil Group	Total Acreage	Percent of Watershed
A	5,373	12.8%
B or B/D	5,392	12.8%
C or C/D	28,159	67.0%
D	194	0.5%
Unclassified	2,919	6.9%
Total	**42,037**	**100%**



Map B-03. Soils of Tenmile Watershed.



Map B-04. Digital Elevation Model of Tenmile Watershed.

4. Land Cover and Use

Land use in the Tenmile Watershed is mixed agriculture, rural commercial, and rural residential. Agriculture in the watershed includes dairies, beef cattle, berry crops, potatoes, corn, hay and silage, and a small number of orchards, tree nurseries, and vegetable crops.

National-scale land cover datasets (such as NOAA's Coastal Change Analysis Program (C-CAP) Land Cover Atlas and the USGS National Land Cover Database (NLCD)) are available for the Tenmile Watershed and provide a general overview of land use in the watershed. However, these national scale land cover data sets lack the specificity and resolution that we required for the watershed assessment modelling and associated outreach. Previous land use characterizations in Whatcom County by Washington State Department of Agriculture and Whatcom County were also reviewed but did not meet the needs of this assessment.

Tenmile Watershed Land Use Survey (2017)

To assess land use in the watershed with specific crop types identified and high spatial resolution, district staff completed a land use survey of the Tenmile Watershed. Table 4 summarizes the results of this survey in the Tenmile Watershed by broad land use categories (Primary category) and more specific subcategories (Secondary category). The land use classification was used in the modeling of land-use based hydrodynamics and pollutant loads, discussed in detail in Section C.

To complete this land use survey, we began by defining land use categories that were specific to uses in the Tenmile but would be relevant and incisive for other watersheds in Whatcom County. Categorization followed a Primary-Secondary categorization scheme (Table 4). Aerial images were used to define areas of different land use within the watershed and classify these areas based on the defined categories. To validate the classifications, district staff performed a "windshield" survey to confirm the initial land use assignments. If the assigned land use did not match actual land, the GIS layer was updated. This windshield survey used ArcMap and ArcCollector software, as well as paper maps to track location and project completion. Finally, farmstead types were checked against our farm planning database and assigned a farmstead type when possible.

Map B-05 through B-09 show results of this land use survey. Map B-05 shows the location of all on-site septic (OSS) systems in the watershed in addition to the Developed land uses.

Table 4. Land Use by Category from 2017 WCD Land Use Survey

Land Use Category (Primary + Secondary)	**Acres by category**	**Percent of total acreage (%)**
Crop	**11009**	**50.3%**
Blueberry	519.8	3.0%
Caneberry	1073.4	5.6%
Corn	856.7	5.7%
Forage High Intensity	1921.5	10.2%
Forage Low Intensity	5166.4	19.3%
Nursey	99.9	0.3%
Orchard	31.8	0.1%
Other	39.5	0.3%
Potatoes	170.1	0.9%
Unmanaged	1130.1	4.9%
Developed	**5146**	**24.8%**
Commercial	368.0	1.2%
Gravel	297.3	1.5%
Lawn	363.8	2.6%
Residential	2964.1	11.7%
Road	541.1	5.1%
Turf Grass	267.7	1.0%
Unmanaged	344.4	1.7%
Farmstead	**705**	**4.1%**
Beef Cattle	9.6	0.1%
Crop	30.4	0.1%
Dairy	156.3	0.6%
Mixed	405.3	2.7%
Horse	74.5	0.4%
Irrigation	1.7	0.02%
Other Animal	3.1	0.02%
Poultry	24.5	0.1%
Natural Space	**5871**	**20.8%**
Forest	4930.2	14.4%
Riparian	414.7	2.8%
Water	324.6	2.2%
Wetland	201.3	1.5%
Grand Total	**22,732 acres**	**100%**

Table 5. Livestock survey results by animal type.

Animal Type	Number of animals	Animal Units* (#)	Percent by Animal Unit (%)	Number of properties by animal type	Percent of total properties (%)
Horse	304	456.0	4.93	95	41.7
Beef	607	607.0	6.56	42	18.4
Dairy	5602	7842.8	84.75	35	15.4
Sheep	41	4.1	0.04	7	3.1
Goat	102	15.3	0.17	12	5.3
Swine	0	0	0	0	0
Camelid	3	2.4	0.03	3	1.3
Poultry	65316	326.6	3.53	33	14.5
Other	3	0.02	0.00	1	0.4
TOTAL	**71978**	**9254.2**	**100**	**228**	**100**

*One "Animal Unit" is the equivalent of 1,000 pounds of animal weight adjusted for the number of animals (eg., a 1,000 pound cow = 1 animal unit; ten 100 pound sheep = 1 animal unit). See Appendix A - Table 10 for Animal Conversion Factors used.

Tenmile Watershed Livestock Survey (2017)

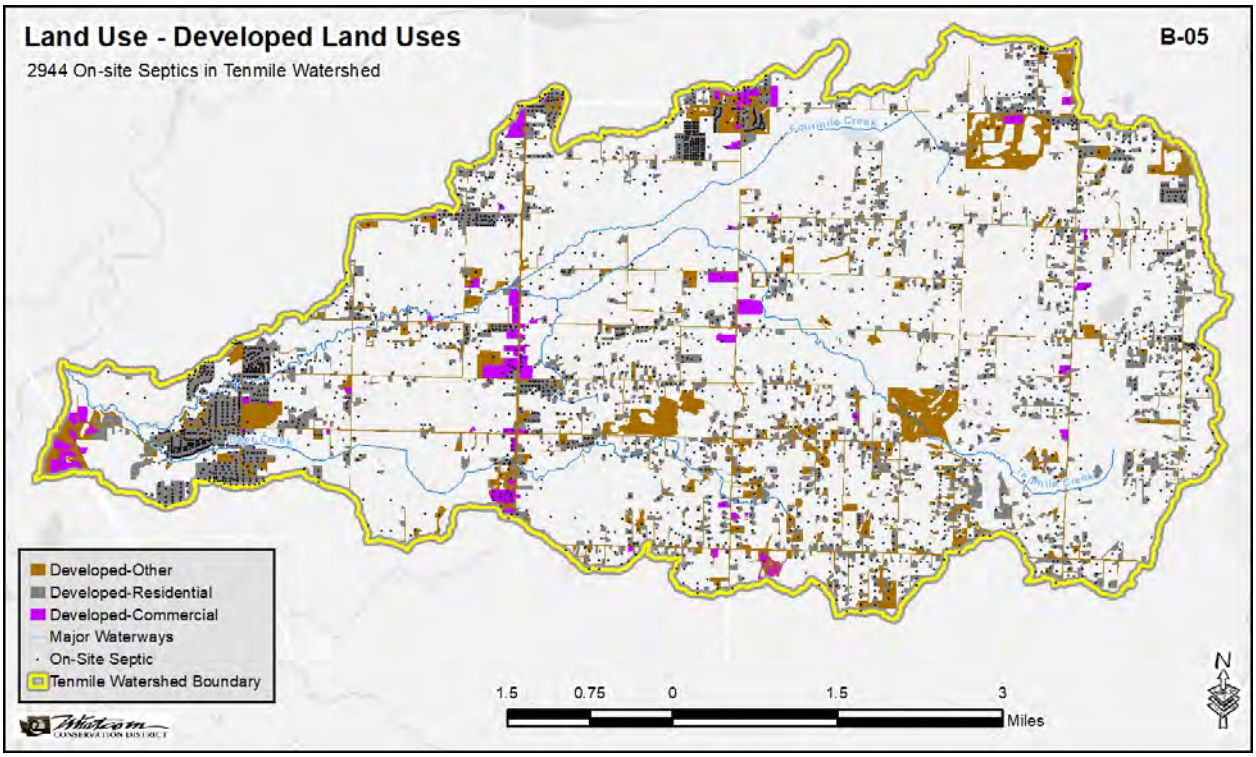
In addition to the Land Use Survey, WCD staff noted livestock and evidence of livestock on parcels within the watershed to complete a "windshield" livestock survey for Tenmile Watershed. The livestock survey results were also checked against our farm planning database and edited where applicable. For data presentation, livestock numbers were converted to total animal units (Appendix A. Table 13). Livestock survey was then compared with the county's parcel layer to determine the number and location of properties (parcels) by animal type. Results of the livestock survey are summarized in Table 5. Livestock survey results by animal type. and Map B-08, which shows livestock numbers by total animal units

The livestock survey results indicate that there are three primary types of livestock husbandry in the Tenmile watershed. Of the 228 total properties identified with livestock; 42% own horses, 18% beef cattle and 15% dairy. These estimates of the total number of livestock and the most common types of livestock owners that live within the watershed was used to develop focus groups for the outreach plan and will help to guide the project outreach in the watershed. These data provide the target audience selection for both the preliminary focus groups and to guide the Social Indicator Survey as discussed in Section F below.

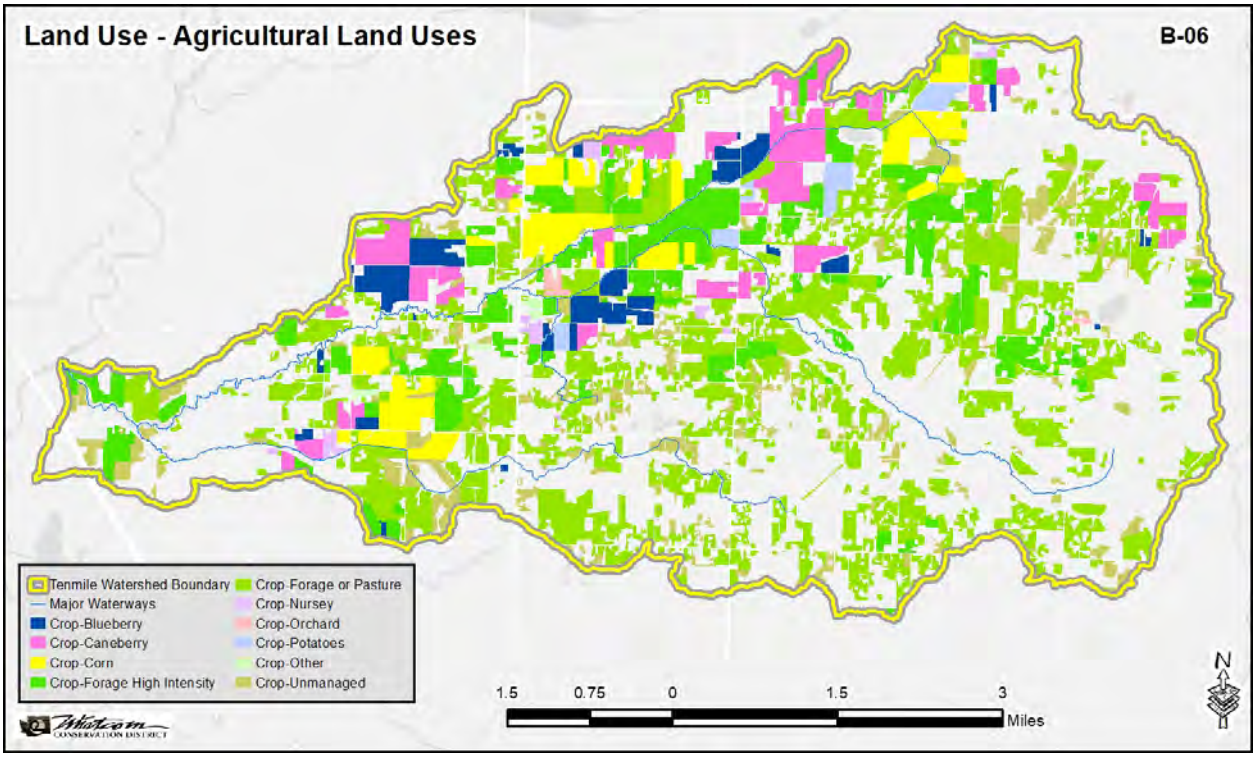
5. Socioeconomic and Demographic Characterization of Watershed

The Tenmile Watershed consist of large acreage agriculture, small acreage hobby farms, high density urban areas, commercial business districts, and rural residential. There are 27 distinct zoning designations and 4,083 individual parcels with 2,958 unique addresses in the 25,404 acre watershed. Over 1,100 parcels are less than 1 acre in size; these are primarily general commercial and rural residential. Over 580 parcels are greater than 10 acres.

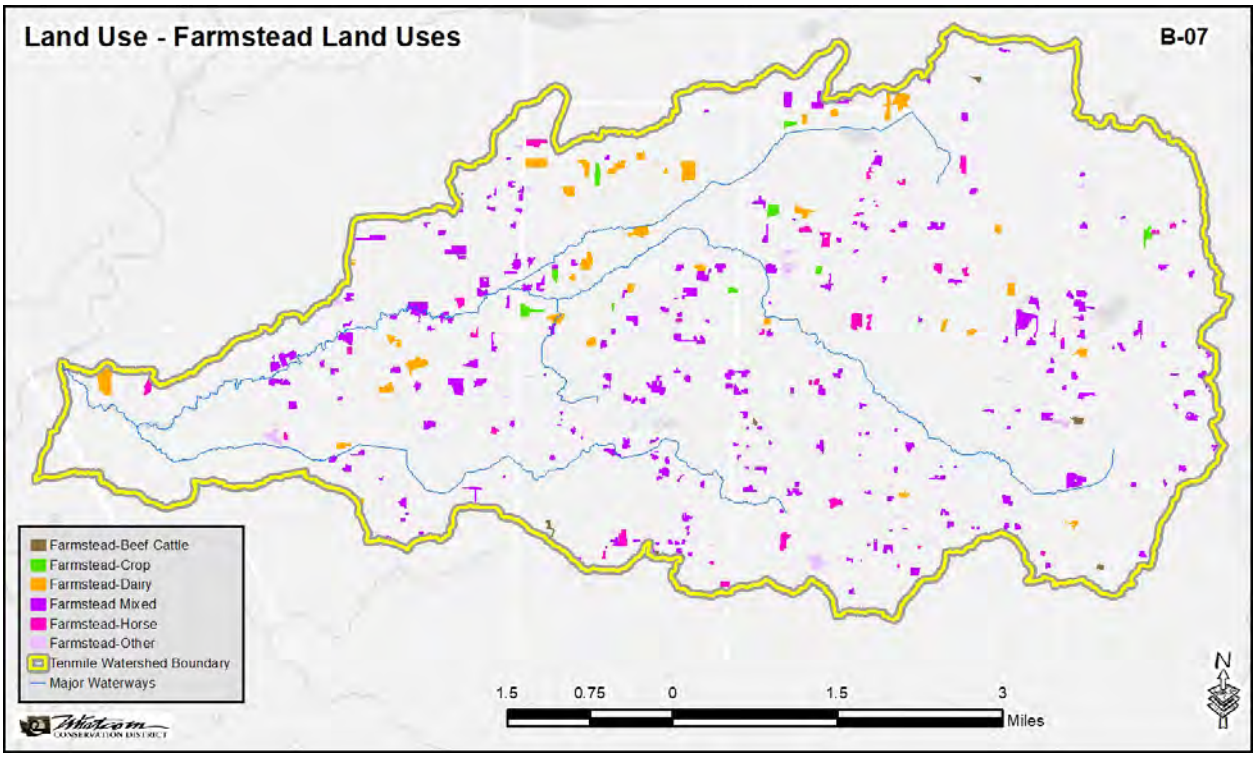
The watershed spans multiple school districts and includes only a small portion of the City of Ferndale, with no defined cultural center within the watershed. The implications of this are discussed in further detail in Section F.



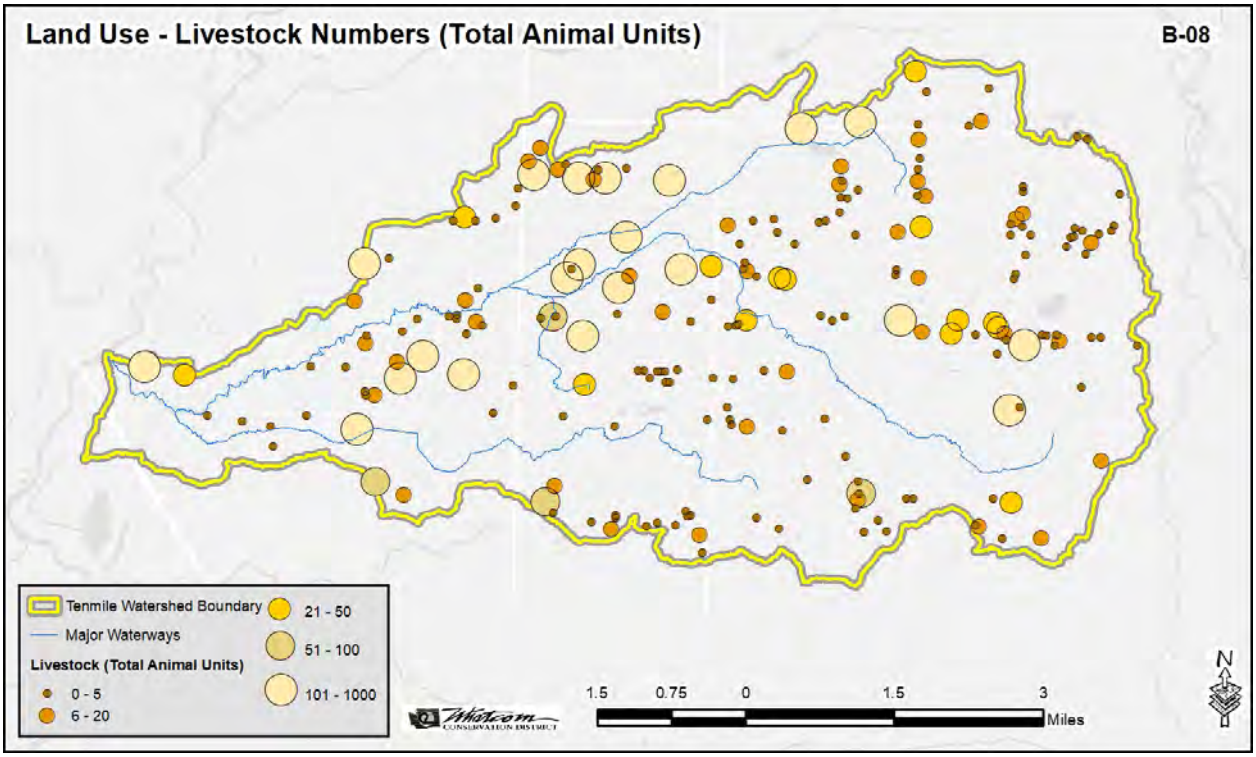
Map B-05. Land Use of Tenmile Watershed: Developed Land Uses.



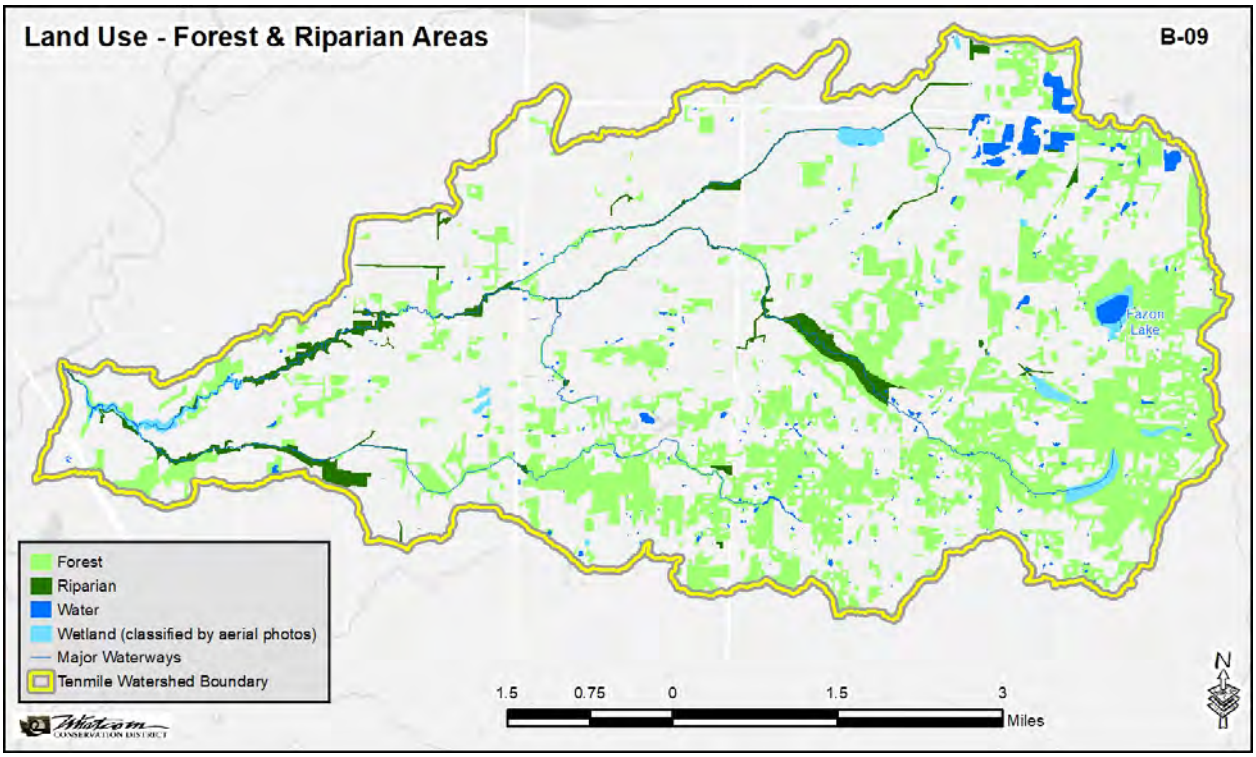
Map B-06. Land Use of Tenmile Watershed: Agricultural Land Uses.



Map B-07. Land Use of Tenmile Watershed: Farmstead Land Uses.



Map B-08. Land Use of Tenmile Watershed: Livestock Numbers (Total Animal Units).



Map B-09. Land Use of Tenmile Watershed: Forest & Riparian Areas.

C. HYDROLOGIC AND WATER QUALITY CHARACTERIZATION

1. Available Water Quality Data and Resources

WA Department of Ecology managed a gauging station on Tenmile Creek above Barret Lake from 2003-2012. This station is no longer active but the data are still available. The location of this station is shown on Map C-01.

There are no current projects to monitor flow in Tenmile, Fourmile or Deer Creeks, though the need for such monitoring has been discussed by WCWP partners. Seasonal flow estimates would enable WCWP partners to estimate bacteria loading based on the bacteria concentrations measured at the ten ambient monitoring stations in the Tenmile Watershed.

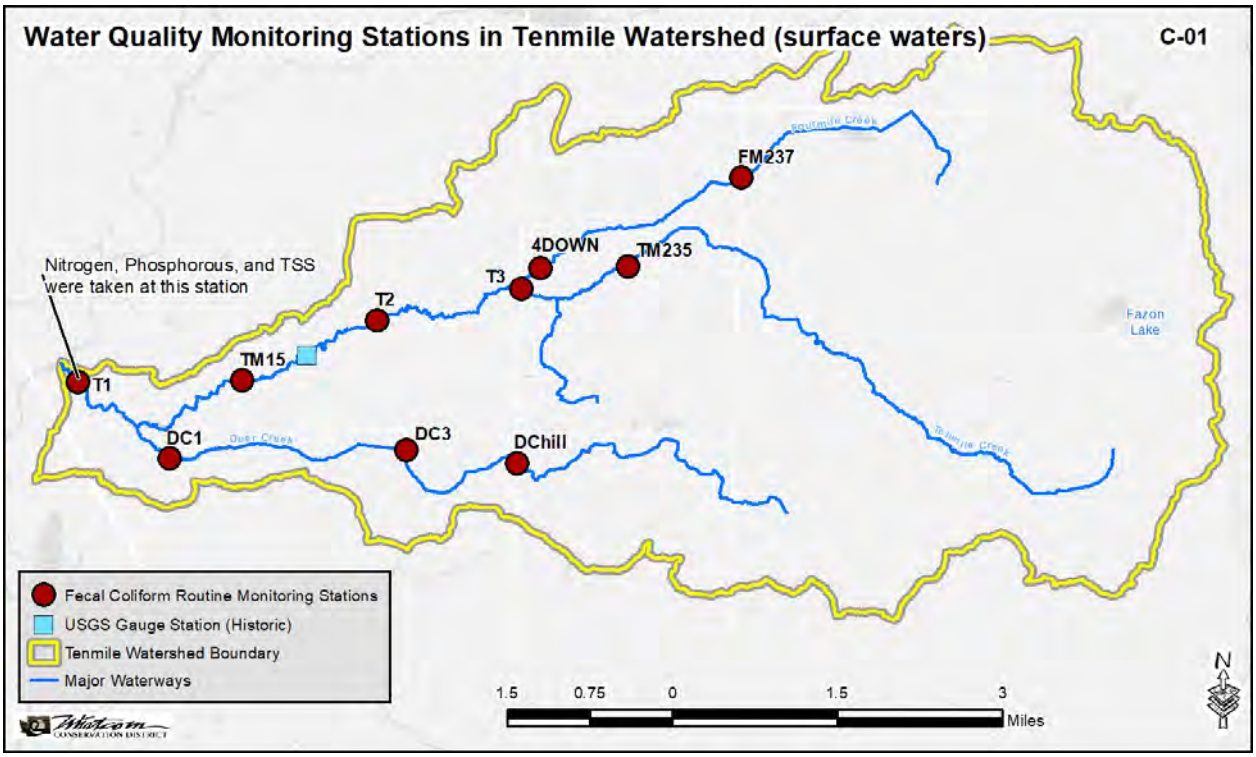
Table 6 summarizes surface water sampling in the Tenmile Watershed for each of the four pollutants of concern in this assessment. Surface water quality monitoring efforts in the watershed focus largely of pathogens, though specific projects have targeted sampling for nitrogen, phosphorus and sediment between 1997 and 2015. Surface water quality monitoring stations are shown on Map C-01.

Pathogen monitoring in this watershed is a collaborative effort by the following agencies and organizations:

- Whatcom County Public Works
- Washington Department of Agriculture
- Washington Department of Ecology
- Tenmile Clean Water Project
- Laurel Watershed Improvement District

Table 6. Surface water quality sampling in the Tenmile Watershed.

Pollutant	Measured as	Sampling Locations	Period of Record
Sediment	Turbidity (NTU)	1 station on Lower Tenmile Creek (T1)	1997-1998, 2004-2006, 2008-2014
Nitrogen	Total Kjeldahl Nitrogen (mg/L) Nitrite+Nitrate (mg/L) Ammonia (mg/L)	1 station on Lower Tenmile Creek (T1)	1997-1998, 2004-2006, 2009-2015
Phosphorus	Total Phosphorus (mg/L) Orthophosphate (mg/L)	1 station on Lower Tenmile Creek (T1)	1997-1998, 2004-2006, 2009-2015
Pathogens	Fecal coliform (CFU/ 100 ml)	10 ambient sampling stations on Tenmile, Fourmile, and Deer Creeks	T1: 2010-2017 All other ambient stations: 2015-2017



Map C-01. Water Quality Monitoring Stations in Tenmile Watershed (Surface Waters).

2. Watershed Hydrology

Relative contribution of the Tenmile Watershed to the Lower Nooksack River

According to the 2000 Nooksack TMDL Report, which calculated a water balance for the 1997-1998 water year, Tenmile Creek comprised 0.9% of the discharge to the Lower Nooksack River. For context, the Upper Nooksack River (measured at North Cedarville) contributed 89.4% of the water balance and larger watersheds in the Lower Nooksack Basin such as Fishtrap and Bertrand Creeks contributed 2.2% and 2.8% of the water balance, respectively (Joy, 2000; Figure 5).

This water balance was calculated using gauging stations on the mainstem Nooksack River and simulated hydrographs for the tributaries. The hydrographs for each tributary were developed from regression equations, comparing tributary flow to the gauging station on Bertrand Creek (Joy, 2000). Any questions of data requests regarding these regression equations and resulting hydrographs should be addressed to Ecology.

The Lower Nooksack Water Budget compiled by Whatcom County and the WRIA 1 Joint Board describes in further detail the water budget of the Lower Nooksack and its tributaries (Bandaragoda et al., 2012). This document provides information on rainfall to runoff ratios (the proportion of rainfall that is converted to streamflow) and seasonal timing of stream flow in the Lower Nooksack and its tributaries.

Seasonality of Water Quantity

Average annual discharge in the Lower Nooksack River is dominated by snowmelt and rainfall in the upper watershed. By contrast, average annual discharge in Tenmile, Deer and Fourmile Creeks is dominated by lowland precipitation- largely as rainfall- between the months of October and April. Thus, flows in these lowland creeks fluctuate throughout the year, with highest flows throughout the winter months and immediately following storm events. Low flows in these waterways during the summer months is typical, with some tributaries and ditch systems drying up completely during this time. Additional information on seasonal patterns of water quality can be found in Section 4.2 of the Lower Nooksack Water Budget (Bandaragoda et al., 2012).

Instream Flow requirements for Tenmile and Deer Creeks are outline in WAC 173-501-030(1) of the Washington Administrative Code (WAC). Year-round limitations to further consumptive use are established in WAC 173-501-040 for Tenmile, Fourmile, and Deer Creeks.

Precipitation-Runoff Budget

The Lower Nooksack Water Budget estimated rainfall-to-runoff ratios for the creeks in Tenmile Watershed and other lower Nooksack watersheds. These estimates range from approximately 25% in Fourmile Creek to 40-50% in Tenmile and Deer Creeks. Rainfall to runoff estimate is highest for the Fazon sub-watershed with a nearly 70% return rate of rainfall into surface waters. No further modelling or estimation of precipitation-runoff budget was performed for this assessment.

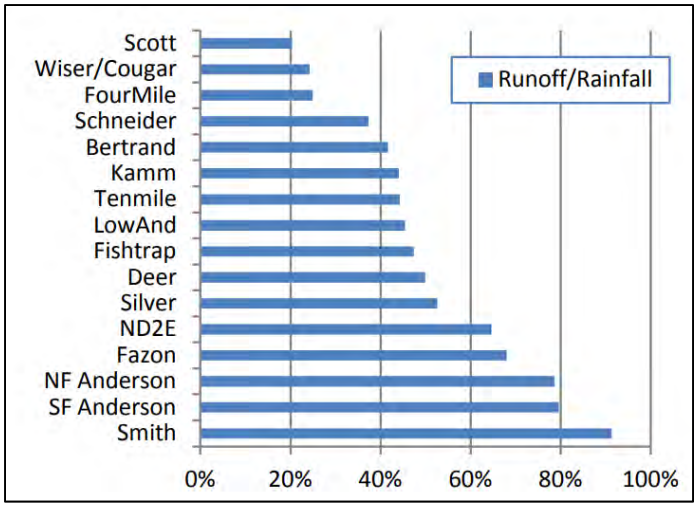


Figure 1. Lower Nooksack Water Budget (Bandaragoda, 2012).

Irrigation in Tenmile Watershed

A study of agricultural irrigation water use was completed in 2016 for the Public Utility District No. 1 of Whatcom County (RH2 Engineering Inc, 2016). According to this study, 2,859 acres in the Tenmile Watershed[1] are irrigated annually (out of a total 6436 agricultural acres in the watershed). Estimates of water use range from 4154 acre-feet per year (afy) to 9434 afy. These estimates were derived from 1) field-specific data from WSDA, and 2) water application efficiencies by irrigation type from Department of Ecology's Water Resources Guidance *GUID-1210 Water Resources Program Guidance for Determining Irrigation Efficiency and Consumptive Use.*The full report is available online at http://wria1project.whatcomcounty.org.

Previous efforts to estimate agricultural water use in the Nooksack Basin are captured in the Lower Nooksack Water Budget Report (Bandaragoda et al., 2012), which can also be found at http://wria1project.whatcomcounty.org.

This NWQI assessment does not evaluate irrigation uses in the Tenmile Watershed and does not account for irrigation in the hydrologic modelling using NSPECT. Further work to incorporate irrigation data into the identification of critical source areas and the evaluation of Agricultural BMP effectiveness is recommended.

While irrigation data on a field use scale is not available for this watershed via our model, a general overview of irrigation practices is presented to assess potential high impact land uses for mitigation. In general, irrigation is conducted for the majority of crops grown. For caneberry and blueberry, tape and drip irrigation systems are present in almost all acres. When applicable, overhead sprinkler type irrigation systems are used for corn, grass, and potato crops. This may be up to half of these acres in the watershed. Orchard, nursery, and vegetable crops use different methods including drip and sprinkler type irrigation systems, but almost all are irrigated. Most irrigation water is from groundwater wells. More work is needed to properly inventory the number of acres irrigated. Challenges include crop rotation and seasonal variability which impact the need to irrigate, which will affect the timing, volume, and number of acres irrigated annually.

[1] The study uses the Department of Ecology name "Barrett Lake Watershed" rather than Tenmile Watershed, which is used by USDA and NRCS. Both names refer to the same watershed.

Modelled Runoff Accumulation

The Watershed Assessment Model (described in Section D) was used to estimate runoff volumes and runoff accumulation within the watershed. Additional information on this modelling effort and the outputs of the model can be found in Section D.1 and Map D-05.

3. Current Water Quality Conditions

Pathogens

In order to track trends in fecal coliform concentrations over time, monitoring results are used to calculate average (geometric mean) and 90th percentile statistics for each monitoring station. Figure 2. Fecal coliform results at station T1 from July 2014 to July 2017. The dashed red line show samples exceeding 200 CFU/ 100 ml. and Maps C-02 and C-03 show the 10 ambient monitoring stations in Tenmile watershed relative to the surface water criteria. Figure 4 shows fecal coliform results at station T1 from July 2014 - July 2017.

Nine out of 10 stations are meeting the criteria for geometric mean (Figure 3). However, all 10 stations fail to meet the criteria for the 90th percentile (Figure 4).

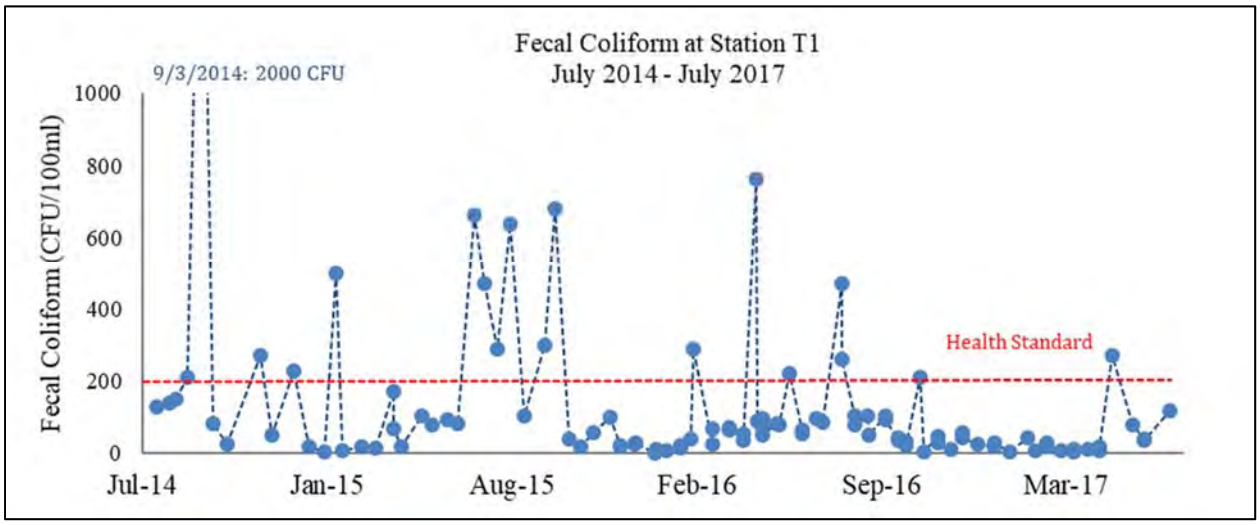


Figure 2. Fecal coliform results at station T1 from July 2014 to July 2017. The dashed red line show samples exceeding 200 CFU/ 100 ml.

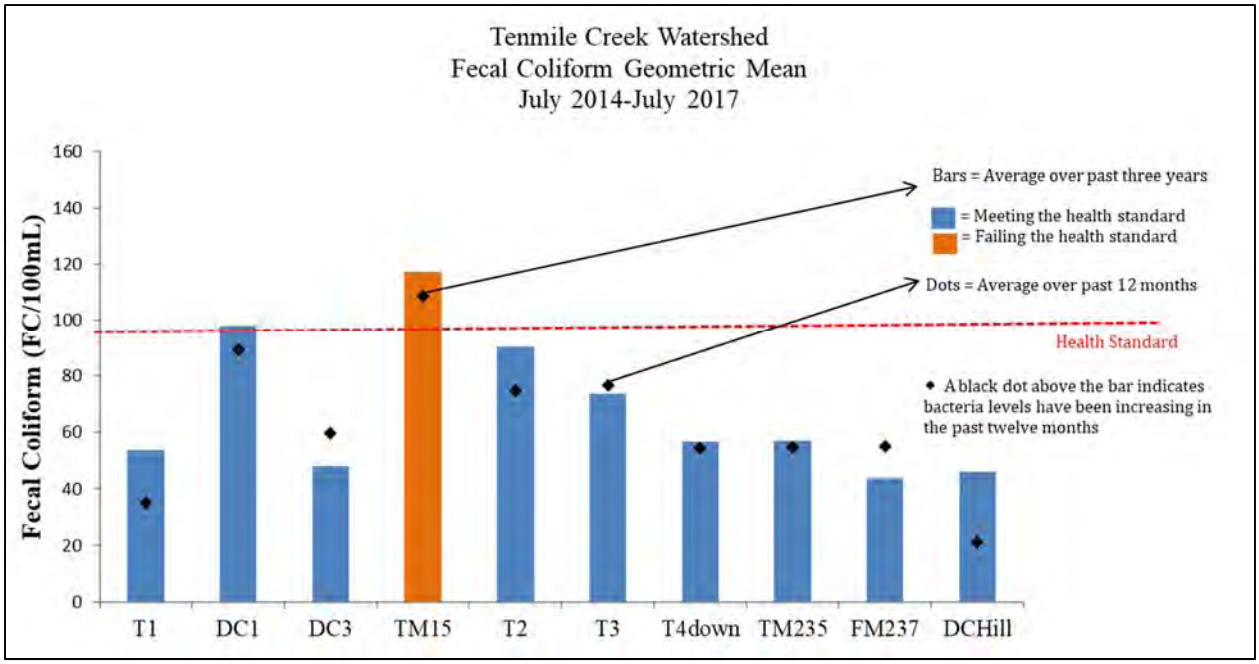


Figure 3. Fecal coliform 3-year geometric mean for Tenmile ambient monitoring stations.

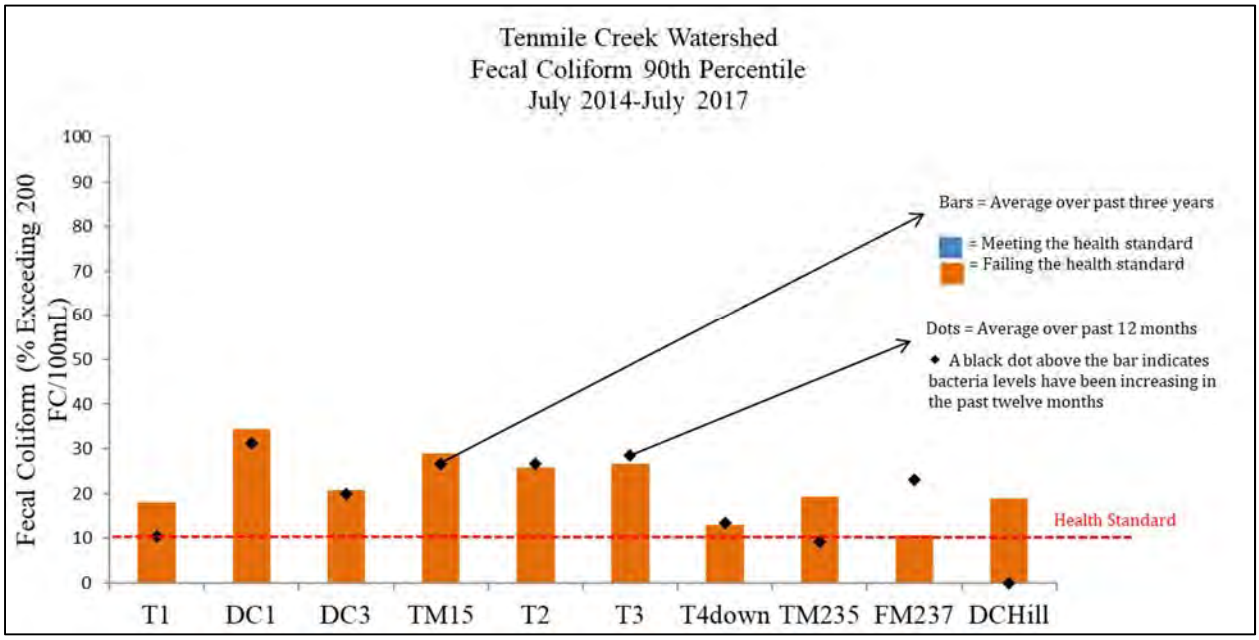
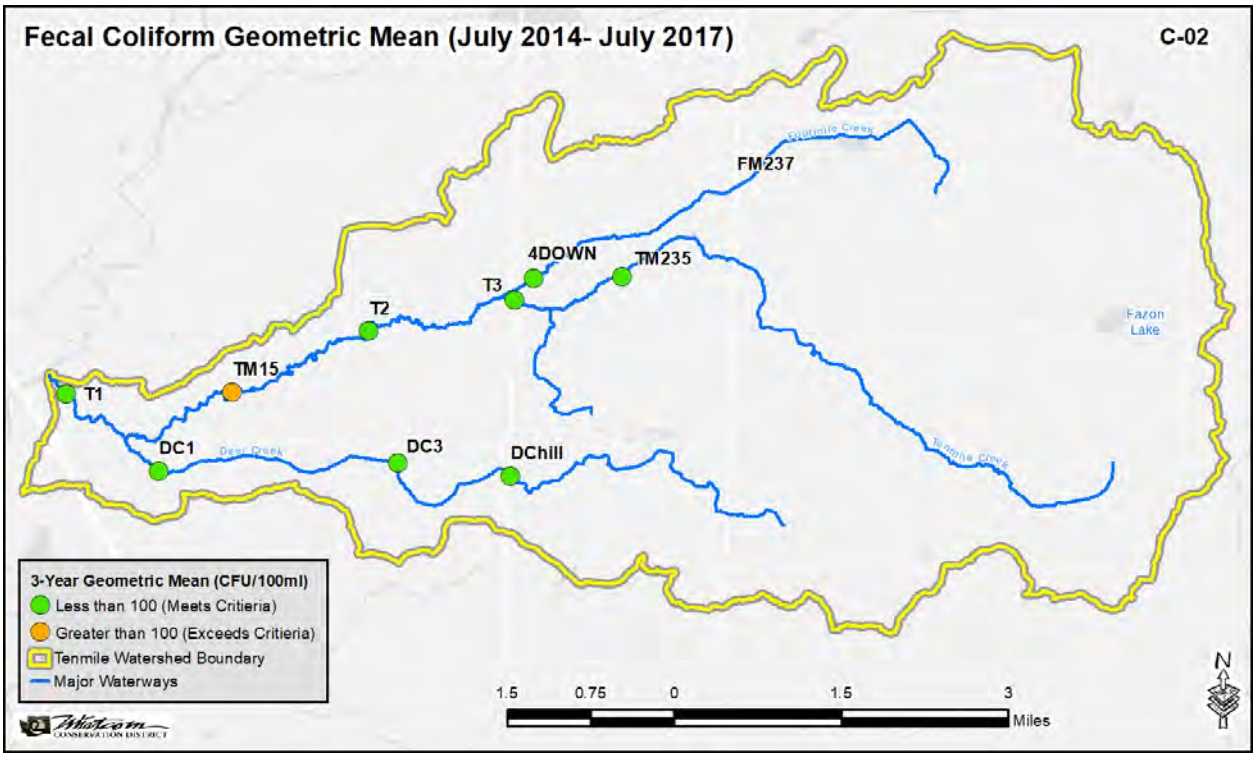
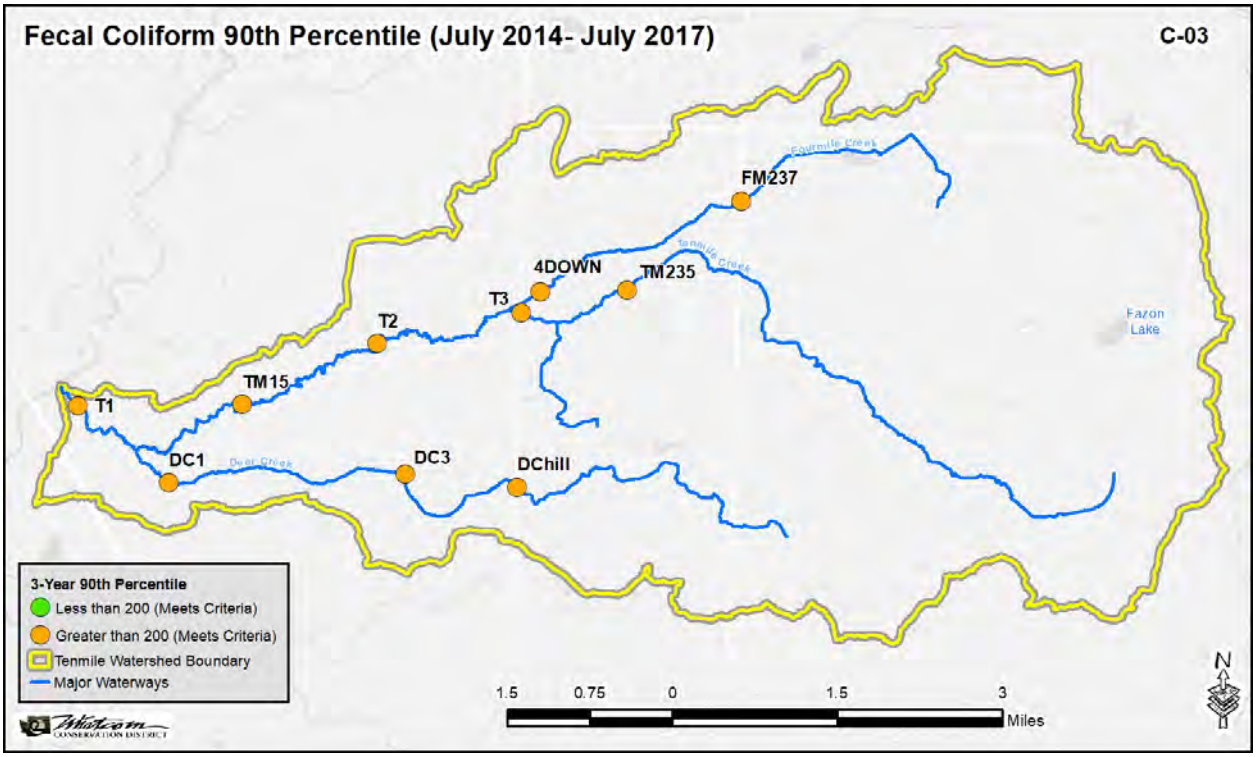


Figure 4. Fecal coliform 90th Percentile for Tenmile ambient monitoring stations. Results are shown as percent of samples exceeding 200 CFU/ 100 ml.



Map C-02. Fecal Coliform Geometric Mean (July 2014-July 2017).



Map C-03. Fecal Coliform 90th Percentile (July 2014-July 2017).

Nitrogen and Phosphorus

Nitrogen and Phosphorus have measured at Station T1 for specific projects between 1997 and 2015. Figure 5 and 6 show these parameters at T1 over time from 1997-1998, 2004-2006, and 2009-2015.

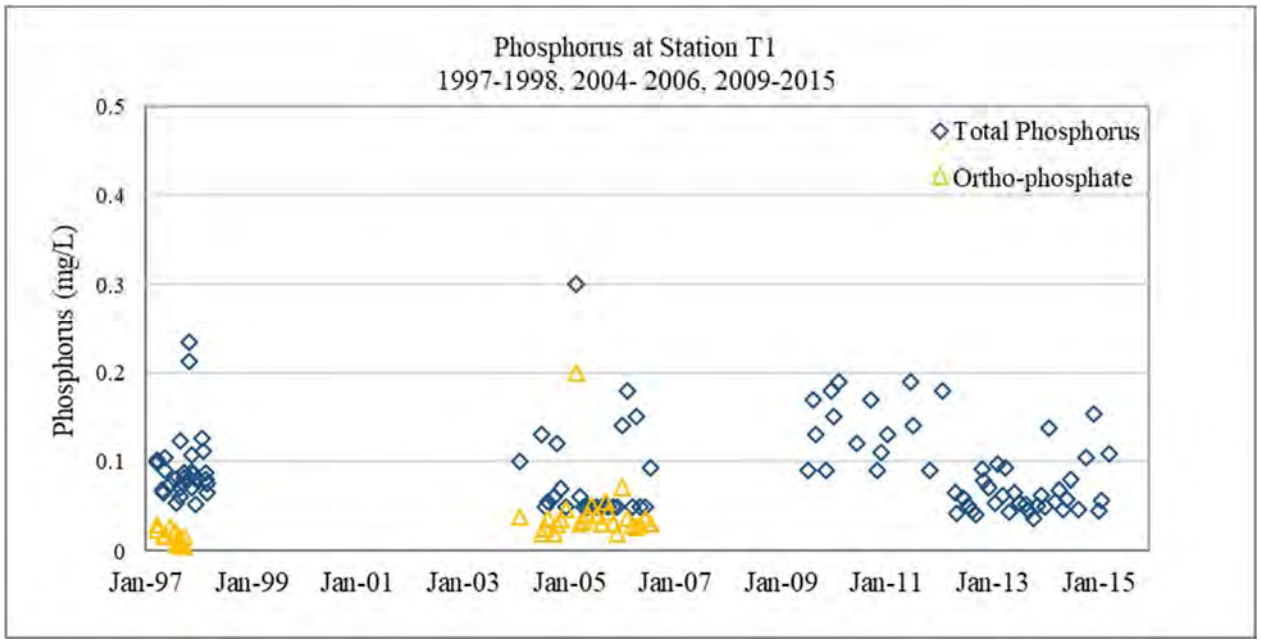


Figure 5. Phosphorus at Station T1 measured as Total P and Ortho-phosphate.

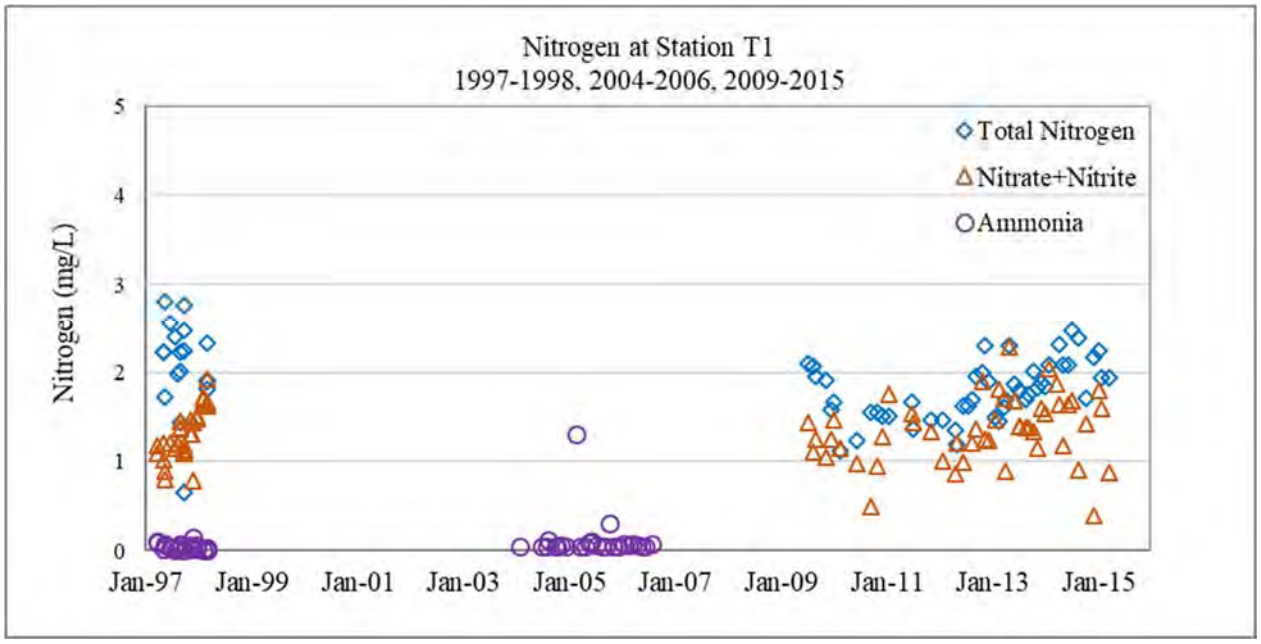


Figure 6. Nitrogen at Station T1 measured as Total N, nitrate+nitrite, and ammonia.

Sediment

Total Suspended Solids (TSS) are not measured at any location in the Tenmile Watershed. Monitoring of TSS does take place at multiple locations on the Mainstem Nooksack River, but the regularity at which this sampling occurs is variable.

Turbidity- a surrogate measurement of suspended sediment that is easier to monitor in the field- has been collected at T1 for select projects between 1997 and 2014. Turbidity measurements were collected during the TMDL work of 1997-1998 (along with N and P) and more recently by Lummi Nation Natural Resources on a semi-annual basis. Figure 7 shows turbidity at T1 over time from 1997-1998, 2004-2006, and 2008-2014.

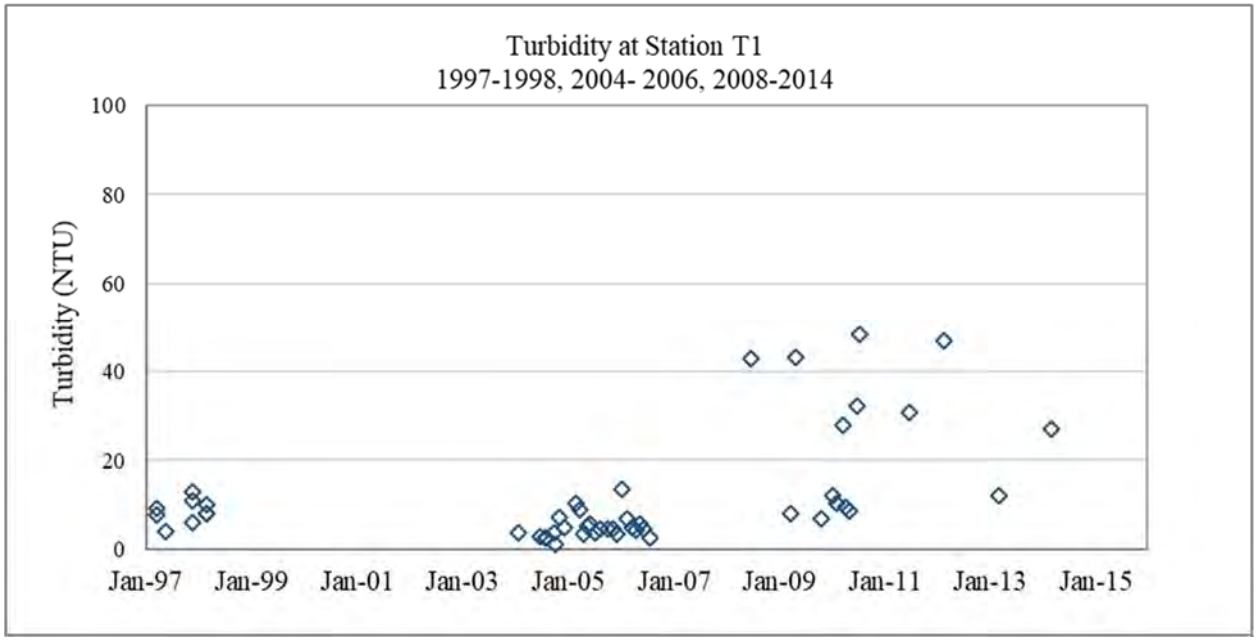


Figure 7. Turbidity (NTU) measured at Station T1.

More regular measurement of either turbidity or TSS in the Tenmile Watershed would provide a better understanding of suspended sediment in the surface waters of the watershed over time. It would be useful to track seasonal trends in sediment concentrations and peak sediment concentrations after "first flush" rain events in the fall. Additionally, in areas with conversion of land use (e.g. from one agricultural land use to another or from an agricultural land use to developed land use), surface water sediment concentrations would provide a more complete picture of the water quality impacts.

D. RESOURCE ANALYSIS ASSESSMENT

1. Overview of Watershed Assessment Model

Objective

The watershed assessment modeling portion of this project has the goal of estimating runoff and pollutant concentrations or loading from specific areas within the watershed, or critical source areas (CSA). Land characteristics (soil, topography, proximity to surface waters) create the potential for pollutant export to surface waters, depending on the land use and land management strategies for that property or area. Potential CSA results from "higher exposure" land uses on areas with "higher risk" characteristics. Thus, the potential CSA account for both factors. Finally, conservation land management practices or "BMPs" can reduce or eliminate the risk of pollutant export, thereby eliminating that critical source area.

The watershed assessment model incorporates spatial data in order to estimate each of these factors (land characteristics, land use, and land management practices) and overlay them spatially in order to identify specific CSA within the watershed.

The OpenNSPECT model

For the hydrological and pollutant source assessments of this project, we used the modeling software OpenNSPECT from the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center. This software is an open source version of the Nonpoint Source Pollution and Erosion Comparison Tool (NSPECT) and was developed to model nonpoint source pollution and erosion bases on land cover and land use type (NOAA Coastal Services Center 2014a). OpenNSPECT is a plug-in for MapWindow GIS, a free, open-source geographic information system (GIS) software package. Information on OpenNSPECT can be found in the *User's Manual for OpenNSPECT, Version 1.2*, *Technical Guide for OpenNSPECT, Version 1.2,* and additional supporting documents. These references can be downloaded from NOAA's OpenNSPECT website: https://coast.noaa.gov/digitalcoast/tools/opennspect. The general process for using OpenNSPECT is diagrammed in Figure 8.

The *Technical Guide for OpenNSPECT, Version 1.2* identifies the following capabilities of the tool (2014b):

1. Estimating runoff volume
2. Estimating pollutant loads and concentrations
3. Identifying areas highly susceptible to erosion by water
4. Estimating sediment loads
5. Assessing the relative impacts of land use changes with scenario analysis

Figure 8. Process diagram for using OpenNSPECT in MapWindow GIS.

OpenNSPECT Model Inputs

Raster Datasets. Four raster datasets are required to run the NSPECT model:

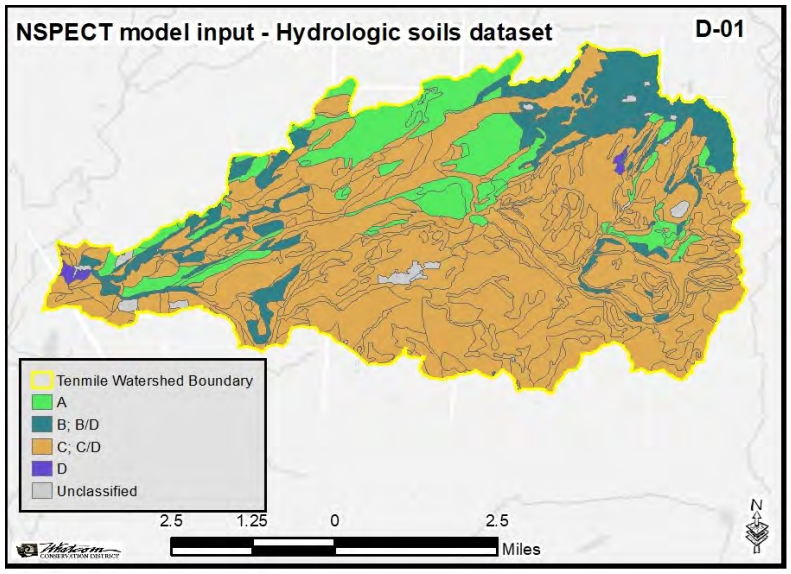
1. Soils grid
2. Precipitation grid
3. DEM grid
4. Land cover grid

These GIS datasets are included in the report as Map D-01 through D-04. More information on the required characteristics of these datasets and how to import them into MapWindow can be found in the NSPECT Support Documents (NOAA Coastal Services Center 2014a, 2014b, 2014c).

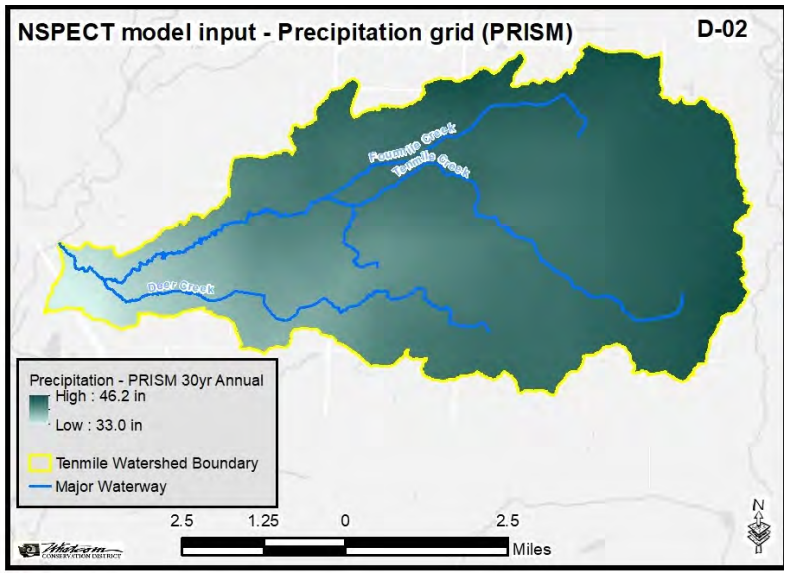
Land Classes and Runoff Curve Numbers. Open NSPECT estimates runoff using the runoff curve number method of the Soil Conservation Service (SCS 1985, 1986). Runoff curve numbers are based on soil type and land cover. Curve numbers are applied to the Modified RUSLE Equation within the NSPECT model, and are used to calculate runoff by cell and accumulated runoff for each cell. It can also be used to calculate erosion, though we did not use the "*Calculate Erosion*" function for this assessment. More information on these methods can be found in *Urban Hydrology for Small Watersheds TR-55* (NRCS 1986) and Section 4 of the National Engineering Handbook (1985). Land cover classes with corresponding runoff curve numbers are found in Appendix A.

Land classes were defined by the WCD as described in Section B- Land Use Survey and shown on Maps B-05, B-06, B-07 and B-09.

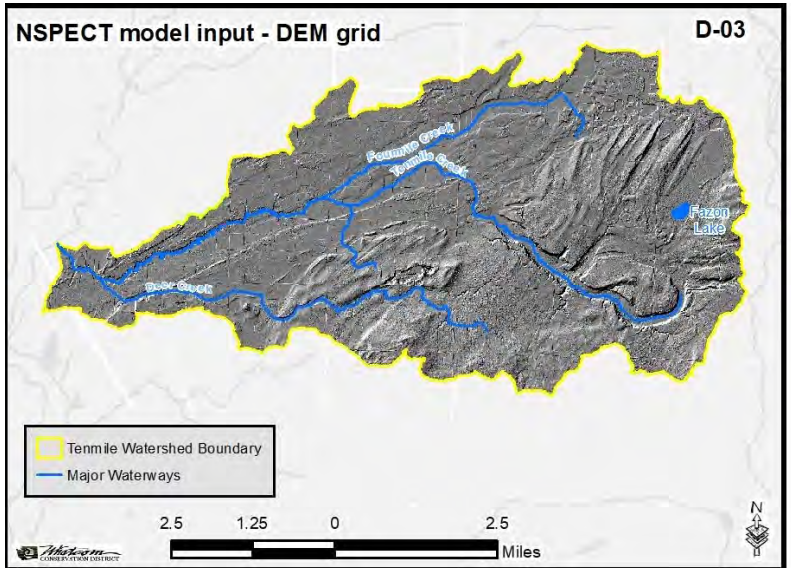
Pollutant Coefficients. Pollutant coefficients are assigned to each land class based on relative rankings or event mean concentrations (EMC). Relative rankings are assigned by the user; EMC values can be estimated from the literature or measured for site-specific conditions. For this assessment, we started with relative rankings from the Puget Sound Characterization Study (Stanley et al., 2016). Then we adjusted the relative rankings for our defined land classes and specific regional conditions using expert elicitation among WCD staff. Pollutant coefficients used in this model are found in Appendix A; the range is 0-10. Pollutant coefficients based on measured EMC would strengthen the modelling effort demonstrated here.



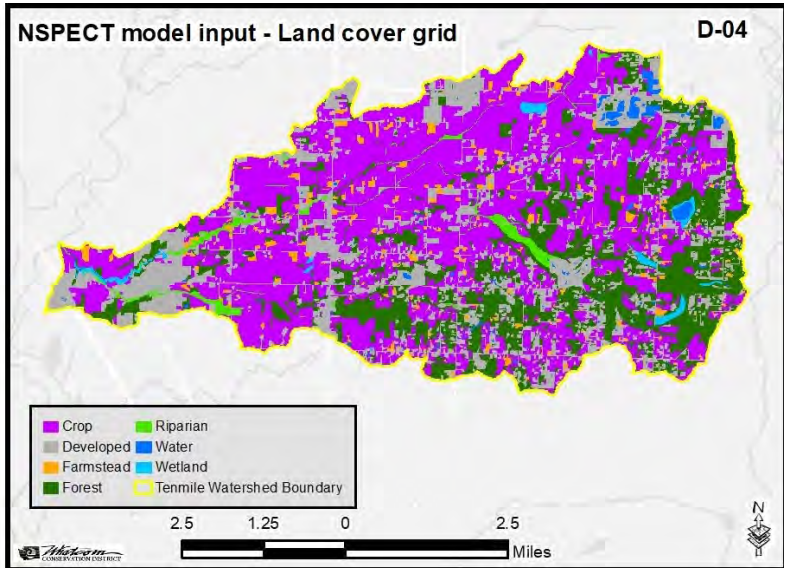
Map D-01. NSPECT Model Input- Hydrologic Soils Dataset.



Map D-02. NSPECT Model Input- Precipitation Grid (PRISM).



Map D-03. NSPECT Model Input- DEM Grid.

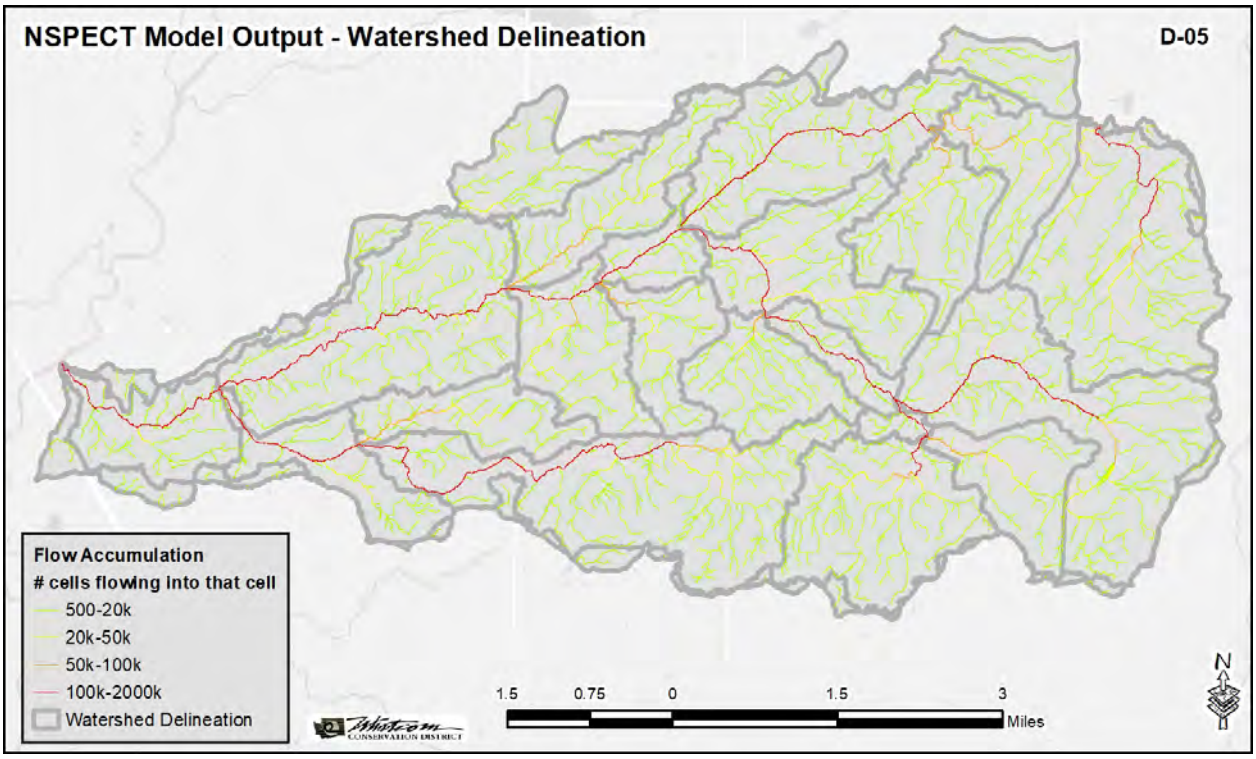


Map D-04. NSPECT Model Input- Land Cover Grid.

Watershed Delineation and Runoff Accumulation

The initial output of the NSPECT model is a watershed delineation that identifies a stream network and smaller polygons (sub-watersheds) based on the DEM (Map D-05). This delineation was consistent with the USGS Watershed Boundary Dataset (National Hydrography Dataset). Map D-05 shows the NSPECT watershed delineation, with the stream network symbolized by the number of cells flowing into a stream cell.

Note: This delineation estimates water flow in the watershed but does not account for man-made ditches that do not follow the natural topography of the watershed. For comparing properties or parcels to nearest waterways, we used the WA State Streams and Major Streams layers (see *Waterways* on Map B-01), which more accurately represents the true location of waterways (e.g. creeks, tributaries, and ditches) in the Tenmile Watershed.



Map D-05. NSPECT Model Output- Watershed Delineation.

2. Critical Source Areas (CSA) Identified

Ranking of Potential Source Contribution

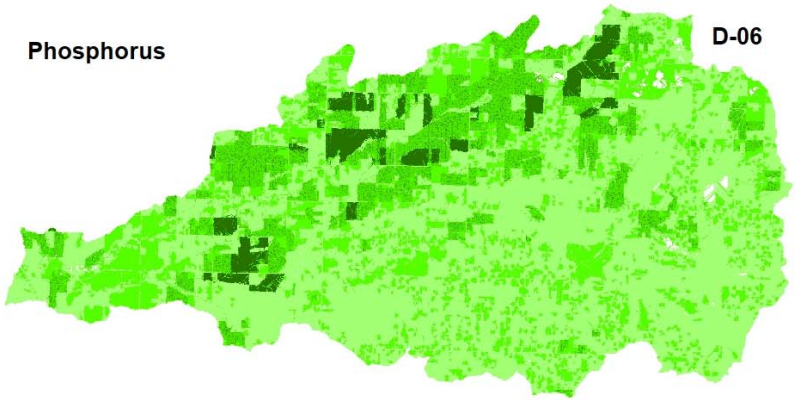
The output of the NSPECT analysis is in a raster where each cell in the model is assigned a ranking of the cell's potential source contribution. (*Note*: The value of this output will always use the same scale as the Pollutant Coefficients, whether those coefficients are set as relative rankings or EMCs. In this case a relative ranking of 0-10.

Maps D-06 through D-09 show the potential source contributions for each of the four pollutants. Darker colors represent higher potential source contributions based on both land characteristics (e.g. soil type, slope, proximity to waterway) and land use classification. Some areas are potential sources for more than one pollutant, while others stand out as a source for a specific

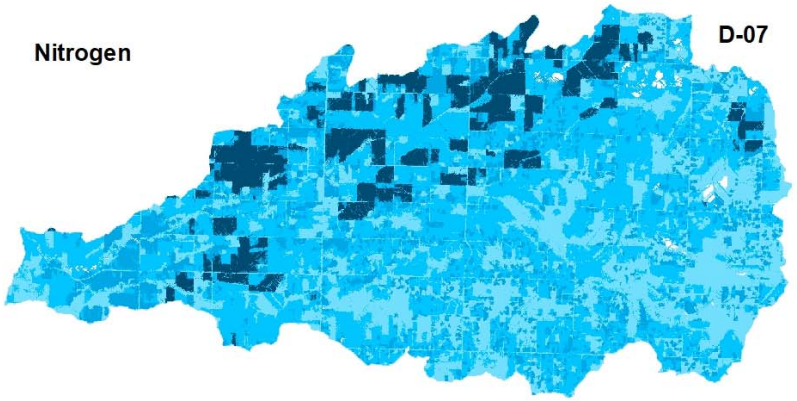
pollutant. For example, the darkest areas (or highest potential source) for TSS in the watershed are associated with gravel operations, while the highest potential source areas for N and P tend to be associated with agricultural uses.

NSPECT Model Output: Ranking of Potential Critical Source Area Contributions

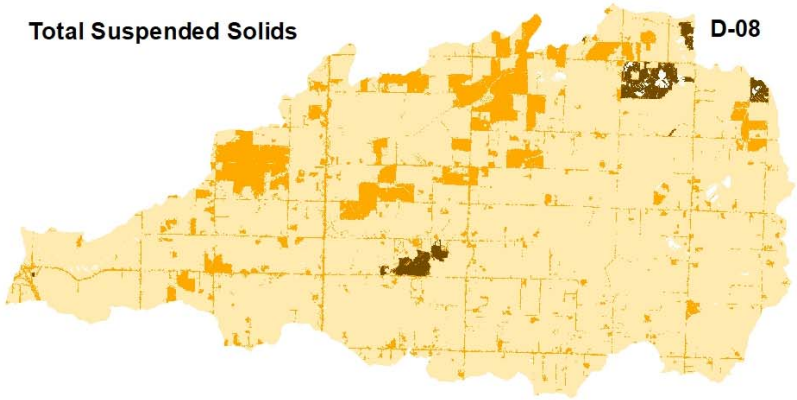
Darker color equals higher source contribution.



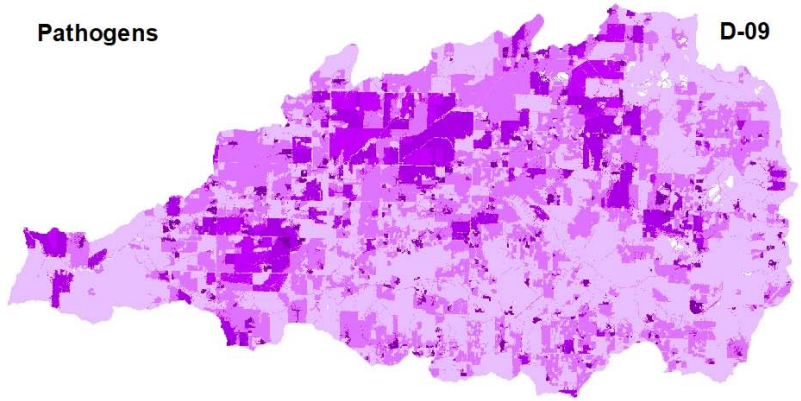
Map D-06. Ranking of Potential Source Contribution- Phosphorus



Map D-07. Ranking of Potential Source Contribution- Nitrogen



Map D-08. Ranking of Potential Source Contribution- TSS



Map D-09. Ranking of Potential Source Contribution- Pathogens

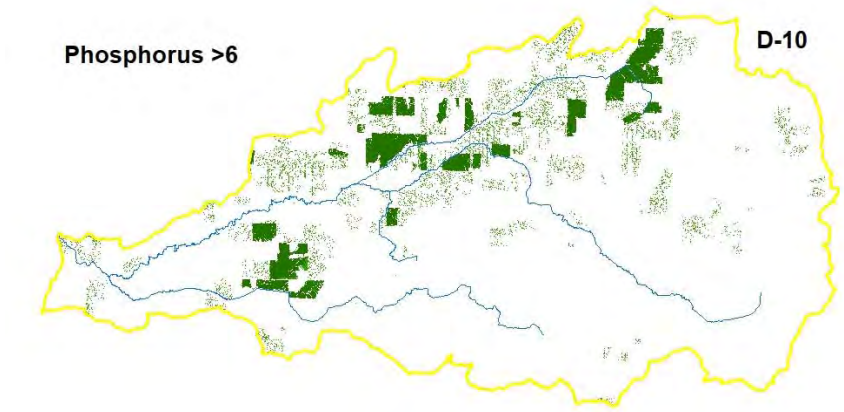
Potential Critical Source Areas

For this assessment any cells with a potential source contribution of 6 or greater (scale of 0-10), are considered potential critical source areas (CSA). Critical Source Areas for each pollutant are represented in Maps D-06 through D-09 as the darker areas, and they are shown as stand-alone polygons on Maps D-10 through D-13.

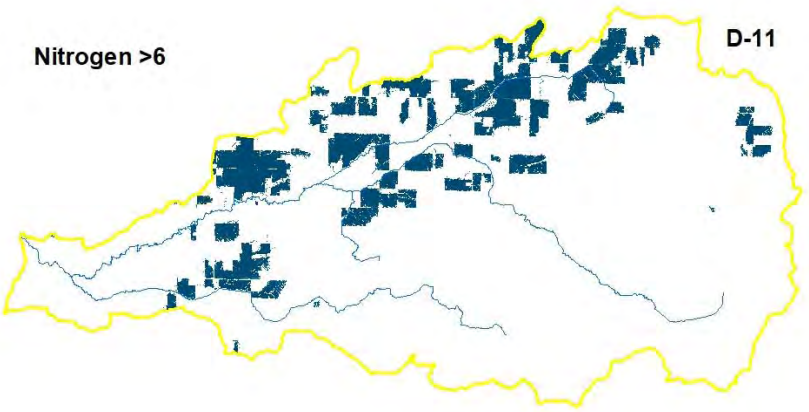
Table 7 shows the potential critical sources areas identified by land use type and acres. This table shows the potential for program implementation by land use type. Further assessment of current land management practices needs to be conducted in the Implementation phase in order to validate the model and/or adjust it based on current activities.

It is important to note that these are areas with the *potential* to be a source of a pollutant (or multiple pollutants) but may not actually act as a source depending on actual land management practices. The model assumes no land management practices are currently in place. In the prior example of the gravel operations, on-site practices to reduce sediment export would reduce or eliminate the potential risk of sediment entering surface waters.

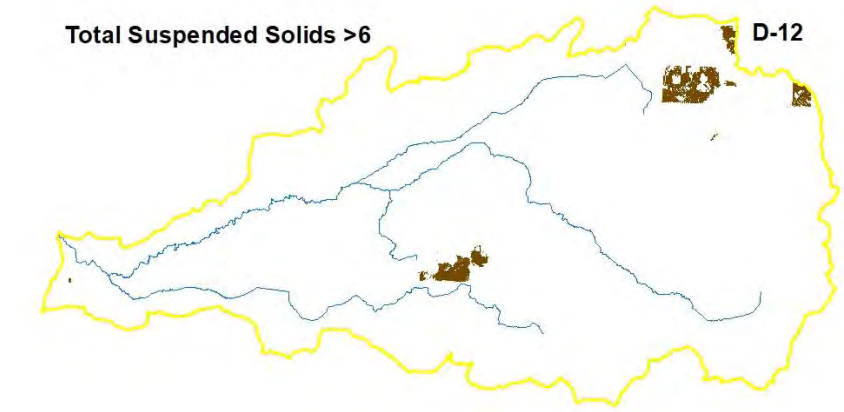
NSPECT Model Output: Greatest Potential Critical Source Area Contributions



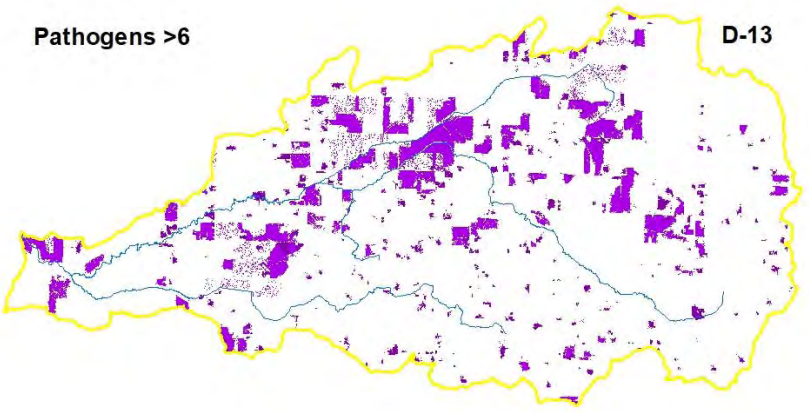
Map D-10. Potential Critical Source Areas- Phosphorus



Map D-11. Potential Critical Source Areas- Nitrogen



Map D-12. Potential Critical Source Areas- TSS



Map D-13. Potential Critical Source Areas- Pathogens

Table 7. Critical Source Areas by Land Use Category (acres). The total area for each Primary category is shown in acres.

Land Use Category (Primary + Secondary)	**Pollutant**			
	Total N	**Total P**	**TSS**	**Pathogens**
Crop (11,009 acres)	**2430.9**	**945.9**	**1.2**	**1400.8**
Blueberry	474.9	0.5	0	1.6
Caneberry	996.2	1.0	0	2.2
Corn	771.6	770.9	0	3.1
Forage High Intensity	10.7	10.3	0	1358.3
Forage Low Intensity	14.2	4.1	1.0	32.8
Nursey	0.9	0.1	0	0.1
Orchard	0	0	0	0.1
Other	0	0	0	0.1
Potatoes	159.1	157.4	0	0.1
Unmanaged	3.4	1.6	0.2	2.4
Developed (5,146 acres)	**17.9**	**3.7**	**267.9**	**16.7**
Commercial	1.2	0.0	0.2	0.4
Gravel*	0	0	266.5	0.0
Lawn	1.0	0.3	0.2	0.9
Residential	7.8	1.3	0.3	8.5
Road	5.8	2.0	0.6	5.7
Turf Grass	0.3	0	0	0.2
Unmanaged	1.8	0.2	.1	1.0
Farmstead (705 acres)	**6.7**	**1.2**	**0**	**430.0**
Beef Cattle	0	0	0	8.1
Crop	1.5	0	0	0.0
Dairy	0.5	0.5	0	0.8
Mixed	4.2	0.6	0	334.1
Horse	0.3	0	0	65.1
Irrigation	0.2	0	0	0
Other Animal	0	0	0	2.5
Poultry	0	0	0	19.4
Natural Space (5,871 acres)	**14.0**	**4.6**	**2.1*** (40.0)	**18.1**
Forest	5.5	1.1	2.1	7.6
Riparian	7.9	3.2	0.0	3.8
Water	0.5	0.3	0 (37.9)*	2.2
Wetland	0.1	0.1	0.0	4.5
Total Acres	**2469.5**	**955.5**	**271.1** (309.0)	**1865.7**
Total (as % of watershed)	**10.9%**	**4.2%**	**1.2%** (1.4%)	**8.2%**

* NSPECT calculates sources based on the grid cells that flow into a given cell. Because the water associated with the gravel operation has many grid cells with high export potential flowing into it- it was itself calculated to be a source of TSS. This is a misclassification of the model and should not be considered in the overall discussion of CSAs and conservation practice implementation. Without these 37.9 acres, total CSA for TSS for natural space is 2.1 acres.

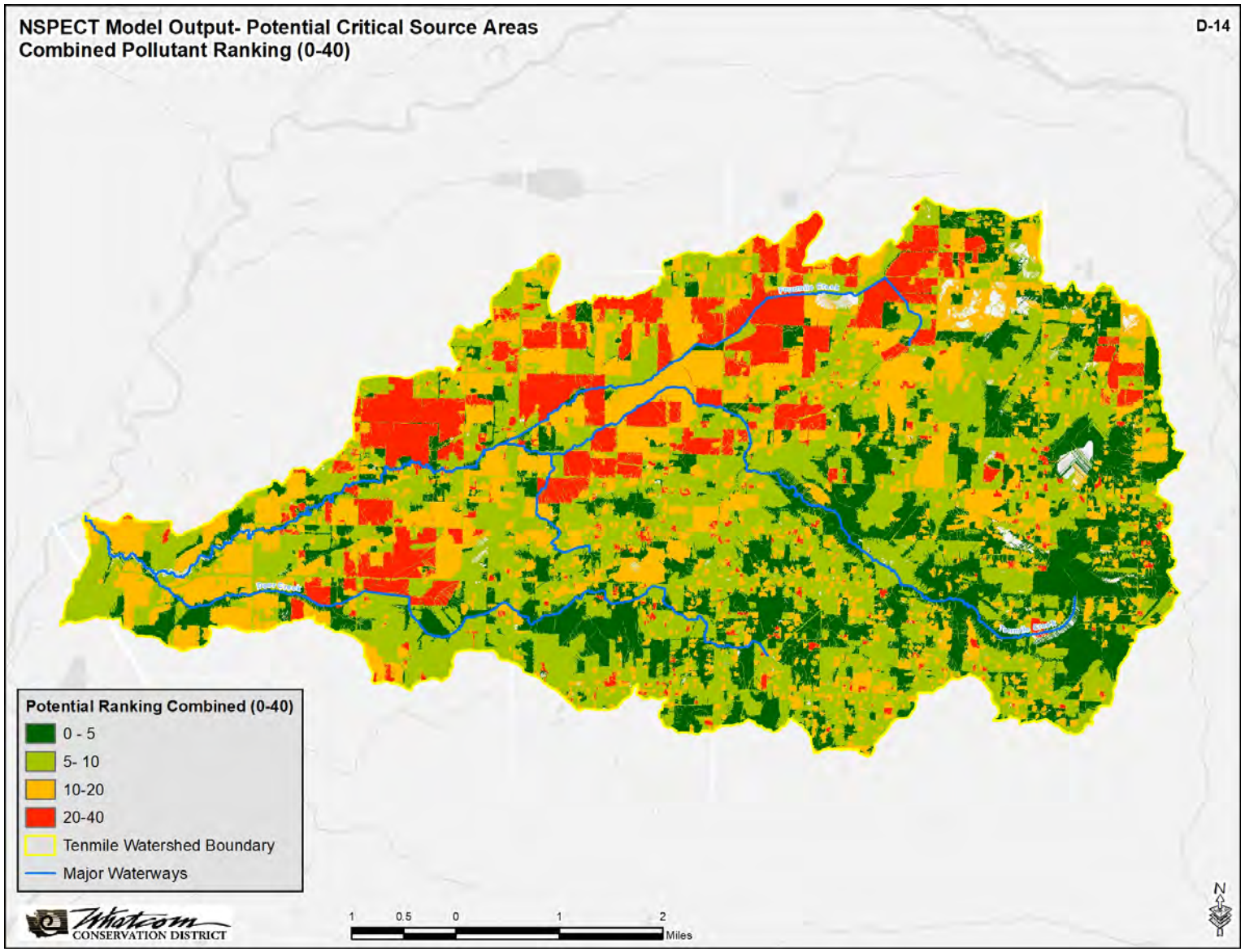
Potential Combined Pollutant Ranking

In addition to identifying individual CSAs by pollutant, we used the potential source contribution to calculate a Combined Pollutant Ranking for each cell (Map D-14). This is an additive ranking that evenly combines the individual rankings for each pollutant (nitrogen, phosphorous, sediment, and pathogens), thus the possible range for the Combined Pollutant Ranking is 0-40 (minimum: 0 x 4 pollutants; maximum: 10 x 4 pollutants). The highest value calculated for any cell in the Tenmile Watershed was 28.

This combined pollutant ranking score is especially relevant for conservation practices that address more than one pollutant simultaneously. For practices that address only a single pollutant, implementation "priority" would be better assessed based on the individual pollutant source contributions (Maps D-06 through D-09 and Table 8). Additionally, a weighted combined pollutant ranking could be created based on the most important criteria for the watershed such as a local TMDL or workgroup focus. For example, pathogens could have a greater weight in the combined ranking (e.g., Pathogen:Nitrogen:Phosphorous:Sediment = 50%:20%:10%:10% vs 25%:25%:25%:25%) giving it more priority, while still considering the other pollutants. It is up to the user to decide when to use an individual pollutant map, an evenly weighted combined pollutant ranking map, or a priority weighted combined pollutant ranking map.

Map D-14 shows the Combined Pollutant Ranking score for each grid cell in the watershed. Low ranking scores (0-5 and 5-10) are shown in green; these represent low source potential for all pollutants. Moderate ranking scores (10-20) are shown in orange; a moderate combined score represents *either* moderate source potential for all pollutants *or* a high source potential for only one pollutant and low potential for the remaining pollutant. For this moderate category, the individual source contribution maps (D-06 thorough D-09) will clarify which of these conditions is driving the combined ranking score. Finally, high ranking scores (greater than 20) are shown in red; a high score represents moderate-high or high source potential for multiple pollutants. These critical source areas with combined pollutant ranking scores greater than 20 can be considered the "top priority" for conservation practice implementation or technical assistance.

In general, the combined ranking shows the "biggest bang for the buck" for targeting land uses for comprehensive surface water quality protection. These are the areas that are recommended for primary outreach implementation of planning and conservation practice evaluation and/or implementation. Table 8 and Table 9 show which of the land uses have the greatest number of acres identified as critical source areas.



Map D-14. Potential CSAs Combined Pollutant Ranking (range is 0-40).

Table 8. Combined Pollutant Raking by Land Use Category (acres). The total area for each primary category is shown in acres. Lowest risk is 0, highest risk is 40.

Land Use Category (Primary + Secondary)	Combined Pollutant Raking			
	0-5	6-10	11-20	21-40
Crop (11,009 acres)	**391.9**	**5966.1**	**2296.5**	**2354.8**
Blueberry	2.0	9.3	59.8	448.7
Caneberry	11.4	14.3	93.8	953.9
Corn	3.5	14.6	63.4	775.1
Forage High Intensity	17.0	54.1	1839.2	11.2
Forage Low Intensity	151.6	4837.5	170.2	7.1
Nursey	90.2	6.6	2.8	0.3
Orchard	28.8	2.7	0.3	0
Other	0.5	3.5	35.5	0
Potatoes	0.3	2.5	11.0	156.3
Unmanaged	86.6	1020.8	20.6	2.1
Developed (5,146 acres)	**204.1**	**4541.5**	**390.9**	**9.8**
Commercial	20.0	343.2	4.3	0.4
Gravel	6.7	13.3	277.3	0
Lawn	13.6	343.3	6.5	0.5
Residential	99.5	2800.0	61.5	3.1
Road	35.0	469.8	31.3	4.9
Turf Grass	11.3	254.8	1.4	0.2
Unmanaged	18.0	317.1	8.6	0.8
Farmstead (705 acres)	**10.2**	**43.5**	**645.2**	**6.5**
Beef Cattle	0.4	0.6	8.6	0
Crop	0.3	1.2	28.3	0.6
Dairy	1.2	10.3	144.3	0.5
Mixed	6.7	25.4	368.3	4.8
Horse	1.0	3.2	69.8	0.5
Irrigation	0.5	1.0	0.2	0.1
Other Animal	0	0.2	3.0	0
Poultry	0.1	1.7	22.7	0
Natural Space (5,871 acres)	**5149.9**	**580.6**	**132.3**	**7.9**
Forest	4504.2	377.8	45.6	2.6
Riparian	306.0	73.7	30.0	5.0
Water	198.0	79.7	46.5	0.3
Wetland	141.8	49.3	10.2	0
Total Acres	**5756**	**11132**	**3465**	**2379**
Total (as % watershed)	**25.3%**	**49%**	**15.2%**	**10.5%**

Table 9. Percent of Each Land Use Category by Pollutant Ranking. Each land use category row sums to 100%.

Land Use Category (Primary + Secondary)	Combined Pollutant Rankings			
	0-5	5-10	10-20	20-40
Crop	3.6	**54.2**	**20.9**	**21.4**
Developed	4.0	**88.2**	7.6	0.2
Farmstead	1.4	6.2	**91.5**	0.9
Natural Space	**87.7**	9.9	2.3	0.1

3. Treatments and Opportunities

Management Practices

Table 10 and Table 11 show the top identified NRCS practices for combined (Nitrogen, Phosphorus, Sediment, and Pathogens) water quality protection for the Crop and Farmstead categories assessed, respectively. Further modeling work needs to be conducted in the Implementation Phase to identify the effectiveness of each practice, for each pollutant, individually. This work first needs the results of the outreach survey, to be conducted in Fall 2017 (see Section F), in order to calibrate the model. Additionally, the other categories assessed in the model (Developed and Natural Space) will also be assessed for NRCS and non-NRCS practices and programs in the next phase.

For more effective use, the information provided in Table 10 and Table 11 should be coordinated with the results presented in Map D-14 to identify the top land uses and areas in the watershed to apply the practices to. In this way, the approach will be targeted to the most effective, and promising land uses.

Table 10. Most effective NRCS practice(s) identified for water quality by agricultural crop

Conservation Management Practice	Row Cover / Cover Crop	Irrigation Water Management	Nutrient Management	Field Border	Underground Outlet (Ditch Cover)	Water Control Structure	Filter Strip	Setbacks	Dust Control	Mowing / Brush Management	Riparian Buffer
NRCS Practice Standard Code	340	449	590	386	620		393		373	314	391
Crop-Blueberry	x	x	x	x	x	x	x	x			x
Crop-Caneberry	x	x	x	x	x	x	x	x			x
Crop-Corn	x	x	x	x	x	x	x	x			x
Crop-Forage High Intensity		x	x	x	x	x		x			x
Crop-Forage Low Intensity & Pasture		x	x	x	x	x		x	x		x
Crop-Nursey	x	x	x					x	x		x
Crop-Orchard	x	x	x					x			x
Crop-Potatoes	x	x	x	x	x	x		x			x
Crop-Unmanaged			x					x		x	

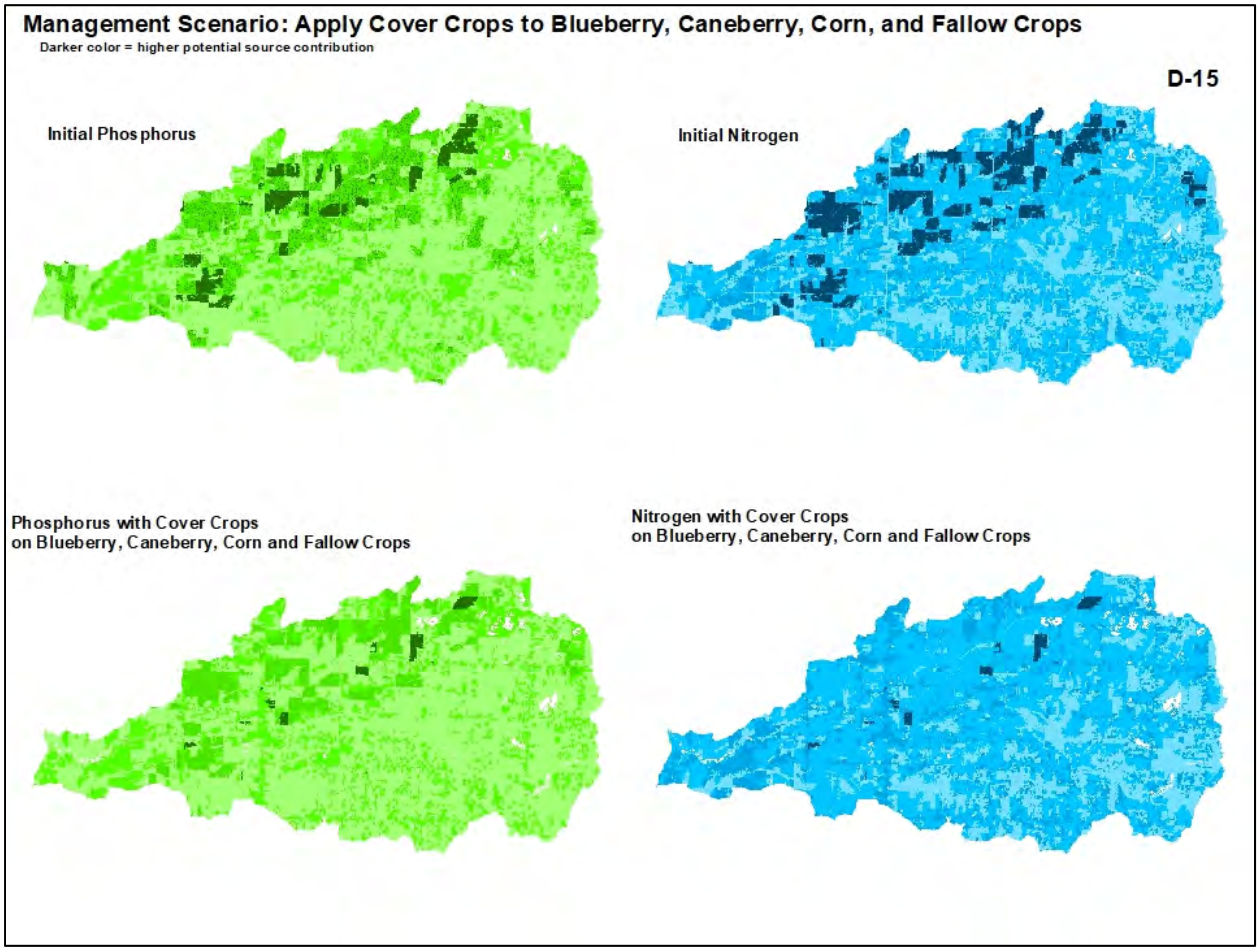
Table 11. Most effective NRCS practice(s) identified for water quality by farmstead type

Conservation Management Practice	Watering Facility	Prescribed Grazing	Fencing / Access Control	Feed Management (Seasonal Feeding)	Field to Road Tracking	Heavy Use Area	Roof Runoff Structure & Outlet	Underground Outlet	Waste Storage Facility	Roofs and Covers	Access Road	Vegetative Treatment Area	Agrichemical Facility (Fertilizer mixing)	Waste Transfer
NRCS Practice Standard Code	614	528	382/472	592		561	558	620	313	367	560	635	309	634
Farmstead-Beef Cattle	x	x	x	x		x	x	x	x	x	x	x		
Farmstead-Crop							x		x				x	
Farmstead-Dairy	x	x			x	x	x	x	x	x	x	x		x
Farmstead-Horse	x	x	x	x		x	x	x	x	x	x	x		
Farmstead-Irrigation Pond									x					
Farmstead-Other Animal	x	x	x	x		x	x	x	x	x	x	x		
Farmstead-Poultry						x	x	x	x	x		x		

NSPECT Model Outputs: Management Scenarios

The NSPECT model can be used to compare management scenarios based on changes in land use type or management. An example of this analysis is shown in Map D-15.

In this example, the model shows how we will be able to evaluate the impact a specific management practice has on a specific land use type. In this example, the model shows the reduction in phosphorous and nitrogen when cover crops are applied to blueberry, caneberry, corn, and fallow areas. The change in potential impact to water quality is significant and exemplifies the positive implantation of conservation practices in high risk areas. Additional assessment such as this will be conducted for every land use and pollutant in the next phase of the project.



Map D-15. Management Scenario for application of cover crops to berry, corn, and fallow crops.

E. SUMMARY AND RECOMMENDATIONS

1. Watershed Assessment Summary

The Tenmile Watershed was identified for this pilot watershed assessment in order to better understand the pollutants of concern, the sources and source areas of these pollutants, and the way in which management practices can be implemented in the watershed to reduce pollutant concentrations and loading.

A geospatial modeling software (Open-NSPECT in MapWindow GIS) was used to estimate runoff volumes, pollutant concentrations and pollutant loading for the watershed with a 3-meter grid resolution. Areas with high potential for pollutant export (based on land characteristics and land use) were identified as potential critical source areas. These critical source areas are areas that can be targeted for management practice implementation, outreach, and even NRCS cost share.

The outreach plan builds on the results of this assessment to engage residential landowners, livestock owners, and agricultural producers within the critical source areas. Once completed, the outreach plan will identify outreach strategies for these "target" audiences as well as outreach strategies for the "non-target" audiences in the watershed.

2. Practice Implementation Recommendations

Tables Table 7, Table 10 and Table 11 identify the land uses and potential conservation practices suggested for the implementation phase. These practices are based on local land use, climate, effectiveness, and practicality. Additional modeling work needs to be conducted to identify the most effective practices for each land use based on current practices by the land owner. This information needs to be gathered on an individual basis through landowner engagement; however, a fraction will also be supplied by the survey to be conducted in Fall 2017.

Estimation of treatments costs for practices will be based on current EQIP cost share rates. For relevancy, we refer to that for current values. Specific rates will be calculated during the outreach/implantation phase.

3. Effectiveness Monitoring and Adaptive Management

Without a strong tracking and monitoring plan in place, it is difficult to assess the impact and success of the recommend watershed improvement plan. It is recommended that the next Implementation Phase of the project define and track *measurable* metrics for progress in the following three categories:

1. **Implementation**: Location of where NRCS practices are being implemented and to what level. This would be conducted by NRCS and partners such as WCD.

2. **Effectiveness**: Water quality at or near implementation sites. Measurable as concentration reductions or load reductions. This would be conducted by local PIC partners and others as applicable.

3. **Broader Impact**: Improvements in *downstream* water quality (T1, Lower Mainstem Nooksack stations, and marine stations) to relate actions in the Tenmile watershed to

improvements in the greater Nooksack Watershed and shellfish restoration objectives. This would be conducted by PIC partners including DOH and LNNR (marine sampling).

Implementation Monitoring

Implementation of conservation practices should be tracked by both NRCS and WCD including: number of landowners/operators contacted, number of landowners/operators participating in programs, type of participation, number and type of pollution sources identified, number of farm plans completed, number of practices planned and installed, and number of acres treated. This information could then be aggregated by land use type and CSA if applicable. The outreach plan may inspire conservation stewardship outside the tracking parameters identified above, intrinsic motivation to change behavior, or management not associated with NRCS or WCD programs. These results are more difficult to quantify, and would require follow up survey post-implementation for adequate assessment.

Water Quality Monitoring

Water quality sampling would provide an on-going real-time way to look at water quality on a scalable level (i.e., by total watershed, sub-watershed, or field level). Recommendations include:

- Continue surface water monitoring of 10 ambient stations for fecal coliform. Additional source identification, or storm event monitoring, at these sites or additional sites is recommended to track and address sources or bacteria pollution within the watershed.
- Regular sampling of nitrogen, phosphorus, and sediment (as TSS or turbidity) at T1 is recommended on a quarterly schedule at minimum. Consistency in which parameters are measured (e.g. nitrate and nitrate or nitrate+nitrite; Total Nitrogen or Total Kjeldahl Nitrogen) between agencies and projects would allow the tracking of trends over time for these nutrients.
- Collect flow measurements at T1 and at additional ambient monitoring stations in order to estimate seasonal or storm-driven flow at these stations and calculate loading based on measured pollutant concentrations. We would recommend that flow be collected at a minimum of 3 stations in the watershed (one station each on Deer, Fourmile, and Tenmile Creeks) on a monthly or twice monthly schedule corresponding to water quality sampling runs.

Data Management and Trends Over Time

It is recommended that work continue with WCWP to access shared bacteria data from multiple partners that are sampling in the watershed. Additionally, access to data for the larger Nooksack Watershed and marine sites in Portage Bay shellfish areas will assist with the long-term and larger goal of assessing how the localized work in Tenmile effects the large scale reduction in water quality impairments. For questions about this shared data repository contact Meg Harris, Water Quality Data Coordinator, at WCD.

Conservation Practice Monitoring

Successful conservation practice monitoring has been shown using edge of field monitoring for assess the impact of land management activities to adjacent surface waters. This system installs surface flow (and sub-surface flow, when appropriate) monitoring equipment at the edge of a field/area in a controlled experimental design (control-treatment scenario) which implements

specific management practices/scenarios on the land surface and measures their potential impact/protection on water quality. Continued edge-of-field monitoring in Whatcom County is recommended in order to collect event mean concentration (EMC) data for various land use types and practices. These EMC values could be used to strengthen the NSPECT modelling described in this assessment or to support other modelling by local and state. Additionally, results will guide recommendation of various conservation practices for maximum protection of water quality.

For more information on the NRCS Edge-of-Field Monitoring program: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/water/quality/tr/?cid=stelprdb1240285

Conservation Planning

Conservation planning, also referred to as "farm planning", is an important part of the overall success and monitoring of the watershed plan. The planning process allows interaction with individual landowners and assessment of their current and planned practices. It also allows a planner to conduct an assessment of their landscape, which can be used to validate the model parameters. Lastly, the final step of the planning process requires the process of adaptive management and plan evaluation. This can be used to track progress of individual landowners in implementation of land use activities and subsequent water quality impacts, both positive and negative.

NRCS Tracking

The NRCS based interim metrics for tracking progress would be through the Protracts Contracting Program that would identify number of clients, acres treated, and practices planned and installed. By combining this with the data from the watershed plan that identifies the number of farms by land use one could derive a goals of implementation matrix.

4. NEPA Concerns

The National Environmental Policy Act of 1964 requires all federal agencies to conduct an environmental review of all federal actions. This requirement also applies to area wide or watershed planning activities. As part of these plans the responsible federal agency is required to evaluate the individual and cumulative effects of the actions being proposed. Any project that has significant environmental impacts must be evaluated with an Environmental Assessment (EA) or Environmental Impact Statement (EIS) unless the activities are eligible under a categorical exclusion or are covered by an existing EA or EIS.

NRCS utilizes a planning process that incorporates an evaluation of potential environmental impacts using an Environmental Evaluation checklist. NRCS also has categorical exemptions for a number of different activities that include many of our conservation practices. These categorical exemptions include conservation practices that reduce soil erosion, involve the planting of vegetation and/or restore areas to natural ecological systems.

The watershed plan for the Tenmile Watershed Plan recommends implementation of conservation practices that have been used in the region for a number of years. These practices include a number of nutrient and erosion control, field based practices that are covered by categorical exclusions and a range of structural practices that are used to address manure management issues on the farmstead. A list of practices that are likely to be used to implement the plan are included in Table 10 and Table 11.

As mentioned above, as part of the planning process, each planned practice will be evaluated individually and combination with other planned practices to ensure it meets the criteria of the categorical exclusions and any existing Environmental Assessments. Any significant negative practice impacts, either individually or cumulatively, will first try to be avoided, then minimized and/or mitigated to the extent possible or eliminated from the individual farm plan if necessary. There is not an expectation that the practices planned for implementation in the Tenmile Watershed will necessitate an Environmental Assessment or an Environmental Impact Statement.

F. OUTREACH

1. Outreach Goals and Strategy

The Tenmile Watershed Plan outreach goals are to:

1. Generate broad awareness of water quality issues throughout the watershed, and
2. Inspire land stewardship and implementation of conservation management practices by landowners located in critical source areas.

This tiered outreach approach follows trusted principles of Community Based Social Marketing (McKenzie-Mohr, 2011) and Social Indicator Planning and Evaluation System (Genskow, 2011). The steps involved are shown below in Figure 9.

Figure 9. Flow diagram Social Indicator Planning and Evaluation process.

During the pilot watershed assessment phase of this plan audience and behavior selection was selected through the Land Cover and Use survey work and identification of critical sources areas (CSA) (Section B-4 and E-2 respectively). The diversity of land use characterized, illustrates the complex social context with which an outreach plan must be developed including: mixed agriculture, rural commercial, and rural residential. Agriculture in the watershed includes dairies, beef cattle, berry (caneberry and blueberry) crops, potatoes, corn, grass hay and silage, pasture, and a small number of orchards, tree nurseries, and vegetable crops. The top four agricultural audiences for targeted outreach have been identified as: Horse owners, Beef producers, Dairy producers, and Blueberry and Raspberry growers.

Preliminary barrier and benefit research was accomplished through a series of focus groups designed for the primary agricultural land users in the watershed. This information informs the Social Indicator Survey that will be implemented during fall 2017. The demographics of those land users within the CSA, and recommended BMPs associated, additionally inform the willingness to participate in the different programs by the different land use groups.

As discuss earlier in Section B-5, there is no defined cultural center for residents of the Tenmile watershed to receive water quality related information or share land management strategies. Therefore, a structured and comprehensive outreach strategy is needed to support the diversity of cultural worldview, socio-economic distribution, and communication differences. In order to understand how this diverse audience receives information the Social Indicator Survey will evaluate the trusted sources of information regarding land management and the preferred methods of communication.

Table 12. Generalization of Social Indicators based on preliminary focus groups.

Land Use Type	Values	Awareness of Water quality issues	Barriers	Motivators
Beef/Cattle	Family Legacy Pride in feeding the world	High awareness of regulations Don't think water quality is impaired	Time Money	Make me Pay me
Horse	Property Aesthetics Animal Health	Water quality is overall okay to good Other ag sources are the cause of impairment	Physical Ability Time	Pay me Do it for me
Berry	Newer industry Pride in feeding the world	Water quality is overall okay to good Development is the cause of impairment	Need proof that it works	Marketability of product Food safety
Dairy	Family Traditions Family Legacy	High awareness of regulations Know that water quality is impaired	Money Willingness to work with gov't	Regulation Other industries also taking action

2. Stakeholder Engagement

As mentioned in Section A-4, there are a variety of organizations that are already working on watershed improvement in some capacity within the Tenmile Watershed. The WCD worked closely with the Tenmile Clean Water Project (TCWP) and the Laurel Watershed Improvement District (LWID) to ensure local stakeholders were involved in process and invested in the outcomes. Both organizations have agreed to partner on the Social Indicator Survey with their logos and signatures on the cover letter. Additionally, these groups helped organized focus groups for a pilot of survey questions and initial assessment of values, awareness, constrains and motivators. The TCWP and LWID have agreed to support efforts associated with the outcomes of this research and have some funding to offer for assistance.

Survey pilot focus groups were formed for four of the primary land use categories identified in the watershed assessment. Adaptation of survey questions for the Social Indicator survey came from these pilot groups along with some initial feedback on outreach messaging and strategies (Table 12).

- Horse owners: 8 participants in evening workshop and survey pilot
- Cattle owners: 9 participants in evening focus group and survey pilot
- Berry growers: 5 participants in survey pilot through Watershed Improvement District
- Dairy operators: 4 participants in survey pilot through Watershed Improvement District

3. Social Indicator Survey Plan

As part of this assessment, in Fall 2017, the WCD will implement a robust Social Indicator Survey of farmers and rural landowners in the Tenmile Watershed to evaluate perceptions of and attitudes towards water quality in the watershed; experience with conservation practices and willingness to implement practices; and source of trusted information and expectations of these sources to provide information or other resources (particularly in the context of water quality and natural resource conservation.)

This survey serves as a baseline measurement against which future survey data is compared, enabling an evaluation of perceptual and attitudinal change over time. Survey design and implementation will follow the guidelines described by The Social Indicator Planning & Evaluation System (SIPES) for Nonpoint Source Management (Genskow, 2011).

Survey Methods

A coded cover letter and paper survey will be sent to all non-commercial residents of the Tenmile watershed managing an acre or more of land (N=2,128). One week following the initial mailing, a reminder postcard with website link to the online version is sent. Depending on the survey response rate a third mailing may be necessary to achieve a 20% response rate based on +/- 5% sampling error to generalize the population. The timeline for this survey process is shown in Figure 10.

Applied Research Northwest (ARN) in partnership with WCD will implement a social indicator survey to the non-commercial, rural residents of the Tenmile watershed. Results of this assessment will attempt to verify assumptions based on preliminary research from survey pilot focus groups (

Table **12**) and address the non-agricultural members of the watershed that manage over an acre of land.

Section D-3 and Tables 7 and 8 identify the top management practices for each land use type and associated effectiveness. The Social Indicator Survey will assess the willingness of land managers to adopt these practices and best method of removing barriers to implementation for the land manager.

To build a robust and successful outreach campaign the following characteristics will be identified through the Social Indicator Survey:

- values and attitudes associated with water quality
- barriers or constraints to behavior change
- motivators to overcome these barriers
- trusted sources or messengers of information
- preferred mechanism of communication

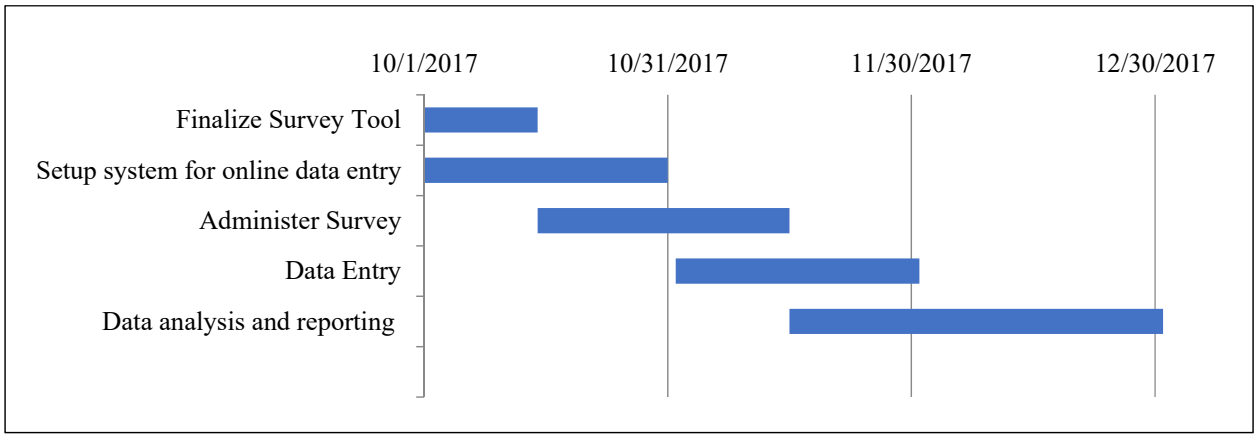


Figure 10. Project Timeline for Social Indicator Survey.

Social Indicator Survey Details

The following outlines the nest steps for the survey:

1. Finalize Survey Tool - The survey is refined based on livestock survey information, the critical source areas identified by the watershed assessment modelling, and feedback from the livestock focus groups.
2. Setup system for online data entry - The online system for hosting the survey and entering data needs is developed and managed.
3. Administer Survey - The survey is sent to all Tenmile Watershed residents with parcels over 1 acre. The survey will consist of an emailed cover letter and survey, mailed cover letter and survey, and reminder postcard.
4. Data Entry - Results are entered into the online system.
5. Data analysis and reporting - Survey results are analyzed and compiled for outreach and reporting.

Use of Survey Results

The results of the survey will be combined with the critical source areas identified, management practices recommended, and the associated target audience to target outreach activities. By setting this baseline for social indictors, the outreach implementation plan can be assessed whether the activities are accomplishing changes expected to improve and protect water quality.

4. Implementation of Outreach Plan

The results of the focus groups, Social Indicator Survey, and other outreach in the Tenmile Watershed will inform the method, messaging, messengers, and content of outreach. There will likely be a multi-tiered strategy including targeted outreach to agricultural producers in or near the critical source areas, encouraging the behaviors most likely to be adopted based on motivators indicated. All survey results are linked to addresses, and therefore associated land use, so outreach can be directed to specific user groups. Based on the survey findings, individuals will be engaged with outreach designed to specifically address their associated values, attitudes, constraints and motivators.

For the target audience within critical source areas, the outreach methods might include:

- Land use specific workshops and field days
- Social media campaigns
- Radio commercials
- Newsletters or e-newsletters
- Displays at local farm and garden centers
- On-Farm demonstrations projects
- Neighborhood gatherings by land use type
- Yard Signs
- Incentives

For the general audience or non-agricultural audience outreach methods might include:

- Social media campaigns

- Informational videos
- Billboards
- Community events and work parties
- Volunteer opportunities

5. Measuring Success

Water quality problems have accumulated over many decades and may take decades to amend; therefore, using water quality as a measure of plan effectiveness may be inadequate for this short time frame. Confirming that awareness and attitudes are changing and behaviors are being adopted could be a better way to demonstrate progress toward water quality goals. After analysis of Social Indicator Survey results in a variety of ways, the information will be used to develop social outcomes and associated metrics. Social outcomes are broadly defined as the social or behavioral changes needed to reach water quality improvement goals. Effective outreach strategies have built in engagement metrics- or ways to measure success- such as sign-in sheets, web analytics, or program sign ups. These will be used for immediate assessment of level of engagement; overtime a follow up survey will be administered to determine some of the following broader social outcomes.

For the target audience in critical source areas, project outcomes will likely include:

- Increased capacity to support appropriate practices in critical areas
- Increase adoption of practices to improve water quality
- Increased awareness of technical assistance programs available
- Reduced barriers or constraints to behavior

For the general audience or non-agricultural audience:

- Increased awareness of water quality issues
- Changes in attitudes toward water quality improvements
- Increased support for water quality improvement projects

The initial survey serves as a baseline measurement against which future survey data will be compared, enabling an evaluation of change over time.

6. Sustainability of Outreach Efforts

Development and implementation of the targeted and general outreach plan for the Tenmile watershed will involve the associated partner organizations to ensure the plan is supported throughout the County. Below is a list of local partners who will be engaged in the outreach effort:

Natural Resource Conservation Service (NRCS)

The Natural Resource Conservation Service (NRCS) conservationists provide technical expertise, conservation planning, and distribute financial assistance for farmers, ranchers and forest landowners wanting to make conservation improvements to their land. The Everson Service Center provides services for all of Whatcom County including Tenmile Watershed.

For information on programs and services in Washington State visit the NRCS website: https://www.nrcs.usda.gov/wps/portal/nrcs/main/wa/programs/

Whatcom Conservation District

The Whatcom Conservation District (WCD) mission is to assist land managers with their conservation choices, through a variety of services including farm planning, habitat programs, outreach, and education. In the Tenmile Watershed, WCD farm planners have worked with farmers and landowners to develop 95 farm plans and install over 200 habitat projects. Many other Tenmile residents and agricultural producers participate in WCD events throughout the year, including the district's Farm Speaker Series and the Annual Small Farm Expo.

Website: http://www.whatcomcd.org/

Whatcom County

Whatcom County Public Works' Pollution Identification and Correction (PIC) Program uses water quality monitoring data to identify areas with high levels of bacteria in surface waters and work with local landowners to reduce these water quality problems. The PIC program provides community outreach and education, technical and financial assistance for landowners, and coordination with County departments and other agencies to identify and address potential bacteria sources.

Whatcom County Health Department (DOH) manages community health and environmental health, including oversight of on-site sewage (OSS) evaluations and code enforcement. Whatcom County Planning & Development Services (PDS) oversees environmental permitting in Whatcom County, including activities that impact shorelines, wetlands, and other critical areas. PDS works regularly with Public Works, DOH, WSDA, and Ecology through the PIC program.

Website: http://wa-whatcomcounty.civicplus.com/1789/Departments
http://wa-whatcomcounty.civicplus.com/1072/Water-Quality

Laurel Watershed Improvement District

The Laurel Watershed Improvement District (WID) is a special purpose district managed by farmers and landowners who live and work within the district. The Laurel WID overlaps much of the Tenmile Watershed, including portions of Tenmile, Deer and Fourmile Creeks.

Website: https://www.laurelwid.com/
http://www.agwaterboard.com/

Tenmile Clean Water Project

The Tenmile Clean Water Project (TCWP) is a citizen-led group whose mission is to work with the community to reduce fecal bacteria in the Tenmile, Deer and Fourmile Creeks. The TCWP group meets monthly and TCWP volunteers participate in regular water quality sampling in the Tenmile Watershed, as well as educational and outreach events.

Website: http://www.re-sources.org/tenmile-creek

Washington State and Federal Partners

State level partners in the Nooksack Basin and Tenmile Watershed included Ecology, Department of Health, and WSDA Dairy Nutrient Management Program. EPA Region 10 is also involved as a partner in a number of water quality projects in the Nooksack Basin. These

agencies participate in Whatcom County through the Whatcom Clean Water Program, which is a collaborative effort between local, state, federal, and tribal partners. The program is coordinated through Ecology and Department of Health.

Website: http://www.ecy.wa.gov/water/whatcomcleanwater/.

Tribal Partners

The Nooksack Tribal Natural Resources and Lummi Nation Natural Resources divisions are active in water quality monitoring throughout the Nooksack basin and Portage Bay. Both organizations also participate as members of the Whatcom Clean Water Program.

Website: http://nooksacktribe.org/departments/natural-resources/
http://lummi-nsn.org/website/dept_pages/natural_resources/natural_home.shtml

G. REFERENCES

Bandaragoda C, Greenberg J, Dumas M, Gill P. 2012. Lower Nooksack Water Budget. Whatcom County, WA: WRIA 1 Joint Board. Accessed 13 September 2017 at http://wria1project.whatcomcounty.org/.

Cox SE, Simonds FW, Doremus L, Huffman RL, Defawe RM. 2005. Ground water/surface water interactions and quality of discharging ground water in streams of the lower Nooksack River Basin, Whatcom County, Washington: U.S. Geological Survey Scientific Investigations Report 2005-5255. Accessed 6 September 2017 at https://pubs.usgs.gov/sir/2005/5255/pdf/sir20055255.pdf.

Cronshey R. 1986. Urban hydrology for small watersheds Technical Release 55. US Dept. of Agriculture, Soil Conservation Service, Engineering Division. Accessed 6 September 2017 at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf

Friang S, Hashagen J, West B. 2014. The Nature Conservancy: Assessment of Scenario Modeling For Best Management Practices On Agricultural Lands. Master's Project. Accessed 6 September 2017 at https://depts.washington.edu/mgis/capstone/files/2014_8_Friang_Hashagen_West.pdf

Genskow, Ken and Linda Porkopy (eds.). 2011. The Social Indicator Planning & Evaluation System (SIPES) for Nonpoint Source Management: A Handbook for Watershed Projects. 3rd Edition. Great Lakes Regional Water Program. Accessed 28 September 2017 http://35.8.121.111/si/Info/pdfs/SI_Handbook_v4_02012012.pdf

Hood S. 2002. Nooksack River Watershed Bacteria Total Maximum Daily Load- Detailed Implementation Plan. WA Department of Ecology Water Quality Program. Accessed 28 September 2017. https://fortress.wa.gov/ecy/publications/documents/0110060.pdf

Joy J. 2000. Lower Nooksack River Basin Bacteria Total Maximum Daily Load Evaluation. WA Department of Ecology- Environmental Assessment Program, Watershed Ecology Section. Accessed 28 September 2017. https://fortress.wa.gov/ecy/publications/documents/0003006.pdf

Meals DW, Sharpley AN, Osmond DL. 2012. Lessons Learned from the NIFA-CEAP: Identifying Critical Source Areas. NC State University, Raleigh, NC. Accessed 6 September 2017 at http://www.soil.ncsu.edu/publications/NIFACEAP/Factsheet_7.pdf

McKenzie-Mohr, D. 2011. Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing, 3rd edition. New Society Publishers: Gabriola Island, BC.

NOAA Coastal Services Center. 2012. "OpenNSPECT: The Open-source Nonpoint Source Pollution and Erosion Comparison Tool." NOAA Office for Coastal Management, Charleston, South Carolina. Accessed 6 September 2017. coast.noaa.gov/digitalcoast/tools/opennspect.

NOAA Coastal Services Center. 2014a. "OpenNSPECT 1.2 Data Acquisition and Preprocessing: Instructions for Your Watershed." Accessed 6 September 2017.

https://coast.noaa.gov/data/digitalcoast/pdf/opennspect-data-acquisition-and-preprocessing.pdf

NOAA Coastal Services Center. 2014b. "Technical Guide for OpenNSPECT Version 1.2." Accessed 6 September 2017. https://coast.noaa.gov/data/digitalcoast/pdf/opennspect-technical-guide.pdf.

NOAA Coastal Services Center. 2014c. "User's Manual for OpenNSPECT Version 1.2." Accessed 6 September 2017. https://coast.noaa.gov/data/digitalcoast/pdf/opennspect-user-manual.pdf

Puget Sound Partnership. 2014. *The 2014/2015 Action Agenda for Puget Sound, Section 4: Local Recovery Actions, Whatcom County/Nooksack Watershed.* Puget Sound Partnership. Accessed 6 September 2017 at http://www.psp.wa.gov/downloads/2014_action_agenda/Final%202014%20action%20agenda%20update/2014-2015_Action_Agenda_for_Puget_Sound.pdf

RH2 Engineering, Inc. 2016. *Public Utility District No. 1 of Whatcom County: Quantification of Agricultural Irrigation Water Use and Water Rights.* RH2 Engineering, Inc. Accessed September 13 at http://wria1project.whatcomcounty.org

Stanley S, Grigsby S, Booth DB, Hartley D, Horner R, Hruby T, Thomas J, Bissonnette P, Fuerstenberg R, Lee J, Olson P, Wilhere G. 2016. Puget Sound Characterization. Volume 1: The Water Resources Assessments (Water Flow and Water Quality). Washington State Department of Ecology. Publication #11-06-016. Olympia, WA. Accessed 6 September 2017 at https://fortress.wa.gov/ecy/publications/SummaryPages/1106016.html

Whatcom County Agriculture-Watershed Pilot Project. 2016. *Agriculture-Watershed Characterization and Mapping Report for the Laurel Watershed Improvement District.* Whatcom County Planning & Development Services, August 2016. Accessed 6 September 2017 at https://sites.google.com/site/wcwatershedag/home.

Whatcom County Agriculture-Watershed Pilot Project. 2017. *Project summary.* Whatcom County Planning & Development Services, August 2016. Accessed 6 September 2017 at https://sites.google.com/site/wcwatershedag/home.

Natural Resources Conservation Service. 2013. National Planning Procedures Handbook (NPPH), Amendment 5. Title 180 – National Planning Procedures Handbook. US Department of Agriculture, Natural Resources Conservation Service. Accessed 6 September 2017 at https://directives.sc.egov.usda.gov/viewerFS.aspx?hid=33232.

H. APPENDIX A

Appendix A. Table 13. Animal Unit Conversion Factors

Animal Type	Animal Unit Conversion Factor
Horse	1.5
Beef	1.0
Dairy	1.4
Sheep	0.1
Goat	0.15
Swine	0.4
Camelid	0.8
Poultry	0.005
Other (Rabbit)	0.006

Appendix A. Table 14. NSPECT input table: Curve numbers by land use category

Land Use Category (Primary-Secondary)	SCS Curve Numbers				RUSLE	
	A	B	C	D	Cover Factor	Wet
Crop-Blueberry	67	78	85	89	0.24	
Crop-Caneberry	67	78	85	89	0.24	
Crop-Corn	67	78	85	89	0.24	
Crop-Fallow	77	86	91	94	0.7	
Crop-Forage High Intensity	30	58	71	78	0.005	
Crop-Forage Low Intensity/Pasture	39	61	74	80	0.005	
Crop-Nursey	32	58	72	79	0.22	
Crop-Orchard	32	58	72	79	0.22	
Crop-Other	67	78	85	89	0.24	
Crop-Potatoes	67	78	85	89	0.24	
Crop-Unmanaged	30	48	65	73	0.014	
Developed-Commercial	89	92	94	95	0	
Developed-Gravel	77	86	91	94	0.7	
Developed-Lawn	39	61	74	80	0.005	
Developed-Residential High Density	77	85	90	92	0.03	
Developed-Residential Low Density	51	68	79	84	0.03	
Developed-Road	83	89	92	93	0	

Developed-Turf Grass	39	61	74	80	0.005	
Developed-Unmanaged	30	48	65	73	0.014	
Farmstead- Mixed	59	74	82	86	0.03	
Farmstead-Irrigation	0	0	0	0	0	X
Farmstead-Beef Cattle	59	74	82	86	0.03	
Farmstead-Crop	59	74	82	86	0.03	
Farmstead-Dairy	59	74	82	86	0.03	
Farmstead-Horse	59	74	82	86	0.03	
Farmstead-Other Animal	59	74	82	86	0.03	
Farmstead-Poultry	59	74	82	86	0.03	
Forest	30	55	70	77	0.007	
Riparian	30	55	70	77	0.007	
Water	0	0	0	0	0	X
Wetland	0	0	0	0	0	X

Appendix A. Table 15. NSPECT input table: Pollutant coefficients by land use category

Land Use Category (Primary-Secondary)	**Relative Pollutant Coefficients (0-10)**			
	Total P	**Total N**	**TSS**	**Pathogens**
Crop-Blueberry	6	10	4	3
Crop-Caneberry	6	10	4	3
Crop-Corn	10	10	2	6
Crop-Fallow	3	2.7	10	1
Crop-Forage High Intensity	6	4	1	7
Crop-Forage Low Intensity/Pasture	1.3	2.7	1	4
Crop-Nursey	1	1	0.2	1
Crop-Orchard	1	1	0.2	1
Crop-Other	5	5	2	3
Crop-Potatoes	10	10	4	2
Crop-Unmanaged	1.3	2.7	0.6	2
Developed-Commercial	1	1	2	2
Developed-Gravel	3	2.7	10	1
Developed-Lawn	3	3	0.6	2
Developed-Residential High Density	2.7	4.5	1.2	2
Developed-Residential Low Density	2.7	5	3	3
Developed-Road	1	1	4	2

Developed-Turf Grass	3	3	0.6	2
Developed-Unmanaged	1.3	2.7	0.6	2
Farmstead- Mixed	2.7	4.5	3	10
Farmstead-Irrigation	1.3	2.7	1	2
Farmstead-Beef Cattle	2.7	4.5	3	10
Farmstead-Crop	2.7	4.5	1.2	5
Farmstead-Dairy	2	2	1.2	6
Farmstead-Horse	2.7	4.5	3	10
Farmstead-Other Animal	2.7	4.5	1.2	8
Farmstead-Poultry	2.7	4.5	1.2	8
Forest	0.8	0.2	0.2	1
Riparian	0.8	0.2	0.2	1
Water	0	0	0	0
Wetland	1.3	2.7	1	2

I. LOCAL CONTACTS

Whatcom Clean Water Program
http://www.ecy.wa.gov/water/whatcomcleanwater/index.html

Washington State Department of Health PIC Programs
https://www.doh.wa.gov/CommunityandEnvironment/Shellfish/EPAGrants/PathogensGrant/PIC

Department of Ecology Bellingham Field Office - Water Quality Program
http://www.ecy.wa.gov/programs/wq/wqhome.html

EPA Region 10
https://www.epa.gov/aboutepa/epa-region-10-pacific-northwest

WSDA Dairy Nutrient Management Program
https://agr.wa.gov/foodanimal/livestock-nutrient/

Whatcom County Public Works
http://www.co.whatcom.wa.us/308/Public-Works
http://wa-whatcomcounty.civicplus.com/1072/Water-Quality

Whatcom County Health Department
http://www.co.whatcom.wa.us/360/Health-Department

Whatcom County Planning & Development Services
http://www.co.whatcom.wa.us/358/Planning-Development-Services

Nooksack Tribal Natural Resources
http://nooksacktribe.org/departments/natural-resources/

Lummi Nation Natural Resources
http://lummi-nsn.org/website/dept_pages/natural_resources/natural_home.shtml

Whatcom Conservation District
http://www.whatcomcd.org/

Washington State Conservation Commission
http://scc.wa.gov/

Laurel Watershed Improvement District
https://www.laurelwid.com/
http://www.agwaterboard.com/

Ag Water Board
http://www.agwaterboard.com/

Whatcom Family Farmers
http://www.whatcomfamilyfarmers.org/
http://www.whatcomfamilyfarmers.org/watershed-improvement-districts.html

Tenmile Clean Water Project
http://www.re-sources.org/tenmile-creek

Nooksack Salmon Enhancement Association
http://www.n-sea.org/