LUMMI NATION
STORM WATER MANAGEMENT PROGRAM
TECHNICAL BACKGROUND DOCUMENT
2011 UPDATE

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(LIBC)

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Water Resources Division
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EXECUTIVE SUMMARY

The goals of the Lummi Reservation Storm Water Management Program are to: 1) minimize the opportunities for storm water to wash pollutants into aquifer recharge zones and resource rich estuaries and tidelands of the Reservation, 2) minimize the downstream impacts of development on storm water quantity and quality, and 3) maximize the opportunities for infiltration and aquifer recharge. These goals are similar to and consistent with the Lummi Nation Wellhead Protection Program goals (LWRD 1997a).

The Lummi Nation finds that contamination of surface waters on the Reservation, tidelands and estuaries, wellhead protection areas, and ground water resources has a direct, serious, and substantial effect on the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation, and that those activities posing threats of such contamination, if left unregulated, also could cause such adverse impacts. Accordingly, the Lummi Natural Resources Department, in conjunction with the Lummi Planning Department, developed a storm water management program for the Reservation based on the foregoing findings and the following considerations:

- With the exception of water discharged into Washington State aquatic lands from two wastewater treatment plants, all water that falls onto or passes through the Lummi Reservation discharges to resource rich tidelands and/or estuaries of the Lummi Nation. These resources, which are culturally and economically important to the Lummi Nation and its members, surround the Reservation uplands. Tideland resources include salmon, shellfish, extensive eel grass beds, herring spawning grounds, surf smelt, sand lance, wildlife, and water supply intakes for a salmon and shellfish hatchery (LNR 2010).
- A goal of the Lummi Nation is for waters of the Reservation to comply with the federal Clean Water Act as development occurs.
- Population projections, planned economic and institutional growth on the Reservation, and the small percentage of Reservation land that has been developed all suggest that portions of existing forested and agricultural lands will be converted to residential, commercial, or community uses in the coming years. Land use changes where forested or agricultural lands are converted to residential, commercial, or community uses can be expected to affect storm water quantity and quality.
- In general, development impacts vegetation and soil properties in a manner that results in greater storm water volumes, higher peak discharges, and lower water quality. Minimizing these adverse impacts from development and maximizing the protection of sensitive and important natural resources is necessary to protect the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation.
- As a finite resource, ground water is one of the most important and critical of the Lummi Nation's resources. Storm water is an important source of ground water recharge and a potentially significant source of ground water contamination.

- Over 95 percent of the residential water supply for the Reservation is pumped from local ground water wells; contamination of Reservation aquifers carries the risk of adversely affecting the health of persons drinking or using water from these supplies.
- The on-Reservation salmon hatchery program, which is culturally and economically significant to the Lummi Nation and its members, is dependent on ground water.
- Ample supplies of good quality ground water are essential to serve the purposes of the Reservation as a permanent economically viable homeland of the Lummi Nation and its members.
- Ground water resources are vulnerable to contamination by pollutants introduced on or near the ground surface by human activities. Agricultural, residential, community, commercial, and industrial land uses increase the potential for ground water contamination.
- Reservation ground water resources are particularly vulnerable to pollution due to geographic and hydrogeologic conditions, which may be exacerbated by future growth and development on the Reservation. The Reservation is located in a coastal area along the inland marine waters of the Puget Sound and Georgia Strait. Most of the existing water supply wells on the Reservation are located within a half mile of marine waters. Progressive salt water intrusion already has led to the closure of several of these public water supply wells. Increased pumping, possible future reductions in ground water recharge areas as the forested Reservation uplands are converted to residential and other uses, and rapid economic and population growth could further threaten the Lummi Nation's ground water resources if such activities are not managed effectively. Managing storm water to minimize water quality impacts of development and to maximize ground water recharge will help to protect the limited and vulnerable ground water resources on the Reservation.
- Ground water contamination could lead to the loss of the primary water supply source for the Reservation because water supply wells are difficult to replace, ground water contamination is very expensive to treat, and some damages to ground water caused by contamination may be unmitigable.
- Alternative water sources to serve the needs of the Reservation are expensive and may not be available in amounts sufficient to replace existing supplies and to provide for future anticipated tribal economic and residential growth. Moreover, alternative water sources would require substantial amounts of funding for the infrastructure upgrades that would be necessary to import larger volumes of water onto the Reservation. Finally, alternative water sources may be subject to service interruptions over the long term due to natural or human caused disasters.

Vegetation removal and replacement with residential, commercial, or community land uses can impact storm water quantity and quality for a number of reasons including:

- The roots, leaves, and stems of vegetation provide surface roughness. This roughness reduces the speed that water can move overland and acts as a filter to trap sediment. The slower that water flows over a surface, the greater the opportunities for ground water recharge. The more water that infiltrates to the soil, the less water is available to flow overland as storm water runoff. Because less water is available for overland flow, the opportunities for erosion and sediment transport by water are also reduced.

- Vegetation provides a protective cover for soil which reduces erosion by absorbing the energy of rainfall.
- Vegetation provides organic matter to the soil and thereby increases its capacity to hold water.
- Plant roots hold soil particles in place and help to prevent soil loss.
- Development increases the area of impervious surfaces which reduces ground water recharge opportunities and increases storm water runoff.
- Because of the higher percentage of impervious surfaces in developed areas, runoff can be expected to be of greater volume, have higher peak discharges, and have a shorter duration relative to the forested condition.
- A reduction in evapotransporation, thru vegetation removal, generally results in an increase in surface water runoff.
- In some cases, ground water recharge can increase as a result of vegetation removal. However, increases in ground water recharge can be offset by the increased surface water runoff (which results in a decrease in the amount of water available for recharge) or increased ground water discharge due to higher hydraulic heads.

In addition to removing existing vegetation (land clearing), development is often associated with earthmoving during construction phases and impacts on storm water quantity and quality once the development is in place. Common storm water related impacts of construction and development include:

- During clearing and construction activities, soil compaction occurs as heavy construction machinery runs over the land surface. Similar to an impervious surface, increased soil compaction reduces infiltration and ground water recharge, which can result in increased surface water runoff.
- Reworking and exposing soil during construction increases opportunities for erosion and sediment transport.
- There are numerous potential storm water pollutants associated with residential, commercial, and community land uses. These pollutants include: oils, metals, household chemicals, lawn and garden chemicals, street litter, and sediment.

Erosion and sediment control during construction is important because:

- Many pollutants adhere to the clay and other fine particles that comprise sediment. Transported sediment increases the potential for the off-site transport of pollutants and the subsequent degradation of water quality in the receiving waters (i.e., the estuaries and tidelands of the Reservation).

- Increases in the quantity of runoff can result in downstream erosion and property damage.
- Increased sediment from erosion can obstruct aquatic habitat and downstream storm water facilities (which will require increased maintenance).
- To reduce the impacts of development on storm water and achieve the storm water management goals, appropriate best management practices (BMPs) must be effectively applied. Effective use of BMPs, coupled with land use zoning, is needed to minimize the impacts of development on storm water. Examples of using BMPs to reduce the impacts of development activities on storm water quantity and quality include:
  - Planning development to fit the topography, soils, drainage patterns, and natural vegetation of the site.
  - Conducting pollution prevention activities including public education and household hazardous waste collection and disposal events.
  - Minimizing impervious areas (i.e., paved or compacted areas).
  - Preserving wetland areas.
  - Controlling erosion and sediment from disturbed areas within the project site or area.
  - Minimizing the extent of disturbed areas.
  - Conducting site disturbance work during the drier parts of the year (i.e., May through September).
  - Stabilizing and protecting disturbed areas from runoff as soon as possible.
  - Minimizing runoff velocities by minimizing slope length and gradient and protecting natural vegetative cover.
  - Implementing a thorough storm water facilities monitoring and maintenance program.
  - Constructing properly designed detention ponds, wetlands, infiltration trenches, grass swales, and filter strips.
  - Using Low Impact Development practices.

Because storm water movement does not follow private property or political boundaries, and because community participation in developing and implementing a storm water management program is necessary for a successful program, community involvement is a key element of the Lummi Reservation Storm Water Management Program. The two elements of the community involvement plan are: 1) community education and, 2) interjurisdictional coordination and cooperation for activities off-Reservation that affect on-Reservation resources.

Ordinances for both the storm water management program and the wellhead protection program were adopted in 2004 as part of the Lummi Code of Laws (LCL) Title 17 Water Resources Protection Code, which is administered by the Lummi Natural Resources Department. In June 2010, new Lummi Administrative Regulations for storm water management, wetland management, technical requirements for ground water wells, and a system for civil fines for violation of LCL Title 17 were approved by Lummi Indian Business Council.

This update of the 1998 Storm Water Management Program technical background document (LWRD 1998c) includes the following primary changes to the earlier version:

- Revised watershed delineation based on higher resolution topography data.
- New section on applicable federal and tribal laws and regulations.
- Updated storm water facilities inventory and updated inventory of potential pollutant sources.
- Updated descriptions of BMPs for storm water management.
- New section on Low Impact Development.
- Updated storm water community and education program.

Funding for the technical background documents and regulation development that form the basis of the Lummi Reservation Storm Water Management Program and the Lummi Nation Wellhead Protection Program was provided by the Bureau of Reclamation, the U.S. Environmental Protection Agency (EPA), and the Lummi Indian Business Council (LIBC).

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1. INTRODUCTION

The goals of the Lummi Nation Storm Water Management Program are to: 1) minimize the opportunities for storm water to wash pollutants into aquifer recharge zones and resource rich estuaries and tidelands of the Reservation, 2) minimize the downstream impacts of development on storm water quantity and quality, and 3) maximize the opportunities for infiltration and aquifer recharge. These goals are similar to and consistent with the Lummi Nation Wellhead Protection Program goals (LWRD 1997a).

The Lummi Nation finds that contamination of surface waters on the Reservation, tidelands and estuaries, wellhead protection areas, and ground water resources has a direct, serious, and substantial effect on the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation, and that those activities posing threats of such contamination, if left unregulated, also could cause such adverse impacts. Accordingly, the Lummi Natural Resources Department, in conjunction with the Lummi Planning Department, developed a storm water management program for the Reservation based on the foregoing findings and the following considerations:

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- The on-Reservation salmon hatchery program, which is culturally and economically significant to the Lummi Nation and its members, is dependent on ground water.
- Ample supplies of good quality ground water are essential to serve the purposes of the Reservation as a permanent economically viable homeland of the Lummi Nation and its members.
- Ground water resources are vulnerable to contamination by pollutants introduced on or near the ground surface by human activities. Agricultural, residential, community, commercial, and industrial land uses increase the potential for ground water contamination.
- Reservation ground water resources are particularly vulnerable to pollution due to geographic and hydrogeologic conditions, which may be exacerbated by future growth and development on the Reservation. The Reservation is located in a coastal area along the inland marine waters of the Puget Sound and Georgia Strait. Most of the existing water supply wells on the Reservation are located within a half mile of marine waters. Progressive salt water intrusion already has led to the closure of several of these public water supply wells. Increased pumping, possible future reductions in ground water recharge areas as the forested Reservation uplands are converted to residential and other uses, and rapid economic and population growth could further threaten the Lummi Nation's ground water resources if such activities are not managed effectively. Managing storm water to minimize water quality impacts of development and to maximize ground water recharge will help to protect the limited and vulnerable ground water resources on the Reservation.
- Ground water contamination could lead to the loss of the primary water supply source for the Reservation because water supply wells are difficult to replace, ground water contamination is very expensive to treat, and some damages to ground water caused by contamination may be unmitigable.
- Alternative water sources to serve the needs of the Reservation are expensive and may not be available in amounts sufficient to replace existing supplies and to provide for future anticipated tribal economic and residential growth. Moreover, alternative water sources would require substantial amounts of funding for the infrastructure upgrades that would be necessary to import larger volumes of water onto the Reservation. Finally, alternative water sources may be subject to service interruptions over the long term due to natural or human caused disasters.

Pursuant to Lummi Code of Laws (LCL) Title 17 and 40 Code of Federal Regulations (CFR) 122.26 (b) (13), storm water is defined as runoff from a storm, snow melt runoff, and surface runoff and drainage. The purpose of the Lummi Nation Storm Water Management Program technical background document is to:

- Describe the occurrence of storm water on the Lummi Reservation;

- Discuss how land use changes affect storm water quantity and quality;
- Identify potential sources of storm water contamination in the watersheds that drain to the adjacent waterways and aquifer recharge zones of the Reservation;
- Identify the best management practices (BMPs) available to achieve the storm water management goals;
- Describe Low Impact Development (LID) and the implementation of LID techniques on the Reservation; and
- Describe storm water management public education on the Reservation.

Effective use of BMPs, coupled with land use zoning, is needed to minimize the impacts of development on storm water. This technical background document, which updates a similar document published in 1998, is intended to serve as the technical basis for storm water management and education on the Reservation.

This update of the 1998 Storm Water Management Program technical background document (LWRD 1998c) includes the following primary changes to the earlier version:

- Revised watershed delineation based on higher resolution topography data.
- New section on applicable federal and tribal laws and regulations.
- Updated storm water facilities inventory and updated inventory of potential pollutant sources.
- Updated descriptions of BMPs for storm water management.
- New section on Low Impact Development.
- Updated storm water community and education program.

This storm water technical background document is based on field inventories of storm water facilities on the Lummi Reservation conducted during 1997 and 2010, literature reviews on the impacts of land use changes on storm water quantity and quality, and a literature review on storm water best management practices (BMPs).

This technical background document is organized into the following ten sections:

- Section 1 is this introductory section.
- Section 2 presents an updated description of the physical characteristics of the study area.
- Section 3 describes storm water management laws and regulations on the Reservation.
- Section 4 presents an updated inventory of storm water facilities on the Lummi Reservation and describes the occurrence of storm water on the Reservation.
- Section 5 describes the potential impacts of land use changes on storm water quantity and quality and presents an updated inventory of potential sources of storm water contamination.

- Section 6 presents an updated literature review on BMPs for storm water.
- Section 7 describes Low Impact Development and implementation on the Reservation.
- Section 8 describes storm water community education and outreach.
- Section 9 summarizes the storm water management program.
- Section 10 lists the references cited in this technical background document.

2. STUDY AREA DESCRIPTION

The Lummi Indian Reservation (Reservation) is located in northwest Washington State, approximately eight miles west of Bellingham, Washington (Figure 2.1). The Reservation is located along the western border of Whatcom County at the southern extent of the Georgia Strait and the northern extent of Puget Sound. Approximately 38 miles of highly productive marine shoreline surround the Reservation uplands on all but the north and northeast borders (LNR 2010). The Reservation includes approximately 12,500 acres of uplands and 7,000 acres of tidelands. The Nooksack River drains a watershed of approximately 786 square miles, flows through the Reservation near the mouth of the river, and discharges to Bellingham Bay (and partially to Lummi Bay during high flows). The Reservation is comprised of a five-mile long peninsula (Lummi Peninsula), which borders Lummi Bay on the west and Bellingham Bay on the east; a northern upland area and the smaller Sandy Point peninsula; the floodplains and deltas of the Lummi River (a.k.a. Red River) and the Nooksack River; Portage Island; and associated tidelands.

To effectively manage storm water on the Reservation, the factors that control its occurrence, movement, quantity, and quality must be known. In this section, the topography, watersheds, climate, hydrogeology, soils, land use, surface water resources, and storm water runoff on the Lummi Reservation are described.

2.1. Topography

The Lummi Reservation is comprised of two relatively large upland areas, a smaller upland area on Portage Island, and the lowland areas of the Lummi River and Nooksack River and the Sandy Point peninsula (Figure 2.2). The maximum elevation of the northwestern upland area of the Reservation is about 216 feet above the North American Vertical Datum 1988 (ft NAVD88). The southern upland area is the Lummi Peninsula with a maximum elevation of about 178 ft NAVD88. The floodplain of the Lummi and Nooksack rivers, with an average elevation of approximately 10 ft NAVD88, is located between the northern and southern upland areas. The Nooksack River and the Nooksack River delta are located along the northeastern extent of the Reservation. The Sandy Point peninsula lies to the southwest of the northwestern upland. Portage Island lies at the southeastern tip of the Lummi Peninsula and has a maximum elevation of approximately 209 ft NAVD88.

The two relatively large upland areas are drained by short, intermittent streams and numerous springs both above and below the line of ordinary high water. These streams and springs discharge onto tribal tidelands along Bellingham Bay, Hale Passage, Lummi Bay, Onion Bay, Georgia Strait, or to the floodplains of the Lummi and Nooksack rivers. The floodplain areas are drained by a network of agricultural drainage ditches and the Lummi River and Nooksack River. The drainage on Portage Island consists of at least two intermittent streams that drain northward to Portage Bay. Springs along the upland areas of Portage Island and below the line of ordinary high water also discharge to marine waters and Reservation tidelands.

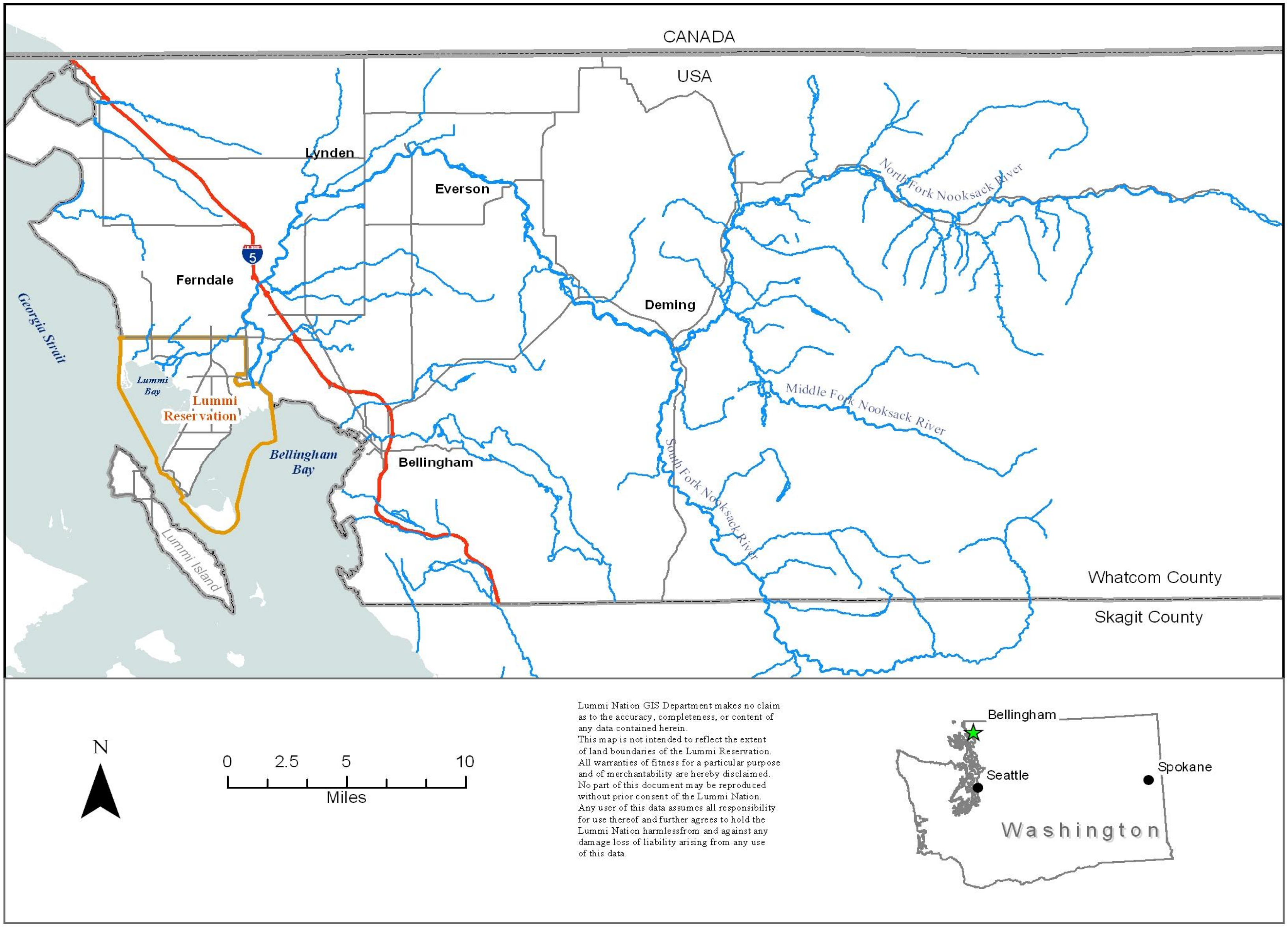

Figure 2.1 Regional Location of the Lummi Indian Reservation

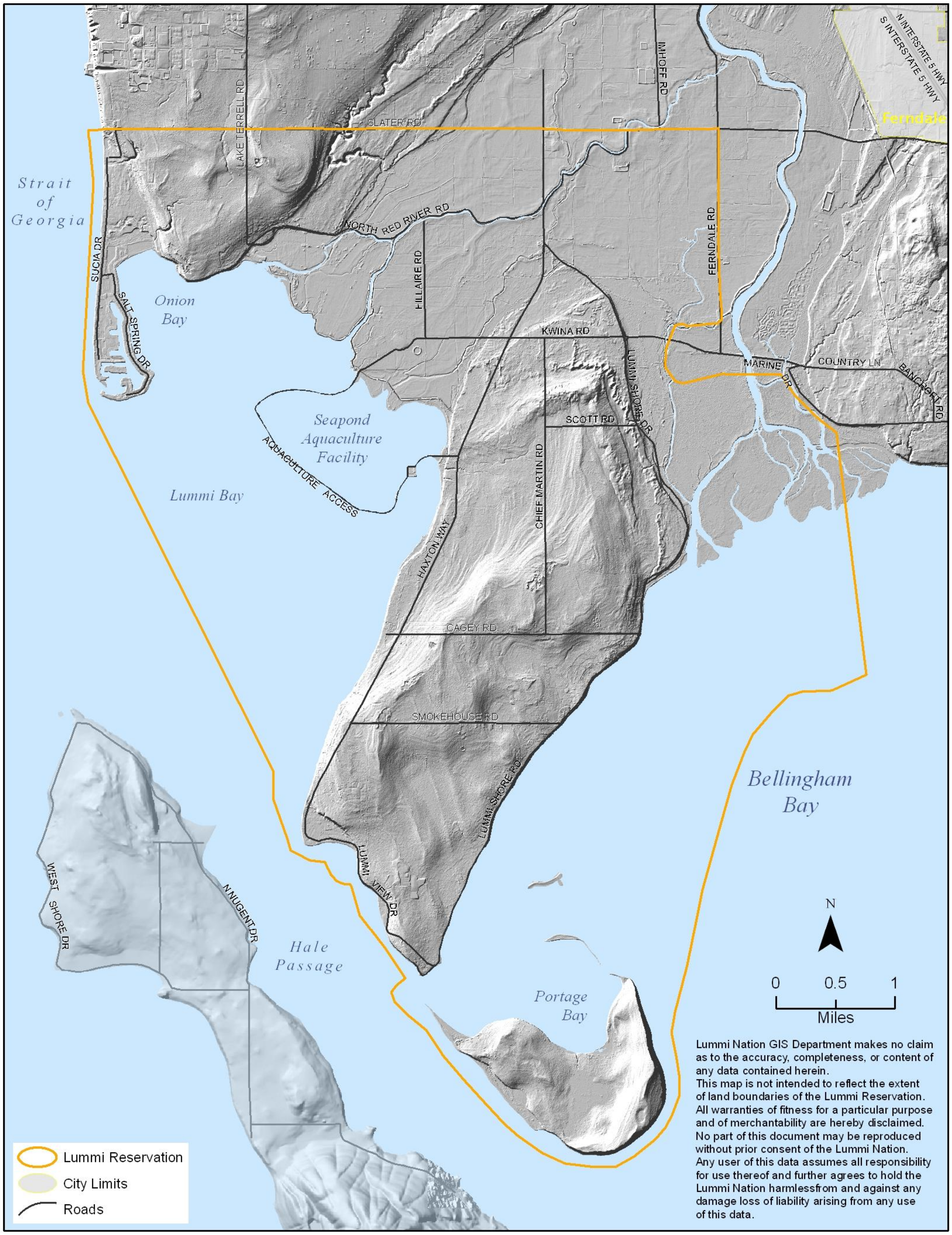

Figure 2.2 Topography of the Lummi Indian Reservation and Adjacent Areas

2.2. Reservation Watersheds

A watershed is a land area defined by topography that is drained by a stream system. Until recently, watershed boundaries were generally delineated using U.S. Geological Survey (USGS) topographic maps and, starting from a point on the stream system that is defined by the geology and topography as the watershed outlet, following the ridgelines shown by the contour lines. This method was commonly used in upland watersheds where the contour lines are relatively closely spaced and a single watershed outlet is apparent. In lowland areas with relatively flat topography, identifying the watershed outlet and associated boundaries is more difficult. Often in lowland or coastal areas there is not a single location or point that can be identified from the topography, geology, and/or hydrography as a watershed outlet.

2.2.1. 1998 Reservation Watershed Delineations

During the preparation of the 1998 version of this technical background document, the four 1:24,000 scale USGS 7.5-minute quadrangle maps that include the Lummi Reservation were used as base maps to identify the boundaries of the Reservation watersheds (LWRD 1998c). These maps have 20-foot contour intervals. Aerial photographs and field observations during the storm water facilities inventory (LWRD 1997b) were used to identify the approximate locations of agricultural drainage ditches, roadside drainage ditches, and unmapped intermittent streams on the Reservation. Field observations made during the storm water facilities inventory were also used to determine the directions of surface water flow and to refine preliminary delineations of the watershed boundaries.

The 1997 storm water facilities inventory identified 48 culverts along upland roadways that discharged directly to either tribal tidelands/marine waters or to the floodplains of the Lummi and Nooksack rivers. Although subdividing the Reservation uplands by delineating the contributing areas to these 48 culverts was considered as an approach to managing storm water, an alternative approach that involved combining drainage areas of topographically adjacent culverts was adopted. This alternative approach was used both to reduce the number of watersheds and to accurately reflect the incomplete knowledge on the exact locations of watershed divides in the relatively flat terrain.

The five-step approach used to delineate watersheds on the Reservation for the 1998 technical background document was the following:

1. Initially, generalized watershed boundaries were delineated from the 1:24,000 scale USGS topographic maps.
    - A total of 19 watersheds were identified on the Reservation (Figure 2.3).
    - Seven of the identified watersheds extend beyond the Reservation boundaries.
    - The remaining 12 watersheds are entirely located within the exterior boundaries of the Reservation.
    - Of the seven watersheds that extend beyond the Reservation boundaries, one is the Nooksack River watershed.
    - The Nooksack River watershed had been previously delineated by the USGS and others (WSDC 1960) and was not delineated as part of this effort.

2. A storm water facilities inventory was conducted to identify the locations of culverts, bridges, tide gates, catch basins, roadside ditches, and agricultural ditches on the Reservation (LWRD 1997b).
3. Intermittent streams that were not shown on the USGS maps were identified during the field inventory and their approximate locations mapped.
4. The flow direction(s) in the identified ditches and channels were identified by field observations made during the storm water facilities inventory and other related studies.
    - Descriptions of the flow paths were entered into a storm water facilities database that is linked to a geographic information system (GIS).
    - The flow direction(s) in the ditches and channels in the floodplain were determined for both high and low tidal conditions.
5. The locations of the generalized watershed boundaries identified from the topographic maps were refined as necessary to be consistent with field observations of topography and flow directions.

The Reservation watersheds were identified alphabetically A through S on an interim basis. It was anticipated that names would be assigned to the watersheds over time (LWRD 1998c) but no names have been assigned to date. The 19 watersheds delineated in 1998 and the assigned identification letters are shown in Figure 2.3.

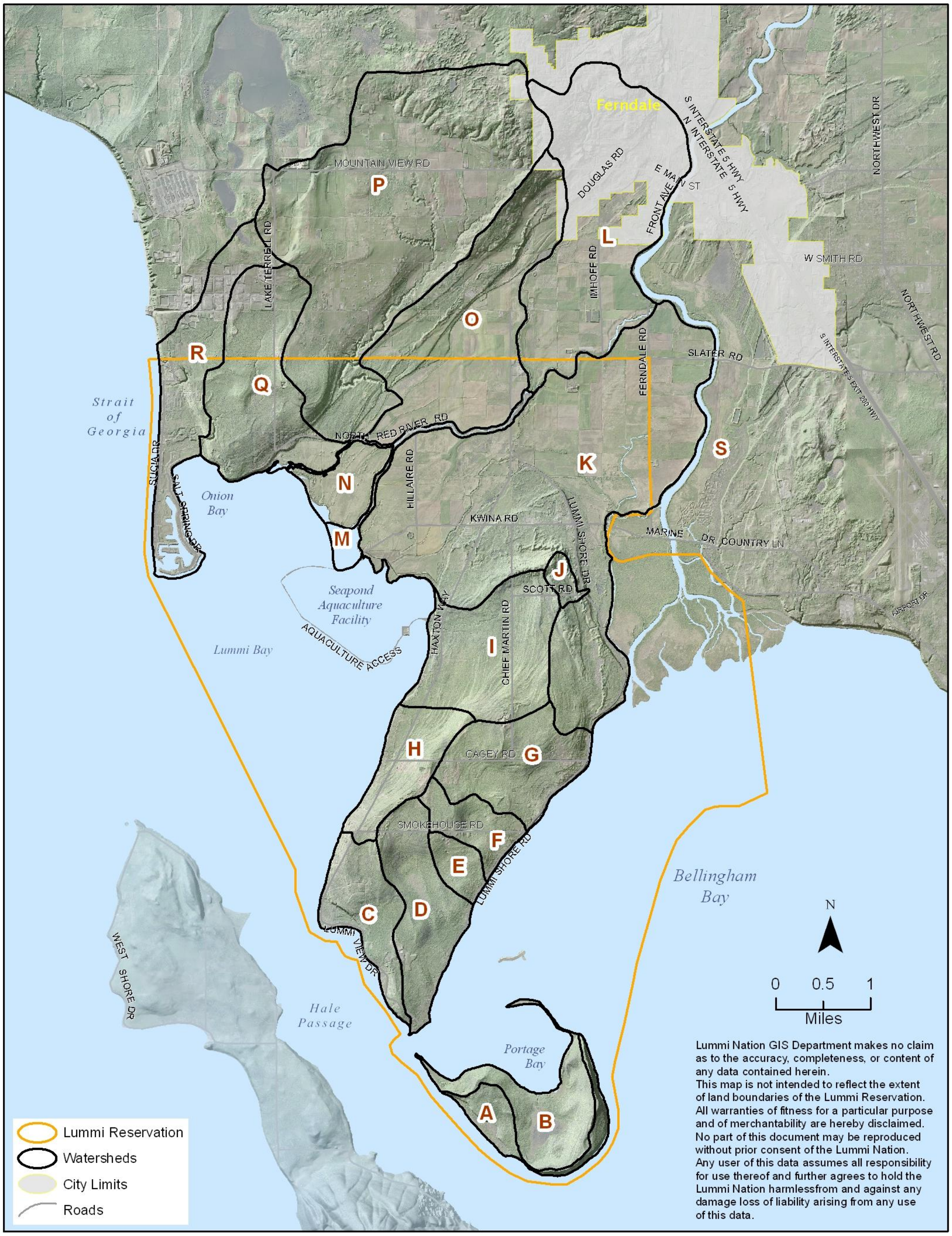

Figure 2.3 Lummi Indian Reservation Watersheds Delineated in 1998

2.2.2. 2010 Reservation Watershed Delineations

In 2010, watershed boundaries for the areas that contribute to surface water flow on the Lummi Reservation were developed from Light Distance and Ranging (LiDAR) data (Figure 2.4) collected during 2005. Using the LiDAR bare-earth point data, digital terrain models (DTMs) were developed using several grid cell sizes and interpolation methods. A root square mean analysis was used to identify the surface model with elevation values most similar to professionally surveyed control points. A three-foot natural neighbor interpolation DTM was identified as the surface model with the highest level of precision and pixel sizes that were large enough to be manageably analyzed using available computer resources.

The three-foot natural neighbor DTM was incorporated into an ESRI ArcGIS 9.3 ArcHydro geodatabase along with point data of storm water facilities and line data of known stream channels and agricultural drainage ditches. The storm water data and surface water hydrography data were used to enforce hydrologic connectivity by computationally breaching LiDAR artifacts such as bridges or culvert passages under roads.

The hydrologically corrected surface model was analyzed using standard GIS procedures including sink filling, identifying flow directions, calculating flow accumulations, and identifying basin boundaries. The final basin boundaries were combined into watershed administrative units based on the watershed units developed as part of the 1998 watershed delineation (LWRD 1998c). A more detailed description of the 2010 watershed delineation is presented in Appendix A.

Figure 2.5 and Table 2.1 show a comparison of the 1998 watershed delineation developed from the USGS topographic maps and the 2010 watershed delineations developed using the LiDAR data. The 2010 watershed delineations resulted in approximately 933 acres being added to the watersheds that contribute overland flow to the Reservation. Two watersheds (M and N) from the 1998 delineation were discontinued. Watershed N was combined with Watershed O as the LiDAR delineation did not identify this area as a separate catchment. Watershed M was a small isolated island located at the mouth of the Lummi River channel and the Lummi River channel downstream from the Schell Creek confluence and waterward of the levees along the channel. This watershed was combined with Watershed L. Watershed T is a newly delineated watershed that isolated a portion of Watershed K from the 1998 delineation. Watershed S includes the entire Nooksack River drainage area, a vast majority of which is not covered by the LiDAR data. Although most of Watershed S extends off-Reservation and beyond the geographic scope of the LiDAR data, the LiDAR data were used to delineate the western extent of Watershed S on the Reservation. The acreage for Watershed S listed in Table 2.1 is the acreage total reported by the WRIA 1 Watershed Management Project (http://wria1project.whatcomcounty.org).

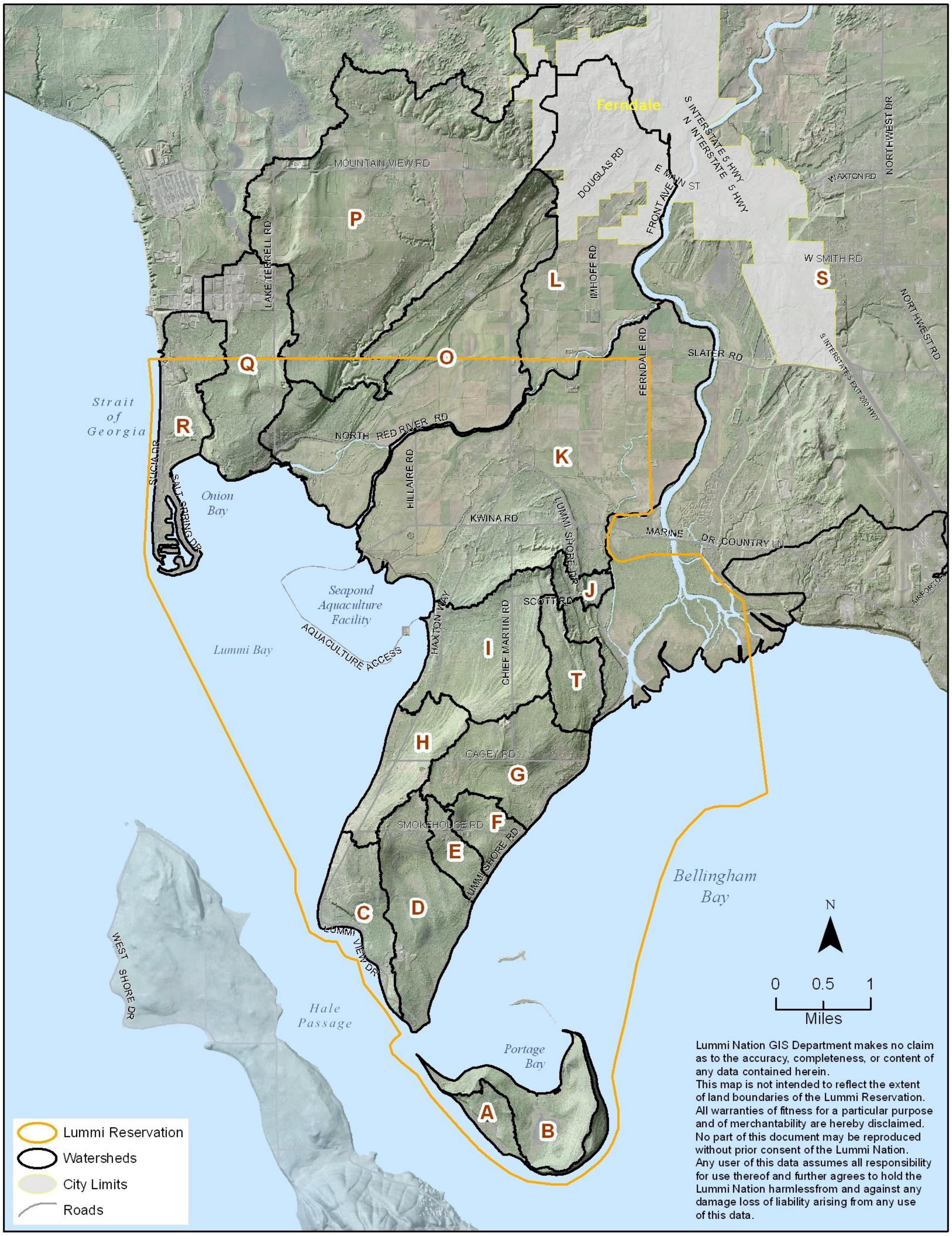

Figure 2.4 Lummi Indian Reservation Watersheds Delineated in 2010

Table 2.1 Watershed Identifiers and Acreage Total Comparisons Between the 1998 Delineation and the 2010 Delineation

Watershed ID	Stream Name	1998 7.5 min Topographic Map Delineations (acres)	2010 LiDAR Delineations (acres)	Difference in Watershed Area (acres)	Difference in Watershed Area (percent difference)
A	unnamed	306.8	279.7	-27.1	-9.7
B	unnamed	633.9	616.7	-17.2	-2.8
C	unnamed	583.3	493.8	-89.5	-18.1
D	unnamed	797.5	894.4	96.9	10.8
E	unnamed	183.2	218.3	35.1	16.1
F	unnamed	326	250.8	-75.2	-30.0
G	unnamed	836.1	883.3	47.2	5.3
H	unnamed	537.3	549	11.7	2.1
I	unnamed	1,142.3	1,058.9	-83.4	-7.6
J	unnamed	86.8	134.2	47.4	35.3
K	Smuggler Slough	4,696.5	4,091.1	-605.4	-14.8
L	Lummi River	2,384.0	2,306.5	-77.5	-3.4
M	unnamed	198.1	combined with Watershed L	n/a	n/a
N	unnamed	333.4	combined with watershed O	n/a	n/a
O	Shell Creek/Northern Distributary of the Lummi River	1,964.3	2,746.8	782.5	28.5
P	Jordan Creek	4,228.9	4,097.1	-131.8	-3.2
Q	Onion Creek	1,291.7	1,096.4	-195.3	-17.8
R	unnamed	1,023.8	721.8	-302	-41.8
S	Nooksack River	517,718 (WRIA 1 area)	South western extent of watershed only	n/a	n/a
T	unnamed	extracted from Watershed K	392.5	n/a	n/a
Total		**21,553.9**	**22,486.7**	932.5	4.2

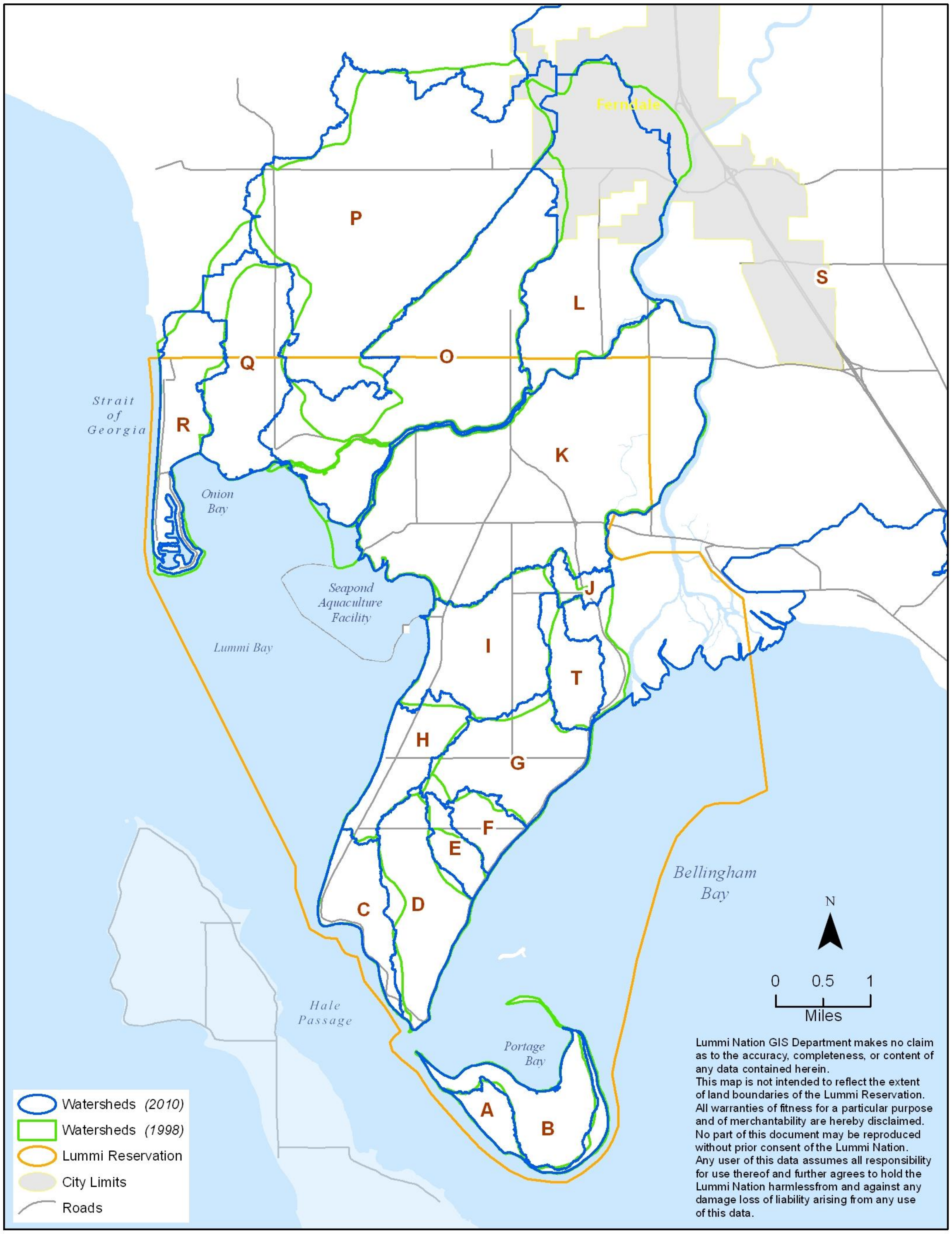

Figure 2.5 Comparison of the 1998 and 2010 Watershed Delineations

2.3. Climate

Pacific Northwest (PNW) climate and ecology are largely a result of the interactions that occur between seasonally varying water patterns and the mountain ranges that characterize the region. Approximately 75 percent of the PNW precipitation occurs in just half the year (October – April) when the PNW is on the receiving end of the Pacific storm track. Based on climate data collected at Bellingham International Airport, the average annual precipitation on the Reservation is approximately 36 inches. On average, November, December, and January are the wettest months; June, July, and August are the driest months.

Factors such as surface cover, drainage area, time between storms, rainfall intensity, and precipitation duration affect the quantity and quality of storm water runoff from a watershed. The "return period" is an expression of the likelihood that a particular sized storm will occur during any year. The probability or chance that a storm with a 2-year return period will occur during any given year is 50 percent. Similarly, there is a 1 percent chance that a "100-year storm" will occur during any year. The precipitation quantities over a 24-hour interval for storms with return periods of 2-, 10-, 25-, and 100-years on the Lummi Reservation are tabulated in Table 2.2.

Table 2.2 The 24-Hour Precipitation Totals for the Lummi Reservation[1]

Return Period (Years)	Probability Of Occurrence During Any Year (Percent)	Precipitation Amount (Inches)
2	50	1.8
10	10	2.5
25	4	2.9
100	1	3.6

[1] **Data Source:** NOAA, 1978

The water quality design storm using the Single Event Hydrograph Method in the Puget Sound basin is identified as the 6-month, 24-hour rainfall event (Ecology 2005). A continuous simulation hydrologic model can also be used to determine the water quality design storm (Ecology 2005). The water quality design storm is used when the storm water management requirement is only to remove pollutants and not to also control peak runoff discharge. For the Puget Sound basin, the water quality design storm can be estimated as 72 percent of the 2-year, 24-hour storm (Ecology 2005). Using this criterion for the Lummi Reservation, the water quality design storm would be 1.3 inches of rain in 24 hours.

The rainfall intensity (inches per hour) over the Reservation for return periods of 5-, 10-, 25-, 50-, and 100-years for durations of 30-, 60-, and 90-minutes are shown in Table 2.3.

Table 2.3 Rainfall intensity, duration, and frequency for the Lummi Reservation[1]

Return Period (years)	Duration: 30 min.	Duration: 60 min.	Duration: 90 min.
	Rainfall Intensity (in/hr)	Rainfall Intensity (in/hr)	Rainfall Intensity (in/hr)
5	0.80	0.58	0.47
10	0.90	0.66	0.52
25	1.90	0.78	0.63
50	1.24	0.88	0.70
100	1.40	0.97	0.78

[1] **Data Source:** Washington Department of Transportation (n.d.)

Temperature on the Reservation is relatively mild year round. Temperature data collected at the Bellingham Airport from 1949 – 2005 indicate that the warmest months are July and August. During these months the average maximum daily temperature is approximately 71 degrees Fahrenheit (^{o}F). December and January are the coldest months when the average minimum daily temperatures are about 32^{o}F. The growing season is "the portion of the year when soil temperature (measured 20 inches below the surface) is above biological zero (5°Celsius [C] or 41°F)". May through September is the approximate growing season for agricultural crops in the area (Gillies 1998).

Evapotranspiration is the combined loss of water to the atmosphere through evaporation from the soil surface, evaporation of intercepted water, and plant transpiration. Evapotranspiration has not been measured on the Reservation but has been estimated. Phillips (1966) estimated the average annual actual evapotranspiration for a 6-inch water holding capacity soil at the Marietta 3 NNW station to be approximately 18.8 inches. This estimate represents about 52 percent of the mean annual precipitation. In 2003, evapotranspiration was calculated from meteorological variables measured on the Reservation from 1997 though 2001 as part of the Lummi Peninsula ground water investigation (Aspect Consulting 2003). Evapotranspiration was computed using the Penman Monteith method with a grass reference crop for a representative evapotranspiration from the land cover of the Lummi Peninsula (Aspect Consulting 2003). The computed average reference evapotranspiration for the Lummi Indian Reservation from 1997 through 2001was approximately 21.1 inches. The average annual precipitation during this same period for a representative watershed on the Lummi Peninsula was 32.8 inches, indicating that approximately 64 percent of the average annual precipitation is lost to evapotranspiration. A review of evapotranspiration estimates from 27 studies conducted in the Puget Sound Lowland (Bauer and Mastin 1997) suggests an average evapotranspiration rate around 17.3 inches. On average, the estimated mean annual evapotranspiration from the 27 studies compiled by Bauer and Mastin (1997) was about 46 percent of the mean annual precipitation.

Wind data for Bellingham indicates that the prevailing wind direction on the Reservation is from the south and southeast with gusts upward of 80 miles per hour. Winds from the west are not as common and generally not as strong (U.S. Army Corps of Engineers 1997). A wind rose developed from meteorological data collected at the north boundary of the ConocoPhillips oil refinery over the August 1982 through March 1984 period (Mobil Oil Corporation 1986) indicated that the wind direction is from the north or northwest about 6 percent of the time. This wind rose is north of the Reservation and near Georgia Strait and indicates that the wind direction is from the northeast about 20 percent of the time. A wind energy development feasibility study, which includes the installation and monitoring of two anemometer towers, is being conducted on the Reservation starting in 2010 and will provide more accurate wind data for the Reservation.

Because most of the precipitation occurs during the winter months when evapotranspiration demand is low, most of the ground water recharge and storm water runoff occurs during this season. After the rainy season and during the summer months when evapotranspiration demand is high and vegetation slows the movement of storm water, the amount of water available for ground water recharge or surface water runoff is small. Despite the lush summer vegetation, infrequent cloud bursts and the relatively impervious soils common to the Reservation can combine to produce storm water runoff during the summer months. Because of the accumulation of debris between the infrequent summer storms, resultant pollutant loading in storm water can be higher during the summer months relative to the rainy season runoff (LWRD and Salix Environmental Services 2006).

2.4. Ground Water Resources

The hydrogeologic conditions on the Lummi Reservation have been described previously by the USGS and others (Washburn 1957, Cline 1974, Easterbrook 1973, Easterbrook 1976, Aspect Consulting 2003). In general, the Reservation is underlain by unconsolidated sediments deposited as glacial outwash, glaciomarine drift, glacial till, and floodplain or delta deposits of Quaternary age (Washburn 1957). The unconsolidated deposits consist of clay, silt, sand, gravel, and boulders. Because the composition of the deposits commonly change laterally over short distances, it is difficult to distinguish between the different stratigraphic units from existing well log data.

2.4.1. Geology

During the Pleistocene, the sea level rose and fell dramatically as the climate changed and the earth’s crust warped. Inundation by seawater caused the glaciers to float and deposit layers of clay, silt, sand, gravel, and boulders. After the glacier receded, the Nooksack River occupied an old channel formed by the glacial melt water and began depositing material on either side of the Lummi Peninsula (then an island). As the river delta grew, it connected the Lummi Peninsula to the mainland.

The sediment units that occur on the Reservation, as described by Cline (1974) and Easterbrook (1976) in order from youngest to oldest, are summarized below.

- **Alluvium:** The alluvium is derived from sediment carried by the Lummi and Nooksack rivers and deposited on the floodplain. It is comprised mostly of clay, silt, sand, and some gravel.
- **Beach Deposits:** The beach deposits are laid by littoral drift processes. The deposits are mostly sand with some gravel and occur mainly at the western part of the Reservation from Neptune Beach to Sandy Point and at Gooseberry Point.
- **Older Alluvium:** The older alluvium was deposited by the Lummi River and Nooksack Rivers when the valley floor was relatively higher than at present. The unit consists mostly of fine sand with some silt and clay located on stream terraces flanking the

uplands above the floodplain. These deposits occur along the southeast flank of the Mountain View Upland and the northeast flank of the Lummi Peninsula.

- **Gravel:** A thin unsaturated gravel unit is exposed at the surface at several locations on the Reservation. The unit consists of gravel and sand/gravel. In places, this unit appears to have been reworked by beach processes during post-glacial uplift and overlies glaciomarine drift.
- **Glaciomarine Drift:** The Glaciomarine Drift unit was deposited late in the Fraser Glaciation (from about 20,000 years ago to about 10,000 years ago [Easterbrook 1973]). The drift is comprised of unsorted clay, silt, sand, gravel, and some cobbles and boulders. The deposits include both Kulshan and Bellingham drifts.
- **Glacial Till:** The glacial till from the Vashon Stade of the Fraser Glaciation is comprised of poorly sorted clay, silt, sane, gravel, and some cobbles and boulders. Because the presence of till is noted in only a few well logs and has been observed at only a few locations along the Lummi Peninsula bluffs, the occurrence of till is believed to be limited.
- **Esperance Sand:** The Esperance Sand unit (Easterbrook 1976), formerly named Mountain View Sand and Gravel, is advance outwash comprised of stratified beds of sand and gravel with stratified lenses of sand. The unit overlies the Cherry Point Silt unit and underlies the glaciomarine drift and till; it is the major water-yielding unit beneath the Reservation.
- **Cherry Point Silt:** The Cherry Point Silt unit is the oldest known unconsolidated stratigraphic unit in the northern Puget Sound lowland. The unit is comprised of a thick sequence of blue to brownish gray stratified clay and silt with minor sandy beds.
- **Bedrock** underlying the Reservation consists mostly of sedimentary rocks such as sandstone, siltstone, shale, and conglomerate. The bedrock is deeply buried by unconsolidated glacial deposits.

2.4.2. Reservation Aquifers

Ground water in the Reservation aquifers is obtained primarily from outwash deposits of sand and gravel in the unconsolidated glacial sediments, which are generally recharged by local precipitation. Glaciomarine drift is at or near the ground surface over much of the upland areas on the Reservation. The glaciomarine drift overlays the outwash deposits and contains substantial amounts of clay. This clay restricts the recharge to the underlying aquifer and promotes storm water runoff.

Two separate potable ground water systems occur on the Reservation. One system is located in the northern upland area. This northern system flows onto the Reservation from the north and drains to the west, south, and east (Aspect Consulting 2009). The second potable ground water system is located in the southern upland area of the Reservation (Lummi Peninsula) and is completely contained within the Reservation boundaries (LWRD 1997a, Aspect Consulting 2003). The floodplain of the Lummi and Nooksack rivers, which contains a surface aquifer that is saline (Cline 1974), separates the two potable water systems. A third potable water system may exist on Portage Island, but information on the water quality and the potential yield of this system is limited and inconclusive.

In general, both the northern and southern ground water systems contain two aquifer types (Washburn 1957, Easterbrook 1976). The upper aquifer type is comprised primarily of lenses of sand or sand and gravel that are in or above the glaciomarine drift. These relatively permeable lenses are not continuous throughout the area. The lower aquifer layer is comprised of advance outwash sand and gravel. The thickness of the lower aquifer, which appears to be semi-confined in places and unconfined in other places, is not known. The pebbly clay in the drift sediments and scattered deposits of till greatly slow the downward percolation of water to the lower aquifer and may act locally as a confining layer.

Because the hydrogeologic conditions on the Reservation vary considerably over short distances, the precise locations of the aquifer recharge zones are not definitively known at this time. It is likely that aquifer recharge areas are distributed over the upland areas. However, given the high runoff potential of the glaciomarine drift that covers much of the Reservation upland, it is also possible that aquifer recharge areas are of limited areal extent and are located primarily in only a few locations around the Reservation. Until information that is more precise is developed, all of the northern and southern upland areas on the Reservation are assumed to be aquifer recharge zones.

2.5. Soils

Soil scientists have identified seventeen general soil units in Whatcom County, six of which are found on the Lummi Reservation (Figure 2.6). The United States Department of Agriculture (USDA) – Natural Resource Conservation Service (NRCS) has further identified and described forty different soil types on the Reservation from the general soil units (USDA 1992). The eight general soil units are:

Mt. Vernon-Puyallup: Very deep, moderately well drained, nearly level soils; located on river terraces and floodplains covered with shrubs or conifers.

Eliza-Tacoma: Very deep, very poorly drained, level soils that generally have been artificially drained; located on floodplains, deltas, and tidal flats lower than 20 feet of elevation.

Kickerville-Barneston-Everett: Very deep, well drained and somewhat excessively drained, level to very steep soils; located on outwash terraces and glacial moraines.

Lynden-Hale-Tromp: Very deep, well drained to somewhat poorly drained, level to generally sloping soils; located on outwash terraces at 50 to 300 hundred feet in elevation.

Whatcom-Labounty: Very deep, moderately well drained and poorly drained, level to very steep soils; located dominantly on glaciomarine drift.

Birchbay-Whitehorn: Very deep, moderately well drained and poorly drained, level to gently sloping soils; located on glaciomarine drift plains.

Estuarine Unit: Very deep, poorly drained, level, located on tidal flats

Unstable Soil Unit: Moderately deep to very deep, well drained soils, very steep slopes, located on mountainsides, canyonsides, and ridges.

As part of the characterization, each soil type was assigned to one of four hydrologic soil groups based on their runoff-producing characteristics (USDA 1992). The hydrologic soil group, along with the cover type, drainage area, channel length, and land slope, can be used in the USDA Curve Number Method (USDA 1970) to estimate runoff volumes, peak discharge, and hydrographs for specified storms. The primary consideration in assigning a soil to a hydrologic soil group is the inherent infiltration capacity of the soil with no vegetation (USDA 1992). The hydrologic soil groups, which are labeled A, B, C, or D are described in Table 2.4. In essence, Group A soils have a low runoff potential and a high infiltration potential whereas Group D soils have a high runoff potential and a low infiltration potential. Group B and Group C soils have runoff and infiltration potentials between Group A and Group D.

As shown in Table 2.4 and Figure 2.7, most of the northern and southern upland areas in the watershed (on and off Reservation) have a moderately high or high runoff potential. About 9.5 percent of the soils within the Reservation watersheds (not including the off-Reservation extents of Watershed S) have a low or moderately low runoff potential (Group A or Group B). The remaining 90.5 percent of the soils on the watersheds have a moderately high or high runoff potential (Group C or Group D). These soil characteristics suggest that less than 10 percent of the watershed uplands have a good aquifer recharge potential.

As shown in Figure 2.7, the Group A and B soils are generally found along some of the low lying coastal areas and the glacial outwash terraces of the Reservation. These soils are concentrated along Haxton Way south of Balch Road, along Lummi View Road near the Stommish Grounds, on Portage Island, and near Fish Point. There is an isolated area of Group B soils along the west side of Chief Martin Road near the abandoned landfill. The Group C and D soils are found along the glaciomarine drift plains in the upland areas and the floodplains of the Lummi and Nooksack rivers. Off-Reservation Group A and Group B soils are mostly found in Watershed P along the east side of Lake Terrell Road. Most of the northern and southern upland areas in the watersheds (on- and off-Reservation) have a moderately high or high runoff potential.

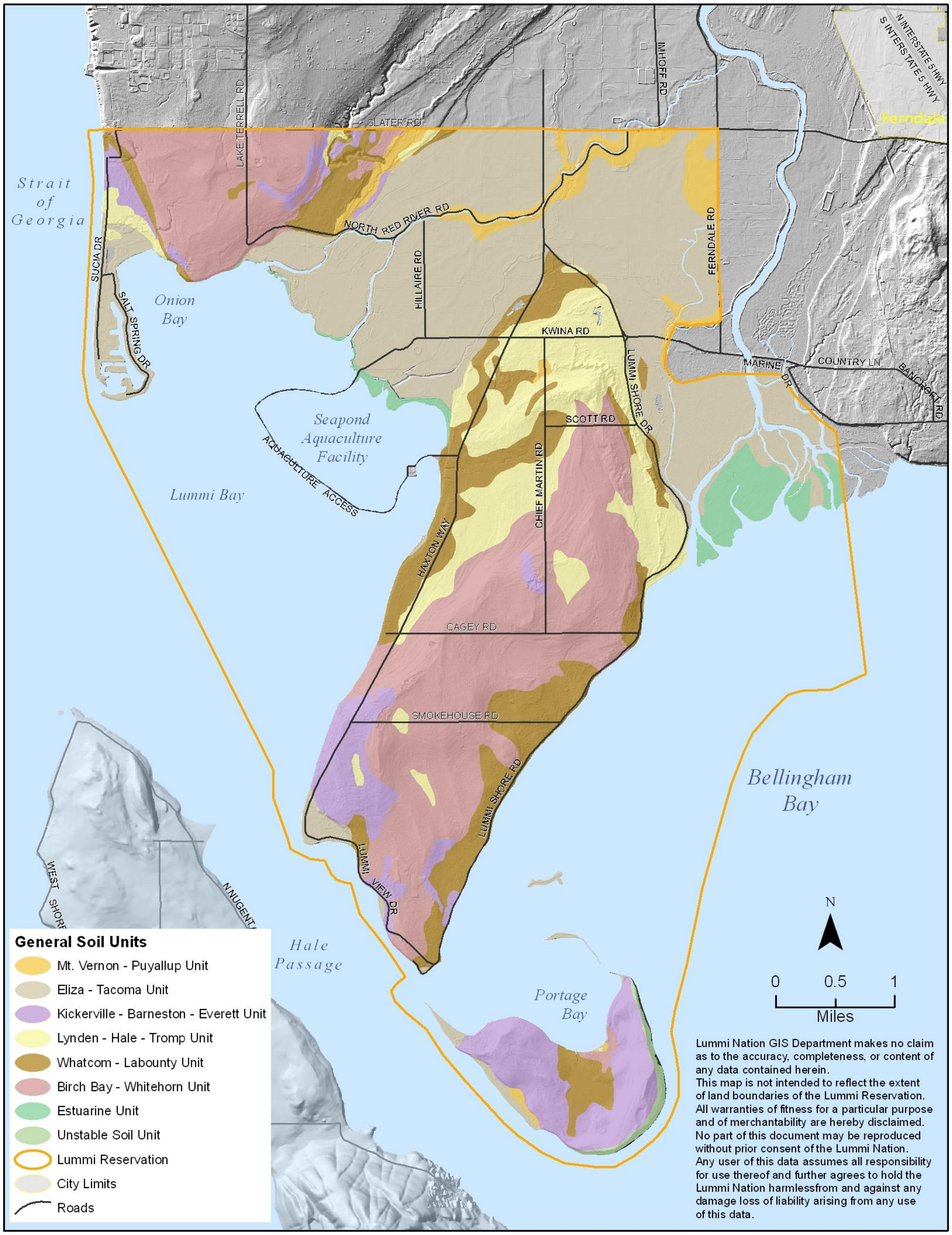

Figure 2.6 General Soil Units of the Lummi Indian Reservation

Table 2.4 Descriptions of Hydrologic Soil Groups of the Reservation Watersheds[1]

Hydrologic Soil Group	Description[2]	Percent of Watershed Soils
A	Soils having high infiltration rates even when thoroughly wetted, consisting chiefly of deep (3 to 6+ ft), well to excessively drained sands (loamy sands, sandy loam, and sands) and/or gravel. These soils have a high rate of water transmission and a low runoff potential.	2.0
B	Soils having moderate infiltration rates when thoroughly wetted; consisting chiefly of moderately deep (20+ inches) and moderately well to well drained soils with moderately fine to moderately coarse textures (loam, silt loam). These soils have a moderate rate of water transmission and a moderately low runoff potential.	7.5
C	Soils having slow infiltration rates when thoroughly wetted; consisting chiefly of: 1) soils with a layer that impedes the downward movement of water, and 2) soils with moderately fine to fine texture (sandy clay loam) and slow infiltration rates. These soils have a slow rate of water transmission and a moderately high runoff potential.	45.3
D	Soils having slow infiltration rates when thoroughly wetted; consisting chiefly of: 1) clay soils with high swelling potential, 2) soils with a high permanent water table, 3) soils with clay pan or clay layer at or near the surface, and 4) shallow soils over nearly impervious materials. These soils have a very slow rate of water transmission and a high runoff potential.	45.2

[1]Not including the off-Reservation extents of Watershed S (Nooksack River watershed)
[2] USDA 1992

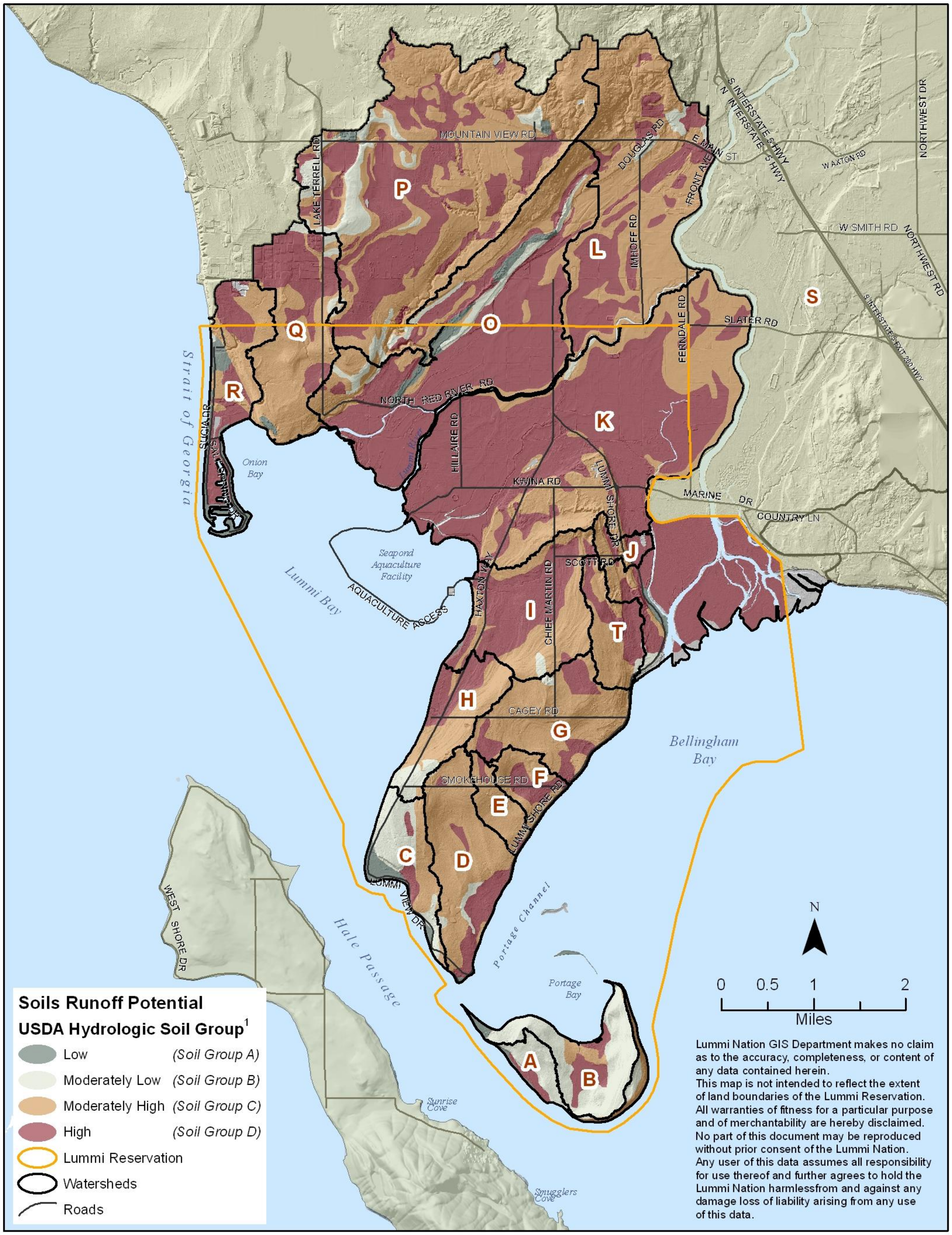

Figure 2.7 Soil Runoff Potential of the Lummi Indian Reservation Watersheds
[1] USDA 1992

2.6. Land Use

Like most places, land use changes on the Reservation have been associated with changes in vegetation types, decreases in the areas covered by vegetation, changes in natural drainage patterns, and increases in impervious surfaces. With the arrival of Euro-Americans, forested land was logged, cleared, and drained for agriculture development, homes, and businesses. Historic and current land uses in the Reservation watersheds and socioeconomic conditions on the Reservation are described below. Much of the information about historic land uses come from the *Lummi Nation Comprehensive Environmental Land Use Plan: Background Document* (LIBC 1996).

2.6.1. Historic Land Use

Before the arrival of Euro-Americans, the Lummi people were a fishing, hunting, and gathering society. Based on the accounts of Lummi Elders, early European explorers, and early photographs of the region, before 1850 old-growth forests of massive Douglas fir, western hemlock, spruce, and western red cedar dominated what was to become the Lummi Reservation. Deciduous trees such as western big leaf maple, black cottonwood, red alder, and western paper birch were also likely present along the rivers, streams, and open areas. Understory vegetation probably included vine maple, Oregon grape, several different willows, ocean spray, salmon berry, thimbleberry, soapberry, and many others. Wetlands, streams, and rivers supported a unique array of plants adapted to wet environments. The marine shoreline was also a unique environment, where only plants adapted to a saltwater-influenced environment thrived.

The forces that shaped vegetation patterns in the Northwest before the arrival of Euro-Americans were forest succession, fires, windstorms, ice storms, floods, and traditional use of natural vegetation by the indigenous peoples. Native American uses of vegetation included the gathering of medicinal plants, the use of willows and other shrubs for fishing, and the extensive use of western red cedar trees for many things, including clothing, baskets, buildings, and canoes. Many plants were also sources of food to complement the traditional diet of fish, shellfish, elk, and deer. Native Americans cultivated some of these plants, such as ferns, camas, and wapato, in prairies along the Nooksack River.

Similar to most areas in the lower Nooksack River watershed downstream from Everson, conversion of forestland to agricultural land occurred on the Lummi Reservation following the arrival of Euro-Americans. In 1896, approximately 1,222 acres were reportedly under cultivation on the Reservation. Along with clearing the forested land for agriculture, Euro-Americans constructed ditches, built roads, drained wetland areas, cleared logjams, diverted the Nooksack River to drain into Bellingham Bay, built a levee that cut off the Lummi River delta from the Nooksack River, and built a seawall along Lummi Bay. These changes in the natural hydrology of the Lummi Reservation changed the distribution and patterns of watercourses and of wetland- and riparian-associated plant communities.

Much of the cedar on the Reservation was cut into shingle bolts and shipped to local shingle mills. The old-growth trees on Portage Island were cut down to fuel steamboats traveling the Nooksack River. One or more large fires swept through the Reservation area between 1850 and 1900. These fires destroyed nearly all of the remaining old growth forests. Since reforestation was not practiced during the early logging period and did not begin until approximately 1980, pioneer tree species, such as alder, willows, and cottonwoods, soon replaced the conifer forests and dominated the landscape (Leckman 1990).

Historically, the Nooksack River flowed (alternately or simultaneously) to both Lummi and Bellingham bays (effectively making the Lummi Peninsula an "island"). Before 1860, the Nooksack River discharged primarily into Lummi Bay by way of the present Lummi River channel, with smaller distributaries flowing into Bellingham Bay (WSDC 1960, Deardorff 1992). In 1860 a logjam blocked the Nooksack River near present-day Ferndale and diverted it to a small stream that flowed into Bellingham Bay (WSDC 1960). Since that time, considerable effort has been expended to keep the Nooksack River discharging into Bellingham Bay because of the increased commercial value of the river that resulted from its proximity to sawmills along Bellingham Bay (Deardorff 1992). Until the early 1900s, the Nooksack River was also the primary transportation corridor for Ferndale, Deming, and Lynden residents traveling to Bellingham. The stream remaining in the channel that discharges into Lummi Bay is called the Lummi River or the Red River (WSDC 1960).

In the 1920s, a reclamation project was initiated both to construct a dike/seawall to keep back the sea along the shore of Lummi Bay and to construct a levee along the west side of the Nooksack River (Deardorff 1992). This project, which was started in 1926 and completed in 1934, initially resulted in the nearly complete separation of the Lummi River from the Nooksack River. However, when saltwater intrusion onto the newly reclaimed farmlands and damage to the dam at the head of the Lummi River occurred during flooding, the dam was replaced with a dam and spillway structure (Deardorff 1992). This spillway structure was also damaged over the years during high-flow conditions and was replaced in 1951 by a five-foot diameter culvert (FEMA 2004) that allowed flow from the Nooksack River into the Lummi River. Currently a partially collapsed four-foot diameter culvert (Deardorff 1992) allows flow to the Lummi River only during relatively high-flow conditions (approximately 10,000 cfs). Levees were also constructed along the Lummi River to prevent saltwater from Lummi Bay from flowing onto adjacent farmlands during higher tides. The dike and levee construction activities were accompanied by agricultural ditching to drain fields and wetland areas. Based on 1887-88 topographic surveys, Bortleson et al. (1980) estimated that wetlands located landward of the general saltwater shoreline in the lower Lummi River watershed decreased from approximately 2.0 square miles to 0.1 square miles (approximately 95 percent) over the 1888-1973 period.

Between 1940 and 1960 several new public roads providing access to Ferndale and Bellingham as well as a toll ferry to Lummi Island contributed to an increase in development on the Reservation. Since 1960 there has been a significant increase in the total population on the Reservation and the number of Tribal members living on the Reservation. This is due to a number of factors including: improved economic conditions within the community, improved utility service and infrastructure, the beginning of tribal self-governance, the increased rate of house construction, and a renewed sense of Lummi cultural identity.

2.6.2. Current Land Use

Over the last century, the increase in population, the construction of extensive road networks, development of wastewater collection and treatment systems, the construction of the Sandy Point Marina, and several Tribal housing projects have fostered a trend towards higher density neighborhoods throughout the Reservation. Several distinct residential neighborhoods now exist, mainly along the shores of the Reservation including Sandy Point, Neptune Beach, Sandy Point Heights, and Gooseberry Point. Higher density residential neighborhoods can also be accessed from the numerous spur roads along Haxton Way and Lummi Shore Road, which are the primary roads along the perimeter of the Lummi Peninsula. Although increased residential and commercial development has occurred on the Reservation in the last few decades, the majority of the Reservation remains rural.

The approximation of the current land cover and land use in the Reservation watersheds is shown in Figure 2.8. This map was derived from the 2006 National Oceanic and Atmospheric Administration (NOAA) database, Classification of Coastal Washington, which is part of the Coastal Change Analysis Program (C-CAP) of the NOAA Coastal Services Center. The map gives an overview of the extent of forest and agricultural lands, residential areas, and wetlands in these watersheds. The estimated distribution of land cover/land use types within the Reservation watersheds is summarized in Table 2.5.

The majority of the forested areas are on the Lummi Peninsula, Portage Island, and the Northwest Uplands. Although there are some conifer groves and Douglas fir plantations, the 2007 inventory of Reservation forests showed that present day forests are largely comprised of deciduous trees, with some mixed deciduous/conifer stands (International Forestry Consultants, Inc. 2007).

The floodplains of the Lummi and Nooksack Rivers are sparsely developed. The most important commercial enterprise in the floodplains is the Silver Reef Hotel, Casino, and Spa and the adjacent gas station and mini-mart. This commercial center is located at the intersection of Haxton Way and Slater Road. The floodplains are dominated by agricultural lands and wetlands, both fresh water and estuarine. The tribal center along Kwina Road includes the LIBC offices and the Northwest Indian College (NWIC). The Northwest Indian College and the LIBC offices are currently undergoing an expansion along the south side of Kwina Road.

Figure 2.8 also displays an important feature of the Reservation, the extent of the tidelands which are essential to the way-of-life of the Lummi People. The seaward boundary of the Reservation is defined as the extent of the tidelands to -4.5 feet Mean Lower Low Water (ft MLLW).

Based on estimates of land cover in Whatcom County (Whatcom County 2005), land cover/use in the Nooksack River watershed is generally dominated by forested areas upstream from the town of Deming and agricultural lands downstream from Deming. The agricultural lands in the lowlands were largely forested before the arrival of Euro-Americans and had been largely denuded of trees by 1925 (Pierson 1953, as cited in Smelser 1970). Population centers such as Ferndale, Lynden, Everson, and Deming are located adjacent to the Nooksack River.

Table 2.5 Current Land-cover/Land-use Types of the Lummi Indian Reservation Watersheds[1]

Land Cover/Land Use	Percent of Area[1]
Residential, Commercial, Industrial, and Municipal	10.97
Forest	35.02
Scrub-Shrub	2.35
Wetlands	17.69
Cultivated Land/Grassland	33.96

[1] Does not include the off-Reservation portion of Watershed S (Nooksack River) or tribal tidelands

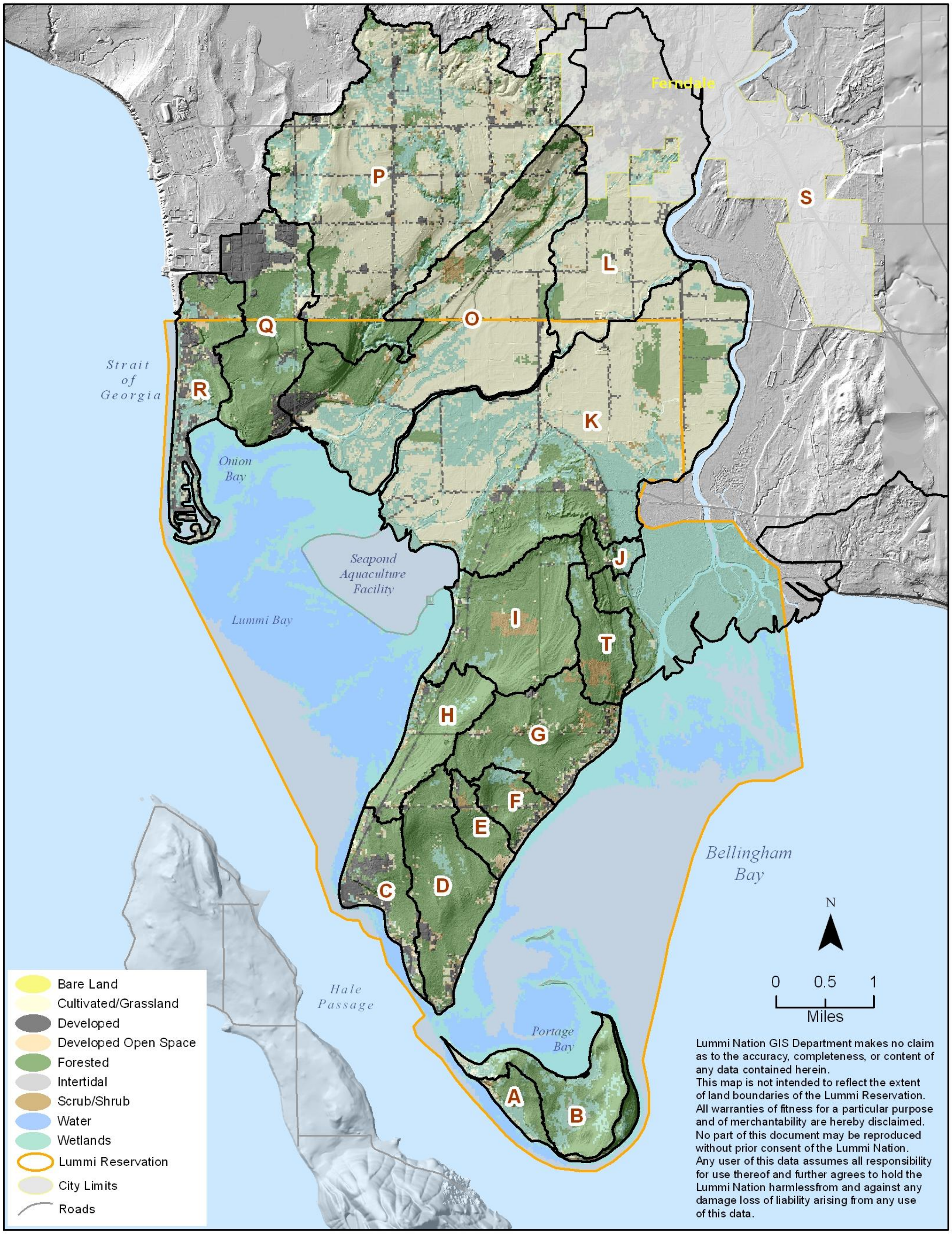

Figure 2.8 Upland Use/Land Cover of the Lummi Indian Reservation Watersheds

2.6.3. Future Land Use

Future development on the Reservation is guided by a number of tribal laws and associated regulations including:

- LCL Title 15: Land Use, Development, and Zoning Code
- LCL Title 15A: Flood Damage Prevention Code
- LCL Title 16: Sewer and Water District Code
- LCL Title 17: Water Resources Protection Code
- LCL Title 22: Building Code
- LCL Title 40: Cultural Resources Preservation Code

Figure 2.9 shows the current official zoning map of the Lummi Reservation. This zoning map was revised and adopted by the LIBC in 2004 as part of the comprehensive planning effort currently underway by the Planning Department. The zoning update incorporated comments from tribal departments and commissions and from public comments received during four community meetings.

The Lummi Planning Department is developing a Comprehensive Plan for the Lummi Reservation. The plan will show, in general, how land on the Reservation will be used over the next 20 years. The Comprehensive Plan will identify areas that will be developed for residential, commercial, mixed uses, industrial, and agricultural purposes, as well as show areas that require protection (e.g., Special Flood Hazard Areas, wetlands, and aquifer recharge zones). To date, a technical background document (LIBC 1996) has been developed, public opinion surveys conducted, drafts of the Comprehensive Plan and maps developed, and focused planning workshops and meetings with commissions and community groups have occurred. The Comprehensive Plan is codified LCL Title 15 (Land Use, Development, and Zoning Code). Title 15 also formalizes an environmental review process that was already largely in place pursuant to LIBC resolutions.

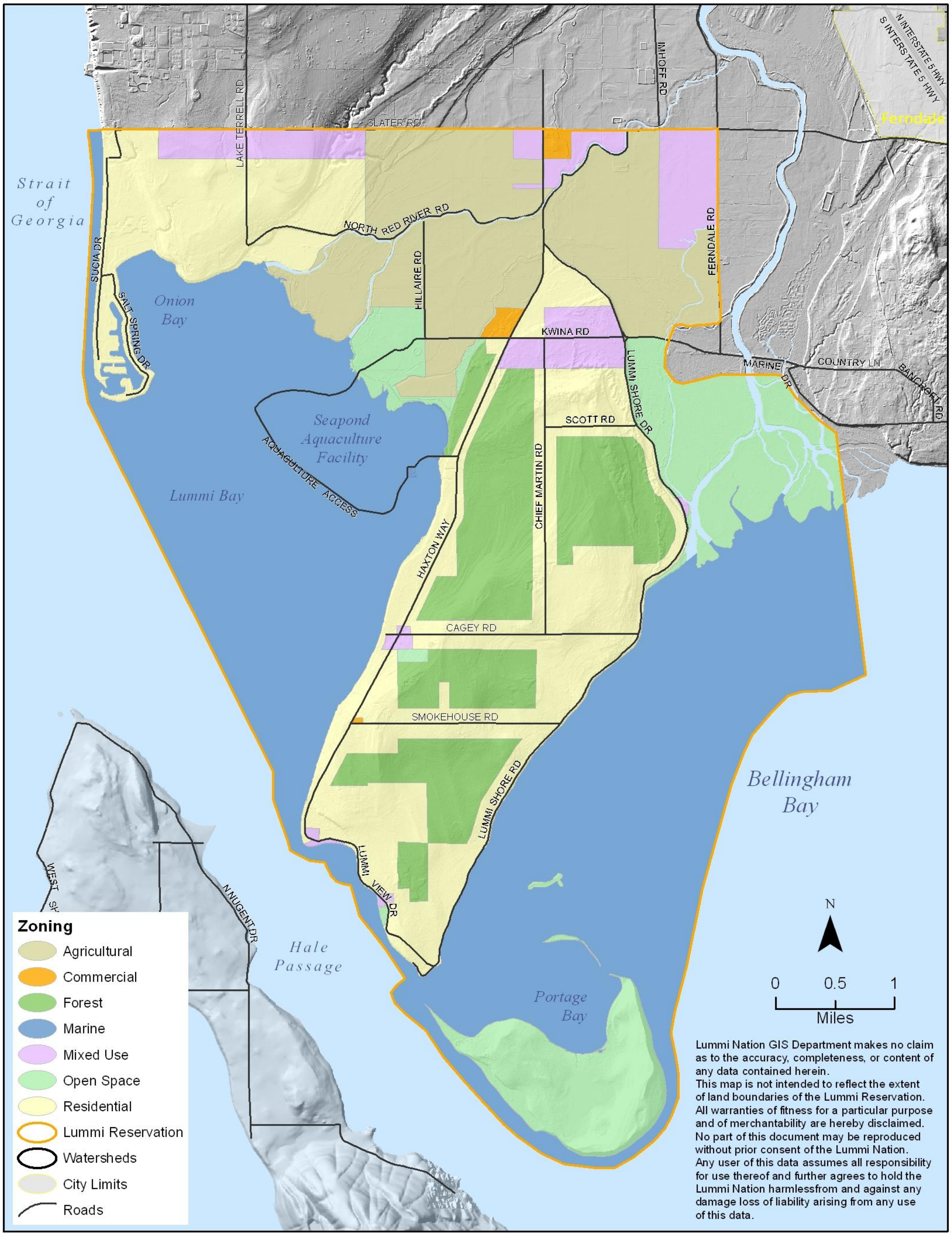

Figure 2.9 Current Land Use Zones on the Reservation

2.7. Surface Water Resources

The Lummi Nation is the largest fishing tribe in Puget Sound and has relied on their water resources since time immemorial for ceremonial, subsistence, and commercial purposes. Surface waters in the study area include the Nooksack River, the Lummi River, sloughs, small streams, roadside and agricultural ditches, springs, wetlands, estuaries, and marine waters. There are approximately 38 miles of marine shoreline surrounding the Reservation (except along portions of the east boundary and the northern boundary). The associated tidelands extend from Georgia Strait to Lummi Bay, Hale Passage, Portage Bay, and Bellingham Bay. In addition to marine waters, there are approximately 24.4 miles of rivers, streams, sloughs, and drainages on the Reservation including the multiple distributary channels of the Nooksack River delta (Figure 2.10). There are no lakes on the Reservation, but there are approximately 13 ponds. Finfish and shellfish spawn, incubate, and grow within and adjacent to Lummi Nation Waters (LNR 2010).

2.7.1. Rivers, Sloughs, Streams, and Ditches

The Nooksack River drains most of western Whatcom County and currently flows through the Reservation close to its mouth and discharges to the marine water of Bellingham Bay near the eastern extent of the Reservation. The Nooksack River reach located on the Lummi Reservation is tidally influenced. Streamside levees are in place to protect agricultural lands from flooding and saline water. Several named sloughs, which are the remains of former river channels, have been incorporated into the agricultural drainage network built on the floodplain of the Lummi and Nooksack rivers.

The Lummi River currently carries storm water runoff from the Ferndale upland as well as the drainage from a complex network of agricultural ditches in the floodplain. Tidal waters enter the Lummi River from Lummi Bay twice daily and, during the late dry season, saline water extends as far upstream as Slater Road. Although Nooksack River water currently flows through a four-foot culvert into the Lummi River channel only during high-flow events (greater than approximately 10,000 cfs), available data indicate that the Lummi River flow was around 200 cfs as recently as June 1955 (WSDC 1964), when a culvert allowed fresh water to flow from the Nooksack River into the Lummi River channel (Deardorff 1992).

There are several mapped and previously unmapped streams on the Reservation. Most of the previously unmapped streams have poorly defined channels and contain surface flow only during the October through April period (wet season). The approximate locations of these streams were identified as part of the inventory of storm water facilities. No flow in the streams was observed during a field survey of all Reservation streams in late August 1996.

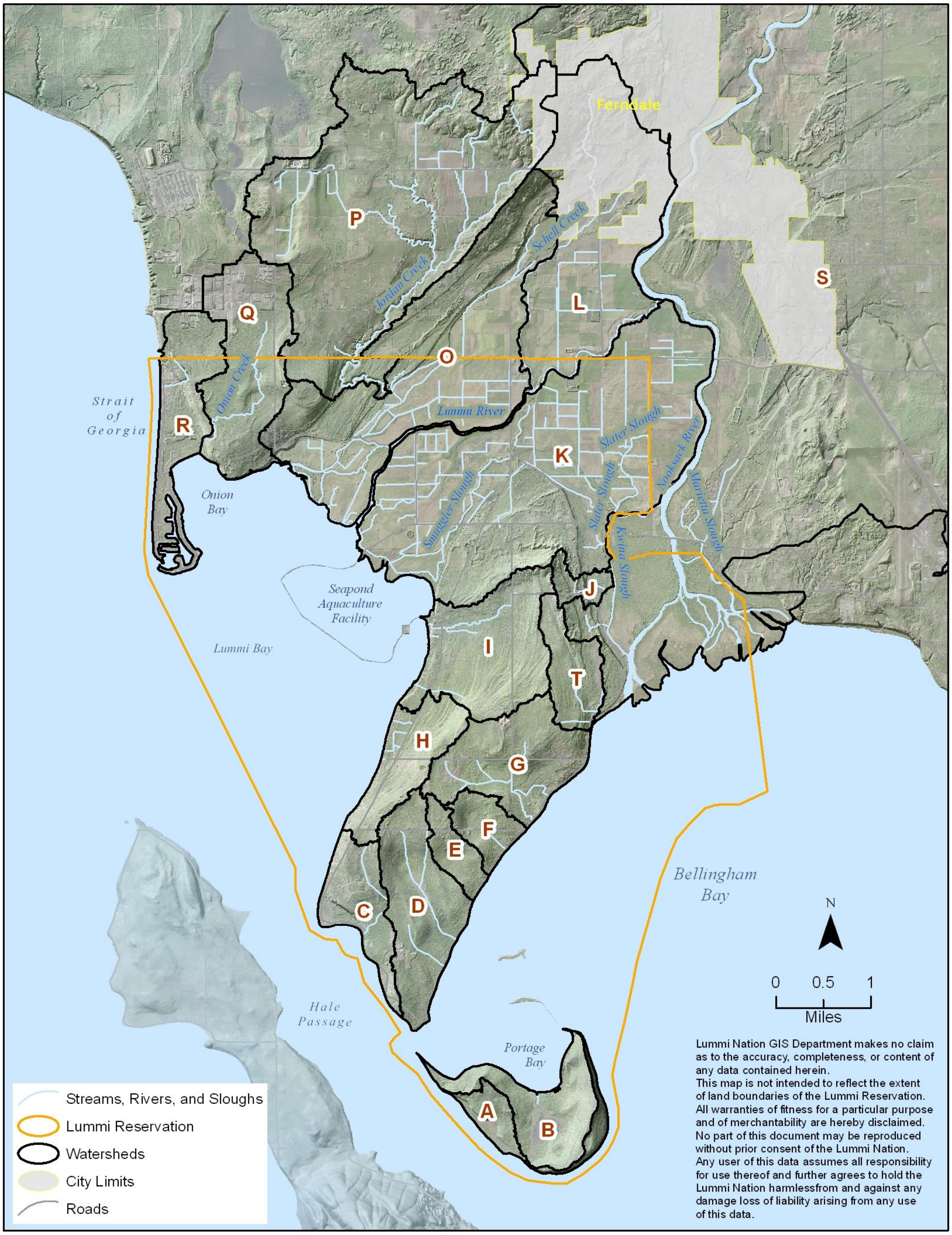

Figure 2.10 Reservation Streams, Rivers, and Sloughs

2.7.2. Springs and Wetlands

Upland springs are found throughout the Reservation and are commonly ground water discharge zones for shallow, perched aquifers. A seep or spring occurs if the land surface intercepts the aquifer, and wetlands may occur at the seep or spring if conditions are favorable (e.g., clayey soils, shallow slope). In addition to upland springs, springs occur along the shoreline or below the ordinary high water line (vegetation line) at numerous locations on the Reservation.

Historically, springs emerging in the uplands served as a water supply for the Lummi people. In many cases, the springs are part of a wetland system in which the water reinfiltrates along the lower terraces to return to ground water. The springs are important for wildlife habitat and for aquifer recharge and protection. Upland aquifers, which provide the primary Reservation drinking water supply as well as water for salmon egg incubation and rearing in the hatchery program, have experienced depletion and saltwater intrusion. Where it occurs, the infiltration of fresh water above the shorelines provides a buffer against saltwater intrusion.

The 1999 comprehensive inventory of Reservation wetlands (Harper 1999, LWRD 2000) indicated that approximately 43 percent of the Reservation land area is either wetlands or wetland complexes. Wetland complexes are areas where wetlands and uplands form a highly interspersed mosaic. During the wetland inventory, boundaries were drawn around the outer edges of the mosaic of upland and wetland areas and the entire area was labeled as a "wetland complex". Consequently, the estimated total wetland area identified in the inventory represents more wetland area than actually exists. Approximately 60 percent of the floodplain on the Reservation was classified as wetlands or wetland complexes (Lynch 2001). An update to the 1999 wetlands inventory is currently underway. The update includes using Global Positioning System (GPS) technology to refine the locations and extent of all wetlands on the Reservation and collecting additional information on the functions and classifications of these wetlands. To date approximately 155 wetlands and 2,216 acres of wetland area have been evaluated as part of the 1999 wetland inventory update (LWRD 2010a). Figure 2.11 presents the results of the 1999 wetland inventory as currently updated.

Most of the once extensive floodplain wetlands of the Lummi and Nooksack rivers have been diked, drained, filled, and cultivated since the late 1800s. Low areas near some of the sloughs still reflect the rich and complex wetland habitat that likely covered most of the lower floodplain before human alteration. Small estuarine wetlands lie in sheltered, low energy areas at Onion Bay, Neptune Beach, Portage Island, the Lummi River floodplain, the Nooksack River delta, and adjacent to the Seaponds dike. Road construction and agricultural activity have altered the wetlands that are north of Marine Drive and adjacent to the Nooksack River. South of Marine Drive, many of the wetlands in the Nooksack River delta have been physically altered by the accumulation of sediment deposited by the Nooksack River as it discharged to the marine waters of Bellingham Bay. The Nooksack River delta was identified as the fastest growing delta relative to its basin size in Puget Sound, with a progradation of approximately one mile over the 1888 - 1973 period (Bortleson et al. 1980). Consequently, a large area that was once intertidal is now supratidal and new wetlands have been formed. In addition to the delta progradation, the wetlands of the Nooksack River delta are likely affected by the low instream flows and poor water quality that characterizes the river during some summer months.

The majority of the estuarine wetlands of the Lummi and Nooksack rivers will be protected and functionally improved in the future through the implementation of the Lummi Nation Wetland and Habitat Mitigation Bank. The mitigation bank will be developed in phases. Phase 1A, which encompasses most of the Nooksack River estuary, is schedule to be in operation during 2011. The area will be protected into perpetuity through a conservation easement and enhancement measures like invasive species control and under planting with conifers will improve the ecological functions of the estuary. The mitigation bank will be used to mitigate unavoidable impacts to habitat and wetlands on the Reservation, but credits will also be available to buyers in the service area surrounding the Reservation (LWRD 2008b).

Remnants of what were once extensive, high-value wetlands are located on the Sandy Point Peninsula between Sucia Drive and the private Sandy Point marina. The private Sandy Point marina and its associated canal system were excavated in the 1960s from uplands that were periodically inundated by marine waters. Road construction, dense residential development and associated shore defense works, and drainage facilities now limit tidal inundation, but wildlife and wetland vegetation is abundant. Plants of traditional cultural significance have been identified in this area. Further north along Sucia Drive, formerly dry and seasonally wet areas are now permanently flooded as a result of road construction that blocked natural drainage.

These palustrine/estuarine emergent wetlands of the lowlands/floodplains are significant for storm water attenuation, floodwater storage, water quality enhancement, fish habitat, wildlife habitat, and for plants with traditional cultural importance. The estuarine wetlands provide critical rearing habitat for migrating salmon, herring, smelt, and other finfish and shellfish. The significance of these wetlands is increasing as wetlands upstream from the Reservation are altered and destroyed. These Reservation wetlands reduce the water quality impacts of off-Reservation land uses on Lummi commercial, ceremonial, and subsistence shellfish beds in Portage and Lummi bays. Protecting and enhancing floodplain and estuarine wetlands is essential to preserving and/or restoring interdependent fish, shellfish, and wildlife habitats in addition to reducing flood damage.

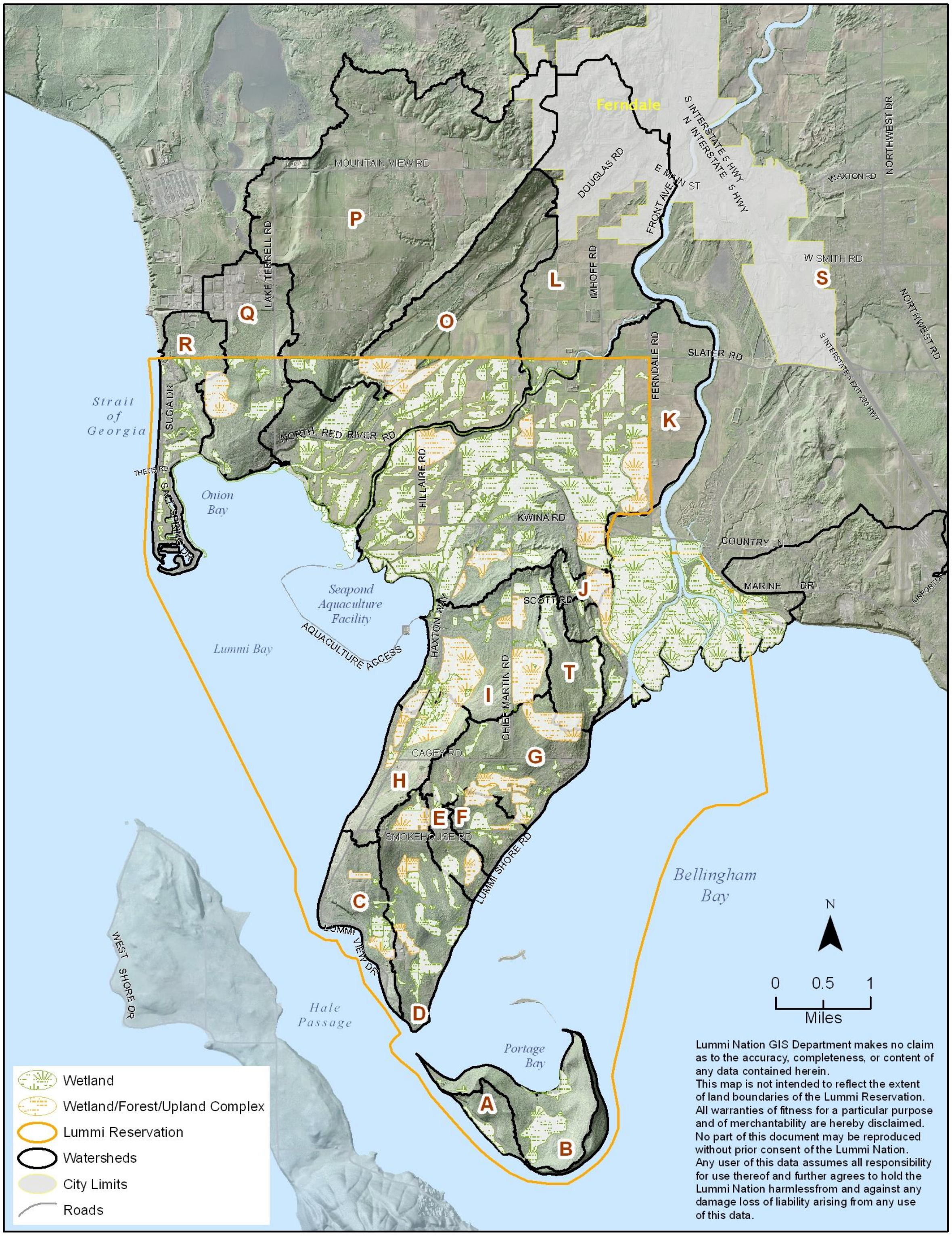

Figure 2.11 Lummi Indian Reservation Wetland Areas

2.7.3. Marine and Estuarine Waters

Brackish estuarine waters grade to marine waters of the Reservation in Lummi Bay, Portage Bay, portions of Bellingham Bay and Hale Passage, and the shoreline along Georgia Strait. Saline water moves across tideflats and into the Lummi and Nooksack river channels twice daily with the tidal cycle. The salt water underlies the less dense fresh water and moves as a wedge upstream. Salt water has been measured upstream as far as Slater Road in the Lummi River and nearly to the fork between the west and east distributaries of the Nooksack River. Tidal effects on the water level (backwater effects) in the Nooksack and Lummi rivers have been observed even further upstream (and possibly occur as far upstream as Ferndale).

Estuarine waters of the Nooksack and Lummi river deltas form the interface between marine and fresh water. Estuarine waters are important habitat for juvenile and adult salmon as they acclimate to either saline or fresh waters during their seaward and landward migrations, respectively. Estuaries also serve as habitat for juvenile and adult individuals of many other important aquatic species (LNR 2010).

The complex and rich aquatic resources that provide feeding grounds for fish also attract a large variety of wildlife. The estuaries of the Lummi and Nooksack rivers are a part of a major Pacific Coast flyway for ducks, geese, swans, and shorebirds. These estuaries are also habitat for the formerly listed peregrine falcon and bald eagle. Estuarine wetland ecosystems in general, including saltwater marshes, are considered among the most productive (in biomass production per unit area) natural ecosystems on earth. In addition to providing rearing habitat for juvenile salmonids and other species, these ecosystems export a large amount of biomass to estuaries. This biomass can form a large portion, sometimes the majority, of the base of the estuarine food web (Mitsch and Gosselink 1993). Small estuarine marshes in Lummi Bay occur in sheltered fringes of diked areas. As mitigation for wetland filling at the casino site at the Slater Road/Haxton Way intersection, a 17.1-acre saltwater marsh was restored along the waterway adjacent to the Lummi Bay seawall in August 2001.

Lummi Bay tideflats are extensive and rich in resources for tribal commercial, subsistence, and ceremonial purposes and as feeding areas for wildlife. Less extensive tideflats at Gooseberry Point, the Stommish Grounds, and Portage Bay are also important to the tribal economy and culture. A Lummi Intertidal Baseline Inventory (LIBI) was conducted in 2010 in order to document the existing diversity, abundance, distribution, and habitats of the biological resources that are found on the Reservation tidelands. The LIBI integrates the results from six surveys that were conducted in 2008 and 2009 with compatible pre-existing information. Over 242 separate taxa were documented on the Reservation during the LIBI (LNR 2010).

2.8. Storm Water Runoff

As shown in Figure 2.10, there are numerous intermittent streams, roadside drainage ditches, and agricultural drainage ditches on the Reservation. These channels convey storm water to either the surrounding marine waters or to the floodplains of the Lummi and Nooksack rivers. Surface water runoff was measure from 1997 through 2001 as part of a Lummi Peninsula ground water investigation (Aspect 2003). Total runoff volumes are a function of precipitation for a given year. The greatest runoff occurred during the wet water year

1998/1999, with runoff ranging from 6 to 14 inches with most of the basins measured in the study having between 10 and 14 inches of runoff (Aspect 2003). The least runoff occurred in the relatively drier water year 2000/2001, with runoff ranging from 2 to 8 inches with most basins between 3 and 5 inches (Aspect 2003). The runoff hydrographs for the study indicated both “flashy” storm water runoff and relatively steady season base flow components. The storm runoff response is rapid, with abrupt runoff peaks occurring at the time of the precipitation event and declining sharply after the end of precipitation. The seasonal baseflow component of flow is relative steady, building and declining slowly over the wet season. Continuous runoff commonly begins occurring by mid-November. The end of continuous runoff ranged from the first week of May in 1998 to late June in 2000. The cessation of runoff is a function of April through June precipitation, with runoff persisting into June during the relatively wetter springs.

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3. STORM WATER LAWS AND REGULATIONS

The United States government has a unique legal relationship with Native American Indian governments based on the Constitution, treaties, statutes, executive orders, and court decisions. Indian tribes have sovereign powers separate and independent from federal and state governments. Tribal sovereignty is the inherent authority of indigenous tribes to govern themselves; tribes have the same power as the federal and state governments to regulate their internal affairs, with a few exceptions. For example, tribes have the inherent power to form a government, to decide their own membership, the right to regulate property, the right to maintain law and order, and the right to regulate commerce. This section gives a brief overview of the federal and tribal laws and regulations that address storm water management on the Lummi Reservation.

3.1. Federal Storm Water Laws and Regulations

In 1972, the United States government passed the Federal Water Pollution Control Act (WPCA). A 1977 amendment to the WPCA renamed this act the Clean Water Act (CWA) and established the basic structure for regulating discharges of pollutants into "waters of the United States". The objective of the CWA is to restore and maintain the chemical, physical, and biological integrity of waters to the level that all waters are clean enough for fishing and swimming (CWA 1972). The U.S. Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers are the primary agencies charged with implementing the CWA.

3.1.1. National Pollutant Discharge Elimination System

The CWA was enacted with the intention of cleaning up polluted waters throughout the United States. Under Section 402 of the CWA, the discharge of pollutants into the "waters of the United States" is generally prohibited without a permit. These permits, called National Pollutant Discharge Elimination System (NPDES) permits, establish water treatment requirements for various municipal, industrial, and other waste discharges.

Initially, NPDES permitting was targeted to point source pollution. Point sources of pollution are any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft from which pollutants are or may be discharged (CWA 1972). After a court ruling in 1977, the focus of water pollution control expanded to include nonpoint pollution sources (Athahyde et al. 1986). Nonpoint source pollution is the contamination of water caused by storm water moving over and through the ground. As the storm water runoff moves downhill, it picks up and carries away naturally occurring pollutants and pollutants resulting from human activity. The storm water eventually deposits the pollutants into lakes, rivers, wetlands, coastal waters, and ground waters (CZMA 1972, EPA 1993).

In 1987, Congress enacted the point source storm water provisions and nonpoint source provisions (Section 319) into the CWA. All storm water point sources of pollution into "waters of the United States" are regulated under Phase I of the federal NPDES storm water program. Phase I includes the regulation of ten categories of industrial facilities, large and medium city storm sewers generally serving populations of 100,000 or greater, and all construction sites that disturb five or more acres. The National Water Quality Inventory 1994 Report to Congress indicated that storm water discharges from a variety of sources, including agriculture, separate storm sewers, construction, waste disposal, and resource extraction activities, continue to be major causes of water quality impairment. In response to this report and related program evaluations, EPA developed new guidelines to further protect water quality.

In 1999 the EPA issued Phase II of the federal NPDES storm water program. Phase II includes a "No Exposure" incentive, regulations for small municipal separate storm sewer systems located in urbanized areas, and regulations for construction activities that disturb one acre or more (EPA 2008a). The "No Exposure" incentive conditionally excludes from the NPDES permit process all handling operations and industrial processes that are not exposed to storm water. The EPA estimated that at least 70,000 industrial facilities will be eligible for the "No Exposure" incentive and will not need to obtain NPDES permits under Phase II of the federal NPDES storm water program. The Phase II regulations for small municipalities and small construction sites rely on the use of Best Management Practices (BMPs) to reduce pollutant flow into surface water. Best management practices related to storm water are generally defined as physical, structural, and/or managerial practices that, when used singly or in combination, prevent or reduce water pollution.

The EPA issued a NPDES Construction Storm Water General Permit (CGP) that covers Indian Country in Washington State (Permit Number WAR10000I) (EPA 2008a). The Lummi Nation issued a conditional Section 401 Water Quality Certification for this permit. A full copy of the CGP can be found at http://www.epa.gov/npdes/pubs/cgp2008_finalpermit.pdf. The permit covers any construction site with land disturbing activities of one acre or more, including smaller sites that are part of a larger common plan of development.

The EPA also issued a NPDES Multi-Sector General Permit (MSGP) for Storm Water Discharges Associated with Industrial Activities (EPA 2008b) that covers facilities located in Indian Country in Washington State (Permit Number WAR05000I). Permit coverage is required for industrial facilities that have specific Standard Industrial Classification (SIC) codes listed in 40 CFR 122.26(b)(14), if they have a discharge of storm water from their industrial areas to a receiving water, or to storm drains that discharge to a receiving water. Regardless of the SIC code, some industries may be required to seek individual rather than general permit coverage for areas of their industrial site that have potential or are causing an impact to receiving waters (EPA 2005). No NPDES permit is required if all the storm water is treated and retained on-site (discharge to ground), although other permits from federal or tribal programs may be required (e.g., underground injection control permits under the Safe Drinking Water Act). Discharges of all storm water to a combined sewer (which goes to a wastewater treatment plant), are not required to apply for coverage. A full copy of the MSGP can be found at http://www.epa.gov/npdes/pubs/msgp2008_finalpermit.pdf.

3.1.2. Nonpoint Source Pollution

Nonpoint source pollution is also addressed under the CWA. Nonpoint-source (NPS) pollution is all pollution that cannot be identified as point source pollution. The definition of a point source from Section 502(14) of the CWA is:

> The term "point source" means any discernible, confined and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.

Nonpoint source pollution is caused by rainfall or snowmelt moving over and through the ground. As the runoff flows, it picks up and carries away natural and human-made pollutants into lakes, rivers, wetlands, coastal waters, and ground waters. The Nonpoint Source Management Program of the CWA (Section 319) provides guidance to tribes and states for controlling nonpoint source pollution. Under Section 319, each state or tribe is required to:

- Identify impaired water bodies or water bodies with a high potential to become impaired;
- Identify those nonpoint sources which add significant pollution to these water bodies; and
- Identify and implement best management practices (BMPs) and measures to reduce pollution loadings from the identified nonpoint sources.

Section 319 also suggests that states and tribes plan development on a watershed by watershed basis.

3.2. Lummi Nation Storm Water Laws and Regulations

The Lummi Nation regulates storm water on the Reservation and other tribal lands pursuant to its inherent authority and authority delegated by the EPA pursuant to Section 518 of the Clean Water Act.

The Lummi Nation Natural Resources Department (LNR) Water Resources Division established a Comprehensive Water Resources Management Program (CWRMP) in response to Lummi Indian Business Council (LIBC) resolutions 90-88 and 92-43. The purpose of the CWRMP is to ensure that land and water resources on the Lummi Indian Reservation are safeguarded against surface and ground water degradation during planning and development activities. Environmental planning intended to protect the Nation’s water resources has included development of a Wellhead Protection Program (LWRD 1997a), a Storm Water Management Program (LWRD 1998c), a Wetland Management Program (LWRD 2000), a Nonpoint Source Management Program (LWRD 2001, LWRD 2002), Water Quality Standards for Reservation surface waters (LWRD 2008a), surface and ground water quality monitoring (LWRD 2010b), and spill prevention and response (LWRD 2005). The various

Lummi Natural Resources Department programs are complemented by several programs administered by the Lummi Planning Department.

In 1990 the Lummi Nation applied for and received "Treatment as a State" (TAS) status from the EPA for the purpose of funding a comprehensive Water Management Plan for Reservation Waters, including development of Water Quality Standards under CWA Section 106. The Lummi Nation was also approved for TAS for CWA 319 in 2002. In 1995 the Lummi Nation applied to the EPA for delegation to administer the CWA 303(c), establishing water quality standards, and CWA Section 401 authority to issue certifications that discharges meet the water quality standards. On March 5, 2007, the EPA approved the Lummi Nation application and authorized the Lummi Nation to administer Water Quality Standards under Section 303(c) of the CWA and to provide water quality certifications pursuant to Section 401 of the CWA for all surface waters within the boundaries of the Lummi Indian Reservation.

As part of the CWRMP, the Water Resources Protection Code (Lummi Code of Laws [LCL] Title 17) was developed to protect, enhance, and restore the water quality of Reservation surface and ground water including the Reservation estuaries and tidelands. Title 17 was adopted by the LIBC in January 2004. The LCL Title 17 includes a chapter addressing storm water management (LCL 17.05). Under LCL 17.05.020 Lummi Natural Resources staff review Storm Water Pollution Prevention Plans (SWPPPs) for small and large construction and land disturbance projects. Small projects, defined in LCL 17.05.030 as land disturbing activities less than one acre, do not require NPDES Construction Storm Water General Permit coverage. Large projects require both a SWPPP approved by the Lummi Water Resources Manager and coverage under the NPDES Construction Storm Water General Permit.

In 2005, the Lummi Nation evaluated the development and implementation of a Lummi Nation NPDES program. The staff recommendation that resulted from the evaluation is that there are not enough facilities and/or construction requiring NPDES permits to justify the cost associated with seeking delegation and administering a NPDES program.

Pursuant to LCL Title 17, the LIBC adopted four Lummi Administrative Regulations (LAR) for: storm water management (17 LAR 05), wetland management (17 LAR 06), technical requirements for ground water wells (17 LAR 04), and a system for civil fines for violation of Title 17 (17 LAR 08) during 2010. The new water resources regulations can be found at the following website: http://lnnr.lummi-nsn.gov/LummiWebsite/Website.php?PageID=53.

4. STORM WATER ON THE LUMMI RESERVATION

Precipitation in the form of rain, sleet, hail, or snow is the source of storm water. Storm water occurs when the infiltration rate of the soil and/or the storage capacity of the soil or land surface is less than the amount of rainfall and/or snowmelt that occurs over a given period of time.

The infiltration rate of porous surfaces (e.g., sand and gravelly soil, vegetated soils) is relatively high. Consequently, there is storm water runoff from these soils and cover types only during larger precipitation events. In contrast, the infiltration rate of impermeable surfaces (e.g., roads, paved parking lots, roofs, driveways), or soils with a large clay or silt component (e.g., soils developed from glaciomarine drift), or bare/unvegetated surfaces is essentially zero and there is storm water runoff as soon as the very low storage capacity of the surface is exceeded. As a result, runoff from impermeable surfaces can occur during small storms.

Watersheds that include wetlands, reservoirs, detention basins, rain water harvesting cisterns, and infiltration trenches or chambers have greater storage capacity and consequently less storm water runoff from common precipitation events than paved or built-over landscapes.

Storm water moves from areas of high elevation to areas of low elevation in response to gravity. Storm water that occurs on the Reservation discharges directly to the surrounding tribal tidelands and marine waters, discharges to the Lummi/Nooksack River floodplain, or infiltrates into the underlying aquifer system. The rate of storm water movement is affected by the characteristics of the surfaces that the storm water encounters as it flows downhill. Vegetated surfaces offer greater resistance to storm water movement and greater infiltration opportunities than paved or compacted surfaces.

4.1. Storm Water Facility Inventories

The inventory of storm water facilities on the Reservation for the 1998 version of this technical background document was conducted during February and March 1997. The inventory was updated in August 2010. Storm water facilities are defined as culverts, bridges, tide gates, catch basins, roadside ditches, and agricultural ditches. During the 1997 inventory, water was flowing in all or most of the roadside and agricultural ditches. Some of the facilities were completely underwater during initial visits and were revisited later in the year when the water had receded. During the August 2010 inventory update, the majority of the storm water facilities were dry and flow paths were not determined at this time but could be inferred by the location on the landscape.

The inventories were conducted to:

- Identify and map where culverts and bridges are located on the Reservation;
- Identify and map the locations of roadside and agricultural ditches on the Reservation;
- Describe the storm water facilities (i.e., diameter, material, condition); and

- Identify the flow paths of water as it drains from upland areas and the floodplain to determine how each culvert or bridge is related to other culverts, bridges, roadside ditches, agricultural ditches, streams, sloughs, wetland areas, and marine waters.

Whatcom County is responsible for the maintenance of most of the roads and associated storm water drainage systems on the Reservation. Consequently, prior to starting the 1997 storm water facilities inventory, the field inventory data sheets and aerial photographs from the culvert inventory conducted by Whatcom County in 1984 were reviewed. Although this information was useful, because it was over 10 years old at the time and a limited field verification effort suggested that some culverts were not accounted for, the 1997 inventory was conducted. The 1997 inventory also allowed the flow direction(s) in ditches and channels, as well as the interrelations between culverts, to be observed. The field observations were recorded on a storm water drainage facilities inventory form (see Appendix B). Appendix B also contains a sample completed field inventory form to illustrate the level of information collected.

Consistent with the approach used in the 1984 Whatcom County inventory of storm water facilities on the Reservation, facilities were initially located and mapped based on a vehicle odometer. Although the accuracy of this method is only approximately ± 0.05 miles (± 264 feet), it was a practical way to field locate a storm water facility without specialized equipment. The location of a culvert or bridge was further defined in the field by drawing a sketch of the culvert or bridge and identifying nearby landmarks (e.g., driveways, signs, other culverts, other intersections). The information collected on the field inventory forms was entered into a computerized database (ACCESS) and the software program ArcGIS was used to map the culvert and bridge locations. The mapped culvert locations were edited as necessary so that they were consistent with field observations.

For greater mapping accuracy, the storm water facilities were located using a global positioning system (GPS) receiver to a horizontal accuracy of ± 5 meters (± 16 feet) during February and March 1998. Incorporation of these location data into the existing database occurred later in 1998. Additional facilities identified or replaced since the 1997 inventory were included in the database in September 2010. The storm water facilities identified in 2010 were located using a GPS receiver with horizontal sub-meter (± 3 feet) accuracy.

The approximate locations of roadside ditches, agricultural ditches, and unmapped intermittent streams were also identified and mapped as part of the storm water facilities inventory. The approximate locations where roadside ditches are present or absent were identified on 1:24,000 scale USGS topographic maps as staff members drove between storm water facilities. The approximate roadside ditch locations were incorporated into the hydrography GIS data layer. The approximate locations of agricultural ditches were identified from aerial photographs and digitized into the hydrography data layer. The flow directions in many of the agricultural drainage ditches were determined by direct field observations during different tidal conditions. Similarly, the approximate locations of intermittent streams were either determined directly by field observations or surmised based on the topography, observed flow directions, and flow quantity in apparently related culverts.

The updated 2010 inventory of storm water facilities on the Reservation is presented in Figure 4.1 and in Appendix C. Culverts identified by Whatcom County within the off-Reservation watershed areas are also incorporated in Figure 4.1. The table presented in Appendix C documents the observed relations between storm water facilities on the Reservation. The inventory indicated that at least 55 culverts along the upland parts of the Reservation discharge storm water directly to marine waters or to the floodplain.

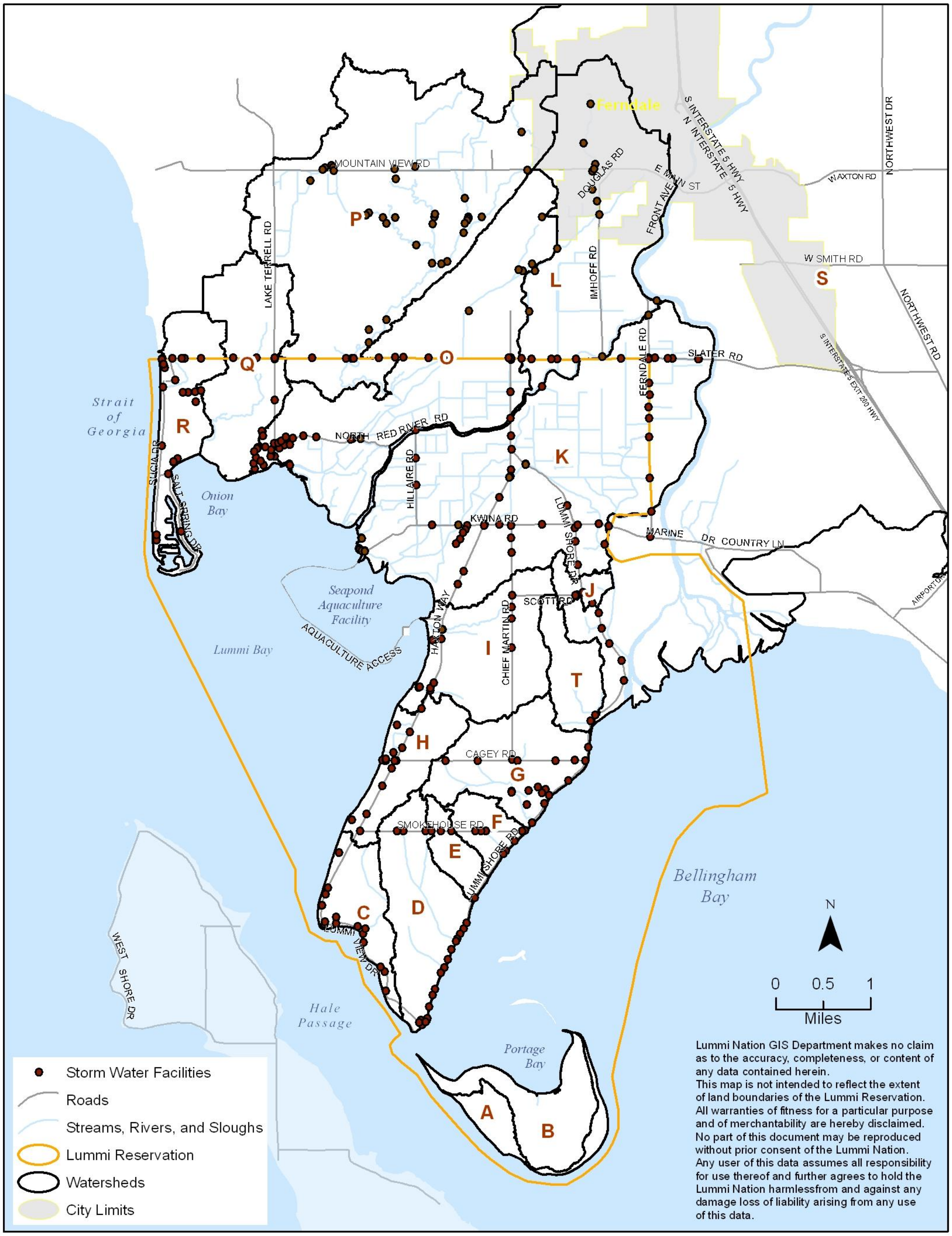

Figure 4.1 Locations of Storm Water Facilities in the Lummi Indian Reservation Watersheds

4.2. Reservation Watersheds and Storm Water Pollution Sources

The characteristics of the 18 watersheds on the Lummi Reservations are summarized in Table 4.1 and the watersheds are illustrated in Figure 2.4. In this section, the dominant land use, the occurrence of storm water and public water supply wells, and other characteristics of the 18 watersheds are summarized.

Watershed A: Watershed A is crescent shaped and located along the southern edge and eastern side of Portage Island. The watershed drains into either Hale Passage or Bellingham Bay. About 66 percent of the watershed is forested. The eastern part of the watershed is characterized by forested uplands and steep bluffs. The southern side is comprised of forested uplands and a mix of grasslands, wetlands, and ponded water located in a low lying area. Beef cattle were grazed on Portage Island in the past and approximately 30 feral cattle remain on Portage Island. The herd of feral cattle is thought to be the main source of high fecal coliform bacteria in Portage Island fresh water streams. Removal of the feral cattle is currently being conducted and will be completed during 2011. There are currently no people living on Portage Island and there are no active ground water wells in this watershed.

Watershed B: Watershed B is dominated by forested land (about 65 percent) and drains the northern and western sides of Portage Island. Storm water from Watershed B discharges primarily into Portage Bay, although a small amount of storm water from along the western extent of the watershed also drains to Hale Passage. Beef cattle were grazed on Portage Island in the past and approximately 30 feral cattle remain on Portage Island. The herd of feral cattle is thought to be the main source of high fecal coliform bacteria in Portage Island fresh water streams. Removal of the feral cattle is currently being conducted and will be completed during 2011. Portage Bay is an important shellfish growing area for the Lummi Nation. Relatively large wetland areas in the central part of Watershed B comprise approximately 29 percent of the total drainage area. These wetlands support one intermittent stream that discharges into Portage Bay. There are currently no people living on Portage Island and there are no active ground water wells in this watershed.

Watershed C: Watershed C is dominated by forested lands (54 percent) and drains the Gooseberry Point area. Storm water from this watershed is discharged into Hale Passage and to Lummi Bay. Gooseberry Point is one of the more densely populated (33 percent urban/residential) and heavily used watersheds on the Reservation. The Fisherman's Cove (boat storage and launching), Fisherman's Cove Mini Mart/Gas Station, a Ferry Terminal (operated by Whatcom County), a seafood buying facility leased by the Lummi Commercial Company, the Little Bear Creek Elder's Home, Finkbonner Shellfish, Stommish Grounds, and the Gooseberry Point Wastewater Treatment Plant are all located in this watershed. Watershed C also contains a relatively dense residential development along the lowlands and the MacKenzie Housing Subdivision and expansion (currently under construction) in the upland areas. The Lummi Nation K-12, the Lummi Youth Academy, and the Lummi Day Care have been built in portions of Watershed C and Watershed D since 2000. Salt water intrusion has occurred in the aquifer in the southwestern part of Watershed C. Several public supply wells near Gooseberry Point have been closed and decommissioned due to high chloride levels induced by overpumping in this watershed. The Lummi Nation currently operates a two public supply well in this watershed (West Shore and MacKenzie 2) and owns two other wells (Gooseberry 3 and 4). One non-tribal water association (Georgia Manor) also operates two water supply wells in the watershed. There are also approximately 30 individual domestic supply wells in the watershed.

Watershed D: Watershed D is about 82 percent forested and drains largely to Bellingham Bay. Residential development is concentrated along Lummi Shore Road in the Hermosa Beach area adjacent to the rich tribal shellfish growing areas of Portage Bay. Hermosa Beach residents rely primarily on shallow, private, domestic ground water supply wells. The upland areas of this watershed are currently largely undeveloped for residential or other uses. Construction of roads and utilities for a residential development (Olsen Subdivision) containing 108 buildable lots is projected to begin in the summer of 2011. Wetlands extend over large areas along Lummi Shore Road north of Hermosa Beach. The Lummi Tribal Sewer and Water District provides potable water and wastewater collection services in this watershed but the Lummi Nation does not operate any public water supply wells in this watershed. Poor storm water management along Lummi Shore Road contributed to the collapse of the road into Bellingham Bay in places. As a result of the deterioration, in 1998 Lummi Shore Road was re-aligned, shore defense works were installed along Bellingham Bay. Lummi View Drive was re-aligned along the southern extent of the peninsula during 2004.

Watershed E: Watershed E is about 77 percent forested and drains to Bellingham Bay. Residential development is concentrated along Lummi Shore Road, Smokehouse Road, and Kinley Way. Smokehouse Village, comprised of four townhouse units owned by the Lummi Housing Authority, is in Watershed E. The Lummi Nation operates one of the most productive public water supply wells of the Reservation (Kinley 1) in this watershed. Poor storm water management along Lummi Shore Road contributed to the collapse of the road into Bellingham Bay in places. As a result of the deterioration, in 1998 Lummi Shore Road was re-aligned along the peninsula and shore defense works were installed along Bellingham Bay.

Watershed F: Watershed F is about 82 percent forested and drains to Bellingham Bay. Residential development is concentrated along Smokehouse and Lummi Shore roads. The Lummi Nation does not operate any public water supply wells in this watershed. Poor storm water management along Lummi Shore Road contributed to the collapse of the road into Bellingham Bay in places. As a result of the deterioration, in 1998 Lummi Shore Road was re-aligned along the peninsula and shore defense works were installed along Bellingham Bay.

Watershed G: Watershed G is about 77 percent forested and drains to Bellingham Bay. This watershed contains the Kel Bay housing development, Lummi Auto Recyclers, and the Crist Gravel Mine. The area north of Cagey Road and east of Chief Martin Road is a large wetland area that discharges to a wetland area south of Cagey Road and then through the drainage network of the largely unbuilt Kel Bay housing development. Residential development is concentrated along Lummi Shore Road, Cagey Road, and Lightening Bird Lane. The Lummi Nation does not operate any public water supply wells in this watershed;

one non-tribal water association (Kel Bay/Bel Bay) operates a well in the watershed. The shoreline areas north of Smokehouse Road around the Kel Bay development have experienced salt water intrusion. Poor storm water management along Lummi Shore Road contributed to the collapse of the road into Bellingham Bay in places. As a result of the deterioration, in 1998 Lummi Shore Road was re-aligned along the peninsula and shore defense works were installed.

Watershed H: Watershed H is about 83 percent forested and drains to the resource rich tidelands of Lummi Bay. The shoreline areas of this watershed are relatively dense residential areas. The Balch Road housing project and the Eagle Haven recreational vehicle park are located in the southern upland area of this watershed. The Lummi Nation currently operates four public water supply wells (Balch, Horizon, Kinley 2, and Kinley 3) in Watershed H. Two non-tribal water associations also operate water supply wells in the watershed (Sunset, Northgate-Leeward). In addition, there are at least 10 individual private domestic supply wells clustered along the shoreline of this watershed north of Smokehouse Road. The Lummi Nation operates a biosolids application site along Haxton Way north of Cagey Road in Watershed H.

Watershed I: Watershed I is about 85 percent forested with residential areas concentrated along the shoreline areas and Haxton Way. This watershed drains to Lummi Bay. The closed Chief Martin Road Solid Waste Dump is located in this watershed. The Lummi Nation operates a shellfish hatchery in Watershed I. The Lummi Nation does not currently operate any public water supply wells in this watershed; one non-tribal water association (Harnden Island View) operates a water supply well near the shoreline of this watershed.

Watershed J: Watershed J is a small forested watershed that drains to wetland areas west of Kwina Slough in the Nooksack River floodplain. A closed solid waste dump is located in this watershed. The Lummi Nation does not currently operate any public water supply wells in this watershed.

Watershed K: Approximately 18 percent of Watershed K is located north of the Reservation boundary. Watershed K is about 49 percent covered with grasses and agricultural lands and about 25 percent wetland area. Watershed K currently contains one dairy operation. Water that enters the Reservation watersheds west of the Nooksack River levee largely drains to the resource rich tribal tidelands in Lummi Bay. At the time of the 1997 storm water facilities inventory and 2010 update, there were nine culverts that drained to Lummi Bay but only one culvert in the floodplain west of the Nooksack River and Kwina Slough that allows water to drain southward over Marine Drive and into Bellingham Bay. Water in this single culvert, which is commonly dammed along the south side by beavers, has been observed flowing to the north toward Lummi Bay. There is also only a single culvert (with a tide gate) south of Marine Drive near the southern terminus of the Kwina Slough levee. This area south of Marine Drive and west of Kwina Slough is part of the former Nooksack River Delta. It is now a large wetland area with numerous beaver dams and beaver lodges. The area north of Marine Drive (Smuggler's Slough and associated wetlands) is in the process of being rechanneled to increase salmonid habitat. The estimated project completion is winter 2010/2011, which will modify the drainage route of Smuggler's Slough. The Lummi Tribal offices, Lummi Head Start, and Northwest Indian College

(NWIC) campus are all located along Kwina Road in this watershed. The NWIC has begun to build new facilities and expanded their campus facilities to include dormitories at their new location along Lummi Shore Road. Construction of a new Tribal Administration Building has begun on Kwina Road across from the existing tribal facilities. The Membrane Bio-Reactor Wastewater Treatment Plant and its associated underground injection well field is located in Watershed K. The residential areas are concentrated along Kwina Road, Lummi Shore Road, Tiopi Loop, and Haxton Way in this watershed. The Lummi Housing Authority recently completed 72 apartment units in 12 buildings along Kwina Road. Ground water in the floodplain and other areas of Watershed K are brackish or saline; the Lummi Nation does not currently operate any public water supply wells in this watershed.

Watershed L: Approximately 94 percent of Watershed L is located north of the Reservation boundary. Watershed L, which is about 49 percent grasses and agricultural land, drains to the Lummi River. The Lummi ("Red") River discharges to the resource rich tidelands of Lummi Bay. This watershed contains several dairy operations, small animal farms, the City of Ferndale, and the City of Ferndale's wastewater treatment plant and associated biosolids application site. All of these facilities are located north of the Reservation boundary. The Lummi Nation does not currently operate any public water supply wells in this watershed.

Watershed M: Discontinued watershed. The LiDAR delineation described previously did not identify this area as a separate catchment and the area was combined within Watershed L.

Watershed N: Discontinued watershed. The LiDAR delineation described previously did not identify this area as a separate catchment and the area was combined with Watershed O.

Watershed O: Approximately 43 percent of Watershed O is located north of the Reservation boundary. Watershed O is about 53 percent grasses and agricultural land and drains to the resource rich tidelands of Lummi Bay via the remnants of what was shown on some historic maps as McComb Slough and the Lummi River delta. Seeps have been observed along terraces just north of Slater Road. There are also several dairy operations and a gas station north of the Reservation boundary in this watershed. The Silver Reef Hotel, Casino, and Spa, a Shell gas station, and the Lummi Liquor Store are in this watershed. A portion of Sandy Point Heights residential development along with a nine hole golf course is located in Watershed O. There is also a residential area along North Red River Road. Although there are several wells north of the Reservation boundary, there are no active wells within the Reservation boundaries in Watershed O.

Watershed P: Approximately 94 percent of Watershed P is located north of the Reservation boundary. Watershed P is about 58 percent grasses and agricultural lands and drains to Lummi Bay. The portion of the watershed on the Lummi Reservation is largely forested and wetlands. There are several dairy operations and numerous water supply wells in the watershed north of the Reservation. This watershed also contains a portion of Barlean's Fishing, Inc and Barlean's Organic Oils, LLC operation north of the Reservation. There is reportedly a productive spring within the Reservation boundary but there are currently no active water supply wells in the portion of the watershed located on the Reservation. Lummi Nation has a well (NW 3) but the chloride levels are too high to be used for public supply.

Watershed Q: Approximately 50 percent of Watershed Q is located north of the Reservation boundary. Watershed Q is about 60 percent forested and drains to Onion Bay. This watershed contains portions of the ConocoPhillips petroleum oil refinery and Barlean's Fishing, Inc and Barlean's Organic Oils, LLC operation north of the Reservation. A portion of Sandy Point Heights residential development is located in the watershed. The Lummi Nation operates three public supply wells (Johnson, NW1, and NW 2) in this watershed. The Johnson Well is primarily used to supply the salmon hatchery and some domestic use.

Watershed R: Approximately 26 percent of Watershed R is located north of the Reservation boundary. Watershed R is not dominated by a single land use but rather contains a mix of forested (29 percent), urban/residential/industrial (28 percent), and wetland areas (16 percent). This watershed drains to Georgia Strait and to Onion and Lummi bays. The Lummi Nation operated Sandy Point Wastewater Treatment Plant and Sandy Point Fish Hatchery are in Watershed R. The private Sandy Point Marina and dense residential development is located within the Reservation boundaries in Watershed R. Portions of the ConocoPhillips petroleum oil refinery are located north of the Reservation boundaries in this watershed. Two non-tribal water associations (Sandy Point Improvement Company and Neptune Beach) operate multiple water supply wells on the Reservation in Watershed R.

Watershed S: Watershed S, which is the Nooksack River basin, is largely located upstream from the Reservation boundaries. As noted previously, the Nooksack River drains primarily into Bellingham Bay with flow discharging to Lummi Bay only during high flow conditions and/or when the levee is overtopped during flood events. On Reservation, Watershed S is mostly the Nooksack River delta, which is designated to be a portion of the Lummi Nation Wetland and Habitat Mitigation Bank. Residential development on Reservation is concentrated along Lummi Shore Drive along the southwestern extent of Watershed S. The Lummi Cemetery and Native American Shellfish buying facility are located in this watershed.

Land use activities upstream from where the Nooksack River enters the Reservation affect both the quality and quantity of water available for tribal uses. Approximately 220 acres of tribal shellfish beds in Portage Bay were closed by the Lummi Nation and the Washington Department of Health from November 1996 to May 2006 due to bacterial contamination attributed to poor dairy nutrient management practices in the Nooksack River watershed (DOH 1997, Ecology 2000).

Following the initial and subsequent downgrades of tribal shellfish beds in Portage Bay several federal, tribal, and state agencies and numerous individuals took a variety of steps to address identified pollutant sources (not all of which were related to agricultural activities). The three key actions that led to the improvement of water quality were: (1) technical and financial assistance (in excess of $8 million) to the dairy industry, private land owners, and municipalities that discharge wastes to the Nooksack River; (2) compliance inspections to enforce provisions of the federal Clean Water Act; and (3) water quality monitoring to identify pollution sources and monitor improvements. These three key actions, along with interagency collaboration, resulted in a reclassification of approximately 75 percent of the "Restricted" shellfish growing beds in Portage Bay to "Approved" status in November 2003 and the reclassification of all of the shellfish growing areas in Portage Bay as "Approved" in

May 2006 – nearly 10 years after the initial closure. Unfortunately these three key actions have not continued at the levels that existed prior to 2003. Increasing levels of fecal coliform bacteria evident in water quality samples over the last seven years indicates that animal waste management practices off-Reservation are not effectively reducing fecal coliform contamination in the Nooksack River watershed.

Watershed T: Watershed T is a newly delineated watershed on the Reservation. Watershed T is dominated by forested land (about 85 percent) and drains into Bellingham Bay. The majority of this watershed is undeveloped.

Table 4.1 Watershed Characteristics

Basin ID	Drainage Area (acres)	Receiving Water Bodies	Hydrologic Soil Group				Number of Storm Water Facilities[2]	Number of Ground Water Wells	Land Use/Land Cover[3]								
			Group A (%)	Group B (%)	Group C (%)	Group D (%)			Water (%)	Coniferous and Mixed Forest (%)	Deciduous Forest (%)	Scrub/Shrub (%)	Grasses and/or Agricultural (%)	Fallow Fields/ Exposed Soils (%)	Urban, Residential, Industrial (%)	Wetland (%)	Other (%)
A	280	Bellingham Bay, Hale Passage	4.9	63.9	20.6	10.6	0	0	0.0	52.4	14.1	2.4	8.5	1.0	0.0	19.0	2.6
B	617	Portage Bay, Hale Passage	2.9	71.5	8.6	17.0	0	1	1.9	59.3	5.3	0.2	3.0	0.8	0.0	29.2	1.1
C	494	Hale Passage, Lummi Bay	13.44	47.77	29.61	9.18	15	39	0.1	32.2	22.0	3.1	6.7	0.7	31.9	4.2	2.2
D	894	Portage Channel, Bellingham Bay	0.4	3.7	75.7	20.2	21	32	0.0	40.6	41.7	2.0	5.6	0.3	6.1	3.1	0.5
E	218	Bellingham Bay	0.0	0.0	90.6	9.4	4	7	0.0	25.9	51.7	5.4	6.7	0.6	8.8	0.8	0.2
F	251	Bellingham Bay	0.00	0.00	64.35	35.65	8	6	0.1	24.8	56.9	7.0	9.0	0.3	9.6	10.1	0.4
G	883	Bellingham Bay	0.00	1.1	79.4	19.5	19	17	0.0	16.9	60.4	5.0	7.5	0.0	5.4	9.0	0.3
H	549	Lummi Bay	0.00	14.7	55.9	29.5	16	27	0.1	15.6	67.8	2.7	3.1	0.0	4.8	4.5	1.4
I	1,059	Lummi Bay	0.4	1.5	45.1	53.0	12	17	0.0	23.3	61.7	5.9	1.3	0.0	2.2	5.5	0.2
J	134	Nooksack River Floodplain	0.0	0.0	56.9	43.0	4	3	0.3	24.0	35.2	1.4	2.0	0.0	3.1	33.5	0.4
K	4,091	Bellingham and Lummi Bays	0.0	0.4	31.4	68.2	65	28	0.0	3.9	17	1.0	48.7	0.1	4.4	24.8	0.1
L	2,306	Lummi River, Lummi Bay	0.0	2.5	67.5	30.0	7	24	0.1	1.7	3.7	0.4	49.2	1.7	37.0	7.7	0.2
O	2,747	Lummi Bay	4.58	5.92	27.97	61.53	29	11	0.0	9.8	9.6	3.9	52.6	0.0	6.0	18.2	0.0
P	4,097	Lummi Bay	0.8	8.5	55.0	35.7	4	61	0.1	4.8	10.6	2.2	57.8	0.0	8.2	16.4	0.0
Q	1,096	Onion and Lummi Bays	1.0	4.0	57.5	37.5	19	22	0.0	21.0	39.0	0.6	8.6	0.0	24.4	5.7	0.2
R	722	Lummi Bay and Georgia Strait	18.9	0.4	40.4	40.3	24	41	1.1	9.2	28.8	2.7	8.8	0.0	28.1	15.5	5.9
S	548,800	Bellingham and Lummi Bays	ND[1]	ND[1]	ND[1]	ND[1]	8	15	ND	ND	ND	ND	ND	ND	ND	ND	ND
T	393	Bellingham Bay	0.0	2.7	57.8	39.5	2	4	0.0	38.8	45.9	10.4	0.8	0.0	0.2	9.0	0.0

[1] ND = Not Determined
[2] Storm water facilities (culverts, catch basins, bridges) inventoried on-Reservation only.
[3] Land uses/land cover types largely estimated from 2006 NOAA database, Classification of Coastal Washington, which is part of the Coastal Change Analysis Program (CCAP of the NOAA Coastal Service Center.

5. LAND USE IMPACTS ON STORM WATER QUALITY AND QUANTITY

The quantity and quality of storm water runoff from a geographic area is a function of several interrelated site characteristics including: drainage area, precipitation quantity, rainfall intensity, vegetation, soil properties, land slope, land use, and the amount of time between storms. Of these site characteristics, vegetation, soil properties, and land use are often altered during development activities.

In this section, the impacts of land use changes on the quantity and quality of storm water are described based on the scientific literature, the results of a computer model, and an inventory of potential storm water contaminants.

5.1. Land Use Impacts on Storm Water Quantity

At present, there have been no data collected to quantify how land use changes have affected the amount of storm water on the Reservation. In the absence of site specific data, the available literature was reviewed to determine the expected impacts of land use changes on the amount of storm water on the Reservation. In addition, a computer model was used to illustrate the hydrologic and hydraulic changes that can be expected when forested lands on the Reservation are converted to residential, municipal, or commercial uses.

5.1.1. Literature Review: Land Use Changes and Storm Water Quantity

The water budget approach, which balances the inflow of water to a system with both the outflow from the system and change in system storage, has been used to model the effects of vegetation change on runoff quantity (Dunne and Leopold 1978). The inflow to a watershed is precipitation, surface water inflow, and/or ground water inflow. The outflow from a watershed is divided among surface runoff, ground water runoff, and evapotranspiration (Lewis and Burgy 1964). If the outflow of water through one route is reduced, either the amount of stored water will increase, the outflow by other routes will increase, or a combination of the two possibilities will occur. In the case where the soil storage capacity is satisfied, or the rainfall intensity (or snow melt rate) is greater than the infiltration rate, water is lost to the system through surface runoff, return flow, or deep percolation (Dunne and Leopold 1978).

Because vegetation influences a variety of hydrologic processes (e.g., interception, stemflow, infiltration, percolation, surface runoff, evaporation, transpiration, water storage, and erosion), a change in vegetation realigns the water balance and changes the importance of the different outflow routes. For example, the removal of vegetation eliminates interception and transpiration losses and thereby increases the amount of water in the system. The water balance method dictates that the additional water must infiltrate and increase the soil moisture storage, percolate to the ground water system (to be stored or to runoff as base flow), evaporate, or runoff as surface flow.

Infiltration is the process that indirectly determines the amount of water available for runoff, soil moisture recharge, plant growth, and for deep percolation and ground water recharge (Gifford and Hawkins 1978). If forested lands are converted to residential, municipal, or commercial uses, the amount of impervious surfaces is increased. Since by definition water cannot infiltrate through impervious surfaces, water cannot increase the soil moisture storage or directly percolate to the ground water system under the covered surface. Infiltration is reduced as forested lands are converted to residential, municipal, or commercial uses which results in an increase in the amount of runoff. Because surface runoff is the primary force initiating erosion and transporting sediment and dissolved solids (Branson et al. 1981), an increase in runoff can be expected to result in increased soil loss.

The effects of vegetation change on runoff and erosion have been studied extensively since the early 1900s. Methods used to examine the effects of vegetation change on runoff and erosion includes paired watershed experiments, plot studies, and time-trend studies. Paired watershed experiments are probably the most effective method for determining how vegetation change affects hydrological responses. The paired watershed method uses a control basin and one or more treated basins selected for their similarity in size, shape, topography, vegetation cover, past land use, climate, and general location (Folliott and Thorud 1975). After a calibration or pre-treatment period and a regression analysis to establish hydrologic relationships between basins, a treatment is applied (e.g., vegetation removal) and data collected for a post-treatment period. Data from the treated watershed is then regressed on the control watershed and differences between the calibration and treatment regressions are interpreted as the effect of treatment (Hibbert 1971).

Numerous studies at forested sites with different climates, soil, and vegetation support the conclusion that increases in water yield following changes to forested lands is related to the amount of precipitation and the amount of vegetation removed (Anderson et al. 1976, Brown et al. 1974, Douglass and Swank 1975, Hibbert 1969, Hornbeck et al. 1970, Hornbeck and Federer 1975, Storey and Reigner 1970, Swank and Miner 1968). The more precipitation and the more vegetation removed, the greater the increase in water yield from a landscape. The increases in water yield will decline if regrowth of vegetation is not controlled.

After reviewing the results of 94 watershed experiments worldwide on both forest and rangeland basins, Bosch and Hewlett (1982) concluded that both evapotranspiration and runoff are affected by the amount, type, and growth form of vegetation cover. Bosch and Hewlett concluded that none of the 94 experiments showed an increase in water yield with an increase in cover (i.e., water yield does not increase with increases in vegetation). Similarly, none of the experiments showed a reduction in water yield with a reduction in cover (i.e., water yield does not decrease with decreases in vegetation).

If forest lands are harvested, and there is less than a 20 percent reduction in watershed forest cover, in general there will not be a detectable increase in annual water yield (Bosch and Hewlett 1982). It has been noted that if watershed forest cover is reduced by more than 20 percent, increases in annual water yield may occur but will generally be too small to detect with currently available streamflow measurement devices (Ziemer 1987). Most of the increase in annual water yield will occur during the winter high runoff season and during wetter years (Keppeler and Ziemer 1990, Ziemer 1987).

Although increases in water yield may be difficult to detect for harvested forest lands, increases in runoff volume and peak discharge can be readily detected when forest lands are converted to urban land uses (e.g., residential, municipal, commercial). Increases in both the impervious surface area and the number of storm water conveyance channels (e.g., curb and gutter systems, roadside ditches) associated with urban land uses results in increased storm water volume, increased peak discharge, shorter amounts of time required to reach the peak discharge, and shorter duration runoff events as the water rapidly drains from the system in the improved conveyance channels.

5.1.2. Computer Model: Land Use Change and Storm Water Quantity

Since there have been no data collected on the Lummi Reservation that allow the effects of land use changes on storm water volume to be quantified, a computer model was used to illustrate the types of hydraulic and hydrologic changes that could occur if forested lands on the Reservation are converted to residential or commercial uses. Hydraulically, largely due to the higher percentage of impervious surfaces, runoff from residential and commercial areas tends to be of greater volume, greater peak discharge, and shorter duration than runoff from forested areas. The hydrologic and hydraulic effects of converting forest lands to agricultural lands are generally less pronounced than converting from forest to residential, municipal, or commercial land uses.

Increasing the impervious surface area of a watershed increases both runoff volume and peak runoff discharge. The computer model WILDCAT4 and a hypothetical 10-acre forested watershed on the Reservation were used to illustrate the types and magnitude of hydrologic and hydraulic changes that can be expected if forested lands are converted to residential or commercial uses. WILDCAT4 is a public domain computer model based on the SCS curve number method (USDA 1970). The curve number method uses a scale of 0 to 100 to reflect differences in runoff expected for various soils and cover types. The larger the curve number, the greater the runoff volume for a particular storm.

The program uses distributed curve numbers to estimate rainfall excess for a “design rainstorm”. A design rainstorm is a timed pattern of rainfall based on the recorded rainfall quantity and distribution over time. The triangular unit hydrograph method is used in the WILDCAT4 computer program to route the rainfall excess and to estimate the storm hydrographs.

As discussed previously, about 87 percent of the Reservation soils are in hydrologic soils groups C or D. The following conditions were used to illustrate how land use changes on the Reservation impact storm water runoff:

- Drainage area: 10 acres
- Design storm hyetograph (i.e., rainfall distribution over time): SCS Type 1A
- Rainfall amount: 2-, 10-, 25-, and 100-year, 24-hour storms
- Land uses and assigned curve numbers (CN): Forest (CN = 78); Residential site with 25 percent impervious surfaces (CN = 98) and 75 percent pervious surfaces (CN=88); Commercial site with 75 percent impervious surfaces (CN = 98) and 25 percent pervious surfaces (CN=88)
- Land slope: 2.5 percent
- Channel length: 1,100 feet

The results of the computer model runs are summarized in Figures 5.1, 5.2, and 5.3. As shown in Figure 5.1, the runoff volume from a storm with a 50 percent chance of occurring during any given year (i.e., 2-year return period) is about 2.7 times greater when the forested area is converted to residential land use and about 3.7 times greater when the forested area is converted to commercial land use. The increased runoff from the converted land suggests that less water is available to infiltrate into the aquifer. For the 100-year event, the runoff volume increased only about 1.7 times when the forested area is converted to residential land use and about 2 times when the forested area is converted to commercial use. This is consistent with the hydrologic maxim that the impact of land use changes on storm water runoff for larger infrequent storms is less than for smaller more common storms.

As shown in Figure 5.2, the peak discharge rate for the storm with a 2-year return period can be expected to increase about 5.2 times when the forested area is converted to residential uses and about 7.4 times when converted to commercial uses. The higher the peak discharge, the greater the erosive power of the water. Similar to runoff volume, the impacts of land use changes on peak runoff discharge decrease with increasing storm size. For the 100-year storm, the peak discharge rate can be expected to increase by about 1.9 times when a forested area is converted to residential and about 2.2 times when a forested area is converted to commercial uses.

As discussed above and as shown in Figure 5.3, the runoff volume (the area under the hydrograph) and peak discharge increases as forested land is converted to residential and/or commercial uses. The surface runoff also begins soon after the start of the storm for commercial and residential land uses. In contrast, the runoff does not begin for the forested land use until over six hours after the start of the storm. For shorter duration storms or smaller sized storm events, runoff from forested land may not occur. Although not represented in Figure 5.3, largely due to the higher percentage of impervious surfaces and the larger number of conveyance facilities (e.g., storm drains, roadside ditches), storm water runoff from residential or commercial areas also tends to be of shorter duration than runoff from forested areas.

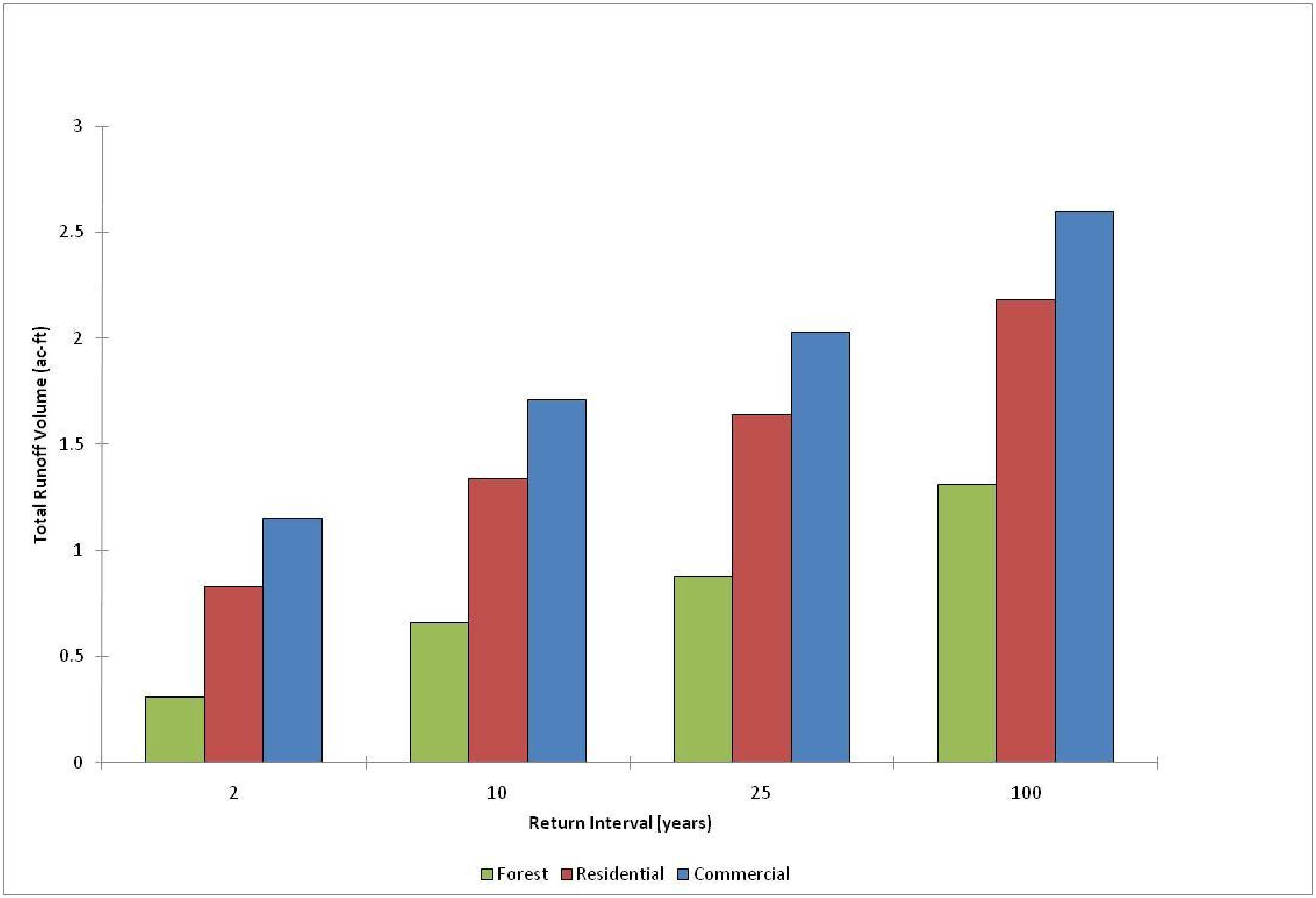

Figure 5.1 Runoff volumes for different land uses for the 2-, 10-, 25-, and 100-year, 24-Hour Design Storm Events

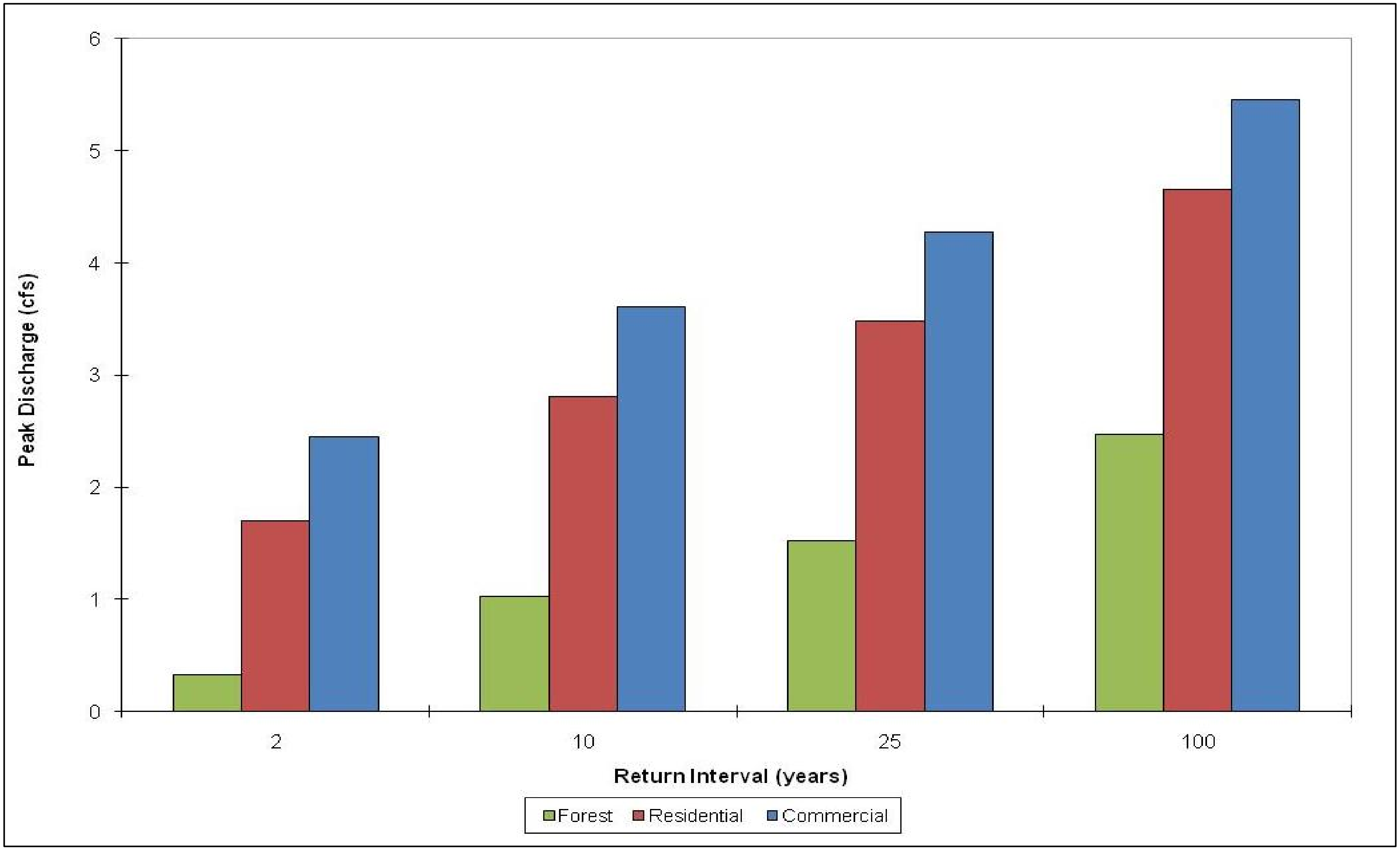

Figure 5.2 Peak runoff flow for different land uses for the 2-, 10-, 25-, and 100-year, 24-Hour Design Storm Events

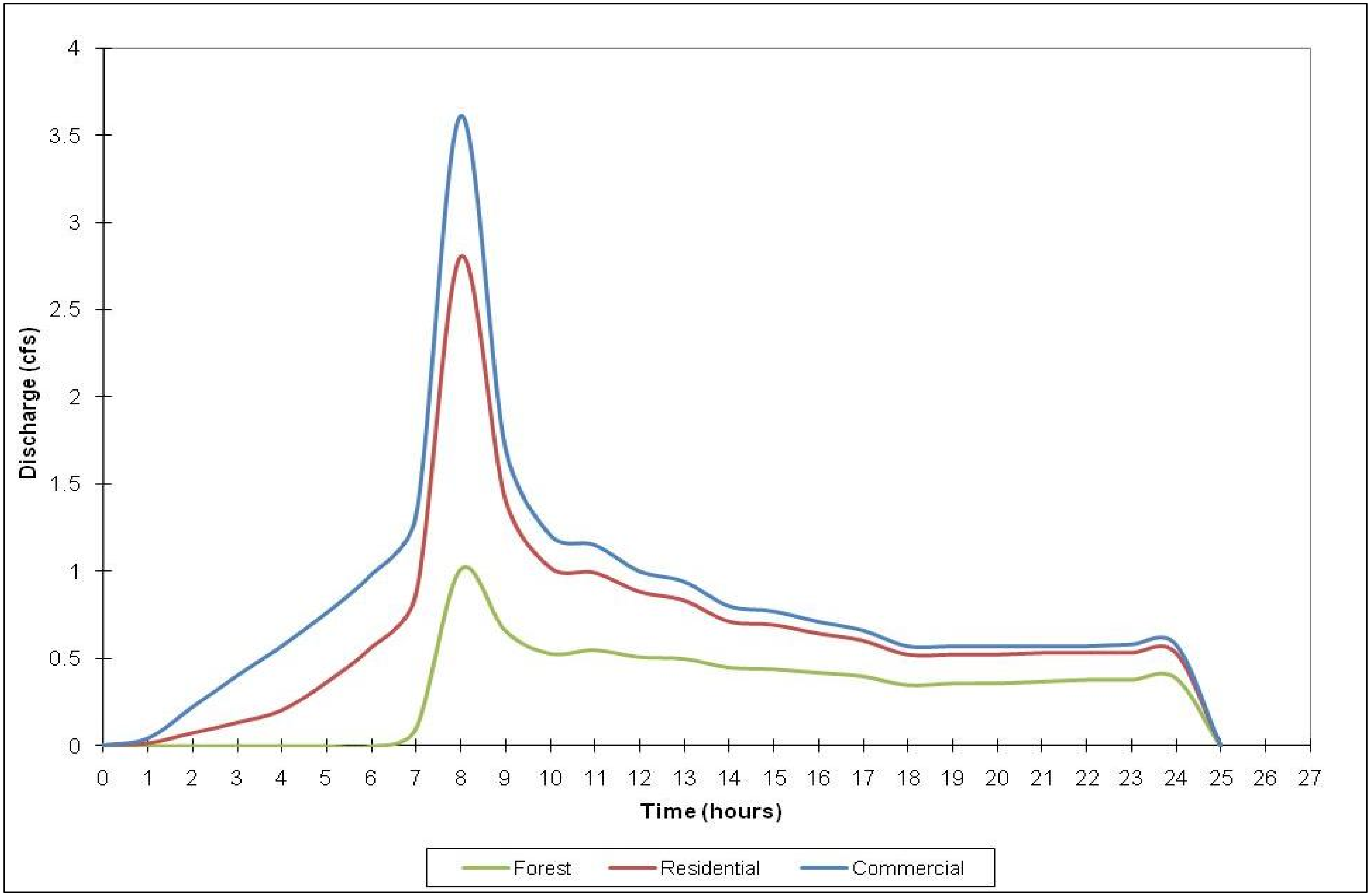

Figure 5.3 Hydrographs for the 10-year, 24-Hour Storm for Different Land Uses on the Lummi Reservation

5.2. Land Use Impacts on Storm Water Quality

Similar to storm water quantity, there have been no water quality data collected that allow the impacts of land use changes on the Reservation and in the watersheds that contribute flow to the Reservation to be quantified. The Lummi Nation Surface and Ground Water Quality Monitoring Program has been ongoing since 1993. Water quality is monitored at 43 surface water sites and 28 ground water sites on the Reservation. All surface water quality samples are tested for conductivity, salinity, temperature, fecal coliform, *E.Coli*, enterococci, turbidity, pH, and dissolved oxygen. Due to the costs of analyzing water quality samples for metals and petroleum products, these parameters are only measured quarterly at two water quality monitoring sites. Nutrients are sampled quarterly at five surface water quality monitoring sites (LWRD 2010c).

With the limited data collected for other pollutants (metals, petroleum products, and nutrients) in the Reservation storm water, the available literature was reviewed to determine the expected impacts of land use changes on storm water quality. In addition, an inventory of potential storm water contaminants sources on the Reservation and in the watersheds that contribute flow to the Reservation was conducted.

5.2.1. Literature Review: Land Use Changes and Storm Water Quality

Urban areas (i.e., residential, municipal, commercial, and/or industrial areas) produce pollutants that affect the water quality of streams draining the sites. Not surprisingly, contaminants originating from urban areas differ from other nonpoint sources. The concentration of pollutants in urban storm water runoff is a function of (Whipple et al. 1983):

- Degree of urbanization,
- Type of land use,
- Amount of motorized traffic,
- Density of animal populations,
- Amount of time since the last rainfall event, and
- Amount of air pollution just prior to a precipitation event

In the following paragraphs, a brief history of urban runoff water quality research is presented, the quality of urban storm water runoff is characterized, and the sources of urban pollution as well as the types and quantities of pollutants produced in urban areas are described.

The earliest reported study of urban storm water quality was a 1936 study of runoff from Moscow in the Soviet Union (APWA 1969). This research was followed by scattered efforts throughout the world and led eventually to the 1978-1983 National Urban Runoff Program (NURP). The NURP was a cooperative U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), and state and local government effort to conform to Section 208 of the 1972 Clean Water Act. Section 208 was contested in court and the case settled in 1977. The 1977 ruling stated that while requiring permits for each pollutant discharge may be cumbersome and complex, the EPA still had to require permits. The court ruled that administrative inconvenience was not an acceptable argument to not regulate nonpoint sources (Athayde et al. 1986). As part of the NURP, the two federal agencies helped twenty-eight cities throughout the country develop urban runoff water quality control plans (Athayde et al. 1986). The overall goal of the NURP was to (Athayde et al. 1986):

> "develop information that would help provide local decision makers, states, EPA, and other interested parties with a rational basis for determining whether or not urban runoff is causing water quality problems and, in the event that it is, for postulating realistic control options and developing water quality management plans consistent with local needs, that would lead to implementation of least cost solutions."

As of 1986, the EPA and the USGS had a combined data base collected from 173 urban stations in 31 metropolitan areas. The different city data bases had in common eleven water quality constituents, three storm characteristics, and nine basin characteristics (Drivers and Lystrom 1986).

A nonpoint source is a widespread, non-centralized, randomly occurring source of pollution that varies in location and concentration over time (Jones and Urbonas 1986). As such, urban storm water runoff differs from point sources of pollution (e.g., discharge pipelines from industries, wastewater treatment plants) in four ways (Mancini and Plummer 1986):

- It is a result of a rainfall event,
- It occurs intermittently with short duration pollutant loading and long durations between events,
- There is high variability within and between events, and
- There is a relatively high suspended solid content in the discharge.

Due to the amount of impervious surfaces, urban storm water runoff exhibits an initial flush effect (APWA 1969). The initial flush results from (Whipple et al. 1983):

- Wash off of loosely attached debris due to rain drop impact and surface flow across the impervious surface,
- Re-suspension and/or dissolution of sediment or other pollutants in catchment basins, sewer lagoons, roads, and storm drains that settled out during the last storm event or fell after the last event, and
- Atmospheric particulate matter that is dissolved and brought down by the rain.

The results of studies differ in magnitude but agree that the peak flush effects on receiving waters can exert a biochemical oxygen demand (BOD) which is 40 to 200 times greater than that of normal dry weather effluent from a sewage treatment plant (Vitale and Sprey 1974).

The first 3.3 inches to 9.8 inches of rainfall generally contains over 85% of the BOD (Vitale and Sprey 1974).

The contamination of storm water may occur in the atmosphere, on the ground, on man-made structures, and in the storm drainage system (APWA 1969). Sources of urban contamination include automobiles, industry, street litter and sediment, lawn and garden chemicals, as well as domestic and feral animals.

Components of automobile exhaust and industrial site emissions that enter the atmosphere, possibly undergo chemical change, and are washed out during the early stages of rainfall events include: lead contaminants, nitrous oxides, hydrocarbons, phosphorus, and sulfides (Whipple et al. 1983). In addition, automobiles pollute the ground surface by depositing oil that contains zinc and phosphorus, worn tire particles containing zinc and oxygen-demanding organic polymers, as well as worn parts containing copper and chromium (Whipple et al. 1983). Storm water runoff from industrial sites can be contaminated with process wastes, raw materials, toxic and hazardous pollutants, oil, and grease (Athayde et al. 1986).

The amount and nature of street litter varies with land use, population, traffic flow, and other indigenous factors (APWA 1969). The soluble dust and dirt fraction of street litter, containing many of the components previously mentioned, exerts the highest BOD on receiving waters (APWA 1969). Storm water runoff can contain salt or other ice control chemicals, insecticides, rodenticides, herbicides, and fertilizers. Animal wastes also deteriorate the quality of storm water runoff by contributing organic matter, nitrogen, phosphorus, bacteria, and viruses (Whipple et al. 1983).

Urbanization can also cause changes in water temperature. Heated storm water from impervious surfaces and exposed treatment and detention ponds discharges to streams with less riparian vegetation for shade (Ecology 2005). Ground water recharge, which is a source of cool water input to a stream system, is also reduced with urbanization. Changes in water temperature have biological impacts to urban streams. Increased water temperature reduces the maximum available dissolved oxygen and may cause algae blooms that further reduce the amount of dissolved oxygen in the water.

The relatively short duration of storm events suggests that the impact on receiving waters may also be for short periods of time and will vary depending on the season and persistence of the pollutant. The NURP found that pollutant concentrations in urban runoff vary considerably during a storm event, from event to event at a given site, and from site to site in a given city and across the country (Tucker 1986). The effects of urban storm water quality on receiving water quality are site specific and depend on (Tucker 1986):

- Type, size, and hydrology of the water body,
- Pollutants that affect the site,
- Designated beneficial use of the site,
- Urban runoff quality characteristics, and
- Local rainfall patterns and land use.

5.2.2. Impacts of Construction Activities on Storm Water Quality

As described above, development impacts vegetation and soil properties in a manner that results in higher storm water volumes, higher peak discharges, and lower water quality. Minimizing these impacts from development and maximizing the protection of sensitive and important natural resources is necessary to protect the political integrity, economic security, and the health and welfare of the Lummi Nation, its members, and all persons present on the Reservation.

Development is often associated with some level of earthmoving during construction phases and some level of impact on storm water quantity and quality both during and after the construction phases. Common storm water related impacts of construction include:

- Soil compaction occurs as heavy construction machinery runs over the land surface during clearing and construction related activities. Similar to an impervious surface, increased soil compaction reduces infiltration and ground water recharge which results in increased surface water runoff.
- Reworking and exposing soil during construction increases opportunities for erosion and sediment transport.

In addition to earthmoving and construction, development is often associated with some level of vegetation removal and replacement with residential, commercial, or community land uses. This change from forested to more urban land uses impacts storm water quantity and quality, particularly during and immediately after the construction phase.

The roots, leaves, and stems of vegetation provides surface roughness. This roughness reduces the speed that water can move overland and acts as a filter to trap sediment. The slower that water flows over a surface, the greater the opportunities for ground water recharge. The more water that infiltrates to the soil, the less water is available to flow overland as storm water runoff. Because less water is available for overland flow, the opportunities for erosion and sediment transport by water are also reduced. Plant roots hold soil particles in place and help to prevent soil loss. In addition, vegetation provides organic matter to the soil and thereby increases its capacity to hold water.

Erosion and sediment control during construction is important because:

- Due to adsorption of pollutants to sediment, transported sediment increases the transport of pollutants.
- Increases in the quantity of surface water can result in downstream erosion and property damage.
- Increased sediment from erosion can obstruct downstream storm water facilities and require increased maintenance.

To reduce the impacts of construction and development activities on storm water and achieve the storm water management goals, appropriate best management practices (BMPs) must be effectively applied. Examples of using BMPs to reduce the impacts of construction/development activities on storm water quantity and quality include:

- Planning development to fit the topography, soils, drainage patterns, and natural vegetation of the site.
- Controlling erosion and sediment from disturbed areas within the project site or area.
- Minimizing the extent of disturbed areas.
- Conducting site disturbance work during the drier parts of the year (i.e., May through September).
- Stabilizing and protecting disturbed areas from runoff as soon as possible.
- Minimizing runoff velocities by minimizing slope length and gradient and protecting natural vegetative cover.
- Implementing a thorough storm water facilities maintenance and follow-up program.
- Constructing properly designed detention ponds, wetlands, infiltration trenches, grass swales, and filter strips.
- Preserving wetland areas.
- Minimizing impervious areas (i.e., paved or compacted areas).
- Conducting pollution prevention activities including public education and household hazardous waste collection and disposal events.
- Anticipating and planning for intense rainfall during construction.

5.2.3. Inventory of Potential Storm Water Contaminants

The risk that storm water will be exposed to contaminants is determined largely by the current and historic presence/use of contaminants in the area where the storm water occurs. In addition to the sources presented previously, storm water contamination can also result from:

- Misuse and improper disposal of liquid and solid wastes.
- Illegal dumping or abandonment of household, commercial, or industrial chemicals.
- Accidental spilling of chemicals from trucks, railways, aircraft, handling facilities, and storage tanks.
- Improper sitting, design, construction, operation, or maintenance of agricultural, residential, community, commercial and industrial storm water drainage systems and liquid and solid waste disposal facilities.
- Atmospheric pollutants.

An inventory of potential contaminant sources in the Reservation watersheds was conducted to help focus storm water quality management efforts. The contaminants associated with each potential source were identified from the literature as typical for the specified land use (EPA 1993) or from the Air Operating Permit list for 2010 provided by the Northwest Clean

Air Agency. The potential storm water contaminants were grouped by the following seven land use categories:

- Construction Sources
- Agricultural Sources
- Residential Sources
- Community Sources
- Commercial Sources
- Industrial Sources
- Industrial Processes

Potential storm water contamination from community sources includes the sewer lines of the Lummi Sewer District. Although the sewer system generally protects storm water quality by replacing septic systems, like all municipal sewer systems, the sewer lines and associated pump stations are subject to equipment malfunctions that could result in spills or overflows. In addition, spills or leaks could result from damage during construction activities or from damage caused by natural events (e.g., floods, earthquakes). It is noted that the alarm and emergency response system of the Lummi Sewer District, which includes back-up generators at pump stations, should minimize the impact of any spills.

Potential storm water contamination from industrial processes include direct conveyance onto the Reservation in surface flow and the deposition of atmospheric pollutants originating from the area directly north of the Reservation boundary, from industries along Bellingham Bay, or from industries in Anacortes approximately 15 air miles from the Reservation. The Cherry Point Heavy Impact Industrial Zone is located immediately north and west of the Reservation watersheds. This heavy impact industrial zone, the largest such zone in Whatcom County, contains two petroleum oil refineries (ConocoPhillips and British Petroleum) and an aluminum smelter (Alcoa-Intalco). One of the oil refineries (ConocoPhillips) is located adjacent to the north Reservation boundary and is partially in Watersheds Q and R. Previous owners of this facility include Mobil Oil, British Petroleum, and Tosco. In addition to sources within the Cherry Point Heavy Impact Industrial Zone, storm water contamination is possible through the deposition of atmospheric pollutants originating from the Tenaska Cogeneration Station in Ferndale, the GN Plywood mill and the Encogen NW Cogeneration Plant in Bellingham, and the Shell and Tesero petroleum oil refineries in Anacortes.

Table 5.1 summarizes the inventory of potential sources of storm water contamination in the Reservation watersheds, the potential contaminants associated with each source, the watersheds where the potential sources are located, and the receiving water bodies.

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
1. Potential Construction Sources				
Machinery, earthmoving, soil compaction, vegetation removal	Oils, waste oils, solvents, grease, hydraulic fluids, transmission fluids, antifreeze, acids, paints, miscellaneous cutting oils, miscellaneous wastes, and sediment	C, D, E, F, G, H, I, J, K, L, O, P, Q, R, S, T	Bellingham Bay, Portage Bay, Hale Passage, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River	• Temporary sources • Location and size of construction activity varied • Best Management Practices are required for all ground disturbing activities on the Reservation
2. Potential Agricultural Sources				
Farm lands used for raspberry, strawberry, silage, forage, grain, and other row crops	Pesticides (e.g., insecticides, herbicides, fungicides), fertilizers, pesticides and fertilizer residue from containers or storage areas; automotive wastes (e.g., gasoline, antifreeze, transmission fluid, battery acid, engine and radiator flushes, engine and metal degreasers, hydraulic fluids, and motor oil)	K, L, O, P, S	Bellingham Bay, Lummi Bay, Lummi River, Nooksack River	• Substantial agricultural lands upstream from the Reservation boundaries and on the Reservation in the floodplain of the Lummi and Nooksack rivers • Small areas of agricultural land in the upland areas of the Reservation
Horses, goats, cattle, sheep, and/or llamas	Livestock sewage wastes; nitrates; phosphates; chloride; coliform and non-coliform bacteria; viruses; chemical sprays for controlling insect, bacterial, viral, and fungal pests on livestock	A, B, K, L, O, P, Q, R, S	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay	• Substantial dairy operations upstream from the Reservation boundaries and on the Reservation in the floodplain of the Lummi and Nooksack rivers • Smaller numbers of livestock on Reservation
3. Potential Residential Sources				
Single or multi-family homes	Household cleaners, oven cleaners, drain cleaners, toilet cleaners, disinfectants, metal polishes, jewelry cleaners, shoe polishes, synthetic detergents, bleach, laundry soil and stain removers, spot removers and	C, D, E, F, G, H, I, J, K, L, O, P, Q, R, S, T	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay,	• Many residential areas are concentrated along the shorelines of the Reservation • Residential areas also concentrated along the Nooksack River in towns such as Ferndale, Lynden, and Deming

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
	dry cleaning fluid, solvents, lye or caustic soda, pesticides, photochemicals, printing ink, paints, varnishes, stains, dyes, wood preservatives (creosote), paint and lacquer thinners, paint and varnish removers and deglossers, paint brush cleaners, floor and furniture strippers, automotive wastes, waste oils, diesel fuel, kerosene, #2 heating oil, grease, degreasers for driveways and garages, metal degreasers, asphalt and roofing tar, tar removers, lubricants, rustproofers, car and boat wash detergents, car and boat waxes and polishes, rock salt, refrigerants, fertilizers, herbicides, insecticides, fungicides, septage, coliform and noncoliform bacteria, viruses, nitrates, heavy metals, synthetic detergents, cooking and motor oils, bleach, septic tank cleaner chemicals, effluents from barnyards, feedlots, septic tanks, gasoline, water treatment chemicals, and well pumping that induces saltwater intrusion into Reservation aquifers		Hale Passage	• A Lummi Nation Integrated Solid Waste Management Plan is under development, which also addresses Household Hazardous Waste disposal

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
4. Potential Municipal Sources				
Roads	Automotive wastes (e.g., gasoline, antifreeze, transmission fluid, battery acid, engine and radiator flushes, engine and metal degreasers, hydraulic fluids, and motor oil), herbicides along road right-of-ways	A,B,C, D, E, F, G, H, I, J, K, L, O, P, Q, R, S, T	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Roads throughout all of the Reservation watersheds including unimproved roads on Portage Island • Similar potential contaminants associated with the Whatcom County Ferry terminal at Gooseberry Point (Watershed C)
Northwest Indian College	Automotive wastes, general building wastes	K	Lummi Bay	• Student housing has been added • Phase 1 of the new south campus is completed along Kwina Road • Phase 2 of the new south campus is expected to be built in the coming years along Kwina Road
Lummi Nation K-12 School, Youth Academy, and Daycare Center	Automotive wastes, general building wastes	C, D	Lummi Bay, Hale Passage, Portage Bay	• New Lummi Nation K-12 School completed in 2004 • Bus yard and maintenance facility onsite
Lummi Tribal Health Center	Automotive wastes, general building wastes, disinfectants, formaldehyde, pharmaceuticals, metals	K	Lummi Bay	• Expansion to include a dental office completed since 1998 • Includes the Lummi Fitness Center and tennis, basketball, and pickle ball courts
Tribal governmental offices	Solvents, pesticides, acids, alkalis, waste oils, machinery/vehicle servicing wastes, general building wastes	C, K	Lummi Bay, Bellingham Bay, Hale Passage	• Addition of a new tribal court building in 2005 • Lummi Commercial Company (LCC) offices moved to a location along Lummi Bay • "East Campus" is new and located at the former K-12 school site • A new Tribal Administrative Center is under construction at the corner of Kwina Road and Chief Martin Road

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
Biosolids application site	Organic matter, nitrates, inorganic salts, coliform and noncoliform bacteria, parasites, and viruses	H	Lummi Bay	• Complies with CWA Section 503 Regulations
Stommish Grounds	Automotive wastes, general building wastes	C	Hale Passage	• Seasonal high use during summer months, when precipitation events are rare
Wex li em Community Building	Automotive wastes, general building wastes	C	Hale Passage	• Periodic but frequent use throughout the year
Wastewater Treatment Plants	Wastewater, biosolids, treatment chemicals (e.g., chlorine), automotive wastes, general building wastes	C, K, L, R, S	Hale Passage, Lummi River, Lummi Bay, Georgia Strait, Nooksack River, Bellingham Bay	• Lummi Nation built a Membrane Bioreactor Plant in 2004 • Plans to replace the Sandy Point Wastewater Treatment Plant • Gooseberry Point Wastewater Treatment Plant will install ultra violet disinfection system in 2011
Cemetery	Leachate, lawn and garden maintenance chemicals, automotive wastes	S	Bellingham Bay	• None
Abandoned landfills	Leachate, organic and inorganic chemical contaminants, wastes from households and businesses, nitrates, oils, metals	I, J, S	Lummi Bay, Bellingham Bay	• Types and quantities of contaminants unknown • Hazardous nature of contaminants unknown • A monitoring study is currently underway to monitor for hazardous waste leachate in the former Chief Martin Landfill
Sewer lines and sewer pump stations (break or malfunction)	Sewage, coliform and noncoliform bacteria, viruses, nitrates, heavy metals, synthetic detergents, cooking and motor oils, bleach, pesticides, paints, paint thinner, photographic chemicals	C, D, E, F, G, H, I, J, K, L, O, P, Q, R, S, T	Lummi Bay, Bellingham Bay, Georgia Strait, Hale Passage	• Potential public health hazard • Installed automated pumps with backup generators in all pump stations along Lummi Shore Road and other pump station sites. • Sewer lines will be installed throughout Sandy Point and septic systems removed in 2011

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
5. Potential Commercial Sources				
Silver Reef Hotel, Casino, and Spa	Automotive wastes, general building wastes	O	Lummi Bay	• Summer of 2010 completed an additional 2.5 acre parking lot
DO Construction	Oils, waste oils, solvents, grease, hydraulic fluids, transmission fluids, antifreeze, acids, paints, miscellaneous cutting oils, and miscellaneous wastes	G	Bellingham Bay	• None
Lummi Auto Recyclers	Waste oils, solvents, acids, paints, antifreeze, and automotive wastes	G	Bellingham Bay	• Large number of potential contaminants • Requires NPDES Multi-Sector Industrial Permit • Lummi Water Resources Division samples storm water runoff annually for potential contaminants • Actively in the process to close the business and remove all motor vehicles from the site • Storm water discharges to a depressional wetland with no outlet
Eagle Haven Recreational Vehicle (RV) park	Septage, gasoline, diesel fuel pesticides, automotive wastes, and household wastes	H	Lummi Bay	• None
Fisherman's Cove (boat storage and launching)	Gasoline, diesel fuel, oil, septage from boat waste disposal areas, hydraulic fluid, automotive wastes, boat paint, antifouling paint	C	Hale Passage, Lummi Bay	• None
Fisherman's Cove Marina (retail grocer and gas station)	Automotive wastes, gasoline (underground storage tanks) general building wastes	C	Hale Passage	• None
Seafood Buying Facility	Automotive wastes, general building waste	C	Hale Passage	• None
Finkbonner Shellfish Inc.	Automotive wastes, general building wastes	C	Hale Passage	• None

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
Native American Shellfish Inc.	Automotive wastes, general building wastes	S	Bellingham Bay	• None
Warrior Construction	Oils, waste oils, solvents, grease, hydraulic fluids, transmission fluids, antifreeze, acids, paints, miscellaneous cutting oils, and miscellaneous wastes	Q	Lummi Bay	• None
Crist Gravel Pit	Oils, waste oils, solvents, grease, hydraulic fluids, transmission fluids, antifreeze, acids, and miscellaneous wastes	G	Bellingham Bay	• None
Barlean's Fisheries, Inc and Barlean's Organic Oil	Automotive wastes, general building wastes, process wastes	P, Q	Onion Bay, Lummi Bay, Lummi River,	• None
Golf Courses	Lawn and garden maintenance chemicals, automotive wastes	O, S	Lummi Bay, Bellingham Bay	• None
Sandy Point Marina	Gasoline, diesel fuel, oil, septage from boat waste disposal areas, and automotive wastes	R	Georgia Strait	• Installed new docks in 2010
Utilities	PCBs from transformers and capacitors, oils, solvents, sludges, acid solution, metal plating solutions (chromium, nickel, cadmium)	C, D, E, F, G, H, I, J, K, L, O, P, Q, R, S	Lummi Bay, Bellingham Bay, Georgia Strait, Hale Passage	• Potential public health hazard
Miscellaneous Commercial Businesses in Ferndale and the Nooksack River Basin	Solvents, pesticides, acids, alkalis, waste oils, machinery/vehicle servicing wastes, gasoline or diesel fuel from storage tanks, general building wastes, automotive wastes	L,O,S	Lummi Bay, Lummi River, Bellingham Bay	• Large number of potential contaminants • Potential hazard of contaminants • Lummi Nation Spill Prevention and Response Plan (LWRD 2005) assessed risk

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
6. Potential Industrial Sources				
ConocoPhillips Refining and Marketing (petroleum oil refinery)	Hydrocarbons, solvents, metals, miscellaneous organics, sludges, oily metal shavings, lubricant and cutting oils, degreasers, metal marking fluids, corrosive fluids, other hazardous and nonhazardous materials and wastes, diesel fuel, herbicides for rights-of-way, creosote for preserving railroad ties	Q, R	Lummi Bay, Onion Bay, Georgia Strait	• Large number of potential contaminants • Potential hazard of contaminants • Lummi Nation Spill Prevention and Response Plan (LWRD 2005) assessed risks.
Miscellaneous Industries in the Nooksack River Basin	Hydrocarbons, solvents, metals, miscellaneous organics, sludges, oily metal shavings, lubricant and cutting oils, degreasers, metal marking fluids, corrosive fluids, other hazardous and nonhazardous materials and wastes, diesel fuel, herbicides for rights-of-way, creosote for preserving, railroad ties, automotive waste	S	Bellingham Bay	• Large number of potential contaminants • Potential hazard of contaminants
7. Potential Sources of Industrial Processes (atmospheric deposition)				
ConocoPhillips Refining and Marketing (petroleum oil refinery)	<u>Criteria Pollutants:</u> Volatile Organic Compounds (VOCs), fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur <u>Toxic Pollutants:</u> benzene, butanes, cyclohexane, ethylbenzene, pentanes, toluene, trimethylbenzene, xylene, and other toxins in quantities less than 5,000 lbs per year	All 18 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
Alcoa-Intalco (aluminum plant)	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: gaseous fluoride	All 18 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
British Petroleum, Inc (petroleum oil refinery)	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: benzene, cyclohexane, ethylbenzene, sulfuric acid, toluene, trimethylbenzene, xylene, and other toxins in quantities less than 5,000 lbs per year	All 18 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
Puget Sound Refinery (Shell Products US)	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: benzene, cyclohexane, ethylbenzene, sulfuric acid, toluene, trimethylbenzene, xylene, and other toxins in quantities less than 5,000 lbs per year	All 18 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
Tesoro Northwest Company (petroleum oil refinery)	Criteria Pollutants: VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur Toxic Pollutants: benzene, cyclohexane, ethylbenzene,	All 18 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River,	• Large number of potential contaminants • Potential hazard of contaminants

Table 5.1 Potential Storm Water Contaminant Sources in Reservation Watersheds

Potential Contaminant Sources	Potential Contaminants[1]	Watershed(s)	Receiving Water Bodies	Comments
	sulfuric acid, toluene, trimethylbenzene, xylene, and other toxins in quantities less than 5,000 lbs per year		Portage Bay, Hale Passage	
GN Plywood, Inc. (plywood manufacturer)	<u>Criteria Pollutants:</u> VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide <u>Toxic Pollutants:</u> acetaldehyde, acetone, barium, benzene, chlorine, formaldehyde, manganese, naphthalene	All 18 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
Encogen NW Cogeneration Plant	<u>Criteria Pollutants:</u> VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur <u>Toxic Pollutants:</u> ammonia, formaldehyde	All 18 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants
Tenaska Washington Partners Cogeneration Station	<u>Criteria Pollutants:</u> VOCs, fine particulate matter, oxides of nitrogen, carbon monoxide, oxides of sulfur <u>Toxic Pollutants:</u> ammonia, benzene, cyclohexane, ethylbenzene, formaldehyde, sulfuric acid, toluene, trimethylbenzene, xylene, and other toxins in quantities less	All 18 watersheds	Bellingham Bay, Lummi Bay, Onion Bay, Georgia Strait, Lummi River, Nooksack River, Portage Bay, Hale Passage	• Large number of potential contaminants • Potential hazard of contaminants

[1] Potential contaminant listings based on literature (EPA 1993) and 2010 emission inventory information provided by the Northwest Air Pollution Authority. Other than emission inventories, site specific inventories of potential contaminants at each location were not conducted.

6. STORM WATER BMPS

Best management practices (BMPs) related to storm water are generally defined as physical, structural, and/or operational practices that, when used singly or in combination, prevent or reduce water pollution. Storm water BMPs are intended to minimize the impacts of land use changes on storm water quantity and/or quality. Effective implementation of BMPs should result in the attainment of the Lummi storm water management goals. That is, effective implementation of storm water BMPs should result in:

- Maximizing both infiltration and aquifer recharge opportunities,
- Minimizing both the amount of storm water and the opportunities for storm water to wash pollutants into aquifer recharge zones, receiving surface waters, and the resource rich tribal tidelands that surround the Reservation uplands, and
- Minimizing the downstream impacts of development on storm water quantity and quality.

Three general types of storm water BMPs are source control, flow control, and runoff treatment (Ecology 2005).

- **Source Control BMPs:** The goal of source control BMPs is to prevent pollutants from entering storm water. Source control BMPs either eliminate the pollutant source or prevent rainfall or storm water from coming in contact with the pollutant source. Like most pollution prevention activities, source control BMPs are the most cost effective method to eliminate or reduce storm water pollution. Examples of practices intended to control or prevent water quality impacts at the source include: applying mulch or placing covers over disturbed soil at construction sites, building roofs over outside storage areas, identifying and eliminating illegal connections to storm drains, reducing or eliminating the use of a particular pesticide, placing rocks or cobbles at the entry ways to construction sites, and public education initiatives.
- **Flow Control BMPs:** The goal of flow control BMPs is to control the rate, frequency, and flow duration of storm water surface runoff. The need for flow control BMPs depends on whether a developed site discharges to a stream system or wetland, either directly or indirectly. Flow control BMPs are intended to reduce the frequency and magnitude of bankfull flow conditions in streams. Bankfull conditions are highly erosive and the frequency of such conditions increases substantially as a result of development and the associated increase in impervious surface area. The BMP measures that detain runoff flows and physically stabilize eroding stream banks can provide stream channel erosion control. In regards to wetlands, flow control BMPs are intended to avoid changes in the natural hydroperiod, which is the timing and duration of water level elevation changes. Examples of practices to control storm water flow include: infiltration basins or trenches, detention basins, vegetative stream bank stabilization, bioengineering methods, and structural stream bank stabilization.
- **Runoff Treatment BMPs:** The goal of runoff treatment BMPs is to reduce pollutant loads and concentrations in storm water runoff using physical, biological, and/or

chemical removal mechanisms. Because it is considerably more difficult and expensive to remove sediments and pollutants from runoff than it is to prevent the introduction of these materials into storm water, treatment BMPs should be a second line of defense in storm water management efforts. The purpose of runoff treatment BMPs should be to remove pollutants that could not be controlled by source control or flow control BMPs. Examples of practices intended to remove sediment and/or pollutants from storm water runoff include: infiltration and filtration basins, detention basins, biofiltration swales or vegetative filter strips, rock check dams, and oil/water separators.

Storm water BMPs can be temporary or permanent. Temporary BMPs are in place for a year or less and are often used during the construction phase of a project. Examples of temporary BMPs include rocked entry ways to construction sites, sediment ponds, and covering exposed soils with mulch. Examples of permanent BMPs include infiltration trenches, detention ponds, and biofiltration swales. Some temporary BMPs can be planned into a development so that they become permanent BMPs as completion of various phases of the development occurs. For example, a rocked entry way can later serve as the base for a paved roadway. Similarly, a sediment pond installed for the construction phase of a development could be modified and used as a detention pond for the developed area. Appropriate storm water BMPs should be the first construction phase for projects regardless if the BMPs are temporary or permanent.

In this section, storm water BMPs are separated into two categories: BMPs for construction sites and BMPs for developed or urban areas. A brief description is provided for each of the identified BMPs. Expanded descriptions of each BMP are available on-file at the Lummi Natural Resources Department (Water Resources Division) and in the literature (MPCA 1989, EPA 1992, Ecology 1992, MWCOG 1992, IDHW 1996, EPA 1996, Ecology 2005) and have not been reproduced in this technical background document.

6.1. Construction Site BMPs

Although construction site BMPs are primarily directed toward either minimizing erosion or controlling offsite sedimentation, they are also intended to minimize the impacts of equipment storage and refueling areas on storm water quality. Minimizing construction site erosion by applying source control BMPs is the first and most cost effective method to eliminate or reduce pollution of storm water from construction sites (Ecology 2005). Source control BMPs at construction sites that reduce erosion include actions such as:

- Stabilizing slopes.
- Creating natural vegetation buffers.
- Diverting runoff from exposed areas.
- Controlling the volume and velocity of runoff.
- Conveying runoff away from the construction site.

Sedimentation control is achieved using runoff treatment BMPs such as silt fences, sediment traps, and cobble check dams. The runoff treatment BMPs for sedimentation are only intended to control sediment from unavoidable erosion. Most sites require the use of several types of BMPs to adequately control erosion and sedimentation (Ecology 2005).

Most of the storm water quantity and quality problems from construction sites are associated with 12 specific elements that must be addressed in Storm Water Pollution Prevention Plans (SWPPPs) (EPA 2008, Ecology 2005). Accordingly, BMPs have been developed to reduce the problems associated with each these elements (Ecology 2005). The 12 elements are:

- Mark clearing limits
- Establish construction access
- Control flow rates
- Install sediment controls
- Stabilize soils
- Protect slopes
- Protect drain inlets
- Stabilize channels and outlets
- Control pollutants
- Control de-watering
- Maintain BMPs
- Project management

Stream and waterway protection is also important but not specifically one of the 12 elements listed above. The goal of stream bank erosion control BMPs is to reduce stream bank erosion that results from increased runoff caused by development. The stream bank erosion control BMPs are intended to reduce the frequency and magnitude of bankfull conditions. Bankfull conditions are highly erosive and the frequency of such conditions can increase substantially as a result of development and the associated increase in impervious surface area (Ecology 1992, Puget Sound Partnership 2005). Conventional flood detention methods do not adequately control stream bank erosion since they only decrease the peak discharge of the stream, not the frequency and duration of bankfull conditions (Ecology 1992, Puget Sound Partnership 2005). Consequently, measures that detain runoff flows and measures that physically stabilize eroding stream banks are identified as stream bank erosion control BMPs. Examples of practices intended to reduce stream bank erosion include: infiltration basins, infiltration trenches, detention basins, vegetative stream bank stabilization, bioengineering methods, and structural stream bank stabilization.

Each of these elements is described briefly below and the BMPs developed to minimize the storm water impacts of each element are summarized in Table 6.1. In general, the most effective BMPs for construction sites are associated with site design and construction management (e.g., fitting the development to the topography, maximizing the preservation of natural vegetation, buffer zones, gradient terraces), site and drainage way stabilization (e.g., stabilized construction entrance, bioengineering of drainage pathways), and flow diversions (e.g., interceptor dikes and swales). Timely installation and maintenance of BMPs is an important factor in their effectiveness.

6.1.1. Preserve Vegetation and Mark Clearing Limits

Protecting adjacent properties and sensitive areas (e.g., streams, wetlands, cultural sites) from accelerated erosion and sedimentation can be achieved by preserving vegetation and clearly marking clearing limits on the project site. Prior to the beginning of land disturbing activities all clearing limits, sensitive areas and associated buffers, and trees that are preserved within the project area need to be clearly marked both in the field and on the site design plans to prevent damage and offsite impacts. The BMPs that can be used to preserve natural vegetation and buffer zones include installing high visibility plastic or metal fencing and/or stake and wire fencing.

6.1.2. Construction Access

Improperly planned or maintained construction access can result in continual erosion problems. Construction vehicle traffic routes are especially susceptible to erosion because they become compacted by heavy vehicle use and collect and convey runoff water along their surfaces. Construction access or activities occurring on paved areas need to be minimized to prevent tracking of sediments onto public roads and sediment from entering Lummi Nation waters. Access points need to be stabilized with a pad of quarry spalls prior to construction and modified if sediment is tracked out onto public roads. If sediment is tracked off-site, additional steps must be taken to remove the sediment by shoveling or pickup sweeping. The BMPs that can be used include: stabilized construction entrance, wheel wash, and construction road/parking area stabilization.

6.1.3. Flow Controls

In order to protect adjacent properties and downstream waterways from erosion due to increases in the volume and peak storm water discharge, storm water from the project site must be controlled. Development should be planned to maintain and use any naturally stabilized drainageways that may exist on or adjacent to a site (Ecology 1992, Ecology 2005). Where increases in runoff volume and velocity are anticipated both during and after construction as a result of changes in soil, vegetative cover, and surface conditions, the capacity of the natural drainage way may need to be increased and the channel stabilized using vegetation and/or structural methods. Downstream analysis is needed to determine if changes in offsite flows could impair or alter conveyance systems, stream banks, bed sediment, or aquatic habitat.

Erosion and sedimentation from surface runoff can be minimized through the use of source control, runoff conveyance, and treatment BMPs. Examples of flow control BMPs include: sediment traps, rock check dams, and temporary sediment ponds.

6.1.4. Sediment Controls

Sediment control BMPs are needed to treat storm water from a disturbed area prior to discharge to a storm water facility or off site. Sediment ponds, vegetated buffer strips, sediment barriers or filters, dikes, rock check dams, and other BMPs are intended to trap sediment on site and prevent sediment-laden storm water from discharging off-site. Sediment control BMPs are also known as runoff treatment BMPs and should be a second line of defense in storm water management efforts. As summarized in Table 6.1, erosion and sedimentation from surface runoff can be minimized through the use of both vegetative and structural methods. Examples of sediment control BMPs include: sediment traps, rock check dams, and temporary sediment ponds.

6.1.5. Stabilize Soils

Although erosion rates on steep exposed slopes are greater than on flat or gently sloping area, all areas of exposed soil are vulnerable to erosion. Exposed and unworked soils need to be stabilized by effective source control BMPs that protect the soil from the erosive forces of raindrop impact, flowing water, and wind. The Lummi Reservation receives approximately 75 percent of the average precipitation from October through April; the remaining 25 percent from May through September. To reduce erosion potential, all exposed or unworked soil should be stabilized within the following time periods:

- During the wet season (October 1 – April 30): 2 days
- During the dry season (May 1 – September 30): 7 days

Applicable BMPs include: temporary and permanent seeding, sodding, mulching, plastic coverings, erosion control fabrics and matting, soil application of polyacrylamine (PAM), the early application of gravel base on areas to be paved, and dust control.

6.1.6. Slopes

Hill slopes and slopes in the site topography greatly increase the potential for erosion. Slopes increase the erosion potential because runoff velocity increases as the slope length (i.e., the distance between the top and the bottom of a hill or slope) and steepness of the slope increase. The higher the runoff velocity, the greater the capacity of the water to detach and transport soil particles (i.e., cause erosion). In general, slope lengths should not exceed (Ecology 1992):

- 300 feet on slopes where the steepness is less than 7 percent;
- 150 feet where the slope steepness is between 7 and 15 percent;
- 75 feet when the slope steepness is greater than 15 percent.

Borrow and stockpile areas present the same erosion and sedimentation control problems as cut and fill slopes. All of the areas are erodible and runoff should be diverted from slope faces and conveyed in stabilized channels to designated stable control points. Problems caused by modifying or creating slopes can be reduced by vegetative stabilization, diversion measures, slope drains, rock check dams, and slope stabilization measures.

6.1.7. Drainage Inlets

Steps must be taken to prevent sediment from entering the storm water drainage system or storm sewer system and to remove sediment from the runoff. All roads should be cleaned periodically and sediment and street wash water should not be allowed to enter the storm drains without prior and adequate treatment. The best way to prevent sediment from entering the storm water drainage system is to stabilize the site as quickly as possible to prevent erosion and stop sediment at its source. The BMPs for storm water drainage systems or enclosed storm sewers include the protection on inlets.

6.1.8. Channels and Outlets

Vegetated drainage channels may be scoured and eroded if the channel capacity is exceeded by the increases in runoff volume and velocity associated with construction activities or development. To safely convey large volumes and high velocities of runoff, an enclosed storm sewer may need to be used. In deciding when to use a storm sewer, the following factors should be considered (Ecology 2005):

- Are existing enclosed storm sewers available within reasonable proximity to the site or is a natural outlet available.
- The actual size of paved areas and the ratio of paved areas to vegetated areas.

Diversion and surface drainage ways are necessary to intercept runoff and convey it to the enclosed storm sewers. The best way to prevent sediment from entering the storm sewer system is to stabilize the site as quickly as possible to prevent erosion and stop sediment at its source. Stabilization of channels and outlets includes: placing armoring material adequate to prevent erosion of outlets and ensuring that adjacent stream banks, slopes, and downstream reaches are armored at the outlet of all conveyance systems. The BMPs for enclosed storm sewers include protection of the channels and outfalls.

6.1.9. Pollutants

All pollutants, including waste materials and demolition debris, must be handled and disposed in a manner that does not contaminate storm water. Petroleum products (e.g., oils, gasoline, diesel fuel, kerosene, lubricating oils, hydraulic fluid, and grease) are widely used at construction sites. Most of these products easily adhere to soil particles and other surfaces. Consequently, one way to control these products on-site is to control erosion and sediment using the methods previously described. Maintenance and repair of heavy equipment and vehicles, which may result in a spillage of pollutants to ground water or into storm water runoff, should be conducted using spill prevention measures such as drip pans. Spill kits containing material and equipment for spill response and cleanup must be maintained at the project site. Contaminated surfaces should be cleaned up immediately and the contaminated material disposed of properly. Other potential pollutant sources found on construction sites include: waste oils, solvents, degreasers, antifreeze, brake fluids, fertilizers, paints, and concrete.

6.1.10. Control De-Watering

Water from foundation, vault, and trench de-watering activities can have similar characteristics as storm water runoff at the site. Methods to remove and discharge excess water from a construction site include pumping water out of areas where it does not otherwise drain or infiltrate, such as sediment traps or sediment ponds. Disposal of de-watering water can also include:

- Infiltration,
- Dispersion into a vegetation buffer,
- Transport offsite in a vehicle, such as a vacuum flush truck,
- Sanitary sewer discharge with written approval from the Lummi Tribal Sewer District, and
- Use of sedimentation bag with outfall to a ditch or swale for small volumes of localized de-watering.

6.1.11. Maintenance BMPs and Management of the Project

An ongoing maintenance program of temporary and permanent BMPs is an important factor in BMP effectiveness. Construction sites must be routinely inspected for the condition of BMPs, especially during and after storms, and any necessary repairs performed in a timely manner. Routine maintenance of BMPs should be coupled with on-site evaluation of the effectiveness of the BMPs. Development of construction projects must be phased to the extent practicable to prevent soil erosion and the transport of sediment from the site during construction. Additional BMPs should be deployed if the existing BMPs are not effectively managing the storm water conditions.

As stated initially, source control activities are the most effective way to minimize the impacts of construction and development activities on storm water quality. Appropriate pollution prevention measures are identified in Table 6.1.

6.1.12. Streams and Waterways

The three storm water management goals for streams and waterways protection on, near, and downstream from construction sites are:

- Increased sediment loads carried by surface runoff from construction sites must not be allowed to enter streams or other waterways.
- Stream banks must be protected from erosion caused by increases in runoff volume and velocity.
- The release rates of increased runoff volume into streams and waterways and the flow velocity in stream channels must be controlled.

As shown in Table 6.1, both vegetative and structural measures can be used to protect stream banks from erosion. As feasible, source control, runoff conveyance, and treatment BMPs should be used together.

Table 6.1 Construction Site Best Management Practices (BMPs)

Problem Area	BMP Category	BMP[1]	Description of BMP[1]
1. Preserve Vegetation and Mark Clearing Limits	Source Control BMPs	C101: Preserving Natural Vegetation	Preserving natural vegetation on steep slopes and near perennial and intermittent water courses or swales is a preferred method for controlling erosion and sediment.
		C102: Buffer Zones	Maintaining a natural vegetative buffer or filter strip along streams, wetlands, other bodies of water and adjacent properties retains sediment on site and is a preferred method for controlling erosion.
		C103: High Visibility Plastic or Metal Fence	Installation of fencing is intended to restrict clearing to approved limits, prevent disturbance of sensitive areas, their buffers, and other areas required to be left undisturbed, limit construction traffic to designated construction entrances or roads and protect areas where marking with survey tape may not provide adequate protection.
		C104: Stake and Wire Fence	Installation of fencing is intended to provide the same protection as C103.
	Runoff Conveyance and Treatment BMPs	C233: Silt Fence	Using filter fabric is applicable for relatively small areas (less than 1 acre and flat areas less than 5 percent slope) and provides a temporary physical barrier to sediment and reduces runoff velocities of overland flow.
2. Establish Construction Access	Source Control BMPs	C105: Stabilized Construction Entrance	Constructing stabilized pads of quarry spalls at entrances to construction sites to reduce the amount of sediment transported onto paved roads by vehicles or equipment.
		C106: Wheel Wash	Washing vehicle equipment and tires to reduce the amount of sediment transported onto paved roads by vehicles or equipment.
		C107: Construction Road/Parking Area Stabilization	Stabilizing development roads, parking areas, and other onsite vehicle transportation routes immediately after grading reduces erosion caused by construction traffic or runoff.
3. Control Flow Rates	Runoff Conveyance and Treatment BMPs	C240: Sediment Traps	Using a small temporary ponding area (either excavated and/or by constructing an earthen embankment) with a gravel or quarry spalls outlet to collect and store sediments from exposed sites.
		C241: Temporary Sediment Pond	Using a temporary ponding area (either excavated and/or by constructing an earthen embankment) with a controlled storm water release structure to collect and store sediments from exposed sites. These sediment ponds should be used for drainage areas less than 10 acres.
4. Install Sediment Control	Runoff Conveyance and Treatment BMPs	C230: Straw Bale Barrier	Using straw bale barriers to decrease velocity of sheet flows and intercept and detain small amounts of sediment from limited disturbed areas preventing sediments from leaving the site. Straw bales are among the most used and least effective BMPs.
		C231: Brush Barrier	Chipped site vegetation, composted mulch, or wood-based mulch are used to provide a temporary physical barrier to reduce the transport of coarse sediment from a construction site.

Table 6.1 Construction Site Best Management Practices (BMPs)

Problem Area	BMP Category	BMP[1]	Description of BMP[1]
		C207: Rock Check Dam	Construct small dams made from quarry spalls or clean cobbles across a swale or drainage ditch to reduce the velocity of concentrated flows, reduce the erosion of the swale or ditch, and to slow the water velocity to retain sediment onsite. The check dam should form a triangle when viewed from the side.
		C232: Gravel Filter Berm	Construction of a berm using gravel or crushed rock near rights-of-way or traffic areas within a construction site to retain sediment onsite.
		C233: Silt Fence	Install silt fence to provide a temporary physical barrier to reduce the transport of coarse sediment and reduces runoff velocities of overland flow. Silt fences are not designed to treat concentrated flows or substantial amounts of overland flow.
		C234: Vegetative Strip	Maintain a continuous strip of dense vegetation with permeable topsoil that must be a minimum of 25-feet wide to reduce the transport of coarse sediment and reduce the velocity of overland flow from a construction site.
		C240: Sediment Traps and C241: Temporary Sediment Ponds	See descriptions presented previously for Control Flow Rates Problem Area.
		C250: Construction Storm Water Chemical Treatment	Implement chemical treatment of storm water runoff from a construction site only with written approval from the Lummi Natural Resources Department. Chemical treatment is used to reduce the turbidity of storm water runoff when traditional BMPs are not adequate to ensure compliance with the water quality standard for turbidity in the receiving water.
		C250: Construction Storm Water Filtration	Installation of a filtration system to reduce the turbidity of storm water runoff when traditional BMPs are not adequate to ensure compliance with the water quality standard for turbidity in the receiving water. Filtration is typically used for treatment of storm water runoff from streets, parking lots, and residential areas not construction sites.
5. Stabilize Soils	Source Control BMPs	C120: Temporary Seeding	Establish temporary vegetative cover on disturbed areas where permanent cover is not necessary or appropriate by seeding with appropriate, rapidly growing annual plants.
		C120: Permanent Seeding and Planting	Establish permanent vegetative cover (e.g., grasses, legumes, trees, shrubs) on disturbed areas to prevent erosion from wind or water and improve wildlife habitat and site aesthetics.
		C121 and C122: Mulching and Nets and Blankets	Application of plant residues, other suitable materials, or matting to the soil surface to provide immediate protection to exposed soils during the period of short construction delays or over the winter months.

Table 6.1 Construction Site Best Management Practices (BMPs)

Problem Area	BMP Category	BMP[1]	Description of BMP[1]
		C123: Plastic Covering	Installation of plastic covering to provide immediate, short term (less than 30 days) erosion control protection particularly for cut and fill slopes and stockpiles.
		C124: Sodding	Establishing permanent grass stands with sod provides immediate erosion protection.
		C126: Polyacrylamide for Soil Erosion Protection (PAM)	Application of PAM to bare soil prior to a rain event increases the soil's available pore volume, thus increasing infiltration through flocculation and reducing the quantity of storm water runoff.
		C130: Surface Roughening	Providing a rough soil surface with depressions perpendicular to the slope to aid in establishing vegetative cover, reducing runoff velocity, increasing infiltration, and providing for sediment trapping.
		C140: Dust Control	Prevent wind transport of dust from disturbed soil surfaces onto roadways, drainage ways, and surface waters.
6. Protect Slopes	Source Control BMPs	C101, C102, C120, C121, C122, C123, C124, and C130	See descriptions presented previously.
		C131: Gradient Terraces	Constructing an earth embankment or a ridge-and-channel with suitable spacing and with an acceptable grade to prevent erosion by intercepting surface runoff and conveying it to a stable outlet at a nonerosive velocity.
	Runoff Conveyance and Treatment BMPs	C200: Interceptor Dike and Swale	Placing a ridge of compacted soil or a vegetated swale along the top or base of a sloping disturbed area to intercept runoff and direct it to a stabilized outlet.
		C201: Grass-Lined Channels	Establish a vegetative channel at the top or base of a sloping disturbed area to contain runoff and direct it to a stabilized outlet.
		C204: Pipe Slope Drains	Extending a pipe from the top to the bottom of a cut or fill slope and discharging the collected water into a stabilized water course, a sediment trapping device, or onto a stabilization area can carry concentrated runoff down steep slopes without causing gullies, channel erosion, or saturation of unstable soils.
		C205: Subsurface Drain	Install a perforated pipe to intercept, collect, and convey excess ground water from a slope, stabilize steep slopes, and lower the water table immediately below a slope to prevent the soil from becoming saturated.
		C206: Level Spreader	Install a temporary outlet for dikes and diversions consisting of an excavated depression constructed at zero grade across a slope in order to convert concentrated runoff to sheet flow and release it into areas stabilized by existing vegetation.

Table 6.1 Construction Site Best Management Practices (BMPs)

Problem Area	BMP Category	BMP[1]	Description of BMP[1]
		C207: Rock Check Dams	Construct small dams made from quarry spalls or clean cobbles across a swale or drainage ditch to reduce the velocity of concentrated flows, reduce the erosion of the swale or ditch, and to slow the water velocity to retain sediment on-site. The check dam should form a triangle when viewed from the side.
		C208: Triangular Silt Dike	Silt dikes are made of urethane foam sewn into a woven geosynthetic fabric and can be used as check dams and for inlet protection. The dike should form a triangle when viewed from the side.
		C209: Outlet Protection	Placing a rock apron or other acceptable energy dissipating devices at the outlets of pipes or paved channel sections to prevent scour and to minimize the potential for downstream erosion by reducing the velocity of the runoff.
		C235: Straw Wattles	Placing straw wattles (straw wrapped in biodegradable tubular plastic) staked or in shallow trenches along the contour of a disturbed or newly constructed slope will reduce runoff velocity, spread the flow of rill and sheet runoff, and capture and retain sediment.
7. Protect Drain Inlet	Runoff Conveyance and Treatment BMPs	C220: Storm Drain Inlet Protection	Preventing coarse sediment from entering the drainage system prior to permanent stabilization of the disturbed areas. Examples of Storm Drain Inlet protection BMPs include: Catch Basin Filters: Using an insert designed by a manufacturer for use at construction sites to prevent sediment from entering the storm system. Catch basin inserts provide five cubic feet of storage and require high amounts of maintenance especially for heavy sediment loads. Filter Fabric Fence: Using a filter fabric fence around a storm drain, drop inlet, or curb inlet to prevent sediment from entering the storm drainage system prior to permanent stabilization of the disturbed area. Using filter fabric is applicable for relatively small areas (less than one acre) and flat areas (less than five percent slope). Block and Gravel Filter: Where flows greater than 0.5 cubic feet per second are expected, inlets can be protected by placing wire mesh and filter fabric over the drop inlet, placing concrete blocks length-wise around the inlet with the open ends facing outward (not upward), place wire mesh over the open ends of the blocks, and placing clean gravel (3/4 to 3 inch gravel) against the wire mesh to the top of the blocks. Gravel and Wire Mesh Filter: Where flows greater than 0.5 cubic feet per second are expected and construction traffic may occur over the inlet, inlets can be protected by placing wire mesh and filter fabric over the drop inlet and placing at least 12-inches of clean gravel over the mesh and filter.

Table 6.1 Construction Site Best Management Practices (BMPs)

Problem Area	BMP Category	BMP[1]	Description of BMP[1]
8. Stabilize Channels and Outlets	Runoff Conveyance and Treatment BMPs	C202: Channel Lining	In areas where water velocities are high and vegetative or combination measure will not work the channel can be lined. This approach requires that the area downstream be hardened.
		C209: Outlet Protection	Placing a rock apron or other acceptable energy dissipating devices at the outlets of pipes or paved channel sections to prevent scour and to minimize the potential for downstream erosion by reducing the velocity of the runoff.
9. Control Pollutants	Source Control	C151: Concrete Handling	Process to minimize and eliminate concrete process water and slurry from entering waters of the Lummi Nation. Concrete slurry and process water can contain high fine particles and high pH which can violate water quality standards.
		C152: Sawcutting and Surfacing Pollution Prevention	Process to minimize and eliminate concrete process water and slurry from entering waters of the Lummi Nation. The concrete slurry and cuttings are vacuumed during the cutting and surfacing operations. Concrete slurry and process water can contain high fine particles and high pH which can violate water quality standards.
		C153: Material Delivery and Storage	Minimize the risk of pollutant discharge into the storm water system by minimizing the storage of hazardous materials, storing material in a designated area, and installing secondary containment. • Store products in weather-resistant sheds where possible. • Line the storage area with double layer of plastic sheeting or similar material. • Create an impervious berm around the perimeter. The bermed area should have the capacity of 110 percent of the largest container. • Clearly label all products. • Keep storage tanks off the ground and securely fasten lids. • Tell contractors what to do in case of spills and post information for procedures in case of spills. Persons trained in handling spills should be on-site or on-call at all times. • Keep materials for cleaning up spills on-site and easily available. Spilled material should be cleaned up immediately and the contaminated material disposed of properly. • Specify a staging area for all vehicle maintenance activities. This area should be located away from all drainage courses. • All storage sheds, dumpsters, or other storage facilities should be regularly monitored for leaks and repaired as necessary. Workers should be reminded during subcontractor or safety meetings about proper storage and handling of materials.

Table 6.1 Construction Site Best Management Practices (BMPs)

Problem Area	BMP Category	BMP[1]	Description of BMP[1]
10. Control De-watering	See measures for slopes and other areas.	See BMPs for slopes and other areas	See description presented previously.
11. Maintain BMPs	Source Control	N/A	Site storm water inspector ensures that all temporary and permanent erosion and sediment control BMPs are maintained and repaired as needed to assure continued performance of their intended function.
12. Manage the Project	Source Control	C162: Scheduling	Sequence a construction project to reduce the amount and duration that soil is exposed to erosion by wind, rain, runoff, and vehicle traffic.
13. Streams and Waterways	Source Control	C120: Permanent Seeding and Planting	Planting vegetation along the banks of swales, creeks, streams, rivers, man-made ditches, canals, and impoundments can reduce wave action and runoff velocity and lead to the deposition of water-borne soil particles. Certain reeds and bulrushes can improve water quality by absorbing certain pollutants such as heavy metals, detergents, phenols, and indols.
	Runoff Conveyance and Treatment BMPs	Riprap	Using permanent, erosion-resistant ground cover of large, loose, angular stone to slow the velocity of concentrated runoff or to stabilize slopes with seepage problems and/or non-cohesive soils.
		Gabion	Using rectangular, pervious, semi-flexible rock-filled wire baskets to provide armor protection against erosion
		Reinforced Concrete	Using reinforced concrete retaining walls or bulkheads to armor eroding sections of stream bank
		Log Cribbing	Using logs to build a retaining structure to protect stream banks from erosion.
		Grid Pavers	Using modular concrete units with interspersed void areas which can be used to armor the stream bank while maintaining porosity and allowing vegetation establishment.
		C207: Rock Check Dams	Construct small dams made from quarry spalls or clean cobbles across a swale or drainage ditch to reduce the velocity of concentrated flows, reduce the erosion of the swale or ditch, and to slow the water velocity to retain sediment on-site. The check dam should form a triangle when viewed from the side.

[1] Complete descriptions of these and other BMPs are presented in the *Storm Water Management Manual for the Puget Sound Basin* (Ecology 1992) and *Stormwater Management Manual for Western Washington* (Ecology 2005)

6.2. Urban BMPs

Storm water best management practices (BMPs) for developed (urban) areas include both structural and non-structural practices. Structural BMPs include facilities such as: extended detention ponds, storm water wetlands, infiltration trenches and/or basins, porous pavement, grassed swales, and filter strips. Structural BMPs are designed to minimize the impacts of land use changes on storm water quantity and/or quality. Non-structural BMPs include practices such as: fertilizer and pesticide management, litter control, street sweeping, catch basin cleaning, household hazardous waste management, and other pollution prevention activities.

6.2.1. Structural BMPs

Twelve structural BMPs are described briefly below and a comparative assessment of the effectiveness of these practices is presented in Table 6.2. The structural BMPs considered are: extended detention ponds, wet ponds, storm water wetlands, multiple pond systems, infiltration trenches, infiltration basins, permeable/porous pavement, sand filters, filtration, grassed swales, filter strips, and water quality inlets.

1. **Extended Detention Ponds:** Extended detention ponds temporarily store a portion of the storm water runoff for up to 24 hours after a storm using a fixed sized outlet. The intent of the ponds is to allow pollutants to settle out of the water column. These ponds are normally "dry" between storm events. Enhanced extended detention ponds are designed to prevent clogging and re-suspension. These enhanced ponds are equipped with plunge pools near the inlet, a smaller pool at the outlet, and use an adjustable reverse-sloped pipe to control the outlet (MWCOG 1992).
2. **Wet Ponds (Wet Pools):** Wet ponds have a permanent pool of water for treating incoming storm water runoff. Pollutant removal is achieved by gravitational settling, algal settling, wetland plant uptake, and bacterial decomposition. Wet ponds may be used only for runoff treatment or they can be combined with a detention pond or vault to also provide flow control (Ecology 2005). Enhanced wet ponds use a forebay to trap incoming sediments (where they can be removed easily) and a fringe wetland is established around the pond perimeter (MWCOG 1992).
3. **Storm Water Wetlands:** Storm water wetlands are shallow pools that create growing conditions suitable for wetland plants. These wetlands are intended to maximize pollutant removal through uptake by wetland plants, retention, and settling. Storm water wetlands are constructed systems, are not typically located within natural wetlands, and do not replicate all of the ecological functions of natural wetlands. Enhanced storm water wetlands include elements such as a forebay, complex microtopography, and pondscaping with multiple species of wetland trees, shrubs, and plants (MWCOG 1992).
4. **Multiple Pond Systems:** "Multiple pond systems" is a collective term for a cluster of pond designs that incorporate redundant runoff treatment techniques within a single pond or series of ponds. The pond designs incorporate a combination of two or more of the following: extended detention, permanent pool, shallow wetlands, or infiltration (MWCOG 1992).

5. **Infiltration Trenches:** An infiltration trench is a shallow, excavated trench generally 24 inches wide that has been backfilled with stone to create an underground reservoir. Storm water diverted into the trench gradually infiltrates from the bottom of the trench into the subsoil and eventually into the aquifer. Pollutant removal is achieved by adsorption, straining, and microbial decomposition in the soil below the trench and trapping particulate matter within pretreatment areas. Enhanced infiltration trenches have extensive pretreatment systems (e.g., grass filter strips, sump pits, plunge pools) to remove sediment and oil (MWCOG 1992).
6. **Infiltration Basins:** Infiltration basins are typically temporary impoundments where incoming storm water runoff is stored until it gradually infiltrates through the soil of the basin floor. Similar to infiltration trenches, pollutant removal is achieved by adsorption, straining, and microbial decomposition in the soil below the basin and trapping particulate matter within pretreatment areas (MWCOG 1992, Ecology 2005).
7. **Permeable/Porous Paving:** Permeable/porous paving is an alternative to conventional pavement. Runoff is diverted through a permeable paving layer and into an underground stone/aggregate reservoir from which the storm water eventually infiltrates into the subsoil. Pollutant removal is achieved by adsorption, straining, and microbial decomposition in the subsoil below the aggregate chamber and trapping particulate matter within the aggregate chamber (MWCOG 1992). The general categories of permeable paving systems (Puget Sound Partnership 2005) include:
    - *Open-graded concrete or hot-mix asphalt pavement* is similar to standard pavement but with reduced or eliminated fine material and special admixtures incorporated. Channels will form between the aggregate in the pavement surface and allow water to infiltrate. Also known as porous or pervious pavement.
    - *Aggregate or plastic pavers* that include cast in place or modular pre-cast blocks. Both systems have wide joints or openings that can be filled with soil and grass or gravel.
    - *Plastic grid systems* that come in rolls and are covered with soil and grass or gravel. The grid sections interlock and are pinned in place.
8. **Sand Filters and Filtration Facilities:** Sand filters are self-contained sand beds that are placed to receive the first flush of storm water runoff. The runoff is strained through the sand, collected in underground pipes, and returned back to the stream or channel. Enhanced sand filters use layers of peat, limestone, and/or topsoil and may have a grass cover crop. Pollutant removal is achieved by straining and by settling on top of the sand bed (MWCOG 1992). Other filter systems can be configured as basin, trenches, or cartridges to remove pollutants. Various media such as perlite, zeolite, and carbon are used to remove low levels of total suspended solids in storm water runoff. Specific media such as activated carbon or zeolite can remove hydrocarbons and soluble metals (Ecology 2005).
9. **Grassed Swales:** Grassed swales are earthen conveyance systems in which pollutants are removed from storm water by filtration through grass and infiltration through the soil. Enhanced grassed swales or biofilters use rock check dams and wide depressions to increase runoff storage and promote greater settling of pollutants (MWCOG 1992).

10. **Filter Strips:** Filter strips are vegetated sections of land designed to accept runoff as overland sheet flow from developments located upslope. These filter strips may be nearly any natural vegetation form, from grassy meadow to small forest. Pollutants are removed by the filtering action of vegetation, deposition in low velocity areas, or by infiltration into the subsoil (MWCOG 1992).
11. **Water Quality Inlets/Oil Grit Separators:** A water quality inlet, also known as an oil/grit separator, is a three-stage underground retention system designed to remove heavy particulates and absorbed hydrocarbons from storm water. Gravitational settling within the first two chambers can achieve partial removal of grit and sediments. An inverted pipe elbow can remove oil by keeping the less dense oil near the surface where it can bind with sediments and ultimately settle. Actual pollutant removal is accomplished when trapped residuals are cleaned out of the inlet (MWCOG 1992).

Table 6.2 A Comparative Assessment of the Effectiveness of Current Urban BMPs[1]

Urban BMP Options	Reliability for Pollutant Removal	Longevity[2]	Applicable to Most Developments	Regional Concerns	Environmental Concerns	Comparative Costs	Special Considerations
1. Extended Detention Ponds	Moderate, but not always reliable	20+ years, but frequent clogging and short detention common	Widely applicable	Very few	Possible stream warming and habitat destruction	Lowest cost alternative in size range	Recommended with design improvements and with the use of micro-pools and wetlands
2. Wet Pond	Moderate to high	20+ years	Widely applicable	Arid and high evapotrans-piration regions	Possible stream warming, trophic shifts, habitat destruction, safety hazards, sacrifice of upstream channels	Moderate to high compared to conventional storm water detention	Recommended, with careful site evaluation
3. Storm Water Wetland	Moderate to high	20+ years	Space may be limiting	Arid and high evapotrans-piration regions, short growing seasons	Stream warming, natural wetland alteration	Marginally higher than wet ponds	Recommended
4. Multiple Pond Systems	Moderate to high, redundancy increases reliability	20+ years	Many pond options	Arid regions	Selection of appropriate pond option minimizes overall impact	Most expensive pond option	Recommended
5. Infiltration Trenches	Presumed moderate	50 % failure rate within five years	Highly restricted (soils, ground water, slope, area, sediment input)	Arid and cold regions; sole-source aquifers.	Depending on land use and soils/geology, slight risk of ground water contamination	Cost-effective on smaller scale, rehabilitation costs can be considerable	Recommended for appropriate land use with pretreatment and geotechnical evaluation
6. Infiltration Basins	Presumed moderate, if working	60 to 100 % failure rate within five years	Highly restricted (see infiltration trench)	Arid and cold regions; sole-source aquifers	Depending on land use and soils/geology, slight risk of ground water contamination	Construction costs moderate, but rehabilitation costs high	Not widely recommended until longevity is improved

Table 6.2 A Comparative Assessment of the Effectiveness of Current Urban BMPs[1]

Urban BMP Options	Reliability for Pollutant Removal	Longevity[2]	Applicable to Most Developments	Regional Concerns	Environmental Concerns	Comparative Costs	Special Considerations
7. Permeable/ Porous Paving	High (if working)	75 % failure rate within five years	Extremely restricted (traffic, soils, ground water, slope, area, sediment input)	Cold climates; wind erosion, sole-source aquifers	Possible ground water impacts; uncontrolled runoff	Cost effective compared to conventional asphalt when working properly	Recommended in highly restricted applications with careful construction and effective maintenance
8. Sand Filters and Other Filters	Moderate to high	20+ years	Applicable (for smaller developments)	Few Restrictions	Minor	Comparatively high construction costs and frequent maintenance	Recommended with local demonstration
9. Grassed Swales	Low to moderate, but unreliable	20+ years	Low density development and roads	Arid and cold regions	Minor	Low compared to curb and gutter	Recommended with check dams as one element of a BMP system
10. Filter Strips	Unreliable in urban settings	Unknown, but may be limited	Restricted to low density areas	Arid and cold regions	Minor	Low	Recommended as one element of a BMP system
11. Water Quality Inlets/Oil Grit Separators	Presumed low	20+ years	Small, highly impervious catchments (less than two acres)	Few	Resuspension of hydro-carbon loadings. Disposal of hydrocarbon and toxic residuals	High, compared to trenches and filters	Not currently recommended as a primary BMP option

[1](MWCOG 1992)
[2] Based on current designs and prevailing maintenance practices

6.2.2. Non-Structural BMPs

In contrast to structural BMPs, non-structural BMPs do not involve the construction of storm water control and/or treatment facilities. Non-structural BMPs are practices such as site planning, storm water facilities maintenance programs, public education initiatives, "good house keeping", and other pollution prevention practices.

1. **Site Planning:** Effective site planning for new developments can greatly improve the chances of achieving storm water management objectives. Goals for effective site planning include (MPCA 1989, Puget Sound Partnership 2005):
   - Reproduce pre-development hydrological conditions.
   - Confine development and construction activities to the least critical areas. The following areas should be avoided when sitting projects: along the shoreline of marine waters, lakes, streams, and wetlands; natural drainageways; and areas dominated by steep slopes, dense vegetation, porous soils, or erodible soils.
   - Fit development to the terrain.
   - Preserve and utilize the natural drainage system.
2. **Storm Water Facilities Maintenance Programs:** Storm water facilities maintenance programs are important for ensuring that the facilities work as intended. A maintenance program is also necessary for removing sediment and other materials from the facilities before they can be re-suspended by subsequent storm water events and washed into receiving waters. For example, catch basins installed in a storm sewer system need to be cleaned out periodically to maintain their sediment trapping ability. During regular inspections conducted as part of a maintenance program, the effectiveness of BMPs and storm water facilities can be evaluated and any corrective actions taken in advance of future storm events.
3. **Public Education and Involvement Initiatives:** Public education and involvement initiatives are important because ultimately individuals are responsible for negative storm water quantity and quality problems. Individuals in the community need to be made aware of household hazardous waste management practices; alternative products available to residential, commercial, and community consumers that are less toxic; and other pollution prevention activities. Community awareness of the importance of keeping storm water ditches and systems free of obstructions and debris contributes to improve functioning of the overall system. Public education and community involvement will continue in the Lummi Storm Water Management Program using a variety of methods including: pamphlets, articles in the community newspaper (*Squol Quol*), and small construction project site visits.
4. **"Good House Keeping":** "Good House Keeping" is an expression for pollution prevention activities like litter control, street sweeping, and household hazardous waste collection and proper disposal. Litter control involves the removal of litter from streets and other surfaces before runoff or wind moves these materials to surface waters or ground water recharge areas (MPCA 1989). In addition to lawn clippings and leaves (which are a major source of phosphorus in urban runoff), litter that should be controlled includes: pet wastes, trash, oil, and chemicals or toxic compounds used around the house, business, or community. Street sweeping involves the removal of

grit, debris, and trash from urban impervious areas (e.g., streets, parking lots, and sidewalks). Because five of the NURP projects that studied the effectiveness of street sweeping found that it does not significantly benefit water quality (MPCA 1989), street sweeping is only recommended as a BMP for immediately following winter snowmelt (to remove sand and other debris) and in the fall after leaves have dropped to remove debris accumulated over the spring and summer before the winter rainy season. Household hazardous waste collection and disposal programs are a way to make it convenient for individuals to properly dispose of leftover paints, thinner, oils, solvents, fuels, batteries, anti-freeze, oily rags, and other potentially hazardous waste.

5. **Other Pollution Prevention Practices:** Other pollution prevention practices that have not been previously mentioned include fertilizer management, integrated pest management, nutrient management, and total farm management. Fertilizer management involves controlling the rate, timing, and method of fertilizer application so that plant needs are met while the chance of polluting surface or ground water is minimized (MPCA 1989). Integrated pest management involves controlling the rate, timing, and application method of chemical, biological, and/or structural pesticides or pest control methods. Nutrient management involves ensuring that manure is stored safely and land applied in a manner that does not exceed the agronomic rate of the cover crop. Total farm management ensures that nutrients are effectively managed, chemicals properly stored and applied, and livestock prevented from direct access to waterways.

7. LOW IMPACT DEVELOPMENT

Conventional storm water management tools are focused on avoiding, minimizing, and mitigating land use changes on storm water and controlling flooding. This conventional strategy emphasizes the efficient collection and conveyance of runoff from residential and commercial development to central control points. Structural approaches to managing storm water runoff have limitations with respect to recovering adequate storage and spatially distributing flow paths in a manner that more closely approximates pre-development hydraulic function and protects aquatic resources from the adverse effects of land development.

Low Impact Development (LID) is a storm water management and land development strategy applied at the parcel and subdivision scale that emphasizes conservation and use of on-site natural features integrated with engineered, small-scale hydrologic and hydraulic controls to more closely mimic predevelopment hydrologic functions. Low Impact Development is a part of an EPA initiative called "Green Infrastructure". The purpose of the Green Infrastructure initiative is to mitigate overflows from combined and separate storm sewer systems and to reduce storm water pollution by encouraging implementation of LID practices in cities and municipal separate storm sewer system (EPA 2008c). The LID strategy is focused on evaporating, transpiring, and infiltrating storm water on-site through native soils, vegetation, and bioengineering applications to reduce and treat overland flow. The LID techniques promote the use of natural systems that can effectively remove nutrients, pathogens, and metals from storm water.

Application of the LID strategy can provide a number of benefits including:

- **Better Protect the Environment –** The LID techniques remove pollutants from storm water, reduce the volume of storm water, manage high storm water flows, and can replenish streams and wetlands.
- **Ground Water Recharge –** The LID practices can be used to infiltrate runoff to replenish ground water and increase stream base flow. Adequate baseflow in streams during dry weather is important because low ground water levels can lead to greater fluctuations in stream depth, flows, and temperatures, all of which can impact aquatic life (EPA 2007).
- **Reduce Flooding and Protect Property –** Many LID techniques can be used to reduce downstream flooding through the reduction of peak flows and the total amount or volume of runoff. Strategies designed to manage runoff on-site or as close as possible to its point of generation can reduce erosion and sediment transport as well as reduce flooding and downstream erosion (EPA 2007).
- **Protect Human Health –** The LID practices can more effectively remove pollutants from storm water since untreated storm water can be unsafe for people to drink or swim in.
- **Economic Benefits –** The LID strategies can help protect shellfish growing areas and businesses, water quality, and marine sediment quality. Also many LID projects are

less expensive to build, which means that developers and builders can often save money on overall development costs by using LID strategies.

- **Cost-Effective Alternatives to Storm Water System Upgrades –** Prior to the 1990s, land development provided little to no storm water treatment. The LID systems, such as bioretention, can be less expensive to install than costly storm water vaults or land-consuming storm water detention ponds.
- **Increase Aesthetics of Communities –** Generally, LID projects leave more native vegetation and have less impervious surfaces, resulting in more vegetation and greener developments and communities. The use of LID designs may increase property values or result in faster sale of the property due to the perceived value of the "extra" landscaping (Puget Sound Partnership 2005).
- **Improve Air Quality –** Trees and vegetation improve air quality by filtering many airborne pollutants and can help reduce the incidence of respiratory illness. Transportation and community planning and design efforts that facilitate shorter commute distances and the ability to walk to destinations will also reduce vehicle emissions (EPA 2008c).
- **Increase Public Safety –** The LID strategy of creating narrow street assists in slowing vehicle traffic and therefore reduces pedestrian accidents and fatalities.

A more detailed description of LID benefits for the environment, developers, local governments and communities can be found in the Puget Sound Partnership's Low Impact Development Brochure in Appendix D.

The *Low Impact Development Technical Guidance Manual for Puget Sound* (Puget Sound Partnership 2005) identifies four key strategies associated with LID:

1. **Conserve and Restore Vegetation and Soils**
    - Maximize retention of native forest cover and restore disturbed vegetation to intercept, evaporate, and transpire precipitation.
    - Preserve permeable, native soil and enhance disturbed soils to store and infiltrate storm flows.
    - Retain and incorporate topographic site features that slow, store, and infiltrate storm water.
    - Retain and incorporate natural drainage features and patterns
2. **Design Development Sites to Minimize Impervious Surfaces**
    - Utilize a multidisciplinary approach that includes planners, engineers, and landscape architects at the initial phases of the project.
    - Locate buildings and roads away from sensitive areas and soils that provide effective infiltration.
    - Minimize total impervious surface area and eliminate effective impervious surfaces.

3. **Distributed and Integrated Management Practices**
    - Manage storm water as close to its origin as possible by utilizing small scale distributed hydrologic controls
    - Create a hydraulically rough landscape that slows storm flows and increases time of concentration.
    - Increase reliability of the storm water management system by providing multiple or redundant LID flow control practices.
    - Integrate storm water control into development design and utilize the controls as amenities – create a multifunctional landscape.
    - Reduce the reliance on traditional conveyance and pond technologies
4. **Provide Maintenance and Education**
    - Develop reliable and long-term maintenance programs with clear and enforceable guidelines.
    - Educate homeowners, building owners, and landscapers on the proper maintenance requirements for LID facilities.
    - Involve neighborhoods in caring for their systems and in protecting their streams, wetlands, and bays.

The LID approach can work almost anywhere. Low impact development can be applied to new development, re-development, or as retrofits to existing development. The LID principles can also be adapted to a range of land uses from high density urban centers to low density development. The following are common LID practices:

- **Preserving – Clustering – Dispersing:** Protecting or replanting a significant portion of the development site vegetation; locating development on a smaller part of the site; and directing runoff to vegetated areas.
- **Bioretention (Rain Gardens):** Shallow landscaped areas composed of soil and a variety of plants. Bioretention cells are stand-alone features while bioretention swales are part of a conveyance system.
- **Soil Amendments:** Compost added to soils disturbed during the construction process. Restores soil health and its ability to infiltrate water.
- **Pervious/Porous Pavement:** Allows water to infiltrate and removes pollutants. Includes concrete, asphalt, pavers, and grid systems filled with grass or gravel.
- **Vegetative Roofs:** Roofs composed of a waterproof layer, root barrier, drainage layer, growth media and plants. Provides slower release of runoff, improves energy efficiency, extends roof life, and provides wildlife habitat and recreation amenities.
- **Rooftop Rainwater Collection:** Catchment systems or cisterns that collect rooftop runoff for irrigation, grey water, or other purposes. Reduces runoff and demand on ground water supplies.

- **Minimal Excavation Foundations:** Alternative building foundation composed of driven piles and a connector at or above grade. Eliminates the need for extensive excavation and reduces soil compaction.

The Lummi Nation has no specific regulations or development standards requiring new development or re-development to utilize LID techniques for development projects. Large construction projects (greater than one acre of land disturbance) are encouraged to use LID techniques. Many municipal projects already use LID techniques to manage storm water because a large percentage of the Reservation is designated wetland area and there is a limited storm water sewer system (pipes and catch basins). Table 7.1 lists constructed, under-construction, and future development projects utilizing LID techniques for permanent storm water management on the Reservation.

Table 7.1 Land Development Projects on the Reservation Using LID Techniques for Permanent Storm Water Management

Development Project on the Reservation	LID Techniques Utilized
Lummi Nation School	Vegetative Swales, Avoid Wetlands, Preserving Vegetation, and Dispersion to Wetland Areas
Northwest Indian College	Infiltration Swales
Silver Reef Hotel, Casino, and Spa	Infiltration Swales, Dispersion Trenches, and Wetland Area Preservation
Lummi View Drive Sidewalk	Pervious/Porous Pavement
Robertson Road Extension	Infiltration Swales and Dispersion Trenches
Haxton Way Pedestrian Path	Pervious/Porous Pavement and Boardwalk over Wetland Areas
Kwina Village Apartments	Infiltration Galleries and Wetland Area Preservation
Tribal Administration Center	Wetland Preservation, Dispersion Trenches, and Infiltration Ponds; Geothermal Heating
Blackhawk Way	Pervious/Porous Pavement
McKenzie Subdivision IV	Dispersion Trenches and Infiltration pond
Olsen Subdivision Phase 1 and Phase 2	Wetland Area Preservation
Erickson Subdivision	Infiltration Swales/Chambers and Wetland Area Preservation
Smuggler’s Slough Restoration Phase 1 and Phase 2	Wetland Area Preservation and Enhancement

8. COMMUNITY EDUCATION AND OUTREACH

Community involvement is a critical element of a storm water management program. Development and implementation of a successful storm water management program depends on good public education and community outreach initiatives. Well thought out initiatives can help to generate an understanding, support, and cooperation for storm water management practices and benefit the Reservation community. Increased education and outreach to the general public typically results in higher participation rates in storm water best management practices and lowers the incidents of illegal dumping of pollutants into storm systems, rivers, or streams.

Community involvement in a storm water management program is necessary for a number of reasons including:

- Community participation in developing and implementing the management plan is critical to program success.
- Storm water movement does not follow private property or political boundaries.

Two elements of community involvement are community education and interjurisdictional coordination and cooperation.

1. **Community Education:** The public education element of the Lummi Storm Water Management Program includes articles in the Lummi Nation newspaper *Squol Quol* describing storm water management and storm water pollution prevention techniques on the Reservation. The Lummi Planning Department and Lummi Natural Resources Department will continue providing copies of storm water management brochures and BMP details to community members. The Lummi Natural Resources Department will also post storm water education materials on BMPs, LID techniques, storm water laws and regulations, and links to other storm water related websites on the Lummi Natural Resources Department website.
2. **Interjurisdictional Coordination and Cooperation:** The interjurisdictional coordination and cooperation element of the plan will continue within the LIBC, with the U.S. Environmental Protection Agency, with the Washington Department of Ecology, and with neighboring Whatcom County. The Lummi Natural Resources Department will continue working closely with the Lummi Planning Department and other LIBC agencies to implement the community education element of the storm water management program and to educate construction contractors, engineers, tribal members, and other Reservation residents about storm water erosion control BMPs and Storm Water Pollution Prevention Plans.

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9. SUMMARY AND CONCLUSION

The goals of the Lummi Reservation Storm Water Management Program are to: 1) minimize the opportunities for storm water to wash pollutants into aquifer recharge zones and resource rich estuaries and tidelands of the Reservation, 2) minimize the downstream impacts of development on storm water quantity and quality, and 3) maximize the opportunities for infiltration and aquifer recharge. These goals are similar to and consistent with the Lummi Nation Wellhead Protection Program goals (LWRD 1997a).

This update of the 1998 Storm Water Management Program technical background document (LWRD 1998c) includes the following primary changes to the earlier version:

- Revised watershed delineation based on higher resolution topography data.
- New section on applicable federal and tribal laws and regulations.
- Updated storm water facilities inventory and updated inventory of potential pollutant sources.
- Updated descriptions of BMPs for storm water management.
- New section on Low Impact Development.
- Updated storm water community and education program.

This technical background document includes:

- Description of the occurrence of storm water on the Lummi Reservation;
- Discussion of how land use changes affect storm water quantity and quality;
- Identification of potential sources of storm water contamination in the watersheds that drain to the adjacent waterways and aquifer recharge zones of the Reservation;
- Identification of the best management practices (BMPs) available to achieve the storm water management goals;
- Description of Low Impact Development (LID) and the implementation of LID techniques on the Reservation; and
- Description of storm water public education on the Reservation.

The Lummi storm water management goals can be achieved by taking actions such as:

- Planning development to fit the topography, soils, drainage patterns, and natural vegetation of a site.
- Encourage developers to implement Low Impact Development techniques.
- Conducting pollution prevention activities including public education and interjurisdicational cooperation.
- Minimizing impervious areas (i.e., paved or compacted areas).
- Preserving wetland areas.

- Controlling erosion and sediment from disturbed areas within the project site or area.
- Minimizing the extent of disturbed areas.
- Conducting site disturbance work during the drier parts of the year (i.e., May through September).
- Stabilizing and protecting disturbed areas from runoff as soon as possible.
- Minimizing runoff velocities by minimizing slope length and gradient and protecting natural vegetative cover.
- Implementing a thorough storm water facilities maintenance and follow-up program.
- Constructing properly designed detention ponds, wetlands, infiltration trenches, grass swales, and filter strips.

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APPENDIX A

DELINEATION OF WATERSHED BOUNDARIES FROM 2005 LiDAR BARE EARTH SAMPLE POINTS

LUMMI INDIAN BUSINESS COUNCIL
2616 KWINA ROAD · BELLINGHAM, WASHINGTON 98226 · (360)384-1489

MEMORANDUM

DATE: October 8, 2010

TO: Jeremy Freimund, P.H., Water Resources Manager

FROM: Gerald Gabrisch, Geographic Information System Manager

SUBJECT: **Delineation of Watershed Boundaries of the Lummi Indian Reservation from 2005 LiDAR Bare-Earth Sample Points**

Purpose:

This memorandum details the methods and results of a Geographic Information Systems (GIS)-based analysis conducted to delineate watershed boundaries for those lands that contribute to overland flow on the Lummi Indian Reservation (Reservation). This watershed delineation utilized Light Distance and Ranging (LiDAR) bare-earth sample point data collected by Terrapoint USA Inc. (Terrapoint) in 2005. Pursuant to our discussion, the resulting watershed delineations will serve as the 'best available' GIS dataset of watersheds for the Reservation, and replace the 1998 watershed delineations developed through a manual interpretation of United States Geological Survey (USGS) 7.5 minute topographic maps (20-foot contour intervals) coupled with the results of a storm water facilities inventory (LWRD, 1998).

Data:

The data used for this watershed delineation include the following:

- XYZ text files of LiDAR bare-earth sample point data collected by Terrapoint in 2005;
- Lummi Nation GIS data of surface water hydrography including stream channels and agricultural irrigation/drainage ditches;
- On-Reservation storm water facility point locations collected by the Lummi Water Resources Division;
- Off-Reservation storm water facilities point location data collected by the Lummi Water Resources Division and/or Whatcom County; and
- Storm water facilities and catchment boundaries of the City of Ferndale (Ferndale) provided by the Ferndale Public Works Department.

All data were re-projected to the North American Datum of 1983, Washington State Plane North (NAD83WaSPN) coordinate system prior to analysis to conform to the datum, projection, and coordinate system of the LiDAR data. All x and y coordinate values are measured in feet. All elevation values (z coordinates) represent feet above the North American Vertical Datum of 1988 (NAVD 88).

Methods:

Text files containing the x, y, and z values of individual LiDAR bare-earth sample points were used to construct an ESRI ArcGIS terrain data model. The resulting terrain model is a single continuous elevation surface model over the extent of the LiDAR collection area. Because this terrain data model cannot be used for hydraulic modeling, the data were subsequently transformed into ESRI Grid (raster) surface models. A total of eight ESRI Grid surface models were created using five different pixel sizes and two different interpolation methods available in the ArcGIS v 9.3 software package (Table 1). To reduce file sizes and speed computer processing time, each Grid surface model was clipped to only include the Reservation areas upland of the tidal vegetation line.

The areas covered by the catchment boundaries of Ferndale were also excluded from the GIS analysis because the natural flow regime within the Ferndale residential and commercial core area is altered by a network of storm water facilities. Additionally, since an extensive body of data was provided by the City of Ferndale including flow directions of storm sewers, outlet locations, and catchment boundaries, the Ferndale data were considered higher quality than the LiDAR/GIS analysis performed for this study for those areas.

Table 1. Surface model cell resolutions and interpolation methods.

Raster Grid Resolution/Cell Size	Interpolation Method	Used For Watershed Delineation
30-feet	Linear	Yes
30-feet	Natural Neighbors	Yes
6-feet	Linear	No
6-feet	Natural Neighbors	No
3-feet	Linear	Yes
3-feet	Natural Neighbors	Yes
1-foot	Linear	No
0.5-foot	Linear	No

Different raster cell sizes and different interpolation algorithms used to generate the raster surface models resulted in different watershed delineations. To assess the quality of the different surface models listed in Table 1, a root mean square error (RMSE) calculation was preformed on each dataset to determine which raster surface had the highest accuracy and therefore would likely result in the highest quality watershed delineation. The RMSE value determines the standard deviation for the interpolated pixel values of the surface model and the values of known surveyed locations (Equation 1)(Wu et al., 2008). The greater the RMSE, the less accurate the model.

Additionally, the RMSE value was generated for a 10-meter pixel USGS surface model for comparison. The surveyed sample points used for the RMSE included 50 locations where the land surface elevation had been determined using professional field survey techniques by Pacific Survey and Engineering and 13 locations surveyed by TerraPoint. Table 2 shows the RMSE values for each surface model.

Equation 1. Root Means Square Error equation to determine the difference in standard deviations (in feet) between the interpolated cell values and the surveyed point elevation values.

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(x_{1,i} - x_{2,i})^2}{n}}.$$

Where X_1 represents the interpolated pixel value at the location of X_2, X_2 is the surveyed elevation value, and n represents the total count of surveyed locations.

Table 2. Root Mean Square Error values showing the standard deviation in feet between the interpolated pixel value and the value at a surveyed location coincident to the interpolated cell.

Surface Model Resolution	Interpolation Method	RMSE (feet)
USGS 10-meter	Unknown	6.583
30-feet	Linear	1.478
30-feet	Natural Neighbors	1.473
6-feet	Linear	1.393
6-feet	Natural Neighbors	1.388
3-feet	Linear	1.393
3-feet	Natural Neighbors	1.387
1-foot	Linear	1.390
0.5-foot	Linear	1.469

The 3-feet grid, natural neighbors interpolation model was selected for the watershed delineation process based on the RMSE values and the available computer processing capabilities. The 1-foot and the 0.5-foot surface models were excluded from the watershed delineation process because the RMSE was similar to the 3-feet grid surface models and the file sizes were too large to process using available desktop computer processors. The surface models using the 6-feet grid cell size were excluded because the RMSE values were nearly identical to the 3-feet RMSE, which better captures elevation heterogeneity through increased cell resolution. The 30-feet and the 10-meter surface models were not used because the RMSE was larger than the surface models developed using the 3-feet grid cell size.

The LiDAR technology cannot capture the flow path of storm water facilities underneath roads because those flow paths are blocked from the aerial view of the LiDAR collection system. To enforce hydrologic connectivity in those areas traversed by raised road beds, 'culvert burning' was used to establish flow paths through storm water facilities (Duke, 2003). The point data of storm water facility locations collected by the Lummi Nation Water Resources Division and Whatcom County were combined into a single dataset of storm water facilities. A 50-feet buffer polygon around each storm water facility was created to sufficiently span the width of the raised road beds. The resulting storm water facility buffers were converted to a 3-feet raster Grid surface model and assigned an elevation value equal to the minimum value of the entire LiDAR dataset. The pixel values of the storm water facility grid were used to computationally replace the coincident pixels in the surface models, thereby establishing a connective flow path across the "obstruction" created by the raised road beds.

The hydrography vector lines were manually edited to ensure that for each individual line segment the line direction of flow matched the direction of flow detailed in the Lummi Nation Storm Water Facilities Inventory. The ESRI ArcHydro geoprocessor cannot calculate flow directions in a network of looping flow paths, for example braided streams or interconnected drainage ditches(Maidment, 2002). For this reason, some hydrography lines had their uphill node disconnected from the network of flow paths to ensure that no flow lines formed closed loops.

The resulting 'culvert burn' surface model and the non-looping hydrography data set were imported into an ArcGIS/ArcHydro geodatabase. The ArcHydro database allowed the stream network (hydrography) to be 'burned' into the surface models, enforcing flow connectivity based on the configuration of the stream network (Maidment, 2002). The resulting hydrologically corrected surfaces were filled using the ArcGIS *fill* function to remove sinks and obstructions from the surface models that might impede the analysis.

The filled surface models were used to generate flow direction surfaces detailing the flow direction from each cell to one of its eight adjacent neighbors (Figure 1). The flow direction surfaces were then used to generate a flow accumulation surface where the numeric value of each pixel represents the total count of individual cells that flow into that cell (Figure 2). The flow accumulation surfaces were used to generate watershed boundaries where all cells that share a "pour point" are assigned a unique nominal numeric value (Figure 3). The basin output was transformed from its grid format into a polygon data structure.

Upon a manual inspection of the Ferndale storm water facility outfall, all Ferndale catchment polygons that contributed to overland water flow onto the Reservation were added to the polygons of basins.

Finally, the polygon data were manually aggregated into watersheds to mimic those watersheds delineated in 1998 based on the 7.5 minute USGS topographic maps (LWRD, 1998).

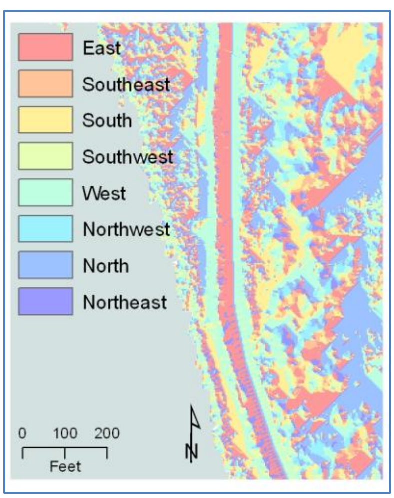

Figure 1. A typical flow direction surface. Each cell stores a numeric value detailing the flow direction in one of eight cardinal directions.

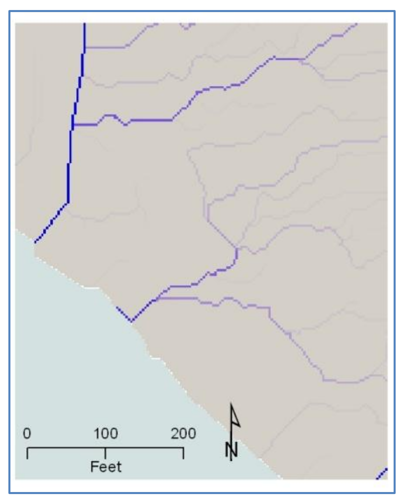

Figure 2. A typical flow accumulation surface; each cell stores the count of cells that pour into that cell. Higher cell counts are displayed as a darker blue. Coloration does not necessarily indicate a perennial or seasonal stream.

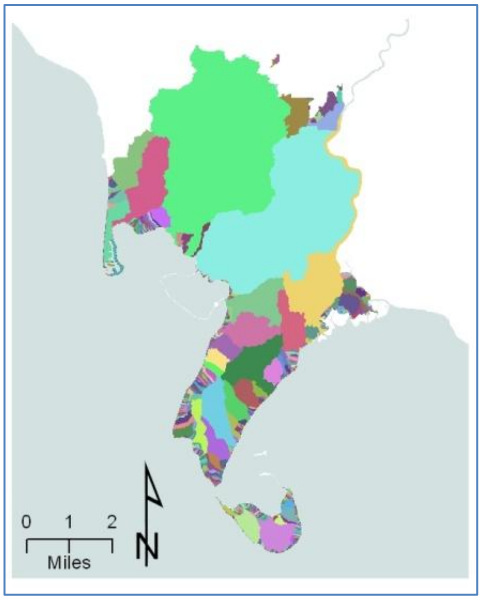

Figure 3. Resulting basin boundaries; each color represents an area that is hydrologically connected. (Catchments are not aggregated into Watersheds and City of Ferndale catchments were not incorporated into this figure.)

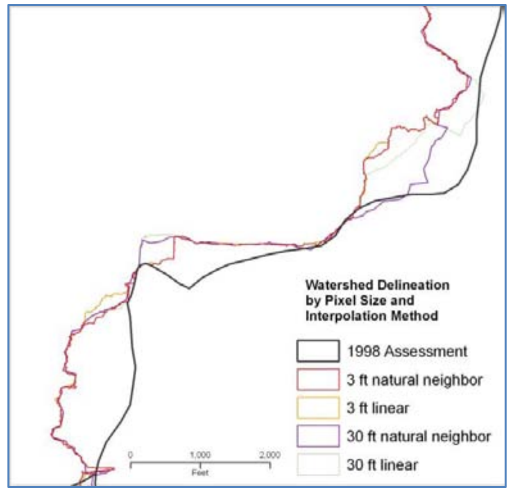

Figure 4. Detail showing the resulting watershed delineations based on different pixel cell sizes and interpolation methods compared with the 1998 topographic map delineation.

Results:

In the coarser surface models, for example in the 30-feet pixel surfaces, the value of the cell is the average value of all LiDAR points that fall within that cell. When the pixel size is larger than the density of the sample points, the RMSE should increase since the surface model is relying more heavily on the interpolation algorithm and therefore more prone to over-estimations and under-estimations(Aguilar, 2006). Because the 3-feet grid, natural neighbor interpolation surface model resulted in the lowest RMSE and provided the highest resolution surface that could be processed with available computers, the 3-feet natural neighbor model was selected as the best available surface from which to generate watershed boundaries. Figure 4 highlights some of the different catchment lines resulting from different pixel sizes and different interpolation algorithms.

Figure 4 demonstrates that given the same elevation sample data, different catchment boundaries will be calculated based on differences in pixel resolution (i.e., cell size). While the 3-feet raster resulted in the highest quality surface model, the catchments generated by this surface model are affected by error introduced in the LiDAR sampling and post processing, the data models, and the assumptions incorporated into the GIS functions and methods. The user of these data should be aware of the inherent abstraction of spatial data when making policy decisions. More extensive field surveys and sampling may be required to confirm/verify the delineated catchment boundaries.

Figure 5 shows the 1998 watershed boundaries developed from the USGS topographic maps compared to the watershed boundaries developed from the LiDAR data. As shown in Figure 5, the boundaries are generally similar with a few notable exceptions.

Table 3 shows a comparison of the 1998 delineation and the 2005 LiDAR-based delineation that resulted from this study. Approximately 933 acres were added to all watersheds that contribute overland flow to the Reservation. Two watersheds from the 1998 delineation (Watershed M and Watershed N) were discontinued. Watershed M was a small isolated island located at the mouth of the Lummi River channel and the Lummi River channel downstream from the Schell Creek confluence and waterward of the levees along the channel. This watershed was combined with Watershed L. Watershed N was combined with Watershed O as the LiDAR delineations did not identify these areas as separate catchments. Watershed T is a newly delineated watershed that isolates a portion of Watershed K from the 1998 delineation. Watershed S includes the entire Nooksack River drainage area, a vast majority of which is not covered by the 2005 LiDAR data. Although most of Watershed S extends off-Reservation and beyond the geographic scope of the LiDAR data, the LiDAR data were used to delineate the western extent of Watershed S on the Reservation. The acreage for Watershed S listed in Table 3 is the acreage total reported by the WRIA 1 Watershed Management Project (www.wria1project.whatcomcounty.org).

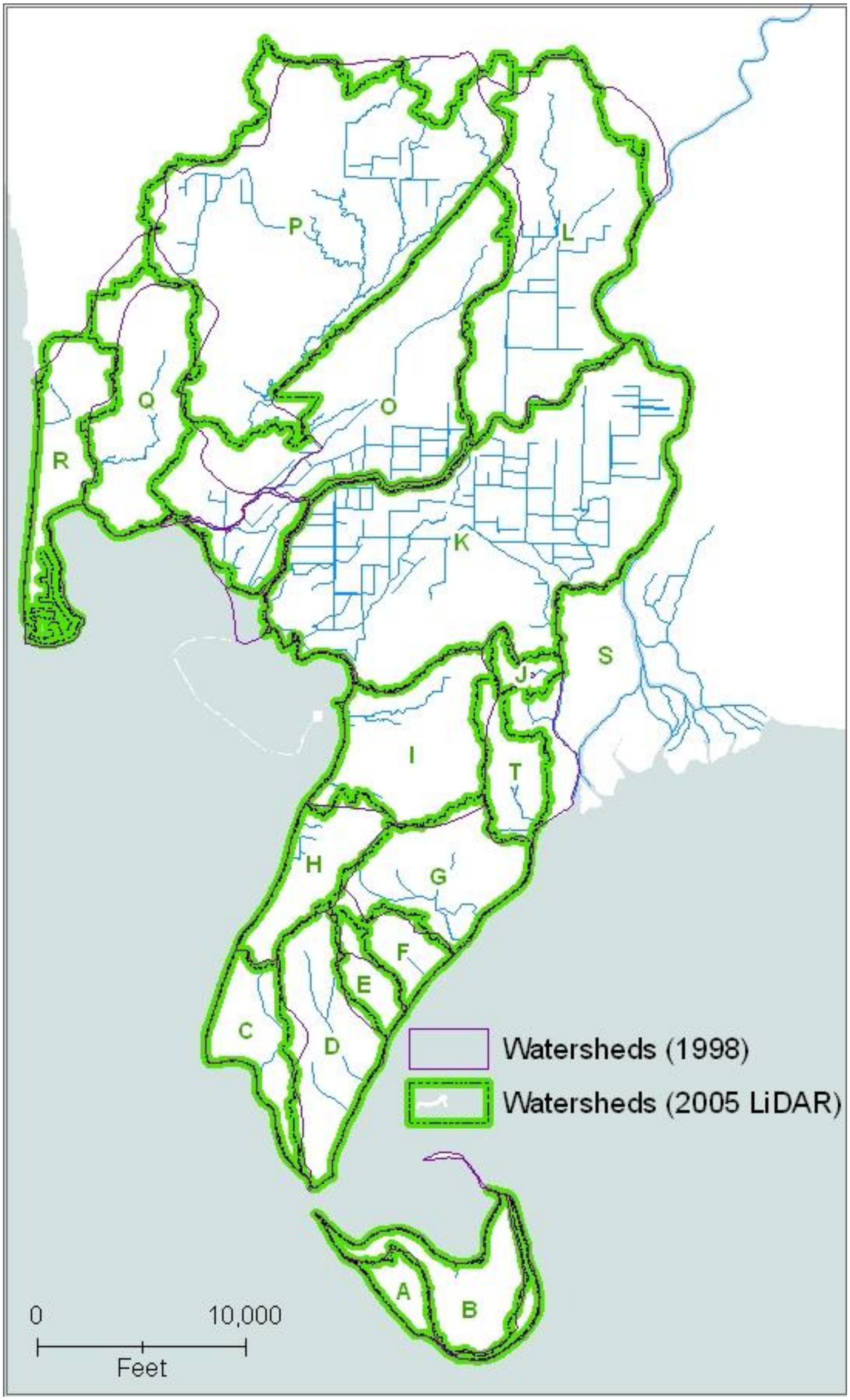

Figure 5. Final watershed delineation based on the 2005 LiDAR data and incorporation the City of Ferndale catchment boundaries.

Table 3. Watershed identifiers and acreage total comparisons between the 1998 delineation and the 3-feet natural neighbors surface model.

Watershed ID	Stream Name	1998 7.5 min Topographic Map Delineations (acres)	2005 LiDAR Delineations (acres)	Difference in Watershed Area (acres)	Difference in Watershed Area (percent difference)
A	Unnamed	306.8	279.7	-27.1	-9.7
B	Unnamed	633.9	616.7	-17.2	-2.8
C	Unnamed	583.3	493.8	-89.5	-18.1
D	unnamed	797.5	894.4	96.9	10.8
E	unnamed	183.2	218.3	35.1	16.1
F	unnamed	326	250.8	-75.2	-30.0
G	unnamed	836.1	883.3	47.2	5.3
H	unnamed	537.3	549	11.7	2.1
I	unnamed	1,142.3	1,058.9	-83.4	-7.9
J	unnamed	86.8	134.2	47.4	35.3
K	Smuggler Slough	4,696.50	4,091.1	-605.4	-14.8
L	Lummi River	2,384.0	2,306.5	-77.5	-3.4
M	unnamed	198.1	combined with Watershed L	n/a	n/a
N	unnamed	333.4	combined with Watershed O	n/a	n/a
O	Schell Creek/Northern Distributary of the Lummi River	1,964.3	2,746.8	782.5	28.5
P	Jordan Creek	4,228.9	4,097.1	-131.8	-3.2
Q	Onion Creek	1,291.7	1,096.4	-195.3	-17.8
R	unnamed	1,023.8	721.8	-302	-41.8
S	Nooksack River	517,718 (WRIA1 area)	south western extent of watershed only	n/a	n/a
T	unnamed	extracted from Watershed K	392.46	n/a	n/a
Total		21,553.9	22,486.7	932.5	4.2

Conclusions:

Using the 2005 Terrapoint LiDAR bare-earth point data, digital terrain models (DTMs) were developed using several grid cell sizes and interpolation methods. A root square mean analysis was used to identify the surface model with elevation values most similar to professionally surveyed control points. A 3-feet natural neighbor interpolation DTM was identified as the surface model with the highest level of precision and that had pixel sizes that were large enough to be manageably analyzed using available computer resources.

The 3-feet natural neighbor DTM was incorporated into an ESRI ArcGIS 9.3 ArcHydro geodatabase along with point data of storm water facilities, and line data of known stream channels and agricultural drainage ditches. The storm water data and surface water hydrography data were used to enforce hydrologic connectivity by computationally breaching LiDAR artifacts such as bridges or culvert passages under roads.

The hydrologically corrected surface model was analyzed using standard GIS procedures including sink filling, identifying flow directions, calculating flow accumulations, and generating basin boundaries to identify the basin boundaries. The final basin boundaries were combined into watershed administrative units based on the watershed units developed as part of the 1998 watershed delineation (LWRD, 1998).

The final watershed boundaries developed from the 2005 LiDAR data resulted in a 584-acre gain (or 4.2 percent increase) in area from the original 1998 delineation. Watershed M from the 1998 delineation was incorporated into Watershed L, Watershed N was incorporated into watershed O, and one new watershed (Watershed T) was added based on the refinement made possible with the 2005 LiDAR data. Watershed S includes those lands that contribute overland-flow to the Nooksack River. Because the 2005 LiDAR coverage does not include the entire Nooksack River basin, only the southwestern extent of Watershed S was determined as part of this analysis. The remainder of the Watershed S boundary was determined as part of the WRIA 1 Watershed Management Project and these results were adopted to estimate the acreage associated with the Nooksack River watershed.

The final dataset was loaded onto the Lummi Nation GIS data server and metadata was created. The final data detailed in this report is available at *Z:\Data\Boundaries\Watersheds\LummiWatershedsBestAvailable.shp*.

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APPENDIX B

LUMMI STORM WATER FACILITIES INVENTORY FORM

LUMMI STORM WATER DRAINAGE FACILITIES INVENTORY FORM

Date: ________________________ Weather Conditions: _______________

Observations By: _________________________ Water Present?: Yes No

Road/Street Name: ____

Intersection Used As Station 0.0 (e.g., Smokehouse Rd./Lummi Shore Road):

____

Direction of Travel from Station 0.0 (e.g., Toward Haxton Way): _______________________

Culvert/Structure Identification Number (1 = Culvert Closest to Station 0.0):_____________

Distance from Station 0.0 (from vehicle odometer): _________________ miles.

Culvert Size (diameter or dimensions): _______________ Units: Feet Inches

Material:

- Galvanized, Corrugated (GALV)
- Corrugated Steel (C/S)
- Corrugated Plastic (ADS)
- Smooth Plastic (SCLAIR)
- Aluminum (ALUM)
- Bell and Spigot Concrete (B/S)
- Tongue and Groove Concrete (T/G)
- Catch Basins (C/B)
- PVC (PVC)
- Unknown (0.00)

Condition:

- Good (1)
- Percent Blocked U/S End (2U) ________
- Percent Blocked D/S End (2D) ________
- U/S End Smashed/Cut (3U)
- D/S End Smashed/Cut (3D)
- Needs Replacement (4)
- Separated (5)
- U/S End Eroding (6U)
- D/S End Eroding (6D)
- U/S End Needs Extension (7U)
- D/S End Needs Extension (7D)
- Needs to be Rechecked (8)
- Other: ____

Inlet:

Defined Stream Channel Flows into Upstream Side of Culvert? Yes No

Roadside Ditch Along Upstream Side and Contributing Flow to Culvert? Yes No

Condition of Roadside Ditch Along Upstream Side of Culvert:

- Grass-Lined (1)
- Dirt-Lined (2)
- Shrub/Brush (3)
- Sparse Vegetation (4)
- Rocked (5)
- No Defined Ditch (6)
- Debris Present (7)
- Oil Present (8)
- Other (9)_______

(Please Complete Back of Form)

Outlet:

Defined Stream Channel Flows Away From Downstream Side of Culvert? Yes No

Roadside Ditch Along Downstream Side and Collecting Flow from Culvert? Yes No

Condition of Roadside Ditch Along Downstream Side of Culvert:

Grass-Lined (1)	Sparse Vegetation (4)	Debris Present (7)
Dirt-Lined (2)	Rocked (5)	Oil Present (8)
Shrub/Brush (3)	No Defined Ditch (6)	Other (9)_______

Diagram:

Make a sketch of the culvert/structure crossing and indicate at least the following items:

Road/street name
Travel direction and distance from Station 0.0
Culvert identification number
Flow direction(s) upstream and downstream side
Landmarks (driveways and street address, road crossings, sewer manholes, etc...)
Driveway culverts (indicate location, material, and diameter)
Nearby culverts crossing road/street (use culvert identification number)
Wetlands and/or areas with ponded water
Condition of roadside ditches
Location of slope breaks (i.e., where flow direction changes) in roadside ditches and approximate distance from slope breaks to culvert.

16

LUMMI STORM WATER DRAINAGE FACILITIES INVENTORY FORM

Date: 2/7/97 Weather Conditions: Sunny

Observations By: JRF FEB Water Present?: ☒ Yes ☐ No

Road/Street Name: Haxton Way

Intersection Used As Station 0.0 (e.g., Smokehouse Rd./Lummi Shore Road): Slater / Haxton

Direction of Travel from Station 0.0 (e.g., Toward Haxton Way): toward Gooseberry Pt

Culvert/Structure Identification Number (1 = Culvert Closest to Station 0.0): 16

Distance from Station 0.0 (from vehicle odometer): 3.75 miles. (FB, SF 3-9-98 mp 3.6)

Culvert Size (diameter or dimensions): 24" Units: ☐ Feet ☒ Inches

Material:

- ☐ Galvanized, Corrugated (GALV)
- ☐ Corrugated Steel (C/S)
- ☐ Corrugated Plastic (ADS)
- ☐ Smooth Plastic (SCLAIR)
- ☐ Aluminum (ALUM)
- ☐ Bell and Spigot Concrete (B/S)
- ☒ Tongue and Groove Concrete (T/G)
- ☐ Catch Basins (C/B)
- ☐ PVC (PVC)
- ☐ Unknown (0.00)

Condition:

- ☐ Good (1)
- ☒ Percent Blocked U/S End (2U) 40%
- ☒ Percent Blocked D/S End (2D) 0%
- ☐ U/S End Smashed/Cut (3U)
- ☐ D/S End Smashed/Cut (3D)
- ☐ Needs Replacement (4)
- ☐ Other: ______
- ☐ Separated (5)
- ☐ U/S End Eroding (6U)
- ☐ D/S End Eroding (6D)
- ☐ U/S End Needs Extension (7U)
- ☐ D/S End Needs Extension (7D)
- ☐ Needs to be Rechecked (8)

Inlet:

Defined Stream Channel Flows into Upstream Side of Culvert? ☒ Yes ☐ No

Roadside Ditch Along Upstream Side and Contributing Flow to Culvert? ☒ Yes ☐ No

Condition of Roadside Ditch Along Upstream Side of Culvert:

- ☐ Grass-Lined (1)
- ☐ Dirt-Lined (2)
- ☒ Shrub/Brush (3)
- ☒ Sparse Vegetation (4)
- ☐ Rocked (5)
- ☐ No Defined Ditch (6)
- ☐ Debris Present (7)
- ☐ Oil Present (8)
- ☐ Other (9)______

(Please Complete Back of Form)

Outlet:

Defined Stream Channel Flows Away From Downstream Side of Culvert? ☒ Yes ☐ No

Roadside Ditch Along Downstream Side and Collecting Flow from Culvert? ☒ Yes ☐ No

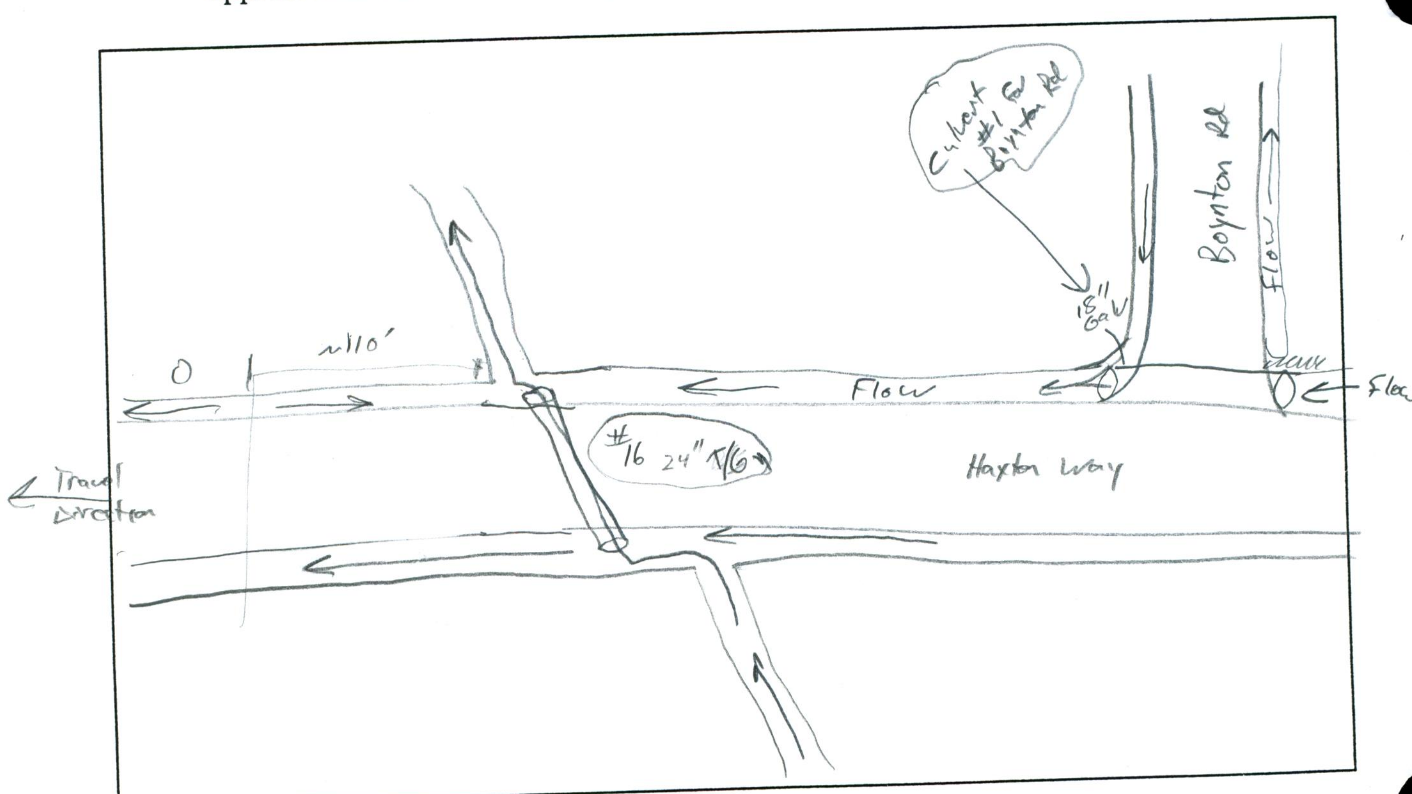
Condition of Roadside Ditch Along Downstream Side of Culvert:

☒	Grass-Lined (1)	☐	Sparse Vegetation (4)	☐	Debris Present (7)
☐	Dirt-Lined (2)	☐	Rocked (5)	☐	Oil Present (8)
☐	Shrub/Brush (3)	☐	No Defined Ditch (6)	☐	Other (9)________

Diagram:

Make a sketch of the culvert/structure crossing and indicate at least the following items:

- ☑ Road/street name
- ☑ Travel direction and distance from Station 0.0
- ☑ Culvert identification number
- ☑ Flow direction(s) upstream and downstream side
- ☑ Landmarks (driveways and street address, road crossings, sewer manholes, etc...)
- ☑ Driveway culverts (indicate location, material, and diameter)
- ☑ Nearby culverts crossing road/street (use culvert identification number)
- ☐ Wetlands and/or areas with ponded water
- ☐ Condition of roadside ditches
- ☐ Location of slope breaks (i.e., where flow direction changes) in roadside ditches and approximate distance from slope breaks to culvert.



268

LUMMI STORM WATER DRAINAGE FACILITIES INVENTORY FORM

Date: 8/23/10 Weather Conditions: sunny/clear

Observations By: JMS & VLJ Water Present?: Yes (No)

Road/Street Name: Lummi Shore Rd.

Intersection Used As Station 0.0 (e.g., Smokehouse Rd./Lummi Shore Road):
Haxton Way/LSR

Direction of Travel from Station 0.0 (e.g., Toward Haxton Way): toward Lummi View

Culvert/Structure Identification Number (1 = Culvert Closest to Station 0.0): 268 ? moved to Replace #27

Distance from Station 0.0 (from vehicle odometer): ~6.12 miles.

Culvert Size (diameter or dimensions): 24" Units: Feet (Inches)

Material:

- Galvanized, Corrugated (GALV)
- Corrugated Steel (C/S)
- X Corrugated Plastic (ADS)
- Smooth Plastic (SCLAIR)
- Aluminum (ALUM)
- Bell and Spigot Concrete (B/S)
- Tongue and Groove Concrete (T/G)
- Catch Basins (C/B)
- PVC (PVC)
- Unknown (0.00)

Condition:

- X Good (1) /New
- Percent Blocked U/S End (2U) ________
- Percent Blocked D/S End (2D) ________
- U/S End Smashed/Cut (3U)
- D/S End Smashed/Cut (3D)
- Needs Replacement (4)
- Separated (5)
- U/S End Eroding (6U)
- D/S End Eroding (6D)
- U/S End Needs Extension (7U)
- D/S End Needs Extension (7D)
- Needs to be Rechecked (8)

Other: ________________________________

Inlet:

Defined Stream Channel Flows into Upstream Side of Culvert? Yes (No)

Roadside Ditch Along Upstream Side and Contributing Flow to Culvert? (Yes) No

Condition of Roadside Ditch Along Upstream Side of Culvert:

- X Grass-Lined (1)
- Dirt-Lined (2)
- Shrub/Brush (3)
- Sparse Vegetation (4)
- Rocked (5)
- No Defined Ditch (6)
- Debris Present (7)
- Oil Present (8)
- Other (9)________

(Please Complete Back of Form)

Outlet:

Defined Stream Channel Flows Away From Downstream Side of Culvert? Yes X No – unknown no water

Roadside Ditch Along Downstream Side and Collecting Flow from Culvert? Yes X (No)

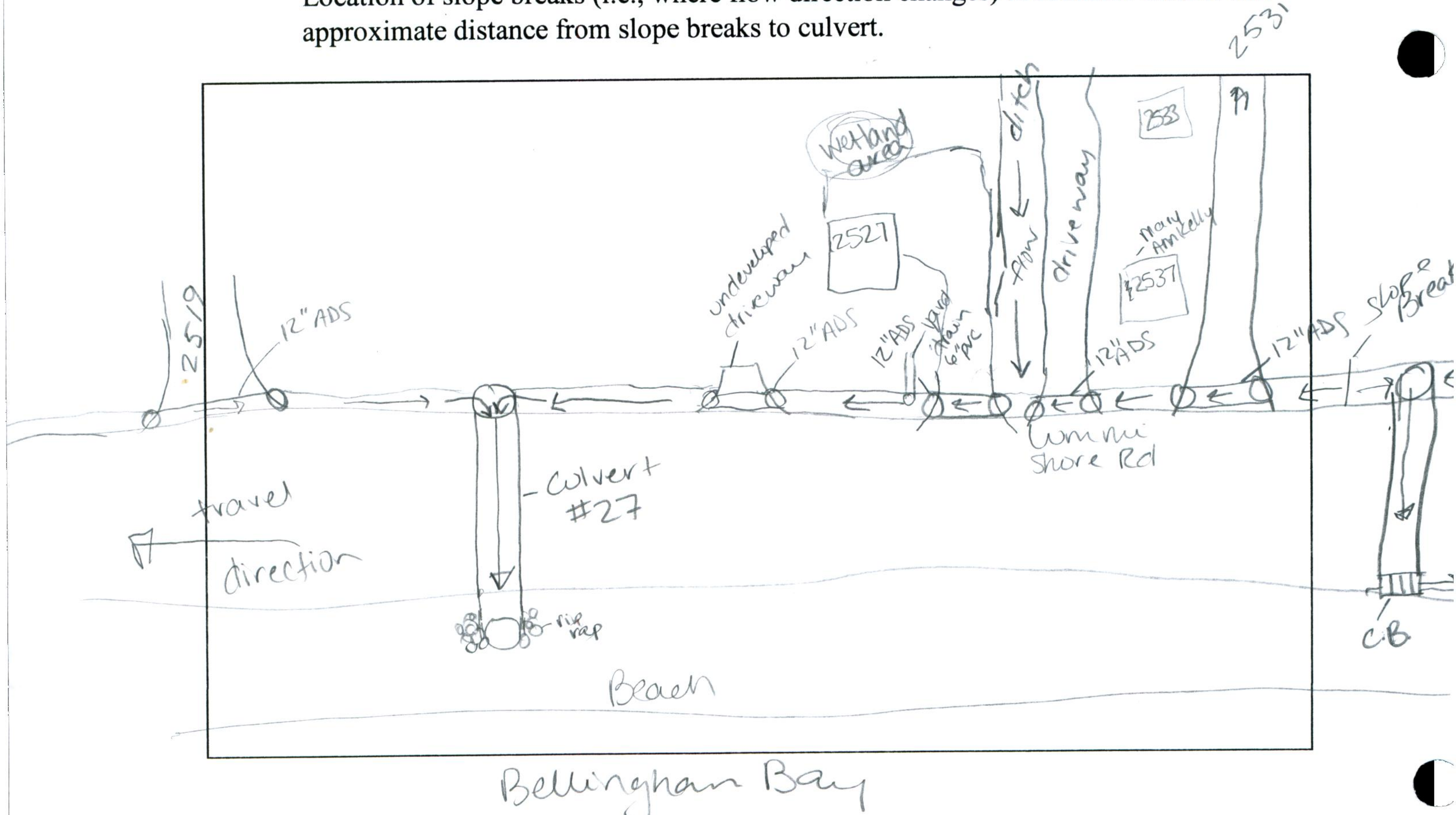
Condition of Roadside Ditch Along Downstream Side of Culvert:

Grass-Lined (1)	Sparse Vegetation (4)	Debris Present (7)
Dirt-Lined (2)	X Rocked (5)	Oil Present (8)
Shrub/Brush (3)	No Defined Ditch (6)	X Other (9) Beach

Diagram:

Make a sketch of the culvert/structure crossing and indicate at least the following items:

- X Road/street name
- X Travel direction and distance from Station 0.0
- X Culvert identification number
- X Flow direction(s) upstream and downstream side
- X Landmarks (driveways and street address, road crossings, sewer manholes, etc...)
- X Driveway culverts (indicate location, material, and diameter)
- Nearby culverts crossing road/street (use culvert identification number)
- Wetlands and/or areas with ponded water
- Condition of roadside ditches
- Location of slope breaks (i.e., where flow direction changes) in roadside ditches and approximate distance from slope breaks to culvert.



APPENDIX C

LUMMI STORM WATER FACILITIES SUMMARY INFORMATION

Appendix C. Lummi Nation 1998 and 2010 Culvert Inventory

Table C.1 Selected 1998 and 2010 Culvert Inventory Data

ID Number	Street Name	Culvert Number	Culvert Size	Comments
1	Haxton Way	1	18	Drains west, crosses to north of Slater in Slater#17, back south in Slater #18
2	Haxton Way	2	18	None
3	Haxton Way	3	0	Bridge over Lummi River
4	Haxton Way	4	36	Flat water in ditches, flow direction estimated
6	Haxton Way	6	36	Ditch invert below culvert invert
7	Haxton Way	7	36	Ditch invert below culvert inlet
8	Haxton Way	8	48	Receives flow from Kwina #1and Lummi Shore Road #2, flows to Lummi Bay
9	Haxton Way	9	12	Wetland to west contributes flow to outlet Roadside Ditch
10	Haxton Way	10	12	Wetland to west contributes flow to outlet Roadside Ditch
11	Haxton Way	11	12	Outlet ditch drains to wetland/floodplain north of Planning Office via 24"
12	Haxton Way	12	18	Drains in ditchline to floodplain and waterway near Kwina#2
13	Haxton Way	13	18	Drains to stream channel; blocked during waterline construction (Fall 1996)
14	Haxton Way	14	18	Drains to area of ponded water, culvert end broken off
15	Haxton Way	15	36	Stream drains area by Scott Road, Discharges to beach near Seaponds Rd
16	Haxton Way	16	24	Discharges to Robertson Rd #1
17	Haxton Way	17	12	Wet areas at inlet and outlet, standing water in both ditches
18	Haxton Way	18	12	Believed to discharge to beach via Robertson#2
19	Haxton Way	19	18	Nearest to Sludge Site. Believed to discharge to beach via Robertson#3
20	Haxton Way	20	18	Discharges to Sunset Way#1 then to Cagey Rd#3
21	Haxton Way	21	18	Discharges to Sunset Way#1 then to Cagey Rd#3
22	Haxton Way	22	12	Ponded area at outlet, stagnant water, no ditch or stream draining outlet
23	Haxton Way	23	18	Berm in ditch just below inlet, Discharges to beach via 8" GALV driveway
24	Haxton Way	24	18	Drains McKenzie Housing (Eagle Rd), 18" PVC, Discharges to beach in 24" PVC
25	Haxton Way	25	24	24" PVC, Joined by 18" PVC from #24, Discharges to beach (24"PVC),tide gate
26	Lummi Shore Road	2	60	Outflow direction is to Haxton Way#8; discharge to Lummi Bay via Kwina#2
27	Lummi Shore Road	3	18	Drains to thick brush and wetland, inlet is residential ditch
28	Lummi Shore Road	4	12	Drains to Culvert #4 on Marine Drive, inlet ditch along south of church
29	Lummi Shore Road	5	12	Drains wetland/standing water; discharges to wetland
30	Lummi Shore Road	6	18	Discharges to wetland area
32	Lummi Shore Road	8	18	Discharges to wetland area
33	Lummi Shore Road	9	18	Discharges to wetland area
34	Lummi Shore Road	10	12	Receives water from wetland area/ponded water; discharges to wetland area
35	Lummi Shore Road	11	18	Discharges to wetland area; tide gate at outlet
36	Lummi Shore Road	12	18	Discharges to wetland area
37	Lummi Shore Road	13	24	Inlet T/G; Outlet GALV, Discharges to beach
38	Lummi Shore Road	14	24	Discharges to beach, drains wetland overflow north of gravel road
39	Lummi Shore Road	15	18	Discharges to beach,outfall combines with stream draining Lummi Shore Rd#14
40	Lummi Shore Road	16	24	Discharges to beach, drains Cagey#9, Lightening Bird Lane#1,& So. of LSR#15
42	Lummi Shore Road	18	24	Discharges to beach, flow from KB#2, probably includes flow from Cagey#7
43	Lummi Shore Road	19	48	Discharges to beach, probably includes flow from Cagey#5 and Cagey#6, KB#7
45	Lummi Shore Road	21	24	Discharges to beach, includes flow from Smokehouse#3, #4, #6, and #7
46	Lummi Shore Road	22	24	Discharges to beach
53	Lummi Shore Road	29	18	Discharges to beach and replaced in 1998
54	Lummi Shore Road	30	18	Discharges to beach; tide gate on inlet
61	Lummi View Drive	2	12	Outlet not located, discharges to beach via ditch

Table C.1 Selected 1998 and 2010 Culvert Inventory Data

ID Number	Street Name	Culvert Number	Culvert Size	Comments
62	Lummi View Drive	3	12	Discharges to beach, gully at outlet
63	Lummi View Drive	4	18	Discharges to beach, drains new McKenzie housing, McKenzie#1, and wetland
64	Lummi View Drive	5	12	Could not locate inlet; outlet discharges to ponded area, no outlet
65	Lummi View Drive	6	12	Discharges to beach, from C/B #1 on Lena Rd.
66	Lena Road	1	12	Discharges to beach via 12" GALV and Lummi View Drive#6
67	Emma Road	1	12	Discharges to beach; via 12" PVC
68	McKenzie Road	1	12	Drains McKenzie housing waterline road, Discharges to Lummi View Dr#4
69	Leeward Place	1	12	Discharges to beach (apparently - outlet on private property)
70	Leeward Way	1	12	Inlet and outlet not found; believed to discharge to beach
71	Boynton Road	1	18	None
72	Boynton Road	2	12	Discharges to Robertson Road#1
73	Robertson Road	1	30	Discharges to beach/Lummi Bay
74	Robertson Road	2	15	Discharges to beach via 12" T/G
75	Robertson Road	3	24	Discharges to beach/Lummi Bay
76	Harnden Road	1	12	Discharges to beach via ditch and channel just north of Harnden Rd.
77	Harnden Road	2	12	Discharges to beach via ditch and channel just north of Harnden Rd.
78	Smokehouse Road	1	18	D/S end covered by gravel, discharges to Lummi Shore Road #20
79	Smokehouse Road	2	18	Discharges to Lummi Shore Road #20
80	Smokehouse Road	3	18	Drains area near Kinley Way, Discharges to B. Bay via Lummi Shore Road#21
81	Smokehouse Road	4	18	Large area of ponded water near inlet & outlet
82	Smokehouse Road	5	8	Non-functional; Inlet above ditch, outlet buried
83	Smokehouse Road	6	18	Outlet ditch discharges to stream from Culvert #3
84	Smokehouse Road	7	18	Discharges via roadside ditch to stream at outlet of Smokehouse#3
85	Smokehouse Road	8	18	Likely drains toward Lummi Shore Road#27-#30
86	Smokehouse Road	9	24	Ponded water west of inlet and outlet
87	Smokehouse Road	10	24	Wetland area around inlet and outlet
88	Smokehouse Road	11	24	Large wetland area around inlet and outlet
89	Smokehouse Road	12	24	Outlet drains north along Haxton Way; crosses at Haxton Way#23
90	Kinley Way	1	12	Kinley Way flow via gutter/curb to C/Bs, 12" T/G cross to Smokehouse#7,6,3
91	Cagey Road	1	12	Drains to Cagey#3 via Sunset Way#1
92	Cagey Road	2	12	Drains to Cagey#1
93	Cagey Road	3	24	Discharges to beach just south of beach access road.
94	Cagey Road	4	18	Outlet to roadside ditch along Haxton Way, flows to beach via Haxton Way#19
95	Cagey Road	5	18	Inlet 18" ADS, small outlet stream flows south
96	Cagey Road	6	12	Drains housing in Zeta Place (perimeter ditch is source of most of flow)
97	Cagey Road	7	18	Drains large wetland area north of Cagey and east of Chief Martin Rd.
98	Cagey Road	8	12	Drains area near Tony's Auto Wrecking
99	Cagey Road	9	12	Discharges to Lummi Shore Road #16
100	Sunset Way	1	24	Discharges to Cagey Road#3
101	Lightening Bird Lane	1	24	Discharges to Lummi Shore Road#16
102	Chief Martin Road	1	12	Contributes flow to Kwina#1, more flow along west side of Chief Martin
103	Chief Martin Road	2	12	Culvert in roadside ditch along west side of Chief Martin Road
104	Chief Martin Road	3	12	Culvert in roadside ditch along west side of road; flows to Chief Martin#2
105	Chief Martin Road	4	18	Drains west part of Scott Road too, contributes to flow at Chief Martin #5
106	Chief Martin Road	5	12	Drains to Lummi Bay via Haxton Way#15
107	Chief Martin Road	6	12	Culvert in ditch along west side of Chief Martin Road

Table C.1 Selected 1998 and 2010 Culvert Inventory Data

ID Number	Street Name	Culvert Number	Culvert Size	Comments
108	Chief Martin Road	7	24	Small streams around culvert inlet drain wetland to east of Chief Martin Rd
109	Chief Martin Road	8	12	Drains to Cagey Road#7
110	Scott Road	1	18	Drains to Scott Road#2, small stream near outlet also contributes flow
111	Scott Road	2	24	Drains to Kwina Slough via Lummi Shore Road#7
112	Kwina Road	1	36	Drains via ditchline around pasture eastern perimeter to Haxton Way#8
113	Kwina Road	2	84	Flow in both directions (tidal influence), box culvert 3ft x 6ft inside
114	Kwina Road	3	24	Submerged, flow may be in both directions (tidal influence)
115	Hillaire Road	1	18	Submerged, flow may be in both directions (tidal influence)
116	Hillaire Road	2	18	Submerged, flow may be in both directions (tidal influence)
117	Hillaire Road	3	0	Bridge over Lummi River, levee on both sides
118	South Red River Road	1	18	Discharges to Beach via Lummi River, suspended pipeline (pumped)
119	South Red River Road	2	24	Discharges to Beach via Lummi River, lower elevation than SRRR#1, tide gate
120	Ferndale Road	1	12	Ponded area near outlet, stagnant water
121	Ferndale Road	2	24	~85% of flow from ditch that originates near Slater #3,#4
122	Ferndale Road	3	24	Discharges to Slater Slough
123	Ferndale Road	4	18	Discharges to Slater Slough via ditchline
124	Ferndale Road	5	0	Bridge over Kwina Slough, levee on north side of slough only
125	Rayhorst Road	1	24	Only culvert on Rayhorst Road, flows to Ferndale Road#3
126	Marine Drive	1	18	Submerged, flow may be in both directions, diameter estimated
127	Marine Drive	2	0	Bridge over Kwina Slough
128	Marine Drive	3	18	Submerged, south end blocked?, flow in both directions?, diameter estimated
129	Marine Drive	4	12	Both ends could not be located, water flows through, discharges to wetland
130	Slater Road	1	48	Outlet to north, ditch at outlet also drains fields to north
131	Slater Road	2	48	Drains to north side of Slater Rd, paired with Slater#1
132	Slater Road	3	48	Ag. ditch at outlet drains to Ferndale Road#6 & #2
133	Slater Road	4	48	Paired with Slater#3, Drains via Ag. Ditch to Ferndale Road#6 & #2
134	Slater Road	5	24	Ponded areas at inlet and outlet, no ditches
135	Slater Road	6	18	Buried outlet, stagnant water at inlet
136	Slater Road	7	60	Inlet and outlet Ag. ditches ~240 ft east of culvert
137	Slater Road	8	60	Inlet and outlet Ag. ditches ~240 ft east of culvert
138	Slater Road	9	60	In tandem with culverts Slater#7 and Slater#8
139	Slater Road	10	36	U/S end buried, non-functional culvert
140	Slater Road	11	0	Bridge over Lummi River
141	Slater Road	12	84	Box culvert, Discharges to Beach via Lummi R., pipe w/ tide gate at levee
142	Slater Road	13	30	Ponded water at inlet and outlet, no ditches
143	Slater Road	14	30	Drains fields to south, flows to ag. ditchline along north side of Slater
144	Slater Road	15	84	Schell Ditch crossing, drains to Lummi River
145	Slater Road	16	18	Drains to south, then to Slater#17 via Haxton Way#1
146	Slater Road	17	24	Drains to north, flows to west, crosses back southward at Slater#18
147	Slater Road	18	42	Ag. Ditch ~210 ft west flows to inlet, drains to Jordan Creek
148	Slater Road	19	24	Discharges to wetland area to south
149	Slater Road	20	36	Inlet stream ~180 ft west, pond; outlet appears to drain to Jordan Creek
150	Slater Road	21	24	A little more flow than Slater#20, source is ditch near Slater#22
151	Slater Road	22	18	Water ponds at outlet, most of water for #21 from ditch ~25 ft east of #22
152	Slater Road	23	18	Ponded water on both sides of culvert
153	Slater Road	24	120	East branch of Jordan Creek (approx. dimensions 8.7' tall, 12.2 ' wide)

Table C.1 Selected 1998 and 2010 Culvert Inventory Data

ID Number	Street Name	Culvert Number	Culvert Size	Comments
154	Slater Road	25	24	West branch of Jordan Creek
155	Slater Road	26	12	Drains to near outlet of Slater#25, ~95% of flow in north ditch flows to#26
156	Slater Road	27	18	Drains toward north side
157	Slater Road	28	18	18" B/S drains roadway near traffic island
158	Slater Road	29	30	Gate w/ apparent filter on 24" ADS that flows to inlet from TOSCO property
159	Slater Road	30	30	In tandem with Slater #29
160	Slater Road	31	24	Drains to southside of Slater then to east to Slater#29,#30 outlet stream
161	Slater Road	32	18	~60% of flow in inlet RDitch continues toward Slater#33
162	Slater Road	33	18	Large areas of ponded water on both sides of road adjacent to RDitches
163	Slater Road	34	24	Ditch network drains field in TOSCO property, outlet flows to creek at #35
164	Slater Road	35	24	~95% of water in stream comes from Slater#33 & #34 area
165	North Red River Road	1	120	Jordan Creek, flows to cutoff Lummi R. Distributary (Dimensions 9.5'x13.5')
166	North Red River Road	2	72	Possibly for flood relief only, no inflow ditch or channel found
167	North Red River Road	3	24	Stream contributing ~85% of flow ~180 ft west
168	North Red River Road	4	12	Outlet discharges to hillslope
169	North Red River Road	5	18	Small stream ~25 ft west contributes ~25% of flow, outlet is gully
170	North Red River Road	6	18	Drains to Shaw Court then to golf course
171	North Red River Road	7	18	Flows toward outlet of No. Red River Road#6
172	North Red River Road (now Lake Terrell Road)	8	18	Wetlands on both sides, flow is toward the west
173	North Red River Road (now Lake Terrell Road)	9	18	18" B/S flows westward along Slater Road, overflow is in 12" B/S to NRRR.
174	Waldron Drive	1	12	Receives flow from Lake Terrell Rd & NE part of Orcas Way
175	Decatur Drive	2	12	Ponded water at inlet, contributes flow to SPH culverts #6, #8, and #9
176	Prevost Way	3	12	C/B at outlet; contributes flow to SPH #16, #14, and #12
177	Prevost Way	4	12	Contributes flow to SPH #16, #14, and #12
178	Prevost Way	5	12	Contributes flow to SPH #10 and #12
179	Saanich Avenue	6	12	Contributes flow to SPH #8, #9, and #11
180	Lopez Drive	7	12	Contributes flow to SPH #8, #9, #11. Drains inner loop of Lopez/Pender Dr.
181	Pender Drive	8	12	Contributes flow to SPH #9, #11.
182	Orcas Way	9	12	Contributes flow to SPH #11
183	Decatur Drive	10	12	Contributes flow to SPH #12
184	Decatur Drive	11	12	Discharges to Beach, drains W. side Lk Terrell Rd and SPH NE of Pender Dr
185	Sinclair Drive	12	18	Discharges to Beach via a 12" GALV, Drains SPH west of Pender Drive
186	Moresby Way	13	12	Contributes flow to SPH #12
187	Cyprus Way	14	12	Contributes flow to SPH #12
188	Cyprus Way	15	18	Discharges to a 12"GALV that flows to SPH #12
189	Moresby Way	16	12	Contributes flow to SPH #14 and #12
190	Waldron Drive	17	12	Contributes flow to N. Red River Road #7
191	Waldron Drive	18	12	Ponded water to west of outlet, overflow to wooded area
192	Waldron Drive	19	12	Contributes flow to SPH #18, water on roadway due to blocked driveway culve
193	Guemes Way	20	12	Contributes flow to N.Red River Road #5
194	Shaw Court	21	12	Drains to Shaw Court outlet at SE end of Shaw Ct; flow goes to golf course
195	Beach Way	1	12	Drains to pasture land, may contribute some flow to Sucia Drive#1
196	Sucia Drive	1	36	Discharges to Beach, C/B at 4780 Sucia also contributes flow
197	Sucia Drive	2	12	Discharges to Beach, wetland at inlet, broken tide gate, 18" GALV outlet
198	Sucia Drive	3	12	Discharges to wetland area via 12" ADS, water ponds at C/B
199	Sucia Drive	4	12	Discharges to wetland area via 12" ADS

Table C.1 Selected 1998 and 2010 Culvert Inventory Data

ID Number	Street Name	Culvert Number	Culvert Size	Comments
200	Maple Lane	1	12	12" PVC connects Maple Lane C/Bs #1 and #2
201	Maple Lane	2	12	12" PVC connects Maple Lane C/Bs #1-3
202	Maple Lane	3	12	12" ADS connects Maple Lane C/B #3 to #4
203	Maple Lane	4	18	Discharges to beach in 18" PVC, flow from Maple Lane C/Bs #1-5.
204	Maple Lane	5	12	Contributes flow to Maple Lane C/B #4, flow over Georgian Dr-no ditch
205	Olympic Drive	1	10	Flows to wetland
206	Germain Road	1	12	Contributes flow to Neptune Circle#1
207	Neptune Circle	1	18	Discharges to hillslope at SW corner of Neptune Circle
208	Neptune Circle	2	12	Depression/ponded area at outlet
209	Beach Lane	1	12	Outlet ditch flows to field at base of hill (may continue to Sucia Dr #1)
210	Cobble Way	1	12	Contributes flow to Beach Lane#1
211	Stuart Circle	1	12	Flow direction could not be determined
212	Stuart Circle	2	12	Flow direction could not be determined
213	Salt Spring Drive	1	12	Discharges to 12" GALV that discharges to beach (Onion Bay)
214	Salt Spring Drive	2	18	Drains lake via box inlet, tide gate, discharges to beach via 18" T/G
215	Salt Spring Drive	3	12	Discharges to beach via tide gate and 12" T/G
216	Dike Road	1	24	Receives flow from Haxton and Haxton#12, discharges to outlet of Kwina#2
217	Dike Road	2	18	Inlet receives flow from curb/gutter & rocked drain, ponded area at outlet
218	Dike Road	3	18	Drains south end of Ti'opi' Loop, fed by ditchline and French drain
219	Dike Road	4	12	On gravel road (private)
220	Dike Road	5	12	Drains 4-5 houses at end of Dike Road (Nick Kinley's)
221	Harbor Lane	1	24	Drains to KB#2 which drains to beach via LSR #18
222	Bayview Drive	2	24	Most of flow from KB#1, Discharges to LSR#18
223	Harbor Place	3	12	Drains to KB#2 then to beach via LSR#18
224	Bay Place	4	18	Drains to KB#1, then to KB#2, then to beach via LSR#18
225	Kel Bay Avenue	5	12	Flow from Cagey#6 & #7 (2/3 to KB#5, 1/3 to KB#6), discharge to KB#4, #1,#2
226	Kel Bay Avenue	6	12	Drains via KB#7 then to beach via LSR#19.
227	Bayshore Drive	7	18	Receives flow from KB#6 and wet area between Bayshore Dr. & Shorewood Lane
228	Shorewood Lane	8	12	Roadside ditch along LSR, drains to LSR#18
229	Postal Avenue	1	18	Drains entire west side of Postal Ave., Discharges to LSR#34
230	Kwina Slough Levee	1	48	Discharges to Beach via Kwina Slough & tidegate - beaver dams alter flow
231	South Road on Levee (seawall)	1	48	Discharges to Beach at NW corner of Seaponds dike, tidegates non-functional
232	North Road on Levee (seawall)	1	0	Discharges to Beach near golf course, Approx. 8ft wide, 6ft deep, tide gate
233	Ferndale Road	6	18	Receives flow from Slater#3 & #4
234	Ferndale Road	7	18	Inlet face covered with dirt, some seepage through as trickle at outlet
235	North Road on Levee	2	0	Discharges to Beach, Approx. 5 ft wide 5.25 ft deep, tide gate
236	North Road on Levee	3	0	Discharges to Beach, Approx. 5 ft wide, 5.25 ft deep, tide gate
237	South Road on Levee	2	48	Discharges to Beach, Non-functioning tide gate, #2 of 6 culverts.
238	South Road on Levee	3	48	Discharges to Beach, Non-functioning tide gate, #3 of 6 culverts.
239	South Road on Levee	4	48	Discharges to Beach, Non-functioning tide gate, six other culverts
240	South Road on Levee	5	48	Discharges to Beach, Non-functioning tide gate, 1 of 6 culverts.
241	South Road on Levee	6	48	Discharges to Beach, Non-functioning tide gates, southern 1 of 6 culverts.
242	Southern Access Road to South Road on Levee	1	42	See maps, discharges to 6 culverts along south levee road with tidegates
243	Southern Access Road to South Road on Levee	2	42	See map,2 of 4 culverts on access road near 6 culverts on South Levee Road.
244	Southern Access Road to South Road on Levee	3	42	3 of 4 culverts near the 6 culverts on South Levee Rd; access by blockhouse
245	Southern Access Road to South Road on Levee	4	42	4 of 4 culverts, access via southern fork of block house road.

Table C.1 Selected 1998 and 2010 Culvert Inventory Data

ID Number	Street Name	Culvert Number	Culvert Size	Comments
246	Northern Access Road to South Road on Levee	1	42	See map, discharges to 6 culverts on S. Levee Road.
263	Haxton Way	5	18	Drains ditchline north of LSR, discharges to slough draining Haxton Way #8
264	Lummi Shore Road	7	36	Receives flow from Culverts #1 & #2 on Scott Rd
265	Lummi Shore Road	17	24	Discharges to beach, probably includes flow from Cagey#8 and replaced in 1998
266	Lummi Shore Road	20	24	Discharges to beach, includes flow from Smokehouse#1 and Smokehouse#2, replaced in
267	Lummi Shore Road	26	24	Discharges to beach and Replaced in 1998
268	Lummi Shore Road		24	New culvert in 1998 and discharges to beach
269	Lummi Shore Road		24	New culvert in 1998 and drains wetland areas
270	Lummi Shore Road		24	New culvert in 1998; drains wetland areas and discharges to beach
271	Lummi Shore Road		24	New culvert in 1998; drains wetland areas and discharges to beach
272	Lummi Shore Road	28	18	Replaced culvert in 1998; Discharges to beach
273	Lummi Shore Road		12	New culvert in 1998; discharges to beach
274	Lummi Shore Road		12	New culvert in 1998; drains wetland areas and discharges to beach
275	Lummi Shore Road	39	18	Replaced culvert in 1998; Dishcarges to the Beach
276	Lummi Shore Road	31	18	Discharges to beach, via 18" ADS; water not flowing, replaced in 1998
277	Lummi Shore Road	32	18	Discharges to beach; via 18"ADS; water not flowing, replaced in 1998
278	Lummi Shore Road	33	18	Discharges to beach; via 18" ADS, replaced in 1998
279	Lummi Shore Road	34	12	Discharges to beach; via 12"ADS, replaced in 1998
280	Lummi Shore Road	35	18	Discharges to beach via 18"ADS, replaced in 1998
281	Lummi View Drive		18	Flows into LSR#280, discharges to beach, new in 2004
282	Lummi View Drive		12	Flows into LVD#281, discharges through LSR#280 onto beach, new in 2004
283	Lummi View Drive	1	18	Discharges to ditch then to beach through 18" ADS, replaced in 2004
284	Chief Martin Road		18	Drains undeveloped and 2008 Timber Harvest property
285	Kwina Road		12	Storm system overflow pipe for Kwina Apartments, new in 2009
286	Blackhawk Way	1	12	Drains swales, gravel parking, and pervious sidewalk that are a part of LNS
287	Lummi Shore Road		18	Drains undeveloped forest, discharges into Smuggler's Slough blind channel

APPENDIX D

PUGET SOUND PARTNERSHIP LOW IMPACT DEVELOPMENT BROCHURE

Low Impact Development: Protecting our waters as we grow

Permeable pavers at I-5 Park and Ride in Marysville virtually eliminate runoff, remove pollutants, and look good. | *Curtis Hinman*

By the year 2025, another 1.4 million people will call the Puget Sound region home.* Accommodating this growth while still protecting our natural resources and quality of life presents major challenges.

Growth results in more rooftops, pavement and stormwater runoff. Traditional ways of protecting water resources from stormwater runoff have not proven fully effective, and Puget Sound is threatened by storm flows and pollutants carried by stormwater.

It's time to grow smarter.

Low impact development (LID) can help. LID is a relatively new approach to developing land and managing stormwater runoff. LID mimics what nature has been doing for ages.

In a mature Pacific Northwest forest, very little rainwater runs off the land. Instead, it soaks into the ground, where the soils remove pollutants naturally. The water nourishes trees and plants and recharges streams, wetlands and groundwater. Or, the rainwater evaporates and becomes rainfall again.

Some of the key features of LID include: replanting or protecting existing vegetation; reducing impervious surfaces such as roads, parking lots and rooftops; using bioretention, pervious pavement and other small-scale stormwater controls; and clustering houses and other buildings on a site so stormwater can follow more natural drainage patterns.

LID not only manages stormwater, it makes communities greener and more beautiful. And in many cases, LID projects are less expensive to build and maintain.

* *Source: Washington State Office of Financial Management*

Why do we need low impact development?

Low impact development can help protect our water resources from the harmful effects of stormwater runoff.

Several species of Northwest salmon face the threat of extinction. Numerous shellfish-growing beaches in Puget Sound are too polluted to harvest. Pollution also threatens the health of our urban waters and underwater sediments.

Runoff from stormwater contributes significantly to these problems, and conventional stormwater management practices don't fully protect our waters.

The problem lies in the way land is typically developed.

Typical land development involves clearing a site of vegetation, grading it, and then installing roads, parking, utilities, buildings and landscaping. Heavy equipment compacts soils. Detention ponds and vaults are expected to prevent flooding, remove pollutants, slow storm flows, and recharge aquifers and streams.

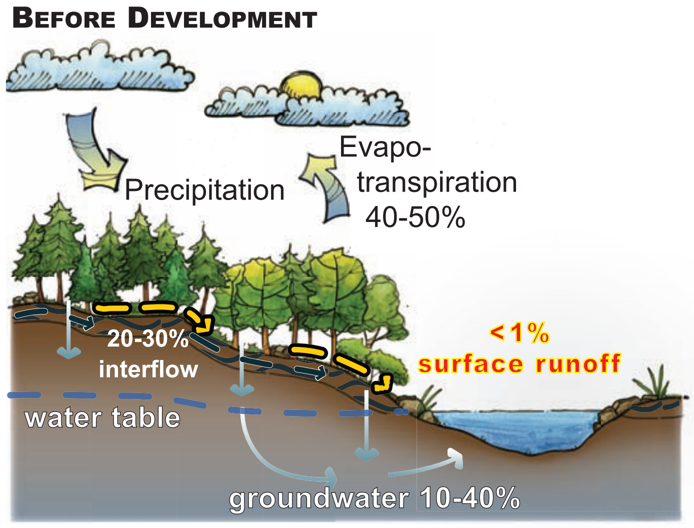
The before-and-after drawings to the right show how development alters the way water moves throughout a site. Under natural conditions—before development—most of the rainfall seeps through the ground (infiltrates), evaporates or is used by vegetation. Very little becomes surface runoff.

After development, less vegetation and more impervious surfaces cause runoff to increase dramatically (up to 20 to 30 times as much as on undeveloped land). Infiltration also decreases, resulting in less water for streams and wetlands. This has two effects: In wet winter months, increased runoff can damage fish and wildlife habitat and cause flooding. And in dry summer months, streams sometimes lack sufficient flows for fish and seasonal irrigation.

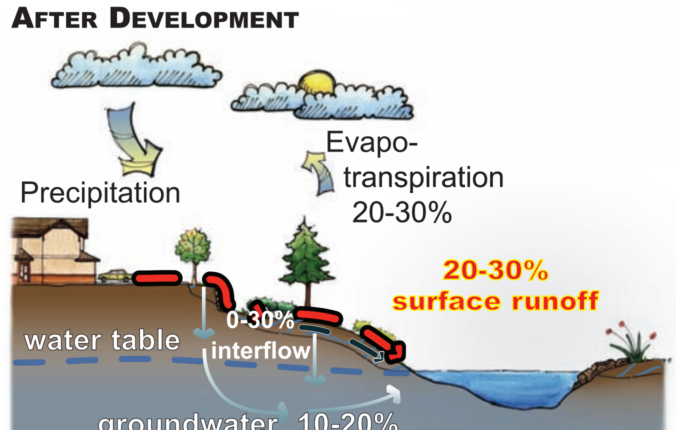
To protect streams from high flows, regulations require developers to install large ponds. Yet ponds don't ensure that streams, wetlands and aquifers are recharged. Ponds don't remove pollutants as effectively as bioretention or native soils. Ponds also take up valuable land, are difficult to maintain, and can be unattractive. In addition, stormwater released from ponds can be too warm for salmon.

In short, LID represents a new set of tools to improve how we develop land and manage runoff in Puget Sound.

Before Development



After Development



Before development (top graphic), almost all rainfall is taken up by plants or evaporates (evapo-transpiration) or infiltrates through the ground. After conventional development (lower graphic), surface runoff increases significantly while evapo-transpiration and infiltration decrease. (Interflow refers to water that moves laterally just below the ground surface.) | *AHBL, Inc. Planners*

Cover panel photo credits *(clockwise from upper left)***:** Seattle City Hall green roof, *City of Seattle* • forest, *stock photo* • bioretention swale, *Seattle Public Utilities, City of Seattle* • chinook salmon, *Ernest Keeley*.

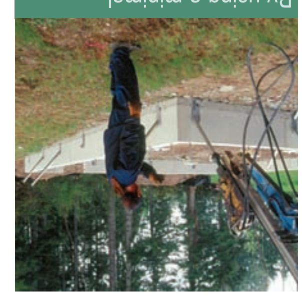
Benefits of low impact development

To the environment

- Helps maintain natural hydrology.
- Helps maintain stream flows and water levels in wetlands.
- Protects streams and fish and wildlife habitat from high storm flows.
- Reduces pollution in runoff.
- Protects shellfish growing areas and beaches from bacterial contamination.
- Preserves and restores trees and other vegetation.

To developers

- Provides new options for site layout, stormwater facilities and recreation.
- Can help reduce building costs for stormwater management facilities.
- Can help produce more attractive neighborhoods that sell faster and for a premium.
- Can provide more buildable lots by reducing size requirements for stormwater ponds and through incentives such as density bonuses.
- Can reduce stormwater utility fees.



By using a minimal excavation foundation, the builder of this home in Pierce County eliminated the need to extensively excavate and compact soils. | *PIN Foundations, Inc.*

To local governments and communities

- Helps prevent flooding.
- Helps protect streams, salmon and other wildlife, and shellfish growing areas.
- Helps maintain drinking water supplies.
- Can help reduce maintenance costs of stormwater facilities.
- Can help lower costs of streets, curbs, gutters and other infrastructure.
- Increases the appearance and aesthetics of communities.
- Can help increase property resale values.
- Provides new tools for cost-effective urban retrofit.
- Helps reduce contamination of sediments in bays and associated cleanup costs.

LID—Part of the solution

LID should be part of a local, comprehensive stormwater management program that:

- Adopts and uses the Department of Ecology's *2005 Stormwater Management Manual for Western Washington* (or an alternative local manual that is technically equivalent).
- Includes regular inspections of construction sites.
- Ensures maintenance of temporary and permanent facilities.
- Controls the release of pollutants.
- Eliminates illegal dumping and discharges.
- Identifies and ranks existing stormwater problems.
- Educates and involves the public.
- Includes watershed or basin planning.
- Ensures stable, ongoing funding.
- Includes programmatic and environmental monitoring.

LID works with local land use planning under the Growth Management Act. Local governments identify areas to preserve and areas to accommodate growth. Once the growth areas are determined, builders and planners can use LID approaches on building sites to reduce the adverse effects of development.

Need more information?

Visit the Puget Sound Action Team's Web site on low impact development at **www.psat.wa.gov/LID**. Find news, educational and technical publications, monitoring results, local government regulations and more.

The Action Team is the state's partnership for Puget Sound. Every two years, the Action Team develops a plan and related budget for restoring and protecting the Sound. LID techniques are featured prominently in the *Puget Sound Conservation and Recovery Plan* as a key tool to combat problems from stormwater runoff.

Learn more about the state's two-year plan for Puget Sound at **www.psat.wa.gov/2005-2007plan**. LID is also included in the *Puget Sound Water Quality Management Plan*—the state and federal governments' long-term plan to protect and recover Puget Sound.

Need this document in an alternative format? Contact 800.54.SOUND or TDD, 800.833.6388.

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Low Impact Development

By the year **2025**, another **1.4 million people** will call Puget Sound their home.

How can we protect Puget Sound as we grow?

Puget Sound Action Team

Office of the Governor, State of Washington

Key strategies of low impact development

1. Conserve and restore vegetation and soils.

- Retain stretches of native forest cover on undeveloped sites. Restore vegetation on land previously cleared. Vegetation captures, infiltrates and evaporates precipitation.
- Preserve well-draining native soil. Use compost to restore the health of soil disturbed by construction. Healthy soils store and infiltrate stormwater and produce healthy plants that require less watering.
- Use the existing topographic features of a site to slow, store and infiltrate stormwater.
- Protect and incorporate natural drainage features and patterns into site design.

2. Design site to minimize impervious surfaces.

Site designers, planners, engineers, landscape architects and architects work together to assess and design the site to:

- Minimize impervious surfaces such as rooftops, road and parking lots. Eliminate as much impervious surface as possible that conveys stormwater directly to streams or other surface waters. Vegetated roofs can replace asphalt rooftops. Pervious pavement can replace impervious pavement.
- Locate homes, other buildings, roads and parking away from critical areas and soils that infiltrate well.

3. Manage stormwater close to where the rain falls.

- Use small-scale, integrated management practices such as bioretention, permeable pavement and vegetated roofs—rather than one large pond.
- Create a landscape that slows storm flows and increases the amount of time storm flows stay on the site. LID tries to mimic the slow movement of water typical in a forested landscape.
- Increase reliability of the stormwater management system by providing multiple, redundant facilities. This reduces the likelihood of system failure.
- Integrate stormwater facilities into a site design to create a landscape that's attractive and also protects the environment. For example, a bioretention area can be a lush garden that beautifies the neighborhood AND manages stormwater.
- Reduce reliance on and use of traditional storm sewers, pipes and ponds.

4. Provide maintenance and education.

- Develop reliable and long-term maintenance programs with clear and enforceable guidelines.
- Educate homeowners, building owners and landscapers on the proper maintenance requirements for LID facilities.
- Involve neighborhoods in caring for their systems and in protecting their streams, wetlands and bays.

LID facts

- From 2000-2003, bioretention at the Seattle Street Edge Alternatives—SEA Streets project—prevented all dry season runoff and 99% of wet season runoff. Performance has improved since installation, resulting in no runoff from the project since December of 2002—even during heavy rains in the fall of 2003.

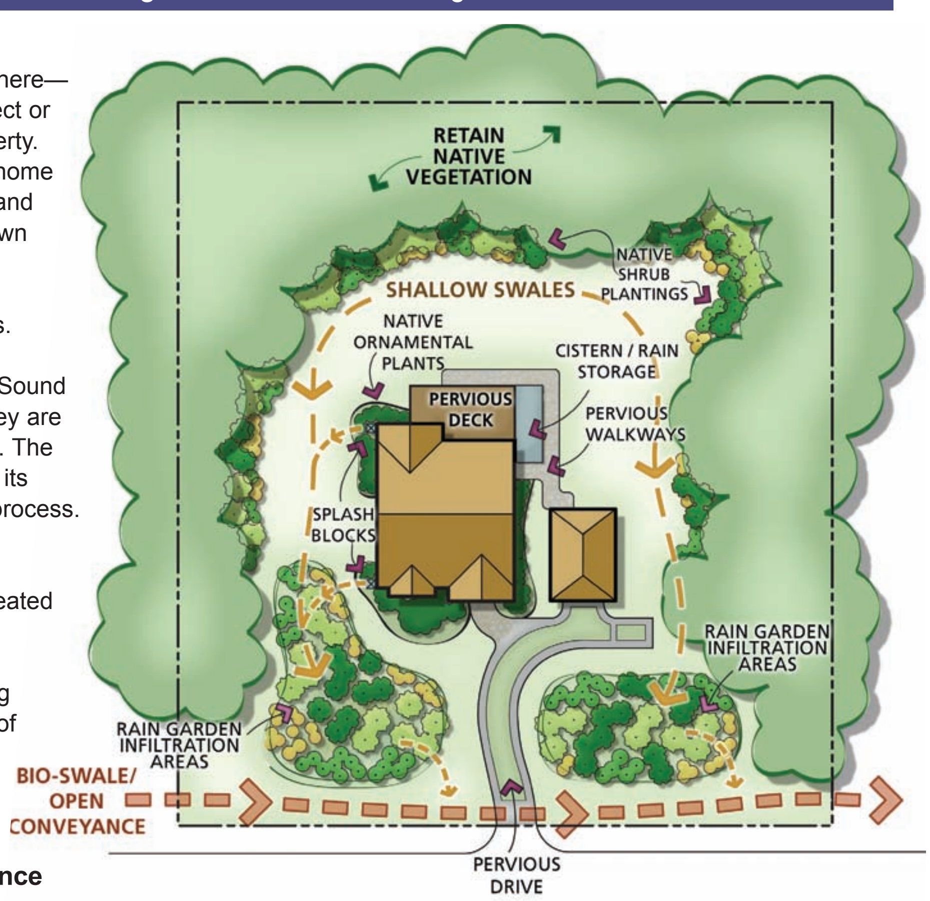
Bioretention swales at SEA Streets in Seattle are attractive and help protect nearby salmon streams by reducing stormwater volume by 99%. | *Seattle Public Utilities, City of Seattle.*

- A variety of permeable paving surfaces at a King County office building infiltrated nearly 100% of stormwater runoff during a 6-year monitoring period. While 97% of the samples from an adjacent conventional asphalt parking lot exceeded toxic levels for copper and zinc, those metals couldn't even be detected in the majority of samples from the permeable paving surfaces.
- Seattle Public Utilities estimates that by using LID techniques, costs can be reduced 24 to 45% in street redesign projects. The Broadview Green Grid produced even greater cost savings. (Cost comparison is based on systems that provide comparable stormwater management.)
- The City of Bellingham estimates it reduced costs by 75 to 80% by constructing bioretention rather than in-ground vault systems in two parking areas.
- A green roof in Portland retained 69% of total rainfall during a 15-month monitoring period. Green roofs in Europe have consistently reduced stormwater runoff up to 50%.
- Bioretention at the University of Maryland removed 87 to 97% of total copper, lead and zinc as well as 73% of phosphorous.

LID—Coming soon to a neighborhood near you

The LID approach works almost anywhere—at the start of a new construction project or to reduce runoff from an existing property. LID works for individual homes, multi-home subdivisions, commercial businesses and industrial sites. LID works in a downtown urban center, in the suburbs, or in the country. Specific techniques will vary, depending on individual site conditions.

Many local governments in the Puget Sound region are finding LID so promising they are revising regulations to spur use of LID. The Puget Sound Action Team has offered its expertise in several ways to help the process.



Numerous residential LID practices, such as those illustrated above, improve stormwater management and provide wildlife habitat while making a more attractive, natural landscape. | *AHBL, Inc. Planners*

Help for cities and counties

In 2005 and 2006, the Action Team created an innovative program that provided technical assistance to 12 cities and seven counties interested in integrating LID into their regulations. Summaries of the LID "Local Regulation Assistance Project" are at **www.psat.wa.gov/lidassistance**.

Manual provides technical guidance

To provide building professionals with a technical resource on LID practices, the Puget Sound Action Team and Washington State University Extension Pierce County developed the *Low Impact Development Technical Guidance Manual for Puget Sound.* The manual is the first in the region to offer technical guidance on LID.

The goal of the manual is to provide a common understanding of:

- Puget Sound hydrology and the effects of urban development.
- LID goals and objectives.
- Site assessment, site planning and layout.
- Vegetation protection and revegetation.
- Detailed specifications for LID integrated management practices.
- Credits for reducing conventional stormwater facilities.
- National and international research findings and monitoring data.

To view or download a copy of the LID manual, visit the Action Team's Web site on LID at **www.psat.wa.gov/LID.**

Common LID practices

Preserving-clustering-dispersing. Protecting or replanting a significant portion of a development site's vegetation; locating development on a smaller part of the site; and directing runoff to vegetated areas. In many cases, the most efficient and cost-effective way to manage stormwater.

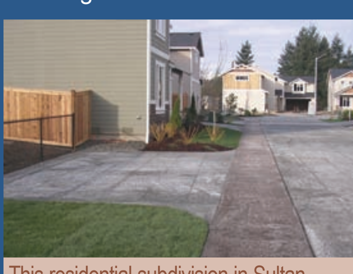
Bioretention--or rain gardens--not only look attractive, they also treat pollutants. | *Bruce Wulkan*

Bioretention (rain gardens). Shallow, landscaped areas composed of soil and a variety of plants. Bioretention cells are stand-alone features while bioretention swales are part of a conveyance system.

Soil amendments. Compost added to soils disturbed during the construction process. Restores soil's health and its ability to infiltrate water.

Pervious pavement. Allows water to infiltrate and removes pollutants. Includes concrete, asphalt, pavers and grid systems filled with grass or gravel.

Vegetated roofs. Roofs composed of a waterproof layer, root barrier, drainage layer, growth media and plants. Provides slower release of runoff, improves energy efficiency, extends roof life and provides wildlife habitat and recreational amenities.



This residential subdivision in Sultan uses pervious concrete for streets and driveways, which reduces stormwater runoff by allowing water to seep through the ground. | *Craig Young*

Rooftop rainwater collection. Catchment systems or cisterns that collect rooftop runoff for irrigation, drinking water, grey water or other purposes. Reduces runoff and demand on groundwater supplies.

Minimal excavation foundations. Alternative building foundations composed of driven piles and a connector at or above grade. Eliminates the need for extensive excavation and reduces soil compaction.