Strategies for Preserving and Restoring Small Puget Sound Drainages

Deliverable for Task 2 – Geospatial Analysis

January 2014

King County

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Strategies for Preserving and Restoring Small Puget Sound Drainages:

Task 2 – Geospatial Analysis

Prepared for:
The State Of Washington Department of Ecology
Interagency Agreement No. C1300210

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Publication Information

This project has been funded wholly or in part by the United States Environmental Protection Agency (EPA) under Puget Sound Ecosystem Restoration and Protection Cooperative Agreement Grant PC-00J20101 with Washington Department of Ecology (Ecology). The funding comes by means of a grant administered by Ecology (Grant No. C1300210). The final report will be available on request from King County and Ecology. The contents of this document do not necessarily reflect the views and policies of the EPA, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

Acknowledgements

We thank the EPA and Ecology for supporting this project via federal EPA pass through funds to King County from the Washington Department of Ecology as part of the Puget Sound Action Agenda: Ecosystem Restoration and Protection. We would like to thank Peter Leinenbach, US EPA Region 10, and Ken Rauscher, King County DNRP for their help generating GIS data for each sampling site including watershed delineation and land use/land cover calculations and Curtis DeGasperi, King County DNRP for his help identifying appropriate gage data and calculating associated hydrologic metrics.

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Citation

King County. 2014. Strategies for Preserving and Restoring Small Puget Sound Drainages: Task 2 – Geospatial Analysis. Prepared by Chris Gregersen, Jo Opdyke Wilhelm, and Chris Knutson, Water and Land Resources Division. Seattle, Washington.

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1.0. BACKGROUND

1.1 Introduction

The overall goal of Washington State's Puget Sound Partnership (PSP) is to restore Puget Sound. Many streams that drain into Puget Sound are threatened from pollutant runoff and altered flow regimes. Such threats may result in extinction of aquatic species or a decline in biodiversity. This project, titled "Strategies for Preserving and Restoring Small Puget Sound Drainages", implements priority work consistent with the Puget Sound Action Agenda for the protection and restoration of Puget Sound by addressing near-term actions C2.1 NTA 2 and C2.3 NTA 2[1] (PSP 2012). The State of Washington Department of Ecology (Ecology) is the lead organization for developing and implementing strategies for watershed protection and restoration, the area of emphasis this project falls within. Federal pass through funds were designated for this project as outlined in Interagency Agreement No. C1300210 between Ecology and the King County Water and Land Resources Division.

One of the PSP's Ecosystem Recovery Targets is based on freshwater benthic macroinvertebrates. Benthic macroinvertebrates play a crucial role in stream ecosystems and are good indicators of ecological health. The multimetric Puget Lowland Benthic Index of Biotic Integrity (B-IBI) is a standardized scoring system applied to samples of benthic macroinvertebrates collected from streams. The B-IBI was developed in the early 1990's and is widely used to report stream biological health by over 20 cities, counties, tribes and state and federal agencies in the Puget Sound Basin. The PSP freshwater benthic macroinvertebrate target states:

> By 2020, 100 percent of Puget Sound lowland stream drainage areas monitored with baseline B-IBI scores of 42-46 or better retain these "excellent" scores and mean B-IBI scores of 30 Puget Sound lowland drainage areas improve from "fair" to "good" (PSP 2012).

The purpose of this project is to develop strategies and cost estimates for addressing this target, specifically preserving all Puget Sound drainages with "excellent" B-IBI scores, and for restoring 30 drainages from "fair" to "good" B-IBI scores. Stream restoration projects are one way to attempt to maintain or restore ecological health at impaired locations and contribute to the recovery of Puget Sound. This document (and accompanying Excel tables[2]) identifies the watersheds with "excellent" and "fair" B-IBI scores which are candidates for protection or restoration and summarizes landscape metrics calculated using Geographic Information Systems (GIS). This deliverable is outlined as Task 2 in the interagency agreement and is the first step before watershed prioritization,

[1] C2.1 NTA 2 is managing urban runoff at the basin and watershed scale; C2.3 NTA 2 is map, prioritize, and restore degraded streams.

[2] Due to the large number of candidate sites, complete summary tables will not be included in this document; they will be sent to Ecology electronically and are available by request.

protection/restoration strategy development, or implementation cost estimates can be completed.

1.2 Macroinvertebrate Data Sources

This project utilizes existing benthic macroinvertebrate monitoring data from streams throughout the Puget Sound drainage basin (Water Resource Inventory Areas [WRIA] 1-19, Table 1) and does not involve collecting new benthic macroinvertebrate data. B-IBI scores[3] were downloaded on November 18, 2013 from a regional database maintained by King County, the Puget Sound Stream Benthos (PSSB) data management system (http://www.pugetsoundstreambenthos.org/).

1190 sites were identified in Puget Sound for the sampling period between 1994 and 2012 (Table 1). 2013 B-IBI scores are not included because the majority of samples had not been processed for taxonomic identification at the time of download. These featured a total of 4488 individual samples for an average of 3.8 samples per site. The following analyses were completed on these downloaded data and are summarized in this document:

- Identified all sites in the PSSB with a maximum B-IBI score ($B\text{-}IBI_{max}$) greater than or equal to 46, and all sites with an average B-IBI score ($B\text{-}IBI_{avg}$) greater than or equal to 46 (46-50 is the range for the "excellent" B-IBI biological condition category, see Appendix A for more detail).
- Identified all sites with $B\text{-}IBI_{max}$ greater than or equal to 42, but less than 46, and all sites with $B\text{-}IBI_{avg}$ greater than or equal to 42, but less than 46 (This score range falls within the "good" B-IBI biological condition category, but the PSP target expanded the range of "excellent" scores to include 42 and above for this project, see Appendix A for more detail).
- Identified all sites with $B\text{-}IBI_{once}$ greater than or equal to 28 and less than or equal to 36 ("fair" scores) and all sites with $B\text{-}IBI_{avg}$ greater than or equal to 28 and less than or equal to 36 ("fair" scores).

[3] The PSSB has several user-defined options for determining how the B-IBI scores are calculated. For this project, the following were chosen for the data download: (1) streams *and* rivers in Puget Sound, (2) all projects, (3) 10-50 B-IBI, (4) replicates combined, (5) taxonomic resolution as defined by project metadata, (6) Wisseman (1998) attributes, (7) subsampling at 500 organisms, (8) all years with available data.

Table 1. Summary table by WRIA of the number of sites with stream macroinvertebrate data considered for this project.

WRIA #	WRIA Name	Total # Sites
1	Nooksack	35
2	San Juan	0
3	Lower Skagit/Samish	2
4	Upper Skagit	3
5	Stillaguamish	61
6	Island	1
7	Snohomish	136
8	Cedar-Sammamish	421
9	Duwamish-Green	136
10	Puyallup-White	40
11	Nisqually	20
12	Clover Creek	2
13	Deschutes	31
14	Kennedy-Goldsborough	1
15	Kitsap	179
16	Skokomish-Dosewallips	16
17	Quilcene-Snow	9
18	Elwha-Dungeness	63
19	Lyre-Hoko	34
TOTAL	**Puget Sound**	**1190**

1.3 Landscape Analysis

For the sites identified as having "fair" or "excellent" B-IBI scores, geographic information systems (GIS) analysis will be conducted to delineate drainage basins and calculate land use/land cover, geology, and other landscape characteristics at buffer and contributing basin scales. These landscape metrics will be briefly summarized in this document.

2.0. "EXCELLENT" SCORES

This section identifies all sites with "excellent" B-IBI scores which will be candidates for protection to achieve the PSP Ecosystem Target of maintaining "excellent" scores. The "excellent" category was broken into two groups, one for scores ≥ 46, and the other for scores ≥ 42 but less than 46 (see Appendix A for description of why "excellent" scores were subdivided). These two categories were further broken down by sites with a maximum B-IBI score ($B\text{-}IBI_{max}$) in each "excellent" category (i.e., the sites that scored "excellent" at least once), and all sites with average B-IBI scores ($B\text{-}IBI_{avg}$) in each "excellent" category.

2.1 Maximum Scores Greater Than or Equal to 46

Overall, there are **43** macroinvertebrate sampling sites throughout Puget Sound that scored greater than or equal to 46 for at least one sampling event (Table 2). These sites are found in nine WRIA's, though 81% of the sites are found in WRIA's 7, 8, and 9 (Figure 1). There are also five sites with $B\text{-}IBI_{avg}$ greater than or equal to 46, however, all five of these sites have only one score (Table 3, Figure 2).

Table 2. Summary by WRIA of the 43 macroinvertebrate sampling sites in Puget Sound with $B\text{-}IBI_{max}$ greater than or equal to 46.

		Sites With $B\text{-}IBI_{max}$ ≥ 46 in Basin					All Sites in WRIA			
WRIA #	WRIA Name	Sites	Mean Samples Per Site	Total Samples	$B\text{-}IBI_{max}$ ≥ 46 in Basin (Samples)	Mean B-IBI	Sites	Total Samples	Sites w/ $B\text{-}IBI_{max}$ ≥ 46 (%)	All Samples w/ $B\text{-}IBI_{max}$ ≥ 46 (%)
7	Snohomish	14	8.1	116	19	37.2	136	508	10.3%	22.2%
8	Cedar-Sammamish	15	6.8	102	32	40.4	421	1909	3.6%	5.3%
9	Duwamish-Green	6	10.2	61	7	38.5	136	894	4.4%	6.8
10	Puyallup-White	1	1	1	1	46	40	192	2.5%	0.5%
11	Nisqually	1	1	1	1	46	20	51	5.0%	2.0%
13	Deschutes	1	7	7	1	40.9	31	118	3.2%	5.9
15	Kitsap	2	4	8	2	38.8	179	436	1.1%	1.8%
16	Skokomish-Dosewallips	1	1	1	1	46	16	18	6.3%	5.6%
18	Elwha-Dungeness	2	1.5	3	2	46	63	113	3.2%	2.7%

Figure 1. Macroinvertebrate sampling sites with B-IBI$_{max}$ in the "excellent" range (≥42).

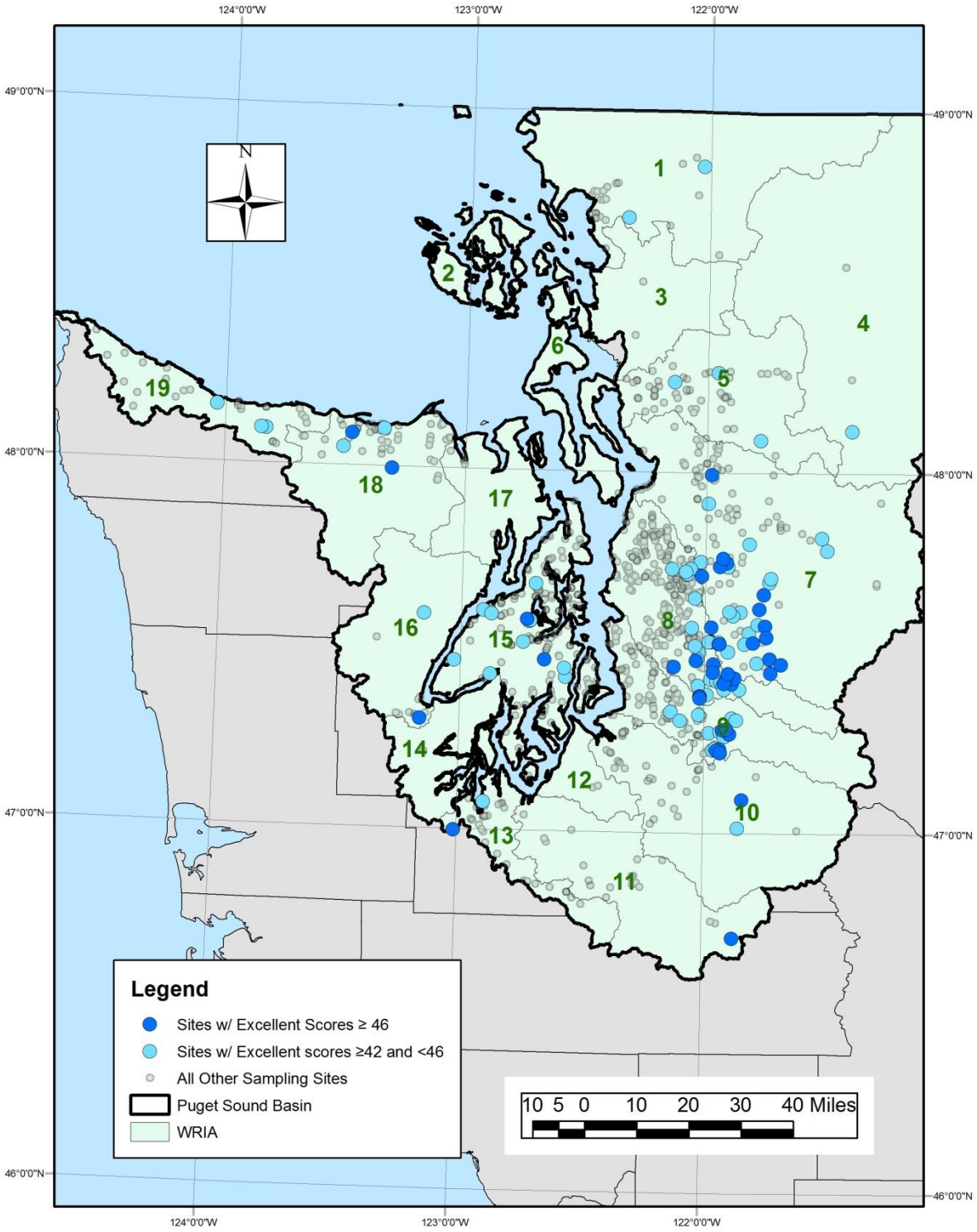
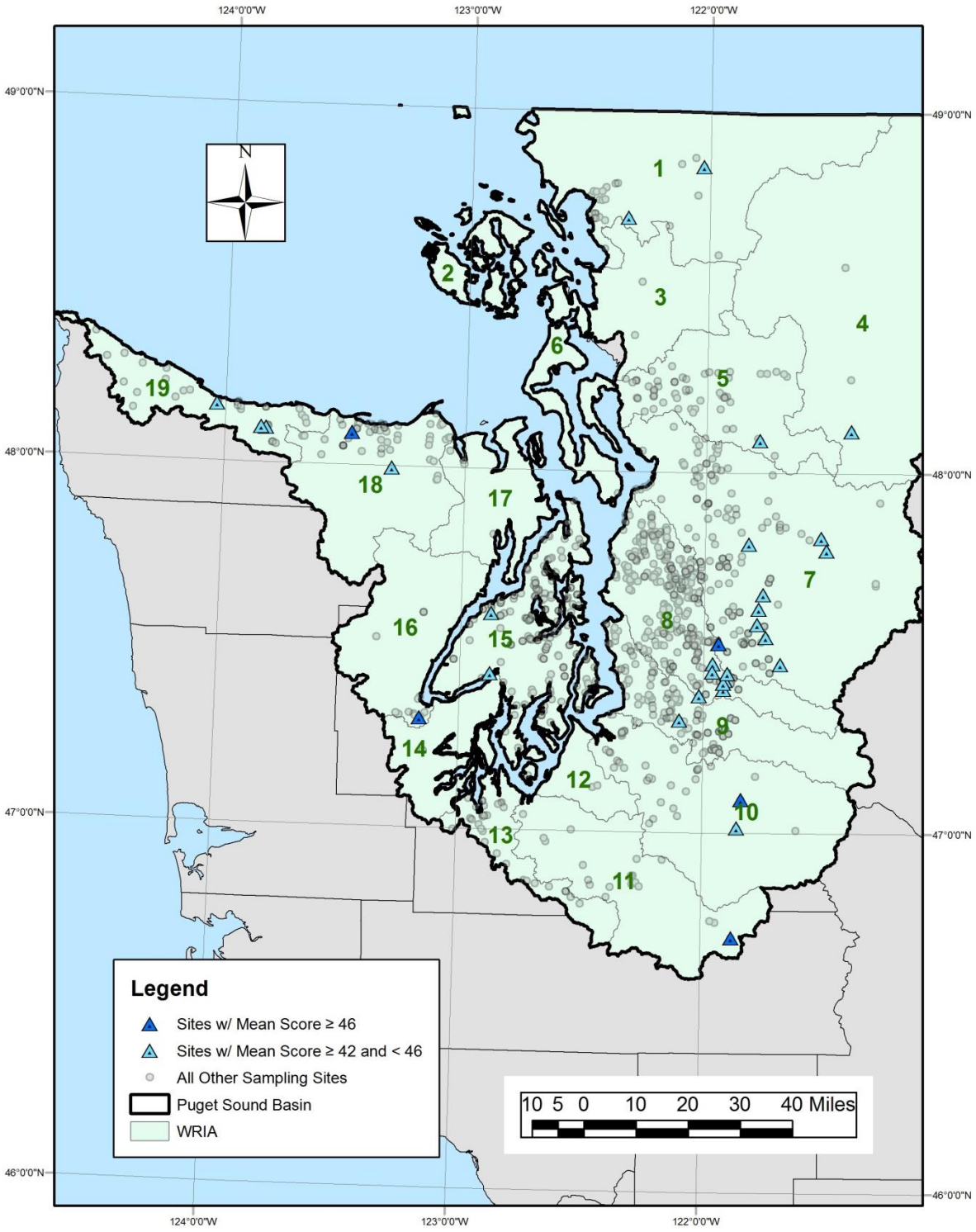


Table 3. Summary by WRIA of the 5 macroinvertebrate sampling sites in Puget Sound with B-IBI$_{avg}$ greater than or equal to 46 (note that n=1 for all sites).

		Sites With B-IBI$_{avg}$ ≥ 46					All Sites in WRIA			
WRIA #	WRIA Name	Sites	Mean Samples Per Site	Total Samples	B-IBI$_{avg}$ ≥ 46	B-IBI$_{avg}$	Sites	Samples	Sites with B-IBI$_{avg}$ ≥ 46 (%)	All Samples B-IBI$_{avg}$ ≥ 46 (%)
8	Cedar-Sammamish	1	1	1	1	46	421	1909	0.2%	0.1%
10	Puyallup-White	1	1	1	1	46	40	192	2.5%	0.5%
11	Nisqually	1	1	1	1	46	20	51	5.0%	2.0%
16	Skokomish-Dosewallips	1	1	1	1	46	16	18	6.3%	5.6%
18	Elwha-Dungeness	1	1	1	1	50	63	113	1.6%	0.9%

Figure 2. Macroinvertebrate sampling sites with B-IBI$_{avg}$ in the "excellent" range (≥42).



2.2 Maximum Scores Greater Than or Equal to 42 and Less Than 46

A total of **78** macroinvertebrate sampling sites throughout Puget Sound have scored greater than or equal to 42, but less than 46 for at least one sampling event (Table 4). These sites are located in 12 WRIA's, though 82% of the sites are found in WRIA's 7, 8, 9, and 15 (Figure 1). There are also 28 sites with B-IBI$_{avg}$ greater than or equal to 42 and less than 46, however, 14 of these sites have only one sampling event (Table 5, Figure 2).

Table 4. Summary by WRIA of the 78 macroinvertebrate sampling sites in Puget Sound with B-IBI$_{max}$ greater than or equal to 42, but less than 46.

		Sites With B-IBI$_{max}$ ≥ 42 & <46					All Sites in WRIA			
WRIA #	WRIA Name	Sites	Mean Samples Per Site	Total Samples	Samples B-IBI$_{max}$ ≥ 42 & <46 in Basin	Mean B-IBI	Sites	Samples	Sites B-IBI$_{max}$ ≥ 42 & <46 (%)	Samples B-IBI$_{max}$ ≥ 42 & <46 (%)
1	Nooksack	2	1.0	2	2	42	35	62	5.7%	3.2%
4	Upper Skagit	1	1.0	1	1	42	3	4	33.3%	25.0%
5	Stillaguamish	3	2.0	6	3	37.7	61	75	4.9%	8.0%
7	Snohomish	15	7.0	105	24	35.7	136	508	11.0%	20.7%
8	Cedar-Sammamish	26	7.1	184	40	35.6	421	1909	6.2%	9.6%
9	Duwamish-Green	13	9.2	120	23	36	136	894	9.6%	13.4%
10	Puyallup-White	1	1.0	1	1	44	40	192	2.5%	0.5%
13	Deschutes	1	7.0	7	1	38	31	118	3.2%	5.9%
15	Kitsap	10	3.5	35	13	37.4	179	436	5.6%	8.0%
16	Skokomish-Dosewallips	1	3.0	3	1	37.3	16	18	6.3%	16.7%
18	Elwha-Dungeness	2	4.5	9	2	34.7	63	113	3.2%	8.0%
19	Lyre-Hoko	3	1.0	3	3	42.7	34	45	8.8%	6.7%

Table 5. Summary by WRIA of the 28 macroinvertebrate sampling sites in Puget Sound with B-IBI$_{avg}$ greater than or equal to 42, but less than 46 (note that n=1 for 4 WRIAs).

		Sites With B-IBI$_{avg}$ ≥ 42 & <46					All Sites in WRIA			
WRIA #	WRIA Name	Sites	Mean Samples Per Site	Total Samples	B-IBI$_{avg}$ ≥ 42 & <46 in Basin	Mean B-IBI	Sites	Samples	Sites with B-IBI$_{avg}$ ≥ 42 & <46 (%)	Samples with B-IBI$_{avg}$ ≥ 42 & <46 (%)
1	Nooksack	2	1	2	2	42	35	62	5.7%	3.2%
4	Upper Skagit	1	1	1	1	42	3	4	33.3%	25.0%
5	Stillaguamish	1	1	1	1	42	61	75	1.6%	1.3%
7	Snohomish	8	5.1	41	24	42.8	136	508	5.9%	8.1%
8	Cedar-Sammamish	8	5.8	46	13	43.8	421	1909	1.9%	2.4%
9	Duwamish-Green	1	1	1	1	44	136	894	0.7%	0.1%
10	Puyallup-White	1	1	1	1	44	40	192	2.5%	0.5%
15	Kitsap	2	1	2	2	43	179	436	1.1%	0.5%
18	Elwha-Dungeness	1	2	2	2	44	63	113	1.6%	1.8%
19	Lyre-Hoko	3	1	3	3	42.7	34	45	8.8%	6.7%

3.0. "FAIR" SCORES

This section identifies all sites with "fair" B-IBI scores which will be candidates for restoration actions to achieve the PSP Ecosystem Target of improving mean B-IBI scores of 30 Puget Sound lowland drainage areas from "fair" to "good".

3.1 All "Fair" Scores

Of the 1190 sites with B-IBI scores downloaded from the PSSB, 648 sites had at least one score ($B\text{-}IBI_{once}$) in the "fair" range (28-36, Figure 3). These sites featured a total of 2893 individual samples for an average of 4.5 samples per site. 480 sites had $B\text{-}IBI_{avg}$ in the "fair" range, though 8 of these sites had no individual sampling events scoring in the "fair" range.

3.2 Filtered "Fair" Scores

To make the data set more manageable and to target sites that best characterize the "fair" range, the number of "fair" sites was filtered to exclude any sites that only had one sample and that hadn't been sampled since 2009 (Figure 3, Table 6). Sites that have only one sample were removed due to low confidence in classifying the site as "fair". Sites that have not been sampled since 2009 were also removed because the current status of the site may have changed over time. This 4 year window was also chosen based on the 4 year sampling interval used in Ecology's Status and Trends B-IBI monitoring program (Cusimano et al. 2006) so that sites were not excluded that are still a part of a regular sampling routine. After this filter, the total number of sites ever scoring in the "fair" range was reduced from 648 to 345, with a total of 2195 individual samples.

Figure 3. Macroinvertebrate sampling sites with "fair" B-IBI (28-36) at least once (yellow) or meeting the following three criteria (orange): (1) scoring "fair" B-IBI at least once, (2) sampled more than once, and (3) sampled at least once between 2009 and 2012.

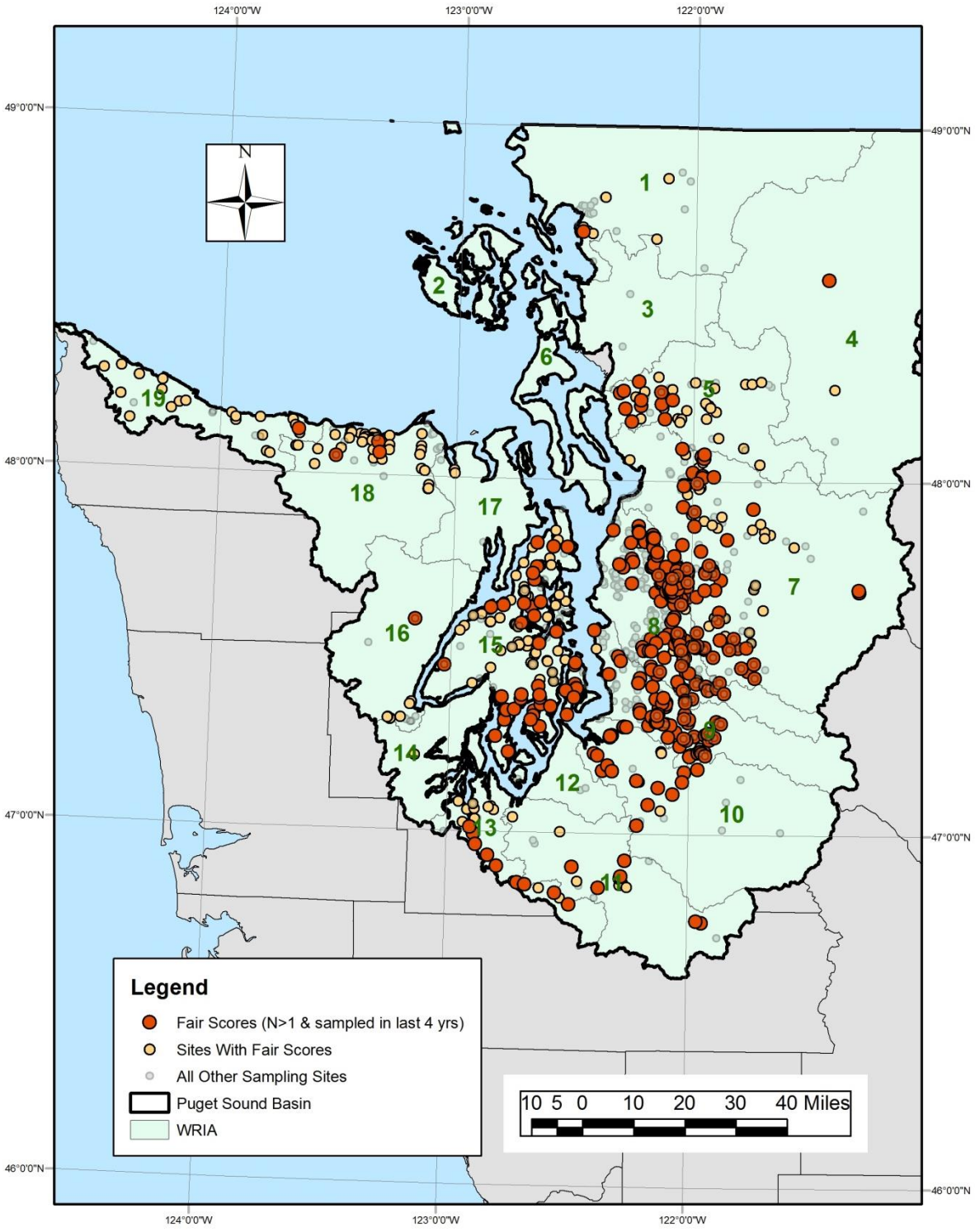


Table 6. Summary by WRIA of the 345 macroinvertebrate sampling sites in Puget Sound with "fair" B-IBI scores (28-36) with two or more sampling visits and sampled at least once between 2009 and 2012. Includes an overview of landcover and geology summaries reported as averages for "fair" sites within each WRIA.

WRIA #	WRIA Name	Sites	Mean Samples Per Site	Total Samples	Mean Site Elevation (m)	Mean Basin Area (ha)	Urbanization (%)		Surficial Geology Permeability (%)*	
							Contri-buting Basin	90-m Buffer in 1km Basin	High Perme-ability	Low Perme-ability
1	Nooksack	1	2.0	2	28.5	1749	5.3	6.2	7.7	92.0
4	Upper Skagit	1	2.0	2	108.4	6876	0.1	0.2	6.6	93.4
5	Stillaguamish	11	2.2	24	60.9	513	6.6	5.7	29.7	70.3
7	Snohomish	50	5.6	282	114.5	1535	6.1	4.7	22.0	77.4
8	Cedar-Sammamish	143	6.8	968	79.6	1916	27.3	23.1	22.8	76.9
9	Duwamish-Green	68	8.4	574	117.2	2471	20.7	17.0	35.4	63.0
10	Puyallup-White	18	7.1	128	100.8	4328	32.5	29.5	19.7	79.9
11	Nisqually	6	3.8	23	146.1	5761	3.2	2.8	15.2	84.4
13	Deschutes	9	3.0	27	86.1	27869	2.6	2.3	34.1	64.7
15	Kitsap	33	3.3	109	12.8	1370	15.2	12.5	19.7	79.9
16	Skokomish-Dosewallips	1	3.0	3	201	10135	0.1	0.0	2.9	96.5
18	Elwha-Dungeness	3	2.7	8	241.1	834	0.6	0.3	15.1	84.9
19	Lyre-Hoko	1	2.0	2	66.5	644	0.7	1.2	0.0	100.0

* High and low permeability do not always sum to 100%. In such cases, open water accounts for the remaining area.

Due to the large number of candidate sites, complete summary tables will not be included in this document; however tables of all "excellent" and all "fair" macroinvertebrate sampling sites will be sent to Ecology electronically (Appendix B).

4.0. SPATIAL DATA

For all macroinvertebrate sampling locations in the PSSB[4], drainage basins were delineated following the methods laid out by Leinenbach (2011a, 2011b) and Wilhelm et al. (2013) based on the 30 meter National Elevation Dataset (2004) available from the National Hydrography Dataset (Figure 4). Landscape sampling was conducted at up to four spatial scales: (1) within the upstream contributing watershed, (2) within a 1-km radius of the contributing watershed, (3) within a 90-m buffer in the contributing watershed, and (4) within a 90-m buffer in the 1-km contributing watershed (Figure 5). These 90-m riparian buffer calculations and "local" (1-km) contributing watersheds are one way to incorporate the proximity to stream of land use/land cover within the drainages.

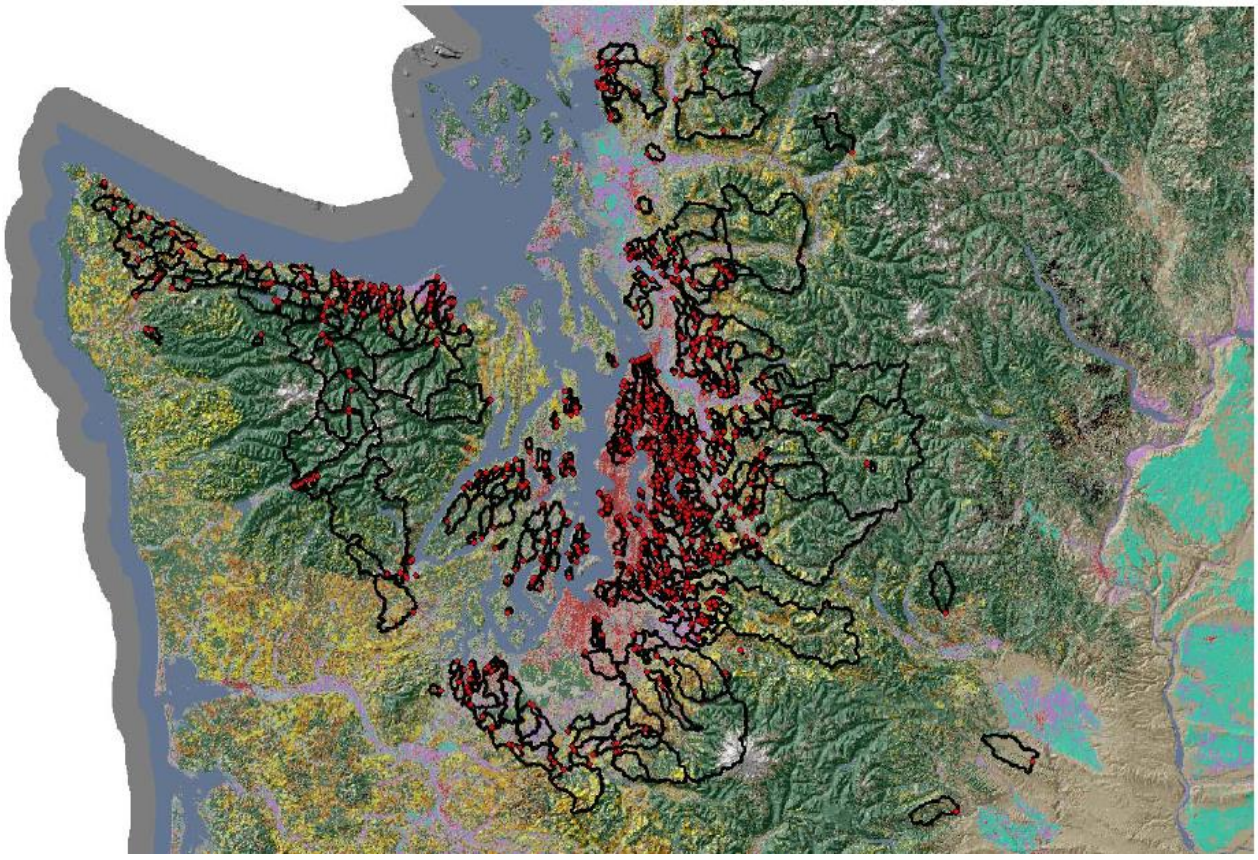


Figure 4. Watershed boundaries for over 1,000 biological monitoring sites within the Puget Sound region.

[4] These GIS analyses have been conducted for all Puget Sound sites (not just "fair" and "excellent" sites) that had data in the PSSB as of spring 2011. Analysis for sites added to the PSSB during the interim will be ready in early 2014. The watershed shapefiles and spatial data summarized in a spreadsheet are available for download on the PSSB under the subheadings GIS Resources/Shapefiles.

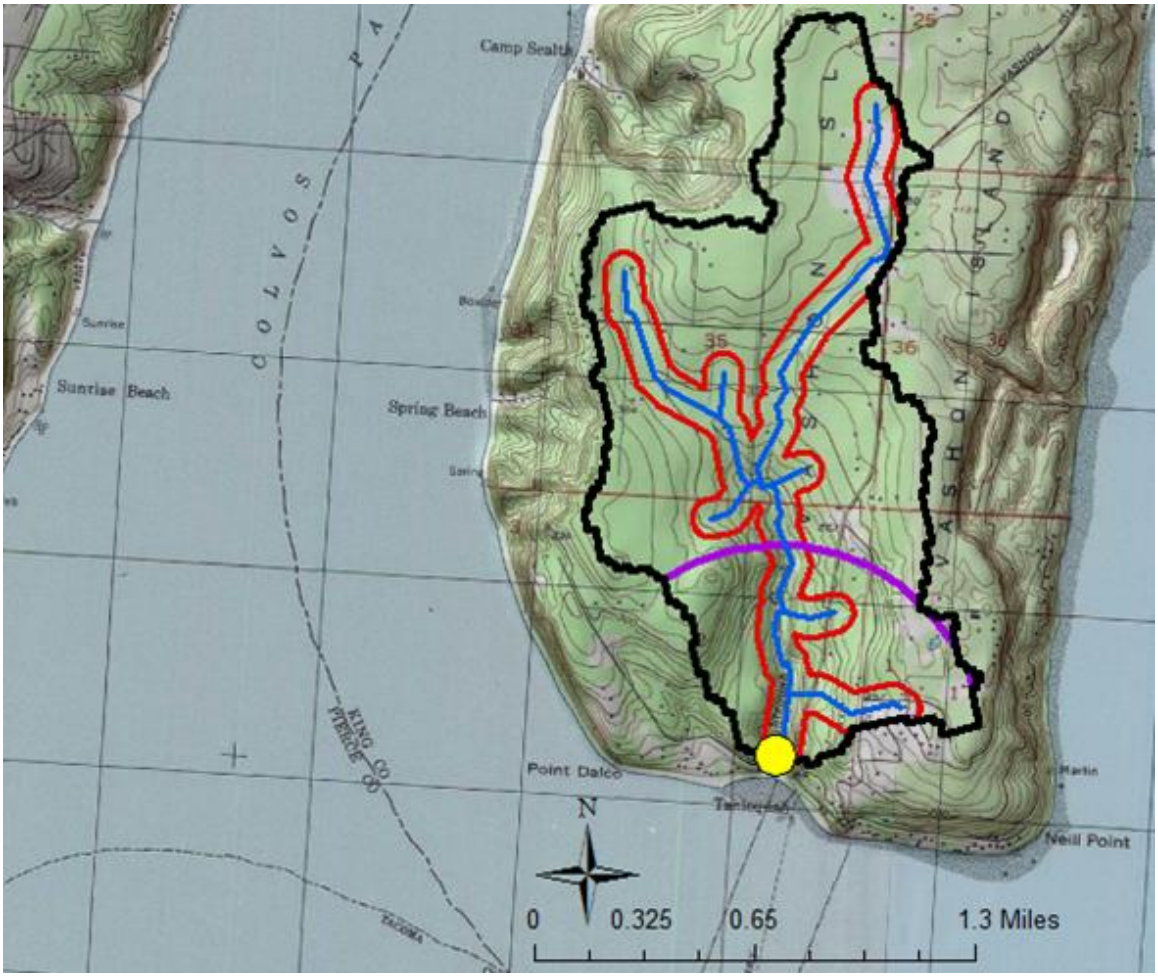


Figure 5. Land use/land cover were evaluated at four spatial scales for each benthic macroinvertebrate sampling location (yellow dot): (1) entire upstream contributing watershed (black line), (2) 90-m buffer within the contributing watershed (red outline), (3) 1-km contributing watershed (purple circle), and (4) 90-m buffer within the 1-km contributing watershed.

Table 7 summarizes the calculated GIS landscape metrics, data sources, and scale for which the data are calculated. Landcover (e.g., percent urban, forest, agriculture, etc.) was calculated from two data sources: 1) the 2006 National Land Cover Database (NLCD, Fry et al. 2011) and 2) the Coastal Change Analysis Program (C-CAP) for a series of years. Surficial geology data originated from the Washington Division of Geology and Earth Resources (1:100,000 scale) and major geologic units for Puget Sound are characterized into high or low permeability for Puget Sound following the approach employed by Ecology (Stanley et al. 2005). In the Pacific Northwest, alluvium in lowland areas and glacial outwash are typically composed of coarse-grained sediment and support high levels of permeability. Additional landscape metrics include road and population density and watershed characteristics such as elevation, slope, mean precipitation, and watershed area. Additional GIS work will be conducted if needed for restoration prioritization or restoration strategy work related to this project (Appendix C). For example, public, private, and jurisdictional ownership likely will be assessed for "fair" sites that have been prioritized for restoration.

Addressing ownership on a parcel by parcel basis across the scale of the entire Puget Sound region is not feasible due to the large number of sites and time requirements for each.

Table 7. Summary of calculated landscape metrics.

Data Source	Scale	Landscape metrics
2006 NLCD	Watershed • All • 1-km 90-m Buffer • All • 1-km	% forest % non-regeneration forest % regeneration forest % young forest (1992-2002 harvest) % older forest (1972-1992 harvest) % wetland % shrub % grasslands % barren % urban % agriculture
NAVTEQ Roads	Watershed • All • 1-km Buffers • None	total road length (m) road density (km/km^2) # road crossings/km stream total # road crossings
2000 Census		population density (count/km^2) total population
PRISM Precipitation		mean, min, max precipitation (mm)
DEM		elevation at pour point (m) mean, min, max elevation (m) mean, min, max % slope
NHD Streams		total stream length (m) stream density (km/km^2)
Physical		watershed and 1-km watershed areas (hectares) longitude and latitude of pour point
Surficial Geology		% High Permeability % Low Permeability
C-CAP (1992, 1996, 2001, 2006)		% Bare, % Snow/Ice, % Tundra, %Water % Ag (Cultivated, Pasture/Hay) % Forest (Deciduous, Evergreen, Mixed) % Urban (Developed open space, high-, medium-, and low-intensity) % Wetland (Estuarine or Palustrine: Aquatic Bed, Emergent, Forested, Scrub/Shrub) % Scrub/Shrub % Grassland

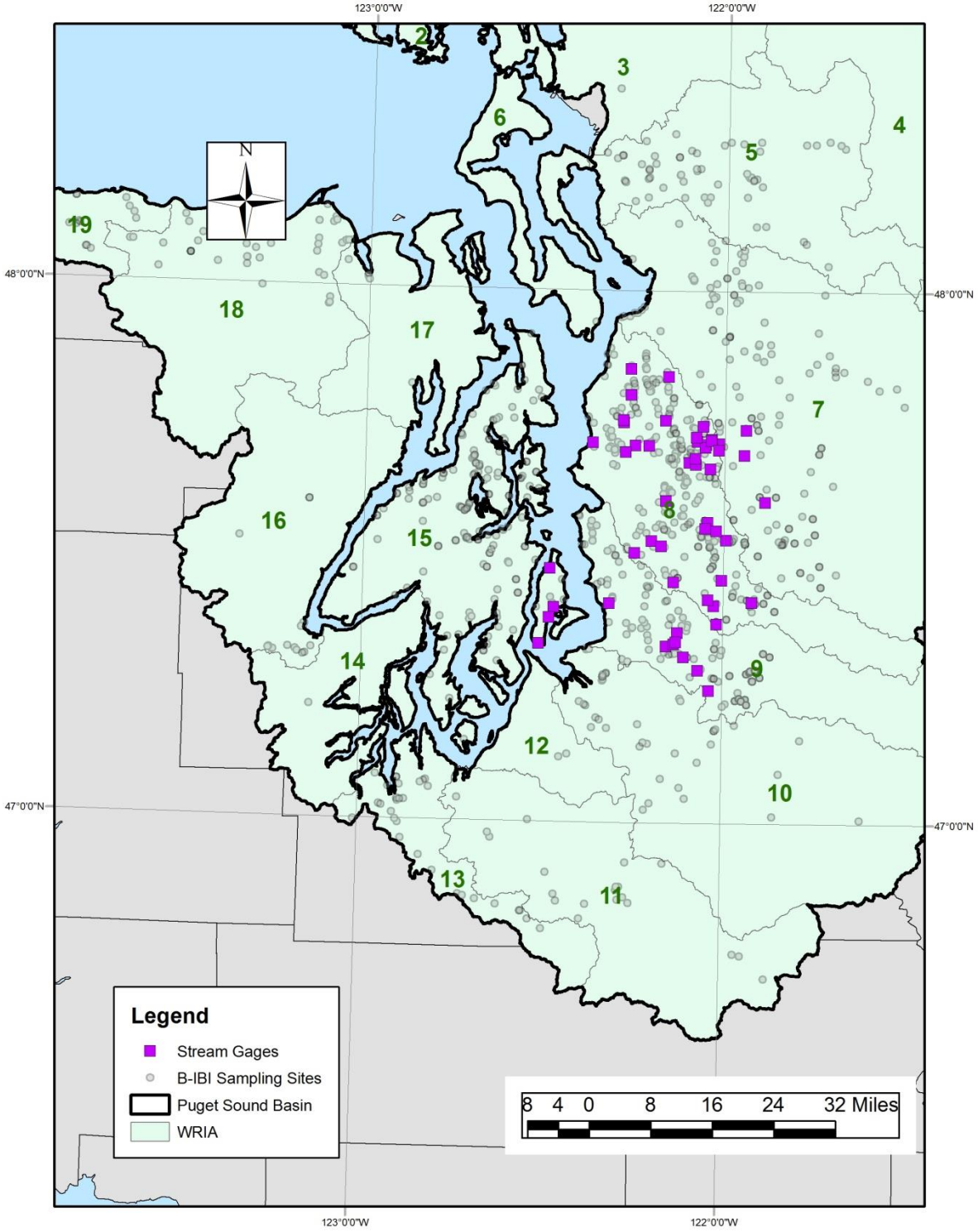
Due to the extensive number of landscape metrics calculated for such a large number of candidate sites, complete site by site summary tables of the GIS data will not be included in this document; however a complete table of GIS metrics will be sent to Ecology (Appendix D). Summary tables for land cover, geology permeability, road and population metrics, and site and watershed metrics are available in the appendices (Appendices E to H).

In addition to gathering landscape scale GIS data, stream flow data was summarized where complete hydrologic records could be identified. This includes 55 gaging locations throughout Puget Sound, all in WRIA's 7, 8, and 9 (Figure 6). Four hydrologic metrics previously identified as correlating with B-IBI were calculated for each gage including measures of frequency (high pulse count), duration (high pulse range), and flashiness (R-B index, T_{Qmean}) (Table 8, DeGasperi et al. 2009). Because gaging data are available for only a small proportion of macroinvertebrate sampling locations, hydrologic metrics likely will not be used as a first cut to prioritize basins for restoration. However, where available, data will be utilized to inform possible restoration strategies.

Table 8. Description of the 4 hydrologic metrics used in this project from DeGasperi et al. (2009).

Metric Name	Definition (Units)	Expected Response to Urbanization
High Pulse Count	# of times/water year that discrete high flow pulses occur (Count)	Increase
High Pulse Range	Range in days between the start of the first high flow pulse and the end of the last high flow pulse during a water year (Days)	Increase
T_{Qmean}	The fraction of time during a water year that the daily average flow rate is greater than the annual average flow rate of that year (Fraction of year)	Decrease
R-B Index	Richards-Baker Flashiness Index: a dimensionless index of flow oscillations relative to total flow based on daily average discharge measured during a water year (Unitless)	Increase

Figure 6. Stream gages identified with relatively complete hydrologic records (55 total).



5.0. CONCLUSIONS & NEXT STEPS

B-IBI data for Puget Sound streams from nearly 1,200 sites were downloaded for this project and includes 121 sites with a maximum score of "excellent" and 345 sites scoring "fair" that have been sampled multiple times and at least once between 2009 and 2012 (Table 9). With these "excellent" and "fair" sites identified, the next steps include watershed prioritization, protection/restoration strategy development, and implementation cost estimates.

Table 9. Summary table by WRIA of the number of sites with "excellent", "fair", or filtered "fair" B-IBI scores.

WRIA #	WRIA Name	Total # Sites	"Excellent" (≥ 42)		"Fair" (28-36)		Filtered "Fair"* (28-36)	
			$B\text{-}IBI_{max}$	$B\text{-}IBI_{avg}$	$B\text{-}IBI_{once}$	$B\text{-}IBI_{avg}$	$B\text{-}IBI_{once}$	$B\text{-}IBI_{avg}$
1	Nooksack	35	2	2	8	7	1	1
2	San Juan	0	0	0	0	0	0	0
3	Lower Skagit/Samish	2	0	0	0	0	0	0
4	Upper Skagit	3	1	1	2	2	1	1
5	Stillaguamish	61	3	1	41	39	11	9
6	Island	1	0	0	0	0	0	0
7	Snohomish	136	29	8	85	64	50	33
8	Cedar-Sammamish	421	41	9	172	90	143	71
9	Duwamish-Green	136	19	1	76	41	68	36
10	Puyallup-White	40	2	2	25	15	18	8
11	Nisqually	20	1	1	14	11	6	4
12	Clover Creek	2	0	0	0	0	0	0
13	Deschutes	31	2	0	23	14	9	8
14	Kennedy-Goldsborough	1	0	0	1	1	0	0
15	Kitsap	179	12	2	118	93	33	23
16	Skokomish-Dosewallips	16	2	1	10	9	1	0
17	Quilcene-Snow	9	0	0	6	5	0	0
18	Elwha-Dungeness	63	4	2	44	39	3	3
19	Lyre-Hoko	34	3	3	23	22	1	1
TOTAL	Puget Sound	1190	121 (10.2%)	33 (2.8%)	648 (54.5%)	452 (38.0%)	345 (29.0%)	198 (16.6%)

* Filtered "fair" includes sites meeting three criteria: 1) scoring "fair" B-IBI at least once, (2) sampled more than once, and (3) sampled at least once between 2009 and 2012.

5.1 Preserving "Excellent" Sites

The 121 "excellent" sites are candidates for preservation and protection to achieve the target of retaining 100% of these "excellent" scores by 2020. Funding for protecting streams is likely limited and therefore prioritizing these 121 sites for protection is necessary to ensure that funding goes to the highest priority areas. This prioritization process may include an evaluation of which sites best characterize a baseline of "excellent". The 33 sites with "excellent" B-IBI$_{avg}$ scores are likely high priority preservation sites. However, some sites sampled multiple times with B-IBI$_{max} \geq 42$ have particularly variable B-IBI scores between sampling events and may score "poor" or "very poor" as often as they score "excellent". Are these truly "excellent" sites worthy of preservation? In other cases, it may have been years since a site has scored "excellent" indicating some level of degradation and it may be too late for protection actions to preserve "excellent" scores. In addition to prioritizing "excellent" sites for protection, preservation strategies and planning level cost estimates will be developed (Task 6).

5.2 Restoring "Fair" Sites

A coarse filtering of "fair" sites reduced the candidates for restoration from 648 to 345 (Table 9). If only sites that *average* "fair" scores and meet the coarse filters are considered, then the number of candidates for restoration is further reduced to 198. The goal of this project is to target 30 small Puget Sound stream drainages from "fair" to "good"; therefore additional criteria will be applied. The next project deliverable includes a decision framework diagram and description for prioritizing restoration sites and includes a summary of a stream basin restoration literature review (Task 3). This process will include a workshop to solicit feedback from the project's stakeholder team on the proposed decision framework.

Once the restoration decision framework is finalized, then the framework will be applied to identify restoration sites (Task 4) and restoration strategies and planning level cost estimates will be developed (Task 5).

6.0. REFERENCES

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APPENDICES

Appendix A: B-IBI Biological Condition Categories

The B-IBI scoring system is a quantitative method for determining and comparing the biological condition of streams. The B-IBI is composed of 10 metrics and each individual metric is given a score of 1, 3, or 5, with higher numbers given to conditions representative of streams unaltered by anthropogenic influence. These metrics are then added together for the single, integrated overall B-IBI score ranging from 10 to 50 which fall in one of five biological condition classes (Table 7).

Table 10. Five classes of biological condition categories modified from Karr et al. (1986) by Morley (2000).

Biological Condition	Description	B-IBI Range
Excellent	Comparable to least disturbed reference condition; overall high taxa diversity, particularly of mayflies, stoneflies, caddis flies, long-lived, clinger, and intolerant taxa. Relative abundance of predators high.	46-50
Good	Slightly divergent from least disturbed condition; absence of some long-lived and intolerant taxa; slight decline in richness of mayflies, stoneflies, and caddis flies; proportion of tolerant taxa increases	38-44
Fair	Total taxa richness reduced – particularly intolerant, long-lived, stonefly, and clinger taxa; relative abundance of predators declines; proportion of tolerant taxa continues to increase	28-36
Poor	Overall taxa diversity depressed; proportion of predators greatly reduced as is long-lived taxa richness; few stoneflies or intolerant taxa present; dominance by three most abundant taxa often very high	18-26
Very Poor	Overall taxa diversity very low and dominated by a few highly tolerant taxa; mayfly, stonefly, caddis fly, clinger, long-lived, and intolerant taxa largely absent; relative abundance of predators very low	10-16

The PSP freshwater macroinvertebrate target specifies that 100 percent of Puget Sound lowland stream drainage areas monitored with baseline B-IBI scores of 42-46 or better retain these "excellent" scores. Therefore, the term "excellent" for the purposes of this project extends from 42 to 50 and includes part of the B-IBI "good" condition class.

Appendix B: B-IBI Tables Submitted Electronically

Due to the large number of candidate sites, complete site by site tables of B-IBI scores are not included in this document. However tables of all "excellent" and all "fair" macroinvertebrate sampling sites will be sent to Ecology electronically in a single spreadsheet accompanying this document. This spreadsheet is available by request. The file includes 9 tabs (Table 11). The B-IBI data tabs are all organized with the same column headings (Table 12).

Table 11. Description of information in the electronic file accompanying this report. This file contains the lists of sites falling into different "excellent" and "fair" categories.

Tab Name in Spreadsheet	# of Sites	Description
ColumnDesc	N/A	Description of the column headers for the tabs with B-IBI data (summarized in Table 12 in this appendix)
AllData	1190	All stream and river B-IBI data downloaded from the PSSB (www.pugetsoundstreambenthos.org) in November 2013 for Puget Sound sampling sites. Data ranges from 1994-2013.
≥46	43	Sites with a B-IBI$_{max}$ ≥ 46 ("excellent")
Avg≥46	5	Sites with B-IBI$_{avg}$ ≥46 ("excellent")
≥42,<46	78	Sites with a B-IBI$_{max}$ ≥42,<46 ("excellent", see Appendix A)
Avg≥42,<46	28	Sites with B-IBI$_{avg}$ ≥42,<46 ("excellent")
≥28,≤36	648	Sites scoring between 28 and 36 at least once ("fair", B-IBI$_{once}$)
≥28,≤36Filtered	345	Sites scoring between 28 and 36 at least once, sampled multiple times, and sampled at least once between 2009 and 2012
Metadata	N/A	Describes the user-defined selections used to download the data from the PSSB

Table 12. Description of the column headers for the tabs in the electronic file listing the sites falling in "excellent" and "fair" B-IBI categories as defined in this project.

Column Name	Description
Site ID	Unique number used in the Puget Sound Stream Benthos
WRIA	Water Resources Inventory Area Name
WRIA#	Water Resources Inventory Area Number (1 through 19)
Basin	Basin name
Subbasin	Subbasin name
Stream	Stream name
Agency	Jurisdiction coordinating sample collection
Project	Name of the project
Site Code	Site name given by coordinating jurisdiction
Latitude	Latitude of sampling location in decimal degrees
Longitude	Longitude of sampling location in decimal degrees
1994 - 2012	B-IBI score for each year
2013	B-IBI score for 2013; data available at time of download (Nov 2013) were downloaded, but 2013 data were omitted from further analysis because most samples had not yet been processed
Avg	Average B-IBI score across years ($B\text{-}IBI_{avg}$)
N	Sample size: number of times a site was sampled across years
$\geq$46	# of times B-IBI scores were greater than or equal to 46 (upper end of "excellent")
$\geq$42	# of times B-IBI scores were greater than or equal to 42 (total "excellent")
28-36	# of times B-IBI scores were between 28 and 36 ("fair")
All$\geq$28	# of times B-IBI scores were greater than or equal to 28 ("fair", "good", and "excellent")
Excellent	% of samples falling in the 46-50 "excellent" range
Good	% of samples falling in the 38-44 "good" range
Fair	% of samples falling in the 28-36 "fair" range
Poor	% of samples falling in the 18-26 "poor" range
Very Poor	% of samples falling in the 10-16 "very poor" range
N 2009-12	# of times sampled between 2009 and 2012 (only in the >=28, <=36 filtered tab)

Appendix C: Additional GIS Work

Additional GIS work will be conducted as this project progresses if needed for watershed prioritization or preservation/restoration strategy development. Some of the GIS work may include the following:

- Finish checking basin delineation for 206 sites added to the PSSB since 2011
- Once basin delineation is deemed correct, integrate GIS results from these new basins into landscape metric spreadsheet (Appendix D)
- Calculate 2011 C-CAP land cover for all basins. 2006 was previously the most recent year available
- Calculate ownership for each site. This is not parcel by parcel information especially for private ownership, but instead the percentage of land within a basin that is public (local government, state, or federally owned), tribal, or private.
- Integrate connectivity and fragmentation into a landscape metric. This might involve utilizing the C-CAP fragmentation tool[5] or something similar.
- Watershed urbanization and effective impervious surface area are highly correlated, but this project currently only has percent urbanization calculated. Calculate impervious surface area if regional experts determine this is a helpful addition.
- Incorporate aspects of Ecology's Puget Sound Watershed Characterization into the decision framework (Stanley et al. 2012, Wilhere et al., 2013)
- Integrate more direct proximity to stream measures where desired instead of relying solely on buffer versus local watershed or entire contributing watershed.

[5] Description of the C-CAP fragmentation tool is available at http://clear.uconn.edu/tools/lft/lft2/index.htm or http://www.csc.noaa.gov/digitalcoast/tools/lft.

Appendix D: GIS Table Submitted Electronically

Due to the extensive number of landscape metrics calculated for such a large number of candidate sites, complete site by site summary tables of the GIS data are not included in this document. However, tables of all landscape metrics will be sent to Ecology and this spreadsheet is available by request. This spreadsheet includes three tabs (Table 13) and 306 columns of spatial data organized into several categories (Table 14). Some of these data are further summarized in Appendices E through H

Table 13. Description of information in the electronic file accompanying this report. This file contains the spatial data for 1131 biomonitoring locations[6].

Tab Name in Spreadsheet	Description
SpatialData	Each row is a biomonitoring site. Each column contains site locator information or calculated landscape metrics as described below.
ColumnDescriptions	Description of the 306 column headers broken down into several categories (Table 14).
Abbreviations&ContactInfo	Description of abbreviations repeatedly used in the metric names and contact information for questions about the spatial data.

Table 14. Categories and description of spatial data calculated for this project.

Category	# of Metrics	Description or Example
Site Information	19	Site names, site codes, lat/long, basin information, etc.
NLCD 2006 Land Cover	44	2006 National Land Cover Data including % forest, agriculture, urban, etc. at various spatial scales (buffer, 1km, entire watershed)
Physical Characteristics	37	Slope, elevation, precipitation, stream length or density, watershed area, etc. Also includes road and population density metrics.
Geology permeability	6	Proportion of 1km or entire watershed falling in high, low, or water categories for surficial geology
C-CAP Land Cover Metrics[7]	168	1992, 1996, 2001, and 2006 C-CAP land cover metrics (e.g., bare, cultivated, grass, hi intensity developed, etc) for 1km or entire watershed spatial scales.
C-CAP Grouped Land Cover Data	32	The C-CAP Land Cover Metrics were grouped into Agriculture, Forest, Urban, and Wetland categories for 1km or entire watershed spatial scales.
Total Metrics	**306**	

[6] An additional 206 basins are being delineated and checked. When this is completed, the landscape metric table will be updated with these data.

[7] 2011 NLCD data are now available and likely will be added to the available spatial data (Appendix C).

Appendix E. Land Cover Summary Statistics

Table 15. Summary statistics for 2006 NLCD landscape metrics for 1,132 B-IBI sampling locations.

Variable Name	Mean	Median	Min	Max	Std. Dev.
% Forest (ws)	56.3	64.4	0.0	100	31.8
% Forest Nregen (ws)	43.7	42.3	0.0	100	27.1
% Forest Regen (ws)	12.5	4.9	0.0	84	16.6
% Forest Young (ws)	3.1	0.5	0.0	71	6.5
% Forest Older (ws)	9.4	3.6	0.0	84	13.3
% Wetland (ws)	1.8	0.9	0.0	36	2.8
% Shrub (ws)	3.2	2.0	0.0	79	4.7
% Grass (ws)	1.7	0.7	0.0	52	2.8
% Barren (ws)	0.5	0.0	0.0	14	1.7
% Urban (ws)	24.7	8.7	0.0	98	30.1
% Agriculture (ws)	11.8	8.7	0.0	62	11.0
% Forest (1 km ws)	50.7	50.1	0.0	100	31.4
% Forest Nregen (1 km ws)	40.8	37.3	0.0	100	27.6
% Forest Regen (1 km ws)	9.9	1.2	0.0	90	17.6
% Forest Young (1 km ws)	2.3	0.0	0.0	71	6.9
% Forest Older (1 km ws)	7.6	0.2	0.0	90	14.7
% Wetland (1 km ws)	4.0	1.5	0.0	67	6.7
% Shrub (1 km ws)	2.7	0.6	0.0	95	6.0
% Grass (1 km ws)	1.6	0.0	0.0	52	3.4
% Barren (1 km ws)	0.3	0.0	0.0	24	1.6
% Urban (1 km ws)	25.5	14.0	0.0	99	28.1
% Agriculture (1 km ws)	15.2	11.3	0.0	83	14.3
% Forest (bf)	57.4	64.2	0.0	100	30.8
% Forest Nregen (bf)	46.3	45.4	0.0	100	27.2
% Forest Regen (bf)	11.2	4.1	0.0	100	15.7
% Forest Young (bf)	2.6	0.2	0.0	100	6.3
% Forest Older (bf)	8.6	3.0	0.0	81	12.7
% Wetland (bf)	3.5	1.7	0.0	100	6.2
% Shrub (bf)	3.0	1.5	0.0	76	4.7
% Grass (bf)	1.4	0.5	0.0	36	2.5
% Barren (bf)	0.3	0.0	0.0	20	1.1
% Urban (bf)	21.8	7.2	0.0	95	27.5
% Agriculture (bf)	12.6	9.8	0.0	87	11.8
% Forest (1km bf)	51.6	53.9	0.0	100	31.0
% Forest Nregen (1km bf)	42.8	41.1	0.0	100	28.2
% Forest Regen (1km bf)	8.7	0.0	0.0	100	17.1
% Forest Young (1km bf)	2.5	0.0	0.0	100	7.3
% Forest Older (1km bf)	6.3	0.0	0.0	92	13.6
% Wetland (1km bf)	6.4	2.3	0.0	100	10.1
% Shrub (1km bf)	2.5	0.0	0.0	92	6.2
% Grass (1km bf)	1.4	0.0	0.0	36	3.4
% Barren (1km bf)	0.3	0.0	0.0	31	1.9
% Urban (1km bf)	22.1	10.8	0.0	98	26.2
% Agriculture (1km bf)	15.7	11.5	0.0	88	15.1

ws = contributing watershed; 1 km ws = 1 km contributing watershed; bf = 90-m buffer for contributing watershed; 1 km bf = 90-m buffer for 1 km contributing watershed; Nregen = non-regeneration forest; Regen = regeneration forest; young forest = harvested 1992-2002; older forest = harvested 1972-1992.

Appendix F. Surficial Geology Permeability

Table 16. Summary statistics for surficial geology permeability for 1,132 B-IBI sampling locations.

Variable Name	min	max	average	median	std dev
High Permeability (1 km ws)	0.0	100.0	44.3	42.3	34.4
Low Permeability (1 km ws)	0.0	100.0	55.3	57.7	34.5
Water (1 km ws)	0.0	25.6	0.4	0.0	2.0
High Permeability (ws)	0.0	100.0	24.0	17.8	23.8
Low Permeability (ws)	0.0	100.0	75.4	81.4	24.0
Water (ws)	0.0	18.5	0.6	0.0	1.8

ws = contributing watershed; 1 km ws = 1 km contributing watershed

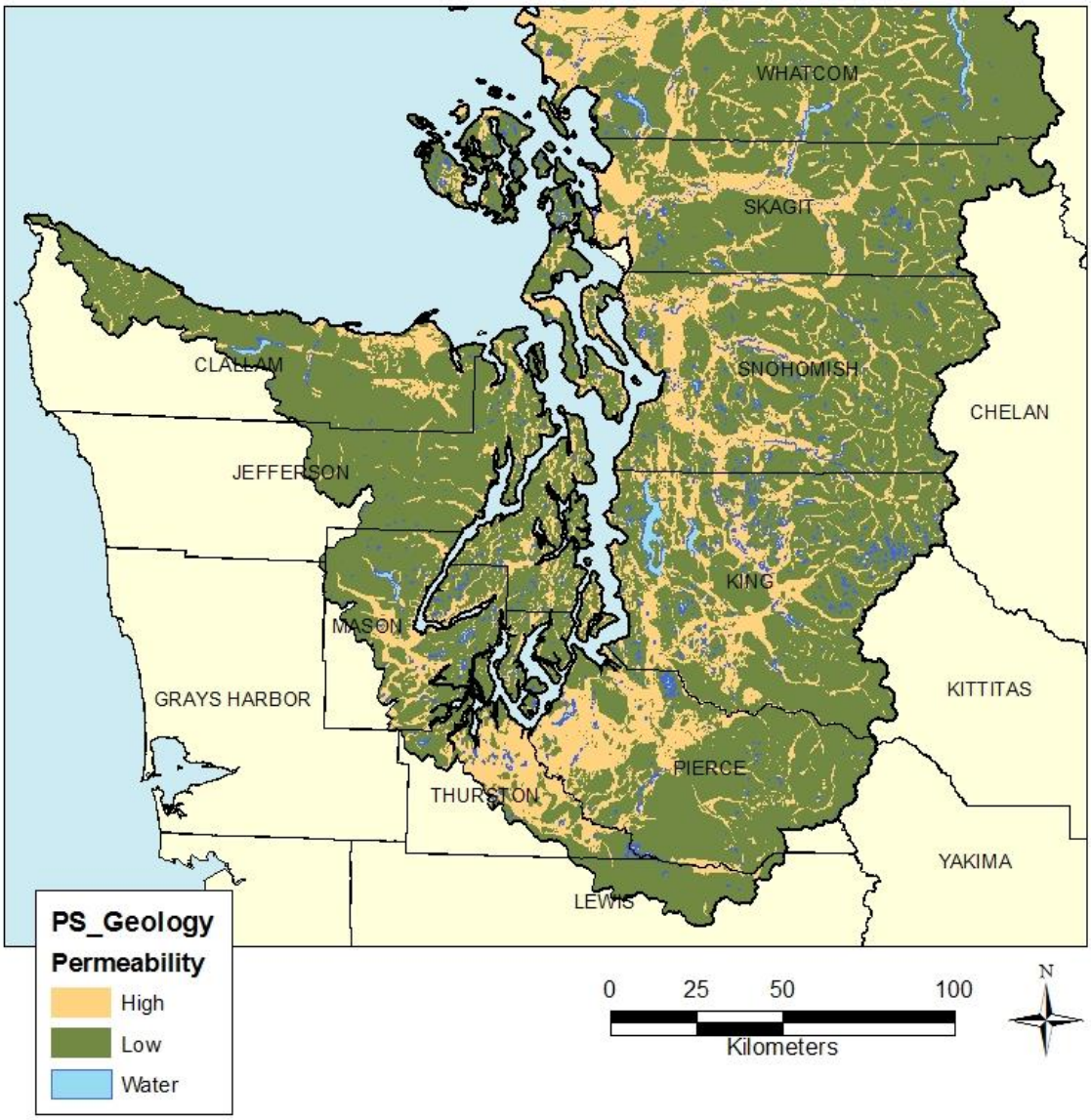

Figure 7. Surficial geology permeability for Puget Sound.

Appendix G. Summary Statistics for Road and Population Metrics.

Table 17. Summary statistics for road and population metrics for 1,132 Puget Sound biologic sampling locations.

Variable Name	Mean	Median	Min	Max	Std. Dev.
Total Road Length (km) (ws)	71.7	22.0	0.0	1904.1	144.5
Road Density (km/km^2) (ws)	4.0	2.3	0.0	18	4.1
Roads per Stream Crossing per km (ws)	2.0	1.1	0.0	14	2.3
Total # Roads Per Stream Crossing (ws)	76.9	21.0	0.0	2045	160.8
Total Road Length (km) (1 km ws)	4.1	2.6	0.0	34.3	4.4
Road Density (km/km^2) (1 km ws)	4.3	3.0	0.0	22	4.0
Roads per Stream Crossing per km (1 km ws)	1.9	1.1	0.0	18	2.2
Total # Roads Per Stream Crossing (1 km ws)	5.0	2.0	0.0	64	6.8
Population Density (#/km^2) (ws)	483.3	93.9	0.0	3266	733.7
Tot Population (ws)	6036.4	805.0	0.0	140682	13523.6
Population Density (#/km^2) (1 km ws)	485.2	118.0	0.0	4117	730.8
Tot Population (1 km ws)	453.1	91.6	0.0	6557	788.2

ws = contributing watershed; 1 km ws = 1 km contributing watershed

Appendix H. Summary Statistics for Site and Watershed Metrics.

Table 18. Summary statistics for site and watershed metrics for 1,132 biologic sampling locations.

Variable Name	Mean	Median	Min	Max	Std. Dev.
Elevation site (m)	92.3	52.7	0.0	1015	114.6
Watershed area (hectare) (ws)	5603.2	906.4	9.2	167650	16166.8
Watershed area (hectare) (1 km ws)	93.7	92.3	3.0	214	41.1
Elevation minimum (m) (ws)	91.2	51.9	0.0	1015	114.6
Elevation maximum (m) (ws)	601.4	232.6	43.7	4385	632.1
Elevation mean (m) (ws)	296.3	153.5	13.5	1404	292.1
% slope minimum (ws)	0.3	0.0	0.0	20	1.3
% slope maximum (ws)	85.6	56.3	3.6	883	85.5
% slope mean (ws)	17.6	9.8	1.5	83	16.1
Precipitation minimum (mm) (ws)	1298.6	1129.5	393.0	3982	548.7
Precipitation maximum (mm) (ws)	1942.5	1447.0	440.0	6756	1186.4
Precipitation mean (mm) (ws)	1575.8	1286.7	432.8	4463	733.4
Length stream (km) (ws)	109.2	17.8	0.0	3240	311.3
Density Stream (km/km^2) (ws)	2.0	2.0	0.0	7	0.4
Elevation minimum (m) (1 km ws)	91.2	52.0	0.0	1015	114.6
Elevation maximum (m) (1 km ws)	213.9	141.8	13.2	1328	188.9
Elevation mean (m) (1 km ws)	141.4	97.6	6.4	1135	136.7
% slope minimum (1 km ws)	0.6	0.2	0.0	21	1.7
% slope maximum (1 km ws)	47.0	40.7	1.9	225	27.7
% slope mean (1 km ws)	13.9	10.1	0.4	80	11.0
Precipitation minimum (mm) (1 km ws)	1323.4	1156.0	400.0	3982	583.5
Precipitation maximum (mm) (1 km ws)	1420.0	1219.0	421.0	4425	653.0
Precipitation mean (mm) (1 km ws)	1366.4	1185.4	406.9	4150	611.1
Length stream (km) (1 km ws)	2.4	2.2	0.0	7.1	1.2
Density stream (km/km2) (1 km ws)	2.6	2.5	0.0	47	1.6

ws = contributing watershed; 1 km ws = 1 km contributing watershed