Stressor Identification and Recommended Actions for Restoring and Protecting Select Puget Lowland Stream Basins

December 2019

King County

Department of Natural Resources and Parks
Water and Land Resources Division

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Water Quality Program

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Funded in part by:

National Estuary Program Stormwater Strategic Initiative

Alternate Formats Available
206-477-4800 TTY Relay: 711

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Acknowledgements

We would like to thank the Washington Department of Ecology (Ecology) for administering the grant and encouraging and facilitating projects related to restoring and protecting streams and their communities. Ecology staff who have helped make this project successful include Lola Flores, Gary Myers, Colin Hume, Derek Day, Chad Larson, Glenn Merritt, Jill Lemmon, and Jack Janisch.

We would also like to thank staff from partnering agencies. Thanks to their help, we included five sites outside of King County in the project. They helped us select sites and obtain access, and shared data and insights about the streams and their basins. In particular we appreciate the help provided by Renee Scherdnik with Kitsap County, Cami Apfelbeck and Christian Berg with the City of Bainbridge Island, Micah Bonkowski with the City of Issaquah, and Sara Brooke Benjamin and Analiese Burns with City of Bellingham.

We are very appreciative of the excellent taxonomic work done by Rhithron Associates, Inc., and we would like to especially thank Sean Sullivan for his advice regarding harmonizing taxonomic data.

We are especially thankful for Liora Llewellyn's help with launching the project, organizing and leading field work, and gathering and managing a wealth of information about the sites. We would also like to thank several more King County staff for their help collecting and presenting field and geospatial data, including Dan Lantz, Houston Flores, Andrew Miller, Brendon Grant, and Fred Lott. Wendy Gable Collins helped us craft the excellent conceptual diagram.

The report was improved thanks to many helpful suggestions from reviewers and colleagues, including Christian Berg, Micah Bonkowski, Analiese Burns, Curtis DeGasperi, Chad Larson, Josh Latterell, Deb Lester, Gary Myers, Doug Navetski, Robert Plotnikoff, Renee Scherdnik, and Tom Ventur.

This project was supported by U.S. Environmental Protection Agency (EPA) National Estuary Program (NEP) funding by means of a grant administered by Ecology (Ecology, Grant No. G1300132).

Cover photo: Big Soos Creek, taken by Liora Llewellyn

Citation

King County. 2019. Stressor Identification and Recommended Actions for Restoring and Protecting Select Puget Lowland Stream Basins. Prepared by Kate Macneale and Beth Sosik, Water and Land Resources Division. Seattle, Washington.

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EXECUTIVE SUMMARY

What is the goal of the project?
The project, titled "Restoration and Protection of Select Puget Lowland Stream Basins," is a phased effort aiming to restore and protect streams throughout Puget Sound. This report is the second of five phases. The goal of this phase is to identify human activities that are impacting a select group of streams and recommend actions to facilitate restoration and protection within the stream basins.

This project is meant to advance the overall goal of the Puget Sound Partnership (PSP) to restore, protect, and sustain Puget Sound. This project specifically addresses the protection and restoration targets for one of PSP's Freshwater Quality indicators: the Puget Lowland Benthic Index of Biotic Integrity (B-IBI). This index is used to characterize stream health, and is based on the variety of stream macroinvertebrates present at a site. Stream macroinvertebrates—the insects, snails, worms, and other small but visible animals that live on the bottoms of streams—are sensitive to degraded environmental conditions and thus can be used as indicators of stream health. The B-IBI scoring system categorizes streams as "very poor" to "excellent," on a scale of 0-100. This report focuses on four "fair" streams in need of restoration, and ten "excellent" streams in need of protection.

Who will use and benefit from this project?
The report is intended to be used by managers of the 14 stream basins that are the focus of the report, as well others interested in restoring and protecting stream conditions and tracking effectiveness of those actions with B-IBI. This includes regional managers and scientists charged with managing and monitoring the effects of urbanization on stream flows, water quality, fish habitat, and B-IBI.

How did we select sites?
We selected 14 sites from over 1,200 B-IBI sites throughout the Puget Sound region using four simple criteria. Sites were selected based on their previous B-IBI scores, size of the stream and basin, and our ability to access the site to conduct habitat surveys. We also considered land use in the basin and how feasible it would be to improve "fair" scores or maintain "excellent" scores based on the constraints that urban development imposes on stream communities and B-IBI scores.

"Fair" sites include:

- Illahee Creek, Kitsap County, Water Resource Inventory Area (WRIA) 15
- Manzanita Creek, City of Bainbridge Island, WRIA 15
- Stensland Creek, King County, WRIA 8
- Tibbetts Creek, City of Issaquah, WRIA 8

"Excellent" sites include:

- Lost Creek, Kitsap County, WRIA 15

- Wildcat Creek, Kitsap County, WRIA 15
- Chuckanut Creek, Whatcom County, WRIA 1
- Margaret Creek, King and Snohomish Counties, WRIA 7
- Big Soos Creek, King County, WRIA 9
- Weiss Creek, King County, WRIA 7
- Rock Creek, King County, WRIA 8
- Cristy Creek, King County, WRIA 9
- Newaukum Creek, King County, WRIA 9
- Boise Creek, King County, WRIA 10

How did we identify what may be impacting each site?
To provide context for the site conditions, we used two approaches to generate a list of conditions that characterize typical "excellent" B-IBI sites and identify thresholds at which communities change in response to degraded conditions. First, we examined the relationships between environmental conditions and B-IBI scores from an extensive set of sites from across Puget Sound. Second, we examined how sensitive macroinvertebrate taxa (independent of B-IBI scores) respond to degraded conditions. We used these analyses to characterize conditions at typical "excellent" sites in the region. We then evaluated each study site, and compared its conditions at the local, riparian, and basin scale to those in typical "excellent" sites. Of the 147 environmental parameters considered initially, 47 were used to characterize conditions affecting each site.

What did we find?
We found what others have observed in studies evaluating the relationship between B-IBI scores and environmental conditions: multiple, related factors associated with urbanization and loss of forest are likely responsible for degraded stream health and negative impacts to B-IBI scores.

Changes in macroinvertebrate community composition are best explained by large-scale stressors (e.g., extent of urbanization in the basin and the associated stressors) rather than a single stressor. At all "fair" sites, we found multiple conditions were degraded. Generally, conditions were most impacted at the basin and riparian scale, and in some cases, less at the local scale. These results corroborate other studies that indicate B-IBI scores are better correlated with basin-scale conditions than with site-scale conditions.

As we expected, environmental conditions at "excellent" sites were much better than conditions at the "fair" sites. However, we were surprised to find evidence of multiple degraded conditions at most "excellent" sites. This suggests macroinvertebrate communities either have some resilience to degraded conditions (e.g., most taxa can tolerate a limited extent of urban development), or the impact of the degraded conditions may be time-lagged. If so, their "excellent" status may be tenuous.

What restoration and protection actions are recommended?
Improving "fair" sites is likely to require actions targeting stormwater management and forest health, both basinwide and in the riparian buffer. The take-home message is to:

- protect intact forestlands,
- establish more forest cover,
- increase vegetation density and the widths of riparian buffers, and
- control and treat stormwater as much as possible.

At "fair" sites, local habitat actions were often ranked less important than actions targeting stormwater control and forest health throughout the basin and riparian buffer. To improve local conditions, stressors affecting conditions at the basin and riparian scale need to be addressed first. Restoration actions targeting site conditions, like reducing excess fine sediment, often require dealing with the source of the problem up in the basin or in the riparian buffer. Once the source of the problem is resolved, local conditions can be restored.

Recommendations for protecting "excellent" basins were highly variable and dependent on basin specific conditions. Some basins were quintessential "excellent" basins, and exhibited almost no degraded conditions and consistent "excellent" B-IBI scores. In these basins, we recommend protecting forests and limiting development to prevent future degradation. Other "excellent" basins had high B-IBI scores despite the presence of multiple degraded conditions. In these basins, we recommend improving stormwater controls, protecting and enhancing riparian buffers, and increasing forest cover throughout the basin.

What is the next phase of this project?
The next phase of this project is to implement the recommendations for these 14 basins. This phase will include developing feasibility studies, completing restoration and protection designs, securing funding, developing partnerships to facilitate and manage implementation, and developing monitoring plans to evaluate effectiveness. As part of the next phase, implementation plans should be coordinated with programs focused on other objectives (e.g., salmon recovery, nutrient management, contaminant source control) to ensure restoration and protection actions are as efficient and as effective as possible. The next phase of this effort will need to be led by local jurisdictions with in-depth knowledge of the sites and basins.

The results of this phase of the project are intended to inform the feasibility and design phases, as well as the monitoring phase. For instance, the parameters and thresholds we found best described "excellent" streams can also be used to help set recovery targets. Our analyses, for example, found that macroinvertebrate communities change significantly when percent impervious surface in the riparian buffer exceeds 2.2%. That threshold gives planners a restoration target to aim for when evaluating how and where impervious surfaces can be removed or avoided.

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1.0 BACKGROUND

1.1 Introduction

The project, titled "Restoration and Protection of Select Puget Lowland Stream Basins," is a multi-phased effort that aims to restore and protect freshwater quality and invertebrate communities in streams throughout Puget Sound. This project aligns with the overall goal of the Puget Sound Partnership (PSP) to restore, protect and sustain Puget Sound, and specifically addresses the protection and restoration targets for one of PSP's Freshwater Quality indicators (Puget Sound Partnership 2012); the Puget Lowland Benthic Index of Biotic Integrity (B-IBI):

> *By 2020, 100% of Puget Sound lowland stream drainage areas monitored with baseline B-IBI scores of 80*[1] *or better retain these "excellent" scores and mean B-IBI scores of 30 Puget Sound lowland drainage areas improve from "fair" to "good."*

The multi-metric B-IBI is a standardized scoring system applied to benthic macroinvertebrates collected from streams (Karr 1996, Morley and Karr 2002). Benthic macroinvertebrates—the insects, snails, crustaceans, worms, and other animals without backbones that live among the rocks in streams—play a crucial role in stream ecosystems and serve as good indicators of ecological health. Some macroinvertebrate taxa are more sensitive to degraded environmental conditions than others, and thus the types and numbers present in a stream indicate how the conditions have been over time. The B-IBI or "the stream bug index," has been adopted throughout the Puget Sound region as the primary biological indicator of stream "health." B-IBI has been used for nearly 30 years to characterize stream health in Puget Sound and throughout the world, and increasingly, it is used to track effectiveness of restoration and stormwater management actions (e.g., Redmond Paired Watershed Study described in City of Redmond 2015). B-IBI scores range from "very poor" to "excellent" on a scale of 0 to 100.

PSP's restoration and protection targets highlight the need to restore basins classified as "fair" and protect those in "excellent" condition. "Fair" B-IBI scores indicate conditions are somewhat degraded and streams no longer support a diverse and sensitive suite of macroinvertebrate taxa, whereas "excellent" scores indicate few if any stressors (e.g., excess fine sediment, flashy flows) are present and the streams sustain a diverse community of sensitive taxa. Of the 1267 Puget lowland sites monitored from 2009-2018, the most recent B-IBI scores indicate that 25% are in fair condition and 16% are in excellent condition (www.pugesoundstreambenthos.org). Of the remaining, 16% are in very poor condition, 18% are in poor condition, and 25% are in good condition.

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[1] The original PSP protection goal refers to "excellent" sites as those scoring 42-26 or better, based on the 10-50 B-IBI scale. For this phase and future phases, "excellent" is defined as 80 or better on the recalibrated 0-100 B-IBI scale.

The work described here represents the second phase of a five-phase effort (Table 1). This phase (Phase II) focuses on 14 B-IBI sites and the stressors impacting them. Phase I developed a framework for selecting and prioritizing stream sites and outlined restoration and protection strategies (King County 2014a, King County 2015b). One of the "next steps" in the Phase I report was to identify a few pilot, or target, restoration and protection basins, identify likely stressors if needed, and develop and implement basin-specific restoration or protection recommendations (King County 2015b). This report describes the target site selection process, stressor identification process, and basin-specific recommendations for restoring four basins and protecting 10 basins. The next phases (III–V) of this effort, if funded, will include design, implementation and effectiveness monitoring (Table 1) and would be led primarily by local jurisdictions and partners.

Table 1. Phases of the Restoration and Protection of Select Puget Lowland Basins effort.

Phase	Description of Phase in Restoration and Protection Effort
I	Develop framework to select basins and complete initial evaluation of actions that may be needed to restore and/or protect basins. *Completed in 2015.*
II	**This project:** Complete more detailed analysis of conditions at the local, riparian and basin-scale, and evaluate how changes in B-IBI scores and macroinvertebrate community composition correspond to changes in conditions. Based on these relationships and present conditions, develop basin-specific recommendations to restore 4 basins and protect 10 basins.
III	Complete detailed basin-specific proposals in cooperation with CIP groups (including pre-build designs as needed, complete budget) for each basin.
IV	Implementation of restoration and protection actions in each basins.
V	Effectiveness monitoring and dissemination of results.

This phase of the project focuses on the scientific and technical challenges associated with stressor identification and development of appropriate solutions. It is anticipated that other considerations, such as identifying funding for design and implementation and securing community partnerships for long-term monitoring, will be developed in future phases.

The intended audience of this report includes managers of the specific basins evaluated here, as well as anyone interested in restoring and protecting stream conditions and tracking effectiveness of those actions with B-IBI. This includes regional managers and scientists charged with managing urban growth and monitoring effects on stream flows, freshwater quality, fisheries habitat, and B-IBI.

Our intention in this report is to add an independent analysis, focused on stream macroinvertebrate communities and the stressors affecting them, to the ongoing regional effort to prioritize and implement stream restoration and protection. Multiple agencies, tribes, and non-profit organizations have developed or are developing plans that call for improved stormwater management, and the restoration or protection of freshwater quality, salmon habitat, and working agricultural and forest lands. These efforts include but are not limited to development of Implementation Strategies for Vital Sign Indicators identified by PSP, development of basin plans as required by new National Pollutant

Discharge Elimination System (NPDES) permits, and Salmon Recovery plans for Water Resource Inventory Areas (WRIAs). In addition, this project can help inform several King County efforts including the Stormwater Master Plan, Land Conservation Initiative, Million Trees Initiative, the Our Green Duwamish effort, Water Quality Benefits Evaluation, and the Clean Water Healthy Habitat Initiative.

While these other projects and efforts are not necessarily focused on macroinvertebrates and B-IBI scores, the recommendations we present here will likely align with recommendations and strategies identified by others. Many human activities (e.g., urban development, deforestation) that alter environmental conditions and create stressors that impact macroinvertebrate communities are the same as those affecting fisheries and water quality. Therefore, many of the recommended actions will be similar.

The future phases of this effort—design, implementation, and effectiveness monitoring—will be managed by local managers and carried out by restoration specialists, engineers, and land managers. Actions may be implemented as Near Term Actions to meet PSP recovery and protection goals, and as required by future NPDES permits.

1.2 The challenge: Identifying stressors and ways to fix them

To improve sites with "fair" B-IBI scores, degraded conditions and stream functions that have led to the decline or loss of sensitive macroinvertebrate taxa need to be improved. The presumption is that if stressors can be identified and alleviated, sensitive taxa will recolonize the site or increase in density resulting in improved B-IBI scores.

A key challenge when restoring streams is to identify the most likely stressors affecting a stream and its basin, and specify how stream functions can be restored so that stressors are alleviated.

To maintain "excellent" B-IBI scores, the physical, chemical, and biological conditions and stream functions that support a diverse macroinvertebrate community need to be maintained. Protection of intact and high quality watersheds has been an effective and efficient strategy for managing regional water resources and water quality.

A key challenge when protecting streams is to identify potential stressors, and specify how stream functions can be protected so that stressors are avoided.

Healthy macroinvertebrate communities persist only when the physical, chemical, and biological conditions they need are of high quality and sustained at the basin scale (Allan 2004). These conditions are created when underlying functions—such as the conveyance of water to and through a stream channel—resemble those we see in undeveloped, forested watersheds. Harman and others (2012) described a stream function pyramid that is useful when trying to identify the ultimate cause of stressors and how we might fix them.

The foundational stream function is hydrology: the movement of water in a watershed to a stream channel. Like other functions, hydrology is affected by natural factors like climate and the geology of the basin, but it can be dramatically altered by the removal of forest vegetation (deforestation), disconnection of the stream from its floodplain, and the installation of stormwater conveyance systems (Booth 2005, DeGasperi et al. 2009, Harman et al. 2012). The next stream function is hydraulics, or how water moves within the stream channel. Hydraulics depend on hydrology, but instream flow dynamics can also be altered by stormwater systems, disconnection from the floodplain, channel shape, and substrate complexity. The next function relates to geomorphology, and how wood and sediment are carried and deposited within the channel and floodplain. Land use conversion and especially riparian buffer conditions can dramatically influence geomorphology. The fourth function in the pyramid is physiochemical, or the instream processes that maintain good water quality. Stormwater systems can dramatically affect water quality, and in particular the concentrations and loads of contaminants. Finally, if all functions in the pyramid are intact, together they create and maintain the conditions needed to support a diverse biological community (Harman et al. 2012).

“Excellent” B-IBI scores indicate stream functions are intact and conditions are good. If stressors are present, they are minimal and the community is resilient. Protection plans for excellent sites and their basins focus on identifying stream functions that may be at risk of disruption and conditions that are therefore at risk of degradation, and laying out strategies to guard against those stressors.

In contrast, when human activities such as deforestation, floodplain disconnection, and urban development disrupt one or more stream functions, numerous stressors can result (Figure 1) (Meyer et al. 2005, Paul and Meyer 2001, Walsh et al. 2005a, Walsh et al. 2005b). Urban development is associated with numerous stressors that impact macroinvertebrates in a variety of ways, directly and indirectly (Figure 1). This universal phenomenon has been called the “urban stream syndrome” (Walsh et al. 2005b). Because there are numerous ways disrupted functions can lead to stressors, and many ways stressors interact to worsen conditions and impact macroinvertebrates, identifying the causes for B-IBI decline and specific remedies for improving B-IBI at any particular site can be challenging (Figure 1).

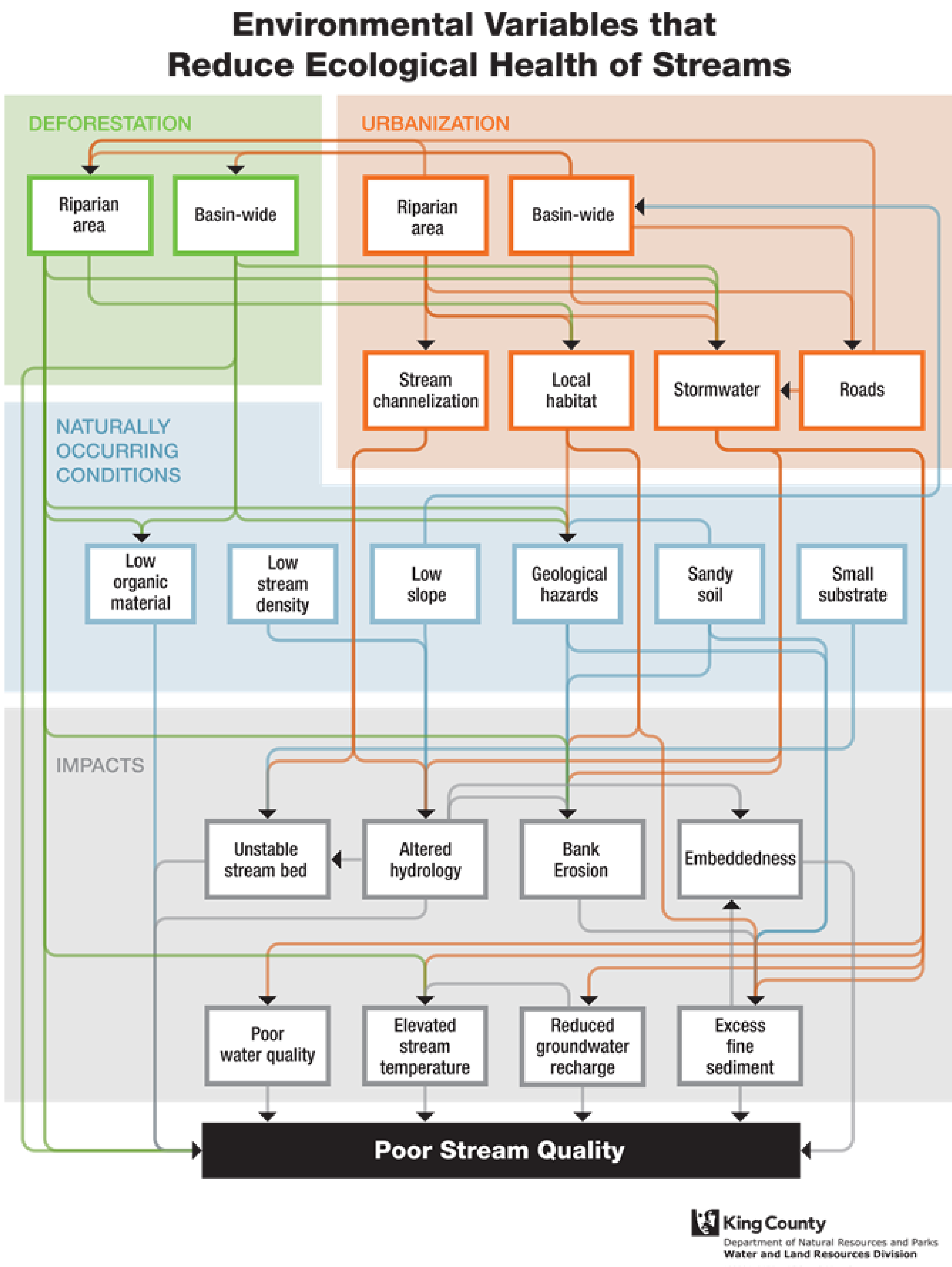

Figure 1. **Conceptual model illustrating how human activities (deforestation and urban development) negatively affect stream quality. Arrows show impact pathways, including pathways involving naturally occuring conditions when those conditions exaccerbate impacts.**

Numerous studies have found that the extent of urban development in a basin is typically one of the best predictors of B-IBI scores in Puget Lowland streams (Figure 2) (DeGasperi et al. 2018, Morley and Karr 2002) as well as throughout the world (Meyer et al. 2005, Paul and Meyer 2001, Walsh et al. 2005a, Walsh et al. 2005b). This pattern is helpful for understanding regional patterns and setting recovery expectations (Figure 2) (Paul et al. 2009); however, it does not diagnose specific stressors affecting a basin nor prescribe remedies to reverse the degradation.

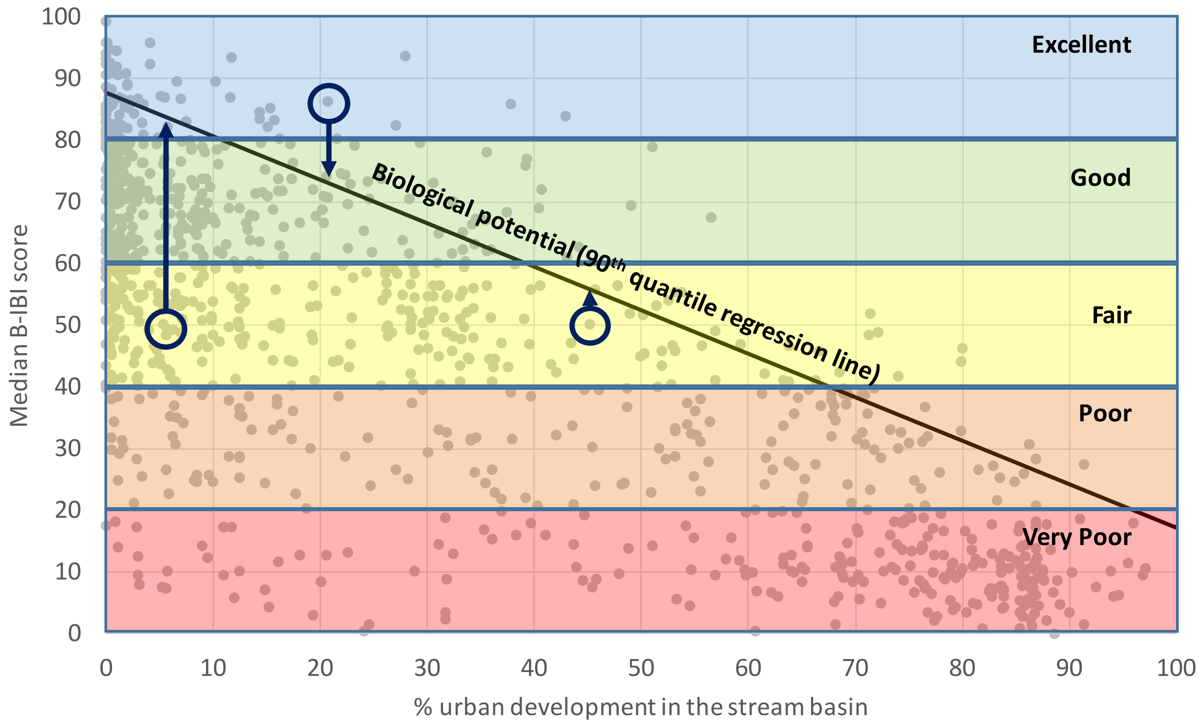

Figure 2. The extent of urban development in a stream basin and the median B-IBI scores for sites (grey dots, n=1061) across Puget Sound. The black line illustrates the 90th percentile or predicted biological potential of sites across the urban gradient. The colored bands indicate the B-IBI categories (e.g., very poor to excellent). Circles illustrate sites (left to right) scoring less than, more than, or just about at their biological potential given the extent of urban development in its basin.

Several studies have tried to isolate the effects from multiple stressors associated with urbanization and identify which are most likely affecting B-IBI scores in Puget Lowland streams (DeGasperi et al. 2009, DeGasperi et al. 2018, King County 2014b, King County 2017, Larson et al. 2019, Marshalonis and Larson 2018, Plotnikoff and Blizard 2013). Overall the findings highlight the importance of flow alteration, excess fine sediment, loss of instream habitat complexity, and loss of vegetation and canopy cover in the riparian area and upland forest. These studies illustrate that multiple stressors typically affect stream health, and they ultimately originate with land clearing followed by urban development.

Appreciating the scale of the problem is critical for fixing it. Restoration studies have repeatedly shown that if underlying functions are not restored at the appropriate scale, stressors will persist and communities will not recover (Kroll et al. 2019, Palmer et al. 2010, Pilotto et al. 2019, Sundermann et al. 2013).

It is also critical to understand a site's recovery potential. Paul and others (2009) have suggested the classic wedge-shaped pattern (Figure 2), of B-IBI scores along the urban development gradient, can be used to help define restoration expectations. Paul and others (2009) have described the outer envelope of scores in the wedge (defined by the 90th quantile regression line) as the observed biological potential. We think of this as a "best case scenario," when considering the extent of urban development in a basin. For example, for sites with 40% urban development in the basin, a B-IBI score over 60 would be over that 90th percentile or about as high as you might expect (see Figure 2). If a site is scoring far less than its biological potential, there may be restoration actions that could help improve its score. In contrast, for sites already at or near their biological potential, there may be constraints on any further increases. In this study we used this concept of observed biological potential to help select sites and evaluate recent scores from sites.

1.3 Study goal and objectives

The overall goal of Phase II was to make progress towards restoring and protecting freshwater quality in Puget Sound streams. PSP's restoration and protection targets call for restoring 30 streams, so that scores improve from fair to good, and protecting all streams that score excellent. Following Phase I, in which selection criteria were established and general strategies were outlined, this next phase was needed to facilitate implementation.

To advance restoration and protection goals, this project aimed to identify site-specific stressors and develop basin-specific recommendations to restore four Puget Lowland stream basins with "fair" B-IBI scores to "good" B-IBI scores, and develop protection plans for 10 Puget Lowland stream basins that currently have "excellent" B-IBI scores.

The project objectives were to:

1. Select four "fair" and ten "excellent" basins using the candidate basin selection criteria developed in Phase I.
2. Gather basin-specific data to help identify stressors and inform development of restoration and protection plans. These data are gathered through physical habitat surveys, macroinvertebrate samples, geospatial analysis, hydrologic measures, and additional site information obtained from managers familiar with the selected basins.
3. Identify stressors that are likely affecting habitat and water quality conditions in the select basins.
4. Create maps of each basin that detail possible stressor location and highlight where actions should be targeted.

5. Develop recommendations for the four "fair" basins with the goal of improving B-IBI scores to "good."
6. Develop recommendations for the ten "excellent" basins with the goal of maintaining their B-IBI scores.

By identifying specific stressors and impacted conditions, managers can implement site-specific, targeted restoration and protection actions to mitigate some of the effects.

2.0 SITE SELECTION

The restoration and protection sites selected for this study (Figure 3) were identified using decision frameworks developed in Phase I, with some minor modifications. The frameworks were used to narrow the list of potential sites by ensuring selected sites have a reliable B-IBI score (e.g., site has been sampled repeatedly and recently), and are within the Puget Sound Basin and the Puget Lowlands ecoregion. Additional selection criteria are described in the sections below.

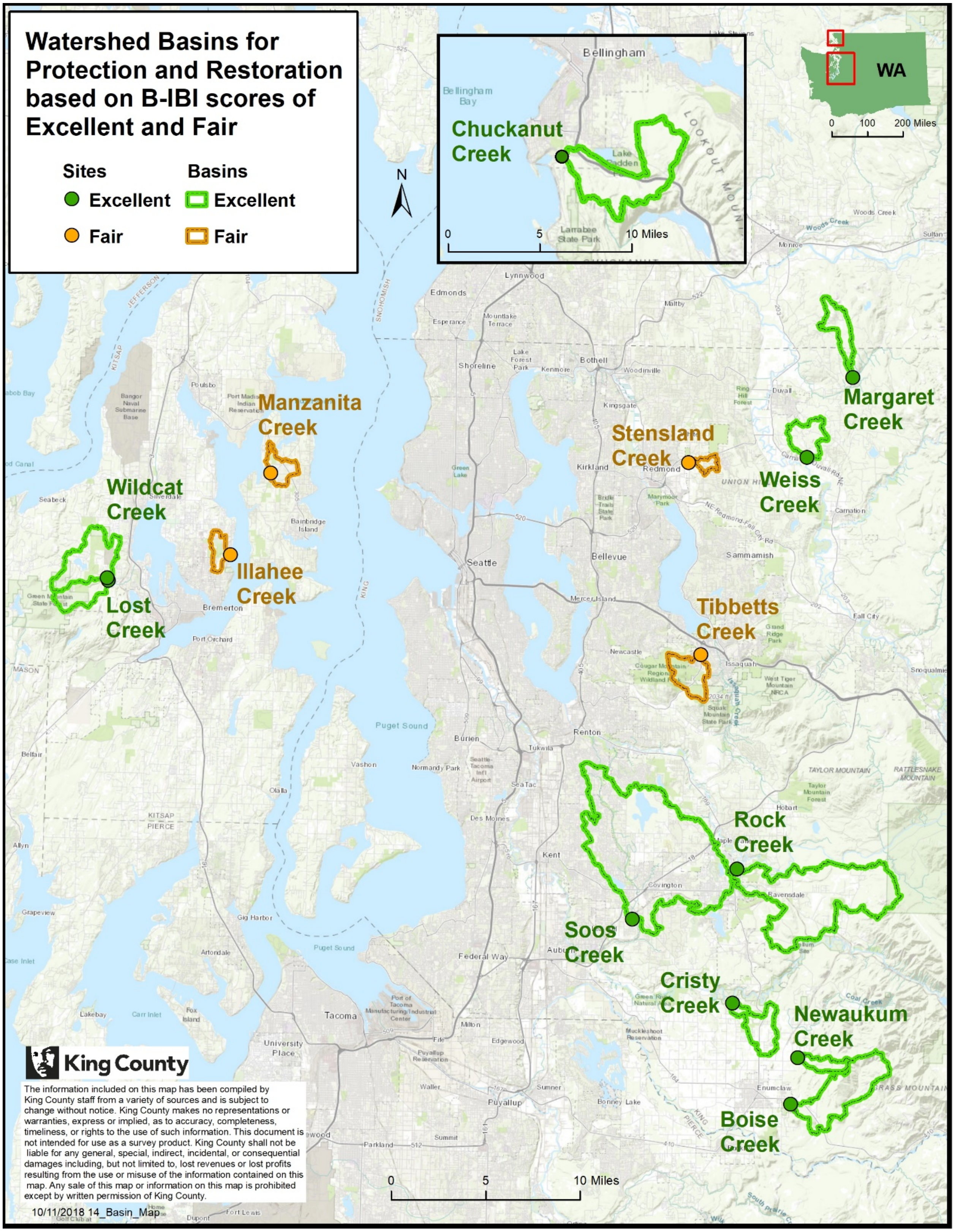

Figure 3. Selected study sites and associated basins.

Selection of potential restoration and protection sites identified in Phase I was based on B-IBI data collected through 2012 (King County 2014a and 2015b). Thus, for Phase II, we repeated the process and included all data collected through 2016. The process was also simplified to ensure future site selection or evaluation could be easily replicated. Summary tables of the revised selection guidelines are included below in sections 2.1 and 2.2.

B-IBI scores were downloaded from the Puget Sound Stream Benthos (PSSB) database on 8/21/2017, and represented 7374 visits at 2052 sites spanning 1994-2016. For this study, data were limited to sites within the Puget Sound basin (WRIAs 1-19), and the Puget Lowlands ecoregion. Specifications for data retrieval from the PSSB included data from (1) all rivers and streams, (2) all publically available projects, and (3) all available years (1994–2016). B-IBI scores were based on the 0–100 scale, with taxonomic resolution defined by metadata and attributes defined by Fore and Wisseman (2012). Replicate samples were combined before scores were calculated, and the number of organisms was defined as a count per visit with a maximum of 500 organisms, then omit/subsample. In a few cases, scores from adjacent sites on the same stream reach were combined and considered as the same site.

2.1 Restoration sites

The initial list of sites was narrowed to 164 that were in Puget Sound, within the Puget Lowland ecoregion, and had a median score of "fair." This list was further reduced to 30 by applying criteria related to sample history, B-IBI scores, basin size, and stream size (Table 2). To select the four restoration sites for evaluation, additional criteria were used to rank sites based on their ecological value and likelihood that restoration actions would be feasible and successful (Table 3).

Table 2. Initial criteria used to select restoration sites.

Type of Information	Required criteria for selected restoration sites
Sample history	Site sampled for at least 5 years, and at least one sample collected within last 5 years.
B-IBI score	Median score of all samples, as well as samples collected in last 5 years, is fair (40-59.99)
Basin size	Contributing basin upstream of site is > 200 acres, but < 3000 acres.
Stream size	Stream is perennial and wadeable (e.g., Strahler order 1-4).

Table 3. Additional criteria considered when selecting restoration and protection sites.

Type of Information	Additional criteria considered when selecting sites	Rationale or Assumptions
Access	Regardless of other criteria, selected sites are accessible to facilitate collection of local habitat data and macroinvertebrate samples. Landowner permission is required if site is located on private land. If site is on public land, there must be project support from the managing public agency.	Access is required for sampling, assessing stressors and implementing restoration actions.

Type of Information	Additional criteria considered when selecting sites	Rationale or Assumptions
Biological potential	The biological potential of sites is evaluated by calculating the difference in the current median B-IBI score and the estimated score, given the current extent of urbanization in the basin. The estimated biological potential is based on the 90th quantile regression line (see Figure 2); this represents the best case scenario for a site given the constraints of urban development in the basin. Restoration sites with the greatest difference between their current score and their estimated biological potential are ranked higher than others. Protection sites scoring among the top 10th percentile for biological potential (or within the limits of their biological potential) are ranked higher.	"Fair" sites that score much lower than their estimated biological potential, given constraints in the basin, may be easier to restore than others that are already scoring as well or better than the estimated biological potential. "Excellent" sites scoring at or above their biological potential may be in need of protection to maintain their excellent status.
Importance and condition of basin	Basins ranked by the Puget Sound Watershed Characterization hydrologic model as least important hydrologically and most degraded, or designated as good for "development", are ranked lower than other potential sites that do not have these designations.	Ecologically valuable basins should be prioritized for restoration and protection.
Salmonid habitat	Sites or basins that provide critical salmonid habitat are ranked higher than those that do not.	These streams may have added value for salmon recovery.
Community engagement*	Sites in basins with active "stream teams", or other citizen groups interested in restoration or protection are ranked higher than those without an engaged community group.	It is more feasible to do restoration in basins with engaged citizens.
Stormwater management*	Potential restoration sites in basins prioritized by local governments for stormwater retrofits or other stormwater management actions were ranked higher than basins without this distinction.	Stormwater retrofits that are already planned or prioritized are more likely to be installed and improve conditions sooner.
Flow data	Potential restoration sites that have existing flow data that may inform stressor identification analyses were ranked higher than those without flow data.	Flashiness metrics based on a lengthy record of flow data are more complete and representative of conditions than metrics based on only one year of data.

*This information was not available for all sites, but if known it was considered.

The final site selection process involved gathering additional information about each site and speaking with local managers about site access, as well as their management priorities and interests in restoration or protection. Due to the project schedule, and need to meet a short sampling window, there was limited time to evaluate sites prior to the 2017 sampling season. As a result, sites for which access could quickly be secured were prioritized. Table 5 lists the four "fair" sites selected for this study. More details about the final 30 candidate restoration sites are included in Appendix A.

Table 4. Restoration sites selected for this study and the supplemental criteria considered in the selection process.

Stream (B-IBI Site Code)	Location	Median B-IBI Score (# years sampled)	Access to Sampling Site	B-IBI Score Far Below Biological Potential	Basin Important and Not Degraded (based on PSWC model)	Provides Salmonid Habitat	Community Interest High	Priority for Stormwater Managers	Flow Data Available
Tibbetts (08LAK3699*)	47.541782, -122.064195	46.4 (13)	✔	✔	**	✔			✔
Illahee (KCSSWM-010)	47.609583, -122.5987	40.2 (9)	✔	✔	✔	✔	✔		✔
Manzanita (ManzBain***)	47.674142, -122.551392	44.3 (5)	✔	✔	✔	✔	✔		
Stensland (Stensland Upper)	47.687381, -122.076594	58.3 (8)	✔		✔	✔		✔	✔

* Site 08LAK3699 had historically been influenced by homeless encampments and was very close to a bridge. For habitat survey and 2017-2018 B-IBI sampling, site shifted upstream to site WAM06600-062567, to ensure there would sufficient stream length to sample. There is a gage on Tibbetts but data were incomplete during the study period and therefore not used in this analysis.

** Basin not evaluated by PSWC model because basin delineation was initially inaccurate.

***Basin was selected based on ManzBain data, but 2017 and 2018 sampling shifted to downstream site because of access.

2.2 Protection sites

The list of potential protection sites was narrowed to 87 by applying criteria related to sample history and B-IBI scores (Table 5). This framework excludes sites if B-IBI scores fall below “excellent” more often than not, or if the most recent scores were lower than excellent. Additional criteria, listed in Table 3, were also considered to facilitate selection of 10 protection sites (Table 6). Appendix A includes information about all 87 sites considered in the final site selection step.

Table 5. Initial criteria used to select protection sites.

Type of Information	Criteria for selected protection sites
Sample history	Sites must have been sampled at least twice between 1994 and 2016, and scored excellent at least once.
B-IBI score	At least one of the following must be true of B-IBI scores from the site: Median score is excellent. A score in the last 2 years (2015-2016) is excellent. Half or more of the scores are excellent. Two or more scores are excellent.
Basin size	Contributing basin upstream of site > 200 acres.
Stream size	Stream is perennial and wadeable (e.g., Strahler order 1-4).

Table 6. Protection sites selected for this study and supplemental criteria considered in the selection process.

Stream (B-IBI Site Code)	Location	Median B-IBI score (# years sampled)	Access to Sampling Site	Within Limits of Biological Potential	Basin Important and Not Degraded (based on PSWC model)	Provides Salmonid Habitat
Rock (08CED4192)	47.374751, -122.017672	89.5 (18)	✓	✓		✓
Soos (09SOO1134)	47.336409, -122.135101	77.0 (14)	✓	✓	✓	✓
Margaret (07CHR070059)	47.75381, -121.8941	76.4 (2)	✓		✓	✓
Cristy (09MID1744)	47.272614, -122.021072	79.2 (14)	✓	✓		✓
Chuckanut (BIO06600-CHUC02)	48.70185, -122.48827	86.9 (4)	✓	✓	✓	✓
Lost (KCSSWM-057)	47.587552, -122.734523	83.0 (2)	✓		✓	✓
Wildcat (KCSSWM-056)	47.589032, -122.736157	87.2 (2)	✓	✓		✓
Newaukum (09NEW2102)	47.231078, -121.94603	82.2 (14)	✓		✓	✓
Boise (BSE_21_GolfCrs)	47.195154, -121.953301	81.9 (2)	✓		✓	✓
Weiss (53E)	47.692487, -121.94356	83.0 (5)	✓	✓		✓

3.0 METHODS

This section describes the field survey methods, geospatial analyses, and statistical analyses conducted to identify stressors and inform restoration and protection strategies for each selected site and basin.

3.1 Field sampling

3.1.1 B-IBI sampling

Macroinvertebrate samples were collected in 2017 and 2018 at each of the 14 sites to confirm the current B-IBI status and provide taxonomic data for statistical analyses. Samples were collected using two standard protocols typically followed by King County and Ecology (see Quality Assurance Project Plan Phase II: Protection and Restoration Plans for Select B-IBI Basins, King County 2018b). The methods are similar and both sample macroinvertebrates from 8 ft^2 of substrate, but the King County method targets riffles (King County 2019a), whereas the Ecology method (Ecology 2016) targets randomly selected transects along a reach at least 150m long. Using both methods allowed us to compare B-IBI scores for the 14 selected sites to data from other studies that had used either method.

Samples collected using King County's methods were compared to results from 169 sites that King County has monitored for nearly two decades. Samples collected using Ecology's method were compared to results from over 80 sites sampled as part of the 2015 Stormwater Action Monitoring (SAM) Status and Trends Study of Puget Lowland Ecoregion Streams (DeGasperi et al. 2018). In addition, replicate samples were collected at two sites in 2018 using the King County method. Thus, four to five macroinvertebrate samples were collected from each site for this project, with one exception. In 2017, samples were not collected from the Boise Creek site due to salmon spawning activity; as such, data collected earlier in the summer for King County's ambient monitoring program were used in the analysis.

3.1.2 Habitat conditions

In 2017 and 2018, local habitat metrics at each of the 14 sites were observed and recorded, using Ecology protocols (Appendix B). These metrics include measures of sediment particle size and distribution, riparian cover, human disturbance and large woody debris. These protocols were also used to assess stream conditions as part of the 2015 SAM study (DeGasperi et al. 2018), which provided context for our results. In 2017, habitat surveys were not conducted in Newaukum and Boise Creeks because of salmon spawning activity. In 2018, surveys were not conducted in Boise Creek because of safety concerns.

Flow data were collected and analyzed to assess potential hydrologic stressors (King County 2018b). At two "restore" sites, Stensland and Illahee, data from existing flow gages were analyzed. At Manzanita, a new flow gage was installed and operated for the 2017–

2018 water year. Flow data collected in Tibbetts Creek were incomplete and therefore were not used in our analyses. In addition, we characterized flow conditions at three "protect" sites, Rock, Chuckanut and Weiss Creeks, using data from existing gages at or near the B-IBI site. For Lost and Wildcat Creek, we calculated flow metrics from a gage on Chico Creek, downstream of the confluence of Lost and Wildcat. Thus, flashiness metrics characterize the larger Chico basin and not the individual creeks. To provide context for this study, we analyzed existing flow data and calculated flashiness metrics from 65 gages located within a half mile of other B-IBI sites. These other sites are in basins similar in size and topography to our study sites.

Continuous temperature data were collected at each site to assess potential thermal stress (King County 2018b). HOBO temperature loggers were installed at each site (fall 2017–fall 2018). Data from each of the selected sites were compared to temperature data from 70 other sites located within a half mile of other B-IBI sites. Temperature data were analyzed using the StreamThermal package in R.

3.2 Geospatial Data

We compiled and analyzed geospatial data to characterize basin conditions and inform recommendations for restoration and protection. We did this for the basin upstream of each of the 14 study sites and for each of the 169 B-IBI sites monitored as part of King County's ambient monitoring program. In particular, we focused on metrics linked to land use, forest metrics, timber harvest history, geology, and urban development characteristics such as road density, age of development, impervious surfaces, and septic risk (Appendix C). These data were summarized by basin, and by the riparian buffer within each basin.

3.2.1 Basin delineation

The basin area for each B-IBI site was defined as the upstream contributing catchment, delineated using Arc Hydro Tools for ArcMap 10.2. The delineations were based on the King County Bare Earth Digital Elevation Mosaic dataset (ground sampling distance 1m), Washington State Department of Transportation (WSDOT) Local Agency Public Roads, King County Streams and Rivers, King County Stormwater Closed Conveyances, and WSDOT Railroads at 1:24K resolution. For sites outside of King County where high resolution digital elevation models (DEMs) and accurate stream layers were not available, the basins were manually digitized from topographic contour interpretation.

3.2.2 Dynamic riparian buffer

Riparian buffers for stream segments within each basin were delineated using the Riparian Buffer Delineation Model (RBDM) Pro toolbox for Arc GIS Pro. These were based on hydrologic estimations of the 50-year flood elevation for each stream order in the region; stream, lakes and HUC12 polygons from National Hydrography Dataset (NHD) Plus data; gridded Soil Survey Geographic Database (gSSURGO) soil data; National Wetlands Inventory data; and King County Bare Earth DEM (reprojected and resampled to 10m resolution).

This delineation process results in a variable-width buffer. This is a different approach than used for previous King County studies, in which a fixed-width buffer was applied to each side of a stream segment for the entire stream length (e.g., a fixed 90-m buffer on each side was considered in King County 2014a). As Abood and others (2012) describe, the variable-width, or "dynamic," buffer is likely more ecologically relevant because it accounts for factors that affect how a stream interacts and is influenced by the riparian zone. A recent literature review of riparian buffers done by King County (2019b) highlights the range of widths needed to maintain various functions (e.g., erosion control, shade). The review did not evaluate this concept of dynamic buffers, but the findings illustrate that riparian functions are maintained at different widths depending on a range of factors including but not limited to the size of stream, soil composition, vegetation type and age, etc. In addition, our analysis considered the riparian buffers for the entire length of the stream upstream of the B-IBI site, and did not distinguish between buffer area near to the site versus those farther upstream. This is in contrast to the SAM Status and Trends study (DeGasperi et al. 2018), which limited the upstream riparian buffer distance based on the watershed area upstream of the pour point. We did not do a comparison of these various methods of riparian buffer delineation and distance, as it was beyond the scope of the study, but this would be an interesting future project.

3.3 Assessment of stressors

A multi-step approach was developed to identify stressors likely influencing B-IBI scores at the selected sites. We developed a logical process in which *possible* stressors were evaluated using available data, and ultimately *likely* stressors were identified based on a weight of evidence. Our approach was informed by the Causal Analysis/Diagnosis Decision Information System (CADDIS) approach, developed by the U.S. Environmental Protection Agency (EPA) (www.epa.gov/caddis).

Throughout the report we use "conditions" to describe various habitat features we measured or characterized (e.g., riparian forest health, flow). Some of these conditions are natural, and not necessarily things we can change (Figure 1) (e.g., slope of a basin). Other conditions can be impacted by deforestation and urban development. When conditions are degraded, they become stressors that impact macroinvertebrate communities (Figure 1). To assess if conditions are degraded and have become stressors, we quantified various parameters that reflect those conditions.

The following steps outline our stressor identification process:

1. Using new and existing regional data, evaluate how macroinvertebrate communities and B-IBI scores change along environmental gradients.
2. Using results of correlation and community change analyses, establish the range of values for each parameter that is typical of "excellent" sites. In other words, define what makes an "excellent" site excellent.
3. For each of the 14 basins, evaluate how far each parameter is from what we see in typical "excellent" sites. The farther the parameter value is from those at typical

"excellent" sites, the more certain we are that the condition is degraded. For instance, if flashiness parameters at a site are outside the ranges of flashiness parameters seen at typical "excellent" sites, we would say flow conditions are likely degraded.

4. For each parameter, weigh how certain we are that it is degraded, and how strong it correlates with B-IBI scores. For conditions with multiple parameters, focus on the parameter that appears to be most impacted and most highly correlated with B-IBI scores.

The approach was as comprehensive as possible, given the scope of the project. However, it is important to point out some limitations of this approach and explain how it differs from other studies.

In most evaluations of B-IBI scores and stressors, the objective is to understand general patterns about a large group of sites (e.g., Larson et al. 2019). In contrast, the focus of this study was to diagnose specific stressors affecting the selected basins. The results of the larger analyses are helpful in narrowing the list of candidate stressors, but ultimately we needed to evaluate the individual site conditions. Like a doctor assessing a patient's risk of heart failure, she considers known risk factors like weight and smoking history but also asks about anything that might be specific to the individual patient.

For this study, we considered multiple parameters for some conditions (e.g., multiple measures of substrate size), because we were interested whether a specific parameter indicated a condition was impacted. For example, rather than selecting a single substrate size parameter to consider, we examined all that were at least moderately correlated with B-IBI scores. We acknowledge many of these parameters are highly correlated with each other and therefore not independent; however, we included them to get the most complete assessment of conditions in each basin. For conditions with multiple parameters, we considered all that were available, but then focused on those with the greatest predicted impact.

We also acknowledge that while many conditions may be correlated with B-IBI scores, correlation does not equal causation. Many of the causal relationships among environmental conditions and B-IBI scores are complex, and resolving those are beyond the scope of this project (Figure 1). Instead, we use the correlation and community change analyses to help create an "excellent" site profile used to evaluate each select site.

Evaluation of conditions and stressors at each site was quantitative, based on the data available, but interpretation was subjective. We developed a reasonable weighting process to categorize stressors but ultimately the conversion of field measures to estimates of impact and then order of importance was based on best professional judgement.

Finally, we did not consider all possible stressors in this process. For instance, due to the high cost, water chemistry was not evaluated as part of this study. The SAM Status and Trends Study (DeGasperi et al. 2018) found most water chemistry parameters from

monthly monitoring did not explain a significant amount of the variation in B-IBI scores. That study and regional data also suggest contaminants are not likely at levels of concern in "fair" and "excellent" basins. That said, because we did not include water chemistry data in our assessment, we may underestimate the possible influence of water quality stressors.

3.3.1 Correlations between B-IBI scores and environmental conditions

We evaluated environmental conditions and their possible relationship with B-IBI scores using correlation analyses. Calculating the correlation matrices was largely to reaffirm patterns others have found in regional studies, as well as to have a consistent measure (Pearson's r) across all possible stressors so the relative strength of each could be compared.

To do this, we used the datasets from the King County ambient freshwater monitoring program and the 2015 SAM study (DeGasperi et al. 2018). We also used flow data from King County gages within a half mile from B-IBI sites to examine correlations among flow metrics and B-IBI scores.

3.3.1.1 Parameters considered for analysis

147 different parameters were screened for correlation with B-IBI. Of these, 93 parameters did not correlate sufficiently to warrant further examination ($r<0.3$), and three parameters were removed for being virtually identical to other parameters included in the analysis (Appendix D). For two parameters, the log-transformed derivatives were used instead of the non-transformed values because they were better correlated with B-IBI. Of the remaining correlating parameters, two metrics for winter temperatures were excluded as they were irrelevant for the basins considered in this study. The 47 parameters included for further analysis are presented in Table 7 below. As noted above, this study has not determined a causal relationship between any of these environmental parameters and B-IBI. We opted to be conservative in our approach by examining any parameters that correlate with B-IBI and have plausible causal mechanisms. In addition, some of these parameters reflect natural conditions that may impact stream macroinvertebrate communities, but cannot be changed.

Table 7. Parameters correlated with B-IBI scores and considered in subsequent steps in the stressor identification process. See below for descriptions of the parameters.

Condition	Parameter
Stream bed stability	Log-transformed Relative Bed Stability
Embeddedness of stream substrate	Embeddedness
	Embeddedness, Center Channel
Fine sediment in stream channel	% Fine Gravel and smaller size particles
	% Fine Sediment
	% Sand/Fine Sediment
Flashiness	High Pulse Count
	High Pulse Duration
	Richard-Baker Index (RBI)
	T-Q Mean

Condition	Parameter
Riparian forest health	% Canopy Cover, Riparian
	% Forest Cover, Riparian
	Mean Basal Area, Riparian
	Mean Forest Age, Riparian
	Old Growth Structure Index, Riparian
Basinwide forest health	% Canopy Cover
	% Forest Cover
	Mean Basal Area
	Mean Forest Age
	Old Growth Structure Index
Large substrate in stream channel	% Boulder
	% Coarse Gravel
	% Coarse Gravel and Above
	% Cobble
	% Small Boulder
	Log10 estimated geometric mean substrate diameter
Organic material in soil	Organic Material
Roads in basin	Road Crossings/ Stream Length (miles)
	Road Density
Local habitat	% Disturbance
	Proportion Mixed Canopy
	Proportion Mixed Understory
	Proportion Understory
	Weighted Proximity of Human Influence
Low slope	Slope, Basin
	Slope, Riparian
Soil composition in basin	% Sand
	% Silt
Stream density throughout basin	Stream Density
Stream temperature	Average Daily Spring Temperature
	Frequency of Spring Temperature Exceeding 10 C
	Frequency of Summer Temperature Exceeding 10 C
Riparian urban development	Developed Open Space, Riparian
	% Impervious Surface, Riparian
	% Urban Cover, Riparian
Basinwide urban development	% Impervious Surface
	% Urban Cover

3.3.1.2 Descriptions of overall conditions

Stream Bed Stability

Bed stability is measured as the log-transformed relative bed stability (RBS), which is the ratio of the geometric mean particle diameter (Dgm) to the estimated critical diameter at

bankfull flow. Poor bed stability can impact macroinvertebrates by physically scouring them from the substrate. Bed stability values were calculated using data from our field habitat surveys conducted in 2017 and 2018.

Embeddedness of Stream Substrate
Embeddedness is the degree to which lithic substrate in the streambed is surrounded by fine sediment. It is mediated by sediment availability and stream flow. High embeddedness can be a naturally occurring physical condition from landslide activity in the stream corridor or the presence of sandy soils that are easily eroded in the basin. It can also be the result of sedimentation from stormwater runoff or localized impacts to the riparian zone. Embeddedness may impact macroinvertebrates by reducing their ability to feed, respire, and hide from predators in interstitial spaces. Embeddedness measures were obtained from our field habitat surveys conducted in 2017 and 2018.

Fine Sediment in Stream Channel
Fine particulate material in stream beds contributes to the observed embeddedness. Fines can be naturally derived if landslides or areas of high erosion risk are present in the basin, or if basin soil composition is rich in sand. Fines can also result from stormwater runoff and erosion derived from human impacts. These data were obtained from our field habitat surveys conducted in 2017 and 2018.

Flashiness
Flashiness metrics included in the study are High Pulse Count (HPC), High Pulse Duration (HPD), Richard-Baker Index (RBI), and T-Q mean (TQM). HPC is the number of times per year that daily flow is greater than twice the long-term average daily flow. A low HPC value generally signifies a more stable annual flow regime. HPD is the average duration of high pulse events per year. High HPD values reflect slower oscillations in the hydrograph, which reduces the power of pulse events by spreading the energy released over time. RBI is the sum of the absolute values of day-to-day changes in mean daily flows, divided by the sum of the mean daily flows for a given time period. A low RBI value indicates a stable flow regime with little day-to-day oscillation in flow. T-Q mean is the fraction of time during a water year that average daily flow is greater than the average annual flow. T-Q mean is lower in urban streams due to increased storm flow volume, rapid recession rates, and lower wet-season base flow.

Flow data were collected from gages at or near the B-IBI sites. Flow metrics can be highly variable from year to year, and sites with a longer period of record will have a greater chance of capturing “off” years that are not truly representative of site conditions when considered alone. Unfortunately, the period of record for stream gages used in this study is not uniform. In our analysis, we examine the worst-case values observed at each site, but also consider the historical context for sites with many years of data.

Flashiness is frequently used as a proxy for stormwater impacts. Flashiness itself may impact macroinvertebrates directly by physically scouring them from the substrate. Stormwater runoff may increase stream sediment load from overland flows of stormwater (reducing macroinvertebrates ability to feed and respire), increase the chemical load from

stormwater (introducing metals, pesticides and other organic contaminants), and increase the stream thermal load from stormwater flowing over impermeable surfaces (affecting hatch timing and increasing thermal stress).

Forest Health (Riparian and Basinwide)

Forest health metrics included in the study are mean basal area, old growth structure index, mean forest age, percent canopy cover, and percent forest cover. These metrics were calculated for the riparian buffer (Riparian forest health) and for the entire basin area (Basinwide forest health). The first four metrics are derived from the Landscape Ecology, Modeling, Mapping & Analysis (LEMMA) group's Gradient Nearest Neighbor (GNN) maps of vegetation structure (Ohmann and Gregory 2002), while the last is derived from the National Land Cover Database. Good forest health benefits macroinvertebrates by slowing or absorbing overland stormwater flow, stabilizing soils, serving as a source of organic material, and providing shade.

Large Substrate in Stream Channel

Large substrate in stream channels provides complex habitat for benthic macroinvertebrates. Adequate substrate size benefits macroinvertebrates by stabilizing the stream bed, providing refuge from predation and scouring in interstitial spaces, enhancing feeding opportunities for filter feeders by allowing insects to occupy various elevation in the stream flow, enhancing feeding opportunities for grazers by increasing benthic surface area, and providing complex hydraulics for greater taxa diversity. Instream substrate data were obtained from our field habitat surveys conducted in 2017 and 2018.

Organic Material in Soil

Low soil organic content is a naturally occurring attribute that would likely be difficult to remedy in a reasonable timeframe. It is included in this study because higher levels of soil organic material appear to be correlated with higher B-IBI scores. The reason for this positive correlation is unclear, but it may be because low soil organic content can affect the moisture holding capacity of the soil, which could affect vegetation growth and runoff characteristics. It is also possible low levels of organic matter limit instream productivity and affect food availability or quality for macroinvertebrates. Historical forest harvest practices may have contributed to low organic content in current soils. Data were from the Gridded Soil Survey Geographic (gSSURGO) Database for Washington.

Roads in Basin

Measures of road impacts include road density in the entire basin and the number of road crossings per stream mile. Roads can impact macroinvertebrates by delivering large volumes of stormwater directly to streams, along with: chemicals associated with vehicles (e.g., metals, polycyclic aromatic hydrocarbons, other contaminants from worn tires); sediment from construction track out and unpaved logging roads; and thermal load from heat transferred from paved surfaces. Road crossings also fragment riparian buffers, and if culverts are not properly sized, can alter natural water and sediment flows and disrupt dispersal corridors. Data for the roads parameters were from the 2010 U.S. Census Topographically Integrated Geographic Encoding and Referencing database.

Local habitat
The scientific literature suggests that B-IBI scores may be influenced by conditions at both large and small spatial-scales, and that small scales are particularly important where regional habitat is of intermediate quality (Stoll et al. 2016). The metrics included in "Local Habitat" are measures of riparian quality in the immediate sampling reach, which may influence local sediment sources and solar cover. These data were obtained from our field habitat surveys conducted in 2017 and 2018. The parameters include percent human influence, weighted proximity of human influence, proportion of transects containing understory, proportion of transects containing mixed understory, and proportion of transects containing mixed canopy.

Low Slope
Low mean slope in a basin is a naturally occurring physical feature that cannot be remedied. It is included in this study because it can exacerbate sediment deposition in the stream by slowing flow velocity. In general, development in low slope areas in the region occurred many years ago and at a higher intensity, making it difficult to parse the effects of low slope from urbanization. Slope estimates for the riparian and basin were derived from the Gridded Soil Survey Geographic (gSSURGO) Database for Washington.

Soil Composition in Basin
Soil composition is a naturally occurring physical condition that cannot be remedied. It is included in this study because poor soil composition may exacerbate sediment deposition within the stream. Soils with high sand content and low silt and clay content are less cohesive, and therefore more prone to erosion. On the other hand, sandy soils may facilitate better groundwater recharge. Soil composition parameters in the basin were derived from the Gridded Soil Survey Geographic (gSSURGO) Database for Washington.

Stream Density throughout Basin
A low ratio of stream length to basin area is generally a naturally occurring attribute that cannot be remedied. It is included in this study because it can exacerbate flashiness by reducing stormwater storage volume. Stream density values were from the National Hydrography Dataset. Because the NHD layer does not always match local maps of stream networks (with NHD underestimating stream length in some basins), this measure should be interpreted with caution.

Stream Temperature
Stream temperature metrics included in the study are average daily spring temperature, frequency of spring temperatures exceeding 10°C, and frequency of summer temperatures exceeding 10°C. These were calculated from continuous temperature data. High in stream temperatures may affect macroinvertebrate hatch timing, thermal stress, and oxygen availability. Interestingly, other parameters related to temperature, including frequency of summer temperatures exceeding 16°C (a state standard for salmonids), were not correlated with B-IBI scores.

Urban Development (Riparian and Basinwide)
Urban land development in this study is measured by percent imperviousness and percent urban land cover in the riparian buffer (Riparian urban development) and throughout the entire basin (Basinwide urban development). In addition, developed open space in the riparian buffer is moderately correlated with B-IBI, and therefore was also considered for riparian urban development. "Urbanization" can be thought of as an umbrella stressor, containing within it some combination of a number of human-derived stressors. The exact combination of stressors may vary from basin to basin, but in general "urbanization" integrates elements of deforestation, stormwater runoff, road impacts, site-specific impacts, flashiness, water chemistry, contamination, stream temperature, stream channel alteration, reduced groundwater recharge, and myriad others. The % urban cover and developed open space metrics were from NOAA's Coastal Change Analysis Program (C-CAP) Regional Land Cover dataset for 2016. The % impervious metrics were from King County Impervious/Impacted Surface Interpretation based on 2015 imagery.

3.3.2 Assessing how communities change along environmental gradients

In addition to examining correlations between environmental parameters and B-IBI scores, we used two methods to examine the relationship between parameters and changes in the macroinvertebrate communities themselves: (1) principal coordinate analysis (PCoA), and (2) Threshold Indicator Taxa Analysis (TITAN) (Baker and King 2010). These analyses represent entirely different, yet complementary ways of using macroinvertebrate data to assess how communities change in response to environmental stressors. Macroinvertebrate data from the King County Ambient Monitoring program, from 2012 through 2018, and the 2015 SAM study (DeGasperi et al. 2018) were analyzed with both of these methods.

Before conducting the PCoA or TITAN analyses, the macroinvertebrate data were harmonized to ensure taxa names were consistent among samples collected over multiple years. This was necessary because, over time, taxonomic classification of a group may change. Within a sample, positive identification to the lowest taxonomic level may not be possible due to damage or developmental stage; thus, organisms in the same group may be split between "parent" and "child" taxonomic levels. Staff at Rhithron Associates, Inc. were consulted to prepare the taxonomic dataset for use across all years and update classifications as needed. We then used the USGS Invertebrate Data Analysis System software to roll-up or roll-down taxonomic levels within a sample, using the Remove Parents or Merge Children by Sample method (Cuffney et al. 2007).

We examined the similarity of macroinvertebrate communities among samples using a PCoA biplot. The plot displays the relative similarities in communities by the distances between points; samples with more taxa in common are closer together, and samples with fewer taxa in common are farther apart. After plotting the data in multidimensional space, we projected vectors representing taxa that are significantly ($p < 0.05$) responsible for the spread of samples in the plot (Figure 4). The plot illustrates the relative similarities among samples based on taxa composition. When samples were color coded by their respective B-IBI score ("excellent" to "very poor"), it was clear that certain taxa were associated with

"excellent" sites while others were associated with "very poor" sites (Figure 4). A clear gradient of B-IBI scores across the community data indicates that distinct invertebrate communities occur at "very poor" (red) sites and "excellent" (dark blue) sites, with a broad range of communities at sites with intermediate scores.

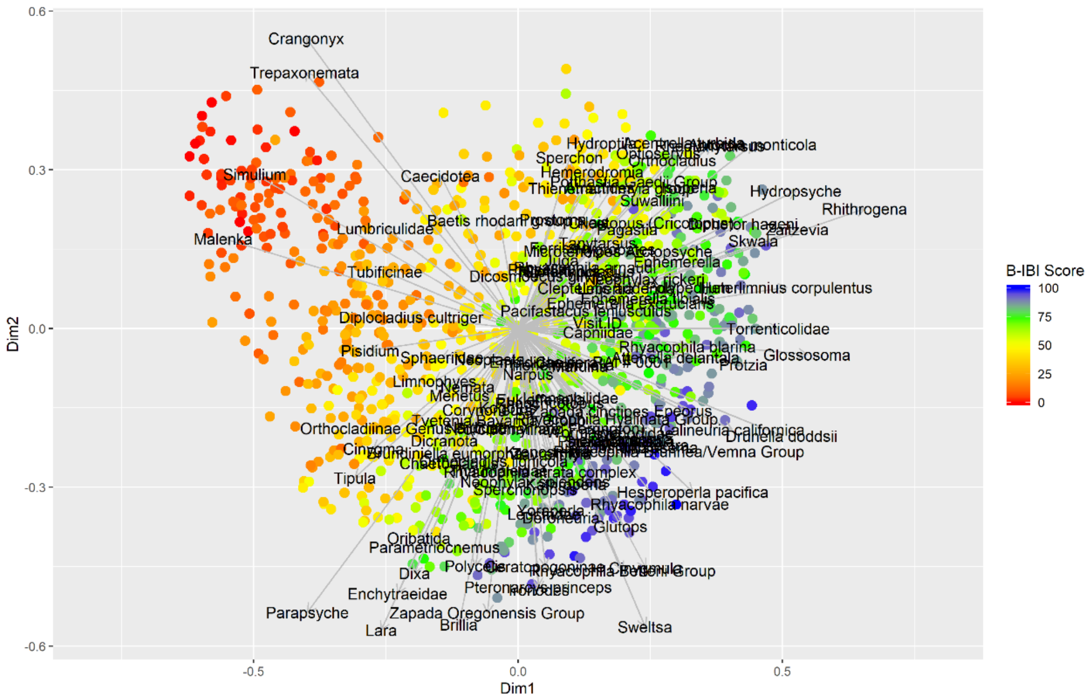

Figure 4. Principal Coordinate Analysis (PCoA) of King County Ambient Monitoring Program samples by community data. Dots represent individual samples; samples that are close together are more similar in community composition. Colors represents the B-IBI score of each sample.

TITAN uses similarity analyses to identify so-called "change points" in the macroinvertebrate community. A change point is the threshold value for an environmental parameter at the point where taxa composition changes rapidly. TITAN allows us to identify parameters that provoke a distinct community response, and estimate the change point value along a gradient. This approach highlights non-linear responses of communities to changes in environmental gradients, whereas the correlation methods described above assume a constant (linear) relationship between a given parameter and B-IBI scores.

TITAN assumes certain taxa increase in response to environmental change, and some will decrease while others will increase; therefore, two community-level change points are possible. The output identifies which taxa are responding to the change, as well as the probable value of the change points for individual taxa, and increasing and decreasing communities. (Figure 5). Because TITAN uses a bootstrapping procedure, the results also provide a measure of uncertainty for each change point value, spanning the 5th to 95th percentile of the predicted change point value distribution. Using the PCoA plot, we visually determined which of the two communities and associated change points are associated with "excellent" B-IBI scores (this community and change point is considered "sensitive"),

and which are associated with "poor" B-IBI scores (this community and change point considered "tolerant"). This classification process is done by examining the general direction of the arrows in the PCoA biplot (Figure 4) for taxa in the two communities identified by TITAN (Figure 5) in relation to the "very poor" to "excellent" gradient.

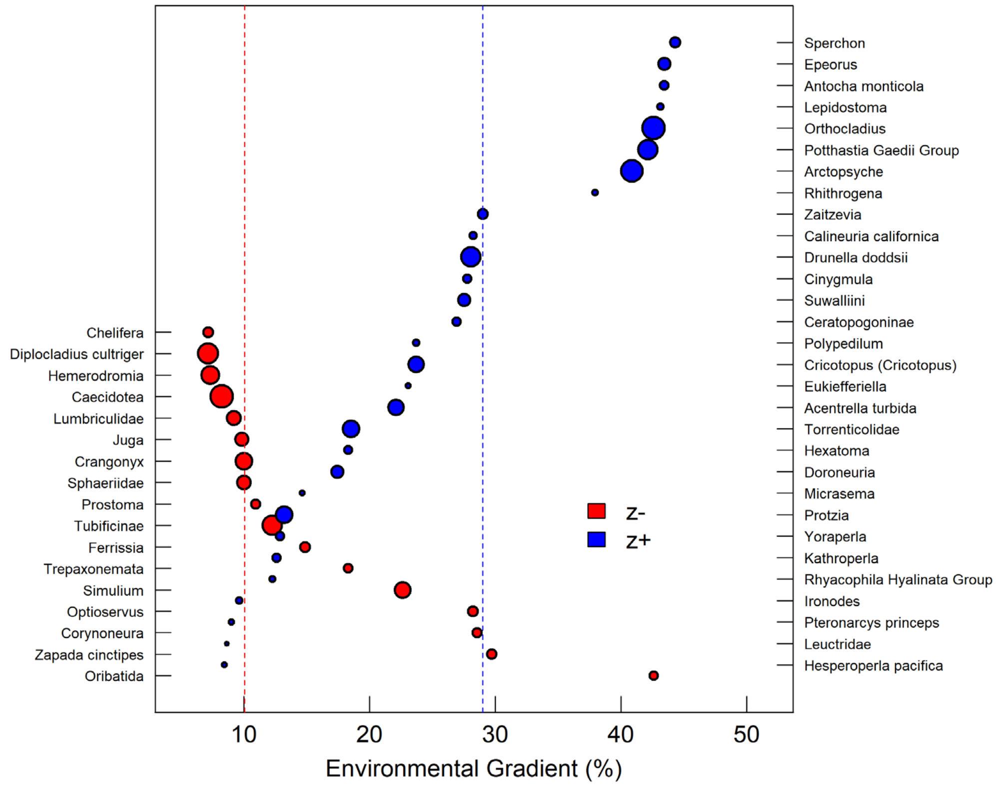

Figure 5. **TITAN output showing tolerant taxa that decrease (in red) and sensitive taxa that increase (in blue) in response to a hypothetical improving environmental gradient. Larger circle size indicates greater response strength. Dashed lines indicate the likely change point value for the overall increasing and decreasing communities.**

For the TITAN to be meaningful, at least a dozen taxa need to respond in a 'pure and reliable' manner. Pureness and Reliability are benchmarks calculated and evaluated within the TITAN algorithm, and automatically filtered (Baker and King 2010). The strength of the community change point was evaluated by summing the z-score of each taxon in the communities that either "increase" or "decrease" along the environmental condition gradient. Because the z-score is standardized, it can be used to compare the strength of response across conditions. Larger summed z-scores indicate stronger responses to a condition. We ignored conditions if the summed z-scores were relatively small, or if they did not display a relatively even, unimodal distribution curve over the condition gradient.

3.3.3 Evaluating the selected restore and protect sites

The results of the correlation and TITAN analyses provided two lines of evidence to help gauge the certainty that conditions within each basin were different enough from typical "excellent" streams and therefore impacted. Standards for communities typically

considered "excellent" were defined using TITAN results and interquartile ranges (IQR) of observed values at "excellent" sites. For each basin, parameters were scored based on whether the value was within or outside of the "excellent" range. We then used these scores, in part, to incorporate uncertainty into the "effective impact" of each parameter in each basin.

Calculating Effective Impact

The "Effective Impact" is based on two measures and is used to evaluate which conditions within a basin are potentially having the greatest effect on B-IBI scores at that particulate site. The first measure is the r^2 value of the Pearson's correlation of the condition and the B-IBI score (Figure 6), which allows us to weigh a highly correlated condition more heavily than a poorly correlated condition. The second part of the equation is our estimation of certainty which is based on two lines of evidence to scale the certainty that the given condition is outside of expected values for an "excellent" site.

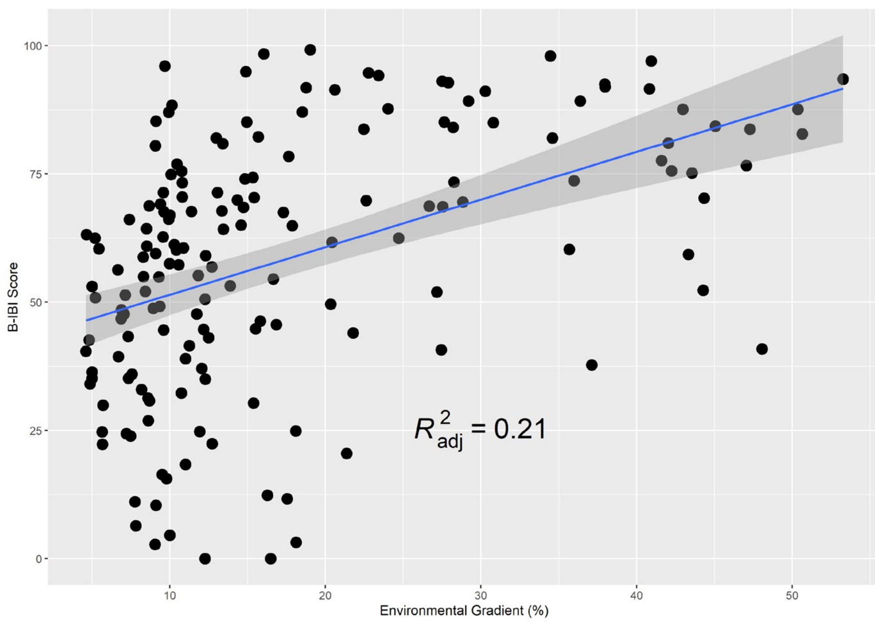

Figure 6. Linear relationship of B-IBI score and an example environmental gradient. In this example, the r^2 indicates the gradient can account for 21% of the variability in the B-IBI dataset.

The first line of evidence is examining the interquartile range (IQR) of conditions at typical excellent sites and comparing those to conditions at our study sites. For conditions with a positive correlation with B-IBI, study site conditions are considered impaired if they fall below the 25th percentile (as defined by the IQR). They are considered meeting expectations if they are within the IQR, and they are exceeding expectations if they are above the 75th percentile (Figure 7). Conversely, conditions with a negative correlation are considered impaired if they are above the 75th percentile, and exceeding expectations if they are below the 25th percentile.

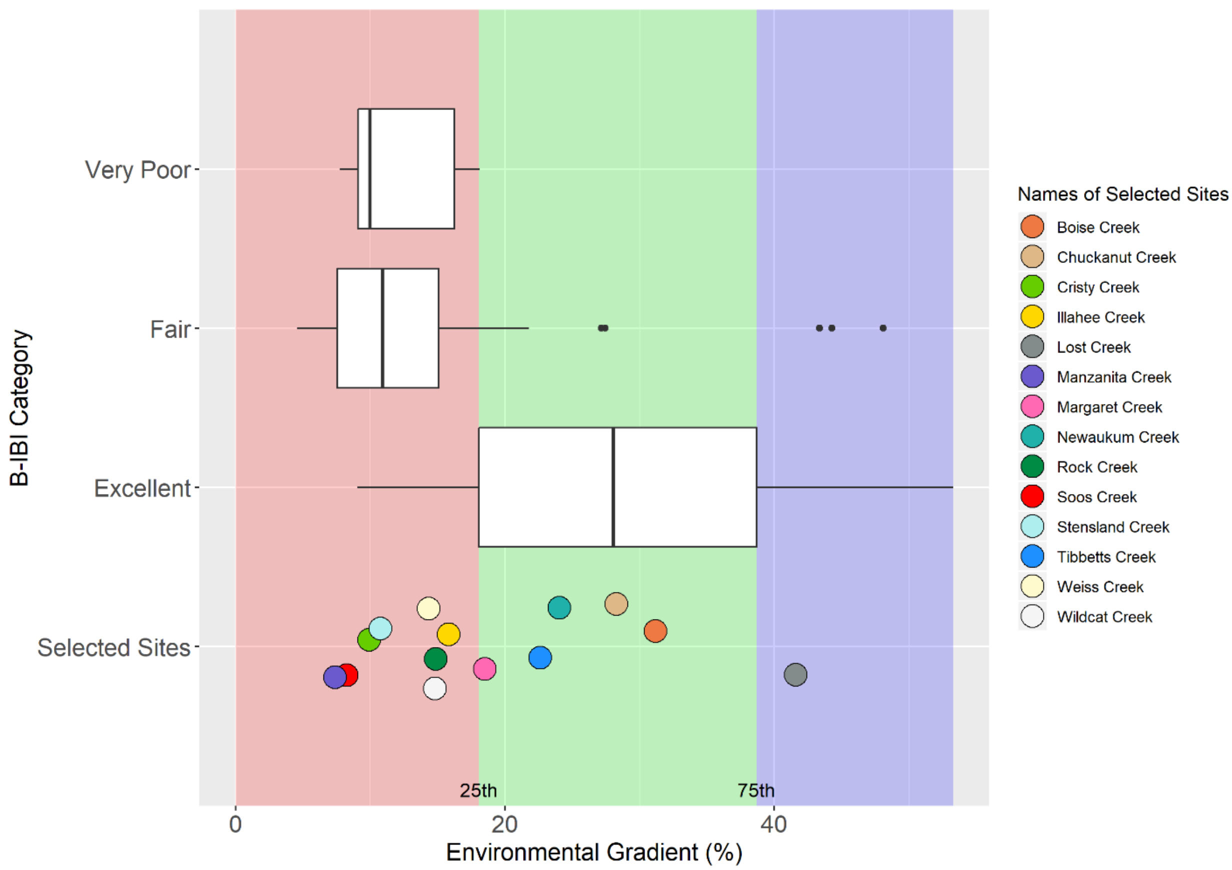

Figure 7. Boxplots of hypothetical values of a stressor from sites with B-IBI scores of "excellent", "fair", and "very poor" in the regional 2015 SAM study, overlaid with hypothetical values from the selected sites (dots dispersed vertically in plot so all can be seen). Values within the red band are below those seen at most "excellent" sites (i.e., <25th percentile). Values within the green band are within the range seen at representative "excellent" sites. Values within the blue band exceed those seen at most "excellent" sites (i.e., >75th pecentile).

The second line of evidence used to scale certainty included examining macroinvertebrate community shifts along condition gradients, using TITAN. As discussed in detail in Section 3.3.2, the results of the analysis provide two change point values corresponding to where, in response to an increasing gradient, one community increases and where another community decreases. The output also provides the 5th and 95th percentiles of the predicted change point value distribution. For conditions where the two communities shift in a way that would increase B-IBI scores with increasing gradient, we observe if the basin value falls: below the likely 'tolerant' change point (Figure 8a); below the 95th percentile of bootstrapped "sensitive" change point values (Figure 8b); below the likely 'sensitive' change point (Figure 8c); above the likely "sensitive" change point (Figure 8d); or above the 5th percentile of bootstrapped "sensitive" change point values (not shown in Figure 8). The same is true for conditions where the community shifts in a way that would decrease B-IBI scores with increasing gradient. We observe if the basin value falls above the likely "tolerant" change point; above the 5th percentile of bootstrapped "sensitive" change point

values; above the likely "sensitive" change point; below the likely "sensitive" change point; or, below the 95th percentile of bootstrapped "sensitive" change point values.

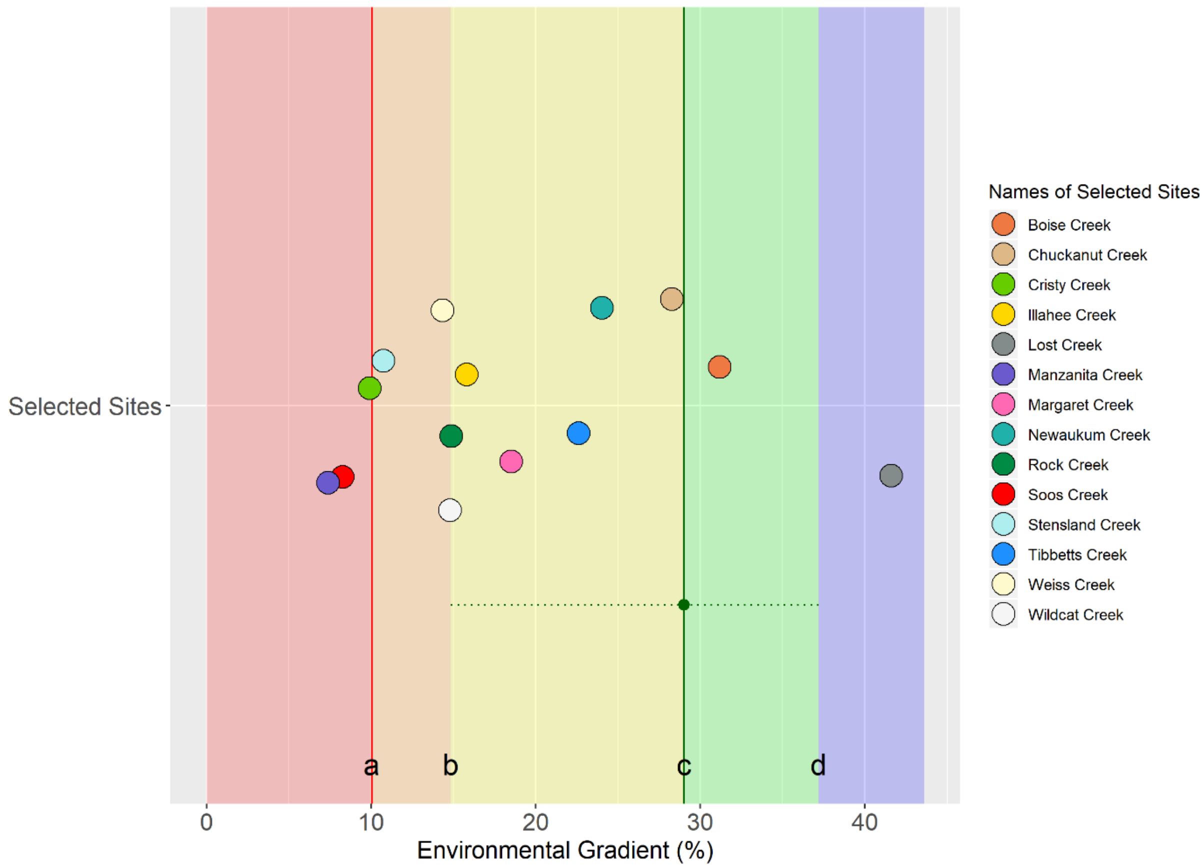

Figure 8. Hypothetical values for basins in this study, overlaid on TITAN results for a hypothetical environmental gradient: (a) 'tolerant' change point; (b) 95th percentile of bootstrapped 'sensitive' change point values; (c) 'sensitive' change point; (d) 5th percentile of bootstrapped 'sensitive' change point values. Dots dispersed vertically in plot so all can be seen. See text for descriptions.

In our hypothetical example (Figure 8), values that fall within the red range (i.e., 0-10) are associated with an increase and dominance of the "tolerant" macroinvertebrate taxa. Values that fall within the pink range are unlikely to be associated with positive shifts of the "sensitive" macroinvertebrate taxa. Values that fall within the yellow range are below the likely 'sensitive' change point value; however, there is some possibility that these values are associated with increases in the "sensitive" macroinvertebrate taxa. Values within the green range are above the likely "sensitive" change point value. Values within the blue range and above are unambiguously associated with increases in the 'sensitive' macroinvertebrate taxa.

The two lines of evidence are then combined to evaluate certainty on a 1 to 7 scale (Figure 9). Larger values (7 to 5) signify greater certainty that the observed basin condition fails to meet expected values for an excellent site, while a score of 4 indicates that the two lines of evidence are in conflict with each other and there is significant uncertainty. Scores

below 4 indicate that both lines of evidence agree to varying degrees that the condition meets expected values for an "excellent" site (Table 8).

It was not appropriate to use TITAN analysis for some conditions (Appendix D). Therefore, only the quantile evaluation was used for these conditions, and certainty values of 1, 3, and 5 were assigned based on whether site conditions exceeded, met, or failed to meet the expected range of values for "excellent" sites.

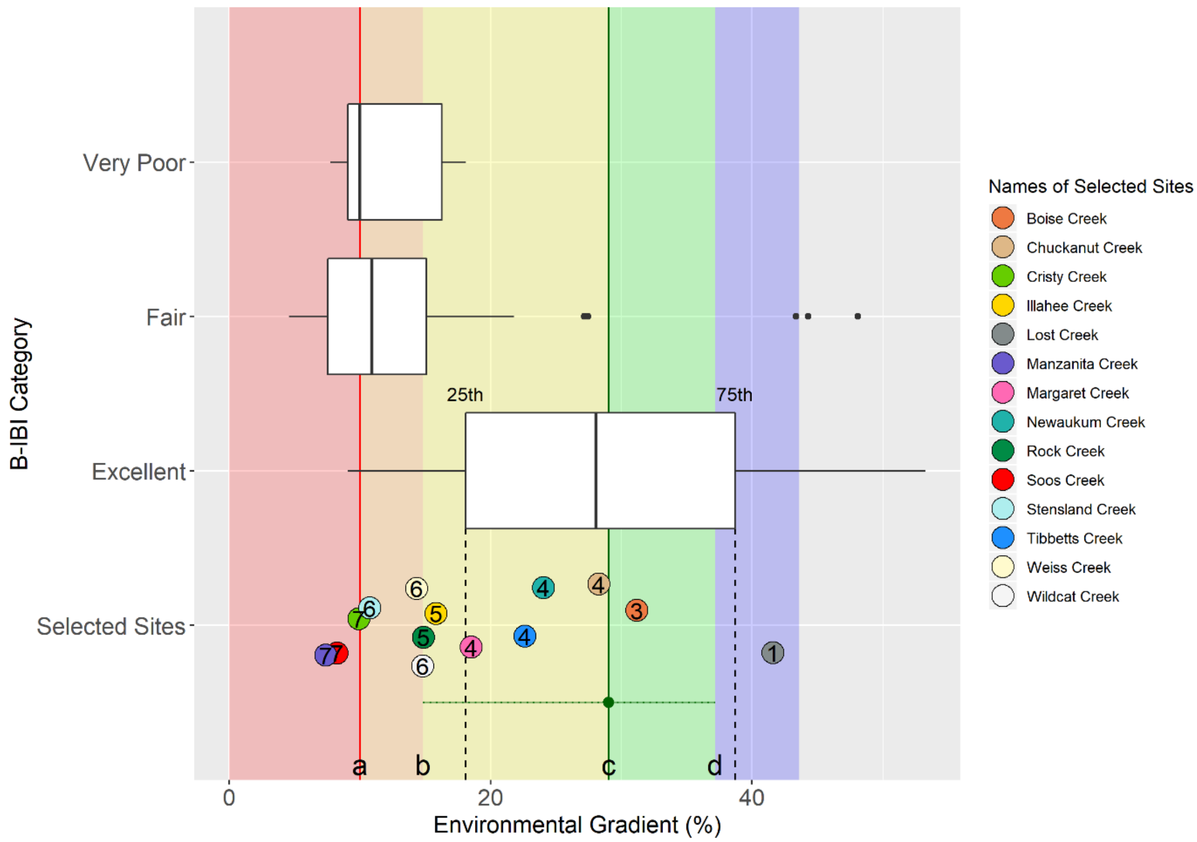

Figure 9. Combined quantile and TITAN results of certainty that the environmental gradient is outside of expected values for an "excellent" site. Larger values within circles signify greater certainty that observed basin condition fails to meet expected values for an "excellent" site.

Table 8. Description of certainty categories used to score site conditions.

Certainty	Description
1	Certain that site value meets or exceeds expectations for an "excellent" site
2	Almost certain that site value meets or exceeds expectations for an "excellent" site
3	Site value probably meets expectations for an "excellent" site
4	Uncertain
5	Site value probably does not meet expectations for an "excellent" site
6	Almost certain that site value does not meet expectations for an "excellent" site
7	Certain that site value does not meet expectations for an "excellent" site

The r^2 value and certainty score were used to calculate the effective impact of a basin condition on the B-IBI score. The cut-off value for considering effective impact was set at 0.63, which is the effective impact that could be achieved for the most poorly correlated condition included in the study (i.e., r^2=0.09) if it scored a certainty of 7 (i.e., r^2*certainty, or 0.09*7=0.63). We also prioritize effective impacts with a certainty score of 5 or higher. For example, average basinwide slope for Manzanita Creek has an effective impact of 0.21*7=1.47, which probably impacts B-IBI scores to some degree. However, the effective impact for Lost Creek was 0.21, which suggests that basinwide slope likely has minimal impact at this location. The effective impact for Tibbetts Creek is 0.84, which is above the 0.63 cut off value, but does not meet the certainty criteria of 5 or greater.

3.4 How effective impacts inform recommendations

Restoration and protection recommendations for each site are based on the specific suite of conditions that are impacted. We developed a simple model to prescribe actions based on the severity of the impact. The list of potential actions was developed in Phase I of the project (King County 2015b), but at that time, we did not attempt to quantify impacts and integrate them into recommendations. The list of actions was informed by a literature review of stream and river restoration studies (King County 2015b); however, there were few examples of studies designed to improve B-IBI scores and even fewer examples demonstrating success. Thus, most of the potential actions are borrowed from studies focused on fish habitat restoration or are based on best professional judgement and our understanding of stream ecology, stressors and B-IBI scores (Figure 1).

The estimated effective impact values were used to inform which actions are recommended to improve basin conditions and B-IBI scores. If any of the parameters for a given condition indicate it is likely impacting the site (certainty >4 and effective impact >0.63), actions are recommended. For example, if any parameter related to fine sediment in the stream channel indicated that condition was outside the typical range of excellent sites and thus impacted, actions related to reducing excess fine sediments would be recommended (see example in Table 9). Table 9 lists the recommended actions for each impacted condition; if a condition could be improved by an action, as indicated by a blue shaded box, that action is recommended. For each site, the value added to each blue box is the maximum effective impact score of all the parameters considered for that condition. The importance of each action for each site is estimated by summing the values for each action.

The values presented in Table 9 present a hypothetical example where local habitat was impacted and had a maximum effective impact of 0.8. In this example fine sediment was also impacted, with the maximum effective impact for that condition of 1.5. Other conditions were also found to be impacted in this example (Table 9), whereas three conditions were not impacted (stream bed stability, stream temperature, and roads in basin). For unimpacted conditions, a "0" was added to applicable boxes indicating no action was recommended based on that condition (Table 9). The importance of each action was

then estimated as the sum of the effective impact values. In this example, the three most important actions relate to stormwater conveyance systems.

For some conditions, such as fine sediment, multiple actions are recommended because there are likely many causes of the problem and therefore many ways to improve it. For other conditions, such as riparian forest health, there is only one action that remedies that impact (planting vegetation and extending the riparian buffer). This model effectively weights actions by the number of impacts they will affect. No other weighting was incorporated, but this could be done as we learn more about restoration effectiveness.

Table 9. Key to identify and calculate importance of recommended actions, based on stream conditions and their effective impact. Blue boxes indicate actions needed to address the impact, as well as the maximum effective impact (EI) value for that condition or a zero if the condition is not impacted. The importance of each action is the sum of the effective impact values for that action. Hypothetical EI values are listed as an example.

Recommended Actions		Stream conditions												Importance (sum of EI scores)
		Local habitat	Fine sediment in stream channel	Large substrate in stream channel	Stream bed stability	Embeddedness of stream substrate	Riparian forest health	Riparian urban development	Stream temperature	Roads in basin	Basin-wide forest health	Basin-wide urban development	Flashiness	
In-stream	Add large substrate		1.5	0.7	0									2.2
	Stablize stream banks		1.5		0	2.2								3.7
Riparian Buffer	Stablize slopes	0.8	1.5			2.2		1.2						5.7
	Plant vegetation, extend buffer	0.8	1.5			2.2	0.7	1.2	0					6.4
Stormwater Conveyance Systems	Increase stormwater flow control	0.8	1.5		0	2.2			0	0		1.9	1.5	7.9
	Improve stormwater treatment	0.8	1.5			2.2				0		1.9		6.4
	Maintain storage and treatment facilities	0.8	1.5		0	2.2				0		1.9	1.5	7.9
	Minimize impact of road runoff	0.8	1.5		0	2.2				0		1.9	1.5	7.9
Forested Land	Maintain or decomission forest roads	0.8	1.5			2.2				0		1.9		6.4
	Allow existing forest to mature		1.5			2.2					1.1		1.5	6.3
	Plant vegetation		1.5			2.2					1.1		1.5	6.3
Agricultural Land	Exclude livestock	0.8	1.5		0	2.2								4.5
	Manage waste	0.8	1.5			2.2								4.5
	Prevent soil loss	0.8	1.5		0	2.2								4.5
Mining Areas	Enforce mining BMPs		1.5			2.2								3.7

3.5 Uncertainty

Due to the nature of both the data and the suite of analyses used for this effort it is important to take the associated inherent uncertainly into account when interpreting the results. There is uncertainty in our quantitative measures (e.g., B-IBI scores, field survey data, geospatial data), as well as the interpretation of these data when assessing impacts

and describing recommendations. Field and laboratory protocols were closely followed as described in the QAPP to minimize errors and uncertainty in the B-IBI scores, habitat survey measures, geospatial data, and statistical analyses. Results from replicate B-IBI samples are described below. Those and other field measures met the data quality objectives outlined at the beginning of the project.

As previously described, B-IBI samples were collected using two methods (King County and Ecology). Initially it was anticipated that results from the two methods would provide comparable B-IBI scores, and samples could be considered replicates. However, to ensure we had sufficient replication, we collected two replicate samples using the King County method at two sites in 2018 (n=2). On average, the B-IBI scores for those samples differed by 7.1 points, which is within the precision described in previous studies (King County 2014c).

Interestingly, samples collected using the Ecology method typically scored an average of 7.3 points higher than those collected in the same reach, on the same day with the King County method (paired t-test, $p<0.003$). The Ecology method samples from any habitat encountered along random transects within the stream, whereas the King County method samples only from riffles. Because macroinvertebrate taxa vary in their habitat preferences, the chance of collecting more taxa may be higher with the Ecology method. While sampling multiple habitat types may result in greater taxa richness and higher B-IBI scores, it may also result in greater score variability if habitat types sampled vary substantially among sites and years. The mean absolute difference in B-IBI scores between 2017 and 2018 was lower for the King County samples than for the Ecology samples (5.4 vs 12.5 points, respectively; paired t-test, $p<0.04$).

In several basins, we observed higher B-IBI scores for the 2017 and 2018 samples than expected based on previous data from the site or basin. In particular, for some of the sites previously classified as “fair,” B-IBI scores were “good” or even “excellent” in 2017 and 2018. There is no obvious explanation for these differences. The variability may be due to natural variation between years and within sites (e.g., patchy distributions of taxa), or differences in sampling personnel (though all were trained similarly and most of the staff sampled both years).

Results for habitat parameters values were fairly consistent between the two survey years, so we used average values to assess if parameters were likely impacted. Some year to year discrepancies can be seen in site summaries included in Appendix D. The variability in habitat measures may be due to natural variation between years and within sites (e.g., random transects fell in different locations each year), or differences in sampling personnel (though all were trained similarly and most of the staff sampled both years). Some measures are more subjective than others (e.g., qualitative vegetation measures vs. pebble counts), but for most measures the variation we found year to year was similar to that found in other studies (Appendix D; King County 2015a).

Uncertainty in geospatial data is a function of the data source. Details regarding geospatial data sources and data quality are included in Appendix C.

Uncertainty in the stressor identification process is due to an incomplete understanding of conditions at each site, and, more generally, an incomplete understanding of the causal relationships among B-IBI scores and stressors. Likewise, there is uncertainty in the recommended actions and the estimates of their importance because we do not know the degree to which the recommended actions will be effective.

4.0 CHARACTERIZATION AND RECOMMENDATIONS FOR RESTORATION SITES

The following sections describe the B-IBI scores, stream and basin conditions, and recommended actions for four "fair" B-IBI sites. Each section briefly describes the basin, the historical and recent B-IBI scores, and current conditions. We recommend restoration actions based on current conditions and additional information pertinent to each basin.

Current conditions are summarized and ranked for each basin, with those most in need of action ranked highest. For each condition, we tallied the number of parameters that indicated the condition was impacted and listed the highest effective impact value for each condition. In addition to conditions affected by human activities, we include natural conditions that may influence B-IBI scores. We generally cannot change natural conditions, but we included them here because they were correlated with B-IBI scores and they may influence or limit recovery. Knowing, for instance, that soils in a basin are naturally high in sand and low in organic matter may help inform instream restoration actions and help define expectations for substrate conditions in the stream.

Other measures, such as the current extent of urban development and median home age in the basin are also included in the discussion for each stream. We estimate the biological potential for each basin based on the current extent of development, and we compare that with current scores to give context for how much restoration work may be needed. The biological potential represents the cutoff for the top 10% of sites with that level of urban development in the basin. If a site is scoring at or above its estimated biological potential, it is doing as well or better than 90% of sites with an equivalent amount of basinwide urban development. If a site is scoring much lower than its estimated biological potential, that potential can be used to set recovery expectations.

We include the median home age because the age of development suggests how likely it is that stormwater controls were required at the time to mitigate stormwater runoff. Before 1990, no stormwater controls were required to mitigate the increased impervious surface cover that came with development. The first stormwater manuals were issued in 1990, and more protective regulations were adopted in 1998. Stormwater regulations were revised again in 2005. Basins with older development may have few existing stormwater control and treatment facilities, but because of this, they may have the most opportunities for improvement.

We used iMap to check the current use status of properties, and specifically to check if a property is designated as timber land, forest land, agricultural land, or open space under the Public Benefit Rating System (PBRS). Under this system, landowners can apply for the special status if their property is zoned for development but is instead designated as one of these alternative land uses. If approved, the property receives a current use taxation status.

This system is desirable for resource protection because it discourages development. The status can be terminated by landowner, if the landowner pays a compensating tax, and therefore does not guarantee indefinite protection. The compensating tax varies based on the specific program and designation but is generally equivalent to the difference between the assessed tax value for the highest and best use and the current use tax value, multiplied by the number of years the land was designated (but no more than 9). As lands become more valuable for development, property owners may be more likely to change the designation and sell.

We also checked the "What's In My Neighborhood" app (https://apps.ecology.wa.gov/neighborhood/), run by Ecology's Toxic Cleanup Program, to check for any historic or current contaminant cleanup activities within each basin. If contaminated properties exist within a basin and may affect water quality, we list the contaminants and what cleanup actions, if any, have been taken. In this report, we use the simple phrase "regulated metals" to refer to the "metals priority pollutants" identified in reports.

4.1 Illahee Creek

The Illahee Creek basin encompasses 880 acres in unincorporated Kitsap County, just northeast of Bremerton city limits. It flows easterly and drains into Port Orchard Passage between Bainbridge Island and the Kitsap Peninsula (Figure 10). Illahee Creek provides habitat for coho salmon, chum salmon, cutthroat and coastal cutthroat trout (streamnet.org, WDFW SalmonScape), as well as steelhead (May and Peterson 2003). Much of the basin is within the Central Kitsap County Urban Growth Area (UGA) and zoned for rural residential development, most of which (77%) was built pre-1990 (median home age of 42 years).

Illahee Creek

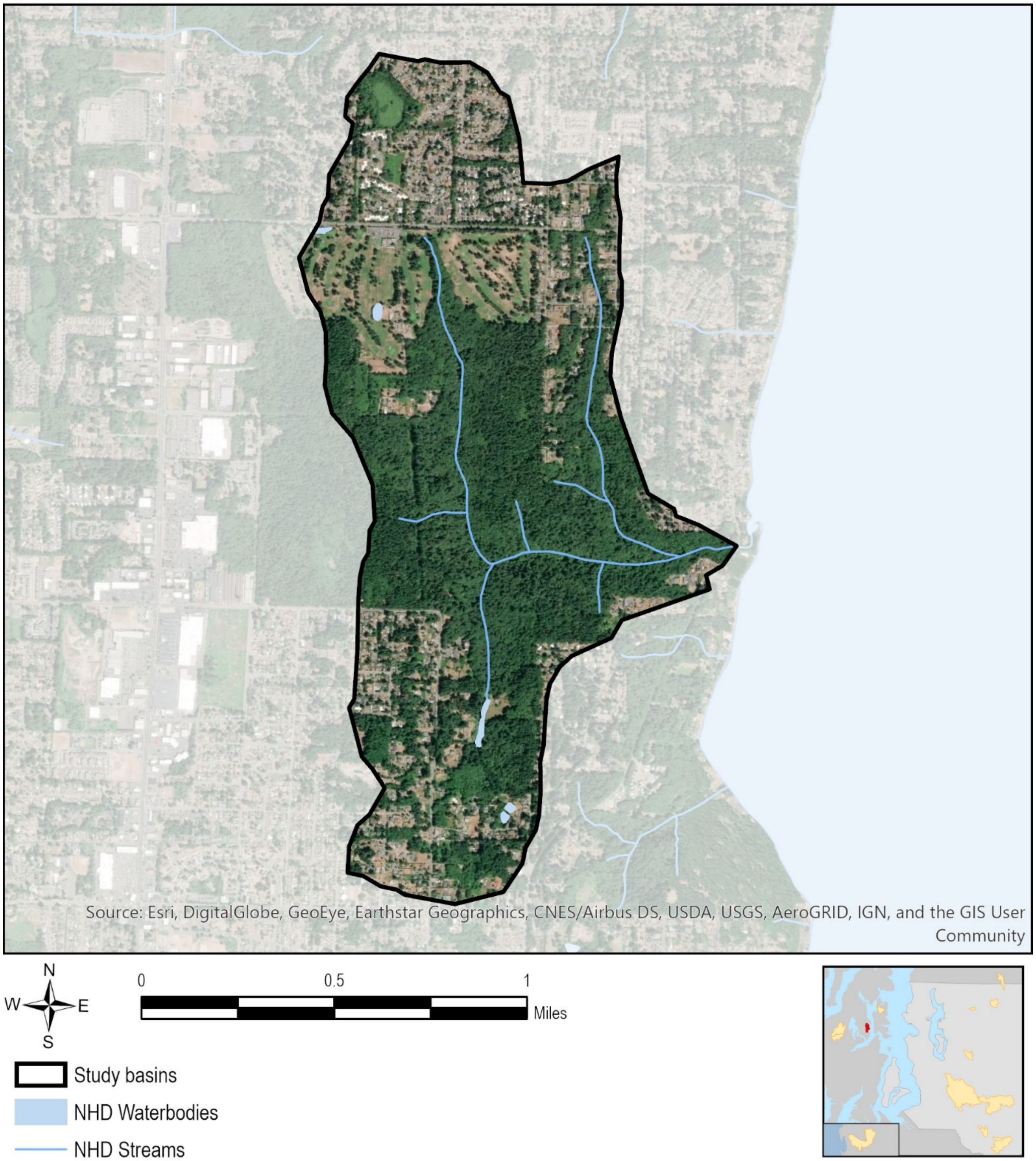

Figure 10. Aerial photo of Illahee Creek and its basin.

Illahee Creek has been championed by local citizens for decades, and thanks to this active community, nearly a third of the basin is protected within the Illahee Forest Preserve (http://www.illaheepreserve.org/). In addition to land conservation, local habitat conditions at the B-IBI site have been enhanced over the years by placement of large logs,

riparian planting, and placement of a large culvert under Illahee Road NE, just downstream of the B-IBI site.

Despite these efforts, habitat conditions remained unstable. Landowners adjacent to the B-IBI site report that large storms in 2007 mobilized huge volumes of sediment and nearly filled the new culvert, threatening to block fish passage. Placed logs were embedded by gravel and sand (Figure 11), and the floodplain aggraded nearly one meter according to the landowner (J. Krigsman, personal communication).

Figure 11. Gravel and sand deposits embedding placed logs in Illahee Creek (2/13/2018).

4.1.1 B-IBI scores and current conditions in Illahee Creek

Kitsap County Public Works has monitored macroinvertebrates in Illahee Creek since 2001 (Table 10), using methods similar to those used by King County (Heine 2015). Based on the history of "fair" scores at the site and their knowledge of the basin, Kitsap County Public Works staff recommended the site as a good candidate for this project. The recovery potential appeared to be quite high given the history of low scores (median 40.2) and the extent of urban development in the basin. The predicted best case scenario for this basin, or its biological potential, given the current extent of urban development (28% urban), is much higher at 68.

Table 10. Illahee Creek B-IBI scores by year and program. PSSB site codes are in parentheses, and sites 15IL01 and KCSSWM-010 are the same location.

Year sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (15IL01)		Kitsap County Watershed Health Monitoring* (KCSSWM-010)
	King County Method	Ecology Method	
2001			38.0
2002			35.9
2003			40.2
2004			38.1
2005			53.6
2006			55.4
2011			33.0
2013			45.0
2015			48.6
2017	46.9	81.9	60.8
2018	46.3	59.9	54.0

* Samples collected from riffles; from 2001–2006 samples collected from 3 ft^2 and from 2011–2018 samples collected from 8 ft^2.

B-IBI scores in 2017 and 2018 were much higher than in previous years (Table 10). On average, B-IBI scores in 2017 and 2018 for both monitoring efforts were nearly twenty points higher (mean 59.2) than historic scores, though variability was also high (46.3 to 81.9). The one "excellent" score (2017 sample, Ecology method), suggests some sensitive macroinvertebrate taxa are present and can be supported in the basin, but score variability suggest the number and density of sensitive taxa remain low.

Results of the habitat survey and geospatial analyses indicate a number of conditions in the Illahee basin are impacted (Table 11). Data for almost all parameters related to basinwide forest health and urban development indicate conditions are degraded and actions are necessary to improve them. Data for parameters related to flashiness and stream channel substrate indicate stormwater runoff and relatively small pebble sizes may limit diversity and quality of available macroinvertebrate habitat.

The most significant stressors in the watershed originate in the upper portions of the basin, where much of the unprotected land is developed open space or low to medium urban development. Urban development in the upper reaches of the riparian buffer on the north and south forks of the creek were also highly impacted. Large substrate is lacking in this part of the basin, and the existing substrate is smaller and more embedded than that typically found at "excellent" sites.

Surprisingly, stream bed stability conditions in Illahee Creek were not substantially different than conditions at "excellent" sites. Results indicate that forest health in the riparian buffer within the lower basin, as well as stream temperature are not impaired. These findings, in addition to the high quality local habitat in the vicinity of the sample site, suggest restoration actions should be focused in the upper basin, while conditions in the lower basin and adjacent to the sampling should be protected.

Table 11. Status of conditions in Illahee Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to improve condition?
Basin-wide forest health	4 of 5	3.6	Action needed
Basin-wide urban development	2 of 2	3.5	
Riparian urban development	3 of 3	3.0	
Flashiness	2 of 4	1.5	
Large substrate in stream channel	3 of 6	1.4	
Fine sediment in stream channel	2 of 3	1.2	
Embeddedness of stream substrate	2 of 2	1.1	
Stream bed stability	0 of 1	NA	No action needed or low priority
Stream Temperature	0 of 3	NA	
Local habitat	0 of 5	NA	
Riparian forest health	0 of 5	NA	
Roads in basin	0 of 2	NA	
Natural condition			
Slope	1 of 2	1.1	Condition may limit recovery
Stream density throughout basin	1 of 1	0.8	
Soil composition in basin	2 of 2	0.8	
Organic material in soil	0 of 1	NA	Condition not likely to affect recovery

Additional issues may affect conditions in the basin and at the B-IBI site. These include:

Geological hazards
The stream valley is rated as having "moderate landslide" and "very severe erosion risk." This classification is consistent with high bed load movement observed during large storms.

Stormwater
Most of the development within the upper reaches of the north fork occurred before effective stormwater regulation existed. In addition there has been significant conversion of forest area to developed open space. As a result of these impacts, the watershed experiences excess stormwater flows. Overland flows and inappropriate stormwater discharge points on steep slopes have exacerbated the natural conditions in the basin, which as previously discussed is already susceptible to erosion and landslides. This has led to bank erosion and slope failure, resulting in excess sediment deposits within the stream (Kitsap County 2008; Aho 2011).

Low Base Flow
Groundwater is the primary source of water in Illahee Creek. This water source is in jeopardy as nearby residential wells draw down the aquifer, and the amount of impermeable surfaces prevent aquifer recharge (Kitsap County 2008; Aho 2011).

Water Quality
Ecology has listed Illahee Creek as a category 5 impaired stream for dissolved oxygen. It was previously listed as a category 5 for fecal coliform, but basin conditions have since improved and the stream is now listed as a category 1 for fecal coliform (Kitsap County 2008).

4.1.2 Recommendations for restoring Illahee Creek

Improving forest health within the Illahee basin is likely to be the most effective and easiest method to improve conditions and B-IBI scores (Table 12). Most of the forest within the basin was clear-cut in the 1930s. However, the riparian buffer within the basin is currently forested with young second growth. Efforts should be focused on preserving existing forested areas and allowing them to mature. The 570-acre Illahee Forest Preserve exists expressly for this purpose, and has been targeting various forested land acquisitions within and adjacent to the stream corridor since 2001. Nearly 300 acres of the preserve lie within Illahee basin, not including the Rolling Hills Golf Club. Community Tree Protection standards set forth in the Illahee Community Plan (Kitsap County 2008) also seek to reduce tree removal throughout the basin in geologically hazardous areas.

Table 12. Management actions needed to improve Illahee Creek B-IBI scores. Importance values indicate the relative need for the action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	2.6
	Stablize stream banks	2.3
Riparian Buffer	Stablize slopes	5.3
	Plant vegetation, extend buffer	5.3
Stormwater Conveyance Systems	Increase stormwater flow control	7.3
	Improve stormwater treatment	5.8
	Maintain storage and treatment facilities	7.3
	Minimize impacts of road runoff	7.3
Forested Land	Maintain or decomission forest roads	5.8
	Allow existing forest to mature	7.5
	Plant vegetation	7.5
Agricultural Land	Exclude livestock	NA
	Manage waste	NA
	Prevent soil loss	NA
Mining Areas	Enforce Mining BMPs	NA

Forest restoration in the basin may provide additional opportunities to improve stream health, particularly within developed open spaces in the riparian buffer. These restoration efforts should include planting a mix of canopy-forming deciduous and coniferous trees, as well as native shrubs to create an understory.

Stream health would also greatly benefit from implementation of low impact development (LID) and stormwater BMPs that reduces direct discharge or overland flow, and promotes aquifer recharge and infiltration (Table 12). Retrofitting already developed areas with stormwater ponds, infiltration wells, and rain gardens would reduce erosion and sediment deposition in wet winter months, and replenish groundwater seeps during dry summer months. This strategy has already been identified in the Port of Illahee Surface Water Management Plan, and the Illahee Creek Headwaters Stormwater Retrofit Project is underway to control stormwater draining from the Rolling Hills Golf Course and Kariotis neighborhood. Additional retrofit and restoration projects are planned but they are not currently funded (personal communication, Renee Scherdnik). In areas where new development is anticipated, permeable surfaces should be used where possible, along with modern stormwater mitigation methods. The Illahee Community Plan also notes the potential benefit of using drain fields rather than sewer lines to maintain aquifer recharge, though care must be taken to avoid water quality issues (e.g., elevated nutrients).

4.2 Manzanita Creek

Manzanita Creek is located on Bainbridge Island, and flows westerly into Port Orchard Passage. The basin encompasses 1,377 acres, which are entirely within the jurisdiction of the City of Bainbridge Island (Figure 12) and the Bainbridge Island UGA. The Manzanita Creek basin is largely zoned for rural residential development, although large areas of second growth forest remain. As of 2016, 17% of the basin was classified as urban. Over

two thirds of the development in the basin (69%) occurred pre-1990, and the median home age is 38 years old. Manzanita Creek provides habitat for coho and chum salmon, as well as coastal cutthroat trout (streamnet.org, WDFW SalmonScape).

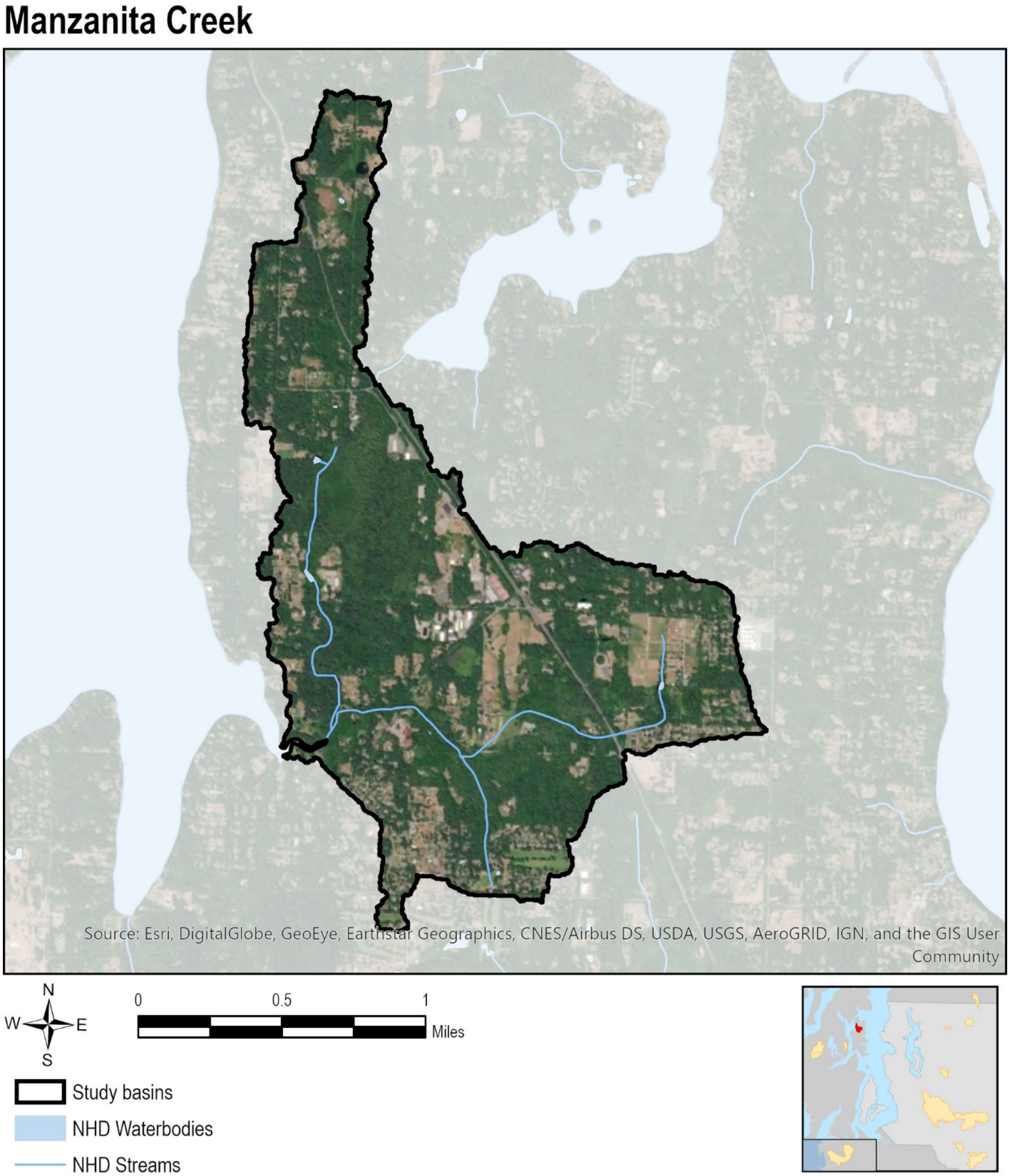

Figure 12. Aerial photo of Manzanita Creek and its basin.

The City of Bainbridge Island has monitored two sites in Manzanita Creek since 2008, using a riffle-based method similar to King County's (Table 13). Based on historic B-IBI scores in the basin and the City's interest in restoring and protecting this basin, the site was recommended for inclusion in the project.

4.2.1 B-IBI scores and current conditions in Manzanita Creek

The average B-IBI scores for Manzanita Creek between 2017 and 2018 were 64.5 (King County method), and 70.3 (Ecology method) (Table 13). These scores indicate stream conditions are "good," whereas City of Bainbridge Island samples collected the same years at the same location (LwrManzBain) were slightly lower and indicate conditions are "fair." Although the 2017 and 2018 scores span the "fair" to "good" range, all were within ±10 points of the average (63.0).

Table 13. B-IBI scores from two sites on Manzanita Creek. PSSB site codes are in parentheses, and sites 15MZ01 and LwrManzBain are the same location; sites ManzBain and ENVVEST-32 are the same location and approximately 1 km upstream from 15MZ01.

Year Sampled (n=1 sample/yr)	Monitoring Effort				
	Restore and Protect Project (15MZ01)		City of Bainbridge Island* (LwrManzBain)	City of Bainbridge Island* (ManzBain)	Navy's Envvest Benthic Monitoring in Kitsap* (ENVVEST-32)
	King County Method	Ecology Method			
2003					38.5
2008				34.9	
2010				56.3	
2011				38.9	
2012				44.3	
2013				55.3	
2015			59.6		
2016			68.1		
2017	62.8	69.7	54.0		
2018	66.1	70.9	54.3		

* Samples collected from 3 ft^2 from riffles.

The "good" B-IBI scores in 2017 and 2018 are unexpected given the previous scores from the same location and from a site upstream (Table 13). Except for one "good" score at LwrManzBain in 2016, all previous B-IBI scores in the basin were "poor" or "fair."

However, the "good" B-IBI scores in 2017 and 2018 are approaching the predicted biological potential for the site. Based on the extent of urban development in the basin (17% urban), the biological potential is estimated to be 76. While historic scores suggested the stream was scoring much lower than expected, the recent scores suggest the stream is scoring closer to its estimated biological potential.

Although the recent B-IBI scores suggest the conditions are better than previously thought, the habitat survey results suggest multiple conditions in the basin are impacted and in need of restoration actions (Table 14). Most of the basinwide forest health parameters and all parameters related to riparian and basinwide urban development indicate current conditions are outside the range typically found at "excellent" B-IBI sites. The results indicate the stream is impacted by an excess of fine sediment, flashy flows, and human disturbance near the sampling site (Table 14). In contrast, road density in the basin is low and stream bed stability and stream temperature appear to be in good condition.

Table 14. Status of conditions in Manzanita Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to improve condition?
Basin-wide forest health	3 of 5	3.1	Action needed
Riparian urban development	3 of 3	3.0	
Basin-wide urban development	2 of 2	2.9	
Flashiness	2 of 4	1.5	
Large substrate in stream channel	3 of 6	1.4	
Riparian forest health	1 of 5	1.4	
Embeddedness of stream substrate	2 of 2	1.3	
Fine sediment in stream channel	3 of 3	1.2	
Local habitat	2 of 5	1.1	
Roads in basin	0 of 2	NA	No action needed or low priority
Stream bed stability	0 of 2	NA	
Stream Temperature	0 of 3	NA	
Natural condition			
Slope	1 of 2	1.5	Condition may limit recovery
Stream density throughout basin	1 of 1	0.8	
Organic material in soil	0 of 1	NA	Condition not likely to affect recovery
Soil composition in basin	0 of 2	NA	

Additional issues that may affect basin conditions and the area adjacent the sampling site. These include:

Geological hazards

The level of fines observed is unlikely to be naturally derived, as basin soils are not naturally high in sand and there are few geologically hazardous areas in the basin. Moderate erosion and landslide risks are only present in relatively small, patchy areas of the basin and the riparian buffer.

Contaminated sites within the basin

Within the Manzanita basin, toxic contamination has been a concern at multiple sites. Many of these sites have been remediated or otherwise issued a "No Further Action letter" by

Ecology. However, the Day Road Industrial Park site requires cleanup. Halogenated organics, metals, priority pollutants, and non-halogenated solvents are suspected in soil and surface water, and confirmed in groundwater at the site.

Sediment runoff

Some past and current land uses may promote sediment runoff to Manzanita Creek. Two gravel mining operations, situated directly adjacent to the stream in a moderate erosion and landslide risk zone, have historically operated in the basin. The former Lovgreen gravel pit has not operated for the last 30 years, and is now owned by the City of Bainbridge Island. The lower excavations of the pit have been reclaimed by wetland vegetation, but the upper excavation area is being used as a repository for road spoils from street cleaning. A non-perennial stream drains the site to Manzanita Creek directly downslope, though turbidity issues have not been observed here. A nearby groundwater production well occasionally produces turbid discharges to the creek from backflushing during maintenance. Slightly further downstream, Tilz Soil and Composts stockpiles landscaping materials for retail sale, and mines for in-fill material. A recent site inspection report by Ecology noted several discharges draining to Manzanita Creek that are not being monitored for water quality. Photos from the site show high sediment load in the infiltration ponds overflowing to Manzanita Creek (Permit Compliance Inspection Report, Permit# WAG503334, 2/27/2019).

Development

Most of the basin is zoned for low density residential (1 unit per 2.5 acres), though there are higher density developments on the southern and eastern edge of the basin, as well as small pockets of business/industrial zoning along the northern edge. Within the low density zoning areas, large tracts of privately owned forested land remain, interspersed with farms. Some of these forests are within designated wetlands, and are protected from development by critical area ordinances. However, large swaths of privately owned forest in the north and southeast portions of the basin may be vulnerable to development.

Septic systems and nutrient loads

All properties within the Manzanita basin utilize onsite septic, and the basin has historically experienced nutrient and fecal coliform bacteria issues as a result of poor septic system maintenance (Apfelbeck 2012). Total phosphorous concentrations in June and December 2010 and June 2011 scored moderate to high concern under Ecology's Freshwater Quality Index. In addition, fecal coliform levels have exceeded state water quality standards every year since monitoring began in 2010. However, in 2011, the City of Bainbridge Island began tracing failing septic systems and addressing problems in Manzanita basin through their Illicit Discharge Detection and Elimination (IDDE) project. As a result, recent water chemistry data indicate that total phosphorus levels have decreased below levels of concern and fecal coliform levels have greatly decreased over the last few years. In 2018, the stream met the geomean criterion (geomean <50 CFU) of the Washington State fecal coliform standards, and was close to meeting the criterion that calls for <10% of the samples >100 CFU (see Appendix III in Berg 2019).

Although relationships between water quality measures and B-IBI scores are not always strong in Puget Sound streams (DeGasperi et al. 2018), excess phosphorus can stimulate excess algal growth and has been linked to diatom communities that thrive in high nutrient conditions (Trophic Diatom Index, DeGasperi et al. 2018).

4.2.2 Recommendations for restoring Manzanita Creek

Enhanced stormwater management in the basin will likely provide the largest benefit to the Manzanita Creek (Table 15), as natural conditions make the basin susceptible to sediment deposition (Table 14). Low slope within the basin and stream hinders its ability to effectively flush fine sediment, and the stream lacks large rocky substrate that could provide macroinvertebrates refuge from embedded conditions. Stormwater retrofits in the vicinity of the junction of Miller Road, NE Day Road W, and Highway 305 would help to reduce flashiness and may prevent potentially contaminated soils from reaching the stream. Elsewhere in the basin, encouraging use of stormwater best management practices (BMPs) on privately owned lands would also help alleviate sediment loading.

Table 15. Management actions needed to improve B-IBI scores in Manzanita Creek. Importance values indicate relative need for action: larger numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	2.6
	Stablize stream banks	2.5
Riparian Buffer	Stablize slopes	6.6
	Plant vegetation, extend buffer	7.9
Stormwater Conveyance Systems	Increase stormwater flow control	8.0
	Improve stormwater treatment	6.5
	Maintain storage and treatment facilities	8.0
	Minimize impacts of road runoff	8.0
Forested Land	Maintain or decomission forest roads	6.5
	Allow existing forest to mature	7.1
	Plant vegetation	7.1
Agricultural Land	Exclude livestock	3.6
	Manage waste	3.6
	Prevent soil loss	3.6
Mining Areas	Enforce Mining BMPs	2.5

The City of Bainbridge Island currently provides resources for citizens and businesses to implement good stormwater practices, including cost sharing to implement farm management plans, incentives for LID, technical assistance to identify and avoid pollutant-generating activities, and guidance on installing and maintaining low-impact technologies. We recommend the City continue to provide these resources, as well as an expansion of their outreach efforts. The City of Bainbridge Island identified several other strategies to reduce fine sediment deposition and elevated levels of metals in the stream in its 2012 State of the Island's Waters report (Apfelbeck 2012). Our findings indicate that the following strategies would be particularly effective for improving stream conditions: implement and maintain sediment and erosion control around construction sites, agriculture, land clearing, and gravel and sand stockpiling; reduce stormwater runoff by

reducing the percentage of impermeable surfaces; and, frequently remove excess sediment from existing stormwater facilities.

Improving forest health may be the easiest condition to improve (Table 15). Large contiguous areas of privately owned forest currently exist within the basin. Efforts should be made to preserve these forests and allow them to mature. Existing regulations surrounding tree removal and Aquifer Recharge Protection Areas (ARPA) already create an obstacle for wholesale clearing of wooded parcels within the basin; most of the zoning within the basin meets the criteria for triggering ARPA designation during development or redevelopment (https://www.bainbridgewa.gov/1115/City-Tree-Regulations). However, the protections provided by these regulations are limited in scope. Trees may still be removed without permits, depending on size and number of trees in a given timeframe. The City recognizes the importance of landmark trees and forest health, and recently the City hired an arborist to help improve protections for trees on the island.

Protective covenants between the local government or land trusts and private citizens may be another cost-effective means of preserving or restoring forested lands. The Bainbridge Island Land Trust currently owns or has conservation easements on three properties within the basin: the Miller-Kirkman Preserve near the mouth of Manzanita Creek, which encompasses the sampling site; the Zumbroich-Van Tobel property; and the Freedman property. The latter two sites contain large areas of hay field or pasture, and present excellent opportunities to increase canopy cover in the basin. In particular, the Freedman property is traversed by a tributary to Manzanita Creek; restoration efforts here could be especially beneficial to the stream.

Additional opportunities for conservation easements should be pursued throughout the basin, particularly within developed open spaces in the riparian buffer that may be readily converted back to forest. These restoration efforts should include a mix of canopy-forming deciduous and coniferous trees, and native shrubs to create an understory. Due to the low slope and topography of the channel, the dynamic riparian buffer is estimated to be especially wide in areas, with widths from the channel in some reaches exceeding 150 meters (Figure 13). This indicates that to fully restore riparian buffer functions (e.g., stabilize banks, provide shade, provide source of large woody debris, and other organic matter), the riparian buffer may be need to be wider than what is typically recommended.

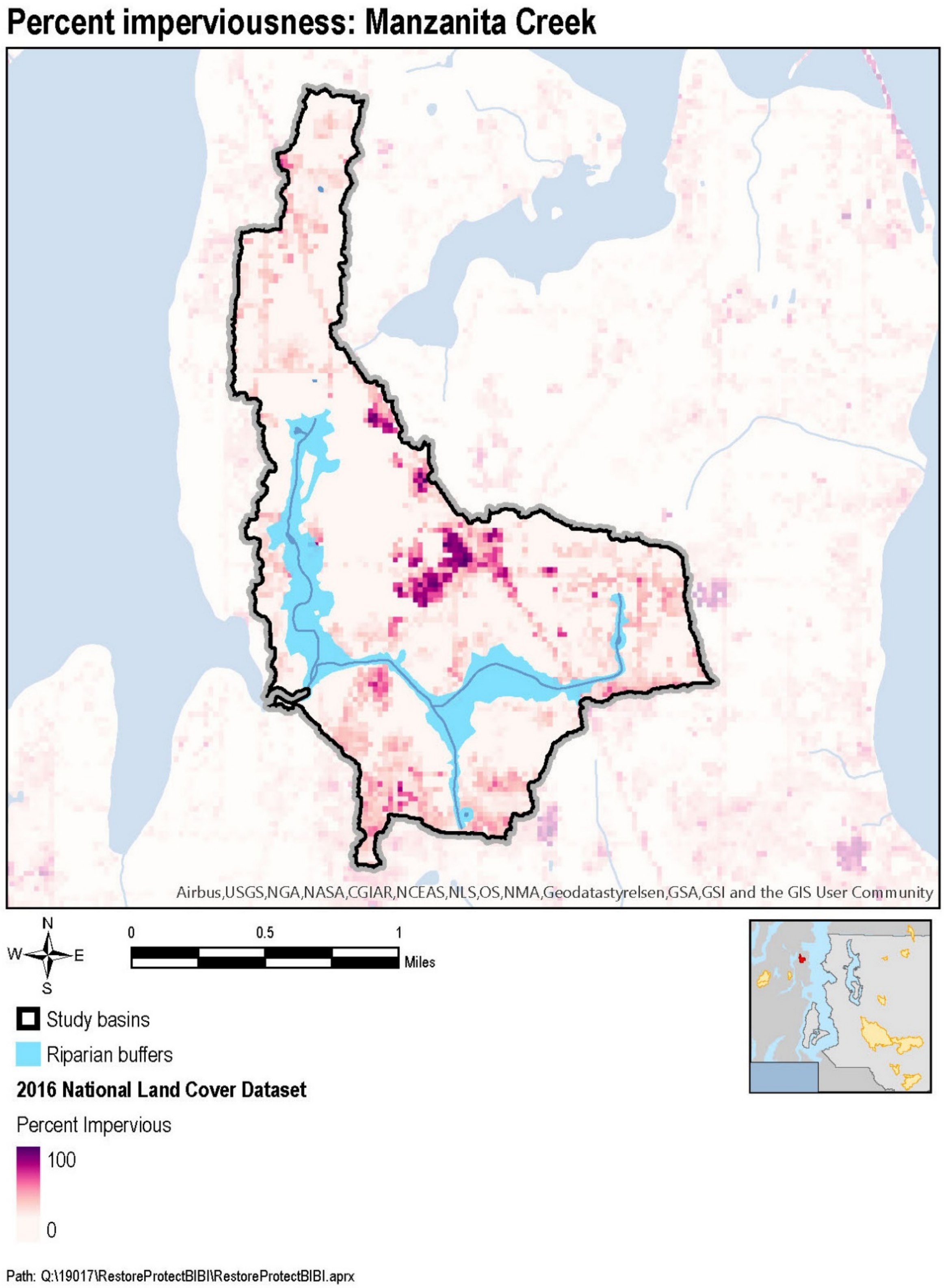

Figure 13. The distribution of impervious surfaces within the Manzanita Creek basin. Note wide width of dynamic riparian buffers, and their overlap with impervious surfaces.

Protecting groundwater supplies from contamination within the basin would also benefit the stream. Already, the City of Bainbridge Island's IDDE project and program endorsed by the City to provide low-interest loans for septic repair has reduced the number of failing septic systems in the basin. As a result, fecal coliform levels and concentrations of total phosphorus have declined. In the same time period, B-IBI scores have improved. While this improvement cannot be directly attributed to the septic system efforts, it is recommended that this work continue. Protecting groundwater around sites identified by Ecology as contaminated may also improve stream health, though this is a more difficult task and the expected amount of improvement is highly uncertain. Working with Ecology to move forward with cleanup efforts would be the best strategy to accomplish this task.

4.3 Stensland Creek

The Stensland Creek basin is within the Bear-Evans Watershed, encompassing 439 acres of unincorporated King County just east of the City of Redmond (Figure 14). Stensland Creek basin is largely zoned for rural residential development, with some parcels listed as agricultural or forest lands under the current use taxation system. As of 2016, 37% of the basin was classified as urban with an additional 12% developed open space. Over two thirds of the buildings in the basin (68%) were built pre-1990, and the median home age is 30 years old. Stensland Creek provides habitat for coho and Chinook salmon, and coastal cutthroat trout (WDFW SalmonScape).

Stensland Creek

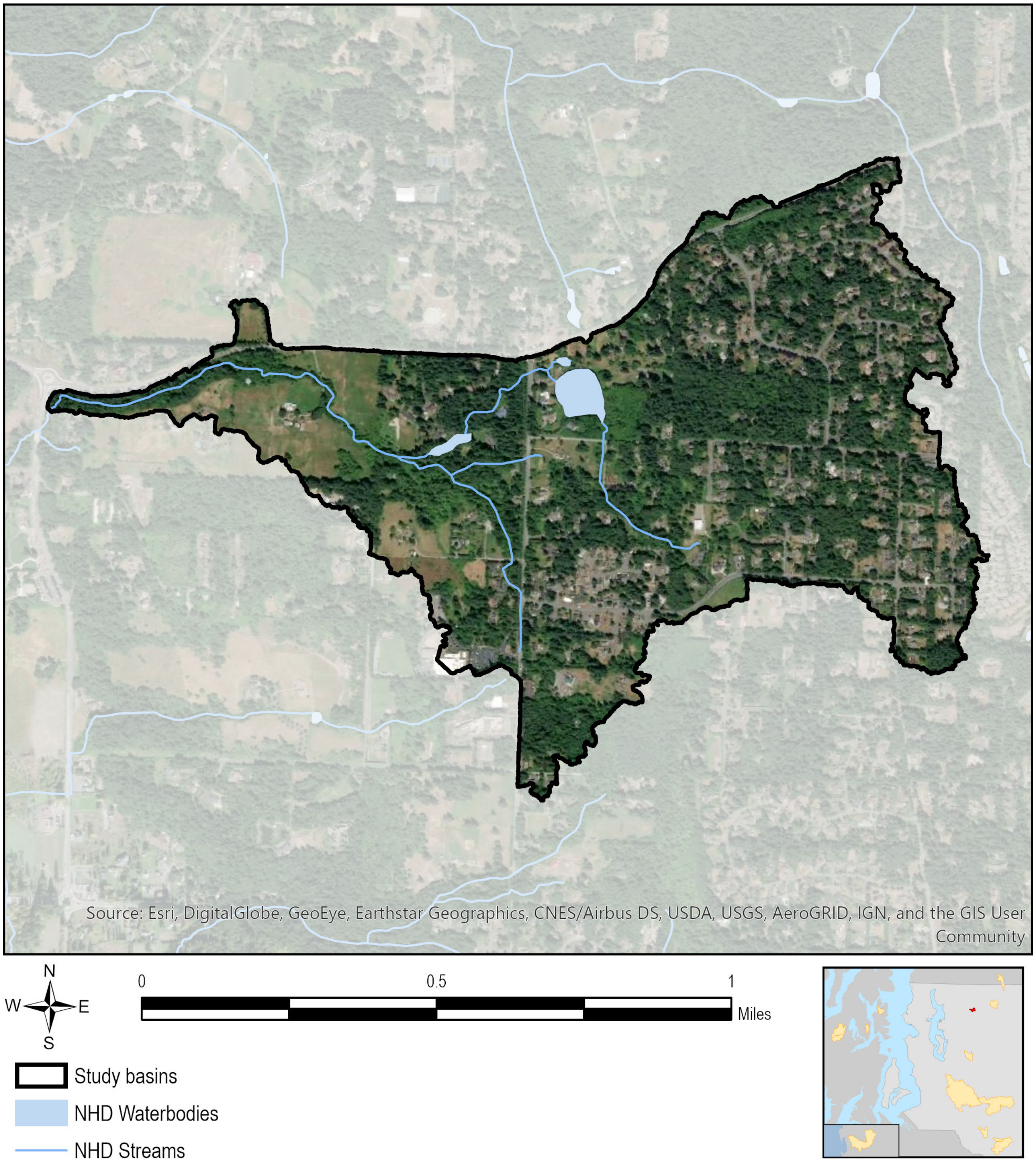

Figure 14. Aerial photo of Stensland Creek and its basin.

4.3.1 B-IBI scores and current conditions in Stensland Creek

The average B-IBI scores for Stensland Creek between 2017 and 2018 were 66.1 (King County method) and 63.8 (Ecology method). Scores in 2018 were substantially higher than in 2017 (Table 16), in keeping with the historic variability in scores at a nearby site farther upstream. The low scores are likely in part due to the lower than expected number of organisms in the samples; the target is at least 500, but most of the historic samples had fewer than 300. The King County Roads protocol samples 3 ft^2 instead of 8 ft^2 which in degraded streams can reduce the likelihood of reaching the 500 count target; however, we failed to get over 300 macroinvertebrates in one 2017 sample despite sampling 8 ft^2 (Table 16).

The biological potential for this basin, based on the 37% urban development, is 62. The recent scores over 62 suggest the stream is doing very well considering the current extent of development. However, the low densities and the variability in B-IBI scores suggest that the basin does not consistently support a thriving and sensitive macroinvertebrate community.

Table 16. B-IBI scores from two sites in Stensland Creek. PSSB site codes are in parentheses. The Stensland Upper site is approximately 250 m upstream of site 08ST01.

Year sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (08ST01)		King County Roads Division CIP Support Project ** (Stensland Upper)
	King County Method	Ecology Method	
2009			76.0
2010			61.2*
2011			65.8
2012			69.3
2013			24.3*
2014			55.3*
2015			48.3*
2016			23.4*
2017	58.8	46.3*	29.2*
2018	73.3	81.3	55.6

* Sample contained less than 300 organisms.
** Samples collected from 3 ft^2 from riffles.

The occasional "good" or "excellent" B-IBI scores are surprising given the current basin and instream conditions (Table 17). We found most conditions in Stensland Creek are degraded, as indicated by nearly all of the parameters considered (Table 17). Of all the sites assessed for this report, conditions in Stensland Creek are the most degraded.

We should note this assessment likely underestimates the effective impact of flashiness at the site. The flow gage is approximately 650 m downstream of the B-IBI site; however, there is a large stormwater pond immediately upstream of the gage that attenuates flows.

Table 17. Status of conditions in Stensland Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to improve condition?
Basin-wide forest health	5 of 5	3.6	Action needed
Basin-wide urban development	2 of 2	3.5	
Riparian urban development	3 of 3	3.0	
Roads in basin	2 of 2	2.3	
Riparian forest health	5 of 5	2.1	
Flashiness	2 of 4	1.5	
Large substrate in stream channel	4 of 6	1.4	
Fine sediment in stream channel	2 of 3	1.1	
Embeddedness of stream substrate	2 of 2	1.1	
Local habitat	3 of 5	1.1	
Stream Temperature	1 of 3	0.8	
Stream bed stability	0 of 1	NA	No action needed or low priority
Natural condition			
Organic material in soil	1 of 1	1.4	Condition may limit recovery
Slope	1 of 2	1.3	
Soil composition in basin	2 of 2	0.8	
Stream density throughout basin	1 of 1	0.8	

Additional issues may affect conditions in the basin and at the B-IBI site. These include:

Geological Hazards

The reach in which sampling occurs is in a landslide and steep slope hazard area, which may naturally contribute fines to the stream channel.

Water Quality

Stensland Creek is listed as a category 4a impaired stream for temperature, and a category 2 for dissolved oxygen. A TMDL is in place for temperature and DO within the Bear-Evans watershed (Ecology 2011a), which includes Stensland Creek. Summer temperatures regularly exceed 16°C, which is considered the upper threshold for salmonid health. Although our overall results show only a modest relationship between B-IBI scores and temperature, one of the three temperature parameters examined for Stensland Creek indicates high temperature may be a limiting condition.

Development

Stensland basin is largely developed, though most of this consists of low intensity developments and developed open spaces (such as lawns). Most structures in the basin were built prior to implementation of stormwater regulations. Along the sampling reach, legacy pipes can be seen emerging from the banks. Most of these appear to no longer be used, but it's unclear what their original function was or if they may convey water to the stream during rainy periods.

Low base flows

Summer base flow in Stensland Creek is primarily reliant on groundwater seeps and springs. Additional development in the basin may lead to increased water withdrawals and reduced groundwater recharge.

Contaminated sites within the basin

Within Stensland basin, soil contamination has been confirmed at one site (Down to Earth Bulldozing). The contaminants of concern are benzene and petroleum products and the site is currently undergoing cleanup.

4.3.2 Recommendations for restoring Stensland Creek

Stensland Creek would benefit from many restoration actions within the basin (Table 18). Of the 14 basins evaluated in this study, the importance scores, which reflect the extent of degradation and the number of actions needed to fix the problems, were highest for Stensland Creek (Table 18). Based on the degradation of conditions across scales (basinwide to instream), multiple actions are needed.

Table 18. Management actions needed to improve B-IBI scores in Stensland Creek. Importance values indicate the relative need for the action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	2.5
	Stablize stream banks	2.2
Riparian Buffer	Stablize slopes	6.3
	Plant vegetation, extend buffer	9.1
Stormwater Conveyance Systems	Increase stormwater flow control	11.4
	Improve stormwater treatment	9.1
	Maintain storage and treatment facilities	10.6
	Minimize impact of road runoff	10.6
Forested Land	Maintain or decomission forest roads	9.1
	Allow existing forest to mature	7.4
	Plant vegetation	7.4
Agricultural Land	Exclude livestock	3.3
	Manage waste	3.3
	Prevent soil loss	3.3
Mining Areas	Enforce Mining BMPs	NA

The Bear-Evans Watershed Temperature, Dissolved Oxygen and Fecal Coliform TMDL (Ecology 2011a) provides a number of recommendations supported by our findings. These include planting and preserving existing trees to eventually achieve a mature riparian corridor, particularly in riparian areas that are currently developed open spaces (i.e., lawns). These plantings should include a mix of canopy-forming deciduous and coniferous trees, and native shrubs to create an understory. Improving forest health within the basin and particularly within the riparian zone may be the most effective to consider. King County has already obtained Natural Resource Protection Easements along approximately 0.25 miles of the stream to protect it as a stream restoration and buffer enhancement site in perpetuity. Within these easements, the Washington Conservation Corps has taken steps to remove invasive plants and restore native vegetation; these efforts should continue and be expanded to poorly vegetated areas within the easement.

The TMDL also recommends protecting summer base flows by using LID and stormwater BMPs to enhance groundwater recharge. Our findings suggest that in addition to improving base flows, this recommendation would greatly benefit stream health by reducing flashiness, stabilizing summer temperatures, and reducing sediment deposition from overland flow. Strategies to consider include using permeable surfaces where possible for new development, and retrofitting already developed areas with stormwater ponds, infiltration wells, and rain gardens.

There are several opportunities to improve upon existing facilities in the basin. In 2003, King County Department of Transportation installed a large stormwater pond system just outside and to the east of the basin. Stormwater from the Novelty Hill Road traffic circle drains to these stormwater ponds, which ultimately release the water northeast to Bear Creek. To accommodate future growth in the area the facility was built oversized for the area it serves. The storm conveyances on Novelty Hill Road could be reconfigured to redirect runoff away from Stensland Creek from about 206th Avenue NE westward. Stormwater from Novelty Hill Road east of about 206th avenue NE to the headwater of Mackey Creek drains to a small King County stormwater storage pond on a private easement, which in turn drains to a larger pond to the south that supplies Stensland Creek. This stormwater pond is very small and was built in the mid 2000s as part of road improvements for the Trilogy at Redmond Ridge development. It appears designed to hold a very small volume of water with minimal treatment. This pond could be re-engineered and enlarged to more effectively store and settle solids from additional runoff coming from further west on Novelty Hill Road.

We should note that the Stensland Creek basin was considered in the Bear Creek Management Study (King County 2018a), but it did not rank as a priority subbasin because of the relative costs associated with potential retrofits. Compared to other Bear Creek subbasins considered in the study, the study determined there was likely need for stormwater controls in the subbasin but they would be relatively expensive to implement given the lack of public land in the basin.

4.4 Tibbetts Creek

The Tibbetts Creek basin encompasses 2,127 acres and drains north into Lake Sammamish. Approximately 568 acres of the lower reaches of the basin are within the city of Issaquah, with the rest in unincorporated King County. Tibbets Creek basin contains large areas of forested public lands, though the lower portion is within an UGA. As of 2016, 93% of the basin was classified as forest, with only 1.8% of the basin was classified as urban. 43% of the development occurred pre-1990, and an additional 20% was pre-1998. The median home age is 26 years old. Tibbetts Creek provides habitat for sockeye and coho salmon as well as coastal cutthroat trout and winter steelhead (WDFW SalmonScape).

Tibbetts Creek

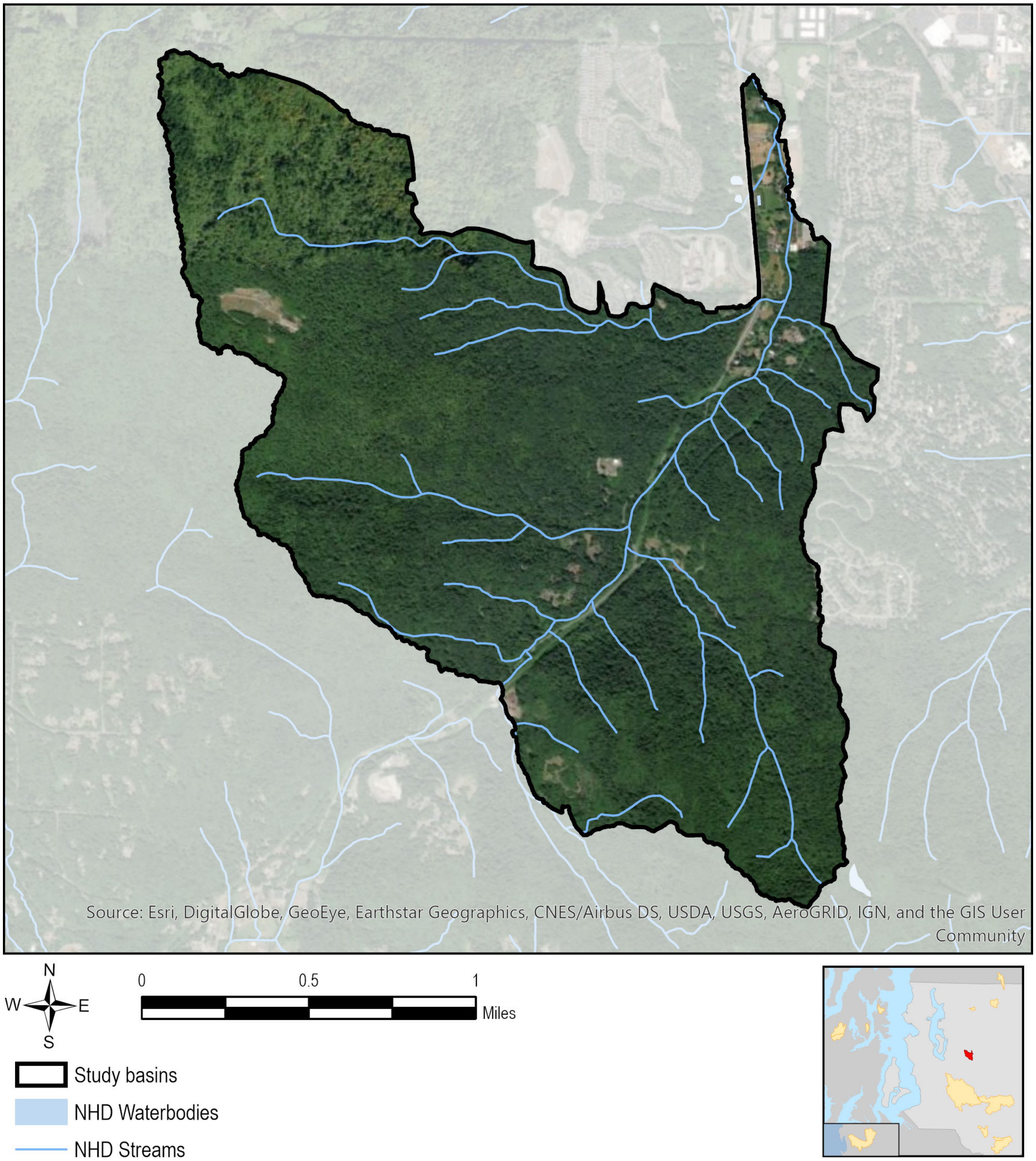

Figure 15. Aerial photo of Tibbetts Creek and its basin.

4.4.1 B-IBI scores and current conditions in Tibbetts Creek

The average B-IBI scores for Tibbetts Creek between 2017 and 2018 were 73.2 (King County method), and 78.8 (Ecology method) (Table 19). While the King County method results were fairly consistent between years, the Ecology method scores ranged widely

from 66.3 in 2017 to 91.2 in 2018. Although most of these scores are still below the predicted biological potential of 86, they are considerably higher than previous scores at the site and other sites nearby.

Table 19. B-IBI scores from three sites on Tibbetts Creek. PSSB site codes are in parentheses, and sites 08LA01 and WAM06600-062567 are the same location; site 08LAK3699 is 300 m downstream and site TCIssManor is 160 m upstream of 08LA01.

Year Samples (n=1 sample/yr)	Monitoring Effort				
	Restore and Protect Project (08LA01)		King County WRIA 8 Status and Trends project* (WAM06600-062567)	King County Ambient Monitoring Program** (08LAK3699)	City of Issaquah Monitoring Program*** (TCIssManor)
	King County Method	Ecology Method			
2003				46.4	
2005				58.0	
2006				44.0	
2007				20.1	55.7
2008				23.0	50.6
2009				28.8	
2010			45.8	55.5	
2011			41.2	18.6	
2012			61.6	58.8	
2013			67.4	69.0	
2014				13.4	
2015				66.4	
2016				53.1	
2017	76.5	66.3		49.3	
2018	69.8	91.2		20.5	

* Samples collected from 8 ft^2 from riffles.
**Samples collected from riffles; from 2003–2011 samples collected from 3 ft^2 and from 2012–2018 samples collected from 8 ft^2.
***Samples collected from 3 ft^2 from riffles.

Despite this variability, scores in both 2017 and 2018 using both methods were substantially higher than most samples taken at a nearby site (08LAK3699), historically and from the same years. The site in this study was identified as fair based on the scores from 08LAK3699, which is a King County Ambient Monitoring site. However, the location was shifted 300 meters upstream to coincide with a pre-existing study site (Table 19; WAM06600-062567). We assumed negligible environmental changes over that distance. Upon examination of our scores and further examination of the site, however, we discovered the King County site is immediately below a stormwater outfall that serves the entirety of the large residential development west of State Route 900. Although close, the site for the current study is almost entirely excluded from this influence.

Based on the environmental conditions present upstream of the site sampled in this study, Tibbetts basin appears to be minimally impacted. Only incomplete data are available to assess the conditions at the downstream Ambient Monitoring Site; however, the level of impact is likely greater there. The stark contrast in scores over such a short distance provides an interesting case study on the effects stormwater can have on macroinvertebrate health.

Table 20. Status of conditions in Tibbetts Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to improve condition?
Riparian urban development	3 of 3	2.5	Action needed
Large substrate in stream channel	3 of 6	1.4	
Embeddedness of stream substrate	2 of 2	1.3	
Fine sediment in stream channel	3 of 3	1.2	
Local habitat	2 of 5	1.1	
Basin-wide urban development	0 of 2	NA	No action needed or low priority
Riparian forest health	0 of 5	NA	
Basin-wide forest health	0 of 5	NA	
Roads in basin	0 0f 2	NA	
Stream bed stability	0 of 1	NA	
Stream Temperature	0 of 3	NA	
Flashiness	NA	NA	Not evaluated
Natural condition			
Organic material in soil	1 of 1	1.4	Condition may limit recovery
Slope	0 of 2	NA	Condition not likely to affect recovery
Stream density throughout basin	0 of 1	NA	
Soil composition in basin	0 of 2	NA	

Prior work in the basin has identified additional issues that may affect conditions in the basin and at the B-IBI site. These include:

Geological Hazards

There are large patches within the basin, particularly on Cougar Mountain, that are in potential landslide and steep slope hazard areas. However, since the overall basin soil is not naturally high in sand content, it is unclear if the levels of fines and embeddedness observed are naturally derived.

Water Quality

Tibbetts Creek is listed as a category 5 impaired stream for temperature, bioassessment (B-IBI), and dissolved oxygen, and a category 4a for fecal coliform bacteria. Summer temperatures in Tibbetts Creek regularly exceed 16°C, which is considered the upper

threshold for salmonid health. However, our results show only a very modest relationship between B-IBI scores and summer temperature. An EPA-approved TMDL plan is in place for fecal coliform bacteria within the Issaquah Creek basin, which includes Tibbetts Creek in its coverage. Nearly all homes within the boundaries of the basin are on septic, and these properties largely sit within or directly adjacent to the riparian buffer. Over a third of these homes were built prior to 1990, and more than two thirds were built prior to 1998. Stormwater regulations when these homes were built were either absent or relatively weak. As noted in Issaquah's State of Our Waters report (City of Issaquah 2011), Tibbetts Creek fecal coliforms tend to experience extreme peaks in concentrations, very responsive to storm events. Failing septic systems combined with poor stormwater management from these areas may contribute to fecal coliform bacteria load within the creek.

Long legacy of human impacts

The area around the Tibbetts basin has been settled since the 1880s, and the evidence of stream disturbance from human activity continues to present day. The sampling site shows evidence of prior bank armoring and pipes from settlements that no longer exist. Buried in the stream bank itself, the field crew found trash piles dating back at least 70 years. Today, a large homeless encampment is frequently present at the site. Contrary to the typical riparian restoration efforts, the Washington Conservation Corps recently removed vegetation from the site to discourage this encampment.

Sediment Deposition

Issaquah's 2011 State of Our Waters report found that between 1998 and 2010, turbidity within the basin periodically spiked up to 6,300 NTUs, two orders of magnitude greater than the sublethal limit for fish. Sources of sediment runoff within the Tibbetts basin include historic and current mining, road runoff, and residential development.

Historic and current mining

A large swath of the basin is currently zoned as Mineral Resource area, and the basin has been impacted by historic and current mining operations. The remains of four abandoned coal mines (New Slope, Harris-Richmond, Queen No. 1 and Issaquah) can be found within the basin, and coal can still be found within the creek itself. In 2002, more than 10,000 cubic yards of mine tailings from the Queen No. 1 mine (formerly operated by Bianco Coal Company) were removed from a gully along Tibbetts Creek. The tailings had been a significant source of sediment to the creek, clogging channels, impeding salmonid migration, and contributing to downstream flooding (Seattle Times, November 22, 2002; Washington State Department of Natural Resources (DNR) mine data).

Quarry operations are currently active in the basin, including Mutual Materials Clay Pit/Strip Mine 3, Pacific Topsoils Sunset Quarry, and Santana Trucking and Excavation. Of these, only Pacific Topsoils is still in operation. The remaining two companies halted operations within the last five years. Pacific Topsoils Sunset Quarry, and Santana Trucking and Excavation each have or had permitted stormwater discharges to Tibbetts Creek. Documents related to the latter permit show numerous permit violations over several years between 2008 and 2014, including two official warnings of permit non-compliance from 2009 and 2014. The issues cited in the inspection reports include unpermitted

surface water discharge to Tibbetts Creek, highly turbid discharge from unstabilized soils and stockpiles, lack of BMP's, track out to SR 900, and lack of a Stormwater Pollution Prevention Plan, Erosion and Sediment Control Plan, and monitoring plan.

Road runoff
Runoff from SR 900 enters a WSDOT stormwater detention pond on the east side of SR 900 before being discharged to a wetland that drains to Tibbetts Creek. As noted above, road track out to SR 900 from mining operations has been an issue in the basin, and would enter Tibbetts Creek through the WSDOT pond.

Residential Development
Over the last decade there has been a flurry of development in the area just west and upslope of Cougar Mountain. Large tracts of forest were clearcut and the slope graded, creating a high potential for construction related runoff to Tibbetts Creek during development, as well as, on-going runoff from the newly urbanized area. Two permitted stormwater discharges in this area enter the basin from Timber Ridge Phase 2, and Talus Parcel 7, 8 & 9. These construction stormwater general permits were initiated in 2014, and will continue through at least 2020. Documents related to Talus Parcel 7, 8 & 9 show several turbidity exceedances in 2015, a field ticket from 2017 citing the operator for not implementing BMPs, and an inspection report from 2018 finding unprotected storm drain outlets, unstable soils without BMPs, and inadequate concrete washout areas.

Further downstream at B-IBI site 08LAK3699 large pipes discharge to Tibbetts Creek. These include permitted construction discharges from Pickering Hills, Talus Parcel 9, Talus 28, and Forest Heights. Talus Parcel 9 has had frequent turbidity exceedances throughout 2018, and a field ticket was issued in May 2018 citing the operator for failing to implement BMPs, lacking a Stormwater Pollution Prevention Plan (SWPPP), not monitoring discharge, inadequate inspections, dumping concrete washout on site, not protecting storm drains, and track out. The Pickering Hills development experienced frequent turbidity exceedances in 2016 and 2017, and an inspection report in 2018 found unstable soils without BMPs, poorly maintained BMPs, and concrete washout dumped on site. In addition to construction related discharges, the area near site 08LAK3699 receives the discharge from the stormwater systems for most of the housing developments on the west side of SR 900.

4.4.2 Recommendations for restoring Tibbetts Creek

Based on conditions at the surveyed B-IBI site and the upstream basin, only a few actions related to riparian forest health are considered highly important (Table 21). However, based on existing knowledge of sampling sites lower in the basin, other actions are likely needed to restore and protect stream health throughout the basin.

Table 21. Management actions needed to improve B-IBI scores in Tibbetts Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	2.6
	Stablize stream banks	2.5
Riparian Buffer	Stablize slopes	6.1
	Plant vegetation, extend buffer	6.1
Stormwater Conveyance Systems	Increase stormwater flow control	3.6
	Improve stormwater treatment	3.6
	Maintain storage and treatment facilities	3.6
	Minimize impact of road runoff	3.6
Forested Land	Maintain or decomission forest roads	3.6
	Allow existing forest to mature	2.5
	Plant vegetation	2.5
Agricultural Land	Exclude livestock	3.6
	Manage waste	3.6
	Prevent soil loss	3.6
Mining Areas	Enforce Mining BMPs	2.5

Issaquah's 2011 State of Our Waters report (City of Issaquah 2011) indicated that water quality in Tibbetts Creek is particularly vulnerable to storm events. This vulnerability is expected to increase as development in the basin increases, bringing more stormwater runoff from construction activity and an increase in impermeable surfaces. LID and stormwater BMPs in the basin will likely provide the largest benefit to the stream. The low scores at B-IBI site 08LAK3699 likely reflect urban stormwater impacts. The difference in B-IBI scores at these two sites, highlights the current opportunity to protect the relatively healthy stream habitat present in the upper basin and improve conditions throughout the watershed.

We recommend using LID and stormwater BMPs wherever possible in new and redevelopments, including use of permeable surfaces, storm water ponds and infiltration wells to moderate the volume of direct discharge into Tibbetts Creek. We also recommend frequent maintenance of existing stormwater facilities to remove excess sediment, and regularly sweeping roads to reduce the potential for sediment to enter the stormwater system. Furthermore, sediment and erosion control around construction sites, land clearing, and gravel and sand stockpiling operations should be implemented and carefully maintained. These recommendations are in line with those outlined by the Issaquah Creek Basin Water Cleanup Plan for the Fecal Coliform Bacteria TMDL. Programs to educate and assist basin homeowners and businesses to implement stormwater BMPs may also help limit sediment inputs to Tibbetts Creek.

Protection of forest lands from conversion to residential would also prevent further stream degradation. The Issaquah Creek TMDL specifically recommends acquisition and protection of riparian areas to enhance water quality and habitat. However, most of the land in the basin and along the riparian buffer is already publicly owned by either King County Parks, the City of Issaquah, or the Washington State Parks. This is the result of an

ongoing effort to create a natural corridor between Squak and Cougar Mountains. Nearly all land zoned as Mineral Resource area has been purchased by King County Parks for permanent preservation, with only Pacific Topsoil Sunset Quarry remaining on a reduced footprint.

Much of the remaining privately owned land in the basin has already been densely developed; only two clusters of minimally developed properties remain. The southern cluster is surrounded by Cougar Mountain Park to the west, the Cougar-Squak Corridor to the south, SR 900 to the east, and City of Issaquah property to the north. Tibbetts Creek skirts the edge of the southern cluster through a well-forested corridor along SR 900. This cluster is in unincorporated King County; Natural Resource Protection Easements should be considered to protect this reach from future development. Two parcels are listed under the PBRS. The northern cluster of properties lies east of SR 900, north of SE 83rd Place, south of Tibbetts Valley Park, and west of Lake Sammamish Trail, and bisected by Tibbetts Creek. These properties are vulnerable to stormwater impacts since construction of a new development, Tibbets Crossing, is planned at the intersection of SR 900 and NW Talus Drive. This new development, spans either side of Tibbetts Creek itself, and will result in 4.5 acres of soil disturbance for residential and utility construction. While other properties in the northern cluster are primarily developed open space (i.e., lawns) with sparse riparian vegetation, this parcel is currently mostly forested with some developed open space fronting to SR 900, while the riparian buffer is fully forested. Efforts should be made to protect the riparian buffer during and after construction, and to protect the stream from construction-related stormwater discharges.

Conservation efforts have been and continue to be successfully implemented. The City has recently acquired the Bergsma property, and this is expected to have a net positive impact on Tibbetts Creek, as it will be preserved as open space (Michal Bonkowski, personal communication). Previously, in 2002, the City of Issaquah worked with environmental groups and developers of Talus to protect 400 acres between Cougar and Squak mountains from future development. In 2001, a working group of local government and tribal agencies, environmental groups, and a private landowner (Rowley Enterprises) constructed about 1,800 square feet of new stream channel and riparian habitat along 17th Avenue NW, using funds donated by the land owner. Replicating this model of cooperation may facilitate protection of the riparian buffer within the future Tibbetts Crossing development. In addition, it may be effective to pre-emptively reach out to the other properties within the northern cluster to seek out long-term protection and restoration of the riparian buffer in that area. These properties are identified as “sending sites” in the City of Issaquah’s Transfer of Development Rights (TDR) program. This program allows developers to purchase zoning privileges from areas with low population needs (“sending sites”), and apply them to areas with high-population needs (“receiving sites”), allowing for permanent conservation of undeveloped or minimally developed lands (Watershed Company 2006). While this strategy has proven to be a cost-effective free-market method for land conservation, high property values within the northern cluster may incentivize owners to sell the land outright for development rather than for conservation.

The Issaquah Creek Basin TMDL also recommends restoration of native riparian vegetation for its water quality and habitat benefits. Opportunities for restoration within this basin have been identified in the Stream and Riparian Areas Restoration Plan (Watershed Company 2006). Five of these opportunities occur within the northern cluster of private properties identified above as being particularly vulnerable to development and stream impacts. However, in 2006 when the report was published, none of the restoration plans for Tibbetts Creek were highly prioritized. We recommend revisiting these proposed projects, and identifying funding sources, as well as public-private partnerships.

Additional restoration opportunities exist at the former Santana Trucking and Excavation and the Mutual Materials Clay Mine sites. Both are now owned by King County, and while some preliminary restoration efforts have occurred, larger scale restoration to stabilize soils and restore canopy cover would benefit the basin. This is especially true at the Santana Trucking and Excavation site, which drains directly to Tibbetts Creek. We recommend considering these sites for inclusion in King County's Million Tree initiative to reforest the parcels.

Some instream and riparian restoration efforts have already occurred within the publicly owned parcels in the basin, including the 2002 Bianca Mine tailings removal and stabilization, and the 2003 Tibbetts Manor Reach restoration which constructed a sedimentation pond, restored riparian vegetation, and made instream habitat improvements. Downstream, between the B-IBI sampling site and the outlet to Lake Sammamish, large reaches of the creek and associated riparian buffer have been restored as part of the Tibbetts Creek Greenway project.

5.0 CHARACTERIZATION AND RECOMMENDATIONS FOR PROTECTION SITES

The following sections describe the B-IBI scores, stream and basin conditions, and recommended actions for ten "excellent" B-IBI sites. These sites and basins were selected because of their history of "excellent" B-IBI scores, and recognition that protecting high quality streams is an important part of ensuring freshwater quality in Puget Sound.

An important finding in Phase I of the project was that nearly 90% of the "excellent" sites were potentially at risk because the basin was not under conservation or preservation status. It was also clear that some sites continued to score "excellent" despite some significant urban development or presence of other human activities associated with degradation. Therefore, we assumed that conditions were likely much better in "excellent" streams than in "fair" streams, but also recognized there may be degraded conditions and need for restoration actions at these sites as well.

The following sections describe each of the 10 sites and include a brief description of the site and basin followed by the B-IBI scores (collected for this project as well as historical samples), and an assessment of conditions. The recommendations illustrate that maintaining excellence may require both protection measures as well as some restoration actions.

5.1 Lost Creek

The Lost Creek basin is in Kitsap County, and encompasses 1,937 acres. Roughly 19 acres in the southern portion of the basin are owned by the City of Bremerton as part of the Union River water supply protected watershed. Lost Creek and Wildcat Creek flow together and become Chico Creek before draining into Dyes Inlet. Lost Creek is zoned largely for forest resource lands and rural wooded lands. As of 2016, 84% of the basin was classified as forest and 14% as scrub/shrub, with <1% as urban. 41% of the buildings in the basin were built pre-1990, and an additional 45% were built pre-1998. The median home age is 25 years old. Lost Creek provides habitat for coho and chum salmon as well as coastal cutthroat, rainbow and winter steelhead trout (WDFW SalmonScape).

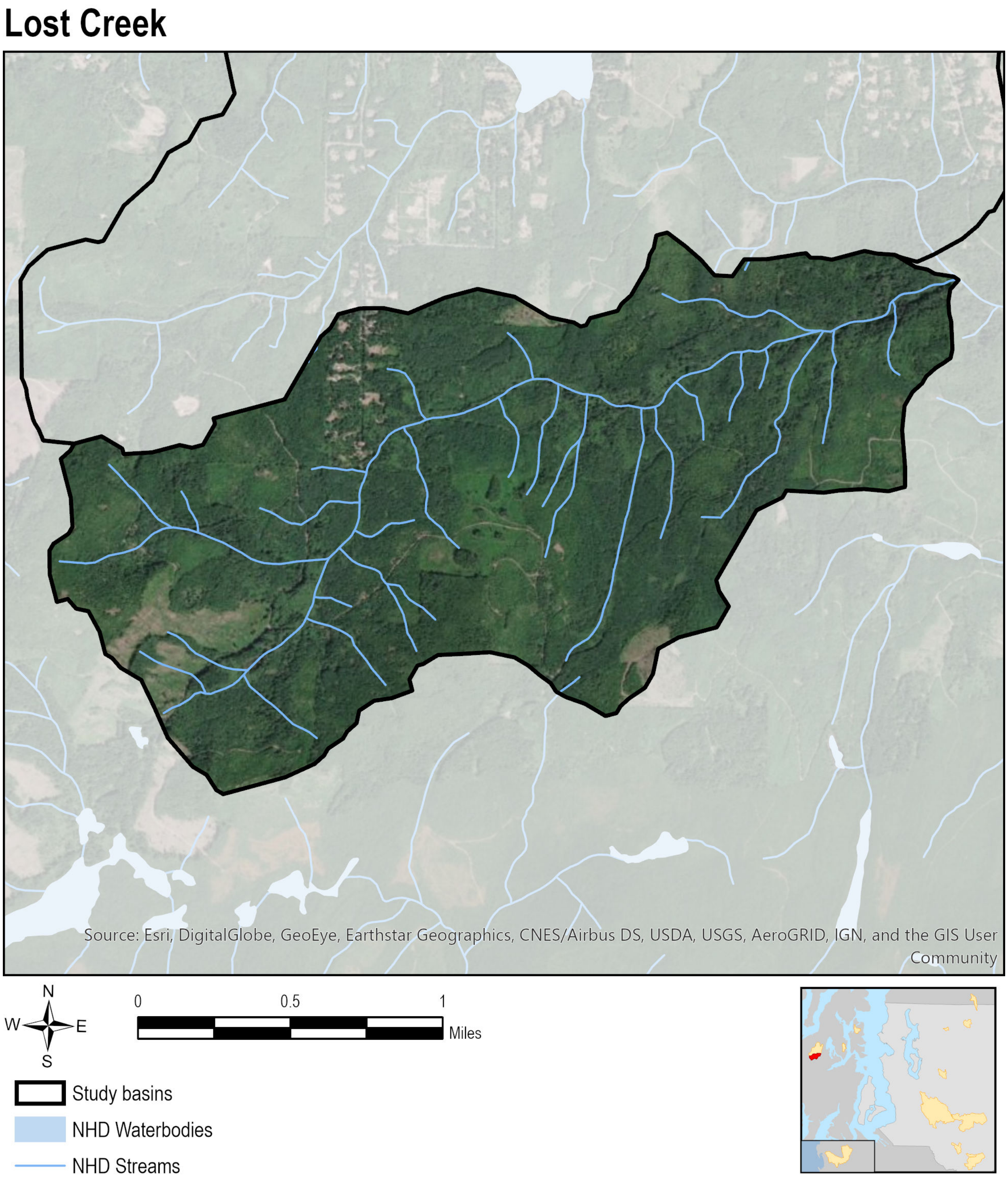

Figure 16. Aerial photo of Lost Creek and its basin.

5.1.1 B-IBI scores and current conditions in Lost Creek

The average B-IBI scores for Lost Creek between 2017 and 2018 were 79.5 (King County method), and 83.7 (Ecology method) (Table 22). These are similar to scores in previous

years, and are approaching the estimated biological potential for the basin. With less than 1% of the basin classified as urban, the biological potential is estimated to be 88.

Table 22. B-IBI scores at one site on Lost Creek. PSSB site codes are in parentheses, and sites 15LT01 and KCSSWM-057 are the same location.

Year Sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (15LT01)		Kitsap County Watershed Health Monitoring* (KCSSWM-057)
	King County Method	Ecology Method	
2015			76.7
2016			89.3
2017	81.3	80.1	
2018	77.6	87.2	

* Samples collected from 8 ft^2 from riffles, similar to King County method.

Based on recent B-IBI scores and current environmental conditions (Table 23), Lost Creek is classified as an "excellent" stream. Flashiness is the only condition that appears to be impacted relative to other typical "excellent" streams. It is important to note, however, that flow data used for this analysis may not adequately characterize conditions in Lost Creek as the flow data are from a gage on Chico Creek, downstream of the B-IBI site and below the confluence with Wildcat Creek.

Table 23. Status of conditions in Lost Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Flashiness	2 of 4	1.5	Action may be needed to maintain excellent B-IBI score
Stream bed stability	0 of 1	NA	Conditions are excellent and should be protected
Local habitat	0 of 5	NA	
Large substrate in stream channel	0 of 6	NA	
Roads in basin	0 of 2	NA	
Riparian urban development	0 of 3	NA	
Stream Temperature	0 of 1	NA	
Basin-wide urban development	0 of 2	NA	
Fine sediment in stream channel	0 of 3	NA	
Embeddedness of stream substrate	0 of 2	NA	
Riparian forest health	0 of 4	NA	
Basin-wide forest health	0 of 5	NA	
Natural condition			
Organic material in soil	1 of 1	1.4	Condition may limit maintenance of excellent B-IBI score
Soil composition in basin	1 of 2	0.7	
Stream density throughout basin	0 of 1	NA	Condition not likely to affect maintenance of excellent B-IBI score
Slope	0 of 2	NA	

Prior work in the basin has identified some conditions and past land use that may influence conditions in the basin and at the B-IBI site. These include:

Soil

The analysis suggests poor soil composition may influence B-IBI scores. While sand content in the basin is below thresholds for both the TITAN and quantile analysis, it is very close to exceeding both. Soil composition in the basin is dominated by clay which may reduce erosion by promoting cohesion; however, clay can contribute to embeddedness within the stream channel.

Landslides and erosion

Most of the stream channel cuts through steep valleys with moderate to high landslide risk and moderate to very severe erosion risk. The steep slopes may also contribute to the elevated flashiness measured downstream in Chico Creek.

Logging

The upper reaches of the stream within Green Mountain State Forest and other state-owned lands were logged prior to 1992 and are the new growth is still maturing, making the basin vulnerable to increased erosion risk and sediment deposition in the stream.

Despite landslide risk and a history of logging, almost all conditions in Lost Creek and its basin appear to be excellent. Flashiness was identified as the only degraded condition, and as mentioned above, the Chico Creek gage may not directly reflect Lost Creek flow conditions. The relatively low effective impact for flashiness (1.5) also indicates less certainty that this condition is impacting or could negatively impact Lost Creek macroinvertebrates.

5.1.2 Recommendations for protecting Lost Creek

Recommendations for Lost Creek stem from the flashiness measured in Chico Creek and include controlling stormwater runoff and restoring forest health (Table 24.) The relatively low importance of these actions, however, suggests the focus should be protecting existing conditions.

Table 24. Management actions needed to maintain excellent B-IBI scores in Lost Creek. Importance values indicate the relative need for the action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	-
	Stablize stream banks	-
Riparian Buffer	Stablize slopes	-
	Plant vegetation, extend buffer	-
Stormwater Conveyance Systems	Increase stormwater flow control	1.5
	Improve stormwater treatment	-
	Maintain storage and treatment facilities	1.5
	Minimize impact of road runoff	1.5
Forested Land	Maintain or decomission forest roads	-
	Allow existing forest to mature	1.5
	Plant vegetation	1.5
Agricultural Land	Exclude livestock	-
	Manage waste	-
	Prevent soil loss	-
Mining Areas	Enforce Mining BMPs	-

Our findings largely support the conclusions described in a 2014 Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions prepared for the Suquamish Tribe (Natural Systems Design, Inc. and ICF, International 2014), which recommends use of land acquisition and conservation easements to preserve conditions in the Chico Creek basin. Extensive protections are already in place throughout much of the basin. The lower 4000 feet of the stream corridor is protected within the Keta Legacy Rhododendron Preserve, parts of which have been preserved since 1915. Consequently, the riparian and floodplain processes are relatively intact in this reach. In addition, the

Preserve has conservation easements surrounding tributaries to Lost Creek on properties owned by Ueland Tree Farm in the southeast part of the basin. A small section of the basin along the southern edge is protected by the City of Bremerton's Union River watershed.

Additional opportunities for protection should also be pursued. Lost Creek runs through a small section of private residential properties within the northwest portion of the basin, and roughly half of the basin is managed by the Washington State Department of Natural Resources (DNR) for timber and recreation. The Watershed Assessment recommends protecting the state lands within the basin from future timber harvest or road construction, and coordinating with residential property owners to obtain conservation easements (Natural Systems Design, Inc. and ICF, International 2014).

5.2 Wildcat Creek

The Wildcat Creek basin is located on the Kitsap Peninsula, and encompasses 4,097 acres of unincorporated Kitsap County. The creek merges with Lost Creek, and becomes Chico Creek before draining into Dyes Inlet. Wildcat Creek is largely zoned for Rural Residential and Rural Wooded, with large areas of forested publicly owned lands. As of 2016, 72% of the basin was classified as forest and 5% as urban. Wildcat Lake and other wetlands comprise an additional 8%. 54% of the development occurred pre-1990, and an additional 23% was pre-1998. The median home age is 29 years old. Wildcat Creek provides habitat for coho and chum salmon as well as coastal cutthroat, rainbow and winter steelhead trout (WDFW SalmonScape).

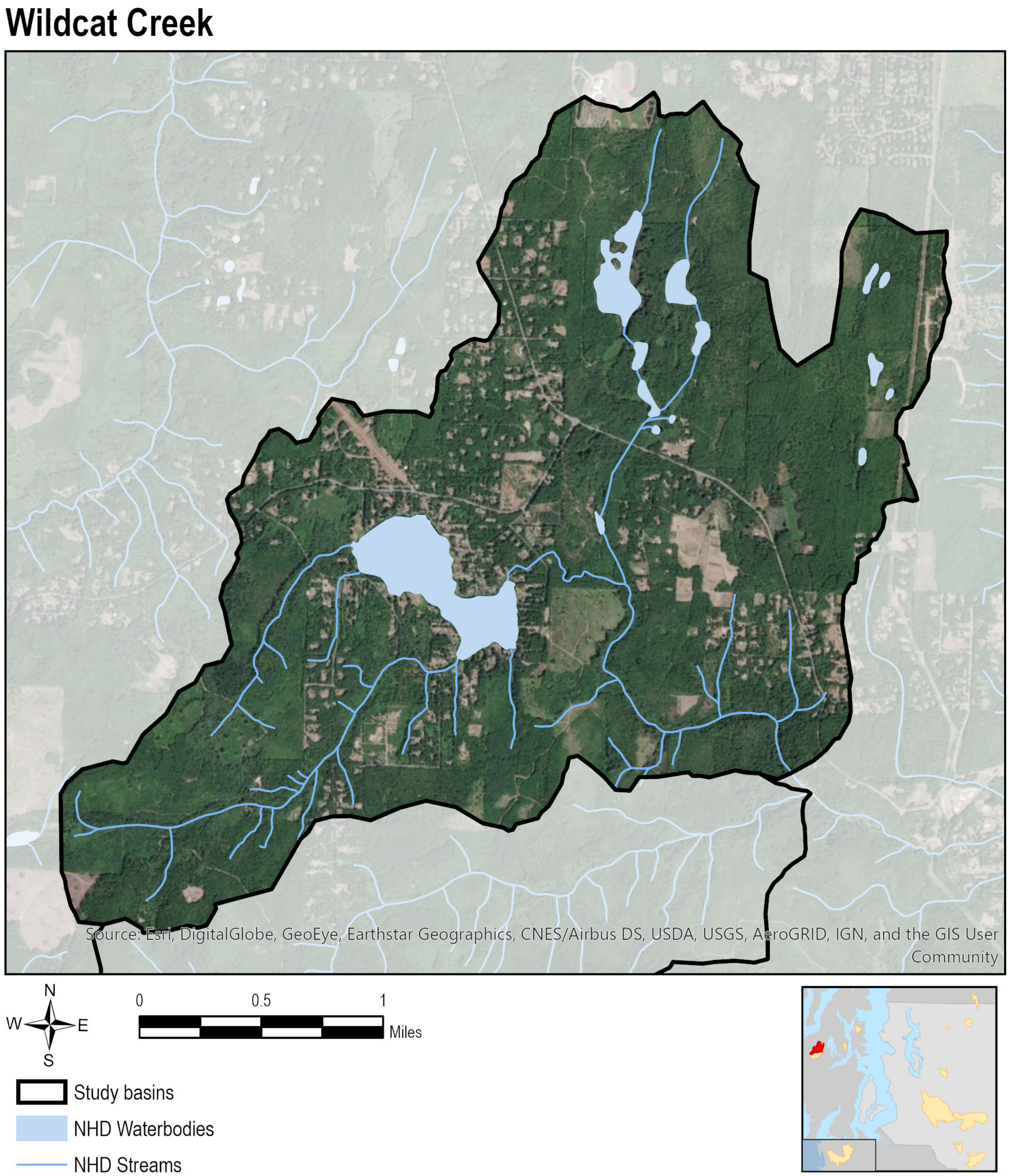

Figure 17. Aerial photo of Wildcat Creek and its basin.

5.2.1 B-IBI scores and current conditions in Wildcat Creek

The average B-IBI scores for Wildcat Creek between 2017 and 2018 were 70.3 (King County method), and 88.8 (Ecology method) (Table 25). These are similar to Kitsap

County's scores, although the recent B-IBI results based on King County's methods are lower than expected given the estimated biological potential for the site. Based on 5% urban development in the basin, the biological potential is estimated to be 84.

Table 25. B-IBI scores from one site on Wildcat Creek. PSSB site codes are in parentheses, and sites 15WC01 and KCSSWM-056 are the same location.

Year Sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (15WC01)		Kitsap County Watershed Health Monitoring* (KCSSWM-056)
	King County Method	Ecology Method	
2015			77.3
2016			97.1
2017	66.6	86.0	80.1
2018	74.0	91.6	

Based on average B-IBI scores and environmental conditions, Wildcat Creek is considered minimally impacted (Table 26). However, some parameters related to basinwide urban development and forest health and all parameters related to riparian forest health indicate actions may be needed to maintain "excellent" B-IBI scores. Despite the results in Table 26 that indicate basinwide and riparian conditions may be impacted, instream conditions are in excellent condition. It is important to note that flashiness values were calculated from flow data from a gage on Chico Creek, downstream of the confluence of Wildcat and Lost Creeks, and therefore may not reflect flow conditions at the B-IBI site.

Table 26. Status of conditions in Wildcat Creek.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Basin-wide urban development	1 of 2	2.9	Action may be needed to maintain excellent B-IBI score
Basin-wide forest health	1 of 5	2.3	
Riparian forest health	5 of 5	2.1	
Flashiness	2 of 4	1.5	
Stream bed stability	0 of 1	NA	Conditions are excellent and should be protected
Embeddedness of stream substrate	0 of 2	NA	
Roads in basin	0 of 2	NA	
Riparian urban development	0 of 3	NA	
Stream Temperature	0 of 3	NA	
Fine sediment in stream channel	0 of 3	NA	
Local habitat	0 of 5	NA	
Large substrate in stream channel	0 of 6	NA	
Natural condition			
Organic material in soil	1 of 1	1.4	Condition may limit maintenance of excellent B-IBI score
Slope	1 of 2	1.3	
Stream density throughout basin	1 of 1	0.8	
Soil composition in basin	2 of 2	0.8	

Additional issues may influence B-IBI scores within the basin. These include:

Logging

The upper reaches of the stream are within the Green Mountain State Forest, which is managed by DNR for timber and recreation. Recent logging on smaller private parcels throughout the basin are evident in aerial photos.

Landslides and Erosion

Most of the stream channel cuts through steep valleys with moderate to high landslide risk and moderate to very severe erosion risk.

Contamination

Several contaminated sites exist in the Wildcat basin. The U.S. Navy Camp Wesley Harris site is awaiting cleanup, and halogenated organics and regulated metals have been confirmed or suspected in soil, groundwater, and surface water. The Kitsap Rifle and Revolver Club site is also awaiting cleanup, and arsenic, lead, mercury, and other metals have been confirmed or suspected in soil and groundwater. This site is within the riparian zone of a tributary to Wildcat Creek. Cleanup has begun at the Gradens Camp Union Grocery site, where benzene, lead, non-halogenated organics, and unspecified petroleum products have been confirmed in soil and groundwater. The Gradens Camp site is located near to Wildcat Lake, which feeds into Wildcat Creek.

Water Quality

Wildcat Creek was included in the Sinclair and Dyes Inlets Fecal Coliform Bacteria Total Maximum Daily Load TMDL and Water Quality Implementation Plan. However, Wildcat Creek itself is listed as a category 1 stream for fecal coliform bacteria, which is a significant improvement from the category 5 listing in 2012 and 2008. Streams in category 1 meet the tested standards for clean water, while streams in category 5 require a water improvement project.

5.2.2 Recommendations for protecting Wildcat Creek

Recommendations for Wildcat Creek (Table 27) largely support the conclusions a 2014 Chico Creek Watershed Assessment for the Identification of Protection and Restoration Actions prepared for the Suquamish Tribe (Natural Systems Design, Inc. and ICF, International 2014), which recommends use of land acquisition and conservation easements to preserve basin conditions in the Chico Creek basin. The Watershed Assessment found that immature forests within Wildcat basin may not effectively mitigate impacts of land use that alter stormwater flows, which can increase peak flows and exacerbate flashiness and erosion.

Table 27. Management actions needed to maintain excellent B-IBI scores in Wildcat Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	-
	Stablize stream banks	-
Riparian Buffer	Stablize slopes	-
	Plant vegetation, extend buffer	2.1
Stormwater Conveyance Systems	Increase stormwater flow control	4.4
	Improve stormwater treatment	2.9
	Maintain storage and treatment facilities	4.4
	Minimize impact of road runoff	4.4
Forested Land	Maintain or decomission forest roads	2.9
	Allow existing forest to mature	3.8
	Plant vegetation	3.8
Agricultural Land	Exclude livestock	-
	Manage waste	-
	Prevent soil loss	-
Mining Areas	Enforce Mining BMPs	-

We recommend protecting existing immature forests and allowing them to reach maturity, with a special focus on the riparian zone. The upper reaches of Wildcat Creek, above Wildcat Lake, are forested by young secondary succession trees, and are on private lands as well as DNR land. Obtaining conservation easements with private landowners in this area may be an effective strategy for improving forest quality in the basin. The Chico Creek Watershed Assessment also recommends acquiring property or obtaining conservation

easements in two additional areas. The first is the 3,500 feet of Wildcat Creek that runs through private property between the Mountaineers Foundation Rhododendron Preserve and DNR land. The second is the confluence of the drainage from the Newberry Hill wetlands and the main outlet of Wildcat Lake, which is on private land and vulnerable to timber harvest or development.

Additional opportunities to improve stream health may come from restoring forests throughout the basin. We recommend working with homeowners to encourage planting native trees and vegetation, especially on properties where grass grows poorly due to soil compaction. The Chico Creek Watershed Assessment (Natural Systems Design, Inc. and ICF, International 2014) recommends restoring riparian vegetation along 500 feet of Wildcat Creek that passes through the old homestead site on the Mountaineers Foundation Rhododendron Preserve, in addition to reopening side channel habitat. These restoration efforts should include a mix of canopy-forming deciduous and coniferous trees, and native shrubs to create an understory.

The Chico Creek Watershed Assessment (Natural Systems Design, Inc. and ICF, International 2014) also found that base flow in Wildcat Creek is naturally low, and is therefore particularly vulnerable to land uses that reduce infiltration and groundwater recharge. The authors noted that some sections of creek dewater entirely during late summer. Protecting instream flows are therefore critical to preserving excellent B-IBI scores within Wildcat Creek. Wildcat Lake and two large wetland complexes within the basin act as natural stormwater buffers, attenuating sediment runoff, and providing storage during storm events that can supply dry-season flows. The two wetland complexes are currently protected within Kitsap County's Newberry Hill Heritage Park. However, as the climate warms and the area develops, surface water supply in the basin is at risk from increased evaporation and groundwater withdrawal. We recommend implementation of LID and stormwater BMPs to reduce direct discharge or overland flow, and promote aquifer recharge and water filtration. Retrofitting already developed areas with stormwater ponds, infiltration wells, and rain gardens would reduce erosion and sediment deposition in wet winter months, and replenish groundwater seeps during dry summer months. In areas where new development may occur, permeable surfaces should be used where possible, along with modern stormwater mitigation methods.

5.3 Chuckanut Creek

The Chuckanut Creek basin is in Whatcom County, encompassing 4,762 acres (ESA, Veda Environmental, and Northwest Ecological Services 2015). The portion of the basin considered for this study includes a slightly smaller area (4,388 acres), with the B-IBI site rather than the Bay defining the downstream end of the basin. The creek flows westerly and drains into Chuckanut Bay. Approximately 460 acres in the lowest portion of the study basin are within the jurisdiction of the City of Bellingham and within the Bellingham UGA. Chuckanut Creek is zoned largely for commercial forestry and rural residential development. As of 2016, 80% of the basin was classified as forest, with 5% as urban. Chuckanut Creek provides habitat for coho and chum salmon as well as coastal cutthroat and winter steelhead trout (WDFW SalmonScape). Chinook salmon have also been

reported to use Chuckanut Creek (ESA, Veda Environmental, and Northwest Ecological Services 2015).

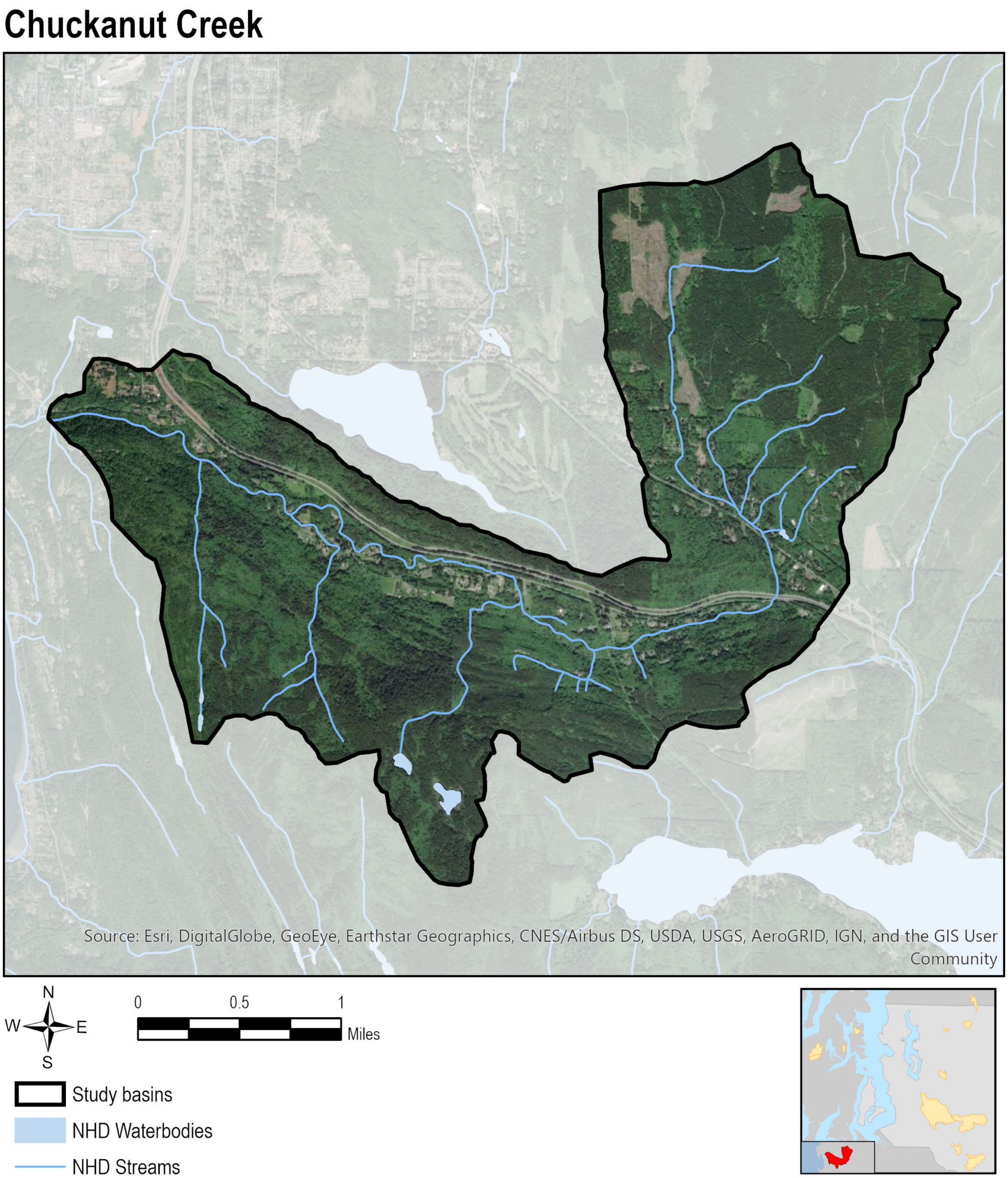

Figure 18. Aerial photo of Chuckanut Creek and its basin.

5.3.1 B-IBI scores and current conditions in Chuckanut Creek

The average B-IBI scores for Chuckanut Creek between 2017 and 2018 were 70.4 (King County method), and 86.7 (Ecology method) (Table 28). The scores based on the Ecology methods are very similar to previous scores from the same site, collected using the same methods (Table 28). The City of Bellingham samples the same site using methods similar to King County's, and the average B-IBI score in 2017/18 was 77.3. Generally the B-IBI scores indicate the sites are "good" to "excellent," with the exception of two "fair" scores from 2011 and 2013. Overall, most Chuckanut Creek B-IBI scores are within 10 to 15 points of the estimated biological potential of 84 (based on 5% basinwide urban development).

Table 28. B-IBI scores from multiple sites in Chuckanut Creek. PSSB site codes are in parentheses, and sites 01CC01 and BIO06600-CHUC02 are the same location. Sites EPA06600-CHUC01, CHCR_0.67 and CHCR_0.83 are approximately 250 m to 500 m upstream of site 01CC01.

Year Sampled (n=1 sample/yr)	Monitoring Effort					
	Restore and Protect Project (01CC01)		Department of Ecology* (BIO06600-CHUC02)	King County WRIA 8 Status and Trends project** (EPA06600-CHUC01)	City of Bellingham**	
	King County Method	Ecology Method			(CHCR_ 0.67)	(CHCR_ 0.83)
2010			86.4			
2011				50.1		76.0
2012				76.4		
2013			82.5	48.2		
2014			87.3			
2015			88.8			
2016			86.4			
2017	67.3	85.2			77.5	
2018	73.4	88.1			77.1	

* Samples collected using Ecology method.
** Samples collected from 8 ft^2 from riffles.

Based on the B-IBI scores and current environmental conditions, the Chuckanut basin is consider to be in good to excellent condition (Table 29). Two parameters related to urban development in the riparian buffer and the basin indicated conditions may be degraded relative to typical "excellent" sites. In addition, both parameters related to embeddedness indicate excess fines may be influencing B-IBI scores, or may affect them in the future (Table 29). Flow data, provided by the City of Bellingham, indicate two of the four flow metrics evaluated indicate flashy flows may affect stream conditions and macroinvertebrate communities. All other parameters indicate instream, riparian and basinwide conditions are in excellent condition.

Table 29. Status of conditions in Chuckanut Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Riparian urban development	1 of 3	3.0	Action may be needed to maintain excellent B-IBI score
Basin-wide urban development	1 of 2	2.9	
Flashiness	2 of 4	1.5	
Embeddedness of stream substrate	2 of 2	1.1	
Large substrate in stream channel	0 of 6	NA	Conditions are excellent and should be protected
Stream bed stability	0 of 1	NA	
Roads in basin	0 of 2	NA	
Stream Temperature	0 of 3	NA	
Fine sediment in stream channel	0 of 3	NA	
Basin-wide forest health	0 of 5	NA	
Local habitat	0 of 5	NA	
Riparian forest health	0 of 5	NA	
Natural condition			
Organic material in soil	1 of 1	1.4	Condition may limit maintenance of excellent B-IBI score
Stream density throughout basin	1 of 1	0.8	
Slope	0 of 2	NA	Condition not likely to affect maintenance of excellent B-IBI score
Soil composition in basin	0 of 2	NA	

Additional issues may influence B-IBI scores within the basin. These include:

Urban Land Development

Most of the urban development in the basin is clustered around the stream itself and associated with the I-5 corridor and low density residential properties. I-5 runs parallel to the stream for most of its length, with 54 stormwater discharges within the basin. Road runoff may contribute to the embeddedness observed in the stream.

Geological Hazards

No landslide hazards exist within the basin, but steep slope hazards are present in the stream ravine.

Water Quality

Within the lower reaches of the basin, Chuckanut Creek is listed as a category 5 stream impaired for fecal coliform bacteria. Water bodies in category 5 are polluted waters that require a water improvement project. The basin is outside out of the city sewer district, and residences within the basin rely on septic systems. Failing septic systems may be contributing to the fecal coliform bacteria issues observed in the stream. For example, in

2014 Ecology identified the McNallie residence, located within the riparian buffer, as discharging polluted runoff without a permit.

Just downstream of the sampling site, the stream is also listed as a category 5 impaired stream for DO, and a category 2 for temperature and pH. Water bodies in category 2 have some evidence of impairment, but not enough to show persistent impairment.

Coal Mines
Several old coal mine prospects are within the basin, including at least two along Samish Lake Drive south of Chuckanut Creek, and one a mile east of Lake Padden near Galbraith Lookout Road (Jenkins, 1923).

Logging
The headwaters of Chuckanut Creek are adjacent to Galbraith Mountain, which is largely privately owned and zoned for commercial forestry. In 2018, the City of Bellingham, Whatcom Land Trust, and Galbraith Tree Farm LLC entered into a recreation easement that secured 2,181 acres of Galbraith Mountain for the public's recreational use and protected the area from development. The City contracted with Whatcom Mountain Bike Coalition to manage recreational use within the easement area. The easement adjoins 4,250 acres of public land managed by Whatcom County. Large portions of the basin in the south and southeast are also zoned for commercial or rural forestry.

5.3.2 Recommendations for protecting Chuckanut Creek

The recommended actions (Table 30), based on relative impacts of the current conditions, align well with the City of Bellingham's own assessment of actions for stream basins within city limits (ESA, Veda Environmental, and Northwest Ecological Services 2015). Of the streams assessed, they found Chuckanut Creek and wetlands within the basin ranked highest for implementation of protection measures, as they provide high-quality habitats that are at risk with further development. Much of the lower portion of the basin is currently within the protected boundaries of the Arroyo Nature Area, Chuckanut Bay Open Space, and the Interurban Trail. However, numerous privately owned parcels zoned residential are undeveloped, primarily along the stream corridor. Larger swaths of forest in the basin are owned by Bloedel Timberlands and Galbraith Tree Farm for commercial forestry, or private citizens for rural forestry.

Table 30. Management actions needed to maintain excellent B-IBI scores in Chuckanut Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	0.0
	Stablize stream banks	1.1
Riparian Buffer	Stablize slopes	4.1
	Plant vegetation, extend buffer	4.1
Stormwater Conveyance Systems	Increase stormwater flow control	5.5
	Improve stormwater treatment	4.0
	Maintain storage and treatment facilities	5.5
	Minimize impact of road runoff	5.5
Forested Land	Maintain or decomission forest roads	4.0
	Allow existing forest to mature	2.6
	Plant vegetation	2.6
Agricultural Land	Exclude livestock	1.1
	Manage waste	1.1
	Prevent soil loss	1.1
Mining Areas	Enforce Mining BMPs	1.1

The Bellingham Habitat Restoration Technical Assessment (ESA, Veda Environmental, and Northwest Ecological Services 2015) recommends acquisition or establishment of conservation easements for parcels along the southeast portion of the basin, and that City and County owned holdings in the southwest portion continue to be managed as open space. Further north in the basin, the Bellingham Habitat Restoration Technical Assessment recommends establishment of conservation easements for key private forested parcels to maintain existing functions. Working with forest land owners to prevent sediment loading from harvest activities, protect forest cover around riparian zones, retain stands of large, old trees, and maintain adequate mean basal area in the basin may sufficiently protect the health of the basin.

We also recommend monitoring stormwater flows and effluent draining from I-5 for turbidity that may negatively impact stream health. As the region develops, increased traffic through the I-5 corridor may result in increased sediment and pollution loading in the stream. Proactive monitoring for these conditions can help protect the stream before habitat quality deteriorates.

Another recommended protective action is reaching out to property owners that live along or adjacent to the creek riparian buffer. This outreach can take a two-pronged approach. First, provide educational opportunities for the public to learn why natural riparian buffers are beneficial and should be maintained. Second, provide resources to help replant native vegetation, and detect and repair faulty septic systems. Given that the bulk of development in the basin is along the stream corridor, this targeted outreach approach may be particularly effective.

5.4 Margaret Creek

The Margaret Creek basin encompasses 1,824 acres northeast of the city of Duvall. The basin spans both King and Snohomish counties, and does not contain any incorporated areas. Margaret Creek basin is largely zoned for commercial forestry in Snohomish County and rural residential in King County, with some parcels listed as forest land under the current use taxation system. As of 2016, 63% of the basin was classified as forest, 18% as scrub/shrub and 13% as lake or wetlands, while only 3% was urban. Over two-thirds of the basin development (71%) occurred pre-1990, and median home age is 40 years old. Margaret Creek provides habitat for coho and Chinook salmon, as well as coastal cutthroat and summer and winter steelhead trout (WDFW SalmonScape).

Margaret Creek

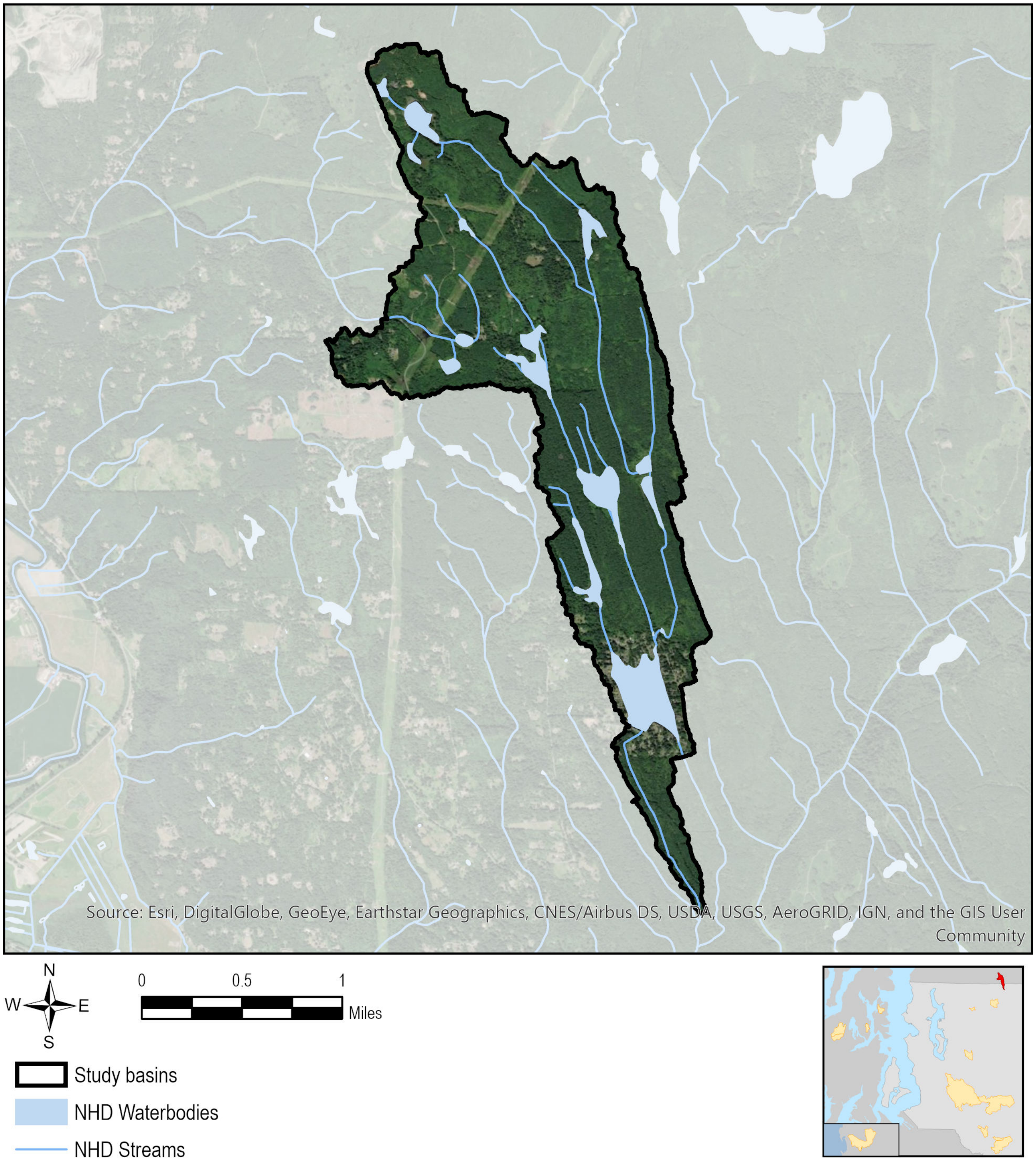

Figure 19. Aerial photo of Margaret Creek and its basin.

5.4.1 B-IBI scores and current conditions in Margaret Creek

The average B-IBI scores for Margaret Creek between 2017 and 2018 were 89.4 (Ecology method) and 88.4 (King County method). King County's Ambient Monitoring program also samples this site, and in 2018 the data from the sample collected using King County's

method was shared between the two programs. These B-IBI scores indicate Margaret Creek typically scores at or above the estimated biological potential of 86.

Table 31. B-IBI scores in Margaret Creek. PSSB site codes are in parentheses in the column headings, and sites 07CH01 and 07CHR070059 are the same location. Scores in parentheses are the same sample, listed in PSSB under both projects.

Year Sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (07CH01)		King County Ambient Monitoring Program (07CHR070059)
	King County Method	Ecology Method	
2015			88.6
2016			64.2
2017	87.1	84.3	90.2
2018	(89.6)	94.4	(89.6)

Based on B-IBI scores and current environmental conditions, Margaret basin is minimally impacted (Table 32). Several, but not all parameters related to riparian urban development, and forest health basinwide and in the riparian buffer indicate conditions are typical of other "excellent" sites, while other parameters indicate some improvements may be needed (Table 32). Almost all other conditions, including instream habitat, appear to be in excellent condition. One substrate parameter suggests the stream lacks cobble; however, all other substrate measures indicate this is not likely impacting B-IBI scores.

Impervious surface area was calculated using the King County portion of the basin. Since the Snohomish County portion of the basin is minimally developed, the values are likely representative of conditions throughout the basin. In addition, there is no flow gage on Margaret Creek, and therefore we did not evaluate flashiness.

Table 32. Status of conditions in Margaret Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Riparian urban development	1 of 3	2.5	Action may be needed to maintain excellent B-IBI score
Basin-wide forest health	2 of 5	2.3	
Riparian forest health	2 of 5	1.4	
Large substrate in stream channel	1 of 6	0.9	
Stream bed stability	0 of 1	NA	Conditions are excellent and should be protected
Basin-wide urban development	0 of 2	NA	
Embeddedness of stream substrate	0 of 2	NA	
Roads in basin	0 of 2	NA	
Stream Temperature	0 of 3	NA	
Fine sediment in stream channel	0 of 3	NA	
Local habitat	0 of 5	NA	
Flashiness	NA	NA	Not evaluated
Natural condition			
Slope	0 of 2	NA	Condition not likely to affect maintenance of excellent B-IBI score
Soil composition in basin	0 of 2	NA	
Organic material in soil	0 of 1	NA	
Stream density throughout basin	0 of 1	NA	

Additional issues that may contribute to low B-IBI scores within the basin. These include:

Logging

The basin is zoned almost entirely for timber harvest outside the residential area of Lake Margaret. The northern portion of the basin is within Snohomish County, and is currently zoned for commercial forestry. In King County, the parcels directly north and south of the populated area around Lake Margaret are owned by a single entity, and designated as forest land which allows timber harvest to occur on the land. South of this, DNR maintains timber harvest rights on the area upstream and surrounding the sampling site.

Future Development

The future land use element of Snohomish County's Comprehensive Plan (https://www.snohomishcountywa.gov/2469/Comprehensive-Plan---Land-Use-Element) includes approximately 300 acres in the center of the basin designated as low density rural (1 DU/20 acres), surrounded by a Forest Transition Area buffer.

Stormwater

In the southern area of the basin within King County, the area immediately surrounding Lake Margaret is zoned for rural area residential, RA-2.5. However, home density here is much higher than current zoning indicates, as most of the structures predate the comprehensive plan. Over 70 percent of the structures in this area were built prior to establishment of stormwater regulations.

5.4.2 Recommendations for protecting Margaret Creek

Recommendations for Margaret Creek are focused on restoring and protecting forest cover in the basin as well as in the riparian buffer (Table 33). Historically, the largest impact to stream health in the Margaret basin has been commercial timber harvesting. However, it may be that this basin can continue to produce excellent B-IBI scores with careful forest management. Modern harvest guidelines require a minimum of 50 foot no-harvest zones on either side of fish bearing streams; most streams within the basin fall into this category. Depending on the site class and stream size, there are additional reduced harvest buffers beyond the no-harvest zone. Roughly 45% of the land in the harvestable portions of the basin are site class II, which requires a reduced harvest buffer of 63 to 78 feet beyond the no-harvest zone. The northern portion of the basin is mostly site class III or IV, which requires a smaller reduced harvest buffer, as little as 23 feet beyond the no-harvest zone. Maintaining the existing forest land use, while adhering to forestry BMPs to retain some ecosystem function, may ultimately be protective of the basin to prevent development. These management practices should include steps to prevent sediment loading from harvest activities, protect forest cover around riparian zones, retain stands of large, old trees, and harvest small areas at a time.

Table 33. Management actions needed to maintain excellent B-IBI scores in Margaret Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	0.9
	Stablize stream banks	-
Riparian Buffer	Stablize slopes	2.5
	Plant vegetation, extend buffer	3.9
Stormwater Conveyance Systems	Increase stormwater flow control	-
	Improve stormwater treatment	-
	Maintain storage and treatment facilities	-
	Minimize impact of road runoff	-
Forested Land	Maintain or decomission forest roads	-
	Allow existing forest to mature	2.3
	Plant vegetation	2.3
Agricultural Land	Exclude livestock	-
	Manage waste	-
	Prevent soil loss	-
Mining Areas	Enforce Mining BMPs	-

The most significant and actionable future threat to stream health in Margaret Creek basin is additional development. The basin is currently composed largely of forest and wetland, with very few residences outside of the perimeter of Lake Margaret. However, Snohomish County expects increased development in the basin in the future, and has designated rural residential future land use in the basin to reflect this. In addition, undeveloped lands within the King County portion of the basin have been rezoned as forest land, but could potentially

be reverted back to rural area and developed. One single entity ultimately owns the bulk of land within the basin in both Snohomish and King Counties. We recommend reaching out to this owner to explore establishing conservation easements. Both King and Snohomish counties have Transfer of Development Right programs, which allow private property owners in designated areas ("sending sites") to sell the development value of their land and establish a conservation easement that permanently prohibits new development on the land. Developers who purchase these rights may then apply them in other designated areas ("receiving sites") where intense development is more appropriate. The privately held lands in Margaret basin designated as commercial forest or forest land qualify for inclusion in these programs as sending sites, and may be a good tool for permanently protecting the basin https://www.kingcounty.gov/services/environment/stewardship/sustainable-building/transfer-development-rights/sending-criteria.aspx.

5.5 Big Soos Creek

The Big Soos Creek basin considered in this study is very large (25,369 acres) and encompasses the city of Covington, most of Maple Valley, and large portions of the cities of Renton and Kent. These incorporated areas are all within the UGA. 13,189 acres of the study basin are in unincorporated King County and largely zoned for rural residential. The basin contains the protected Lake Youngs reservoir and watershed, which provides drinking water to Seattle. As of 2016, 40% of the basin was classified as urban, with an additional 14% developed open space. 53% of the development occurred pre-1990, and an additional 19% was developed pre-1998. The median home age is 31 years old. Big Soos Creek provides habitat for coho and Chinook salmon, as well as coastal cutthroat and winter steelhead trout (WDFW SalmonScape).

Soos Creek

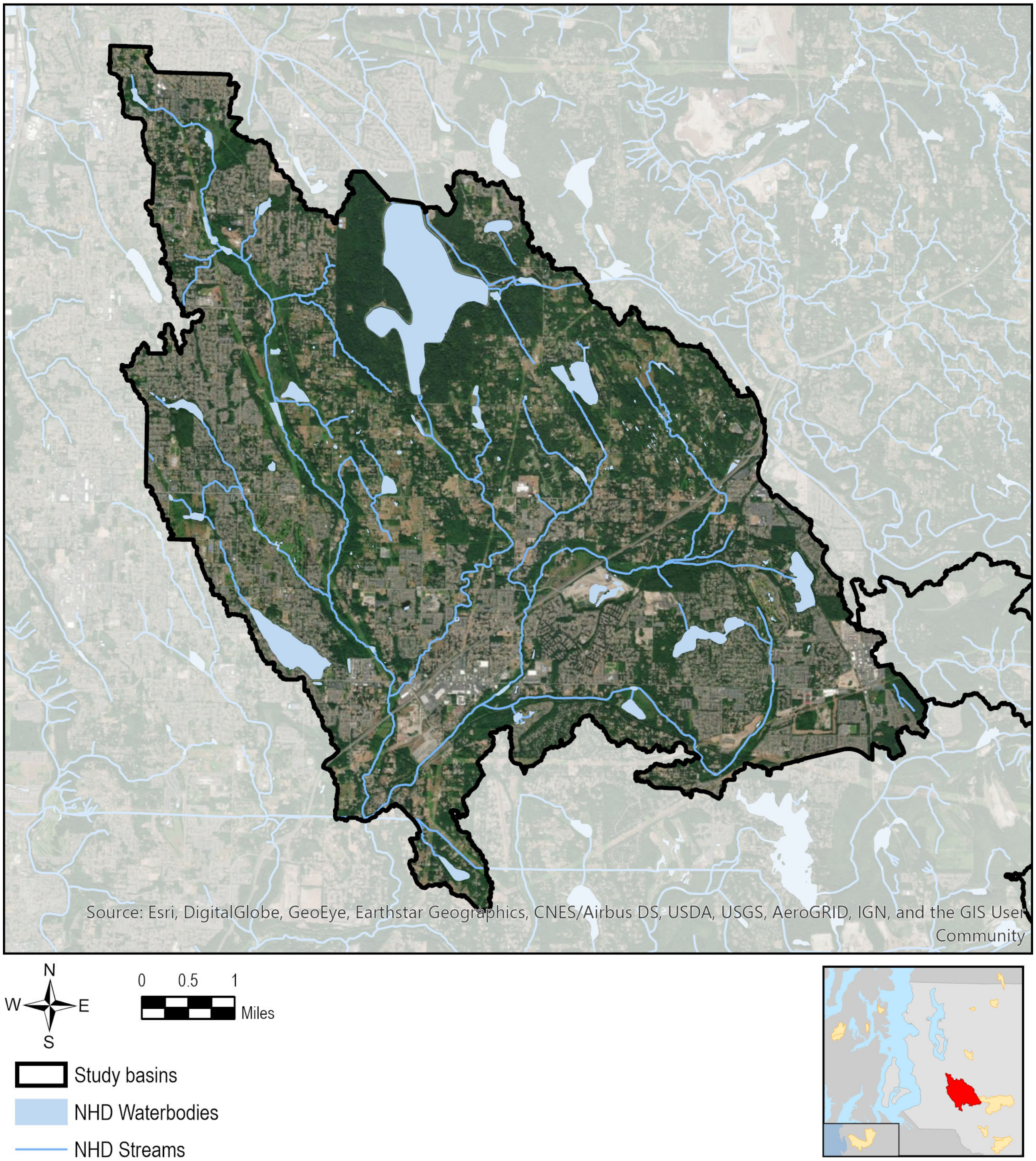

Figure 20. Aerial photo of Big Soos Creek and its basin.

5.5.1 B-IBI scores and current conditions in Big Soos Creek

The average B-IBI scores for Big Soos Creek between 2017 and 2018 were 67.8 (King County method), and 70.6 (Ecology method) (Table 34). Scores from 2017/18 range from "fair" to "excellent," and with the exception of the 2018 B-IBI score based on Ecology's

method, these scores are generally lower than previous scores measured by King County's Ambient Monitoring Program (Table 34).

Table 34. B-IBI scores from one site on Big Soos Creek. PSSB site codes are in parentheses, and sites 09SC01 and 09SOO1134 are the same location.

Year Sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (09SC01)		King County Ambient Monitoring Program* (09SOO1134)
	King County Method	Ecology Method	
2002			77.7
2003			68.2
2005			47.5
2006			70.6
2007			87.9
2008			70.6
2009			73.1
2010			74.7
2011			79.2
2012			81.7
2013			83.5
2014			78.8
2015			76.2
2016			84.7
2017	64.7	56.2	87.1
2018	58.8	85.0	70.6

*Samples collected from riffles; from 2002–2011 samples collected from 3 ft^2 and from 2012–2018 samples collected from 8 ft^2.

Although lower than some historic B-IBI scores, the most recent scores are more closely aligned with the estimated biological potential of 60, based on the 40% urban development in the basin. This site was selected as a protection site in part because it had consistently scored exceptionally high given the extent of development in the basin. The high scores indicate that sensitive taxa had been able to persist despite development and associated stressors. This refuge of sensitive taxa was seen as an important source of colonists, or a "stepping stone," for other sites in the basin and in adjacent basins. Recent B-IBI scores remain near the biological potential, which is encouraging, but the decline indicates the stream is likely being impacted by the degraded basinwide and riparian buffer conditions (Table 35).

Based on recent B-IBI scores and current environmental conditions, Big Soos Creek is impacted (Table 35). Almost all parameters related to forest health and urban development in the riparian buffer and in the basin indicate conditions do not reflect those typical for an "excellent" basin. In addition, over half of the parameters related to instream or local riparian habitat quality indicate conditions are degraded (Table 35). Many additional

issues were identified as well, and detailed below. Given the site conditions, it is surprising that B-IBI scores have remained high.

Table 35. Status of conditions in Big Soos Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Basin-wide forest health	5 of 5	3.6	Action may be needed to maintain excellent B-IBI score
Basin-wide urban development	2 of 2	3.5	
Riparian urban development	2 of 3	3.0	
Roads in basin	1 of 2	2.3	
Riparian forest health	5 of 5	2.1	
Local habitat	3 of 5	1.1	
Embeddedness of stream substrate	1 of 2	1.0	
Stream Temperature	2 of 3	0.9	
Stream bed stability	0 of 1	NA	Conditions are excellent and should be protected
Fine sediment in stream channel	0 of 3	NA	
Large substrate in stream channel	0 of 6	NA	
Flashiness	NA	NA	Not evaluated
Natural condition			
Slope	1 of 2	1.5	Condition may limit maintenance of excellent B-IBI score
Organic material in soil	1 of 1	1.4	
Stream density throughout basin	1 of 1	0.8	
Soil composition in basin	2 of 2	0.8	

Many issues within the basin may contribute to variable and declining B-IBI scores. These include:

Development

Large areas of intense development are present within the basin, particularly in the southern portion, and on the eastern edge in the headwaters of Big Soos Creek, along a tributary to Big Soos Creek and around Lake Meridian. The remainder of the basin is rural area residential, zoned primarily for 1 dwelling unit per 5 acres. However, the rural area of the basin is within an UGA and more development is expected in the future.

Stormwater

Over King County 50 stormwater outfalls discharge to Big Soos Creek, and another 19 WSDOT outfalls discharge directly to the streams or wetlands in the basin. There are also over 120 construction stormwater permits with associated outfalls within the basin as well. In addition, over half the buildings in the basin were constructed prior to implementation of effective stormwater regulations. Many of the older homes are in the most densely developed areas within the basin.

Livestock
Numerous parcels within the basin are used for agriculture. Livestock for food and non-food purposes is the most common agricultural land use in the basin, and large parcels of livestock pasture area are present in the riparian buffer. The presence of livestock in the riparian zone can contribute to poor stream health by contributing fecal material, damage to riparian habitat and increasing sediment runoff. Within the Big Soos basin, some segments of the riparian zone contain no riparian vegetation at all except grass due to livestock use.

Contamination
Approximately 48 toxic cleanup sites exist within the creek basin. Of these, 30 have not been remediated and are either suspected or confirmed to have a wide range of soil, groundwater, and surface water contamination. Surface- and ground-water contamination have been confirmed or suspected at 3 sites, and an additional 14 have confirmed or suspected contamination of groundwater. Petroleum contamination is the most prevalent form of contamination, from gas stations, industrial sites, and heating oil tanks. Metals, organics, solvents, pesticides, PCBs, and PAHs are also common contaminants suspected or confirmed within the basin. However, about half of the unremediated sites have been issued No Further Action Required notifications, and further cleanup is unlikely to occur. Of the remaining sites, cleanup has started at all but one site.

Water Quality
Water quality throughout the basin does not meet water quality standards. Meridian Lake is listed as a category 5 impaired lake for fecal coliform bacteria, total phosphorus, dioxin, dieldrin, hexachlorobenzene, PCBs, total chlordane, toxaphene, chlordane, and as a category 2 impaired lake for 2,3,7,8-TCDD TEQ. Jenkins Creek is listed as a category 5 impaired stream for temperature and bioassessment. Little Soos Creek is listed as a category 5 impaired stream for temperature, DO, bioassessment, fecal coliform bacteria, and as a category 2 impaired stream for pH. A tributary to Big Soos Creek is listed as a category 5 impaired stream for bioassessment. Lower Big Soos Creek is listed as a category 5 impaired stream for bioassessment and fecal coliform bacteria, and as a category 2 impaired stream for DO. Upper Big Soos Creek is listed as a category 5 impaired stream for DO and fecal coliform bacteria, and as a category 2 impaired stream for pH, Ammonia-N, and temperature. A multiparameter TMDL Water Quality Improvement Project is in the process of being developed for temperature, DO, and bioassessment (B-IBI) within the Soos Creek watershed, with an expected publication date in 2022.

Aquatic Plant and Algae Management
Shadow Lake, which drains to Little Soos Creek, has an Aquatic Plant and Algae Management Permit to control Eurasian Milfoil. The permit allows use of a specific list of aquatic-labeled herbicides, algaecides, biological water clarifiers, adjuvants, marker dyes, shading products, and phosphorus inactivation products into the lake.

Sand and Gravel
Several sand and gravel pits operate or have operated in the Big Soos Creek basin, with associated longstanding stormwater issues.

King County has three sand and gravel general permits within the Big Soos Creek basin: the Summit Pit, Covington Pit, and Calhoun Pit. The Calhoun Pit ended mining operations in 2016, and had not been significantly mined since 1997 (DNR letter). A construction site associated with the Calhoun Pit, Lift Number 46 Conveyance, had unmonitored discharges to Jenkins Creek in 2015 during construction of a stormwater conveyance. An administrative order from Ecology from 2015 noted that the site had contaminated groundwater with the potential to discharge in stormwater and dewatering water. The order required strict measures to prevent contamination of surface water.

A sand and gravel pit formerly owned by Lakeside Industries had numerous water quality problems in the late 1990s, resulting in administrative orders and large fines levied by Ecology. A number of these issues persisted into the next two decades. In 2005, a site inspection observed that flow from the facility was likely a significant contribution to flow in Jenkins Creek, along with untreated discharges and poor chemical storage that violated permit conditions and state code. Another inspection, performed in 2009, found numerous permit violations at the site during inspections going back to 1997, resulting in a warning letter. Another inspection was performed in 2015 at the behest of the Muckleshoot Indian Tribe. At that time, the facility was no longer mining gravel, but continued as a hot mix asphalt plant. Attempts to draw down the water level in the pit pond using a 700-gpm pump resulted in sudden surges in stream flow to Jenkins and Soos Creeks. The Ecology hydrogeologist explained that water in the pit represented the exposed regional aquifer, and therefore lowering the water level was unlikely. In 2016 the facility was transferred to Lakepointe. Some turbidity complaints persisted after transfer of ownership, but inspections have found better management practices at the site.

Another sand and gravel pit owned by Iddings, Inc. has also experienced multiple stormwater issues. An inspection in 2008 showed that operators were not aware that they had a sand and gravel permit, and did not have any of the required documents, including a monitoring plan, stormwater pollution prevention plan, or inspection reports. Poor chemical storage and track out was observed. Another business located on-site—Girard Resources & Recycling—was cited in 2012 for recycling concrete without a sand and gravel permit. Poor chemical storage, petroleum sheens, sediment track out to roads, and large volumes of industrial process water and concrete washout dumped on site resulting in extremely high stormwater pH were observed during inspections later that year and again in 2013. Follow-up inspections in 2017 found that required permit documents, which were not available in the 2012 and 2013 inspections, still could not be provided. Road track out and chemical storage also remained issues. In addition, inspectors found unmonitored and unpermitted surface water discharges to Big Soos Creek, unpermitted filling operations, nonfunctional stormwater drainage systems, and dumping of industrial process water from vactor trucks. An additional inspection in 2018 continued to find poor chemical storage practices, as well as ineffective BMPs between the site and Big Soos Creek.

5.5.2 Recommendations for protecting Big Soos Creek

Most recommendations for protecting Big Soos Creek and the remaining sensitive taxa that live there include important restoration actions (Table 36). The number of actions recommended and their relative importance (especially compared to other "protection" streams) illustrate the urgent need for action.

Table 36. Management actions needed to maintain excellent B-IBI scores in Big Soos Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	-
	Stablize stream banks	1.0
Riparian Buffer	Stablize slopes	5.1
	Plant vegetation, extend buffer	8.0
Stormwater Conveyance Systems	Increase stormwater flow control	8.8
	Improve stormwater treatment	7.9
	Maintain storage and treatment facilities	7.9
	Minimize impact of road runoff	7.9
Forested Land	Maintain or decomission forest roads	7.9
	Allow existing forest to mature	4.7
	Plant vegetation	4.7
Agricultural Land	Exclude livestock	2.1
	Manage waste	2.1
	Prevent soil loss	2.1
Mining Areas	Enforce Mining BMPs	1.0

The TMDL being developed for Big Soos Creek will not be completed until 2022. However, in the interim the workgroup has provided a number of recommendations for local residents to follow to improve stream water quality. Our findings especially support the following recommendations:

- Plant trees, especially along stream buffers
- Keep as much native vegetation and undisturbed land as practicable
- Practice "only rain down the drain" for stormwater conveyances
- Exclude livestock from streams and stream buffers
- Install rain gardens
- Ensure a properly functioning on-site sewage system
- Practice water conservation
- Wash cars on lawns or using a commercial car wash
- Practice "don't drip and drive"

Marshalonis and Larson (2018) found that flashiness, fine sediment, and habitat alteration were the stressors most likely contributing to biological impairments within the entire

Soos Creek basin. These findings are largely consistent with findings from Plotnikoff and Blizard (2013), which assessed stressors across six sites in several sites within the study basin. No flow gage was available within a half mile of the sampling site; therefore, we cannot evaluate the impact of flashiness in this basin. In addition, our study results differed from Marshalonis and Larson (2018) in finding that stream temperatures, specifically spring temperatures, likely impact B-IBI scores in Big Soos Creek. Regardless, the weight of evidence described here suggests that B-IBI scores in Big Soos Creek would greatly benefit from preservation and restoration of canopy cover, particularly within the riparian buffer, as well as improved stormwater infrastructure.

There are numerous opportunities to improve forest health in the basin. The riparian area within the King County's Soos Creek Park contains very little canopy cover and is a prime candidate for inclusion in King County's Million Trees initiative. This park is unique in that it encompasses almost the entire length of Big Soos Creek above the confluence with Little Soos Creek. As such, the entire riparian buffer could potentially be restored to functional habitat which would help ensure Big Soos Creek could continue to act as source of macroinvertebrate colonists for other reaches and nearby streams. Restoration efforts in Soos Creek Park should include a mix of canopy-forming deciduous and coniferous trees, and native shrubs to create an understory. Elsewhere in the basin, educational outreach to property owners in riparian areas and acquisition of conservation easements through livestock pastures in riparian areas may also yield some tangible improvements to forest cover in the basin.

We also recommend preservation of existing forested lands in the basin. Some areas are already protected by the King County Water and Land Resources Division. King County's Rural and Regional Services Section is currently acquiring a conservation easement on 4.6 acres adjacent to Shadow Lake, and 5.6 acres along Jenkins Creek for habitat protection. The former Calhoun Gravel Pit is now managed by King County Parks, and Seattle Public Utilities protects the watershed around Youngs Lake Reservoir. To protect the stream from impacts of future development, we recommend additional land or conservation easement acquisitions targeting privately owned undeveloped tracts that contain stream segments.

Better stormwater management in the basin will likely provide a large benefit to the stream, as the natural basin conditions leave it especially susceptible to sediment deposition. The low slope of the basin and stream hinders its ability to effectively flush sediment runoff. Stormwater retrofits would also help to reduce possible flashiness in the stream. Elsewhere in the basin, encouraging use of stormwater BMPs on privately owned land may also alleviate sediment loading. We recommend the following strategies to improve stream conditions: implement, maintain, and enforce sediment and erosion control around construction sites, agriculture, land clearing, and gravel and sand stockpiling; reduce stormwater runoff by reducing the percentage of impermeable surfaces; and, frequently remove excess sediment from existing stormwater facilities.

5.6 Weiss Creek

The Weiss Creek basin encompasses 1,864 acres of unincorporated King County southeast of the city of Duvall. The creek drains into the Snoqualmie River. The Weiss Creek basin is largely zoned for rural residential, with some parcels listed as forest land enrolled in the PBRS. As of 2016, 68% of the basin was classified as forest, and 11% as scrub/shrub. 7% of the basin was classified as urban and 9% as agricultural. Sixty percent of the development occurred pre-1990, and an additional 18% was pre-1998. Median home age is 33 years old. Weiss Creek provides habitat for coho salmon (WDFW SalmonScape).

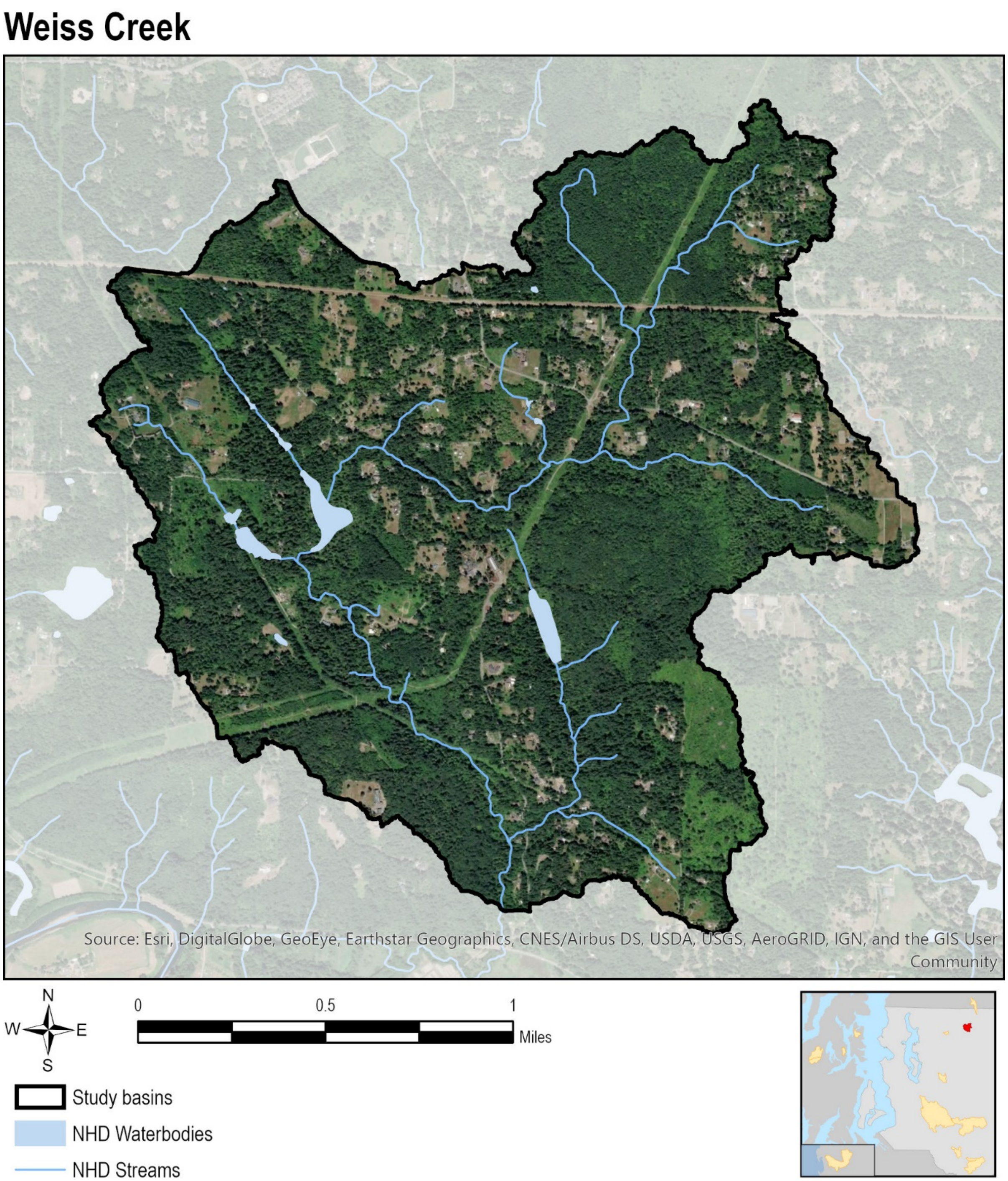

Figure 21. Aerial photo of Weiss Creek and its basin.

5.6.1 B-IBI scores and current conditions in Weiss Creek

The average B-IBI scores for Weiss Creek between 2017 and 2018 were 74.3 (King County method) and 84.7 (Ecology method) (Table 37), and range from "good" to "excellent." Other scores for the site between 2008 and 2018 ranged widely from 50.5 to 85.3, or "fair" to "excellent." Instream fish passage work conducted by the Wild Fish Conservancy in the

upper reaches of the basin occurred in the summers of 2008 and 2009 (http://www.wildfishconservancy.org/projects/upper-weiss-creek-fish-passage), which may have contributed to low scores observed in 2009 and 2010. Overall, B-IBI scores on Weiss Creek are often near the estimated biological potential of 84, based on 7% urban development in the basin.

Table 37. B-IBI scores from one site on Weiss Creek. PSSB site codes are in parentheses, and sites 07WE01 and 53E are the same location.

Year Sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (07WE01)		King County Regulatory Effectiveness Project* (53E)
	King County Method	Ecology Method	
2008			83.0
2009			58.5
2010			50.5
2011			85.3
2012			84.0
2017	78.6	81.3	
2018	69.9	88.0	62.5

* Samples collected from 3 ft^2 from riffles.

Considering this is an "excellent" stream, some conditions appear to be more impacted than would be expected (Table 38). Some parameters related to urban development in the basin and riparian buffer indicated that Weiss Creek may be impacted by development and the associated stressors. Instream parameters related to substrate size also indicate the site may be impacted by excess fine sediment (Table 38). Other instream conditions and forest health within the basin and riparian buffer appear to be in excellent condition.

Table 38. Status of conditions in Weiss Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Basin-wide urban development	1 of 2	2.9	Action may be needed to maintain excellent B-IBI score
Flashiness	2 of 4	1.5	
Large substrate in stream channel	2 of 6	1.4	
Fine sediment in stream channel	3 of 3	1.1	
Embeddedness of stream substrate	2 of 2	1.1	
Riparian urban development	1 of 3	0.9	
Local habitat	1 of 5	0.7	
Stream bed stability	0 of 1	NA	Conditions are excellent and should be protected
Roads in basin	0 of 2	NA	
Stream Temperature	0 of 3	NA	
Basin-wide forest health	0 of 5	NA	
Riparian forest health	0 of 5	NA	
Natural condition			
Organic material in soil	1 of 1	1.4	Condition may limit maintenance of excellent B-IBI score
Slope	1 of 2	1.3	
Stream density throughout basin	1 of 1	0.8	
Soil composition in basin	0 of 2	NA	Condition not likely to affect maintenance of excellent B-IBI score

Additional issues that may influence B-IBI scores within the basin include:

Geological Hazards

There are large patches along the riparian buffer that are potential landslide and steep slope hazard areas, which may naturally contribute excess fines, as well as the embeddedness observed in the stream. The lower portion of the basin is high risk for deep-seated landslides and shallow debris slides, with debris from prior slides evident in the stream valley.

Contamination

Regulated metals, non-halogenated solvents, and unspecified petroleum products have been confirmed or suspected in soil, groundwater, and surface waters at the C and F Auto Wrecking site, which is awaiting cleanup. This site was assessed to be in the highest risk category.

Water Quality

The lower reach of Weiss Creek, just above the sampling site, is listed as a category 4a impaired stream for temperature. Streams in this category already have an EPA-approved TMDL plan in place. In this case, Weiss Creek is included in the Snoqualmie River Basin

Temperature TMDL Water Quality Improvement Report and Implementation Plan (2011). However, our results suggest that temperature is not currently impacting B-IBI scores.

Development
The entire basin is zoned as rural residential development. Large swaths of undeveloped parcels persist in the basin; however, some have been subdivided for development. The Faye Ridge development was planned along the south eastern edge of the basin, but permit applications were cancelled in 2017. A number of parcels zoned for rural residential have received current use designations of forest land, but this designation could be reverted back and the land developed.

5.6.2 Recommendations for protecting Weiss Creek

Given the potential for development in the basin, preserving forest land to retain undeveloped lands in the basin should be a priority for maintaining basin health (Table 39). A number of private properties that have current use forest land designations are zoned for rural residential, with single family homes as their highest and best use. We recommend that these properties be targeted for acquisition or conservation easements.

Table 39. Management actions needed to maintain excellent B-IBI scores in Weiss Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	2.5
	Stablize stream banks	2.2
Riparian Buffer	Stablize slopes	3.8
	Plant vegetation, extend buffer	3.8
Stormwater Conveyance Systems	Increase stormwater flow control	7.4
	Improve stormwater treatment	5.9
	Maintain storage and treatment facilities	7.4
	Minimize impact of road runoff	7.4
Forested Land	Maintain or decomission forest roads	5.9
	Allow existing forest to mature	3.7
	Plant vegetation	3.7
Agricultural Land	Exclude livestock	2.9
	Manage waste	2.9
	Prevent soil loss	2.9
Mining Areas	Enforce Mining BMPs	2.2

Due to the presence of several landslide-prone areas within the basin, and sediment-related impacts evident in the stream, we recommend that any development or timber harvest activities occurring in the basin be set well back from steep slopes, and extra precautions be taken to stabilize the soil.

Actions to help control and treat stormwater were identified as the most needed in the basin. In areas where new development may occur, permeable surfaces should be used where possible, along with modern stormwater mitigation methods. Stormwater retrofits

should also be considered in the basin to reduce existing flashiness, which in turn may reduce sedimentation due to soil erosion. Controlling overland flow may be particularly important along roads and residential areas in steep slope hazard areas. Educational outreach to property owners in these areas regarding LID and stormwater BMPs may be an effective strategy. These recommendations are in agreement with the Snoqualmie River Temperature TMDL (Svrjcek et al. 2011), which calls for erosion control to reduce warming from the wide and shallow stream reach, and stormwater infiltration to increase cool groundwater inputs during summer months.

5.7 Rock Creek

The Rock Creek basin is located just east of Maple Valley, and encompasses 14,143 acres. City of Kent owns a 287-acre parcel (17 acres are within the city of Maple Valley) in the lowest part of the basin. A small UGA has been designated around Lake 12. Rock Creek is largely zoned for rural residential and commercial forestry, with several large areas of publicly owned forest land. As of 2016, 62% of the basin was classified as forest, 17% as scrub/shrub, 8% as agricultural, and 7% as urban. Forty-four percent of the development occurred pre-1990, and an additional 15% was pre-1998. Median home age is 27 years old. Rock Creek provides habitat for coho, Chinook, and sockeye salmon, and winter steelhead (WDFW SalmonScape).

Rock Creek

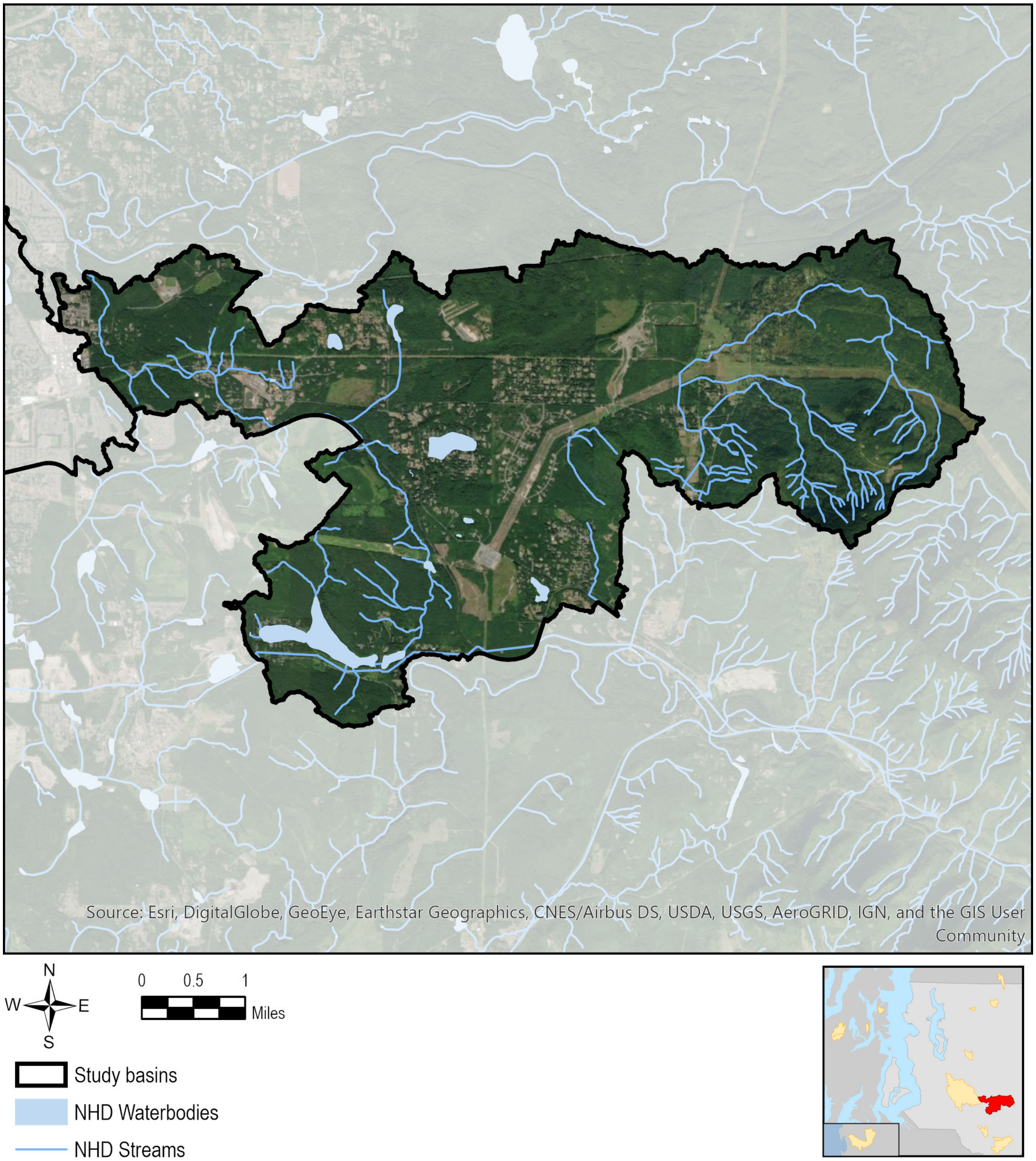

Figure 22. Aerial photo of Rock Creek and its basin. The stream layer shown is from the National Hydrography Dataset and is incomplete for portions of Rock Creek.

5.7.1 B-IBI scores and current conditions in Rock Creek

The average B-IBI scores for Rock Creek in 2017 and 2018 were 94.7 (King County method) and 94.2 (Ecology method). These scores are consistent with scores from the

same year for another program, as well as historic scores for the site (Table 40). While scores have been variable over time (e.g., range 66.3–96.9), the most recent six scores for Rock Creek were all above 92 (Table 40). The estimated biological potential for Rock Creek, based on 7% urban development in the basin, is 83. Thus, Rock Creek is scoring well above the estimated biological potential.

Table 40. B-IBI scores from one site on Rock Creek. PSSB site codes are in parentheses, and sites 08CE01 and 08CED4192 are the same location.

Year Sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (08CE01)		King County Ambient Monitoring Project* (08CED4192)
	King County Method	Ecology Method	
1996			66.3
1997			80.2
1998			96.9
2000			92.9
2002			66.3
2003			86.4
2005			83.3
2006			90.4
2007			93.6
2008			96.5
2009			87.9
2010			92.1
2011			87.7
2012			89.5
2013			94.5
2014			89.4
2015			85.9
2016			92.1
2017	94.4	93.2	93.9
2018	94.9	95.1	92.6

*Samples collected from riffles; from 2002–2011 samples collected from 3 ft^2 and from 2012–2018 samples collected from 8 ft^2.

Based on the available data, Rock Creek B-IBI scores are "excellent" despite some impacted conditions (Table 41). All parameters related to riparian forest health and several related to basinwide forest health indicate conditions are degraded relative to those found in typical "excellent" streams. In contrast, all of the instream parameters indicate site conditions are in excellent condition (Table 41).

Flashiness may be slightly higher in Rock Creek compared to other "excellent" streams, but that has not caused an excess of fines or embeddedness at the B-IBI site (Table 41). Flashiness metrics are highly variable from year to year in Rock Creek, and since 2010,

some of the best T-Q mean values of all King County sites in the Ambient Monitoring program have been observed here. These data suggest that flashiness is not consistently an issue in the basin.

Table 41. Status of conditions in Rock Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Basin-wide urban development	1 of 2	2.9	Action may be needed to maintain excellent B-IBI score
Riparian urban development	1 of 3	2.5	
Basin-wide forest health	2 of 5	2.5	
Riparian forest health	5 of 5	1.7	
Flashiness	1 of 4	1.3	
Stream bed stability	0 of 1	NA	Conditions are excellent and should be protected
Embeddedness of stream substrate	0 of 2	NA	
Roads in basin	0 of 2	NA	
Stream Temperature	0 of 3	NA	
Fine sediment in stream channel	0 of 3	NA	
Local habitat	0 of 5	NA	
Large substrate in stream channel	0 of 6	NA	
Natural condition			
Slope	1 of 2	1.1	Condition may limit maintenance of excellent B-IBI score
Stream density throughout basin	1 of 1	0.8	
Soil composition in basin	1 of 2	0.8	
Organic material in soil	0 of 1	NA	Condition not likely to affect maintenance of excellent B-IBI score

Despite the high B-IBI scores, there are several factors may affect conditions in Rock Creek. These include:

Logging

Large portions of the basin are zoned for commercial forestry. In addition, a number of parcels zoned for rural residential development have been designated through the current use taxation program as forest land or timber land. This status protects the land from urban development but does allow timber harvest to occur. There are active Forest Practices permits, for timber removal within the riparian buffer, in the southern portion of the Rock Creek basin.

Contamination

There are several contaminated sites in the basin.

- The Safford property is awaiting cleanup. Base/neutral/acid organics, corrosive wastes, halogenated organics, regulated metals, non-halogenated solvents, other

reactive wastes, and unspecified petroleum products are suspected or confirmed in soil, groundwater, and surface water.

- The former company mill town of Selleck is also awaiting cleanup of regulated metals and PAHs that are suspected in soil and groundwater.
- Cleanup has begun at the former Landsburg Mine for base/neutral/acid organics, inorganic conventional contaminants, halogenated organics, regulated metals, non-halogenated solvents, unspecified petroleum products, phenolic compounds, and PCBs that are confirmed in soil and suspected in groundwater. Ecology designated this site to be in the highest risk category.

Development

Although large swaths of undeveloped land are present in the basin, these areas have a high potential for development. Most of the central and northwest basin is zoned for rural residential development. Much of the undeveloped land has been designated as forest land, timber land, or open space through the current use taxation program. However, land use designations under this program can revert back and be developed. Currently, a large development (Sugarloaf Estates) in the central basin is converting approximately 640 acres of undeveloped forest to large luxury homes with lawns. Additionally, the land around Lake 12 has been designated as a UGA. This lake feeds into a tributary to Rock Creek, and is surrounded by older homes on half- to one-acre lots. The UGA designation allows this area to be redeveloped at a higher density.

Current and Historic Mining

Two areas in the basin are zoned for mineral extraction. One area is the Kent Kangley pit, owned by Merlino Holdings LLC. Based on activity seen in recent aerial photos, the site appears active; however, part of area zoned for mineral extraction has received current use taxation status as forest land. The second area is the Elk Pit Mine, owned by Mutual Materials. It also appears active based on recent aerial photos. In addition, at least 14 coal mines operated in the basin between the late 1800s and 1950s. The workings of these mines remain in place.

Ravensdale Fill and Grade Project

A contentious fill and grade project underway for the last seven years has applied to continue operations and to expand and extend the original project scope. The Ravensdale Fill and Grade project is run by Erickson Logging LLC. The project initially proposed (King County permit GRDE15-0049) to reclaim land damaged by coal mining operations from the 1940s and 1950s, by filling select mine trenches and planting trees to restore the land to commercial forestry. Ravensdale LLC was subsequently established to accept fill materials as part of a "soil recycling" business. Customers pay per load to dump spoils from vactor trucks, mud, saturated soils, and clean fill into the trenches.

During the initial phase of the project, mine trenches were filled at a volume 2.5 times more than the permit allowed, which violated the approved engineering plans. According to comments from the Greater Maple Valley Unincorporated Area Council (GMVUAC), the overfilled trenches were left unplanted with no soil stabilization for over a year, which

resulted in major sediment runoff issues to nearby streams and wetlands feeding into Rock Creek. The GMVUAC also claims that Erickson Logging has violated the terms of several conservation easements that Forterra holds on the property. King County Department of Permitting and Environmental Review issued a stop work order (King County enforcement case ENFR18-0080), and required Erickson Logging LLC file for an additional permit to cover the overfilled area. Under the second permit, Erickson Logging has proposed to expand the business and fill additional trenches on the property.

According to SEPA comments from local citizens, the expanded project is proposing to fill "trenches" within Rock Creek basin that are natural depressions and not associated with mining. These depressions currently function as commercial forestry purposes without intervention (despite the purpose of the project to restore the land to commercial forestry). The comments also indicate that the expanded project would fill trenches that contain critical areas recognized as class II wetlands, and eliminate wetland buffers. The affected wetlands are the headwaters of Rock Creek, as well as Crow Marsh and Lake 12. Additional concerns were raised about filling of trenches that are hydrologically connected to Rock Creek via subsurface flow, which may alter drainage patterns and serve as a pathway to introduce contamination.

5.7.2 Recommendations for protecting Rock Creek

Protecting Rock Creek will require implementation of several restoration and preservation actions (Table 42). Controlling and treating stormwater runoff and improving basinwide and riparian forest health are important to maintain exceptional B-IBI scores. Given the potential for development in the basin, preserving current open space, natural areas, and forest land uses to retain undeveloped lands in the basin should be a priority for maintaining basin health.

Table 42. Management actions needed to maintain excellent B-IBI scores in Rock Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	-
	Stablize stream banks	-
Riparian Buffer	Stablize slopes	2.5
	Plant vegetation, extend buffer	4.1
Stormwater Conveyance Systems	Increase stormwater flow control	4.2
	Improve stormwater treatment	2.9
	Maintain storage and treatment facilities	4.2
	Minimize impact of road runoff	4.2
Forested Land	Maintain or decomission forest roads	2.9
	Allow existing forest to mature	3.7
	Plant vegetation	3.7
Agricultural Land	Exclude livestock	-
	Manage waste	-
	Prevent soil loss	-
Mining Areas	Enforce Mining BMPs	-

A number of undeveloped private properties are zoned rural residential, with single family homes as their highest and best use. Many of these properties have been designated as forest land, timber land, or open space through the current use taxation program; however, those designations can be changed if the landowner pays a compensating tax. We recommend that these properties be targeted for acquisition or conservation easements. We also recommend that areas zoned for forest land as their best and highest use retain that zoning in the future.

Some forested areas are likely to be preserved without addition actions. Forest lands on the northern edge of the basin are within Seattle Public Utility's Cedar River Watershed, and are protected from development. Along the north eastern edge, large parcels of forest land are owned by the Muckleshoot Indian Tribe, the Bonneville Power Administration, and DNR, and are also largely protected from development. In contrast, forest land on the ridge above Ravensdale is privately owned and more vulnerable to forest clearing and non-forestry uses. The Ravensdale Fill and Grade project is an example of non-forestry land uses occurring on forest land.

King County Parks owns seven parks, open space, or natural areas within the basin, including Sugarloaf Mountain Forest, Ravensdale Retreat Natural Area, Ravensdale Park, Cemetery Reach Natural Area, Danville-Georgetown Open Space, Crow Marsh Natural Area, and Rock Creek Natural Area. The King County Sheriff's firing range is on a large parcel in the center of the basin that is mostly forested, and King County Roads owns a parcel identified as the Lake Retreat Pit that appears to be entirely forested. In addition, King County is pursuing acquisition of the forested portion of the Elk Pit Mine.

We recommend that King County-owned parcels in the basin be managed to maintain a healthy, multiage forest, particularly within the Rock Creek riparian buffer, which appears to be the most impacted. Currently, King County Parks is planning to thin and replant sections of Ravensdale Retreat Natural Area to increase forest diversity (http://gmvuac.org/environment/). We recommend the oldest and biggest trees remain in place, while new plantings consist of a mix of canopy-forming deciduous and coniferous trees, and native shrubs to create an understory.

We strongly recommend avoiding any additional trench filling as part of the Ravensdale Fill and Grade Project. Trenches F and J in particular are within the Rock Creek basin, and several other trenches are likely hydrologically connected via subsurface flows. This project risks altering drainage patterns in the Creek's headwaters, introducing heavy sediment loads by filling source wetlands with unstable soils, and contaminating the creek with mine effluent. In the Lower Cedar River Basin and Nonpoint Pollution Action Plan (King County 1997), Rock Creek is identified as "the highest quality remaining tributary habitat in the lower Cedar River and greater King County area." Given the risks posed and significant issues already encountered with the project, it is unlikely that expansion of the Ravensdale Fill and Grade project is consistent with protection of water quality in Rock Creek basin.

Any new development in the basin should include adequate stormwater infrastructure, and care should be taken to follow BMPs during construction. This is particularly true of any redevelopment that may occur around Lake 12 in the headwaters of Rock Creek. B-IBI scores are particularly vulnerable to urbanization; dense development in the upper basin has the potential to affect stream conditions and B-IBI scores throughout the basin.

5.8 Cristy Creek

The Cristy Creek basin encompasses 2,130 acres of unincorporated King County just north of the city of Enumclaw. The creek drains into the Green River through Flaming Geyser State Park. The Cristy Creek basin is largely zoned for rural residential development, with several large areas of publicly owned forest land and areas designated as agricultural under the current use taxation system. As of 2016, 32% of the basin was classified as forest, 15% as urban, and 31% as agricultural. Most of the development (64%) occurred pre-1990, and an additional 20% was pre-1998. The median home age is 36 years old. Cristy Creek provides habitat for coho salmon, and winter steelhead and coastal cutthroat trout (WDFW SalmonScape).

Cristy Creek

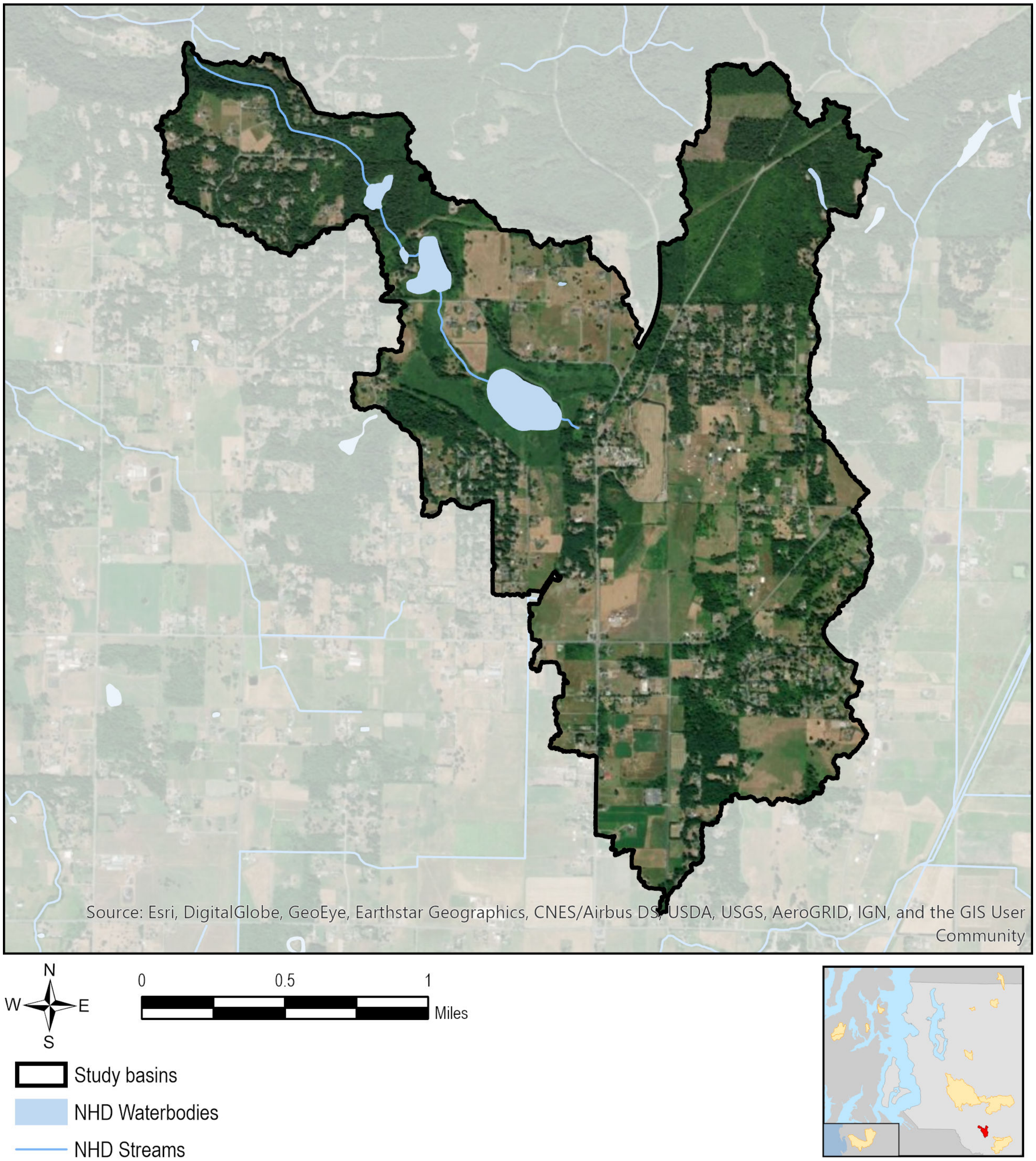

Figure 23. Aerial photo of Cristy Creek and its basin. Note: stream layer is from National Hydrography Dataset and does not include smaller stream segments in the upper basin.

5.8.1 B-IBI scores and current conditions in Cristy Creek

The average B-IBI scores for Cristy Creek in 2017 and 2018 were 88.0 (Ecology method) and 87.3 (King County method). These scores are consistent with values from recent years, which suggest an improving trend since the early 2000s. The site consistently scores higher than the estimated biological potential for the site (77 based on 15% urban development in the basin). Interestingly, a B-IBI site farther upstream (09MID1817) has consistently scored lower (Table 43). It may be that riparian and instream conditions lower in the basin are able to buffer problems impacting the basin further upstream.

Table 43. B-IBI scores at two sites in Cristy Creek. PSSB site codes are in parentheses, and sites 09MD01 and 09MID1744 are the same location. Site 09MID1817 is approximately 1.2 km upstream of 09MD01. Scores in parentheses are the same sample, but listed in PSSB under both projects.

Year Sampled (n=1 sample/yr)	Monitoring Effort			
	Restore and Protect Project (09MD01)		King County Ambient Monitoring Program*	
	King County Method	Ecology Method	(09MID1744)	(09MID1817)
2002			89.3	67.5
2003			68.1	76.9
2005			44.3	69.0
2006			70.7	69.0
2007			77.8	66.0
2008			89.3	57.1
2009			71.6	59.8
2010			84.8	59.0
2011			69.5	63.0
2012			66.8	44.3
2013			94.8	82.6
2014			85.5	50.0
2015			94.8	66.0
2016			80.3	66.4
2017	87.0	90.6	82.3	58.8
2018	(87.6)	86.4	(87.6)	69.1

*Samples collected from riffles; from 2002–2011 samples collected from 3 ft^2 and from 2012–2018 samples collected from 8 ft^2.

Based on B-IBI scores and environmental conditions, the Cristy Creek basin supports a diverse and sensitive macroinvertebrate community despite being moderately impacted (Table 44). All parameters related to basinwide and riparian forest health, and basinwide urban development indicate conditions in Cristy Creek basin are degraded compared to conditions in typical "excellent" streams (Table 44). Forest land in the basin has largely been converted to farm land, and riparian vegetation is mainly absent except in the reach between Beaver Lake and the sampling site. Two local habitat parameters indicate the area

immediately around the sampling site is impacted, but overall instream conditions appear to be excellent. We did not assess flow conditions in Cristy Creek because there is no gage near the site.

Table 44. Status of conditions in Cristy Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Basin-wide forest health	5 of 5	3.6	Action may be needed to maintain excellent B-IBI score
Basin-wide urban development	2 of 2	2.9	
Riparian forest health	5 of 5	2.1	
Local habitat	2 of 5	1.0	
Stream bed stability	0 of 1	NA	Conditions are excellent and should be protected
Embeddedness of stream substrate	0 of 2	NA	
Fine sediment in stream channel	0 of 3	NA	
Roads in basin	0 of 2	NA	
Riparian urban development	0 of 3	NA	
Stream Temperature	0 of 3	NA	
Large substrate in stream channel	0 of 6	NA	
Flashiness	NA	NA	Not evaluated
Natural condition			
Slope	1 of 2	1.5	Condition may limit maintenance of excellent B-IBI score
Stream density throughout basin	1 of 1	0.8	
Organic material in soil	0 of 1	NA	Condition not likely to affect maintenance of excellent B-IBI score
Soil composition in basin	0 of 2	NA	

Additional features in the basin may influence B-IBI scores for better or worse. These include:

Stream Density

The NHD stream layer used to calculate stream density includes less stream length than the King County stream layer; however, most of the additional stream length in the King County data layer comes from drainage ditches. While habitat quality of these ditches is likely poor, they may provide storage during rain events, reducing the impact of stormwater runoff on the stream.

Lakes

Cristy Creek drains through a number of lakes and wetland complexes, including the Bass Lake Complex, Beaver Lake, and Dandy Lake. Although it is unclear how the wetlands and lakes affect nearby stream communities, these water bodies attenuate flows and likely trap sediment, thereby ameliorating some of the effects of development in the upper basin.

Agriculture
Farming is a dominant land use in the Cristy Creek basin. Thirty-one percent of the basin and 13% of the riparian buffer is classified as agricultural land use.

Water Quality
Cristy Creek is listed as a category 2 impaired stream for biological assessment, based on inconsistent B-IBI scores from ambient monitoring sites 09MID1744 and 09MID1817. Water bodies designated as category 2 have some evidence of impairment, but not enough to show persistent impairment. The basin is also covered by the Green River Temperature TMDL, though our results suggest that temperature is typically within the ranges observed in other excellent sites and therefore not likely impacting B-IBI scores.

5.8.2 Recommendations for protecting Cristy Creek

Recommendations for protecting Cristy Creek are based on the stressor identification process and the suite of actions that are usually prescribed to fix impacted conditions (Table 45). However, due to features specific to the Cristy Creek basin (e.g., lakes and wetlands, extensive agricultural land use), some recommendations need additional context.

Table 45. Management actions necessary to maintain excellent B-IBI scores in Cristy Creek. Importance values indicate relative need for action, with larger numbers indicating a more urgent need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	-
	Stablize stream banks	-
Riparian Buffer	Stablize slopes	1.0
	Plant vegetation, extend buffer	3.1
Stormwater Conveyance Systems	Increase stormwater flow control	4.0
	Improve stormwater treatment	4.0
	Maintain storage and treatment facilities	4.0
	Minimize impact of road runoff	4.0
Forested Land	Maintain or decomission forest roads	4.0
	Allow existing forest to mature	3.6
	Plant vegetation	3.6
Agricultural Land	Exclude livestock	1.0
	Manage waste	1.0
	Prevent soil loss	1.0
Mining Areas	Enforce Mining BMPs	-

A sensitive and diverse macroinvertebrate community persists in Cristy Creek despite widespread deforestation in the basin and riparian buffer, as well as low-density urban development throughout the basin. The presence of this community may be due to a number of factors. First, while forest cover in the riparian buffer is extremely low, the non-forest land is largely agricultural and not urban. Although agricultural practices can impair water and habitat quality, the agriculture in the upper portion of the Cristy basin does not appear to be degrading conditions at the B-IBI site. Based on these factors, we recommend

maintaining current land use and zoning densities in the basin to prevent conversion of farmland to residential, commercial, or industrial land uses.

An additional factor to consider is the presence of the Bass Lake Complex Natural Area in the northwest portion of the basin upstream of the B-IBI sampling site. The lakes may serve as a settling basin and stormwater storage pond, buffering the downstream reach from the negative impacts higher in the basin. King County has acquired 470 acres of land around the lakes, and much of it remains deforested. We recommend King County revegetate this area, and consider it for inclusion in the Million Trees initiative. We also recommend that the county continue to acquire lands in the vicinity of the lakes.

Finally, though the riparian buffer throughout the basin is sparsely forested, the riparian buffer between the lakes and B-IBI sampling site is quite healthy. Forest cover in this portion of the basin is also higher, and may be protective. In this particular basin, local scale effects may be far more important than basin scale effects. We recommend targeted action in this portion of the basin to preserve existing tree cover which could be accomplished through homeowner educational campaigns, conservation easements, or land acquisition.

5.9 Newaukum Creek

The Newaukum Creek basin encompasses 894 acres in unincorporated King County, northeast of the city of Enumclaw. As of 2016, 74% of the basin was classified as forest, 10% was classified as scrub/shrub, 1% as urban, and 10% as agricultural. Although there is little development in the basin, most occurred before stormwater controls were required: 61% occurred pre-1990, while 21% occurred pre-1998. The median home age is 36 years old. Newaukum Creek provides habitat for coho and chum salmon, and coastal cutthroat trout (WDFW SalmonScape).

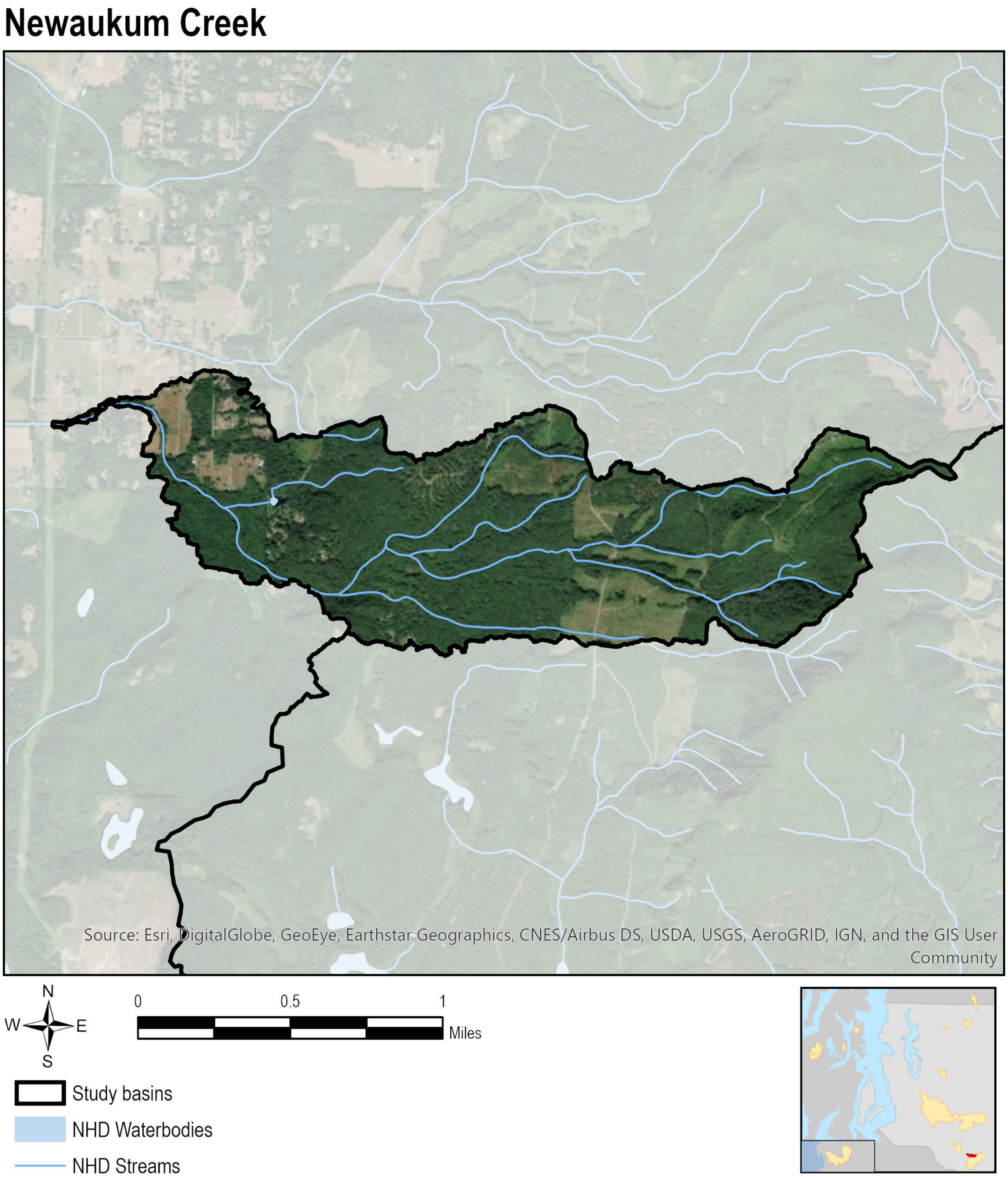

Figure 24. Aerial photo of Newaukum Creek and its basin.

5.9.1 B-IBI scores and current conditions in Newaukum Creek

The average B-IBI scores for Newaukum Creek in 2017 and 2018 were 90.3 (Ecology method) and 85.8 (King County method) (Table 46). King County's Ambient Monitoring Program also samples this site, and in 2018 the sample was shared between the two

projects. These "excellent" scores are consistent with previous scores, and are consistent with the estimated biological potential of 87 for the site (based on 1% urban development). These data indicate Newaukum Creek is scoring at or near the top 10% of sites with little or no urban development in the basin.

Table 46. B-IBI scores at one site in Newaukum Creek. PSSB site codes are in parentheses, and sites 09NE01 and 09NEW2102 are the same location. Scores in parentheses are the same sample, listed in PSSB under both projects.

Year Sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (09NE01)		King County Ambient Monitoring Program* (09NEW2102)
	King County Method	Ecology Method	
2002			74.0
2003			71.6
2005			96.9
2006			71.8
2007			82.7
2008			81.6
2009			85.7
2010			64.6
2011			84.0
2012			75.4
2013			89.4
2014			79.0
2015			89.3
2016			82.7
2017	87.7	83.3	80.3
2018	(83.9)	97.2	(83.9)

*Samples collected from riffles; from 2002 – 2011 samples collected from 3 ft^2 and from 2012 – 2018 samples collected from 8 ft^2.

Despite the consistent "excellent" scores, some conditions in the basin may be impacted (Table 47). All parameters related to excess fine sediment and embeddedness indicate instream habitat is degraded compared to other "excellent" sites (Table 47). Several parameters related to forest health, forest age in particular, (see Newaukum table in Appendix D), also indicate conditions in the Newaukum Creek basin are impacted (Table 47). Road density in the basin is also higher than density typical of "excellent" basins, though most are logging roads. While logging roads may not have as great an impact on flow volumes as paved roads, they may be more likely to contribute to excess fines and embeddedness.

Table 47. Status of conditions in Newaukum Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Roads in basin	1 of 2	2.3	Action may be needed to maintain excellent B-IBI score
Riparian forest health	2 of 5	1.6	
Basin-wide forest health	1 of 5	1.6	
Large substrate in stream channel	2 of 6	1.4	
Fine sediment in stream channel	3 of 3	1.2	
Embeddedness of stream substrate	2 of 2	1.1	
Local habitat	2 of 5	1.1	
Stream bed stability	0 of 1	NA	Conditions are excellent and should be protected
Basin-wide urban development	0 of 2	NA	
Riparian urban development	0 of 3	NA	
Stream Temperature	0 of 3	NA	
Flashiness	NA	NA	Not evaluated
Natural condition			
Organic material in soil	1 of 1	1.4	Condition may limit maintenance of excellent B-IBI score
Slope	0 of 2	NA	Condition not likely to affect maintenance of excellent B-IBI score
Soil composition in basin	0 of 2	NA	
Stream density throughout basin	0 of 1	NA	

Additional factors may influence Newaukum Creek B-IBI scores. These include:

Geological Hazards

Large patches within the upper reaches of the basin tare designated as potential steep slope hazard areas which may contribute to sediment load.

Logging

Most of the Newaukum basin is zoned for forestry, and active logging operations are evident within the basin (Figure 24).

Agriculture

The lower reaches of the basin include agricultural properties focused on hay/silage production and cattle and horse pasture. Above the sampling site, the stream cuts through horse pasture where the riparian buffer is particularly narrow.

Water Quality

Newaukum Creek has a current TMDL for temperature and a TMDL under development for fecal coliform bacteria. Newaukum Creek is also listed as impaired (category 2) for bioassessment (B-IBI). This listing is based on older scores throughout the basin; recent scores at some sites indicate conditions have improved.

5.9.2 Recommendations for protecting Newaukum Creek

The stressor identification process (Table 47) and recommendations (Table 48) indicate restoration and protection actions should focus on reducing inputs of excess fines to the stream. Newaukum Creek is one of the few "excellent" streams that has almost no urban development in the basin, scores at or near its biological potential, and yet based on current conditions multiple restoration actions are recommended (Table 48). The recommended actions are derived from the conditions and the actions considered most effective or improving them (see Section 3.4 and Table 9). Because multiple conditions related to instream habitat were impacted, multiple actions are recommended. In particular, excess fines and embeddedness are degraded. Because all management actions can help influence fines and embeddedness, all actions are recommended (Table 48).

Table 48. Management actions needed to maintain excellent B-IBI scores in Newaukum Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	2.6
	Stablize stream banks	2.3
Riparian Buffer	Stablize slopes	3.4
	Plant vegetation, extend buffer	5.0
Stormwater Conveyance Systems	Increase stormwater flow control	5.7
	Improve stormwater treatment	5.7
	Maintain storage and treatment facilities	5.7
	Minimize impact of road runoff	5.7
Forested Land	Maintain or decomission forest roads	5.7
	Allow existing forest to mature	3.9
	Plant vegetation	3.9
Agricultural Land	Exclude livestock	3.4
	Manage waste	3.4
	Prevent soil loss	3.4
Mining Areas	Enforce Mining BMPs	2.3

Given the historic use of this area as timber land, it appears this basin can support diverse and sensitive macroinvertebrate communities with careful forest management. The Muckleshoot Indian Tribe owns most of the forest land in the basin, and they have stated their intention to manage the land for timber harvest while preserving fish and wildlife habitat. Working with the Tribe to prevent sediment loading from harvest activities (especially around steep slope hazard areas and roads), protect forest cover around riparian zones, retain stands of large, old trees, and maintain adequate mean basal area in the basin may sufficiently protect the health of the basin. We recommend maintaining the existing forest land use, while adhering to forestry BMPs to retain ecosystem functions.

Additionally, we recommend enhanced protections for the riparian buffer in the agricultural portions of the stream. These reaches may be appropriate for Natural Resource

Conservation Easements to maintain the existing riparian forest cover and replant vegetation where needed.

5.10 Boise Creek

The Boise Creek basin encompasses 5,566 acres in southern King County. Approximately 24 acres in the lowest portion of the basin are within jurisdiction of the City of Enumclaw, with the rest in unincorporated King County. The Boise Creek basin is largely zoned for commercial forestry. As of 2016, 77% of the basin was classified as forest, 10% as scrub/shrub, and less than 2% as urban. Although there is little urban development in the basin, most occurred before the most protective stormwater regulations were in place; 47% of the development occurred pre-1990, and an additional 20% was pre-1998. The median home age is 29 years old. Newaukum Creek provides habitat for Chinook, sockeye, coho, and pink salmon, and rainbow and coastal cutthroat trout (WDFW SalmonScape).

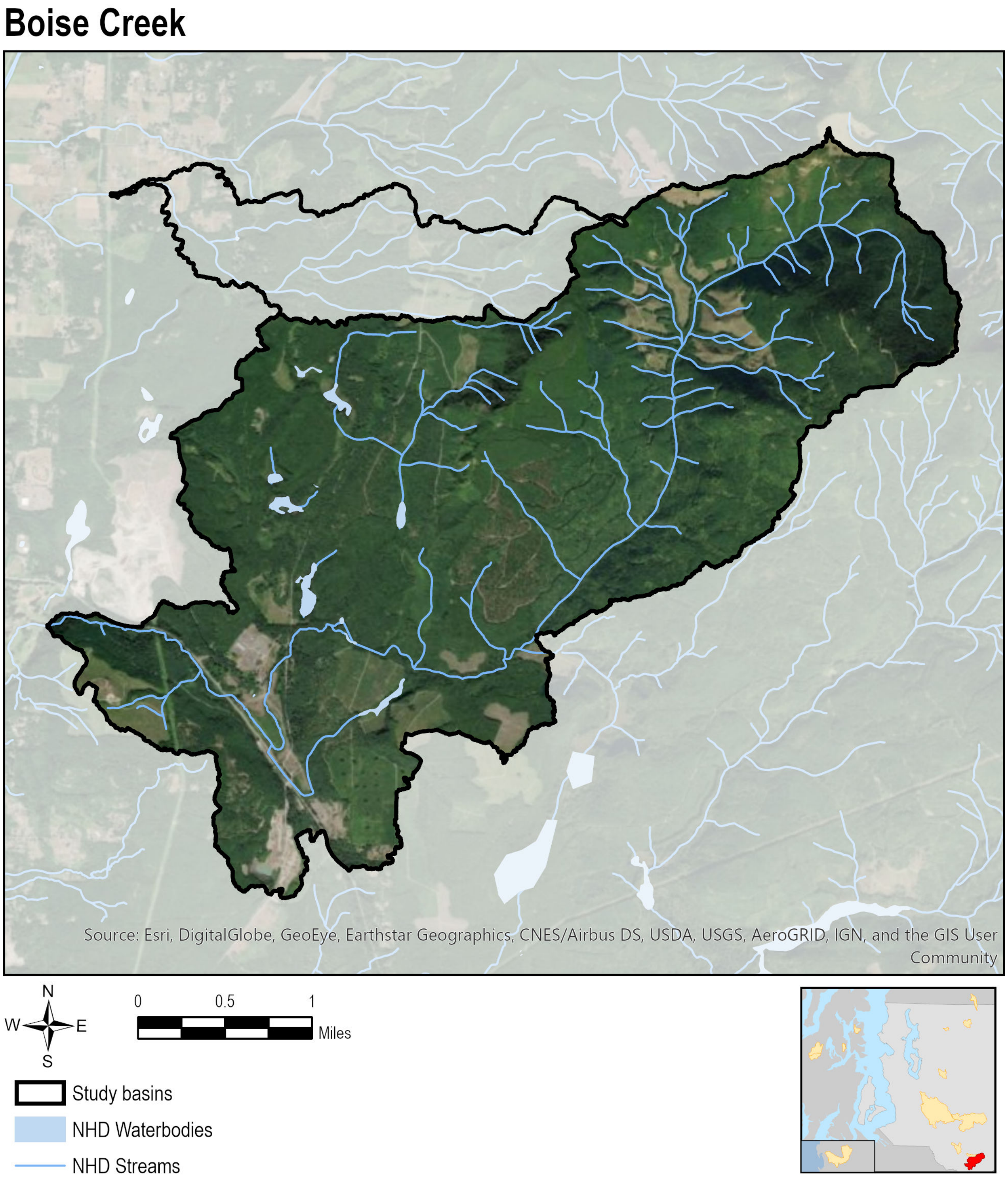

Figure 25. Aerial photo of Boise Creek and its basin.

5.10.1 B-IBI scores and current conditions in Boise Creek

The average B-IBI score for Boise Creek in 2017 and 2018 was 88.5 (King County method) (Table 49). Only one sample was collected using the Ecology method, which scored 91.7.

Although there are limited data for this site, most scores are higher than the estimated biological potential of 86.

Table 49. B-IBI scores from one site in Boise Creek. PSSB site codes are in parentheses, and sites 10BS01 and BSE_21_GolfCrs are the same location. Scores in parentheses for a given year are the same sample, listed in PSSB under both projects.

Year Sampled (n=1 sample/yr)	Monitoring Effort		
	Restore and Protect Project (10BS01)		King County Ambient Monitoring Program (BSE_21_GolfCrs)
	King County Method	Ecology Method	
2014			94.5
2016			69.3
2017	(87.1)		(87.1)
2018	(89.9)	91.7	(89.9)

Habitat surveys were not conducted at this site due to the presence of spawning salmon (2017) and an active homeless encampment (2018); therefore, we were unable to assess bed stability, embeddedness, fines, site-specific impacts, or substrate. Hydrologic data were also not available for this site; therefore, flashiness could not be assessed.

Based on environmental conditions that could be evaluated, the riparian buffer of Boise Creek basin is moderately impacted (Table 50). Half of the eight parameters related to riparian urban development and forest health indicated riparian conditions were degraded compared to riparian conditions at a typical "excellent" site. Road density is also higher than what is typical of "excellent" basins, though most are logging roads. Logging roads may not influence flow volumes to the same degree as paved roads; however, they can be sources of excess fines. Other parameters related to forest health and urban development basinwide were similar to other "excellent" stream basins.

Table 50. Status of conditions in Boise Creek and its contributing basin.

Condition	Number of parameters that indicate condition is degraded	Maximum Effective Impact	Action needed to maintain condition?
Riparian urban development	2 of 3	2.5	Action may be needed to maintain excellent B-IBI score
Roads in basin	2 of 2	2.3	
Riparian forest health	2 of 5	1.4	
Basin-wide urban development	0 of 2	NA	Conditions are excellent and should be protected
Stream Temperature	0 of 3	NA	
Basin-wide forest health	0 of 5	NA	
Embeddedness of stream substrate	NA	NA	Not evaluated
Stream bed stability	NA	NA	
Fine sediment in stream channel	NA	NA	
Local habitat	NA	NA	
Large substrate in stream channel	NA	NA	
Flashiness	NA	NA	
Natural condition			
Organic material in soil	1 of 1	1.4	Condition may limit maintenance of excellent B-IBI score
Stream density throughout basin	1 of 1	0.8	
Slope	0 of 2	NA	Condition not likely to affect maintenance of excellent B-IBI score
Soil composition in basin	0 of 2	NA	

The NHD stream layer used to calculate stream density shows fewer streams in the basin than the King County data indicate. However, given that density based on NHD data is very nearly equal to the quantile-derived threshold for excellent sites, it is unlikely that the basin is truly impacted by low stream density.

Additional issues that may influence B-IBI scores within the basin include:

Logging

Timber logging is the primary use for over 90% of the basin, currently and historically. The majority of this land is owned and managed by the Muckleshoot Indian Tribe, with some parcels owned by Weyerhaeuser and DNR.

Mining

Several quarries in the basin along Highway 410 have permitted discharges to Boise Creek. These include Western Wood 410 Quarry, NW Aggregate White River Quarry, and the Corliss Enumclaw Gravel Pit. NW Aggregates Quarry frequently exceeded water quality criteria for pH and turbidity in the early 2000s, but no issues have been documented in recent years. Corliss Gravel Pit has had multiple water quality issues over the last decade. This plant produces concrete, in addition to mining sand, gravel, and crushed rock. In 2011, Ecology issued a fine to Corliss Gravel Pit for repeatedly not submitting monitoring reports,

and not having the required permit documents. In addition, a field ticket that same year cited the owners for not maintaining BMPs, not conducting required monitoring, and not having a Stormwater Pollution Prevention Plan (SWPPP) that meets permit requirements. Prior to 2014, site discharges regularly exceeded water quality criteria for both minimum and maximum pH, and total dissolved solids. Another field ticket issued in 2018 cited the owner for severe and persistent sediment track out from construction vehicles to Highway 410, discharging untreated process water, not completing inspections, and not using secondary containment for chemical storage. The plant has a surface water discharge that drains to Boise Creek just below the sampling site and is therefore outside the basin; however, groundwater discharges and sediment track out issues are within the basin.

Contaminated Sites
The presence of regulated metals, non-halogenated solvents, petroleum products, phenolic compounds, PCBs, and PAHs had been confirmed or is suspected in soil, groundwater, and surface water at the former Weyerhaeuser Enumclaw Millpond. Ecology indicates cleanup has started though it not when it was initiated or when it will be completed (Cleanup Site ID 1246).

Water Quality
Boise Creek is listed as a category 5 impaired stream for pH. Water bodies in category 5 are polluted waters that require a water improvement project. A tributary to Boise Creek is also listed as a category 5 for temperature; however, the main branch of Boise Creek is listed as category 2. Water bodies in category 2 have some evidence of impairment, but not enough to show persistent impairment.

Boise Creek has been identified as the largest source of fecal coliform load to the Puyallup River; however, most sources were traced to areas downstream of the study site (Ecology 2011b). In 2012, the reach of Boise Creek within the study area was changed from a category 2 to a category 1 listing for fecal coliform bacteria. Water bodies in category 1 meet the tested requirements for clean water.

Channelization
A large tributary to Boise Creek below the former Weyerhaeuser Mill site drains through a 42-inch, approximately 200-foot-long culvert (Boise Creek Rapid Rural Reconnaissance Report, King County 2004). The site is currently a privately owned industrial facility.

Encampments
A large homeless encampment was present within and just above the stream sampling reach in 2018. As a result, we were unable to collect habitat measures at the site. We observed piles of fresh trash and large debris in the stream and in the riparian buffer from the active encampment, as well as a fish trap that was constructed in the creek.

5.10.2 Recommendations for protecting Boise Creek

The most important actions identified to protect the current excellent health of Boise Creek are restoration of the riparian buffer condition, controlling and treating stormwater runoff

and improving forest health throughout the basin (Table 51). These recommendations are based on the conditions that were evaluated; therefore additional conditions that could not be evaluated (with habitat surveys) may be impacted or at risk. For instance, enforcement of mining BMPs was not recommended by the quantitative analysis because excess fines and embeddedness (conditions that would have triggered an action recommendation if impaired) were not evaluated. That said, mining activities within the basin were identified as a potential source of sediment and contaminants that likely needs attention.

In addition, the encampment should be removed to help protect the riparian buffer at and upstream of the B-IBI sampling site. The encampment likely degrades water quality and habitat quality throughout the sampling reach.

Table 51. Management actions needed to maintain excellent B-IBI scores in Boise Creek. Importance values indicate relative need for action; higher numbers indicate greater need.

Target Area or Land Use	Management Action	Importance
In-stream	Add large substrate	-
	Stablize stream banks	-
Riparian Buffer	Stablize slopes	2.5
	Plant vegetation, extend buffer	3.9
Stormwater Conveyance Systems	Increase stormwater flow control	2.3
	Improve stormwater treatment	2.3
	Maintain storage and treatment facilities	2.3
	Minimize impact of road runoff	2.3
Forested Land	Maintain or decomission forest roads	2.3
	Allow existing forest to mature	-
	Plant vegetation	-
Agricultural Land	Exclude livestock	-
	Manage waste	-
	Prevent soil loss	-
Mining Areas	Enforce Mining BMPs	-

Timber harvesting may also pose a risk to the basin, as most stream segments are non-fish bearing tributaries, which have fewer logging restrictions in the riparian zone (Washington State Department of Natural Resources 2017). However, given the history of timber harvest in the basin, it may be that this basin can continue to support a diverse and sensitive macroinvertebrate community with careful forest management. The Muckleshoot Indian Tribe has stated their intention to manage the land for timber harvest while preserving fish and wildlife habitat. Working with the Tribe to continue to prevent sediment loading from harvest activities, protect forest cover within riparian buffers, retain stands of large, old trees, and maintain adequate mean basal area in the basin may sufficiently protect forest health in the basin.

The Boise Creek Rapid Rural Reconnaissance Report (King County 2004) recommends three habitat restoration activities within the basin. Although these recommendations are more than 15 years old, they are still applicable. One recommended action is to place large

woody debris in the channel adjacent to Highway 410 near the former Weyerhauser Mill to control erosion, reduce downstream sedimentation, and increase channel and habitat complexity. Another is to plant coniferous trees in the reach between Highway 410 and the Enumclaw Golf Course. The third recommendation is to daylight the 200 feet of stream flowing through a culvert under the former Weyerhauser Mill, as well as restoring the former 24 acre wetland complex on the site.

The first two recommendations may improve stream quality downstream below the sampling site, where sedimentation has been a documented problem. However, based on visual observations, sedimentation does not appear to be an issue within the sampling reach. The Rural Reconnaissance Report (King County 2004) characterizes the substrate in the reach that flows through the golf course as good quality gravel.

The last recommendation is considered a low priority, as the mill site is above a natural fish barrier that pre-emptively prevents the culvert from acting as a fish barrier. The culvert may be best left in place for another reason: the adjacent mill pond, which is the remains of the former wetland complex on the site, is contaminated with a long list of chemicals in the soil, groundwater, and surface water. The wetland complex was filled and converted to log storage in the early 1990s; prior to this, several fish kills were documented in Boise Creek, including a1983 event that killed fish all the way to the mouth of the creek and resulted in a fine levied against Weyerhauser. Rerouting the creek or restoring the wetland complex increases the risk that these chemicals could enter the stream. Should any restoration in this reach occur in the future, care must be taken to ensure the contaminants are contained or removed.

6.0 CONCLUSIONS AND NEXT STEPS

This phase of the Restore and Protect B-IBI Basins Project assessed stressors in 14 Puget Sound stream basins and recommended actions to restore and protect stream conditions. This report provides a model of how stressor analyses can be used to inform restoration and protection plans in B-IBI basins, and it moves the region one step closer to implementation. Many of the conclusions from the stressor identification analyses and the subsequent recommendations are intuitively predictable, but this process helps quantify the relationships and recommendations.

6.1.1 Conclusions by project objective

1. *Select four "fair" and ten "excellent" basins using the candidate basin selection criteria developed in Phase I.*

We used a modified site selection framework developed in Phase I, and with it selected four "fair" and ten "excellent" sites for the study. These selected sites were chosen from 30 "fair" and 87 "excellent" sites that met the selection criteria but were inaccessible or otherwise less applicable for this study. Although they were not selected for this study, the remaining sites are likely good candidates for restoration and protection actions and should be considered for future stressor identification analyses and management actions.

If the site selection process were repeated, to identify additional sites or to incorporate new B-IBI scores, it could be done in two ways. The first option would be to repeat the process used for this project and consider all possible sites in the region. All available information for each potential site would be considered, and sites could be ranked by the criteria described here (e.g., access, value as fish habitat, biological potential, etc.). While this process is thorough and ensures the most current available data are used, this option is time consuming and results in a long list of "fair" and "excellent" sites. All of the sites may be worthy of restoration and protection, but selecting the final few to focus on may require extra time and resources. Alternatively, local managers could evaluate a smaller set of sites in their watershed of interest or even a single site using criteria identified here (Tables 2 and 5). If sites meet the minimum criteria, we recommend that managers move forward and identify stressors, develop restoration and protections plans and implement actions. There are many barriers to restoring and protecting streams, and site selection should not be one of them.

In addition, when selecting sites for evaluation, it is important to take into account the fluctuation of scores over time. In this study, scores at several "excellent" sites had declined during the study, while scores at several "fair" sites increased. This variation in scores does not invalidate the status of these sites as "fair" or "excellent" (e.g., median scores may still be "fair" or "excellent"), but it is important to take into consideration when setting expectations for recovery or protection. If scores at an "excellent" site are decreasing,

stressors may be impacting the stream and therefore maintaining "excellent" conditions may require more work than anticipated. Likewise, if scores at "fair" sites occasionally increase, fewer restoration actions may be needed than first anticipated.

It is also important to note that it would not be possible to do this project and have the enormous number of sites to choose from were it not for the local, state, tribal and federal monitoring efforts in Puget Lowland streams. Maintaining consistent monitoring programs that sample annually or at a regular interval is critical for the region to maintain our understanding of the status and trends in stream conditions. There is tremendous value in long-term data sets, and the value only increases as the data record lengthens. As many programs try to balance monitoring needs with cost and benefits, we strongly urge programs to continue their monitoring efforts using established protocols, as well as to continue sharing data regionally.

2. *Gather basin-specific data to help identify stressors and inform development of restoration and protection plans.*

Gathering site and basin-scale data was critical for understanding stressors affecting each site. We used both the regional context provided by other studies and site-specific information to interpret our findings and better understand each site and basin. A good example is Tibbetts Creek, where understanding the stormwater conveyance system helped explain why sites only 300 meters apart have very different B-IBI scores.

Data collection and review required a significant effort, and the stressor identification process could not have been accomplished without this work. The level of effort is proportional to the insights gained. While not every metric measured was informative, all types of data collected (e.g., macroinvertebrate data, habitat surveys, geospatial data, etc.) yielded some insights. The geospatial data were useful in identifying basinwide and riparian stressors, and habitat surveys tended to confirm the extent and severity of degradation of local conditions. Although the geospatial data were generally most influential in calculating the effective impacts (because of the stronger correlations between those measures and B-IBI scores), the habitat survey data provided additional lines of evidence that contributed to the ranking and importance of the recommended actions. Therefore, this comprehensive approach resulted in a thorough assessment of likely stressors at multiple scales. Unfortunately this means we did not identify a more efficient way to collect the wealth of information necessary to identify stressors. Likewise, we are likely missing some insights because we did not collect data for some measures (e.g., water chemistry data) or enough information about others (e.g., flow data).

Although there is a clear benefit in collecting all types of data for the stressor identification analyses, we appreciate this level of effort is not practical if we were to scale the assessment to meet the restoration and protection goals for Puget Sound. Based on our analyses, we suggest geospatial data should be used as an initial screening tool to identify stressors. Many of the identified stressors, in both the "fair" and "excellent" basins, were quantified using geospatial data. Habitat survey data, including substrate type, embeddedness, and local habitat conditions, were useful in confirming conditions were

indeed degraded, but in most "fair" basins the habitat survey data added to the lines of evidence but did not change the overall assessment.

3. *Identify stressors that are likely affecting habitat and water quality conditions in the select basins.*

Multiple conditions were degraded at all "fair" sites. Generally, the greatest effective impacts were identified for conditions at the basin or riparian scale and not at the local scale. These results corroborate other studies that indicate B-IBI scores, and changes in the macroinvertebrate community composition, are best explained by large scale stressors associated with development and forest clearing at the basinwide and riparian scale rather than local stressors.

As expected, environmental conditions at "excellent" sites were much better than those at "fair" sites. However, we were surprised to find evidence of multiple degraded conditions at most "excellent" sites. In most "excellent" basins, some riparian and/or basinwide conditions appeared to be degraded relative to typical excellent basins. In contrast, local conditions appeared to be degraded in only five of these basins. This suggests that in some basins, local conditions remain excellent despite degraded conditions in the riparian buffer and upstream basin. For those basins that have some degraded local, riparian and basinwide conditions, but still have excellent B-IBI scores, macroinvertebrate communities either have some resilience to degraded conditions, or the impact of the degraded condition is time-lagged. If so their "excellent" status may be tenuous.

Similar to other studies, we found that many parameters are correlated with B-IBI scores, and most are correlated with each other. Some measures characterize stressors (e.g., embeddedness), while others characterize the extent of human activities (e.g., % urban development in the basin) that ultimately create multiple stressors. As other studies have concluded, we found some of the strongest correlations with basinwide measures of human activity, and some of the weaker relationships with stressors themselves.

As part of our stressor identification process, we used two separate analyses to identify how macroinvertebrate communities respond to environmental gradients. One examined correlations between B-IBI scores and environmental parameters, and the other used macroinvertebrate taxonomic data to examine how community composition changes along those gradients. We found that despite the difference in how these analyses used macroinvertebrate information, they resulted in very similar profiles of "excellent" conditions. These similarities—in quantiles from the correlation analyses and in change points from the community change analyses—gave us greater confidence in the stressor identification process because they represent two independent measures of macroinvertebrate community response to environmental gradients.

Results of the two analyses also shed light on how we think human activities impact stream macroinvertebrate communities. Although basinwide conditions, such as % urban development, were more highly correlated with B-IBI scores than local or riparian conditions, the thresholds at which we see communities change were lower at the riparian

scale. This supports other research findings that indicate high quality riparian buffers are extremely important and need to be restored or protected to a higher standard than the rest of the basin.

Although the relationships with stressors were not always strong, characterizing conditions for a wide range of parameters was helpful in assessing how likely conditions were impacted or not. Thus, a significant product of this project is the list of parameters that correlate with B-IBI scores and the range of values that are typical of "excellent" Puget Lowland streams (Appendix D). The list was not intended to define reference conditions, rather it was used to characterize conditions of randomly selected Puget Lowland streams that have "excellent" B-IBI scores. The ranges are based on limited data (SAM study [DeGasperi et al. 2018] and data from the King County Ambient Freshwater Benthic Macroinvertebrate Monitoring Program) and from a limited area (Puget Lowlands); however, they provide context for others evaluating stream conditions and their potential effects on B-IBI scores.

These parameters and the range in values that are typical of "excellent" streams can also be used to help set recovery targets. For example, the TITAN results indicate sensitive macroinvertebrate taxa are especially sensitive to development in the riparian buffer, and communities change significantly when the percent impervious surface in the riparian buffer exceeds 2.2%. That threshold gives planners a value to aim for when evaluating how and where impervious surfaces can be removed or avoided.

4. *Create maps of each basin that detail possible stressor location and highlight where actions should be targeted.*

Maps were helpful in confirming that identified stressors were likely present and affecting stream conditions. For example, maps of the dynamic riparian buffer overlaid with aerial photos of the basin often revealed gaps in the buffer. Maps also helped identify where actions were needed. For instance, in Cristy Creek, aerial photos and land use coverage maps highlight that conditions in the lower forested portion of the basin are likely in great shape, while conditions in residential areas in the upper basin may be in need of restoration.

5. *Develop recommendations for the four "fair" basins with the goal of improving B-IBI scores to "good."*

Recommendations for improving "fair" sites highlight the need for actions targeting stormwater management and forest health in the riparian buffer, as well as basinwide. Local habitat actions were often ranked less important in "fair" basins. This was not necessarily because those conditions weren't impacted. Rather, we found those conditions were degraded but the impacts were most likely caused by disruptions to foundational stream functions such as hydrology, hydraulics and geomorphology. To improve local conditions, underlying stressors at the basin and riparian scale need to be addressed first.

Recommendations were developed using a simple model based on measured conditions and the actions or tools that could be applied to shift those conditions towards the range seen in typical “excellent” sites. It’s worth noting that the “tool box” for restoring stream conditions for macroinvertebrates is largely untested. As a result, actions are left somewhat vague. It is also difficult to recommend specific, targeted actions because many of the impacts can and need to be addressed by multiple actions (e.g., all actions are recommended if excess fine sediment is a problem because all actions will help reduce delivery or retention of excess fine sediment).

6. *Develop recommendations for the ten “excellent” basins with the goal of maintaining their B-IBI scores.*

The “excellent” sites assessed in this study vary in their condition and vulnerability. Thus, the recommendations for maintaining excellence are basin specific. In some cases, very few actions are recommended, other than protecting the current forest cover as is. For instance, all conditions in Lost Creek were excellent, and there were few indications B-IBI scores are at risk of declining. In contrast, in Big Soos Creek, many if not all conditions appear degraded and it is surprising that the site continues to score “excellent” even occasionally. We anticipate restoration actions are more important in the Big Soos basin than they are in some of the “fair” basins.

In most of the “excellent” basins, several conditions are degraded and need actions. As with the “fair” basins, for most of the “excellent” basins actions related to managing stormwater runoff and improving basinwide forest health are most important. Actions focused on instream conditions are relatively less important, or should be addressed after more important, large scale stressors are alleviated.

An important finding is that the recommendations for both “fair” and “excellent” sites are driven by our understanding of conditions throughout the basin and in the riparian buffer, and not conditions at the site. Our recommendations were also broadly consistent across basins: increase and protect forest cover, improve stormwater management and take all actions possible to reduce excess fine sediment. While additional data will inform site and basin-specific actions, these general recommendations are applicable to all basins.

6.1.2 Next phases: design, implementation, effectiveness monitoring

Restoration and Protection goals will only be met if recommendations are ultimately implemented and evaluated for their effectiveness. Therefore, the next steps in this overall effort are to design, implement, and monitor. These steps will be more straightforward in some basins than others, and a feasibility analysis should be a first step in the design stage.

Additional factors to consider in future phases:

- **Secure access to sites.** We found lack of access to sites was a significant barrier when selecting sites, and depending on where and what type of actions need to be implemented, guaranteed long-term access may be an important consideration.
- **Take basinwide approach.** Scientists and regional planners have advocated for a whole-basin, or watershed plan approach (James 2019) to restoring and protecting streams. We agree that the most efficient and effective way to manage restoration and protection actions within a basin would be to fund, design, implement, and monitor at the basinwide scale. This will require commitments of funding, and coordination among governing agencies (e.g., cities and counties), stakeholders, and affected landowners throughout the design, implementation, and monitoring phases.
- **Be realistic about how actions will be implemented**. Although a coordinated basinwide plan is ideal, it is more likely that smaller scale actions, such as retrofits, riparian plantings, community outreach and education programs, will be implemented opportunistically. When possible, these actions should be planned and sequenced to optimize effectiveness and ensure they are not undermined by other actions in the basin. For instance, if flashy flows are a stressor, instream restoration work should not be completed until flow control is improved.
- **Clearly define restoration goals and expectations**. Although the estimates of biological potential indicate B-IBI scores could be improved at "fair" sites, there is likely a limit that is ultimately dependent on the unalterable extent of urban development in the basin. It may be possible to "lift" this limit, or extend the upper range of B-IBI scores, if stressors associated with current developed lands are reduced. However, until actions are implemented on that scale, it is important to consider the observed biological potential when setting recovery targets.
- **Develop and fund a comprehensive monitoring plan**. Monitoring the effectiveness of restoration actions is challenging especially when multiple conditions are changing simultaneously within a basin (Kroll et al. 2019). Critical elements of a monitoring design include having sufficient pre-project data (3–5 years for B-IBI scores), adequate control basins where few if any changes are anticipated, and clear expectations (from modeling and power analyses) for measured response variables. Stressors, especially land use change, instream sediment composition, and flow, should be monitored consistently along with B-IBI scores.

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Appendix A: Candidate Restoration and Protection Sites

Information about candidate restoration and protection sites considered for this study. As described in Section 2.0, sites were selected based on several criteria. Tables A1-A4 list potential "fair" and "excellent" B-IBI sites that were considered for restoration and protection, respectively, in the final site selection step. In addition to the criteria listed, all sites in Tables A1-A4 provide salmonid habitat. Basins for several sites were not initially delineated correctly, and for those we do not have results from the Puget Sound Watershed Characterization model.

Table A-1 Location information for the 30 "fair" or potential restoration sites considered in the final stages of the site selection process. The top four sites on the list were selected for this study.

Stream	Monitoring Agency	Site Code (listed in PSSB)	WRIA	Latitude	Longitude
Illahee Creek	Kitsap County	KCSSWM-010	15	47.609583	-122.5987
Manzanita Creek	City of Bainbridge Island	ManzBain	15	47.674142	-122.551392
Stensland Creek	King County - Roads	Stensland Upper	8	47.687381	-122.076594
Tibbetts Creek - Lower	King County - DNRP	08LAK3699	8	47.541782	-122.064195
Anderson Creek (Kitsap)	Kitsap County	KCSSWM-019	15	47.523923	-122.682634
Artondale Creek	Pierce County	GH_ARTO_0.30	15	47.300062	-122.622276
Canyon Creek (Puyallup)	Pierce County	BiBi-026 - Canyon Creek	10	47.17819	-122.35834
Carpenter Creek (Kitsap)	Kitsap County	KCSSWM-022 - Upper	15	47.810435	-122.521057
Coal Creek (Lake Wash.)	City of Bellevue	CoalBelRM4.0	8	47.542	-122.143
Cold Creek	King County - DNRP	08BEA3321	8	47.757983	-122.106299
Dutchers Creek	Pierce County	KP_DUTC_0.61	15	47.317284	-122.76854
Ebright Creek	King County - DNRP	08LAK3627	8	47.608613	-122.073354
Evans Creek tributary (0108)	King County - DNRP	08EVA3640	8	47.674662	-122.072706
High School Creek	City of Redmond	HSRed210	8	47.709755	-122.124835
Indian Creek (Lower Deschutes)	Thurston County	IndianThCoWheeler	13	47.035544	-122.881733
Jump Off Creek	Kitsap County	KCSSWM-030	15	47.8068	-122.6692
Laughing Jacobs Creek	King County - DNRP	08LAK3879	8	47.56535	-122.045569
Little Bear Creek	King County - DNRP	08LIT2603	8	47.847646	-122.163836
Little Boston	Kitsap County	KCSSWM-031	15	47.85565	-122.5716
Mackey Creek	City of Redmond	MacRed212	8	47.694974	-122.056067
Mill Creek (Auburn)	King County - DNRP	09MIL0390	9	47.303166	-122.260837
Mill Creek (Auburn)	King County - DNRP	09MIL0340	9	47.303209	-122.272324
Molasses Creek	King County - DNRP	08CED2518	8	47.466198	-122.159083
Mosher Creek	Kitsap County	KCSSWM-012	15	47.6122	-122.6547
Nelyaly Creek	Pierce County	GH_NELY_0.02	15	47.344317	-122.647626
North Creek tributary	King County - DNRP	WAM06600-053755	8	47.872103	-122.223749
Ray Nash Creek	Pierce County	GH_RAYN_0.04	15	47.31866	-122.65909
Springbrook Creek (Bainbridge)	City of Bainbridge Island	SpringBain	15	47.643873	-122.566852
Stensland Creek	King County - Roads	Stensland Middle	8	47.686306	-122.080869
Stensland Creek	King County - Roads	Stensland Lower	8	47.68585	-122.081875

Table A-2 B-IBI median scores and additional site and basin information for 30 "fair" or potential restoration sites considered for this study. The top four sites on the list were selected for this study.

Stream	Site Code (listed in PSSB)	Median B-IBI Score	Years of Data (#)	Basin Size (acres)	Stream Order	Gage Present	B-IBI Score relative to Biological Potential	Puget Sound Watershed Characterization Result
Illahee Creek	KCSSWM-010	40.2	9	800	3	yes	< 50th	Conservation
Manzanita Creek	ManzBain	44.3	5	787	2	-	< 50th	Protection/Conservation
Stensland Creek	Stensland Upper	58.3	8	368	2	-	50th < site < 90th	Highest Restoration
Tibbetts Creek - Lower	08LAK3699	46.4	13	2548	3	yes	< 50th	NA
Anderson Creek (Kitsap)	KCSSWM-019	50.3	6	1184	2	yes	< 50th	Highest Protection
Artondale Creek	GH_ARTO_0.30	49.4	9	1968	3	-	< 50th	Highest Protection
Canyon Creek (Puyallup)	BiBi-026 - Canyon Creek	42.2	5	695	1	-	50th < site < 90th	Development/Restoration
Carpenter Creek (Kitsap)	KCSSWM-022 - Upper	49.2	10	565	1	-	< 50th	Conservation
Coal Creek (Lake Wash.)	CoalBelRM4.0	43.1	8	2053	3	-	< 50th	Conservation
Cold Creek	08BEA3321	59.8	13	1099	1	-	50th < site < 90th	Conservation
Dutchers Creek	KP_DUTC_0.61	42.4	5	1307	2	-	< 50th	NA
Ebright Creek	08LAK3627	46.1	14	863	1	yes	~50th	Highest Restoration
Evans Creek tributary (0108)	08EVA3640	51.1	14	359	1	-	50th < site < 90th	Protection/Conservation
High School Creek	HSRed210	45.9	5	337	2	-	50th < site < 90th	Development/Restoration
Indian Creek (Lower Deschutes)	IndianThCoWheeler	49.0	9	1063	1	-	> 90th	Highest Restoration
Jump Off Creek	KCSSWM-030	49.3	5	831	2	-	~50th	Highest Restoration
Laughing Jacobs Creek	08LAK3879	55.8	14	2870	2	yes	> 90th	Highest Restoration
Little Bear Creek	08LIT2603	55.3	14	787	2	-	> 90th	Restoration/Development
Little Boston	KCSSWM-031	49.4	8	602	3	-	< 50th	NA

Stream	Site Code (listed in PSSB)	Median B-IBI Score	Years of Data (#)	Basin Size (acres)	Stream Order	Gage Present	B-IBI Score relative to Biological Potential	Puget Sound Watershed Characterization Result
Mackey Creek	MacRed212	56.5	5	377	1	-	50th < site < 90th	Conservation
Mill Creek (Auburn)	09MIL0390	54.1	14	2802	2	yes	> 90th	Restoration/Development
Mill Creek (Auburn)	09MIL0340	44.5	12	454	2	-	50th < site < 90th	Restoration/Development
Molasses Creek	08CED2518	46.7	14	1171	1	-	50th < site < 90th	Restoration/Development
Mosher Creek	KCSSWM-012	53.3	6	1052	3	-	> 90th	Highest Restoration
Nelyaly Creek	GH_NELY_0.02	48.1	5	491	2	-	< 50th	Protection/Conservation
North Creek tributary	WAM06600-053755	46.2	5	2330	2	-	> 90th	Restoration/Development
Ray Nash Creek	GH_RAYN_0.04	50.6	7	1298	3	-	< 50th	Highest Protection
Springbrook Creek (Bainbridge)	SpringBain	52.7	7	945	2	yes	< 50th	Highest Protection
Stensland Creek	Stensland Middle	59.6	8	400	2	-	50th < site < 90th	Highest Restoration
Stensland Creek	Stensland Lower	52.3	5	447	2	-	50th < site < 90th	NA

Table A-3 Location information for the 87 "excellent" or potential protection sites considered in the final stages of the site selection process. The top ten sites on the list were selected for this study.

Stream	Agency	Site Code	WRIA	Latitude	Longitude
Boise Creek	King County - DNRP	BSE_21_GolfCrs	10	47.195154	-121.953301
Chuckanut Creek	WA Department of Ecology	BIO06600-CHUC02	1	48.70185	-122.48827
Cristy Creek	King County - DNRP	09MID1744	9	47.272614	-122.021072
Lost Creek (Dyes Inlet)	Kitsap County	KCSSWM-057	15	47.587552	-122.734523
Margaret Creek	King County - DNRP	07CHR070059	7	47.75381	-121.8941
Newaukum Creek	King County - DNRP	09NEW2102	9	47.231078	-121.94603
Rock Creek (Lower Cedar)	King County - DNRP	08CED4192	8	47.374751	-122.017672
Big Soos Creek	King County - DNRP	09SOO1134	9	47.336409	-122.135101
Weiss Creek	King County - DNRP	53E	7	47.692487	-121.94356
Wildcat Creek (Dyes Inlet)	Kitsap County	KCSSWM-056	15	47.589032	-122.736157
Adair Creek	King County - DNRP	ADR_UPD	7	47.714301	-122.015439
Austin Creek	WA Department of Ecology	BIO06600-AUST02	1	48.7065	-122.34257
Beaver Creek (Snoqualmie)	King County - DNRP	Bvr_KC_Biosolids	7	47.623065	-121.777309
Big Beef Creek	WA Department of Ecology	BIO06600-BEEF02	15	47.628586	-122.792834
Black Nugget Creek	King County - DNRP	issaq08	8	47.550459	-122.009355
Boxley Creek tributary	King County - Roads	E1045	7	47.445891	-121.728739
Boyce Creek	Kitsap County	KCSSWM-009	15	47.608833	-122.9098
Brockway Creek	King County - Roads	E2153	7	47.529513	-121.802481
Canyon Creek (Snoqualmie River)	King County - Roads	E949	7	47.572258	-121.973315
Carey Creek	King County - DNRP	08ISS4724	8	47.426952	-121.97338
Cherry Creek	King County - DNRP	07CHR045515	7	47.74605	-121.89852
Cherry Creek	King County - DNRP	05B	7	47.740049	-121.941377
Cherry Creek - N Fork	King County - Roads	E1078	7	47.750501	-121.911981
Cherry Creek - N Fork tributary	King County - Roads	E1239	7	47.763669	-121.927195
Cherry Creek tributary	King County - Roads	E1076	7	47.740329	-121.906761
Chico Creek	Kitsap County	KCSSWM-002 - Mountaineers	15	47.586363	-122.729751

Stream	Agency	Site Code	WRIA	Latitude	Longitude
Coal Creek (Snoqualmie River)	King County - Roads	E1191	7	47.526182	-121.837064
Cottage Lake Creek	King County - DNRP	WAM06600-076119	8	47.725774	-122.079922
Covington Creek	King County - DNRP	09COV1165	9	47.31919	-122.11905
Covington Creek	King County - DNRP	09COV1756	9	47.32877	-122.022072
Crandall Creek	WA Department of Ecology	WAM06600-000987	7	47.803542	-121.821326
Crescent Creek	Pierce County	GH_CRES_0.81	15	47.357793	-122.578397
Creswell Creek	Snohomish County	cresup	7	47.994799	-121.980586
Cuttrhoat Creek (0083)	King County - DNRP	08LIT2876	8	47.799615	-122.143116
Deep Creek (Green River)	King County - DNRP	09DEE2163	9	47.282302	-121.932687
Deep Creek (Green River)	King County - Roads	E365/366	9	47.285648	-121.923668
Dickerson Creek	Kitsap County	KCSSWM-008 - (Chico Trib)	15	47.5831	-122.7168
Dickerson Creek	Kitsap County	KCWQ-3	15	47.581217	-122.721167
Dickerson Creek	Kitsap County	KCSSWM-046	15	47.586477	-122.714796
Ellis Creek (Deschutes)	Thurston County	EllisThCoPriestPt	13	47.076595	-122.891136
Evans Creek tributary (0108A)	King County - DNRP	08EVA3813	8	47.673727	-122.063887
Fennel Creek	Pierce County	BiBi-011 - Fennel Creek	10	47.15135	-122.216511
Fifteenmile Creek	King County - DNRP	08ISS4294	8	47.484906	-122.028632
Fifteenmile Creek	King County - Roads	E1139	8	47.483739	-122.029482
Fiske Creek	Pierce County	BiBi-048 - Fiske Creek	10	47.037271	-122.196026
French Creek (Snohomish)	Snohomish County	7-221	7	47.915396	-121.990731
Horn Creek	Pierce County	BiBi-017 - Horn Creek	11	46.904797	-122.477777
Hotel Creek (0342)	King County - DNRP	08CED4975	8	47.40985	-121.923313
Jenkins Creek	King County - DNRP	soos05	9	47.346408	-122.120757
Lemolo/Klebeal Creek	Kitsap County	KCSSWM-052	15	47.7287	-122.6109
Little Bear Creek	King County - DNRP	08LIT2692	8	47.811464	-122.158997
Little Minter Creek	Pierce County	KP_LMIN_0.34	15	47.381585	-122.695308
Mackey Creek	City of Redmond	MackRed107	8	47.696021	-122.081867
May Creek (Skykomish River)	Snohomish County	MAY	7	47.850936	-121.669858
McDonald Creek (Issaquah)	King County - Roads	E1138	8	47.479231	-122.035462

Stream	Agency	Site Code	WRIA	Latitude	Longitude
McLane Creek	Thurston County	McLaneThCoDNR	13	46.997729	-123.009667
Mud Creek	WA Department of Ecology	WAM06600-001415	7	47.564284	-121.853897
N Fork Stillaguamish Trib	Snohomish County	stnftr99	5	48.253099	-122.096189
Newaukum Creek	King County - DNRP	09NEW2151	9	47.224415	-121.931257
Newaukum Creek	King County - DNRP	09NEW1657	9	47.250042	-122.037744
Newaukum Creek - N Fork	King County - DNRP	09NEW2128	9	47.234245	-121.93519
Newaukum Creek - N Fork	King County - Roads	E445	9	47.235914	-121.952347
Parish Creek	Kitsap County	KCSSWM-018 - (Gorst Trib)	15	47.5284	-122.7142
Perry Creek (Deschutes)	Thurston County	PerryThCoHealth	14	47.04939	-123.00531
Rock Creek (Lower Cedar)	King County - Roads	E633-CIP-2	8	47.379986	-122.017264
Rock Creek (Upper Cedar)	King County - DNRP	WAM06600-027251	8	47.39922	-121.91942
Rock Creek (Upper Cedar)	King County - DNRP	08CED5032	8	47.415086	-121.887131
Rutherford Creek	King County - DNRP	08EVA4077	8	47.651647	-122.04153
Schneider Creek	Thurston County	SchneiderT-ThCoHealth	14	47.09206	-123.07072
Seidel Creek	King County - DNRP	08BEA3737	8	47.718328	-122.073941
Stillaguamish River - N Fork	Snohomish County	5-037	5	48.230383	-122.090312
Stillaguamish River - N Fork tributary	Snohomish County	stnftr115	5	48.230478	-122.077969
Struve Creek	King County - DNRP	08BEA3826	8	47.7336	-122.05881
Swartz Lake Creek	Snohomish County	swlkrm	7	48.071716	-121.963319
Tate Creek	King County - DNRP	Tat_KC_Biosolids	7	47.545198	-121.746851
Taylor Creek/Jem Creek (Lower Cedar)	King County - Roads	E660	8	47.408665	-122.026802
Taylor Creek/Jem Creek (Lower Cedar)	King County - DNRP	cedar06	8	47.413358	-122.019732
Taylor Creek/Jem Creek tributary	King County - DNRP	cedar07	8	47.421117	-122.030588
Tokul Creek	King County - DNRP	Tok_KC_Biosolids	7	47.66349	-121.759554
Tuck Creek	King County - Roads	P752	7	47.753839	-122.018795
Tumwater Creek	WA Department of Ecology	WAM06600-001556	18	48.090744	-123.472647
Union River	Kitsap County	KCSSWM-043	15	47.5119	-122.7917

Stream	Agency	Site Code	WRIA	Latitude	Longitude
Walsh Lake Diversion	King County - DNRP	08CED4479	8	47.384812	-121.989235
Williams Creek	King County - DNRP	WAM06600-015443	8	47.40053	-121.85634
Woodard Creek	Thurston County	WoodardThCoHealth	13	47.09142	-122.86323
Woods Creek (Monroe) - W Fork	Snohomish County	WOODS298	7	47.902231	-121.907884
Woods Creek (Monroe) - W Fork	Snohomish County	woodsfr	7	47.899632	-121.908951

Table A-4 B-IBI median scores and additional site and basin information for 87 "excellent" or potential protection sites considered for this study. The top ten sites on the list were selected for this study.

Stream	Site Code	Median B-IBI Score	Years of Data (#)	Basin Area (acres)	Stream Order	Gage Present	B-IBI Score relative to Biological Potential	Puget Sound Watershed Characterization Result
Boise Creek	BSE_21_GolfCrs	81.9	2	6677	4	-	~90th	Protection
Chuckanut Creek	BIO06600-CHUC02	86.9	4	4449	3	-	> 90th	Conservation
Cristy Creek	09MID1744	79.1	14	381	1	-	> 90th	Restoration/Development
Lost Creek (Dyes Inlet)	KCSSWM-057	83.0	2	1898	3	yes	~90th	Conservation
Margaret Creek	07CHR070059	76.4	2	1850	3	-	50th < site < 90th	Highest Protection
Newaukum Creek	09NEW2102	82.2	14	1050	3	-	~90th	Protection
Rock Creek (Lower Cedar)	08CED4192	89.5	18	4914	3	yes	> 90th	Restoration/Development
Big Soos Creek	09SOO1134	77.0	14	25462	4	-	> 90th	Restoration
Weiss Creek	53E	83.0	5	1964	3	-	~90th	Development/Restoration
Wildcat Creek (Dyes Inlet)	KCSSWM-056	87.2	2	4082	3	yes	> 90th	Development/Restoration
Adair Creek	ADR_UPD	85.9	8	517	2	-	> 90th	Development/Restoration
Austin Creek	BIO06600-AUST02	85.8	4	357	2	-	~90th	Protection/Conservation
Beaver Creek (Snoqualmie)	Bvr_KC_Biosolids	89.0	8	4061	4	-	> 90th	Highest Protection
Big Beef Creek	BIO06600-BEEF02	79.7	3	7623	1	-	~90th	Highest Restoration
Black Nugget Creek	issaq08	78.8	4	272	1	-	> 90th	Development/Restoration
Boxley Creek tributary	E1045	63.1	11	398	2	-	< 50th	Highest Protection
Boyce Creek	KCSSWM-009	70.9	9	1007	3	-	50th < site < 90th	Highest Protection
Brockway Creek	E2153	66.4	11	1150	2	-	< 50th	Protection/Conservation
Canyon Creek (Snoqualmie River)	E949	75.2	11	458	3	-	50th < site < 90th	Protection/Conservation
Carey Creek	08ISS4724	73.3	12	2894	3	-	50th < site < 90th	Protection/Conservation
Cherry Creek	05B	74.6	5	835	2	-	50th < site < 90th	Conservation
Cherry Creek	07CHR045515	86.8	2	10113	4	-	~90th	Protection
Cherry Creek - N Fork	E1078	73.2	10	1125	3	-	50th < site < 90th	Protection/Conservation

Stream	Site Code	Median B-IBI Score	Years of Data (#)	Basin Area (acres)	Stream Order	Gage Present	B-IBI Score relative to Biological Potential	Puget Sound Watershed Characterization Result
Cherry Creek - N Fork tributary	E1239	95.8	7	869	3	-	> 90th	Highest Protection
Cherry Creek tributary	E1076	78.5	12	584	2	-	~90th	Restoration/Development
Chico Creek	KCSSWM-002 - Mountaineers	67.9	11	6051	4	yes	~50th	NA
Coal Creek (Snoqualmie River)	E1191	71.8	7	1950	3	-	~90th	Restoration/Development
Cottage Lake Creek	WAM06600-076119	79.6	7	7083	4	-	> 90th	Restoration/Development
Covington Creek	09COV1756	73.6	16	2445	4	yes	50th < site < 90th	Restoration
Covington Creek	09COV1165	72.1	18	12945	4	-	~90th	Restoration
Crandall Creek	WAM06600-000987	91.1	2	991	3	-	> 90th	Highest Protection
Crescent Creek	GH_CRES_0.81	76.0	8	3061	3	-	~90th	Development/Restoration
Creswell Creek	cresup	73.2	2	336	2	-	50th < site < 90th	Conservation
Cuttrhoat Creek (0083)	08LIT2876	70.1	2	777	2	-	> 90th	Development/Restoration
Deep Creek (Green River)	09DEE2163	70.5	14	2157	4	-	50th < site < 90th	Highest Protection
Deep Creek (Green River)	E365/366	73.0	7	2091	4	-	50th < site < 90th	Highest Protection
Dickerson Creek	KCWQ-3	81.2	8	1452	2	yes	50th < site < 90th	Highest Protection
Dickerson Creek	KCSSWM-046	79.1	4	1511	2	yes	50th < site < 90th	Highest Protection
Dickerson Creek	KCSSWM-008 - (Chico Trib)	88.2	4	1492	2	yes	> 90th	Highest Protection
Ellis Creek (Deschutes)	EllisThCoPriestPt	76.3	10	661	2	-	> 90th	Highest Restoration
Evans Creek tributary (0108A)	08EVA3813	62.1	14	154	1	-	~90th	Restoration/Development
Fennel Creek	BiBi-011 - Fennel Creek	75.8	8	8971	3	-	> 90th	Restoration/Development
Fifteenmile Creek	08ISS4294	69.2	18	2645	4	-	50th < site < 90th	Protection
Fifteenmile Creek	E1139	76.3	12	2636	4	-	50th < site < 90th	Protection
Fiske Creek	BiBi-048 - Fiske Creek	82.3	2	1769	3	-	50th < site < 90th	Protection/Conservation

Stream	Site Code	Median B-IBI Score	Years of Data (#)	Basin Area (acres)	Stream Order	Gage Present	B-IBI Score relative to Biological Potential	Puget Sound Watershed Characterization Result
French Creek (Snohomish)	7-221	86.5	2	264	2	-	~90th	Restoration/Development
Horn Creek	BiBi-017 - Horn Creek	63.4	7	5474	3	-	~50th	Restoration/Development
Hotel Creek (0342)	08CED4975	85.0	12	1822	2	-	~90th	Highest Protection
Jenkins Creek	soos05	72.1	4	11389	4	-	> 90th	Restoration
Lemolo/Klebeal Creek	KCSSWM-052	83.4	3	504	1	-	> 90th	Devleopment/Restoration
Little Bear Creek	08LIT2692	70.5	13	3774	2	yes	> 90th	Development/Restoration
Little Minter Creek	KP_LMIN_0.34	82.1	2	1451	2	-	> 90th	Highest Restoration
Mackey Creek	MackRed107	75.5	12	1072	2	-	> 90th	Development/Restoration
May Creek (Skykomish River)	MAY	71.3	2	5507	4	-	50th < site < 90th	Highest Protection
McDonald Creek (Issaquah)	E1138	79.6	7	3050	4	-	> 90th	Restoration
McLane Creek	McLaneThCoDNR	77.8	10	1168	4	-	50th < site < 90th	Conservation
Mud Creek	WAM06600-001415	65.0	2	126	1	-	< 50th	Protection/Conservation
N Fork Stillaguamish Trib	stnftr99	80.6	2	982	3	-	50th < site < 90th	Highest Protection
Newaukum Creek	09NEW1657	62.8	14	16428	3	-	50th < site < 90th	Protection
Newaukum Creek	09NEW2151	85.3	13	765	3	-	~90th	Protection
Newaukum Creek - N Fork	09NEW2128	72.8	14	1410	3	yes	50th < site < 90th	Highest Restoration
Newaukum Creek - N Fork	E445	77.7	15	1551	3	-	50th < site < 90th	Highest Restoration
Parish Creek	KCSSWM-018 - (Gorst Trib)	61.5	6	1129	2	yes	50th < site < 90th	Development/Restoration
Perry Creek (Deschutes)	PerryThCoHealth	82.8	16	4346	4	-	~90th	Restoration/Development
Rock Creek (Lower Cedar)	E633-CIP-2	79.3	8	5085	3	-	~90th	Restoration/Development
Rock Creek (Upper Cedar)	08CED5032	81.8	12	1353	3	-	50th < site < 90th	Highest Protection
Rock Creek (Upper Cedar)	WAM06600-027251	85.2	4	3615	3	-	~90th	Protection

Stream	Site Code	Median B-IBI Score	Years of Data (#)	Basin Area (acres)	Stream Order	Gage Present	B-IBI Score relative to Biological Potential	Puget Sound Watershed Characterization Result
Rutherford Creek	08EVA4077	66.3	8	1876	1	-	> 90th	Restoration/Development
Schneider Creek	SchneiderT-ThCoHealth	71.5	15	4134	3	-	50th < site < 90th	Highest Restoration
Seidel Creek	08BEA3737	69.1	14	883	3	-	50th < site < 90th	Development/Restoration
Stillaguamish River - N Fork	5-037	77.9	2	395	1	-	50th < site < 90th	Highest Protection
Stillaguamish River - N Fork tributary	stnftr115	85.8	3	509	2	-	~90th	Highest Restoration
Struve Creek	08BEA3826	73.2	14	458	2	yes	> 90th	Development/Restoration
Swartz Lake Creek	swlkrm	71.3	2	140	3	-	50th < site < 90th	Restoration
Tate Creek	Tat_KC_Biosolids	86.6	8	1773	3	-	~90th	Highest Protection
Taylor Creek/Jem Creek (Lower Cedar)	E660	75.0	13	2142	2	-	> 90th	Restoration/Development
Taylor Creek/Jem Creek (Lower Cedar)	cedar06	74.6	2	1919	2	-	> 90th	Restoration/Development
Taylor Creek/Jem Creek tributary	cedar07	86.2	4	473	2	-	> 90th	Development/Restoration
Tokul Creek	Tok_KC_Biosolids	90.8	7	1520	4	-	> 90th	Highest Restoration
Tuck Creek	P752	79.4	6	1451	2	-	> 90th	Development/Restoration
Tumwater Creek	WAM06600-001556	90.8	4	2298	4	-	> 90th	Conservation
Union River	KCSSWM-043	75.6	4	4518	4	-	50th < site < 90th	Protection
Walsh Lake Diversion	08CED4479	72.6	10	7719	4	-	50th < site < 90th	Protection
Williams Creek	WAM06600-015443	86.3	4	1431	3	-	~90th	Protection
Woodard Creek	WoodardThCoHealth	68.2	15	3312	3	-	> 90th	Highest Restoration
Woods Creek (Monroe) - W Fork	woodsfr	79.4	2	14887	4	-	50th < site < 90th	Conservation
Woods Creek (Monroe) - W Fork	WOODS298	86.8	2	13916	4	-	> 90th	Conservation

Appendix B: Habitat Protocols

The protocols used in the 2017 and 2018 field habitat surveys are listed in Table B-1. Field measurements and observations were entered on an electronic form (Ecology 2017g) and data were uploaded to Ecology's EIM Watershed Health database.

Table B-1 Measures and methods used to characterize stream habitat conditions during field surveys.

Measures	Method	Number of samples/measurements per site
Macroinvertebrates	Targeted riffle: King County 2019a	8, 1ft^2 samples collected from up to 4 riffles, composited
Macroinvertebrates	Transect-based: Ecology 2016	8, 1 ft^2 samples, collected from 8 random transects, composited
Continuous temperature	City of Redmond 2015	Continuous, 1-hr interval
Continuous water level	City of Redmond 2015	at "fair" sites, for one year, using new or established gages
Current velocity and discharge	City of Redmond 2015	8-10 times per site, if site has new gage
Site verification and layout	EAP106 (Ecology 2017m)	1
Reach Slope	EAP122 (Ecology 2017e)	1
Bearing	EAP123 (Ecology 2017c)	20
Thalweg Profile	EAP119 (Ecology 2017l)	10
Habitat Unit	EAP120 (Ecology 2017k)	1+
Channel Dimensions	EAP113 (Ecology 2017h)	11
Fish Cover	EAP116 (Ecology 2017i)	11
Bank Erosion	EAP112 (Ecology 2017a)	11
Substrate and Embeddedness	EAP114 (Ecology 2017j)	11
Human Influence	EAP118 (Ecology 2017f)	11
Riparian Vegetation Structure	EAP117 (Ecology 2017b)	11
Riparian Cover	EAP115 (Ecology 2017d)	11
Large Woody Debris	EAP121 (Ecology 2017n)	11
Location coordinates	EAP107 (Ecology 2017o)	3 per site

Appendix C: Geospatial Data Sources

The geospatial data considered in this study are listed in Table C-1.

Table C-1. Geospatial data layers that were reviewed in the course of the study.

https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-app-c.xlsx

Appendix D: Environmental Conditions Considered in the Stressor Identification Analyses

This appendix contains tables that list the environmental conditions, and the individual parameters for each condition, that were used to characterize each selected B-IBI site and its basin. As described in Section 3.0, we generated the list of parameters by first running Pearson correlation analyses between environmental parameters and B-IBI scores from the 2015 SAM study (DeGasperi et al. 2018). Each of the parameters listed in Table D-1 was at least weakly correlated with B-IBI scores (r^2>0.09). Additional parameters were evaluated but are not included here because the correlation of each with B-IBI had an r^2 <0.09.

Data tables for the select basins are here:
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-app-d.xlsx

Notes for interpreting datasheet for individual basins in Excel sheets:

- Large substrate, Site-Specific Habitat Impacts, Fine Sediment, Bed Stability, and Embeddedness values are averages of 2018 and 2019 measurements.
- If B-IBI score has a positive relationship with the factor, a negative difference between expected and observed values indicates a failure to meet expected value for "excellent" sites.
- If B-IBI score has a negative relationship with the factor, a positive difference between expected and observed values indicates a failure to meet expected value for "excellent" sites.
- Red cells indicated a failure to meet expected value for "excellent" sites for the corresponding threshold.
- Pink cells indicate a failure to meet expected value for "excellent" sites in one of two survey years for the corresponding threshold.

Table D-1 Conditions and parameters that are correlated with B-IBI scores and the TITAN change points and quantile thresholds that describe conditions in typical "excellent" B-IBI sites.

Condition	Parameter	Correlation with B-IBI	Pearson r^2 with B-IBI	Measurement Unit	Excellent Site Values are > or < Change Point and Threshold?	TITAN Change Point	Quantile Threshold
Basinwide forest health	% Canopy Cover	0.72	0.52	%	>	53.29	64.57
	% Forest Cover	0.70	0.50	%	>	67.56	72.39
	Old Growth Structure Index	0.68	0.46	mean	>	18.42	18.50
	Mean Basal Area	0.68	0.46	mean m^2/hectare	>	25.56	29.52
	Mean Forest Age	0.56	0.32	mean years	>	62.92	44.35
Embeddedness of stream substrate	Embeddedness, Center Channel	-0.38	0.15	%	<	38.48	39.09
	Embeddedness	-0.43	0.18	%	<	42.75	53.31
Fine Sediment	% Fine Gravel and Below	-0.45	0.20	%	<	36.58	44.59
	Pct SandFine Sediment	-0.43	0.19	%	<	23.38	27.71
	% Fine Sediment	-0.39	0.16	%	<	9.52	9.52
Flashiness	RBI	-0.55	0.30		<	NA	0.22
	High Pulse Count	-0.35	0.12	count	<	NA	12.00
	T-Q Mean	0.50	0.25		>	NA	0.33
	High Pulse Duration	0.35	0.12		>	NA	3.48
Large substrate in stream channel	% Coarse Gravel and Above	0.48	0.23	%	>	61.47	50.22
	Log10 estimated geometric mean substrate diameter	0.46	0.21		>	0.86	0.86
	% Cobble	0.31	0.10	%	>	15.80	6.49
	% Coarse Gravel	0.43	0.18	%	>	NA	26.84
	% Small Boulder	0.32	0.10	%	>	1.95	0.00
	% Boulder	0.30	0.09	%	>	1.95	0.00

Condition	Parameter	Correlation with B-IBI	Pearson r^2 with B-IBI	Measurement Unit	Excellent Site Values are > or < Change Point and Threshold?	TITAN Change Point	Quantile Threshold
Local habitat	% Disturbance	-0.39	0.15	%	<	9.09	27.27
	Weighted Proximity of Human Influence	-0.38	0.15		<	0.08	0.48
	Proportion Mixed Canopy	0.38	0.14	%	>	0.41	0.45
	Proportion Mixed Understory	0.32	0.11	%	>	NA	0.36
	Proportion Understory	0.31	0.10	%	>	NA	1.00
Low slope	Slope	0.46	0.21	%	>	29.01	15.95
	Slope, Riparian	0.32	0.10	%	>	NA	14.75
Organic material in soil	Organic Material	0.45	0.20	%	>	9.30	7.56
Riparian forest health	% Forest Cover, Riparian	0.52	0.28	%	>	85.27	74.66
	% Canopy Cover, Riparian	0.54	0.30	%	>	51.32	61.16
	Mean Forest Age, Riparian	0.48	0.23	mean years	>	66.73	50.65
	Old Growth Structure Index, Riparian	0.48	0.24	mean	>	18.85	19.66
	Mean Basal Area, Riparian	0.44	0.20	mean m^2/hectare	>	38.67	30.63
Riparian urban development	% Urban Cover, Riparian	-0.71	0.50	%	<	2.46	3.15
	% Impervious Surface, Riparian	-0.64	0.41	%	<	2.24	2.99
	Developed Open Space, Riparian	-0.35	0.13	%	<	0.68	0.15
Roads in basin	Road Density	-0.68	0.47	miles/acre	<	NA	0.01
	Road Crossings/ Stream Length (miles)	-0.51	0.26	#/mile	<	NA	2.37
Soil composition in basin	% Sand	-0.34	0.12	%	<	62.96	63.19
	% Silt	0.33	0.11	%	>	32.31	27.49
Stream Bed Stability	Log-transformed Relative Bed Stability	0.54	0.29		>	-1.22	-1.85

Condition	Parameter	Correlation with B-IBI	Pearson r^2 with B-IBI	Measurement Unit	Excellent Site Values are > or < Change Point and Threshold?	TITAN Change Point	Quantile Threshold
Stream density throughout basin	Stream Density	0.41	0.17	miles/acre	>	NA	0.01
Stream temperature	Frequency of Summer Temperature Exceeding 10°C	-0.34	0.12	count	<	NA	92.00
	Frequency of Spring Temperature Exceeding 10°C	-0.42	0.18	count	<	NA	50.00
	Average Daily Spring Temperature	-0.39	0.15	°C	<	NA	10.34
Basinwide urban development	% Impervious Surface	-0.77	0.59	%	<	NA	6.27
	% Urban Cover	-0.76	0.58	%	<	2.60	4.03

Appendix E: Links to Maps of Basins

Boise Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Boise.pdf

Chuckanut Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Chuckanut.pdf

Cristy Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Cristy.pdf

Illahee Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Illahee.pdf

Lost Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Lost.pdf

Manzanita Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Manzanita.pdf

Margaret Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Margaret.pdf

Newaukum Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Newaukum.pdf

Rock Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Rock.pdf

Soos Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Soos.pdf

Stensland Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Stensland.pdf

Tibbetts Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Tibbetts.pdf

Weiss Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Weiss.pdf

Wildcat Creek
https://your.kingcounty.gov/dnrp/library/2019/kcr3098/kcr3098-Wildcat.pdf