Coal Creek Watershed Assessment Report

prepared in support of the City of Bellevue Watershed Management Plan

Final

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Bellevue Utilities Department

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Preface

Urban development in the lowland regions of the Puget Sound over the past 150 years has resulted in the conversion of large tracts of forested area to residential, industrial, and commercial land uses. Changing environmental conditions that resulted from this land conversion have dramatically impacted the health of the region's streams, lakes, and marine water bodies. Common symptoms of water resource degradation from urbanization include poor water quality, loss of riparian and aquatic habitat, and stream channel erosion. In combination, these impacts have resulted in widespread disruption in the ecological function of water bodies causing sensitive aquatic life to decline in abundance or disappear completely. To address this problem, state and local jurisdictions are making a concerted effort to rehabilitate these water bodies through coordinated planning efforts that direct new storm and surface water management practices to existing urban development that was built with stormwater detention and water quality controls that do not meet current requirements and standards.

Commensurate with these regional efforts, the City of Bellevue (City) is committed to improving and protecting the aquatic health of water bodies within its boundaries. To that end, the City is developing a Watershed Management Plan (WMP) that will focus on improving the health and condition of the City's streams using a toolbox of holistic storm and surface water management practices. The WMP will direct investments to high-priority watersheds providing measurable environmental benefits to stream health within a shorter time frame than past or current approaches. The WMP will also help prevent further degradation in non-priority watersheds. The WMP will include an implementation plan with recommended projects, policies, programs, and operational plans to meet performance goals for Bellevue's streams, and to provide multiple benefits that help advance City objectives across departments and programs.

The City is preparing a series of watershed assessment reports and watershed improvement plans that will provide the basis for the recommended actions in the WMP. A Watershed Assessment will be prepared for each of the City's major watersheds: Coal Creek, Greater Kelsey Creek, the Lake Sammamish tributaries within Bellevue (including Lewis Creek), and the small Lake Washington tributaries within Bellevue.

This report is an assessment of the current conditions in the Coal Creek Watershed. This information, along with other subsequent reports, will be used to develop the final WMP.

City of Bellevue Watershed Management Plan

Coal Creek Watershed Assessment Report

EXECUTIVE SUMMARY

Purpose of This Assessment

The purpose of this report is to assess the conditions in the Coal Creek Watershed that are limiting the health of its streams. The evaluation of potential limiting factors from the Conceptual Model that describes the primary effects of urban runoff on streams (brown boxes in Figure 1, next page) and their consequences for stream health.

The City is preparing a series of watershed assessment reports (ARs) that will provide the basis for the recommended actions to improve stream health culminating into a city-wide Watershed Management Plan (WMP). One Watershed Assessment report will be prepared for each of the City of Bellevue's (City) major watersheds: Coal Creek, Greater Kelsey Creek, the Lake Sammamish tributaries within Bellevue (including Lewis Creek), and the small Lake Washington tributaries within Bellevue.

In addition to the watershed assessment, each report will include limiting factors, data gaps (if any), and identified opportunities for improving in-stream conditions. The Watershed Assessments are based on data from three primary sources: 1) A recent Open Streams Condition Assessment performed by the City (2018-2020); 2) Existing data collected by the City from past projects and ongoing monitoring efforts; and 3) Existing project and environmental monitoring data collected by a variety of public resource agencies.

Description and History of the Coal Creek Watershed

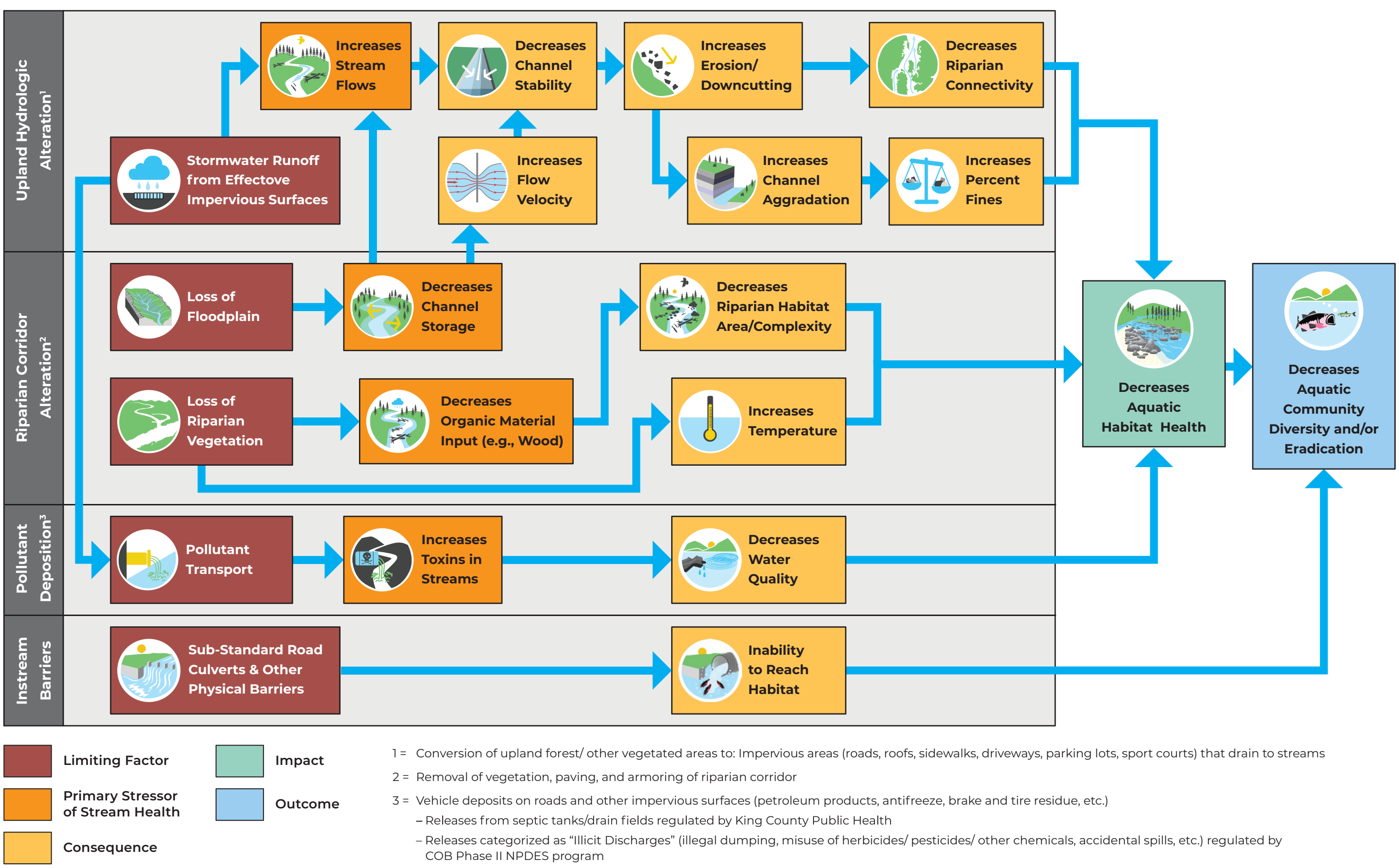
The headwaters of Coal Creek originate in the steep terrain of Cougar Mountain at an elevation of about 1,400 feet. The creek flows for about seven miles through a series of steep, narrow ravines before entering Lake Washington. The Coal Creek Watershed encompasses a total area of approximately 4,550 acres, with 63 percent of this area located within the City of Bellevue and the remainder is within King County and the City of Newcastle.

The geology of the Coal Creek Watershed is primarily sedimentary deposits that overlay bedrock, yet there are many locations within the middle and upper portions of the watershed with exposed bedrock which is fairly unique for Bellevue streams. The coal beds and seams for which the watershed is named, formed within organic material that was deposited between 56 to 33.9 million years ago . These coal beds and seams can extend 1,500 feet below the ground surface.

Naturally erosive and unstable soil conditions have been exacerbated by past logging and nearly a century of coal-mining activities that began in the late 1860s. The legacy of this coal mining includes channelized portions of streams and some destabilized hillslopes. Mine tailings were disposed along the streambanks and within the canyon at the historic Cinder Mine, located approximately a mile downstream of Lakemont Boulevard.

The riparian corridor of Coal Creek has been designated as a priority habitat by the Washington State Department of Fish and Wildlife. Several rare and sensitive species with special status have been documented within the Coal Creek Watershed. The aquatic habitat in the Coal Creek Watershed, with a largely intact riparian corridor, has significant potential to support salmonids. Several factors, however, such as uncontrolled stormwater runoff, high rates of sediment loading and sedimentation, and limited off-channel habitat, are severely limiting that potential.

Figure 1. Conceptual Model of the Major Unmanaged Effects of Urbanization on Stream Health

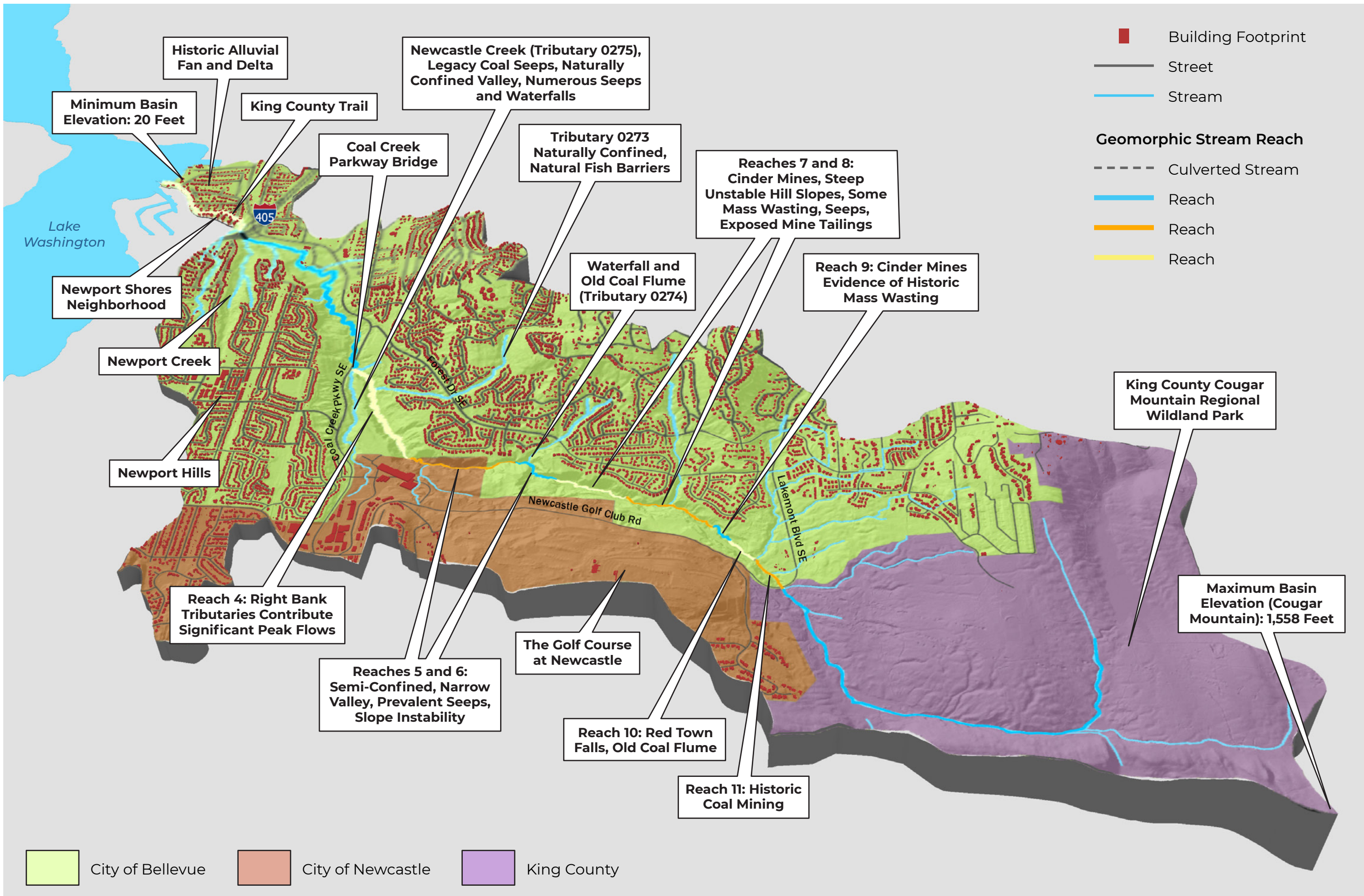


1 = Conversion of upland forest/ other vegetated areas to: Impervious areas (roads, roofs, sidewalks, driveways, parking lots, sport courts) that drain to streams

2 = Removal of vegetation, paving, and armoring of riparian corridor

3 = Vehicle deposits on roads and other impervious surfaces (petroleum products, antifreeze, brake and tire residue, etc.)
– Releases from septic tanks/drain fields regulated by King County Public Health
– Releases categorized as "Illicit Discharges" (illegal dumping, misuse of herbicides/ pesticides/ other chemicals, accidental spills, etc.) regulated by COB Phase II NPDES program

Figure 2. Features of the Coal Creek Watershed



Since 1988, well-trained and committed City of Bellevue Stream Team volunteers have monitored streams in the Coal Creek Watershed, visiting each site twice a week from September through December, and reporting when, where, and what type of salmon are sighted. From 1997 to 2015, volunteers with the King County Salmon Watcher Program recorded salmon observations at various locations along the mainstem of Coal Creek. They consistently observed Coho, Chinook, and Sockeye salmon. Beginning in the late 2000's, the City of Bellevue implemented weekly surveys throughout the salmon spawning season in the lower and middle reaches of the mainstem to document spawning activity and location of salmon redds (or nests) in Coal Creek.

The earlier survey results suggest that adult salmonids (primarily Coho Salmon and adfluvial Cutthroat Trout) were returning to spawn in relatively low numbers. Data from 2008 to the present suggest that, in conjunction with fish passage improvements, Chinook and Coho utilization of Coal Creek spawning habitat is increasing.

Past and Present Investments in the Coal Creek Watershed

The City and King County collaborated on a Coal Creek Basin Plan (published in 1987), which identified needs of the then largely unincorporated Coal Creek Watershed. In addition to the improvements implemented from the 1987 Plan, the City a has invested tens of millions of dollars in the Coal Creek Watershed over the past 15 years on projects that include repairing stormwater outfalls, stabilizing stream slopes, removing fish passage barriers, catching and removing large amounts of transported sediment (on a regular basis), and improving conveyance to reduce flooding.

Factors that Limit the Health of the Coal Creek Watershed

The following were identified as limiting factors for the Coal Creek Watershed per the Conceptual Model (Figure 1), in general order of importance:

1. Stormwater Runoff from Impervious Surfaces: Increased stormwater runoff flow rates and volumes during storm events from impervious surfaces in the watershed, in combination with historic channel alterations from logging and coal mining land uses, are contributing to negative effects on fish & wildlife habitat. As shown in Figure 1, these effects can include channel, bank, and slope instability. These effects are noticeable in the middle and upper reaches of Coal Creek. The majority of the development in the Coal Creek Watershed was built prior to the requirement for stream protection-based stormwater controls. Changes in rainfall patterns in the region may also be contributing to increased effects of stormwater runoff on stream health.

2. Loss of Floodplain: Urban development in the middle and lower reaches of the watershed has largely confined Coal Creek to its channel and limited any interaction with its historic floodplain. This artificial confinement has significantly reduced floodplain connectivity and thereby reduced access to flood, sediment, and nutrient storage within the floodplain.

3. Pollutant Transport: Even though three segments of Coal Creek are identified as "impaired" water bodies by the Department of Ecology, the computed Water Quality Index (WQI) scores from the available data generally indicate water quality is a "moderate concern." Stormwater runoff from impervious surfaces (limiting factor #1) causes erosion from higher flows, and transports pollutants (metals, nutrients, fecal coliform, and others) associated with urban development that are detrimental to the health of aquatic organisms. Approximately 97 percent of the developed area within the Bellevue portion of the watershed does not include treatment of stormwater runoff based upon an analysis of age of development and the associated stormwater requirements at the time of that development that are detrimental to the health of aquatic organisms.

4. Loss of Riparian Vegetation: The tree canopy in the Coal Creek Watershed is largely concentrated in the Cougar Mountain Regional Wildland Park (outside of Bellevue) and Coal Creek Park and Natural Area (within Bellevue) which spans the riparian corridor down to the point where it intersects Interstate Highway 405. The riparian canopy vegetation is primarily deciduous and more coniferous canopy is needed to promote riparian diversity and habitat. Given that the riparian corridor is relatively intact, loss of riparian vegetation is likely a less constraining limiting factor relative to those identified above.

5. Sub-Standard Road Culverts and Other Physical Barriers: Although a number of physical barriers to fish passage have been identified in Coal Creek, removal of these barriers would only provide substantial benefit once the quality of physical habitat in upstream reaches constrained by the aforementioned limiting factors can be improved. Efforts to improve fish passage should be focused on City of Bellevue and private infrastructure downstream of Reach 6 to prioritize access to migratory salmonid species.

[1] Waters whose beneficial uses (such as for drinking, recreation, aquatic habitat, and industrial use) are impaired by pollutants.

1. Introduction

This section discusses the watershed management planning, process, introduces the Coal Creek Watershed, and describes the document organization.

1.1 The Watershed Management Planning Process

For all documents prepared as part of the City's Watershed Management Plan, the word 'watershed' will be used to describe the boundaries of the large areas that drain to creeks and waterbodies. The word 'subbasin' will be used to describe the smaller drainages within the watersheds. For this planning effort, the City has defined the following four (4) watersheds: Greater Kelsey Creek, Coal Creek, Small Lake Washington Tributaries, and Lake Sammamish Tributaries. These four (4) watersheds are made up of a total of twenty-six (26) subbasins, as shown in Figure 3.

The City of Bellevue (City) is developing the Watershed Management Plan (WMP) using a stepwise process that builds on information obtained from each proceeding step to ensure the final plan is comprehensive, makes the best use of new and existing data and information, and reflects the community's values and goals. As shown in Figure 1, this stepwise process leading up to WMP development includes the following major components:

- **Foundational Element Memoranda** will be prepared at the onset of WMP development to define critical inputs to the process including the overarching framework for the plan (Foundational Element #1), the metrics that will be used to measure progress towards meeting stream health goals (Foundational Element #2), and the approach that will be used for prioritizing watersheds (Foundational Element #3).
- The **Open Streams Condition Assessment (OSCA)** was initiated by the City in 2018 to survey approximately 80 miles of open stream within the City limits. Completed in the fall of 2020, the data generated from this effort will be used in three aspects of the WMP: 1) provide a current understanding of the physical habitat of Bellevue streams through the development of stream habitat reports; 2) provide baseline data to assess if future improvements to stream health are successful; and 3) provide a comprehensive "boots-on-the ground" assessment of opportunities to improve the physical, chemical, and biological health of the streams.
- **Watershed Assessment Reports (ARs)** will be prepared to characterize existing conditions in the City's watersheds: Greater Kelsey Creek, Coal Creek, Small Lake Washington Tributaries, and Lake Sammamish Tributaries (including Lewis Creek). Each Watershed AR will identify limiting factors, data gaps (if any), and opportunities for improving watershed health. These ARs will be developed based on data from three primary sources: 1) the OSCA described above; 2) existing data collected by the City from past projects and ongoing monitoring efforts; and 3) existing project and environmental monitoring data collected by a variety of public resource agencies.
- **A Watershed Management Toolbox** will be prepared to identify and document the different tools (or strategies) that could be used to meet the WMP goals. These tools could include stormwater Best Management Practices (BMPs), policy/regulatory changes, operational strategies, engineered solutions, management strategies, etc. The toolbox will also indicate which stressors on stream health are addressed by each individual tool or management strategy.
- **Initial and Revised Watershed Prioritizations** will be performed to identify which subbasins within the City's watersheds would have the quickest positive response to rehabilitation efforts, with the goal of maximizing return on the City's investments in stream health. The initial prioritization (performed

before and during AR development) will also provide the technical basis for meeting regulatory requirements for watershed planning that stem from the City's Phase II Municipal Stormwater Permit (Phase II Permit). The revised prioritization (performed after the ARs are complete) will include input from Community Metrics (see below) and other stakeholders and will guide all subsequent phases of WMP development.

- **Community Metrics** will be identified based on community values and goals for quantifying ancillary benefits that may be realized from the WMP in addition to those directly related to improved stream health. These metrics will be formed during a robust public engagement process. For example, these metrics might quantify benefits from the plan related to increased access to open space, educational opportunities, enhanced aesthetics, and/or environmental and social justice issues.

- **Watershed Improvement Plans (WIPs)** will be prepared for each watershed that list and describe each of the solutions and/or opportunities recommended for watershed improvement with associated costs and a schedule for implementation. These plans will provide details on the tools and opportunities considered for watershed improvement, provide information on how the opportunities were evaluated, and the results of those evaluations. The WIPs will focus on investments to improve stream health rather than broader community goals, which will be addressed in the WMP itself.

All the work performed to develop these components of the WMP will be informed by a conceptual model (Figure 2) that was created by the City to describe the primary effects of urbanization on stream health. This model shows the linkages between specific sources of stress on stream health (e.g., stormwater runoff) and the consequences, impacts, and outcomes that collectively contribute to degraded stream health. This model will be particularly important for identifying the specific limiting factors that are responsible for impaired stream health during preparation of the ARs and the appropriate solutions for improving conditions during preparation of the WIPs.

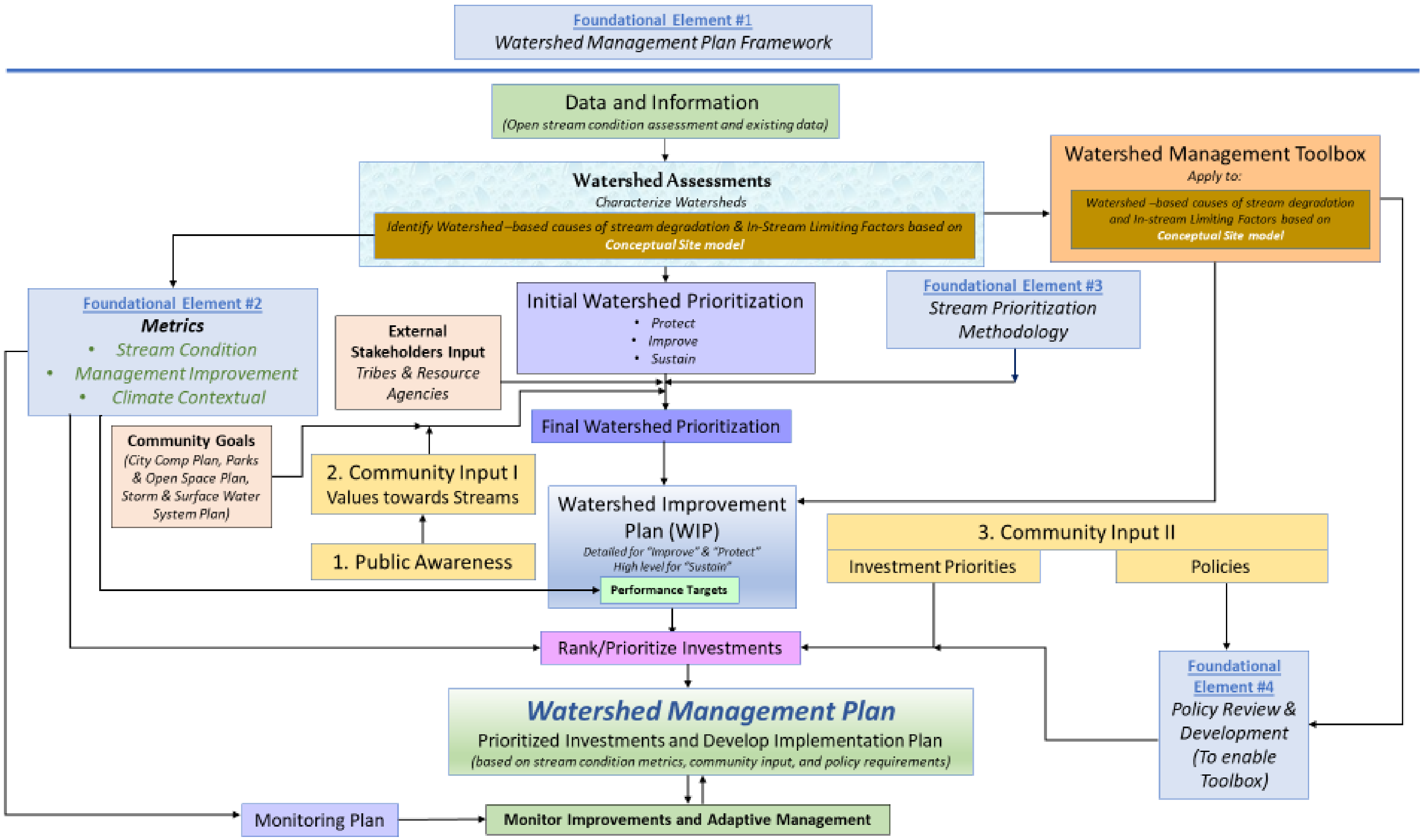


Figure 1. Watershed Management Plan Development Process.

1.2 The Coal Creek Watershed

The Coal Creek Watershed spans the City's southern jurisdictional borders with King County and the City of Newcastle and includes two major subbasins for Coal Creek and Newport Creek (Figure 3). The watershed encompasses a total area of approximately 4,550 acres with 63 percent of this area located within the City's jurisdictional boundary. The remaining 37 percent of the watershed is split between King County (24 percent) and the City of Newcastle (13 percent). The headwaters of Coal Creek originate in the steep terrain of Cougar Mountain at an elevation of about 1,500 feet (NAVD 88, OCM Partners 2020). Coal Creek flows for about 7 miles through a series of steep, narrow ravines before entering Lake Washington.

This Watershed AR was prepared to meet the following objectives:

- Characterize the current watershed and instream conditions and identify any trends compared to previously collected data.
- Identify limiting factors to stream health, data gaps (if any), and opportunities for improvement.
- When combined with the other three ARs, provide input into prioritizing subbasins for health improvement.

1.3 Organization

This Watershed AR is organized to include the following information for the Coal Creek Watershed under separate sections:

Existing conditions – a summary of existing conditions for the following attributes: watershed characteristics, built infrastructure, and natural systems.

Limiting factors – based on an analysis of existing conditions, a summary of the primary factors from the conceptual model in Figure 2 that are limiting aquatic health in the watershed.

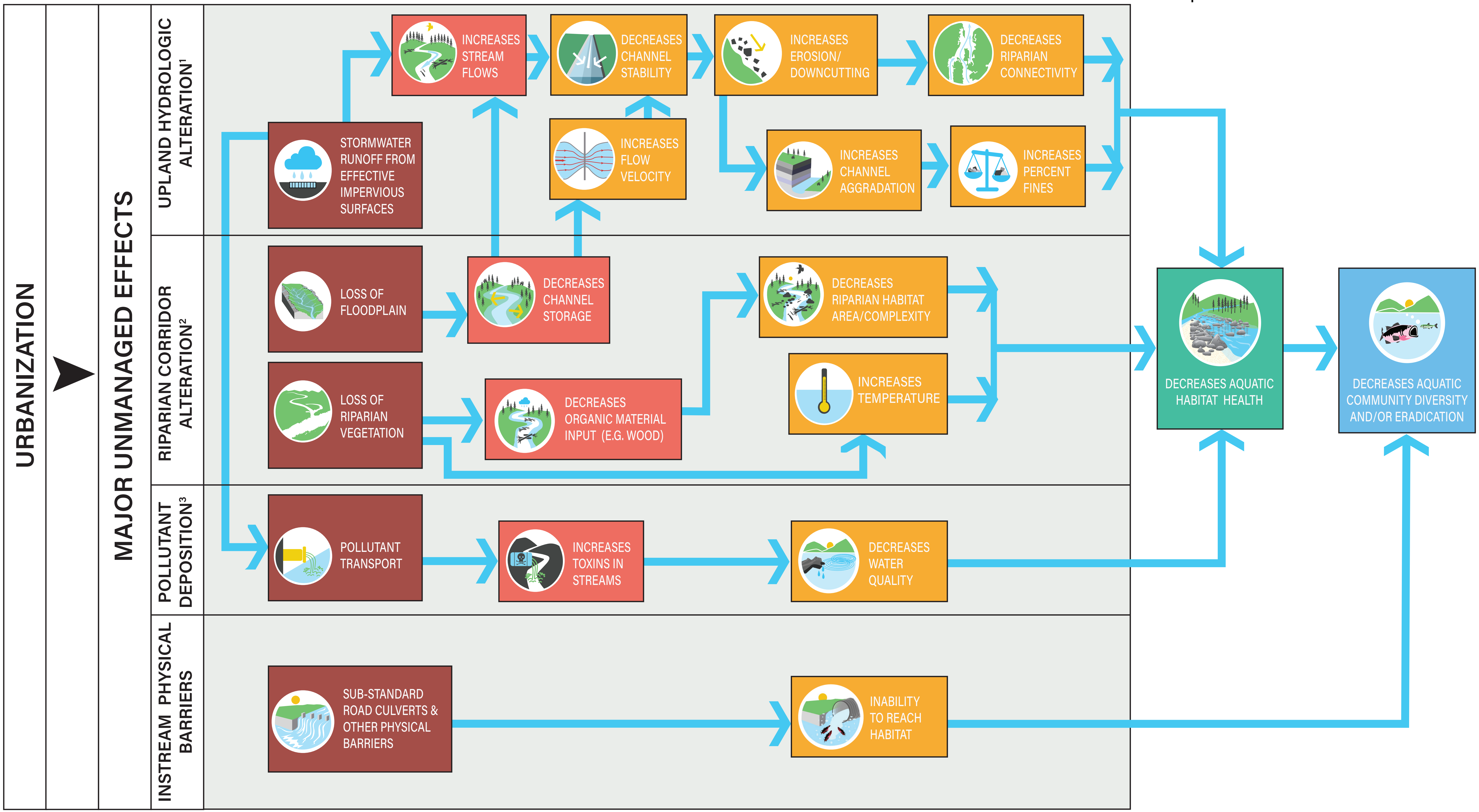
Past and present investment – a summary of investments that have already been made to improve stream health in the watershed.

Future opportunities – a summary of future opportunities that could be implemented to improve stream health in the watershed based on the current understanding of existing conditions and limiting factors.

Data gaps – missing or incomplete information that were not available to inform this Watershed AR or future phases of WMP development.

CONCEPTUAL MODEL OF THE IMPACTS OF URBANIZATION ON STREAM HEALTH

Figure 2. Conceptual Model for the Primary Impacts of Urbanization on Stream Health



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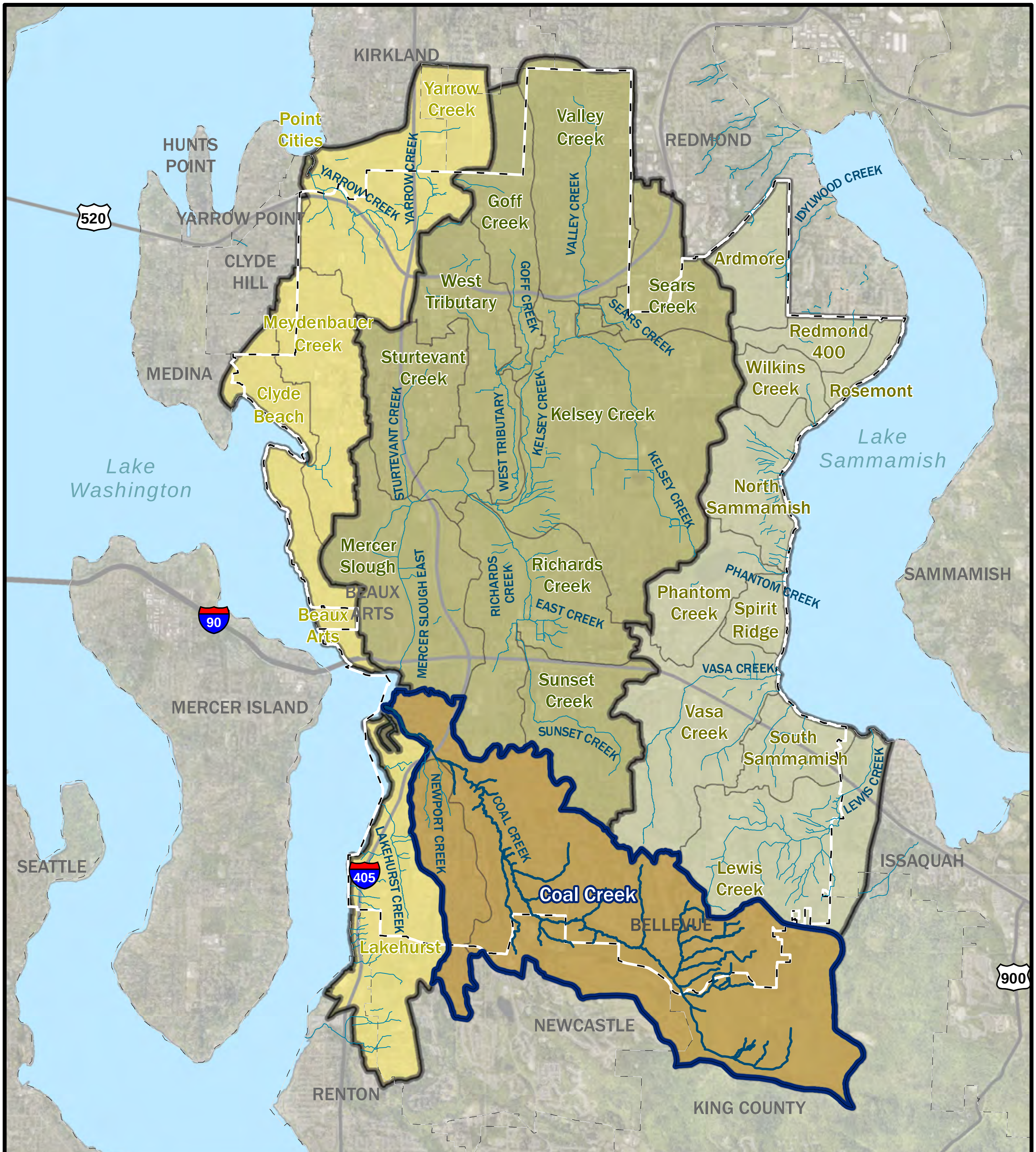

Figure 3. City of Bellevue Watersheds Vicinity Map.

0 3,400 6,800 13,600 Feet

King County Aerial (2019)

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2. Existing Conditions

This section documents existing conditions in the Coal Creek Watershed under separate subsections for the following attributes: watershed characteristics, built infrastructure, and natural systems. Data sources and methods used to summarize geospatial attributes in this section are presented in Appendix A.

2.1 Watershed Characteristics

Existing conditions in the Coal Creek Watershed are summarized herein for the following attributes: climate, geology and soils, topography and geomorphology, surface water features, and groundwater.

2.1.1 Climate

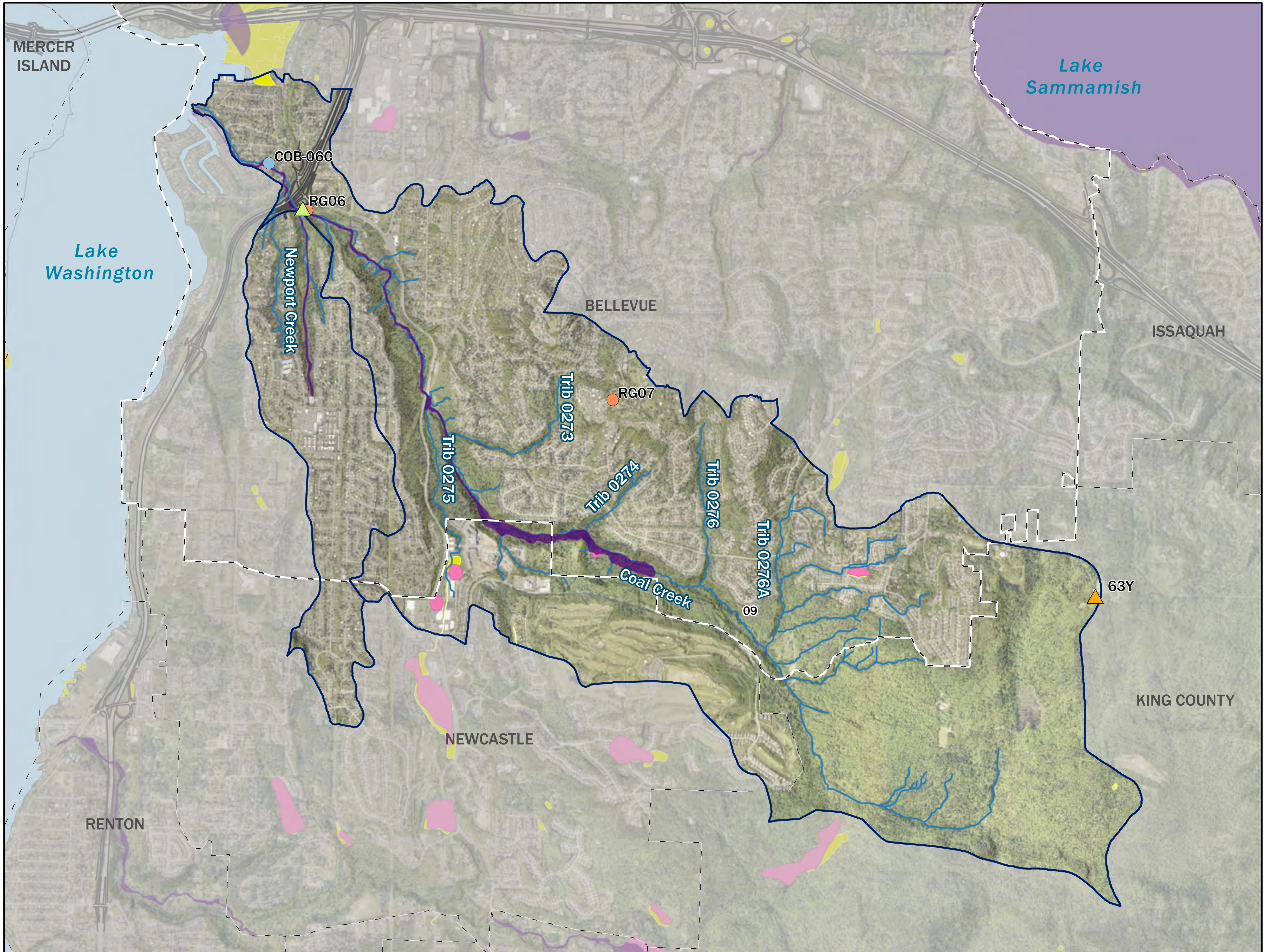
As shown in the conceptual model (Figure 2), climate and associated precipitation patterns have a significant influence on stressors from urbanization that influence stream health. Specifically, precipitation falling on impervious surfaces from urbanization drive increases in stormwater runoff that are associated with upland hydrologic alteration and pollutant transport. Collectively, these stressors degrade both aquatic habitat and water quality.

Existing climatic conditions in the Coal Creek Watershed are characterized by cool, dry summers and mild, wet winters that are typical of maritime regions (Tetra Tech *et al*. 2006). Seasonal and spatial precipitation patterns within the watershed were analyzed based on data collected from two rain gauges in the watershed that are maintained by the City (RG6 and RG7, respectively) and one rain gauge that is maintained by King County (63y). As shown in Figure 4, RG6 is located near the Newport Creek Tributary, and the intersection of Coal Creek Parkway and Interstate Highway 405. RG6 has an approximate elevation of 80 feet and is the closest rain gauge to the terminus of Coal Creek at Lake Washington. RG7 is located approximately 1.5 miles southeast of RG06 near the intersection of Highland Drive and 139th Ave SE. RG7 has an approximate elevation of 800 feet and is located in the mid to upper section of the Coal Creek Watershed. Finally, 63y is located near the top of Cougar Mountain at an elevation of approximately 1,400 ft and is the upper most rain gauge within the Coal Creek Watershed.

Rain gauge data for both RG6 and RG7 were analyzed for the period spanning from January 1, 2015 to December 31, 2019 while rain gauge data from 63y were analyzed for the period spanning from October 1, 1996 to January 31, 2021. For these time periods, the average annual precipitation for RG6, RG7, and 63y were 41.3, 46.9, and 53.5 inches, respectively. On average, the watershed received the most precipitation during the months of November and December. As shown in Figure 5, RG7 and 63y consistently measured a greater amount of precipitation than RG6. These data suggest the upper portion of the Coal Creek Watershed receives more rainfall than the lower portion.

While it is difficult to infer any long-term trends from the limited data that is available from the gauges identified above, regional studies on climate change are predicting a modest increase (15 percent) in the average of the annual daily maximum rainfall total over the period from 2020 to 2050, with larger storms (storms with over 3 inches of rain per 24-hour period) generally predicted to be more frequent and smaller storms generally predicted to be smaller (King County 2014). Analyses of historic data collected from 1977 to 2017 by the City of Seattle have also shown there has been a statistically significant positive trend in various metrics for extreme precipitation over this period after accounting for variation stemming from the oceanic phenomenon known as the Pacific Decadal Oscillation (Tetra Tech 2017). This trend provides strong quantitative support for anticipated changes in precipitation extremes over future decades in the region. Based on this shift in precipitation patterns, the impacts from urbanization noted above are anticipated to become more severe as impervious surfaces intercept additional rainfall that would normally have infiltrated to groundwater under natural, forested conditions.

Figure 4.
Coal Creek Watershed Surface Water Features and Monitoring Sites.



Legend

King County Monitoring (King County 2020)
- Precipitation Gauge, Active
- Water Quality Index, Active

City of Bellevue Monitoring (City of Bellevue 2020)
- Precipitation Gauge, Active
- Stream Gauge, Active
- OSCA Stream Reach (City of Bellevue 2020)
- Highway (City of Bellevue 2020)
- Watershed (City of Bellevue 2020)
- FEMA 100 Year Floodplain (King County 2020)
- King County Sensitive Area Ordinance Wetlands (2020)
- NWI Wetlands (2020)
- Bellevue City Limits (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)

Note: Federal Emergency Management Area (FEMA), National Wetland Inventory (NWI), Open Stream Conditions Assessment Database (OSCA).

King County Monitoring Stream gauge COB-CCF not included on this figure due to inactive status.

Jacobs
HERRERA

0 1,250 2,500 Feet

King County Aerial (2019)

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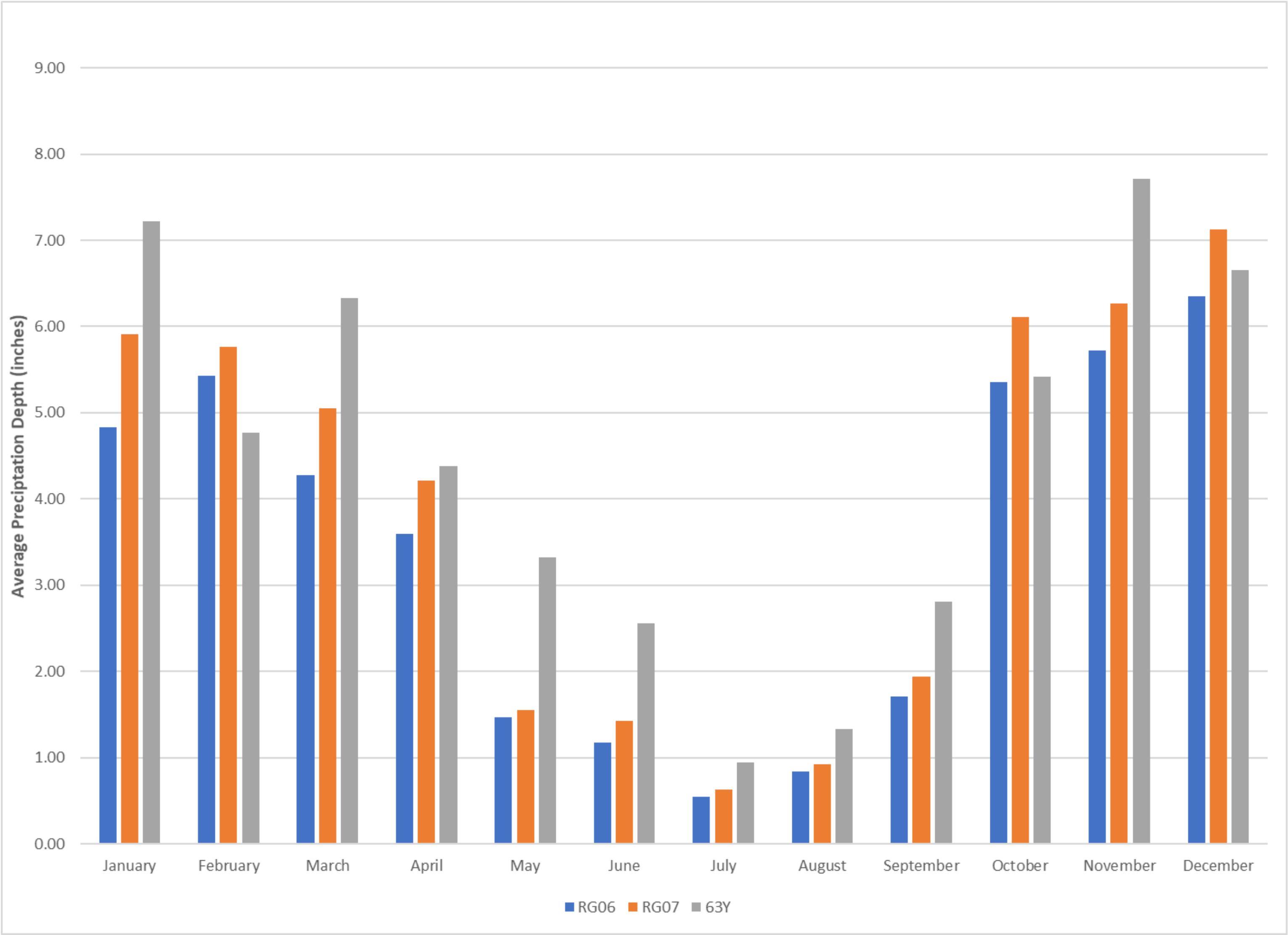


Figure 5. Precipitation Depth by Month in the Coal Creek Watershed.

2.1.2 Geology and Soils

The regional and local geologic setting has a significant influence on the physical characteristics of a watershed, such as the watershed area, the geometry of the channel, floodplain, and valley, and how water and sediment move through the watershed and its channels. These physical characteristics in turn influence the responsiveness of a river or stream to changes (whether anthropogenic impacts or attempted restoration efforts), affect the feasibility of infiltration, and therefore drive the levels of biological activity that are even possible in a watershed. As illustrated by the conceptual model presented in Figure 2, understanding the relationships between these physical characteristics and the biological functioning in watersheds is important for both the identification of limiting factors as well as the development of opportunities for improvement. Coal discovered in the Coal Creek Watershed has also led to anthropogenic changes in the watershed and related impacts on stream health. The impact of historic coal mining is presented in various sections below, including Section 2.3.2.3 Legacy Coal Mining.

2.1.2.1 Geology

As a part of the Puget Lowland, the Coal Creek Watershed has been formed by a long history of tectonic and depositional processes; yet the geologic episode with the most influence on the current landscape was the last glaciation that culminated approximately 16,000 years ago. As a result, the surface geology of the Coal Creek Watershed is primarily characterized by a combination of glacial and post-glacial deposits located towards the middle and downstream portions of the watershed, and older volcanic and sedimentary bedrock formations located towards the middle and upstream (also higher elevation) portions of the watershed, as depicted in Figure 6 (USGS 2016).

The Coal Creek Watershed is unique within the City because although sedimentary glacial and post-glacial deposits mostly overlay the bedrock geology, there are also many locations within the middle and upper portions of the watershed in which the bedrock is exposed and even encountered by the streambed and banks. The sandstone bedrock in the Coal Creek Watershed is referred to as part of the Renton Formation that was deposited during the Eocene period between 35 and 58 million years ago.

The coal beds and seams, for which the watershed is named, are associated with the Renton formation. This formation is characterized by nonmarine fine- to medium-grained arkosic sandstone and siltstone containing abundant subbituminous coal beds and carbonaceous shale. Although the original formation deposited in horizontal beds, uplifting eventually resulted in an approximate 38- to 45-degree angle tilt. The coal beds and seams formed within organic material that also deposited during the Eocene period. These coal beds and seams can extend 1,500 feet below the ground surface (Booth *et al*. 2012; Livingston 1971).

The uppermost portion of the watershed within Newcastle and the Cougar Mountain Regional Wildland Park is underlain by volcanic bedrock referred to as the Tukwila formation and the Newcastle Hills anticline. The Tukwila formation also deposited during the middle to late Eocene period and is composed of Andesitic to dacitic volcanic sandstone, siltstone, shale, tuff-breccia, tuff, volcanic mudflow (lahar), carbonaceous shales, and minor lava flows or sills. The Newcastle Hills anticline is a bedrock fold that extends to the front of the Cascade Range (Booth *et al*. 2012; Mullineaux 1970).

Table 1 provides a summary of the percentages of the mapped surface geologic types for the Coal Creek and Newport Creek subbasins as well as for the entire Coal Creek Watershed (USGS 2016). The predominant surface geologic type in the Coal Creek Watershed was deposited during the Vashon state of the Fraser glaciation, approximately 13,000 to 16,000 years ago. In Coal Creek, these glacial sediments consist primarily of Lawton Clay, Esperance sands, and Vashon Till. The Lawton Clay is relatively erosion resistant and impermeable. The Esperance sands often found above the Lawton Clay, is an advance outwash deposit that is more permeable but susceptible to erosion. Finally, the Vashon Till was deposited and consolidated at the base of the Vashon Glacier and consists primarily of dense and erosion resistant silty sand with gravels and cobbles (Booth *et al.* 2012; Livingston 1971).

The valley that currently contains Coal Creek was formed by the incision of the erosive glacial meltwaters into the glacial deposits described above. Although ongoing channel incision is a part of a natural geologic and geomorphic process, there are some places within the watershed where the rates of channel incision have been exacerbated by hydrologic alterations, described later in this report.

2.2.2.1 Soils

The soil types that have deposited above the glacial geologic layers present many challenges for using infiltration-focused stormwater management BMPs. As described below, the soils at the surface tend to be highly erodible and the soils just below the surface tend to have a low permeability. Table 2 provides a summary of the percentages of different soil types within the Coal Creek and Newport Creek subbasins as well as the entire Coal Creek Watershed. As shown in Figure 7, both Alderwood and Beausite soils are found throughout the uplands of the Coal Creek Watershed. Alderwood and Beausite gravelly sandy loams cover nearly 75 percent of the watershed (Bellevue 2020a; Snyder *et al.* 1973). Alderwood soils belong to hydrologic soil group B and consist of moderately deep, moderately well drained gravelly sandy loams that sit on top of a very slowly permeable layer of consolidated glacial till. Beausite soils belong to hydrologic soil group C and consist of well-drained gravelly sandy loams that sit on top of sandstone. Both Alderwood and Beausite soils are found in glaciated foothills of Western Washington with rolling to very steep slopes (Snyder *et al.* 1973). Alderwood and Beausite soils have severe erosion potential for slopes greater than 15 percent. Sections of the steep narrow ravines surrounding Coal Creek have a natural severe potential for erosion.

Arents Alderwood material (Am) consist of heavily graded and compacted Alderwood soils which can no longer be classified as Alderwood, and thus the associated hydrologic soil group for Arents Alderwood is B/D, as typical of modified soils. Arents Alderwood can be found in the uplands of the Newport Hills, and Lake Heights areas. The extents of Arents Alderwood soil have likely expanded with the area’s extensive development since the soil survey took place in 1973.

Alderwood and Kitsap soils (Ak) are found in the valley surrounding Coal Creek and account for approximately 10 percent of the watershed’s soil cover. The Alderwood and Kitsap soils belong to hydrologic soil group B, are typically found on very steep slopes, and have a high potential for erosion.

The heavily compacted glacial till geology underlying the majority of the Coal Creek Watershed is a deposit that is generally more resistant to change and thus affords the watershed some resiliency from the full force of the hydrologic changes that could otherwise result from upland urbanization and unmanaged stormwater runoff. At the same time however, the Alderwood and Beausite soils that have deposited above the till have severe erosion potential that is easily exacerbated by increased delivery of concentrated flows and stormwater runoff leading to increased rates of upper slope instability, mass-wasting, and the delivery of fine sediment to downstream reaches in the watershed. Further, the very low permeability of the glacial till geology will limit the effectiveness of infiltration-focused stormwater management techniques in the watershed.

Table 1. Surface Geology in the Coal Creek Watershed.

Geologic Map Unit	Geologic Unit Age	Geologic Type	Geologic Description	Coal Creek Subbasin (% Area)	Newport Creek Subbasin (% Area)	Entire Coal Creek Watershed (% Area)
wtr	Holocene	Water	Water	0	0	0.1
Qa	Holocene	Alluvium	Moderately sorted deposits of cobble gravel, pebbly sand, and sandy silt along major rivers and stream channels; some fan material	1.9	0.1	1.6
Qp	Holocene - Pleistocene	Peat deposits	Quaternary bog, marsh, swamp, or lake deposits	0.6	0	0.5
Qgo	Pleistocene	Recessional continental glacial outwash, Fraser-age	Stratified sand and gravel, moderately to well sorted, and well-bedded silty sand to silty clay deposited in proglacial and ice-marginal environments	1.3	0	1.2
Qgt	Pleistocene	Continental glacial till, Fraser-age	Mix of clay, silt, sand, and gravel with isolated boulders deposited as diamicton directly by advancing glacier ice; gray where fresh, light yellowish brown where oxidized; cobbles and boulders commonly faceted and (or) striated and glacially polished; unsorted and highly compacted; permeability very low; most commonly matrix supported, but locally clast supported; matrix more angular than water-worked sediments; varies in thickness from 1 ft to about 80 ft and averages about 50 ft thick.	74.7	91.1	76.7
Qga	Pleistocene	Advance continental glacial outwash, Fraser-age	Well-bedded sand and gravel deposited by streams and rivers issuing from advancing ice sheet. Generally unoxidized. Almost devoid of silt or clay, except near base of the unit and as discontinuous beds	2.2	7	2.8

Geologic Map Unit	Geologic Unit Age	Geologic Type	Geologic Description	Coal Creek Subbasin (% Area)	Newport Creek Subbasin (% Area)	Entire Coal Creek Watershed (% Area)
Qgpc	Pleistocene	Continental glacial drift, pre-Fraser, and nonglacial deposits	Pleistocene undifferentiated glacial and nonglacial deposits of pre-Fraser age	0.5	0.1	0.4
OEn	Oligocene-Eocene	Nearshore sedimentary rocks	Tertiary sedimentary rocks and deposits	3.9	0	3.4
Ec(2r)	Eocene	Continental sedimentary deposits or rocks	Massive to thin-bedded, feldspathic to arkosic sandstone, siltstone, shale, and carbonaceous shale; becomes mostly marine in the western foothills of Cascade Mountains where coal beds are abundant.	12.1	0	10.6
Evc(t)	Eocene	Volcaniclastic deposits or rocks	Tertiary fragmental volcanic rocks and deposits (includes lahars; predominantly andesite flows and breccia; includes some basalt flows)	2.8	1.7	2.7

Table 2. Soils in the Coal Creek Watershed.

Hydrologic Soil Group *(reference: Bellevue 2020a)*	**Soil Classification**	**Relative Infiltration Potential**	**Soil Notation**	**Percentage of Coal Creek Subbasin**	**Percentage of Newport Creek Subbasin**	**Percentage of Coal Creek Watershed**
A	Everett gravelly sandy loam	High	EvC	0.7%	0.0%	0.6%
A/D	Norma sandy loam, Orcas peat	High (drained condition); Very low (undrained/high-water table condition)	No, Or	0.6%	0.1%	0.6%
B	Alderwood gravelly sandy loam, Alderwood and Kitsap soils very steep	Moderate	AgB, AgC, AgD, AkF	43.5%	30.6%	41.9%
B/D	Arents Alderwood, Briscot silt loam, Seattle muck, Sammamish silt loam	Moderate (drained condition); Very slow (undrained/high-water table condition)	AmC, Br, Sk, Sh	5.0%	58.8%	11.7%
C	Beausite gravelly sandy loam, Ovall gravelly loam,	Slow	BeC, BeD, OvD	48.1%	5.2%	42.7%
Not Identified	Urban land	N/A	Ur	2.1%	5.2%	3.1%
Area (acres)	*NA*	N/A	*NA*	3,978	573	4,551

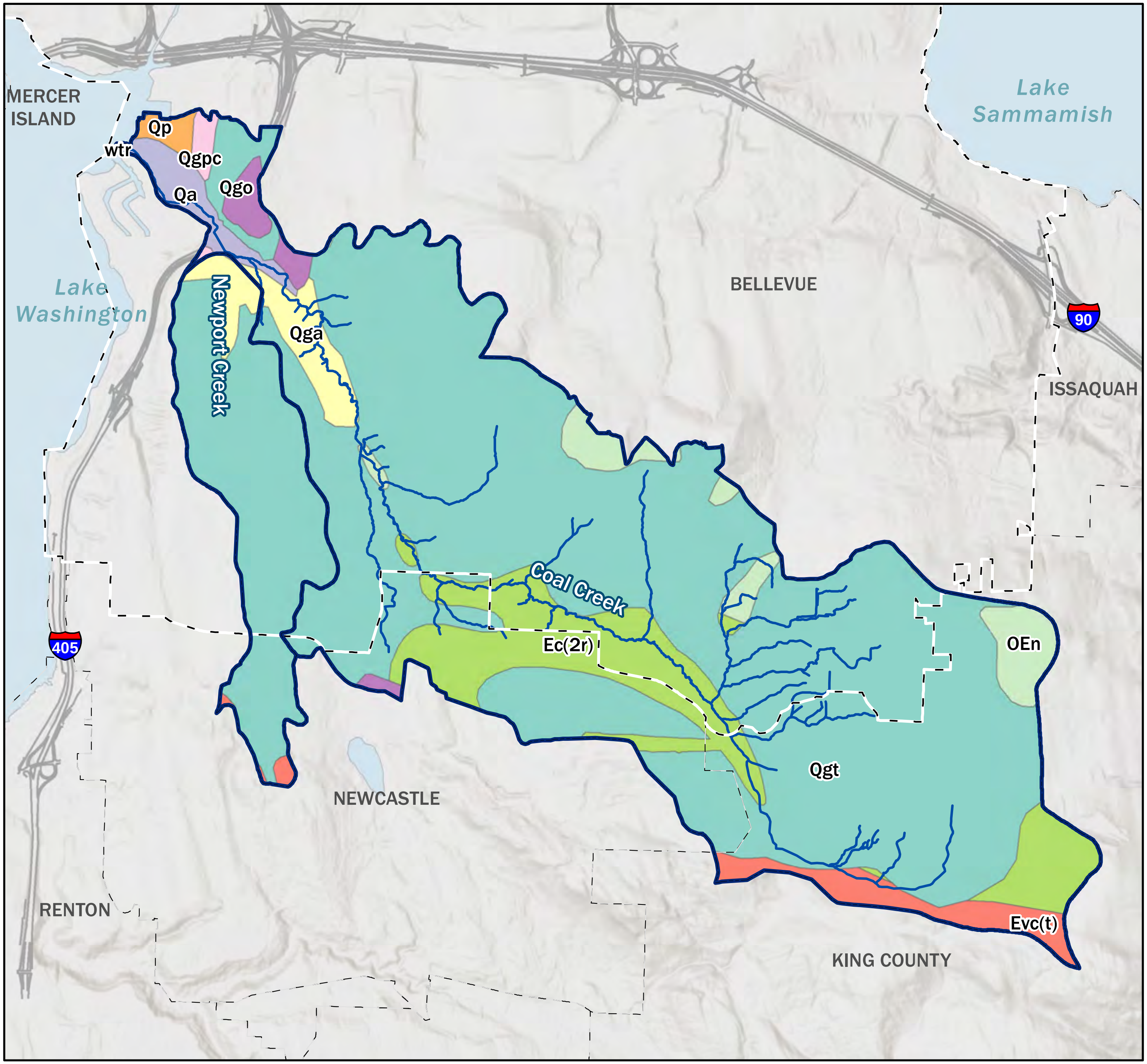


Figure 6.
Coal Creek Watershed Geology.

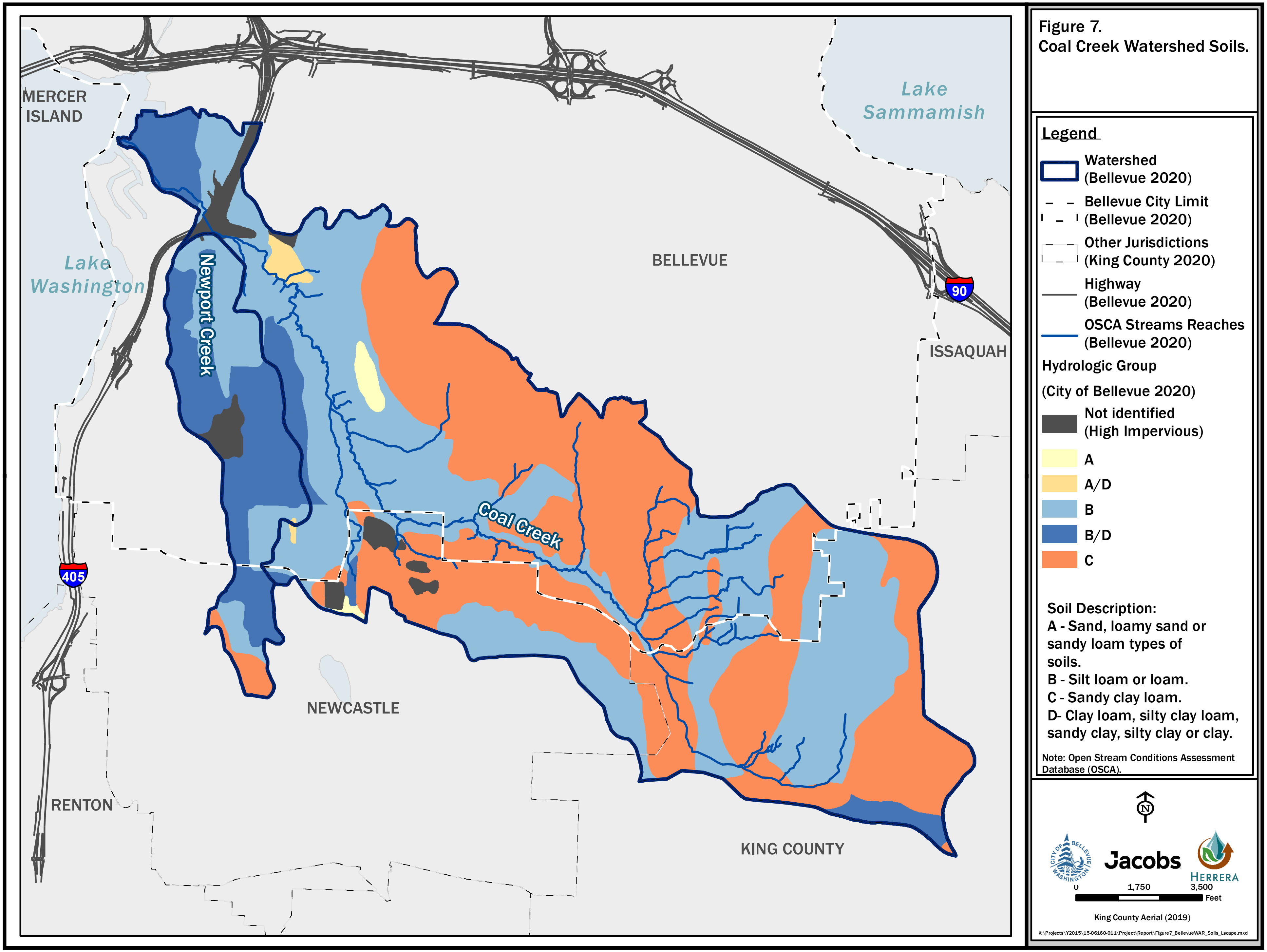


Figure 7.
Coal Creek Watershed Soils.

2.1.3 Topography and Geomorphology

The Coal Creek Watershed is characterized by some of the most significant topographic relief of all the City watersheds. Topographic relief and contributing drainage area combine to provide the watershed with a significant potential for generating and transporting sediment and potentially other pollutants (as shown in Figure 2) to downstream reaches. If downstream reaches were unaltered and unconfined with connected floodplains, alluvial fans, and deltas, they would have the capacity for storing sediment, accommodating geomorphic change, and attenuating pollutants. However, when development and related hydrologic and geomorphic changes inhibit this capacity and restrict floodplain functions, channels are prone to losing their dynamic equilibrium and instead develop reach-scale trends of chronic vertical channel change (e.g., chronic aggradation or incision) or lateral bank instability (Booth 1990; Buffington and Montgomery 1999; Komura and Simmons 1967; Williams and Wolman 1984).

As shown in Figure 8, the headwaters of Coal Creek initiate at elevations around 1500 feet above sea level (NAVD 88; OCM Partners 2020) within the rolling hills of the King County Cougar Mountain Regional Wildland Park. Downstream from Cougar Mountain to the intersection with Interstate Highway 405 (I-405), Coal Creek flows through a relatively steep and erosive canyon and ravine with an average slope of about 2.5 percent. Almost the entire riparian corridor adjacent to this stretch of Coal Creek is contained within the City's Coal Creek Natural Area, which is a 550-acre park with approximately three miles of unpaved trails. Several tributaries, including Newport Creek and Tributary 0275 (Newcastle Creek), primarily drain flatter upland plateau areas with predominantly single-family residential development, and drops into steep, incised ravines before joining the mainstem of Coal Creek. Downstream of I-405, Coal Creek flows in a modified and relatively narrow channel through its historic alluvial fan and delta, now dominated by the single-family residential development of the Newport Shores Neighborhood, to its confluence with Lake Washington at approximately 20 feet above sea level (OCM Partners 2020).

The existing geomorphic conditions within the Coal Creek Watershed are a product of the topography, geology, and soil conditions, combined with the hydrologic changes and hydromodifications associated with land use and land cover change within the last century. The prevalence of naturally erosive soil types at the ground surface sitting above consolidated glacial material and bedrock combined with the steep ravines and valley walls described above present a natural recipe for soil slippage and high erosion potential throughout the entire length of the Coal Creek (OSCA reaches 3 through 12) and Newport Creek (OSCA reaches 1 and 2) stream corridors to approximately the intersection with I-405 (GeoEngineers 1997; King County and Bellevue 1987; TetraTech/KCM 2005). Episodic shallow landslides have been documented primarily in the uppermost reaches of Coal Creek within the City and along the Newport Creek Tributary. These shallow landslides are associated with stream erosion and active springs that maintain high groundwater levels (GeoEngineers 1997; King County and Bellevue 1987; Tetra Tech/KCM 2005). Other common sources of erosion and sediment supply in the watershed result from streambank and terrace erosion, streambed and bar incision, hydrologic changes from land clearing activities and development, and coal mine waste debris flows (King County and Bellevue 1987; Tetra Tech/KCM 2005).

Naturally erosive and unstable soil conditions have been exacerbated by a legacy of coal mining activities that lasted for almost 100 years, which not only destabilized streambanks and hillslopes, but also channelized the stream and dispose of mine tailings along the streambanks and within the canyon in the historic Cinder Mine Location located approximately a mile downstream of Lakemont Boulevard (Figure 8). Waste piles consisting of rock, clay, and considerable quantities of low-grade coal particles were ignited and burned for years, leaving behind cinder ash that was further mined for commercial use, as well as numerous voids and unstable slopes within the waste piles (Spearman Engineering 1997). These mine waste deposits have been documented as ranging from 5 to 40 feet deep along the streambank of Coal Creek (GeoEngineers 1997; Hart Crowser and Associates 1985) and continue to present an ongoing source of sediment and water quality impact to Coal Creek. It has also been speculated that the mine waste dumping near the cinder mine along the south or left bank of Coal Creek in the canyon encouraged the creek to migrate towards the steep, erosive, landslide-prone slopes adjacent to the north or right bank of Coal Creek (Tetra Tech/KCM 2005).

In general, the morphologic reach types in Coal and Newport Creek subbasins transition from source, to transport, to response in the upstream to downstream direction, as is typical of watersheds in the western Cascade foothills (Montgomery and Buffington 1997).

Morphologic Reach Type (Montgomery and Buffington 1997)	
Source	Headwater, colluvial channels; act as transport-limited; sediment storage locations subject to debris flow scour
Transport	Morphologically resilient, supply-limited reaches (bedrock/cascade/step-pool); rapidly convey increased sediment inputs
Response	Lower gradient, transport-limited reaches (plane-bed/pool-riffle/dune-ripple); morphological adjustments occur in response to increased sediment supply

The geomorphic stream reaches in Coal and Newport Creeks were defined during the citywide OSCA surveys (Bellevue 2020b). The specific morphologic reach types and channel types for each of these reaches are also described further in Appendix B. However, in general, the channel morphology transitions from source to transport to response in the downstream direction. The channels are more confined and generally steeper along the tributaries and upper reaches of Coal Creek and therefore have sufficient transport capacity to mobilize incoming bedload sediment supply. The channel transitions to response morphology through the middle and downstream reaches as the gradient lessens and the valley floor widens. Gravel and cobble-sized bedload is temporarily stored in bar deposits in these more responsive reaches, often only mobilizing once or twice a year, sometimes remaining in storage for several years. However, the smaller suspended loads (silts to fine sands) are often transported down to the historic alluvial fan and delta of Coal Creek, if not all the way to Lake Washington.

The delta at the mouth of Coal Creek, upon which the Newport Shores neighborhood was developed, initially formed during the last glacial retreat approximately 13,000 years ago and has experienced significant hydromodifications in the last century. Although actual extents are unknown, it is likely that much of the delta was underwater prior to the 1917 lowering of Lake Washington (following completion of the Hiram M. Chittenden Locks in the Ballard neighborhood of Seattle).

Historical aerial imagery from the 1930s indicate that the mouth of Coal Creek was historically located at the western point of its delta, approximately 1,300 feet to the southwest of its current location; however, several distributed abandoned channel positions were also visible from this imagery. The area was influenced by agriculture by the 1940s and an airfield was constructed on the interior of the delta around the same time. The stream mouth was relocated across the delta several times and in 1958 was channelized and moved to approximately its current location to enable the development of Newport Shores. The artificial confinement of the realigned stream significantly reduced floodplain connectivity and thereby reduced access to flood, sediment, and nutrient storage within the floodplain. Sediment that otherwise would have deposited within the floodplain instead was deposited within the channel or transported downstream, contributing to a western and then northern progression of the delta into the mid-1980s. During this same period, however, sediment supply to the delta also significantly increased from estimated background levels. The long-term average rate of sediment deposition on the delta between 1958 and 2003 was estimated to be about 3,000 cubic yards per year (NHC 2004), with higher rates of about 5,000 cubic yards per year estimated in the 1990s (GeoEngineers 1997). Both rates are significantly greater than the 250 cubic yards per year estimated during the post-glaciation period (GeoEngineers 1984).

As described later in this report, in efforts to reduce the impacts of sedimentation and flooding of downstream areas, the City has made considerable investments to promote stream and bank stability in the upper and middle reaches and provide both natural and artificial locations for sediment storage in the middle and lower reaches of Coal Creek. The City continues to maintain these sediment detention facilities. These efforts, coupled with several recent culvert replacements within Newport Shores, have significantly reduced the effects of sedimentation and flooding problems experienced within the delta (NHC 2015).

2.1.4 Surface Water Features

The presence, type, and distribution of surface water features are important factors that can influence the severity of impacts from urbanization described in the conceptual model (Figure 2). For example, wetlands can play an important role in storing stormwater from impervious surfaces that might otherwise flow directly to streams. Natural processes in wetlands are also effective at removing or sequestering many common pollutants that are present in stormwater runoff.

As shown in Figure 4, Coal Creek is the predominant drainage feature of the Coal Creek Watershed and a tributary to Lake Washington. Coal Creek flows from the headlands of Cougar Mountain approximately 7 miles to Lake Washington’s Newport Shores. While Newport Creek and its tributary are the primary tributaries to Coal Creek, the watershed contains numerous smaller tributaries, the most notable of which are Tributary 0273 (Forest Hills), Tributary 0274, Tributary 0275 (Newcastle Creek), Tributary 0276, and Tributary 0276A (Lakemont).

In addition to fluvial channels and tributaries, surface water features in the Coal Creek Watershed include floodplains and wetlands. However, as described in preceding sections, much of upper Coal Creek is characterized by steep ravines and narrow valleys, which do not support broad floodplains nor the development of wetlands outside of the immediate riparian zone. Figure 4 depicts the mapped floodplains and wetlands present in the Coal Creek Watershed. The active floodplain of Coal Creek is relatively narrow, yet the geology depicted in Figure 6 (alluvium and outwash) and the topography shown in Figure 8 suggest that the floodplain widths along Reaches 1 through 3 of Coal Creek and Reach 1 of Newport Creek could be much broader than they are today. As described previously, channel incision exacerbated by upland hydrologic changes coupled with armoring and development that confine alluvial processes have separated the channel from its floodplain and reduced the effectiveness of the floodplain’s ability to attenuate peak flows, store nutrients and attenuate pollutants, and support the channel complexity important to aquatic habitat.

Figure 4 shows wetlands that have been both delineated and mapped by the National Wetland Inventory (NWI; USFWS 2021) as well as King County (King County 2021). There is some partial overlap of these wetland areas, but when merged and after accounting for these overlapping areas, the wetland areas are found to be 71 , 5, and 76 acres of wetlands for the Coal Creek Subbasin, the Newport Creek Subbasin, and the total Coal Creek Watershed, respectively. These areas correspond to approximately 1.8 percent, 0.9 percent, and 1.7 percent of the Coal Creek Subbasin, the Newport Creek Subbasin, and the total Coal Creek Watershed areas, respectively. The NWI indicates that there is a heavily disturbed wetland at the intersection of 163rd Place Southeast and Southeast 65th Place. The wetland is isolated and located upstream in the Coal Creek Watershed in a residential neighborhood not far from the Cougar Mountain

Regional Wildland Park. The wetland is categorized as Type 4 (lowest levels of wetland function, USFWS 2021).

The King County Wetlands Inventory indicates that there are three other wetlands located in the Coal Creek Watershed (King County 2021). The first wetland that is shown in the King County Wetlands Inventory is located on Coal Creek completely within the Coal Creek Natural Area and adjacent to the Forest Glen East Neighborhood Park. This wetland is listed as Type 3, wetlands that generally have been disturbed and are less diverse or more isolated from other natural resources. The remaining two wetlands that were identified by the King County Wetlands Inventory are located in Newcastle between Coal Creek Parkway, Newcastle Way, and 132nd Place Southeast. These two wetlands are listed as Type 2, or difficult but not impossible to replace.

2.1.5 Groundwater

In areas that have not been disturbed by urbanization, very little precipitation contributes to direct surface flow. Precipitation typically infiltrates into the surface soils until meeting the low permeability Vashon till layer below. Groundwater accumulates above this impermeable layer and flows laterally, either emerging as seeps or springs or interacting with the hyporheic flow associated with Coal Creek or one of its tributaries. As mentioned in Sections 2.3.3 Groundwater Quality and 2.3.5 Instream Habitat, the surface expression of these springs or seeps across steep slopes with unstable surface soils, or otherwise to areas of previous soil disturbance from mining activities or fill placement, often leads to slope instability, mass wasting, and in some cases streambank instability as well. The potential for groundwater springs and seeps to potentially exacerbate slope instability should be considered when evaluating and locating upslope stormwater infiltration. Rainfall that does not flow laterally through the soils can slowly penetrate to deeper groundwater aquifers or may enter abandoned mine shafts before eventually discharging into Coal Creek at surface openings.

Historic mining impacts, including subsurface mine drainage, in the Coal Creek Watershed, continue to affect groundwater flow in the basin. The Richmond Tunnel was constructed below the headwaters of Tributary 0275 (Newcastle Creek) in the late 1800s, was later mined (MacDonald and MacDonald 1987), and continues to provide a conduit of baseflow to Coal Creek. Another mine adit located along Tributary 0276 (Lakemont) also provides an avenue for baseflow conveyance to downstream areas. Given the extensive mining activity in the watershed, there are likely numerous other mine adits contributing baseflow in the watershed that have not been formally identified (Tetra Tech *et al.* 2006).

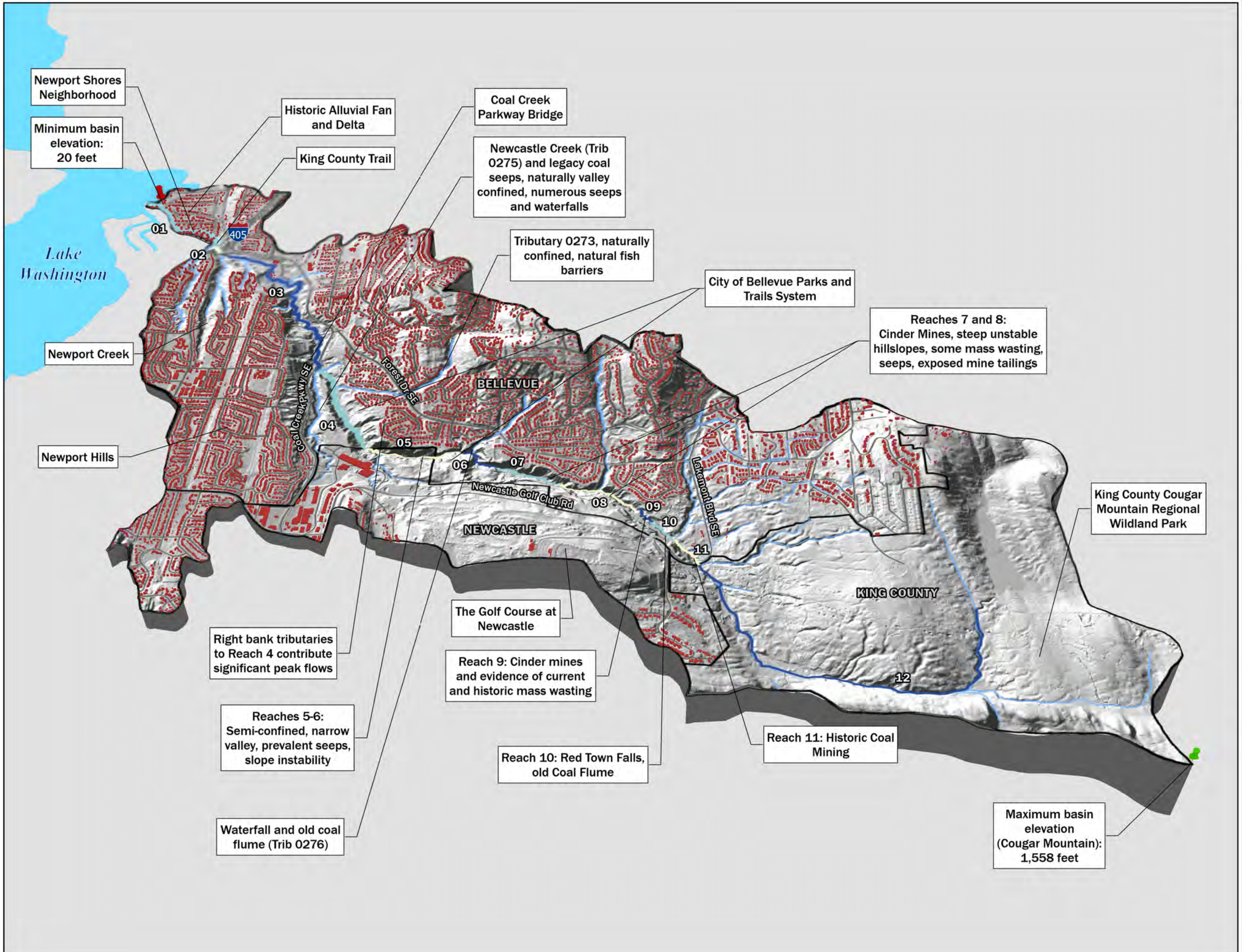


Figure 8 – Coal Creek Watershed Topography and Geomorphology.

Legend

- Building footprints
- Street
- Stream
- OSCA stream reach
  - Reach 01, 04, 07, 10
  - Reach 02, 05, 08, 11
  - Reach 03, 06, 09, 12
- Jurisdictional boundary

Vertical Datum:
North American Vertical Datum of 1988 (NAVD 88)

Data Sources:
a) City of Bellevue, WDFW Fish Distribution, OSCA
b) OCM Partners 2020, LiDAR

N

Jacobs

HERRERA

0 750 1,500
Feet

2.2 Built Infrastructure

Existing conditions are summarized below for the following built infrastructure attributes: land cover and land use, and stormwater infrastructure.

2.2.1 Land Cover and Land Use

Existing land cover in the Coal Creek Watershed is predominantly (57 percent) urban tree canopy (the layer of leaves, branches, and stems of trees that cover the ground when viewed from above), with 23 percent impervious surface and 16 percent non-canopy (herbaceous groundcover) vegetation (Bellevue 2013, 2017). Road right-of-way represents approximately 22 percent of the total impervious surface in the Coal Creek Watershed. Bare soil, scrub/shrub, and water surface together comprise less than 5 percent of total land cover (see Figure 9). Notably, urban tree canopy in the watershed is largely concentrated in the Cougar Mountain Regional Wildland Park and along the riparian corridor of Coal Creek down to the point where it intersects Interstate Highway 405 (see Section 2.3.4 Riparian Corridor). The land cover in the Coal Creek Watershed is unique compared to other City watersheds with a higher percentage of tree canopy and lower percentage of impervious surface. Table 3 compares the change in canopy cover and impervious surfaces between 2006 and 2017 between the Coal Creek and Newport Creek subbasins (HRCD 2021). Although the Coal Creek subbasin had a greater decrease in canopy cover (39.4 acres) and increase in impervious surfaces (37.2 acres), the percent change (1.0 percent and 0.9 percent change, respectively) was less than the Newport subbasin because the total area in the Coal Creek Watershed is much larger.

As shown in Figure 10, the land use results echo the land cover results for the Coal Creek Watershed with the predominant land use types including single family residential (53 percent) and parks (42 percent). The areas with developed land use types within the watershed (e.g., commercial, industrial, mixed use, and single- or multi-family residential) include approximately 80 miles of streets (mostly local access streets). Other developed land use types in the watershed include less than 2 percent multi-family land use and less than 1.5 percent mixed use. Commercial/office and industrial land use types each comprise less than 1 percent of the total existing land use in the watershed.

As the second most predominant land use type in the watershed, park space correlates with most of the urban tree canopy land cover present within the riparian corridor of Coal Creek. These park areas include the City parks and trail system within the Coal Creek Natural Area, multiple smaller parks, and the King County Cougar Mountain Regional Wildland Park in the undeveloped upper portion of the watershed. The Park area also includes the Golf Club at Newcastle, a 36-hole golf course surrounded by residential development.

Though not currently active, some historic land uses such as coal mining operations, continue to influence the watershed today. Mining operations have been recorded from as far downstream as Southeast 62nd Street, all the way up to the headlands of Cougar Mountain (Figure 10). Currently the Golf Club at Newcastle, the largest private property owner directly adjacent to Coal Creek, is located on the site of former mining activities. As noted elsewhere in this document, erosion, and subsequent transportation of sediment along Coal Creek to Lake Washington is linked to this historic coal mining.

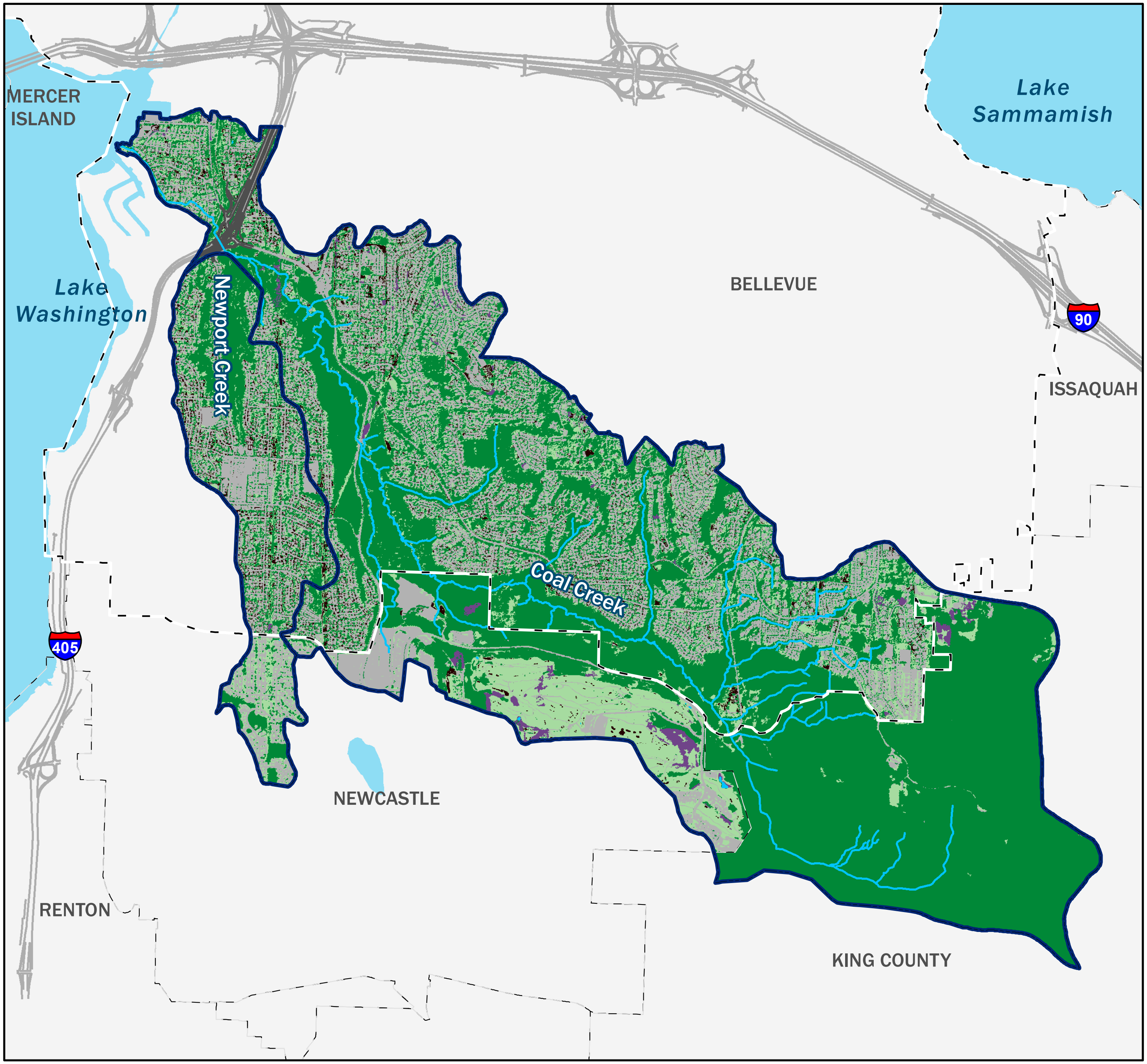
Within Bellevue, the ownership of the land adjacent to the mainstem of Coal Creek is approximately 96 percent City (primary Parks Department) and 4 percent private or owned by other jurisdictions. Among the largest tributaries (Newport Creek, including its tributary), Tributary 0275 (Newcastle Creek), and Tributaries 0273 (Forest Hills), 0274, 0276, and 0276A (Lakemont), the ownership numbers are 100 percent City. This is important for developing stream improvement plans as the City's current approach limits using public resources that improve stream channel conditions or riparian corridors to only City-owned property. The City may also fund programs to provide information that assists stream-side residents in improving steams/riparian corridors or incentive programs promoting green stormwater infrastructure on private properties.

Table 3. Change in Tree Canopy and Impervious Surfaces from 2006 to 2017 in Coal Creek and Newport Creek Subbasins [a].

	2006-2009	2009-2011	2011-2013	2013-2015	2015-2017	Total Change in Area - acres (% of subbasin)
Coal Creek Subbasin						
Change in Tree Canopy (acres)	-11.4	-5.1	-3.3	-13.2	-6.1	-39.1 (-1.0%)
Change in Impervious Surfaces (acres)	+5.7	+1.6	+4.9	+9.8	+15.1	+37.2 (+0.9%)
Newport Creek Subbasin						
Change in Tree Canopy (acres)	-3.0	-0.4	-0.3	-0.2	-6.8	-10.8 (-1.9%)
Change in Impervious Surfaces (acres)	+1.6	0.0	0.0	0.0	+6.5	+8.1 (+1.4%)

[a] Includes subbasin areas outside of City of Bellevue's jurisdictional boundaries.

Figure 9.
Coal Creek Watershed Land Cover/Tree Canopy.



Legend

- Watershed (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- Highway (City of Bellevue 2020)

Landcover Class

(City of Bellevue 2020)

- Bare Soil Dry Vegetation
- Impervious
- Non-Canopy Vegetation
- Tree Canopy
- Scrub/Shrub
- Water

Note: Open Stream Conditions Assessment Database (OSCA).

N

0 1,750 3,500 Feet

King County Aerial (2019)

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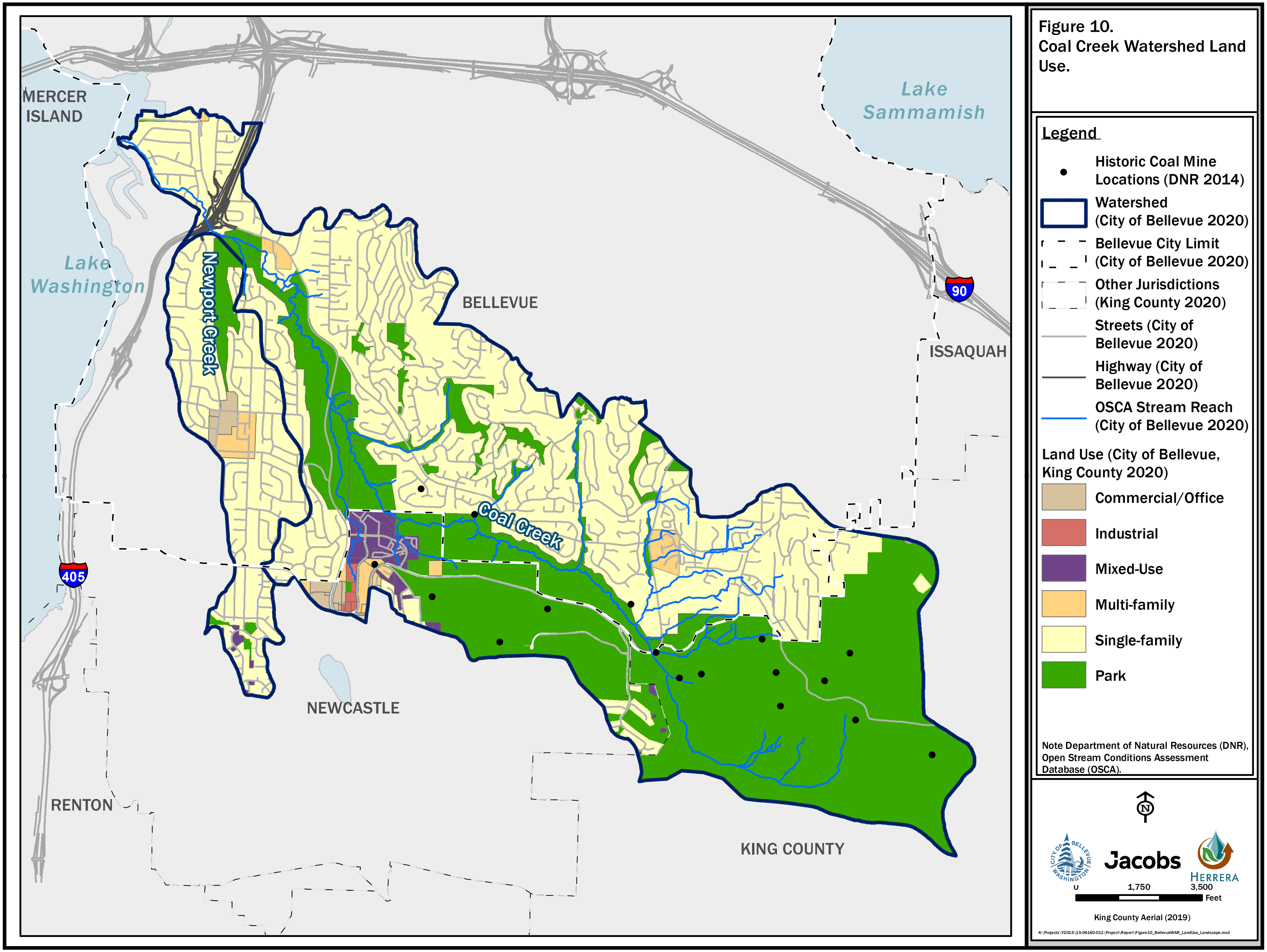


Figure 10.
Coal Creek Watershed Land Use.

2.2.2 Stormwater Infrastructure

Stormwater infrastructure can provide the following functions in a watershed:

- Effectively convey stormwater to a nearby water body to prevent flooding.
- Promote natural hydrologic processes that occurred prior to urbanization such as infiltration, filtration, storage, evaporation (on-site stormwater management or low impact development).
- Reduce the peak flow rate and volume of stormwater that is delivered to a water body (flow control).
- Remove pollutants from stormwater (runoff treatment).

Hence, stormwater infrastructure is extremely important for mitigating the impacts to streams from urbanization that are described in the conceptual model (Figure 2).

Stormwater infrastructure in developed areas of the Coal Creek Watershed is primarily comprised of formal curb and gutter conveyance with some areas drained by roadside ditches. Runoff from impervious surfaces is collected and discharged through numerous pipes, ditches, culverts, and outfalls along Coal Creek, Newport Creek, and their tributaries, as shown in Figure 11. Less common open drainage ditches are also mapped along roads within the watershed (such as Lakemont Boulevard Southeast).

The age of development has a significant influence on the amount and types of infrastructure present for managing stormwater, especially on-site stormwater management, flow control, and runoff treatment. In general, older development was either built with no stormwater infrastructure or facilities that do not meet current standards. To evaluate the adequacy of stormwater management in the Coal Creek Watershed, the age of development was used to classify specific areas into one of five categories that indicate when requirements for improved stormwater management infrastructure became effective in the City (Table 4). Some portions of the watershed were developed under King County stormwater management rules prior to annexation by the City. King County rules were similar but not identical to the City's.

These are generalized categories representing the relative age of development for both the City and King County regulations centered on changes to City regulations (a significant portion of the Coal Creek Watershed was first developed under King County stormwater management requirements). Regulations established by both the City and King County typically must meet minimum requirements established by the Washington State Department of Ecology (Ecology). This information will be used to rate the relative degree of flow control and water quality treatment within the watershed as well as to ascertain where stormwater retrofits may be useful. Note that treatment of stormwater runoff was not required in the City until 2010. This means that water quality treatment facilities were not required for approximately 97 percent of the current *developed* area in the Bellevue portion of the Coal Creek Watershed, including road projects.

As shown in Figure 12, areas with different ages of development are concentrated in different portions of the watershed. For example, older development constructed before 1975 with no stormwater management infrastructure is concentrated in the lower portion of the watershed and along Newport Creek; this portion represents approximately 19.3 percent of the total watershed area (Table 4). More recent development (1975 to 1987) with some stormwater management infrastructure is clustered in the middle of the watershed (10.2 percent of the total watershed area), whereas the newest development (1988 to present) is clustered in the upper portions of the watershed along tributaries to Coal Creek (11.6 percent of the total watershed area). The distribution of stormwater management infrastructure reflects the advent of these requirements with highest density of individual facilities (i.e., wet vaults, wet ponds, dry ponds, detention pipes, and detention vaults) located in areas with the newest development (Figure 13).

The effectiveness of these stormwater facilities in protecting the stream from the negative effects of stormwater runoff from impervious areas is an inverse of their age; the older the facility, the less effective. Facilities designed and built in the mid-1970s though the mid-1990s provide little or no benefit to the stream in terms of flow control to protect from stream erosion and other negative effects of runoff. Those designs have been found to be inadequate for stream protection purposes. These facilities plus those areas that developed prior to any stormwater control requirements, make up approximately 86 percent of the current *developed* area in the Bellevue portion of the watershed.

Notable stormwater infrastructure that provides direct benefits to streamside property owners are three “regional“ facilities that are located in or adjacent to the Coal Creek main channel (Figure 13 and Figure 27):

- I-405 Regional Detention/Sedimentation Facility
- Lower Coal Creek Off-Channel Sediment Pond (Anna’s Pond)
- Coal Creek Parkway Sedimentation facility

All three of these facilities capture transported sediment prior to reaching the creek delta. Sediment is removed from these facilities by City crews on a regular basis.

Table 4. Development Age Categories, Stormwater Management Requirements in the Coal Creek Watershed (Bellevue portion).

Category	Stormwater Management Requirements	Percentage of Coal Creek Watershed within Bellevue
2017-Current	The 2017 Surface Water Engineering Standards updated the On-site Stormwater Management requirements (List #1, List #2, or LID Performance Standard) and adopted the 2012/14 Department of Ecology Stormwater Management Manual for Western Washington.	0.3
2010-2016	The 2010 Surface Water Engineering Standards added water quality requirements, flow control requirements, and continuous modeling per the 2005 Department of Ecology Stormwater Management Manual for Western Washington. On-site Stormwater Management was also included either applying default LID credits or deriving LID credits with demonstrative modeling.	0.9
1996-2009	Bellevue adopts the Department of Ecology's1992 Stormwater Management Manual for the Puget Sound Basin (Technical Manual) ▪ 2-year peak develop flow matches 50% of 2-year pre-developed flow ▪ 10-year peak developed flow matches 10-year pre-developed flow ▪ 100-year peak developed flow matches 100-year pre-developed flow ▪ Unit-hydrograph method required for detention sizing ▪ 1.18 to 1.5 safety factor required for pond sizing dependent on percent impervious area	4.7
1988-1995	Bellevue introduces Large Site stormwater controls for sites serving more than 5 acres and within ¼-mile of a stream (large subdivisions developed in the Coal Creek Watershed during this time). ▪ 10-year peak developed flow matches the 2-year peak pre-developed flow (using computer modeling), 24-hour event ▪ 100-year peak developed flow matches the10-year peak pre-developed flow (using computer modeling), 24-hour event A 30% increase in detention volumes for the Cookbook Method was adopted for all other sites.	5.7
1975-1987	The first set of Storm and Surface Water Utility Engineering Standards (published in 1975) focused on detention that could store the difference in runoff volume between the post-development 100 year, 4 hour storm and the pre-development 10 year, 4-hour event. To meet this requirement, a maximum allowable release rate of 0.2 cfs per acre and a storage requirement of 1.0 inch per impervious acre and 0.5 inch per pervious acre were required (Also known as the "Cookbook Method").	10.2
Prior to 1975	No stormwater management required.	19.3

cfs: cubic feet per second

LID: low impact development
Sources: Tetra Tech. *et al.*, 2006 and Bellevue 1994, 2015

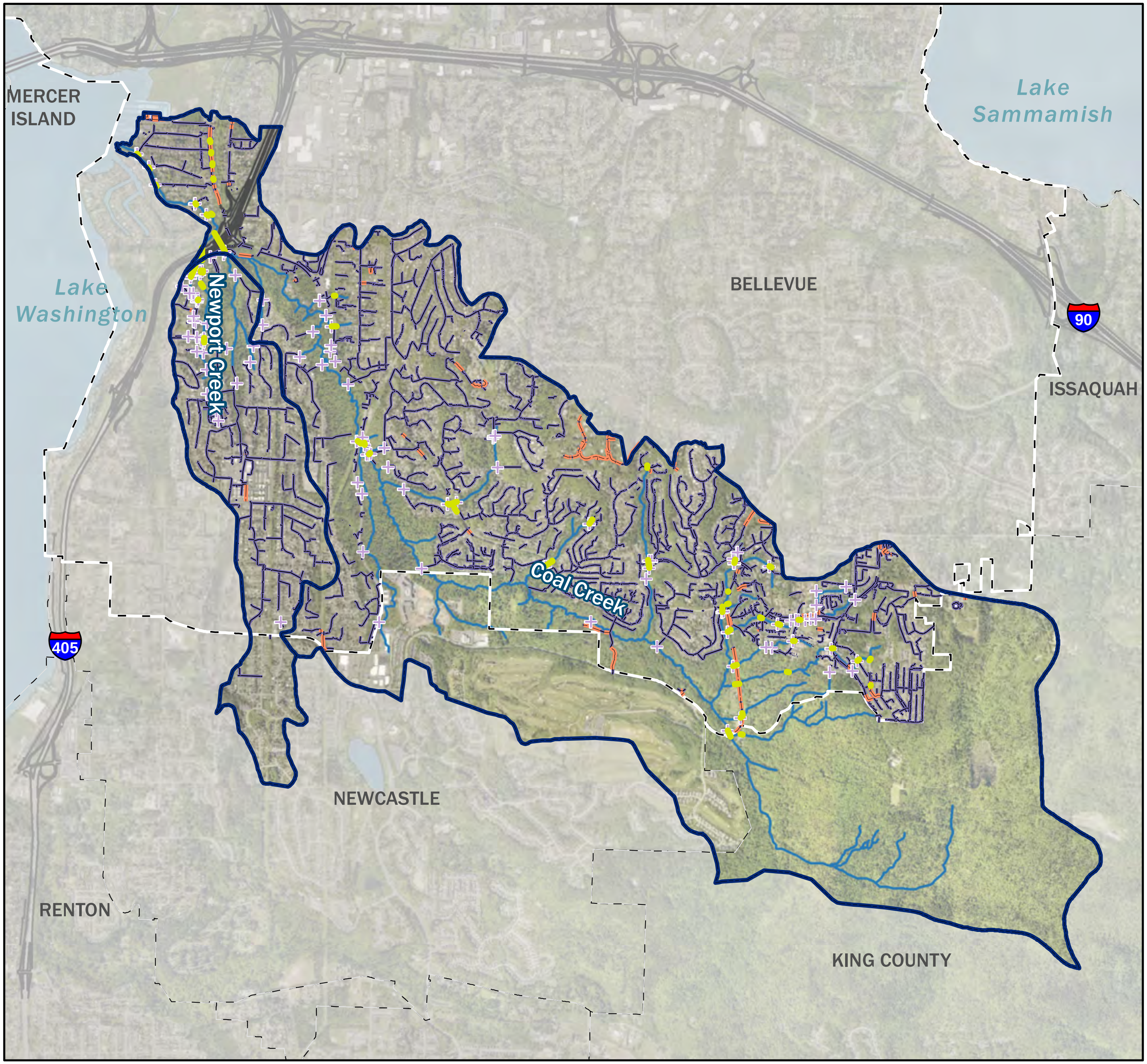


Figure 11. Coal Creek Watershed Stormwater Conveyance Network.

Legend

- Watershed (City of Bellevue 2020)
- Culverts (City of Bellevue 2020)
- Outfall to Stream (City of Bellevue 2020)
- Stormwater Conveyance Ditch (City of Bellevue 2020)
- Stormwater Conveyance Pipe (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- OSCA Stream Reaches (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Note: Open Stream Conditions Assessment Database (OSCA).

0 1,750 3,500 Feet

King County Aerial (2019)

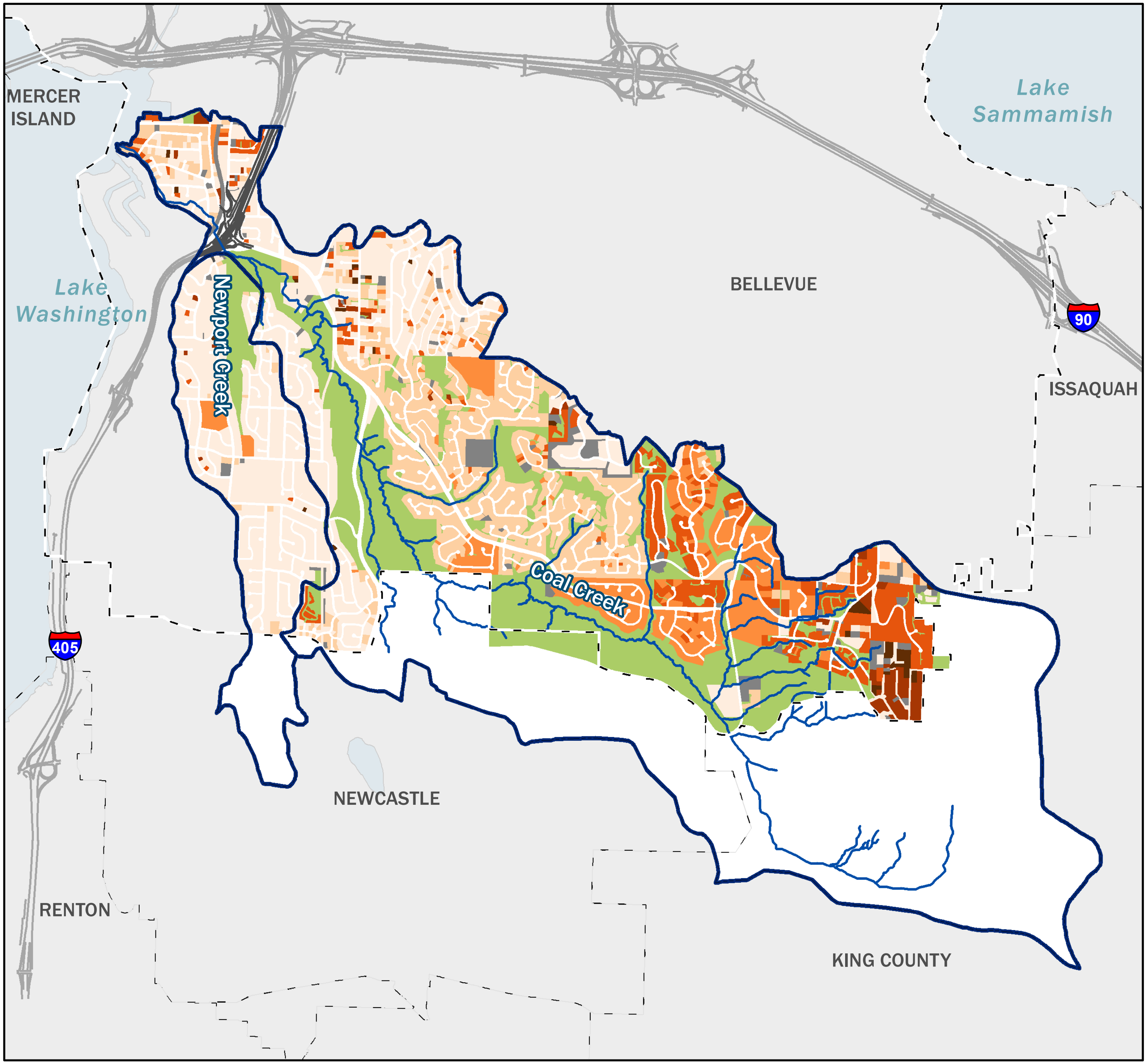


Figure 12. Age of Development in the Coal Creek Watershed within the Bellevue City Limits.

Legend

- Watershed (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue 2020)
- Other Jurisdictions (King County 2020)
- OSCA Stream Reach (City of Bellevue 2020)
- Highway (City of Bellevue 2020)

Age of Development Rating (City of Bellevue 2020)

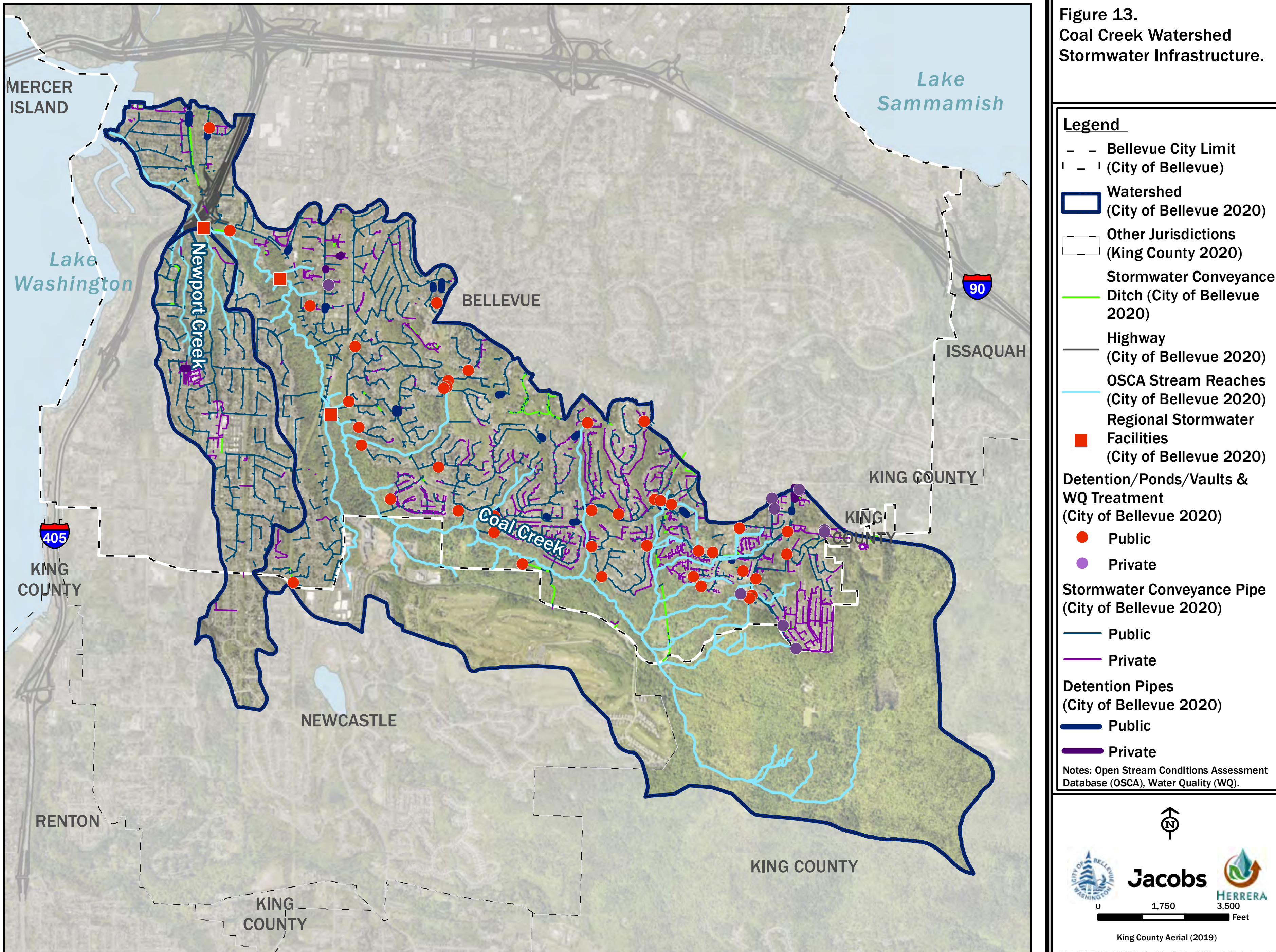
- 6 (2017-Current)
- 5 (2010-2016)
- 4 (1996-2009)
- 3 (1988-1995)
- 2 (1975-1987)
- 1 (1974 and earlier)
- Park, Open or Tract
- Vacant or Undeveloped

Note: Open Stream Conditions Assessment Database (OSCA).

0 1,750 3,500 Feet

King County Aerial (2019)

Figure 13.
Coal Creek Watershed
Stormwater Infrastructure.



2.3 Natural Systems

Existing conditions are summarized below for the following natural system attributes: stream flow, surface water quality, groundwater quality, instream habitat, and aquatic species.

2.3.1 Stream Flow

As a watershed urbanizes, natural vegetation and forest is replaced by impervious surfaces such as buildings, driveways, roadways, and other hard surfaces. These impervious surfaces cause rainfall to quickly flow toward local streams instead of infiltrating into the ground where it can slowly migrate to the stream via shallow interflow or groundwater flow. One consequence is that streamflow becomes increasingly "flashy" as their response to rainfall is more immediate when compared to a forested watershed. Commensurate with these changes to the hydrograph form are increases in peak flows within the stream and the duration of higher flows. As shown in Figure 2, hydrograph form and other related changes in streamflow characteristics can negatively impact stream habitat in several ways including decreased channel stability, increased channel erosion and/or aggradation, and decreased riparian connectivity. As described in Section 2.1.1 Climate, projected increases in extreme precipitation events will likely exacerbate these negative impacts.

Streamflow data are available from two stream gauges on Coal Creek that are or were operated and maintained by King County (2020a). Both gauges captured flows downstream of the confluence of Coal and Newport creeks and the cumulative flows of both creek systems. Gauge COB-CCF was established in January 2012 at a location approximately 500 meters upstream of where Coal Creek enters Lake Washington (Figure 4); it was deactivated in October 2019. Gauge COB-06C was established in October 2018 and is located approximately 280 meters upstream of Gauge COB-CCF. The combined data from both gauges are summarized in Figure 14. The resultant hydrograph from these data shows the characteristic flashy signal described above that is typical for streams in an urban setting.

To evaluate the effects of urbanization on the hydrology of Coal Creek, scores for the following stream hydrologic metrics were computed using data from both gauges for individual years having a complete dataset: High Pulse Count, High Pulse Range, Richards-Baker Flashiness Index (RBI), and TQ mean. Table 5 provides a definition for each stream hydrologic metric with their expected response to urbanization. Complete datasets were available for five years (2014, 2015, 2016, 2017, and 2019) from Gauge COB-CCF and one year (2019) from COB-06C.

The computed stream hydrologic metrics are summarized in Table 6 with a comparison to metrics obtained from a highly urbanized watershed and a forested watershed. The highly urbanized watershed is Tyler's Creek in the City of Redmond. The Tyler's Creek watershed has a drainage area of 168 acres with 35 percent of this area covered by impervious surfaces. This watershed is a control site for a long-term study of Redmond's watersheds (Herrera 2015). The forested watershed is Big Beef Creek in Kitsap County. The Big Beef Creek watershed has a drainage area of 8,649 acres with 2.7 precent of this area covered by impervious surfaces (Rosburg *et al.* 2017). It serves as the forested reference watershed for the Ecology Watershed Health Monitoring Program. For comparison, the Coal Creek Watershed has a drainage area of approximately 4,550 acres; 23 percent of this area is covered by impervious surfaces. To aid in the interpretation of these results, Table 6 also provides representative TQ mean values from Konrad *et al.* (2002) from watersheds categorized as urban (road density 9.1 to 11.3 kilometers per square kilometer [km/km^2]), suburban (road density 4.7 to 7.9 km/km^2), and rural (road density 2.1 to 2.6 km/km^2).

As shown in Table 6, scores computed for Coal Creek for all four metrics generally fell between those of Tyler's Creek and Big Beef Creek. The scores for Tyler's Creek and Big Beef Creek are generally consistent with the expected responses shown in Table 5 for watersheds that have more and less urbanization, respectively. The one exception were the scores for TQ mean where the median scores for Tyler's Creek and Big Beef Creek were relatively similar at 0.29 and 0.30, respectively. Collectively, these data generally suggest there is a moderate degree of hydrologic alteration in Coal Creek relative to these other creeks with highly urbanized and forested watersheds, respectively. However, comparisons of the median scores for TQ mean for all three creeks to those reported in Konrad *et al.* (2002) suggest hydrologic conditions in both Tyler's Creek and Big Beef Creek are consistent with conditions typical of creeks with more urban or suburban watersheds whereas the scores for Coal Creek are consistent with creeks with more suburban or rural watersheds.

There is also anecdotal evidence to suggest the hydrology of Coal Creek has been dramatically altered due to progressive urbanization in the watershed. Specifically, one long-term resident who frequently visited the creek for recreational purposes reported seeing dramatic increases in flows and sediment deposition following housing and commercial property construction in the watershed starting in the 1980's (K. Burton, personal communication, December 2020). This observation aligns with the supposition that the stormwater control facilities from that era do not provide adequate stream protection.

When considering potential sources of hydrologic impairment in Coal Creek, it is worth noting that analyses performed by Tetra Tech *et al.* (2006) showed the following four tributaries drain large areas of developed land within the associated watershed and make a substantial contribution to the flows in the mainstem: Tributaries 0275 (Newcastle), 0273 (Forest Hills), an unnamed tributary that enters the main stem just upstream of the Coal Creek Parkway crossing, and 0276A (Lakemont). For example, modeling results from these analyses indicate the average annual mainstem flow increases from 7.6 cubic feet per second (cfs) to 18.4 cfs immediately downstream of the confluence of Tributary 0273 (Forest Hills) at Coal Creek Parkway; this represents an increase from 45 percent of the total average annual flow to 88 percent. Similarly, modeling shows the predicted 100-year peak flow rate is 75 percent higher (103 cfs) on the mainstem of Coal Creek downstream of the confluence of Tributary 0276A (Lakemont) below Lakemont Boulevard. The areas that drain to these tributaries are prime targets for potential stormwater retrofit projects.

Table 5. Definitions for Hydrologic Metrics.

Component	Metric Name	Definition	Units	Expected Response to Urbanization
Frequency	High Pulse Count	Number of high pulse events per year. A high pulse event occurs when daily flow exceeds twice the water year average daily flow. A single event covers all consecutive days then this condition is met. Thus, consecutive high pulse days comprise a single event.	Count	Increase
Duration	High Pulse Range	Number of days between the first and last pulse event of the water year.	Days	Increase
Flashiness	Richards-Baker Index	An index of flow oscillations relative to total flow based on daily average discharge during the water year.	Unitless	Increase
Flashiness	TQ mean	The fraction of the time during the water year that the daily average flow rate is greater than the annual average flow.	Fraction of the year	Decrease

Table 6. Hydrologic Metric Scores from Coal Creek Compared to Scores from Other Watersheds and Literature Values.

Water Year	Watershed Type	High Pulse Count (number per year)	High Pulse Range (days)	Richards-Baker Flashiness Index	TQ Mean (fraction of the year)
Coal Creek: COB-O6C Station					
2019	Urban/Forested	13	179	0.32	0.35
Coal Creek: COB-CCF Station					
2019	Urban/Forested	4	136	0.30	0.37
2017	Urban/Forested	15	145	0.49	0.36
2016	Urban/Forested	9	234	0.26	0.33
2015	Urban/Forested	10	312	0.28	0.27
2014	Urban/Forested	6	113	0.35	0.28
Median (Range)	**Urban/Forested**	**9 (6 – 15)**	**145 (113 – 312)**	**0.30 (0.26 – 0.49)**	**0.33 (0.27 – 0.37)**
Tyler ' s Creek: TYLMO Station					
2019	Urbanized	16	317	0.57	0.30
2018	Urbanized	27	243	0.57	0.30
2017	Urbanized	33	221	0.76	0.28
2016	Urbanized	30	326	0.82	0.24
Median (Range)	**Urbanized**	**29 (16 – 33)**	**280 (221 – 326)**	**0.67 (0.57 – 082)**	**0.29 (0.24 – 0.30)**
Big Beef					
2019	Forested	5	57	0.23	0.24
2018	Forested	9	174	0.20	0.30
2017	Forested	12	140	0.24	0.39
2016	Forested	4	109	0.23	0.30
2015	Forested	6	135	0.23	0.33
2014	Forested	7	113	0.18	0.30
Median	**Forested**	**7 (4 – 12)**	**124 (57 – 174)**	**0.23 (0.18 – 0.24)**	**0.30 (0.24 – 0.39)**
Konrad et al., 2002					
Medan (Range)	**Urban**	**ND**	**ND**	**ND**	**0.29 (0.25 – 0.30)**

Water Year	Watershed Type	High Pulse Count (number per year)	High Pulse Range (days)	Richards-Baker Flashiness Index	TQ Mean (fraction of the year)
Medan (Range)	**Suburban**	**ND**	**ND**	**ND**	**0.33** **(0.31 – 0.39)**
Medan (Range)	**Rural**	**ND**	**ND**	**ND**	**0.35** **(0.27 – 0.35)**

ND – No data for this metric

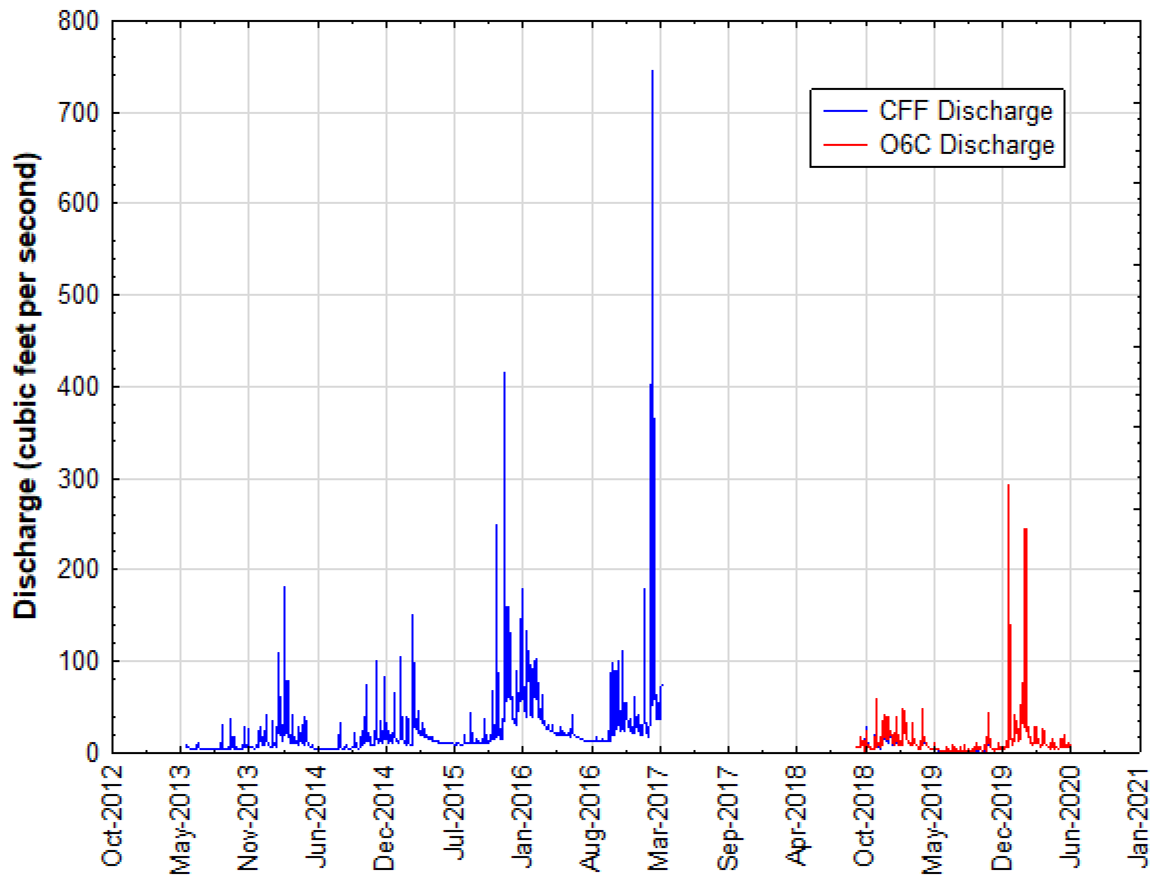


Figure 14. Coal Creek Hydrograph from Stations COB-CFF and COB-O6C.

2.3.2 Surface Water Quality

Untreated stormwater runoff from impervious surfaces is a primary cause of pollutant transport to surface waters (Figure 2). As described above, the vast majority of the Coal Creek Watershed was developed prior to the requirement for water quality treatment; hence, most runoff that enters Coal Creek is untreated. Common pollutants from urbanized areas that are detrimental to aquatic health include nutrients (i.e., nitrogen and phosphorus), heavy metals (i.e., Pb, Zn, Cu, Cd), organics (e.g., petroleum hydrocarbons), pathogens, suspended solids, and salts. Many of these pollutants can cause acute toxicity in fish and other aquatic organisms. Runoff from warm impervious surfaces during the summer and early fall can raise stream temperatures causing a host of negative impacts to streams from altering the benthic invertebrate community to the making it difficult for native salmonids to thrive.

Recent studies have shown a compound found in automobile tires is responsible for Coho Salmon (*Oncorhynchus kisutch*) mortality in urban creeks (Tian *et al.* 2020). Pollutants can also cause chronic toxicity that may be directly lethal or produce sublethal effects such as decreased growth, reduced reproduction, or behavioral changes. In a study of streams in the Puget Sound lowlands, May *et al*. (1997) found concentrations of pollutants (primarily metals) were insufficient to produce these adverse effects during baseflow conditions and storm events in streams with a low to moderate percentage of effective impervious surfaces in their watersheds; however, the potential for these effects increases substantially in highly urbanized basins when effective impervious surfaces occupy greater than 45 percent of the total watershed area. For reference, impervious surfaces occupy approximately 23 percent of the total Coal Creek Watershed area.

Water quality data for the Coal Creek Watershed are available from sampling conducted by King County, the City, and Ecology. Water quality impairment is assessed herein based on the following data and information:

- Washington State Department of Ecology’s 303(d) list
- Water Quality Index (WQI) scores that were computed by King County
- Legacy coal mining activity in the watershed

2.3.2.1 Stream Water Quality Impairments

Section 303(d) of the Clean Water Act requires Ecology to assess water bodies in Washington State to determine if their quality is adequate to fully support designated beneficial uses (such as for drinking, recreation, aquatic habitat, and industrial use). The assessed water bodies are placed into one of five categories on the 303(d) list based on their water quality status. Water bodies that are not supporting beneficial uses are placed in the polluted water category (Category 5) and prioritized for water cleanup plans. The most recent assessment for the 303(d) list was completed in 2012.

Three segments of Coal Creek are identified as Category 5 water bodies on the 303(d) list due to low dissolved oxygen concentrations or bioassessment scores. As shown in Table 7, the mainstem (from 119th Avenue Southeast to headwaters) of Coal Creek was placed on the 303(d) list because dissolved oxygen concentrations did not meet water quality standards for Washington State (WAC 173-201A). The data are from 2004 to 2008; thus, they may not be representative of current conditions. Nevertheless, adequate concentrations of dissolved oxygen are essential to support aquatic life. Low dissolved oxygen can be caused by several factors including excessive algae growth caused by phosphorus that is carried into streams from human sources. As the algae die and decompose, the process consumes dissolved oxygen. The loss of shade providing riparian canopy cover may also contribute to low dissolved oxygen because high water temperatures reduce the holding capacity of water for this parameter. The listing for dissolved oxygen in Coal Creek was derived based on monitoring conducted over the period from 2002 through

2008. As described in the next subsection, more recent data collected by King County do not indicate dissolve oxygen concentrations are at levels that warrant concern.

The bioassessment score is assessed using Benthic Index of Biotic Integrity (B-IBI) scores that are calculated from samples of benthic macroinvertebrates. These scores provide a broad indication of stream health that integrates potential impairment from multiple sources (e.g., poor water quality and/or physical habitat). As shown in Table 7, two segments of Coal Creek were placed on the 303(d) list due to biotic impairment because B-IBI scores indicate stream health conditions are poor (see additional details in Section 2.3.6 Aquatic Species). The data are from 2006 to 2010; thus, they may not be representative of current conditions. One segment is located on the mainstem of Coal Creek extending from 119th Avenue Southeast to its headwaters. The other segment extends the entire length of Tributary 0273 (Forest Hills). No segments of Newport Creek are identified as impaired on the 303(d) list.

2.3.2.2 Water Quality Index

The WQI is computed using data from the following parameters: fecal coliform bacteria, dissolved oxygen, pH, total suspended solids, temperature, turbidity, total phosphorus, and total nitrogen. It provides a broad assessment of water quality that can be used to categorize waters in terms of the 'level of concern' for potential impairment. In general, stations scoring 80 and above are meeting water quality standards or guidelines and are of "low concern", scores 40 to 80 indicate "moderate concern", and scores below 40 are of "high concern."

While the WQI provides an easy method for categorizing water quality and for comparing between water bodies, like all indices it has weaknesses. For example, a parameter that has a high degree of variability, such as fecal coliform bacteria, can easily skew the results based on one or a few high values. The WQI also does not provide any evidence for why a water body may be rated low. For this reason, it continues to be important to evaluate the individual parameters that comprise the WQI. Finally, it should be noted that sampling conducted by King County to obtain data for computing WQI scores has not explicitly targeted storm events. Hence, the scores may underestimate the true level of impairment from parameters that are commonly associated with stormwater runoff.

King County (2020b) computed WQI scores based on data from monthly grab samples that were collected at Site 0442 on Coal Creek over the period from 1972 to 2008 and 2014 to 2018. This station is located upstream of both I-405 and the confluence with Newport Creek (Figure 4); hence, results from this sampling do not reflect potential influences on water quality from pollutants that are associated with these potential sources. Each monthly grab sample was analyzed for the suite of parameters used to calculate WQI scores.

Average annual WQI scores from this station are shown in Figure 15 for the period extending from 2000 through 2018. The median value from these data (65) generally indicates water quality is a "moderate concern" in Coal Creek. As shown in Table 8, high fecal coliform bacteria concentrations (with a median WQI score of 58 over the 2008 to 2018 time period) were the primary factor driving the moderate score for the stream; all other parameters generally scored very near or just above 80. Sources of fecal coliform bacteria in urban streams include pet waste, homeless encampments, cross connections between sewer and stormwater conveyance systems, and urban wildlife.

In connection with Ecology's Stormwater Action Monitoring (SAM) program, data for computing WQI index scores were collected from 52 sites in streams located in the Puget Lowland ecoregion from January to December 2015; 24 of these sites were located in streams outside the urban growth area (UGA) in more rural settings while 28 of these sites were located in streams within the UGA in more urban settings. These data provide a good frame of reference for comparing the scores from Coal Creek to scores from other streams in the region. As reported in DeGasperi *et al.* (2018), a greater proportion of stream length outside the UGA was in good condition (67 percent) relative to streams within the UGA (43 percent). Median annual WQI scores for streams within and outside the UGA were 75.3 and 86.9, respectively. These data suggest water quality in Coal Creek is moderately low relative to conditions in comparable streams located within the UGA from this study.

2.3.2.3 Legacy Coal Mining

As described above, coal mining was prevalent in significant portions of the Coal Creek Watershed. As a result of these mining operations, numerous deposits of mine tailings, seeps, and remnant mining infrastructure (e.g., coal flumes) are present along the banks of Coal Creek that could be impacting water quality. Potential impacts from these features include discharges of highly acidic water containing heavy metals (arsenic, copper, and lead) and orange deposits of ferric hydroxide in the stream channel. Through the OSCA surveys, ferric hydroxide deposits have been documented on the stream channel in several reaches that are likely related to these features (Figure 16, Appendix B). As shown in Figure 17, seeps have been identified in reaches where coal mining activity was both prevalent and absent. A sediment sample collected through the Stormwater Action Monitoring (SAM) program in 2015 from Coal Creek also had a sediment arsenic concentration (35.9 milligrams per kilogram) but was less than the Sediment Screening Level (DeGasperi *et al.* 2018). It is not known if this arsenic is naturally occurring or directly related to the coal mining features. Finally, while low pH does not appear to be an issue in the Creek based on the data presented in Table 7 from the WQI scores, other potential water quality impacts (e.g., discharges of heavy metals) from historic coal mining operations would not be directly reflected in these data.

Table 7. Category 5 Segments of Coal Creek on the 303(d) List.

Parameter	Listing ID	Period Collection for Listing Data	Location
Dissolved Oxygen	12668	2004 - 2008	Mainstem Coal Creek - 119th Avenue SE to headwaters
Bioassessment	70191	2006 - 2010	Mainstem Coal Creek - 119th Avenue SE to headwaters
Bioassessment	70090	2007-2010	Tributary 0273 (Forest Hills)

Table 8. Water Quality Index Scores by Year and Parameter for Site 0442 on Coal Creek.

Year	WQI Score	WQ concern	Fecal Coliform	DO	pH	TSS	Temperature	Turbidity	TP	TN
2018	78	Moderate	73	81	83	90	79	87	80	95
2017	57	Moderate	66	85	85	58	83	59	52	85
2016	50	Moderate	63	86	84	52	83	53	44	64
2015	64	Moderate	60	79	83	77	79	80	81	74
2014	43	Moderate	49	74	83	69	73	69	67	82
2013	NA	NA	--	--	--	--	--	--	--	--
2012	NA	NA	--	--	--	--	--	--	--	--
2011	NA	NA	--	--	--	--	--	--	--	--
2010	NA	NA	--	--	--	--	--	--	--	--
2009	NA	NA	--	--	--	--	--	--	--	--
2008	71	Moderate	72	76	83	79	78	74	90	83
2007	70	Moderate	60	74	80	92	82	84	81	69
2006	66	Moderate	52	77	77	98	85	90	87	76
2005	75	Moderate	64	83	83	97	79	90	83	92
2004	52	Moderate	35	83	88	90	79	84	83	76
2003	71	Moderate	56	79	86	94	83	88	85	71
2002	67	Moderate	52	77	88	93	78	84	88	64
2001	57	Moderate	39	83	83	83	85	83	84	84
2000	47	Moderate	44	78	81	66	80	75	76	57
Median	65		58	79	83	86.5	79.5	83.5	82	76

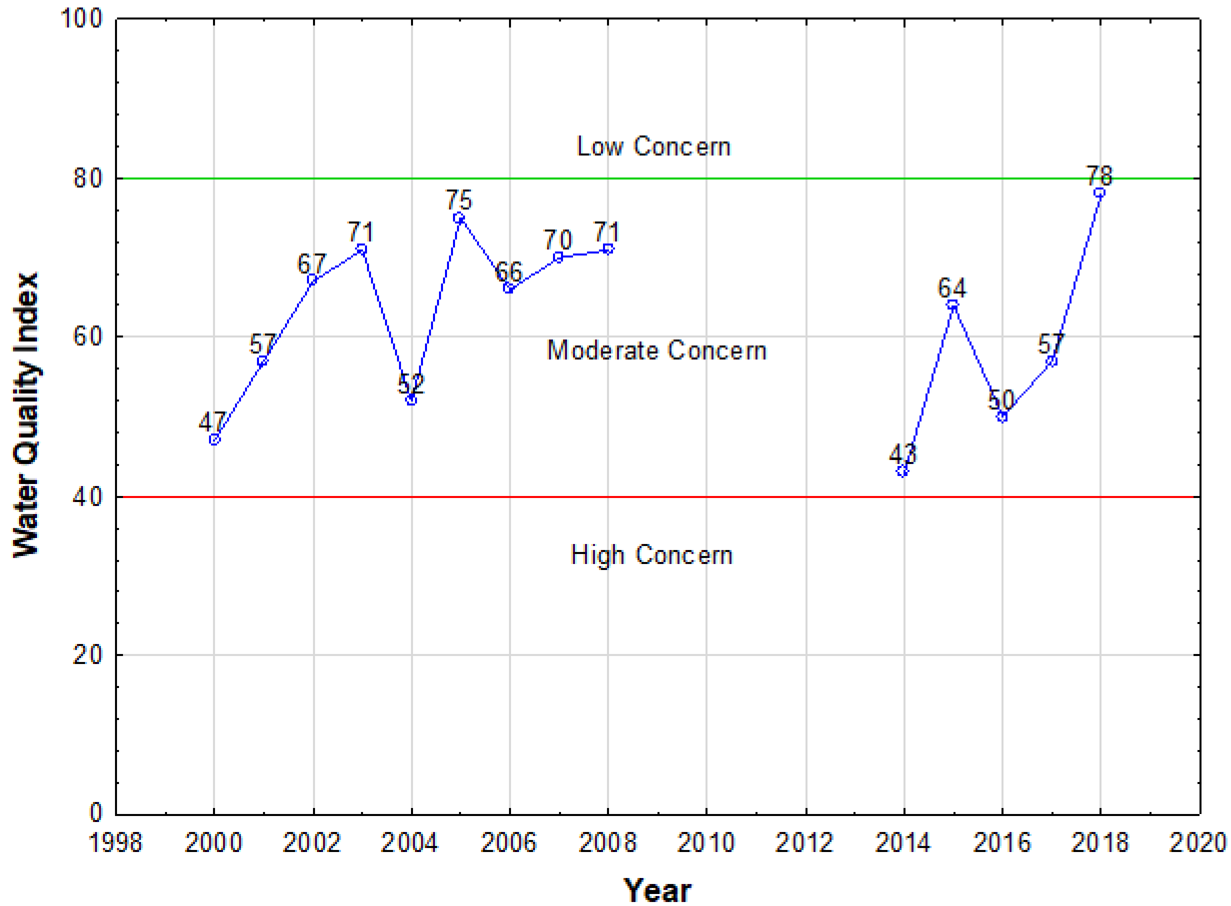


Figure 15. Water Quality Index Scores for Site 0442 on Coal Creek.

Figure 16. Ferric hydroxide (or iron oxide) deposits observed in Reach 10 of the Coal Creek mainstem..

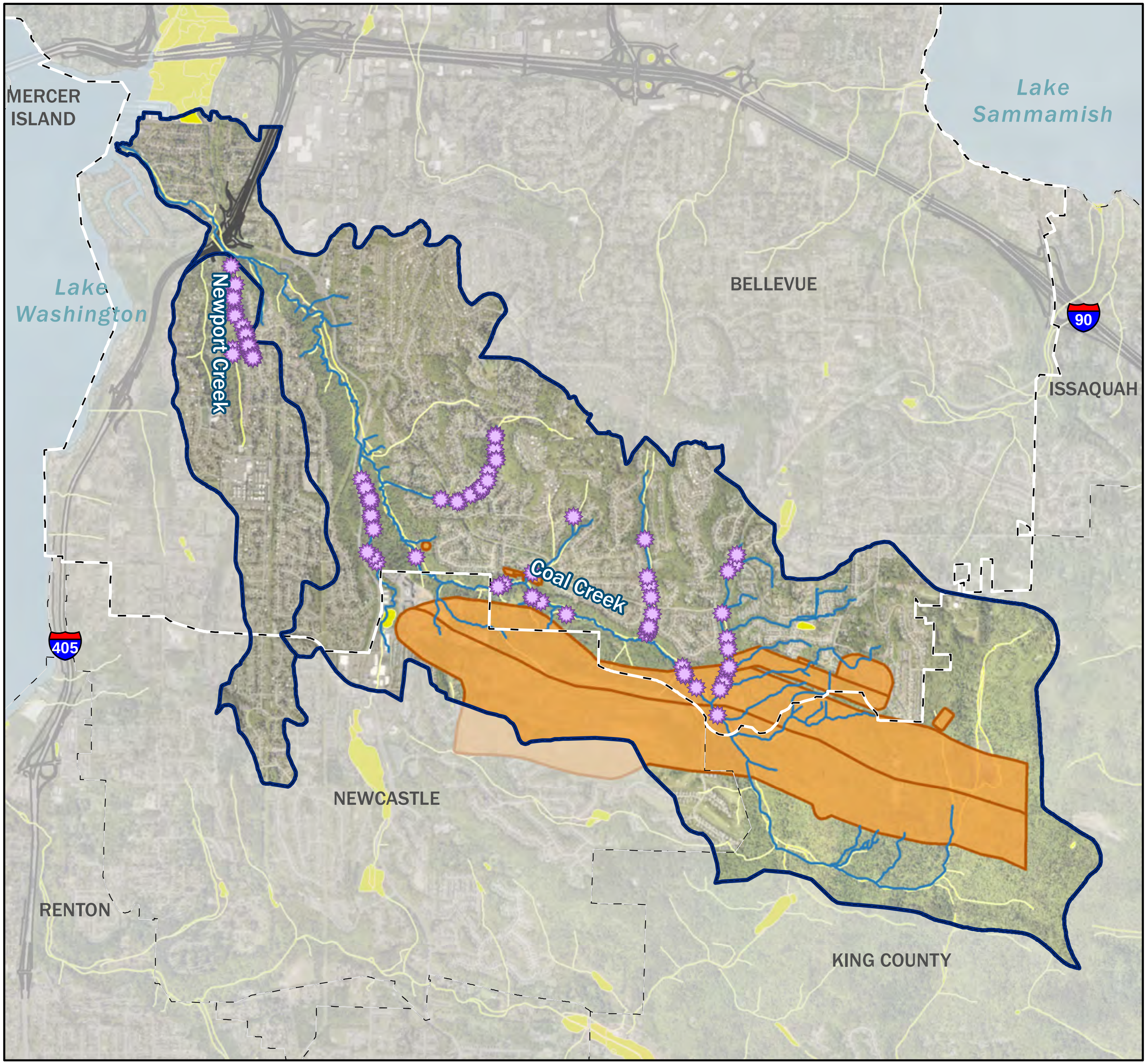


Figure 17.
Coal Creek Watershed
Observed Seep Locations.

Legend

- OSCA Observed Seep Location (City of Bellevue 2020)
- Watershed (City of Bellevue 2020)
- Bellevue City Limit (City of Bellevue)
- Other Jurisdictions (King County 2020)
- Coal Zone (City of Bellevue)
- NWI Wetlands (NWI 2020)
- Highway (City of Bellevue 2020)
- OSCA Stream Reaches (City of Bellevue 2020)

Note: National Wetland Inventory (NWI), Open Stream Conditions Assessment Database (OSCA).

N

Jacobs HERRERA

0 1,750 3,500 Feet

King County Aerial (2019)

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2.3.3 Groundwater Quality

The Coal Creek Watershed has no Group A City drinking water wells and wellhead protection areas. There are also no active hazardous waste sites that might pose a threat to groundwater quality in the watershed based upon the Washington State Department of Ecology Site Hazard List most recently published July 1, 2020. No data were found to assess the quality of the groundwater in the Coal Creek Watershed. As noted in the previous subsection, numerous seeps have also been identified in reaches where coal mining activity was both prevalent and absent (Figure 17). No data were found to evaluate the potential water quality impacts from these seeps where they are present in areas with coal mining activity.

2.3.4 Riparian Corridor

Riparian corridors are complex ecological systems located at the land-water interface adjacent to streams, rivers, lakes, ponds, and wetlands. Riparian corridors serve important functions related to nutrient cycling, soil and bank stabilization, soil and water chemistry and quality, and provide both terrestrial and aquatic habitat. As described in the conceptual model (Figure 2), reductions in riparian corridor width and loss of riparian vegetation due to urbanization is associated with decreased stream wood inputs, decreased riparian habitat, and increased bank instability and stream temperatures.

Tree canopy in the riparian corridor of Coal Creek was assessed based on land cover data from 2013 and 2017, representing the area within 100 feet on both sides of the stream (Bellevue 2018). Within this area, tree canopy cover in the majority of reaches ranged from 84 percent to 100 percent, with one reach (Coal Creek Reach 1) at 39 percent. As these data indicate, the Coal Creek Watershed has excellent riparian canopy cover, in large part because much of the mainstem channel corridor (upstream of Reach 3) lies within the Coal Creek Natural Area and the King County Cougar Mountain Region Wildland Park. Although the width and quality of the riparian corridor adjacent to reaches 1 through 3 is severely impacted by development, the riparian corridor and canopy cover in the overall Coal Creek Watershed is the highest quality observed in the City of Bellevue.

Large woody material (LWM) are pieces of wood (fallen trees, logs, and branches) that are at least 4 inches wide and 6 feet long. LWM plays a critical role in many Washington streams through its influence on aquatic habitat and stream geomorphic processes. The diverse habitat formed in association with LWM is used as basking and perching sites for reptiles and birds, and as cover and refuge for fish and other aquatic organisms.

Although tree canopy cover is good, forest managers from Bellevue's Parks department are investigating species diversity and forest succession throughout the Coal Creek riparian corridor through ongoing monitoring efforts. Data from these efforts have generally shown that cover in the riparian corridor is provided primarily by deciduous species, such as Black Cottonwood (*Populus trichocarpa*), Red Alder (*Alnus rubra*), and Bigleaf Maple (*Acer macrophyllum*) (Bellevue 2006). Further, the City's forest managers have encountered challenges with attempts to improve upon forest succession and develop mature coniferous canopy. Increased coniferous species and riparian diversity are needed to reduce the extents of invasive and noxious vegetation, to maintain a sustainable forest canopy, and provide longer-lasting large woody material (LWM).

Several invasive plant species are prevalent within the riparian corridor along Coal Creek and its tributaries, including Himalayan blackberry (*Rubus armeniacus*), English ivy (*Hedera helix*), and bindweed (*Convolvulus arvensis*), as the most frequently encountered. Japanese knotweed (*Polygonum cuspidatum*), a King County Class B noxious weed, was recently identified in two isolated areas (Bellevue 2020b). Immediate control is recommended to prevent its spread.

2.3.5 Instream Habitat

Instream habitat conditions for Coal Creek and its significant tributaries (including Newport Creek, Newcastle Creek, and Tributaries 0273, 0274, 0276, and 0276A; Figure 4) were assessed by the City during the summer and fall of 2018 and spring of 2019 as part of the citywide OSCA surveys (Bellevue 2020b). The OSCA surveys followed the US Forest Service Region 6 Level II Stream Inventory Protocol (USFS 2012), with some minor modifications as described in Appendix B. All surveys were performed during low or base stream flows and included assessment of channel morphology and riparian corridor conditions, instream and off-channel habitat composition, LWM, substrate composition, streambank conditions, aquatic habitat conditions and fish passage barriers, as well as identification of potential opportunities that could improve instream habitat conditions. The data presented here are summarized at the watershed level. Stream- or subbasin-level summaries can be found in Appendix B, and detailed stream reach-level summaries can be found in the Coal Creek Watershed OSCA Report (Bellevue 2021). Habitat and substrate composition data presented below do not include Tributaries 0274, 0276, 0276A, or the upper half of Tributary 0273 because these smaller tributaries were surveyed under a reduced protocol.

2.3.5.1 Channel Morphology

The Coal Creek Watershed consists of numerous tributaries of varying sizes that feed into one mainstem channel, Coal Creek. The tributaries and the upper portion of the mainstem are generally valley confined with a moderate to high gradient, whereas the valley floor widens and the channel gradient lessens in the downstream direction through the middle and lower reaches of Coal Creek. The mainstem is primarily composed of pool-riffle and plane-bed channel types. In general, the Coal Creek Watershed has excellent riparian cover (see Section 2.3.4 Riparian Corridor). Although the lower reaches of the Coal Creek mainstem and some of the tributaries are impacted by residential development, much of the mainstem channel corridor lies within the Coal Creek Natural Area. The riparian buffer width and canopy cover in the Coal Creek Watershed is the highest quality observed in the City of Bellevue.

2.3.5.2 Habitat Unit Composition and Off-Channel Habitat

Streams in the Coal Creek Watershed are predominantly composed of riffle, or fast water, habitat. The tributaries to Coal Creek generally have greater than 90 percent riffle habitat by area, but the mainstem provides greater habitat diversity with 52 percent riffle, 20 percent pool, and 13 percent glide habitat (Figures 18 and 19). Across the watershed, the ratio of the area of riffles to pools is 3.3. Although a ratio of approximately one is considered ideal for juvenile salmonid productivity (Naman *et al*. 2018), the riffle to pool ratio observed in the Coal Creek Watershed is second only to that of the Kelsey Creek Watershed within the City of Bellevue. Pool habitat within the Coal Creek Watershed is primarily restricted to the mainstem of Coal Creek and in the downstream-most reach of both Newport Creek and Newcastle Creek. Within these reaches, pool habitat is neither as abundant nor as deep as expected from “properly functioning” streams (NOAA 1996), indicating that a lack of pool habitat may be a limiting factor for healthy fish populations.

Off-channel habitat is limited in the Coal Creek Watershed. There are only a few instances of side channels in the mainstem of Coal Creek and in lower Newport Creek and Newcastle Creek, but valley confinement and residential development restrict channel migration and a natural floodplain despite the low frequency of bank armoring. Coal Creek Reach 3 (upstream of I-405) is the most dynamic reach, having good floodplain connectivity and access to a wide channel migration zone.

2.3.5.3 Large Woody Material

The Coal Creek Watershed has the highest frequency of stream-associated LWM in the City. The average wood frequency for the watershed is 476 pieces/mile (30 pieces/100 m), which is just slightly below the median LWM frequency for similarly sized reference streams (Fox and Bolton 2007). However, the LWM distribution is not equal throughout the watershed (Figure 20). Most of the Coal Creek mainstem, lower Newport Creek, and Newcastle Creek have excellent LWM levels at or exceeding the reference median value, while the smaller tributaries and mainstem Reaches 1, 4, and 6 have low LWM levels falling below the reference 25th percentile. Of the LWM observed throughout the watershed, 83 percent is presumed to be of natural origin and 17 percent was placed. The mainstem of Coal Creek and lower Newport Creek host the greatest abundance of placed wood in the watershed. The excellent riparian canopy found throughout much of the watershed provides the opportunity for natural LWM recruitment. Unfortunately, the reaches with the lowest LWM frequency have a correspondingly low riparian canopy, so natural recruitment potential is limited in areas where it is most needed. Wood recruitment into Reach 1 from upstream reaches is restricted by the I-405 trash rack.

2.3.5.4 Substrate Conditions

Streambed substrate composition in the Coal Creek Watershed is predominantly gravel and cobbles (Figure 21). Fines make up 20 percent of the substrate, which is lower than that observed in most other Bellevue streams. A high percentage of fines is associated with some stormwater outfalls and in upstream source/transport reaches where coal mining impacts remain. Overall, the substrate present in the Coal Creek Watershed is suitable for salmonid spawning, incubation, and rearing. Throughout the watershed, there are portions of exposed bedrock or glacial till accounting for about 3 percent of the total stream substrate composition.

2.3.5.5 Streambank Conditions

Streambank armoring is minimal in the Coal Creek Watershed compared to other basins within the City, in large part due to the riparian corridors that help buffer the streams from local impacts of development. Throughout the watershed, 7 percent of the streambank is armored and nearly a quarter of that armoring consists of bioengineering. The streambank armoring is almost exclusively found in the mainstem of Coal Creek and Newport Creek (Figure 22), both of which have been the focus of bank stabilization efforts. Additionally, much of the armoring in the lower Coal Creek mainstem is associated with residential properties.

Streambank instability is moderately high in the Coal Creek Watershed. Across the watershed, 19 percent of the streambanks are experiencing erosion, which is greater than that observed in 75 percent of subbasins within the City. Within the watershed, erosion ranges from 6 percent to 30 percent of the streambank (Figure 23). Although some of this bank erosion is expected at meander bends or where toe scour occurs along the water line in alluvial riffle-pool channel types (Montgomery and Buffington 1997), much of the erosion observed in the Coal Creek Watershed is indicative of the channel adjusting to hydrologic and other watershed-scale changes. There is evidence of landslides and mass-wasting events along the mainstem of Coal Creek and in some of the tributaries. Channel incision is occasionally pronounced, especially in some of the steeper tributaries, indicating that the streams are still adjusting and being impacted by flashy stormwater runoff. Throughout the watershed, 8 percent of the streambanks are undercut, with a higher percentage of undercut banks in the mainstem. Coal Creek Reach 3 is notable for having areas of undercut but stable banks where toe scour occurs only along the waterline, providing good fish habitat.

2.3.5.6 Fish Habitat and Passage Barriers

The best fish habitat in the watershed is located in the lower portion of the Coal Creek mainstem. Anadromous fish use is inversely related to channel gradient, and relevant regional studies suggest that gradients of 5 to 7 percent may represent a threshold for some Pacific salmon (Burett *et al.* 2007; Seixas *et al.* 2019). Mainstem Reaches 6, 9, and 11 and most of the tributaries have slopes greater than 6 percent. Therefore, Coal Creek Reaches 1 through 5 likely support the greatest anadromous fish habitat potential in Coal Creek, and juvenile salmonid rearing and late summer to early fall salmon migration are likely focused within Reaches 1 through 3 due to the shallow riffle and pool depths observed upstream. Reach 3 provides the best spawning habitat with the deepest pools, edge habitat (or under bank cover), and an abundance of good spawning gravels and cobbles. Historically, this reach has hosted numerous redds (surveyed from 2008 to present) (see Section 2.3.6 Aquatic Species). Although the lower mainstem reaches provide the best fish habitat, it should be noted that low numbers of resident Cutthroat Trout were observed during the OSCA surveys upstream into Reach 10. Additionally, fish were observed in the lower reach of Newport Creek.

In addition to the low flow concerns previously mentioned, there are physical obstructions that may challenge fish passage. The Washington State Fish Passage database lists five partial barriers in the mainstem of Coal Creek (as shown in Figure 24; WDFW 2020). These barriers include culverts (see Figure 11), grade control structures, and coal mining relics, and are discussed in more detail in Appendix A. Additionally, there are several natural barriers in the tributaries on the north bank of Coal Creek that may impede or prevent upstream fish migration.

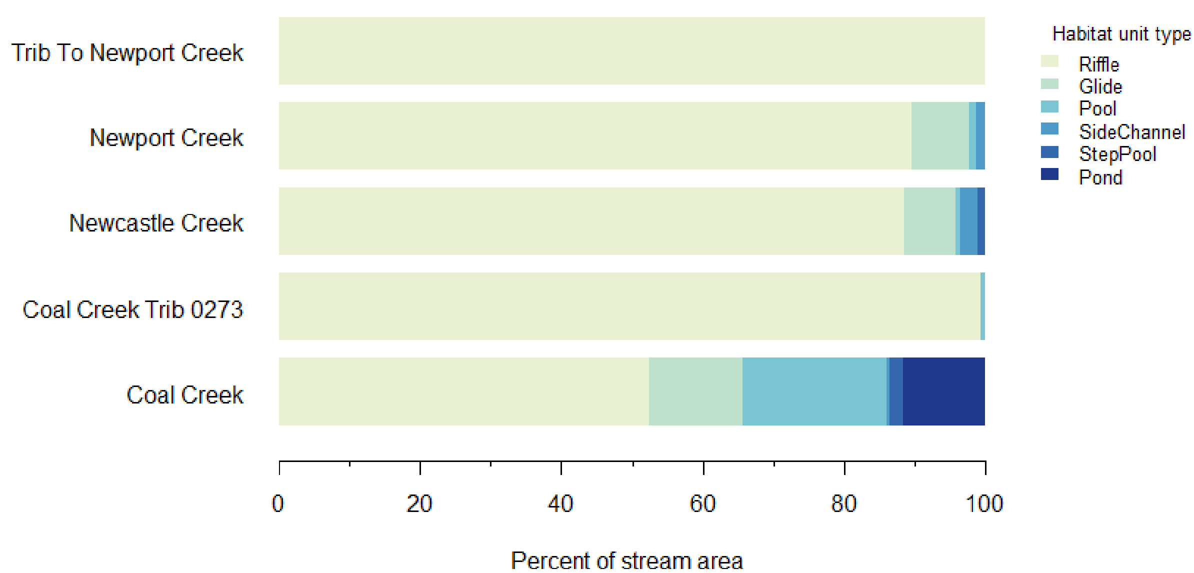


Figure 18. Habitat Unit Composition (by percent area) of Streams in the Coal Creek Watershed.

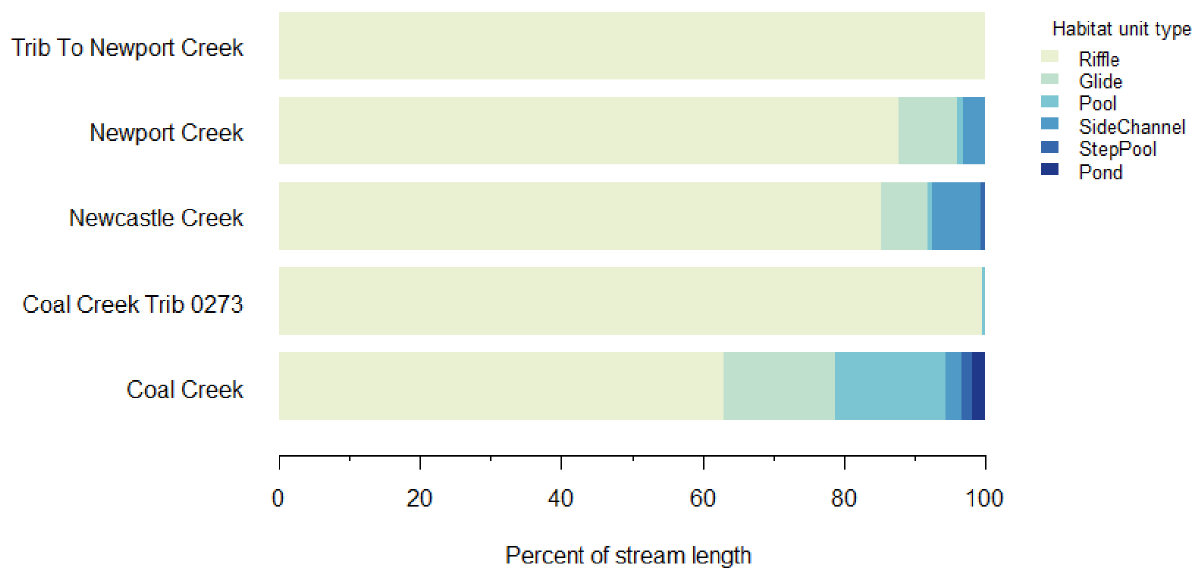


Figure 19. Habitat Unit Composition (by percent length) of Streams in the Coal Creek Watershed.

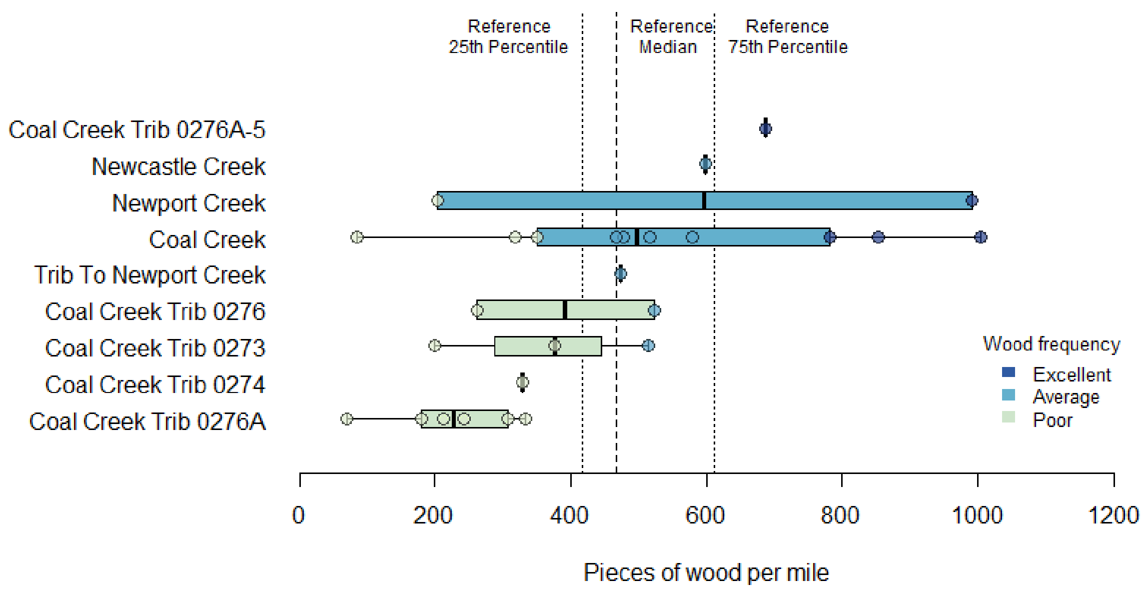


Figure 20. Boxplot of the Large Woody Material Frequency for Streams of the Coal Creek Watershed.

*Points represent the LWM values for individual reaches. Points are colored by LWM frequency and boxes are colored by median LWM frequency, grouped as poor, average, and excellent based on reference conditions.

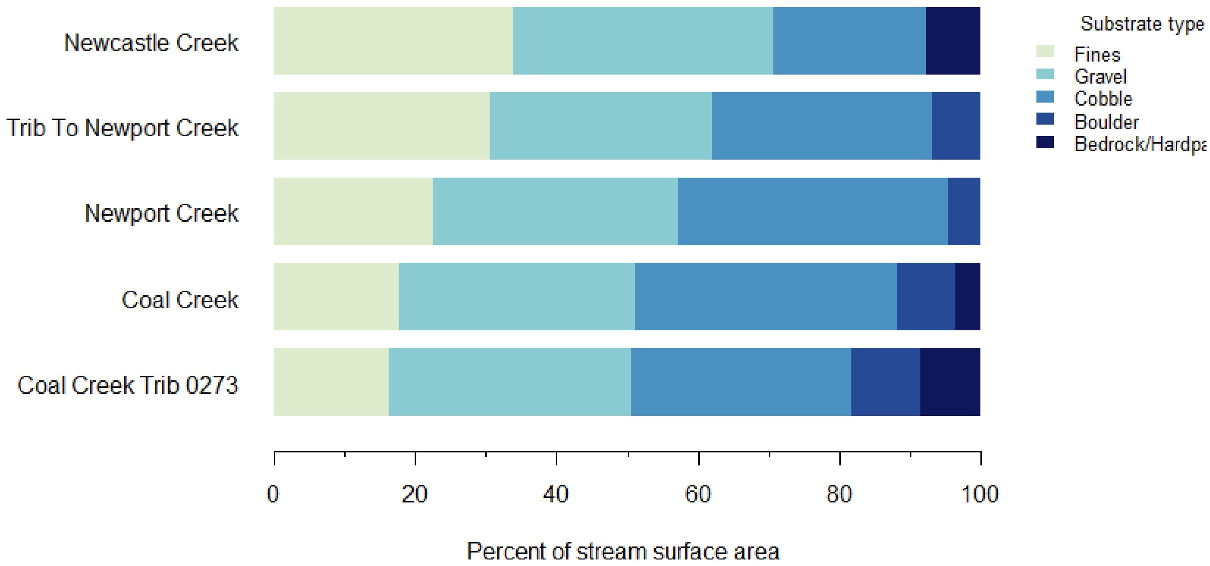


Figure 21. Substrate Composition of Riffle Habitat for Streams in the Coal Creek Watershed, Determined by Visual Estimation.

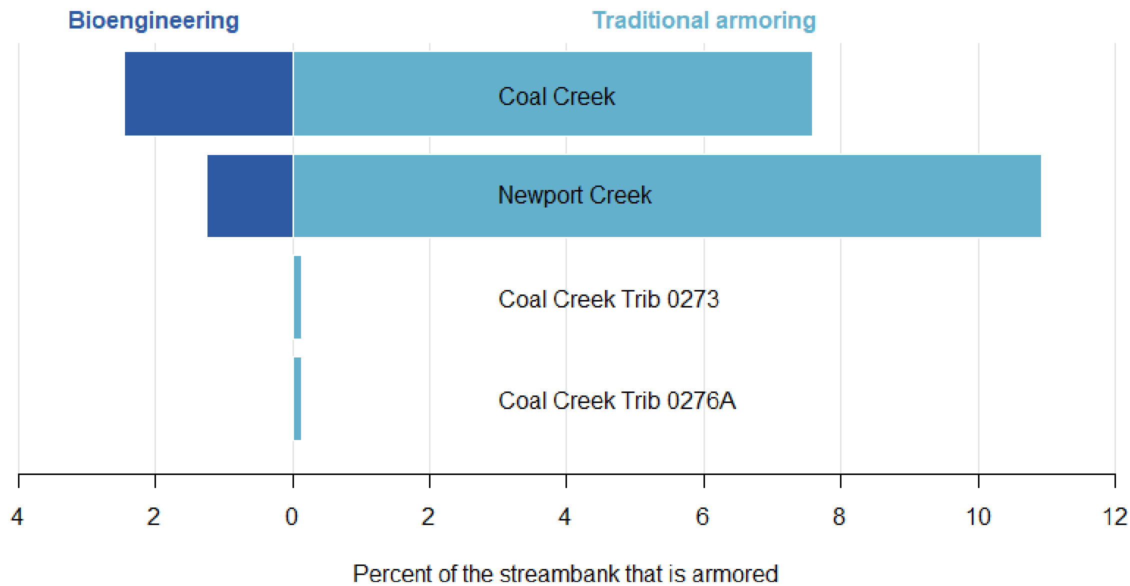


Figure 22. Diverging Bar Chart Showing the Proportion of Armored Streambank Using Traditional Materials (right) and Bioengineering (left).

*Streams that are not listed here had no armoring.

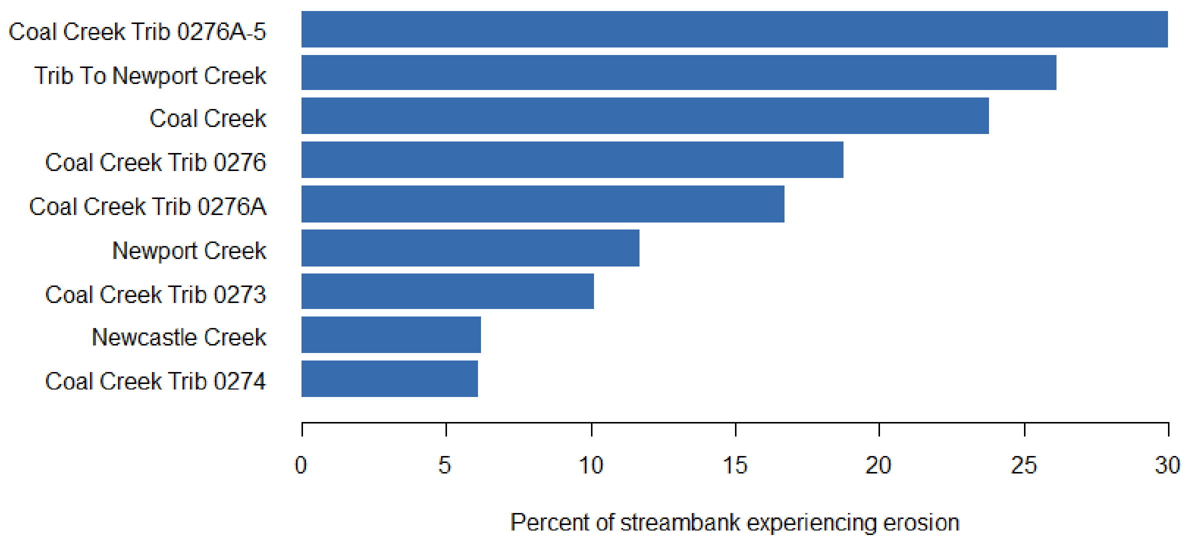
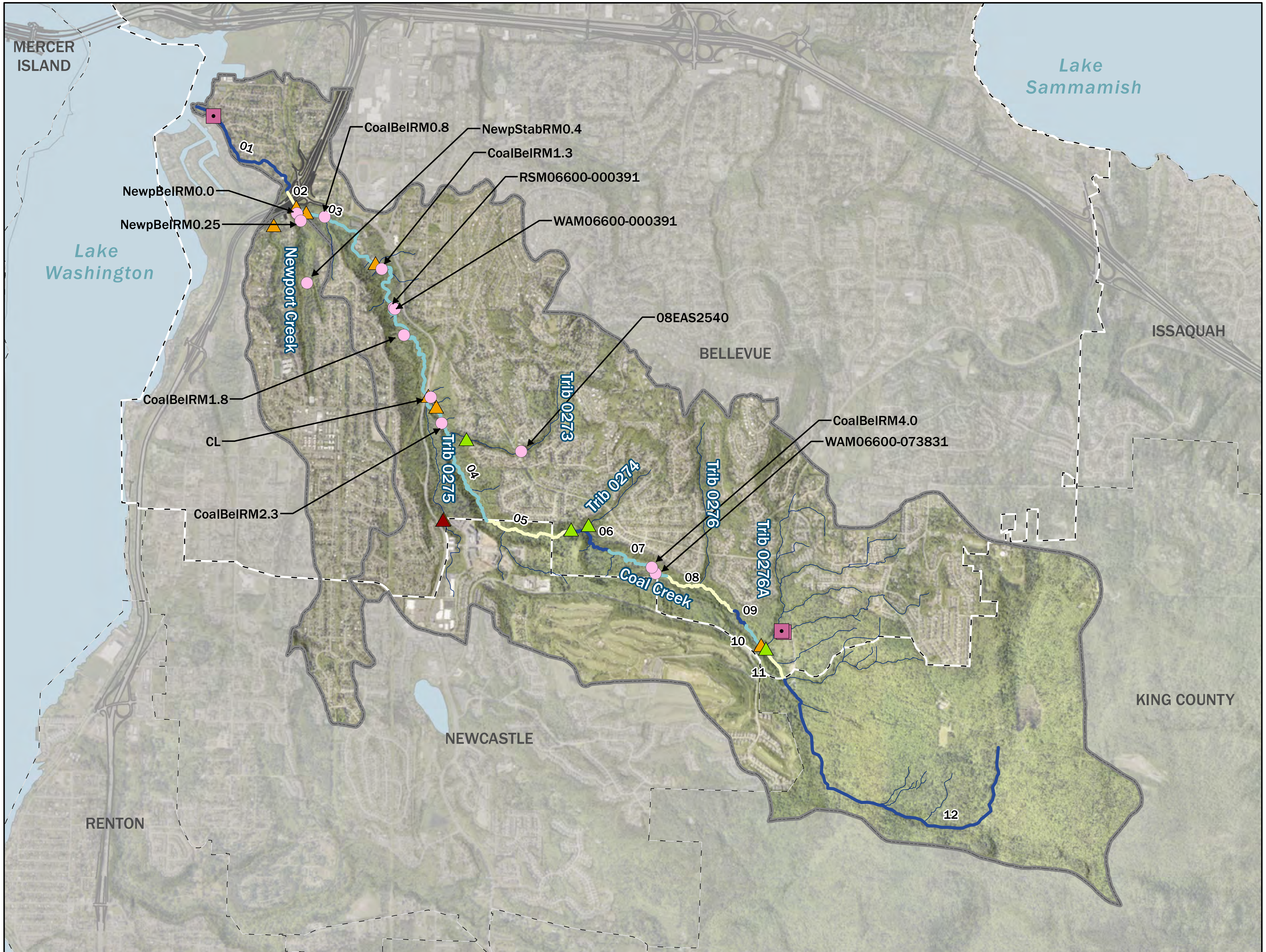


Figure 23. Percentage of Each Stream in the Coal Creek Watershed Experiencing Erosion.

Figure 24.
Coal Creek Watershed Fish Passage Barriers and B-IBI sampling locations.



2.3.6 Aquatic Species

Aquatic species within Coal Creek are described herein under separate subsections for fish species, invasive species, and benthic macroinvertebrates.

2.3.6.1 Fish Species

The Coal Creek riparian corridor is designated as a priority habitat by the Washington State Department of Fish and Wildlife (WDFW) and identified as a biodiversity area and corridor, providing freshwater forested/shrub wetlands (WDFW 2021a). The Coal Creek Watershed has a long history of supporting salmonids and other native fish species. Priority species include Chinook (*Oncorhynchus tshawytscha*), Coho, and Sockeye (*O. nerka*) salmon and steelhead (*O. mykiss*) and resident Cutthroat Trout (*O. clarkii*) (WDFW 2021a). Lower Coal Creek was known to have a circuit of ponds and wetlands that supported amphibians and Cutthroat Trout into the 1970s (K. Burton, personal communication, December 2020). According to anecdotal accounts, land use change throughout the surrounding hillsides and headwater streams, and the associated impacts to the hydrologic regime, resulted in rapid fish decline and habitat loss (K. Burton, personal communication, December 2020).

Beginning in 1996, resident fish data were collected by the City using electrofishing surveys throughout the Coal Creek Watershed; specifically, at five capital improvement project (CIP) locations on Coal Creek and two CIP locations on Newport Creek (Heltzel 2019). These data show an interesting trend of increasing species diversity observed over time, which may indicate that aquatic health is slowly improving and recovering from a long legacy of coal mining impacts. Species encountered during these surveys includes Rainbow and Cutthroat Trout, Coho Salmon, sculpin, and lamprey.

As described in the Instream Habitat section (Section 2.3.5 Instream Habitat) and anecdotal accounts above, the aquatic habitat in the Coal Creek Watershed has significant potential to support salmonids; however, several factors such as uncontrolled stormwater runoff, high rates of sediment loading and sedimentation, and limited off-channel habitat, are severely limiting potential fish use. In particular, salmonid spawning and rearing habitat are constrained primarily to the lower 3.5 river miles (RMs) of the Coal Creek mainstem (Reaches 1 through 5).

From 1997 to present, volunteers with the Salmon Watcher Program (King County and the City) recorded salmon observations at various locations in Coal Creek. Volunteers consistently observed Coho Salmon, with Chinook and Sockeye Salmon observed less frequently (King County 2016). In 2008, the City began annual professional salmon spawner surveys that extend from the mouth of Coal Creek (RM 0.0) to the boundary between Reaches 5 and 6 (RM 3.5). Surveyors count live and dead fish and map the location of the salmon redds (or nests). These professional salmon survey results are summarized in Table 9. Mapped redd locations indicate that 72 percent of the spawning activity has taken place downstream of Coal Creek Parkway, primarily in Reach 3, where 64 percent of redds have been observed since 2008. According to WDFW (2020b), lower Reach 6 has a natural barrier and is the upstream-most reach accessible to anadromous salmonids. Salmon spawner surveys have documented Coho Salmon and their redds in lower Reach 6, but only in years when fish returns were high (i.e., 2014 and 2019; see descriptions, below). Resident Cutthroat Trout have been observed as far upstream as Reach 10.

Information on priority fish species in Coal Creek is provided below.

Chinook Salmon (*Oncorhynchus tshawytscha*)

The Puget Sound Chinook Salmon Evolutionarily Significant Unit (ESU) has been listed as threatened by the National Marine Fisheries Service (NMFS) under the Endangered Species Act (ESA). Salmon species are differentiated between their life-style strategy based on their preferred spawning timing. Chinook Salmon within the Lake Washington basin are composed of fall-run Chinook Salmon. The fall-run Chinook Salmon spawn in lower reaches of Lake Washington streams between August and November with peak spawning occurring between September and November (Kerwin 2001). Due to their size, most Chinook Salmon use the mainstem of Coal Creek for spawning and the smaller tributaries or accessible off-channel habitats for rearing. Recent professional salmon spawner surveys report a positive trend in the utilization of Chinook Salmon in lower Coal Creek, primarily spawning in mainstem Reaches 1 and 3 (WDFW 2021b). Water depth during the fall migration is likely a primary factor limiting Chinook Salmon spawning distribution throughout the Coal Creek Watershed, especially into mainstem Reaches 4 and 5.

Coho Salmon (*Oncorhynchus kisutch*)

Coho Salmon found in Coal Creek are part of the Puget Sound/Strait of Georgia ESU and are listed as a "Species of Concern" under the Endangered Species Act by NMFS. WDFW has identified Coho Salmon in Coal Creek as part of the Lake Washington/Sammamish population, which is listed as "depressed" (R2 Resources Consultants 2016; Tetra Tech/KCM *et al*. 2006). Lake Washington Basin Coho Salmon typically return to freshwater from August to early December and spawn between mid-October and early December (Kerwin 2001). Coho Salmon have historically used Newport Creek and Coal Creek primarily downstream of RM 2.5 (mainstem Reaches 1, 3, and the lower portion of Reach 4, all located downstream of Tributary 0273) (Bellevue 2003; CH2M Hill 2001; Kerwin 2001).

In 2013 and 2014, the City and the Muckleshoot Indian Fisheries staff released adult Coho Salmon from the Issaquah Fish Hatchery into Coal Creek with the goal of bolstering natural production. This project demonstrated positive results with 41 percent and 22 percent spawning success in 2013 and 2014, respectively (742 Coho Salmon were released in Coal Creek in 2013, resulting in 152 redds; and 1,573 Coho Salmon were released in 2014, resulting in 173 redds). Although average Coho Salmon returns were documented at the Ballard Locks in 2016 and 2017, Coal Creek Coho Salmon redd survey results from those years demonstrate a higher-than-normal return, a likely result of the hatchery Coho Salmon adult release that occurred 3 years earlier in 2013 and 2014. Coho salmon have a 2- to 3-year life history; therefore, it is believed that some of the 2016 and 2017 Coho Salmon observed spawning in Coal Creek were natural-origin progeny of the hatchery adults released in 2013 and 2014. These results were so favorable that an additional 1,049 Coho Salmon (512 females) were released in 2019, resulting in 115 redds (22 percent spawning success). This suggests Bellevue streams are capable of producing natural-origin Coho Salmon through good in-gravel survival and juvenile rearing, and that the practice of using adult transplants from Issaquah Fish Hatchery may be an effective tool for augmenting Coho Salmon returns in these streams in future years (WDFW 2021b). Coho Salmon redds were found up to RM 3.6 in 2014 and 2019, indicating that when there is competition for spawning habitat, the adult Coho Salmon can access and utilize spawning habitat into lower Reach 6.

Although Coho Salmon migrate in late October when higher stream flows allow them to more easily bypass physical barriers that may impede Chinook or Sockeye salmon access to portions of Coal Creek, they are threatened by potentially toxic stormwater runoff from the surrounding impervious surfaces. Coho Salmon are considered an important sentinel species for stormwater and water quality in urban streams (Spromberg and Scholz 2011). Observations of Coho Salmon pre-spawn mortality and impaired swimming ability (loss of equilibrium, circular surface swimming, gaping, and immobility) have been linked to urban areas with more roads and impervious surfaces (Feist *et al.* 2018). These symptoms and death can affect as much as 90 percent of the returning fall-run salmon in urbanized areas (Spromberg and Scholz 2011). Recently, researchers from the Center for Urban Waters in Tacoma, the University of Washington, and Washington State University were able to identify that a chemical biproduct of automobile tires leached onto roadways is the source of the high observed Coho Salmon mortality (Tian *et al*. 2020). Bioinfiltration methods that allow the stormwater to contact organic matter before entering the stream substantially reduce or even negate the toxic effect of stormwater on fishes (Spromberg *et al.* 2015).

Sockeye Salmon (*Oncorhynchus nerka*)

Sockeye Salmon that use Coal Creek are part of the Baker River ESU and are not ESA-listed by NMFS. WDFW has identified Sockeye Salmon in Coal Creek as part of the Lake Washington/Sammamish stock, which is listed as "depressed" (Tetra Tech/KCM *et al*. 2006). In addition to the Lake Washington/Sammamish stock, a hatchery program in the Cedar River also releases between 2 to 20 million Sockeye Salmon hatchery fry into the neighboring Cedar River each year. Sockeye Salmon that use Coal Creek for spawning are likely adult fish from the Cedar River population (of both natural and hatchery origin). Sockeye Salmon return to freshwater between mid-May through November and spawn from September through January in the mainstem of Coal Creek downstream of RM 2.5 (Bellevue 2003; CH2M Hill 2001; Kerwin 2001), with redds mapped in Reaches 1 and 3 (WDFW 2021b).

Kokanee, a lake-bound form of Sockeye Salmon, have historically used Bellevue streams for spawning but have rarely been observed in tributaries to Lake Washington over the past decade. Growing regional interest in these fish have resulted in confirmed observations in other small Lake Washington tributaries including Swamp, McAleer, Lyon, and May Creeks (J. Bower, personal communication, February 2021). A 1946 Washington Department of Game survey reported the kokanee run in Coal Creek as "excellent" (Garlick 1946), but there has been very little information about kokanee spawning in Bellevue streams until recently, when a spawning pair was observed in 2020 in mainstem Reach 1 (WDFW 2021b).

Winter steelhead (*Oncorhynchus mykiss*)

Winter-run steelhead that use Coal Creek are part of the Puget Sound ESU and were ESA-listed as threatened by NMFS in 2007. WDFW has identified the steelhead in Coal Creek as members of the Lake Washington stock, which is listed as "critical" (Tetra Tech/KCM *et al.* 2006). The winter-run steelhead enter the Lake Washington Basin in December and generally spawn from February through May (Kerwin 2001). Coal Creek steelhead were last observed in June of 1998, with two redds near the confluence with Tributary 0273; one located in mainstem Reach 4 and the second in the lower portion of Tributary 0273 (WRIA 8 2001). Little is known about historic presence or habitat utilization by steelhead throughout the Coal Creek Watershed, although it is possible that they historically were found into the Coal Creek headwaters.

Cutthroat Trout (*Oncorhynchus clarkii*)

Cutthroat Trout found in Coal Creek are part of the Puget Sound ESU and are not an ESA-listed species under NMFS. WDFW has identified the Cutthroat Trout in Coal Creek as members of the South Puget Sound stock complex, the status of which is currently unknown. Spawning normally occurs from December through May depending on the stock (Anderson 2008). Cutthroat Trout use both Coal Creek and Newport Creek (CH2M Hill 2001; King County 2016). Anecdotal information supports a healthy Cutthroat Trout population in Newcastle Creek into the 1990s, at which time water quality became impaired (J. Bower, personal communication, February 2021). Resident Cutthroat Trout were historically found into the headwaters of the Coal Creek Watershed prior to coal mining impacts that resulted in fish passage barriers and altered hydrology in the upper watershed, primarily outside of the City. The 2018 OSCA survey documented Cutthroat Trout into mainstem Reach 10. Adfluvial (adult fish that migrate from lakes to streams to spawn) Cutthroat Trout are regularly observed spawning throughout the lower mainstem reaches of Coal Creek, primarily in mainstem Reaches 1 and 3 (WDFW 2021b).

2.3.6.2 Invasive aquatic species

Although New Zealand Mud Snails (NZMS; *Potamopyrgus antipodarum*) have been documented in the greater Lake Washington Watershed and nearby streams, there have not yet been any observations or detections of invasive mud snails in the Coal Creek Watershed (Bellevue 2020a). The City has monitored for NZMS in Coal Creek using environmental DNA sampling methods from 2014 to 2020 and all results have been negative. Community awareness and prevention is necessary to protect the Coal Creek Watershed from this unwanted, harmful, and highly invasive snail.

2.3.6.3 Benthic Macroinvertebrates

Benthic macroinvertebrates are aquatic animals without backbones that are visible to the naked eye, including insects, crustacea, worms, snails, and clams, that spend all or most of their lives living in or on the bottom of the streambed (King County 2002). Benthic macroinvertebrates are monitored because they are good indicators of the biological health of stream systems and play a crucial role in the stream ecosystem (Karr and Chu 1999). Since they complete most or all of their life cycle in the aquatic environment and they are relatively sedentary, benthic communities are reflective of the local sediment, water quality, hydrologic and habitat conditions (Booth *et al.* 2001). Thus, monitoring of macroinvertebrate populations provides a relatively inexpensive and powerful tool to assess short and long-term effects from the primary stressors of stream health identified in Figure 2.

B-IBI scores provide a measure of stream health that is derived from samples of benthic macroinvertebrates that are collected from the streambed. B-IBI scores are computed on a scale that ranges from 0 to 100 to indicate relative stream health as follows: 80 to 100 for "excellent", 60 to 79 for "good", 40 to 59 for "fair", 20 to 39 for "poor", and 0 to 20 for "very poor". In a study of streams in the Puget Sound lowlands, May *et al.* (1997) showed B-IBI scores declined rapidly in early stages of watershed urbanization such that high B-IBI scores (greater than 60) were observed only at low levels of imperviousness (less than 5 to 10 percent). For reference, impervious surfaces occupy approximately 23 percent of the total watershed area for Coal Creek. One drawback of the B-IBI is it does not identify the specific stressor responsible for the decline in stream health. Typically, a more detailed evaluation of the macroinvertebrate community assemblage or supplemental data collection for other chemical and/or physical parameters is required to make such inferences.

From 1994 to 2019, 76 macroinvertebrate samples were collected from the Coal Creek Watershed by King County, the City, Ecology and University of Washington (PSBD 2020) at 16 locations in the Coal Creek Watershed (see Figure 24). Most of the samples (56) were collected from the mainstem of Coal Creek, 14 samples were collected from Tributary 0273, and 6 samples were collected from Newport Creek. Appendix C summarizes the available data from each sample by site and subbasin.

B-IBI scores from sites located on the Coal Creek mainstem, Newport Creek, and Tributary 0273, respectively, were aggregated over the most recent five years (2015–2019) to assess current stream health based on relatively recent macroinvertebrate sampling. As shown in Table 10, these data indicate stream health in the Coal Creek mainstem is generally "poor" with a median score of 36.3, stream health in Tributary 0273 on Coal Creek is "fair" with a median score of 44.0, and stream health in Newport Creek is "very poor" with a median score of 19.9.

The following five sites on Coal Creek can be used to assess conditions longitudinally along the stream channel at distances of 0.8, 1.3, 1.8, 2.3, and 4.0 miles from the mouth of the creek: CoalBelRM0.8, CoalBelRM1.3, CoalBelRM1.8, CoalBelRM2.3, and CoalBelRM4.0. Based on median B-IBI scores from these sites from the most recent five years of sampling (2015–2019), stream health generally increases with increasing distance up the stream channel (Figure 25). For example, the median B-IBI scores at distances up to 1.5 miles from the stream mouth indicate habitat conditions are “poor”, whereas scores at distances from 1.8 to 4.0 miles from the stream mouth indicate stream health is “poor” to “fair”. The decrease in stream health in the lower reaches of the creek could be related to a variety of factors identified in the conceptual model (Figure 2) including loss of riparian canopy cover, poor water quality, and degraded physical habitat conditions due to sediment deposition and/or channel instability.

Data were available from two stations (08EAS2446 and 08EAS2540) on the mainstem of Coal Creek that spanned an eighteen-year period extending from 2002 to 2019 (Appendix C). A trend analyses (Kendall tau test for correlation) that was applied to these data showed there were not statistically significant (α = 0.05) increasing or decreasing trends in the B-IBI scores for these stations over this period.

In connection with Ecology’s SAM program, data for computing B-IBI scores were collected from 104 sites in streams located in the Puget Lowland ecoregion in the summer of 2015; 45 of these sites were located outside the UGA in more rural settings while 59 of these sites were located within the UGA in more urban settings. These data provide a good frame of reference for comparing the scores from Coal Creek to scores from other streams in the region. As reported in DeGasperi *et al.* (2018), the B-IBI scores for streams within the UGA showed a greater proportion of stream length in poor condition (82 percent) compared to streams outside of the UGA (30 percent). Median B-IBI scores for streams within and outside the UGA were 38.6 and 72.7, respectively. These data suggest stream health in the Coal Creek subbasin is similar to conditions in comparable streams located within the UGA from this study (mainstem median score of 36.3). Stream health in the Newport Creek subbasin the based on median B-IBI score of 19.9, is low in comparison.

Table 9. Summary of Professional Salmon Survey Results for Coal Creek from 2008 to 2020 (WDFW 2021b*)*

Coal Creek								
Year	Chinook			Sockeye		Coho		
	Redds	Live Fish	Carcasses	Live Fish	Carcasses	Redds	Live Fish	Carcasses
2008	0	0	0	0	0	6	0	3
2009	0	0	0	0	0	0	5	1
2010	1	1	0	0	0	0	1	0
2011	0	0	0	1	0	1	2	1
2012	1	19	1	66	8	2	17	2
2013	3	8	2	1	1	152*	921*	340*
2014	2	1	0	2	0	174*	1032*	210*
2015	2	10	3	0	0	2	8	1
2016	7	13	4	17	8	13	43	15
2017	3	9	8	6	4	21	48	12
2018	0	0	2	0	0	68	39	11
2019	7	21	11	2	0	114*	521*	259*
2020	3	11	9	0	0	7	1	2

* Years when returned Coho Salmon adults were released from the Issaquah Fish Hatchery.

Table 10. Median B-IBI Scores Measured Over the Period from 2015 to 2019.

Subbasin	B-IBI Median Score	B-IBI Rating
Coal Creek Mainstem	36.3	Poor
Coal Creek Tributary 0273	44.0	Fair
Newport Creek	19.9	Very Poor

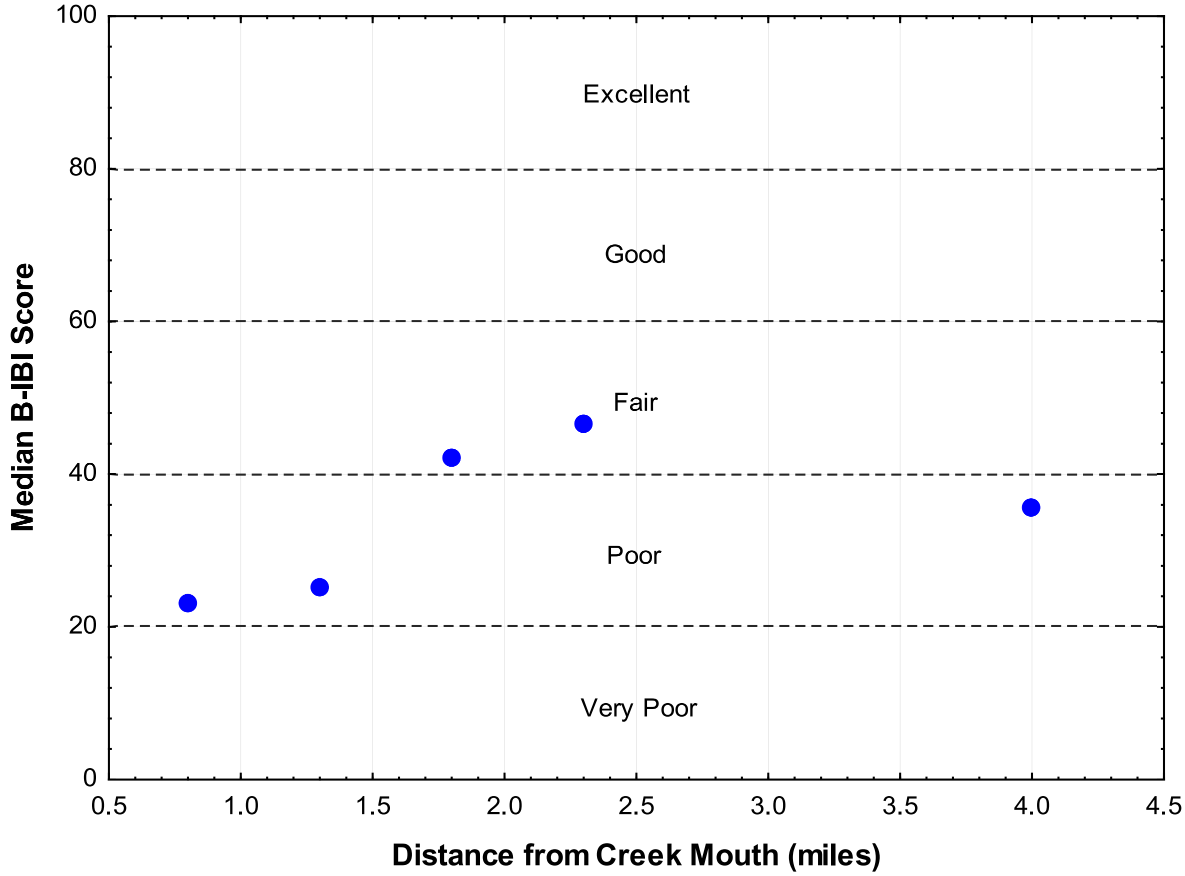


Figure 25. B-IBI Scores Measured Along the Coal Creek Stream Channel.

3. Limiting Factors

The information presented in the previous sections was evaluated to identify potential factors limiting aquatic health in the Coal Creek Watershed. This information was also summarized in a workshop for City staff that was held on October 26, 2020. The specific goal of this workshop was to obtain input on potential limiting factors from City staff in departments overseeing resource management in the watershed and possessing institutional knowledge that is directly relevant to this question. The evaluation of potential limiting factors specifically focused on the "sources of stressor" elements (Figure 26) from the conceptual model that describes the primary effects of urban runoff on stream health (Figure 2).

Further, these limiting factors discussions for the Coal Creek Watershed must also acknowledge that the Coal Creek Watershed is unique among City watersheds because it continues to reflect a legacy of coal mining impacts in addition to those from urbanization. The coal mining history amplifies several limiting factors, including hydrologic impacts, loss of floodplain, pollutant transport, riparian corridor alterations, and physical barriers. The evaluation of limiting factors as they relate to the coal mining legacy is outlined alongside the discussion of limiting factors related to urbanization as presented below.

Based on this evaluation pertinent to both urbanization and the coal mining legacy, the following limiting factors were identified for the Coal Creek Watershed in general order of decreasing importance:

1) **Stormwater runoff from impervious surfaces**: Increased stormwater runoff flow rates and volumes during storm events from impervious surfaces in the watershed are contributing to negative effects on fish and wildlife habitat. As shown in Figure 2, these effects can include channel, bank, and slope instability. These effects are noticeable in the middle and upper reaches of Coal Creek.

   Evidence supporting prioritizing this limiting factor is found in the text provided above are other sources that follow:

   - Impervious surfaces occupy approximately 23 percent of the total watershed area for Coal Creek. This percentage exceeds levels beyond which impairments to stream health have been well documented (Alberti *et al.* 2007; Booth and Henshaw 2001; May *et al.* 1997; Morley and Karr 2002).
   - As cited in Section 2.2, much of the Watershed (19.3 percent of the total watershed area) was developed prior to the advent of stormwater management regulations. Further analysis shows that approximately 86 percent of the developed area within the Bellevue portion of the watershed has no stormwater control or controls that are inadequate by today's standards for stream protection.
   - The hydrograph form for the mainstem of Coal Creek and computed hydrologic metrics provide some evidence of hydrologic alteration.
   - There are documented incidences (Section 2.1.3 Topography and Geomorphology, Appendix B) in the Coal Creek mainstem of mass wasting (Reaches 3, 7, 8, and 9), and bank erosion, channel incision, scour, and/or downcutting (Reaches 5 through 11).
   - The channel degradation, incision and downcutting, noted above was also observed by the OSCA surveys (Bellevue 2020b) as associated with simplified channel types, reduced pool frequencies and depths, and limited floodplain connectivity that in turn limit aquatic habitat area and fish utilization (Bellevue 2020b).
   - Sediment mobilized by channel, bank, and slope instability (negatively influenced by past coal mining activity) has contributed to long-term sediment aggradation in the lower reaches of the mainstem of Coal Creek (King County and Bellevue 1987; NHC 2015; Tetra Tech/KCM 2005) that

has required installation of sediment management facilities and regular stream sediment removal efforts by the City. This channel instability also directly impacts physical habitat quality in a significant portion of the mainstem that likely limits aquatic health and biotic potential (Bellevue 2020b).

2) **Loss of Floodplain**: Dense urban development in the lower and middle reaches of the watershed has largely confined the mainstem of Coal Creek to its channel and limited any interaction with its historic floodplain. This artificial confinement (by streambank armoring and channel incision) has significantly reduced floodplain connectivity and thereby reduced access to flood, sediment, and nutrient storage within the floodplain. Sediment and nutrients that otherwise would have deposited within the floodplain is instead deposited within the channel or transported downstream, contributing to sediment aggradation in the lower mainstem reaches as discussed above. This channel confinement has also reduced habitat complexity that likely reduces aquatic and riparian biodiversity. Evidence supporting prioritization of this limiting factor from the text provided above are other sources are as follows:

   - Current floodplain widths illustrated in Figure 4 are only a fraction of the historic floodplain, alluvial fan, and delta widths illustrated by the geologic and topographic maps presented in Figures 6 and 8, respectively, and as described by the historic land use (Section 2.2.1 Land Cover and Land Use) and geomorphic (Section 2.1.3 Topography and Geomorphology) changes that occurred adjacent to mainstem reaches 1 through 3.
   - Floodplain development and the associated channel confinement and armoring has cut off access to historic distributary channels present at the Coal Creek delta and affected the deposition of sediment within the delta (Section 2.1.3 Topography and Geomorphology, Appendix A).
   - The OSCA surveys (Bellevue 2020b) noted simplified channel types and limited floodplain connectivity in Reach 1 of Coal Creek as well as opportunities for improved floodplain connectivity in Reach 3 of Coal Creek (Section 2.3.5 Instream Habitat). Side channel habitat only composes 1 percent of each the Coal Creek and Newport Creek subbasin instream habitat area (Bellevue 2020b).
   - Loss of channel complexity and connectivity, as well as the lack of LWM in Reach 1 of Coal Creek downstream of I-405, was identified by the City (Bellevue 2020b) as limiting to fish use and likely contributing to the sediment transport and erosion problems in the watershed.

3) **Pollutant Transport**: Even though three segments of Coal Creek are identified as Category 5 (polluted and requiring improvement) water bodies on the 303(d) list, the computed WQI scores from the available data generally indicate water quality is only a “moderate concern”. However, it should be noted that targeted studies have not been conducted to evaluate potential water quality impacts from legacy coal mining at its source and downstream waterbodies in a large portion of the Coal Creek Watershed. Stormwater runoff from impervious surfaces (limiting factor #1) not only brings the negative effects to the physical stream environment (erosion and slope instability), it also washes in pollutants associated with urban development that are detrimental to the health of aquatic organisms. Analysis of age of development data matched up with the timeline of stormwater treatment requirements indicate that approximately 97 percent of the developed area within the Bellevue portion of the watershed does not include treatment of stormwater runoff.

4) **Loss of Riparian Vegetation**: As shown in Figure 9, the urban tree canopy in the Coal Creek Watershed is largely concentrated in the Cougar Mountain Regional Wildland Park (outside of Bellevue), and Coal Creek Park and Natural Area (within Bellevue) which spans the riparian corridor of Coal Creek down to the point where it intersects I-405. Given that so much of the riparian corridor in the Coal Creek Watershed is relatively intact, the loss of riparian vegetation is likely a less constraining limiting factor relative to those identified above. However, impacts to the riparian corridor and vegetation within the

watershed certainly exist and evidence supporting prioritization of this limiting factor from the text provided above are other sources are as follows:

- The riparian corridor within Reach 1 of Coal Creek mainstem is extremely constrained by residential development, which affects both the physical width and continuity of the corridor, the ability of the riparian corridor to support nutrient cycling, attenuation of pollutants, and bank and soil stability, as well as the extents and quality of both terrestrial and aquatic habitat in Reach 1.
- The riparian canopy vegetation is primarily deciduous and more coniferous canopy is needed to promote riparian diversity and habitat. Forest managers from the City Parks department have encountered ongoing challenges with improving the forest succession and achieving coniferous canopy (Bellevue 2006).

5) **Sub-Standard Road Culverts and Other Physical Barriers**: Although a number of physical barriers to fish passage have been identified in Coal Creek (Figure 24), the benefit of removing barriers upstream of Reach 5 would be limited while the quality of physical habitat in upstream reaches is constrained by the limiting factors identified above. The City of Bellevue has also invested in several culvert replacements that have improved fish passage conditions (e.g., the Lower Coal Creek Flood Hazard Reduction Project Culvert Replacements and Coal Creek Parkway Culvert Replacement described in Section 4). Nonetheless, some important evidence supporting prioritization of this limiting factor from the text provided above are other sources are as follows:
   - There are several documented partial barriers located downstream of Reach 5 as shown in Figure 24 (WDFW 2021).
   - The I-405 culvert and associated fishway is long and presents challenges to fish passage. The I-405 culvert and trash rack also blocks the recruitment of LWM and other organic debris from entering Reach 1. Although this culvert is outside City jurisdiction, the City could recommend improvements to be made to this structure to better ensure fish passage.
   - In Reach 3 of Coal Creek, upstream of I-405, instream structures previously placed to protect regional sewer line crossings may be partially restricting fish access and could be further evaluated to determine if future improvements are feasible.

As mentioned in Section 2.3.6.3 Benthic Macroinvertebrates, B-IBI scores do not identify the specific stressor(s) responsible for a decline in stream health. The B-IBI scores for the Coal Creek Watershed, however, do confirm that the aforementioned limiting factors are negatively affecting the stream health. B-IBI scores will be a valuable tracking metric to monitor future trends in the health of Coal Creek.

This ordering of limiting factors is generally consistent with the hierarchical model of stream functions that was described previously by Herrera (2013). This approach builds on the knowledge that efforts to improve physical habitat quality will be substantially more difficult if conducted in highly impacted watersheds with altered sediment budgets and a flashy hydrologic regime (Roni *et al.* 2002). Stream channel rehabilitation is most effective in watersheds that have a natural hydrograph and minimal sediment loading (Suren and McMurtrie 2005). Figure 27 also presents a Stream Functions Pyramid model prepared by Harman (2009) which, along with the hierarchical model of stream functions, suggests improved stream health (located at the top of the pyramid) is most effectively attained by first addressing stressors at the lower levels of the pyramid. The intention of the pyramid is to show the dominant cause and effect relationships. In general, biodiversity is dependent on habitat structure and quality, which are dictated by the lower levels of the pyramid beginning with hydrologic conditions.

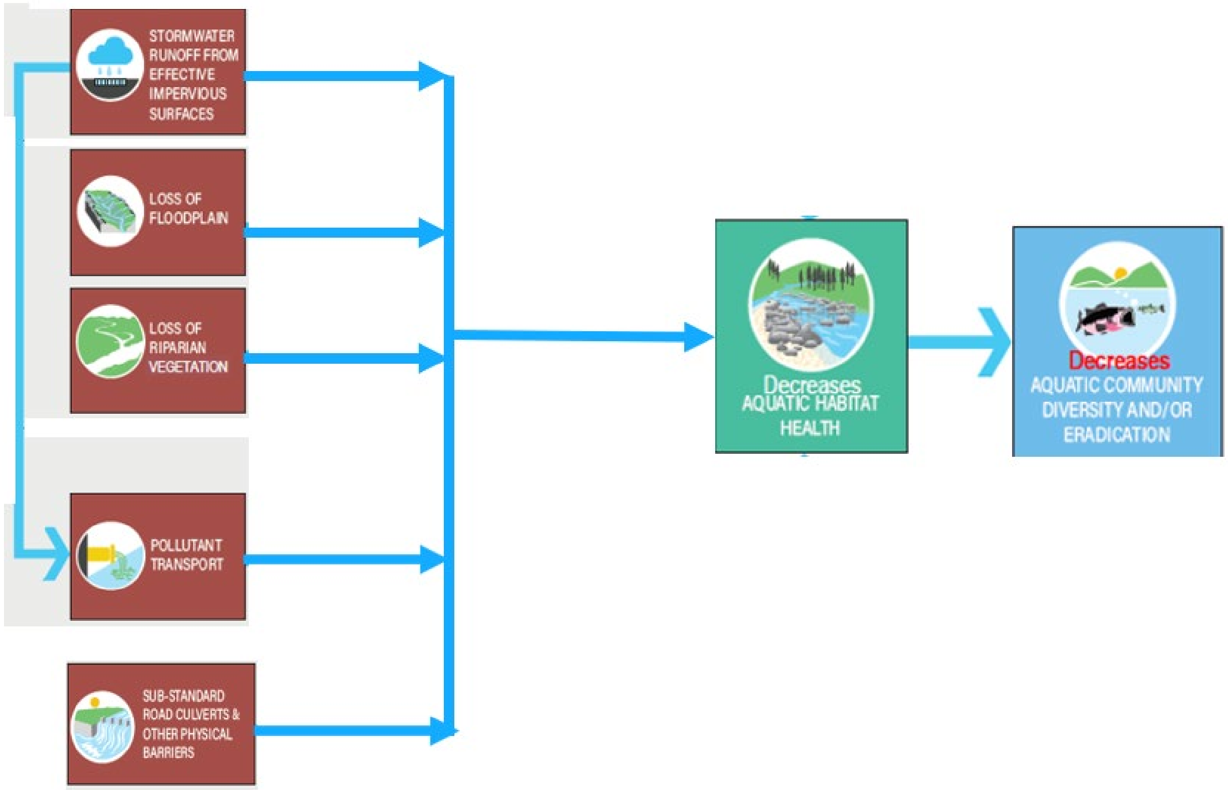


Figure 26. Source of Stressor Elements from the Conceptual Model.

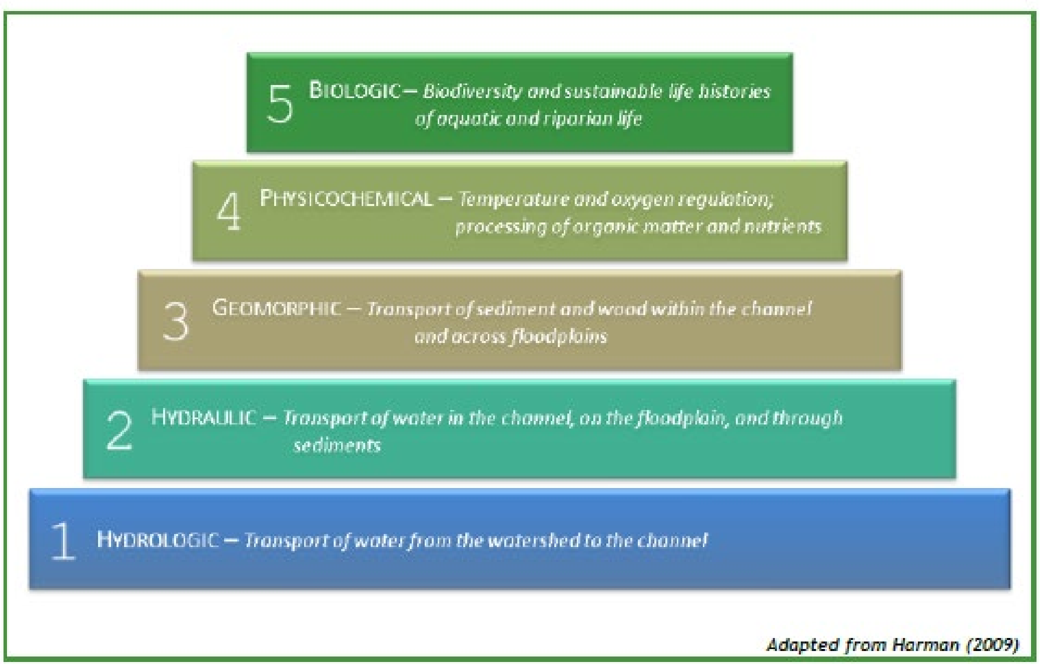


Figure 27. Stream Functions Pyramid.

4. Past and Present Investments

The City and King County collaborated on a Coal Creek Basin Plan (published in 1987), which identified needs of the then largely unincorporated Coal Creek Watershed. In addition to those improvements specified by the plan, the City has put in place a number of channel and bank stabilization structures as well as sedimentation facilities to address sediment concerns in the downstream reaches of Coal Creek. The City has also invested in several culvert replacements and fish habitat improvement projects in the past 10 years. The following specific investments have been made by the City (or else by King County, before areas were annexed into the City) in the Coal Creek Watershed (Figure 28):

- Coal Creek Upper Main Channel Stabilization Project – Upstream of Cinder Mines (1988, Bellevue)
- Bank Stabilization and Bed Control Structures near Cinder Mines (1995, King County)
- Cinder Mine Hillslope Stabilization project (1995, King County)
- Upper Coal Creek Reach Bank Stabilization Project (2008, Bellevue)
- Coal Creek Parkway Sedimentation Basin (1996, Bellevue; in-line pond on Coal Creek upstream of the concrete detention facility)
- Coal Creek Parkway Regional Detention Facility (1996, built by King County; located upstream of Coal Creek Parkway)
- Middle Reach Bank Stabilization Project near the SPU pipeline (2005/2006, Bellevue)
- Coal Creek Off-channel Sediment Pond (Anna's Pond, Bellevue)
- Coal Creek/I-405 Regional Detention/Sedimentation Facility and Bypass Pipe (1994, 2010, Bellevue)
- Overbank Stormwater Outfall Improvements (various locations, not shown on Figure 28; 2005/2006, Bellevue)
- Coal Creek Parkway Culvert Replacement (2013/2014, Bellevue)
- Channel Modifications at Newport Shores (not shown on Figure 28; 1987, Bellevue)
- Lower Coal Creek Flood Hazard Reduction Project Culvert Replacements (2017-2019, Bellevue; with new single-span bridges at Newport Key, Glacier Key, Upper Skagit Key, Lower Skagit Key, and Cascade Key)
- Lower Newport Creek Ravine Bypass Piping (1983, King County)
- Upper Newport Creek Ravine Bypass Piping (1994, Bellevue)
- Newport Creek Channel Stabilization (1983, King County; 1994, Bellevue)
- Newport Hills Outfall Improvements (not shown on Figure 28; 1990s, King County and Bellevue)
- Newport Creek Fish Passage Improvement Project (not shown on Figure 28; 2015 Bellevue)

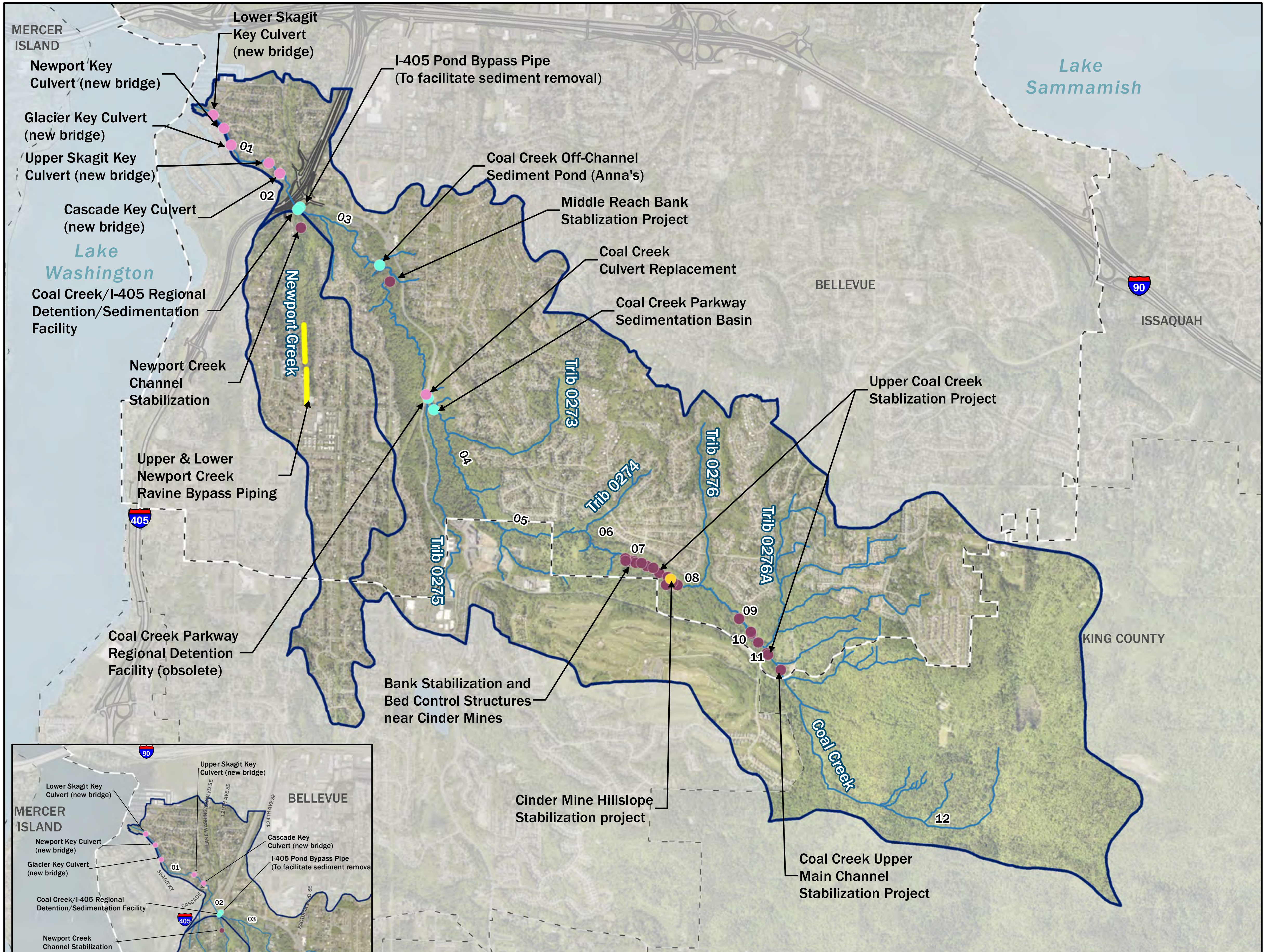


Figure 28.
Past City of Bellevue Investments in the Coal Creek Watershed.

5. Potential Instream Enhancement Opportunities

The instream opportunities listed in Table 11 were identified during the OSCA field work. These in-stream opportunities will be included with upland opportunities that will be described in the forthcoming WIPs to address limiting factors. Upland opportunities that may explored in the WIPs include:

- Retrofits of existing stormwater facilities (for both flow control and water quality)
- Implementation of new stormwater facilities (for both flow control and water quality)

Table 11. Potential Future Instream Project Opportunities in the Coal Creek Watershed, by Stream Reach.

Reach	Instream Project Opportunity
1	Investigate potential fish passage improvements associated with the I-405 culvert and fishway
1	Remove remnant creosote pilings from the old Burlington Northern Santa Fe (BNSF) railway impacting the stream at the King County trail
3	Evaluation of potential fish passage improvements needed for previously placed instream structures
3	Improve fish passage at instream structures associated with protecting regional sewer line crossings located upstream from I-405
3-11	Install LWM
3	Off-channel enhancement and spawning channel creation to benefit sediment storage and salmonid spawning and rearing habitat
3-11	Maintain and repair City trails and footbridges to reduce impact to bed and bank stability
3 and 4	Maintain unimpeded fish passage at instream structures associated with sedimentation collection facilities
3	Remove or modify King County vault structure that is a part of the Coal Creek Parkway Regional Detention Facility located upstream of Coal Creek Parkway to promote fish passage and habitat improvements
3 and 4	Remove abandoned sewer infrastructure associated with proposed from King County Trunk Sewer Line decommissioning and retore creek habitat and channel and floodplain connectivity.
5	Improve flow control and outlet energy dissipation at stormwater outfalls to improve bed and bank stability
8	Retrofit outfalls to improve energy dissipation
8,9	Stabilize disturbed slopes
11	Replace the undersized culvert under Lakemont Boulevard
Newport Creek Reach 1 and 2	Evaluate potential fish passage improvements needed for previously placed instream structures

6. Data Gaps

Missing or incomplete information that were not available to inform this Watershed AR or future phases of WMP development are as follows:

- Data to assess potential water quality impacts (e.g., discharges of heavy metals) from historic coal mining operations in Coal Creek.
- Stream water temperature data to assess water quality impacts associated with the loss of riparian corridor width, changes to canopy cover, and warm runoff from impervious surfaces.
- Watershed-scale evaluation of retrofit opportunities for existing, underperforming stormwater facilities, including an assessment of public and private ownership and responsibility.
- Evaluation of chronic channel bed instability along Coal Creek between Reaches 6 and 11 for reduction of stream incision and reduction of fine sediment delivery to downstream reaches.

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Appendix A
Data Sources and Methods Used to Summarize Geospatial Watershed Attributes

Appendix A. Coal Creek Watershed Assessment Report: Data Sources and Methods Used to Summarize Geospatial Watershed Attributes

1.1 Introduction

This appendix to the Coal Creek Watershed Assessment Report (AR) describes the spatial data sources and calculation methods Herrera employed to generate figures referenced in the main text of the document. Spatial data was predominantly sourced from the City of Bellevue; additional spatial data sources are also listed at the end of this appendix. Calculations were generally derived by intersecting spatial data within specific boundaries (entire Coal Creek watershed, City of Bellevue city limits, Newport Creek subbasin, Coal Creek subbasin). Additional analysis methods are described in detail below. The presentation of this information is organized under the major section titles and figure/table names (and numbers) from the main text.

1.2 Basin Characteristics

1.2.1 Coal Creek Watershed Geology (Figure 6) and Soils (Figure 7)

Geology and soil data were intersected within the Coal Creek watershed, Newport Creek subbasin, and Coal Creek subbasin. For geology, each Geologic Type total area was calculated. For soil, each Hydrologic Soil Group total area was calculated (Table 1).

Table 1. Coal Creek Watershed Soils

Hydrologic Soil Group	Soil Classification	Soil Notation	Percentage of Coal Creek Subbasin	Percentage of Newport Creek Subbasin	Percentage of Coal Creek Watershed
Hydrologic A (%)	Everett gravelly sandy loam	EvC	0.7%	0.0%	0.6%
Hydrologic A/D (%)	Norma sandy loam, Orcas peat	No, Or	0.6%	0.1%	0.6%
Hydrologic B (%)	Alderwood gravelly sandy loam, Alderwood and Kitsap soils very steep	AgB, AgC, AgD, AkF	43.5%	30.6%	41.9%
Hydrologic B/D (%)	Arents Alderwood, Briscot silt loam, Seattle muck, Sammamish silt loam	AmC, Br, Sk, Sh	5.0%	58.8%	11.7%
Hydrologic C (%)	Beausite gravelly sandy loam, Ovall gravelly loam,	BeC, BeD, OvD	48.1%	5.2%	42.7%
Hydrologic Not Identified (%)	Urban land	Ur	2.1%	5.2%	3.1%
Area (acres)	*NA*	*NA*	3,978	573	4,551

NA: not applicable

1.3 Built Infrastructure

1.3.1 Coal Creek Watershed Landcover/Tree Canopy (Figure 9)

Landcover analysis for the Coal Creek watershed was performed by using a raster mosaic of the 2017 and 2013 Landcover; these data were provided by the City of Bellevue in Tag Image File Format (TIF) files. The more recent 2017 Landcover only contained data from within the City of Bellevue city limits; however, the Coal Creek watershed boundary extends beyond these limits. Due to this consideration, the more recent 2017 Landcover classifications were used as the default in the landcover analyses. To represent areas in the watershed not covered by the 2017 Landcover, the 2013 Landcover classifications were paired to match the 2017 Landcover classifications as follows:

2013 Deciduous classification = 2017 Tree Canopy classification
2013 Evergreen classification = 2017 Tree Canopy classification
2013 Non-Woody classification = 2017 Non-Canopy Vegetation classification

The mosaic data from the 2017 and 2013 Landcover were subsequently converted to polygons to facilitate tabulation of each landcover class for the Coal Creek and Newport Creek subbasins and for the entire Coal Creek watershed (Table 2).

Table 2. Landcover in the Coal Creek Watershed

Watersheds	Coal Creek Subbasin	Newport Creek Subbasin	Entire Coal Creek Watershed
Bare Soil and Dry Vegetation (%)	2.5%	6.9%	3.1%
Impervious (%)	20.8%	38.8%	23.1%
Non-Canopy Vegetation (%)	15.3%	19.2%	15.8%
Scrub/Shrub (%)	1.0%	0.0%	0.9%
Urban Tree Canopy (%)	60.3%	35.1%	57.1%
Water (%)	0.0%	0.0%	0.0%
Total (ac)	**3,978.32**	**573.08**	**4,551.40**

ac = acre

1.3.2 Coal Creek Watershed Land Use (Figure 10)

Land use analysis for the Coal Creek Watershed required merging of three different Land Use datasets from the City of Newcastle, the City of Bellevue, and King County. All three datasets were intersected for the Coal Creek and Newport Creek subbasins and for the entire Coal Creek watershed. To account for detailed land use classifications and naming convention variation across three different datasets, a broad standardized land use classification was created. Each dataset specific, unique land use classification was grouped under a broad, standardized land classification (see Table 3). The total area for each land classification was then calculated for all subbasin/watershed boundary. Land use was additionally represented in GIS differently, where Newport Creek did not include land classifications for roads and streets as Bellevue and King County. These areas are reported as unknown land classification values. The resultant tabulation of land use is shown in Table 4 by subbasin and for the entire Coal Creek watershed.

Table 3. Land Use Classifications

Original Classification	Standard Classification
City of Newcastle	
Single Family	Single-family

Original Classification	Standard Classification
Golf	Park
Private Open Space	Park
Public Open Space	Park
Public Park	Park
Recreational Facility	Park
Apartment	Multi-family
Condominium	Multi-family
Critical Area Tract	Mixed-Use
Mixed-Use	Mixed-Use
Stormwater	Mixed-Use
Utility	Mixed-Use
Vacant	Mixed-Use
Light Manufacturing	Industrial
Warehouse	Industrial
Convenience Retail	Commercial
Null	Unknown
King County	
King county Open Space System	Park
Rural Area (1 du/2.5-10 acres)	Single family
City of Bellevue	
Community Business	Retail
Neighborhood Business	Retail
Multifamily High-density	Multi-family
Multifamily Low-density	Multi-family
Multifamily Medium-density	Multi-family
Park Single-family Low-density	Single-family
Park Single-family Medium-density	Single-family
Public Facility Single-family High-density	Single-family
Public Facility Single-family Medium-density	Single-family
Single-family High-density	Single-family
Single-family Low-density	Single-family
Single-family Medium-density	Single-family
Single-family Urban Residential	Single-family

Table 4. Coal Creek Watershed Land Use

Land Use	Coal Creek Subbasin	Newport Creek Subbasin	Entire Coal Creek Watershed
Commercial/Office (%)	0.4%	3.1%	0.8%
Industrial (%)	0.2%	0.0%	0.2%
Mixed-Use (%)	1.5%	0.8%	1.4%
Multi-family (%)	1.5%	4.3%	1.8%
Single family (%)	49.6%	80.0%	53.4%
Unknown values (%)	0.0%	3.8%	0.5%
Park (%)	46.7%	8.0%	41.8%
Total (ac)	**3,978.32**	**573.08**	**4,551.40**

ac: acre

1.3.3 Coal Creek Watershed Age of Development Ratings (Figure 12)

To evaluate the adequacy of stormwater management in the Coal Creek Watershed, the age of development was used to classify specific areas into one of six categories that indicate when requirements for improved stormwater management infrastructure became effective (Table 5). The age of development was determined using the existing attributes in the Parcel Time of Development and Stormwater Standards layer (YearBuiltRes) for the City of Bellevue. Park and Vacant/Undeveloped parcels were not placed into any of the categories. The data layer was limited to the City of Bellevue city limits and did not cover the entire Coal Creek watershed. The resultant tabulation for age of development is shown in Table 5 by subbasin and for the entire Coal Creek watershed.

Table 5. Development Age Categories for Assessing Stormwater Management Infrastructure Require

Category	Age	Stormwater Management Requirements	Percentage of Coal Creek Watershed within Bellevue
6	2017-Current	The 2017 Surface Water Engineering Standards updated the On-site Stormwater Management requirements (List #1, List #2, or LID Performance Standard) and adopted the 2012/14 Department of Ecology Stormwater Management Manual for Western Washington.	0.3
5	2010-2016	The 2010 Surface Water Engineering Standards added water quality requirements, flow control requirements, and continuous modeling per the 2005 Department of Ecology Stormwater Management Manual for Western Washington . On-site Stormwater Management was also included either applying default LID credits or deriving LID credits with demonstrative modeling.	0.9
4	1996-2009	Bellevue adopts the Department of Ecology's1992 Stormwater Management Manual for the Puget Sound Basin (Technical Manual) ▪ 2-year peak develop flow matches 50% of 2-year pre-developed flow ▪ 10-year peak developed flow matches 10-year pre-developed flow ▪ 100-year peak developed flow matches 100-year pre-developed flow	4.7

Category	Age	Stormwater Management Requirements	Percentage of Coal Creek Watershed within Bellevue
		▪ Unit-hydrograph method required for detention sizing ▪ 1.18 to 1.5 safety factor required for pond sizing dependent on percent impervious area	
3	1988-1995	Bellevue introduces Large Site stormwater controls for sites serving more than 5 acres and within ¼-mile of a stream (large subdivisions developed in the Coal Creek Watershed during this time). ▪ 10-year peak developed flow matches the 2-year peak pre-developed flow (using computer modeling), 24-hour event ▪ 100-year peak developed flow matches the10-year peak pre-developed flow (using computer modeling), 24 hour event A 30% increase in detention volumes for the Cookbook Method was adopted for all other sites.	5.7
2	1975-1987	The first set of Storm and Surface Water Utility Engineering Standards (published in 1975) focused on detention that could store the difference in runoff volume between the post-development 100 year, 4 hour storm and the pre-development 10 year, 4-hour event. To meet this requirement, a maximum allowable release rate of 0.2 cfs per acre and a storage requirement of 1.0 inch per impervious acre and 0.5 inch per pervious acre were required (Also known as the "Cookbook Method").	10.2
1	Prior to 1975	No stormwater management required.	19.3

LID: low impact development

cfs: cubic feet per second

1.4 Natural Systems

1.4.1 Average Reach Slope

The upstream and downstream node elevations of each reach were captured using LiDAR and the difference was divided by each segment length to approximate the average reach slope. The LiDAR was a mosaic of 2017 King County and Bare Earth orthomosaic that captured the boundaries of the entire Coal Creek watershed.

1.4.2 Riparian Canopy Composition and Vegetated Scores

The 2017 and 2013 Landcover polygons referenced above were used to calculate Riparian Canopy Composition and Riparian Vegetated Canopy scores. The Tree Canopy classification was used as a determinant for riparian corridor vegetation. After discussions with City of Bellevue staff, 100 ft was selected as a satisfactory minimum forested buffer width for riparian buffer evaluation. A polygon corresponding to the 100 ft buffer from the stream centerline as well as the start and end of each reach was created and then intersected with the combined 2013/2017 Tree Canopy landcover polygons. The total 100ft buffer area and the percentage total tree canopy area within each 100ft buffer reach polygon was then calculated.

1.4.3 Subbasin Areas

Subbasin areas were calculated for major reaches in the Coal Creek and Newport Creek subbasins. 2017 PSLC Lidar and Spatial Analyst toolbox was used to determine fill, flow direction, and flow accumulation. Pour points were created at the start of each reach using the flow accumulation and then used in the *Watershed Tool* to delineate contributing basins. The basin boundaries were modified based on available stormwater pipe data and outfall data provided by the City of Bellevue. Other jurisdiction stormwater pipe data outside of the City of Bellevue were not available and LiDAR was supplemented to determine flow direction. Reach 84_02 in the Coal Creek subbasin is a culvert; hence, the area that would constitute its contributing basin was apportioned to the contributing basins for reaches 84_01 or 84_03.

1.4.4 Aquatic Species

Washington Department of Fish and Wildlife data was intersected with Open Streams Conditions Assessment stream data to identify specific species that might be present.

1.5 Geospatial Data Sources

City of Bellevue. 2013. Bellevue_2013_landcover_101214Proj_NAD83_2011.tif. Provided to Herrera by City of Bellevue, June, 2020.

City of Bellevue. 2017. Bellevue_LC6Class_2017_ClassField.tif. Provided to Herrera by City of Bellevue, June, 2020.

Bellevue. 2020. Open Streams Condition Assessment Database. Provided to Herrera by City of Bellevue Utilities, October, 2020.

Bellevue. 2020. As Built Storm Database. Provided to Herrera by City of Bellevue Utilities, May, 2020.

Bellevue. 2020. Parcel Time of Development and Stormwater Standards layer. Provided to Herrera by City of Bellevue, August, 2020.

City of Bellevue, 2020. GIS Data Portal. Available at https://bellevuewa.gov/city-government/departments/ITD/services/maps/g-i-s-data-portal.

City of Newcastle, 2020. GIS Portal. Land Use. Available at https://data-newcastlewa.opendata.arcgis.com/search?collection=Dataset.

King County, 2020. King County GIS Open Data Portal. Available at https://gis-kingcounty.opendata.arcgis.com/.

King County, 2020. King County Pictometry Basemap Aerial 2019. Available at https://gismaps.kingcounty.gov/arcgis/rest/services/BaseMaps/KingCo_Aerial_2019/MapServer.

OCM Partners. 2020. 2016 - 2017 PSLC Lidar DEM: King County, WA, https://www.fisheries.noaa.gov/inport/item/53392.

USGS, 2020. Washington Division of Geology and Earth Resources, 2016, Surface geology, 1:100,000--GIS data, November 2016: Washington Division of Geology and Earth Resources Digital Data Series DS-18, version 3.1, previously released June 2010.

WDFW. 2020. Salmonscape fish distribution. Washington State Department of Fish and Wildlife. Online mapping accessed in summer, 2020 at: http://apps.wdfw.wa.gov/salmonscape/.

Appendix B
Open Streams Condition Assessment Subbasin Summaries for the Coal Creek Watershed

Appendix B

Open Streams Condition Assessment Subbasin Summaries

for the Coal Creek Watershed

April 2021

Bellevue Utilities Department

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Brianna Pierce
Christa Heller

Table of Contents

B.1 Introduction

Physical habitat conditions for the mainstem of Coal Creek and its significant tributaries were assessed from June of 2018 to June of 2019 by City of Bellevue staff as part of the Open Streams Condition Assessment (OSCA), an effort to obtain baseline habitat conditions across streams throughout the City of Bellevue (Bellevue 2020). This appendix provides an overview of the methods and a summary of results at the subbasin or stream level.

B.2 Methods

B.2.1 Rationale for Protocol and Metric Selection

The US Forest Service Region 6 Level II Stream Inventory Protocol Version 2.12 (USFS 2012) was selected due to its rapid, repeatable, and unbiased design. Its watershed approach to habitat assessment allows a comprehensive baseline dataset to be established that will help the Utilities Department define and prioritize its role as a steward of Bellevue streams. Results from this comprehensive survey will help fill data gaps and identify project sites for capital improvement, fish habitat enhancement, and mitigation projects and opportunities.

Physical habitat metrics in this study were selected based on their biological importance to stream health and/or their role as indicators of stream degradation.

- *Channel dimensions:* Altered hydrology can impact the stream size and channel dimensions, often resulting in wider, more incised channels (Chin 2006). Streams in healthy, "properly functioning" condition are expected to have a bankfull width to depth ratio of less than 10 (NOAA 1996). Conversely, channel modifications such as bank armoring can reduce the channel width. Additionally, urban streams tend to have less flow, and therefore shallower water depths, during the dry summer months. This can create low flow barriers for migratory fishes. Migrating adult trout require a minimum depth of 0.4 ft and Chinook Salmon require at least 0.8 ft (Thompson 1972).
- *Pools:* Pools provide a velocity and thermal refuge as well as a refuge when steamflows decrease and water depths elsewhere in the channel become too low to support aquatic life. For salmon, pools provide beneficial foraging habitat for juveniles (Naman *et al.* 2018) and resting areas for adults migrating to the spawning grounds. Pool frequency and volume is positively correlated to salmon production (Nickelson *et al.* 1979). Therefore, pool frequency, expressed as either pools per unit length or channel widths per pool, is a useful indicator of stream health (NOAA 1996). Pool depth is also an important metric. The residual pool depth is defined as the pool depth if stream flow was reduced to zero (i.e. maximum pool depth minus the pool tailout depth). The residual pool depth necessary for resident adult trout is one foot (Behnke 1992) and salmon are generally considered to require a residual pool depth of three or more feet (Marcotte 1984 as cited in CDFG 1998, NOAA 1996).
- *Habitat composition:* Streams impacted by urbanization tend to have reduced habitat complexity, longer habitat units, and a higher percentage of glide habitats (Riley *et al.* 2005). Channel modifications such as weirs, culverts, failed bank armoring, or sediment detention ponds can also alter the habitat composition of a stream. Having a mixture of both fast- and slow-water habitat increases

the diversity of stream-dwelling organisms, and juvenile salmonid productivity is highest when there is a roughly equal proportion of riffle and pool habitat area (Naman *et al.* 2018).

- *Large woody material:* Large woody material (LWM) increases habitat complexity by aiding pool formation and providing cover, facilitates trapping and sorting of sediments, and attenuates flow velocities (Bisson *et al.* 1987). Salmonid abundance is positively correlated with LWM abundance (Hicks *et al.* 1991), and dwindling levels of LWM from land use practices have been implicated in the decline of salmon populations. Studies that have determined the LWM abundance in relatively unimpacted streams (e.g. Fox and Bolton 2007) provide a useful reference benchmark for comparing LWM abundance. Such studies often present both the abundance and volume of wood present. However, since secondary growth, urban riparian areas cannot be expected to contain the large, old growth trees present at reference sites, the present study will only compare wood abundance.
- *Substrate:* Substrate size is highly influential to stream biota, determining the algal and macroinvertebrate communities and structuring the food web. Substrate size also determines the available fish spawning habitat. Salmonids require gravel to cobble-sized substrate for spawning, and a high percentage of fine sediment can trap or suffocate the eggs and juveniles of gravel-spawning fish (Bjornn and Reiser 1991).
- *Erosion:* Erosion is a natural process; however, altered hydrology and reduced riparian vegetation in urban areas frequently contribute to increased bank instability (May *et al.* 1998). Therefore, the percent of banks experiencing erosion can be a useful indicator of degradation but should be interpreted while considering the stream's position and function in the watershed.
- *Bank armoring:* Channel hardening results in altered habitat composition, flow, erosion, and sediment deposition (Stein *et al.* 2012), frequently disconnecting the stream from its historic floodplain. The percent of streambanks that are armored strongly correlates with urban impact. However, the type of armoring can strongly influence its impact on the stream. Bioengineering, or "soft" armoring, that uses rounded boulders, rootwads, and logs can provide bank stabilization while mimicking and facilitating natural stream processes. Therefore, this study presents both the total percent armored banks and the percent bioengineered banks.

B.2.2 Physical Habitat Assessment

Geomorphic stream reaches within the jurisdictional boundaries of Bellevue were delineated and verified as part of this stream habitat assessment. It is assumed that these same reaches will be used in future assessments to maintain consistency for their evaluation over time. All surveys took place during low or base stream flows.

Minor modifications were made to the Forest Service (USFS 2012) protocol. Instead of estimating widths and depths and developing statistically valid correction factors for each observer on each stream, actual measurements were collected at representative locations along each habitat unit using a laser range finder, measuring tape and/or stadia rod. A minimum of two thalweg depths, representative and maximum, were collected per habitat unit. The thalweg length of every habitat unit was measured using a hip chain or measuring tape. Habitat units were categorized as a pool, riffle, glide, step pool, side channel, pond, or tributary. Other habitat features such as chutes, falls, beaver dams, or seeps/springs were noted. Streambed substrate was visually estimated for fast water units (i.e. riffles and glides) as fines, gravel, cobble, boulder, and bedrock (or hardpan). Floodprone widths, bankfull depths, and Wolman pebble counts were not collected as part of this assessment.

Three levels of assessment were established to efficiently survey the basin to the greatest extent possible. Table 1 details the decision matrix and level of effort associated with the three assessment levels. Level 1 inventory methods were utilized in the mainstem and significant fish bearing streams, whereas Level 2 or 3 inventory methods were used to evaluate the condition and health of steep tributaries and headwater portions throughout the basin.

Table 1. Decision matrix for determining the level of assessment

Assessment	Scale	Fish Use [1]	Summary
Level 1	Habitat Unit	F/PF	Full inventory at the habitat unit level for habitat and streambed substrate, unit length, width, depth; bank instability/armoring; LWM; photo documentation; and reference points (including channel profile data).
Level 2	Reach	F/PF/NF	Simplified inventory at the reach scale. Includes quantification of LWM, armoring, bank instability with data for pool and side channel habitat types and basic channel profile data. Photo documentation and documentation of tributaries and off-channel areas.
Level 3	Reach to Basin	Primarily NF	Consists primarily of spot checks with alerts, photo documentation, and general qualitative observations.

[1] Fish use categories relate to water type classifications where "F/PF" denotes a stream used by fish or has the potential to support fish populations and has perennial flow; "F/PF/NF" denotes a stream that may be used by fish, but that may have reaches above a natural barrier, may be intermittent, or not have flowing water all year; "NF" denotes a stream that is not used by fish and that does not have perennial flow.

B.2.3 Large Woody Material

Pieces of large woody material (LWM) were categorized by length, diameter, and position within the stream channel based on protocols for Wadeable Streams of Western Washington (Ecology 2009). Wood counts by size class were converted to volume using the formula established by Robison (1998). Wood smaller than the minimum length and diameter thresholds in Table 3 were not counted but may have contributed to the creation of log jams with small woody material. All LWM were noted as naturally recruited or human-placed and as anchored or unanchored. Log jams were also noted, and for Level 1 surveys, the habitat type in which the wood was located was also recorded, but those data are not included in this report.

Table 2. Size categories for large woody material.

Length	Diameter
Short (6-16 feet)	Thin (4-12 inches)
Medium (16-50 feet)	Medium (12-24 inches)
Long (>50 feet)	Wide (>24 inches)

B.2.4 Riparian and Streambank Condition

Riparian vegetation was not quantitatively assessed during the stream habitat surveys but was generally characterized using Geographic Information System (GIS) aerial imagery and field verified at the reach scale. Stands of Japanese knotweed (knotweed) were mapped and measured as a lineal metric and density described as low (less than 10 square feet), medium (10-500 square feet), or high (greater than 500 square feet).

Streambank erosion and armoring were each mapped and measured as a linear metric and described as low (0-5 feet), medium (5-10 feet) or high (greater than 10 feet). Undercut banks were noted and measured; a representative measurement was recorded for each incidence of erosion or scour, and the maximum was noted if it was substantially greater than the representative value. Bank armoring material was documented and specified as riprap, rocks, metal, concrete, gabion baskets, logs, rootwads, bioengineering, etc.

Anthropogenic features such as culverts, bridges, weirs, outfalls, and litter were also documented when observed but are generally not included in this report.

B.2.5 Fish Habitat and Passage Barriers

Fish presence was documented by species, when possible, and abundance was estimated as low, medium, or high. Field protocols for this habitat assessment did not include a formal fish survey nor a fish passage barrier assessment, although locations of potential barriers, type and material of barrier, jump heights, and photos were collected. This information will aid further investigations through Bellevue's Fish Passage Improvement Program.

B.3 Summary of Results

Coal Creek mainstem Reaches 1 through 10 were surveyed during the summer low flows of 2018. Reach 2 was not surveyed as it is a long culvert under Interstate 405. Reach 11 was dry in the summer and thus not surveyable until December of 2018. Additional stream reaches exist upstream of Reach 11 outside City of Bellevue jurisdictional boundaries just east of Lakemont Blvd in unincorporated King County in an area known as the Cougar Mountain Regional Wildland Park. Newport Creek and the lower half of Tributary 0273 were surveyed in the fall of 2018 and the other tributaries to Coal Creek were surveyed in the spring of 2019. Figure 1 and Table 3 present the surveyed streams within the Coal Creek Watershed and the survey level used for each. Additional small tributaries or stream reaches were inventoried as part of this assessment, but they are not mentioned in this summary as there were no quantitative data collected.

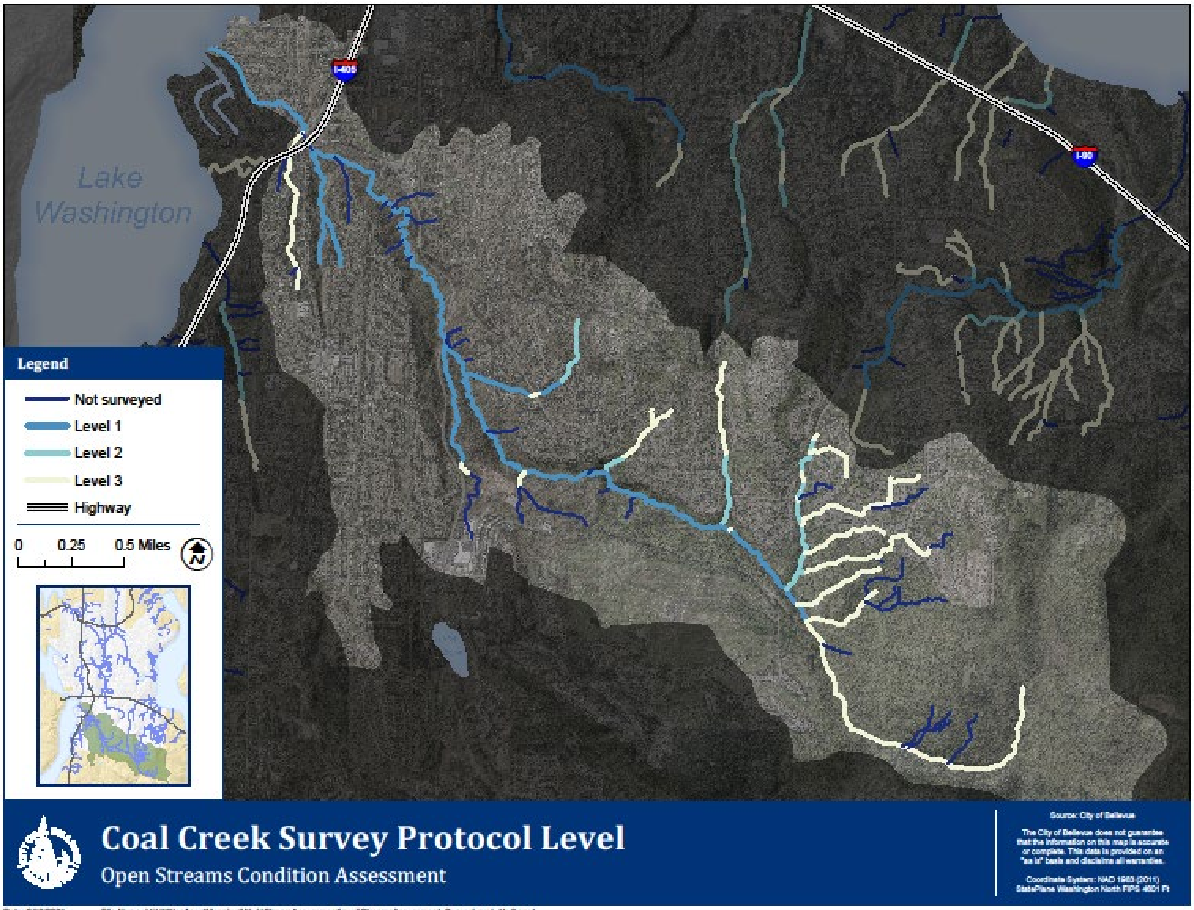

Figure 1. Map showing the survey protocol level used for streams in the Coal Creek Watershed

Table 3. List of inventoried Bellevue streams, including Bellevue Stream Segment number and Water Resource Inventory Area (WRIA) number, organized from downstream to upstream.

Stream Name	WRIA #	Bellevue Stream Reach	Bellevue Stream Segment ID	Assessment Level
Coal Creek	08.0268			
		Reach 1	84_01	1
		Reach 3	84_03	1
		Reach 4	84_04	1
		Reach 5	84_05	1
		Reach 6	84_06	1
		Reach 7	84_07	1
		Reach 8	84_08	1
		Reach 9	84_09	1
		Reach 10	84_10	1
		Reach 11	84_11	1
Trib 0268Z	08.0268Z		84_01_11	3
Newport Creek	08.0269			
		Reach 1	84_03_11	1
		Reach 2	84_03_12	1
Tributary to Newport Creek			84_03_12_11	1
Newcastle Creek (Tributary 0275)	08.0275			
		Reach 1	84_03_101	1
		Reach 3	84_03_103 (not in Bellevue)	3
Tributary 0273	08.0273			
		Reach 1	84_04_21	1
		Reach 3	84_04_23	1, 2
		Reach 4	84_04_24	2
Tributary 0268D	08.0268D		84_05_11 (not in Bellevue)	3
Tributary 0274	08.0274	Reach 1	84_06_11	2,3

Stream Name	WRIA #	Bellevue Stream Reach	Bellevue Stream Segment ID	Assessment Level
Tributary 0276	08.0276			
		Reach 1	84_08_11	2
		Reach 2	84_08_12	2
Tributary 0276A	08.0276A			
		Reach 1	84_10_11	2
		Reach 2	84_10_12	2
		Reach 4	84_10_14	2
		Reach 6	84_10_16	2
		Reach 9	84_10_19	2
		Reach 11	84_10_111	2
		Reach 13	84_10_113	3

B.3.1 Coal Creek Mainstem

Figure 2. Map identifying the mainstem reaches of Coal Creek

B.3.1.1 Channel Morphology and Riparian Corridor

The Coal Creek mainstem reaches (Figure 2) are primarily composed of pool-riffle and plane-bed channel types. Table 4 provides channel attributes for the mainstem reaches. The upper reaches of the mainstem are valley confined with slopes ranging from 2.4% to 7.5%, and the lower, response reaches have 1.1% to 2.4% slopes. In general, the Coal Creek Watershed has excellent riparian cover. Although the lower reaches are impacted by residential development, the middle and upper portion of the mainstem are surrounded by the Coal Creek Natural Area and the King County Cougar Mountain Regional Wildland Park.

Table 4. Coal Creek mainstem reach attributes

	84_01	84_03	84_04	84_05	84_06	84_07	84_08	84_09	84_10	84_11
Reach Mileage Boundaries	0.00 – 0.60	0.70 – 2.23	2.23 – 2.95	2.95 – 3.45	3.45 – 3.69	3.69 – 4.02	4.02 – 4.44	4.44 – 4.55	4.55 – 4.71	4.71 – 4.89
Reach Morphology	Response	Response	Response	Response	Transport	Transport	Transport	Transport	Response/ Transport	Source
Channel Type	Plane-bed	Pool-riffle	Plane-bed	Plane-bed / Pool-riffle	Cascade	Forced Pool-riffle	Plane-bed	Step-pool	Forced Pool-riffle	Forced Pool-riffle
Avg Reach Slope (percent)	1.1	1.2	1.3	2.4	6.0	2.4	3.8	6.2	3.3	7.5
Drainage Area (acres)	4551.4	3782.2	2924.2	2593.0	2283.7	2123.3	2043.5	1776.0	1762.4	1267.2
Riparian Canopy Cover (percent Urban Tree Canopy)	39	84	89	100	100	99	100	100	94	87
Reach Length (ft)	3,642	8,461	3,977	2,627	1,199	1,838	2,288	591	793	976

Across all reaches, the median wetted and bankfull widths are 13.7 ft and 21 ft, respectively. Channel widths generally decrease as you proceed upstream (Figure 3). The bankfull widths are notably confined in Reach 1 as a result of residential development. In the upstream reaches, the bankfull widths become constrained due to valley confinement. Widths are highly variable in Reach 3, in part due to the presence of three in-stream sediment detention ponds and a few dry side channels.

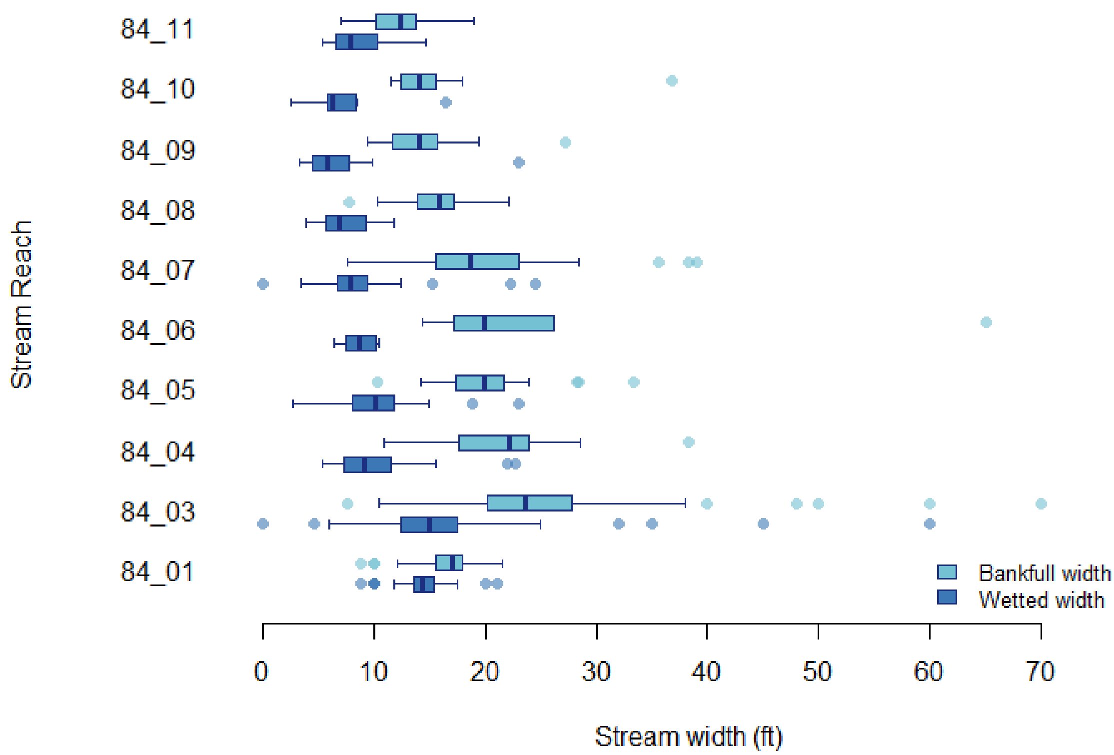

Figure 3. Boxplot of the wetted and bankfull widths for the Coal Creek mainstem reaches. Dry side channels are represented here with a width of 0 ft

The median representative wetted channel depth of 0.6 ft is fairly consistent across all reaches with a few notable exceptions: Reaches 1 and 3 tend to be slightly deeper and Reach 10 is much shallower (Figure 4). Median minimum depths range from 0.1 ft (Reaches 6 and 10) to 0.5 ft (Reach 3), indicating that summer low-flow conditions may create barriers to migratory fish. Trout and Coho Salmon generally require a minimum depth of 0.4 and 0.6 ft, respectively (Thompson 1972).

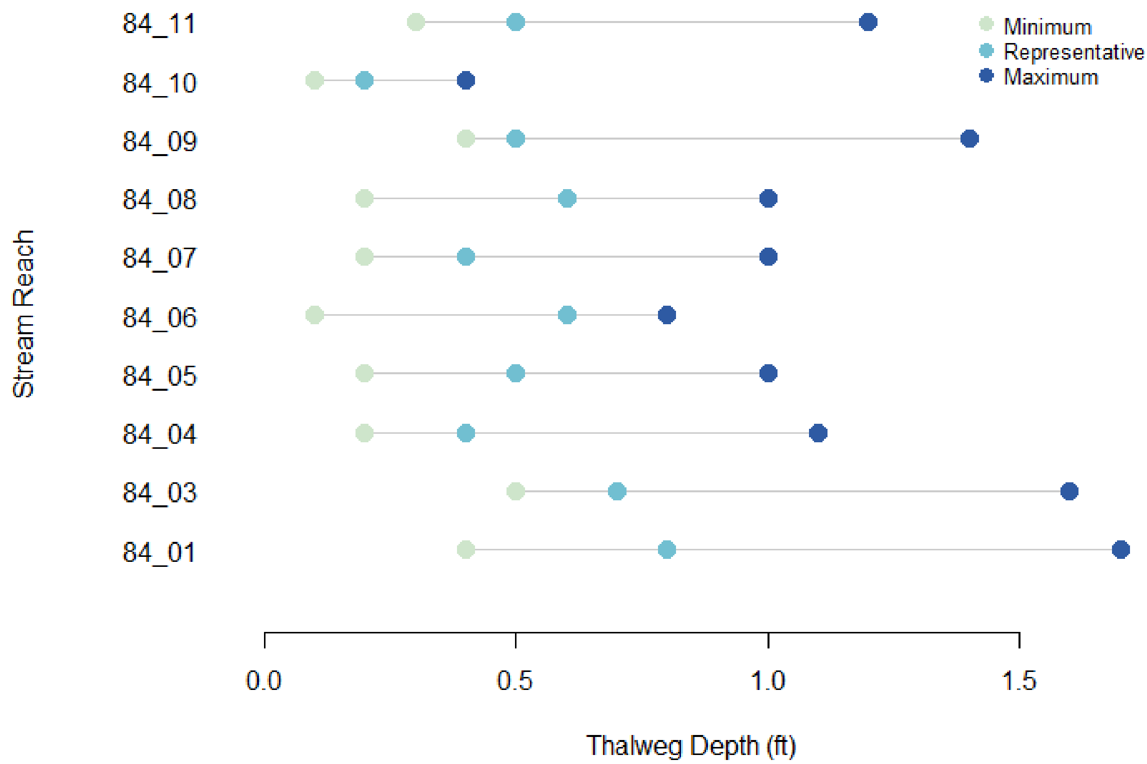

Figure 4. Dumbbell plot of wetted stream depths. Points represent the median value for the minimum, representative, and maximum depth in each reach of the Coal Creek mainstem

B.3.1.2 Habitat Unit Composition and Off-Channel Habitat

The Coal Creek mainstem reaches are dominated by riffle habitat, which comprises 52% of the stream by area and 63% by length (Figure 5 and Figure 6). Pools are the second-most common habitat unit, comprising 20% of the stream by area and 16% by length. While ponds only account for 2% of the stream length, they comprise 12% of the stream area due to their substantial widths.

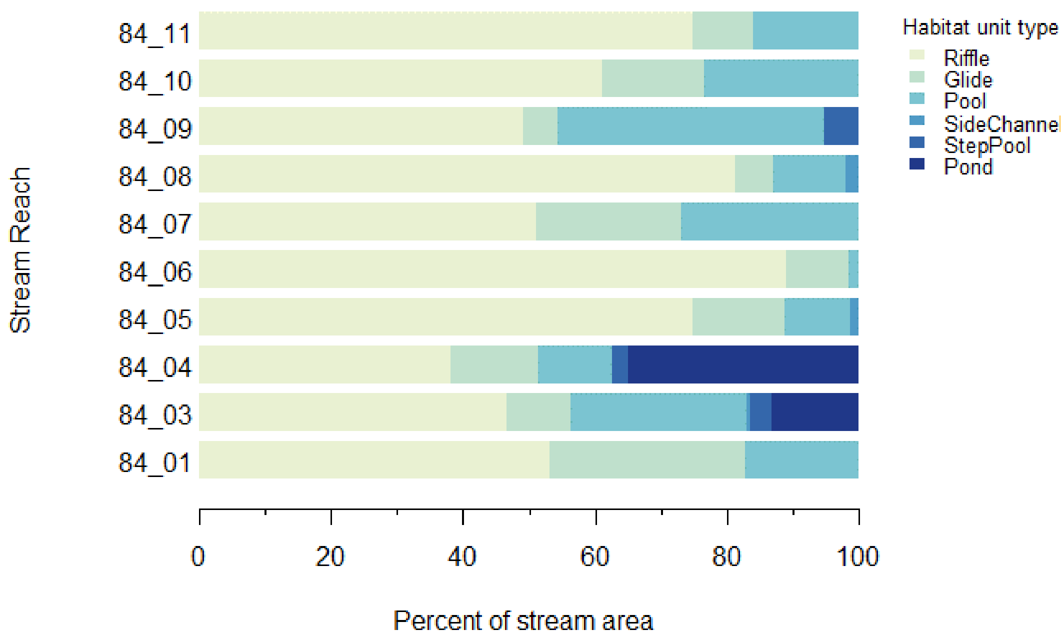

Figure 5. Habitat unit composition (by percent area) of the Coal Creek mainstem reaches

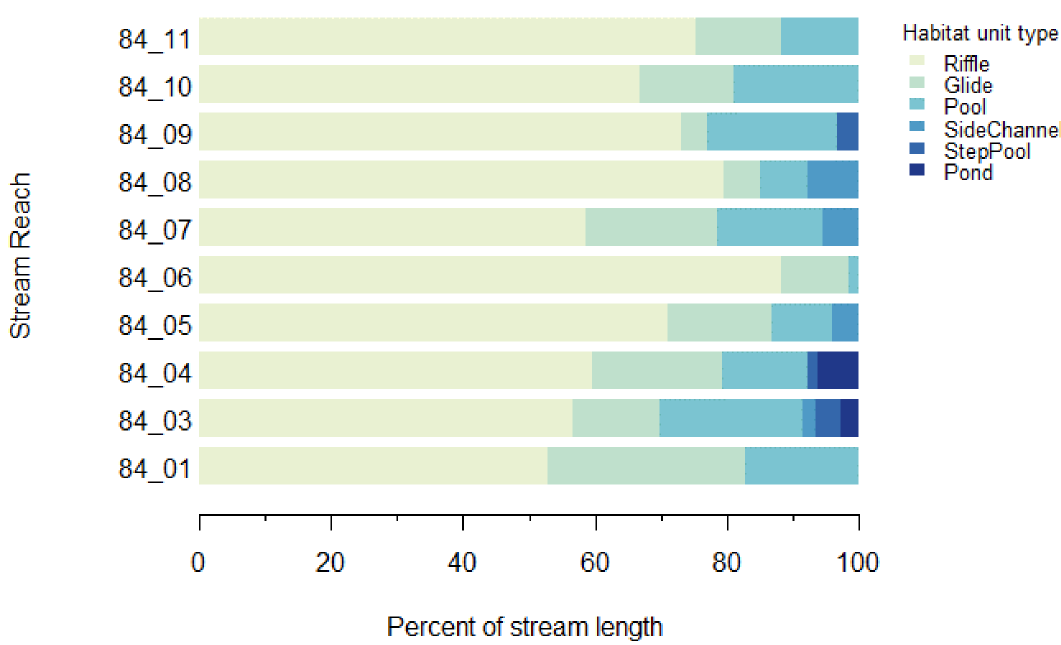

Figure 6. Habitat unit composition (by percent length) of the Coal Creek mainstem reaches

Pool habitat is somewhat lacking in the Coal Creek mainstem. Juvenile salmonid productivity is highest when the ratio of riffle area to pool area is approximately 1 (Naman *et al.* 2008). The Coal Creek mainstem has an overall riffle to pool ratio of 2.6, indicating that lack of pool habitat may be a limiting factor for fish populations. Overall, the Coal Creek mainstem has a pool frequency of 19 pools/mile (1 pool/100 m) or approximately 13 channel widths per pool and a median distance between pools of 143 ft. Similarly sized, "properly functioning" streams are expected to have around 55 pools/mile (NOAA 1996). Furthermore, only 9 pools (< 10% of all pools) in the Coal Creek mainstem have a maximum depth greater than 3 ft (Figure 7), which is considered the minimum threshold for high quality pools in salmon-bearing streams (NOAA 1996). Reach 3 has the greatest number of pools and the deepest pools, which are often associated with large wood accumulations from nearby landslides and slope failures. Additionally, Reach 3 pool frequency and complexity is enhanced by the abundant beaver population throughout this portion of the Coal Creek Natural Area. Although most Coal Creek pools do not meet the minimum criteria for high quality pools, they are nevertheless generally deeper than pools found in Bellevue's other watersheds. The median residual pool depth for the mainstem reaches is 1.6 ft, which is above the 75th percentile for stream reaches in Bellevue.

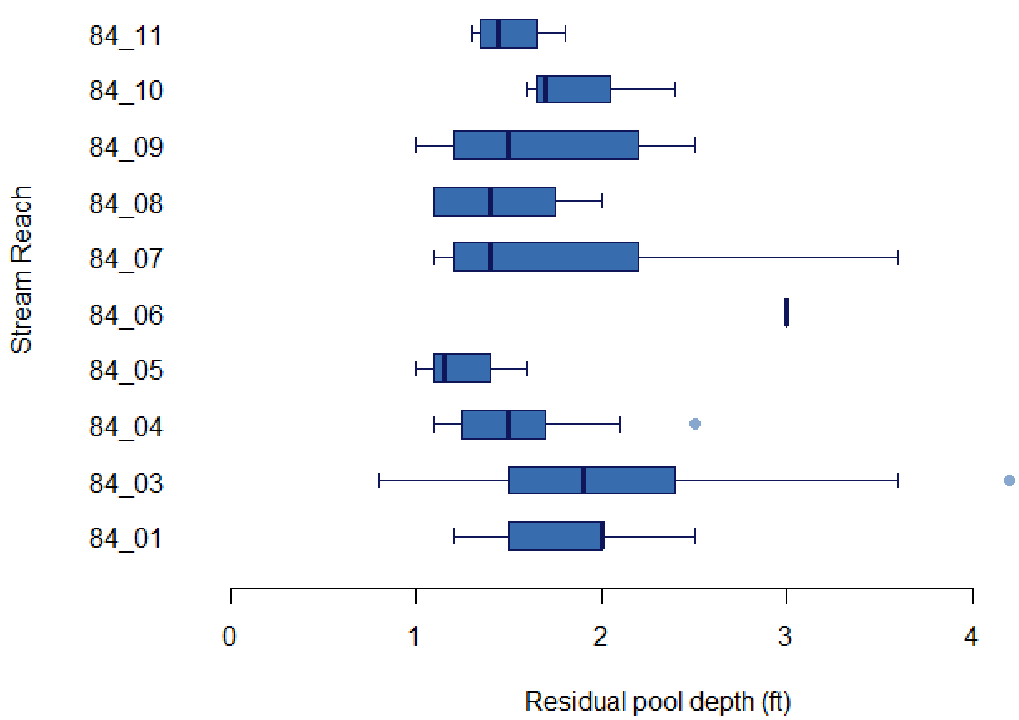

Figure 7. Boxplot of residual pool depths observed in the mainstem reaches of Coal Creek

Off-channel habitat is limited in Coal Creek. Reach 1 is restricted by residential development and the uppermost reaches are valley confined. Side channel habitat units are present in Reaches 3, 5, 7, and 8 (Figures 5 and 6), but they tend to be small in extent and several were dry at the time of the surveys. Compared to the other mainstem reaches, Reach 3 is the most dynamic, having floodplain connectivity and access to a wide channel migration zone. Process-based restoration would be an option for Reach 3 habitat creation.

B.3.1.3 Large Woody Material

The Coal Creek mainstem has the highest levels of large woody material (LWM) found in the City of Bellevue. The average wood density for the mainstem reaches is 488 pieces/mile (30 pieces/100 m), which is comparable to the median value observed in relatively pristine reference streams (Fox and Bolton 2007; Figure 8). Reaches 7 through 11 have excellent LWM levels exceeding the reference 75th percentile. Only three reaches (1, 4, and 6) fail to reach the 25th percentile reference levels, indicating that they have deficient LWM levels. Wood placement in these reaches could effectively increase and enhance habitat complexity.

In addition to the good riparian tree canopy, restoration and bank stabilization projects have contributed placed LWM that has benefited the stream. More than half of the wood observed in Reach 10 was placed, as was more than 15% of the wood observed in Reaches 3, 7, and 8 (Figure 9). As may be expected from a young, secondary growth riparian area, the LWM present in Coal Creek is relatively small. Only 6% of the documented wood is greater than 2ft in diameter.

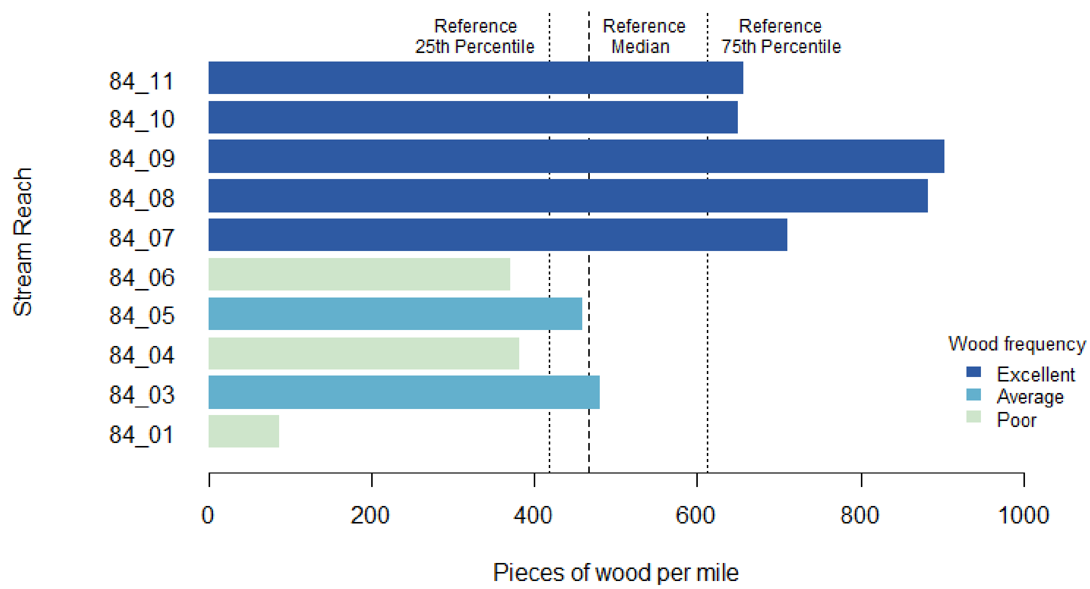

Figure 8. Large woody material (LWM) frequency in the mainstem of Coal Creek compared to reference levels (Fox and Bolton 2007)

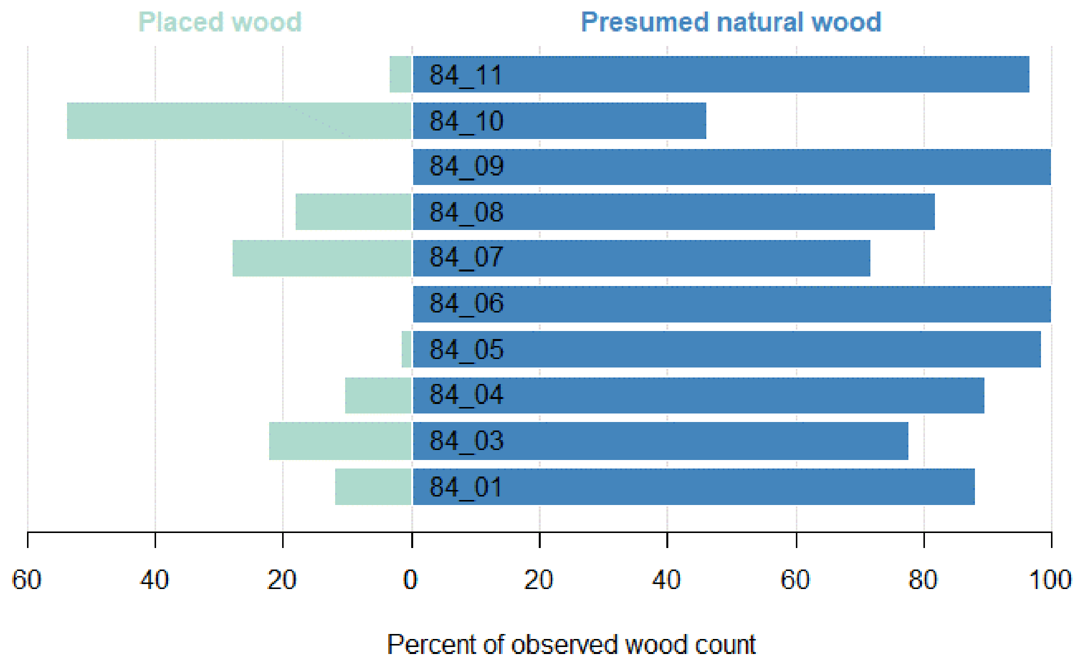

Figure 9. Diverging bar graph showing the proportion of wood observed in each stream reach that is of natural origin or was placed

B.3.1.4 Substrate Conditions

Substrate composition (Figure 10) is predominantly gravel and cobbles throughout the stream corridor, consistent with sizes suitable for spawning, migration, and rearing habitat. Percent fines are around 20% or greater only for the downstream most response reaches 1 and 3, and the upstream-most source/transport reaches 10 and 11, where coal mining impacts remain. The percent of fines in the substrate are generally less for Coal Creek than in the majority of other streams in Bellevue. Also unique in comparison to other Bellevue watersheds, the middle and upper reaches of Coal Creek contain significant boulder substrate and exposed bedrock or glacial till.

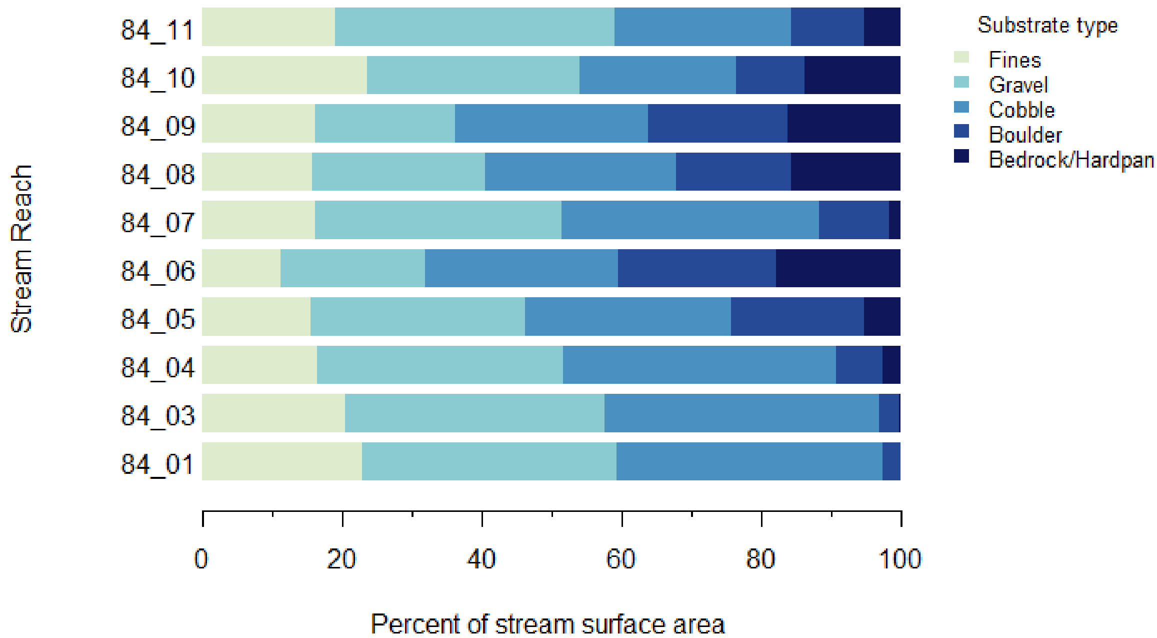

Figure 10. Substrate composition of riffle habitat in the Coal Creek mainstem reaches, determined by visual estimation

B.3.1.5 Streambank Conditions

Bank armoring along the mainstem reaches of Coal Creek is relatively low, in large part due to the park space that helps to buffer the creek from local impacts of development through much of the stream corridor. Overall, 10% of the Coal Creek mainstem banks are armored (8% traditional armoring and 2% bioengineering; Figure 11). Reaches 5, 6, 7, and 9 are completely free of armoring and all armoring in Reaches 8 and 10 is bioengineering. Bank armoring is greatest along Reach 1, which flows through the Newport Shores community, as well as in the upstream most reaches, 10 and 11, where there are several trail crossings and remnants from historic coal mining, such as old flumes.

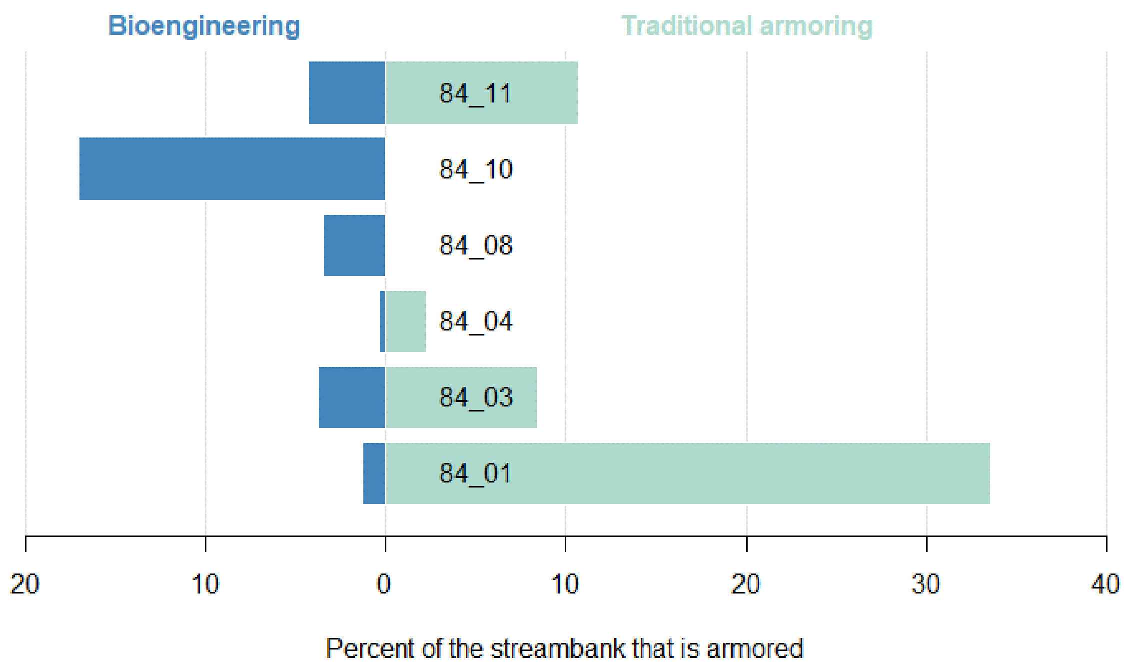

Figure 11. Diverging bar chart showing the proportion of the stream bank that is armored using traditional materials (right) and bioengineering (left)

The Coal Creek mainstem reaches generally have a higher percent of bank instability than other stream reaches in the City of Bellevue, in part due to legacy impacts from coal mining and logging activities. Evidence of landslides and mass-wasting events are evident in Reaches 3, 6, and 9. Overall, 24% of the mainstem banks are experiencing erosion, with the greatest erosion occurring in Reaches 5 and 9 (Figure 12). Correspondingly, the percent of the streambank that is undercut is greater in Coal Creek than in most other streams in Bellevue, with a total of 11% of the mainstem channel having undercut banks. Undercutting is greatest in Reaches 1 and 5, and generally decreases upstream (Figure 13). Reach 3 is notable for having areas of undercut but stable banks where toe scour occurs only along the waterline, providing good fish habitat.

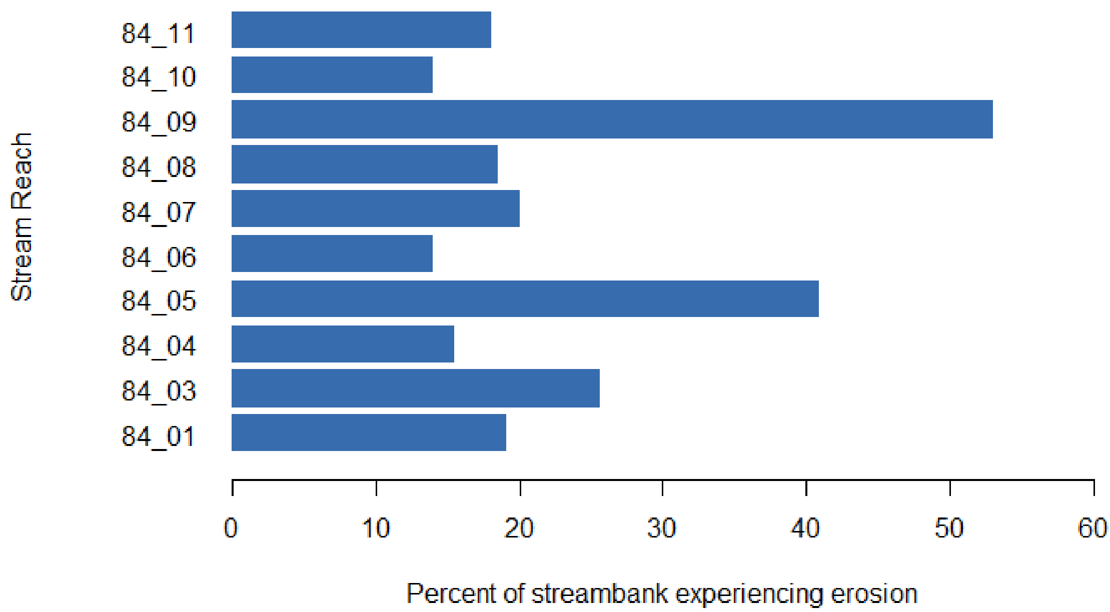

Figure 12. Percent of each stream reach that is experiencing erosion in the Coal Creek mainstem

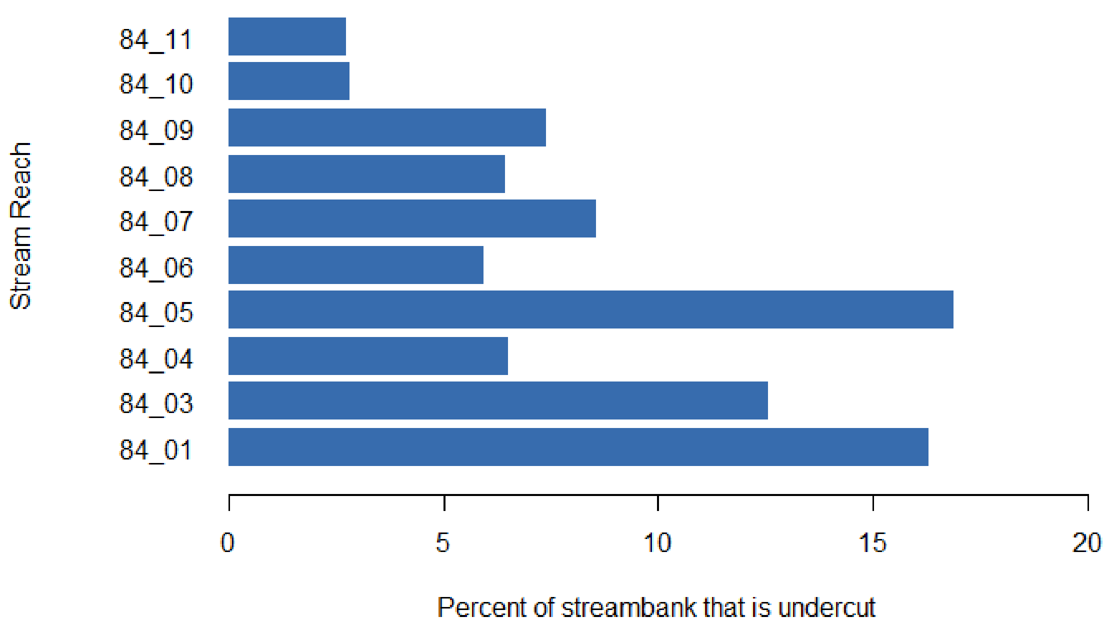

Figure 13. Percent of each Coal Creek mainstem reach that has undercut banks

B.3.1.6 Fish Habitat and Passage Barriers

The best fish habitat in the Coal Creek mainstem occurs in the lower reaches. Anadromous fish is inversely related to channel gradient, leading to a proposal that gradients of 5 to 7% can may represent a threshold for some Pacific salmon (Seixas *et al.* 2019). Reaches 6, 9, and 11 all have channel gradients greater than 6% (Table 4). Therefore, Reaches 1 through 5 likely support the greatest potential anadromous fish habitat in Coal Creek. Juvenile salmonid rearing and late summer to early fall salmon migration are likely limited to Reaches 1 through 3 due to the shallow riffle and pool depths observed upstream. Reach 3 provides the best spawning habitat with the deepest pools and an abundance of good spawning gravels and cobbles, and historically this reach has hosted numerous redds (surveyed from 2008 to present). Although the lower reaches provide the best fish habitat, it should be noted that Cutthroat Trout were observed during the OSCA habitat surveys into Reach 10 in low numbers.

In addition to the low flow concerns previously mentioned, there are physical obstructions that may challenge fish passage. The Washington State Fish Passage database does not list any complete fish passage barriers in the Coal Creek mainstem Reaches 1-11, but there are five partial barriers (WDFW 2020). These partial barriers, including grade control structures and coal mining relics, are discussed in more detail in the reach descriptions of the Coal Creek OSCA Report.

B.3.1.7 Opportunities

While the overall habitat quality of the mainstem reaches of Coal Creek is excellent for Bellevue and other urban watersheds throughout the region, there are still opportunities to protect, improve, and sustain Coal Creek and its tributaries. Opportunities for fish habitat enhancement should be focused in Reaches 1-5, while slope stability, reforestation, and upland stormwater detention are key priorities for the upper mainstem reaches and tributaries. Site specific recommendations are provided in the reach descriptions of the Coal Creek OSCA Report (Bellevue 2021), which should be implemented in conjunction with the forthcoming programmatic and policy recommendations provided in the city-wide Watershed Management Plan.

B.3.2 Primary Tributaries to Coal Creek

There are numerous tributaries in the Coal Creek Watershed, ranging from small, steep, seasonal drainages to larger, fish-bearing streams. Four tributaries were considered important enough to the watershed to warrant a Level 1 survey (Figure 14). These include Newport Creek, Tributary to Newport Creek, lower Newcastle Creek, and the downstream half of Tributary 0273 which were surveyed in the fall of 2018.

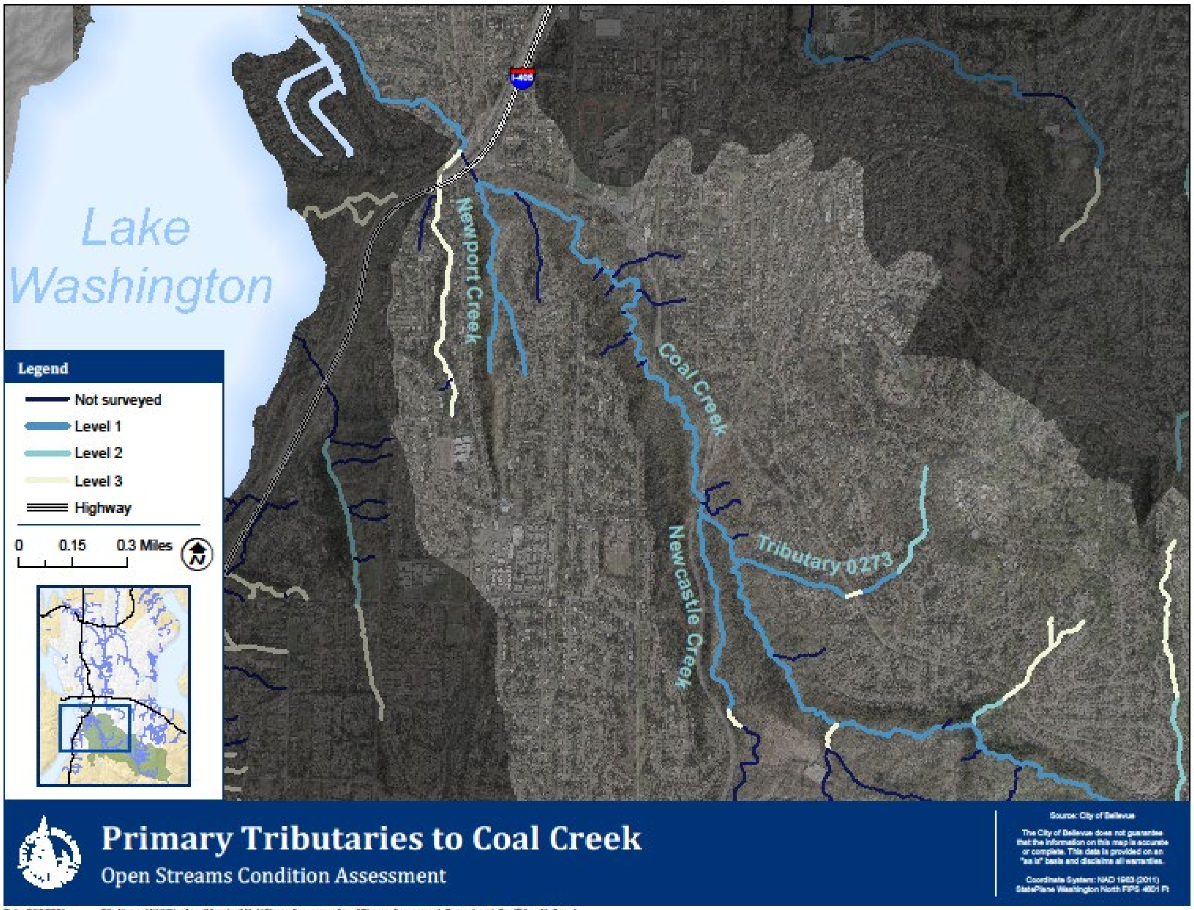

Figure 14. Map showing the location of the primary tributaries to Coal Creek that were surveyed under a Level 1 protocol

B.3.2.1 Channel Morphology and Riparian Corridor

The primary tributaries to Coal Creek are generally characterized by a moderate to high gradient (Table 5) and narrow valley confinement. They are prone to channel incision with some areas scoured to exposed glacial till. Newport Creek, in particular, has been the focus of restoration efforts to promote bank stabilization and the retention of sediment within the basin. Due to their ravine-like nature, these tributaries generally have an intact riparian buffer with a healthy tree canopy.

Table 5. Stream reach attributes of the primary tributaries to Coal Creek

	Newport Creek		Tributary to Newport Creek	Newcastle Creek (Trib 0275)	Tributary 0273	
Reach Segment ID	**84_03_11**	**84_03_12**	**84_03_12_1 1**	**84_03_101**	**84_04_21**	**84_04_23**
Reach Mileage Boundaries	0.00 – 0.34	0.34 – 0.58	0.00 – 0.25	0.00 – 0.61	0.00 – 0.34	0.38 – 0.59
Reach Morphology	Transport	Transport	Source	Transport	Transport	Source
Channel Type	Plane-Bed	Forced Step-Pool	Headwater/ Colluvial	Plane-Bed	Cascade	Headwater/ Colluvial
Avg Reach Slope (percent)	3.7	5.9	12.1	4.3	12.4	10.6
Drainage Area (acres)	432.9	323.8	76	175.9	160.4	262.8
Riparian Canopy Cover (percent Urban Tree Canopy)	94	93	84	92	91	85
Reach Length (ft)	1850	1101	1045	3523	1566	714

The primary tributaries to Coal Creek are moderate in size, with an average wetted width ranging from 3.6 to 8.1 ft and an average bankfull width of 8.4 to 14.3 ft (Figure 15). Channel depth varies considerably with tributary size; Newcastle Creek has the second highest median representative depth observed in the entire Coal Creek Watershed at 0.7 ft, while the other tributaries tend to be quite a bit shallower (Figure 16).

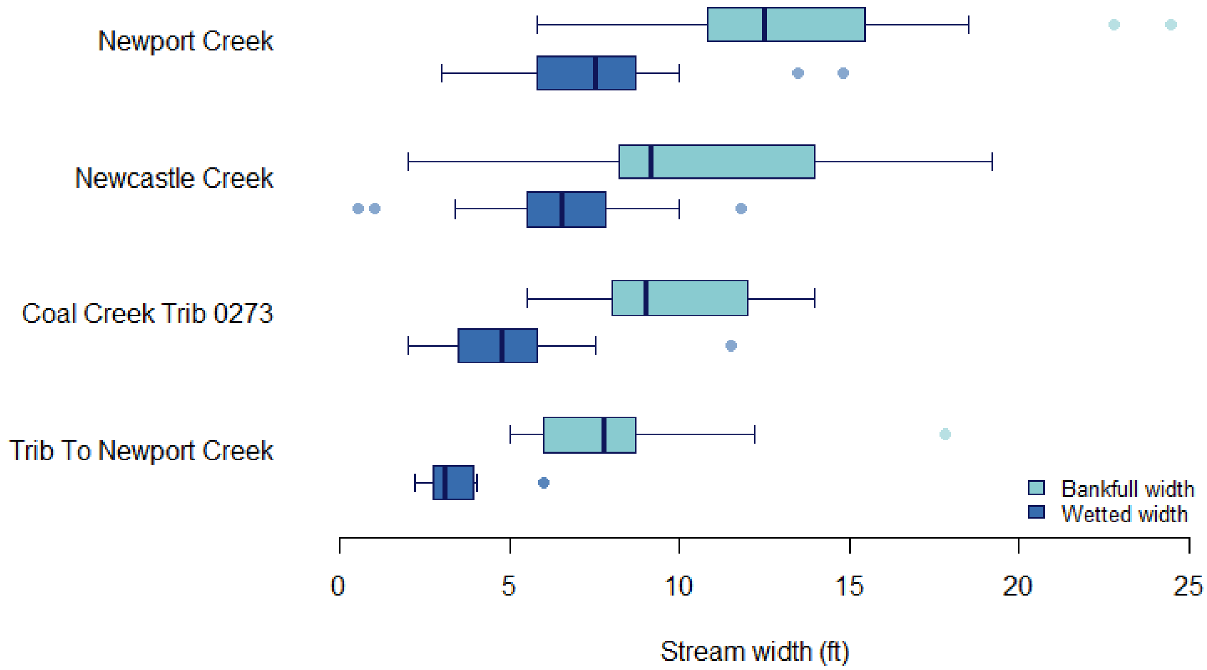

Figure 15. Boxplot of the wetted and bankfull widths for the primary Coal Creek tributaries

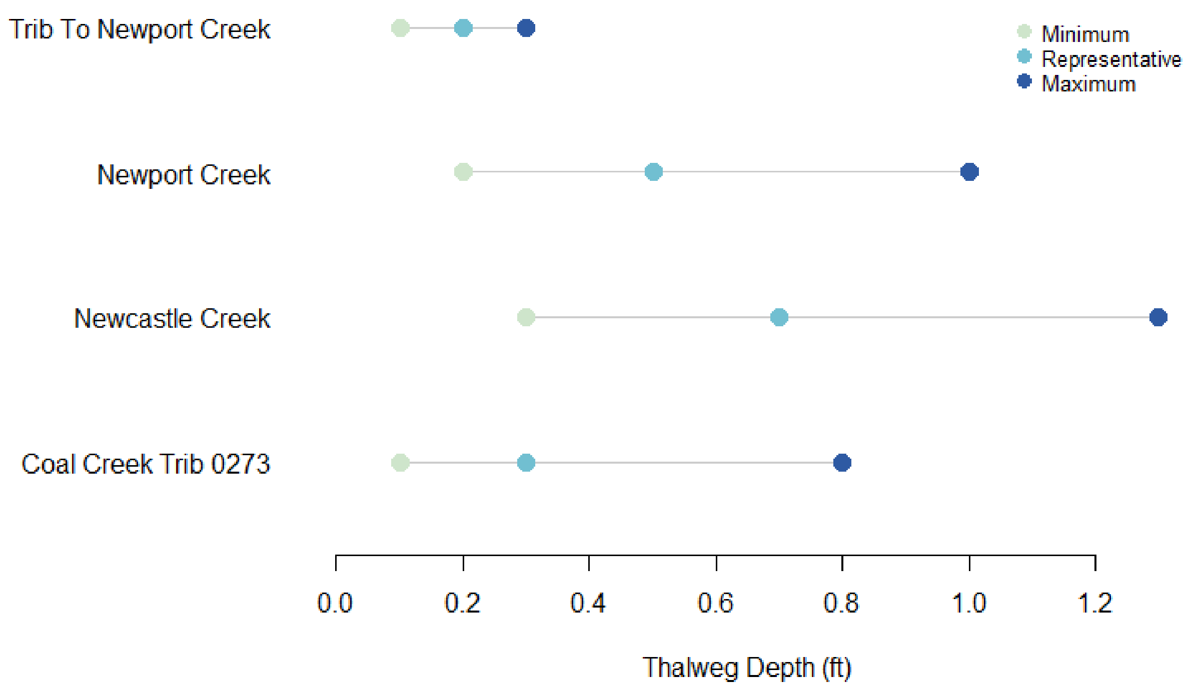

Figure 16. Dumbbell plot of wetted stream depths. Points represent the median value for the minimum, representative, and maximum depth in each of the primary tributaries to Coal Creek

B.3.2.2 Habitat Unit Composition and Off-Channel Habitat

Habitat in the Coal Creek tributaries is highly homogenous with riffle (and cascade) habitat being almost entirely predominant (Figures 17 and 18). A few small side channels are present in Newcastle Creek and lower Newport Creek, but, for the most part, there is limited potential for off-channel habitat due to the valley-confined nature of these tributaries. Pool habitat is very scarce and, when present, comprises only 1% of the stream reach area. As such, these tributaries do not currently provide ideal fish habitat. Although some pocket pools are present under weir sills, they do not meet our criteria for pool classification.

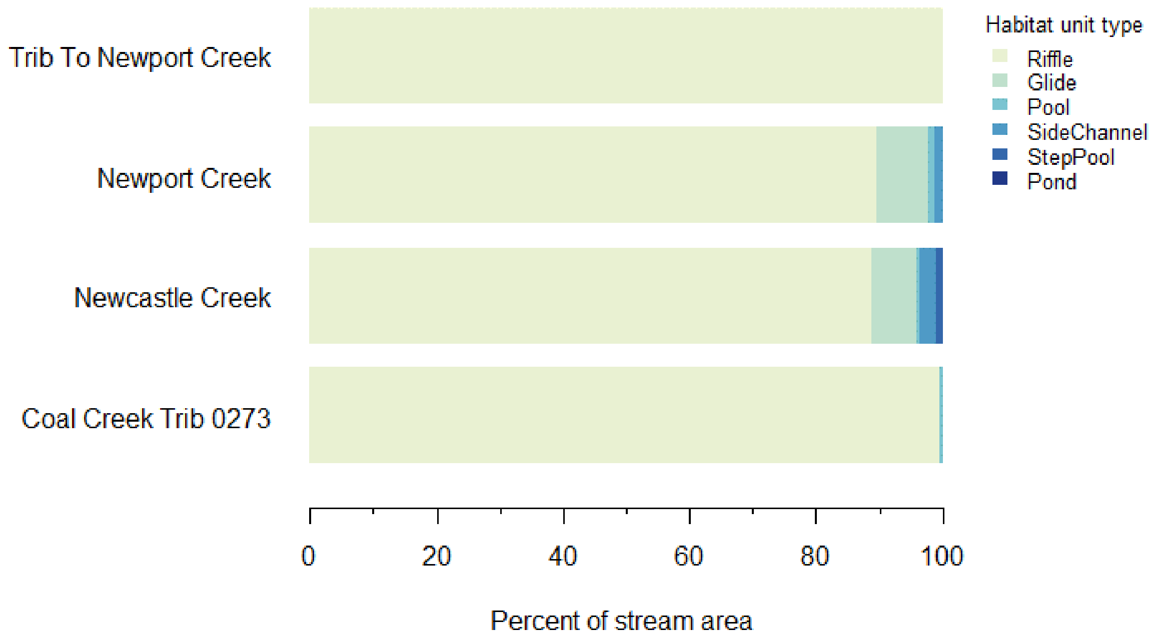

Figure 17. Habitat unit composition (by percent area) of the primary Coal Creek tributaries

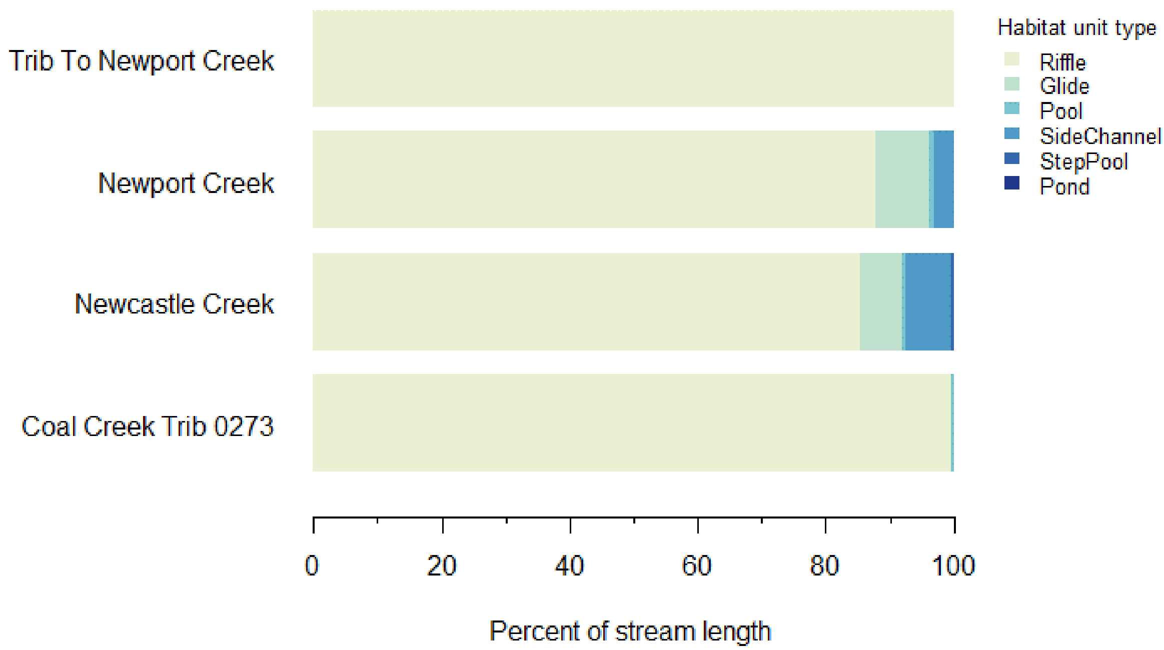

Figure 18. Habitat unit composition (by percent length) of the primary Coal Creek tributaries

B.3.2.3 Large Woody Material

Like the rest of the Coal Creek Watershed, the primary tributaries to Coal Creek have a healthy abundance of stream-associated large woody material (LWM; Figure 19). On average, the tributaries have a wood frequency of 605 pieces/mile (38 pieces/100 m), which is well above the 75th percentile for all stream reaches in the City of Bellevue. Only upper Newport Creek falls short of reference levels of LWM, while lower Newport Creek greatly exceeds reference conditions (Fox and Bolton 2007). The high quantity of LWM in lower Newport Creek is largely due to restoration and bank stabilization efforts that utilized placed LWM, accounting for 71% of all wood observed in this reach. For the rest of the tributary reaches, the observed wood is predominantly of natural origin and the intact riparian canopy provides opportunities for additional natural recruitment of LWM.

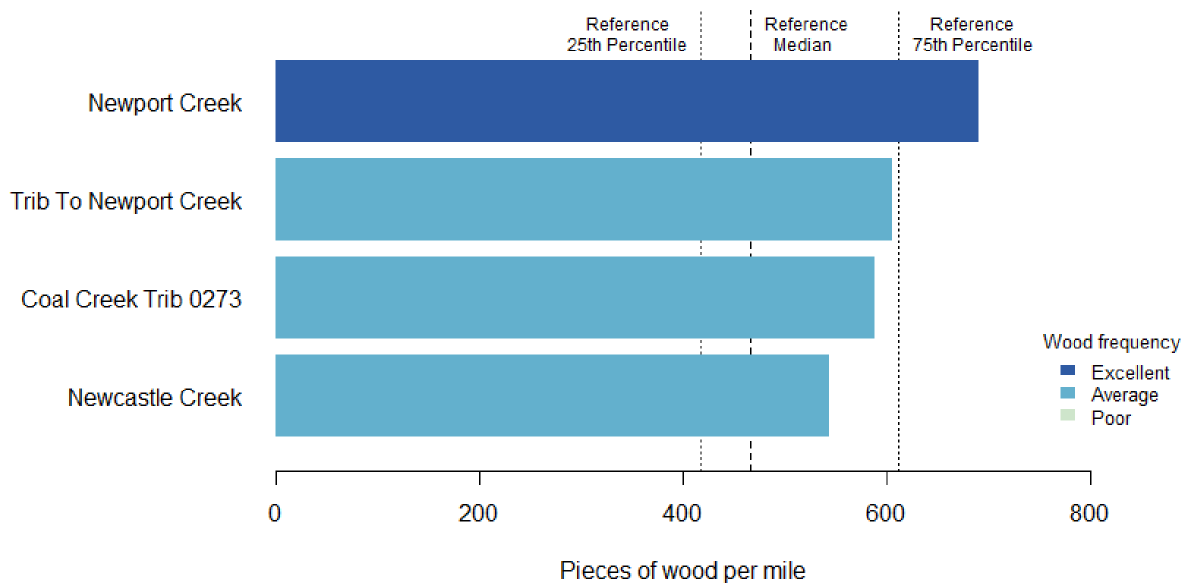

Figure 19. Large woody material (LWM) frequency in the primary tributaries to Coal Creek compared to reference levels (Fox and Bolton 2007)

B.3.2.4 Substrate Conditions

Substrate composition for the Coal Creek tributaries is predominantly composed of gravels (36%), cobbles (30%), and fines (26%) (Figure 20). Compared to the mainstem reaches of Coal Creek, the tributary reaches have a higher percent of fines and lower percent of boulders and exposed glacial till. There is intermittent exposed glacial till only in the lower portions of Tributary 0273 and Newcastle Creek. In Newport Creek, there is considerable sand and fines associated with stormwater outfalls.

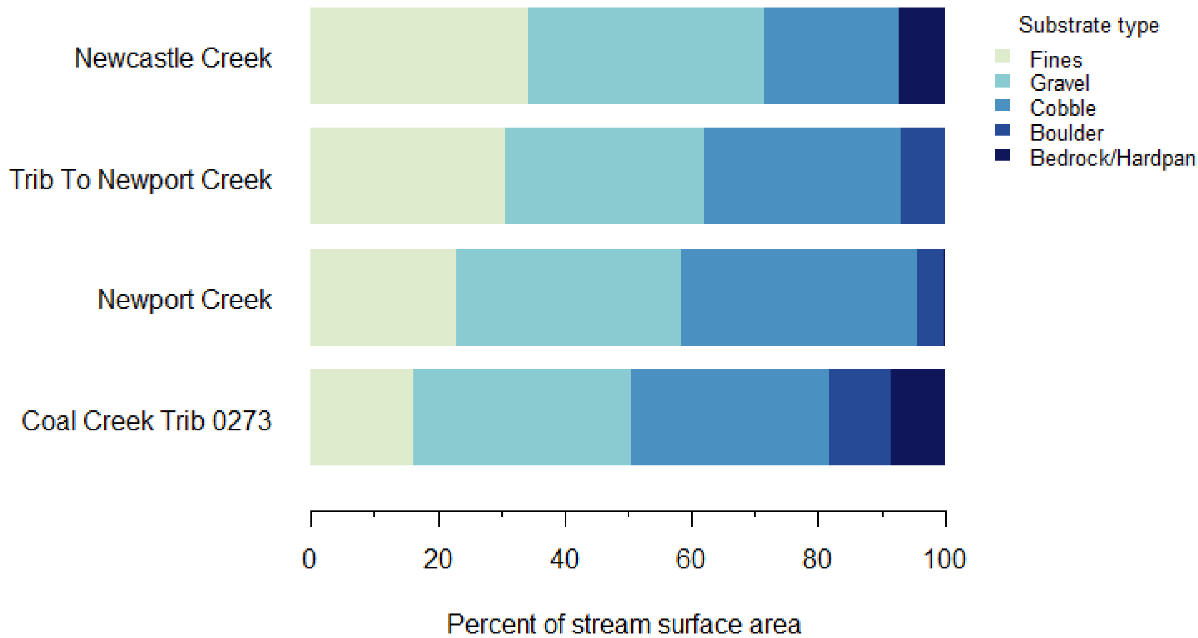

Figure 20. Substrate composition of riffle habitat in the primary tributaries to Coal Creek, determined by visual estimation

B.3.2.5 Streambank Conditions

Overall, streambank armoring is minimal in the tributaries to Coal Creek. The one exception is Newport Creek, which is the ninth-most armored stream in the City of Bellevue with armoring along 13% of its length. Most of that armoring occurs in the upper portion of the creek (Reach 2 is 29% armored) and is predominantly traditional armoring, with only a short portion of bioengineering in Reach 1.

Bank instability is somewhat common, though generally not severe, in the tributaries to Coal Creek (Figure 21). Erosion ranges from 6% of the streambank in Newcastle Creek (Tributary 0275) to 33% in the tributary to Newport Creek. City-wide, Bellevue streams have a median of 4% bank erosion, so the erosion observed in the tributaries to Coal Creek is higher than average. Bank stabilization efforts have taken place in Newport Creek, as it has a history of erosion issues. In general, the erosion is low (less than 5 ft in height), but each stream does have erosion up to 10 ft in height, and greater than 10% of the erosion observed in Newport Creek is greater than 10 ft in height. Erosion in the primary Coal Creek tributaries tends to be patchy and short in extent; the median length of erosion instances is approximately 25 ft. Undercutting is moderately low in the Coal Creek tributary streambanks and is associated with bank instability, ranging from 2% (Newcastle Creek) to 8% (Tributary to Newport Creek and Tributary 0273) of the stream (Figure 22).

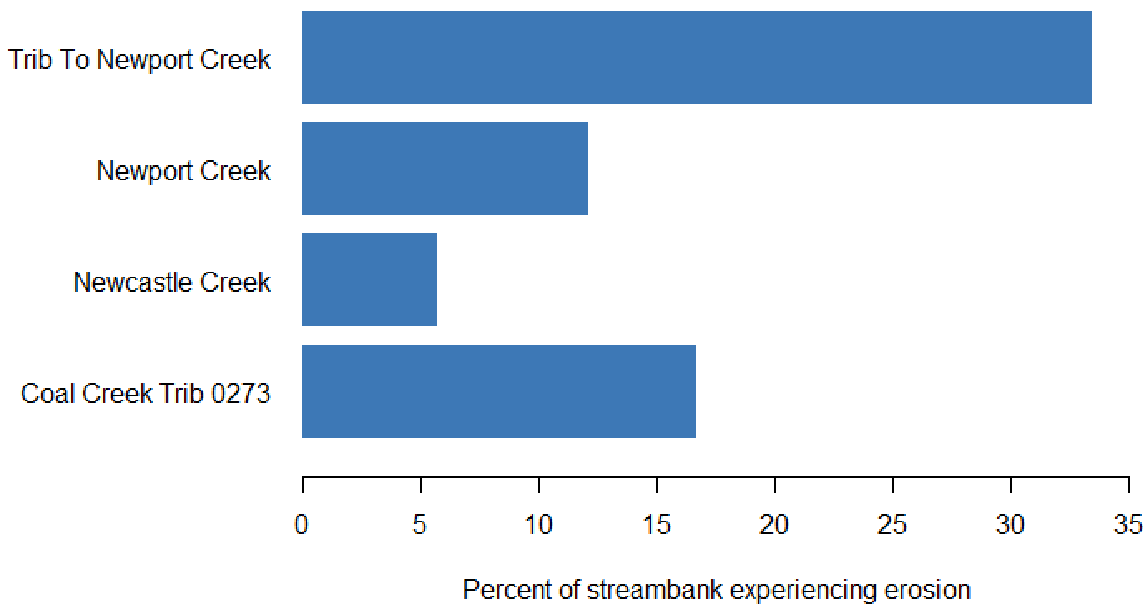

Figure 21. Percent of each stream that is experiencing erosion in the primary Coal Creek tributaries

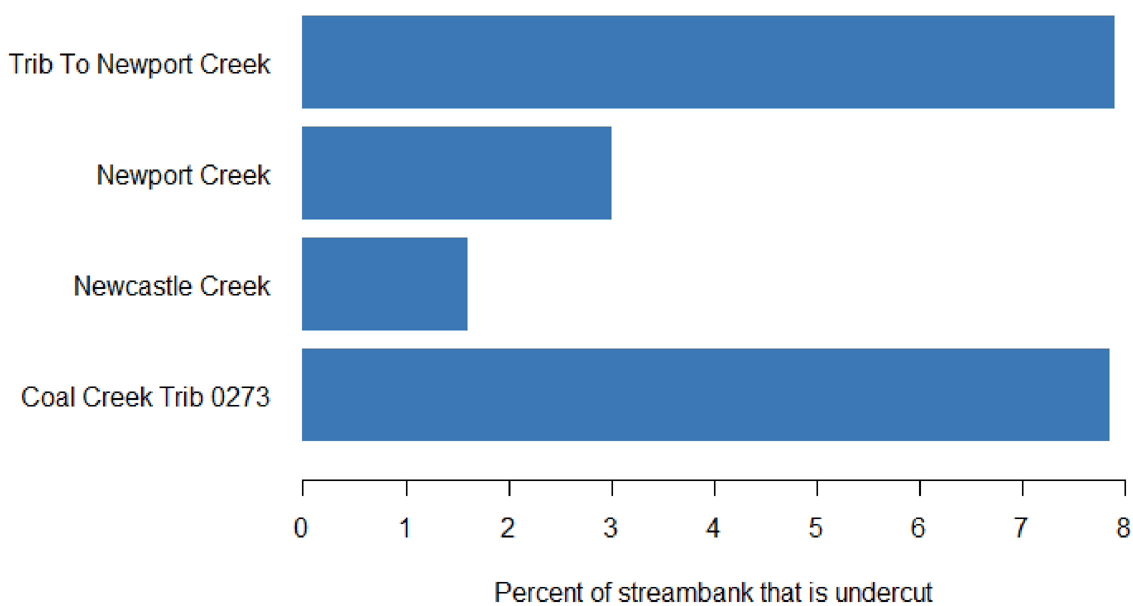

Figure 22. Percent of each stream that has undercut banks in the primary Coal Creek tributaries

B.3.2.6 Fish Habitat and Passage Barriers

Of the primary Coal Creek tributaries, Newport Creek and Newcastle Creek provide the best potential fish habitat. During OSCA surveys, fish were observed sporadically in the lower portion (Reach 1) of Newport Creek and at the confluence of Newcastle Creek with the mainstem of Coal Creek. Coho Salmon were historically documented using the lower portion of Newport Creek, up to RM 0.5 (WRIA 8 2001). Buchanan (2003) reports that during 1987 and 1988 construction of the Coal Creek Parkway Flood Control Structure (located just downstream from the mouth of Newcastle Creek), resident Cutthroat Trout and Coho Salmon were observed as “abundant and healthy” in Newcastle Creek. However, urbanization and altered hydrology impacting legacy coal seeps has impaired the stream’s water quality and substrate throughout the lower portion of Reach 1, resulting in a highly embedded and calcified streambed crust that was not observed prior to 1987 and 1988 (Buchanan 2003). Today, Newcastle Creek is considered to be a potentially fish bearing stream, but no fish were observed during the OSCA survey. Tributary 0273 was the last documented location in the Coal Creek Watershed to provide spawning habitat for steelhead. In June of 1998, live steelhead were observed at the confluence of Trib 0273 and the mainstem of Coal Creek (WRIA 8 2001). The tributary to Newport Creek is documented as a non-fish bearing stream due to its grade and shallow water depth. Fish habitat in the primary Coal Creek tributaries could be improved if overall habitat complexity and the number of pools were increased.

There are no WDFW documented fish passage barriers in Newport Creek or Tributary 0273 (WDFW 2020). However, the OSCA surveys documented a 7.5 ft tall waterfall in Tributary 0273 approximately 400 ft upstream of the confluence with Coal Creek that forms a natural barrier. Additionally, several weirs in the upper half (primarily Reach 2) of Newport Creek are likely complete fish passage barriers. Newport Creek has 37 weirs, which is the second highest weir frequency observed in the City of Bellevue. In Newcastle Creek, there is a log weir forming a partial barrier (WDFW Barrier Site ID: 602667) just downstream of a submerged 57 ft culvert that forms a complete fish passage barrier (WDFW Barrier Site ID: 994740, WDFW 2020). This barrier, associated with a relic King County detention pond, has caused localized erosion, streambed scour, and altered hydrology upstream into the City of Newcastle. OSCA surveys did not extend further into the City of Newcastle to examine upstream habitat quality.

B.3.2.7 Opportunities

The primary tributaries to Coal Creek provide opportunities for fish habitat enhancement only in the lower reaches of Newport and Newcastle Creeks. Fish habitat would be improved by an increase in habitat complexity and pool abundance. All the surveyed tributaries would benefit from invasive plant control and native revegetation (with an emphasis on conifers). Likewise, all the surveyed tributaries would benefit from projects targeting the impact of stormwater on the streams as well as the retention of sediment within the watershed. In particular, we recommend projects focused on improving upland stormwater detention and flow control and improving energy dissipation at stormwater outfalls.

B.3.3 Lesser Tributaries to Coal Creek

Although not considered primary fish habitat, several other tributaries to Coal Creek are important for their impact on the watershed through sediment transport and water quality and were therefore surveyed under a Level 2 protocol in the spring of 2019. These streams include the upper reaches of Tributary

0273, the first reach of Tributary 0274, lower Tributary 0276, and Tributary 0276A (Figure 23). Key features of those streams are discussed in this section.

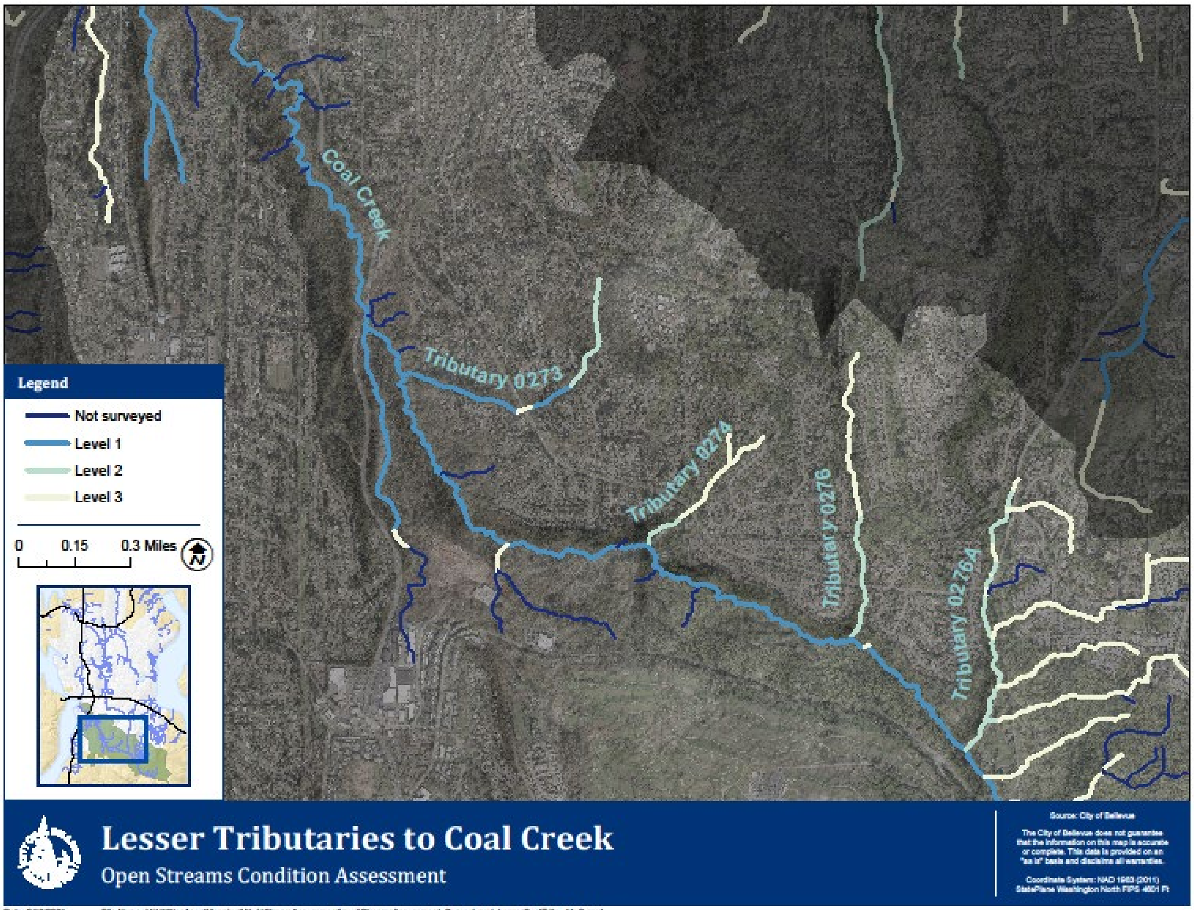

Figure 23. Map showing the location of the lesser tributaries to Coal Creek that were surveyed under a Level 2 protocol

Water quality is a concern in Tributary 0274 and Tributary 0276A, possibly resulting from historic coal mining activities. Ferric hydroxide deposits are frequent in these tributaries. In Tributary 0274, the source of the iron oxide was traced to an orange-colored seep or water upwelling out of what is presumed to be an old mine shaft along the right streambank at approximately RM 0.03 or 182 feet upstream from the confluence with Coal Creek Reach 6. The source was covered with chain link fence material that is now in need of replacement. In Tributary 0276A, the source of the iron oxide was traced again to a presumed old mine shaft along the left streambank at approximately RM 0.25. The impacts to water quality resulting from legacy coal mining remain largely unknown. Studies addressing this data gap and exploring the opportunities for mitigating the impact to the stream would be highly beneficial.

Seeps and springs are common throughout the lesser Coal Creek tributaries, and streambank erosion is generally higher than average for Bellevue streams. Channel incision is distinctly evident in places, especially in Tributary 0276A. Unlike the primary tributaries and mainstem of Coal Creek, the lesser tributaries generally have poor LWM frequency. These tributaries could benefit from the installation of LWM and projects targeting stormwater control and upland detention.

Cascades, chutes, and waterfalls over exposed glacial till are common features of Coal Creek tributaries and form natural barriers to upstream fish migration. Tributary 0274 has a waterfall located approximately 350 ft upstream from its confluence with Coal Creek, and Tributary 0276 has a 10 ft waterfall approximately 225 ft upstream from its confluence with Coal Creek. Tributary 0276A has a significant natural barrier, known as Red Town Falls, directly at the confluence with Coal Creek. Although these barriers prevent upstream fish migration, resident fish populations could persist. However, no fish were observed in these tributaries during the habitat surveys.

Tributary 0276A is liberally strewn with large litter, including numerous household appliances, an old wooden pipe (potentially a relic from the old coal mines), and a vintage car. Trash removal and channel restoration is recommended to improve stream health and water quality.

Knotweed is present just downstream of the Utilities sediment pond at 6719 155th Pl SE and 7219 Lakemont Blvd SE. Knotweed is virtually absent from the Coal Creek Watershed; the only other observation occurred at the mouth of Coal Creek. Early control is critical for preventing the spread of this invasive plant throughout the watershed.

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Appendix C
Coal Creek Watershed Benthic Index of Biotic Integrity Scores

Coal Creek Watershed Benthic Index of Biotic Integrity Scores

Stream	Agency	Site Code	Latitude	Longitude	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Coal Creek	King County - DNRP	0442 Coal	47.56624	-122.17896								39.2																		
Coal Creek	King County - DNRP	08EAS2446	47.55253	-122.16512									31.5	27.7		26.4	46.3	41.4	26.7		24.3	11.8	24.1	53	32.4	42.7	36.3	43.8	45.6	32.6
Coal Creek	University of Washington	CL	47.55377	-122.16615	32.9	25.7																								
Coal Creek	City of Bellevue	CoalBelRM0.8	47.566	-122.1773																							14.4			
Coal Creek	City of Bellevue	CoalBelRM1.3	47.5625	-122.1714																				17.6						23.1
Coal Creek	City of Bellevue	CoalBelRM1.8	47.558	-122.169					31.1			17.1	20.4										28.5			13.7	36.3			
Coal Creek	City of Bellevue	CoalBelRM2.3	47.552	-122.165					45.5			26.4	27.7			34.4	38.6	31.4					23						42.1	
Coal Creek	City of Bellevue	CoalBelRM4.0	47.542	-122.143					58.8			31.5	35.9			62.9	52.6	42.6					41			43.6		49.4		
Coal Creek	Washington State Department of Ecology	RSM06600-000391	47.55987	-122.17009																						35.6				
Coal Creek	Washington State Department of Ecology	WAM06600-000391	47.55987	-122.17009																54.7				47.9						
Coal Creek	King County - DNRP	WAM06600-000391	47.55978	-122.16999																	16.1	18.4	34.6	53.7						
Coal Creek	King County - DNRP	WAM06600-073831	47.5424	-122.14336																	46.5	56.1	44.9	69.5						
Coal Creek - tributary (0273)	King County - DNRP	08EAS2540	47.55017	-122.15687									25.9					24.4	17.7	21.5	19.6	35.3	15.8	22.9	28.4	19.9	45.3	47.5	44	39.1
Newport Creek	City of Bellevue	NewpBelRM0.0	47.5662	-122.1801																							18.5		10.1	
Newport Creek	City of Bellevue	NewpBelRM0.25	47.5657	-122.1797																							8.5			
Newport Creek	City of Bellevue	NewpStabRM0.4	47.56143	-122.17894																	12.5			10.2				10.4		