CHAPTER 6 CURRENT CONDITIONS - STATE OF THE STORM AND SURFACE WATER SYSTEM

This chapter describes the state of the natural and constructed storm and surface water system as it exists in the first decade of the 21st century. Existing or baseline conditions of the storm and surface water system are described and used to evaluate the system that forms the basis of the Storm and Surface Water Basin Plan recommendations. This chapter is organized into three major categories 1) Flood Protection, 2) Water Quality Protection, and 3) Fish and Wildlife Habitat. Storm and Surface Water System Plan recommendations are based on analyses of each of these categories.

Existing Conditions of the Storm and Surface Water System

Background

Historic logging in western Washington created long-term impacts to streams and watersheds.

The City of Bellevue is part of the larger Puget Sound drainage basin. Located in the Lake Washington/Cedar/Sammamish Water Resource Inventory Area, stormwater originating in Bellevue either drains to Lake Sammamish east of the city or Lake Washington to the west. Lake Sammamish itself is a tributary to Lake Washington via the Sammamish River. Lake Washington drains to the Puget Sound via the Lake Washington Ship Canal (Ship Canal) at Montlake, then to Lake Union, and eventually through the Hiram M. Chittenden Locks (Ballard Locks) in Seattle to the Puget Sound. The storm and surface water system in Bellevue consists of a series of open streams, a network of pipes, storage facilities, lakes, ponds, wetlands, collection, and treatment facilities all in a mix of public and private ownership. As described in the City's original Drainage Master Plan (KCM-WRE/YTO 1976), the mosaic of public and private drainage system components work together to perform the system's critical functions of conveyance, flood protection, and environmental protection.

Bellevue's storm and surface water system is a direct result of the topography, current and historic land uses, regulations, and geology of the area. The city covers approximately 32 square miles. There are about 79 miles of streams within the city limits; approximately 13 miles of large-lake shoreline (Lake Washington and Lake Sammamish); and 3 small lakes (Larsen Lake, Lake Bellevue, and Phantom Lake). Figure 6-1 shows the open channel stream system in Bellevue, including the 26 drainage basins.

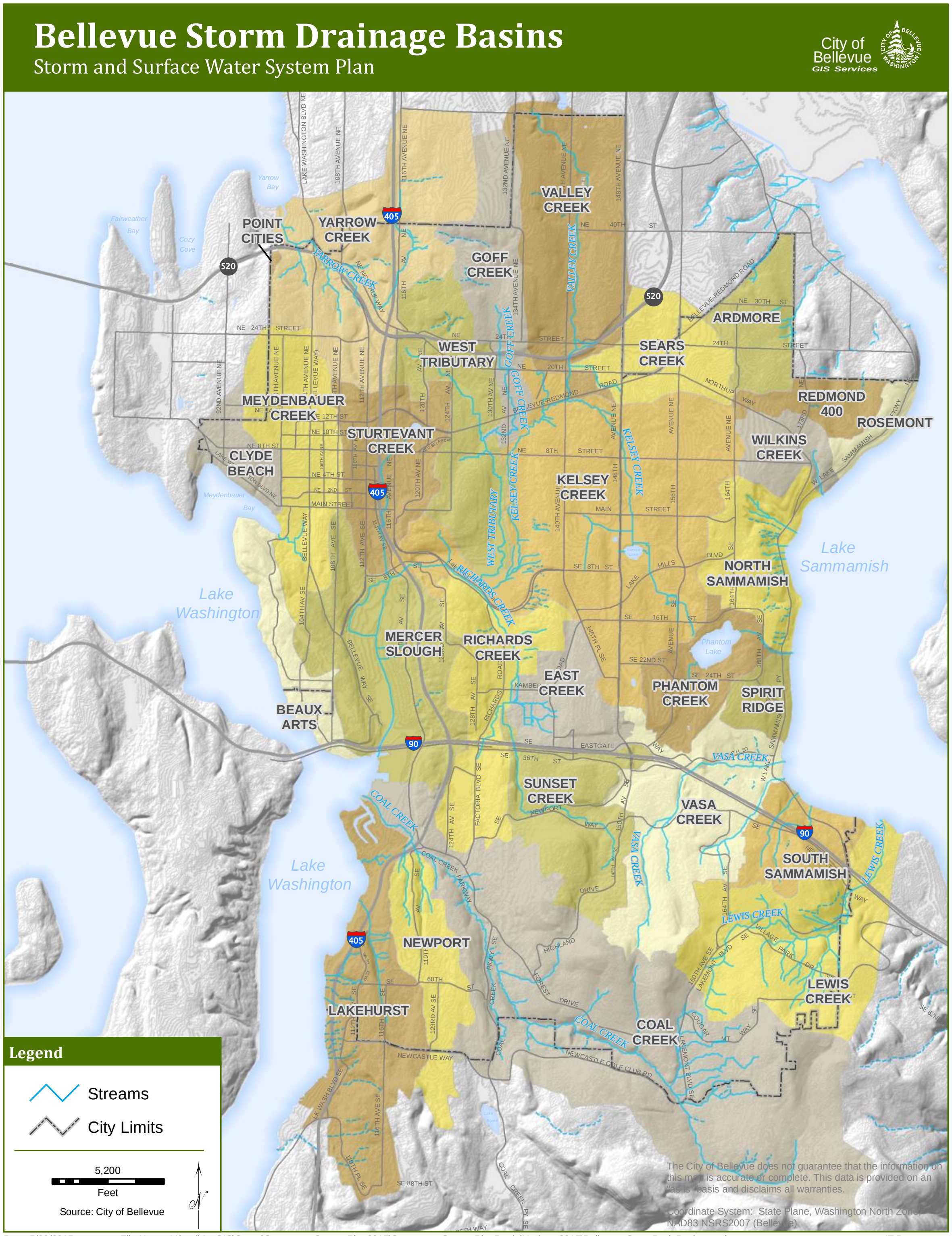


Figure 6-1. City of Bellevue streams and drainage basins.

Stormwater systems collect and convey the portion of total rainfall that is not otherwise lost to evaporation, plant uptake, or soil storage. The “excess” rainfall flows through pipes and streams while making its way to the receiving water body. Establishing the existing conditions of the storm and surface water system requires a brief discussion of the variables that contribute to the state of the system. The quality, volume, and rate of stormwater runoff is influenced by rainfall patterns, soils, geology of the area, land surfaces, vegetative cover, and social behavior. Appendix B-1 provides the Bellevue Stormwater Basin Fact Sheets for each drainage basin.

Rainfall

Storm and surface water systems are intrinsically related to climate. The timing and distribution of rainfall events in the Pacific Northwest have sculpted the physical, biological, and chemical balances of open stream systems. Bellevue receives on average 36.6 inches of rain each year (see Figure 6-2 Annual Rainfall). The historical Pacific Northwest rainfall pattern is distinctly divided into two seasons—a dry summer and fall followed by a prolonged rainy season in the winter. On average, 79 percent of the annual precipitation falls during the wet season from October through April (see Figure 6-3 Average Monthly Rainfall).

Because most of the precipitation occurs during the winter months, plant uptake and evaporation have marginal effects on rainfall consumption. The remainder must either be stored in the soil profile or it becomes the source of water for streams. In October, when the rainy season begins, the soil profile has been largely depleted of excess moisture because the growing season has just ended. The availability of soil moisture storage is an important component for overall stormwater management. Flood control, water quality improvement, and habitat protection are directly affected by how much of the total amount of precipitation becomes stormwater runoff rather than being infiltrated into the soil profile, or lost to plant uptake and evaporation. What remains, the excess precipitation, becomes the stormwater runoff that the Utilities Department and private property owners are tasked with managing. Over the last few years, rainfall has not followed historical patterns. Staff will be monitoring rainfall to determine whether there are consistent changes in the timing or intensity of rainfall.

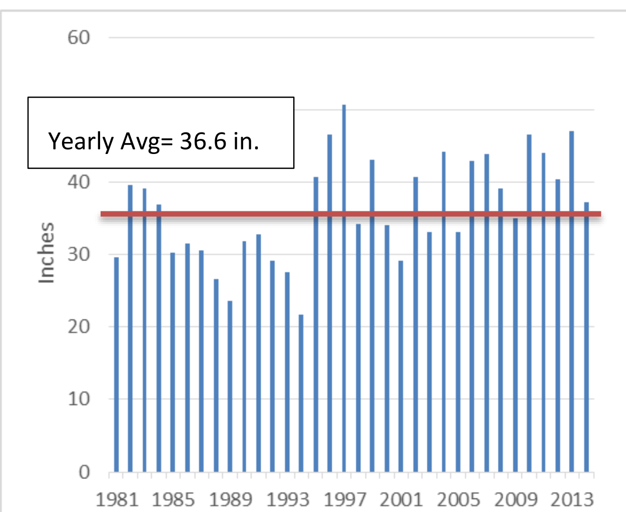


Figure 6-2. Annual rainfall, Bellevue, WA, 1981-2014.

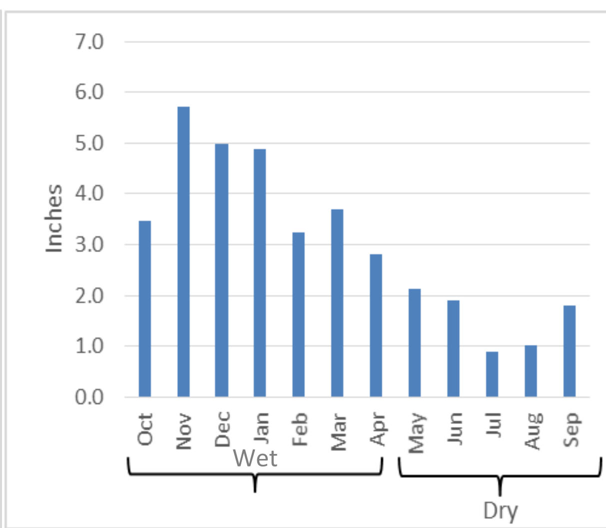


Figure 6-3. Average monthly rainfall, Bellevue, WA, 1981-2014

Soils and Geology

Soils and geology are important to surface water management because they directly affect the extent to which water soaks into the ground or runs off. The surface soils and geology in Bellevue were generally formed by glaciers, which receded approximately 10,000 years ago. Soils were originally mapped by the Soil Conservation Service (SCS) (Snyder et al. 1973). Most soils in Bellevue can be classified as glacial till, glacial outwash, or wetland soils. Till soils are generally compacted and do not readily allow water to infiltrate. Outwash soils mostly consist of sand and gravel, and tend to allow water to infiltrate. Wetland soils are generally at low elevations that receive water, and are saturated with water or ponded for most of the year.

The SCS maps provide the City with a coarse-scale soils map that helps determine locations in Bellevue where significant stormwater infiltration capacity is likely. Determining the infiltration rate for a particular location requires a more detailed soils analysis. As an example, in 2006, geotechnical engineering data were used to update the SCS soil maps in three small areas in Bellevue including the Bel-Red area (GeoMapNW 2006). The Bel-Red data changed about 36 percent of the soils map and resulted in identification of significantly more infiltration opportunities in the Bel-Red area. Additional work is being done to evaluate areas with greater opportunity to infiltrate stormwater through LID techniques.

The SCS categorizes soils into four hydrologic soil groups. The groups are denoted by letters A, B, C, and D with runoff potential ranging from low to high. Table 6-1 shows the existing soil conditions for Bellevue based on the hydrologic soil groups.

Table 6-1. Hydrologic soil grouping for Bellevue

Hydrologic Soil Group	Description	Runoff Potential	Portion of Total Area for Bellevue
A	These soils have a high infiltration rate, deep, well-drained sands or gravels (outwash).	Low	14.1%
B	These soils have a moderate infiltration rate, moderately deep, well-drained, and fine to moderately coarse texture.	Low to moderate	2.6%
C	Slow infiltration rate, well drained soils of moderately fine to moderately coarse texture (till).	Moderate to high	75.7%
D	Very slow infiltration, chiefly clay soils with high water table, compacted or shallow soil profile (dense till).	High	7.6%

What is evident from Table 6-1 is that according to the SCS soils map, infiltration of stormwater is very limited, and most of the area in Bellevue has a moderate to high potential for stormwater runoff.

Land Cover

Impervious surfaces are any type of land surface that does not allow water to soak into the ground below. Roof tops, parking lots, and roadways act as barriers for rainfall to infiltrate the native soil profile. Because impervious surfaces block rainfall from infiltrating the soil profile, they have a negative effect on the condition of the streams receiving the runoff. The water that was once stored in the soil profile is now directed to local streams. The extra rate and volume of stormwater carries pollutants to the stream. The extra volume flowing in the stream erodes stream banks in steep sections and deposits sediment in flatter sections. As of 2008, 46 percent of the total area in Bellevue was impervious. Coal

Creek basin was the least impervious (20 percent) and Sturtevant Creek basin the highest (71 percent). For a detailed list of the impervious area organized by stormwater basins, see Appendix B-2. Figure 6-4 depicts the contrasting rainfall distributions between urban land cover and undeveloped land cover.

Vegetative Cover

Trees and other plants slow rainwater from reaching the storm and surface water system. Tree roots promote infiltration; their leaves act as small storage facilities allowing rain droplets to evaporate or to delay the rainwater from reaching the streams or stormwater pipes. Leaves, branches, and other vegetative detritus make the ground surface more uneven, producing small pockets where rainwater can be stored. Once delayed on the ground, rainwater can potentially infiltrate or be used by the plants. All of these functions reduce the amount of rainwater that reaches the storm and surface water system and delay the time that water reaches the system. Flood risk is diminished when excess rainfall flowing towards the stream is delayed until the rain stops. A large tract of vegetative cover can act as a large "green infrastructure" feature that provides shade and plays a significant role in reducing the rate and volume of stormwater runoff entering the storm and surface water system.

There is an inverse relationship between impervious area and vegetative cover. As of 2006, the tree canopy in Bellevue was at 36 percent of the total area. Table 6-2 shows the types of land cover area for the city of Bellevue in 2006 (American Forests 2008).

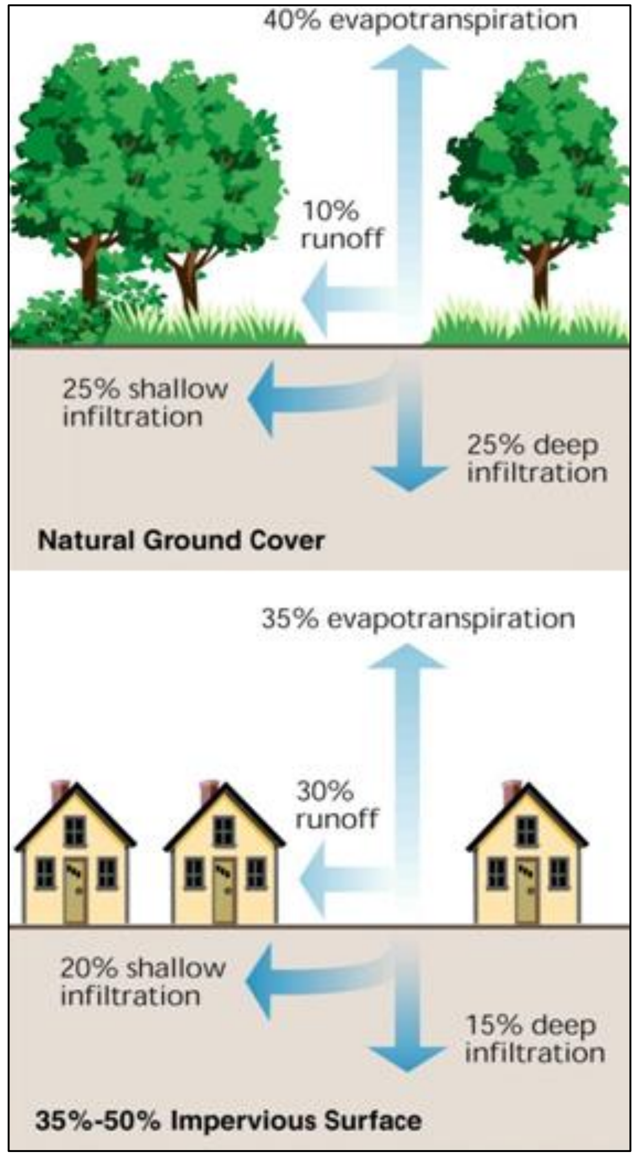


Figure 6-4. Contrasting rainfall distributions between urban land cover and undeveloped land cover.

Source: Adapted from FISRWG (1998) and the LID Guidance Manual (Hinman 2005).

Built Environment

The built storm and surface water system in public ownership consists of constructed pipes, catch basins, and other equipment used for conveyance, treatment, and monitoring including culverts; flow control facilities (ponds, bioretention facilities, tanks, and vaults); sediment retention basins; water quality treatment facilities; and rain, stream, and lake gauges. The City of Bellevue Utilities Department owns over 400 miles of storm drainage pipes that convey runoff to underground pipes, open channels, wetlands, streams, or lakes. Bellevue's storm and surface water system is separate from the sanitary sewerage system; stormwater runoff is not treated before entering streams, wetlands, and lakes. In addition, there are almost 20,500 catch basins, 11 regional detention facilities, and hundreds of other facilities.

Table 6-2. Land cover area

Land Cover Type	Acres	Percent of Total Area
Impervious Surfaces (other)	2,131.0	10.0%
Impervious Surfaces - Buildings/Structures	3,097.7	14.5%
Impervious Surfaces - Paved	4,484.4	21.0%
Open Space – Grass/Scattered Trees	3,38.8	15.8%
Shrubs	338.6	1.6%
Trees	7,300.2	34.1%
Trees - Impervious Understory	408.1	1.9%
Urban Bare	105.2	0.5%
Surface Water Area	126.3	0.6%
Total	21,377.4	100%

The public system includes five high-flow bypass pipes that remove peak flows from stream channels that routinely flooded or had serious erosion problems. Three were built in the 1980s and two were built in the late 1990s. Most of the regional detention facilities were built in the early 1980s, except for Coal Creek, which has ponds built in the early to mid-1990s, and Lakemont Facility in the Lewis Creek basin that was built in 1991. Approximately 250 miles of privately owned stormwater pipes and numerous water quality and detention facilities built, owned, and maintained by the private sector connect to the public system. Collectively, the system of pipes and other facilities in both public and private ownership function to collect, convey, detain, treat, and monitor stormwater.

The asset management program evaluates the life span of publicly owned drainage assets (like pipes and detention vaults) to inform the Utilities Department on the timing of replacing or repairing the asset. The evaluation considers asset material, type of construction, site conditions, and other factors to determine if the asset is nearing its useful life span. The asset management program seeks to establish a savings plan that will provide the necessary resources for replacement of the drainage asset. For more information, refer to Chapter 8 Asset Management.

Water Quality

Clean surface water protects human health, supports a healthy aquatic ecosystem, and enables beneficial uses of streams and lakes as designated by the Clean Water Act, such as swimming and aquatic life support.

Pollutants enter surface water in a variety of ways. Pollutants are washed off natural, landscaped, and impervious surfaces during rain events, poured down storm drains (non-point pollution), and discharged from industrial sites (point pollution), for example. The term, pollution, includes not only chemicals, like pesticides or petroleum, but also sediment and temperature whose levels are changed due to human activities. During storms, pollution that has accumulated on roads and landscaped areas is washed into storm drains and streams, so water samples taken during storms characterize the mixture of pollutants contributed over the course of time. Water quality in Bellevue's lakes and streams has been monitored for over 20 years. A description of the general quality of these resources is provided in the following sections.

Water Quality of Bellevue's Lakes

All of Bellevue's runoff eventually goes to either Lake Washington to the west, or Lake Sammamish to the east. These two large lakes receive runoff from many other jurisdictions, and their water quality is monitored by King County.

Lake Washington has become slightly warmer over time. The temperature has increased approximately 0.98 degrees Celsius on average since 1964 (King County 2007), with warmer and colder trends occurring in some years. The warming is most significant in spring, and causes summer lake stratification to occur earlier and last longer than in the past. This trend is common across lakes in King County, and likely beyond, and is believed to be linked to climate changes rather than human activities. Lake Washington is directly connected to and at a similar pool elevation as Mercer Slough. This linkage strongly limits the movement of water in the slough, causing the slough to exhibit more lake-like water quality conditions, such as higher temperature and lower dissolved oxygen in the summer.

Of particular concern is the sensitivity of lakes to phosphorus—a nutrient that contributes to algae growth and leads to other water quality and public safety issues. Phosphorus is present in almost all urban runoff because it occurs in naturally high concentrations in native soils. Phosphorus promotes dense algae growth and occasional cyanobacteria blooms, which can be toxic to people, pets, and wildlife. Algal blooms also result in low dissolved oxygen, which harms aquatic life and causes odors. Nutrient treatment facilities that filter phosphorus particles out of the water are required at many developing properties that drain to Lake Sammamish or Lake Bellevue. As of 2000, Bellevue's Parks Department stopped using fertilizers containing phosphates on turf at city facilities, ball fields, parks, and schools in order to minimize phosphorus input into sensitive water bodies.

Lake Sammamish, Phantom and Larsen Lakes, and Lake Bellevue have been monitored for indicators of water quality including clarity, nutrients (phosphorus), and algae (chlorophyll-a) to evaluate trends and determine whether water quality goals are being met for these parameters. All of these lakes have naturally high concentrations of phosphorus and regional goals were established to continue to meet health and recreation objectives into the future.

Lake Sammamish goals for phosphorus and transparency have been met each year between 1996 and 2006 at two stations, except in 2004 and 2006 when the phosphorus goal was not met at one of the stations (King County major lake monitoring, http://green2.kingcounty.gov/lakes/map.aspx).

Phantom Lake water quality monitoring began in the 1990s to evaluate lake water quality management actions. No significant trends have been observed since management efforts began in the 1990s. Water quality monitoring will be discontinued following final monitoring in 2015.

Phantom Lake water quality results from the upper water column (0.5 and 3.5-ft) were averaged for the summer months (June to September) from 1994 to 2014 and compared to their water quality goals; see Figure 6-5. The water quality goal for clarity was met for all 21 years. The goal for nutrients were met 11 of 21 years and 8 of 21 years for algae. The total phosphorus results in 2012 and 2013 were significantly higher than other year averages; however, lake visibility remained consistent and no visible evidence (e.g., algae blooms) were observed.

In Lake Bellevue, phosphorus, oils, water clarity, and algae growth were sampled in 2004 and 2005 to determine how to manage algae, odor, and oils in the lake (Tetra Tech, Inc. 2006). The analysis determined that only 24 percent of the phosphorus came from urban runoff to the lake; the remaining

76 percent was the result of phosphorus cycling among internal lake water, sediment, plants, and biota. Oil sheens were not attributed to stormwater runoff, but were likely from oil spills, creosote pilings, and near-shore parking lots. Water treatment best management practices (BMPs) and low impact development (LID) for redeveloping properties, education about spill prevention, lake aerators, alum treatments to reduce phosphorus, and ongoing monitoring were recommended in a 2006 Lake Bellevue Water Quality study (2006, Lake Bellevue Water Quality Study and Management Recommendations) to meet water quality goals for Lake Bellevue. In accordance with Bellevue policy, these recommendations would be implemented through either private actions or a lake management district.

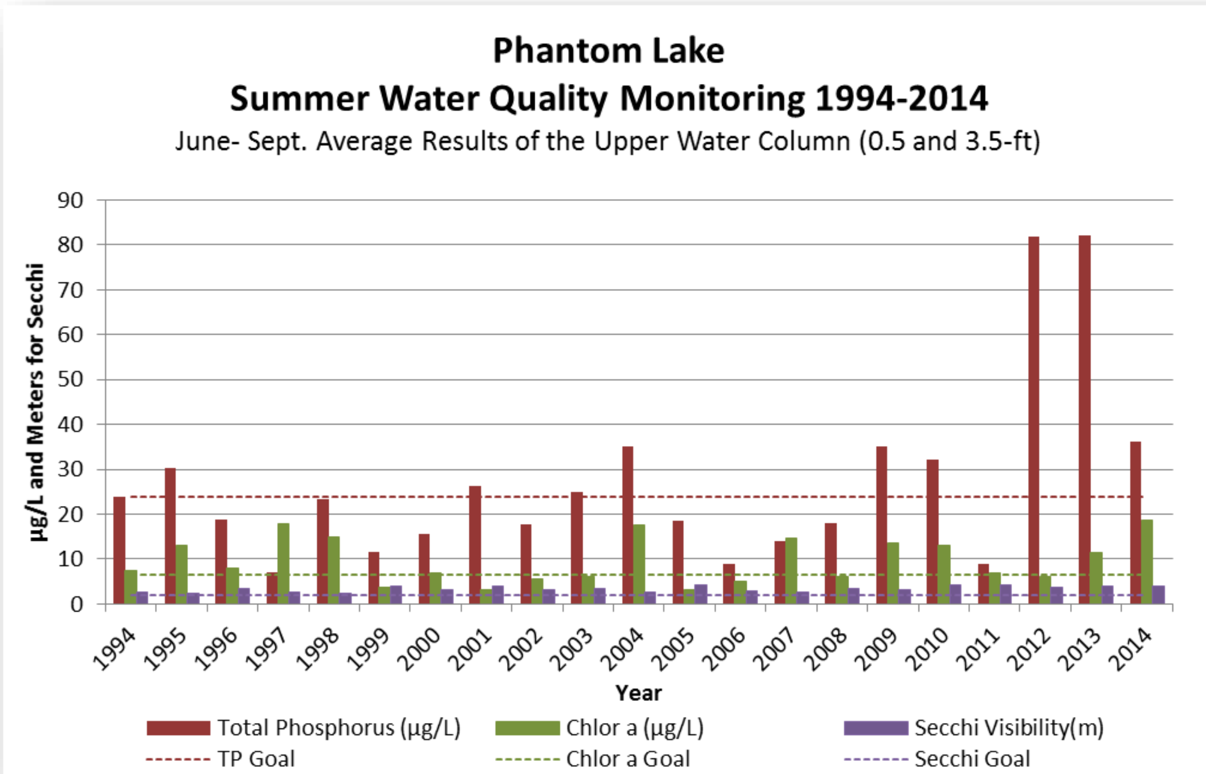


Figure 6-5. Phantom Lake water quality monitoring results (bars) and goals (dashed lines) from 1994 through 2014 for total phosphorus (TP), chlorophyll-a (Chlor a), and Secchi visibility.

Water Quality of Bellevue Streams

Water quality in Bellevue streams has been characterized and evaluated through a number of different monitoring studies and ongoing efforts by multiple agencies, including the City of Bellevue. More detail can be obtained from the original sources listed below:

- Bellevue Urban Runoff Program (BURP) (City of Bellevue 1984; U.S. Environmental Protection Agency [USEPA] 1983);
- City of Bellevue Characterization and Source Control of Urban Stormwater Quality: Volume 1 Technical Report (City of Bellevue 1995);
- King County Ambient Water Quality Monitoring Program (King County 2009); and

- Various pesticide studies, including Bellevue streams (U.S. Geological Survey 1999; Evans/McDonough Company 2000; Bortleson and Davis 1997; and Voss and Embrey 2000).

Urban stormwater constituents include a variety of pollutants including sediment, nutrients, metals, oil and grease, pesticides, organics, and gross pollutants (e.g., trash and debris). Other parameters, such as temperature and pH, are also used to assess water quality and can affect aquatic life.

General Stream Water Quality

The general quality of stormwater and stream water quality has stayed the same or improved between 1988 and 1993, despite urban development, which is a 32 percent increase in population, and a 21 percent increase in city land area when compared to data collected before 1980 (City of Bellevue 1995). Lead concentrations have decreased (due to the phasing out of lead gasoline); however, copper, lead, and zinc still often exceed USEPA water quality criteria. Phosphates in Bellevue streams are generally high, and fecal coliform bacteria exceeds state standards during most storms and often during base flow conditions. New National Pollutant Discharge Elimination System (NPDES) operations and education programs, as well as emerging technologies such as rain gardens and other LID techniques, should improve water quality because they keep the pollutants from entering with surface water runoff.

Stream Temperature

In a pilot project, continuous temperature measurements were taken at nine sites along Kelsey Creek and its tributaries from mid-August through mid-October 2001 (C. Paulsen, unpublished data; Figure 6-6). Warm stream temperatures during the early fall can affect adult salmon spawning and migration. Warmer water does not hold as much dissolved oxygen, which salmon and other aquatic life breathe. Water temperature was warmest in late August, and declined at all sites over the course of the sampling period. In August, most of the sites were too warm for Chinook holding and migration, but the temperatures fell to acceptable ranges for migration by early September and for holding by late September or early October. Larsen Lake temperatures were the highest, but the next site downstream was among the lowest, likely because of the cooling influence of the wetlands and groundwater between Larsen Lake and 148th Ave NE. Temperatures became cool enough for Chinook migration by early September, which is when the first adult Chinook are generally seen during fall surveys for spawning salmon. Temperatures became cool enough for sockeye migration by late September or early October. Temperatures are influenced by land use, rainfall, and air temperatures. Since climate varies each year, in warmer years temperatures may delay Chinook and sockeye spawning runs. Reducing impervious surfaces and increasing tree canopy and infiltration sites for runoff could reduce temperatures in some areas.

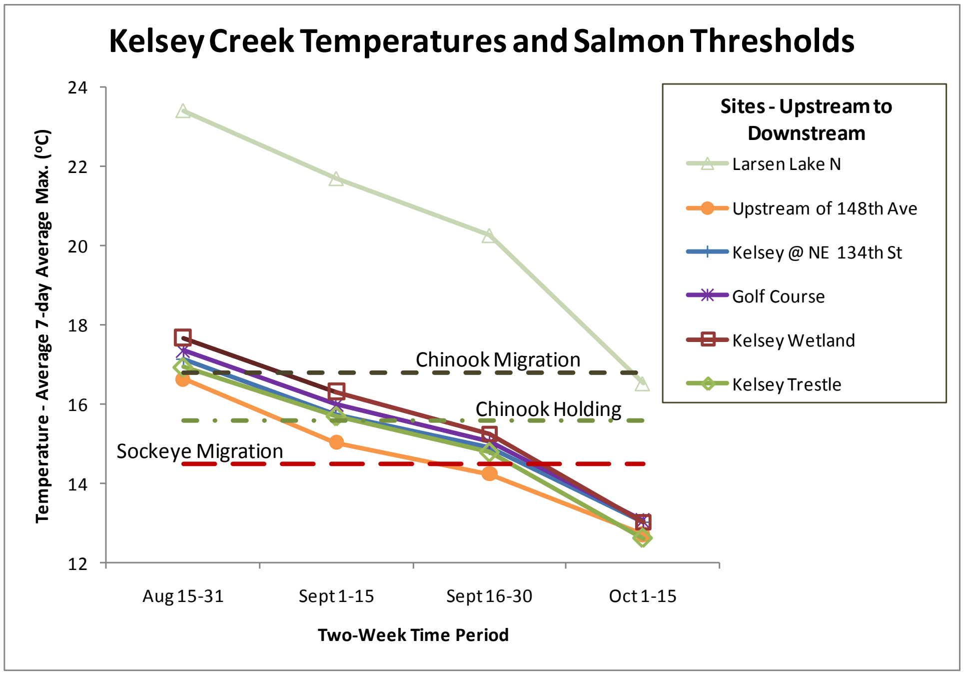


Figure 6-6. Kelsey Creek stream temperatures (°C) (7-day average maximum) averaged over approximately 2-week time periods during the start of the salmon spawning in 2001.

Note: Sites are listed in order from upstream to downstream. Upper temperature limits for Chinook holding and migration and sockeye migration are shown as dashed lines.

Pesticides

Pesticide concentrations were measured in streams in the Puget Sound area, including streams in Bellevue, beginning in the late 1980s and early 1990s. A study by the U.S. Geological Survey found a large number of pesticides in Bellevue creeks (13 in Kelsey Creek/Mercer Creek), but mostly in very low concentrations (Bortleson and Davis 1997). As a result of concerns about pesticides, the Bellevue Parks Department initiated efforts to reduce the use of pesticides on City property. In addition, the Utilities Department began programs to proactively inform and educate residents about gardening and landscaping practices to reduce home pesticide use. Surveys of Bellevue residents conducted in 2000 and 2005 indicate that approximately 40 to 50 percent of residents use pesticides in their yards. Yard care professionals also use pesticides on residential and commercial properties in Bellevue. Comprehensive pesticide sampling in Bellevue was last conducted in 1998, so the overall effects of changed practices over the 15 years between 1995 and 2010 are unknown. The earlier studies found the following:

- Mercer Slough and Kelsey Creek were sampled for pesticides from 1987 to 1995 as part of a study of small streams in the Puget Sound basin (Bortleson and Davis 1997). This study concluded
  - Concentrations of pesticides were generally low.
  - Twenty-three different pesticides were detected in streams across Puget Sound, and a mix of pesticides was present in each creek. The effects of mixtures of pesticides on aquatic life are largely unknown.
  - Five different insecticides exceeded federal standards for maximum concentrations for the protection of aquatic life (U.S. Geological Survey 1999).

    - Stream sediments contained pesticides that were banned from use in the United States, including the fungicide pentachlorophenol (PCP), insecticides DDT and its degradation products, and chlordane (Bortleson and Davis 1997).
- Stream runoff was sampled for pesticides in Valley, Sunset, and Lewis Creeks during a storm event in 1998 (Voss and Embrey 2000). The sampling effort found
    - Seventeen pesticides or pesticide transformation products were detected in Sunset Creek, 14 in Valley Creek, and 13 in Lewis Creek.
    - None of the herbicides detected exceeded aquatic life criteria, although aquatic life criteria do not exist for many of the compounds.
    - Aquatic life criteria were exceeded for two commonly used insecticides: diazinon at all three sites, and lindane at Valley Creek.
- Surveys of Bellevue residents in 2000 and 2005 did not show a marked difference in residential pesticide use over that 5-year period. The surveys found
    - 40 percent of Bellevue residents reported using “weed and feed products, pesticides or chemical lawn fertilizers,” compared to only 29 percent county-wide in a telephone survey conducted in 2000 (Evans/McDonough Company 2000).
    - 43 percent of respondents reported using pesticides, and 50 percent reported using weed and feed type products (which contain herbicides) in a survey in 2005 (Dethman & Associates 2006).
- In the Puget Sound basin, more pounds of pesticides were applied in urban areas than in rural areas (U.S. Geological Survey 1999). This survey indicated the following
    - Some pesticides commonly found in stream runoff were those with high retail sales, such as the insecticide diazinon.
    - Pesticides not sold in retail stores were also common. A wide variety of pesticide licenses allow application of pesticides not available at retail stores. These pesticides may have been applied to public and private properties by private individuals, companies, or other licensed pesticide applicators.
    - Since these results were published, federal regulations restricted the use of diazinon, and Bellevue Parks and Utilities Departments changed their pesticide practices.

More recently, the Bellevue Parks Department has collected water quality data to better understand how their maintenance practices affect water quality. Grab samples were collected annually along streams both upstream and downstream of managed properties and from a golf course pond. Nutrients, pesticides, and metals were sampled between 2004 and 2010. Information from this sampling program and input from the Utilities and Development Services Departments were used to develop the Parks Department’s Environmental Best Management Practices and Design Standards Manual (2006). This manual is reviewed and updated periodically, based on continued monitoring results and new BMPs.

The Parks Department also collected sediment samples over several months using filters under storm drains (The Watershed Company 2005-2009). Pesticide concentrations were rarely detected downstream of the parks, despite being present upstream in some cases. In 2005 and 2006, pesticides were detected in higher concentrations downstream, but management practices were changed, and they have not been detected since that time. Dissolved metals (zinc and manganese) were detected at one site each season since they began testing for them in spring 2008. Nutrient levels were generally lower or the same after passing through the parks, and in the two cases in which they were higher, the increase was small. The sediment and water quality tests were used to improve operations and indicated that Parks Department operations were not substantially affecting the water quality of streams.

King County Ambient Water Quality Monitoring

King County has an ambient water quality monitoring program at streams where major wastewater facilities are located. Several sites in Bellevue are included Kelsey Creek at the Mercer gauge, the West Tributary, Coal Creek, Ardmore (Idylwood) Creek, Yarrow Creek, and Lewis Creek downstream of Bellevue (King County 2009). Samples were collected during different time periods and for different durations at these sites, primarily between the mid-1970s and 2008. Monthly grab samples were collected during base flow and storm events. While one-time samples do not provide a true characterization of pollutant loading, they do indicate the general quality of the water. King County base flow samples appear to be generally consistent with base flow median concentrations reported by the City of Bellevue (1995) for conventional constituents, pH, bacteria, nutrients, and metals for Kelsey Creek, even though sampling methods were different.

Habitat

Fish and wildlife habitat protection is the third component of the Utilities Department Storm and Surface Water Mission Statement. The aquatic environment in open streams are the primary “receiving waters” of the stormwater system in Bellevue. Water quality and quantity affect fish and wildlife habitat.

Impervious surfaces such as roofs and parking lots have been directly linked to changes in flows and in pollutant loading. Trees and other vegetation slow rainwater, prevent erosion due to branches and roots, and filter and cool the water on its way to the stream. Impervious surfaces, on the other hand, do not allow water to soak into the ground. They warm the water in summer and direct it quickly to a drain or pipe, collecting pollutants on the way. Significant changes to stream habitat are generally observed when the effective impervious area (the area directly connected via pipes and conveyance systems) in a basin reaches 10 percent (Booth and Jackson 2002). Because Bellevue is well over 10 percent impervious in every drainage basin, the streams are expected to be negatively affected by urban runoff.

The amount of intact vegetation and lack of impervious surface immediately adjacent to streams, as well as throughout stream drainage basins, has been directly correlated with the health of aquatic life at individual sites within those same drainage basins (Morley and Karr 2002). Figure 6-7 shows city averages for overall impervious (light grey), percent impervious surface within 100 feet of open streams (dark grey), overall forest cover (light green), and forest cover within 100 feet of open streams (dark green).

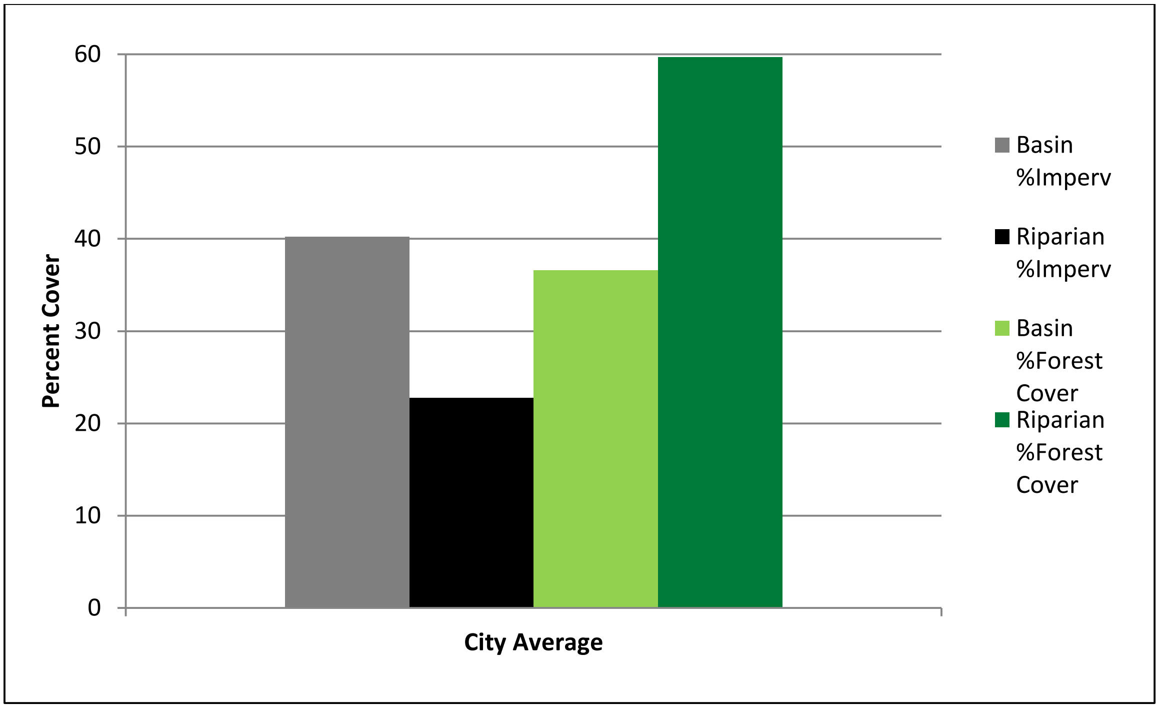


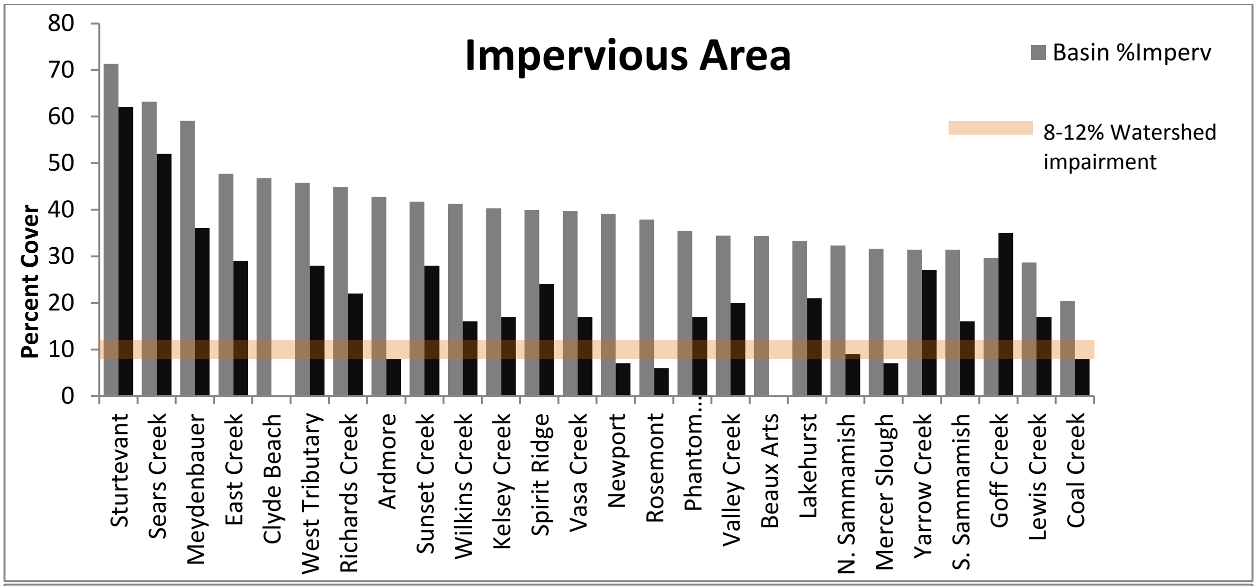
Figure 6-7. Total impervious area and percentage within the 100-foot stream buffer and total tree canopy cover and within basin stream buffers within Bellevue city limits.

Figure 6-7 shows that stream buffers have been more protected from urban development and tree removal than those areas of the drainage basins away from the stream corridor. In general, tree canopy is higher and impervious area lower around the streams than in the overall drainage basin. This can be attributed to stream vegetation protections afforded by the Critical Areas Ordinance (Bellevue Land Use Code 20.25H) that restrict development in streams and buffers, formerly the Sensitive Areas Ordinance.

Tree canopy cover city-wide is 36 percent based on an analysis done in 2007 (American Forests 2008). Tree canopy cover in the city decreased 20 percent between 1986 and 2006. American Forests recommends a city-wide goal in urban areas of 40 percent tree canopy to maintain environmental benefits, including carbon sequestration. While it has been shown that vegetation along streams is related to the health of aquatic invertebrates, there are currently no guidelines for urban riparian forest cover needed to sustain conditions for aquatic life.

Figure 6-8 shows impervious and forest cover for individual basins illustrating the range of conditions across basins within Bellevue. Newport, North Sammamish, Spirit Ridge, and Coal Creek have over 85 percent tree canopy in their buffers, the highest in the city. Basins that currently meet the American Forests recommendation of 40 percent tree canopy include Beaux Arts, Coal Creek, Goff Creek, Lewis Creek, Mercer Slough, North Sammamish, Phantom Creek, South Sammamish, Vasa Creek, and Yarrow.

Rosemont, Mercer Slough, and Newport have less than 8 percent impervious in their stream buffers—the lowest city-wide.



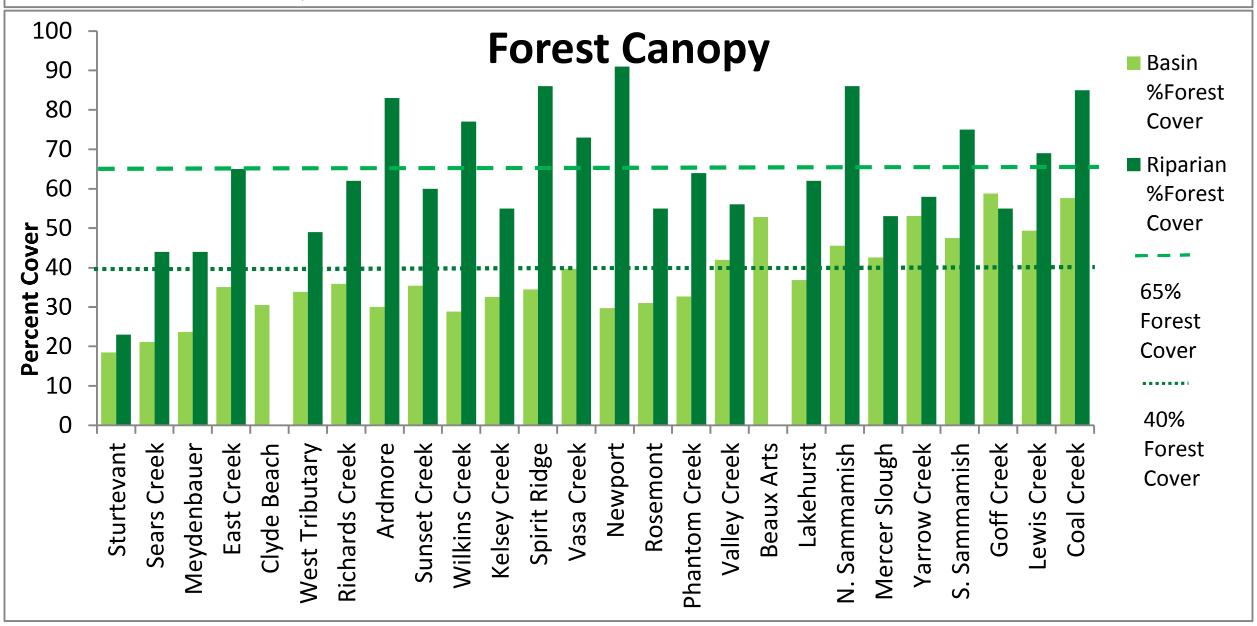


Figure 6-8. Total impervious area percentage of each drainage basin and within the 100-foot stream buffer (upper graph), and tree canopy cover of each drainage basin and within basin stream buffers (lower graph) within Bellevue city limits.

Note: Beaux Arts and Clyde Beach do not have streams, so stream buffer measurements were not made.

Goals and Evaluation Criteria

As described in Chapter 3 Community Vision and Regulatory Framework, stormwater management is guided by the vision of the Bellevue community as well as the regulatory framework imposed by federal, state, and local regulations and requirements. Priorities include flood management, management of open streams and piped conveyances, and protection of water quality and aquatic habitat. The Storm and Surface Water Utility's Mission Statement is:

> *A surface water system that controls damage from storms, protects surface water quality, supports fish and wildlife habitat, and protects the environment.*

Achieving the goals in the Mission Statement depends on a number of factors, including the degree to which drainage basins have been affected by urbanization, the desired level of protection, the authority and influence the City has, and the resources needed to mitigate those impacts. Often in an urban environment, there is a balance of competing interests at a site, including flood amelioration, salmon spawning habitat, erosion, or other development needs at a particular location. Meeting multiple objectives is always desired, though it is not always attainable at a project scale.

The Utilities Department's stormwater management goals are derived directly from the Mission Statement, while also meeting regulatory obligations. The specific goals are to:

- Minimize damages from floods, including flooded buildings, street closures, and stream bank erosion;
- Improve water quality within the City's jurisdiction to meet federal and state water quality standards; and
- Improve aquatic habitat within the city's open stream channels and lakes to foster the continued existence of native fish and other aquatic organisms.

Basin Evaluation Criteria

Evaluation criteria and associated indicators of physical, biological, and water quality conditions were selected to evaluate whether storm and surface water management goals are being met (Table 6-3). These criteria will be used to evaluate system goals into the future, and to target actions to specific issues. The planning criteria are evaluated at the basin level because land use and other activities in each drainage basin directly affect the function of the storm and surface water system in that basin. This also allows actions to be targeted to address issues at their specific locations.

Much of the information needed to evaluate the system is currently available, but some of the specific evaluation metrics are not. For example, limiting the evaluation metric data to events larger than the 100-year, 24-hour storm severely reduced the number of data points available to analyze. Similarly, the number of secondary street closures during some large storm events since 2003 is known, but there is no record of the number of hours each street was closed. In such cases, recommendations are included to capture these data in the future. Appendix B-3 has the individual data points for all of the evaluation metrics. In addition, Appendix B-4 provides supporting information on road closures due to storm events.

In addition to the evaluation metrics, additional information was compiled to assess the overall state of the system. This includes effects of public regional stormwater detention, age of development, land cover, flow, and riparian condition, sedimentation, observed stream issues, and salmon migration and spawning. The evaluation criteria does not address the constructed utility systems for connectivity, ability to meet capacity needs, or the condition of the infrastructure because those issues are determined by regulations during development of the system. The age of development and general age of the constructed system is included in this chapter to provide an indication of standards that were used for detention and conveyance capacity design, as well as an indication of areas where infrastructure may be nearing the end of its functional life span. For more information about the constructed utilities system and the results of its evaluation see Chapter 8 Asset Management.

Table 6-3. Planning criteria and evaluation metrics or indicators used to evaluate basins in terms of storm and surface water goals

Goals	Planning Criteria	Evaluation Metrics
Control Damage from Storms	Minimize damage from the 100-year, 24-hour storm event	1) Flooded structures during large storms 2) Number of flood damage claims 3) Number of street closures
Protect Surface Water Quality	Identify pollution "hot-spots"	1) Percent compliance with NPDES Permit 2) Number of Clean Water Act Violations 3) Number of Illicit Discharge Corrections 4) Number of basins classified as Impaired under Clean Water Act Section 303(d) 5) Number of basins classified as a high risk for water quality problems
Support Fish and Wildlife Habitat	Improve stream habitat conditions and biotic integrity (B-IBI) scores	1) Large woody debris frequency per channel width 2) Pool frequency per channel width 3) B-IBI score 4) Number of stream reaches with hardened banks
Protect the Environment	Incorporated above	Combination of all categories

Evaluating Flow Control and Flood Protection

Bellevue does not have widespread flooding problems, but there are still recurring problems at some locations. Figure 6-9 shows the flooding problem at NE 21st Street on December 12, 2010. Flooding has the potential to threaten or damage health, safety, and property by creating hazardous conditions in streets, blocking street access, causing damage to buildings, and/or eroding streets or landscaped areas. During large storm events some flooding is expected, but smaller events can also cause flooding when debris clogs storm drains or grates, if runoff water has been redirected, or if conveyance system capacity is exceeded. As described in Table 6-3, flood control is focused on:

Figure 6-9. NE 21st Street floods on December 12, 2010.

1. Structural flooding. Flooding or the threat of flooding to a structure. It does not include flooding of yards or other "nuisance" flooding.
2. Flood damage claims. These are liability claims made against the City for storm-related damages.
3. Street closures. Primary and secondary streets closed due to flooding.

The evaluation metrics are followed by additional background information, such as the estimated age of the infrastructure and land cover that provides context for understanding how flooding issues can arise and for identifying potential future problems.

Flooded Structures during Storm Events

The number of flooded structures includes known buildings, businesses, homes, garages, basements, and crawl spaces that flooded during storm events during the evaluation period (2000 to 2014). The source of information was a database that tracked surface water work orders in response to customer requests to the Operations and Maintenance Division. If the cause of the structural flooding was due to privately owned property, these work orders were excluded. The remaining work orders were included, even though it was not always possible to confirm that the cause was due to a City-owned ("public") system malfunction. Figure 6-10 highlights the stormwater basins where flooded structures were located.

For each basin, "Few" means zero to two flooded structures, "Moderate" means three or four flooded structures, and "Many" means five or more flooded structures. The number of flooded structures among basins ranged from a minimum of two (East Creek basin) to a maximum of 14 (Kelsey Creek basin) (see details in Appendix B-5).

All flooding reports are investigated and actions are taken for public safety and protection of property.

Any area where recurring public maintenance issues might occur are placed on a Routine Flood Prevention Maintenance Inspection List that is frequently updated (see Appendix B-5). Flooding incidents that may require infrastructure improvements are reviewed as part of the Capital Investment Program. In two cases, affected properties have been acquired.

Number of Flood Damage Claims

The City maintains a database of claims brought by residents attempting to receive financial compensation for damage to private property. Claims due to flooding or other property damage were evaluated from October 1, 1996 to December 2014 (Figure 6-11). Of 59 storm-related flooding claims, 15 were determined to have City liability, resulting in payment to the claimant.

Number of Road Closures

Primary and secondary streets are those identified in the City's emergency response plan as major routes for use during emergencies. Street closures for the period of 1996 through 2011 were used as an evaluation metric for flooding. Some of the major storms that caused street closures are reported in "Storm Reports" submitted to the City Council following major storm events. Figure 6-12 shows the street closures due to flooding. Storm Reports are prepared at the Utilities Department Director's request and are available for five major storms since November 2001. Each is summarized in Appendix B-4. These included storms on the following dates:

1. November 14–15, 2001 when 3.5 inches of rain fell in 35 hours;
2. October 20–21, 2003 when 5.1 inches of rain fell in 38 hours;
3. November 5–7, 2006 when 3.2 inches of rain fell in 59 hours;
4. December 2–4, 2007 when 6.1 inches of rain fell in 48 hours; and
5. December 11–12, 2010 when 4.0 inches of rain fell in 24 hours.

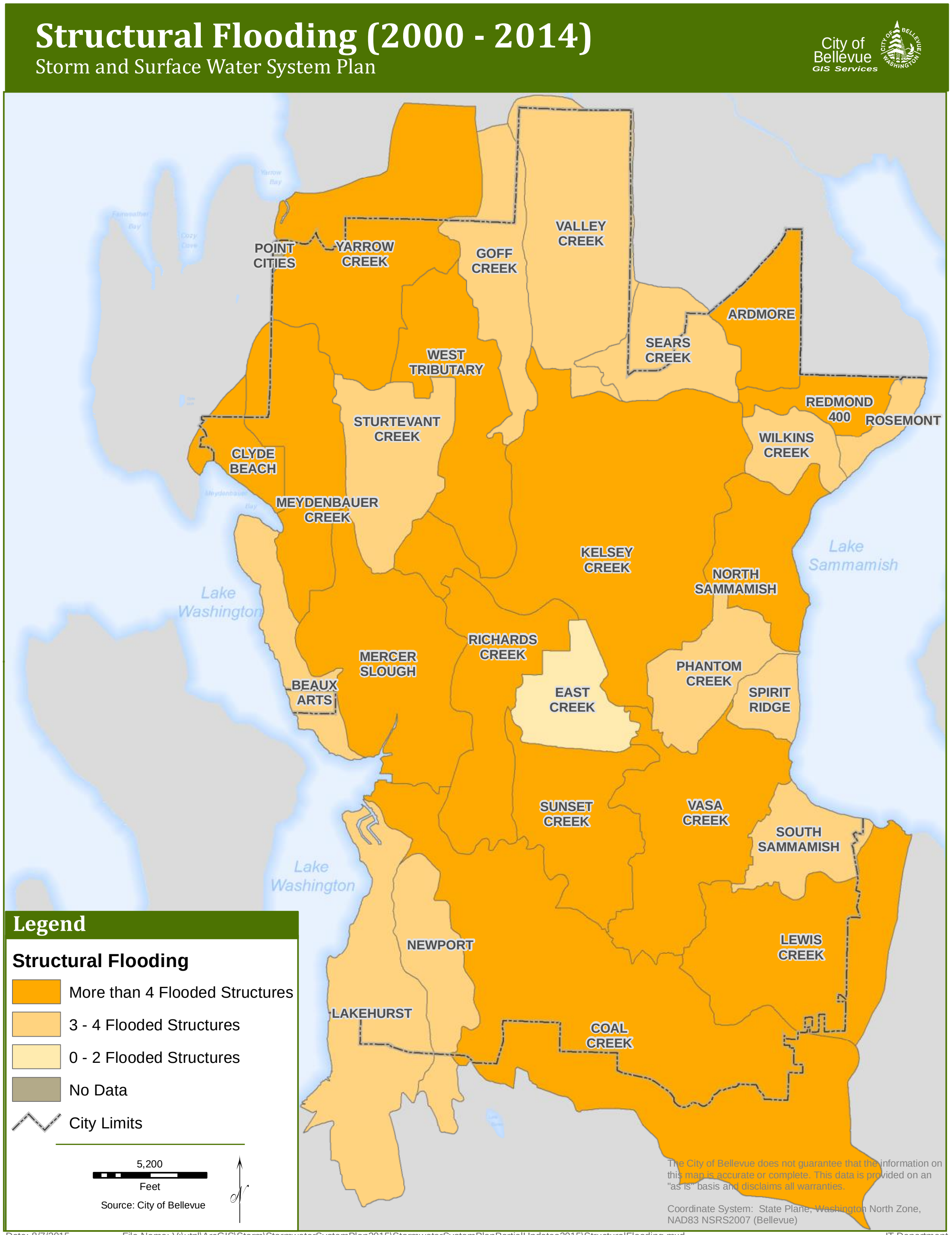


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Figure 6-10. Structural flooding map.

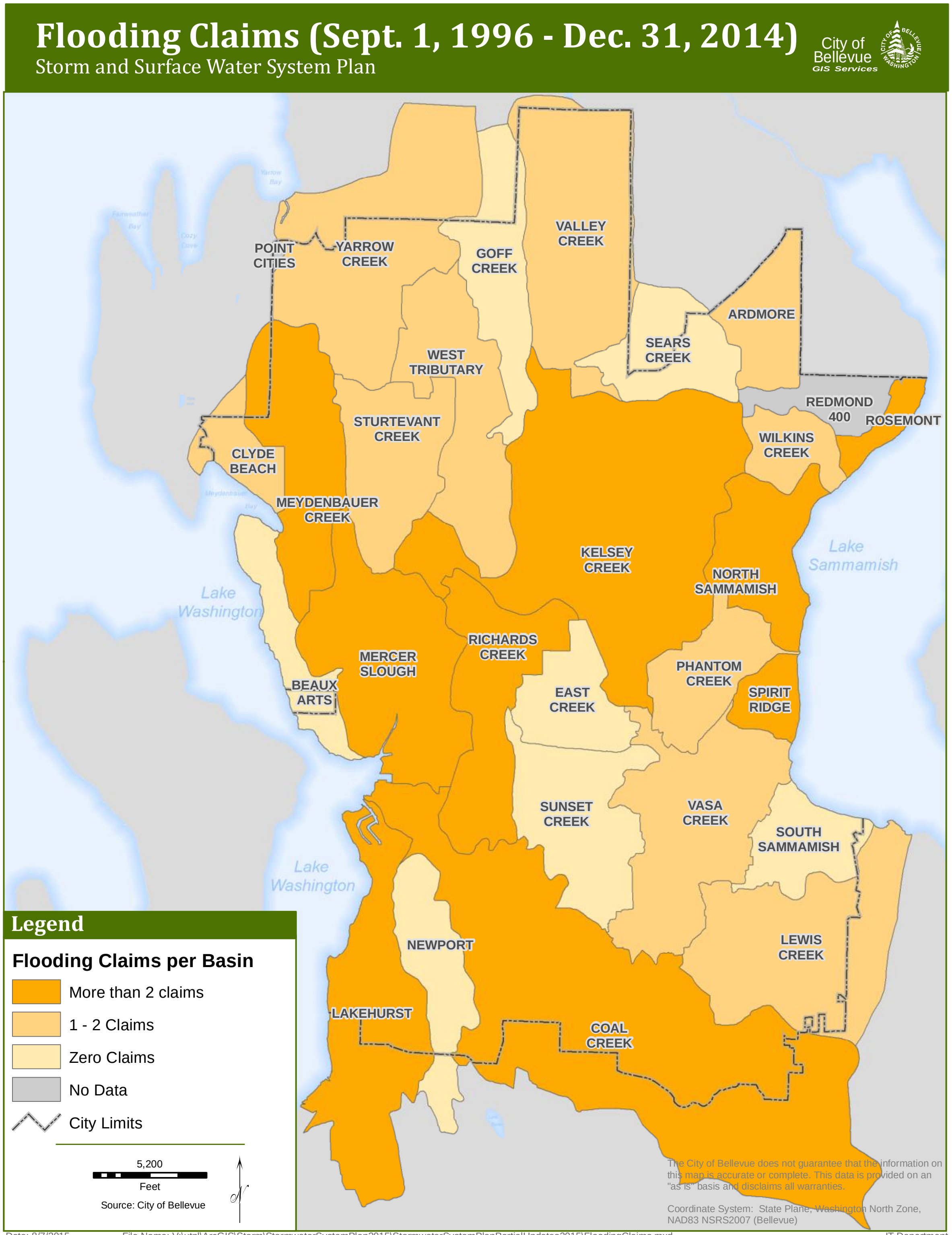

Figure 6-11. Paid flood claims basin map.

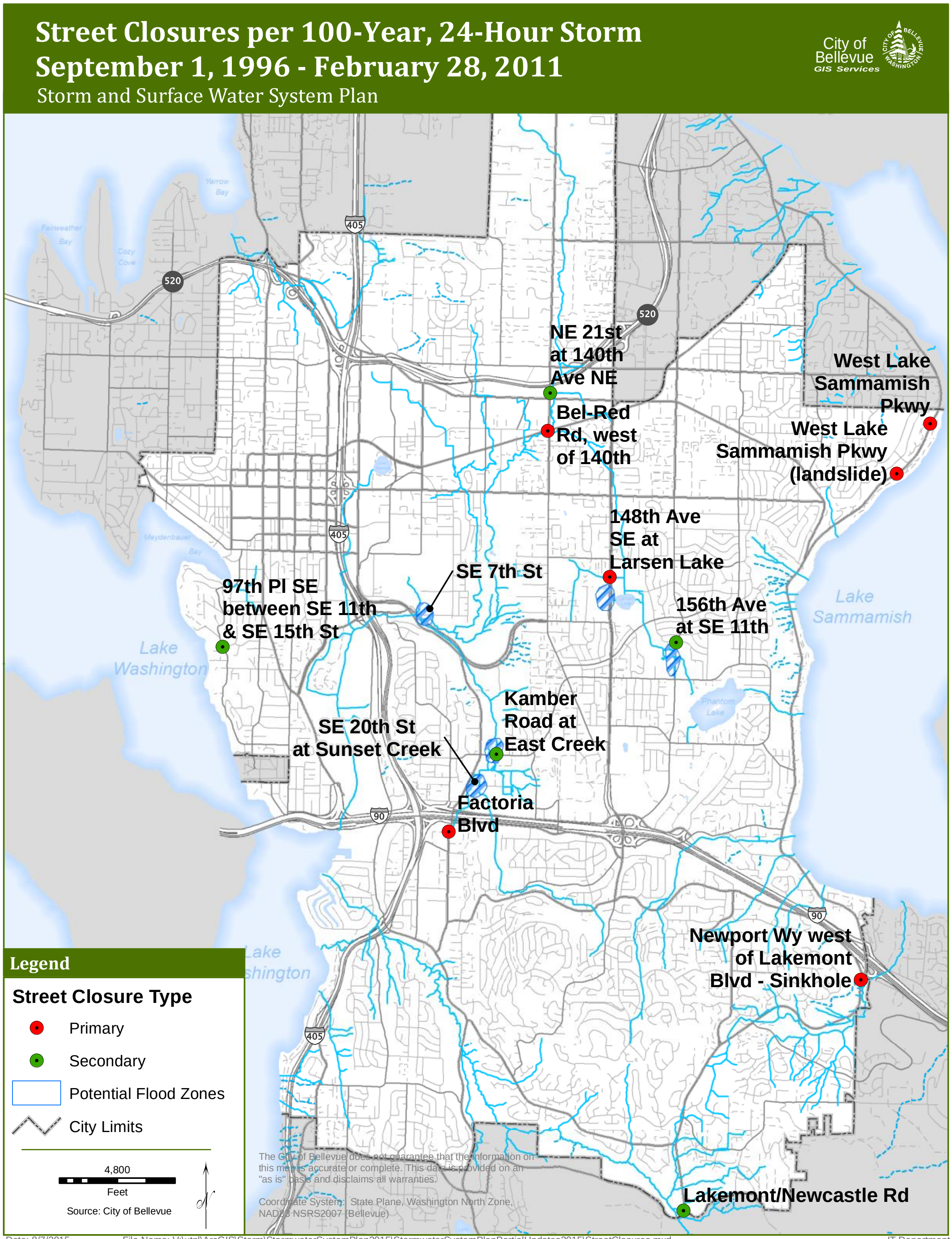

Figure 6-12. Street closure map due to flooding.

Of the five storm events described in the above-mentioned Storm Reports, three of the five were considered 100-year, 24-hour storm events; one was considered a 10-year, 24-hour storm event, and one storm was less than a 10-year, 24-hour storm event (but still caused flooding). The Storm Reports did not include information about the duration of secondary road closures, so only the number of primary and secondary road closures were used as evaluation metrics. Each storm event resulted in two or three primary road closures, and one or two secondary road closures (see Appendix B-4). No other arterial or collector routes were closed. Temporary closure of collector streets due to flooding is considered acceptable, so those were not tallied.

Background Information on Flooding

Flood protection is a central function of the Utilities Department. The aforementioned evaluation metrics enabled a basin-scale analysis of flood protection. Additional information that was considered in the evaluation follows and is focused on the evolution of stormwater regulations, age of development, and the effects of inherited stormwater systems through annexation.

Effects of Public Regional Stormwater Detention

The effects of urban development on stream flow can be partially mitigated by holding water on-site or in detention facilities and releasing the stored water slowly downstream. There are 11 engineered regional stormwater detention facilities owned by the City, and their combined water storage capacity volume for the Kelsey Creek, Coal Creek, and Lewis Creek basins is estimated at over 206.8 acre-feet (regional facility locations are shown in Figure 6-13, and volume storage capacities are available in Appendix B-6). The volume of storage can also be represented as the number of inches of rain that, if it fell over that drainage basin, landed on impervious area and was directed to the regional facility for storage. The Kelsey Creek basin regional facilities could hold almost an inch of rain (0.9 inch); the Coal Creek regional facility could store less than 1/3 of an inch of rain; and the Lewis Creek regional facility could store over 4.5 inches of rain. Additional storage is provided by flow control facilities on both public and private property.

Figure 6-14 is a flow frequency graph comparing existing flow conditions that benefit from the regional detention facilities located in the Kelsey Creek basin to a hypothetical condition, one in which the detention facilities were removed (Northwest Hydraulic Consultants 2002). The graph shows that for a given flow rate (750 cubic feet per second [cfs]), the chance that such an event would happen is reduced from 20 percent (a 1-in-5 chance of occurring any year) to 10 percent (1-in-10 chance).

To completely mitigate the approximately 40 percent of impervious area across the city to the 2010 flow control standard, the system would need to store a volume over 10 times what it currently captures, approximately 2,450 acre-feet of runoff (imagine 1860 football fields). However, as redevelopment occurs and new detention and infiltration techniques are employed, runoff should be reduced and the needed storage volume to more closely mimic natural conditions should decrease.

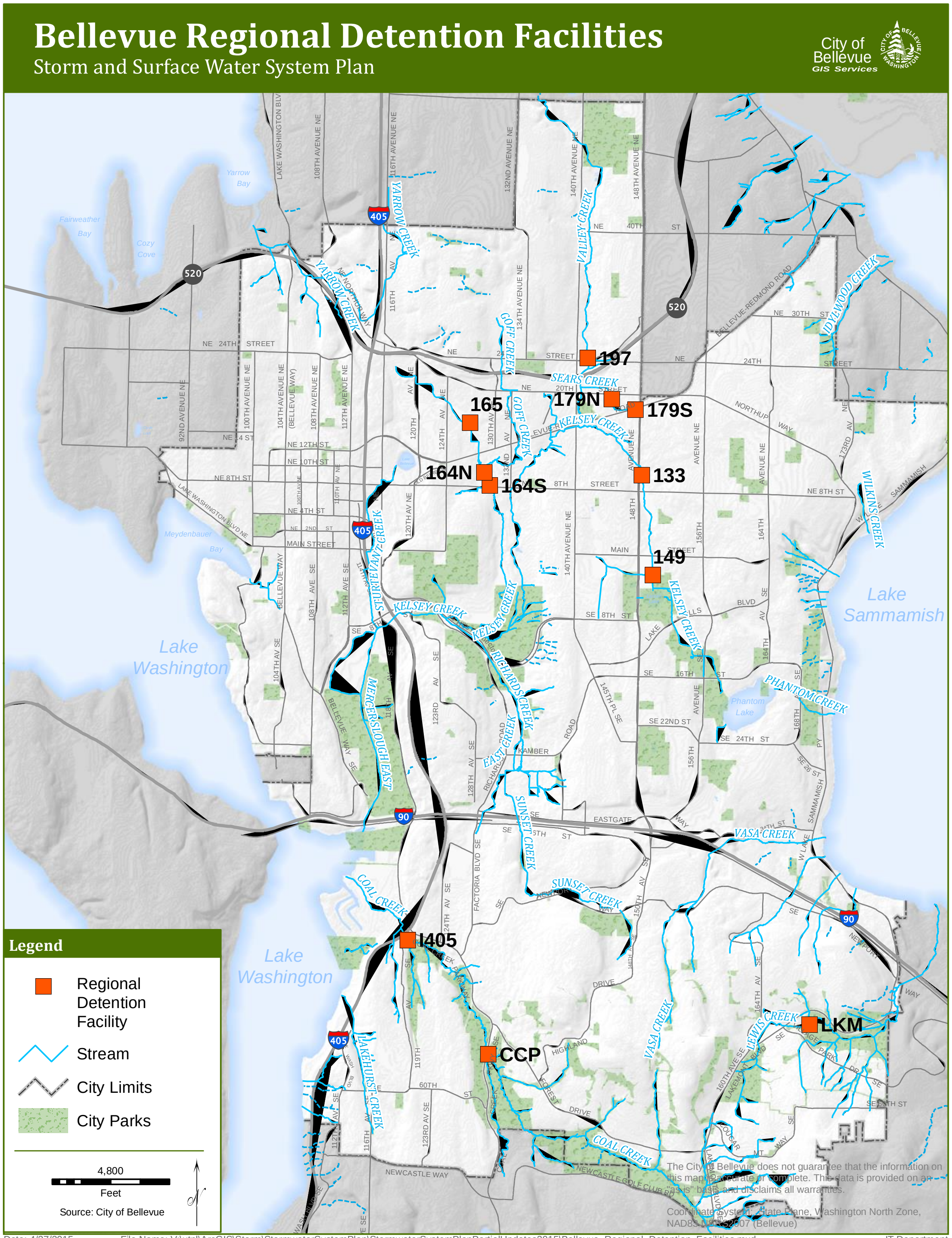

Figure 6-13. Regional detention facilities.

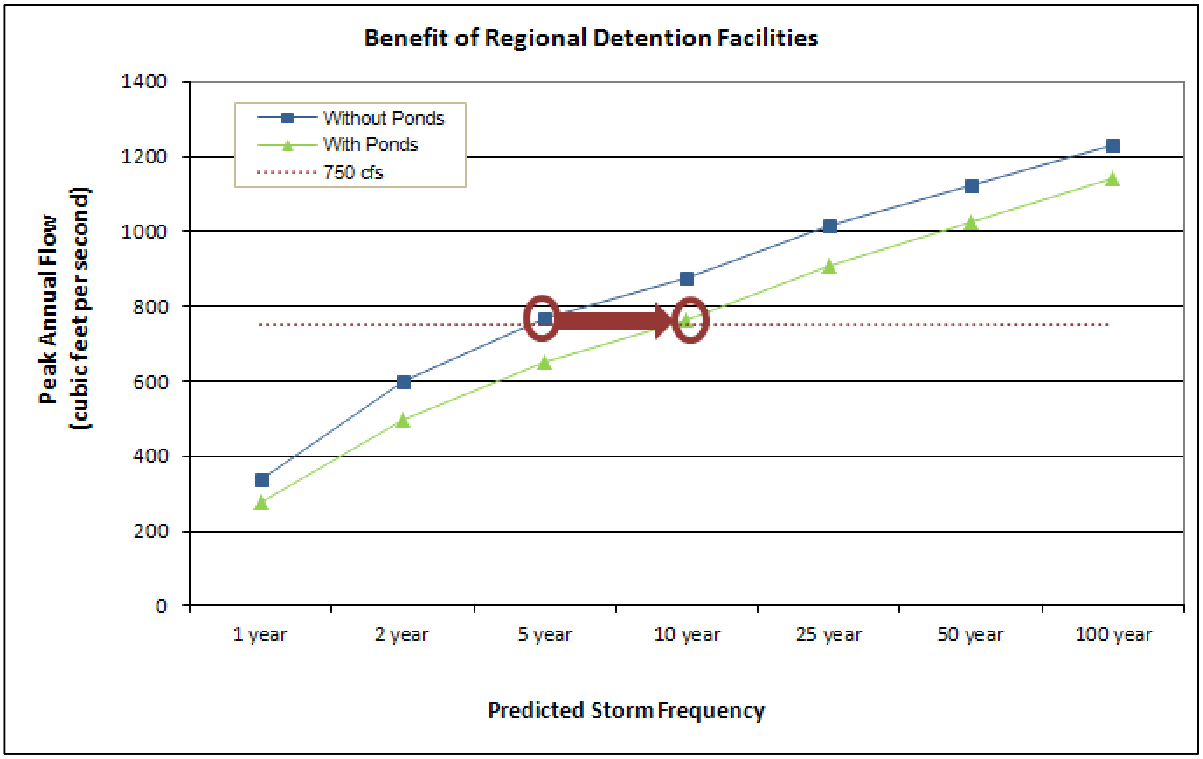

Figure 6-14. Effect of regional detention in Kelsey Creek.

Age of Development

Approximately 31 percent of the city was developed prior to 1975. The King County Assessor's office provided the City with a list of parcels and the year of the most recent development on each parcel (see Figure 6-15 Parcel Development). Table 6-4 breaks out the age of development of the city with key milestone periods associated with changing stormwater design standards. The information is based on parcel development date available in June, 2015.

As illustrated by Table 6-4, the city developed under a variety of development standards for flow control and conveyance. The descriptions of flow control and conveyance standards below are simplified, and represent only the general application of the standards.

- Prior to 1974–Flow control standards did not exist; therefore, development occurred with no appreciable flood protection.
- 1974 to 1987–Requirements were to regulate a 4-hour, 100-year storm, which was approximately 1.7 inches of rain, to a rate of 0.2 cfs per acre. To achieve this standard, new and redeveloping properties were required to provide 1 inch of detention per impervious acre and 0.5 inches of storage per pervious acre (City of Bellevue Department of Public Works 1975).
- 1988 to 1995–This standard required detention of two sizes of storm events, as follows: peak runoff from the larger 100-year, 24-hour storm event was mitigated to the pre-developed 10-year, 24-hour peak runoff rate; the post-developed 10-year, 24-hour peak flow was mitigated to the pre-developed 2-year, 24-hour peak flow event (City of Bellevue 1988).

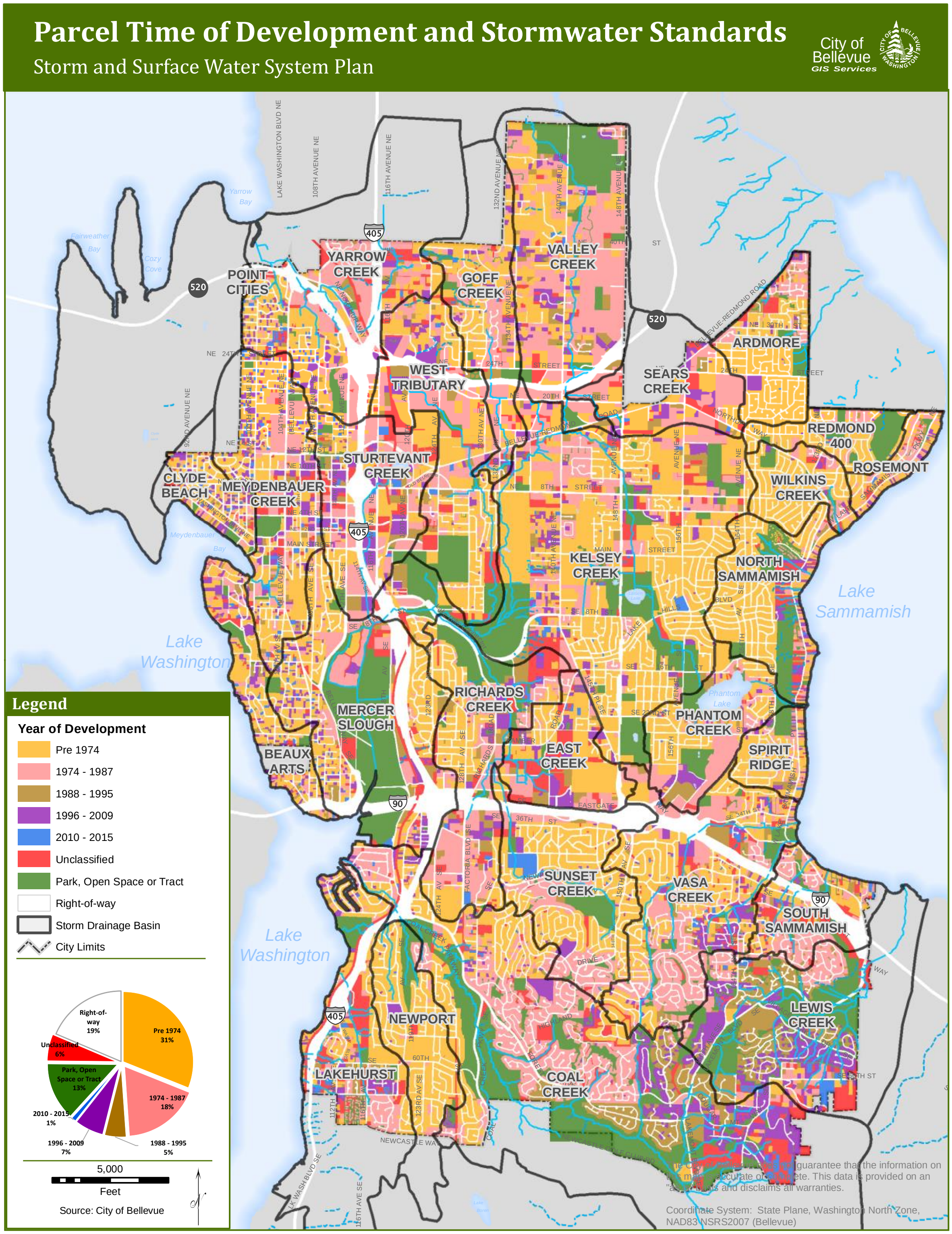

Figure 6-15. General time of development or redevelopment for parcels in Bellevue outside the right-of-way, and corresponding stormwater development standards for that time period.

- 1996 to 2009–Flow control was required to mitigate the post-developed runoff rates for the 100- and 10-year, 24-hour storms to their "existing" land-cover runoff rates, and the post-developed 2-year, 24-hour storm to 50 percent of the 2-year "existing" land-cover runoff rates. This code effectively limited application of runoff control to only new or added impervious area. Because the mitigation standard was "existing" land cover at the time of construction, a redevelopment project that converted one type of impervious land surface to another type, e.g., parking lot to roof top, did not need to provide mitigation of runoff from those existing impervious areas (City of Bellevue Utilities Department 1998).
- 2010 to 2015–The flow control standard required new and redeveloping properties to mitigate runoff to a pre-developed forested land-cover type, specifically by reducing the duration and peak flows from storms ranging from half of the 2-year to the 50-year storms (City of Bellevue Utilities Department 2015).

Table 6-4. Age of built developments in Bellevue

Year Parcel Developed or Redeveloped	Number of Acres	Portion of 2015 City Area	Bellevue Conveyance Standard	Bellevue Flow Control Standard
Pre-1974	6,775	31%	None	None
1974-1987	3,879	18%	10-year event	0.2 cfs per acre
1988-1995	1,091	5%	10-year event	10-year to 2-year and 100-year to 10-year
1996-2009	1,463	7%	100-year event	Developed mitigated to existing land use: 100-year to the 100-year and 10-year to 10-year and 2-year to 50% of 2-year
2010-2015	245	1%	100-year event	Forested pre-developed runoff rates
Parks, Open Space or Tract	2,925	13%	-	-
Unclassified	1,360	6%	-	-
Right-of-way	4,054	5%	-	-
Total	21,792	100%	-	-

Detention standards are intended to slow runoff from built, impervious surfaces and prevent stormwater from overwhelming the capacity of the system. These standards have changed over time to require that more volume be controlled on site to better mitigate development impacts. Developments built before flow control standards existed, or under less stringent standards, are required to upgrade to the current standards when they redevelop. Developments designed under past standards contribute higher volumes of runoff to the system immediately after each storm event.

Conveyance standards (minimum size requirements for storm drains, pipes, open channels, and other facilities that carry water from its source to the downstream receiving water) have also changed over time. In 1974, storm conveyance systems were required to be sized to carry at most the 10-year storm event. It was not until 1996 that new conveyance systems were required to contain up to the 100-year storm event.

As of 2010, Bellevue adopted the state's stormwater manual, which establishes requirements for stormwater runoff, conveyance, and water quality treatment. Bellevue enforces these requirements through Utility codes and engineering standards for new and redeveloping properties. Figure 6-15 shows the time of development and the stormwater management standard in place for most parcels in Bellevue.

Annexation

Much of the built system was inherited by the City through annexation. In 1953 when the City incorporated, the city area was less than 10 square miles and by 2015 the city limits expanded in area to almost 34 square miles. Figure 6-16 shows what areas were annexed by decade. The Bellevue Storm and Surface Water Utility was formed in 1974, so stormwater infrastructure built prior to that date was designed by King County Standards and areas developed after 1974 were either designed by City standards or the County, depending on the annexation date and the date of development.

Knowing when a parcel was developed and which jurisdictional standards were used helps with flood protection analyses and to explain why some of the stormwater infrastructure data are missing. Figure 6-16 shows the age of development for parcels in the city.

The inventory of stormwater infrastructure records is inconsistent. Often, the infrastructure location, material, size, and date of construction are missing. Prior to 1974 (when the Storm and Surface Water Utility formed), organizing and keeping detailed records of stormwater infrastructure appears to have been a low priority. It was common practice to install drainage facilities in a manner that simply removed stormwater runoff from the site as quickly as possible, often without regard to downstream impacts and with inconsistent records of the built system. The annexation areas were developed using King County standards for utility services including stormwater infrastructure design. Assessing and describing existing conditions of the built stormwater system is challenging because of the inconsistent records; therefore as a proxy, the age of the development was used.

Ongoing Problem Flooding Locations

Flooding due to debris, such as fallen leaves, is a recognized concern at 64 City-owned drainage facilities. These sites are routinely inspected and cleaned prior to storm events to avoid or minimize flooding (Figure 6-17). If the system is modified and results in a permanent solution, sites are removed from the preventative maintenance site list. Undersized public conveyance that causes flooding is addressed through the Capital Investment Program.

Evaluating Water Quality Protection

Clean surface water protects human health, supports a healthy aquatic ecosystem, and enables beneficial uses of streams and lakes as designated by the Clean Water Act, such as swimming and aquatic life support.

Pollutants enter surface water in a variety of ways. Pollutants are washed off natural, landscaped, and impervious surfaces during rain events, poured down storm drains (non-point pollution), and discharged from industrial sites (point pollution), for example. During storms, pollution that has accumulated on roads and landscaped areas is washed into storm drains and streams, so water samples taken during storms characterize the mixture of pollutants contributed over the course of time. The pollutants that most affect human health and aquatic life include pesticides, temperature, heavy metals, nutrients, and other sources (Table 6-5). Additional discussion of the impacts of road runoff will be discussed in a later section in this chapter, "Salmon Pre-spawn Mortality."

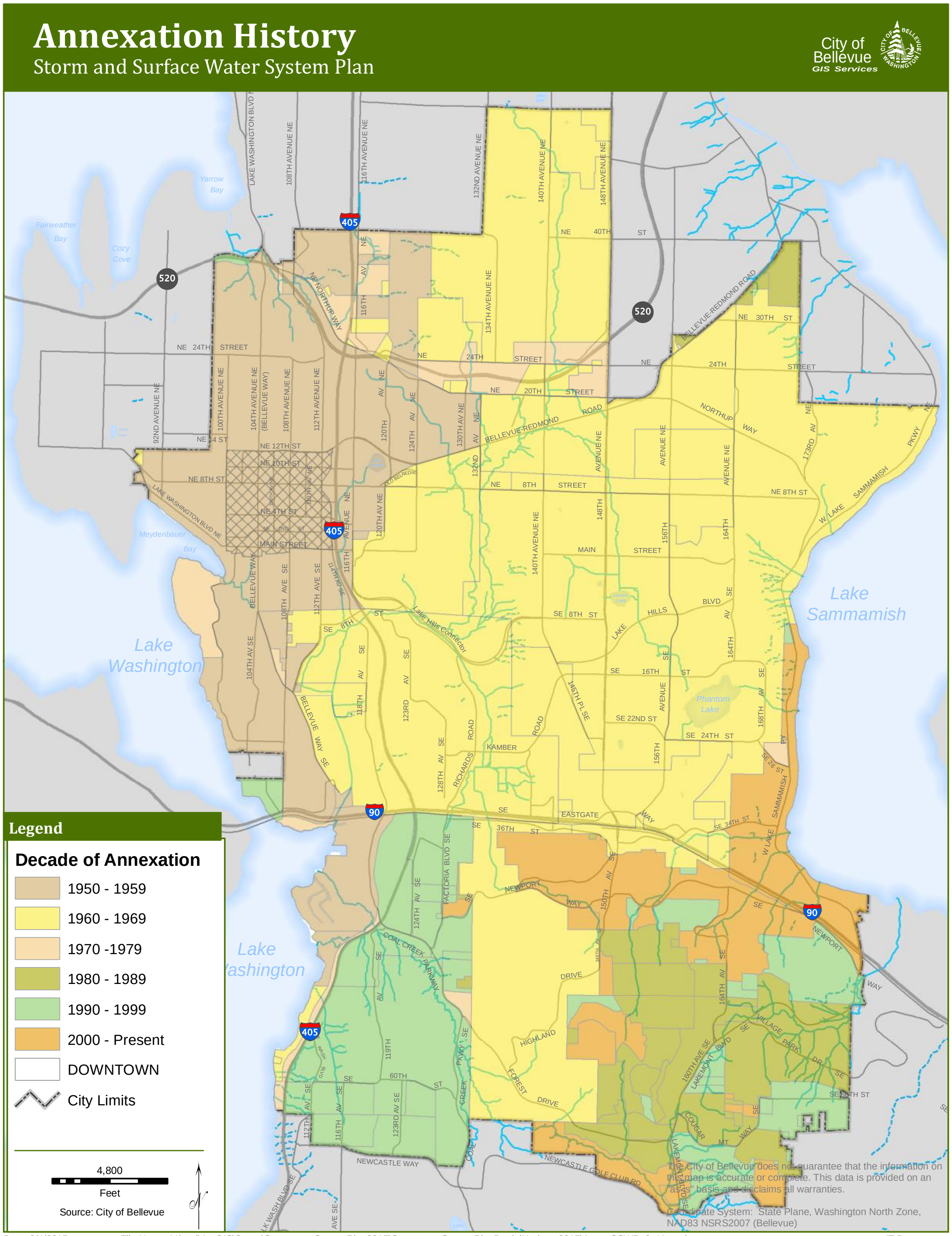

Figure 6-16. Annexation history illustrates that much of the city was already developed prior to implementing stormwater regulations.

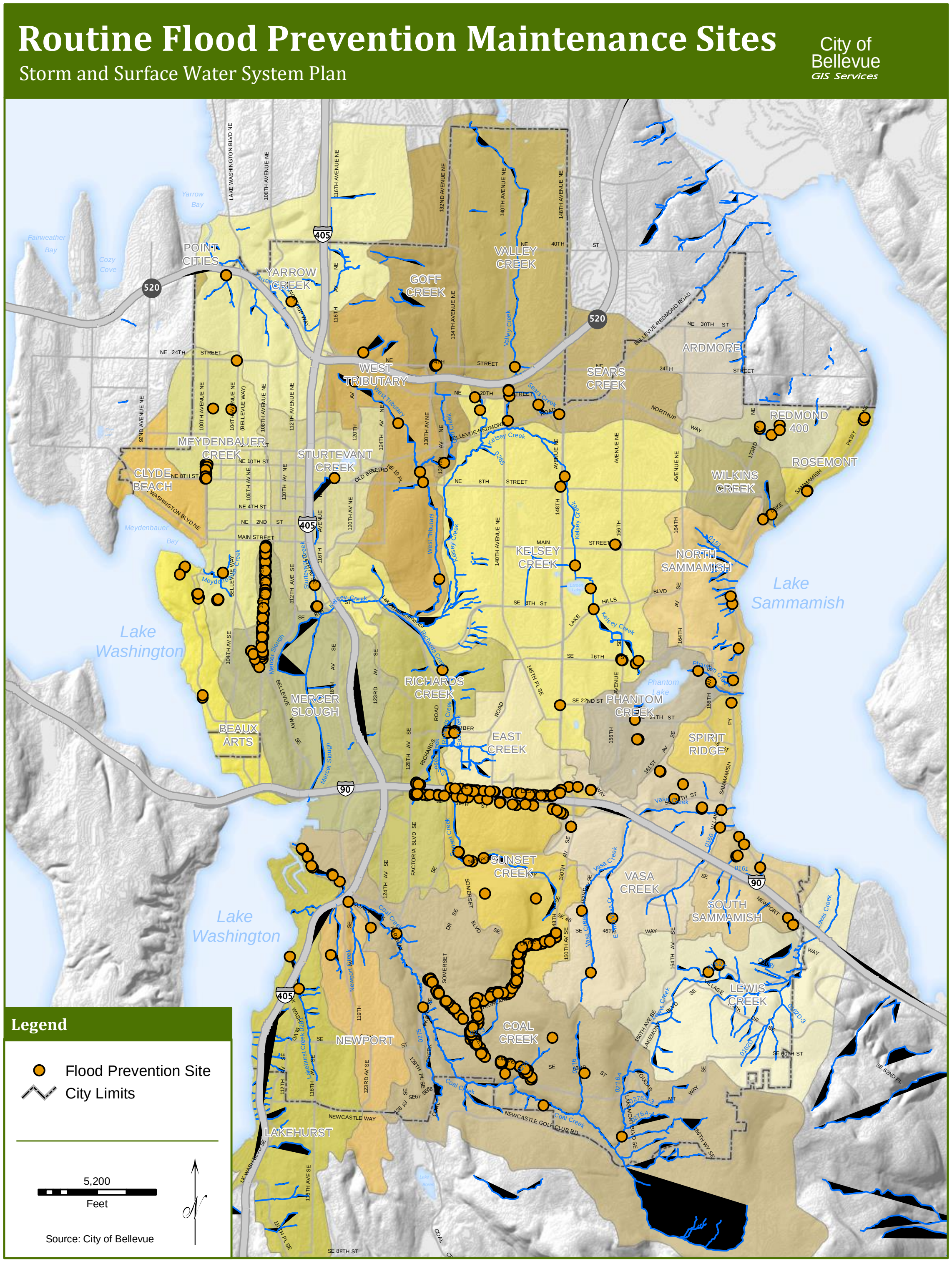

Figure 6-17. Example of sites surveyed routinely during storm events to prevent flooding. If needed, debris is cleared from grates, or other maintenance is performed.

Note: This map is dynamic and constantly being revised.

Table 6-5. Common pollutants and their impacts on aquatic systems

Pollutant	Sources	Impacts
Sediment	Sediment is a common component of stormwater, and can be a pollutant. Sediment is the primary component of total suspended solids (TSS), a common water quality analytical parameter.	Sediment can be detrimental to aquatic life (primary producers, benthic invertebrates, and fish) by interfering with photosynthesis, respiration, growth, reproduction, and oxygen exchange in water bodies. Sediment can transport other pollutants that are attached to it including nutrients, trace metals, and hydrocarbons.
Nutrients	Nutrients including nitrogen and phosphorous are the major plant nutrients used for fertilizing landscapes, and are often found in stormwater.	Nutrients can result in excessive or accelerated growth of vegetation, such as algae, resulting in impaired use of water in lakes and other sources of water supply. Algae growth reduces water clarity, and when algae dies, it absorbs oxygen from the water as it decomposes. This harms fish and causes unpleasant odors. In addition, un-ionized ammonia (one of the nitrogen forms) can be toxic to fish.
Bacteria and Viruses	Bacteria and viruses are common contaminants of stormwater. For separate storm drain systems, sources of these contaminants include animal excrement and sanitary sewer overflow.	High levels of indicator bacteria in stormwater have led to the closure of beaches, lakes, and rivers to contact recreation such as swimming.
Oil and Grease	Sources of oil and grease include leakage, spills, cleaning, and sloughing associated with vehicle and equipment engines and suspensions, leaking and breaks in hydraulic systems, restaurants, and waste oil disposal.	Oil and grease includes a wide array of hydrocarbon compounds, some of which are toxic to aquatic organisms at low concentrations.
Metals	Metals including lead, zinc, cadmium, copper, chromium, and nickel are commonly found in stormwater. Many of the artificial surfaces of the urban environment (e.g., galvanized metal, paint, automobiles, or preserved wood) contain metals, which enter stormwater as the surfaces corrode, flake, dissolve, decay, or leach. Over half the trace metal load carried in stormwater is associated with sediments.	Metals are of concern because they are toxic to aquatic organisms, can bioaccumulate (accumulate to toxic levels in aquatic animals such as fish), and have the potential to contaminate drinking water supplies.
Organics	Organics may be found in stormwater in low concentrations. Often synthetic organic compounds (adhesives, cleaners, sealants, solvents, etc.) are widely applied and may be improperly stored or disposed, or deliberately dumped into storm drains and inlets.	Organics cause harm to aquatic life living in waterways.
Pesticides	Pesticides (including herbicides, fungicides, rodenticides, and insecticides) have been repeatedly detected in stormwater at toxic levels, even when pesticides have been applied in accordance with label instructions.	Accumulation of pesticides in simple aquatic organisms, such as plankton, provides an avenue for bio-magnification through the food web, potentially resulting in elevated levels of toxins in organisms that feed on them, such as fish and birds.
Gross Pollutants	Gross pollutants include trash, debris, and floatables. These items may contain heavy metals, pesticides, and bacteria. Typically resulting from an urban environment, industrial sites and construction sites, trash and floatables may create an aesthetic "eye sore" in waterways. Gross pollutants also include plant debris (such as leaves and lawn clippings from landscape maintenance), animal excrement, street litter, and other organic matter.	Gross pollutants may harbor bacteria, viruses, vectors, and depress the dissolved oxygen levels in streams, lakes, and estuaries, sometimes causing fish kills.

Source: Adapted from California Stormwater Quality Association. 2003. California Stormwater BMP Handbook, Municipal, Errata 9-2004. www.cabmphandbooks.com. Accessed March 2, 2010.

Everyone has a responsibility to discharge clean water from their property. Local, state, and federal governments create rules to protect water quality and use BMPs while conducting operations. Individual actions of residents and businesses have direct impacts on surface water quality because runoff is not treated at a centralized treatment plant and there are many sources of pollution, including atmospheric deposition, byproducts of vehicle use such as gas, oil, and brake pad particles. Small actions by many people can have a large cumulative impact.

Water Quality Evaluation

The analysis to evaluate water quality protection looked at five measurable criteria available to the City. They are: 1) compliance with the NPDES Municipal Stormwater Permit, 2) number of Clean Water Act Violations, 3) number of illicit discharge corrections, 4) stream segments classified as being impaired water bodies, and 5) the water quality risk associated with each stormwater basin.

Compliance with NPDES Municipal Stormwater Permit and Clean Water Act

The City has been in 100 percent compliance with the NPDES Municipal Stormwater Permit since it first took effect in 2007 and has had no fines for Clean Water Act violations during the permit period.

Illicit Discharge Corrections

Illicit discharges are discharges into the storm drainage system (or direct discharges to a surface waterbody) that are not entirely composed of stormwater (or non-stormwater discharges allowed by the NPDES Municipal Stormwater Permit). Generally these pollutant discharges result from human activities, infrastructure failures, accidents, illegal actions or connections.

The NPDES Municipal Stormwater Permit has specific illicit Discharge Detection and Elimination (IDDE) Program requirement, including a requirement to annually report the number of illicit discharges responded to by the City. There is currently two years of data for calendar years 2012 and 2014. Reporting was not required in 2013 because it was a transition year between the direst and second NPDSE Permits. There were 176 illicit discharges reported in 2012 and 297 in 2014. All of the illicit discharges were responded to and eliminated by City staff.

Waters Classified as Impaired

Bellevue contributes runoff to nine stream segments, two Lake Washington sampling sites, and two Lake Sammamish sampling site that were rated as impaired in 2012 based on state criteria for water quality support of beneficial uses under the Clean Water Act; see Figure 6-18 (Ecology 2012). King County collected monthly grab samples over several years, which were used as the basis for the ratings. Streams were rated as impaired due to high fecal coliform bacteria counts, high water temperatures, and/or low dissolved oxygen; these affect their acceptability for human recreation (primary physical contact) and aquatic life support. However, one reach in Mercer Slough had high temperatures and is heavily influenced by water temperatures in Lake Washington, and is therefore unlikely to ever meet the stream temperature criteria. Fecal coliform bacteria are highly variable in the natural environment, and common sources include human septic systems, pet waste, and wildlife.

Mercer Slough, Coal Creek, Ardmore (Idylwood) Creek, Lewis Creek, and two sites along Kelsey Creek were sampled and rated as meeting tested standards (Category 1) under the Clean Water Act, Section 305(b), for pH or ammonia-nitrogen; see Figure 6-18 (U.S. Environmental Protection Agency 2010).

Statewide, less than three percent of streams and rivers were assessed, and of those, 80 percent were rated as impaired, and 20 percent were rated as meeting criteria for beneficial uses.

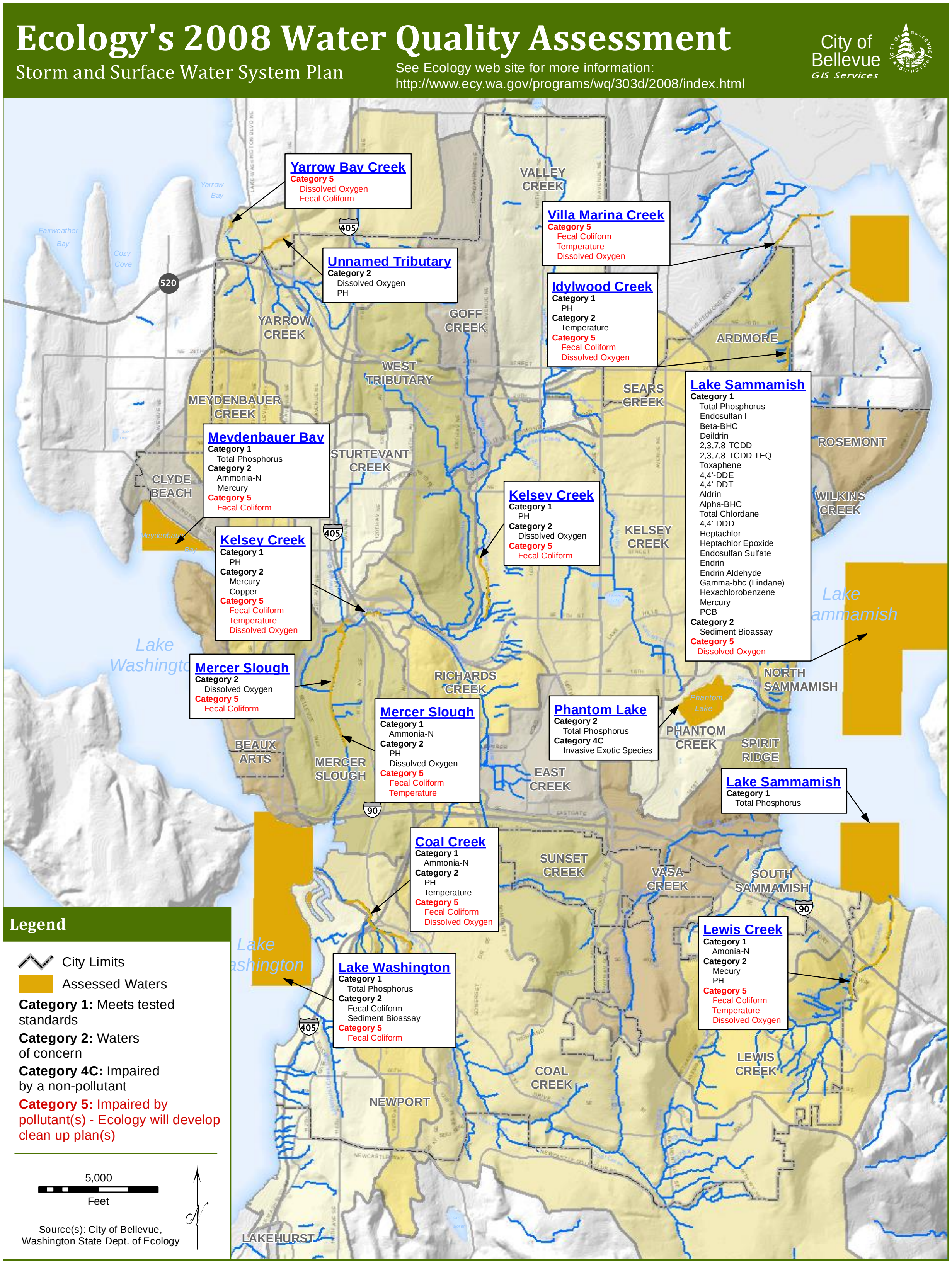

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Figure 6-18. 2008 Water Quality Assessment map showing ratings for water bodies in Bellevue and the vicinity based on state and federal water quality criteria for beneficial uses.

Water Quality Risk Assessment

Stream segments were prioritized according to the likelihood of illicit discharges based on several land use and biological criteria as part of the City's NPDES program. Criteria used to rank each stream segment included:

- Fish bearing;
- Impaired water quality according to the state 303(d) list in 2009;
- Percent impervious area;
- Septic system areas;
- Density of outfall pipes greater than 24 inches directed to stream;
- Adverse history of stream water quality issues;
- Land use; and
- Industrial permits.

Each stream segment was ranked high, medium, or low water quality risk level (Figure 6-19), which corresponds to the Illicit Discharge Detection and Elimination (IDDE) program's receiving waters risk assessment, outfall reconnaissance inventory class. This classification of stream segments was used to prioritize inspections of outfalls based on the likelihood of pollutants entering the system through the outfalls. This ranking summarizes multiple factors for water quality risk in a watershed.

Water Quality Summary of Bellevue's Streams

Overall, Bellevue waters show similar water quality impacts as other urban streams, including increased summer temperature, lower dissolved oxygen, and increased fecal coliform bacteria—constituents identified by the Washington State Department of Ecology (Ecology). A basin-scale summary of the water quality evaluation metrics follows:

- 100 percent compliance with NPDES Municipal Stormwater Permit conditions;
- Zero Clean Water Act violations;
- 182 illicit discharge corrections; (2010)
- 5 basins with water quality impairments; and
- 10 basins with a high risk for illicit discharges.

Federal and state regulations for some widespread pollutants may be the best way to reduce their impact on water quality. For example, lead was commonly found above acutely toxic levels in Bellevue stormwater in the 1980s, when leaded gasoline was commonly used. Federal regulation restricted the use of lead in gasoline, and by 1990s, the amount of lead in Bellevue's surface runoff was dramatically reduced, from average 170 micrograms per liter (µg/L) to 10 µg/L (City of Bellevue 1995), which followed the national trend (U.S. Geological Survey 2001). Similar regulations limiting the use of toxic metals in car brake pads were recently passed. As they go into effect over the next several years, the amount of copper found in stormwater runoff should be reduced (Washington Senate Bill 6557; http://apps.leg.wa.gov/billinfo/summary.aspx?bill=6557&year=2009).

Evaluating Stream Habitat

The evaluation criteria for stream habitat were based on standards used by NOAA Fisheries to determine potential impacts of projects on Chinook salmon or their habitat, which is protected under the Endangered Species Act (ESA). Another indicator of stream health is aquatic benthic macroinvertebrates—the small organisms that live on the stream bottom and have different sensitivity to pollutants and habitat disturbance. There is limited information about stream habitat conditions, but in areas with information on the number of large woody debris pieces per channel width and pool quality, data generally indicate degraded habitat similar to other urban streams (see Figure 6-20).

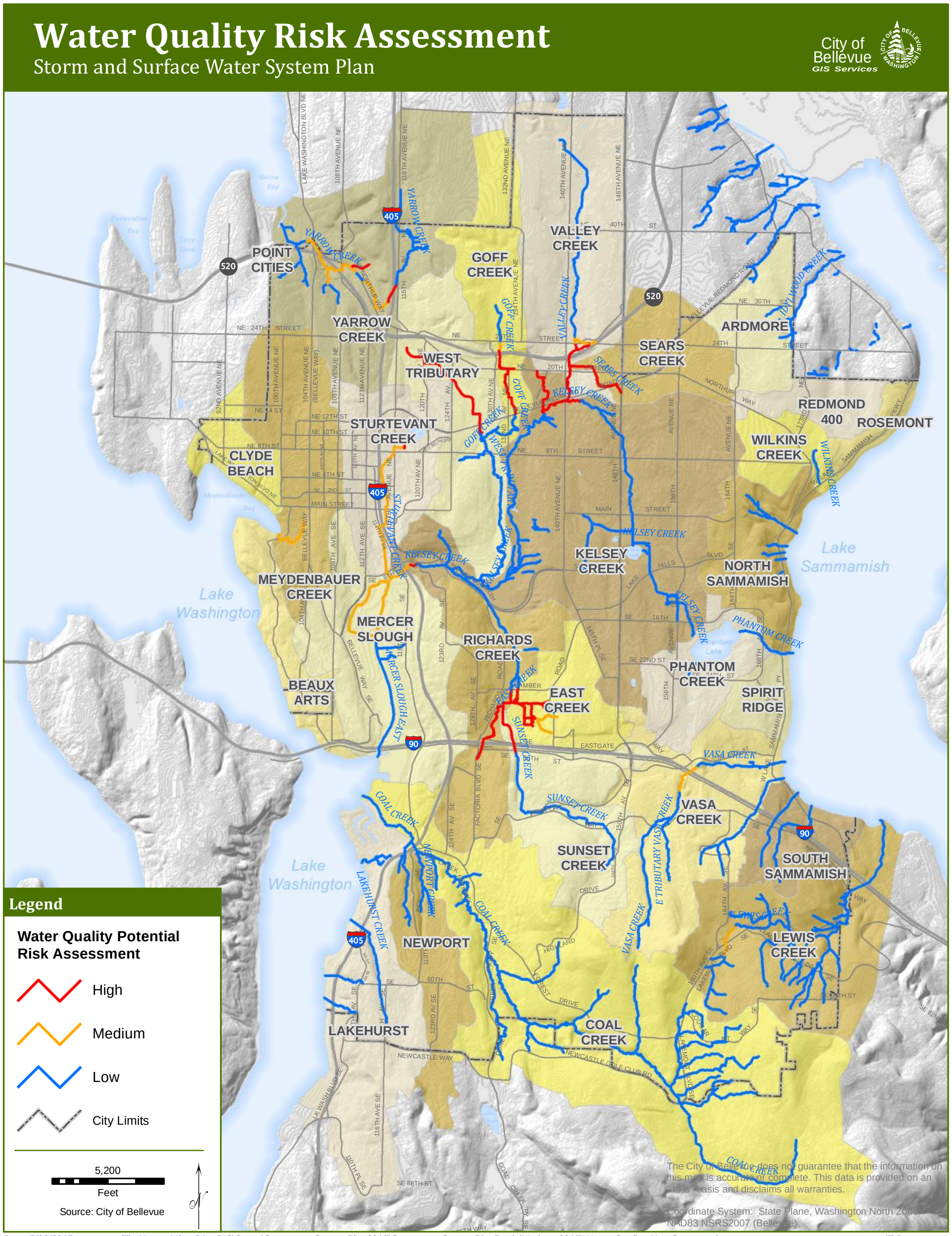


Figure 6-19. Water quality risk assessment that identifies potential risk areas for pollution entering streams, based on land use, outfalls to streams, and fish use.

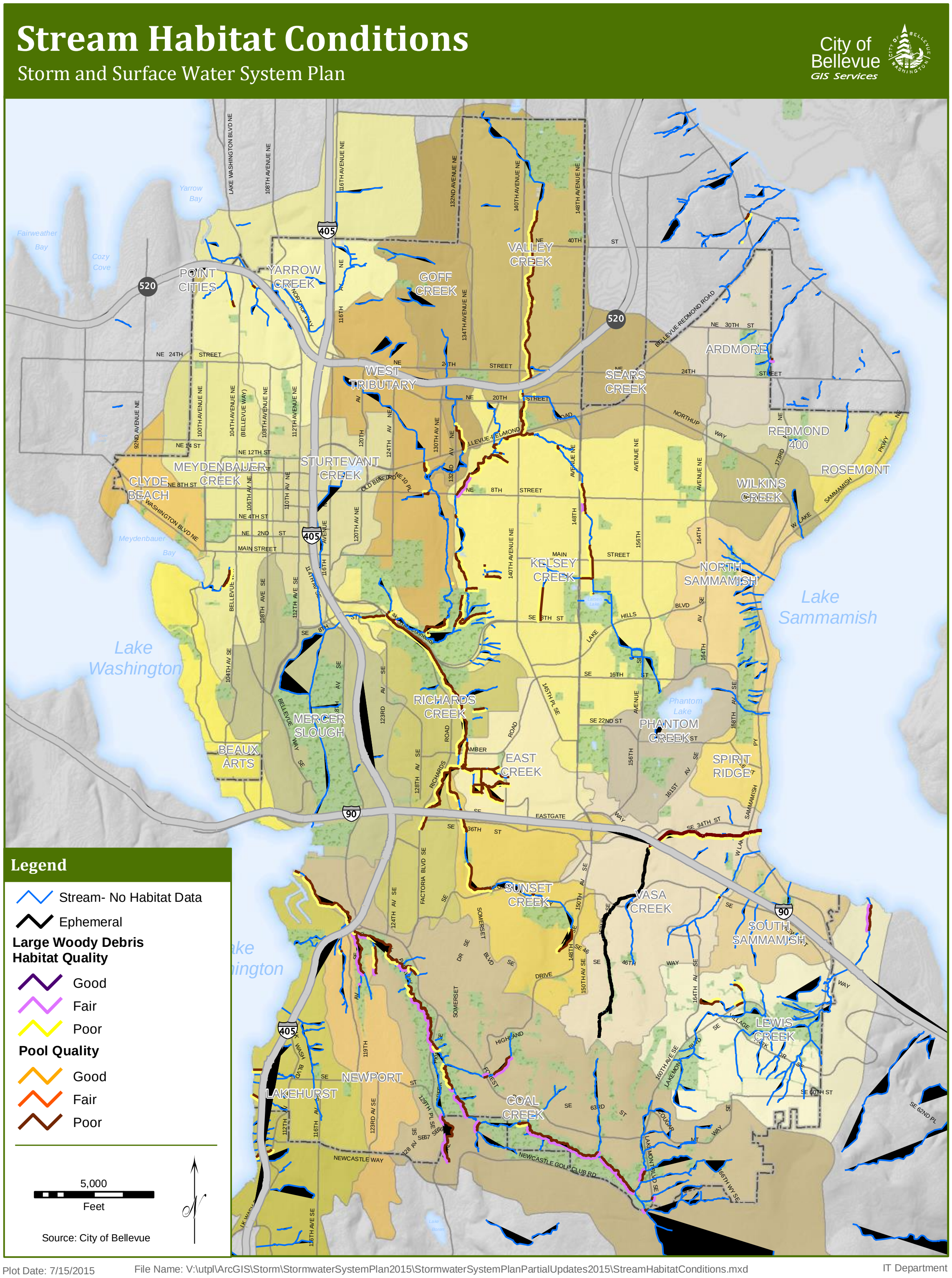


Figure 6-20. Stream habitat conditions map.

Wood Pieces per Channel Width

Pieces of large woody debris (commonly referred to as LWD) or logs in stream channels improve stream habitat for fish and wildlife. Wood captures sediment, protects banks from erosion, shades the water, creates hiding places, forms deep pools where fish can rest and feed, and feeds invertebrates, which supports the stream food web. Wood was historically very abundant, but much of it was removed in the past two centuries for logging, and riparian trees were cut down, eliminating the source for much new wood. Current restoration efforts include placing logs directly in streams as well as planting trees near streams to supply wood in the future. The amount of wood along a stream channel per each channel width is a metric for habitat quality. Habitat quality is considered good when there are more than two pieces of large wood per channel width, fair with one to two pieces per channel width, and poor with less than one piece per channel width (Kerwin 2001). Of the few Bellevue streams that have been surveyed for wood, most are considered poor habitat quality due to a lack of wood; see Figure 6-20 (Stream Habitat Conditions). Only Coal Creek was ranked fair. Since the wood surveys, several projects were completed where wood was placed in the stream channel—these are located in Coal, Valley, Newport, Yarrow, and Sunset Creeks, and the West Tributary. Large woody debris density may have improved in Coal Creek and locally where projects have been implemented. Analyses of Vasa Creek in 2014 have shown the lower extent draining into Lake Sammamish has poor large woody debris habitat zones, and a northern extent that does not flow during the summer months.

Pool Quality

Large pools in streams provide slow-moving water that provides resting places for migrating adult salmon as well as for fish that live in the streams year-round. Deep pools with cool water and cover (an overhanging log or vegetation hanging over from the bank) provide places for fish to feed and hide from predators. Streams rate “good” for pool quality if they have frequently spaced pools over 1 meter deep with cover and cool water, and “poor” if they only have shallow pools or pools without cover or cool water, as described in Kerwin (2001). Bellevue data did not incorporate water temperature, so ratings were based on pool depth and cover. Of the six basins with data, none met standards for “good” pool quality. Fifteen basins had no data and five basins do not have perennial streams. For example, in the Kelsey Creek basin, pool frequency was less than 13 pools per mile, and the distance between pools was 22.1 bankfull widths (channel widths) on average, more than 10 times the recommended distance (Kerwin 2001).

Benthic Macroinvertebrates and Biotic Integrity

Macroinvertebrates (insects, snails, worms, and other spineless creatures big enough to see with the naked eye) that live in gravel substrate of streams are sampled each year because they are a valuable indicator of stream health. These benthic macroinvertebrates are not able to move quickly to avoid undesirable conditions, and are sensitive to the following factors:

- Flow rates;
- Timing of storm flows;
- Pollutants in the water such as heavy metals and pesticides;
- Water temperature;
- Dissolved oxygen levels in the water;
- Fine sediments from upstream erosion; and
- Amount of food available in the form of leaf litter and smaller organisms.

As conditions in the streams change, the benthic macroinvertebrate community changes in predictable ways (Marangelo and Bollman 2010). Because many water quality problems are short-lived, they are difficult to measure by traditional water quality sampling. The number and diversity of benthic macroinvertebrates, on the other hand, represent a good indicator of both the water quality and habitat condition of a stream.

Scientists use a rating system to score samples based on the types of groups and number of macroinvertebrates in a sample, known as the Benthic Index of Biotic Integrity (B-IBI) (Fore et al. 1996). B-IBI scores can range from 0 (very poor condition) to 100 (pristine condition). Researchers have found the B-IBI score to be significantly correlated with the amount of urbanization in a watershed, measured by percent impervious area (Alberti et al. 2007; Booth et al. 2004; Morley and Karr 2002). Generally, when a watershed becomes more than 10 percent impervious, the score is lower. Scores below 60 are currently considered biologically impaired (City of Seattle et al. 2010).

Thirty-six sites in 13 Bellevue drainage basins were sampled for benthic macroinvertebrates between 1998 and 2014 (Appendix B-7). Sampling sites were selected based on adequate sampling conditions for macroinvertebrates, a need for information, and available staff resources. B-IBI scores and site ratings are based on regionally accepted protocols (City of Seattle et al. 2010). Sites with at least 3 years of B-IBI sampling between 1998 and 2007 were analyzed for trends, but none were detectable with so few data points (Bollman 2009).

The most recent B-IBI scores show 46 percent of all Bellevue sites ranked in the second lowest category (poor), and 25 percent ranked in the lowest category (very poor) (see Figure 6-21). Some Lewis Creek and Coal Creek sites ranked fair between 1998 and 2006, but scored lower in more recent years. All sites in Bellevue had B-IBI scores between 0 and 62.9 out of a highest possible score of 100 over all the years sampled (see Appendix B-7). Bellevue site ratings are consistent with other urban sites sampled in the Puget Sound lowlands. Regional sites meeting the higher ratings were found in more pristine streams in the foothills of the Cascades east of Bellevue. The range of B-IBI scores for Bellevue streams from 1998 to 2014 are shown in Figure 6-22. B-IBI scores for Bellevue streams are consistent with other urbanized sites around the Puget Sound basin (see Figure 6-23).

A more detailed look at components of the scores are used for diagnosing issues at each site. For example, Bellevue sites generally have low clinger richness and high numbers of tolerant invertebrate species. This generally indicates water quality issues such as elevated nutrient levels and possibly high concentrations of metals, erosion and deposition of fine sediments, or scouring flows at some sites. Streams requiring actions to improve biological communities can be identified by using B-IBI scores, along with other indicators of the stream's physical, biological, and water quality conditions.

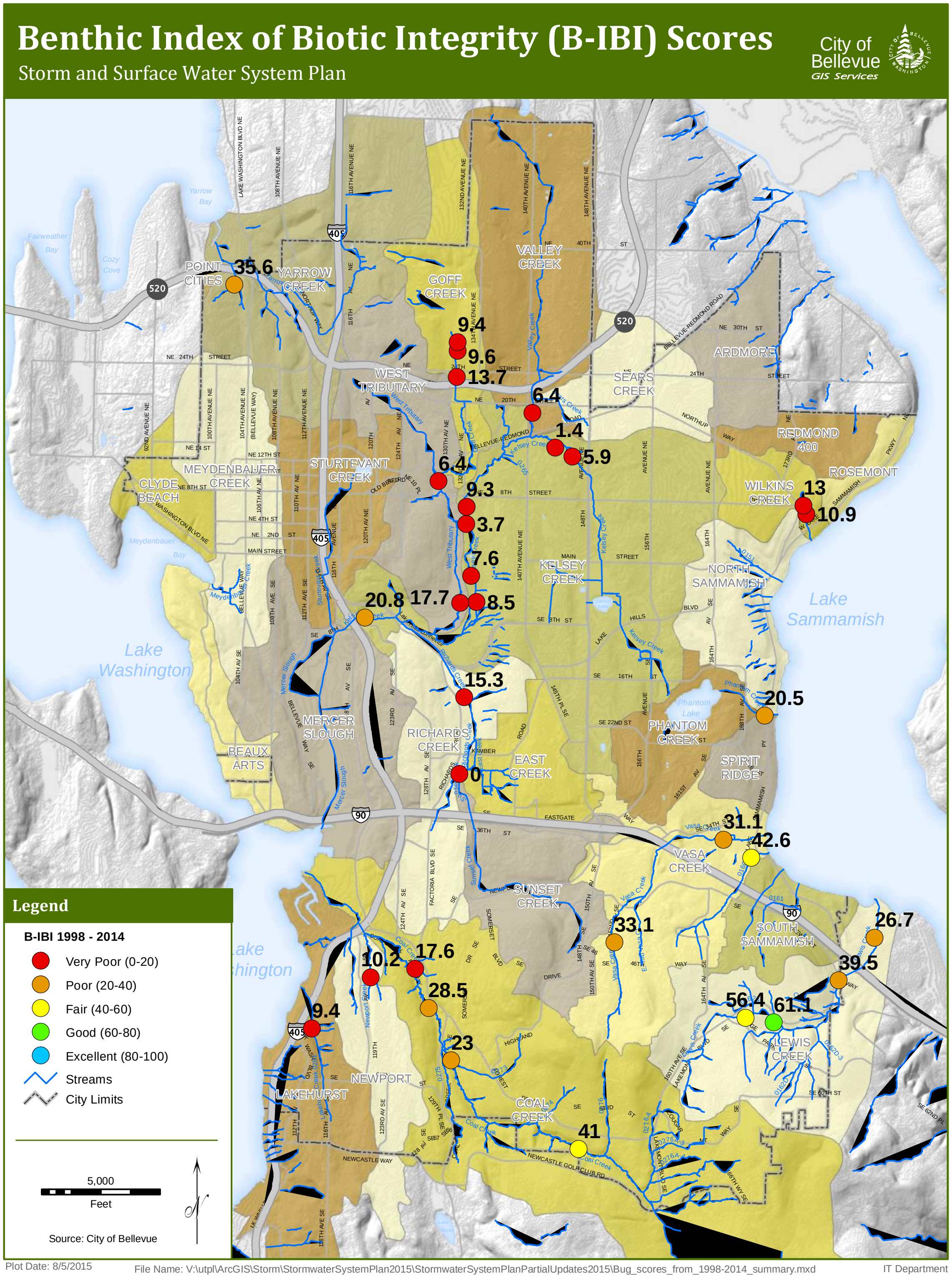


Figure 6-21. Benthic macroinvertebrate sites sampled in Bellevue between 1998 and 2014, and the most recent B-IBI site score and corresponding rating for each site.

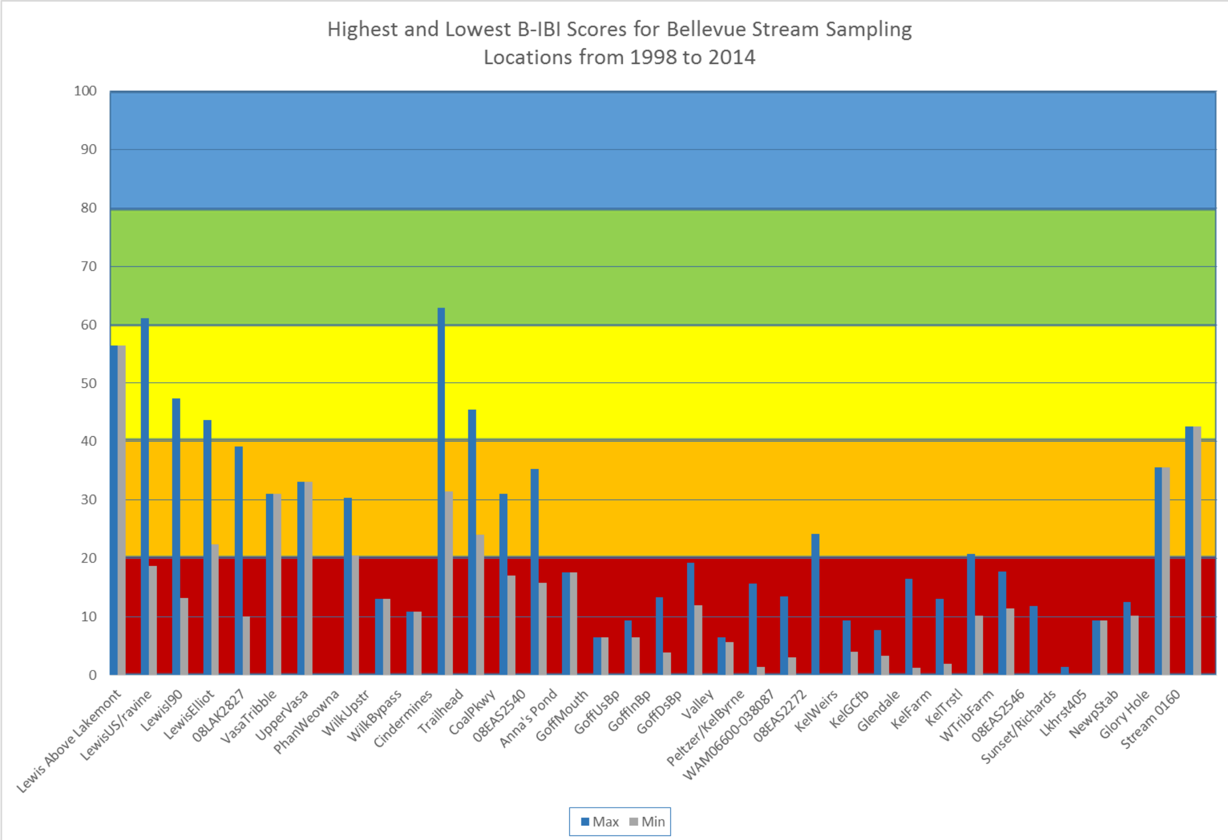


Figure 6-22. Highest and lowest B-IBI scores for all sites sampled in and near Bellevue from 1998 through 2014.

Note: The scores represent the variability within the sites, not trends over time. Sites with the same high and low score were only sampled once.

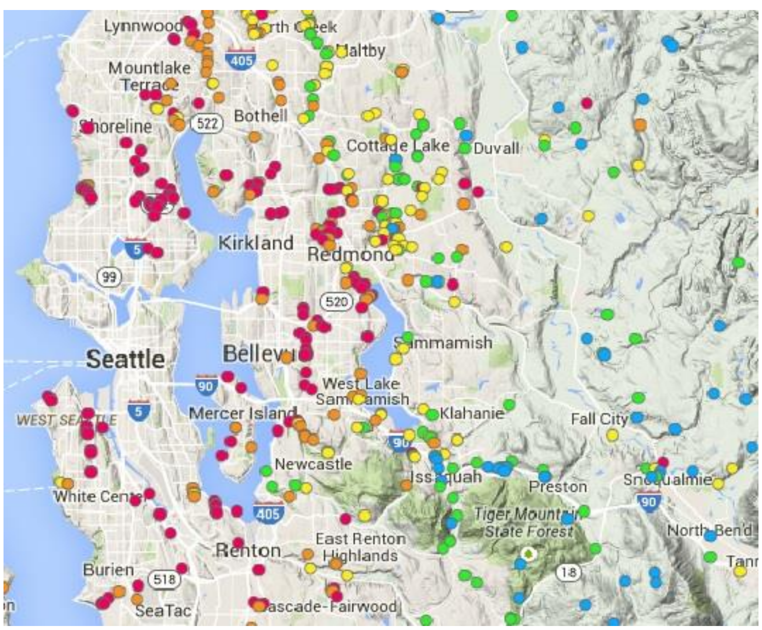


Figure 6-23. B-IBI scores for sites in Bellevue and the greater Puget Sound region, showing that Bellevue sites are consistent with sites in nearby urbanized areas.

Source: Puget Sound Stream Benthos website, accessed March 30, 2015.

Bank Hardening

Bank hardening is a term used to describe the condition of stream banks. NOAA Fisheries established standards for bank hardening as a measure of aquatic habitat condition. Lowland stream banks naturally consist of sandy or gravelly soils with thick native vegetation. Urbanization causes more runoff to streams, which can cause natural rates of bank erosion to increase dramatically in some places. When structures such as houses, roads, or businesses are built close to a stream, the banks are often hardened with large rocks or walls in order to prevent bank failure and protect infrastructure. This keeps streams from naturally moving and meandering back and forth within the floodplain, and can cause more erosion and flooding downstream. Bank hardening information is collected by walking the streams and measuring the extent of hardening materials present. To date, this information has not been collected in Bellevue; therefore, data are not available for this evaluation.

Supplemental Stream Condition Information

This section of the chapter contains supplemental information used to complement the evaluation data used to assess the condition of the storm and surface water system in Bellevue. The sections that follow refer to and describe numerous data resources that are relevant to the stormwater system in Bellevue. While the data may not have been used directly for the evaluation of the system, the data provide additional supporting documentation for other metrics used in the evaluation (for instance, stream flow that affects flooding and habitat quality). The following sections provide additional information about the system captured in numerous natural resource reports prepared by the Utilities Department.

Stream Flow

As established earlier, the amount of surface runoff that flows into streams, lakes, and wetlands increases significantly when areas are developed. Not only is the volume increased, but it reaches the stream much faster than in an undeveloped area, and then decreases to low levels more quickly after the storm has ended. This dramatic fluctuation is due largely to changes in the infiltration rates of the soil, which is paved, covered, and compacted so that water is less able to soak in and slowly seep towards the streams after each storm (Booth and Jackson 1997). Stormwater detention requirements mitigate the increased runoff from a developed site by storing the excess stormwater in ponds or vaults and then slowly releasing the stored water over a long period of time. The mitigated peak runoff rate mimics the natural peak flow, but because of the additional quantity of water in a developed basin, the peak extends for a much longer time period than in a forested basin (Figure 6-24). This general stream response to development and stormwater detention strategies is one reason there is strong interest in implementing LID techniques that allow water to soak into the ground, rather than run off. An example from Kelsey Creek is available in Figure 6-25.

Citizens often ask whether a large rain event was a “100-year storm” or complain that, “100-year storms seem to happen every year.” This type of terminology refers to the flow frequency, or the probability that a flow of a given magnitude (or larger) will occur in a given year. For example, the 2-year flow has a 1-in-2, or 50 percent chance of occurring during a year, whereas a larger, 100-year flow has only a 1-in-100, or 1 percent chance of occurring during any particular year. Urbanization has increased flow volumes and peak flows in stream corridors that were shaped by a forested landscape; as a result, both the 2-year and 100-year flow frequencies in Bellevue have increased over time. This increase in flow frequencies directly affects the stability of stream channels, level of erosion and sedimentation, and ultimately aquatic life.

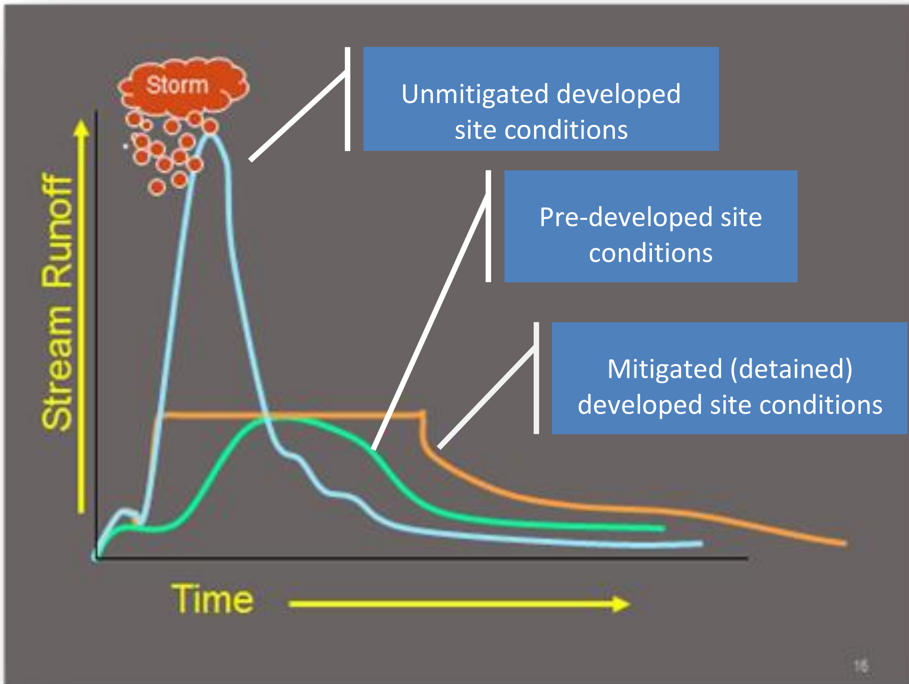


Figure 6-24. Hypothetical runoff hydrographs illustrating effect of land use.

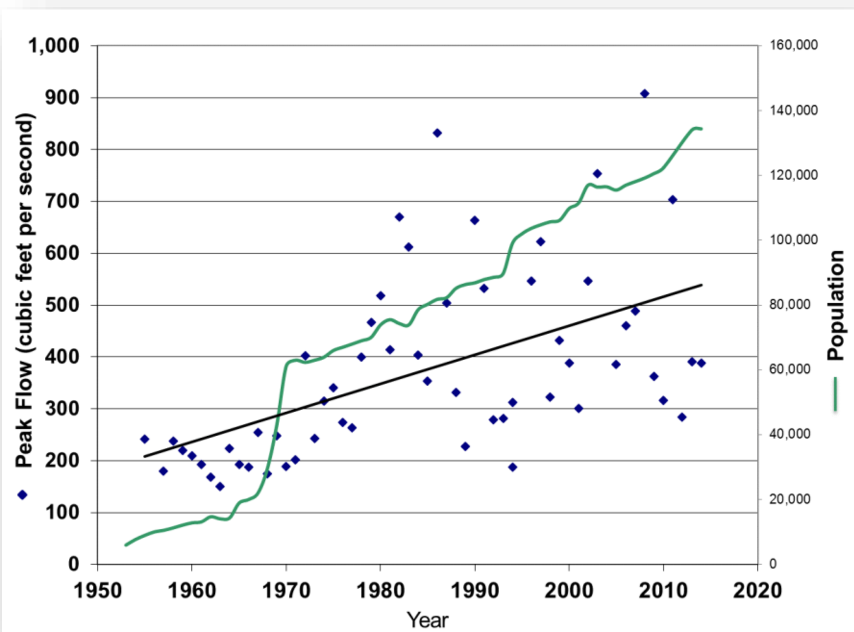


Figure 6-25. Peak annual flow at the Mercer Gauge on Kelsey Creek compared to human population in Bellevue each year from 1953 through 2014.

Note: The straight black line shows the peak annual flow has an upward linear trend over time.

Higher and more frequent peak flows in Bellevue’s streams due to urbanization are evident when comparing trends in annual peak flows in Kelsey Creek between 1953 and 2014 (U.S. Geological Survey 2015) to Bellevue’s human population (City of Bellevue 2015; US Census Bureau 2015). The human population increased 35 times between 1953 (when Bellevue incorporated) and 2014 (Figure 6-25). During the same period, the highest flow over the course of a year in Kelsey Creek became more erratic and trended higher. Between the 1950s and the early 1970s, the highest flow recorded was under 300 cfs. Between 1970 and 2014, the peak annual flow has been over 600 cfs (double the highest flow before the early 1970s) seven times.

According to an analysis of water quantity trends for King County completed in 2001, the peak daily flow in Kelsey Creek (measured at the USGS gauge at Mercer Slough) was increasing, and the average 7-day low flow volume was also increasing for the period between 1956 and 1996 (Wetherbee and Houck undated). In the Kelsey Creek basin, low flow volume has increased, which is unusual for urban areas, where low or base flows typically decrease because impervious land surfaces usually have a negative impact on static groundwater levels. A declining groundwater supply to streams typically results in lower base flows, but in the Kelsey Creek basin it is theorized that potable water being added to the surface water system from irrigation practices has buttressed summer stream flows in this basin. Larsen Lake at the headwaters and large wetlands along Kelsey Creek could also factor in stable low flow volumes (David Hartley, Northwest Hydraulic Consultants, pers. comm.). Maintaining natural low flow conditions is critical for sustaining aquatic life, as it maintains cooler water and a larger physical space within the wetted channel for organisms.

In a study conducted by King County in 2009, stream flow rates were found to be changing significantly over time in Kelsey Creek, in ways that are expected with increased impervious area (DeGasperi et al. 2009). This study found that eight different measures of stream flow “flashiness” are highly correlated with the quality of the aquatic macroinvertebrate community (e.g., mayflies and snails) living in the stream. Stream flow “flashiness” refers to the rate stream flows rise and fall in response to a rain event. A “flashy” stream rises quickly once rain starts and falls just as quickly once the rain stops. Flashy flows adversely affect salmon productivity because the rapid decline of stream flows can leave salmon stranded on top of beaver dams or in the floodplains next to streams.

A measure of stream flashiness, TQ mean, is the proportion (or relative amount) of time that measured flows in a given water year are above the average flow for that year. A declining TQ mean indicates a stream that is becoming increasingly flashy. The TQ mean for Kelsey Creek has been in decline since 1956; however, it appears to be leveling off (Figure 6-26). The decline in TQ mean indicates that storm flows in Kelsey Creek are typical of urban streams, more quickly rising above and falling below the mean annual flow.

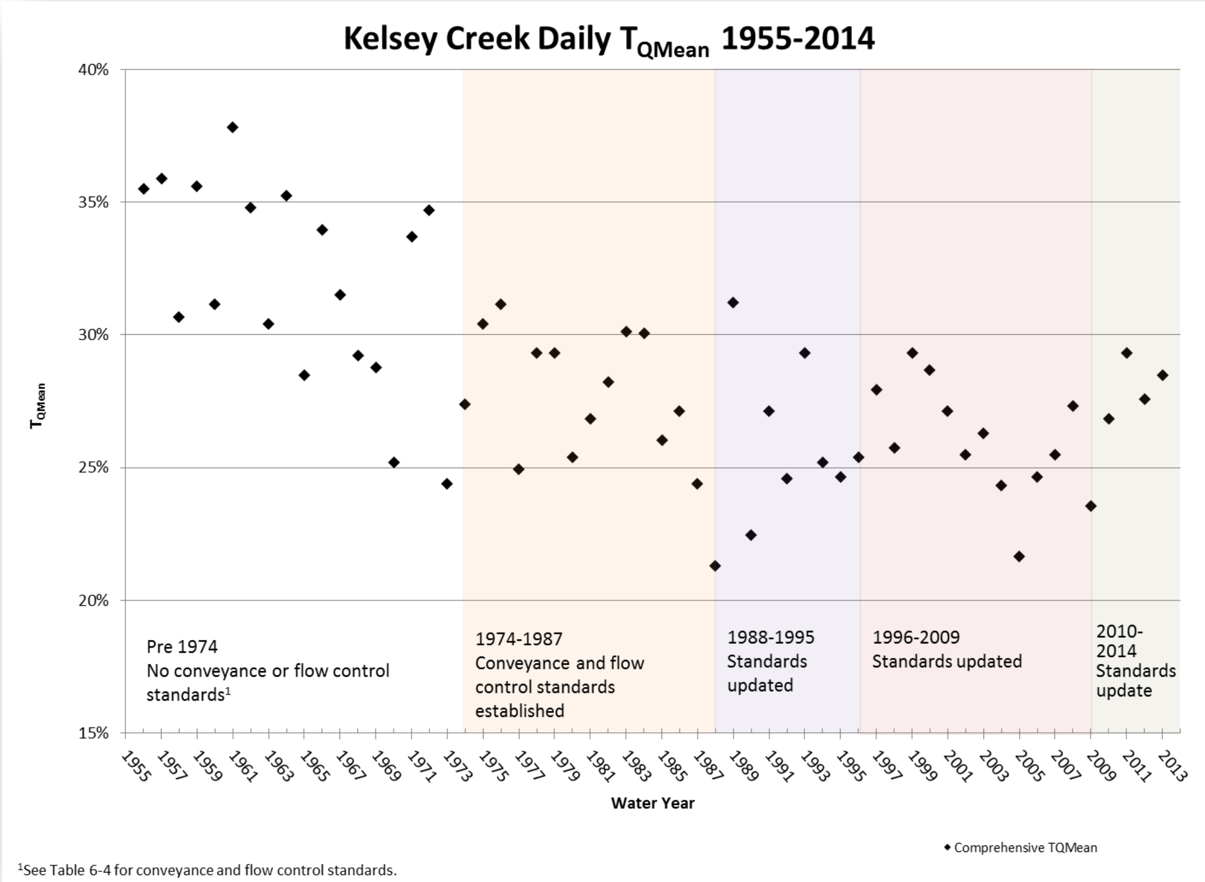


Figure 6-26. TQ mean (proportion of time stream flow was above the mean daily flow during the water year) for Kelsey Creek from 1956 to 2014.

Note: The decline indicates an increase in flashy stream flows, which harms aquatic habitat and is typical of a highly impervious basin.

Stream Channel Condition

Maintaining stable stream conditions in Bellevue is important to minimize streambank erosion, delta formation, flooding, and property damage as well as maintaining aquatic life in streams and lakes, including salmon listed under the ESA. There are two primary sources for current stream habitat (channel condition) information in Bellevue: 1) the Habitat Limiting Factors Report, and 2) the Citywide Streams Assessment. The descriptions of the stream channel conditions in Bellevue summarized in the sections below are from the following reports:

- The Salmon and Steelhead Habitat Limiting Factors Report (Kerwin 2001) summarized the best available science and habitat data collected in 1996 and 1997 on Kelsey Creek and its tributaries (including Richards, Valley, Sunset, and others), and in 1998 on Coal Creek. It rated the habitat condition of these basins from the perspective of salmon habitat, which can also be used as an indicator of ecological health. The Habitat Limiting Factors Report rated streams using categories of good, fair, and poor. For additional details on the basis of the ratings, see the report (Kerwin 2001).

- The City conducted a Citywide Assessment of stream channel conditions from 1998 to 2002 (City of Bellevue Utilities Department 2003). The Citywide Assessment consisted of a review of stream channel work orders and problems, a citizen survey, and visual surveys of every stream in Bellevue. Streams were mapped using Global Positioning System units, and problems that could be addressed through the Capital Investment Program were described, photographed, and ranked by severity. Land cover analyses were updated based on information collected in 2007 (Sanborn Map Company 2007).

Riparian Condition

The most effective, least expensive way to maintain stable stream conditions and protect habitat for aquatic life is to maintain natural riparian zones around streams that are wider than 30 meters, continuous, and composed of wetland or mature mixed deciduous and coniferous forest canopy (May and Horner 2000). The riparian zone impervious area ranged from 6 to 62 percent along the city's streams (see black bar graph in Figure 6-7); forest canopy along streams ranged from 23 to 91 percent (see green bar graph in Figure 6-7), as described above.

Riparian condition was rated poor for all Bellevue streams in the Habitat Limiting Factors Report (Kerwin 2001) based on narrow forested buffer width and less than 30 percent cover by coniferous (evergreen) trees (Table 6-6). Restrictions on development in stream and wetland buffers and City efforts to purchase lands with important surface water functions have protected riparian zones in some basins. However, the forest canopy does not contain a high percentage of mature evergreen trees.

Table 6-6. Stream habitat quality ratings based on habitat suitability for salmon from the Salmon and Steelhead Habitat Limiting Factors Report (Kerwin 2001)

Stream*	Riparian Condition	Floodplain Connectivity	LWD	Pools	Side Channel Habitat	Substrate Fines
Kelsey	Poor	Poor	Poor	Poor	ND	Poor
Mercer Slough	Poor	Poor	ND	ND	ND	ND
Sturtevant	Poor	ND	ND	ND	ND	ND
Valley	Poor	ND	Poor	Poor	ND	ND
West Tributary	Poor	ND	ND	ND	ND	ND
Goff	Poor	ND	ND	ND	ND	ND
Richards	Poor	ND	Poor	Poor	ND	ND
East	Poor	ND	Poor	Poor	ND	ND
Sunset	Poor	ND	Poor	Poor	ND	ND
Coal	Poor	Poor	Fair**	ND	Poor	ND
Meydenbauer	Poor	ND	ND	ND	ND	ND
Yarrow	Poor	ND	ND	ND	ND	ND
Lewis	Poor	Poor	ND	ND	ND	ND

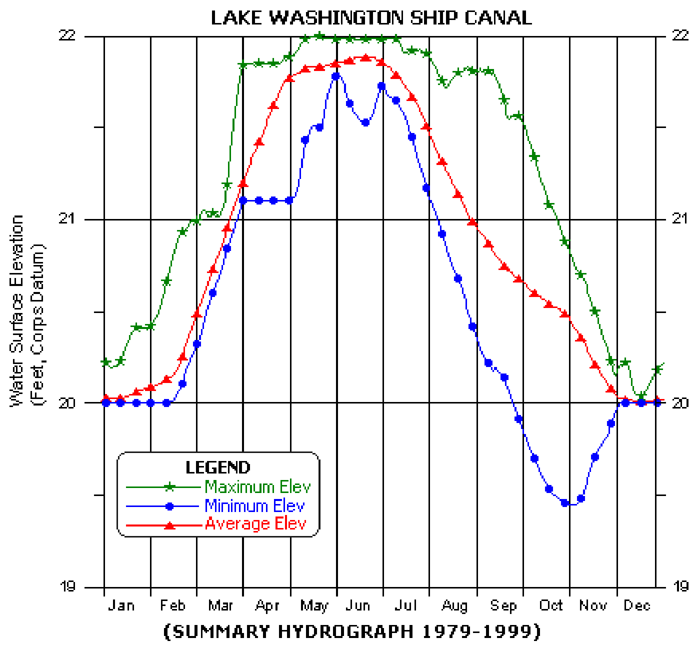
***Ratings were not available for Ardmore, Wilkins, Vasa, or Phantom Creeks**
****Rating based on data not included in Habitat Limiting Factors Report.**
ND = No data available.

Lake Physical Characteristics

There are two large lakes that border Bellevue: Lake Washington to the west and Lake Sammamish to the east. In addition, Bellevue has three small lakes: Lake Bellevue, Larsen Lake, and Phantom Lake.

Lake water surface elevations affect shoreline properties. They rise and fall in response to precipitation and the hydrologic control (e.g., culvert or weir) at the outlet. Lake Washington, for example, was lowered 8 feet when the Ship Canal was completed in 1934 to allow ships access to Lake Union. The level of Lake Washington is now closely managed by the U.S. Army Corps of Engineers to stay within a

2-foot height range (U.S. Army Corps of Engineers 2004), primarily to protect floating bridges and sewer connections. Average, minimum, and maximum Lake Washington water surface elevations, averaged over 20 years, are shown in Figure 6-27.



Notes:

1. The Lake Washington Ship Canal is operated primarily as a navigation facility connecting Puget Sound and Lakes Union and Washington. Project authorization documents state that under normal operation the Lake Washington Ship Canal should be maintained within a 2-foot range between 20.0 feet and 22.0 feet (U.S. Army Corps of Engineers Datum), respectively. The minimum elevation is maintained during the winter months to allow for annual maintenance on docks, walls, etc., by businesses and lakeside residents, minimize wave and erosion damage during winter storms, and provide storage space for high inflow. The storage between 20 and 22 feet is used to augment Lake Washington Ship Canal inflows for use in operating the locks, the saltwater return system, the smolt passage flume, and the fish ladder facility.
2. The locks and spillway dam regulate the elevation of Salmon Bay, Lake Union, Lake Washington, and the Lake Washington Ship Canal. The level of Lake Washington was lowered about 8 feet by the construction of the Lake Washington Ship Canal, but it is still the second largest natural lake in the state, with a surface area of 22,138 acres and shoreline of about 91 miles at elevation 22 feet.

Source: U.S. Army Corps of Engineers (2004)

Figure 6-27. Lake Washington average water levels over a year based on daily measurements (collected at 8:00 am) at the Ship Canal, measured between 1979 and 1999.

Lake Sammamish water levels respond to precipitation amounts and inflow from many tributary streams, especially Issaquah Creek. It flows out the Sammamish River and through Lake Washington, and eventually exits to Puget Sound via the Ship Canal. In 1964, the Sammamish River was dredged and straightened by King County and the U.S. Army Corps of Engineers, and a weir was installed at the lake outlet (The Watershed Company 2004). The average daily water level on the southwest side of the lake shows fluctuations of approximately 3 to 4 feet every year, with peaks during the winter and spring, and lows in the summer and early fall (see Figure 6-29). The peak elevation observed since the gauge was installed in 1939 was 37.02 feet (NAVD88) on February 12, 1951; the lowest lake level observed was 28.71 feet (NAVD88) during August 25-27, 1951 (U.S. Geological Survey, 2015).

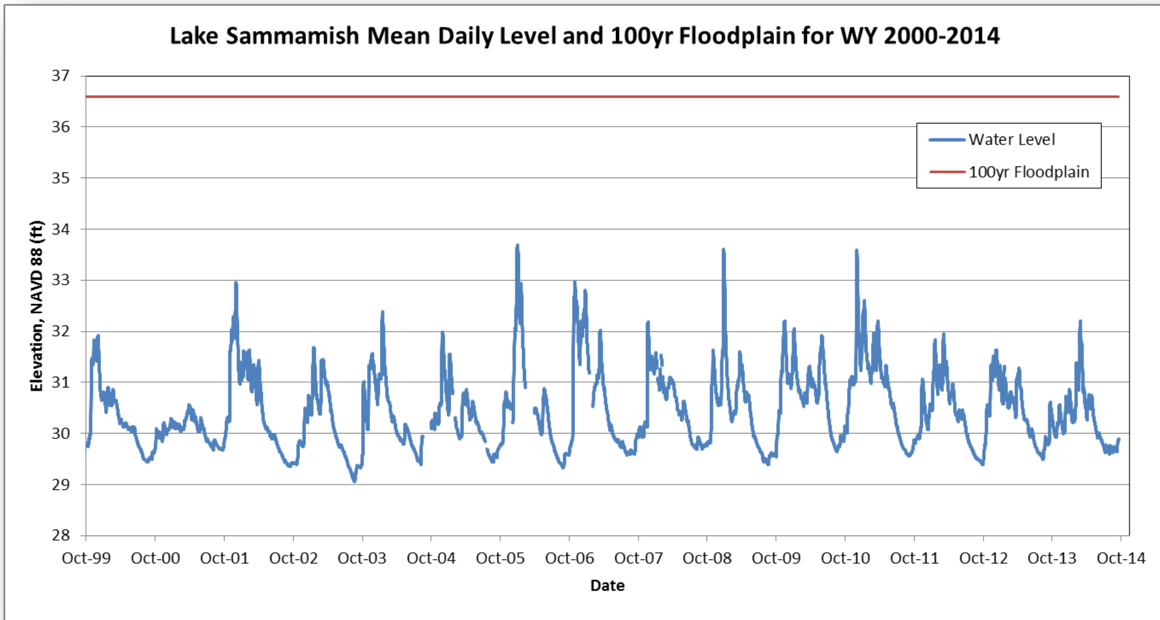


Figure 6-29. Water level elevation of Lake Sammamish, as measured from USGS gauge 12122000, for water years 2000 through 2014.

Larsen Lake, in the headwaters of Kelsey Creek, is part of a regional detention facility. An adjustable gate controls the outlet and helps mitigate flooding for small storm events. However, due to the flat topography in the area, heavy precipitation still results in occasional flooding of 148th Avenue NE near the lake.

Phantom Lake was historically the headwaters of Kelsey Creek, but was diverted into Lake Sammamish in the 1880s or 1890s (McDonald 1984). The lake has a weir at the outlet that can be raised or lowered to help maintain summer water levels. This was done to reduce phosphorus-laden groundwater interflow into Phantom Lake during summer months to improve water quality. The outlet control is not operated to control flooding. Phantom Lake water level generally fluctuates between 260 and 262 feet (NAVD88 datum) over the course of a year (see Figure 6-29), which is well below the 100-year floodplain elevation as shown the Flood Insurance Rate Map (Federal Emergency Management Agency 2007). Mean annual water elevation has also fluctuated by approximately 2 feet, according to the data, although the elevation gauge was not calibrated until 2007, so prior data are not reliable. These apparent fluctuations could be due to precipitation patterns, soil conditions, natural lake processes such as sediment building up in the lake bed and sediment and vegetation constricting the outlet channel, beaver activity, and/or lake outlet management activities. Bellevue Utilities has been working with property owners around the lake. It was agreed in 2012 that the weirs would not be installed and to monitor the lake for three years to see if there was a decline in water clarity.

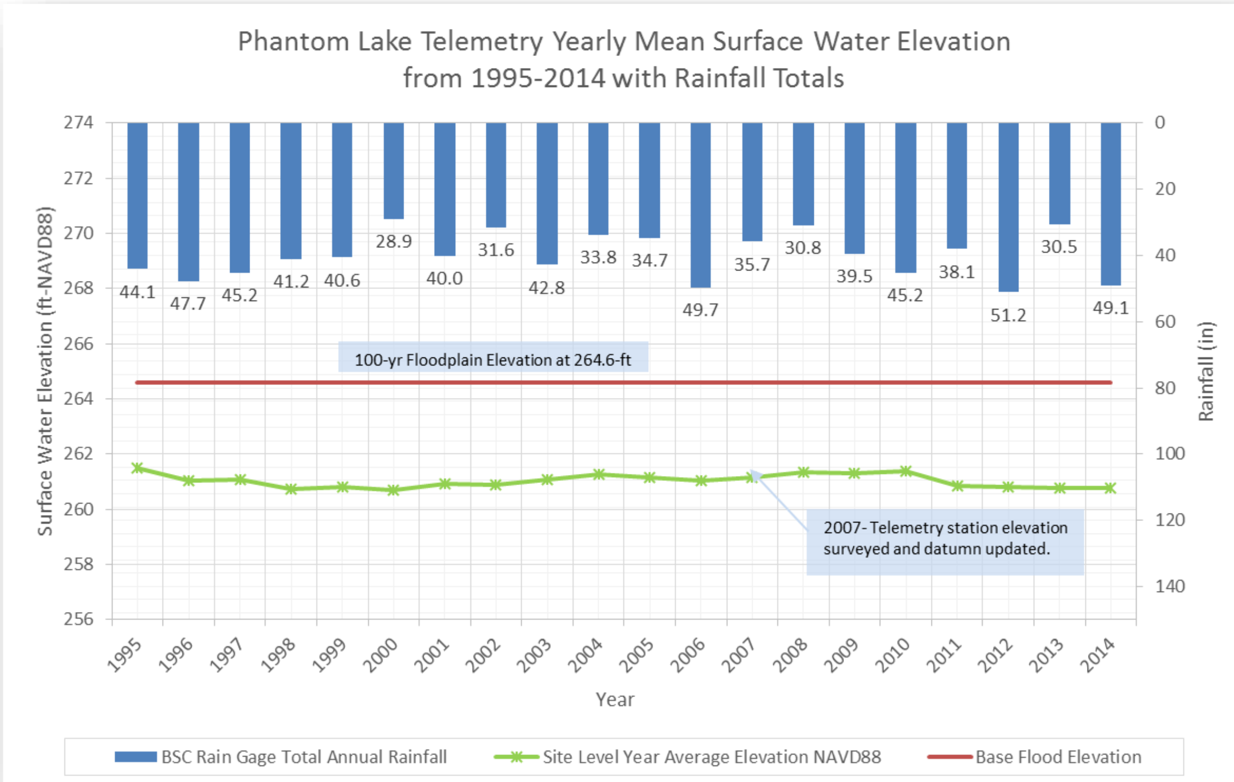


Figure 6-29. Mean annual Phantom Lake water level elevations as measured by City of Bellevue, from 1995 through 2014, and total annual rainfall in north Bellevue.
(100-year floodplain Base Flood Elevation as established by FEMA in 1978, from Federal Emergency Management Agency 2007)

Lake Bellevue does not have a continuously recording water level gauge. Vegetation removal work on the outlet channel in 2010 resulted in the water level of the lake dropping about half a foot, as recorded at a temporary staff gauge. The water level change indicates that the outlet channel is the hydraulic control for Lake Bellevue.

Sedimentation

Stream erosion is a natural process. The degree to which streams naturally erode depends on a number of factors such as geologic setting, stream bed material, and natural flow regime. It is well documented that with increased flows following urbanization, stream erosion increases (Hammer 1972; Leopold 1973; Booth 1990). Excessive erosion caused by urban stream flow results in fine sediments depositing in stream gravels and is known as sedimentation. Sedimentation degrades aquatic habitat by filling the void spaces in stream gravels where macroinvertebrates live, eliminating pools that provide resting areas for fish, and smothering salmon eggs after they are buried in the stream gravels to incubate.

Figure 6-30 shows fine sediment data points from Coal Creek and Kelsey Creek (Kerwin 2001) and from recent sediment monitoring for a capital project on Sunset Creek. For more information about the Sunset Creek study and the effectiveness of a capital project to reduce sediment impacts, see Appendix B-8. Fine sediments were found to be above the thresholds that impair salmon egg survival (9 percent) at all sites and above thresholds that kill salmon eggs (20 percent) in some samples. Fine sediments were also substantially above salmon thresholds in Coal Creek below I-405, but it is not clear whether the fine sediments would naturally be high in this delta depositional area.

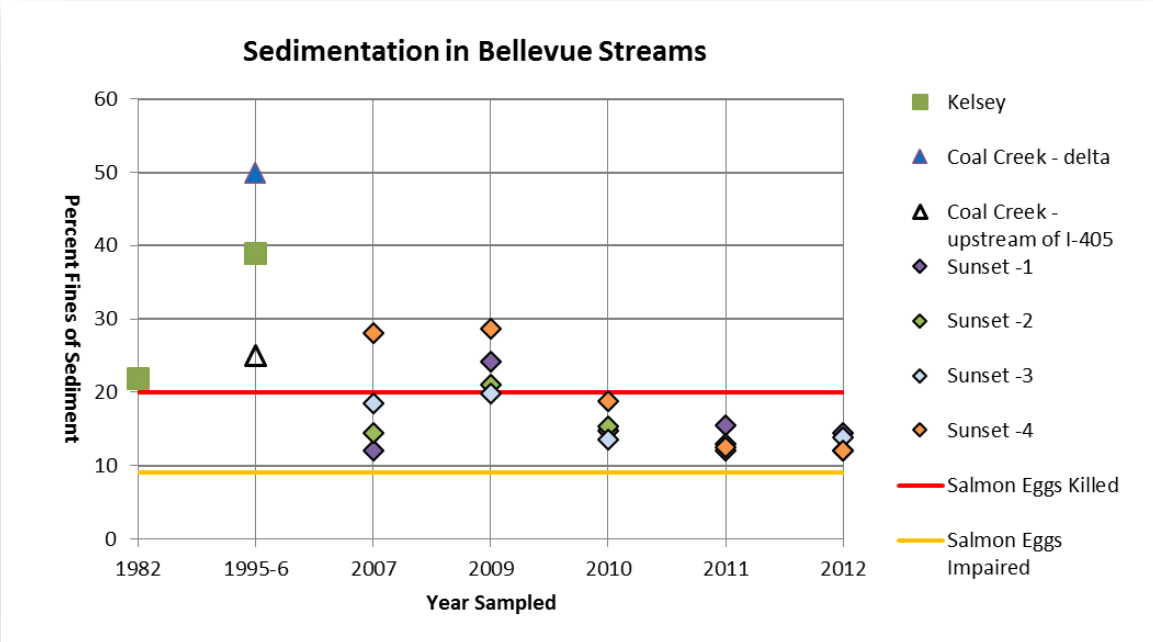


Figure 6-30. Percent fine sediments (<0.85 mm) in stream gravels at three sites were higher than recommended for salmon habitat.
Note: Fine sediment levels that impair (orange line) or kill (red line) salmon eggs incubating in stream gravels are shown for comparison.

In addition to affecting salmon egg incubation and other aquatic life, management and removal of sediment is a significant capital project and operational effort. In 2011, maintenance crews removed 5,176 cubic yards of sediment from facilities built to manage sediment loads in streams. In 2010, 990 cubic yards were removed, illustrating the variability in sediment deposition in streams and facilities maintenance needs.

This photo shows the Coal Creek off-channel sediment pond, ready for sediment removal.

Observed Stream Issues

During field surveys conducted from 1998 to 2001 of all Bellevue streams, City staff described and photographed 245 stream issues, categorized in Figure 6-31 (City of Bellevue Utilities Department 2003). Only 2 percent of these issues were ranked as severe, meaning there was a threat to life or health; 30 percent were ranked as a threat to a structure, and 68 percent were considered a threat to property or cause of minor damage. A review of 3,425 City records showed the majority of stream-related work requests from staff and residents between 1989 and 1999 primarily addressed issues with flooding (Figure 6-32).

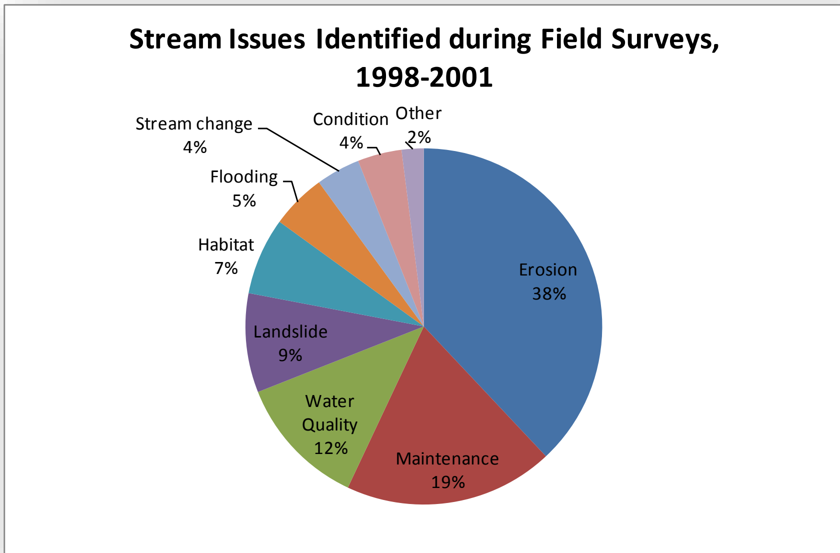


Figure 6-31. Stream issues identified by field crews during Citywide Stream Assessment surveys between 1998 and 2001.

Note: Issue category terms are defined in Table 6-7.

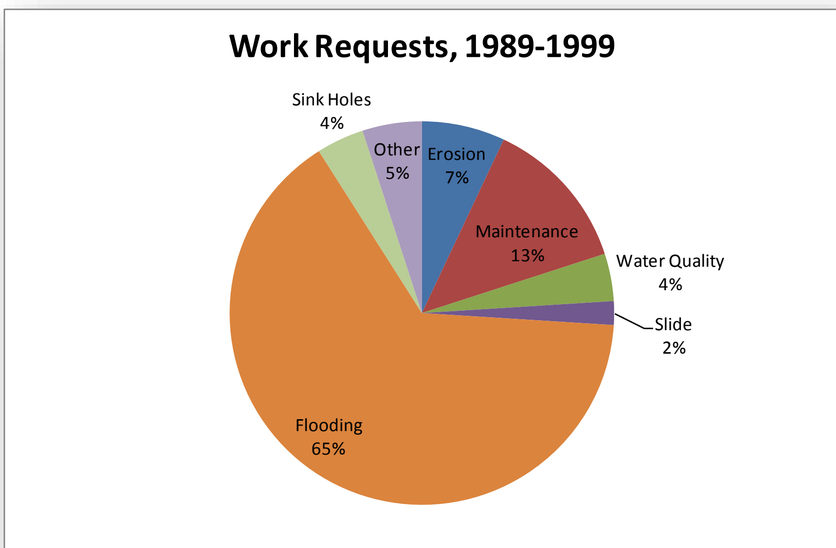


Figure 6-32. Drainage-related issues from surface water work requests between 1989 and 1999 during a Citywide Stream Assessment.

Table 6-7. Definitions of stream issues identified during the 1998 to 2001 Citywide Stream Assessment

Category	Field Observations
Condition	Crushed culvert, abandoned pipe, collapsed structure
Erosion	Stream incision, deposition, stream bed or bank erosion, outfall erosion
Flooding	Undersized culvert, overbank flow evidence, flooded street or yard
Habitat	Fish migration barrier, shallow water, riparian zone lacking
Maintenance	Debris in channel or pipe, infrastructure failure
Other	Large-scale infrastructure failure, such as exposed utility pipe
Stream change	Avulsion, abandoned floodplain channel
Landslide	Large-scale bank erosion, upper slope failure
Water Quality	Excessive nutrients (algae growth), odor, iron bacteria, septic systems

The 1989 to 2001 records of stream issues are based on outreach survey mailings to all Utilities Department customers, work requests, and field surveys. Most observed problems were related to stream erosion and flooding. Reported problems were most prevalent in the larger drainage basins (Kelsey Creek, Coal Creek, West Tributary, Vasa Creek, and North Sammamish), probably because of the larger area and numbers of residents (City of Bellevue Utilities Department 2003). When the numbers are adjusted for basin size, the basins with the most problems were markedly different. Clyde Beach, Meydenbauer, Rosemont, Ardmore, and Wilkins had the most drainage problems per basin area. The basins with the most stream issues per 1,000 feet of stream were Meydenbauer (3.5), Sears (3.1), Lakehurst (1.6), and North Sammamish, Sturtevant, and Vasa (each had 1.5). These streams have not been re-evaluated to see if capital projects have addressed the problems. For example, projects on Ardmore Creek and Wilkins Creek have been implemented to address erosion and bank stability issues.

Fish Access, Passage Barriers, and Spawning Habitat

Salmon and other fish migrate up and down streams to access food, cover, and breeding sites. Of the 79 miles of stream in the city limits, approximately 31 percent are used by salmon, and 49 percent have non-migratory fish. Fish can jump some barriers, but others are considered either partial or complete blockages to fish passage. Some fish are better at passing through barriers than others; for example, peamouth were not able to spawn in great numbers above the Mercer Slough fish ladder until it was rebuilt with smaller jumps in 2003; coho salmon are able to reach higher places than other species in some watersheds because they are well adapted to passing around or jumping over beaver dams and other barriers. Culverts often act as barriers to fish passage due to their length, slope, and resulting water velocity, and/or the vertical distance from the culvert's downstream end to the stream below.

Fish passage was initially determined during a comprehensive city-wide survey in 1998 (Menconi and Johnson 1998) and a follow-up survey in 2001. Since those surveys, however, additional fish passage barriers and culverts have been identified throughout the City. Culverts may be added to the inventory list as new information is identified or culvert conditions change. Primary salmon barrier will be fixed with Utilities CIP program, other barriers will be replaced with road improvements. All known fish passage barriers and culverts in Bellevue streams, last updated in 2015, are shown in Figure 6-33. Partial barriers are not identified in the figure.

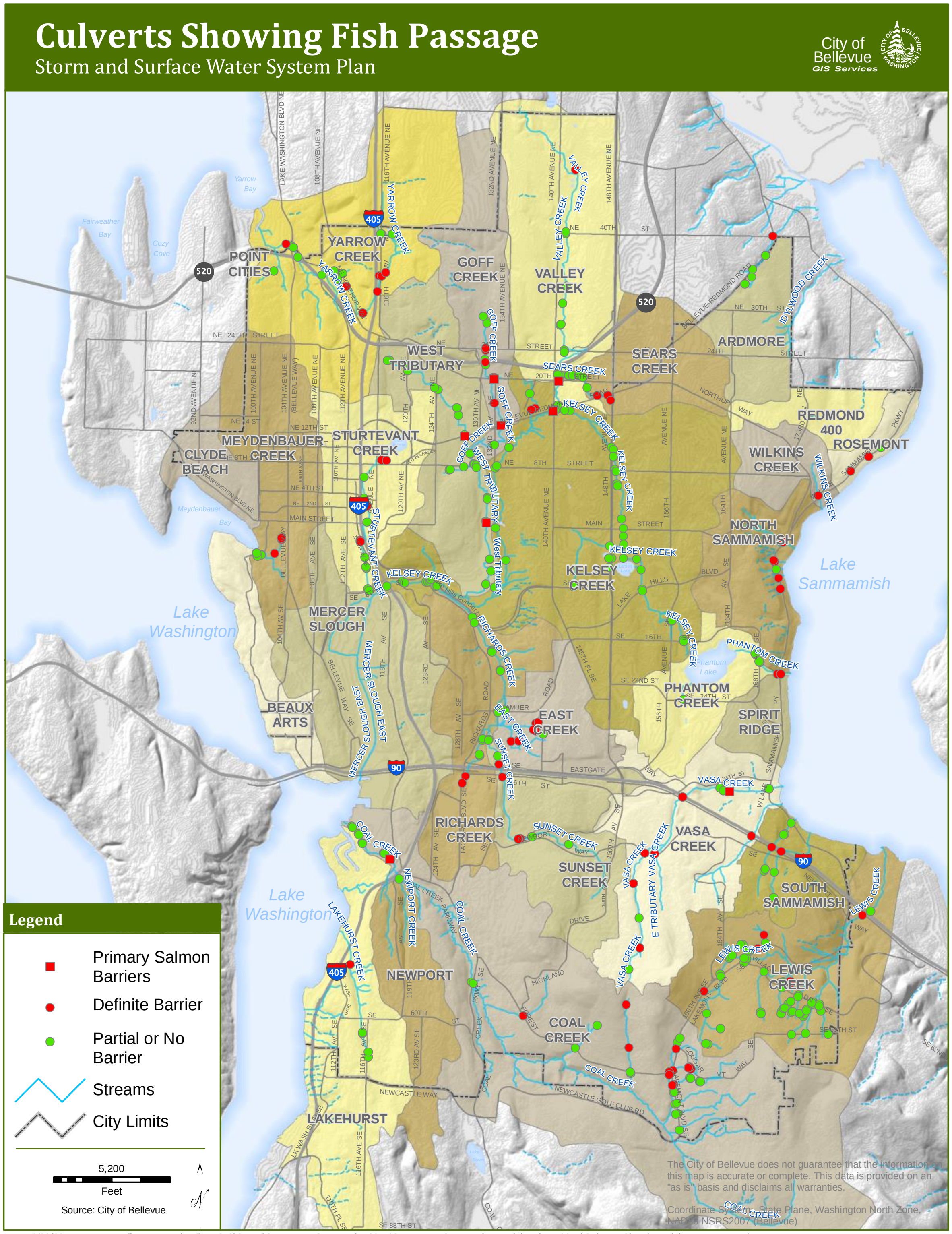


Figure 6-33 Fish Passage barriers in Bellevue streams.

Note: Partial barriers may be passable by some fish during low or high flows. Culverts are owned by Bellevue Utilities Department and others.

Available Salmon Spawning Habitat

The availability of salmon spawning habitat is primarily determined by topography because moderate gradients are usually the location for appropriate stream velocity and gravel size to support egg incubation. Given that all basins have unique characteristics of size and gradient, there are no standards for the amount of spawning habitat that should be present in a basin. The amount of spawning habitat, though, is a primary habitat factor for maintaining salmon populations and lack of clean, stable gravel is often a limiting factor for salmon survival. City-wide, 19 percent of all the open streams have suitable spawning habitat, and 8 percent (5.7 miles) is on City-owned land, including parks and land owned by the Utilities Department (Figure 6-34). The remainder is private property. Basins with the most spawning habitat are Coal, Kelsey, Valley, and the West Tributary (see Figures 6-34 and 6-35). Coal Creek has 56 percent of the total City-owned potential spawning habitat. Unfortunately, historical land-use practices in the basin have increased the sediment transport rates and instability of the system, substantially reducing salmon spawning success. Kelsey Creek, West Tributary, and Valley Creek have the majority of successful salmon spawning reaches in the city. The small proportion of suitable habitat on City-owned property limits the City's ability to improve spawning habitat due to the limitations of working on private properties.

The amount of spawning habitat suitable for Chinook, coho, and sockeye salmon in Bellevue's streams was calculated using geographic information system (GIS) analysis (see Table 6-8). Suitable spawning habitat was defined as stream segments known to have fish, downstream of known fish barriers, without adjacent wetlands, and with gradients between 0.1 and 3 percent (Montgomery et al. 1999). Streams with adjacent wetlands are generally very low gradient, and were excluded because they generally do not have suitable spawning gravels. The resulting areas classified as suitable spawning habitat likely exclude some small areas with suitable spawning habitat, and do not include reaches that these species must pass through to reach suitable spawning habitat. Cutthroat and rainbow trout are likely to spawn in additional areas with steeper gradients.

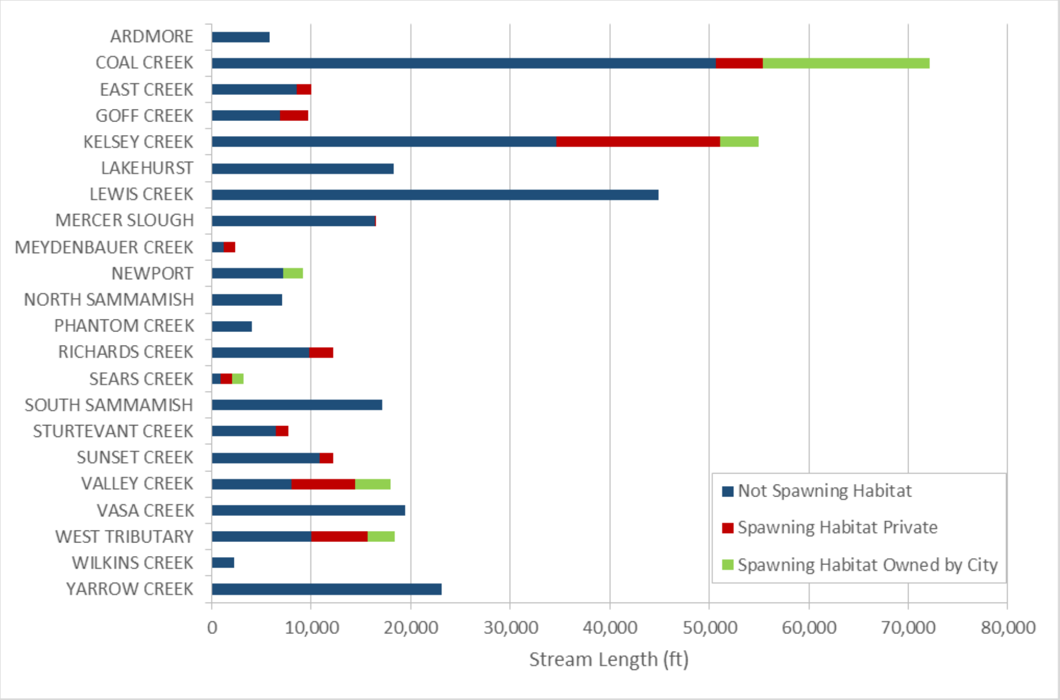


Figure 6-34. Length of stream in each basin, with the amount suitable for salmon spawning on City-owned property and private property.

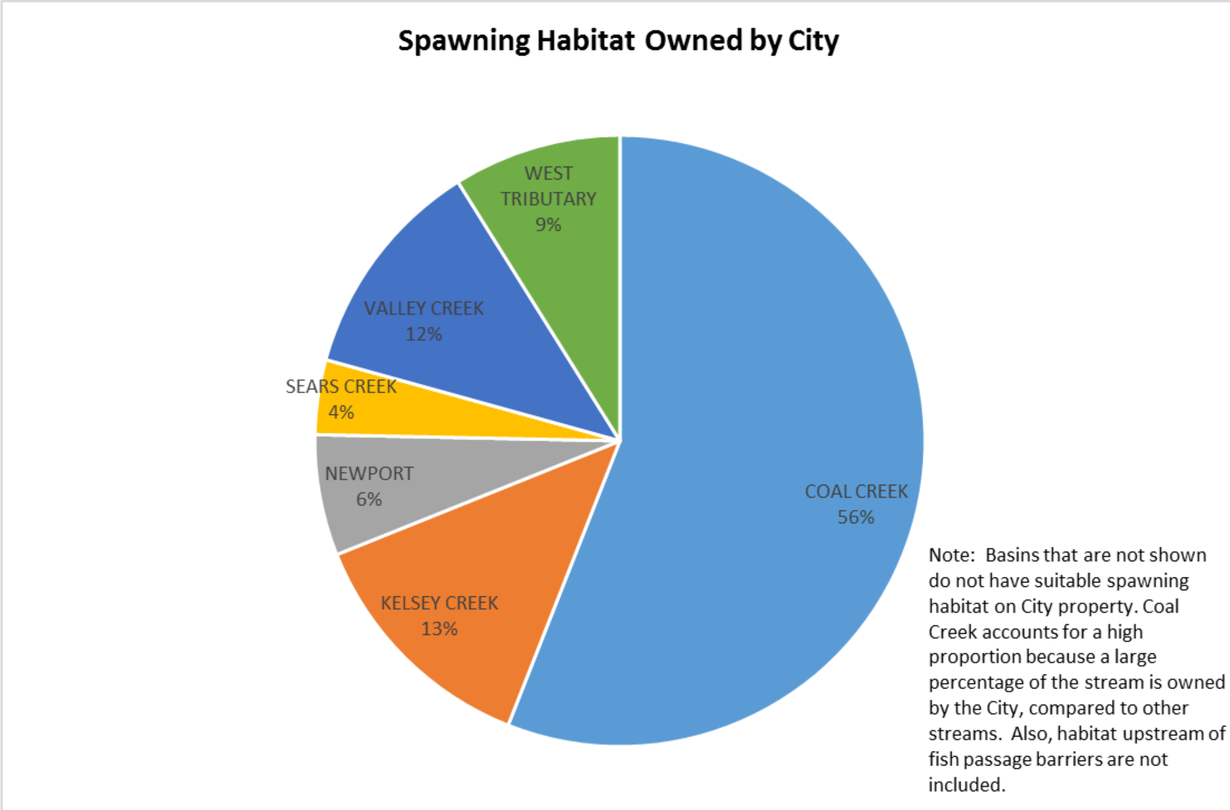


Figure 6-35. Proportion of the 5.7 miles of City-owned suitable spawning habitat in Bellevue's drainage basins.

Table 6-8. Suitable stream spawning habitat for Chinook, coho, and sockeye salmon in each drainage basin, based on a GIS analysis

Drainage Basin	Total Stream Length (miles)	Total Suitable Spawning Habitat (miles)	Percent Suitable Spawning Habitat
Ardmore	1.1	-	0%
Coal Creek	13.7	4.1	30%
East Creek	1.9	0.3	15%
Goff Creek	2.4	0.5	22%
Kelsey Creek	10.8	3.9	36%
Lakehurst	3.5	-	0%
Lewis Creek	8.5	-	0%
Mercer Slough	3.1	0.0	0%
Meydenbauer Creek	0.7	0.2	31%
Newport	1.7	0.4	21%
N. Sammamish	1.3	-	0%
Phantom Creek	0.8	-	0%
Richards Creek	2.3	0.5	20%
Rosemont	0.3	-	0%

Table 6-8. Suitable stream spawning habitat for Chinook, coho, and sockeye salmon in each drainage basin, based on a GIS analysis

Drainage Basin	Total Stream Length (miles)	Total Suitable Spawning Habitat (miles)	Percent Suitable Spawning Habitat
S. Sammamish	0.6	0.4	72%
Sears Creek	3.2	-	0%
Sturtevant Creek	1.5	0.2	17%
Sunset Creek	2.3	0.3	11%
Valley Creek	3.4	1.9	55%
Vasa Creek	3.7	0.0	0%
West Tributary	3.7	1.6	43%
Wilkins Creek	0.4	-	0%
Yarrow Creek	4.4	-	0%
Total City-wide	75.4	14.2	19%

Note: Included are stream segments with fish use, gradients >0.1- 3%, and location downstream of known fish passage barriers. Stream reaches with adjacent wetlands (per Sensitive Areas Notebook [1987]) are not included.

Presence of Aquatic Species

The living creatures that make up the biological component of the surface water system are an indicator of the quality of the aquatic habitat. They respond directly to both the physical and chemical environment, and those that are predators are also affected by the abundance and quality of the animals they rely upon as food. The presence and abundance of spawning and resident salmon in streams where they were historically present is a general indicator of stream health, but many salmonids also live part of their lives in lakes and the ocean.

As discussed earlier, aquatic macroinvertebrates living in the substrate of the streams are a strong indicator of the habitat's health. The B-IBI (discussed earlier) has been created to quantify the relative health of the habitat based on these animals.

Fish

Fish known to live or spawn in Bellevue's streams include salmonids, peamouth, three-spined stickleback, long-nosed dace, large-scale suckers, lamprey, and sculpin. Non-native fish adapted to lakes have been found in the streams as well, including sunfish and bluegill.

Salmon Spawning

In the Lake Washington/Cedar/Sammamish Chinook Salmon Recovery Plan, Kelsey Creek was identified as the only urban stream to have consistent annual salmon spawning populations. Salmonids in Bellevue include Chinook, coho, and sockeye salmon, cutthroat and rainbow trout, steelhead (last seen in 1996), and kokanee; their distribution is shown in Figure 6-36. The number of adults returning to spawn varied substantially between 2000 and 2014, and is dependent on previous adult spawning returns and productivity; habitat and food availability in streams, lakes and oceans; water quality; fishery harvest; and many other factors. Estimates of the number of spawners in Bellevue are important for tracking regional patterns of salmon survival and abundance, and salmon presence or absence is a good indicator of some stream conditions, especially physical barriers such as culverts and low flows, and water quality barriers such as high temperatures. Counting spawning salmon (the proportion of marked hatchery fish to unmarked native spawning fish) and redds (egg nests) provides an indication of the success of salmon, but can be confounded by changes in harvest and ocean conditions. To fully understand whether the habitat supports salmon survival, it would be necessary to count the number of salmon redds, then count the number of juvenile salmon migrating out of the stream towards marine waters. However, even though conducting both spawning and outmigrant surveys is a recommendation in the Lake Washington/Cedar/Sammamish Watershed Chinook Salmon Recovery Plan, funding has not been available.

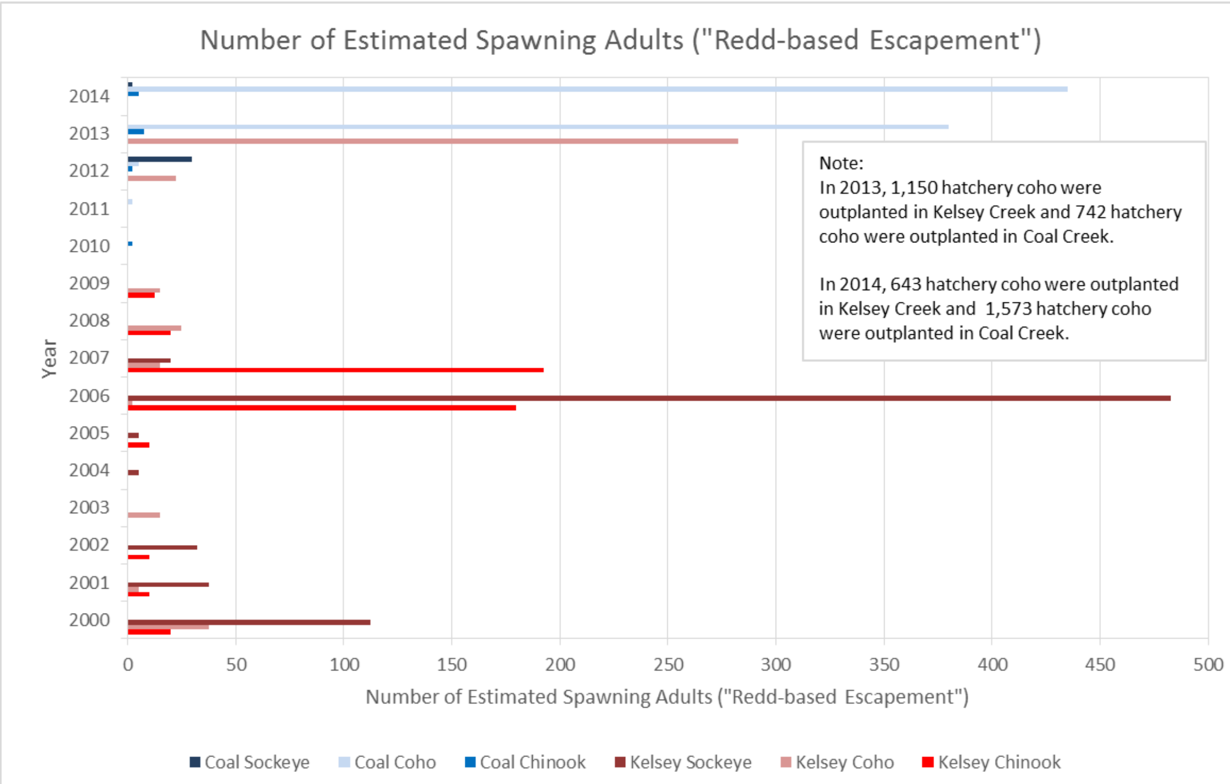


Figure 6-36. Salmon escapement (estimated number of adults returning to spawn based on number of redds or egg nests) for Kelsey & Coal Creek from 2000 to 2014.

Adult salmon spawn in Kelsey Creek, Goff Creek, Valley Creek, Richards Creek, West Tributary, Coal Creek, and Lewis Creek between September and early January. Wild and hatchery Chinook salmon, which are listed as endangered, continue to spawn in Kelsey Creek and its tributaries each year. Other fall spawners include coho, kokanee, and sockeye (see Figure 6-37). The numbers of spawning salmon fluctuated greatly between years, as indicated by adult salmon return numbers for Kelsey Creek. These fluctuating return numbers indicate that the populations may not be able to sustain spawning in these streams. Additional information about fall spawning salmon in Bellevue's creeks can be found in annual salmon spawner reports (e.g., The Watershed Company 2008, 2009). In 2013 & 2014, a collaboration between The City of Bellevue and the Muckleshoot Tribe led to the outplanting of many Coho spawners. 2013 outplanting occurred at Kelsey (1050 Coho) and Coal Creek (742 Coho), as well as the West Tributary (100 Coho). In 2014, outplanting occurred at Kelsey Creek (643 Coho) and Coal Creek (1573 Coho). These totals have been omitted from the salmon escapement figure above.

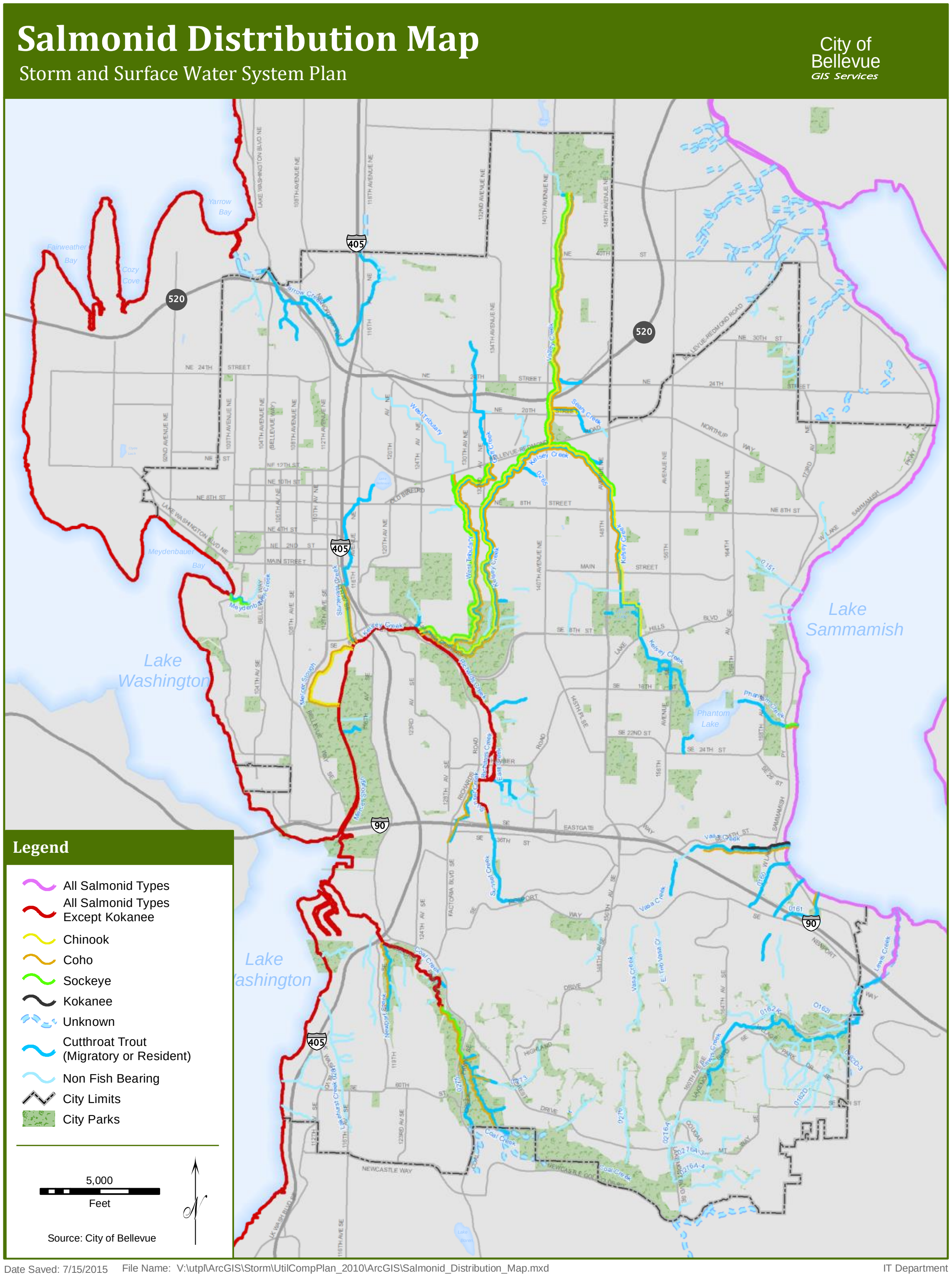


Figure 6-37. Adult salmon and trout distribution in Bellevue streams, 1996 - 2015.

Salmon Pre-spawn Mortality

Beginning in the late 1990s, several jurisdictions in the greater Seattle area, including Bellevue, noticed a high rate of mortality among coho salmon females during fall surveys. Salmon were found dead and dying in the creeks before they had spawned. Adult coho from several streams had similar symptoms before death, including disorientation, lethargy, loss of equilibrium, gaping, and fin splaying (Northwest Fisheries Science Center 2007). Such pre-spawn mortality (PSM) has been observed in many lowland urban streams in the Puget Sound basin, with overall rates ranging from ~20 to 90 percent of the fall runs. By comparison, the rate of die-offs in non-urban (e.g., forested) drainages appears to be less than 5%. The precise cause of PSM is not known. However, scientific research at the Northwest Fisheries Science Center at NOAA suggests that the coho die-offs are a consequence of non-point source water pollution; specifically, the complex mixture of metals, pesticides, and other toxic substances that are washed into streams from urban and residential areas during fall storms (e.g., Laetz et al. 2009).

Adult female coho salmon that died before spawning; note the large quantity of eggs.
Source: NOAA Fisheries Service, Northwest Fisheries Science Center

PSM was first documented in Bellevue streams in 2000. Salmon sometimes die before spawning for reasons other than water quality, but at very low levels. Some are stranded on the banks after high flows recede, and others are eaten by predators. Rates of PSM due to unknown causes ranged from zero to 100 percent in the Kelsey Creek spawner index reaches during survey years between 2000 and 2014 (see Appendix B-9).

In 2013 and 2014, the City of Bellevue worked with Muckleshoot Indian Fisheries staff to release adult coho salmon from the Issaquah Hatchery into Kelsey and Coal Creeks. This project clearly illustrated the reduced spawning success in Kelsey Creek.

In Kelsey Creek, 1150 coho were released in 2013, resulting in 113 redds (approximately 0.03% spawning success). In 2014, 643 coho were released, but no fish were observed in the system after four days, and no redds were found (0% spawning success).

In comparison, 742 coho were released in Coal Creek in 2013, resulting in 152 redds (41% spawning success). In 2014, 1573 coho were released, resulting in 173 redds (22% spawning success).

Recent research by NOAA Fisheries, US Fish and Wildlife, and WSU have found that highway and dense urban street runoff is correlated with coho prespawn mortality. They have determined that urban runoff is toxic at acute (lethal) and chronic levels. If the coho eggs and juveniles survive, common sub-lethal effects include developmental delays, reduced eye size, swelling around the heart, and deformed jaws and hearts. However, when the urban runoff is filtered through Ecology recommended biofiltration material (sand and compost), all the coho survived and most sub-lethal effects were avoided. The biofiltration experiment mimicked low impact development techniques that are required to become the preferred stormwater management approach, where feasible. Additional studies are being conducted to determine the potential for these new techniques to reverse the pre-spawn mortality problems in urban streams.

Peamouth

Peamouth appear to be thriving in Bellevue streams. Peamouth, a relatively large (12-inch-long adults, on average) minnow, live most of their life in large lakes, and spawn in Kelsey Creek, West Tributary, Sturtevant Creek, and Lewis Creek between mid-April and June. For the last several years, up to six spawning events were observed in Kelsey Creek, with hundreds or thousands of fish leaving a blanket of eggs along the stream bottom; in 2015, five spring spawning events were documented by volunteers. During and after such events, wildlife such as great blue herons, wood ducks, and river otters congregated to feed on the remnant fish and eggs. Peamouth eggs incubate and hatch within 1 week, in contrast to salmon eggs, which incubate over several winter months. Likely because of the short time they are in the stream, the spring timing of their spawning, and their tolerance of warm water, peamouth do not appear to be as influenced as salmon urban stream conditions.

Peamouth and eggs (yellow) in Kelsey Creek near 121st Avenue SE, near the Wilburton Trestle

Summer Fish Presence and Distribution

Summer fish surveys are conducted to determine fish species presence and distribution. These surveys provide indications of local habitat conditions, as the presence of the fish are not affected by harvest or ocean conditions. Results show that native fish diversity and abundance have been maintained in most surveyed streams, with the exception of juvenile coho, which have been decreasing over time.

Surveys were conducted at varying sites in 1983, 1996 (Ludwa et al. 1997), 2002 (The Watershed Company 2002), 2007, and 2010 through 2014 (Table 6-9). The 1996 study evaluated correlations between fish, habitat, and land use. Cutthroat trout juveniles were the most abundant fish, and have become more abundant in recent years as the number of coho juveniles have declined. This is consistent with studies in urban streams indicating that where fewer coho salmon juveniles were found, cutthroat trout were more abundant (Lucchetti and Fuerstenberg 1993). Non-native fish species have been observed sporadically throughout the years. This is likely due to differences in sites surveyed, stream conditions, and other factors affecting fish distribution, including introduction of fish to new areas by local residents.

Regionally, sculpin were found to be more abundant in less urbanized basins in 1996, which could account for their absence from Kelsey Creek basin streams in more recent years. Sculpin rely on stream bottom habitats, which are subject to more scour in urban streams (Ludwa et al. 1997). Since sculpin cannot jump barriers, weirs and other obstructions can restrict their presence in streams that would otherwise support sculpin populations. U.S. Fish and Wildlife began research in 2014 to determine whether recent improvements in fish passage could restore and sustain sculpin populations in Kelsey Creek. Prickly sculpin (Cottus asper) were captured from downstream in Mercer Slough and Lake Washington, tagged, and moved into Kelsey Creek. Fish movement and presence will be monitored for a number of years to determine whether the new habitat conditions will allow them to survive in Kelsey Creek.

Table 6-9. Fish observed during summer electrofishing surveys at several sites in the Kelsey Creek basin and its tributaries, 1983, 1996, 2002, 2007, and 2010 through 2014.

Fish Observed		Year								
Common Name	**Scientific Name**	**1983**	**1996**	**2002**	**2007**	**2010**	**2011**	**2012**	**2013**	**2014**
Coho salmon	*Oncorhynchus kisutsch*	●	●	●	●	●	●	●	●	●
Cutthroat trout	*Oncorhynchus clarki*	●	●	●	●	●	●	●	●	●
Rainbow trout/Steelhead	*Oncorhynchus mykiss*	●	●	No data	●					
Sculpin	*Cottus* spp.	●	●					●		
Brook lamprey	*Lampetra richardsoni*		●	●	●	●		●	●	●
Dace	*Rhinichthys* spp.		●	●	●	●		●	●	●
Sucker	*Catostomus* spp.		●		●	●				
Three-spine stickleback	*Gasterosteus aculeatus*	●	●		●	●				
Bluegill*	*Lepomis macrochirus*		●	●		●				
Pumpkinseed*	*Lepomis gibbosus*		●	●						●
Green sunfish*	*Lepomis cyanellus*					●				
Largemouth bass*	*Micropterus salmoides*		●							
Smallmouth bass*	*Micropterus dolomieui*					●				
Yellow perch*	*Perca flavescens*	●								
Crappie*	*Pomoxis* spp.	●				●				
Catfish*	*Ictalurus* spp.	●								
Carp*	*Cyprinus carpio*					●				

*Non-native species

Wetlands

Wetlands are low areas that naturally store water. They can help lessen flooding during storms by storing runoff and releasing it slowly downstream. Bellevue has approximately 860 acres of wetlands that were mapped in the 1970s and 1980s for the Sensitive Areas Notebook (City of Bellevue 1987). The survey included a few built detention and retention ponds, which are specifically excluded from the definition of wetlands in Bellevue's current Critical Areas Ordinance (CAO) [Land Use Code 20.25H]. As shown in Figure 6-38, the wetlands were mapped based on aerial photography, and some of them were field verified. The map likely does not include all wetlands and wetland boundaries can change over time.

New wetlands or recent wetland delineation reports and maps submitted for permits are not added to the City's GIS map of wetlands, but there are plans to do so in the future. Wetlands were rated in 1987 according to size and degree of isolation from other surface water bodies. The wetland rating system was changed when the new CAO went into effect in 2006 to match Ecology's rating system, but Bellevue's wetlands have not been categorized under the new system. Bellevue does not currently have a wetland monitoring or management program.

Summary – State of the System

Bellevue is an urban city with a mix of residential, commercial, industrial, and public land uses. Much of the storm and surface water drainage system is privately owned. The public pipes, open ditches, and other facilities that average 35 years old will eventually need to be replaced to avoid failures. Flooding concerns are limited, even though much of the city was developed prior to storm detention and conveyance standards. Tree canopy covers approximately 37 percent of the city, and impervious surfaces cover over 40 percent, which is considered urban development.

Bellevue initiated stormwater detention requirements in 1974 and has limited flooding issues. Out of 27 drainage basins, 1 basins had little to no structural flooding locations; 12 basins had 3 to 4 structural flooding locations; and 14 basins had more than 4 structural flooding locations during the period of 1996 to 2014. Nine basins had more than 2 claims for damages (up to 9 paid claims); 10 basins had 1 to 2 claims, and 8 basins had no claims. Thirteen street locations are known to have risk of flooding. To protect public safety, the Utilities Department works closely with emergency personnel to ensure alternative routes are available.

Bellevue has lakes in which people can swim, fish, and recreate, as well as streams that provide aesthetic value and important environmental functions. The storm and surface water system is also critical for maintaining Bellevue's economy, by providing aesthetic value as well as protecting safety, mobility, and property by preventing extensive floods. Fish still live in the streams and lakes in Bellevue, even though the fish species and abundance are different than they were historically. Endangered Chinook salmon continue to spawn in Bellevue's streams each fall, although they appear to be in decline. Peamouth from Lake Washington spawn in great abundance in Kelsey Creek each spring.

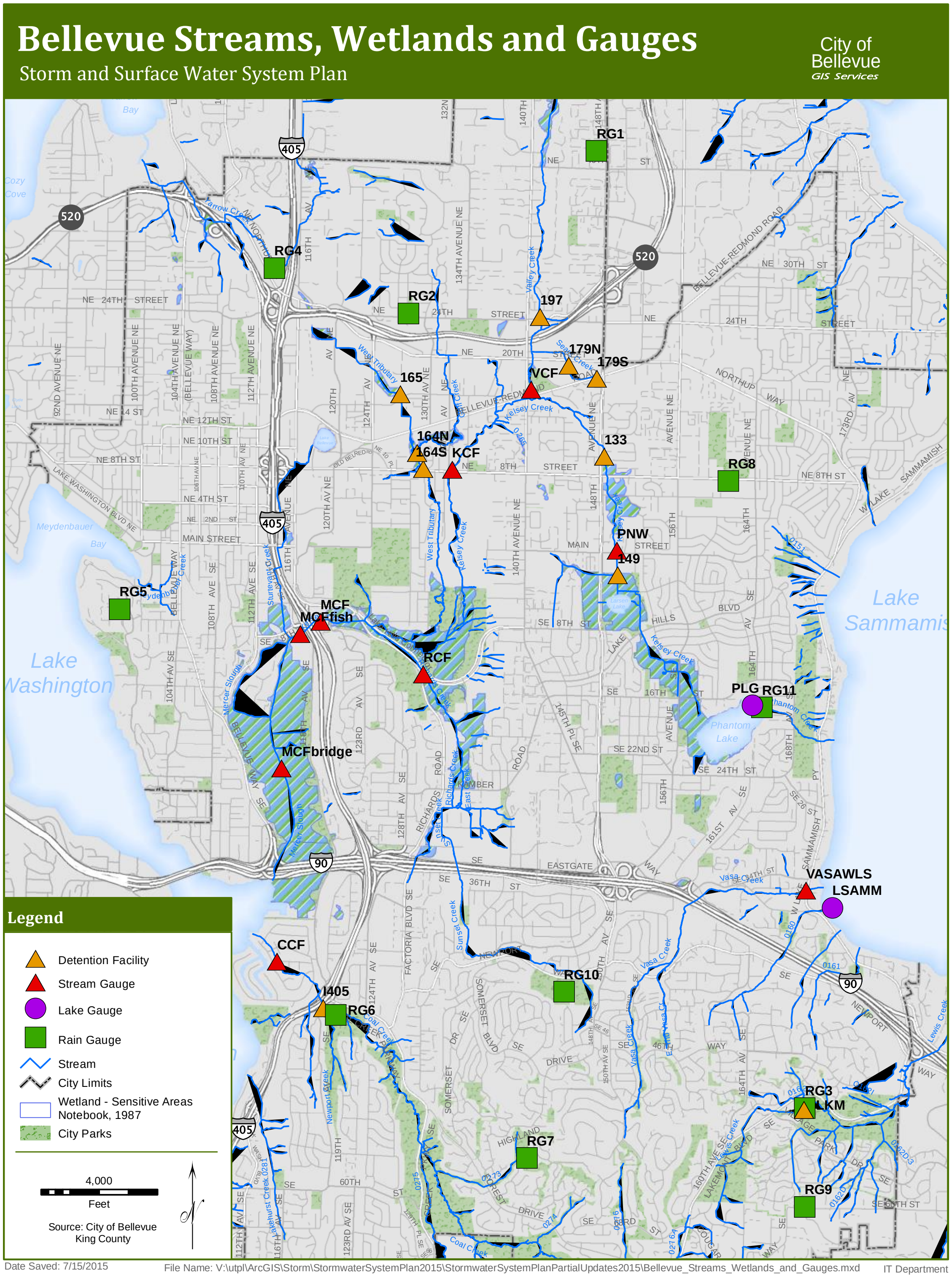


Figure 6-38. Streams, lakes, wetlands, and currently active gauge stations in Bellevue.

Note: Some constructed retention/detention ponds are shown here as wetlands, but are no longer defined as wetlands according to Bellevue's Critical Areas Ordinance.

The open streams show the impacts found in all urban areas, including lack of wood and pools, increased erosion, degraded habitat, more pollutants, impaired macroinvertebrate and fish communities, increased flooding, and flashy flows that increase quickly after a rain event, then decrease quickly when the rain subsides. Capital improvement projects provide regional detention and sediment storage, improve fish passage through culverts, stabilize stream channels, and add large wood. They also operate and maintain facilities and regulate development to slow runoff from urban areas; all these actions provide some benefits to stream channels. However, it is difficult to measure the effect of any specific stormwater management effort due to the multitude of stressors, both current and historic, and diffuse sources of pollutants. At this time, there is no standard that provides an indication of what level of habitat quality is necessary to maintain aquatic life in an urban area.

Data Gaps and Recommendations

Physical System

In order to detect trends in stream habitat, it is important to have many monitoring sites and conduct surveys consistently over at least 10 to 20 years (Larsen et al. 2004). Stream flow rates can be a good indicator of the effectiveness of stormwater management practices. Currently, only the USGS station at Mercer Slough has a long enough period of record for flow data to assess change, although Bellevue has multiple sites where stream flows are measured. These data could be used if they were verified using robust quality assurance/quality control procedures, if the rating curves were applied to convert the stage readings to flow rates, and the data were analyzed appropriately to determine flow frequency probabilities and other statistics; see Appendix B-10 Hydrologic Monitoring Plan.

A program to monitor large Utilities Department capital projects to determine whether project goals are met would benefit future project planning and prioritization. For future use of the street closure flood protection evaluation metric, work order tracking should clearly indicate whether the cause of structural flooding is due to public or private drainage system components, and street closure durations need to be recorded. The Asset Management program addresses data gaps and recommendations for the built components of the storm and surface water system in Chapter 8.

Water Quality

Chemical water quality data in Bellevue was characterized in the early 1990s. National efforts to characterize the water quality of urban runoff have been able to consistently characterize runoff based on land use, so additional efforts to characterize the water chemistry of the city would be expensive, and would not likely provide significant new information. King County ambient monitoring provides a snapshot of indicators of water quality, but budget cuts are reducing the number of streams being monitored. Phantom Lake and Larsen Lake phosphorus, chlorophyll-a, and water clarity sampling meet the monitoring objectives for those lakes, so no additional monitoring is recommended. Appendices B-11 and B-12 provide additional details on water quality and pollution export in Bellevue's lakes. The illicit discharge outfall monitoring programs meet the requirements of the NPDES Municipal Stormwater Permit, but as the program continues, some limited additional outfall monitoring could be considered to document the effectiveness of remediation efforts.

Stream temperature is critical to spawning salmon, and the 2001 pilot temperature study showed that warm temperatures in Kelsey Creek may delay spawning salmon migration in the late summer and early fall. The rapid changes in temperature during summer rain storms may also affect juvenile coho and other aquatic life. It is recommended that water temperature be monitored at key sites along Kelsey Creek and the Mercer Slough annually from August through October using a continuous temperature gauge to identify areas that may need special consideration for reducing summer temperatures.

Appendix B-13 shows precipitation patterns for 1962 and 1999, which were similar to the stream discharge rate at the Mercer Creek stream gauge.

Biological

Fish and stream macroinvertebrates are biological indicators used to assess the health of the aquatic habitat in Bellevue's streams. Adult salmon spawning distribution and abundance is important for regional endangered salmon recovery and Kelsey Creek is the only urban stream in the watershed that has had consistent returns of adult salmon. Continued spawner surveys are recommended to determine the effectiveness of capital projects, establish long-term trends, and contribute rare data to salmon recovery efforts. To directly determine local stream condition effects on salmon spawning effectiveness, the number of young salmon produced from salmon redds can be measured. As noted in the regional salmon recovery recommendations, salmon spawning and out-migrating juveniles should be monitored, if funding can be found.

Benthic macroinvertebrates are a good indicator of stream health, but their communities and resulting scores are considered impaired, even in basins with low percentages of impervious surfaces. Bellevue has sampled five to eight sites during most years since 1998. It is recommended that samples be collected annually from up to five core sites and a rotating panel of additional sites to identify trends over time and/or responses to management changes.