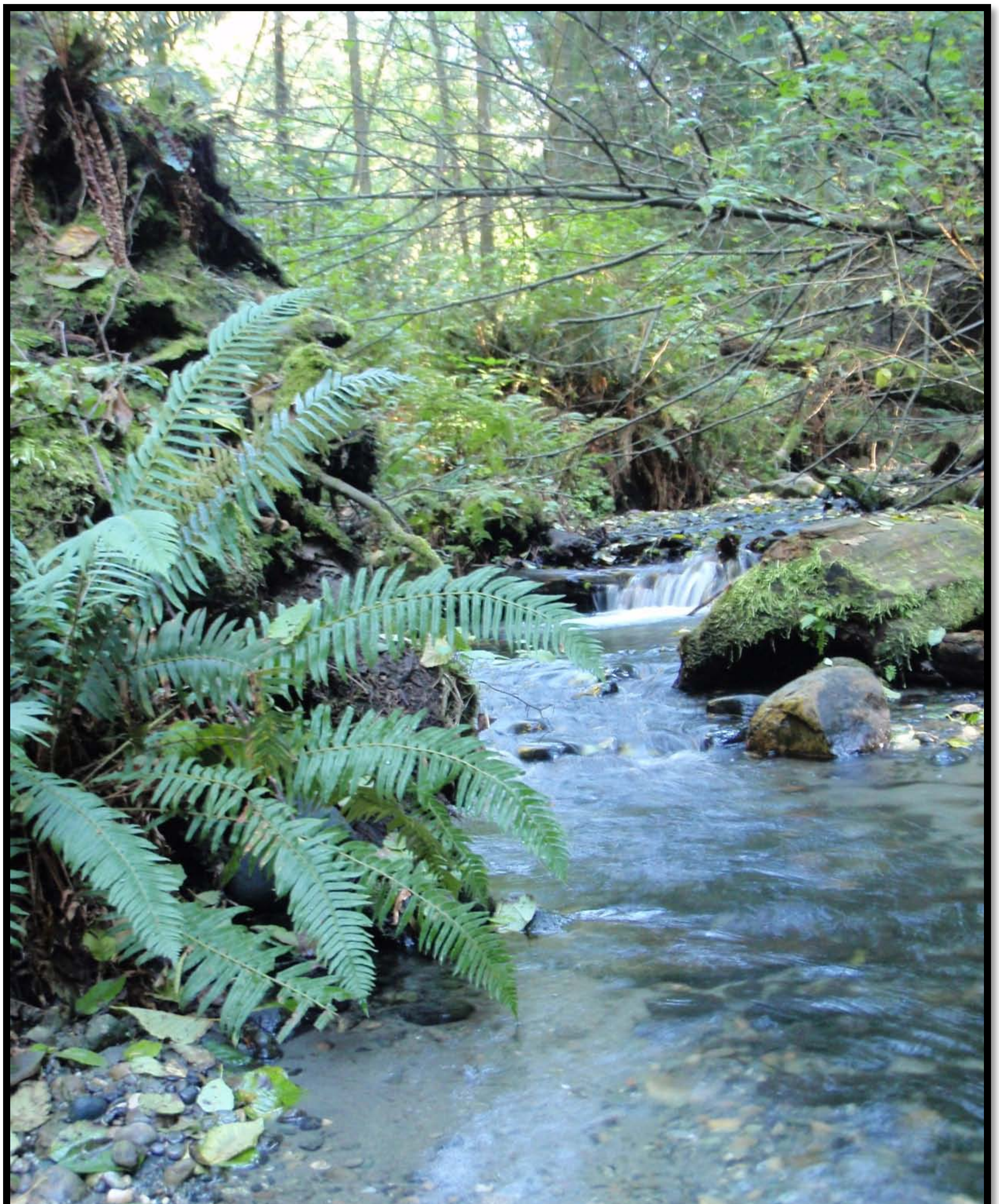
2009 Fresh Water Assessment Report

State of the Water Quality in Shoreline Streams, Lakes and Wetlands



2009 Fresh Water Assessment Report

State of the Water Quality in Shoreline Streams, Lakes and Wetlands

June 2010

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State of the Water Quality in Shoreline Streams, Lakes and Wetlands

Executive Summary

The City of Shoreline's Surface Water and Environmental Services Program within the Public Works Department routinely monitors the quality of stream systems and surface waters within the City of Shoreline. This report summarizes the results of water quality data collected between 2002 and 2009.

The findings of this report will help to:

- Document the current condition of the City's fresh-water resources and provide a basis of comparison for future water quality studies.
- Assist City Staff with the prioritization of restorative actions, the generation of program policy and rules, and inform the direction of future monitoring efforts.
- Determine whether water quality improvement programs are effective and current practices sustain or improve conditions.
- Foster a broader awareness within the community of the current conditions of the City's water resources and the need to manage the aquatic environment and pollution sources to improve water quality.

For this study, water quality parameters, were assessed in local streams, lakes and wetlands, collectively referred to as water bodies. Nine streams were assessed: Boeing Creek, Thornton Creek, Littles Creek, Meridian Creek, McAleer Creek, Cedar Brook Creek, Storm Creek, Barnacle Creek and Ballinger Creek. Two lakes were assessed: Echo Lake and Hidden Lake. Other water bodies assessed include Ronald Bog, a mined former-peat bog wetland that now resembles a lake, and Meridian Park Wetland.

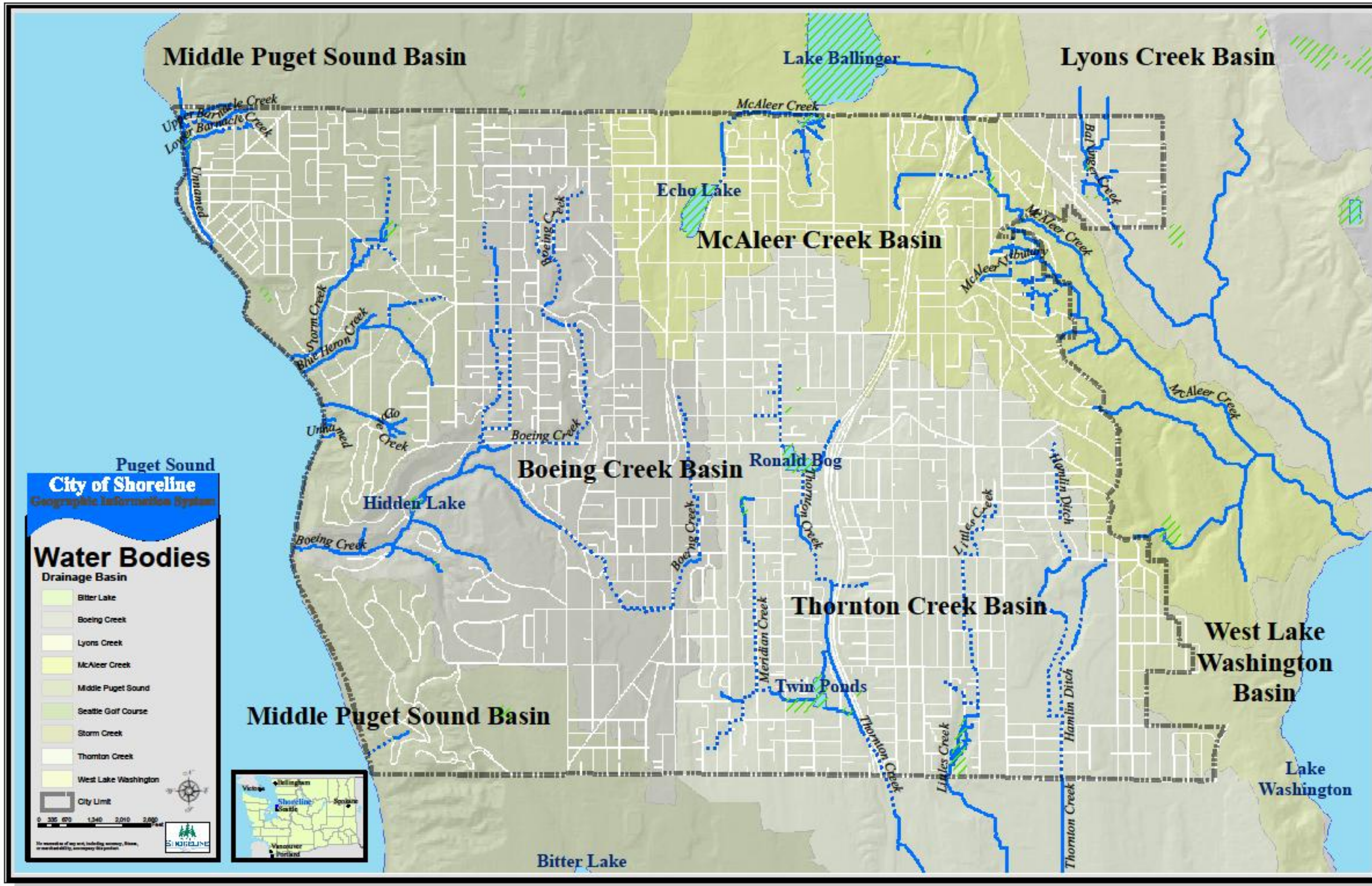

Figure ES-1 - Drainage Basins

The water quality assessment indicated that all nine streams were degraded and didn't meet at least one water quality standard in the beneficial use category. Water quality ratings ranged from good to poor for individual parameters. Water quality parameters can be affected both by human-induced or natural influences. Since natural influences cannot be controlled, the City will focus on improving the adverse effects on water quality due to human activities.

1 INTRODUCTION

1.1 Geographic Area and History of Development

The City of Shoreline is located in the northwestern corner of King County along the shores of Puget Sound. Shoreline is generally bounded by the City of Lake Forest Park to the east, the City of Seattle to the south, Puget Sound to the west, and Snohomish County to the north (including the Cities of Mountlake Terrace, Edmonds, and the Town of Woodway). Puget Sound is the City's only "shoreline of statewide significance," as defined by the Washington State Shoreline Management Act, but the City has several lakes and ponds including Echo Lake, Hidden Lake, Ronald Bog and Twin Ponds. Numerous small streams and creeks are also found within or adjacent to the City of Shoreline. Three of the most significant basins within the City are Boeing Creek basin, Thornton Creek basin and McAleer Creek basin (Figure 1).

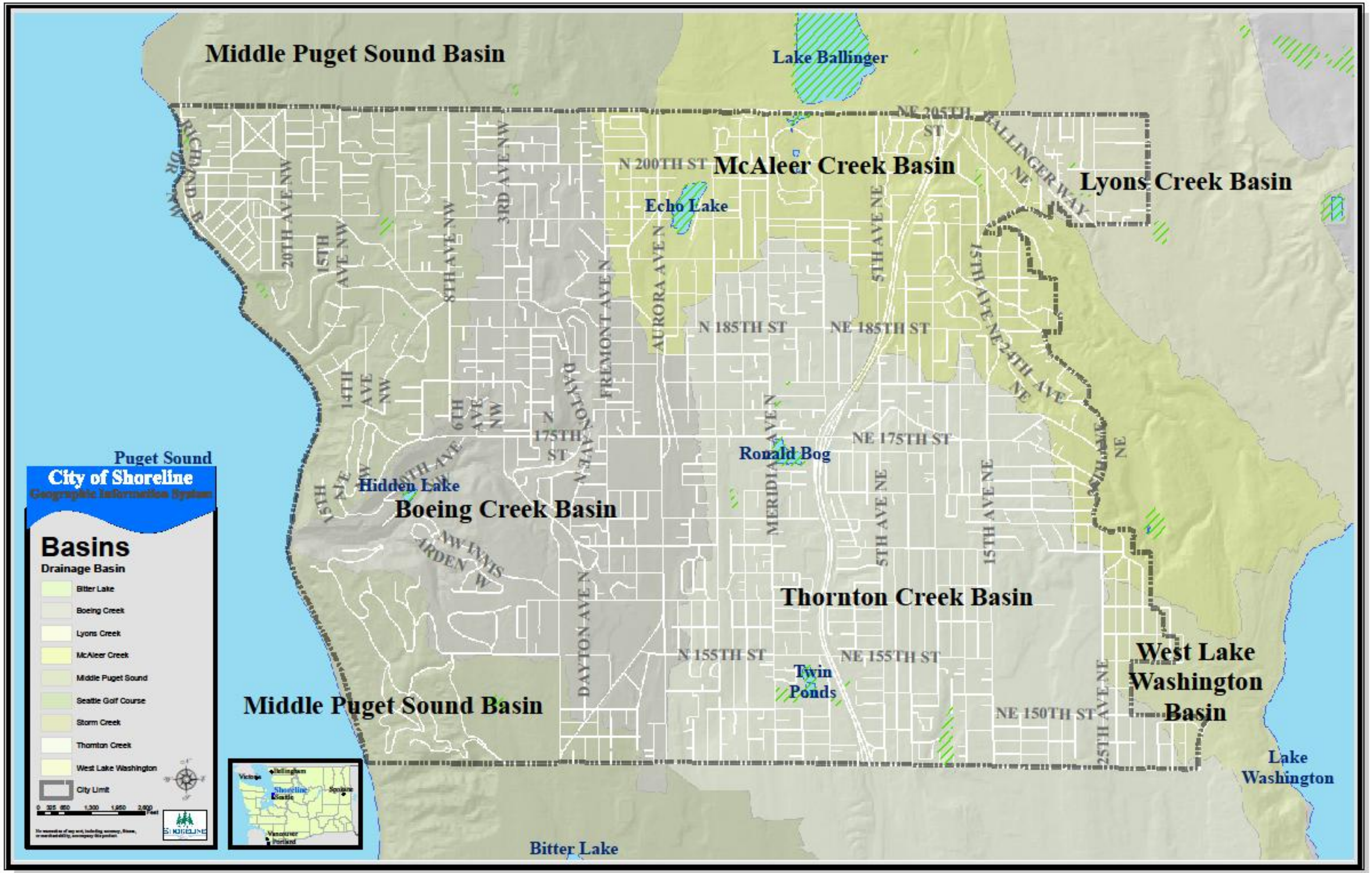

Figure 1 - Drainage Basins

Over many years, urban development in the City of Shoreline has drastically altered the City's watersheds. Previously forested areas and wetlands have been replaced with residential and commercial land uses. Limited areas of open space remain. Shoreline's development history began with original settlements dating back to the late 1800s. As the City developed over time, most of this development took place prior to the implementation of stormwater mitigation regulations in the 1970s. Currently, the City is substantially developed, with only about one percent of the total land area remaining vacant.

Shoreline is primarily residential in character and over 50 percent of the households are single family residences. Commercial development is predominantly located along Aurora Avenue, with other neighborhood centers located at intersections of primary arterials, such as N 175th Street at 15th Avenue NE and N 185th Street at 8th Avenue NW. There is limited industrial development within City limits. Currently, development within the City is primarily in the form of redevelopment and infill. Urban development has produced a large amount of impervious surface including streets, sidewalks, parking lots, and roofs. When rain falls on these impervious surfaces the water runoff flows directly into streams and local water bodies instead of naturally being absorbed into the ground or retained by wetlands. Surface water runoff picks up soil, chemicals and other pollutants and carries them into our lakes, rivers and marine waters. This large amount of impervious surface in the City of Shoreline greatly affects the condition of the City's surface waters.

1.2 Purpose

The City of Shoreline's 2007-2008 Strategic Directions document states that one of the City goals is for surface water quality within the City to meet or exceed state and federal water quality standards. The goal states that performance measures to be used in this determination are percent of surface water tests meeting adopted targets or standards. This report will help establish a baseline for measurement of that goal but will also be useful to the City in many other ways.

The findings of this report will help to:

- Document the current condition of the City's fresh-water resources and provide a basis of comparison for future water quality studies.

- Assist City Staff with the prioritization of restorative actions, the generation of program policies and rules, and inform the direction of future monitoring efforts.
- Determine whether water quality improvement programs are effective and current stormwater management practices sustain or improve conditions.
- Foster a broader awareness within the community of the current conditions of the City's water resources and the need to manage the aquatic environment and pollution sources to improve water quality.

Stormwater runoff is the number one urban water pollution problem in the state, according to the Washington State Department of Ecology. Streams [and local waterbodies] are usually the first aquatic system to receive stormwater runoff, and their water quality can be compromised by the pollutants it contains. (CWP 2003) The City of Shoreline is a highly urbanized area and a large amount of stormwater runs off urban surfaces and enters local waterbodies during rain events. Because of the known impact that stormwater can have on water quality, the City regularly monitors local surface waters to help determine the level of impairment. To track the condition of the City's surface waters over time, the City has been conducting monthly water quality monitoring since 2002.

This report presents baseline water quality data, expressed in percent compliance with water quality standards, for significant waterbodies within the City. Previously collected water quality monitoring data was compared to the Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC), as amended by the Department of Ecology on November 20, 2006, for fresh water supporting Core Summer Salmonid Habitat, Salmonid Spawning, Rearing and Migration and Primary Contact Recreation. The five water quality parameters identified in the standards are temperature, turbidity, pH, dissolved oxygen and fecal coliform bacteria.

The water quality parameters identified in the standards are important because if these parameters are not within certain limits (water quality standards) they can have an adverse effect on beneficial uses and freshwater habitat. Fish and aquatic organisms must live in an environment that is within a certain temperature range. Specifically, temperatures that are above the upper limit for development and survival can result in reduction of these aquatic populations. Indirectly, higher temperatures can affect other conditions that lead to harmful aquatic environments. For example, higher temperatures can increase algae growth which can lead do decreased oxygen levels when it decomposes. Dissolved oxygen is important because fish and aquatic organisms cannot live without having enough oxygen available to them in the water. Aquatic organisms have adapted over time to survive and reproduce in a relatively narrow pH range. However, most fish and aquatic organisms can only survive and reproduce in water that is not very acidic or basic, but in water that is "just right". They reproduce and survive best under "neutral" pH conditions. In water that is very acidic (low pH values), the concentration of heavy metals ions (copper, aluminum, etc.) increases and, this in turn, has negative effects on the health of aquatic organisms. Turbidity can have a negative effect on fish and aquatic organisms. High turbidity indicates that there is a greater amount of sediment in the water than normal. Suspended sediment can choke the gills of fish, settle on fish spawning beds rendering them unusable and smother fish eggs and aquatic organisms on the bottom. Fecal Coliform bacteria have much less of an impact on aquatic organisms than it does on human health. High bacteria levels indicate a higher potential for transmission of harmful pathogens. Pathogens can make humans sick if they drink or come in contact with the water. Baseline data of these parameters are needed to compare future data and document progress towards meeting water quality goals.

This report will serve as an assessment of water quality conditions as of December 2009 and as a benchmark for comparison to future changes in water quality. The City currently implements policies and programs to help reduce water pollution. New policies and programs will be implemented, according to the schedule set forth in the Western Washington Phase II Municipal Stormwater Permit (i.e. the National Pollutant Discharge Elimination System (NPDES) Phase II permit) issued by the Washington State Department of Ecology and according to priorities determined by City staff and the City Council. As part of the NPDES Phase II permit requirements, the effectiveness of the programs implemented must be measured. Future water quality data and studies can be compared to the 2009 conditions set forth in this report in order to determine program effectiveness and shape future programs and projects aimed at improving water quality.

2 DESCRIPTION OF WATER RESOURCES

2.1 Streams

There are six drainage basins within the Shoreline city limits. The significant drainage basins, listed from west to east are the Middle Puget Sound, Boeing Creek, Thornton Creek and McAleer Creek basins (Figure 1). Small portions of the Lyons Creek and West lake Washington Drainage basins are also within the City limits. The Middle Puget Sound and Boeing Creek Basins flow west into Puget Sound. Thornton Creek, McAleer Creek, Lyons Creek and the West Lake Washington Basins flow east into Lake Washington. All of the urban streams within these basins are fed primarily by groundwater and surface runoff. Surface runoff inputs are characterized primarily by urban stormwater flows during rain events. Water bodies within the City of Shoreline boundary support aquatic life uses of Salmonid Spawning, Rearing and Migration or Core Summer Salmonid habitat. Shoreline water bodies are designated for primary contact recreation. The categories are defined in the Water Quality Standards for Surface Waters of the State of Washington Chapter 173-201A WAC as amended November 20, 2006.

2.1.1 Boeing Creek Basin: Boeing Creek

The Boeing Creek Basin is located almost entirely within the Shoreline City Limits and drains approximately 1,753 acres within the central portion of the City (Figure 1). There is a very small portion of the basin that extends south into Seattle. Boeing Creek is the second largest basin within the City. The City's largest, natural riparian areas are within the Boeing Creek Basin.

Current land use is dominated by urban development and the entire length of the stream channel has been highly impacted by this development. Much of it has been buried in pipes or placed into artificial open channels. In all, just 26% of the stream remains as a natural channel (Table 1). Other modifications include 4-dams of varying proportions, functionality, and design. Only the first 701 meters of lower reach is accessible to anadromous fish use. The health of the riparian zone declines from the downstream mouth to the more developed upstream reaches of the creek.

A detailed description of the basin can be found in the Boeing Creek basin characterization study (Tetra Tech/KCM 2004c).

Table 1 - City of Shoreline Watershed Characteristics

	Watershed Characteristics					Stream Characteristics		
Stream	Size (acres)	Impervious (%)	Roads (mi/mi^2)	Lakes/ Ponds (acres)	Wetland (%)	Piped (%)	Artificial Channel (%)	Natural Channel (%)
Thornton Creek	1,172	44	27.3	11.7*	9.7 acres (1%)	63	19	18
McAleer Creek	4,018	46	18.6	114.9**	23.4 acres (1%)	46	28	26
Boeing Creek	1,753	44	20.2	1.4	.5 acres (.003 %)	63	11	26
Storm Creek	474	36	19	0	3 acres (.01%)	29	25	46

*Ronald Bog is 7.7 acres and Twin Ponds is 4 acres.

**Echo Lake is 13 acres and Lake Ballinger is 101.4 acres.

2.1.2 Thornton Creek Basin: Thornton Creek, Meridian Creek, Littles Creek and the Ronald Bog Inlet

The headwaters of the Thornton Creek Basin are located in the central portion of the City (Figure 1). Approximately 48% of the basin is located within Shoreline City limits. The Thornton Creek Basin drains approximately 2,418 acres in the southeast quarter of the City of Shoreline before entering the Seattle City limits and ultimately flowing into Lake Washington. The City monitors the main branch of Thornton Creek as well as Meridian Creek, which is the largest tributary to Thornton Creek within Shoreline City limits. The headwaters to another tributary, Littles Creek, also originate in this basin and merge with Thornton Creek south of the City of Shoreline in Seattle.

Urban development and automobile transportation infrastructure are the dominant land uses in the watershed. Conditions of the riparian zone are highly fragmented with a lack of high quality habitat. The largest continuous areas of high quality riparian habitat are located within city parks (Tetra Tech/KCM inc. 2004a). (Landscape Stream Channel Condition) The stream channel has been highly impacted by urban development. Relative to all streams in the city, Thornton Creek contains the least amount of natural channel. Nearly 63% is found within a pipe, while 18% is considered as a natural channel (Table 1).

Two large wetlands exist within the Thornton Creek basin with a combined open water component of 11.7 acres. These wetlands, Ronald Bog and Twin Ponds, originated as peat bogs. They were commercially mined beginning in approximately the 1940s and then allowed to go fallow. Each is now within a City Park and functions as a shadow bog. Shadow bogs are systems that have been modified to the extent that their hydrology and vegetation community no longer causes the formation of peat, but peat soils still dominant the wetland soils. Thornton Creek flows freely into both water bodies and no bog vegetation has been noted. Peat soils still exist at each location but to what extent the peat deposits remain is unknown (Tetra Tech/KCM inc. 2004a)

A detailed description of the basin can be found in the Thornton Creek basin characterization study (Tetra Tech/KCM 2004a).

2.1.3 McAleer Creek Basin: McAleer Creek and Cedar Brook Creek

The McAleer Creek Basin is located on the east side of the City and drains approximately 4,018 acres upstream of the monitoring station at 196th St NE (Figure 1). The reach length of McAleer Creek located within the City is 1,200 meters long.

The Creek has more than one distinct headwater stream. One of the headwaters originates south of Echo Lake, within the City of Shoreline, and flows north out of Echo Lake and into Lake Ballinger. Several other streams, the largest being Halls Creek located on the north end of Lake Ballinger in Snohomish County, feed Lake Ballinger. McAleer Creek flows east out of Lake Ballinger, is jointed by the Cedar Brook Creek Tributary at the boundary with The City of Lake Forest Park, flows through the Nile Golf course and The City of Lake Forest Park on the way to Lake Washington.

Urban development dominates McAleer Creek's watershed within City of Shoreline. The level of impervious surfaces in the watershed is currently at 46% (Table 1). The northern part of Aurora Avenue, Ballinger Way, 205th, and part of Interstate 5 represent major urban modifications within the watershed. The length of channel buried in pipes is 46% with the remaining 28% as artificial channel. (Table 1). While some high quality forested habitat exists within 50 feet along short reaches of McAleer Creek, the overall quality diminishes with distance from the stream. Some reaches of the stream lack high quality habitat within 50 feet due to existing single-family homes, apartments, and lawns.

There is one dam located on the main stem of McAleer Creek at NE196th St . It is designed to alleviate peak flows by impounding stream flow during storm events. Stream flow is controlled by a sluice gate. Under normal flow circumstances, no water is impounded upstream of the dam. The entire main stem of McAleer Creek within the City of Shoreline up to I-5 is utilized by anadromous fish. Little is known about the anadromous use of the various tributaries. Other notable water features include the two lakes, Echo (13.5 acres) and Ballinger (101.4 acres). Both lakes are known for having peatland wetland systems (Mike Shaw pers. comm. 2003).

A detailed description of the basin can be found in the McAleer Creek basin characterization study (Tetra Tech/KCM 2004b).

2.1.4 Puget Sound Basin: Storm Creek and Barnacle Creek

The Middle Puget Sound Basins (north and south) empty into Puget Sound through dozens of small creeks and storm drainage systems (Figure 1). The portions of the Puget Sound drainages that lie within the City of Shoreline encompass approximately 1,250 acres north of Boeing Creek and about 30 acres south of Boeing Creek. The two basins are hydraulically separated by the Boeing Creek Basin. There is record of only one relatively small stream in the southern section of the basin. There are two significant streams, Storm Creek and Barnacle Creek, located within the north section of the basin (Figure 1). There are also several other smaller streams in the basin. The basin extends both north and south past the City boundary into Edmonds and Seattle, respectively.

According to a 1997 estimate by Tetra Tech/KCM (KCM, Inc. 1997), the North portion of the Middle Puget Sound Basin is almost 90 percent developed, while the South portion of the Middle Puget Sound South Basin is approximately 67 percent developed. The amount and health of riparian corridor decreases as one moves inland from Puget Sound and as one moves perpendicular away from the streams as noted in Tetra Tech/KCM 2004d. Current land use is mostly single-family residential, followed by roads. Small areas are developed as multifamily, schools, commercial, and parks and open space. Commercial areas are primarily along the Richmond Beach Road corridor.

The portion of Storm Creek below NW 191st Street flows southwest for 3,000 feet through the privately owned Eagle Reserve in Innis Arden before entering Puget Sound. (City of Shoreline 2005). Barnacle Creek is located in the Upper Puget Sound Basin. Little is known about the characteristics of this stream. It has a north stem and a south stem that join together before flowing into Puget Sound. This stream flows through highly developed residential areas. The lower section of Barnacle Creek is tidally influenced upstream for a distance of about 20 feet. (City of Shoreline 2005).

A detailed description of the basin can be found in the Middle Puget Sound basin characterization study (Tetra Tech/KCM 2004d).

2.1.5 Lyons Creek Basin: Ballinger Creek

The Lyons Creek watershed comprises approximately 2,500 acres and lies within five municipal jurisdictions. Ballinger Creek is a tributary to Lyons Creek. The size of the basin within Shoreline's city limits is approximately 184 acres. The basin is located along the eastern-most boundary of the City (Figure 1). The majority of the Lyons Creek Basin is located in the Cities of Mountlake Terrace, Brier and Lake Forest Park. Lyons Creek flows south east from the City of Shoreline and into Lake Washington.

The most common land use is single family and multifamily residential, but there is a mix of all other land uses in the area. Commercial developments are clustered along NE Ballinger Way north of 19th Avenue NE. Multifamily developments are found along NE Ballinger Way, mostly south of 19th Avenue NE. A large school complex is at the intersection of 25th Avenue NE and NE 200th Street. Bruggers Bog and Ballinger Park are located along 25th and 24th Avenues NE, respectively (KCM 1997). Much of the watershed was developed in the 1960s and 1970s, during which the conversion in land use was accompanied by little or no construction of stormwater flow control facilities (Kerwin 2002). This conversion of pervious surfaces to impervious surfaces without hydrologic mitigation measures caused peak flows to increase significantly in the stream channel network during storm events (King County 2008).

The headwaters of Ballinger Creek are located within the Lyons Creek basin. Ballinger Creek flows south into the City of Lake Forest Park before joining Lyons Creek. Lyons Creek is a tributary to Lake Washington. A detailed description of the basin can be found in the Lyons Creek basin characterization study (Tetra Tech/KCM 2004b).

2.2 Lakes

2.2.1 Echo Lake

Echo Lake is located in the north central portion of the City in the McAleer Creek Drainage Basin. Echo Lake covers an area of 13 acres and has a maximum depth of 30-feet. The lake is surrounded by private properties except for a public park and swimming beach located at the north end of the lake. The lake is primarily fed by groundwater but there is significant inflow to the lake in the form of surface water runoff from surrounding residential roadways, residential and commercial properties and Highway 99. For approximately 6 to 8 months of the year the lake is high enough for there to be flow at the outlet. When there is outflow, this water flows north, across the City boundary into Lake Ballinger. Water flows out of Lake Ballinger as McAleer Creek and a portion of McAleer Creek flows south through Shoreline on its way to Lake Washington.

Land use along the lake edge is single family and multi-family development. There is a small City park located at the north end of the lake. Further to the west of the lake is the Aurora Highway and associated commercial developments. Echo Lake receives significant runoff contribution from this heavily developed area. Further north of the Lake is the City of Mountlake Terrace Boundary and a large commercial development and Metro Transit Center. The majority of the runoff from this development does not flow into Echo Lake.

A more detailed description of Echo Lake can be found in the McAleer Creek basin characterization study (Tetra Tech/KCM 2004b).

2.2.2 Hidden Lake

Hidden Lake is a smaller lake located in the southwest portion of the city in the Boeing Creek Drainage Basin. The lake occupies approximately 2.1 acres. Hidden Lake is primarily surrounded by private, residential properties. The north end of the lake is accessible from Boeing Creek and Shoreview parks and is visited frequently by dog owners who bring their dogs to swim in the water. Hidden Lake is in-line with the Boeing Creek channel and Boeing Creek flows into and out of this lake.

Hidden Lake is primarily surrounded by City park land and single family residential developments. The lake is fed by Boeing Creek and there is a large regional stormwater pond located approximately a quarter mile upstream of the lake. Stormwater contributions to that stormwater pond include a large amount of runoff from the Aurora Highway Commercial zone to the east. The North portion of the lake functions as a settling basin to capture sediment entering the stream and is periodically dredged to retain storage capacity. There is a stormwater structure at the outlet of the lake preventing natural drainage of the lake.

A more detailed description of Hidden Lake can be found in the Boeing Creek basin characterization study (Tetra Tech/KCM 2004c).

2.3 Wetlands

There are several identified and unidentified wetlands within the City of Shoreline limits and they vary significantly in size. For the purpose of this report, the City focused on three of the largest wetland systems in the City.

2.3.1 Meridian Creek Wetland

Meridian Creek wetland is located in the Thornton Creek drainage basin. This wetland comprises the majority of Meridian Park and is at the headwaters of Meridian Creek, a west-branch tributary to Thornton Creek. Meridian Park Wetland is approximately 1.1 acres in size. It is classified as Palustrine Forested and Palustrine Scrub-Shrub (Tetra Tech/KCM 2004a). It is the only true wetland of significant size within City limits that retains standing water for at least 6-months out of the year.

The dominant land use surrounding the Meridian park wetland is single family residential. There is a school located immediately north of the wetland. A trail constructed of earthen fill material separates two portions of the wetland. A Hydraulic connection between the two portions is provided by a culvert placed in the fill.

A more detailed description of the wetland can be found in the Thornton Creek basin characterization study (Tetra Tech/KCM 2004a).

2.3.2 Ronald Bog and Twin Ponds

Ronald Bog and Twin Ponds are two unique resources in the City that are considered wetlands but resemble lakes on the surface. These two resources are located in the Thornton Creek basin and originated as peat bogs. They were commercially mined beginning in approximately the 1940s and then allowed to go fallow. Each is now within a City Park and functions a shadow bog. Shadow bogs are systems that have been modified to the extent that their hydrology and vegetation community no longer causes the formation of peat, but peat soils still dominant the wetland soils. Because of these characteristics, Ronald Bog and Twin Ponds do not fit neatly into the lake or wetland categories. For the purpose of this report, these features were categorized as wetlands.

Ronald Bog occupies approximately 7.7 acres and is located at the upper most headwaters of Thornton Creek. The wetland portion around the edge occupies approximately 1 acre (Otak December 2001). Single family residential developments, residential roads and a major arterial street are located north of the bog. Residential developments are located to the east and south. Single family residential developments, residential roads, a major arterial street and a school are located west of the bog.

Twin Pond occupies approximately 5.4 acres and is located just upstream of where the Meridian Creek Tributary flows into Thornton Creek. Of those 5.4 acres, approximately 2.4 acres wetlands classified as either forested or emergent. (TetraTech/KCM 2004a). Land use surrounding Twin Ponds is primarily City park land and single family residential. On the east side of the pond is a synthetic-turf soccer playfield, an arterial street and an assisted living development.

A more detailed description of these resources can be found in the Thornton Creek basin characterization study (Tetra Tech/KCM 2004a).

Data was collected and analyzed only from Ronald Bog for this report.

3 METHODS

3.1 Sampling Station Selection

3.1.1 Streams

There are 15 sampling stations that were monitored for this report (Figure 2). Selection of individual sample locations was based on the contributing watershed area of a particular basin/sub-basin or water body and accessibility to the site. For the majority of streams, the monitoring stations selected were relatively close to the mouth of the basin stream network. Each of these sample locations is representative of water quality throughout the basin since, with few exceptions, all creeks in the City of Shoreline are tributaries and contribute runoff that passes through these stations. For lakes and wetlands, the sampling locations were primarily accessed from shore. The one exception to that was the data collected for the King County Lake Stewardship Program at Echo Lake. That sampling site was accessed by boat.

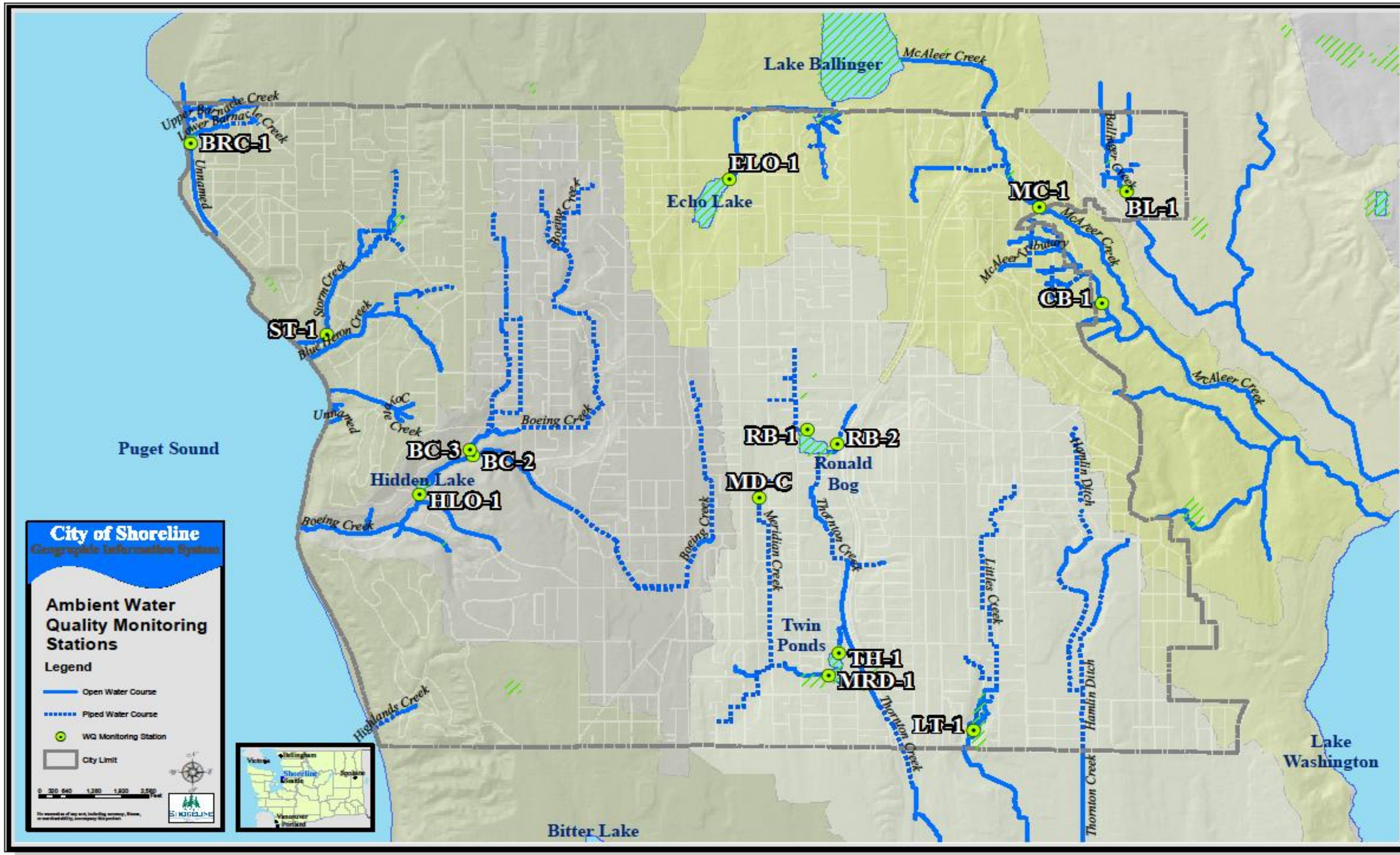

Figure 2 - Sampling Stations

Boeing Creek Sample Location

Two sites (BC-2 and BC-3) were selected for monthly chemical, physical (ambient) and bacteriological monitoring. The both sites are located downstream of the North Pond dam confluence (Figure 1). The site BC-2 is located on the north branch of Boeing Creek. The site BC-3 is located on the south branch of Boeing Creek. The two branches merge approximately 250 feet downstream of the sampling sites.

Thornton Creek Sample Location

One site (TH-1) was selected for monthly chemical, physical (ambient) and bacteriological monitoring. The site is located about 30 feet upstream of the Thornton Creek confluence with Twin Ponds (Figure 1).

Ronald Bog Inlet Sample Location

One site (RB-2) was selected for monthly chemical and physical (ambient) monitoring. The sampling site is at the confluence of the Ronald Bog inlet stream and Ronald Bog. The location is in the northeast corner of the bog about 15 feet upstream of where the two join (Figure 1).

Meridian Creek Sample Location

One site (MRD-1) was selected for monthly chemical and physical (ambient) monitoring. The site is located about 5 feet upstream of the Meridian Creek confluence with Twin Ponds (Figure 1).

Littles Creek Sample Location

One site (LT-1) was selected for monthly chemical, physical (ambient) and bacteriological monitoring. The site is located within Paramount Park and is about a quarter mile upstream of the point where Littles Creek flows across the City of Seattle City limit boundary (Figure 1).

McAleer Creek Sample Location

One site (MC-1) was selected for monthly chemical, physical (ambient) and bacteriological monitoring. The site is located upstream of 196th crossing and the dam (Figure 1). The sampling location is located just upstream of the City of Shoreline-lake Forest Park boundary.

Cedar Brook Creek Sample Location

One site (CB-1) was selected for monthly chemical, physical (ambient) and bacteriological monitoring. The site is located along the west side of a residence located at 18709 23rd Ave NE, adjacent to the intersection of Perkins Way and 23rd AVE NE. This station is located just east of the City of Shoreline-City of Lake Forest Boundary in the City of Lake Forest Park (Figure 1).

Storm Creek Sample Location

One site (ST-2) was selected for monthly chemical, physical (ambient) and bacteriological monitoring. The site is located immediately downstream of the intersection of 15th AVE NW and NW 190th Street. This location is approximately half way between the headwaters and the mouth of Storm Creek (Figure 1). Downstream of this sampling station, storm creek flows through a primarily natural, riparian area.

Barnacle Creek Sample Location

One site (BRC-1) was selected for monthly chemical and physical (ambient) monitoring. The site is located at the mouth of the creek where it flows into Puget Sound, on the east side of the BNSF railroad tracks (Figure 1).

Ballinger Creek Sample Location

One site (BL-1) was selected for monthly chemical, physical (ambient) and bacteriological monitoring. The site is located along 25th Ave NE the west side of a residence located at 18709 23rd Ave NE, adjacent to the intersection of Perkins Way and 23rd AVE NE. This station is located just east of the City of Shoreline-City of Lake Forest Boundary in the City of Lake Forest Park (Figure 1).

3.1.2 Lakes

Echo Lake Sample Location

One site (ELO-1) was selected for monthly chemical, physical (ambient) and bacteriological monitoring. Echo Lake is located along Ashworth Ave N, southwest of the intersection of Ashworth Ave N and N 200th Street. The specific location is adjacent to the Echo Lake park beach on the north end of the lake (Figure 1).

Hidden Lake Sample Location

Two sites were selected for water quality monitoring at Hidden Lake. One site (HLO-1) was selected for monthly chemical and physical (ambient) monitoring (Figure 1). Another site chosen for bacteriological monitoring is located adjacent to the shore at the northeast end of the lake. Hidden Lake is located along NE Innis Arden Way on the North side of the roadway. The nearest residence to the HLO-1 sampling site, which is located at the lake outlet point at the south end of the lake, is 944 NW Innis Arden Way.

3.1.3 Wetlands

Meridian Park Wetland Sample Location

One site (MD-C) was selected for monthly chemical and physical (ambient) monitoring. The sampling site is located at the outlet of the bog along the southern-most boundary of the wetland. The sampling location is immediately north of the property located at 1632 N 167th Street (Figure 1).

Ronald Bog Inlet Sample Location

One site (RB-1) was selected for monthly chemical and physical (ambient) monitoring. Ronald Bog is located southeast of the intersection of N 175th Street and Meridian Ave N. Sampling station RB-1 is located south of the bus shelter east of the intersection along N 175th Street, adjacent to the shore line (Figure 1).

3.2 Water Quality Parameters and Monitoring Methods

3.2.1 Chemical and Physical

3.2.1.a Temperature

Measurements were collected using a YSI 85 multi meter. The meter probe was inserted into the water column and the readings were displayed electronically on the meter screen. The measurement was recorded when the number on the screen stabilized. Temperature was recorded in degrees Celsius.

Samples were collected at each ambient monitoring station on a monthly basis.

3.2.1.b Dissolved Oxygen

Measurements were collected using a YSI 85 multi meter. The meter probe was inserted into the water column and the readings were displayed electronically on the meter screen. The measurement was recorded when the number on the screen stabilized. Dissolved oxygen (DO) measurements were recorded in milligrams per liter (mg/L).

Samples were collected at each ambient monitoring station on a monthly basis.

3.2.1.c pH

A YSI pH 100 meter was used for pH measurements. The meter probe was inserted into the water column and the readings were displayed electronically on the meter screen. The measurement was recorded when the number on the screen stabilized. Results were recorded in pH units.

Samples were collected at each ambient monitoring station on a monthly basis.

3.2.1.d Turbidity

An Orber-Hellige portable turbidity meter Model 966 was used to collect turbidity readings. A sample of water was collected in a clear, glass vial. That vial is inserted into the meter, a cap is placed on top and a button is depressed to obtain the reading. Results are recorded in Nephelometric Turbidity Units (NTU).

Samples were collected at each ambient monitoring station on a monthly basis.

3.2.2 Biological

3.2.2.a Bacteria (Fecal Coliform) Monitoring

Fecal coliform samples were collected using grab-sample techniques. Grab samples are water samples that are collected at one discreet moment in time from one discreet location. Following the King County Sampling Protocol (King County 2005), sample containers were submerged below the stream surface, filled to within one inch of the container opening and then capped. Collected samples were then delivered to a laboratory for analysis. The laboratory analysis results were reported to City staff by the laboratory.

Samples were collected at Echo and Hidden lakes on a bi-weekly basis approximately May through September of each year. Fecal coliform samples were collected at the Thornton Creek (TH-1), Cedarbrook Creek (CB-1), McAleer Creek (MC-1), Littles Creek (LT-1), Storm Creek (ST-2) and Boeing Creek (BC-2 and BC-3) sampling stations on a monthly basis in conjunction with chemical and physical (ambient) monitoring.

3.2.3 Quality Assurance and Quality Control of Collected Data

The collection of water quality parameters was performed by the City Water Quality Specialist. To ensure the accuracy and precision of water quality data collected, all meters were calibrated at a minimum of once per month. Manufacturing suggestions were utilized for the calibration. All data collected in the field was recorded on-site in a field log book and transferred to an Excel database in the office.

Fecal coliform samples that were collected were put on ice and delivered to the King County Environmental Lab within six hours of collection. Standard chain-of-custody procedures were followed. The King County Environmental Laboratory conducts an internal QA/QC program.

3.3 State Water Quality Standards and Ambient Monitoring Data Analysis

The state freshwater standards apply to Shoreline-area urban watercourses and lakes. All of these waterbodies fit the definition of waters of the state. In the state of Washington, waters of the state are protected by the federal Clean Water Act (CWA; 33 U.S.C. 1251 et seq.) and the state Water Pollution Control Act (Chapter 90.48 RCW). The Surface Water Quality Standards (Chapter 173-201A WAC) are the means for implementing these laws.

3.3.1 Determination of Designated Use Support Rating

Water bodies within the City of Shoreline support aquatic and water contact recreation designated uses. The water bodies are classified as supporting either Core Summer Salmonid Habitat or Salmonid Spawning, Rearing and Migration designated aquatic life uses. The water bodies are also designated for Primary Contact Recreation under the fresh water contact recreation bacteria criteria category. The water quality standards for those categories, as defined by these designated uses, are listed in Table 2. Collected water quality data was compared to these standards.

Table 2 - Water Quality Standards

Category (Designated Use)	Temperature (Highest 7-DAD Max) (Section 3.3.2)	Dissolved Oxygen (Lowest 1-DAD Min) (Section 3.3.3)	Turbidity (Section 3.3.5)	pH (Section 3.3.4)	Bacteria Indicator/Fecal Coliform Standards (Section 3.3.6)
Core Summer Salmonid Habitat	16 °C	9.5 mg/L	Turbidity shall not exceed 5 NTUs over background when the background is 50 NTU or less	pH shall be within the range of 6.5 to 8.5, with a human-caused variation within the above range of less than 0.2 units	X
Salmonid Spawning, Rearing and Migration	17.5 °C	8.0 mg/L			X
Primary Contact Recreation	X	X	X	X	Not more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies /100 mL. Geometric mean not to exceed 100 cfu /100 mL

Results of the analysis and comparison to water quality standards are expressed in percent compliance with the water quality standards. The United States Environmental Protection Agency (EPA) recommends using the specific frequency that data *exceed* numeric criteria to assess level of support for each designated use (EPA 1997). In the recommendation, results of the data comparison to water quality standards are expressed in percentage of readings not meeting state standards (percent not in compliance). The water quality condition of the water body or parameter was then rated according to EPA guidelines based on those percentages. If 25% or greater of the data exceed any one criterion, support of the specific use was considered "poor". If more than 11% but less than 25% of the data exceed the criterion, support of the specific use was assessed as "fair". If less than 10% of the data exceed the criterion, support of the use was considered "good". Waters that rate fair or poor for any given parameter are considered to be impaired.

For the purpose of this report, the percentages of compliance with standards were expressed as the frequency of data points *meeting* the water quality standards. The EPA recommended ranges were adjusted to reflect this and the percentages were reversed for each category. In other words, if the water body complied with standards 90% of the time or greater then the condition of the water body for that beneficial use was rated as "good". If the water body complied with the standard 75% to 90% of the time then the condition of the water body for that beneficial use was rated as "fair". If the water body complied with standards less than 75% of the time then the condition of the water body for that beneficial use was rated as "poor". (Table 3)

Table 3 - Designated Use Support Rating Categories

Percentage of Data Points Meeting Water Quality Standards	Designated Use Support Rating
90% or greater	Good
75% to 90%	Fair
Less than 75%	Poor

3.3.2 Temperature

The water quality standard for temperature is based on the 7-day average of the daily maximum temperature (7-DADmax). The 7-DAD Max is calculated for any given day by averaging the maximum temperature for the specific day as well as the three days prior and after the date. The data available for this study consists of only one discreet temperature value taken once per month at each location. Therefore, a direct comparison to water quality standards is not possible. For the purpose of this study, each discreet temperature value was compared directly to the water temperature maximum. It was determined that a reasonable assumption could be made by the results of that comparison. The direct comparison would still yield a percentage of temperature readings that are within the limits of the standard. It is assumed that this percentage is somewhat representative of what the results might be if compared to continuous temperature data.

In the future, temperature loggers might be deployed at priority stream sites in order to collect continuous data. It may be possible to calculate the 7-DAD Max and compare that to the water quality criteria in order to obtain a more accurate comparison to temperature water quality standards.

Temperature values were compared to the Aquatic Life Temperature Criteria for both Core Summer Salmonid Habitat and Salmonid Spawning, Rearing and Migration of 16 °C and 17.5 °C, respectively. The values exceeding these temperature limits were considered to be not in compliance

3.3.3 Dissolved Oxygen (DO)

The water quality limit for DO is a discreet value and is expressed as a 1-DAD Max which means the daily average of DO readings is directly compared to the standard. Because the water quality readings were collected at a discreet time point there is only one reading per day, per month. For the purpose of this study, each discreet DO value was compared directly to the DO minimum. The direct comparison would still yield a percentage of DO readings that are within the limits of the standard. It is assumed that this percentage is somewhat representative of what the results might be if compared to continuous temperature data.

Measured values were compared to the Aquatic Life DO Criteria for both Core Summer Salmonid Habitat and Salmonid Spawning, Rearing and Migration of 9.5 mg/L and 8.0 mg/L, respectively. The values that were below the DO minimum limits were considered to be not in compliance.

3.3.4 pH

Measured values were compared to the Aquatic Life pH Criteria for both Core Summer Salmonid Habitat and Salmonid Spawning, Rearing and Migration. For the "Core Summer Salmonid Habitat" category the water quality range for pH is between 6.5 and 8.5, with a human-caused variation within the range of less than 0.2. For the "Salmonid Spawning, Rearing and Migration" category the water quality range for pH is between 6.5 and 8.5 with a human-caused variation within range of less than 0.5 units. The difference between these two categories is the amount of human-caused variation allowed. For the purpose of this study, the more restrictive of the two categories was used.

The values that were above or below the allowable pH range were considered to be out of compliance.

3.3.5 Turbidity

Water Quality Standards for turbidity are based on background levels of turbidity, or turbidity levels that were present before development or modification of the watershed. The standard limit is relative to that background level. The water quality standard reads that the turbidity level must not exceed 5 NTUs above the background level.

Determining natural background levels of turbidity of urban streams is difficult. Streams and watersheds have been so extensively modified by urban development (in shoreline this modification began many years ago before any kind of monitoring was conducted) that merely sampling will not yield true background levels. No data exists during predevelopment or what might be considered the pre-development conditions, which are necessary for determining the natural background levels of a stream. Although background turbidity for these creeks has not been determined, it is likely similar to the lower range of values observed at the sample stations. A background turbidity that is between 1-5 NTU is realistic. For the purposes of this comparison, background turbidity levels are assumed to be a conservative value of 1 NTU. Therefore, the recorded turbidity levels above 6 NTU are considered to have exceeded water quality standards. The number of data points that were above the turbidity limit were considered to be out of compliance.

3.3.6 Fecal Coliform

Measured values were compared to the Water Contact recreation bacteria Criteria. The water quality standard in this designated use category states that Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies /100 mL, with not more than 10 percent of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies /100 mL. The geometric mean for each sampling station was calculated (Appendix C) and the results were analyzed for percentage of compliance with these standards. Individual bacteria readings at each station that exceeded 200 colonies /100 mL were identified.

4 RESULTS

4.1 Streams

Tables 4, 5 and 6 show the designated use support ratings for each stream monitoring station across all categories. Following the tables is a discussion of scoring results for each stream sampling station. For detailed scoring information at each specific sampling station, please see the tables in Appendix A and B.

Table 4 - Aquatic Life Designated Use Support Ratings for Streams											
	Boeing Creek (BC-2)	**Boeing Creek (BC-3)**	**Thornton Creek (TH-1)**	**Ronald Bog Inlet (RB-2)**	**Littles Creek (LT-1)**	**Meridian Creek (MRD-1)**	**McAleer Creek (MC-1)**	**Cedar Brook Creek (CB-1)**	**Storm Creek (ST-2)**	**Barnacle Creek (BRC-1)**	**Ballinger Creek (BL-1)**
Temperature; Core Summer Salmonid Habitat	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Fair
Temperature; Salmonid Spawning, Rearing and Migration	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	Poor	Fair	Poor	Poor	Poor	Poor	Poor	Fair	Poor	Poor	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	Good	Good	Fair	Poor	Fair	Poor	Good	Good	Good	Good	Fair
pH; Core Summer Salmonid Habitat **AND** Salmonid	Good	Good	Good	Good	Good	Fair	Good	Good	Good	Good	Good
Turbidity; Core Summer Salmonid Habitat **AND** Salmonid Spawning, Rearing and Migration	Good	Good	Fair	Poor	Fair	Poor	Fair	Fair	Good	Poor	Fair

Table 5 - Primary Contact Recreation Designated Use Support Rating for Streams By Season		
Sampling Site	**Year**	**Designated Use Support Rating**
Boeing Creek (BC-2)	2007	Good
	2008	Good
	2009	Good
Boeing Creek (BC-3)	2007	Good
	2008	Good
	2009	Good
Thornton Creek (TH-1)	2007	Poor
	2008	Poor
	2009	Poor
Littles Creek (LT-1)	2007	Poor
	2008	Poor
	2009	Poor
McAleer Creek (MC-1)	2007	Poor
	2008	Good
	2009	Fair
Cedar Brook (CB-1)	2007	Fair
	2008	Poor
	2009	Fair
Storm Creek (ST-2)	2007	Poor
	2008	Fair
	2009	Fair

Table 6 - Primary Contact Recreation Designated Use Support Rating for Streams By Geometric Mean	
Sampling Site	**Designated Use Support Rating**
Boeing Creek (BC-2)	Good
Boeing Creek (BC-3)	Good
Thornton Creek (TH-1)	Poor
Littles Creek (LT-1)	Poor
McAleer Creek (MC-1)	Good
Cedar Brook (CB-1)	Poor
Storm Creek (ST-2)	Poor

Boeing Creek (BC-2)

The Aquatic Life Designated Use Support Ratings at Boeing Creek water quality at station BC-2 were primarily “good”. This station scored “good” in all categories except the Core Summer Salmonid habitat category for dissolved oxygen, which received a rating of “Poor”. There were no exceedances of standards for temperature. Dissolved oxygen and pH standards in the Salmonid Spawning, Rearing and Migration aquatic life category were exceeded less than 5% of the time.

Boeing Creek station BC-2 received ratings of “good” in all Primary Contact Recreation Designated Use Support criteria categories.

Boeing Creek (BC-3)

The Aquatic Life Designated Use Support Ratings at Boeing Creek water quality at station BC-3 were primarily “good”. This station rated good in all categories except the Core Summer Salmonid habitat category for dissolved oxygen, which received a rating of fair. There were no exceedances of standards in temperature. dissolved oxygen and pH standards in the Salmonid Spawning, Rearing and Migration aquatic life category were exceeded less than 5% of the time.

Boeing Creek station BC-3 received ratings of “good” in all Primary Contact Recreation Designated Use Support criteria categories.

Thornton Creek (TH-1)

The Aquatic Life Designated Use Support Ratings at the Thornton Creek water quality at station ranged from “good” to “poor”. This station rated “good” in temperature and pH categories. “Fair” ratings were received in dissolved oxygen for Salmonid Spawning, Rearing and Migration and Turbidity aquatic life categories. However, the percentage of compliance in those categories was not far below the “good” rating threshold. The rating for dissolved oxygen in the Core Summer Salmonid Habitat aquatic life category was poor.

Thornton Creek received ratings of “poor” in all Primary Contact Recreation Designated Use Support criteria categories.

Ronald Bog Inlet (RB-2)

The Aquatic Life Designated Use Support Ratings at the Ronald Bog Inlet water quality at station ranged from "good" to "poor". This station received a good rating in the temperature and pH categories. The ratings were poor in dissolved oxygen and turbidity categories. Standards were exceeded less than 5% of the time in both temperature categories.

Littles Creek

The Aquatic Life Designated Use Support Ratings at the Littles Creek water quality at station ranged from "good" to "poor". This station rated "good" in temperature and pH categories. There were no exceedances of standards for the temperature; Salmonid Spawning, Rearing and Migration and pH categories. "Fair" ratings were received in dissolved oxygen for Salmonid Spawning, Rearing and Migration and turbidity. However, the percentage of compliance in those categories was not much below the good rating threshold. The rating for Dissolved Oxygen; Core Summer Salmonid Habitat was "poor".

Littles Creek received ratings of "poor" in all Primary Contact Recreation Designated Use Support criteria categories.

Meridian Creek (MRD-1)

The Aquatic Life Designated Use Support Ratings at the Meridian Creek water quality at station ranged from "good" to "poor". This station rated "good" in both temperature categories. There were no exceedances of temperature standards. The water quality condition for pH was rated as "fair". A "poor" rating was given to this water body in both dissolved oxygen categories and turbidity. Of the streams assessed, Meridian Creek exceeded the dissolved oxygen standards the most frequently.

McAleer Creek (MC-1)

The Aquatic Life Designated Use Support Ratings at the McAleer Creek water quality at station ranged from "good" to "poor". This station rated "good" in temperature, Dissolved Oxygen; Salmonid Spawning, Rearing and Migration and pH categories. Standards for both temperature categories, Dissolved Oxygen for Salmonid Spawning, Rearing and Migration and pH were exceeded less than 5% of the time. A "fair" rating was received for turbidity. However, the percentage of compliance was not much below the "good" rating threshold. The rating for Dissolved Oxygen; Core Summer Salmonid Habitat was "poor".

The Primary Contact Recreation Designated Use Support criteria ratings for McAleer Creek ranged from “good” to “poor”. In 2007, the seasonal rating was “poor”, in 2008 the rating was “good” and in 2009 the rating was “fair”. The rating based on the geometric mean was “good”.

Cedar Brook Creek (CB-1)

The Aquatic Life Designated Use Support Ratings at the Cedar Brook Creek water quality were either “good” or “fair”. This station received a “good” rating in all categories except Dissolved Oxygen; Core Summer Salmonid Habitat and turbidity. Cedar Brook Creek rated “fair” in those categories. There was no exceedance of standards in the Temperature; Salmonid Spawning, Rearing and Migration category. Temperature; Core Summer Salmonid Habitat, Dissolved Oxygen for Salmonid Spawning, Rearing and Migration and pH standards were exceeded less than 5% of the time.

The Primary Contact Recreation Designated Use Support criteria ratings for Cedar Brook Creek were either “fair” or “poor”. In 2007, the seasonal rating was “fair”, in 2008 the rating was “poor” and in 2009 the rating was “fair”. The rating based on the geometric mean was “poor”.

Storm Creek (ST-2)

The Aquatic Life Designated Use Support Ratings at the Storm Creek water quality were either “good” or “poor”. This station received a “good” rating in all categories except Dissolved Oxygen; Core Summer Salmonid Habitat in which a “poor” rating was received. However, the percentage of compliance in that category was not much below the fair rating threshold. There was no exceedance of standards in the Temperature; Salmonid Spawning, Rearing and Migration category. Temperature; Core Summer Salmonid Habitat, Dissolved Oxygen for Salmonid Spawning, Rearing and Migration and pH standards were exceeded less than 5% of the time.

The Primary Contact Recreation Designated Use Support criteria ratings for McAleer Creek ranged from “fair” to “poor”. In 2007, the seasonal rating was “poor” and in 2008 and 2009 the rating was “fair”. The rating based on the geometric mean was “poor”.

Barnacle Creek (BRC-1)

The Aquatic Life Designated Use Support Ratings at the Barnacle Creek water quality were either “good” or “poor”. This station received a “good” rating in all categories except Dissolved Oxygen; Core Summer Salmonid Habitat and turbidity. There were no exceedances of standards in the Temperature; Salmonid Spawning, Rearing and Migration and pH categories. Temperature; Core Summer Salmonid Habitat standards were exceeded less than 5% of the time. Cedar Brook Creek rated poor in the Dissolved Oxygen; Core Summer Salmonid Habitat and turbidity categories. However, the percentage of compliance in the turbidity category was not much below the “fair” rating threshold.

Ballinger Creek (BL-1)

The Aquatic Life Designated Use Support Ratings at the Ballinger Creek water quality ranged from “good” to “poor”. This station rated “good” in Temperature; Salmonid Spawning, Rearing and Migration and pH categories. Standards for those categories were exceeded less than 5% of the time. A “fair” rating was received for Temperature; Core Summer Salmonid Habitat, Dissolved Oxygen; Salmonid Spawning, Rearing and Migration and Turbidity categories. The percentage of compliance was not much below the “good” rating threshold for Temperature; Core Summer Salmonid Habitat and Turbidity though. The rating for Dissolved Oxygen; Core Summer Salmonid Habitat was “poor”.

4.2 Lakes

Tables 7, 8 and 9 show the designated use support ratings for each lake monitoring station across all categories. Following the tables is a discussion of scoring results for each lake sampling station. For detailed scoring information at each specific sampling station, please see the tables in Appendix A and B.

Table 7 - Aquatic Life Designated Use Support Ratings for Lakes		
	Echo Lake (ELO-1)	**Hidden Lake (HLO-1)**
Temperature; Core Summer Salmonid Habitat	Poor	Good
Temperature; Salmonid Spawning, Rearing and Migration	Poor	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	Poor	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	Poor	Good
pH; Core Summer Salmonid Habitat **AND** Salmonid	Fair	Good
Turbidity; Core Summer Salmonid Habitat **AND** Salmonid Spawning, Rearing and Migration	Fair	Fair

Table 8 - Primary Contact Recreation Designated Use Support Rating for Lakes By Season		
Sampling Site	**Year**	**Designated Use Support Rating**
Echo Lake (ELO-1)	2004	Fair
	2005	Good
	2006	Fair
	2007	Good
	2008	Good
	2009	Good
Hidden Lake (HLO-1)	2004	Poor
	2005	Good
	2006	Fair
	2007	Poor
	2008	Fair
	2009	Fair

Table 9 - Primary Contact Recreation Designated Use Support Rating for Lakes By Geometric Mean	
Sampling Site	**Designated Use Support Rating**
Echo Lake (ELO-1)	Good
Hidden Lake (HLO-1)	Poor

Echo Lake (ELO-1)

The Aquatic Life Designated Use Support Ratings for Echo Lake water quality ranged from “poor” to “fair”. This station received a “poor” rating in all categories except pH and turbidity.

The Primary Contact Recreation Designated Use Support criteria ratings for Echo Lake were primarily “good”. The seasonal ratings were “good” for 2005, 2007, 2008 and 2009. In both 2004 and 2006 and in 2008 the ratings were “fair”. The rating based on the geometric mean was “good”.

Hidden Lake (HLO-1)

The Aquatic Life Designated Use Support Ratings for Echo Lake water quality ranged from “good” to “poor”. This station rated “good” in temperature, Dissolved Oxygen; Salmonid Spawning, Rearing and Migration and pH categories. Standards for those categories, with the exception of pH, were exceeded less than 5% of the time. A “fair” rating was received in the turbidity category. The percentage of compliance was not much below the good rating threshold though. The rating for Dissolved Oxygen; Core Summer Salmonid Habitat was “poor”.

The Primary Contact Recreation Designated Use Support criteria ratings for Hidden Lake ranged from “good” to “poor”. In 2004 he seasonal rating was “poor”. In 2005 that rating was “good”. In 2006, 2008 and 2009 the ratings were “poor”. In 2007 the rating was “fair”. The rating based on the geometric mean was “poor”.

4.3 Wetlands

Table 10 shows the Aquatic Life Designated Use support ratings for each wetland monitoring station across all categories. Following the tables is a discussion of scoring results for each wetland sampling station. For detailed scoring information at each specific sampling station, please see the tables in Appendix A.

Table 10. Designated Use Support Rating for Wetlands		
	Meridian park Wetland (MD-C)	**Ronald Bog (RB-1)**
Temperature; Core Summer Salmonid Habitat	Good	Poor
Temperature; Salmonid Spawning, Rearing and Migration	Good	Poor
Dissolved Oxygen; Core Summer Salmonid Habitat	Poor	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	Poor	Poor
pH; Core Summer Salmonid Habitat **AND** Salmonid	Poor	Good
Turbidity; Core Summer Salmonid Habitat **AND** Salmonid Spawning, Rearing and Migration	Poor	Poor

Meridian Park Wetland (MDC-1)

The Aquatic Life Designated Use Support Ratings for Meridian Wetland water quality were “good” or “poor”. This station received a “poor” rating in all categories except temperature. In the temperature category, standards were exceeded less than 5% of the time. The percentages of compliance in the “poor” categories were below 65%. All dissolved oxygen readings for Meridian Park Wetland did not meet standards.

Ronald Bog (RB-1)

The Aquatic Life Designated Use Support Ratings for Ronald Bog water quality were “good” or “poor”. This station received a “poor” rating in all categories except pH. The percentages of compliance in the “poor” categories were below 66%. The lowest frequency of compliance was in the Dissolved Oxygen; Core Summer Salmonid Habitat category. Water quality standards were only met 28.2% of the time in this category.

5 SUMMARY

5.1 Streams

In most water quality categories, streams within the City of Shoreline rated as "good". The majority of the streams met standards for temperature, pH and Dissolved Oxygen greater than 90% of the time for the Salmonid Spawning, Rearing and Migration beneficial use category. The most common water quality violation was in the Dissolved Oxygen, Core Summer Salmonid category. That means that the majority of streams failed to meet the dissolved oxygen standard of 9.5 mg/L more than 25% of the time. Turbidity ratings were almost as frequently in the "good", "fair" and "poor" categories, demonstrating that that parameter was highly variable.

In addition to stormwater inputs, streams are fed by groundwater to a significant degree. Groundwater tends to exhibit more stable water quality characteristics and typically contains far less pollutants than stormwater. The significant groundwater contribution may help dilute polluted runoff and stabilize water quality parameters closer to levels of natural, undisturbed stream surface water. Water bodies that receive more stormwater and less groundwater inputs are more likely to have impaired water quality.

In 2007 the City began estimating the water quality condition at a few stream monitoring stations using the Department of Ecology Water Quality Index (WQI) Scoring method (Ecology 2002). Collected water quality data was entered into the formula spreadsheet and a water quality "score" for that stream was calculated. The WQI score is a unitless number ranging from 1 to 100; a higher number is indicative of better water quality. In general, stations scoring 80 and above met expectations for water quality and are of "lowest concern," scores 40 to 80 indicate "marginal concern," and water quality at stations with scores below 40 did not meet expectations and are of "highest concern." Table X shows the stations for which a WQI score was calculated and the resulting score.

Table 11 - Water Quality Index Score and Impairment Levels for Selected Streams			
Sampling Station	**Year**	**Numerical Score**	**WQI Impairment Level**
Boeing Creek (BC-2)	2007-2008	55	Marginal Concern
	2008-2009	74	Marginal Concern
Boeing Creek (BC-3)	2007-2008	60	Marginal Concern
	2008-2009	76	Marginal Concern
Thornton Creek (TH-1)	2007-2008	32	Highest Concern
	2008-2009	29	Highest Concern
Littles Creek (LT-1)	2007-2008	26	Highest Concern
	2008-2009	15	Highest Concern
McAleer Creek (MC-1)	2007-2008	35	Highest Concern
	2008-2009	57	Marginal Concern
Cedar Brook Creek (CB-1)	2007-2008	46	Marginal Concern
	2008-2009	56	Marginal Concern
Storm Creek (ST-2)	2007-2008	29	Highest Concern
	2008-2009	26	Highest Concern

There are several reasons why the WQI score cannot be directly compared to the results of this report. First, calculations for the WQI score are based on the water year, September through October of each year, instead of the calendar year. Second, the WQI score is an imperfect number designed to give decision makers that are not water quality experts general information on water quality conditions that can be a helpful guide when making water quality decisions. Thirdly, the calculation used in the WQI matrix is based on state water quality standards but the method for calculating the score is different than the one used in this report. However, the WQI scores can loosely be compared to the results of this report for relative water quality impairment levels. The WQI Impairment levels in the selected streams indicate that these streams are moderately to severely impacted by urbanization which is consistent with the findings of this report.

5.2 Lakes

In most water quality categories, lakes within the City of Shoreline rated as "fair" or "poor". Both Echo Lake and Hidden Lake did not meet standards more than 25% of the time in the Dissolved Oxygen; Core Summer Salmonid Habitat category and were rated "poor". Both lakes rated "fair" in the turbidity category and the ratings in the other categories varied primarily between "good" and "poor", indicating that there was high variability. In the categories where there was high variability, Hidden Lake primarily received good ratings while Echo Lake primarily received poor ratings. This indicates that the overall health of Hidden Lake was better than that of Echo Lake.

These lakes receive water from stormwater runoff, streams and groundwater, but the percentage of each that the lakes receive is highly varied. Boeing Creek flows all-year-round into Hidden Lake. The lake water is essentially being "flushed" from the lake on a constant basis. Boeing Creek does receive a large amount of stormwater input at the headwaters located along the Highway 99 business district. However, that runoff passes through stormwater treatment and detention ponds before continuing to flow into Hidden Lake. The land immediately surrounding Hidden Lake is primarily undeveloped or lightly developed residential parcels. Therefore, Hidden Lake receives little direct stormwater runoff.

In contrast, the inputs to Echo Lake consist only of stormwater runoff and groundwater. No streams flow into this lake so the water contained in the lake primarily remains there until the lake level is high enough for there to be outflow to Lake Ballinger. The lake receives direct stormwater runoff from the highly-traveled Highway 99 (Aurora Highway) to the west. The land surrounding the lake is primarily residential and commercial developments.

The monitoring results of the Echo Lake chemical and physical parameters indicate that the lake is moderately to severely impacted by stormwater. The chemical and physical condition of Hidden Lake is better than Echo Lake. However, bacteria levels in Hidden Lake exceed water quality standards more often than at Echo Lake.

In 2005 the City began monitoring Echo Lake as part of the King County Lake Stewardship Program. Regular monitoring has been continued through 2009. Samples collected are analyzed for phosphorous, nitrogen, chlorophyll and phytoplankton. Temperature is measured at the time of sample collection. Data collected by the City is submitted to King County for analysis. This information is summarized in a report provided to the City. These reports state that, overall, Echo Lake is high in primary productivity (eutrophic) with fair water quality. The parameters that are measured can be related to runoff from the surrounding lands and the fair water quality may indicate that the lake is impacted by that runoff. This assessment is consistent with the findings of this report.

5.3 Wetlands

In most water quality categories, wetlands within the City of Shoreline rated "poor". Meridian Park Wetland and Ronald Bog did not meet standards more than 25% of the time in dissolved oxygen and turbidity categories and so they rated "poor" in these categories. In the pH category, the frequency of standards met was at two extremes. Ronald Bog met pH standards more than 90% ("good" rating) of the time while Meridian Creek met standards less than 75% ("poor" rating) of the time. The frequency with which water quality standards were met in the temperature categories was also at two extremes. Meridian Park Wetland met standards over 90% ("good" rating) of the time and Ronald Bog met standards less than 75% ("poor" rating) of the time. Both wetlands rated "poor" in the turbidity category.

Wetlands receive water inputs from stormwater runoff, streams, and groundwater. Wetlands, like lakes, are considered a "window" into the groundwater water table and the water tends to flow much more slowly through them than in streams. This means that the water in wetlands is not getting the chance to mix with oxygen on the surface, as it does in many streams. In addition, the slow moving water has more residence time in a wetland and can be more affected by the process of decaying organic material. Decaying organic material tends to consume oxygen in the process of decomposition. Turbidity can also be affected by the decaying matter and detritus that is present in a wetland. These detritus particles can be suspended in the water column on a frequent basis and are easily stirred up into the water column during sampling activities. Although low dissolved oxygen levels and high turbidity levels are present in most stormwater runoff, the inherent quality of wetlands can make it hard for the water to recover from those variances once it reaches the wetland.

6 CONCLUSION

The findings of this report indicate that the water quality in Shoreline waterbodies is moderately to severely impacted by stormwater and the effects of urbanization. These findings are consistent with the findings of the 2007 City of Shoreline Bioassessment Report (Watershed Company 2009) which assessed the biological and habitat conditions of five Shoreline streams. The condition classification based on level of biological impairment in all sites surveyed was "extreme". The report also indicated that the level of channel entrenchment, which is related to quantity of runoff to that creek, was moderate to high. The report concluded that in 2007 each of the streams surveyed showed some evidence of historical degradation, which is likely the result of urbanization; that finding is consistent with the results of this report.

Three water quality parameters that could be improved in Shoreline streams and lakes were identified by the results of this report. The parameters include dissolved oxygen, turbidity, and fecal coliform. Only Boeing Creek consistently rated "good" in all dissolved oxygen and turbidity categories. Bacteria levels were identified as a significant problem in Thornton Creek, Littles Creek, McAleer Creek and Hidden Lake. If water quality improved in these three categories, the water quality in Shoreline streams might more consistently meet state water quality standards and be considered to be in good condition.

Many factors can contribute to the levels of the parameters analyzed in this report and the frequency with which water quality standards are not met. The parameters can be affected by both natural and artificial inputs. For example, temperature naturally fluctuates with the season and air temperature. The temperature of the water body will be significantly higher in the summer than in the winter and can be significantly affected by hot, dry weather patterns. As noted earlier in the report, areas of slower moving water can be more affected by decaying matter. This decaying matter can have a significant influence on dissolved oxygen and turbidity levels. The City cannot control or significantly influence the natural factors that may affect water quality but can influence the artificial and human induced adverse impacts on water quality.

According to the Washington State Department of Ecology, stormwater is the number one water pollution problem in the urban areas of our state. By reducing the volume of stormwater runoff flowing into Shoreline water bodies, or amount of contaminants contained in it, water quality can be improved. To reduce the impacts of stormwater, the City implements programs and projects designed to control the source of contaminants on the ground that can be carried away by runoff and the amount or runoff being produced. The City already has many programs in place such as the Illicit Discharge Detection and Elimination Program, the Car Wash Kit Program, and the Commercial Storm Drain Inspection Program. Examples of capital projects that will improve water quality include the recently constructed Panterra, Boeing Creek Park, and Cromwell Park stormwater facilities and Greenworks Program (Low-impact development stormwater retrofit program). By continuing to increase the program and capital project efforts, the City may help to improve stream water quality conditions. For example, new treatment facilities placed in line with stormwater systems, or at the end of pipes of older stormwater systems could also reduce the amount of contaminants and volume of stormwater flowing from these systems.

This report serves as a base line for future water quality comparisons, will assist in tracking measurable improvements and will help to guide future management activities. To get the best overall picture of water body health and trends, data must be tracked over many years. A negative trend is more easily identified and proven than a determination of water quality improvement. Only the comparison of several years of water quality data to this study will provide a more comprehensive view of water quality trends within the City of Shoreline. The City will continue to monitor water quality in the waterbodies identified in this report. This future data will be compared to the findings of this report and will help determine if current water quality programs and regulations are effective in maintaining or improving water quality; as a result, the City will be able improve existing programs, create new programs and capital projects, and provide potential regulatory recommendations to improve the water quality within Shoreline and downstream neighboring jurisdictions.

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8 APPENDICES

APPENDIX A

Detailed Sampling Station Aquatic Life Designated Use Support Rating Information

Streams

Boeing Creek (BC-2)

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	100%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	63.6%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	96.3%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	98%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	91.6%	Good

Boeing Creek (BC-3)

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	100%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	83.2%	Fair
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	97.2%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	99%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	93.8%	Good

Thornton Creek

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	90.8%	Good
Temperature; Salmonid Spawning, Rearing and Migration	99.1%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	53.8%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	89.6%	Fair
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	95%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	88.2%	Fair

Ronald Bog Inlet (RB-2)

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	95.8%	Good
Temperature; Salmonid Spawning, Rearing and Migration	97.2%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	33.8%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	52.1%	Poor
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	63.6%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	55.6%	Poor

Littles Creek

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	98.1%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	27.6%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	88%	Fair
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	100%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	87.2%	Fair

Meridian Creek

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	100%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	4.9%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	13.4%	Poor
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	75%	Fair
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	74.3%	Poor

McAleer Creek

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	95.3%	Good
Temperature; Salmonid Spawning, Rearing and Migration	98.1%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	63.8%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	98.1%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	98%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	88.9%	Fair

Cedar Brook Creek

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	96.2%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	77.5%	Fair
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	97.1%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	99%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	87.9%	Fair

Storm Creek

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	96.2%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	73.8%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	98.1%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	95.9%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	91.4%	Good

Barnacle Creek

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	96.2%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	60%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	90.9%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	100%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	74.6%	Poor

Ballinger Creek

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	88.8%	Fair
Temperature; Salmonid Spawning, Rearing and Migration	97.2%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	43.8%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	79%	Fair
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	96.9%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	88.2%	Fair

Lakes

Echo Lake

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	58.1%	Poor
Temperature; Salmonid Spawning, Rearing and Migration	63.5%	Poor
Dissolved Oxygen; Core Summer Salmonid Habitat	31.9%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	54.2%	Poor
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	85.1%	Fair
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	85.2%	Fair

Hidden Lake

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	96.1%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	69.3%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	96%	Good
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	93.7%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	72.7%	Fair

Wetlands

Meridian Park Wetland

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	98.4%	Good
Temperature; Salmonid Spawning, Rearing and Migration	100%	Good
Dissolved Oxygen; Core Summer Salmonid Habitat	0%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	0%	Poor
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	34.5%	Poor
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	64%	Poor

Ronald Bog (RB-1)

	Percent Compliance with Standards	Designated Use Support Rating
Temperature; Core Summer Salmonid Habitat	60%	Poor
Temperature; Salmonid Spawning, Rearing and Migration	65.7%	Poor
Dissolved Oxygen; Core Summer Salmonid Habitat	28.2%	Poor
Dissolved Oxygen; Salmonid Spawning, Rearing and Migration	51.5%	Poor
pH; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	88.2%	Good
Turbidity; Core Summer Salmonid Habitat AND Salmonid Spawning, Rearing and Migration	56.9%	Poor

APPENDIX B

Detailed Sampling Station Primary Contact Recreation Designated Use Support Rating Information

Streams

Annual Data Point Analysis

Sampling Site	Year	Percent Compliance With Standards	Exceeded Water Quality Standard*	Designated Use Support Rating
Boeing Creek (BC-2)	2007	91.7%	No	Good
	2008	100.0%	No	Good
	2009	100.0%	No	Good
Boeing Creek (BC-3)	2007	91.7%	No	Good
	2008	91.7%	No	Good
	2009	100.0%	No	Good
Thornton Creek (TH-1)	2007	33.3%	Yes	Poor
	2008	58.3%	Yes	Poor
	2009	58.3%	Yes	Poor
Littles Creek (LT-1)	2007	50.0%	Yes	Poor
	2008	75.0%	Yes	Poor
	2009	33.3%	Yes	Poor
McAleer Creek (MC-1)	2007	83.3%	Yes	Poor
	2008	91.7%	No	Good
	2009	83.3%	Yes	Fair
Cedar Brook (CB-1)	2007	75.0%	Yes	Fair
	2008	58.3%	Yes	Poor
	2009	75.0%	Yes	Fair

* Not More than 10% of all samples used to calculate GEOMEAN (per season) can exceed the standard of 200 cfu/100mL

Geometric Mean Analysis

Sampling Site	Percentage WITHIN Geomean*	Designated Use Support Rating
Boeing Creek (BC-2)	100.0%	Good
Boeing Creek (BC-3)	100.0%	Good
Thornton Creek (TH-1)	12.5%	Poor
Littles Creek (LT-1)	20.8%	Poor
McAleer Creek (MC-1)	91.7%	Good
Cedar Brook (CB-1)	37.5%	Poor
* The frequency of data points that were within the standard of 100 cfu/100mL.		

Detailed Sampling Station Primary Contact Recreation Designated Use Support Rating Information

Lakes

Annual Data Point Analysis

Sampling Site	Year	Percent Compliance With Standards	Exceeded Water Quality Standard*	Designated Use Support Rating
Echo Lake (ELO-1)	2004	89.0%	Yes	Fair
	2005	95.0%	No	Good
	2006	89.0%	Yes	Fair
	2007	100.0%	No	Good
	2008	100.0%	No	Good
	2009	95.0%		Good
Hidden Lake (HLO-1)	2004	72.0%	Yes	Poor
	2005	94.0%	No	Good
	2006	80.0%	Yes	Fair
	2007	75.0%	Yes	Poor
	2008	79.0%	Yes	Fair
	2009	84.0%	Yes	Fair

* Not More than 10% of all samples used to calculate GEOMEAN (per season) can exceed the standard of 200 cfu/100mL

Geometric Mean Analysis

Sampling Site	Percentage WITHIN Geomean*	Designated Use Support Rating
Echo Lake (ELO-1)	94.6%	Good
Hidden Lake (HLO-1)	65.6%	Poor
* The frequency of data points that were within the standard of 100 cfu/100mL.		

APPENDIX C

Geometric Mean Calculation

The geometric mean (GEOMEAN) was calculated for the data points at each station. It is recommended that when averaging bacteria sample data for comparison to the geometric mean criteria, the data be averaged by season (Chapter 173-201A WAC). After the data was divided into subsets by year the geomean was calculated using the method used by King County (Elliot C. 2010). This method utilizes an Excel spreadsheet and the Excel GEOMEAN calculation. The geomean calculation multiplies the number string and then takes the square root instead of adding and then dividing and gives a more accurate estimate of the central tendency of the number population. To calculate the geomean for a particular data point, the data point and the 4 proceeding data points are entered into the equation. Because of this calculation, the first 4 readings of the season don't have an associated Geomean (the calculation requires 5 readings in order to get a geomean). The total number of geomean results exceeding this standard each season was identified and divided by the total number of data points in that seasonal subset. The resulting percentage reflected the frequency of which the data points were out of compliance with the standard. This percentage was then subtracted from 100 to obtain the percentage of readings that were in compliance with the standard.