Appendix F
Stream Habitat Report

Final Report

Stream Inventory and Habitat Evaluation Report

Including Juanita Creek, Forbes Creek, Yarrow Creek, and Cochran Springs Creek

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ACRONYMS

BFW	bankfull width
B-IBI	benthic index of biotic integrity
BNRR	Burlington Northern Railroad
BNSF	Burlington Northern and Santa Fe Railway Company
CAD	computer aided drafting
cfs	cubic feet per second
CIP	Capital Improvement Plan
City	City of Kirkland
cm	centimeters
DBH	diameter at breast height
DNR	Department of Natural Resources
Ecology	Washington State Department of Ecology
HGM	hydrogeomorphic
GIS	geographic information system
GPS	global positioning system
LWD	large woody debris
MGMC	moderate gradient mixed control
MS	mainstem
MWD	medium woody debris
NOAA	National Oceanic and Atmospheric Administration
NMFS	National Marine Fisheries Service
NWI	National Wetland Inventory
OHWM	ordinary high water mark
RCU	riparian condition unit
RCW	Revised Code of Washington

ACRONYMS (Continued)

ROW	right-of-way
RM	river mile
SWD	small woody debris
SWM	Surface Water Management
TIA	total impervious area
TSS	total suspended sediment
USDOT	U.S. Department of Transportation
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USBEM	Urban Stream Baseline Evaluation Method
USGS	U.S. Geologic Survey
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources
WSDOT	Washington State Department of Transportation
WRIA	Watershed Resource Inventory Area

EXECUTIVE SUMMARY

The City of Kirkland (City) is in the process of updating their Capital Improvement Plan (CIP). To begin the process, the City contracted Parametrix to conduct a detailed assessment of streams within the City limits to document existing (baseline) conditions. Information on baseline conditions collected during the inventory will allow the City to comply with state and federal regulations, assess ecosystem functions and processes, identify conservation and restoration opportunities (including opportunities to restore or improve salmonid habitat), and develop a science-based selection process for CIP projects.

STUDY APPROACH AND METHODS SUMMARY

Information from existing literature was supplemented with field reconnaissance to obtain an overall picture of the stream environments associated with the City's four major streams: Forbes Creek, Juanita Creek, Yarrow Creek, and Cochran Springs Creek. (Note: the inventory focused on instream conditions and riparian conditions immediately adjacent to the stream banks.) Detailed instream surveys were conducted for Forbes Creek and Juanita Creek. The instream survey was conducted according to the wadeable stream survey methods used by both King and Snohomish counties (King County 2001 and Parametrix 2001). Both existing data and data obtained from the instream survey were analyzed using the Urban Stream Baseline Evaluation Method (USBEM) developed for wadeable rivers and streams in the King/Pierce/Snohomish County region (R2 Resource Consultants et al. 2000). According to the USBEM, there are 10 variables critical to the evaluation of fish habitat:

- Bank condition
- Large woody debris (LWD)
- Passage barriers
- Water temperature
- Riparian condition
- Substrate composition in spawning areas
- Embeddedness in spawning areas
- Pool frequency
- Benthic invertebrate community
- Channel pattern and floodplain connectivity

Ratings of *Good, Fair,* or *Poor* were designated for each habitat variable using USBEM criteria, and the results are presented in this document. Data were also evaluated according to criteria developed by the National Oceanic and Atmospheric Administration Fisheries division (NOAA Fisheries, also known as the National Marine Fisheries Service, or NMFS) for salmonid habitats, and the results are presented in an appendix B. While the two methods evaluate essentially the same habitat variables, each has slightly different criteria for individual variables. To facilitate the evaluation of conditions, the area was divided into reaches. Forbes Creek was divided into seven reaches. Juanita Creek was divided into six reaches, three of which were surveyed by King County and three by the City's consultant. Only one reach of Yarrow Creek was sampled within the City limits.

KEY FINDINGS

Both Forbes and Juanita Creeks have similar impacts and resulting habitat implications. The single reach examined in Yarrow Creek was within a relatively undisturbed forest and shrub wetland near Lake Washington. This reach does not have the same limiting factors as the other streams. Cochran Springs Creek, portions of Forbes Creek with limited access, and a tributary of Juanita Creek were evaluated qualitatively. The limiting factors and habitat implications of Forbes, Juanita, and Cochran Springs Creek are:

Limiting Factors

- High sediment mobility
- Increased frequency of peak flows
- Lack of LWD
- Lack of channel complexity
- Lack of riparian vegetation

Habitat Implications

- Poor spawning habitat due to fine sediment and increased sediment transport
- Disconnected floodplain and riparian areas in forested reaches
- Fish blockages caused by sediment mobility
- Lack of sufficient pools and off-channel habitat for migration and rearing
- Low potential to recruit LWD

RESTORATION AND CONSERVATION OPPORTUNITIES

Properly functioning conditions will be difficult, if not impossible, to achieve for most habitat elements in Kirkland streams. Restoration to historical conditions is probably not feasible in urbanized watersheds (Booth et al. 2001), but the City may be able to improve ecosystem functions and prevent further habitat degradation by implementing a focused habitat conservation and rehabilitation program.

Specific CIP project sites are identified in Chapter 4. These represent various categories of habitat improvement defined by the Washington Joint Natural Resources Cabinet, which include property acquisition, fish passage improvement (removal of barriers), instream habitat improvement (such as bank stabilization), riparian improvements (planting native woody vegetation on stream banks), and community outreach and education. The following are opportunities to enhance and restore Kirkland streams.

- Restoring natural bank condition in areas where existing revetments have failed
- Installing LWD to build channel complexity and create functional pools

- Acquiring undeveloped areas along the stream banks to prevent further degradation of shoreline habitat
- Preserving and enhancing wetlands and high-quality riparian areas through regulatory controls and public outreach

Many of the factors that affect habitat quality result from actions that extend beyond the City's jurisdiction. Additional measures that address basin hydrology, sediment transport, impervious surface area, and water quality at a watershed scale will need to be explored and pursued in conjunction with neighboring jurisdictions and the Washington State Department of Transportation (WSDOT) if long-term and sustainable habitat improvements are to be achieved.

1. INTRODUCTION

The City of Kirkland (City) is in the process of updating their Capital Improvement Plan (CIP). To begin this process, the City contracted Parametrix to conduct a detailed assessment of streams within the City limits and to document existing (baseline) conditions. Information collected on baseline conditions during the inventory will allow the City to comply with state and federal regulations, assess ecosystem functions and processes, identify conservation and restoration opportunities to improve salmonid habitat, and develop science-based selection process for CIP projects.

1.1 PURPOSE AND ORGANIZATION OF REPORT

This report presents the methods and results of a quantitative stream inventory of the City's major streams and subbasins, Forbes Creek and Juanita Creek, and a qualitative assessment of Kirkland's smaller drainages (Figure 1-1). The 1998 document; *Kirkland's Streams, Wetlands and Wildlife Study* (Watershed Company 1998) provides a summary of the City's watershed conditions including land use, wetlands, fish, and wildlife. Because general conditions have changed little since 1998, this report will not reiterate the watershed conditions presented in the 1998 document, but will instead address the site-specific conditions within these streams. In some cases, instream habitat degradation has become more pronounced since 1998 and will require a prioritized approach to capital improvement. Specifically, this report describes the data sources and methods used to identify, map, and assess existing stream habitat conditions and recommends specific projects to improve stream habitat. The report is organized as follows:

Chapter 2 describes stream inventory methodologies and data analysis.

Chapter 3 describes the specific habitat attributes of individual stream reaches and evaluates habitat information and potential limiting effects of habitat on salmonids.

Chapter 4 identifies potential ecosystem based CIP projects the City may undertake to enhance stream habitat. The projects were developed using information on limiting factors and observations during the instream survey.

Data was assessed using the Urban Stream Baseline Evaluation Method (USBEM) developed by the Tri-County Urban Issues Advisory Committee (R2 Resource Consultants 2000). This methodology provides a more detailed assessment of habitat conditions within an urban system than the National Marine Fisheries Services' (NMFS) Pathways and Indicators Analysis of Limiting Factors (NMFS 1996). The USBEM and NMFS methodologies use different criteria and assess slightly different habitat parameters. The NMFS methodology uses criteria based on forested, non-impacted stream basins while the USBEM methodology was specifically designed to evaluate streams in somewhat disturbed urban settings. There is no direct correlation between the two methodologies.

Figure 1-1 Kirkland Stream Basins

2. METHODS

This project involved detailed assessment of selected streams within the Kirkland city limits to document existing (2003) conditions. Detailed instream surveys were conducted on selected reaches of Juanita Creek, Forbes Creek, and Yarrow Creek. The instream surveys measured and evaluated habitat attributes, including bankfull width (BFW), large woody debris (LWD), pool frequency, bank condition, substrate composition, fish passage barriers, and riparian vegetation according to USBEM (R2 Resource Consultants 2000). Ecosystem functions associated with other streams located with the City (e.g. Cochran Springs Creek) were characterized based on qualitative field verification. A detailed description of the study methods is provided below.

2.1 INSTREAM SURVEY

2.1.1 Study Area

The study area for the quantitative instream survey included the mainstem of Forbes, Juanita, and Yarrow Creeks within the limits of the City of Kirkland. Additionally, portions of Forbes Creek with limited access, Cochran Springs Creek, and a tributary of Juanita Creek were evaluated qualitatively. In Forbes Creek, physical habitat surveys were conducted in seven reaches, encompassing nearly the entire mainstem, with the exception of portions of the two, large wetlands downstream of 108th Avenue NE. Three reaches of Juanita Creek were surveyed, this data supplementing data gathered in a previous survey by King County (King County 2002). All of these survey efforts took place in September 2003. Quantitative stream data for one reach of Yarrow Creek were obtained from a stream survey, using similar methodology, performed by Parametrix in the spring 2002 for the Washington Department of Transportation SR 522 project (Parametrix in preparation). Geographic Information System (GIS) data sets for the project area were obtained from the City of Kirkland.

2.1.2 Field Data Collection

The instream survey field protocol was based on wadeable stream survey methods used by both King County (King County 2001) and Snohomish County (Parametrix 2001). Field crews walked Juanita Creek, Forbes Creek, and Yarrow Creek, collecting habitat data within individual stream reaches. The standard survey unit (reach) length varied from about 800 to 1800 feet. In cases where there were significant changes in the stream system and/or channel characteristics (e.g., landform, floodplain width, gradient, channel form, adjacent land use, or major stream confluences), the reach was ended and a new reach assessment begun. Where possible, an effort was made to end reaches at known geographic points (e.g. major road crossing or tributary confluences). Data collection began at the downstream end of each reach and proceeded upstream.

Seven reaches were sampled along Forbes Creek, three along Juanita, and one along Yarrow Creek (Table 2-1 and see Figure 1-1). Stream reaches were identified in the field as J (Juanita Creek), F (Forbes Creek), or Y (Yarrow Creek) with a number corresponding to the spatial order of the reaches going upstream (e.g., J1 would be the farthest downstream reach surveyed on Juanita Creek). The reach start location was identified with a description of geographic features (e.g., road crossings, prominent buildings, etc.). Reaches on Juanita Creek previously surveyed by King County are identified using the alphabetical code KC, with a number corresponding to the location of the reach relative to the current survey reach numbers (e.g., KC1 is located immediately upstream from J1).

Table 2-1. Start and End Points for Stream Reaches[1]

Stream	Reach Number	Feet Surveyed	Start Point	End Point
Forbes Creek	F1	543.9	Market Street Bridge	543 feet upstream (east) of start point
	F2	810	108th Avenue	810 feet upstream (east) of 108th Avenue
	F3	1149	810 feet upstream (east) of 108th Avenue	About 40 feet upstream (east) of Forbes Creek Road
	F4	1509	About 40 feet upstream (east) of Forbes Creek Road	About 1,540 feet upstream (east) of Forbes Creek Road
	F5	763.5	About 1,540 feet upstream (east) of Forbes Creek Road	At parking lot of Rockwell Industries
	F6	796.2	Immediately upstream of I-405	265 feet upstream from start
	F7	1426.5	Immediately upstream (east) of Slater Avenue NE	At outlet of Forbes Lake
Juanita Creek	J1	1842	30 feet upstream from Lake Washington	Foot bridge in apartment complex just upstream from Juanita Park boundary
	KC1	492	Juanita Beach Park Property	490 feet upstream of start location
	J2	1223.1	Immediately upstream of NE 120th Street	450 feet downstream of culvert replacement at Apartment Complex
	KC2	999.4	NE 122nd Street	750 feet upstream from 124th Street
	J3	1221.6	At dual bridges near Apartment Complex	At NE 129th Place
	KC3	1485.8	NE 129th Place	500 feet upstream from Edith Moulton Park
Yarrow Creek	Y1	414.6	417 feet downstream of confluence with East Tributary of Yarrow Creek	Confluence with mainstem of Yarrow Creek

[1.] This table does not include sections of Kirkland Streams that were assessed qualitatively.

Field crews created a photographic record of significant habitat problems and sites of potential restoration. Photographs were taken using a digital camera and stored electronically. Field crews recorded instream data using a Juniper Systems Allegro™ Field PC. Data collection methods for each variable are summarized below. Appendix A contains a more detailed description of the field protocol.

2.1.2.1 Bankfull Width

Bankfull width (BFW) is the primary measure of channel size and is a criteria used to determine the minimum size of functioning pools and woody debris along the reach. It is the width of a stream channel at the point where overbank flow begins during a flood. BFW indicators include: the top of deposited bed load (gravel bars); stain lines; the lower limit of perennial vegetation, moss or lichen; a change in slope or particle size of the stream bank; and undercut banks (U.S. Forest Service [USFS] 1999).

The field crew measured BFW width three times within each reach: at the crest of the first riffle, at a riffle near the reach midpoint, and at the last riffle in the reach. Straight, low-gradient riffles with uniform banks were the best indicators of bankfull stage, and therefore BFW. When assessing BFW, the field crew avoided atypical riffles such as those undercutting banks or occurring in a bend. The field crew also recorded the wetted width of the stream at each BFW station.

2.1.2.2 Bank Condition

Bank conditions were recorded to assess channel response to watershed conditions. Stream bank instability and hydromodification were measured along both banks. The following features were noted:

- **Bank Instability.** Indications of breakdown, slumping, fracture, or banks that are vertical and eroding (Bauer and Burton 1993).

- **Hydromodification.** Seven categories of hydromodification were noted:

  DI: Dike/Levee/Berm
  RE: Revetment
  BU: Bulkhead
  BR: Bridge Footing
  BE: Beaver Dam
  DA: Dam
  CU: Culvert

  Hydromodification was further defined based on material composition:

  RI: Riprap – bank material over 10 inches (25.4 cm) in diameter
  RU: Rubble – bank material less than 10 inches (25.4 cm) in diameter
  ST: Structural – synthetic material such as wood, concrete, or metal gabion
  EA: Earth – artificially placed soil as well as other "natural" toe materials
  BE: Beaver Dam – material that was placed by beavers (*Castor canadensis*)

2.1.2.3 Wood Structure

The presence of wood in the stream was recorded to assess the type and amount of wood providing habitat complexity, hydraulic roughness, and hydrologic variability in the reach. Wood structures were classified into three categories (LWD, stumps, and small woody debris [SWD]) using the following definitions:

- **LWD.** Downed wood that substantially intercepted bankfull flow and was large enough to influence the formation of habitats (USFS 1999). "Key pieces" of LWD met the minimum criteria listed in Table 2.1-2, which are based on the initial BFW of the reach.

- **Stump.** A root wad with a diameter greater than or equal to 3 feet and not meeting the criteria for LWD. The root wad or attached bole significantly intercepted bankfull flow.

- **SWD.** Wood greater than 6 feet in length and 4 inches in diameter at the narrowest end.

Table 2-2. Minimum Size for LWD to Qualify as a Key Piece

Bankfull Width		Diameter		Length	
Meters	Feet	Meters	Feet	Meters	Feet
0 – 5	0 – 15	0.40	1.3	8	26
6 – 10	15 – 30	0.55	1.8	10	33
11 – 15	30 – 45	0.65	2.1	18	60
16 – 20	45 – 60	0.70	2.3	24	79

Source: WDNR (1997)

In addition to dimensions, LWD was characterized by root wad presence, wood type, decay class, and association with a jam. Field crews also noted the location and approximate size of woody debris that did qualify as a key piece of LWD, but in their professional judgment contributed significantly to the habitat structure and hydrologic roughness of the stream. These pieces are technically SWD and were included in the small wood tally. However, they are also noted separately in the results as medium woody debris (MWD).

2.1.2.4 Riparian Condition

Riparian vegetation influences the productivity and habitat quality of a stream reach by regulating stream temperatures and providing a source of nutrients and woody debris. During the instream survey, field crews visually assessed riparian vegetation from the stream channel. Their assessment was typically 50 to 100 feet from the ordinary high water mark (OHWM). Riparian condition units (RCUs) were identified based on the dominant vegetation composition and mapped (Table 2-3) (WDNR 1997). RCUs dominated by trees were further classified according to size (Table 2-4) and density (Table 2-5).

Table 2-3. Riparian Vegetation Types for King County Stream Surveys

Type	Code	Description
Conifer dominated	C	Forested, more than 70% of the trees are conifer
Deciduous dominated	H	Forested, more than 70% of the trees are deciduous
Mixed	M	Forested, no dominance greater than 70%
Shrub	S	Dominated by woody stemmed vegetation that does not reach > 40 feet at maturity, e.g., willows (*Salix* spp.), dogwood (*Cornus* spp.), and salmonberry (*Rubus spectabilis*)
Grass or Cleared	G	Pasture, row crops, maintained rights-of-way, orchards, parkland, landscaped areas, vacant fields, marshes, and wetlands not in open water.
Urban	U	Greater than 70% of RCU is paved or built-up. Includes roads, levees, railroads, and bridges

Table 2-4. Size Classifications for Riparian Trees

Type	Code	Description
Small	S	Dominant trees in the RCU: DBH between 3" and 12"
Medium	M	Dominant trees in the RCU: DBH between 12" and 20"
Large	L	Dominant trees in the RCU: DBH greater than 20"
Not applicable	X	Value applied to the shrub, grass, and urban classes

DBH = diameter at breast height.

Table 2-5. Density Classes for Riparian Trees

Type	Code	Description
Dense	D	More than one-third of the RCU is covered by trees
Sparse	S	Less than one-third of the RCU is covered by trees
Not applicable	X	Value applied to the shrub, grass, and urban classes

RCUs on each bank are identified using acronyms for vegetative type, size, and density on the field form. For example, a riparian zone on the left bank with a typical stand of 20-year-old alder would be classified HMD (deciduous dominant, medium-sized, dense canopy cover).

2.1.2.5 Pools, Riffles, and Substrate

Pools, riffles, and substrate measurements are required to characterize fish habitat within the stream longitudinal profile and are particularly important for assessing the habitat of spawning fish. Field crews identified functional pools according to Shuett-Hames et al. (1994). Data collected included maximum residual depth, as well as wetted and functional measurements of length, width, and area (See Appendix A for more detail).

Spawnable riffles are defined by the set of habitat conditions under which salmon will create redds. Numerous general references note that salmon and trout typically prefer to spawn on the leading edge of riffles, especially just below runs or pool tailouts (Scott and Crossman 1973; Wydoski and Whitney 1979). Salmon and trout select redd sites based on a number of connected factors, including substrate composition, water depth and velocity, bed gradient, water temperature, presence of subsurface flow or

groundwater influence, and competition from other spawners (Scott and Crossman 1973; Orsborn 1981; Crisp and Carling 1989; Kondolf and Wolman 1993). Because the survey was performed prior to the period of active migration and spawning, field teams professional judgment was based on qualitatively assessable parameters such as substrate composition (gravel or cobble dominant) and stream gradient (presence of pool/riffle morphology, not cascade or step/pool morphology). If a spawnable riffle was present, field crews determined the dominant and subdominant substrate according to the sizes defined by Bovee (1982).

Embeddedness also was measured in all riffles that potentially supported spawning. Embeddedness is the percent of substrate interstitial spaces that are filled with small-grain particles and is another indicator of spawning habitat quality. Embeddedness can also be used as a general measure of fine-sediment concentrations in the substrate (May et al. 1997). Embeddedness was visually estimated as low, medium, or high for each potential spawning riffle.

2.1.2.6 Secondary Channel Habitat

Secondary channels provide significant habitat for spawning and rearing. Secondary channels are defined as channels separated from the main channel by a stable island and containing the smaller portion of the total flow. Off-channel habitats are different from secondary channels and include marshes, ponds, and oxbow lakes that are outside the bankfull channel.

Secondary channels and off-channel habitats were evaluated using the qualitative habitat assessment sheet (Appendix A). No quantitative measurements of these features were taken, but the location (reach number, hip chain distance, right or left bank) was recorded on the sheet with a brief description of any significant features, such as amount of flow in the channel. Field crews determined whether the secondary channel was dry, connected at one end (channel type SC1), or connected at both ends (channel type SC2) at the time of the survey and recorded the corresponding code on the survey form.

2.1.2.7 Fish Passage Barriers

A fish barrier is any physical, physiographic, chemical, or biological obstacle to migration or dispersal of aquatic organisms (Armantrout 1998). Only physical barriers were examined instream. Field crews performed a rapid assessment of fish barriers based in part on the Washington Department of Fish and Wildlife (WDFW 2000) Level-A approach for culverts and non-culvert blockages (e.g., dams, bedrock-dominated shallow glides, cascades, etc.). This procedure examines barrier characteristics such as drop distance at culvert outlets, culvert gradient, roughness of inner culvert surfaces, depth of plunge pools at culvert outlets, and culvert length. In most cases, culverts either were or were not obvious barriers. It should be noted that the WDFW method is specific to upstream migration of adults but does not present criteria for assessing downstream juvenile migration or habitat-forming processes such as sediment and wood transport.

Surveyors walked or otherwise inspected perennial tributaries in their lower reaches, or at strategic points higher in the basin to assess culverts and channel gradient. Where access was available, surveyors walked upstream to a point at which the gradient increased to the probable extent of upstream fish passage. Surveyors determined the extent of possible upstream migration using their best professional judgment. In most cases, this point was unambiguous.

2.1.2.8 Benthic Index of Biotic Integrity (B-IBI)

The B-IBI for Puget Sound lowland streams (Kleindl 1995) represents the overall biotic condition of a stream using attributes of benthic macro-invertebrates. This index is one way to quantify the cumulative

impacts of development on the ecosystem and the level of degradation relative to a range of watershed conditions within the Puget Sound lowlands. B-IBI data were not collected during the instream survey, but data for Forbes and Juanita Creeks were obtained from the City and from King County Surface Water Management (SWM). Table 2-6 describes habitat conditions typically associated with different B-IBI scores.

Table 2-6. Description of Habitat Conditions Associated with B-IBI Scores

B-IBI Score	Associated Conditions
42-50	The best conditions without human disturbance; includes taxa most intolerant to disturbance; long-lived taxa are present; high richness within dominant orders and overall taxa; and large proportions of predators within trophic hierarchy
32-42	Lower taxa richness; loss of most disturbance-intolerant and long-lived species; however, richness is still high across major orders
25-31	Loss of intolerant taxa as well as some of the intermediately tolerant taxa; lower proportion of predator richness
18-24	Loss of most of the intermediate tolerant taxa, including loss of entire orders, leading to a higher proportion of highly tolerant taxa
10-18	Loss of most major orders; very low species richness; loss of nearly all predators; highly tolerant taxa remain

Note: Information modified from Karr and Chu. (1997).

2.1.3 Data Analysis According to the USBEM

Data from the instream survey and existing information review were analyzed according to the criteria outlined in the USBEM developed for rivers and streams in the King/Pierce/Snohomish county region (R2 Resource Consultants et al. 2000). According to the USBEM, there are 10 variables critical to the evaluation of fish habitat: bank condition, LWD, riparian condition, pool frequency, embeddedness in spawning areas, substrate composition in spawning areas, channel pattern and connectivity, passage barriers, water temperature, and benthic invertebrate community (Table 2-7). Of these, channel pattern was not assessed in this study. Each variable can be assigned a rating of good, fair, or poor based on specific criteria (Table 2-8). The criteria differ according to stream type (R2 Resource Consultants et al. 2000). For this study, field crews determined that all surveyed streams were floodplain-type streams.

2.1.4 Data analysis according to National Marine Fisheries Service

The intention of this report is to assess the urban streams of Kirkland using the USBEM. It is the opinion of the author that USBEM presents a more detailed assessment of the conditions within these urban streams. However, it is recognized that the National Marine Fisheries Service's (NMFS) "Pathways and Indicators of Limiting Effects" is an important assessment tool. The NMFS matrix and a summary table of the properly functioning conditions of the City's stream is presented in Appendix B, but is not discussed further in this report.

2.1.5 Supplemental Pool and Riffle Data Analysis

In addition to collecting and analyzing the habitat variables defined by USBEM, Parametrix conducted a more detailed evaluation of riffle habitat to obtain a more complete assessment of habitat quality.

Table 2-7. Overview of Instream Data Collection and Analysis Based for Habitat Variables Used in the USBEM

USBEM Habitat Variable	Description	Data Collection Method	Data Assessment Method
Bank Condition (Stability and Hydro-modification)	Assesses channel stability and response to watershed conditions.	Measured bank instability (e.g., slumping) and hydromodification (e.g., rip rap) extent based on observation of soil, vegetation and presence of artificial bank protection.	The total bank length of each reach was calculated as twice the reach length. The percent unstable and/or hydromodified bank was calculated by dividing the total unstable or hydromodified reach length by the total bank length per reach. Percent bank instability and percent hydromodification received a Good, Fair, or Poor habitat rating according to criteria in Table 2.1-7.
LWD	Type and amount of wood providing habitat complexity.	Counted stumps, SWD, and key pieces of LWD.	The total pieces (stumps, SWD, and LWD) and key LWD pieces were each divided by the reach length in units of BFW (as with the pool frequency measurement, stream reach lengths were converted to units of BFW) to determine total and key LWD densities. Total and key LWD densities were used to determine a Good, Fair, or Poor rating for each stream reach according to criteria in Table 2.1-7.
Riparian Condition	Streamside vegetation within 100 feet of the OHWM affects LWD recruitment potential. Other effects of the riparian condition such as shade, habitat complexity, and contribution of organic matter are not directly considered in the USBEM analysis.	Recorded and mapped riparian plant community based on dominate species composition, age class, and density.	Calculated the percent area of each type of riparian habitat within 100 feet of each reach's banks. Results are presented in terms of the Good, Fair, or Poor LWD recruitment potential criteria shown in Table 2.1-7.
Pool Frequency	Habitat area available for holding and rearing.	Criteria for minimum pool size are based on BFW and residual depth.	The reach length was first converted to units of BFW by dividing it by the mean BFW (the average of the three BFW measurements). Pool frequency was calculated by dividing the reach length in units of BFW by the number of pools in a reach (Greenberg 2002 personal communication). Pool frequency received a Good, Fair, or Poor habitat rating based on criteria in Table 2.1-7.
Embeddedness and Substrate	Substrate refers to the materials that compose the streambed. Embeddedness is the percent of interstitial spaces filled with small-grain particles. Both are important for spawning and egg incubation.	Dominant and subdominant particle size was assessed qualitatively. Embeddedness was assessed visually. Only spawnable riffles were assessed.	The number of riffles in a reach having identical embeddedness ratings (e.g., Good, Fair, and Poor) was divided by the total number of spawnable riffles in a reach to determine the percent of riffles in a reach having a Good, Fair, or Poor embeddedness rating. The number of riffles in a reach having identical substrate habitat ratings (e.g., Good, Fair, and Poor) was divided by the total number of spawnable riffles in a reach, to determine the percent of riffles in a reach having a Good, Fair, or Poor spawning substrate composition rating.

Table 2-7. Overview of Instream Data Collection and Analysis Based for Habitat Variables Used in the USBEM (continued)

USBEM Habitat Variable	Description	Data Collection Method	Data Assessment Method
Channel Pattern	Includes channel connectivity to off-channel habitat (e.g., wetlands and other areas of inundation), the relation of existing channel morphology to the stream's expected or historical condition, and channel sinuosity.	Secondary channels were identified and assessed qualitatively.	Channel patterns were not quantitatively assessed.
Passage Barriers	Physical constraints to fish movement or water quality barriers that limit access to habitat.	Physical passage barriers were assessed in the field using the Level A protocol defined by WDFW (2000).	Empirical results were compared to the USBEM criteria in Table 2.1-7.
Water Temperature	Desired or required water temperatures for spawning, incubation, rearing, and migration.	The instream survey did not include water temperature measurements. The City of Kirkland provided temperature data.	USBEM provides separate temperature criteria for the spawning and rearing of salmonids and bull trout. Bull trout have not been reliably documented in within the City of Kirkland; therefore, stream temperature data were compared to relevant published salmonid thresholds (McCullough 1999). Data were analyzed for the number of samples within the Good, Fair, or Poor range (per criteria in Table 2.1-8). Temperature habitat ratings were classified according to the maximum sampled temperature, although the distribution of temperatures was also provided.
Benthic Invertebrate Community	Species composition and diversity of stream invertebrates.	The instream survey did not include B-IBI assessment. The City of Kirkland provided B-IBI data.	B-IBI index values received a Good, Fair, or Poor habitat rating according to criteria in Table 2.1-8.

BFW is not assessed as a separate variable according to USBEM, but is needed to assess LWD, pool frequency, and other habitat parameters.

Table 2-8. USBEM Criteria for Rating Habitat Conditions[1]

Habitat Parameter	Habitat Condition[2]		
	Good	Fair	Poor
Bank Condition	>80% of banks are perennially vegetated and not artificially hardened	50 to 80% of banks are perennially vegetated and not artificially hardened	<50% of banks are perennially vegetated and not artificially hardened
LWD	If BFW is 33 to 66 ft, >0.50 key pieces/BFW;	If BFW is 33 to 66 ft, 0.20 to 0.50 key pieces/BFW;	If BFW is 33 to 66 ft, <0.20 key pieces/BFW;
	If BFW is <33 ft, >0.30 key pieces/BFW and >2 total pieces/BFW	If BFW is <33 ft, 0.15 to 0.30 key pieces/BFW and 1 to 2 total pieces/BFW	If BFW is <33 ft, <0.15 key pieces/BFW and <1 total piece/BFW
Riparian Condition	High recruitment potential	Medium recruitment potential	Low recruitment potential
Pool Frequency	If BFW is <60ft, <2 BFW/pool	If BFW is <60ft, 2 to 4 BFW/pool	If BFW is <60ft, >4 BFW/pool
Embeddedness	<20% in riffles and pool tailout units	20 to 40% in riffles and pool tailout units	>40% in riffles and pool tailout units
Substrate Composition in Spawning Areas	Gravel or cobble dominant	Gravel or cobble subdominant	Sand, silt, or bedrock dominant
Channel Pattern	Sinuous pattern with intact connections to adjacent wetlands or side channels	Sinuous pattern with connections to adjacent wetlands or side channels	Straightened pattern with disconnected wetlands or side channels
Passage Barriers	Upstream and downstream movement by species of concern is not restricted by barriers	Upstream and downstream movement by species of concern is restricted by barriers at some flows	Upstream and downstream movement by species of concern is restricted by barriers at most flows
Water Temperature	10 to 13.9 °C	13.9 to 15.6°C (spawning) 13.9 to 17.8°C (Migration and rearing)	>15.6°C (spawning) >17.8°C (Migration and rearing)
Benthic Invertebrate Community	BIBI > 32	BIBI 25 - 32	BIBI <25

[1] Taken from Table 5-7, R2 Resource Consultants (2000).

[2] Floodplain thresholds for 33 to 66 ft. BFW, MGMC thresholds for < 33 ft BFW.

Note: °C = degrees Celsius

2.1.5.1 Spawnable Versus Non-spawnable Riffles

Non-spawnable riffles are not included in the USBEM analysis of substrate composition and embeddedness. However, non-spawnable riffles are an important indicator of habitat quality. Therefore, we calculated the percent of spawnable riffles within each reach by dividing the number of spawnable riffles by the total number of riffles within a reach and converting to units of percent.

2.1.5.2 Pool to Riffle Ratio

Although not included in the USBEM, the pool to riffle ratio is another common indicator of salmon habitat quality. Nickleson et al. (1992) state that a 1 to 1 pool to riffle ratio is optimum for salmonid aquatic habitat. Platts et al. (1983) concur and note that a 1 to 1 ratio is commonly considered optimum,

but that the ratio may be skewed as far as 0.4 to 1 (Platts 1974) and still support a high biomass of salmonids. The pool to riffle ratio was calculated as the quotient of the total length of functional pools in a reach and the total length of riffles in a reach. Additionally, a pool to riffle to other ratio was calculated. Because neither of these ratios is described by USBEM, the results are not categorized in terms of a Good, Fair, or Poor rating.

2.1.6 Data Management and Quality Control

All data collection and analysis procedures underwent extensive quality assurance and quality control procedures, from designing the survey protocol to creating the summary tables and graphics in this report.

Field crews collected data electronically on a hand-held field PC. The field leader downloaded (i.e., backed-up) the field files the same day the data were collected. The field leader also checked all data in the office the day they were collected. Data errors were either corrected using logic, memory, or field notes or documented as incorrect.

Upon completing the instream data collection and initial quality check, the database manager compiled reach files into a single database. The field leader reviewed the data informally for macro-errors occurring across the entire database (e.g., to discover if data were entered under an incorrect header).

2.1.7 Qualitative Data Collection

Cochran Springs Creek, portions of Forbes Creek with limited access, and a tributary of Juanita Creek were evaluated qualitatively. The qualitative information was collected on a qualitative datasheet (Appendix A). These qualitative data are summarized by stream in the results section below.

3. RESULTS

The following are summaries of the reach-level stream assessments for Forbes, Juanita, and Yarrow Creeks using USBEM (R2 Resource Consultants 2000). The reach level is an appropriate scale of assessment in the development of CIP projects. It should be noted that several USBEM attributes easily lend themselves to a reach-level average (e.g. pool frequency) so that an overall assessment of the reach can be provided. For example, Forbes Creek Reach 3 had a very low pool frequency and was rated Poor for the entire reach. However, other attributes are not averaged over the reach, rather, their quality is reflected as a percentage of occurrence. For example, in the same reach of Forbes Creek there are 12 spawnable riffles, 28 percent of which had substrate with low embeddedness indicating Good quality, while 72 percent rated Fair due to increased embeddedness. Sub-reach-level data (raw data) are available in Appendix C and provide locations, relative to the reach starting point, of areas that have variable habitat ratings.

Below are summaries of the Forbes, Juanita, and Yarrow Creeks quantitative assessments followed by the qualitative assessments preformed on the smaller Kirkland drainages.

3.1 FORBES CREEK

3.1.1 Instream Conditions and USBEM Results

Forbes Creek was divided into seven reaches for the instream survey (F1 through F7) (Table 3-1 and Figure 3-1). Five of the reaches were located downstream of I-405, and two were located upstream between I-405 and Forbes Lake.

Table 3-1. Start and End Points of Stream Reaches

Stream	Reach Number	Feet Surveyed	Start Point	End Point
Forbes Creek	F1	543.9	Market Street Bridge	543 feet upstream (east) of start point
	F2	810	108th Avenue	810 feet upstream (east) of 108th Avenue
	F3	1149	810 feet upstream (east) of 108th Avenue	About 40 feet upstream (east) of Forbes Creek Road
	F4	1509	About 40 feet upstream (east) of Forbes Creek Road	About 1,540 feet upstream (east) of Forbes Creek Road
	F5	763.5	About 1,540 feet upstream (east) of Forbes Creek Road	At parking lot of Rockwell Industries
	F6	796.2	Immediately upstream of I-405	265 feet upstream from start location
	F7	1426.5	Immediately upstream (east) of Slater Avenue NE	At the outlet of Forbes Lake

Figure3-1 Forbes Stream Reaches

3.1.1.1 Passage Barriers

There are eight fish barriers in the mainstem of Forbes Creek (Table 3-2) according to the WDFW method. Two complete blockages that occur in Reach 4 have viable anadromous salmonid habitat upstream. Although these blockages are assessed as *complete* using the WDFW method, it is likely that some salmonids may pass under certain rare conditions. This may also be the case for the block under the railroad grade in Reach F5. However, under the Air Show Parking lot at 10801 120th Ave NE there is an absolute blockage. The culvert at this location outfall onto an approximately 20-foot-high riprap retaining wall and represents a total barrier to anadromous fish. The area upstream of this blockage was assessed for viable resident salmonid habitat. Because of these conditions, Forbes Reaches F1 through F3 receive a Good rating for passage and Reaches F4 through F7 receive a Poor rating.

Table 3-2. Fish Passage Problems on Forbes Creek

Reach Number	Type of Blockage	Location	Comment
F2	Partial	108th Avenue	Dual culverts blocked with sediment
F4	Complete	113 yards upstream from Forbs Creek Drive Crossing	Perched culvert with 1.6-foot drop
F4	Complete	310 yards upstream from Forbs Creek Drive Crossing	Concrete wall of old diversion dam has 1.6-foot drop into weir-formed pool. Ten feet further downstream is a weir wall where the stream then falls an additional 1.8 feet to rock.
F5	Complete	Under active rail road line	Greater than 1% grade and a velocity barrier
F5	Complete	Under the Air Show Parking lot at 10801 120th Avenue NE	350-foot-long culvert with 3-foot drop to riprap wall about 20 feet high. Complete block at end of reach.
F6	Partial	Slater Avenue NE	3-foot culvert with 0.8-foot hanging above rocks.
F7	Complete	South of NE 100th Street	In-line pond filled with sediment and metal trash rack with restricted openings.

3.1.1.2 LWD Recruitment Potential

Table 3-3 summarizes recruitment potential by reach in terms of the percent land cover within 100 feet of the stream bank providing Good, Fair, or Poor LWD recruitment potential. Three downstream surveyed reaches of Forbes Creek (F1 through F3) display the lowest recruitment potential, primarily because the riparian areas are composed of smaller hardwood trees, shrubs, and wetland type vegetation. Reaches F4 and F5 show higher recruitment potential, because they have a well-developed forested riparian zone associated with a lack of wetlands and residential development adjacent to these reaches. Upstream of I-405, the varied recruitment potential represents the mix of forested and residential land uses along the stream reaches.

Table 3-3. Recruitment Potential of LWD by Reach in Forbes Creek

Reach	USBEM Recruitment Potential Category (Percent of Total Area)			
	Good (High)	Fair (Medium)	Poor (Low)	None (Culvert)
F1	0	0	100	0
F2	19	0	81	0
F3	0	0	94	6
F4	0	65	28	6
F5	25	0	54	21
F6	23	41	34	2
F7	0	29	59	12

3.1.1.3 Large Woody Debris

Large woody debris conditions generally improve as one moves upstream from the stream's mouth, consistent with the LWD recruitment data. However, LWD density is rated Poor in three reaches (F1, F3, and F7), which contain no key pieces of LWD. Several of the LWD pieces that are found in Reach F4 and F5 are relic buried logs that are now engaging with the channel as the bed continues to erode. A large number of MWD pieces (i.e., LWD not meeting the USBEM key pieces criteria but still having a significant hydrologic effect on the stream) were observed and are detailed by reach in Table 3-4. These MWD pieces offer some channel structure diversity within the channel, but often do not provide the geomorphic functions of LWD such as sediment detention. The loss of in-channel LWD and the limited potential of future LWD, coupled with increased hydrological disturbance common in urban streams, leads to increased sediment mobility and subsequent loss of pool and riffle habitat.

Table 3-4. LWD Conditions by Reach in Forbes Creek

Reach	Pieces of MWD	Key Pieces of LWD	Total Pieces of MWD per BFW	Key pieces per BFW	USBEM LWD Condition
F1	8	0	0.52	0.00	Poor
F2	18	1	1.78	0.10	Poor
F3	18	0	2.00	0.00	Poor
F4	74	3	7.66	0.31	Good
F5	9	2	0.98	0.22	Fair
F6	50	5	5.54	0.55	Good
F7	2	0	0.28	0.00	Poor

3.1.1.4 Pool and Riffle Habitat

USBEM describes criteria for three measures of pool and riffle quality: pool frequency; riffle substrate composition; and riffle substrate embeddedness. This section also reports supplemental results that are not required by USBEM but provide a more complete view of pool and riffle habitat in Forbes Creek.

Pool Frequency

Table 3-5 describes the pool frequency habitat rating for each reach in terms of the number of BFWs one must walk upstream before encountering a pool. For example, if the BFW is 10-feet, USBEM assumes that if one pool exists for every 20 feet of stream channel length (one pool for every two BFWs), then the stream has "good" habitat rating. USBEM assumes that if there is one pool for every four or more BFWs, the stream is in poor condition. Reach F2 has the highest pool frequency (best conditions) within Forbes Creek, with one pool for every 11.5 BFWs, while Reach F7 has the worst pool frequency with only one pool for every 100 BFWs. All of the surveyed reaches within Forbes Creek received a Poor pool frequency rating. The frequency of functional pools are below optimal level, a condition likely attributable to pool sediment, the loss of scour pools in meanders due to channelization, and the lack of LWD[1].

Table 3-5. Pool Frequency by Reach in Forbes Creek

Reach	Pool Count Number	Mean BFW (Ft)	Reach Length (Ft)	Pool Frequency (BFW/Pool)[1]	USBEM Habitat Rating
F1	2	15.50	543.9	17.5	Poor
F2	7	10.10	810.0	11.5	Poor
F3	5	9.00	1149	25.5	Poor
F4	13	9.67	1509	12.0	Poor
F5	4	9.20	763.5	20.7	Poor
F6	4	9.03	796.2	22.0	Poor
F7	2	7.13	1426.5	100.0	Poor

[1] (Reach length/BFW)/pool count)

Riffle Substrate Condition

Table 3-6 describes substrate composition and embeddedness in spawnable riffles. The substrate composition rating is generally Good for all seven reaches, with riffle substrate dominated by gravels and cobbles. Reach F7 had the highest proportion of riffles with a Poor substrate rating, likely due to the dominant sand substrate within the low gradient sand-dominated reach. Embeddedness ratings are generally Fair. Reaches F3 and F5 have the least amount of substrate embeddedness, and Reach F7 is dominated by highly embedded riffles (again likely due to the low gradient and sand-dominated substrate). Reach F5 is downstream of a low gradient reach confined by a culvert. Fine material is deposited in this low-gradient basin, and this may account for the generally good substrate conditions present in Reach F5. Likewise, Reach F4 has a higher gradient than the downstream reaches and contains a large diversion dam and weirs that may function to trap sediment transported from upstream.

[1] In highly urbanized streams, sediment mobility can exceed the capacity of the limited LWD to provide stable scour pools.

Table 3-6. Spawnable Riffle Substrate Condition by Reach in Forbes Creek

Reach	Number of Spawnable Riffles	Attribute	USBEM Habitat Rating		
			Good (%)	Fair (%)	Poor (%)
F1	0	Composition	NA	NA	NA
		Embeddedness	NA	NA	NA
F2	17	Composition	91	0	9
		Embeddedness	5	86	9
F3	12	Composition	100	0	0
		Embeddedness	28	72	0
F4	21	Composition	99	0	1
		Embeddedness	3	94	3
F5	8	Composition	100	0	0
		Embeddedness	100	0	0
F6	11	Composition	94	0	6
		Embeddedness	0	94	6
F7	4	Composition	78	0	22
		Embeddedness	0	26	74

Supplemental Pool and Riffle Habitat Analysis

Table 3-7 describes the relative quantity of pool and riffle habitat in Forbes Creek and provides two comparisons of these attributes. All of the surveyed reaches, except Reach F7, showed pool to riffle ratios much less than the optimum of 1.0 suggested by Platts et al. (1983). Although Reach F7 has a nearly 1 to 1 pool to riffle ratio, habitat conditions for salmonids in the reach is poor, as 87 percent of the reach is glide habitat. When combined with pool frequency data, the calculated ratios indicate that Forbes Creek is dominated by riffles and glides, with relatively little pool habitat. Only about 10 percent (37 pools comprising 721 foot lineal length) of the total surveyed stream length (7,000 feet total) was composed of pool habitat. Although fine sediment did not dominate in riffles, many of the observed pools showed signs of filling with sediment.

Table 3-7. Comparison of Pool and Riffle Habitat in Forbes Creek

Reach	Total Reach Length (ft)	Total Pool Length (ft)	Total Riffle Length (ft)	Total Other Length (ft)	Pool/Riffle Ratio[1]	Pool:Riffle:Other[1] % of Total Length
F1	543.9	112.8	0.0	431.1	No riffles present	21:0:79
F2	810	129.6	387.9	292.5	0.33:1	16:48:36
F3	1149	52.8	957.0	139.2	0.06:1	5:83:12
F4	1509	171.0	1057.8	280.2	0.16:1	11:70:19
F5	763.5	81.0	493.5	189.0	0.16:1	11:65:25
F6	796.2	76.2	451.8	268.2	0.17:1	10:57:34
F7	1426.5	97.8	85.8	1242.9	1.14:1	7:6:87

[1] "Other" includes runs and glides.

3.1.1.5 Bank Condition

Bank condition is assessed in terms of bank stability and bank modification. Table 3-8 describes the percent of total bank length that is either unstable or modified and the corresponding habitat rating for these two parameters. All of the surveyed reaches show a bank condition rating of Fair or Good. The most downstream reaches (F1 and F2) have the best bank condition, largely due to the hydrologically connected wetlands within these reaches. The majority of Forbes Creek has stable banks, which is largely the result of the moderate hydromodification that has occurred along potions of the channel. In general, the data shows an inverse relationship between bank stability and the degree of hydromodification. The largest amount (16 percent) of bank instability occurred in Reach F6 while a moderate degree of hydromodifications, consisting of riprapped banks and culverts, exist in the middle and upper reaches of the stream, particularly within Reaches F3 and F5.

Table 3-8. Bank Stability and Modification in Forbes Creek

	Bank Condition			
Reach	**% Unstable Bank**	**% Modified Bank[a]**	**% Total**	**USBEM Rating**
F1	0.9	0.0	0.9	Good
F2	4.9	0.0	4.9	Good
F3	9.1	21.4	30.5	Fair
F4	6.9	12.7	19.6	Good
F5	2.8	33.7	36.5	Fair
F6	15.8	2.6	18.3	Good
F7	0.0	14.9	14.9	Good

[a] Modified length/total bank length

3.1.2 Benthic Index of Biotic Integrity

B-IBI scores are a measure of the general health of the instream invertebrate community and can be used as an indicator of overall habitat quality. The City of Kirkland maintains B-IBI monitoring at three stations along Forbes Creek. The data indicate that Forbes Creek has poor biotic integrity (Table 3-9).

Table 3-9. B-IBI Scores and Habitat Ratings in Forbes Creek

Reach	City Sampling Site	Year	Score[a]	Habitat Rating
		2001	14	Poor
F6	FC1	2002	14	Poor
		2003	18	Poor
		2001	16	Poor
F5	FC2	2002	12	Poor
		2003	20	Poor
		2001	14	Poor
F2	FC3	2002	14	Poor
		2003	16	Poor

[a] Refer to Table 2-6 for a description of the B-IBI scores.

3.1.3 Water Temperature

The City of Kirkland provided water temperature data for three stations along Forbes Creek. Table 3-10 describes the distribution of water temperatures from spring 2002 through winter 2003. While USBEM requires 7-day average maxim, the data contained here are grab samples taken once per month[2]. About 60 percent of these limited sample sites have optimal spawning temperatures under 15.6 degrees Celsius [57°F], and for rearing (over 17.8 °C [75.4 °F]). Poor conditions are common in the upper reach and Fair conditions throughout.

According to McCullough (1999), the maximum temperature for salmonid spawning is 57 °F (15.6 °C), the same as has been suggested by the USBEM for salmonids in general (except bull trout). A more complete temperature data set from Forbes Creek (including continuous temperature data) is needed to adequately evaluate any warming trends and the potential risk to ESA-listed fish species or salmonids in general.

Table 3-10. Frequency of Forbes Creek Water Temperature Grab Samples as Good, Fair, or Poor

City of Kirkland Station ID	Location	USBEM Rating as a Percent of Total Samples		
		Good	Fair	Poor
Spawning				
FC Site 2	Reach 2 - Directly upstream of the 108th Ave NE	60	35	5
FC Site 3	Reach 4 - Adjacent to overflow outfall of Coor's Pond	62	19	10
FC Site 4	Reach 6 - 50' Downstream of Slater Ave NE	60	10	30
Rearing				
FC Site 2	Reach 2 - Directly upstream of the 108th Ave NE	60	40	0
FC Site 3	Reach 4 - Adjacent to overflow outfall of Coor's Pond	62	33	5
FC Site 4	Reach 6 - 50' Downstream of Slater Ave NE	60	30	10

3.2 JUANITA CREEK

3.2.1 Instream Conditions and USBEM Results

Data was collected on the entire length Juanita Creek within the City limits; data from three reaches were collected in summer 2000 by King County (Reaches KC1-KC3) (King County 2002) and the remaining three reaches in fall 2003 by Parametrix (Reaches J1-J3) (Figure 3-2 and Table 3-11). The 2000 and 2003 data were assessed using USBEM guidelines (R2 Resource Consultants 2000). However, due to slightly different sampling protocols, some of habitat data collected by King County could not be assessed using the USBEM methodologies. The following sections report the results obtained from the empirical data analysis.

[2] USBEM acknowledges the difficulty of obtaining continuous water temperature data, which were not available for this study.

Figure 3-2 Juanita Stream Reaches

Table 3-11. Start and End Points for Stream Reaches on Juanita Creek

Stream	Reach Number	Feet Surveyed	Start Point	End Point
Juanita Creek	J1	1842	30 feet upstream from stream mouth at Lake Washington	Foot bridge in apartment complex just upstream from Juanita Park boundary
	KC1	492	Juanita Beach Park property line	490 feet upstream of start location
	J2	1223.1	Immediately upstream of NE 120th Street	450 feet downstream of culvert replacement project at Apartment Complex
	KC2	999.4	NE 122nd Street	750 feet upstream from 124th Street
	J3	1221.6	At dual bridges near Apartment Complex	NE 129th Place
	KC3	1485.8	NE 129th Place	500 feet upstream from Edith Moulton Park

3.2.1.1 Passage Barriers

There are no fish barriers in the mainstem of Juanita Creek; however, a culvert on the east branch of Juanita Creek is a total barrier to fish. The east branch of Juanita Creek enters this culvert in the western portion of Juanita High School via a drop culvert and travels 400 to 500 feet to its outfall adjacent to 103rd Place. The grade and length likely create a velocity barrier, and the drop structure into the culvert also creates a complete jump barrier. Within the City limits, Juanita Creek receives an overall rating of Good.

3.2.1.2 Recruitment Potential

Table 3-12 summarizes recruitment potential by reach in terms of the percent land cover within 100 feet of the stream bank providing Good, Fair, or Poor LWD recruitment potential. Recruitment potential was not available for the stream reaches surveyed by King County. All three surveyed reaches of Juanita Creek display a Poor recruitment potential, primarily because the riparian areas lack larger trees and are dominated by smaller hardwood trees, grass, or shrubs. Much of Reach J1 is located within open areas of Juanita Park, while Reaches J2 and J3 are dominated by residential and commercial development with landscaped lawns or shrubs adjacent to the streams.

Table 3-12. Recruitment Potential of LWD by Reach in Juanita Creek

Reach	USBEM Recruitment Potential Category (Percent of Total Area)			
	Good (High)	Fair (Medium)	Poor (Low)	None (Culvert)
J1	0	0	97	3
J2	0	0	100	0
J3	0	14	83	3

3.2.1.3 Large Woody Debris

LWD density is rated Poor for every reach Parametrix surveyed in Juanita Creek except reach J3, which had a LWD jam with several pieces of wood (although the remainder of the reach is devoid of LWD). However, a large number of MWD pieces (i.e., LWD not meeting the USBEM key pieces criteria but still having a significant hydrologic impact on the stream) were observed and are reported by reach in Table 3-13. It should be noted that King County protocol defines LWD criteria as wood that is greater than 15 centimeters (cm) in diameter, while USBEM protocol defines LWD as wood greater than 10 cm in diameter. Much of the MWD that Parametrix tallied as SWD ranged in diameter from 10 to 15 cm. Regardless, it is apparent that in both data sets, LWD conditions generally improve as one moves upstream from the mouth. This trend is consistent with the LWD recruitment data. The most upstream reach (J3) has over twice as much LWD as the lower reach (J1). The loss of in-channel LWD and the limited potential of future LWD, coupled with increased hydrological disturbance common in urban streams have likely contributed to increased sediment mobility and subsequent loss of pool and riffle habitat within Juanita Creek.

Table 3-13. LWD Conditions by Reach in Juanita Creek

Reach	Pieces of MWD	Key Pieces of LWD	Total Pieces of MWD per BFW	Key pieces per BFW	USBEM LWD Condition
J1	19	0	1.23	0.00	Poor
KC1	2	NA	0.10	NA	Unknown
J2	38	1	2.31	0.06	Poor
KC2	9	NA	0.51	NA	Unknown
J3	57	8	3.42	0.48	Good
KC3	13	NA	0.64	NA	Unknown

3.2.1.4 Pool and Riffle Habitat

USBEM describes criteria for three measures of pool and riffle quality: pool frequency; riffle substrate composition; and riffle substrate embeddedness. This section also reports supplemental results that are not required by USBEM, but provide a more complete view of pool and riffle habitat in Forbes Creek.

Pool Frequency

Table 3-14 describes the pool frequency habitat rating for each reach in terms of the number of BFWs one must walk upstream before encountering a pool. For example, if the BFW is 10 feet, USBEM assumes that if one pool is located for every 20 feet of stream channel length (one pool for every two BFWs), then the stream has good habitat. USBEM assumes that if there is one pool for every four or more BFWs, the stream is in poor condition. Only one reach (KC3) received a pool rating of Fair, all others received a rating of Poor. The frequency of functional pools is below optimal level, a condition likely attributable to sediment filling, the loss of scour pools in meanders due to channelization, and the lack of pool-forming LWD.

Table 3-14. Pool Frequency by Reach in Juanita Creek

Reach	Pool Count Number [a]	Mean BFW (Ft)	Reach Length (Ft)	Pool Frequency (BFW/Pool)[b]	USBEM Habitat Rating
J1	6	15.5	1842.0	19.8	Poor
KC1	6	18.4	492.0	4.6	Poor
J2	17	16.4	1223.1	4.4	Poor
KC2	13	17.4	999.4	4.3	Poor
J3	10	16.7	1221.6	7.3	Poor
KC3	19	20.7	1485.8	3.8	Fair

[a] For King County surveyed reaches, the number of pools was back calculated from pool frequency data.

[b] (Reach length/BFW)/pool count

Riffle Substrate Condition

Table 3-15 describes substrate composition and embeddedness in spawnable riffles. Only the three reaches surveyed by Parametrix were included because substrate and embeddedness information was not available for the reaches previously surveyed by King County. The substrate composition rating is Good for all three reaches. However embeddedness ratings, which are a better measure of fine sediment deposition at levels below the bed surface, range from Good to Poor, indicating that the substrate quality appears to decline as one moves upstream. Reach J1 is riprapped over much of the reach, leading to higher peak flows, which in turn may act to mobilize bed material and transport fine sediments to the mouth of the stream, where large amounts of sands and silts are deposited.

Table 3-15. Spawnable Riffle Substrate Condition by Reach in Juanita Creek

Reach	Number of Spawnable Riffles	Attribute	USBEM Habitat Rating		
			Good (%)	Fair (%)	Poor (%)
J1	9	Composition	100	0	0
		Embeddedness	59	41	0
J2	19	Composition	87	3	10
		Embeddedness	25	36	40
J3	12	Composition	89	0	11
		Embeddedness	18	33	48

Supplemental Pool and Riffle Habitat Analysis

Table 3-16 describes the general magnitude of pool and riffle habitat in Juanita Creek and provides two comparisons of these attributes. Half of the Reaches (KC1, J3, and KC3) have pool to riffle ratios near the optimum pool to riffle ratio of 1.0 suggested by Platts et al. (1983). Furthermore, the pools and riffles in those three reaches, composing 75 to 88 percent of the available habitat. However, when pool to riffle ratio data is analyzed in conjunction with pool frequency data, the results indicate that, in general, Juanita Creek has adequate pool and riffle habitat available.

Table 3-16. Comparison of Pool and Riffle Habitat in Juanita Creek

Reach	Total Reach Length (ft)	Total Pool Length (ft)	Total Riffle Length (ft)	Total Other Length (ft)	Pool/Riffle Ratio[a]	Pool:Riffle:Other[b] % of Total Length
J1	801.0	244.2	322.8	1275.0	0.76	13:18:69
KC1[a]	990.2	NA	NA	NA	1.15	46:40:14
J2	716.0	647.1	303.9	272.1	2.13	53:25:22
KC2[a]	722.0	NA	NA	NA	2.07	62:30:8
J3	1111.6	445.8	474.0	301.8	0.94	36:39:25
KC3[a]	227.4	NA	NA	NA	0.87	41:47:12

a From King County 2002

b "Other" includes runs and glides.

Note: NA = Data not available

3.2.1.5 Bank Condition

Bank condition is assessed in terms of bank stability and bank modification. Table 3-17 describes the percent of total bank length that is either unstable or modified and corresponding rating for bank condition. Bank condition ratings range from Good to Poor. The greatest bank instability occurred in Reach KC2, where 18 percent of the banks are unstable. However, more than 80 percent of banks are stable for every reach, likely the result of the extensive hydromodification that has occurred along the stream. A relatively high degree of hydromodification exists throughout the stream, particularly within the two lowest reaches (J1 and KC1) where over one half the total bank length of reach KC2 is hydromodified, primarily with riprap.

Table 3-17. Bank Stability and Modification in Mainstem Kirkland Creek

	Stability			
Reach	% Unstable Bank	% Modified Bank[a]	% Total	USBEM Rating
J1	5	27	32	Fair
KC1	0	57	57	Poor
J2	1	15	16	Good
KC2	18	18	36	Fair
J3	7	20	27	Fair
KC3	0	9	9	Good

[a] Modified length/total bank length

3.2.2 Benthic Index of Biotic Integrity

B-IBI scores are a measure of the general health of the instream invertebrate community and can be used as an indicator of overall habitat quality. The City of Kirkland maintains B-IBI monitoring at four stations along Juanita Creek. The data indicate that Juanita Creek has poor biotic integrity (Table 3-18).

Table 3-18. B-IBI Scores and Habitat Ratings in Juanita Creek

Reach	City Sampling Site	Year	Score[a]	Habitat Rating
KC3	JC1 (2001/2002)	2001	14	Poor
		2002	14	Poor
	JC1 (2003)	2003	22	Poor
J3	JC2 (2001/2002)	2001	18	Poor
		2002	18	Poor
	JC2 (2003)	2003	16	Poor
KC2	JC3 (2001/2002)	2001	16	Poor
		2002	16	Poor
	JC4 (2001/2002)	2001	16	Poor
		2002	16	Poor
J1	JC4 (2003)	2003	18	Poor

[a] Refer to Table 2-6 for a description of the B-IBI scores.

3.2.3 Water Temperature

Since 1976, King County has been conducting monthly baseline monitoring at two sites along Juanita Creek. One site is located at the USGS Gaging station north of Juanita Park, and the other is located at the bridge on NE 128th, east of 100th NE. The average baseflow temperatures at both stations were slightly above the median range for all stream sites combined (King County 2004). Twelve percent of the baseflow temperature measurements at the mouth of the creek and 10 percent of the upstream baseflow measurements exceeded the state temperature criterion. Since 1979, there has been a trend toward increasing temperatures at the mouth of Juanita Creek.

3.3 OTHER DRAINAGES

The City has assessed in other efforts other urban drainage basins within the city limits such as Kirkland Slope, Moss bay, Houghton Slope, Carillon Creek, and portions of Yarrow Creek. The conditions of these channels are not reported in this document, however, suggestions for potential CIP projects in these areas are addressed in the following chapter. The lower reach of Yarrow Creek was assessed quantitatively during a stream survey performed by Parametrix in spring 2002 for a WDOT SR 522 project (Parametrix in preparation). Additionally, the lower reach of Cochran Springs was assessed qualitatively during the 2003 effort. Summaries of these two reaches are provided below.

3.3.1 Yarrow Creek

3.3.1.1 Instream Conditions and USBEM Results

Quantitative stream data for one reach of Yarrow Creek were obtained from a stream survey, using similar methodology, performed by Parametrix in the spring 2002 (Figure 3-3 and Table 3-19). The reach is located in the Yarrow Creek wetlands, near the mouth at Lake Washington. Survey results were converted to numerical criteria that could be evaluated according to USBEM guidelines (R2 Resource Consultants 2000). Because only one of the reaches surveyed in this study was in the City limits, only a brief summary of the results are provided below.

Figure 3-3 Yarrow and Cochran Springs Creek Reaches

Table 3-19. Start and End Points for Stream Reaches

Stream	Reach Number	Feet Surveyed	Start Point	End Point
Yarrow Creek	Y1	414.6	417 feet downstream of confluence with East Tributary of Yarrow Creek	Confluence with mainstem of Yarrow Creek

Within this lower reach of Yarrow Creek, in the study area (downstream of Lake Washington Boulevard), there are no known fish passage barriers, however there are numerous complete and partial fish passage barriers located outside the study area, within the City of Bellevue, and adjacent and under SR 520. Because of these conditions, Y 1 receives a Good rating for passage.

Reach Y1 is located within a wetland, and the riparian area consists exclusively of scrub/shrub vegetation, having a recruitment potential rating of Poor. This reach also contains no key pieces of LWD, likely because it flows through a scrub/shrub wetland.

Reach Y1 was rated Poor for its low pool density. The substrate composition of the riffles rate as Good (cobbles and large gravels predominate), but it should be noted that this rating is based on the results of a single pebble count. However, reach Y1 is predominantly run/glide habitat (66 percent) with 21 percent being riffles and 13 percent pools. Furthermore, these pools were often small and relatively shallow.

Finally, this reach has a bank condition rating of Good. No unstable banks were present and only 9 percent of the bank is hydromodified and consisted of a single bridge. This reach represents good quality rearing habitat for salmonid species, particularly coho salmon.

3.3.2 Cochran Springs Creek

Cochran Springs Creek was assessed qualitatively between the culvert under the steep slope beneath the Burlington Northern and Santa Fe Railway Company (BNSF) and Lake Washington Boulevard. This reach has adequate bank cover and riffle abundance, but LWD is completely lacking, riparian cover is limited, and there is no viable salmon spawning riffles or rearing pools. There is a complete fish block at the culvert under NE 38th Place, as the culvert appears to have several bends under the road before it outfalls as a perched culvert onto rocks. Additionally, the stream generally flows at a steep gradient from the BNSF railroad culvert to approximately NE 37th Circle. At this location, the channel grade flattens and fine material begins to deposit. This material is creating a fish block and has nearly blocked the culvert under Lake Washington Boulevard. More importantly, the aggrading channel has increased overbank flooding downstream of Lake Washington Boulevard causing several instances of flooding of the Yarrow Bay Business Park. For more information see NE 35th Street Culvert Report (Penhallegon 2000).

4. RECOMMENDATIONS FOR IMPROVING STREAM HABITAT

Factors limiting stream habitat occur at various scales. As a result, projects that improve stream habitat range in scale from site specific to reach specific to watershed level approaches. For example, changes in dynamic processes such as water and sediment delivery to streams may be addressed by comprehensive, watershed-scale management frameworks for stormwater control, development of regulations, and conservation partnerships. Limiting factors can also be improved at a smaller scale as the habitat quality changes across streams, reaches, or sites. This chapter describes a range of potential stream improvement opportunities and recommends projects that may enhance habitat for salmonids and other aquatic resource functions at these different scales.[3]

According to Washington Joint Natural Resources Cabinet (2001), instream habitat can be improved using the following categories of projects: acquisition, fish passage, instream habitat, riparian habitat, and upland habitat. This report also discusses environmental education as a tool for stream rehabilitation, which Booth et al. (2001) describe as "crucial" to any urban stream management plan.

Acquisition or Easements

Acquisition is the purchase of land, access, or utilization rights in fee title or perpetual easements (Washington Joint Natural Resources Cabinet 2001), and is intended to protect existing functioning habitat or, where possible, to restore limiting habitat conditions. A corollary to acquisition is the implementation of regulatory controls such as zoning to protect undeveloped or restored lands. These tools are most effective in areas where habitat-forming riparian vegetation exists, including wetlands and tracts of native vegetation.

Fish Passage

Fish passage projects allow fish to move to and from spawning and rearing habitats. Improperly designed structures such as bridges, culverts, dams, and fishways may impede migration, constrict the channel, diminish floodplain connectivity, and contribute to unstable banks and lack of riparian vegetation. Rehabilitation of fish passages is intended to further limit the inherent disturbance in these areas.

Instream Habitat

Improving instream habitat involves work within the stream banks (below the OWHM) such as stabilizing banks and removing armoring, creating secondary channels, rehabilitating pool/riffle habitat, and placing LWD. These projects have the most direct impact of aquatic habitat.

Riparian Habitat

Riparian habitat, even if it does not actively contribute LWD to the stream, is important to a number of stream functions. Stable riparian areas contribute organic litter, filter runoff, stabilize banks, provide cover for fish and wildlife, and inhibit the introduction of invasive species. Riparian cover also helps moderate water temperature.

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[3] Additional guidance on the topic can be found in King County SWM (1996) and R2 Resource Consultants (2001).

Upland Habitat

Upland habitat includes those areas outside the riparian corridor that affect water quality, hydrology, sediment, and temperature control. Management of these areas involves controlling sources of sediment and toxic chemicals, limiting impervious areas, and controlling stormwater. This study is limited to the stream channels, and recommendations on upland enhancements are outside of its scope.

Community Outreach and Education

In urban environments like Kirkland, private landowners control a majority of the streamside property, and their actions are not entirely within the City's control. Consequently, community outreach and education are critical to the success of any stream rehabilitation program. Outreach and education can be implemented on a broad scale through civic activities such as distribution of written materials; exhibits for community events; interpretative signs in trails, parks, and other community facilities; formal presentations to citizen groups; and in-school education. This report provides recommendations for outreach at individual sites including informal visits to landowners and lending technical expertise to affect positive change in the stream environment. Please see Booth et al. (2001) for further reading on community outreach programs for urban.

4.1 CIP RECOMMENDATIONS FOR STREAM REHABILITATION

Using the assessment in Chapter 3, a complete list of problems and opportunities in Kirkland drainages was developed. A brief synopsis of limiting factors and exceptional habitat for Juanita Creek and Forbes Creek is provided below and a complete list of problem areas is available in Appendix D. Parametrix and City of Kirkland team discussed the complete list of problems and potential CIP opportunities to determine feasible projects which, considering limitations such as costs, property access, and cumulative effects of urban impacts, had the most benefit for the ecosystem. CIP projects were identified that will assist in the rehabilitation of Kirkland stream systems by enhancing or creating habitat at degraded sites and conserving habitat at exceptional sites. These recommendations are discussed separately for Forbes Creek, and Juanita Creek. The other urban drainages within the City are summarized in Table 4-3 below.

4.1.1 Forbes Creek

Forbes Creek has a floodplain morphology that has been affected by the encroachment of development along its shoreline. Limiting factors and habitat implications are summarized below.

Limiting Factors

- High sediment mobility
- Increased frequency of peak flows
- Lack of LWD
- Lack of channel complexity
- Lack of riparian vegetation

Habitat Implications

- Poor spawning habitat due to fine sediment and increased sediment transport
- Disconnected floodplain and riparian in forested reaches
- Fish blockages resulting from sediment mobility

- Lack of sufficient pools and off-channel habitat for migration and rearing
- Limited forage opportunities for juvenile fish due to a simplified invertebrate community
- Low potential to recruit LWD

4.1.1.1 Potential CIP Projects

Acquisition and/or Easements

Some sites along Forbes Creek are less developed and contain potential habitat and functional riparian areas; therefore, acquisition or easements may be a successful tool for rehabilitation. Two potential acquisition or easement sites are identified below; however, because the sites are privately owned, further study will be needed to determine whether acquisition is feasible.

- A stream floodplain exists between Forbes Creek Drive and 116th Avenue NE. This portion of the stream contains functional riparian habitat that is currently disconnected from the stream (see instream habitat enhancement). Ownership of this property will allow long-term management of this stream section. Increasing LWD in the stream will increase sediment retention and overbank flow. These elements will decrease sediment mobility to lower reaches. The riparian corridor is forested, and although the LWD recruitment is currently low, it will increase as trees mature.

- The configuration of the confined basin between 120th Avenue NE and I-405 offers an opportunity to increase in-channel stormwater detention. Ownership of this property will allow long-term management of this stream section, which is not accessible to anadromous fish.

Passage Barriers

There are seven fish passage barriers within Forbes Creek[4] (see Table 3-2). Blockages low in the watershed restrict salmonid access to viable spawning and rearing habitat. However, a series of culverts between the BNSF railroad line near 120th Avenue NE and I-405 are barriers that would be both cost prohibitive to repair and would provide little ecological benefit to anadromous fish. Therefore it is recommended that the following blockages downstream of the BNSF railroad line be repaired:

- Partial fish passage blockage under 108th Avenue NE. One of a pair of culverts is constricted with sediment. The road is placed in a grade break and will likely to continue filling with fine sediment. Increasing the culverts size will increase conveyance and reduce sediment within the culvert.

- The culvert under an access road south and west of the Forbes Creek Drive stream crossing is a complete blockage. The channel within this bottomless culvert is incising as a result of bedload mobilization within this reach. The incising channel is compromising the integrity of the culvert footings and wing walls. An approximately 4-by-12 inch timber was placed at the downstream edge of the culvert to prevent further erosion. The channel drop over the weir has created a complete fish blockage. The placement of a series of weirs from Forbes Creek Drive to the Culvert will help raise the channel bed elevation, which in turn will eliminate the fish blockage and prevent further degradation of the culvert.

[4] There may be an additional blockage under I-405 that was not assessed during this study.

- The hydrologic drop over a remnant portion of a concrete diversion dam between Forbes Creek Drive and the BNSF railroad is a complete fish blockage. A previous repair attempted to provide a step pool, however, both the step pool and the concrete walls require a salmon to jump greater than 0.8 meters and are considered blockages by WDFW. The placement of a series of weirs will help raise the channel bed elevation, which in turn will eliminate the fish blockage.

Instream Habitat

LWD and Pools

A very low number of key LWD was identified during the Forbes Creek instream survey. Some of the pieces provide bank stability and limited refuge for rearing fish during high flows. The two reaches with a USBEM Good rating, Reaches 4 and 6, are primarily forested. Much of the wood in Reach 4 was remnant LWD that is now being engaged with the channel as the streambed degrades from sediment mobility. All reaches in Forbes Creek have low pool frequencies, therefore, where site conditions are appropriate (e.g. forested acquisition areas), LWD should be placed in sufficient quantities to significantly impact pool formation and other habitat functions (Table 4-1). Additionally, the placement of LWD within Reaches F4 and F5 will detain sediment and assist in raising the channel bed elevation.

Table 4-1. Number of Key LWD Needed to Achieve Better USBEM Rating in Mainstem Forbes Creek

Stream	Reach Subunit	Key LWD Density (Key LWD / BFW)	Key LWD Count	Number Key LWD to Add	
				Fair[a]	Good[b]
Forbes	F1	0.00	0	2	5
	F2	0.10	1	0	2
	F3	0.00	0	1	3
	F4	0.31	3	0	0
	F5	0.22	2	0	1
	F6	0.55	5	0	0
	F7	0.00	0	1	2

[a] Minimum LWD Density for Fair Rating equals 0.2 pieces/BFW for BFW > 33 ft, 0.15 pieces/BFW for BFW <33 ft.
[b] Minimum LWD Density for Good rating equal 0.5 pieces/BFW for BFW >33 ft., 0.3 pieces/BFW for BFW < 33 ft.

Sediment Control

Sediment mobility within Forbes Creek has created habitat problems in several locations. In the lower reaches, sediment aggradation has created fish passage problems and compromised a previously installed high-flow bypass intended to protect a restoration site. In the upper reaches, sediment degradation has compromised culverts and wing-walls, exposed sub-grade utilities, and has disconnected the stream channel from the floodplain. The following are recommendations for sediment management:

- Placement of several LWD weirs between Forbes Creek Drive and the BNSF railroad line. These weirs would help raise the elevation of the channel bed and increase overbank flow within this confined reach. Overbank flow would, in turn, further decrease the mobilization of bed material.

- Removal of the high-flow bypass immediately downstream of Forbes Creek Drive should be considered. The bypass was put into place to protect a downstream restoration site while it stabilized. This site is now stable and the bypass currently prevents sediment from providing material to downstream reaches and thereby increasing downstream channel degradation

- Increase conveyance at 108th Avenue NE by increasing the culvert size. This would disperse fine sediment to the wetland downstream from this crossing rather than in the culvert.

Riparian Planting

The majority of the publicly owned portions of Forbes Creek are forested. However, a publicly owned site at which planting could be initiated is located in the Forbes Creek Park wetland east of Market Street to the existing shrub/forest community. This location is dominated by reed canary grass. Planting this city-owned area with shrubs would increase shade and cover in the lower reaches of the system. The upper, privately owned portions of Forbes Creek have poor riparian cover and higher stream temperatures. These reaches will require public outreach (see below).

Outreach and Education

Much of the upper reaches of Forbes Creek are within private property. Most of these reaches have poor riparian cover and higher stream temperatures; therefore, if riparian conditions are to improve in these areas, outreach and education directed at private landowners should be considered. Specific sites at which education efforts may lead to riparian and in channel enhancement projects include:

- Reach 7 from Slater Road to Forbes Lake, which flows predominately through yards. Outreach to these landowners would be essential to the management of the riparian and in-channel conditions in this upper section.

- A private landowner at 10041 Slater Ave. NE has a bridge in serious disrepair. This bridge is constructed on three series of three metal 50-gallon drums welded end to end. Over these, fill and timbers were placed. The homemade culverts are extremely rusted, and the bridge is likely to collapse in the near future.

4.1.2 Juanita Creek

Juanita Creek is a moderate-gradient channel with a shoreline that has been heavily encroached on by development. Limiting factors and habitat implications are summarized below.

Limiting Factors

- High sediment mobility
- Increased frequency of peak flows
- Lack of LWD
- Lack of channel complexity
- Lack of riparian vegetation

Habitat Implications

- Poor spawning habitat due to fine sediment and increased sediment transport
- Disconnected floodplain and riparian in forested reach
- Lack of sufficient off-channel habitat for migration and rearing
- Low potential to recruit LWD
- Limited forage opportunities for juvenile fish due to a simplified invertebrate community

4.1.2.1 Potential CIP Projects

Acquisition or Easements

The majority of Juanita Creek within the City limits is privately owned and does not contain significant riparian and instream habitat. Therefore, acquisition would not provide a successful tool for rehabilitation on this channel.

Passage Barriers

There are no fish barriers in the mainstem of Juanita Creek. However, there is a complete fish block on the east branch of Juanita Creek. This culvert is located under Juanita High School property and 103rd Place. The east branch enters this culvert in the western portion of Juanita High School via a drop culvert and travels approximately 400 to 500 feet to its outfall near 103rd Place. However, due to the limited habitat upstream, replacing this fish blockage is not a high priority.

Instream Habitat

LWD and Pool Formation

LWD density is rated Poor for every reach Parametrix surveyed in Juanita Creek except Reach J3, which had one LWD jam with several pieces of wood. However, the remainder of the reach is devoid of LWD. Some of wood found within Juniata Creek provide bank stability and limited refuge for rearing fish during high flows. All reaches in Juanita Creek have low pool frequencies; therefore, where site conditions are appropriate (e.g. publicly owned parks in the lower reaches), LWD should be placed in sufficient quantities to significantly impact pool formation and other habitat functions (Table 4-2). To achieve and maintain adequate LWD recruitment levels, trees must be established in the riparian zone.

Table 4-2. Number of Key LWD Needed to Achieve Better USBEM Rating in Mainstem Forbes Creek

Stream	Reach Subunit	Key LWD Density (Key LWD / BFW)	Key LWD Count	Number Key LWD to Add	
				Fair[a]	Good[b]
Juanita	J1	0.00	0	2	5
	KC1	NA	NA	3[c]	6[c]
	J2	0.06	1	1	4
	KC2	NA	NA	3[c]	5[c]
	J3	0.48	8	0	0
	KC3	NA	NA	3[c]	6[c]

a Minimum LWD Density for Fair Rating equals 0.2 pieces/BFW for BFW > 33 ft, 0.15 pieces/BFW for BFW <33 ft.
b Minimum LWD Density for Good rating equal 0.5 pieces/BFW for BFW >33 ft., 0.3 pieces/BFW for BFW < 33 ft.
c Key LWD information is not available for King County reaches. These numbers assumes that there is currently no key LWD present.

Sediment Control

Reaches KC1, J3, and KC3 have a healthy pool to riffle ratio of nearly 1 to 1. Reaches J2 and KC2 have a higher percentage of pools, resulting in a pool to riffle ratio of nearly 2 to 1. Although these upper reaches have a near ideal pool to riffle ratio, the riffles themselves have a high amount of fine material embedded in the interstitial areas of the larger gravels, leaving approximately 40 to 50 percent of the riffles in poor

condition. These embedded fines reduce the ability of dissolved oxygen to reach the deeper portions of the riffle, and thereby impact the viability of salmon eggs in Juanita Creek.

Finally, Reach J1, near the mouth of Juanita Creek, has a pool to riffle ratio of nearly 1 to 1; however, about 70 percent of this reach is composed of run/glide areas. The run/glide areas are generally used as corridors for salmonids, providing limited resting, feeding and redd habitat. Juanita Creek has a lower grade in this reach than other reaches within the city. As the grade flattens near its mouth at Lake Washington, the fine material is deposited. Because this low-gradient reach is naturally a depositional area, it is unlikely that a rehabilitation project can be successful. However, increasing LWD in the upstream reaches will detain contain fine sediment and ameliorate these down stream problems. Additionally, controlling upstream sources of fine sediment material at erosive sites will also assist in limiting further habitat impacts. The City is aware of the on-going erosion problems that are outside the scope of this project (e.g. City of Kirkland problem codes SD-0038 and SD-0039).

Bank Modification

The bank conditions within Juanita Creek are generally in fair condition, with an average of one third of the channel having modified banks. KC2 had the highest proportion of unstable banks (18 percent). These unstable banks should be examined by a City ecologist to determine if bank restoration projects are feasible in these locations. One unstable bank in J3 is located on the river right between NE 126th Street and NE 128th Street, where erosion has exposed the storm sewer line, underground power lines, and cables.

KC1 has 57 percent hydromodified banks, giving it a USBEM rating of Poor. The properties along this reach are private; therefore engineering designs to provide habitat and bank stabilization should be incorporated in conjunction with future requests for the City to repair existing armored banks.

Riparian Planting

The low-gradient, sand-dominated portions of Reach J1 are within the publicly owned parks. These areas have limited riparian cover and provide the best opportunity for riparian planting within the City limits. Other opportunities exist on privately owned property, but would require outreach and education (see below).

Outreach and Education

Much of Juanita Creek is within private property, therefore, outreach and education directed at private landowners should be included in any rehabilitation program. Private landowner's requests for repair or additional placement of armored bank structures provide an ideal opportunity to discuss bioengineering alternatives. In addition, property owners should be informed of the importance of a properly functioning riparian buffer zone.

Juanita High School also provides another opportunity for education that may lead to riparian enhancement. Students living in the adjoining neighborhoods to the south frequently cross the portion of the east branch of Juanita Creek behind the high school. The students cross the stream by placing wood pallets in the stream or by cutting alders and dropping them into the channel. The City and the high school could place a footbridge at this location and incorporate a school-based monitoring program to evaluate its ecological benefit.

4.2 CIP SUMMARY

Table 4-3 and Figure 4-1 present a summary of recommended projects for the City of Kirkland streams.

Table 4-3. Recommended CIP Projects

Problem ID	City CIP	CIP Project Type	Address	Problem Description	Project Description	Project Benefit	Associated Projects	Estimated Cost
FO-01	N/A	Fish Passage/ Flooding	108th Ave NE between Forbes Creek Drive and NE 108th Street	Road floods and one of the dual culverts is blocked with sand.	Place curb cuts at low point of road; replace culverts.	Improved drainage, improved fish passage to spawning and rearing habitat.	Existing sedimentation basin downstream of Forbes Creek Drive, and Projects FO-05 and FO-07	$129,000
FO-03	N/A	Flood Control	NE 95th Street at 126th Ave NE	Road and several crawl spaces flood.	Raise grade of flood-prone area on affected property.	Prevent flooding of residence crawl space.	Stormwater detention on NE 85th Street and Project FO-04	$43,000
FO-04	SD-0537	Streambank Stabilization	NE 86th Street at Forbes Creek	Uncontrolled flows from NE 85th Street causing channel erosion.	Add grade control and bank stabilization structures, and riparian planting	Reduce downcutting and sediment supply.	NE 85th stornwater detention facility	$385,000
FO-05	N/A	Bank Protection/ Fish Passage	113-148 yards upstream from Forbs Creek crossing of Forbes Drive	Gabion wall on left bank upstream is unstable. Stream has eroded under the culvert footings. Hanging outfall downstream of culvert has created a complete fish blockage.	Install log-boulder grade controls to promote channel aggradation up to and inside the culvert. Repair gabion wall and stabilize adjacent streambanks.	Stabilize culvert footings, improve fish passage, and stabilize upstream bank.	Project FO-07	$249,000
FO-06	N/A	Outreach/ Fish Passage	10041 Slater AVE NE	Continued deterioration of private driveway culverts constructed with 50-gallon drums may result in fish passage impediment.	Replace existing culverts with bottomless arch culvert.	Reduce risk of fish passage impediment and/or flooding caused by the current deteriorated crossing.	(Recommended for prioritization) Fish passage improvement under Interstate 405	$48,000
FO-07	N/A	Channel Stabilization/ Riparian Connection/ Fish Passage	148 - 310 yards upstream from Forbs Cr Crossing	Incised channel with floodplain disconnection and low pool density. Diversion dam and associated weir are fish passage barriers.	Install log-boulder grade control structures in the channel, cut down height of weir and diversion dam, and install instream LWD habitat structures.	Channel aggradation and reconnection of floodplain, improved instream habitat, improved fish passage.	Project FO-05 (Recommended) Flow control improvements	$234,000
FO-08	N/A	Fish Passage	Under active BNSF rail road line	Two culverts, in series, convey Forbes Creek under an abandoned railroad spur embankment and then under an active railroad track embankment. The grade of the existing culvert under the active rail embankment is greater than 1 percent, creating an impediment to fish passage.	Replace culvert with open channel under the abandoned rail spur. Replace the culvert under the active rail line with a bottomless arch culvert.	Improved fish passage. Low priority due to limited upstream viable salmonid habitat.	Project FO-09	$194,000
FO-09	N/A	Fish Passage	Under Air Show Parking lot at 10801 120th Ave NE	Outfall of 350-foot culvert under a parking lot is perched 20 feet, forming a complete barrier to fish passage.	Replace culvert with open channel and connect it to an existing tributary channel on the west side of the parking lot. Improve tributary channel connection (approximately 190 feet) as necessary to convey increased flows. Plant riparian vegetation along the banks of the new channel.	This project will provide access to suitable spawning habitat upstream of the culvert.	Project FO-08	$2,727,000
FO-10	N/A	Riparian Planting	Between Market Street Bridge and 181 Yards upstream (east) of bridge	Riparian vegetation is lacking.	Plant trees and shrubs along approximately 550 feet of riparian zone.	Planting will provide shading for the stream, which will reduce water temperature impacts.	None	$58,000
FO-11	N/A	Fish Passage	South of NE 100th St	Area surrounding two in-line ponds is poorly vegetated, resulting in heating of standing water. Trash rack grate at pond outlet prevents fish passage.	Plant riparian vegetation in and around ponds. Remove or replace trash rack.	Reduced temperatures and improved fish passage.	This project gains priority if fish passage is improved under Interstate 405.	$76,000
FO-12	SD-0033	Water Quality	NE 90th Street at 120th Ave NE, between NE 90th Street and Forbes Lake.	Sedimentation and pollution in wetland.	Install treatment device. Possible solution is to install a centrifugal-type pollution treatment in nearby abandoned well.	Reduced sedimentation and pollution in Forbes Lake wetlands.	None	$169,000
JU-10	N/A	Streambank Stabilization	390 feet downstream of NE 122nd Street.	Eroding/slumping streambank, exposed storm drain outfall pipe, poor riparian vegetation.	Use bioengineering methods to stabilize and vegetate banks. Plant riparian vegetation.	Reduce sediment supply to Juanita Creek and protect adjacent property.	None	$97,000
JU-09	N/A	Flood Control	Totem Lake Blvd at about 119th Ave NE	Road floods during mid- to large-size storms.	Raise low spot in road, or improve stormwater detention facilities and, if necessary, install	Reduced frequency and magnitude of flooding.	None	$1,017,000 (Road regrade only)

Comment [KAL1]: Combines previous projects FO-E-5, FO-E-6, FO-H-2.

Comment [KAL2]: Combines previous projects FO-H-3, FO-H-4

Comment [KAL3]: Formerly FO-E-WQ-1

Table 4-3. Recommended Rehabilitation Projects (continued)

Problem ID	City CIP	CIP Project Type	Address	Problem Description	Project Description	Project Benefit	Associated Projects	Estimated Cost
					pump station.			
JU-02	N/A	Outreach/ Riparian Planting	Juanita Creek - upstream of Juanita Drive in Park Juanita Beach Park	Sediment deposition, poorly vegetated banks, and poor riparian cover.	Stabilize and vegetate banks, plant riparian vegetation, and install instream habitat structures.	Improved habitat, increased pool density, reduced erosion and sediment supply, increased shading, and reduced temperature impacts.	None	$262,000
JU-03	N/A	Channel Stabilization	NE 126th Pl at 94th Ave NE (Juanita Cr. Trib 0125)	Poor riparian vegetation (blackberries), downcutting channel, illegal rockery on right bank.	Remove blackberries and plant riparian vegetation. Install log-boulder grade controls in channel within City-owned easement.	Reduced downcutting and sediment supply, increased shading, and reduced temperature impacts.	Project JU-04	$164,000
JU-04	N/A	Sediment Control/ Riparian Planting	NE 125th Place at 95th Ave NE (Juanita Cr. Trib 0125)	Sedimentation and poor riparian vegetation (blackberries). Opportunity for sediment control basin.	Excavate in-line pond and construct outlet structure to provide sediment storage, stabilize banks, plant riparian vegetation. Design should include a low-flow channel and control structure.	Reduced sediment supply, increased shading, and reduced water temperature impacts.	Project JU-03	$169,000
JU-06	N/A	Riparian Planting	Downstream of NE 128th Street near city-owned pond on 100th Ave NE	Poor riparian vegetation.	Plant riparian vegetation.	Increased shading and reduced water temperature impacts.	None	$69,000
JU-11	SD-0337	Outreach/ Riparian Planting	South edge of Juanita High School property	Straightened and degraded channel and existing pedestrian crossing is water quality and safety hazard.	Create a designated, stabilized footpath and construct footbridge. Eliminate other footpaths and plant riparian vegetation.	Reduced sediment supply, improved safety and aesthetic quality for pedestrian crossing.	None	$269,000
CO-01	N/A	Flood Control	Cochran Springs Creek at Lake Washington Boulevard	Culvert is creating backwater and sedimentation, which impedes conveyance and creates an ongoing maintenance task. Backwater conditions may improve fish passage, but sedimentation may increase flooding in Yarrow Bay business park.	Replace culvert, regrade channel to remove downstream control, install instream habitat structures, and plant riparian vegetation. Consider berm on left bank to protect existing development.	Improved fish passage to breeding and rearing habitat, increased culvert capacity will reduce flooding on Lake Washington Boulevard.	None	$845,000
UD-01	SD-0437	Slope Stabilization	Slater St S/Cedar St (Rudy's Ravine) at Slater St at 2nd Ave S	Streambank and slope instability.	Use bioengineering methods and planting to stabilize slopes.	Increased slope stability and reduced sediment supply.	Kirkland Avenue Sidewalk Project	$390,000
UMB-01	N/A	Bank Protection / In channel	Everest Park 8th Street S at ~ 3rd Ave S	Channel downcutting, unstable banks, poor quality riparian vegetation, and invasive vegetation.	Install log-boulder channel grade control structures, use bioengineering methods to stabilize banks, and remove blackberries and plant riparian vegetation.	Reduced channel downcutting and stabilized banks, reduced sediment supply, increased shading, and decreased water temperature impacts.	Riparian planting immediately downstream of project site.	$518,000
UMB-02	N/A	Bank Protection / In channel	Post Office Creek, 4th Avenue (unopened row) between 10th Street and 721 4th Ave (the Post Office)	Flooding of business park caused by heavy weed/grass growth in channel, 90-degree channel turn, and undersized culvert. Poorly vegetated banks. Channel requires ongoing dredging.	Improve or remove culvert under Post Office property fence, remove invasive vegetation and plant native riparian vegetation that will not obstruct channel.	Reduced frequency and magnitude of flooding, reduced need for channel dredging.	None	$161,000

1. Photos are provided in Appendix C

Figure 4-1 Map of Recommended CIP Sites

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APPENDIX A

Instream Survey Protocol

APPENDIX B

NMFS Pathways and Indicators of Limiting Factors

Several aquatic habitat components were assessed for their potential to limit salmon production. The National Marine Fisheries Service (NMFS) of the National Oceanic and Atmospheric Administration (NOAA) provides some of these assessment criteria in their *Coastal Salmon Conservation* (NOAA, 1996), which are reiterated in Chapter 4 of the Amended Sections of the *Pacific Coast Salmon Plan* (Pacific Fishery Management Council [PFMC], 2000). These criteria are grouped into three categories to represent different habitat conditions: *properly functioning*, *at risk*, and *not properly functioning*, and they categorize several habitat components of Pacific Northwest streams to help determine whether these components have a limiting effect on salmon.

Table B-1. Matrix of Pathways and Indicators[1]

Pathway	Indicators	Properly Functioning	At Risk	Not Properly Functioning
Water Quality:	Temperature	50-57° F[2]	57-60° (spawning) 57-64° (migration and rearing)[3]	>60° (spawning) >64° (migration and rearing)[3]
	Sediment/Turbidity	<12% fines (<0.85 mm) in gravel[4], turbidity low	12-17° (west-side)[4], 12-20° (east-side)[3], turbidity moderate	>17% (west-side)[3], >20% (east-side)[2] fines at surface or depth in spawning habitat[3], turbidity high
	Chemical Contamination/ Nutrients	Low levels of chemical contamination from agricultural, industrial and other sources, no excess nutrients, no CWA 303d designated reaches[6]	Moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one CWA 303d designated reach[6]	High levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one CWA 303d designated reach[6]
Habitat Access:	Physical Barriers	Any man-made barriers present in watershed allow upstream and downstream fish passage at all flows	Any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at base/low flows	Any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a range of flows
Habitat Elements:	Substrate	Dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%[4]	Gravel and cobble is subdominant, or if dominant, embeddedness 20-30%[4]	Bedrock, sand, silt or small gravel dominant, or of gravel and cobble dominant, embeddedness >30%[2]
	Large Woody Debris	Coast: >80% pieces/mile >24"' diameter >50 ft. length[4]; East-side: >20 pieces/mile >12" diameter >35 ft. length[3]; and adequate sources of woody debris recruitment in riparian areas	Currently meets standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard	Does not meet standards for properly functioning and lacks potential large woody debris recruitment
	Pool Frequency channel width / # pools/mile[6] 5 ft. 184 10 ft. 98 15 ft. 70 20 ft. 56 25 ft. 47 50 ft. 26 75 ft. 23 100 ft. 18	Meets pool frequency standards (left) and large woody debris recruitment standards for properly functioning habitat (above)	Meets pool frequency standards but large woody debris recruitment inadequate to maintain pools over time	Does not meet pool frequency standards

Table B-1. Matrix of Pathways and Indicators (continued)

Pathway	Indicators	Properly Functioning	At Risk	Not Properly Functioning
	Pool Quality	Pools >1 meter deep (holding pools) with good cover and cool water[4], minor reduction of pool volume by fine sediment	Few deeper pools (>1 meter) present of inadequate cover/temperature[4], moderate reduction of pool volume by fine sediment	No deep pools (>1 meter) and inadequate cover/temperature[4], major reduction of pool volume by fine sediment
	Off-channel Habitat	Backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)[4]	Some backwaters and high energy side channels[4]	Few or no backwaters, no off-channel ponds[4]
	Refugia (important remnant habitat for sensitive aquatic species)	Habitat refugia exist and are adequately buffered (e.g., by intact riparian reserves); existing refugia are sufficient in size, number and connectivity to maintain viable populations or sub-populations[8]	Habitat refugia exist but are not adequately buffered (e.g., by intact riparian reserves); existing refugia are insufficient in size, number and connectivity to maintain viable populations or sub-populations[8]	Adequate habitat refugia do not exist[8]
Channel Conditions and Dynamics:	Width/Depth Ratio	<10[3,5]	10-12 (we are unaware of any criteria to reference)	>12 (we are unaware of any criteria to reference)
	Streambank Condition	>90% stable; i.e., on average, less than 10% of banks are actively eroding[3]	80-90% stable	<80% stable
	Floodplain Connectivity	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian vegetation/succession altered significantly
Flow/Hydrology:	Change in Peak/Base Flows	Watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography	Some evidence of altered peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	Pronounced changes in peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography
	Increase in Drainage Network	Zero or minimum increases in drainage network density due to roads[9,10]	Moderate increases in drainage network density due to roads (e.g., =5%)[9,10]	Significant increases in drainage network density due to roads (e.g., =20-25%)[9,10]
Watershed Conditions:	Road Density and Location	<2 mi/mi^2 [12], no valley bottom roads	2-3 mi/mi^2, some valley bottom roads	>3 mi/mi^2, many valley bottom roads
	Disturbance History	<15% ECA (entire watershed) with no concentration of disturbance in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs). >15% retention of LSOG in watershed[11]	<15% ECA (entire watershed) but disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; and for NWFP area (except AMAs). >15% retention of LSOG in watershed[11]	<15% ECA (entire watershed) and disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area; does not meet NWFP standard for LSOG retention

Table B-1. Matrix of Pathways and Indicators (continued)

Pathway	Indicators	Properly Functioning	At Risk	Not Properly Functioning
	Riparian Reserves	The riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition >50%[12]	Moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (=70-80% intact), and/or for grazing impacts: percent similarity potential natural community/composition 25-50% or better[13]	Riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/compostion <25%[12]

Note: The Ranges of criteria presented here are not absolute, and may be adjusted for unique watersheds.

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CHECKLIST FOR DOCUMENTING ENVIRONMENTAL BASELINE AND EFFECTS OF PROPOSED ACTION(S) ON RELEVANT INDICATORS

Stream				**Forbes**						**Juanita**			
INDICATORS	**F1**	**F2**	**F3**	**F4**	**F5**	**F6**	**F7**	**J1**	**KC1**	**J2**	**KC2**	**J3**	**KC3**
Water Quality:													
Temperature													
Sediment	Unknown												
Chemical Contamination/ Nutrients	Unknown												
Habitat Access:													
Physical Barriers	PF	PF	PF	NPF	NPF	NPF	NPF	PF	PF	PF	PF	PF	PF
Habitat Elements:													
Substrate	NPF	AR	AR	AR	PF	AR	NPF	NPF	NA	AR	NA	AR	NA
Large Woody Debris	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Pool Frequency													
Pool Quality	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Off-channel Habitat	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Refugia	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Channel Condition and Dynamics:													
Width/Depth Ratio													
Streambank Condition	PF	PF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	PF
Floodplain Connectivity	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Flow/Hydrology:													
Peak/Base Flows	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Drainage Network Increase	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Watershed Conditions:													
% Total Impervious. Surface	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Disturbance History	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF
Riparian Reserves	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF	NPF

PF = Properly Functioning Conditions
AR = At Risk Conditions
NPF = Not Properly Functioning Conditions

APPENDIX C

Raw Survey Data

APPENDIX D

Flooding, Habitat, Erosion, and Water Quality Problems

Appendix D-1. Table of Flooding, Habitat, Erosion, and Water Quality Problems in Kirkland Drainages

Problem Type				Problem Location							
F	H	E	WQ	Basin	Name	Address	Problem ID[c]	City Project Number	Problem Description	Comments	Associated Projects
		X		Forbes	Road Rilling	Entrance to sewer pump station at Forbes Creek Drive.	FO-E-1		Erosion at entrance to sewer pump station at Forbes Cr. Drive.		
	X	X		Forbes	High Flow Bypass Park at Forbes Creek dredging	Forbes Creek Drive at about 112th Ave NE	FO-E-H-2	FO-2	Gravel movement and dredging are fish issues. Channel aggrading and compromising by-pass design		
		X		Forbes	Streambank Stabilization Program - NE 86th Street	NE 86th Street east of 128th Ave NE	FO-E-3	SD-0537	Uncontrolled flows from NE 85th Street causing erosion		
		X		Forbes	Exposed Sewer Pipes	23 yards upstream from Forbs Cr Crossing	FO-E-4		Channel degrading and exposed 6-in sewer pipes		Channel Degradation Between Forbes Drive and BNSF Railroad
		X		Forbes	Eroded Footings	145 yards upstream from Forbs Cr Crossing	FO-E-5		Exposed footings of 12 foot wide bottomless squash culvert.		Channel Degradation Between Forbes Drive and BNSF Railroad
		X		Forbes	Leaning Gabion	148 yards upstream from Forbs Cr Crossing	FO-E-6		Gabion wall above the culvert on river left is leaning over the channel and may collapse		
		X		Forbes	Exposed Conduit	408 yards upstream from Forbs Cr Crossing	FO-E-7		Top of an exposed 12-inch CMP conduit (?) Crossing streambed?		Channel Degradation Between Forbes Drive and BNSF Railroad
		X		Forbes	Unstable bridge	10041 Slater AVE NE	FO-E-8		Bad bridge of fill over 3 culverts each made of 3-4 50 gallon drums end to end		
X				Forbes	108th Avenue Flooding	108th Ave NE between Forbes Creek Drive and NE 108th Street	FO-F-1	FO-1	Road floods and on of the duel culverts is blocked with sand.		
X				Forbes (east branch)	NE 95th/126th Ave NE flooding	NE 95th Street at 126th Ave NE	FO-F-2	FO-3	Road and several crawl spaces flood, possibly due to sediment buildup in wetland		
	X			Forbes	Fish Passage Problem	113 yards upstream from Forbs Cr Crossing	FO-H-2		Hanging outfall downstream of 12 foot wide bottomless squash culvert.	Bed should rise up about 3 feet to meet outfall.	
	X			Forbes	Disconnected Floodplain	148 - 310 yards upstream from Forbs Cr Crossing	FO-H-3		Overall degrading box channel that is dissociated with floodplain. Only pools associated with remnant wood exposed as channel degrades.		Channel Degradation Between Forbes Drive and BNSF Railroad
	X			Forbes	Fish Block	310 yards upstream from Forbs Cr Crossing	FO-H-4		Concrete wall of old diversion (?) dam 1.6-foot drop to pool being weir 10 foot out for wall. Stream falls 1.8 feet to rock	Fix with need several weirs and remove riprap.	Channel Degradation Between Forbes Drive and BNSF Railroad
	X			Forbes	Fish Passage Complete Block	Under active rail road line	FO-H-5		Velocity greater then 1% grade. Low priority for replacement due to limited habitat upstream.	Low priority due to limited upstream viable salmonid habitat	
	X			Forbes	Fish Passage Complete Block	Under Parking lot	FO-H-6		350 foot long culvert with 3-foot drop to rock app. 20 high Complete block at end of reach	Low priority due to limited upstream viable salmonid habitat	
	X			Forbes	Fish Passage Problem	Slater Ave. NE Crossing	FO-H-8		3-foot culvert with 0.8 foot hanging above rocks	Low priority due to limited upstream viable salmonid habitat	
	X			Forbes	Limited riparian cover	Between Market Street Bridge and 181 Yards upstream (east) of bridge	FO-H-9		Dominated by reed canary grass, no shading	Opportunity for planting of wetland shrub species.	
	X			Forbes	Fish Passage Problem	South of NE 100th St	FO-H-10		In-Line pond filled with sediment and has blocks		
		X	X	Forbes	NE 90th Street/120th Ave NE Sediment Control	NE 90th Street at 120th Ave NE	FO-E-WQ-1	SD-0033	Sediment filling in channel between NE 90th and Forbes Lake, and there is evidence of oil and other pollutants just north of NE 90th/120th Ave NE		

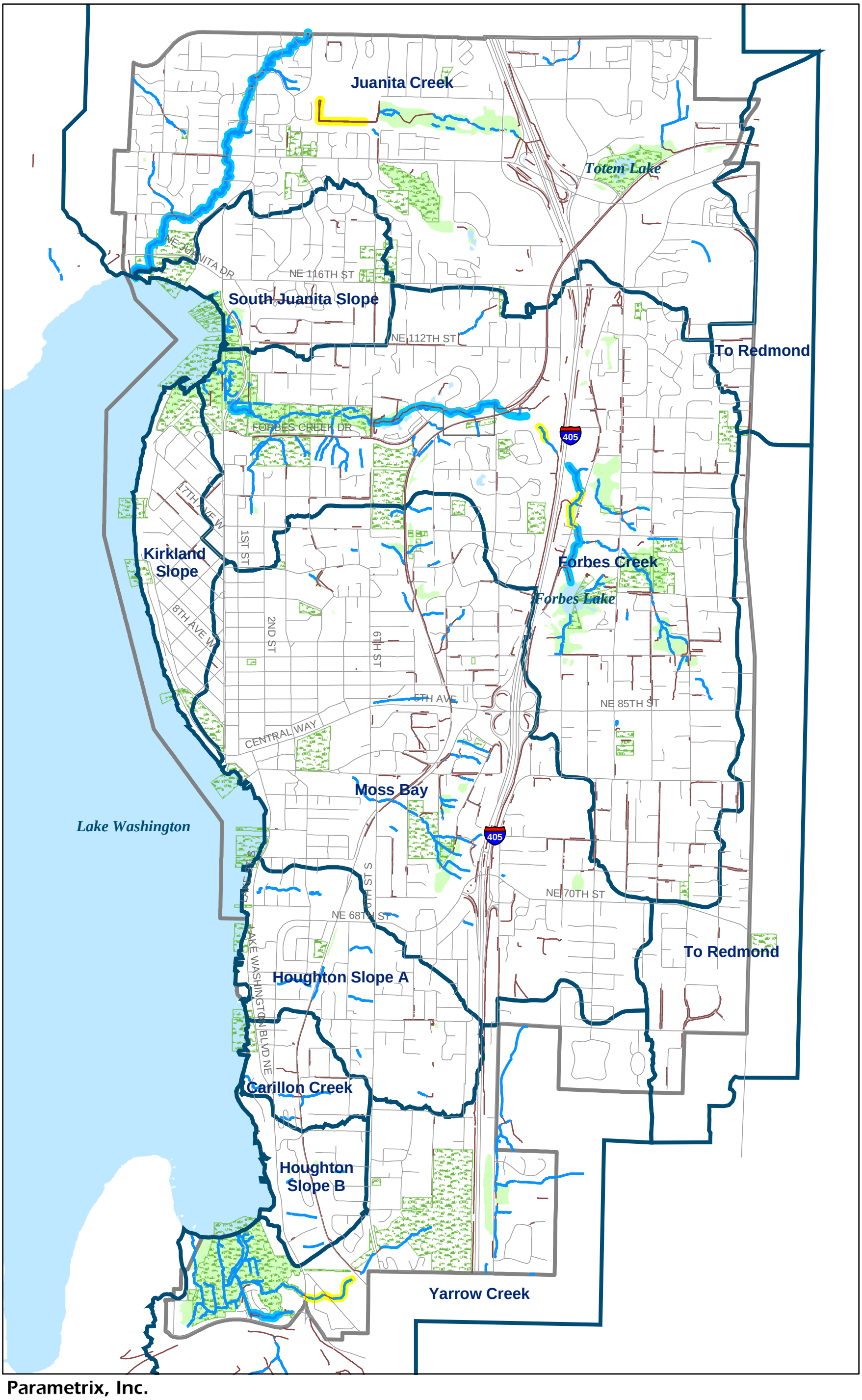
Appendix D-1. Table of Flooding, Habitat, Erosion, and Water Quality Problems in Kirkland Drainages (continued)

Problem Type				Problem Location							
F	H	E	WQ	Basin	Name	Address	Problem ID[c]	City Project Number	Problem Description	Comments	Associated Projects
		X		Juanita	Juanita Creek - mouth	Juanita Beach Park	JU-E-1	JU-1	Sediment buildup at mouth, reach in park is aggraded		
		X		Juanita	Potential restoration site in area between NE 128th Street an 100th Ave NE	West of 100th Ave NE just north of NE 128th Street	JU-E-2	JU-8	Erosion threatens condo complex, and fix may provide restoration opportunity		
		X		Juanita	NE 126th Place/128th Ln NE Erosion Control	Northeast of Totem Lake at NE 126th Pl/128th Ln NE	JU-E-3	SD-0038	Stream flowing down off landslide hazard hillside takes a right-angle bend into City row at bottom of a steep hill then flattens out. Sediment buildup has caused water to overtop channel and flood warehouse parking below.		
		X		Juanita	NE 126th St/94th Ave NE Erosion Control	Stream coming from King County passes through area near NE 128th Ln/94th Ave NE	JU-E-4	SD-0039	Eroded sand settles in Juanita Creek mainstem. Area deeded to King County (now Kirkland?) for sediment control as part of Juanita PUD at 94th Ave NE/NE 128th Ln.		
		X		Juanita	Exposed utilities on eroded bank	Reach 3 are 333 to 340 yards	JU-E-5		Extremely unstable eroded slope on river right with exposed storm sewer pipes, underground power, and cable.		
X				Juanita	Totem Lake Boulevard Flooding	Totem Lake Blvd at about 119th Ave NE	JU-F-1	JU-9	Road floods during mid- to large-size storms		
	X			Juanita	Juanita Creek - upstream of Juanita Drive in Park	Juanita Beach Park	JU-H-1	JU-2	Sediment deposition and low riparian cover		
	X			Juanita	Juanita Creek - Trib 125	NE 126th Pl at 94th Ave NE	JU-H-2	JU-3	Potential restoration opportunity identified by the City.		
	X			Juanita	Juanita Creek - Trib 125	NE 125th Place at 95th Ave NE	JU-H-3	JU-4	Potential restoration opportunity identified by the City.		
	X			Juanita	Juanita Creek - Totem Lake Trib		JU-H-4	JU-5	Culvert between high school and Springbrook is a blockage		
	X			Juanita	Juanita Creek - main stem	Downstream of NE 128th Street behind city-owned pond on 100th Ave NE	JU-H-5	JU-6	Potential restoration opportunity identified by the City.		
			X	Juanita	Juanita High School Stabilization	south edge of Juanita HS property	JU-WQ-1	SD-0337	Straightened and degraded channel and existing pedestrian crossing is water quality and safety hazard		
	X			Cochran Springs	Cochran Springs Creek	Lk WA Blvd just north of Points Drive intersection	CS-H-1	CO-1	culvert at Lk WA Blvd may be fish barrier, and sediment buildup on west side of Lk WA Blvd causes water to jump banks and flood Yarrow Bay business park. sediment building up downstream of Lk WA Blvd causing flooding of private property	- see NE 35th St culvert report	
		X		Urban - Moss Bay	Streambank Stabilization Program - Slater St S/Cedar St (Rudy's Ravine)	Slater St at 2nd Ave S	UD-E-1	SD-0437	bank erosion, slope stability		
		X		Urban - Moss Bay	Everest Park	8th Street S at ~ 3rd Ave S	UD-E-2	UMB-1	bank erosion, invasive plants, in-line sediment pond. habitat degradation, sediment delivery to closed drainage system		
X				Urban - Moss Bay	Post Office Creek	4th Avenue (unopened row) between 10th Street and 721 4th Ave (the Post Office)	UD-F-1	UMB-2	water from small unnamed creek in city right of way floods private property including offices because of vegetation that clogs the channel combined with high flows - maintenance crews cleared channel and built berm, but we'd like a more permanent solution		No

Basin
FO = Forbes Creek Basin
JU = Juanita Creek Basin
YA = Yarrow Creek Basin
CS = Cochan Springs Creek Basin
CA = Carillon Creek Basin
UD = Urban Drainage Basin

APPENDIX E

Photographs



Prepared by Parametrix Inc 11 November 2004 2004 K:\GIS\1802\5581802035\Figure1-1_StreamsBasins.mxd

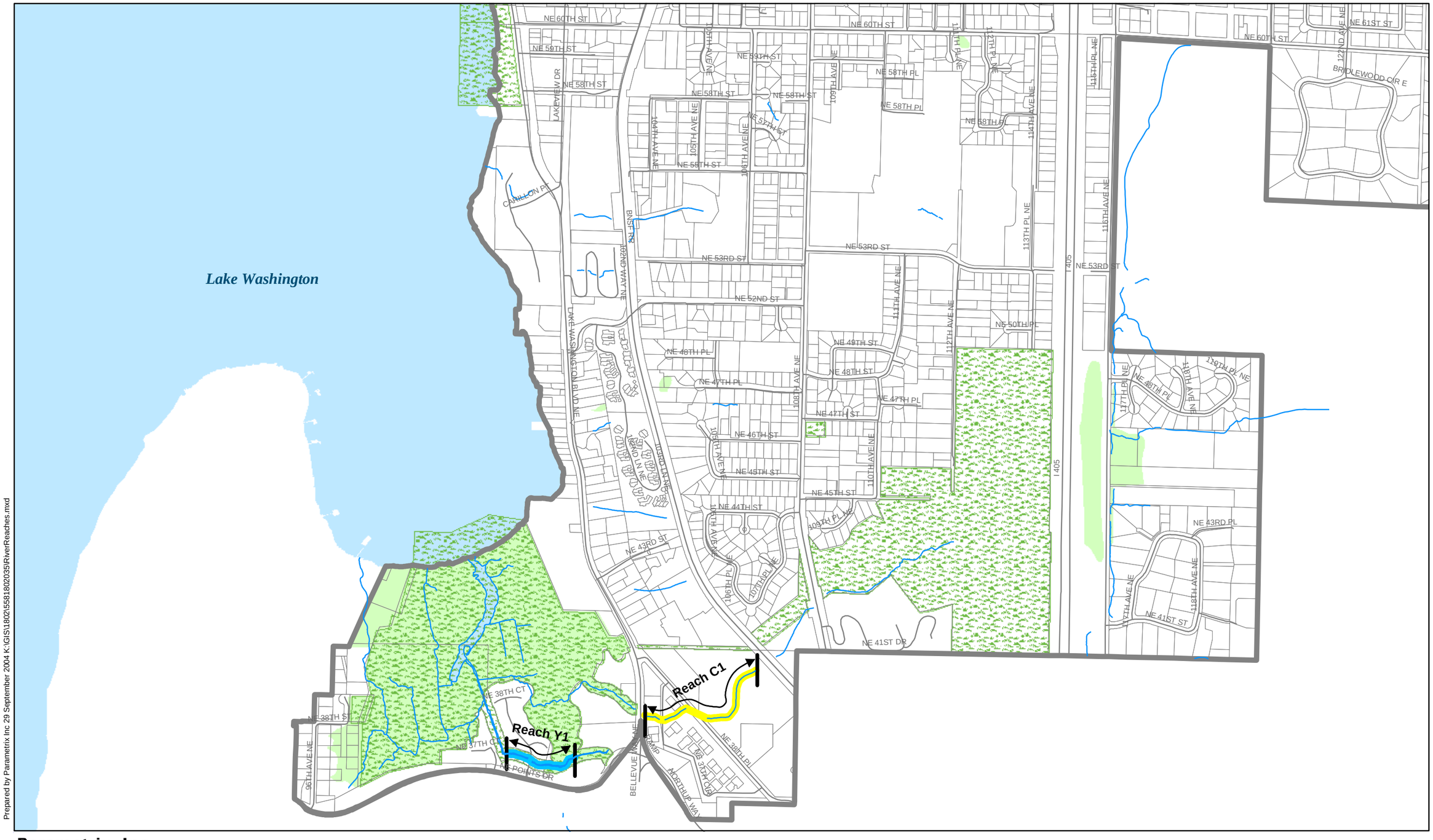
Parametrix, Inc.

N

0 1,000 2,000 Feet

Street Centerline
Stream
Ditch or Culvert
City Limit
Quantitative Stream Survey
Qualitative Stream Survey
Park
Lake
Wetland
Basin Boundary

Figure 1-1
Streams and Basins in the City of Kirkland, WA



Prepared by Parametrix Inc 29 September 2004 K:\GIS\18021558180203 5\RiverReaches.mxd

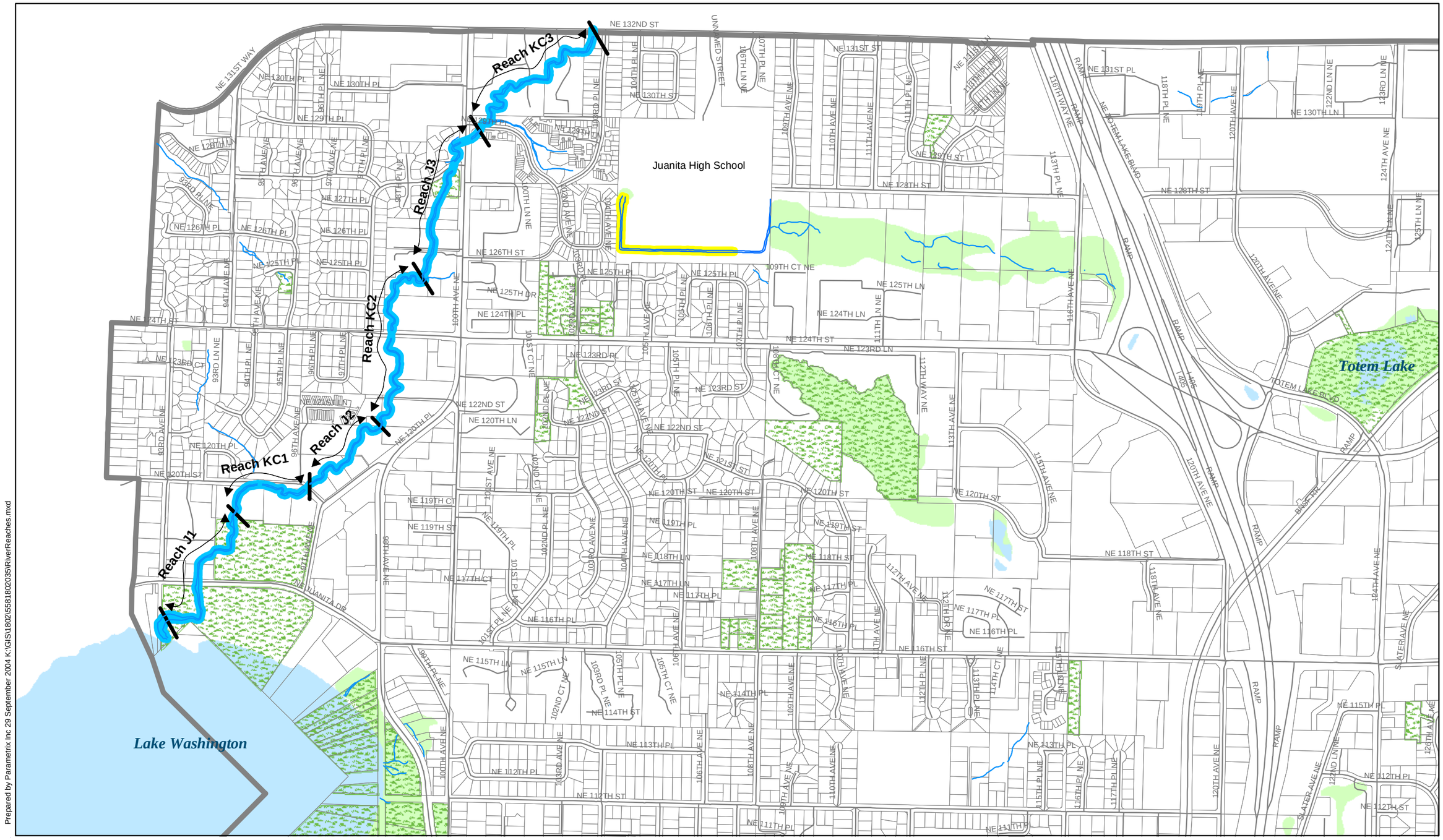
Parametrix, Inc.

0 400 800 Feet

N

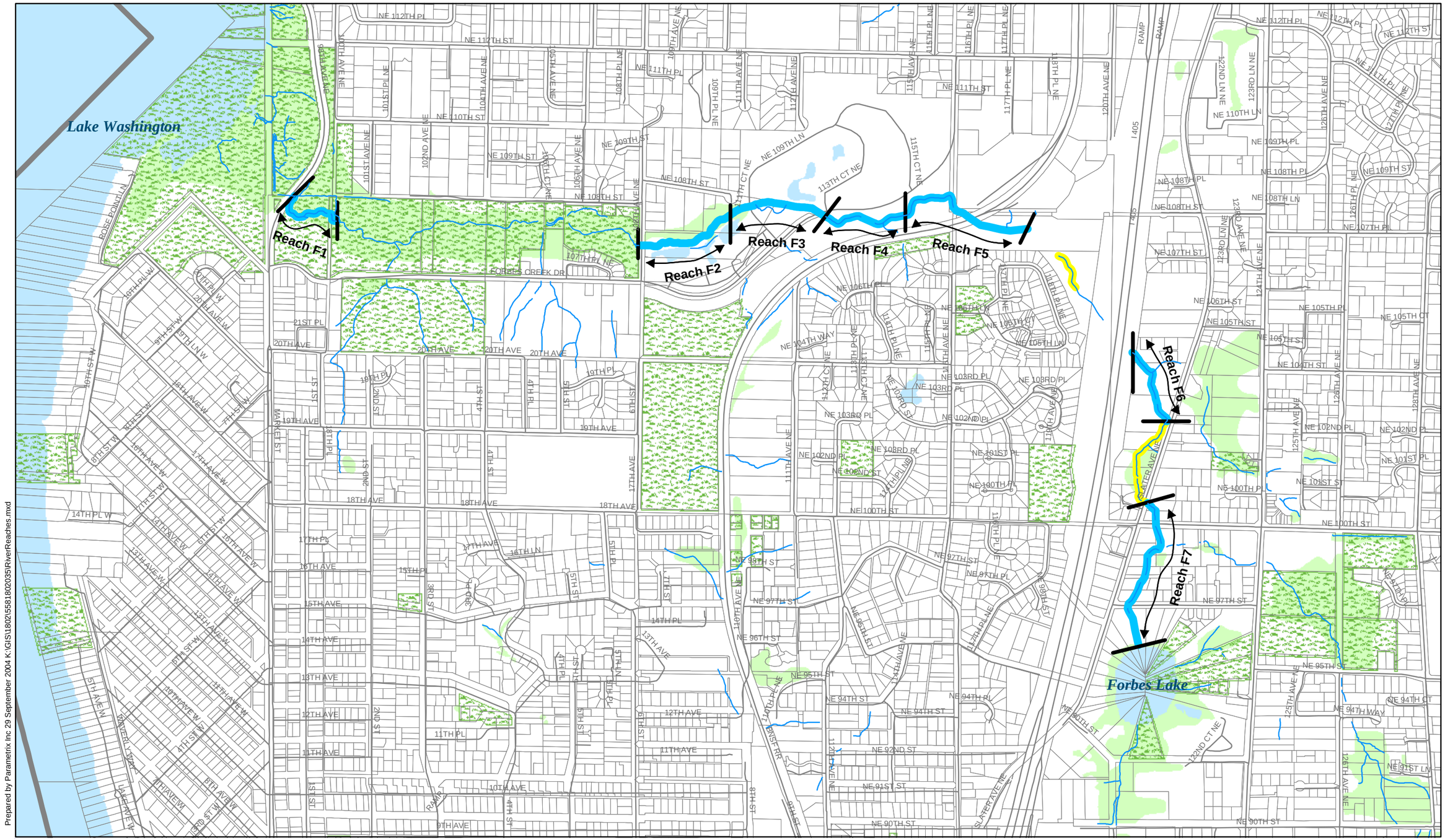
Reach Extent
Street Centerline
Stream
City Limit
Quantitative Stream Survey
Qualitative Stream Survey
Parcel
Park
Lake
Wetland

Figure 3-3
Yarrow and Cochran Springs Creek Survey Reaches



Prepared by Parametrix Inc 29 September 2004 K:\GIS\1802\5581802035\RiverReaches.mxd

Figure 3-2
Juanita Creek Survey Reaches



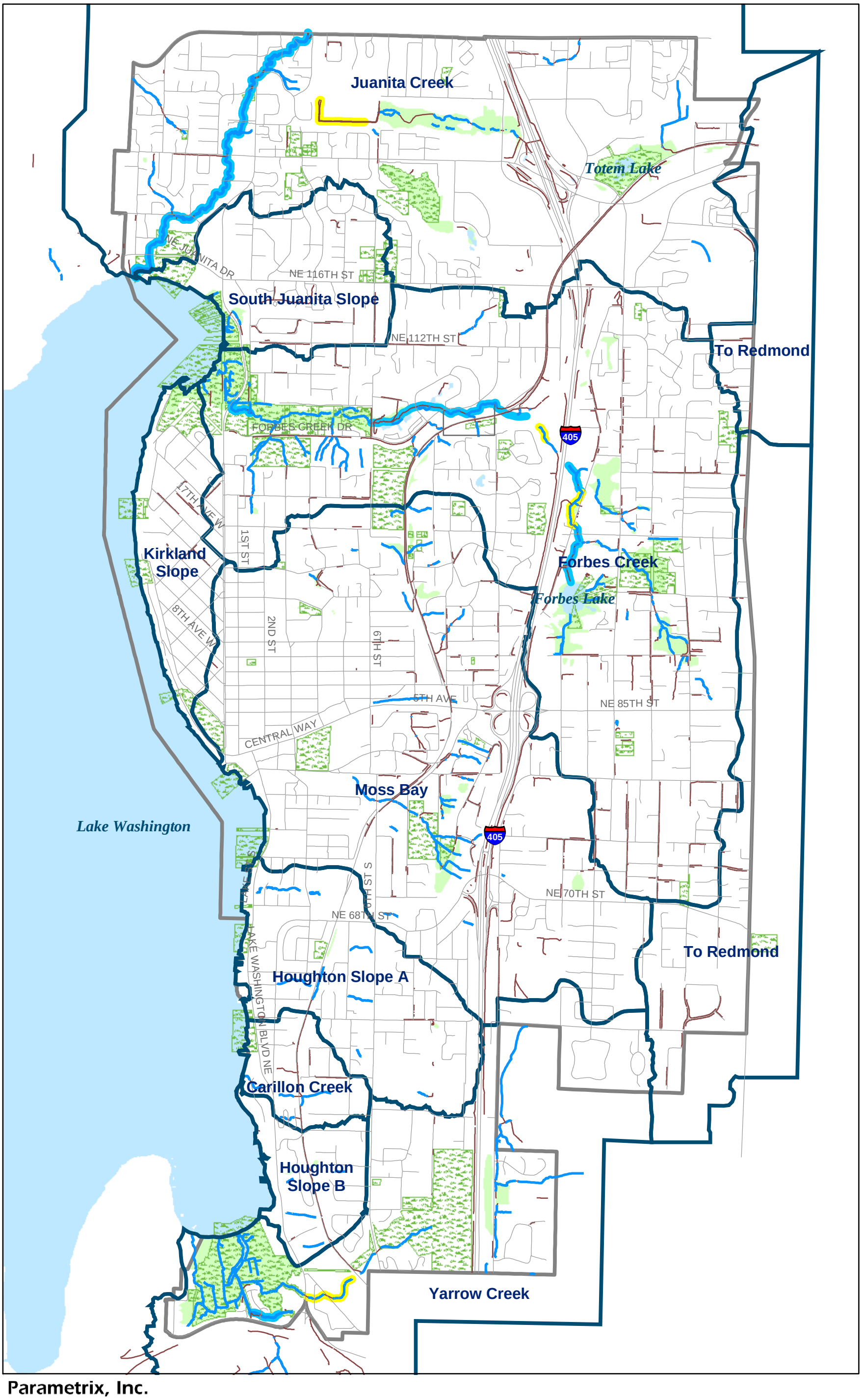
Parametrix, Inc.

0 400 800 Feet

N

Reach Extent
Street Centerline
Stream
City Limit
Quantitative Stream Survey
Qualitative Stream Survey
Parcel
Park
Lake
Wetland

Figure 3-1
Forbes Creek Survey Reaches



Prepared by Parametrix Inc 29 September 2004 K:\GIS\1802\558180203\Figure2-1_StreamsBasins.mxd

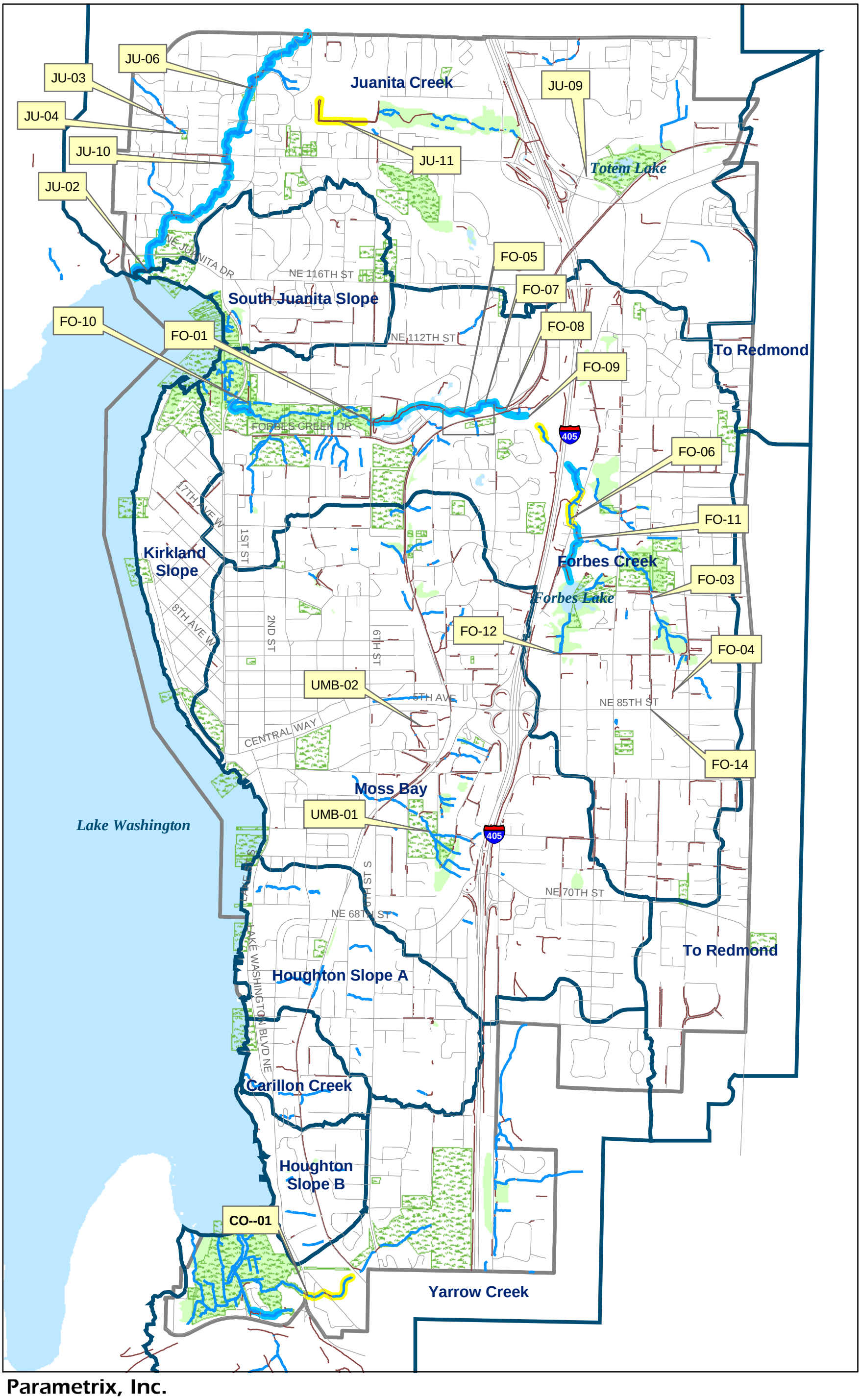
Parametrix, Inc.

N

0 1,000 2,000 Feet

Street Centerline
Stream
Ditch or Culvert
City Limit
Quantitative Stream Survey
Qualitative Stream Survey
Park
Lake
Wetland
Basin Boundary

Figure 2-1
Streams and Basins in the City of Kirkland, WA



Prepared by Parametrix Inc 29 September 2004 K:\GIS\1802\5581802035\PotentialCIPProjects_v2.mxd

Parametrix, Inc.

Street Centerline
Stream
Ditch or Culvert
City Limit
Quantitative Stream Survey
Qualitative Stream Survey
Park
Lake
Wetland
Basin Boundary

N

0 1,000 2,000 Feet

Figure 7-1
Recommended CIP Projects within Streams and Basins in the City of Kirkland, WA