1.2 WATER QUALITY

1.2 WATER QUALITY

EXECUTIVE SUMMARY

This chapter provides an assessment of the water quality conditions in the Green/Duwamish watershed from existing water quality reports and from analysis of water quality data collected during the past four years (1996-1999) by the King County Streams Monitoring Program, the Muckleshoot Indian Tribe, and the City of Tacoma. The water quality data were compared to Washington State water quality standards (WAC 173-201A), EPA water quality criteria and appropriate toxicity screening thresholds to assess potential for biological significance. Where possible and when data or studies are available, water quality trends are examined and acute/chronic concentrations are specifically related to conditions that are known to be or may be a factor of decline for salmonids. Available aquatic insect data were also evaluated as a measure of the aquatic ecosystem condition of selected streams. Finally, data gaps are identified for potential future investigations.

The analysis for this report divides the Green/Duwamish basin into four subbasins on the mainstem (Upper, Middle and Lower Green River, and the Duwamish River) and five tributaries (Crisp, Newaukum, Soos, and Mill (Hill) creeks, and the Black (Springbrook) River). The state water quality standards classify the water bodies in this basin as follows: (1) Class B (fair) – Duwamish River; (2) Class A (good) – lower and middle Green River up to river mile (RM) 42.3, Crisp, Newaukum, Soos, and Mill creeks, and the Black River; and (3) Class AA (extraordinary) – middle Green River, from RM 42.3 to the headwaters.

Numerous stream systems throughout the Green/Duwamish watershed are listed on the State's 1998 303(d) list of impaired water bodies. Section 303(d) of the Clean Water Act requires Washington State to identify those water bodies that do not meet water quality standards. The State is then responsible for prioritizing the list and developing Total Maximum Daily Loads (TMDLs) for every water body and pollutant on the list. Some segments are also listed for sediments and tissues, but they are beyond the scope of this report. In the Green/Duwamish watershed, water body segments have been listed for failing to meet water quality standards for one or more of the following parameters: fecal coliform, temperature, dissolved oxygen (DO), pH, ammonia, and metals (cadmium, chromium, copper, mercury, and zinc).

GENERALIZED WATER QUALITY CONDITIONS

Water quality in the Green River and its tributaries varies widely depending on location in the watershed, intensity of land use (level of urbanization), and human activities (King County 1989). The upper Green River watershed is mostly forested and has been minimally altered by human activities (with the exception of construction of the Howard Hanson and Tacoma Diversion dams and logging activities), and thus generally has the best water quality. The middle Green River is dominated by agricultural land use, mixed forest, and rural residential development, and generally still exhibits fairly good water quality conditions. The lower Green River and Duwamish River are the most urbanized and industrialized portions of the watershed and generally have the most degraded water quality conditions in the mainstem.

Of the tributaries assessed, water quality is also closely linked to the level of urbanization and intensity of land use. Crisp Creek has the best overall water quality and is the least developed of the tributaries assessed. Newaukum Creek, which has extensive agricultural land use, generally has good water quality but suffers from occasional depressions in DO levels. Soos Creek has some of the region's best water quality of the smaller creeks in the urban portion of King County. Mill and Springbrook (Black River) creeks are the most heavily urbanized of the tributaries evaluated in this report and exhibit the most degraded water quality conditions.

KEY FINDINGS

This section summarizes some of the key findings from the water quality assessment of existing conditions and trends (where available) for the mainstem and major tributaries. Tables WQ-E1 and WQ-E2 provide a summary of the projected factors of decline for salmonids by subbasin and parameters, providing a quick reference for areas of concern. The criteria used to determine whether a parameter is a factor of decline for salmonids include comparison with water quality standards and toxicity screening thresholds, and listing on the State's 1998 303(d) list. Factors of decline are rated as probable, possible, unlikely, or unknown on the following basis:

1. **Probable**. Probably a factor that contributes to the decline of salmonids based on frequent small exceedances of water quality standards or less frequent significant exceedances, often combined with 303(d) listing for the water body.

2. **Possible**. Possibly a factor that contributes to the decline of salmonids based on occasional small exceedances of water quality standards, or a 303(d) listing for the water body.

3. **Unlikely**. Unlikely to be a factor that contributes to the decline of salmonids based on infrequent or no exceedances of water quality standards and no 303(d) listing for the water body.

4. **Unknown**. No or insufficient data to make a determination or no water quality standards available for evaluation.

The projected water quality factors of decline represent a preliminary assessment based on the best available information. Several factors may contribute to uncertainty in this assessment. First, because this assessment is made by subbasin, the results are generalized, and thus may not show the potential for substantial variability within a subbasin. Second, the sparse data coverage in several subbasins may result in overlooking impaired water quality conditions in some areas. Finally, the lack of continuous data or information on the duration of exposure may lead to an incorrect determination about whether a given parameter is or is not a factor of decline. The key findings are as follows:

1. Water quality conditions in the Lower Green and Duwamish River have improved from the poor water quality conditions that existed in the 1960s. This is a result of the reduction of municipal and industrial discharges (including higher levels of wastewater treatment and reduction of combined sewer overflows (CSOs)) and the relocation of the south municipal wastewater treatment plant outfall to Puget Sound.

2. There has been a trend towards increasing surface water temperatures in most tributaries in the urban and urbanizing areas of the region over the past 20 years, probably attributable to urbanization and development, including increased runoff from impervious surfaces and loss of riparian vegetation.

3. Temperatures in the mainstem during the summer have peaked between 23 and 24 ^{o} C at stations in the Lower and Middle Green River in studies involving continuous monitoring probes, based on available data. In some years, this is probably of concern for adult chinook migration up the Green River in August and early September. Water temperatures in some tributaries of the Mill (Hill) and Springbrook subbasins have been historically high and are probably of concern for salmonid rearing. Water temperatures during spawning and rearing are also of concern for several Soos Creek tributaries. There are insufficient data and information on the distribution of bull trout in the watershed to assess to what extent localized temperature conditions are a concern for bull trout.

4. Dissolved oxygen (DO) levels are one of the most significant issues for salmonids in the basin. In the mainstem, DO levels in the Duwamish and Lower Green rivers are of concern for salmonid rearing on some occasions. In the mainstem above RM 24 (where most mainstem spawning occurs), DO levels in the Middle Green River are occasionally of concern during incubation. DO for incubation and rearing is a probable factor of decline for salmonids in several tributaries, particularly Springbrook Creek, Mill (Hill)[1] Creek, Soos Creek and Newaukum Creek. The most severe documented DO problem in the basin is in Mill Creek (just north of SR-18).

5. Turbidity and total suspended solids (TSS) are possible factors of decline in terms of water column impacts for the Duwamish River, Lower Green River, Mill Creek and Springbrook Creek. However, no data were available for the duration of exposure, so it is difficult to determine the extent to which TSS is of concern. TSS may be a concern in terms of sedimentation in some areas, but this was outside the scope of this study, and would be better characterized by analysis of sediment deposition or embeddedness.

6. Based on the King County Streams water quality data evaluated from 1996 to 1999, pH, ammonia, and metals are unlikely to be factors of decline for salmonids at the locations analyzed. Ammonia may be a factor of decline in the Mill Creek basin based on data collected between 1990 and 1991 by King County. Metals (cadmium, chromium, copper, mercury, and zinc) may be of concern in Springbrook Creek based on sampling carried out by Ecology and King County (Metro) between 1984 and 1990 that led to its listing on the 303(d) list. It is possible that there are localized areas near stormwater outfalls to smaller tributaries where metals could also be of concern.

7. No data were available to assess to what extent organic chemicals such as pesticides, polycyclic aromatic hydrocarbons (PAHs), and phthalates are a factor of decline for salmonids.

[1] Mill Creek (also known as Hill Creek) flows through the City of Auburn and will hereafter be referred to as Mill Creek throughout this report.

8. In the Duwamish Estuary, risks to water column dwelling organisms are minimal; however, there are potential risks to benthic organisms from several chemicals in the sediments, most notably bis(2-ethylhexyl)phthalate, 1,4-dichlorobenzene, mercury, polycyclic aromatic hydrocarbons (PAHs), PCBs, and tributyltin (TBT) (King County, 1999). Risks to the benthic community can potentially translate to risks to salmonids via food-chain transfer (bioaccumulation in prey), reduction in function of immune systems, or from potential toxicity to prey organisms (reduction in available food).

9. Biological monitoring of macroinvertebrates in the Soos Creek basin (1995-98) found highly variable conditions. Five of eight stations monitored had benthic index of biotic integrity (B-IBI) scores in the fair range, two were in the poor range and one station was in the very poor range. Seven stations monitored in 1999, located throughout the mainstem of the Green River all had B-IBI scores in the fair range. Mill (Kent) and Meridian Valley creeks had B-IBI scores in the very poor range.

10. Although aluminum concentrations often exceed the EPA national criterion throughout the watershed, this does not necessarily indicate aluminum is a factor of decline. Measurements of total aluminum include several forms, such as aluminum that is occluded in minerals, clay and sand or is strongly sorbed to particulate matter, that are not toxic or are not likely to become toxic under natural conditions (U.S. EPA 1988). Therefore, this criterion may be overprotective when based on the total recoverable method because the digestion procedure dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988).

Table WQ-E1. Projected water quality factors of decline based on data evaluated in this report.

Parameter Subbasin	Temperature	DO	TSS*	pH	Ammonia	Metals	Pesticides, PAHs, Phthalates
Upper Green	Possible	Unknown	Unlikely	Unknown	Unknown	Unknown	Unknown
Middle Green	Possible	Possible	Unlikely	Unlikely	Unlikely	Unlikely	Unknown
Lower Green	Probable	Possible	Possible	Unlikely	Unlikely	Possible	Unknown
Duwamish	Probable	Possible	Possible	Unlikely	Unlikely	Possible	Unknown
Crisp	Possible	Possible	Unlikely	Unlikely	Unlikely	Unlikely	Unknown
Newaukum	Possible	Probable	Unlikely	Unlikely	Unlikely	Unlikely	Unknown
Soos	Probable	Probable	Unlikely	Unlikely	Unlikely	Unlikely	Unknown
Mill (Hill)	Probable	Probable	Possible	Unlikely	Possible	Unlikely	Unknown
Springbrook (Black R.)	Possible	Probable	Possible	Unlikely	Unlikely	Possible	Unknown

* Due to lack of data on duration for TSS, further investigation is needed for all locations
TBD = To be determined.

Table WQ-E2. Detailed water temperature and dissolved oxygen projected factors of decline[1].					
Parameter	**Temperature**			**Dissolved Oxygen**	
Subbasin	Migration	Rearing	Spawning[2]	Rearing	Incubation[2]
Upper Green [2]	Unlikely	Unlikely	Possible	Unlikely	Unknown
Middle Green	Unlikely	Possible	Possible	Unlikely	Possible
Lower Green	Possible [3]	Probable	N/A	Possible	N/A
Duwamish	Possible [3]	Probable	N/A	Possible	N/A
Crisp Creek	Unlikely	Possible	Possible	Unlikely	Probable
Newaukum	Unknown [4]	Unknown [4]	Possible	Probable	Probable
Soos	Possible [3]	Probable	Probable	Probable	Probable
Hill/Mill	Possible [3]	Probable	Probable	Probable	Probable
Springbrook (Black River)	Unknown [4]	Possible	Possible	Probable	Probable

[1] This evaluation does not include temperature and DO requirements for bull trout.
[2] Proposed spawning and incubation standard only applies from Sept 15 to June 1.
[3] Migration exceedances only occurred during July/August; therefore, only possible concern if salmonids migrating upstream at this time.
[4] No continuous temperature data were available to determine whether this was a factor of decline (other determinations for Newaukum and Springbrook based on discrete data).
N/A = Not applicable; salmonids are not known to spawn in the Lower Green or Duwamish subbasins.

DATA GAPS

This section summarizes some of the data gaps that exist for the mainstem and major tributaries based on the findings of this report.

1. **Spatial availability of water quality data.** The spatial availability of water quality data is highly variable across the watershed. There is a paucity of sampling locations for the mainstem of the Green River, with only four sampling stations between the Duwamish River (RM 11) and the Tacoma diversion dam (RM 61). Conversely, some tributaries such as Newaukum and Soos creeks have a dense spatial representation, with 18 and 17 sampling stations, respectively. Such sparse coverage in some subbasins could potentially overlook some areas with impaired water quality in the Green River, and result in greater uncertainty in this assessment.

2. **Lack of continuous temperature data for some subbasins.** There is a lack of continuous temperature data for the mainstem and several tributaries. Continuous data are necessary to determine maximum daily temperatures and the duration of temperature exceedances that have the greatest potential to impact salmonids. For example, temperature conditions in Crisp Creek were determined to be unlikely as a factor of decline based on routine monthly monitoring. However, examination of continuous temperature data indicated somewhat frequent small exceedances of the proposed rearing and spawning standards leading to a possible factor of decline determination.

3. **No or insufficient data for some parameters**. Data are lacking for many of the water quality parameters that may adversely affect salmon. Available TSS data do not include any information on the duration of exposure, which is needed to evaluate accurately potential effects on salmonids. In an urban watershed with extensive commercial and industrial development characteristic of the Lower Green River and Duwamish River segments, other

parameters that could be of concern include metals, pesticides and herbicides, PAHs, and phthalate esters. There is a shortage of data available for these parameters in the water column. Most of the existing data is for sediments.

4. **Lack of baseflow data for metals**. The majority of the ambient metals data in the Green River watershed were collected as part of the stormwater monitoring program; therefore, baseflow metals concentrations are generally unknown. Furthermore, between 1996 and 1999, metals data were available in only seven locations in the watershed. Therefore, the subbasins are not well characterized for metals with the current data.

5. **No or insufficient data on additive or synergistic effects**. There is insufficient information on the combined effects of toxicants, such as metals or organic chemicals, on salmonids. Additivity is the characteristic property of a mixture of toxicants that exhibits a total toxic effect equal to the arithmetic sum of the effects of the individual toxicants (U.S. EPA 1991). Synergism is the characteristic property of a mixture of toxicants that exhibits a greater-than-additive total toxic effect (U.S. EPA 1991).

6. **Poor or insufficient data on aquatic insects**. Unlike chemical data that yield a snapshot of aquatic conditions at the time of sampling, aquatic insects provide an integrated view of overall water quality conditions at a given location. Unfortunately, the only available aquatic insect data (as measured by B-IBI) in the Green River basin was for the Soos Creek subbasin from 1995, 1997, and 1998, and from selected stations on the Green and two tributaries in 1999. Thus, this is a data gap for the basin as a whole.

7. **Historic water quality limitations for salmonids**. There is a need to define closer links between water quality data and site conditions with the historic, current, and potential future distribution of salmonids. It is likely that water quality conditions limited salmonid distribution in the past, even without extensive human activities. For instance, DO and temperature conditions in areas with extensive open water wetlands may not be compatible with fish presence. Also, the DO and temperature requirements for salmonid migration, rearing, and spawning/incubation vary considerably.

8. **Lack of reference stream site information**. There is an interest in having reference sites based on different geomorphic systems to define background water quality conditions. Without reference sites, it is difficult to define the relative contribution of anthropogenic activities to degraded water quality conditions.

1. INTRODUCTION

This report provides an assessment of the water quality conditions in the Green/Duwamish watershed focusing on water quality concerns for anadromous and resident salmonids. The specific objectives of the report are as follows:

- To identify subbasins/streams with impaired water quality and what parameters are likely causing the impairment;
- To identify subbasins/streams with good water quality and what parameters are not likely to be of concern;
- To categorize parameters as possible, probable, unlikely, or unknown water quality factors of decline for salmonids;
- To identify trends in water quality conditions, where possible;
- To summarize water quality impairment based on Washington State's 303(d) listings; and
- To identify major water quality data gaps for potential future investigations.

SCOPE

The scope of this report includes an assessment of water quality in the mainstem of the Green River and Duwamish Estuary, as well as the major tributaries to the Green River. These tributaries include the Newaukum Creek subbasin, Crisp Creek, Soos Creek subbasin, Mill/Hill Creek subbasin, and Black River (Springbrook Creek) subbasin (Figures WQ-1 through WQ-3). The scope does not include an assessment of tributaries in the upper Green River or the Duwamish Estuary, nor does it include the independent tributaries to Puget Sound or Elliott Bay.[2]

The water quality assessment is based on existing water quality reports and from analysis of water quality data collected during the past four years (1996-1999). Summaries from existing water quality reports (published within the past decade) are presented for different segments of the mainstem and its tributaries, where available. Current water quality conditions are characterized from recent water quality data from the King County Streams monitoring program and samples collected by the Muckleshoot Indian Tribe Fisheries Department (MITFD) for the Newaukum and Soos subbasins. To ensure that the summary accurately reflects existing and not historical conditions, only the last four years of data were evaluated. Therefore, all of the data included in this summary were collected between October 1996 and December 1999. These data were collected as part of routine monthly stream monitoring or targeted monitoring of streams during storm conditions. New data were not collected as a part of this evaluation.

This report focuses on water quality parameters that may cause direct toxicity or harm to salmonids. These parameters include temperature, dissolved oxygen (DO), total suspended solids

[2] King County's Central Puget Sound Team is conducting a separate evaluation of water quality in Elliott Bay and the independent tributaries to Puget Sound.

(TSS), pH, ammonia, and metals. This report does not assess to what extent temperature conditions are a concern for bull trout, because of a lack of sufficient data and information on bull trout distribution in the watershed. Data were not readily available for other parameters, such as organic chemicals (e.g., pesticides), that may also cause direct toxicity, or direct and indirect adverse impacts to salmonids. Other water quality parameters, such as increased levels of nitrate, phosphorus, and fecal coliforms can result in water quality concerns; however, they were not evaluated in this report as they are not thought to have direct effects on salmonids.

To assess whether water quality may result in conditions that are known to be or may be a factor of decline for salmonids, water quality data were compared to Washington State water quality standards (WAC 173-201A), the proposed new state water quality standards for temperature and DO, EPA water quality criteria and appropriate toxicity screening thresholds from the scientific literature.

In addition, stream segments throughout the Green/Duwamish watershed that are listed on the State's 1998 303(d) list of impaired water bodies are identified. Section 303(d) of the Clean Water Act requires the State to identify those water bodies that do not meet water quality standards. The State is then responsible for prioritizing the list and developing Total Maximum Daily Loads (TMDLs) for every water body and pollutant on the list. Some segments in the Green/Duwamish watershed are also listed for sediments and tissues, but they are beyond the scope of this report.

REPORT ORGANIZATION

Following this section, the report includes an overall discussion on the available water quality data (section 2). Section 2 presents the locations of the sampling data, more detail on the parameters evaluated and a summary of the major data gaps common throughout the report. Section 3 is a brief summary of the available biological data used in this report. Section 4 presents the existing and proposed Washington State water quality standards and EPA water quality criteria used in this report. For those parameters without standards, a summary of the toxicity thresholds used from the scientific literature is presented. Finally, Section 4 presents a summary of the 303(d) listed waterbody segments in the Green/Duwamish Watershed. Section 5 presents the detailed water quality assessment by subbasin. The subbasins include the mainstem (Upper, Middle and Lower Green River, and the Duwamish River) and five tributaries (Crisp, Newaukum, Soos, and Mill (Hill) creeks, and the Black (Springbrook) River).

2. AVAILABLE WATER QUALITY DATA

Most of the water quality data used in this report for the Green/Duwamish watershed has been collected by King County Department of Natural Resources (previously Metro), but data has also been collected by the Department of Ecology, MITFD, USGS, Corps of Engineers, Port of Seattle, Boeing, City of Tacoma, and selected cities within the basin. For the existing conditions analysis in this report only the King County, MITFD, and City of Tacoma data were used, because they were recent (1996 to 1999), readily available, and in a useable format. A variety of reports and studies containing water quality data were also available for specific sub-basins. The more recent studies are summarized in this report. Students at Green River Community College sampled water on several occasions in the 1980s, but there is little documentation of these data and no available QA/QC, so it was not used in the following analysis.

King County (Metro) has been sampling in the Green/Duwamish watershed for a variety of water quality parameters since 1970. In the mid-1970s, it was recommended that Metro institute an ongoing program to monitor water quality in the 26 subbasins within the western third of King County (Metro 1978). The goal of the monitoring program was to provide information about local surface waters in the Seattle Metropolitan area in support of programs designed to protect water quality and abate water pollution. Fourteen stations in the Green River basin have been monitored as part of this program since the mid-1970s.

The frequencies of sampling and types of indicators measured have varied over the years, but samples have been collected at least monthly. Samples for the King County Streams Monitoring Program were collected beneath the water surface, in the top meter and as close to the center of the channel as possible. For the Duwamish River Water Quality Assessment (King County 1999), King County also collected samples at depth (one meter above bottom to a maximum depth of 20 meters) and near the banks in the Duwamish River.

SAMPLING LOCATIONS AND FREQUENCY

Water quality data were available from 66 locations throughout the Green River basin as part of the King County Streams Monitoring Program, MITFD and the City of Tacoma Public Utilities Water Quality Division monitoring programs for the time period investigated (1996-1999). King County and MITFD sampling occurs routinely as part of monthly monitoring (typically during ambient flow conditions) and specifically during storm conditions. Although most data were collected during both ambient and storm conditions, the majority of the metals sampling occurred only during storm conditions. Storms are characterized by at least 0.25 inches of rain within a 24-hour period with at least 24 hours of dry antecedent conditions. City of Tacoma monitoring occurred on a weekly basis. Figures WQ-1 through WQ-3 identify all of the sampling locations analyzed in this report from the King County and Muckleshoot Indian Tribe Streams Program as well as the City of Tacoma Public Utilities Water Quality Division. All data used were from samples collected between October 1996 and December 1999. In addition, continuous temperature monitoring data were available for stations in the Soos Creek (Covington, Jenkins, Little Soos, and Soosette), Mill Creek and Crisp Creek subbasins from the King County Stream Gauging Program and USGS (Big Soos Creek).

SUMMARY OF PARAMETERS INCLUDED IN ANALYSIS

This report focuses mostly on those water quality parameters that are potential water quality factors of decline for salmonids, based on the scientific literature or where water quality standards have been promulgated. It does not contain a review of all water quality data collected in the watershed. For instance, fecal coliforms are the most common water quality parameter listed on the 1998 303(d) list in the watershed, but because fecal coliforms are thought to not adversely affect fish, they are not discussed in this report.

Parameters covered in this report include:

- Conventionals (temperature, dissolved oxygen, pH, turbidity and total suspended solids);

- Ammonia-nitrogen, and
- Metals (such as copper, cadmium, and zinc).

Other parameters that are known to adversely affect fish, but for which little or no data were available or standards not developed (e.g., pesticides, petroleum aromatic hydrocarbons (PAHs) and phthalates), are not analyzed in this report. The only exception was pentachlorophenol, where data from the Duwamish River were compared with marine standards.

DATA GAPS

The spatial availability of water quality data is highly variable across the watershed. There is a paucity of sampling locations for the main stem of the Green River for which King County data are available, with only four sampling stations between the Duwamish River (RM 11) and the Tacoma diversion dam (RM 61). There are two sampling stations in the Lower Green River spanning 21 miles, and only two stations in the Middle Green River, spanning 29 miles. Conversely, some tributaries such as Newaukum and Soos creeks have a dense spatial representation, with 18 and 17 sampling stations, respectively. Such sparse coverage in some subbasins could potentially overlook some areas with impaired water quality in the Green River, and result in greater uncertainty in this assessment.

There are probably sufficient data to characterize temperature, DO, pH, and ammonia at each of the sampling locations for purposes of assessing preliminary areas of concern for salmonids. However, as noted above, the current station locations do not yield adequate spatial coverage. Continuous temperature data exist for only some subbasins; thus, for other subbasins, it was not possible to determine maximum temperatures and the duration of temperature exceedances that have the greatest potential to impact salmonids.

Data are lacking for many of the other water quality parameters that may adversely affect salmon. In an urban watershed with extensive commercial and industrial development characteristic of the Lower Green River and Duwamish River segments (RM 0 – 32), typical parameters that can be of concern include metals, pesticides and herbicides, PAHs, TSS, and phthalate esters. Potential sources of these pollutants in stormwater and CSOs are described below:

- Metals can originate from a variety of sources including exposed metal surfaces, treated lumber and vehicles, including brake pad residues and tires.
- Pesticides and herbicides (e.g., 2,4-D, Diazinon, Malithion) applied to crops and landscaping can be transported into nearby streams via wind drift and stormwater runoff. This is an issue for agricultural areas such as those in the Middle Green River basin, as well as commercial and residential areas in the more developed portions of the basin (Hoffman et al. 2000).
- PAHs are formed as the result of incomplete combustion of organic compounds with insufficient oxygen (U.S. EPA 1980a), and have been detected in cigarette smoke and gasoline exhaust condensates (U.S. EPA 1980b).

- Phthalate esters are a large group of chemicals used primarily as plasticizers, which can be present in concentrations up to 60 percent of the total weight of a plastic. Phthalate esters are loosely linked to the plastic polymers and are easily extracted (Mathur 1974 as cited by U.S. EPA 1980c).

- In sub-basins with extensive impervious surface coverage, such as the Lower Green River, TSS is a concern due to washoff of urban surfaces as well as increased stormwater runoff which can lead to instream erosion. However, because TSS effects are highly dependent on the duration of exposure, information on both concentration *and* duration are needed to evaluate its effects to salmonids.

Concentrations of pesticides and herbicides in surface water are expected to be highest in highly developed areas (including areas with extensive homeowner usage) and where there are intensive agricultural activities (such as in the Middle Green River basin) (Hoffman et al. 2000). There is also some pesticide use in the Upper Green River basin along access roads and utility rights-of-way. There likely are fewer sources of metals, PAHs, phthalate esters and TSS in the less developed areas, however, these parameters should be evaluated to characterize the baseline and upstream conditions.

The majority of the metals data in the Green River watershed were collected as part of the stormwater monitoring program; therefore, baseflow metals concentrations are generally not available. Furthermore, between 1996 and 1999, metals data were available in only seven locations in the watershed. Therefore, the subbasins are not well characterized for metals with the current data.

3. AVAILABLE BIOLOGICAL DATA

King County uses a method called the Benthic Index of Biotic Integrity, or B-IBI, as a “report card” for measuring the health of the benthic aquatic insect community and for the stream ecosystem as a whole (Fore et al. 1997). Data are limited for the Green River basin, but the B-IBI measure still provides a useful tool to compare different subbasins with one another.

BENTHIC INDEX OF BIOTIC INTEGRITY

The B-IBI is composed of ten “metrics” (Fore et al. 1997). Metrics measure different aspects of stream biology, including the diversity of species, abundance of certain species, presence/absence of species that are tolerant and intolerant to pollution, their reproductive strategy, feeding ecology, and population structure. Each metric is assigned a value of 1, 3, or 5 depending on what species are present at a site. A score of 5 is used to indicate little or no degradation, a score of 3 to indicate moderate degradation, and a score of 1 to indicate severe degradation. All ten metric scores are added together to get a value ranging from 10 to 50. A score of 46-50 is generally considered excellent, 38-44 good, 28-36 fair, 18-26 poor and 10-16 very poor.

It is important to note that scores vary across a watershed and region based on a combination of physical conditions and water quality. The type of substrate, flow, and riparian buffer/vegetation can influence the B-IBI in addition to water quality conditions (e.g., temperature, DO, TSS, metals).

SAMPLING LOCATIONS

Aquatic insect data were collected at eight locations by staff from King County in the Soos Creek subbasin on two or three occasions in 1995, 1997 and 1998. Additionally, data were also collected by volunteers in 1999 under the direction of the SalmonWeb program (Salmon Web 2000). Seven locations on the mainstem of the Green River, one location on Mill Creek (Kent) in the Black River Basin, and one location on Meridian Valley Creek in the Big Soos Creek subbasin were sampled. SalmonWeb (2000) noted that the protocols use sampling methodologies and scoring criteria developed and calibrated for small streams (2^{nd} to 4^{th} order), and for this reason the results for the Green River should be considered preliminary. Results of the biological monitoring are presented in the subbasin sections below.

4. IDENTIFICATION OF WATER QUALITY STANDARDS

Throughout this chapter, references are made to various water quality standards for comparison purposes. These include: (1) Water Quality Standards for Surface Waters of the State of Washington, Chapter 173-201A WAC, (2) National Recommended Water Quality Criteria for Priority Toxic Pollutants (63 FR 68354-68364), and (3) 1999 Update of Ambient Water Quality Criteria for Ammonia (U.S. EPA 1999). In addition, comparisons are also made with Ecology's proposed use-based standards for temperature (Hicks 2000a) and DO (Hicks 2000b) that take into account requirements of salmonids for rearing, spawning and incubation. These new standards are scheduled for public hearing in March 2001 and scheduled for adoption by August 2001. Thus, they are still undergoing stakeholder review and agency consideration. For indicators where no water quality standards exist, some comparisons are made with other streams or toxicity values from the scientific literature.

STATE WATER QUALITY DESIGNATIONS AND BENEFICIAL USES

The Water Quality Standards for Surface Waters of the State of Washington (Chapter 173-201A WAC) provides a set of classifications for water bodies in the state, ranging from Class AA (extraordinary) to Class C (fair) based on the "beneficial uses" of the water, or what uses the water might support. The beneficial uses describe allowable water uses (domestic, industrial, agricultural), salmon fishery uses (migration, rearing, spawning, harvesting) and contact recreation (swimming, wading) for each classification. Table WQ-1 summarizes the state water quality beneficial uses for each classification.

Table WQ-1. Water quality beneficial uses for surface waters of the State of Washington.			
Characteristic/WQ Parameter	**Class AA (Extraordinary) (Upper Green R.)**	**Class A (Excellent) (Lower Green R.)**	**Class B (Good) (Duwamish R.)**
Allowable Water Uses	Domestic Industrial Agricultural	Domestic Industrial Agricultural	Industrial Agricultural
Salmonid Uses	Migration Rearing Spawning Harvesting	Migration Rearing Spawning Harvesting	Migration Rearing Harvesting
Contact Recreation	Primary(swimming)	Primary(swimming)	Secondary (wading)

The Duwamish River, from its mouth at Elliott Bay to the confluence with the Black River (river mile 11.0) is designated Class B. The lower and middle Green River is designated Class A from river mile 11.0 to river mile 42.3 at Flaming Geyser State Park. From river mile 42.3 to the headwaters, the Green River is designated Class AA. The Black River, Mill Creek, Soos Creek, Crisp Creek, and Newaukum Creek subbasins are all designated Class A. All tributaries to the Green River above river mile 42.3 are designated Class AA (see Figures WQ-1 through WQ-3 for river mile markings).

STANDARDS FOR WATER QUALITY PARAMETERS

In this section, the various standards/criteria and toxicity thresholds from the scientific literature used in this assessment are presented. Wherever possible, the water quality data were compared to state and federal standards to estimate which parameters at specific locations may potentially be of concern for salmonids. The National Marine Fisheries Service and U.S. Fish and Wildlife Service have raised the issue of whether water quality standards are adequate to protect listed salmonids. Ecology is proposing new use-based state standards (with salmon-specific thresholds) to address these concerns. [It is important to note that these standards (based on rearing, spawning and incubation needs for salmonids) have not yet been adopted.] A description of the standards and thresholds used in this report to characterize the existing conditions is provided below.

The state water quality standards contain numerical and narrative standards. Numerical standards consist of minimum levels or concentrations of specific water quality parameters that are established to protect aquatic biota and support beneficial uses. Different levels or concentrations have been established for temperature, turbidity, pH, DO, and fecal coliform bacteria based on the beneficial uses for various water quality class designations. For other parameters, such as metals and organic chemicals, the concentrations do not change based on the designated classification. Table WQ-2 summarizes the numeric state water quality standards for temperature, turbidity, pH, DO and fecal coliforms in freshwater for each of the three classifications present in the Green/Duwamish watershed.

Table WQ-2. Water quality standards for freshwater based on beneficial use classification.			
Characteristic/ WQ Parameter	**Class AA (Extraordinary) (Upper Green Ri.)**	**Class A (Excellent) (Lower Green Ri.)**	**Class B (Good) (Duwamish Ri.)**
Temperature (°C)	< 16	< 18	< 21
pH	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
Dissolved Oxygen (mg/L)	> 9.5	> 8.0	> 6.5
Turbidity (NTU)	< 5 over background when <50 NTU, <10% increase when over 50 NTU	< 5 over background when <50 NTU, <10% increase when over 50 NTU	< 10 over background when <50 NTU, <20% increase when over 50 NTU
Fecal Coliforms (Colonies/100mL)	GM < 50, not more than 10% over 100	GM < 100, not more than 10% over 200	GM < 200, not more than 10% over 400

Narrative standards are designed to protect beneficial uses in the absence of numeric criteria. Narrative standards can be used to establish levels of protection for parameters where numeric standards do not exist and to enforce the states antidegradation policy (Chapter 173-201A-070 WAC).

More detailed discussions of these standards are presented below. Also included in these detailed discussions are the proposed use-based standards for temperature and DO, the metals standards, and the toxicity thresholds from the scientific literature for those parameters lacking state or federal standards.

TEMPERATURE

Existing state temperature standards are based on the surface water classification (see Table WQ-2). In addition to these, there are marine water standards that were used for the Duwamish Estuary. For marine water, Class B surface waters (Duwamish River) shall not exceed 19°C; there are no Class A or Class AA marine surface waters in the Green/Duwamish watershed. Analysis in support of Ecology's proposed use-based[3] standards has determined that the existing standards are inadequate to fully protect all aquatic communities (Hicks 2000a). Therefore, several new alternative temperature standards have been proposed. Ecology's preferred alternative is as follows:

- Waters used for *spawning* by Pacific salmon, steelhead trout, or cutthroat trout: Human-caused conditions and activities are not to cause temperatures to exceed 15 °C as a moving 7-day average of the daily maximum temperatures, with no single daily maximum temperature greater than 17.5 °C from June 1-September 14; and 12 °C as a 7-day average of the daily maximum temperatures; with no single daily maximum temperature exceeding 14.5 °C during the period from September 15-May 31.

[3] Applying use-based standards requires that waterbodies be assigned to appropriate use-categories, such as char spawning or salmon spawning, etc. Not all use-category definitions are detailed here (e.g., char spawning, warm water species spawning) as they are either not applicable to the Green-Duwamish watershed or superceded by a more stringent use-category standard.

- Waters used for *rearing, migration, or holding by adult or juvenile* Pacific salmon, steelhead trout, or cutthroat trout: Human-caused conditions and activities are not to cause temperatures to exceed 15 °C as a moving 7-day average of the daily maximum temperatures, with no single daily maximum temperature greater than 17.5 °C.

In the Green/Duwamish Watershed, salmonid spawning starts at RM 24 in the Lower Green River and continues upstream. Salmonid spawning does not occur in the Duwamish River because of several factors, including the influence of the saltwater wedge that extends up to the turning basin (RM 11). Therefore, in this analysis the spawning temperature standard was applied to all subbasins except for the Duwamish River. The rearing standard was applied to all subbasins including the Duwamish River.

Seven-day average temperature data were not available for many of the stations being evaluated. For such stations, discrete data were compared with the 17.5°C and 14.5°C single daily maximum proposed standards for rearing and spawning waters, respectively. Daily maximum temperatures rising above 21°C are widely cited as causing a barrier to migrating adult chinook salmon (Hicks 2000a). When applicable, this migration threshold was included in the analysis. Where continuous temperature data were available, data were compared with the 15°C and 12°C 7-day average daily maximum for rearing and spawning waters, respectively. This report does not assess to what extent temperature conditions are a concern for bull trout, because of a lack of sufficient data and information on bull trout distribution in the Green/Duwamish Watershed.

DISSOLVED OXYGEN

As with temperature, current state DO standards are based on the surface water classification (see Table WQ-2). There are also marine water quality standards for DO that were used for the Duwamish Estuary. For marine water, Class B surface waters (Duwamish River) shall exceed 5 mg/L DO. Again, however, Ecology has re-evaluated the existing DO standards (Hicks 2000b) and proposed new use-based standards. Ecology's preferred alternative is as follows:

- During the *incubation period* for salmonids (in areas used for spawning), human-caused conditions and activities are not to cause daily minimum DO levels in the water column to fall below 10.5 mg/L. [The period from September 15 to May 31 should be used to apply the incubation criteria where more accurate waterbody-specific information is unavailable. Where such knowledge exists, the site-corrected incubation period should be formally noted in the water quality standards for the waterbody.]

- During all other times of the year or for waters used by salmonids *for life-stages other than incubation*, human-caused conditions and activities are not to cause daily minimum DO levels in the water column to fall below 8.0 mg/L.

Chinook eggs will incubate for the period from October into February depending upon spawning date and water temperature (Williams et al. 1975). However, in order to account for other salmonids spawning in the Green/Duwamish Watershed, this analysis adopted the Ecology defined incubation period of September 15th through May 31st (Hicks 2000b) for purposes of comparing water quality data to DO standards. However, some salmonids (e.g., winter and summer steelhead) may have incubation periods that overlap the June 1 through September 14th window.

In this analysis the incubation temperature standard was applied to all subbasins except for the Duwamish River from September 15th through May 31st. The rearing standard was applied year-round to all subbasins except the Duwamish River.

TURBIDITY / TOTAL SUSPENDED SOLIDS

Standards are established for turbidity based on surface water classification (see Table WQ-2). Application of this standard for discharges requires concurrent measurement of upstream (i.e., background) turbidity, and either discharge turbidity or turbidity in the downstream receiving water (Austin personal communication 2000). No concurrent data for upstream and downstream locations were available for point sources; therefore, the potential impacts of turbidity could not be quantified for this analysis.

As an alternative, we used total suspended solids (TSS) data to evaluate adverse effects to salmonids from suspended sediments in the water column. In addition, most of the studies conducted on the effects of suspended sediments measure TSS rather than turbidity. Because Ecology does not have water quality standards for TSS, data were used from the scientific literature to establish thresholds for salmonids.

Suspended sediment generally includes particles less than 0.25 mm (Newcombe and Jensen 1996), and is usually measured in mg/L. Various recommendations of what levels are adequate for fish protection have been proposed (NAS 1973, U.S. EPA 1976, EIFAC 1964, Alabaster and Lloyd 1982, U.S. EPA 1986, Lloyd 1987). Among these documents the most frequently-cited level of suspended sediment below which adverse effects to fish are unlikely to occur was 25 mg/L (Lloyd 1987).

Recent reviews of the available literature have determined that the duration of the exposure for salmon is equally as important as concentration relative to toxicity (Newcombe and Jensen 1996). Therefore, one cannot evaluate the effects of a specific suspended sediment concentration without considering its duration. For example, extremely high pulses (>1000 mg/L) can be sustained for several days, but sub-lethal and adverse behavioral effects can be important for streams that exhibit chronic (long-term) suspended sediment loading even at relatively low concentrations (around 20 mg/L). Sub-lethal effects could be expected from exposure to 31 mg/L for a period greater than three to seven hours, or from a 215 mg/L exposure over a period greater than one hour (Newcombe and Jensen 1996).

Another adverse effect of increased suspended sediments on salmonids is an increase in the concentration of fine sediments in the streambed substrate. Fine sediments adversely affect survival during egg incubation by coating egg surfaces or by clogging interstitial gravel spaces and reducing water flow (i.e., reduction in dissolved oxygen) or trapping emerging fry (Chapman 1988). In addition to direct mortality, fine sediments can result in delayed emergence or smaller fry (Chapman 1988). Furthermore, fine sediment can affect fry survival by filling the interstitial areas between cobbles and other small-sized substrate and thereby reducing important hiding places for rearing fish. Fine sediment is also know to negatively affect macroinvertebrate communities (May et al. 1997), because of the reduction of available surface area and interstitial areas used as cover (Cordone and Kelly 1961). Therefore, fine sediment also indirectly impacts rearing salmonids by reducing important prey items. The water quality data evaluated for this study do not have information on fine sediments in the streambed substrate, so this will not be evaluated in this report.

pH

The current state pH standards for freshwater are 6.5 to 8.5 for all classifications (see Table WQ-2). As with temperature and DO, there are also marine water standards that were used for the Duwamish Estuary. For marine water, the pH standards are 7.0 to 8.5 for all classifications. Direct effects to salmonids are not expected in this range, however the toxicity of some chemicals (e.g., metals and ammonia) is greatly influenced by pH. Data were evaluated against the state standard. Data were also used to help evaluate the ammonia and pentachlorophenol toxicity standards and thresholds (see below).

AMMONIA-NITROGEN

In aqueous solution, ammonia primarily exists in two forms, unionized ammonia (NH_3) and ammonium ion (NH_4^+). The state standards are based on the unionized fraction of ammonia because it is much more toxic than ammonium ion (U.S. EPA 1986). Unionized ammonia is the more toxic form because it is a neutral molecule and thus able to diffuse across epithelial membranes of aquatic organisms (e.g., fish gills) much more readily than the charged ion (U.S. EPA 1998). The unionized fraction is both pH and temperature dependent; therefore the standard is pH and temperature dependent. As pH and temperature increase, ammonia toxicity increases, and the standards decrease. In addition, the standards change (i.e., become less stringent) if the surface water is not used by salmonids. The standards used for this analysis are based on salmonids being present.

In 1998, EPA revised the freshwater national ammonia water quality criteria to account for total ammonia (both NH_3 + NH_4^+). However, in developing the new chronic criteria, EPA excluded the salmonid (i.e., rainbow trout) toxicity data because of variability in the study results. This resulted in a less stringent freshwater chronic standard. Because of the uncertainty regarding the level of protection of the new EPA chronic ammonia criteria for salmonids, Ecology is considering adopting EPA's new acute criterion[4], while maintaining their existing chronic criterion (C. Neimi personal communication 2000). Therefore, both the existing state standards and the new EPA criteria were used in this analysis.

Available pH and temperature data for the Green River watershed were averaged for each sample location to develop acute and chronic ammonia freshwater standards specific to each location. Depending on the receiving water's pH and temperature, EPA standards in freshwater ranged from 2.86 to 38.99 mg/L (acute) and 1.40 to 7.09 mg/L (chronic). When converted to total ammonia, state freshwater standards ranged from 2.38 to 35.80 mg/L (acute) and 0.75 to 2.70 mg/L (chronic). For the Duwamish River, conservative state and EPA marine standards were used representing the worst-case combination of pH, temperature and salinity based on the 1996

[4] The 1999 EPA acute criterion continues to incorporate salmonid toxicity data; only the 1999 chronic criterion excluded it.

to 1999 data. When converted to total ammonia, the acute marine standard was 1.3 mg/L and the chronic marine standard was 0.2 mg/L.

METALS AND PENTACHLOROPHENOL

In fish, at exposure concentrations that produce acute effects, gills are the principal site of toxicity (Evans 1987, Wood 1992). Gill function includes gas exchange and active ion uptake to counter ion changes down their electrochemical gradients. Metals bind to anionic sites on the gills and disrupt gill transport functions. If a metal cannot bind to the site of uptake, it will not be acutely toxic (Bergman and Dorward-King 1997).

Measurement of the total recoverable metal (TRM) includes some fraction of the metal that is bound to suspended solids or is strongly complexed with organic matter or other ligands and cannot bind to gill receptor sites. Therefore, standards for the majority of the metals are based on the dissolved fraction of the metal, as opposed to the TRM, as it more closely approximates the metal's bioavailable fraction, and thus, its toxicity (Prothro 1993, U.S. EPA 1993). On the other hand, metals bound to suspended solids may settle and contribute to sediment metal loads. These sediments may be incidentally ingested by salmonids or accumulate into benthic organisms and thus enter into the food chain. However, mechanisms of chronic toxicity from dietary exposure are not understood and therefore beyond the scope of this analysis.

The National Recommended Water Quality Criteria for Priority Toxic Pollutants were developed by EPA and subsequently adopted by Ecology for Washington State. Both acute (short-term) and chronic (long-term) criteria have been established for various metals and organic chemicals in fresh and marine waters. The acute standards are based on short-term toxicity tests evaluating lethal endpoints and reflect the highest surface water concentration to which aquatic life can be exposed for a brief period of time without causing unacceptable mortality levels. The chronic standards are based on long-term sub-lethal toxicity tests with endpoints such as survival, growth, reproduction and development, and reflect the highest instream concentration of a toxicant to which aquatic life can be exposed indefinitely without causing an unacceptable effect (U.S. EPA 1991).

The state water quality standards for metals and pentachlorophenol are listed in Table WQ-3. As noted in the table, a number of the freshwater standards are dependent on the hardness of the receiving water. The water hardness affects the bioavailable[5] fraction of the metal. As the hardness increases, the metal is less bioavailable, and therefore, less toxic. For those metals that are hardness dependent, a hardness of 40.5 mg/L $CaCO_3$ was used for the Middle and Upper Green River and their tributaries. This value was calculated from the average of all the available calcium and magnesium concentration data (1996 through 1999) within the Green River watershed.

[5] Bioavailability is the degree to which a contaminant in a potential source is free for uptake (movement into or onto an organism) (Hamelink et al. 1994).

Table WQ-3. State water quality standards for metals and pentachlorophenol (µg/L).				
	Freshwater		Marine	
Parameter	Acute	Chronic	Acute	Chronic
Aluminum, total	750**	87**	N/A	N/A
Arsenic, dissolved	360	190	69	36
Cadmium, dissolved*	1.4	0.5	42	9.3
Chromium (VI), dissolved	15	10	1100	50
Chromium (III), total*	261.6	84.8	N/A	N/A
Copper, dissolved*	7.3	5.2	4.8	3.1
Lead, dissolved*	23.8	0.9	210	81
Mercury, dissolved	2.1	N/A	1.8	N/A
Mercury, total	N/A	0.012	N/A	0.025
Nickel, dissolved*	658.4	73.1	74	8.2
Pentachlorophenol	***	***	13	7.9
Selenium, total	20	5	290	71
Silver, dissolved*	0.7	N/A	1.9	N/A
Zinc, dissolved*	66.3	60.6	90	8.1

* Criteria hardness dependent. Value shown based on 40.5 mg/L $CaCO_3$.
** Chapter 173-201A does not contain numeric water quality criteria for aluminum, so the EPA water quality criteria for aluminum is used.
*** Freshwater pentachlorophenol standards were not included as no freshwater pentachlorophenol data were available.
N/A = not available.

Water quality data for metals and pentachlorophenol were compared to the standards shown in Table WQ-3 to determine potential factors of decline for salmonids. The freshwater standards were applied throughout the watershed, except for the Duwamish. In the Duwamish, at least 90 percent of the samples would be classified as marine according to WAC 173-201A-060 (salinity of greater than or equal to one part per thousand). The small percentage of samples below one part per thousand were measured either on the surface at the upper end of the Duwamish River or during high river flows combined with low tides. However, it is unlikely that true freshwater species will inhabit an estuarine environment where salinity exceeds one part per thousand over 90 percent of the time. Therefore, marine standards were applied in the Duwamish.

Because acute standards represent a one-hour average concentration not to be exceeded, the maximum values for each of the parameters were compared to the acute water quality standards. On the other hand, chronic standards represent the four-day average concentration not to be exceeded. Therefore, arithmetic mean values (or geometric mean values when the coefficient of variation was greater than 100 percent) were compared to the chronic water quality standards.

It is important to note that detection limits for some metals were higher than their corresponding standards or criteria. For example, method detection limits for the selenium (50 µg/L) analyses conducted prior to 1998 were greater than the state acute and chronic water quality standards for freshwater (20 and 5 µg/L, respectively). In addition, method detection limits for aluminum (100 µg/L) were greater than the EPA chronic freshwater criterion (87 µg/L). Where these metals were not detected, comparisons to the appropriate standards or criteria could not be made, as the true concentration was unknown. When detected, though, concentrations of these metals were known to be higher than the appropriate standards or criteria, and the detection limits were not an issue.

Similarly, method detection limits for total mercury (0.2 µg/L) were greater than the state chronic freshwater standard (0.012 µg/L). However, this standard is based on the protection of human health from consuming fish and is lower than the levels associated with toxicity to aquatic life, including salmonids (0.77 µg/L, 63 FR 68354-68364). Therefore, because mercury was never detected in freshwater and the method detection limits are below levels associated with toxicity to aquatic life, mercury in the water column is not expected to be of concern to aquatic life, including salmonids.

DESIGNATION OF 303(D) LISTED WATER BODIES

Numerous stream systems throughout the Green/Duwamish watershed are listed on the State's 1998 303(d) list of impaired water bodies. Section 303(d) of the Clean Water Act (CWA) requires the State to identify those water bodies that do not meet water quality standards. The State is then responsible for prioritizing the list and developing Total Maximum Daily Loads (TMDLs) for every water body and pollutant on the list. In the Green/Duwamish watershed, water body segments have been listed for failing to meet water quality standards for one or more of the following parameters: fecal coliform, temperature, DO, pH, ammonia, and water column metals (cadmium, chromium, copper, mercury, zinc). The water bodies and parameters on the 1998 303(d) list are shown in Table WQ-4 and Figure WQ-4.

It is important to note that there has been no comprehensive assessment of water quality to determine which water body segments do or do not meet water quality standards. The water bodies on the 1998 303(d) list mostly reflect exceedances where water quality data have been collected. It should not be inferred that all other segments meet water quality standards. Some segments have been regularly monitored and meet water quality standards; however, other segments may exceed standards, but are not on the 303(d) list because they have never been monitored. It is also important to note that Duwamish River sediments and tissues are also listed on the 303(d) list for numerous metals and organic chemicals. This may be a significant issue for salmonids; however, sediment quality is not the subject of this report.

Table WQ-4. Summary of Water Bodies and Parameters on 1998 303(d) List for Water.

Subbasin[1]	Specific Water Body	Parameters
Duwamish Waterway and River		pH, DO, Fecal coliform,
Lower Green River		Temperature, Fecal coliform, Chromium, Mercury
Middle Green River		Temperature, Fecal coliform
Upper Green River		Temperature
Black River	Springbrook Creek	Temperature, DO, Fecal coliform, Cadmium, Chromium, Copper, Mercury, Zinc
Hill (Mill) Creek	Hill (Mill Creek)	Temperature, DO, Fecal coliform
	Mullen Slough	Temperature, DO, Fecal coliform
Soos Creek		Temperature, DO, Fecal coliform
Newaukum Creek		DO, Fecal coliform, Ammonia-N
Crisp Creek		Fecal coliform

[1] Only particular water bodies of these subbasins are on the 303 (d) list, based on the specific location of available water quality data.

5. WATER QUALITY ASSESSMENT BY SUBBASIN

The following section provides a summary of existing water quality conditions by subbasin for four reaches along the mainstem and five tributaries. Each subsection has a brief description of the physical information about the subbasin including location, watershed area, and land use, followed by a summary of existing water quality reports for that subbasin, if available. While some of the water quality information presented from existing reports is as much as 12 years old, the information often represents good spatial coverage for the subbasin in comparison with recent data. Next, data from the King County Streams program (1996-99) is presented and comparisons are made to water quality standards and toxicity screening thresholds. This is followed by a description of any available biological data. Finally, any subbasin-specific data gaps are also identified if appropriate.

UPPER GREEN RIVER

For purposes of the Water Quality Assessment of the Green River, the watershed boundary for the upper watershed was defined as Tacoma Headworks Dam. The Upper Green River watershed drains approximately 231 square miles of mountainous and heavily timbered terrain above the City of Tacoma's Headworks and Diversion Dam (RM 61). Land use in the basin is primarily forest and used for commercial timber production and domestic water supply. There is limited recreational use, primarily in the upper more remote sections of the watershed. Approximately 42 miles of gravel forest roads and up to 824 miles of road access exist within the basin to support logging activities.

Erosion and its resulting impact on turbidity and suspended solids transport is an ongoing concern in the watershed (King County 1989). Primary causes of erosion in the watershed include logging activities, road construction and maintenance, landslides and breakdown of stream channels during peak runoff periods (King County 1989). Application of herbicides for vegetation control is carried out by several landowners along access roads and power line rights-of-way in the basin, and in some instances for broad-leaf plant control after logging. The reach of the Green River between the Tacoma diversion dam and the Howard Hanson dam (HHD) is listed on the 1998 303(d) list for temperature.

Inflow temperatures to the HHD reservoir exceed 16^{o}C during the summer in most years (USACE 1995). As a result of drawing water from the lower, colder stratum, releases from HHD during the early summer are usually below expected normal temperatures. Later in the summer and in early fall, as cooler water is depleted and warmer surface water is released, temperatures are higher than would be expected under a natural, unimpounded flow. These artificially higher temperatures can adversely affect salmon spawning behavior and may accelerate maturation of developing salmon eggs (Tacoma Public Utilities 1999).

There have been no recorded observations in the upper Green River or in the HHD reservoir where DO levels have fallen below 9.5 mg/L (the standard for Class AA waters), although there has been little sampling in these waters (TPU 1999). Turbidity is greatest during flood events and when HHD reservoir levels are low, both of which can cause water at the diversion dam to be too turbid for use by Tacoma Water. Natural flows have been artificially manipulated by the dams, resulting in modified hydrologic conditions downstream.

WATER QUALITY—EXISTING CONDITIONS

King County does not collect any water quality data in the Upper Green River as part of its stream monitoring program. However, the Tacoma Public Utilities Water Division monitors temperature and turbidity on a weekly basis at four locations (2, 4, 5 and 8) on the mainstem of the Upper Green River (Figure WQ-3). They also collect fecal coliform data, but the results are not presented in this report. The following is an analysis of the last four years of data provided by the Water Division.

Temperature

None of the 659 water temperature measurements analyzed were measured above the salmonid migration threshold (21°C), and only 10 of these exceeded the proposed salmonid rearing threshold (17.5°C). The maximum recorded water temperature was 20°C. Sixty-three of the 659 water temperature measurements exceeded the proposed salmonid spawning threshold (14.5°C), however, all of these excursions occurred between July and September. Only six of these occurred within the defined spawning season (September 15 through May 31). Taken together, these data would suggest that water temperature is not likely to be of concern for salmonids, however, water temperature readings were only taken weekly and do not necessarily represent peak temperatures.

Turbidity

The average turbidity of all 655 measurements analyzed from the four stations was 2.67 NTU, with a maximum of 234 NTU. This peak measurement probably occurred during or shortly after a storm event or some other disturbance that caused a short-term increase in turbidity. The second highest turbidity value was 22.2 NTU. All other measurements were below 20 NTU, and only 18 of 655 measurements were greater than 10 NTU. Although TSS concentration and duration data were not available, these consistently low turbidity data suggest that elevated solids are not likely to be of concern for salmonids.

BIOLOGICAL MONITORING IN THE UPPER GREEN RIVER

Aquatic insect sampling occurred at two stations on the mainstem in the upper Green River during 1999 (SalmonWeb 2000). One station was located above the Howard Hanson Dam and the other was located above the Tacoma diversion dam (RM 63.5). The B-IBI scores were 32 and 28 above the Howard Hanson and Tacoma diversion dams, respectively. These scores are characterized as fair on the B-IBI index.

DATA GAPS

Temperature, turbidity and fecal coliform data are the only water quality data available in the upper Green River. Fecal coliform data were not analyzed for this report, because fecal coliforms are not thought to be a factor of decline for salmonids. The lack of continuous temperature data is a data gap because data do not necessarily reflect maximum temperatures that have the greatest potential to impact salmonids. There is limited DO data. Thus, the lack of DO, pH, metals and organics data is a data gap.

MIDDLE GREEN RIVER

The Middle Green River basin begins at the Tacoma Diversion dam (RM 61) and continues downstream to the Auburn Narrows (RM 34) (see Figure WQ-2). Development in the basin is scattered with the largest portion of the basin in undeveloped open space. A substantial portion of the western half of the basin is used for agriculture. Most of the residential development is rural in nature, as most of the basin is on the east side of the Urban Growth Boundary. Small portions of Auburn and Black Diamond are the only urban areas in the basin, but together they constitute less than five percent of the watershed area.

The lower reach of the middle Green River sub-basin between RM 32 and RM 42.3 (west boundary of Flaming Geyser State Park) is classified as a Class A surface water in Chapter 173-201A WAC. Between RM 42.3 and the headwaters (including the Green River Gorge), the Green River and tributaries are Class AA. Temperature is the only parameter listed for the Middle Green River on the State's 303(d) list of impaired water bodies for failing to meet state surface water standards. This listing is based on multiple excursions above the state standard between RM 35 and RM 61.8 from 1991 to 1996.

Temperature data were collected by the Muckleshoot Tribe (Caldwell 1994) on the mainstem of the Green River in the summer and early fall of 1992. This was partly in response to a Corps of Engineers report (Grette and Salo 1986) that indicated that elevated Green River temperatures caused a delayed upstream migration of early-run fall chinook and may also influence utilization of the lower Green River by juvenile steelhead, chinook, and coho. The objective of the study was to document temperatures in the Green River between RM 12 and 64.5, describe the extent and duration of high summer temperatures, and investigate temperatures in deep pools and shallow stream margins. The following conclusions were drawn from this study:

- The maximum summer temperatures in 1992 were 23.5°C and 22.5°C at RM 35 (Nealy Bridge) and 41.5 (Whitney Bridge), respectively during mid August;
- Temperatures over 18°C were measured between two and three times more often at RM 13 (in the lower Green River) than RM 41.5 (Middle Green River); and
- Temperatures in deep pools between RM 35 and 41.5 were found to be the same as in other habitats. Shallow stream margins in the same reach had the potential to be 0.5-2.0°C higher than deeper habitats, depending on whether the shallow water was flowing or standing. In the shallow waters, water velocities and not water depth was the most important factor influencing temperatures.

There were no other historic reports on water quality in the middle Green with the exception of the annual Metro water quality reports from the 1980s. The King County streams program has collected water quality data since 1976 at two stations on the middle Green River.

WATER QUALITY—EXISTING CONDITIONS

The two sampling locations for which data are available between 1996 and 1999 are located above the confluence of Big Soos Creek (Station A319 at approximately RM 34.5) and above the confluence of Newaukum Creek (Station B319 at approximately RM 41.5) (see Figure WQ-2).

These locations are dominated by black cottonwood trees, and represent a more natural riparian habitat than the sampling locations of the lower Green River.

The parameters, number of samples analyzed, and number of storm samples varied for the two stations between 1996 and 1999. At station A319, temperature, DO, pH, turbidity, TSS and ammonia were analyzed for 36 to 39 samples during nonstorm conditions. These same parameters were analyzed for one storm on December 29, 1998 at station A319. For station B319, these same parameters were measured during both nonstorm (36 to 40 samples) and storm (13 to 15 samples) conditions. Additionally, total and dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) were analyzed at station B319 during storm conditions on roughly 14 and 8 occasions, respectively. Total aluminum was analyzed on three occasions during storm conditions. Comparisons of data to standards or criteria are detailed below.

Temperature

Based on water quality data from 1996 through 1999, temperatures for each location were within the Class A and proposed rearing standard ranges. A number of temperature measurements at each location exceeded the proposed spawning standard; however, most of these exceedances do not occur during the defined spawning season (September 15 through May 31). Two exceedances of the proposed spawning standard (15 and 15.1°C at A319 and B319, respectively) occurred on September 15, 1998. This would suggest that temperature may not be of concern for salmonids, however temperature readings are only taken monthly and do not necessarily represent peak temperatures during the spawning season. In addition, temperature may be of concern for other salmonids whose spawning season overlaps the June 1 through September 14 window (e.g., winter and summer steelhead).

Dissolved Oxygen

Based on water quality data from 1996 through 1999, DO concentrations for each location are always greater than the minimum Class A and proposed salmonid rearing standard (8.0 mg/L). However, 12 of 37 DO measurements at station A319 were below the proposed salmonid incubation standard (10.5 mg/L), with a minimum value of 9.4 mg/L. At station B319, 9 of 50 DO measurements were below the proposed salmonid incubation standard, with a minimum value of 8.5 mg/L. As with temperature, most of these exceedances occur in the summer and do not coincide with the defined incubation period. This would suggest that dissolved oxygen is not a factor of decline in this reach; however, DO may be of concern for any salmonids whose incubation period overlaps the June 1st through September 14th window (e.g., winter and summer steelhead).

Turbidity/TSS

Average non-storm turbidity is approximately 2 to 3 NTUs, with a peak measured storm turbidity of 84 NTUs on December 28, 1998 for the period between 1996 and 1999. Total suspended solids concentrations averaged 3 to 5 mg/L for both locations during non-storm sampling, with a peak storm measurement of 114 mg/L. Therefore, a few measurements exceed levels that could cause sub-lethal effects if the concentrations were maintained for a long enough duration. However, the duration of these elevated TSS concentrations is unknown and therefore, the potential effects cannot be determined. On average, TSS does not appear to be of concern for salmonids, although more data, including concentration and duration, are needed.

pH

The average pH of the King County data from 1996 to 1999 was 7.0. However, one of 95 measurements was 6.4, or 0.1 units below the Class A/AA minimum standard of 6.5. All other measurements were between 6.5 and 8.2. Given that only one measurement exceeded the state standard, pH is not expected to elicit any direct effects to aquatic life. Therefore pH in the middle Green River is unlikely to be of concern, although it may influence the potential toxicity of other chemicals (e.g., metals).

Ammonia

The ammonia data collected from 1996 to 1999 were below both the acute and chronic state water quality standards for ammonia. Therefore, ammonia is not expected to be of concern for salmonids.

Metals

The metals evaluated here (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) suggest that they are not of concern, with the possible exception of aluminum. Although there are no state water quality standards for aluminum, all three aluminum samples exceeded the EPA chronic water quality criterion (87 µg/L). One of the three samples (1,960 µg/L) exceeded the EPA *acute* water quality criterion (750 µg/L). Although the limited data exceed the EPA criterion, it is not likely in a toxic form because the analytical method for determining total recoverable aluminum probably dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988). In addition, these data were collected under storm conditions where elevated suspended solids and organic matter concentrations tends to bind more of the dissolved metal, thereby reducing its bioavailability[6]. However, because data are limited, further evaluations of aluminum should be conducted to confirm whether it is of concern for salmonids.

The same pattern for the basin as a whole is applicable to the Middle Green River data with regards to the detection limits for mercury and selenium (see section 4).

BIOLOGICAL MONITORING IN THE MIDDLE GREEN RIVER

Aquatic insect sampling occurred at four stations on the mainstem of the middle Green River during 1999 (SalmonWeb 2000). Table WQ-5 shows the B-IBI scores for the four locations in the middle Green River from the SalmonWeb data. There was a very small range in scores (28-30), with all scores characterized as fair on the B-IBI index.

[6] Bioavailability is the degree to which a contaminant in a potential source is free for uptake (movement into or onto an organism) (Hamelink et al. 1994).

Table WQ-5. B-IBI scores for Middle Green River stations in 1999 (SalmonWeb 2000).	
Macroinvertebrate Monitoring Sites	**1999 Scores**
Middle Green River (below Tacoma diversion dam, RM 60.5)	30
Middle Green River (at Flaming Geyser State Park, RM 42.5)	28
Middle Green River (at Whitney Bridge, RM 41.5)	30
Middle Green River (upstream of Soos Creek confluence, RM 34)	28

DATA GAPS

There are probably sufficient data to characterize temperature, DO, pH and ammonia at Stations A319 and B319; however, no other King County data between 1996 and 1999 were available for the mainstem of the middle Green River. Therefore, the spatial variability of these parameters in the middle Green River is a data gap, especially given the length of the river in this sub-basin (approximately 30 miles). The lack of continuous temperature data is a data gap because data do not necessarily reflect daily maximum temperatures and the duration of temperature exceedances. In addition, available TSS data do not include duration, therefore, potential effects cannot be accurately evaluated. Furthermore, there are relatively few metals data (three to 15 samples), and all were collected under storm conditions. Therefore, additional metals data are needed, especially under baseline (non-storm) conditions.

Other classes of parameters for which no data were available represent significant data gaps. No data were available for pesticides and herbicides, PAHs, or phthalate esters.

LOWER GREEN RIVER

The Lower Green River basin begins at the Auburn Narrows (RM 31) and continues to just downstream of the confluence with the Black River in Tukwila (RM 11) (see Figure WQ-1). The lower Green basin is composed of two areas that are split by the Black River basin to the north and the Mill Creek basin to the south. It is mostly on the urban side of the Urban Growth Boundary and contains portions of the cities of Kent, Auburn, Tukwila, Federal Way, and SeaTac. Land uses include residential, commercial, industrial, and agricultural, as well as some major highways, including Interstate 5. There are extensive areas of office/commercial and multi-family residential development. This area has developed rapidly over the past 20 years.

The Lower Green River is classified as a Class A surface water in Chapter 173-201A WAC. Temperature, fecal coliforms[7], chromium, and mercury are listed for the Lower Green River on the State's 303(d) list of impaired water bodies for failing to meet state surface water standards. For temperature, this listing is based on multiple excursions above the state standard between RM 12.5 and RM 27 from 1991 to 1996. For mercury, this listing is based on multiple excursions measured in 1988 at Stations 0311 and 3106, as well as multiple excursions measured between Tukwila and RM 18.3 between 1987 and 1991.

There were three temperature stations in the Lower Green River included in the Muckleshoot Indian Tribe's study (Caldwell 1994) in 1992. The stations were located along the mainstem in

[7] Fecal coliforms will not be addressed in this section, because it is not a factor of decline for salmonids.

Tukwila (RM 13), Kent (RM 20) and Auburn (RM 27). The following conclusions were drawn from this study:

- The maximum summer temperatures in July and August were between 23.0 and 24.0°C at RM 12. The degree-hours value above 18.0°C (an indicator of the duration of elevated temperatures) was three times the value measured in the Middle Green (RM 41.5). Minimum temperatures at RM 12 during July and August were 15-16°C, comparatively high compared to most other stations;

- The maximum summer temperatures were 23.0 and 22.5°C at RM 20 and 27, respectively. The degree-hours value above 18.0°C were approximately 70 and 50 percent, respectively of the value at RM 12; and

- The study concluded that these temperatures were within the range where, according to some studies, salmonids would avoid this reach if possible. It was also concluded that there is potential for blockage or delay of upstream migration of adult anadromous salmon in August.

There were no other historic reports on water quality in the Lower Green River with the exception of the annual Metro water quality reports from the 1980s. The King County streams program has collected water quality data since 1970 at two stations on the lower Green River (0311, 3106).

WATER QUALITY – EXISTING CONDITIONS

The two locations for which data are available between 1996 and 1999 (Stations 0311 and 3106) are located near I-405 at approximately RM 12, where the land use is characterized by roadways, office and commercial development, Fort Dent Park and a golf course (see Figure WQ-1).

At station 0311, six parameters (temperature, DO, pH, turbidity, TSS and ammonia) were analyzed for 35 to 39 samples during nonstorm conditions and on one occasion during storm conditions on December 29, 1998. For station 3106, these same parameters were measured during both nonstorm (36 to 43 samples) and storm (12 to 14 samples) conditions. Additionally, total and dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) were analyzed at station 3106 during storm conditions on 13 and 7 occasions, respectively. Total and dissolved aluminum were analyzed on three and one occasions, respectively, during storm conditions. Comparisons of data to standards or criteria are detailed below.

Temperature

Based on King County's water quality data from 1996 through 1999, a number of temperature measurements for each location exceeded the Class A, proposed rearing and spawning standards (18, 17.5 and 14.5°C, respectively). Temperatures were never measured above the migration blockage threshold (21°C). The spawning threshold would not be applicable to these locations (approximately RM 12) because chinook and other salmonids are not known to spawn in this area. For chinook, most spawning is further upstream, between RM 24 to RM 61 (Williams et al. 1975). However, because several temperature measurements exceeded the Class A and rearing threshold, particularly during the mid- to late-summer, temperature may be of concern for salmonids in the Lower Green. It is important to note that temperature readings were only taken monthly and thus do not necessarily represent peak temperatures.

Dissolved Oxygen

Some DO concentrations for the two locations from 1996 to 1999 are below the Class A standard and proposed salmonid rearing standard (8.0 mg/L), and several measurements are below the proposed salmonid incubation standard (10.5 mg/L). Again, however, the incubation standard would not be applicable for these locations since salmonids are not known to spawn in this reach. Because six of the non-storm measurements were below the rearing threshold (ranging from 7.6 to 7.9 mg/L), there is some concern for salmonids during the summer months. Given that the solubility of oxygen in water is temperature dependent, it is not surprising to find dissolved oxygen exceedances co-located and concurrent with temperature exceedances.

Turbidity/TSS

Average non-storm turbidity is approximately 4 to 5 NTUs, with a peak storm turbidity measurement of 89 NTUs on December 28, 1998. Non-storm TSS concentrations averaged 8 to 11 mg/L for both locations during non-storm sampling, with a peak storm measurement of 114 mg/L during December 1998. A few measurements exceeded levels that could cause sub-lethal effects to salmonids if the concentrations were maintained for a long enough duration. However, the duration of these elevated TSS concentrations is unknown and therefore the potential effects cannot be determined. On average TSS does not appear to be of concern, though more data, including concentration and duration, is needed.

pH

Nearly all measurements evaluated in this analysis were between 6.5 and 8.1, a level at which there is not expected to be any direct effects on aquatic life (U.S. EPA 1986). The average pH was 7.0, however, five of 80 measurements were below the Class A standard of 6.5, with a minimum value of 6.2. Overall, pH is probably not a concern, though it may influence the potential toxicity of other chemicals (e.g., metals).

Ammonia

The ammonia data collected from 1996 to 1999 were below both the acute and chronic state water quality standards for ammonia. Therefore, ammonia is not expected to be of concern for salmonids.

Metals

Based on data collected from 1996 and 1999, metals (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) do not seem to be a concern for salmonids, with the possible exception of aluminum.

Although there are no state water quality standards for aluminum, each of the three aluminum samples exceeded the EPA chronic water quality criterion (87 µg/L). One of the three samples

(1,540 µg/L), exceeded the EPA *acute* water quality criterion (750 µg/L). Although the limited data exceed the EPA criterion, it is not likely in a toxic form because the analytical method for determining total recoverable aluminum probably dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988). In addition, these data were collected under storm conditions where elevated suspended solids and organic matter concentrations tends to bind more of the dissolved metal, thereby reducing its bioavailability. However, because data are limited, further evaluations of aluminum should be conducted to confirm whether it is of concern for salmonids.

The same pattern for the basin as a whole is applicable to the Lower Green River data with regards to the detection limits for mercury and selenium (see section 4).

BIOLOGICAL MONITORING IN THE LOWER GREEN RIVER

Aquatic insect sampling occurred at one station on the mainstem in the lower Green River during 1999 (SalmonWeb 2000). The station was located at Lea Hill in Auburn at RM 28. The B-IBI score was 28, which is characterized as fair on the B-IBI index. This score is in the same range as those observed for the middle and upper Green River stations.

DATA GAPS

There are probably sufficient data to characterize temperature, DO, pH and ammonia at Stations 0311 and 3106; however, no other King County data between 1996 and 1999 were available for the lower Green River. Therefore, the spatial variability of these parameters in the lower Green River is a data gap. The lack of continuous temperature data is a data gap because data do not reflect daily maximum temperatures and the duration of temperature exceedances. In addition, there is no duration data available for TSS, thus the potential effects cannot be accurately evaluated. Furthermore, there are relatively few metals data (one to 16 samples), and nearly all were collected under storm conditions. Therefore, additional metals data are needed, especially under baseline (non-storm) conditions.

Other classes of parameters for which no data were available represent significant data gaps. No data were available for pesticides and herbicides, PAHs, or phthalate esters.

GREEN/DUWAMISH ESTUARY

The following description of the Duwamish River basin is summarized from the Combined Sewer Overflow Water Quality Assessment (WQA) for the Duwamish River and Elliott Bay (King County 1999). It is followed by a description of trends in Duwamish River since the 1960s, which is summarized from the draft Water Quality Trends report prepared by Pentec (2000). Finally, this is followed by a description of the existing water quality conditions, which includes some more recent data from the King County Streams Monitoring Program and compares it to both fresh and marine water quality standards, including the newly proposed use-based standards for temperature and DO.

The Duwamish River and Elliott Bay together make up a highly industrialized and urbanized estuary that has been extensively altered from its historic condition. The estuary is located on the eastern shore of Puget Sound and is surrounded by the City of Seattle. It is the location of heavy industry and a major shipping center as well as being home to a diverse array of fish, bird, mammal, and plant species. It is also used for tribal commercial and subsistence fishing and for recreation. Pollutants can enter the estuary from a variety of sources including industrial and commercial activities, storm drains, combined sewer overflows (CSOs), treatment plant emergency outfall, illegal dumping, atmospheric deposition, and groundwater.

The lower Duwamish River, from the river mouth to approximately 6 miles upstream from Harbor Island, is a highly industrialized salt wedge type estuary that is influenced by river flow and tidal effects. As is typical of salt wedge estuaries, the Duwamish is characterized by a sharp interface between freshwater outflow at the surface and saltwater inflow at depth. The layer of salt water is thicker near the river mouth, occupying most of the water depth, but tapers down toward the head (upriver portion) of the estuary. The location where saltwater intrusion tapers off to zero is called the toe of the salt wedge. In the Duwamish River the toe of the salt wedge is located approximately 11 miles upstream of the river mouth.

The lower portion of the river, below the turning basin (7 miles from the mouth) was straightened, dredged and armored with rocks in many areas to facilitate navigation and industrial development. The depth of the river portion varies from approximately 17 meters near the river mouth at Harbor Island to less than 1 meter in the upper river. Bottom sediments in the river range from sands to muds, depending on the sources of sediment and the current speeds. The flow of the river is largely controlled by releases from the Howard Hanson Dam. Summer flows in the river, gauged at Auburn, are in the range of 250 cubic feet per second (cfs). Winter flows average about 1,500 to 2,000 cfs, with peaks to more than 12,000 cfs as measured at the Auburn gage during storm events.

Over the last 125 years, the drainage area of the Duwamish River has been reduced by about 70 percent due to development and flow diversion. Most (98 percent) of approximately 1,270 acres of tidal marsh and 1,450 acres of flats and shallows, and all of about 1,250 acres of tidal wetland, have been eliminated (Blomberg et al. 1988). The intertidal habitat that remains in the Duwamish River is important for the survival of juvenile salmon, other predator fish, birds, and mammals that feed on invertebrates and small fish found in shallow areas of the estuary. Kellogg Island is the largest remnant of intertidal habitat remaining in the Duwamish River Estuary (Tanner 1991). Habitat associated with the island includes high and low marsh, intertidal flats, and filled uplands (Canning et al. 1979). Kellogg Island provides important nesting and feeding habitat for waterfowl and other birds. Small patches of other intertidal areas occur in the estuary as marsh and unvegetated intertidal benches. Sections of natural shoreline only occur in the Duwamish River above the head of navigation, located at approximately River Mile 6 (Tanner 1991).

WATER QUALITY TRENDS IN THE DUWAMISH RIVER[8]

Overall, water quality in the Duwamish estuary was probably poorest in the early 1960s. Since the 1980s, however, water quality impacts from the discharge of industrial and domestic waste have been significantly reduced as a result of increased surveillance monitoring and the construction of the wastewater effluent transfer line. The removal of the South (Renton) Treatment Plant outfall led to significant decreases in the ammonia and phosphorus

[8] Summarized from the draft Water Quality Trends report prepared by Pentec (1999)

concentrations in the Green River. Temperature, turbidity, and nitrate levels have decreased significantly, and DO and pH have increased (King County 1989).

In the 1940s and 1950s, there were a large number and wide variety of direct point-source discharges to the Duwamish River (e.g., Foster 1945, Sylvester et al. 1949, Peterson et al. 1955). These discharges included metal wastes from foundaries, shipyards, and aircraft manufacturing operations; chemical wastes from a variety of industries; blood and paunch manure from meat-packing plants; vegetable wastes; fish packing wastes; concrete and clays; and domestic sewage.

Temperature, bacteria, nutrients, and oxygen levels historically created biological problems in the Duwamish River (Ecology 1988). Levels of metals and/or other pollutants were sufficient to cause fish kills as early as 1948 (Fasten 1948), and as recently as 1985 (possibly from low DO; L. Kittle, Washington State Department of Ecology, personal communication in Grette and Salo 1986).

The following presents a description of water quality trends in the Duwamish River. These trends are based on temperature, DO, and metals water quality data, most of which have been collected by King County (Metro) at 17 stations throughout the Duwamish River since the 1970s. Three stations have the most complete data set over the last 40 years: the West Waterway Spokane Street Bridge (station 0305 at RM 1/4), 16th Avenue Bridge (station 0307 at RM 3.5), and the East Marginal Way Bridge (station 0309 at RM 6.75)[9].

Temperature

Since 1970, temperature has been recorded monthly at stations 0305, 0307, and 0309. These stations have seen an overall increase of maximum temperatures of approximately 2°C since the 1970s (Figure WQ-5, Pentec 1999). The frequency of freshwater temperature criterion exceedances has increased from one in the 1970s to three in the 1980s, and seven from 1990 to 1998. The frequency of marine water temperature criterion exceedances has increased from 3 in the 1970s to 13 in the 1980s, and 15 from 1990 to 1998. However, due to sampling depths (0.5 m) and location of stations 0307 and 0309, the freshwater water criterion is more applicable. Using the freshwater criterion for the 16th Avenue and East Marginal Way bridge stations, and the marine criterion at the West Waterway Spokane Street Bridge station, there was one exceedance in the 1970s, three in the 1980s, and six in the 1990s (through 1998).

Dissolved Oxygen

During the mid-1950s, the Washington State Pollution Control Commission (Peterson et al. 1955) conducted sanitary-quality surveys in the Green and Duwamish rivers, collecting data on bacteriological character, DO, BOD, and toxic compounds. They sampled DO through the summer and fall of 1955 and found two instances of values below 5 mg/L. The authors concluded that the DO levels in the Duwamish River were satisfactory but noted that river flows were unusually high and temperatures unusually low during that year.

In the 1960s, Santos and Stoner (1972) conducted a study of physical, chemical, and biological aspects in the Duwamish Estuary at four locations. They concluded that the DO in the surface

[9] Class B standards for temperature and DO are applied in the following discussion.

water decreased in a downstream direction, but usually contained enough oxygen to support aquatic life. Minimum DO values occurred in late summer in the bottom layer, and ranged from 7.7 mg/L to 10.4 mg/L. However at low rates of freshwater inflow and minimal tidal exchange, DO was reported as low as 1 mg/L in the 1960s (Metro 1985). Comparing older data with the data collected during their study, Santos and Stoner suggested that a slight decrease in the annual minimum DO concentrations had occurred from 1960 to early 1970.

Completion of the Howard Hanson Dam in 1962 provided low-flow augmentation during the summer months and helped offset, to a degree, increases in sewage discharges from the expanding population of the watershed (US Army Corps of Engineers 1997). The East and West Marginal interceptors were constructed by Metro in 1964 and 1967, respectively, allowing industrial discharges to be removed from the Duwamish and diverted to the West Point Treatment Plant (Metro 1985). In 1965, the Diagonal Way sewage treatment plant was closed and the sewage was diverted to West Point. The South (Renton) Treatment Plant was also constructed in 1965. The Kent and Auburn sewage lagoons were discontinued in 1973 and 1977, respectively, and the sewage was diverted to the South (Renton) Treatment Plant. With the removal of these two effluent discharges to the Green River system, the South Treatment Plant became the only municipal point source of effluent to the Duwamish (Metro 1985).

The South (Renton) Treatment Plant discharge adversely affected water quality by depressing DO levels and increasing levels of nutrients and ammonia beyond EPA guidelines. Diversion of the Plant's outfall to a new deepwater diffuser in Puget Sound in 1987 produced marked improvements in water quality in the Duwamish Estuary. These improvements resulted in marked increases in the minimum DO in the estuary.

Trends from stations 0305, 0307, and 0309 show that the annual minimum DO has been increasing since the 1970s, and that there was a jump in the rate of increase in the mid-1980s, corresponding to the diversion of the South Treatment Plant discharge. As a result, low DO levels and resulting mortalities or delays in upstream migrations of chinook, which used to occur frequently in the Duwamish (Salo 1969; Grette and Salo 1986), have not been reported since this diversion.

Metals

Beginning in the 1970s, enforcement of the Clean Water Act and implementation of National Pollutant Discharge Elimination System (NPDES) prohibitions against discharge of toxic or deleterious materials markedly reduced point-source discharges, from municipal and industrial sources, to the Green/Duwamish River and Estuary. From 1981 to 1988, almost 2.4 billion gallons of untreated sewage and stormwater were discharged from combined sewer overflows (CSOs) to the Duwamish Estuary and Elliott Bay, Lake Washington and Ship Canal. Since 1989, the volume of untreated sewage and stormwater discharged from CSOs to these receiving waters has been reduced to 1.8 billion gallons per year (King County 1999).

The combination of these controls of point-source discharges, and increased emphasis on stormwater controls and associated best management practices have greatly improved water quality conditions in the Duwamish. For example, the Pacific Marine Environmental Laboratory monitored the Duwamish River from 1981 to 1986 and showed dramatic decreases of copper, lead, and zinc concentrations in the water. In 1986, dissolved lead discharges into the Duwamish River were only one percent of the amount discharged in 1981; dissolved copper and zinc discharges were only five and 10 percent, respectively, of amounts discharged in 1981 (King County 1989).

The result of all of the controls implemented in the 1970s and 1980s on levels of many toxicants was dramatic, as shown in the marked drops in levels of several metals in the lower Duwamish River. In most cases, levels of cadmium, chromium, copper, iron, lead, mercury, nickel, and zinc, which were often above toxic thresholds in the early 1980s, have dropped below the State's chronic water quality standards (173-201A WAC).

In summary, it is clear that water quality conditions in the Duwamish Estuary today are much improved over conditions from the 1940s through the mid-1980s. During the period from 1970 to the present, water quality, with the exception of temperature, has shown a clear trend of improvement in virtually all measured parameters. An assessment of current water quality is presented in the following two sections.

DUWAMISH RIVER AND ELLIOTT BAY WATER QUALITY ASSESSMENT

In 1996, the King County Department of Natural Resources (King County 1999) studied the existing conditions in the Duwamish, as well as the County's combined sewer overflows (CSOs) and their effects on water quality in the Duwamish River using a risk assessment approach. The risk assessment looked at several receptors, including aquatic life, benthos, shorebirds, wading birds, raptors, mammals, and humans. The study investigated several chemicals in water and in sediment, physical disturbances, and changes in salinity, DO, pH, and water temperature (King County 1999).

Overall, the Water Quality Assessment (WQA) found minimal risks to aquatic life from chemicals in the water column, no risk of mortality to juvenile salmon from direct exposure to chemicals in the water, and no risk of mortality to salmon smolt from consuming amphipods in the Duwamish Estuary. More specifically, the study found the following:

- Risks to water column dwelling organisms, from exposure to chemicals of potential concern in the water of the Duwamish River and Elliott Bay, appear to be minimal. Any potential risks are below the level used by U.S. EPA to develop water quality criteria. These predicted risk levels were confirmed by the observed lack of chronic toxicity to sensitive organisms from undiluted effluent from the Brandon Street CSO.

- There was no apparent risk of mortality to salmon from exposure to chemicals in the water column.

- There was no apparent risk of mortality to salmon from concentrations of copper, lead, zinc, tributyltin (TBT) or polychlorinated biphenyls (PCBs) (Aroclors 1254 and 1260) in their prey. Other chemicals were not evaluated because of a lack of appropriate data.

The WQA found potential risks to the benthic community from several chemicals in the sediments, most notably bis(2-ethylhexyl)phthalate, 1,4-dichlorobenzene, mercury, polycyclic aromatic hydrocarbons (PAHs), PCBs, and TBT. PCBs and TBT were found to pose the greatest potential risks to benthic organisms.

WATER QUALITY—EXISTING CONDITIONS

The Duwamish River is listed on the State's 303(d) list of impaired water bodies for multiple sites and parameters. Although water in the Duwamish River is only listed for exceeding pH, fecal coliforms and DO standards, sediments exceed standards for numerous chemicals including a variety of metals, PAHs, PCBs, phthalate esters and phenol.

Recent King County data were available for a total of 19 stations in the Duwamish River. Sixteen of these stations were sampled from nine sites in 1996 and 1997 for the Duwamish River and Elliott Bay WQA, and represent either east bank, center channel or west bank sampling within the Duwamish River channel at six sites (CSO locations). At each station, samples were collected both one meter under the surface and one meter above the bottom (or at 20 meters depth if bottom depth was greater than 20 meters). Table WQ-6 below describes the site abbreviations used for the Duwamish River WQA, and sampling locations are depicted in FigureWQ-1.

Table WQ- 6. Site abbreviations from the Duwamish River WQA.

Site	East Bank (1,2)	Center Channel (1,2)	West Bank (1,2)
Norfolk		NFKBLB	
S/W Michigan	SWM/E	SWM/C	SWM/W
Brandon	BRN/E	BRN/C	BRN/W
Chelan	CHE/E	CHE/C	CHE/W
Hanford	HNF/E	HNF/C	HNF/W
Connecticut	HNF/E	HNF/C	HNF/W

1 = surface and 2 = depth (e.g., SWM/E1 and SWM/E2).

Data are also available between 1996 and 1999 for three other stations sampled as part of the Streams Monitoring Program (0305, 0307, 0309). These stations are also depicted in Figure WQ-1. Table WQ-7 summarizes the number of samples analyzed for each parameter at all locations in the Duwamish River (WQA and Streams Monitoring Program) between 1996 and 1999.

Table WQ-7. Number of Non-storm and Storm Samples Collected in Duwamish (1996-99).				
Parameter	**Non-storm**	**Storm**	**# of Stations**	**# of Sites**
Arsenic, Dissolved	272	90	31	6
Cadmium, Dissolved	272	88	31	6
Chromium, Dissolved	242	80	31	6
Chromium, Total	521	286	31	6
Copper, Dissolved	254	90	31	6
Lead, Dissolved	264	90	31	6
Mercury, Dissolved	33		7	4
Mercury, Total	63		31	6
Nickel, Dissolved	246	90	31	6
Nitrogen, Ammonia	810	302	36	9
Oxygen, Dissolved	571	212	35	8
Pentachlorophenol	114	88	30	5
pH	817	302	36	9
Selenium, Dissolved	262	82	31	6
Selenium, Total	526	258	31	6
Silver, Dissolved	272	90	31	6
Solids, Suspended, Total	1479	599	36	9
Temperature, Sample	841	296	36	9
Turbidity	149	5	5	3
Zinc, Dissolved	272	87	31	6

Temperature

Based on the water quality data collected between 1996 and 1999, all temperature measurements were below the migration blockage threshold (21°C) and the Class B marine standard (19°C) at all stations except 0307 and 0309. At station 0307, five of 55 surface (0-1 m) temperature measurements exceeded the Class B marine standard, with a maximum of 20.4°C; no exceedances were measured at depth. At station 0309, five of 38 temperature measurements exceeded the Class B marine standard and one of those exceeded the migration blockage threshold, with a maximum of 21.7°C. These data suggest that peak summer temperatures may be of concern for salmonids rearing in or migrating through the upper reach of the Duwamish River. It is important to note that temperature readings were only taken monthly and thus do not necessarily represent peak temperatures.

Dissolved Oxygen

A total of 783 DO measurements were taken at the Duwamish River stations between 1996 and 1999. At Station 0305, two DO measurements were below the Class B marine standard (5 mg/L), with a minimum of 4 mg/L. These data suggest that DO concentrations may be of concern for salmonids rearing in the Duwamish River.

Turbidity/TSS

Turbidity data were only available at three stations within the Duwamish River, with between 37 and 59 measurements at stations 0305, 0307 and 0309. Average turbidity measurements (both surface and depth) ranged from 2.0 to 6.4 NTUs during non-storm conditions, with a maximum of 24 NTUs. Storm turbidity measurements at these locations ranged from 14 to 92 NTUs.

Between 37 and 66 samples were measured for TSS at all sampling stations within the Duwamish River, except at NFKBLB, where only three samples were collected. Average non-storm TSS ranged from 3.6 to 19.3 mg/L, and average storm TSS ranged from 13.7 to 22.4 mg/L at all stations except 0305, 0307 and 0309. Only one or two storm samples were collected at each of these three stations, and measurements ranged from 23.6 to 122 mg/L. These data suggest that TSS concentrations in the Duwamish River occasionally exceeded levels that could cause sub-lethal effects, especially during storm conditions, if the concentrations were maintained for a long enough duration. However, the duration of the elevated TSS concentrations is unknown, and therefore, potential effects cannot be determined. More data, including concentration and duration, are needed.

pH

Between 30 and 60 pH measurements at each sampling station were recorded between 1996 and 1999. All pH measurements were between the Class B marine standards of 7.0 to 8.5 at all stations except BRN/E1, 0305, 0307 and 0309. One of 32 measurements station BRN/E1 and one of 59 measurements at station 0305 was below 7.0, with a minimum of 6.9 for each. At station 0307, four of 60 measurements were below 7.0, with a minimum of 6.8, and one measurement was 8.6. At station 0309, 10 of 38 measurements were below 7.0, with a minimum of 6.3. However, given that no adverse effects to salmonids are expected at pH levels between 6.5 and 9.0 (U.S. EPA 1976), and that only one of the total of 1119 pH values was below 6.3, pH is not likely to be a factor of decline for salmonids, although it may influence the potential toxicity of other chemicals (e.g., metals).

Ammonia

The ammonia data collected from 1996 to 1999 were below both the acute and chronic state water quality standards for ammonia. Therefore, ammonia is not expected to be of concern for salmonids.

Metals

Based on the data collected by King County and MIT from 1996 to 1999, the metals evaluated here (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) suggest that they are not of concern.

Organic Chemicals

The pentachlorophenol data collected in 1996 and 1997 for the Duwamish River and Elliott Bay WQA were below both the acute and chronic state marine water quality standards. Therefore, pentachlorophenol is not expected to be of concern for salmonids. No other King County data for organic chemicals with standards or criteria developed were available.

CRISP CREEK

The Crisp Creek subbasin is a small tributary to the Green River located just west of the City of Black Diamond. The basin is approximately 4.5 square miles in area and flows into the Green River at river mile 40. Crisp Creek drains flat to gently rolling terrain in the upper portion of the watershed then drops steeply from the plateau through the valley walls of the Green River before flattening out in the alluvial valley. The entire basin is located in unincorporated King County in the rural zone, mostly consisting of pre-existing one, 2.5 or 5-acre lots or in current 5-acre zoning.

Crisp Creek is not listed on the state's 303(d) list of impaired water bodies. A Water Quality and Quantity Concerns report was completed for the Crisp Creek watershed because of concerns about impacts on operation of the Muckleshoot Tribe's Keta Creek Hatchery (Muckleshoot Indian Tribe 1992). This report identifies risks to fish resources, water quality, and water quantity, but no water quality data are presented. The report identifies the planned and potential conversion of forested lands to residential developments as the greatest risk to water quality.

WATER QUALITY—EXISTING CONDITIONS

King County has collected data from two locations on Crisp Creek as part of its Stream Monitoring Program. Station F321 is located immediately upstream of the Keta Creek Hatchery, and Station 0321 is within one mile downstream of the hatchery (see Figure WQ-2).

At station 0321 and F321, six parameters (temperature, DO, pH, turbidity, TSS and ammonia) were analyzed in 38 to 46 samples during nonstorm conditions between 1996 and 1999. These same parameters were measured during storm conditions on 15 to 17 occasions. Additionally, total and dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) were analyzed at station 0321 during storm conditions on roughly 17 and 11 occasions, respectively. Total and dissolved aluminum were analyzed on three and one occasions, respectively, during storm conditions. Comparisons of data to standards or criteria are detailed below.

Temperature

Continuous water temperature data were collected at the King County stream gauge near the mouth of Crisp Creek (station 40D) from October 1997 to September 1999 (water years 1998 and 1999). The maximum recorded daily temperature during this period was 20°C on five days in July and August 1998. During the two year period, the Class A standard of 18°C and the proposed 17.5°C rearing standard were exceeded on 12 and 17 days, respectively, in July and August 1998. The proposed 14.5°C spawning standard (September 15 to May 31) was exceeded on seven days in late September 1998 (maximum of 16°C) and two days each in late May 1998 and 1999 (maximum of 17°C in 1998).

The proposed rearing standard of 15°C for the moving 7-day average of the daily maximum temperatures was not exceeded during water year 1999, but was exceeded on 69 days during water year 1998 from early July to mid-September. The maximum 7-day average was 18.7°C. The proposed spawning standard of 12°C for the moving 7-day average of the daily maximum temperatures (September 15 to May 31) was exceeded on 13 days in April and May of 1999 (maximum of 14°C) and 15 days in late September 1999 (maximum of 13°C). In water year 1998, the spawning standard was exceeded on nine, 23, and 15 days in October 1997, May and September 1998, respectively. The maximum was 14.7°C in September 1998. These data suggest that temperature is a possible factor of decline for salmonids in Crisp Creek, based on occasional exceedances of the Class A standard and somewhat frequent exceedances of the proposed rearing and spawning standards of from 1 to 3°C.

Dissolved Oxygen

Based on the available water quality data collected between 1996 and 1999, DO concentrations at either location were always greater than the minimum Class A and proposed salmonid rearing standard (8.0 mg/L). However, 22 of 50 DO measurements at station 0321 were below the incubation standard (10.5 mg/L) during the potential salmonid incubation period (September 15 to May 31), with a minimum value of 8.3 mg/L. At station F321, one DO value in October was 10.4 mg/L, but all other measurements were greater than 10.5 mg/L. Therefore, DO may be of concern for salmonids below the Keta Creek Hatchery.

Turbidity / TSS

Based on the available water quality data from 1996 through 1999, average non-storm and storm turbidity was 2.5 and 3.5 NTUs, respectively. The maximum turbidity was 13 NTUs. Geometric mean non-storm and storm TSS was 5 and 7 mg/L, respectively, with a maximum concentration of 48.5 mg/L. The next highest recorded measurement was 17.4 mg/L. Therefore, at least one measurement exceeded levels that could cause sub-lethal effects if the concentration was maintained for a long enough duration. However, the duration of the elevated TSS concentration is unknown and therefore, potential effects cannot be determined. On average, TSS does not appear to be of concern for salmonids, although more data, including concentration and duration, are needed to be more certain.

pH

Based on the available data from 1996 through 1999, pH is always between 6.6 and 8.1. This range is not expected to elicit any direct effects to aquatic life, and therefore, pH is unlikely to be of concern for salmonids in Crisp Creek, although it may influence the potential toxicity of other chemicals (e.g., metals).

Ammonia

The ammonia data collected from 1996 to 1999 were below both the acute and chronic state water quality standards for ammonia. Therefore, ammonia is not expected to be of concern for salmonids.

Metals

The metals evaluated at station 0311 (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) are not of concern for salmonids, with the possible exception of aluminum. Although there are no state water quality standards for aluminum, two of the three aluminum samples exceeded the EPA chronic water quality criterion (87 µg/L).

Although the limited data exceed the EPA criterion, it is not likely in a toxic form because the analytical method for determining total recoverable aluminum probably dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988). In addition, these data were collected under storm conditions where elevated suspended solids and organic matter concentrations tends to bind more of the dissolved metal, thereby reducing its bioavailability. However, because data are limited, further evaluations of aluminum should be conducted to confirm whether it is of concern for salmonids.

The same pattern for the basin as a whole is applicable to the Crisp Creek data with regards to the detection limits for mercury and selenium (see section 4).

DATA GAPS

There are probably sufficient data to characterize temperature, DO, pH and ammonia conditions in Crisp Creek. Available TSS data do not include information on duration, without which potential effects cannot be accurately evaluated. Furthermore, although there are adequate metals data at station 0321, all were collected under storm conditions. Therefore, additional metals data are needed to describe baseline (non-storm) conditions, especially for aluminum. There are no metals data available at station F321.

Other classes of parameters for which no data were available represent significant data gaps. No data were available for pesticides and herbicides, PAHs, or phthalate esters.

NEWAUKUM CREEK

The Newaukum Creek subbasin is located in southeast King County near the City of Enumclaw. The basin is over 27 square miles in area and flows into the Green River at river mile 40.7 (see Figure WQ-2). Extensive water quality sampling has been carried out in the subbasin since 1995 by the Muckleshoot Indian Tribe Fisheries Department and the King County Department of Natural Resources (Wachter 1999).

The headwaters of Newaukum Creek begin at an elevation of 5,000 feet near Boise Ridge and are dominated by forest activities. The middle subbasin, the Enumclaw plateau, consists mostly of agricultural activities and is relatively flat. The lower subbasin consists of a steep ravine and descent to the Green River. Land uses in the middle and lower subbasins include dairy and cattle farming, and rural residential development (Wachter 1999). The southern portion of the middle subbasin also contains the City of Enumclaw. In the agricultural areas, extensive ditching has occurred for stormwater conveyance and field application of manure and fertilizers is common. Salmonids present in this subbasin include coastal cutthroat, chinook, coho, winter steelhead, sockeye and chum.

Four reaches along Newaukum Creek are listed on the state's 303(d) list of impaired water bodies for failing to meet state surface water standards. All four reaches are listed for fecal coliforms. One reach is also listed for DO and another reach is listed for ammonia. Since the results reported by Wachter (1999) are based on the King County and MIT streams data collected from 1995 to 1997, which overlaps with the existing data from 1996 to 1999, no results from that report are summarized here.

WATER QUALITY—EXISTING CONDITIONS

King County and the MITFD collected data from 18 locations on Newaukum Creek as part of the Stream Monitoring Program (Figure WQ-2) between 1996 and 1999. Extensive sampling during baseflow and storm conditions occurred at station 0322, located approximately one mile upstream of the confluence with the Green River. Table WQ-8 summarizes the number of samples analyzed for each parameter at each of the other 17 locations during storm and nonstorm conditions between October 1996 and December 1999.

Table WQ-8. Summary of Number of Samples Analyzed from October 1996 to December 1999 for Each Parameter in the Newaukum Creek Basin.

Sampling Station	Non-storm/storm	Nitrogen, Ammonia	DO	pH	TSS	Temp	Turbidity
AA322	N	9	9	8	9	9	9
	S	2	2	1	2	2	2
AB322	N	11	11	9	11	11	11
	S	3	3	2	3	3	3
AC322	N	10	10	8	10	10	10
	S	2	2		2	2	2
AD322	N	11	11	9	11	11	11
	S	2	4		2	2	2
AE322	N	10	11	8	10	10	10
	S	3	3	2	3	3	3
AF322	N	10	10	8	10	10	10
	S	2	2	1	2	2	2
AG322 / M322	N	18	18	8	19	19	19
	S	3	3	1	3	3	3
AH322	N	10	10	7	10	10	10
	S	2	2	1	2	2	2
AI322 / P322	N	33	35	7	34	34	34
	S	4	4	1	4	4	4
AJ322	N	9	9	7	9	9	9
	S	2	2	1	2	2	2
D322	N	35	41		36	37	36
	S	2	2		2	2	2
F322	N	34	37	7	35	36	35
	S	3	3	1	3	3	3
H322	N	36	39	9	37	38	37
	S	4	5	1	4	4	4
J322	N	35	36	9	36	37	36
	S	3	3	1	3	3	3
K322	N	22	23		23	24	23
N322	N	34	42	7	35	36	35
	S	3	3	1	3	3	3
T322	N	35	41		36	36	36
	S	2	2		2	2	2

Note: Some stations had more than one identifier during the study period (1996-99).

At station 0322, five parameters (temperature, DO, turbidity, TSS and ammonia) were analyzed in 71 to 76 samples during nonstorm conditions between 1996 and 1999. Measurements of pH were made for 36 samples during nonstorm conditions. All six parameters were measured during storm conditions on 13 to 16 occasions. Additionally, total and dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) were analyzed at station 0322 during storm conditions on roughly 13 and 7 occasions, respectively. Total aluminum was analyzed on three occasions during storm conditions. Comparisons of data to standards or criteria are detailed below.

Temperature

No continuous temperature data were available for Newaukum Creek. Based on the available water quality data from 1996 though 1999, temperatures were always below the migration blockage threshold (21°C), the Class A standard (18°C), and the proposed salmonid rearing standard (17.5°C). However, a number of individual measurements exceeded the proposed spawning standard (14.5°C) during the summer, with a maximum of 15.5°C. These exceedances do not coincide with the spawning of fall chinook. In addition, the proposed spawning standard would not apply to the period when exceedances were measured (Hicks 2000a). This suggests that temperature is not a factor of decline for chinook salmon in Newaukum Creek; however, temperature readings are only taken monthly and do not necessarily represent peak temperatures during the spawning season. Given that spawning standards were exceeded in the summer, temperature may be of concern for any salmonids (e.g., winter steelhead) that spawn or incubate during summer months.

Dissolved Oxygen

As noted above, DO is listed on the State's 303(d) list of impaired water bodies for failing to meet state surface water standards for one segment of Newaukum Creek. This listing is based upon data collected at RM 10.1 at the confluence with Stonequarry Creek. Between 1991 and 1997, eight of 15 samples at this location were below the state standard. Based on the available water quality data from 1996 through 1999, all DO concentrations are greater than the minimum Class A and proposed salmonid rearing standard at all sampling locations except for D322 and AC322. At D322, 12 of 41 measurements were below 8.0 mg/L with a minimum of 5.9 mg/L, and at AC322, five of 10 DO concentrations were below 8.0 mg/L, with a minimum of 5.8 mg/L. Therefore, when evaluating individual DO readings, the recent data support the listing because water quality standards are still exceeded.

When comparing these data to the proposed salmonid incubation standard, there were individual measurements below 10.5 mg/L at all locations, except AJ322. In addition, all sampling locations had DO concentrations below the proposed spawning standard during the defined spawning season (September 15th through May 31st) between 1996 and 1999. Therefore, DO is probably of concern for salmonids in Newaukum Creek.

Turbidity / TSS

Based on the available water quality data from 1996 through 1999, average non-storm turbidity ranged from 1.4 to 5.8 NTUs, with a maximum value of 15 NTUs. The storm turbidity data ranged from 0.6 to 51 NTUs, although only seven of 58 storm turbidity measurements were greater than 20 NTUs.

Average non-storm TSS ranged from 1.2 to 10.7 mg/L, with peak measurements as high as 95.6 mg/L. Although these were not classified as storm samples, these peak measurements likely occurred shortly after a storm event or some other disturbance (such as maintenance activities) that caused a short-term increase in TSS. Storm TSS measurements ranged from 0.6 to 120 mg/L, indicating that TSS concentrations occasionally exceeded levels that could cause sub-lethal effects if the concentrations were maintained for a long enough duration. However, the duration of the elevated TSS concentrations is unknown, and therefore, potential effects cannot be determined. On average, TSS does not appear to be of concern, although more data, including concentration and duration, are needed.

pH

Based on the available data from 1996 through 1999, pH was between 6.5 and 8.5 at all sampling locations except AA322 and AD322. At AA322, two of nine measurements were 8.6. Given that the magnitude of the exceedance is within the tolerance limits of the instrument used to measure it, pH at AA322 is not expected to elicit any direct effects to aquatic life. At AD322, one of nine measurements was 9.8. If this datum was representative of the creek, pH would likely have adverse effects on aquatic life. However, given that 177 of the 178 pH measurements in Newaukum Creek were within 6.5 to 8.6, this value is probably an anomaly or resulted from equipment malfunction. Therefore, pH is not likely a concern for salmonids, although it may influence the potential toxicity of other chemicals (e.g., metals).

Ammonia

One segment of Newaukum Creek, just upstream of station 0322, is listed on the State's 303(d) list of impaired water bodies for failing to meet the state surface water ammonia standard. This listing is based upon three excursions beyond the standard collected between 1991 and 1997 at RM 2.1. Based on the available water quality data from 1996 through 1999, ammonia never exceeded either its acute or chronic water quality standard; therefore, ammonia is not likely a concern for salmonids.

Metals

The metals evaluated here (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) suggest that they are not of concern, with the possible exception of aluminum. Although there are no state water quality standards for aluminum, all three aluminum samples at station 0322 exceeded the EPA chronic water quality criterion (87 µg/L). Two of the three samples exceeded the EPA *acute* criterion (750 µg/L). Although the limited data exceed the EPA criterion, it is not likely in a toxic form because the analytical method for determining total recoverable aluminum probably dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988). In addition, these data were collected under storm conditions where elevated suspended solids and organic matter concentrations tends to bind more of the dissolved metal, thereby reducing its bioavailability. However, because data are limited, further evaluations of aluminum should be conducted to confirm whether it is of concern for salmonids.

The same pattern for the basin as a whole is applicable to the Newaukum Creek data with regards to the detection limits for mercury and selenium (see section 4).

DATA GAPS

There are probably sufficient data to characterize temperature, DO, pH, turbidity and ammonia in Newaukum Creek. The lack of continuous temperature data is a data gap because data do not necessarily reflect daily maximum temperatures and the duration of temperature exceedances. Similarly, available TSS data do not include duration, without which potential effects cannot be accurately evaluated. Furthermore, although there are adequate metals data at station 0322, all were collected under storm conditions. Therefore, additional metals data are needed to describe baseline (non-storm) conditions, especially for aluminum. There were no metals data available for other sampling locations in Newaukum Creek.

Other classes of parameters for which no data were available represent significant data gaps. No data were available for pesticides and herbicides, PAHs, or phthalate esters.

SOOS CREEK

The Soos Creek subbasin lies north and east of the Green River and southeast of Renton and east of Kent. The Soos Creek system drains an area of 70 square miles and consists of several streams including Big Soos, Little Soos, Soosette, Covington, and Jenkins. All major tributaries in the subbasin have similar physical characteristics, draining flat to rolling terrain and converging below river mile 5.0 of Big Soos Creek. Many reaches of the upper plateau flow through extensive wetlands where pools are deep and velocities slow. There are also numerous lakes in the Soos Creek subbasin, including Lake Youngs, Lake Meridian, Shadow Lake, Lake Sawyer, Lake Wilderness, Pipe Lake/Lake Lucerne, Ginger Lake, Ravensdale Lake, and Lake Morton.

Most of the Soos Creek basin is developed as either urban or rural land uses. The north and west portions of the basin have a pattern of high-density residential and commercial development. The north portion of Jenkins Creek and the west portion of Covington Creek contain rural residential areas consisting of small farms and pastures. Sand, gravel and clay are mined in the hills east and northeast of Black Diamond, and coal is mined near the northeast corner of Ginger Lake.

Ten reaches within the Soos Creek basin are listed on the state’s 303(d) list of impaired water bodies for failing to meet state surface water standards. Nine reaches are listed for fecal coliforms, three reaches are listed for dissolved oxygen and one reach is listed for temperature. In addition, Lake Meridian is listed for total phosphorus.

There were no historic reports on water quality in the Soos Creek basin with the exception of the annual Metro water quality reports from the 1980s. The King County streams program has collected water quality data since 1976 at five stations in the Soos Creek basin on Covington, Jenkins, Soosette, Big Soos and Little Soos creeks.

WATER QUALITY—EXISTING CONDITIONS

King County and the Muckleshoot Indian Tribe have collected data from 17 locations in the Soos Creek subbasin as part of the Streams Monitoring Program: five locations on Big Soos Creek, three on Little Soos Creek, one on Jenkins Creek, and four on both Covington Creek and Soosette Creek (see Figure WQ-1). The number of samples analyzed for each parameter at each location between 1996 and 1999 during non-storm and storm conditions is given below.

Storm samples were analyzed for six parameters (temperature, pH, DO, turbidity, TSS and ammonia) on two occasions at stations C320, D320, G320, and L320 and on one occasion at stations B320, Q320, R320, S320 and U320. Non-storm sampling occurred for these same six parameters on 35 to 55 occasions at three stations in Big Soos Creek (A320, L320, N320), two stations in Little Soos Creek (G320, U320), three stations in Covington Creek (C320, R320, S320), and one station each in Jenkins Creek (D320) and Soosette Creek (B320). Non-storm sampling occurred on 19 to 27 occasions at two stations in Big Soos Creek (M320, P320) and three stations in Soosette Creek (V320, X320, Y320), on 15 to 17 occasions at station T320 in Little Soos Creek and 10 to 11 occasions at Q320 in Big Soos Creek.

Temperature

One segment of Little Soos Creek is listed on the State's 303(d) list of impaired water bodies for failing to meet the temperature standards. The listing of Little Soos Creek is based on seven excursions measured between 1991 and 1997 at sampling station T320 (RM 3.2). Continuous temperature data were collected between 1996 and 1999 for most subbasins. Different water years are available for five locations in the basin for Big Soos, Little Soos, Jenkins, Covington, and Soosette creeks.

Big Soos Creek

Continuous water temperature data were collected at the King County stream gauge near the mouth of Big Soos Creek (station 54A) from October 1997 to September 1999 (water years 1998 and 1999). The maximum recorded daily temperature during this period was 21.7°C in late July 1998. During the two-year period, the Class A standard of 18°C and the proposed 17.5°C rearing standard were exceeded on 28 and 40 days, respectively in 1998, and on 11 and 20 days, respectively in 1999, between mid-May and September. The proposed 14.5°C spawning standard (September 15 to May 31) was exceeded on seven days from late April to late May 1998 (maximum of 17.1°C) and eight days in late September 1998 (maximum of 15.6°C). During 1999, it was exceeded on eight days from mid-April to late May (maximum of 18.1°C) and four days in late September (maximum of 15.3°C).

The proposed rearing standard of 15°C for the moving 7-day average of the daily maximum temperatures was exceeded on 68 and 104 days in 1998 and 1999, respectively, from late May to mid-September (maximums were 20.0 and 17.3°C). The proposed spawning standard of 12°C for the moving 7-day average of the daily maximum temperatures (September 15 to May 31) was exceeded on 11 and 13 days in October 1997 and 1998, respectively (maximum of 13.5 and 12.6°C), 38 and 21 days in mid-April to late May 1998 and 1999, respectively (maximum of 15.4 and 16.0°C) and 16 days during late September in both 1998 and 1999 (maximum of 15.7 and 14.6°C). These data suggest that temperature is a probable factor of decline for salmonids in Big Soos Creek. This is based on somewhat frequent exceedances of the Class A and proposed rearing and spawning standards (both maximum and the moving 7-day averages) of from 1 to 4°C.

Little Soos Creek

Continuous water temperature data were collected at the King County stream gauge near the mouth of Little Soos Creek (station 54I) from October 1998 to September 1999 (water year 1999). The maximum recorded daily temperature during this period was 21.7°C in mid-June 1999. During the one-year period, the Class A standard of 18°C and the proposed 17.5°C rearing standard were exceeded on 62 and 71 days, respectively, between mid-May and September. The proposed 14.5°C spawning standard (September 15 to May 31) was exceeded on five days in October 1998 (maximum of 16.3°C), 14 days in mid-April to late May 1999 (maximum of 19.4°C), and 11 days in late September 1999 (maximum of 18.3°C).

The proposed rearing standard of 15°C for the moving 7-day average of the daily maximum temperatures was exceeded on 124 days from late-May to late-September 1999 (maximum of 20.4°C). The proposed spawning standard of 12°C for the moving 7-day average of the daily maximum temperatures (September 15 to May 31) was exceeded on 19 days in October 1998 (maximum of 14.6°C), 39 days in late April to mid-May 1999 (maximum of 17.4°C) and 16 days in late September 1999 (maximum of 17.3°C). These data suggest that temperature is a probable factor of decline for salmonids in Little Soos Creek, based on frequent significant exceedances of the existing Class A standard, and proposed rearing and spawning standards (for both maximum and moving 7-day averages) of from 1 to 6°C.

Jenkins Creek

Continuous water temperature data were collected at the King County stream gauge near the mouth of Jenkins Creek (station 26A) from October 1997 to September 1999 (water years 1998 and 1999). The maximum recorded daily temperature during this period was 17.8°C in late July 1998. During the two-year period, the Class A standard of 18°C was never exceeded and the proposed 17.5°C rearing standard was exceeded on two days in late July 1998. The proposed 14.5°C spawning standard (September 15 to May 31) was exceeded on one day in late May 1999 (maximum of 15.1°C) and on three days in late September 1999 (maximum of 14.6°C).

The proposed rearing standard of 15°C for the moving 7-day average of the daily maximum temperatures was exceeded on 55 days from mid-July to mid-September 1998 (maximum of 17°C) and for 40 days from mid-July to late August 1999 (maximum of 15.9°C). The proposed spawning standard of 12°C for the moving 7-day average of the daily maximum temperatures (September 15 to May 31) was exceeded on 13 days in late April to mid-May 1998 (maximum of 13.5°C) and 15 days in late September 1998 (maximum of 14.6°C). In water year 1999, the spawning standard was exceeded on 12 days in mid- to late-May (maximum of 14.1°C) and 15 days in late September (maximum of 14.2°C). These data suggest that temperature is a possible factor of decline for salmonids in Jenkins Creek, based on somewhat frequent exceedances of the proposed rearing and spawning standards (based on moving 7-day averages) of from 1 to 2°C.

Covington Creek

The maximum recorded daily temperature in Covington Creek (station 9A) during water years 1998 and 1999 was 20.2°C in early August 1998. During the two-year period, the Class A standard of 18°C was exceeded on 14 days in July/August 1998 and two days in early September 1999. The proposed 17.5°C rearing standard was exceeded on 17 and four days in 1998 and

1999, respectively. A single measurement (23.2°C) was above the migration threshold of 21°C at station R320 (collected as part of routine monitoring). The proposed 14.5°C spawning standard (September 15 to May 31) was exceeded on two and one days in late May 1998 and May 1999, respectively (maximum of 16.8°C), on 10 days in late September/October 1998 (maximum of 17.3°C) and on 10 days in September 1999 (maximum of 17.6°C).

The proposed rearing standard of 15°C for the moving 7-day average of the daily maximum temperatures was exceeded on 66 days from mid-July to mid-September 1998 (maximum of 18.8°C) and for 17 days from late August to mid-September 1999 (maximum of 16.6°C). The proposed spawning standard of 12°C for the moving 7-day average of the daily maximum temperatures (September 15 to May 31) was exceeded on six days in October 1997 (maximum of 13.7°C), 24 days in May 1998 (maximum of 13.1°C), and 16 days in late September 1998 (maximum of 14.6°C). In water year 1999, the spawning standard was exceeded on 13 days in October 1998 (maximum of 14.8°C), nine days in late May 1999 (maximum of 13.1°C) and 16 days in late September (maximum of 15.7°C). These data suggest that temperature is a probable factor of decline for salmonids in Covington Creek, based on frequent exceedances of the proposed rearing and spawning standards (based on moving 7-day averages) of from 1 to 4°C.

Soosette Creek

Continuous water temperature data were collected at the King County stream gauge near the mouth of Soosette Creek (station 54H) from October 1998 to September 1999 (water year 1999). There were considerable data gaps in water year 1998, so those data are not included in this analysis. The maximum recorded daily temperature during this period was 20.2°C in early August 1999. During the one-year period, the Class A standard of 18°C and the proposed 17.5°C rearing standard were exceeded on 34 and 57 days, respectively, between late May and September. The proposed 14.5°C spawning standard (September 15 to May 31) was exceeded on 20 days from mid-April to late May 1999 (maximum of 18.3°C), and 16 days in late September 1999 (maximum of 17.8°C).

The proposed rearing standard of 15°C for the moving 7-day average of the daily maximum temperatures was exceeded on 132 days from late-May to late-September 1999 (maximum of 19.6°C). The proposed spawning standard of 12°C for the moving 7-day average of the daily maximum temperatures (September 15 to May 31) was exceeded on 19 days in October 1998 (maximum of 13.5°C), 51 days in mid-April to late May 1998 (maximum of 17.1°C) and 16 days in late September 1998 (maximum of 17.8°C). These data suggest that temperature is a probable factor of decline for salmonids in Soosette Creek, based on frequent significant exceedances of the existing Class A standard, and proposed rearing and spawning standards (for both maximum and moving 7-day averages) of from 1 to 6°C.

In summary, temperature is a probable factor of decline for salmonids in the Soos Creek basin for both rearing and spawning in the Soosette, Little Soos and Covington tributaries and the mainstem of Big Soos and a possible factor of decline in Jenkins Creek.

Dissolved Oxygen

Segments of Big Soos, Little Soos and Soosette Creeks are listed on the State's 303(d) list of impaired water bodies for failing to meet state surface water quality DO standards. The listings are based on numerous excursions measured between 1991 and 1997 at sampling stations L320 (Big Soos RM 10.5), M320 (Big Soos RM 10.0), U320 (Little Soos RM 4.7), X320 (Little Soos RM 3.1), and Y320 (Soosette RM 3.9).

Based on water quality data from 1996 through 1999, the following conclusions can be drawn:

1. **Big Soos Creek**. Fifty-four of 141 DO measurements at stations L320, M320, N320 and Q320 were below Class A and proposed salmonid rearing standard (8.0 mg/L); none of the 76 DO measurements at A320 and P320 were below this standard. In addition, 146 of 217 DO measurements at all sampling locations were below the proposed incubation standard (10.5 mg/L); many of these excursions occurred during the defined salmonid incubation period.

2. **Little Soos Creek**. Twenty of 51 DO measurements were below the Class A and proposed salmonid rearing standard (8.0 mg/L) at sampling station U320; none of the 53 measurements at stations G320 and T320 were below this standard. In addition, 70 of 104 DO measurements were below the proposed salmonid incubation standard (10.5 mg/L) at all sampling locations; many of these excursions occurred during the defined salmonid incubation period.

3. **Jenkins Creek**. All data at sampling station D320 were greater than the Class A and proposed salmonid rearing standard. However, 14 of 39 DO measurements were below the proposed salmonid incubation standard (10.5 mg/L), and many of these occurred during the defined salmonid incubation period.

4. **Covington Creek**. All 127 DO measurements at sampling stations C320, R320 and S320 were greater than the Class A and proposed salmonid rearing standard (8.0 mg/L). However, 44 of 127 DO measurements at all stations were below the proposed salmonid incubation standard (10.5 mg/L); many of these excursions occurred during the defined salmonid incubation period.

5. **Soosette Creek**. Twenty-two of 100 DO measurements at all stations were below than the Class A and proposed salmonid rearing standard (8.0 mg/L). In addition, 44 of 100 DO measurements at all stations were below the proposed salmonid incubation standard (10.5 mg/L); many of these excursions occurred during the defined salmonid incubation period.

In summary, it appears that DO is probably of concern for salmonids in the Soos Creek subbasin. When evaluating individual DO readings, the King County data from 1996 through 1999 exceeded the water quality standards on some occasions, and therefore, support the 303(d) listing.

Turbidity/TSS

None of the Soos Creek subbasin is listed on the State's 303(d) list of impaired water bodies for failing to meet state surface water turbidity standards. Based on the available water quality data from 1996 through 1999, average non-storm turbidity ranged from 0.6 to 4.9 NTUs. The limited storm turbidity data ranged from 0.7 to 5.1 NTUs, except for one measurement at station B320 that was 22 NTUs. When considering all of the data (both non-storm and storm), all but four measurements were less than 20 NTUs; the maximum turbidity measurement was 27 NTUs at sampling station B320.

Average non-storm TSS in the Soos Creek subbasin ranged from 0.66 to 6.06 mg/L, although a few individual measurements were as high as 137 mg/L. Although these were not classified as storm samples, these peak measurements probably occurred shortly after a storm event or some other disturbance that caused a short-term increase in TSS. Storm measurements ranged from <0.5 to 22 mg/L. These data suggest that TSS concentrations in the Soos Creek subbasin occasionally exceed levels that could cause sub-lethal effects if the concentrations were maintained for a long enough duration. However, the duration of the elevated TSS concentrations is unknown and therefore, potential effects cannot be determined. On average, TSS does not appear to be of concern for salmonids, although more data, including concentration and duration, are needed.

pH

None of the Soos Creek subbasin is listed on the State's 303(d) list of impaired water bodies for failing to meet state surface water pH standards. Based on the available data from 1996 through 1999, pH is always between 6.5 and 8.0 at all stations except L320, G320, T320, U320 and X320. At Big Soos (station L320), the two excursions (out of 39 measurements) were 6.1 and 6.4. At the Little Soos Creek sampling stations, one of 39 measurements was 6.3 at G320, two of 16 measurements were 6.4 at T320, and two of 38 measurements were 6.3 at U320. Finally, at Soosette Creek station X320, one of 22 measurements was 6.3. Overall, however, 451 of 459 pH measurements in the Soos Creek subbasin were between 6.5 and 8.0. Therefore, pH is unlikely to be of concern for salmonids, although it may influence the potential toxicity of other chemicals (e.g., metals).

Ammonia

Based on the available water quality data from 1996 through 1999, ammonia is not expected to be of concern for salmonids as none of the data exceed either the acute or chronic water quality standard for ammonia.

Metals

The metals evaluated here (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) suggest that they are not of concern for salmonids, with the possible exception of aluminum. Although there are no state water quality standards for aluminum, all three aluminum samples at station A320 exceeded the EPA chronic water quality criterion (87 µg/L). Although the limited data exceed the EPA criterion, it is not likely in a toxic form because the analytical method for determining total recoverable aluminum probably dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988). In addition, these data were collected under storm conditions where elevated suspended solids and organic matter concentrations tends to bind more of the dissolved metal, thereby reducing its bioavailability. However, because data are limited, further evaluations of aluminum should be conducted to confirm whether it is of concern for salmonids.

The same pattern for the basin as a whole is applicable to the Soos Creek data with regard to the detection limits for mercury and selenium (see section 4).

WATER QUALITY TRENDS IN THE SOOS CREEK BASIN

A recent analysis of 20-year trends (1980-99) in King County streams (King County, 2000) examined trends for data collected at four stations (A320, C320, D320, G320) in the Soos Creek Basin (see Figure WQ-2). Time-series plots were used as a preliminary screening tool to examine trends. If a trend was suggested by the time-series plot, the data were then assessed using a Seasonal Kendall's Trend test to test for statistically significant trends. Summary results of the study follow:

1. **Dissolved Oxygen**. During baseline conditions, average DO levels at Soos Creek (A320) were 11.3 mg/L, the highest concentration of any stations in the study. There was no long-term increasing or decreasing trend in DO levels at the four sites.

2. **Temperature**. Temperature has increased at 19 of 23 sites in the study over the 20-year period, including two of four in the Soos Creek basin (based on the Seasonal Kendall's Trend test). It was concluded that most of this increase is probably attributable to urbanization and development, including increased stormwater runoff, and loss of riparian vegetation. This is because there were no temperature trends detected for the same period from two sites on the Middle Green River (stations A319 and B319), both of which are in areas that have experienced little development.

3. **Turbidity/TSS**. Soos Creek (A320) typically exhibited the lowest average turbidity and TSS over the 20-year period for the 23 sites. Baseflow turbidity averaged 1.4 NTU and 2.8 NTU during the dry and wet seasons, respectively. TSS values at Soos Creek averaged 3.4 mg/L. There were no apparent trends for turbidity, but time-series plots suggested that baseflow levels of TSS have been decreasing over time. Only Little Soos Creek (G320), however, showed a statistically significant decreasing trend. Soos Creek (A320) exhibited the highest storm turbidity value (272 NTU) of the nine sampling locations in King County for which stream storm data were available during the 20-year study period (King County 2000).

4. **Ammonia**. Soos Creek also had the lowest average value for ammonia at 0.035 mg/L. Covington Creek (C320) was the only Soos subbasin site to experience a statistically significant increase in ammonia over the study period, but it does not exceed the state standard.

Water quality trend data were not available for other parameters, such as metals.

Turbidity

It is important to note that turbidity data for the Soos Creek basin have been highly variable. As noted above, Soos Creek exhibited the lowest average turbidity (1.4 NTU) during baseflow conditions over the 20-year study period for the 23 sites monitored. Conversely, it also exhibited the highest storm turbidity value (272 NTU) of nine sites monitored during storm conditions during this same period. For the most recent data evaluated in this report (1996-99), the highest turbidity value observed during storm conditions was 27 NTU and average non-storm turbidity ranged from 0.6 to 4.9 NTU.

Contrary to the recent data, however, hatchery staff at the Soos Creek State Fish Hatchery notes that there are problems with excess turbidity in Soos Creek (Kerwin personal communication 2000). The hatchery utilizes a 1/8-acre pond as a settling basin to remove sediment from creek flows prior to its incubation room. Even with the settling basin, there are occasions during the wet season when it is necessary to sweep silt off the eggs up to three times per week. This phenomenon may be explained by either or both of the following scenarios: (1) possible discrepancies between direct observations on a regular basis and data collected during infrequent sampling events, and/or (2) the potential adverse impacts of even moderate turbidity levels during storms on salmonid eggs.

BIOLOGICAL MONITORING IN THE SOOS CREEK BASIN

The Soos Creek basin has been the most extensively monitored for aquatic insects in theGreen/Duwamish watershed. Table WQ-9 shows the B-IBI scores for eight different monitoring stations in the Soos Creek basin between 1995 and 1998. Lower Soosette Creek had the highest index (average = 35) and Little Soos Creek had the lowest index (average = 14). Five of the eight stations were characterized as fair, two of the eight stations were characterized as poor, and one very poor.

Aquatic insect sampling also occurred at one station on Meridian Valley Creek in the Big Soos Creek basin by SalmonWeb (2000) during 1999. The B-IBI score was 14, which is characterized as very poor on the B-IBI index.

TableWQ-9. B-IBI scores for streams in the Soos Creek Basin for 1995 to 1998.

Macroinvertebrate Monitoring Sites	1995 Scores	1997 Scores	1998 Scores
Lower Covington Creek	34	30	N/A
Upper Covington Creek	*	32	N/A
Lower Soos Creek	28	28	N/A
Upper Soos Creek	20	20	N/A
Lower Jenkins	30	28	30
Upper Jenkins	N/A	N/A	22
Lower Soosette Creek	36	N/A	34
Little Soos Creek	14	14	N/A

* Indicates that scores could not be calculated.
N/A = not available.

DATA GAPS

There are probably sufficient data to characterize temperature, dissolved oxygen, pH and ammonia in the Soos Creek subbasin. Available TSS data do not include duration, without which potential effects cannot be accurately evaluated. Furthermore, there are relatively few metals data (between three and 16 occasions), and all were collected under storm conditions. Therefore, additional metals data are needed, especially under baseline (non-storm) conditions.

Other classes of parameters for which no data are available represent significant data gaps. No data were available for pesticides and herbicides, PAHs, or phthalate esters.

MILL (HILL) CREEK

Mill Creek originates from Lake Doloff and Lake Geneva on the plateau west of the Green River Valley. The creek flows from these lakes down Peasley Canyon, a steep ravine that reaches the valley floor near the intersection of SR-18 and SR-167. The Mill Creek basin is approximately 22 square miles in area and also includes Mullen Slough and Midway Creek (see Figure WQ-1). Five jurisdictions are contained in the Mill Creek basin: King County, Federal Way, Algona, Kent, and Auburn. A comprehensive Mill Creek Water Quality Management Plan was completed by King County in 1993 (King County 1993).

Most of the upland plateau area in the west of the basin is residential. Much of the valley floor to the east is a mixture of commercial and industrial structures, agriculture, idle pasture, and open space with scattered homes. The southeastern and southern areas are heavily urbanized.

Mill Creek is classified as a Class A surface water (WAC-173-201A-120). According to the Green/Duwamish Nonpoint Action Plan (King County 1989), the Mill Creek, Mullen Slough, and Midway Creek drainages are "the most polluted streams draining into the Green/Duwamish system." Metro (1991) identifies Mill Creek as one of two streams in its survey having the poorest water quality, with chronically low dissolved oxygen (DO) levels and high temperatures, bacterial counts, nutrients and turbidity.

Three reaches along Mill Creek are listed on the state's 303(d) list of impaired water bodies for failing to meet state surface water standards. The reach near the mouth of Mill Creek is listed for fecal coliforms and DO. Further upstream on Mill Creek, these same two parameters and temperature are listed. Lastly, the reach of Mill Creek just upstream of Peasley Canyon is listed for fecal coliforms. The reach of Mullen Slough near its mouth at the Green River is also listed for fecal coliforms, temperature, and DO.

According to the Mill Creek Water Quality Management Plan (King County 1993), the most significant water quality problems in Mill Creek are:

- A severe depression or sag in DO levels between approximately river mile (RM) 5.6 and RM 3.3 in Auburn (see Figure WQ-6). Dissolved oxygen levels in this reach are regularly below the standard of 8 mg/L and often as low as 3 mg/L. There are also extremely low DO levels in the Algona tributary that enters Mill Creek at the SR-18 and SR-167 intersection.

- High summer water temperatures in the Algona tributary and in Mill Creek from the outlet of Peasley Canyon to the mouth. Average daily maximum temperatures from July 20 to September 10, 1991 were nearly 20^{o}C in Mill Creek.

- Erosion of stream banks in Peasley Canyon, causing high suspended solids and turbidity downstream.

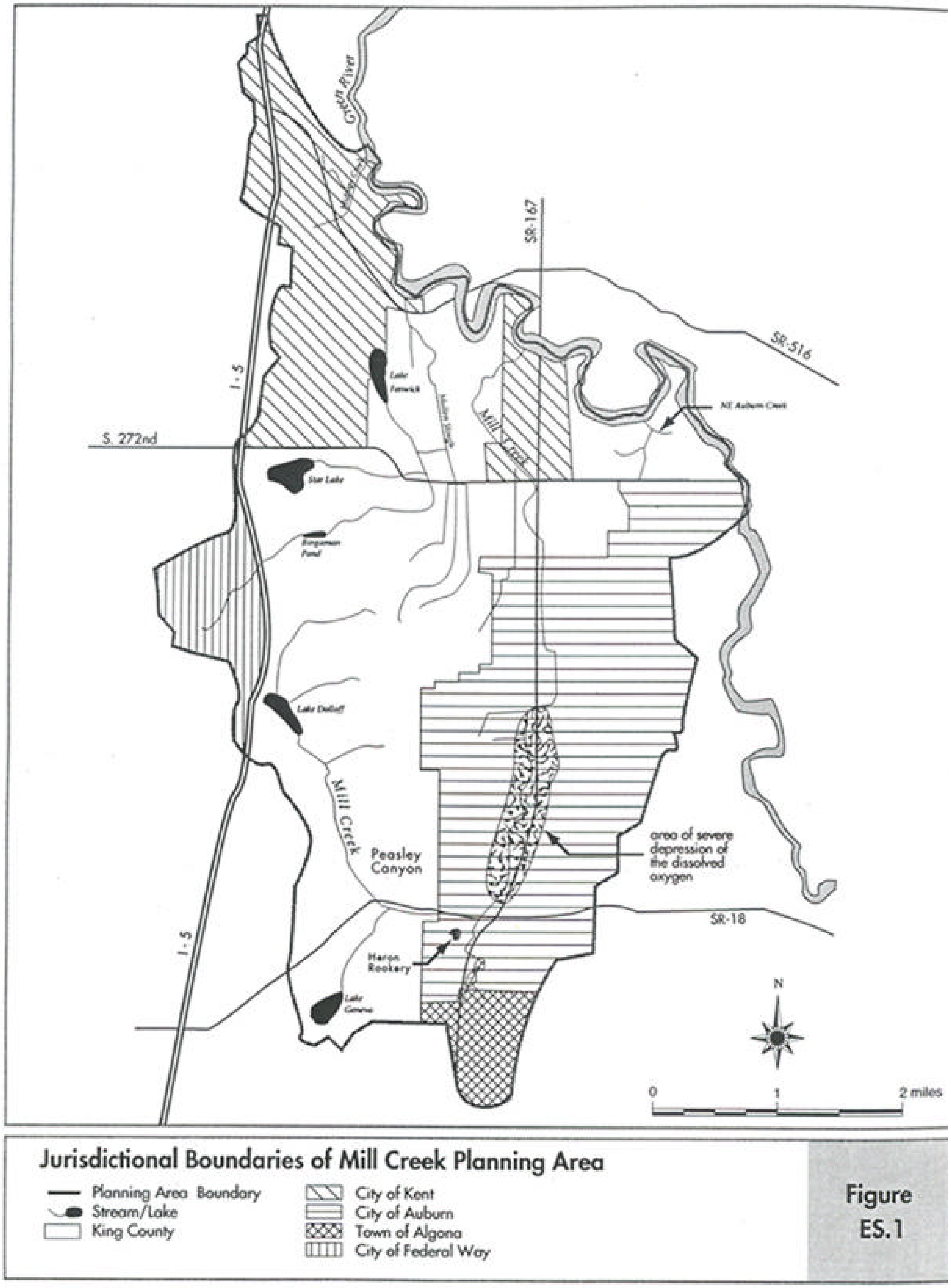

Figure WQ-6. Location of Dissolved Oxygen Sag on Mill Creek (Mill Creek Water Quality Management Plan, King County 1993).

MULLEN SLOUGH

The Mullen Slough watershed, within the Mill Creek Basin, covers approximately 3,400 acres in area. Three small streams flowing from the uplands along the west side of the basin originate in Lakes Star and Fenwick and Bingaman Pond. Land use in the valley floor is essentially agriculture, wetlands, or idle lands, and residential or undeveloped forest in the uplands. Baseflow and storm events were sampled by King County between February 1990 and February 1991. The most significant water quality problems in Mullen Slough identified by King County (1993) are similar to Mill Creek, including low DO levels, high summer water temperatures, and high ammonia-nitrogen concentrations.

- DO levels in flows coming from the uplands, entering Mullen Slough from the west, typically range between 8 and 12 mg/L. However, downstream in Mullen Slough, near the confluence with the Green River, DO is typically below 6 mg/L and frequently as low as 2 mg/L. Low values have been measured even during the winter months.

- Temperatures in Mullen Slough regularly exceed state standards during the summer months. From July 20 to September 10, 1991, maximum daily temperatures averaged 22^{o}C during low flow conditions.

- Ammonia-nitrogen concentrations in lower Mullen Slough during the sampling period (King County 1993) were measured between 4 and 8 mg/L, considerably higher than the chronic standard of about 1.8 mg/L. Because the upland station did not exhibit such elevated levels, poor manure handling practices in the valley floor appear to be the primary source of elevated ammonia levels.

MIDWAY CREEK BASIN

The Midway Creek basin encompasses about 750 acres in the northern portion of the Mill Creek basin. The upland area is mostly developed. South of SR-516 is mostly developed in residential uses with discharges to a steep ravine in the south fork of Midway Creek. The watershed has approximately four miles of heavily used roads (Interstate-5, SR-516 and Military Rd.). The Kent-Highlands landfill site (90 acres) is also within this watershed; however, the stormwater that directly enters Midway Creek does not appear to come from refuse areas.

Analysis of data from 1986 to 1989 from Station 8 in Kent (near the mouth of Midway Creek) (Kent 1991) indicates that the water quality is generally good, with the exception of fecal coliforms (King County 1993). Temperature, DO and metals typically met standards, although the DO concentrations were usually less than 100 percent saturation (King County 1993).

WATER QUALITY—EXISTING CONDITIONS

Only one station in the Mill Creek subbasin was included in the King County Streams program between 1996 and 1999. The station (A315) is located near the mouth of Mill Creek just west of the West Valley Highway (Hwy 167) (Figure WQ-2). The surrounding area contains several major roadways, pastureland and low-density residential development.

At station A315, six parameters (temperature, DO, pH, turbidity, TSS and ammonia) were analyzed in 36 to 38 samples during nonstorm conditions between 1996 and 1999. These same parameters were measured during storm conditions on 14 occasions. Additionally, total and dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) were analyzed at station A315 during storm conditions on roughly 13 and 7 occasions, respectively. Total and dissolved aluminum was analyzed on three and one occasions, respectively, during storm conditions. Comparisons of data to standards or criteria are detailed below.

Temperature

Continuous water temperature data were collected at the King County stream gauge near the mouth of Mill Creek (station 41A) from October 1999 to September 2000 (water year 2000). The maximum recorded daily temperature during this period was 23.8°C in late June 2000, which exceeds the migration blockage threshold (21°C). The Class A standard of 18°C and the proposed 17.5°C rearing standard were exceeded on 69 and 77 days, respectively, between May and September 2000. The proposed 14.5°C spawning standard (September 15 to May 31) was exceeded on 33 days in April and May of 2000 (maximum of 19.3°C).

The proposed rearing standard of 15°C for the moving 7-day average of the daily maximum temperatures was exceeded on 121 days during water year 2000 from early May to mid-September. It was continuously over 15°C from mid-May to mid-September. The maximum 7-day average was 22.5°C in early August. The proposed spawning standard of 12°C for the moving 7-day average of the daily maximum temperatures (September 15 to May 31) was exceeded continuously from April 3 to May 31, 2000 (maximum of 17.7°C in late May). No data were available for late September 2000. These data indicate that temperature is a probable factor of decline for salmonids in Mill Creek, based on frequent large exceedances of the Class A standard and proposed rearing and spawning standards of 4 to 6°C.

Dissolved Oxygen

Numerous DO concentrations (minimum of 2.5 and 4.8 mg/L for non-storm and storm conditions, respectively) were below the Class A and proposed salmonid rearing water standard (8.0 mg/L). In addition, DO concentrations were always below the proposed salmonid incubation standard (10.5 mg/L) at station A315 between 1996 and 1999 during the defined incubation period (see Figure WQ-7). Chinook are not known to spawn in this reach of Mill Creek, however, coho, chum, and winter steelhead adults have been observed spawning in Mill Creek (WDFW Spawning Ground Survey database, Malcom pers comm, see FOD subbasin chapter). Thus, the incubation standard would be applicable to this location, indicating that this reach is a known problem area for salmonids. This reach had the lowest DO concentrations during the 1996-99 study period. Based on DO levels falling below both the incubation and rearing standard for this reach, DO in this area is a probable factor of decline for salmonids.

Turbidity/TSS

Average turbidity is 8 and 13 NTUs for non-storm and storm conditions, respectively, with a peak storm turbidity measurement of 34 NTUs. TSS concentrations averaged 6 and 18 mg/L for storm and non-storm conditions, respectively, with a peak storm measurement of 54 mg/L.

During storm events, TSS concentrations occasionally exceeded levels that could cause sub-lethal effects if the concentrations were maintained for a long enough duration. However, the duration of the elevated TSS concentrations is unknown, and therefore, the potential effects cannot be determined.

pH

Nearly all measurements were between 6.5 and 7.6. Only four of 52 measurements were below the Class A standard of 6.5, with a minimum measurement of 6.3. Therefore pH in Mill Creek in the vicinity of A315 is unlikely to be of concern for salmonids, although it may influence the potential toxicity of other chemicals (e.g., metals).

Ammonia

The ammonia data collected from 1996 to 1999 were below both the acute and chronic state water quality standards for ammonia. Therefore, ammonia is not expected to be of concern for salmonids at station A315. However, it should be noted that historic data indicated a problem with ammonia levels exceeding the chronic standard along Mullen Slough.

Metals

The metals evaluated at station A315 (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) are not of concern for salmonids, with the possible exception of aluminum. Although there are no state water quality standards for aluminum, each of the three aluminum samples (collected during storm conditions) exceeded the EPA chronic water quality criterion (87 µg/L). Two of the three samples (1,410 and 1,610 µg/L), exceeded the EPA *acute* water quality criterion (750 µg/L). Although the limited data exceed the EPA criterion, it is not likely in a toxic form because the analytical method for determining total recoverable aluminum probably dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988). In addition, these data were collected under storm conditions where elevated suspended solids and organic matter concentrations tends to bind more of the dissolved metal, thereby reducing its bioavailability. However, because data are limited, further evaluations of aluminum should be conducted to confirm whether it is of concern for salmonids.

The same pattern for the basin as a whole is applicable to the Mill Creek data with regards to the detection limits for mercury and selenium (see section 4).

DATA GAPS

There are probably sufficient data to characterize temperature, DO, pH and ammonia at station A315; however, no data were available for any other location on Mill Creek. Therefore, the spatial variability of these parameters in Mill Creek is a data gap, since station A315 is likely not representative of the entire subbasin. For instance, historic data on Mullen Slough showed exceedances of the chronic ammonia standard, even though they did not occur on Mill Creek. Available TSS data do not include information on duration, therefore, potential effects cannot be accurately evaluated. Furthermore, there are relatively few metals data (between one and 13 occasions), and all were collected under storm conditions. Therefore, additional metals data are needed, especially under baseline (non-storm) conditions.

Other classes of parameters for which no data were available represent significant data gaps. No data were available for pesticides and herbicides, PAHs, or phthalate esters.

BLACK RIVER BASIN (SPRINGBROOK CREEK)

The Black River has undergone major changes over the past century. Significant drainage modifications have substantially reduced the size of the Black River basin to a 24-square mile area on the east side of the Green River south of Renton. Springbrook Creek, originating in the south of the basin in Kent, is the primary stream draining this basin. The Black River Basin Water Quality Management Plan (City of Renton 1993), developed by the City of Renton, contains the most detailed information on water quality for this basin. Water quality data (Kent 1991) and fisheries assessment information (Kent 1995) has also been collected by the City of Kent in the lower portion of the basin. One station at the mouth of Springbrook Creek (0137) is regularly monitored for water quality by the King County streams program.

The entire Black River basin is developed in urban land uses, lying west of the urban growth boundary. Approximately 27 percent of the basin lies in Renton, 65 percent in Kent, less than 2 percent in Tukwila, and the remainder in unincorporated King County. Land uses within the basin are primarily residential, commercial, and industrial with several major freeways (Interstate 405, Highway 167). There is also a Superfund site at Western Processing in Kent.

Springbrook Creek is on the 303(d) list for DO, temperature, fecal coliforms, and a variety of metals (chromium, cadmium, copper, mercury, and zinc). A segment of Mill Creek (Kent), which drains into Springbrook Creek, is also on the 303 (d) list for metals (cadmium, copper, zinc) and sediment (based on a sediment bioassay).

WATER QUALITY—HISTORICAL CONDITIONS

Water quality and flow data have been collected at station 0317 since 1977 by King County (Metro). The Department of Ecology collected water quality data near the mouth of Mill Creek (station 09E070) from 1984 to 1990. Chronic water quality problems in the basin include exceptionally low concentrations of DO, high turbidity, high levels of fecal coliform bacteria, TSS, and ammonia.

Springbrook Creek DO has been as low as 2.1 mg/L with a mean of 6.4 mg/L between 1986-1991 (based on the Metro data). During this same period, mean turbidity was 26 NTU (range: 2.2 to 170) and mean suspended solids was 61 mg/L (range: 5.1 to 2,384). The mean for copper was 9.8 µg/L (range: <2 to 29) in comparison to the chronic criterion of 7 µg/L (for a hardness of 50 mg/L).

Water quality was monitored for the Black River Basin Plan from September 1991 to April 1992 (City of Renton 1993). Two stations were located on Springbrook Creek and one on the Black River. These study results were similar to the previous data, including elevated temperatures and low DO levels (although it is important to note that no summer sampling was included in this study). There were also high levels of metals, fecal coliform bacteria, nutrients and turbidity during storm flows.

Stream sediment loading within the basin is contributed from two primary sources: soil erosion and stream channel erosion (City of Renton 1993). Soil erosion is caused primarily by land clearing activities associated with construction and development. Stream channel erosion is common in the steeper gradient portions of Panther Creek and Springbrook Springs tributary where excess runoff from development has accelerated natural erosion processes. Sediment deposits in the lower section of Springbrook Springs have reached depths of five feet (King County 1987).

The Black River Basin plan (City of Renton 1993) notes that under present conditions, the lack of suitable spawning habitat and questionable rearing capacity due to degraded water quality, especially during warm summer months, result in both Springbrook Creek and Panther Creek offering little in the way of fish habitat. It further states that the presence of heavy metals represents a potentially adverse factor for the aquatic resources of the basin.

The City of Kent Water Quality Program report (Kent 1991) summarizes results of sampling from 1986 to 1989 at six stations in the basin for eight parameters (temperature, DO, turbidity, ammonia, nitrate, fecal coliform, zinc, and total phosphorus). The report noted that water quality at most sampling stations was poor, with particularly degraded conditions at station 1 (Springbrook Creek just downstream of the confluence with Mill Creek) and station 5 (lower Mill Creek). Standards were routinely exceeded for DO, zinc, fecal coliforms, and turbidity.

WATER QUALITY—EXISTING CONDITIONS

King County collected data from one location near the mouth of Springbrook Creek (sampling station 0317) for the Stream Monitoring Program between 1996 and 1999 (Figure WQ-1). At station 0317, six parameters (temperature, DO, pH, turbidity, TSS and ammonia) were analyzed in 37 samples during nonstorm conditions between 1996 and 1999. These same parameters were measured during storm conditions on 13 occasions. Additionally, total and dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) were analyzed at station 0317 during storm conditions on roughly 12 and 6 occasions, respectively. Total aluminum was analyzed on three occasions during storm conditions. Comparisons of data to standards or criteria are detailed below.

Temperature

The 303(d) temperature listing for Springbrook Creek is based on excursions measured at Ecology sampling stations 09E070 (RM 0.1) and 09E090 (RM 1.5) on Mill Creek between 1988 and 1996. No continuous temperature data were available for Springbrook Creek. Based on the water quality data from station 0317 from 1996 through 1999, only one exceedance of the Class A standard (18°C) was measured. However, 14 of 37 measurements exceeded the proposed salmonid spawning standard (14.5°C), two of which occurred during the salmonid spawning season. In addition, two of the 37 measurements exceeded the proposed salmonid rearing standard (17.5°C). No temperature measurements exceeded the salmonid migration threshold (21°C). Together, these data suggest that temperature is a possible factor of decline for salmonids in Springbrook Creek.

Dissolved Oxygen

The 303(d) DO listing for Springbrook Creek is based on multiple excursions measured at the same Ecology sampling stations that exceeded temperature standards. Based on the water quality data from station 0317 from 1996 though 1999, only nine of 38 measurements met the Class A and proposed salmonid rearing standard (8.0 mg/L), and only two of those met the proposed salmonid incubation standard (10.5 mg/L). Therefore, DO is of concern for salmonids.

Turbidity/TSS

Based on the available water quality data from 1996 through 1999, average turbidity was 15 NTUs for both non-storm and storm data, with maximum values of 30 and 22 NTUs, respectively. Only eight of 37 non-storm measurements and two of 12 storm measurements were greater than 20 NTUs; however, no samples were less than 6.4 NTUs.

Average TSS was 9.1 and 29.7 mg/L for non-storm and storm measurements, respectively. The maximum non-storm TSS measurement was 36.8 mg/L; the other 36 non-storm measurements were between 3.2 and 20.6 mg/L. The maximum storm TSS measurement was 75.3 mg/L, suggesting that TSS concentrations occasionally exceed levels that could cause sub-lethal effects if the concentrations were maintained for a long enough duration. However, the duration of the elevated TSS concentrations is unknown, and therefore, potential effects cannot be determined. More data, including concentration and duration, are needed.

pH

Based on the water quality data from 1996 through 1999, 35 of 37 non-storm measurements were between 6.5 and 7.4; two measurements were below at 6.3 and 6.4. Three of 13 storm measurements were below 6.5, with a minimum of 6.1. All other storm measurements were between 6.8 and 7.3. Therefore, overall pH is unlikely to be of concern for salmonids, although it may influence the toxicity of other chemicals (e.g., metals).

Ammonia

Based on the available water quality data from 1996 though 1999, ammonia is not expected to be of concern for salmonids as none of the data exceed either the acute or chronic water quality standard for ammonia.

Metals

The 303(d) listings for cadmium, copper, chromium, mercury and zinc are based on excursions beyond state standards measured between 1984 and 1990 at Ecology sampling stations 09E070 (Mill RM 0.1) and 09E090 (Mill RM 1.5), King County sampling station 0317 (Springbrook RM 1.0), and at stations described in Yake (1985). Metals evaluated in this report (aluminum, arsenic, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver and zinc) using the 1996 though 1999 data suggest that metals are not of concern for salmonids, with the possible exception of aluminum. Although there are no state water quality standards for aluminum, all three aluminum samples at station 0317 exceeded the EPA chronic water quality criterion (87 µg/L). Two of the three samples exceeded the EPA *acute* criterion (750 µg/L). Although the limited data exceed the EPA criterion, it is not likely in a toxic form because the analytical method for determining total recoverable aluminum probably dissolves some aluminum that is not toxic and cannot be converted to a toxic form under natural conditions (U.S. EPA 1988). In addition, these data were collected under storm conditions where elevated suspended solids and organic matter concentrations tends to bind more of the dissolved metal, thereby reducing its bioavailability. However, because data are limited, further evaluations of aluminum should be conducted to confirm whether it is of concern for salmonids.

The same pattern for the basin as a whole is applicable to the Springbrook Creek data with regards to the detection limits for mercury and selenium (see section 4.).

BIOLOGICAL MONITORING IN MILL CREEK (KENT)

Aquatic insect sampling occurred at one station on Mill Creek (Kent) in the Black River Basin at Earthworks Park in Kent during 1999 (SalmonWeb 2000). The B-IBI score was 10, which is characterized as very poor on the B-IBI index. This was the lowest score recorded in the Green/Duwamish watershed from the biological monitoring effort.

DATA GAPS

There are probably sufficient data to characterize temperature, DO, pH and ammonia in Springbook Creek. The lack of continuous temperature data is a data gap because data do not necessarily reflect daily maximum temperatures and the duration of temperature exceedances. Similarly, available TSS data do not include duration, without which potential effects cannot be accurately evaluated. Furthermore, although there appears to be adequate metals data collected during storm events at station 0317, no baseline (non-storm) data were available. Therefore, additional data are needed, especially for aluminum. There are no recent metals data available for other stations in the Black River Basin.

Other classes of parameters for which no data were available represent significant data gaps. No data were available for pesticides and herbicides, PAHs, or phthalate esters.

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