Appendix D.

Emergency Overflow Surface Water Impacts Analysis

**DRAFT
SUPPLEMENTAL
ENVIRONMENTAL
IMPACT STATEMENT**

**Brightwater
Regional Wastewater
Treatment System**

Technical Appendices

King County **Brightwater**
TREATMENT SYSTEM

Appendix D

Emergency Overflow Surface Water Impacts Analysis

April 2005

Prepared by King County

Alternative formats available upon request
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Executive Summary

This report documents the assessment of impacts to surface water quality under worst-case assumptions in which a seismic event affects the ability to treat wastewater at the proposed Brightwater Treatment Plant. The general approach was to analyze the impacts from overflows expected to occur should the Brightwater plant be unable to treat wastewater during a 1 in 20-year storm event assuming overflows would have similar chemical composition to the influent at the South Treatment Plant.

Under peak flow rates from a 20-year storm (worst-case), conveyance to both West Point and South wastewater treatment plants would be at full capacity, resulting in overflows to North Creek, Swamp Creek, the Sammamish River, and Lake Washington. Overflows would only occur at flow rates greater than maximum monthly. Of all the seismic scenarios, the greatest ecological impacts in freshwaters would occur under Scenario B because the total period of risk for overflows would be the longest. The likelihood of Scenario B occurring is extremely low. The major ecological impacts to freshwaters from untreated wastewater overflows under these worst-case assumptions are potential mortality of aquatic species from reduced water quality in receiving water and sediment.

Discharges of untreated or partially treated wastewater to Puget Sound were predicted to occur under Scenarios B and C. Adverse impacts to marine species are expected to be minimal and limited to potential mortality of benthic invertebrates in the immediate vicinity of the diffuser.

Introduction

This document was written to support the Supplemental Environmental Impact Statement (SEIS) written by King County for the Brightwater Regional Wastewater Treatment System. This appendix contains a discussion of all the potential ecological impacts associated with wastewater overflows that may occur after a major seismic event and describes the data assessment and modeling that was conducted as a basis for this discussion. The discussion includes a comprehensive description of the potential ecological impacts that may or may not occur from wastewater overflows to all surface waters except Little Bear Creek (covered by Appendix E). In addition, in any given overflow condition, none, some or all of the following impacts may occur. It is important to note that the evaluations conducted represent extreme worst case conditions, with a very low probability of occurrence. Impacts to freshwaters are discussed first followed by impacts to Puget Sound.

Ecological Impacts: Freshwater

The ecological impacts in freshwaters will be dependent upon the volume, frequency and duration of overflows, and will be greater under high flow, high frequency, and long duration conditions. This section discusses impacts to freshwater ecology from untreated wastewater overflows within the context of the worst-case conditions: under Scenario B during the wet season, where flow rates fluctuate with rainfall and may periodically reach peak flow. The conveyance system is projected to have sufficient capacity to re-route wastewater to the South and West Point Treatment plants under dry conditions. Overflows to North Creek are only expected to last a several hours until the diversion of wastewater to the West Point and South Treatment plants begins. However, overflows to Swamp Creek, Sammamish River, and eastern Lake Washington may continue intermittently for approximately 6 months.

Water Quality

This section describes the data analysis conducted to estimate water quality impacts from overflows associated with the peak flow condition of 170 MGD. For data analysis purposes, wastewater characteristics are assumed to be similar to influent at the South Treatment Plant (STP), which currently serves a separated sewer system and much of the Brightwater service area. Estimates of where water quality standards would not be met are obtained by using dilution modeling of the overflow discharges.

Wastewater Influent Sampling and Analysis

King County collects samples of influent to the wastewater treatment plants to characterize the untreated wastewater and as part of the monitoring routinely done for permit compliance. Untreated influent samples are analyzed daily for conventional water quality constituents (e.g., pH, total suspended solids) at the STP. In addition, intensive influent sampling events for conventionals, bacteria, and priority pollutant chemicals are conducted generally twice per year, about every six months, once each during the wet and dry seasons. Since 1997, the influent intensive sampling events generally have involved collection of daily composite samples on three consecutive days, with some additional samples collected occasionally. Prior to 1997, the intensive sampling events encompassed five to seven days. In addition, daily metals analyses were conducted prior to 1997.

Data used in this document to characterize influent wastewater came from two data sources:

- The process laboratory (i.e., at the STP) stores the daily conventional, nutrient and coliform data for the influent, and secondary treated effluent in a custom database.

- The King County Environmental Laboratory's (KCEL) Laboratory Information Management System (LIMS), an Oracle©-based database, stores results of analyses of each water type conducted by the King County Environmental Laboratory.

Priority was given to the process laboratory data for parameters with data available from both sources. Process laboratory and KCEL data were reviewed to ensure that only data representative of influent, primary effluent, and secondary effluent of appropriate data quality were used. Tentatively identified compounds, quality control data (e.g., surrogates and blanks), and “R” qualified data (“rejected”) were excluded from the analysis. If a parameter was analyzed for but not detected, then the full Method Detection Limit (MDL) was assumed to be the value for that record. If the record indicated the result was not detected, and no MDL was available, then the record was excluded. Furthermore, the following parameters stored in LIMS were not evaluated, as the data are not water quality parameters:

Client Locator
Delta Time (Accum.)
Field Personnel
Sample Code
Sample Description
Sample Function
Sample Start Time
Sample Unit
Sampling Method
Storm Or Non-Storm
Time Span
Time Unit

Influent wastewater concentrations are provided in Attachment D1 at the back of this document.

Dilution Models

A submerged outfall discharge, such as those in Lake Washington and in the Sammamish River at the Hollywood and Woodinville Pump Stations, is characterized by two distinct zones of mixing: nearfield and farfield. Nearfield mixing is characterized by rapid dissipation of a plume’s momentum. This momentum, directly related to the initial velocity, defines the plume trajectory and dilution factor. Farfield mixing is characterized by the receiving water properties. There are EPA-approved hydrodynamic computer models in which a mathematical approximation can be made in determining a dilution factor (e.g., PLUME and RIVPLUME). The models are utilized to “estimate” the dilution factor and output can be within 25 percent of the actual dilution factor determined in the field. The reason for the range of accuracy is that the model cannot account for every variable in a natural environment. Such variables include the receiving water’s vertical and horizontal profiles.

The two EPA-approved hydrodynamic models used to assess dilution factors are PLUMES for the discharge into Lake Washington and RIVPLUME for the discharge into the Sammamish River. Model input parameters included the following:

- Discharge flow and temperature

- Lake current speeds and temperatures

- River geometry and velocity

- Discharge port geometry and depth.

Sammamish River Dilution and Water Quality

The peak flow condition of 170 MGD is associated with the 20-year storm, which would create high flows in both the Sammamish River and Swamp Creek. Final EIS Appendix 3-E “Flow Management and Safety Relief Point” provided a characterization of the Sammamish River under high flow conditions. For this analysis it was assumed that a Sammamish River flow rate of 2800 cfs, representing a 1 in 20 year return interval, would be appropriate to correspond to the 1in 20 year storm flows. The predicted overflows into the Sammamish River include 23 MGD through a 30 inch overflow pipe at the Hollywood Pump Station, 17 MGD through a 24 inch overflow pipe at the Woodinville Pump Station, and 42 MGD from manhole W11-51A in Kenmore and possibly other manholes along the Kenmore-Bothell Interceptor. In addition, the 12 MGD that overflows into Swamp Creek will reach the Sammamish River upstream of Kenmore.

The RIVPLUME model (Ecology, http://www.ecy.wa.gov/programs/eap/pwspread/pwspread.html) was used to estimate the downstream distance required to achieve complete mixing of each discharge with the river. These results are tabulated in Attachment D2 along with the overall dilution of wastewater in the Sammamish River. The dilution at complete mixing refers to the dilution achieved at complete mixing of each overflow, while the overall dilution includes the effect of wastewater that has overflowed into the river upstream at other overflow locations. The concentration of wastewater constituents will decrease downstream of the discharge until complete mixing with the river is achieved. Complete mixing may be achieved closer to the discharge location as this model neglects any initial mixing due to the energy of the discharge as it enters the river.

The discharges that may occur at manhole W11-51A in Kenmore, along the Kenmore-Bothell Interceptor, and along the Swamp Creek Trunk are lumped together as one point of discharge. Separating these discharges out would tend to increase the predicted dilution, as would including the additional dilution of Swamp Creek on overflows along the Swamp Creek Trunk.

Table 1. Distance to complete mixing and dilution factors for different locations

Discharge Location (distance upstream)	Distance to complete mixing	Dilution at complete mixing	Overall Dilution
Hollywood P.S. (11.5 km)	1.6 miles	74:1	74:1
Woodinville P.S. (8.5 km)	1.1 miles	99:1	42:1
Swamp Creek and Kenmore @ manhole W11-51A (0.1 km)	Not complete before Lake Washington	26:1*	16:1*

* at complete mixing, not obtained before flow enters Lake Washington

The water quality standards for conventionals applicable to the Sammamish River are given in Table 2. Temperature of influent wastewater is likely to be similar to the river temperature based on the large volume of runoff entering both the river and the collection system. However, it is possible that there could be a measurable change from natural conditions. Influent temperatures recorded at STP have varied between 52F and 70F, which is within the recorded temperature range of the Sammamish River.

The pH of influent to the STP averages 7.1, with variations recorded between 5.9 and 7.8. pH measured at the mouth of the Sammamish River between 1998 and 2002 varied between 6.9 and 7.6. Therefore, short-term variations of pH in wastewater overflows into Sammamish River may lower pH below ambient levels before complete mixing is achieved, but dilution upon mixing should be sufficient to keep the pH from dropping significantly and causing adverse effects to aquatic life.

Previous work has estimated the turbidity of STP influent at 100 NTU (Final EIS Appendix 3-E), requiring a 20:1 dilution to meet the water quality standard of not exceeding 5 NTU over background conditions. This degree of dilution will occur downstream of the Hollywood and Woodinville pump station discharges, but the additional overflows at Swamp Creek and Kenmore will require additional dilution in Lake Washington before this standard is met.

The dissolved oxygen content of the wastewater will be near 4 mg/L (Final EIS Appendix 3-E). This combined with high levels of biochemical oxygen demand (BOD) will depress oxygen levels in the river downstream of each overflow location. Dissolved oxygen in the Sammamish River varies between about 7 mg/L in the summer and 12 mg/L in winter months suggesting that oxygen levels are likely to be high at the time of year an overflow would be expected to occur. The reduction in dissolved oxygen content of the river was modeled using the Streeter-Phelps equation and the spreadsheet model DOSAG2 (Ecology, http://www.ecy.wa.gov/programs/eap/pwspread/pwspread.html). The modeled scenario was simplified with all overflows discharging from the same location. The initial reduction in DO from the combined discharges was predicted to be 0.3 mg/L, followed by a further reduction due to BOD. The rate of oxygen demand by BOD is sufficiently slow (3.8 days to lowest DO) that the overflows will reach Lake Washington (< 5 hours) and be subject to additional dilution from mixing within Lake Washington. The reduction in DO after 5 hours was predicted to be 1.4 mg/L. This model assumes complete mixing of the discharge with the river, thus lower values of DO are to be expected close to the discharge locations. The minimum value of DO near the discharge will not be below the dissolved oxygen concentration of the overflow (4 mg/L). Dissolved oxygen concentrations below 5 mg/L could pose a possible risk of mortality and adverse effects to early life stage fishes including salmonids, but little risk of acute mortality to most adult fishes (USEPA, 1986, and King County, 2003a).

The acute and chronic fecal coliform standards are based on risk to human health. Fecal coliforms do not pose an ecological health risk. See the Section 5.5 of the SEIS for discussion of human health impacts.

Table 2. Water Quality Standards

Parameter	**Acute Water Quality Standard[1] (mg/L)**	**Chronic Water Quality Standard[1] (mg/L)**
Fecal coliform	[2]	[2]
Dissolved oxygen [3]	9.5 mg/L	9.5 mg/L
Temperature [4]	60.8°F (16°C)	60.8°F (16°C)
pH [4]	6.5 - 8.5	[4]
Turbidity [5]	[5]	[5]

Notes:

[1] from draft 173-201A WAC.

[2] Does not exceed a geometric mean value of 50 colonies/100 mL and does not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100 mL.

[3] The 1-day minimum should not fall more than 0.2 mg/L less than the criteria of 9.5 mg/L in freshwater that supports salmon and trout spawning, core rearing, and migration unless due to natural conditions.

[4] The 7-day average of the daily maximum temperature should not exceed 60.8°F (16°C) in freshwater that supports salmon and trout spawning, core rearing, and migration.

[5] Shall not exceed a 5 NTU increase in turbidity when the background turbidity is less than 50 NTU.

Lake Washington Dilution and Water Quality

Overflows would enter Lake Washington from the Sammamish River and from emergency outfalls associated with pump stations along the eastern shore that could be shut down. In accordance with King County's emergency overflow management procedures (King County, 2001), wastewater would be diverted at York Pump Station to the East Side Interceptor (ESI) to minimize uncontrolled overflows and overflows to freshwater streams. This may exceed the capacity of the ESI. To prevent uncontrolled overflows along the ESI, King County would shut down pump stations with overflows into Lake Washington to maintain capacity in the ESI. The pump stations that could be shut down include Juanita, Kirkland, Yarrow Bay, Medina, North Mercer, and South Mercer. Each of these pump stations would then overflow and discharge into Lake Washington through a submerged outfall.

The dilution at each outfall will depend on the difference in temperature between Lake Washington and the wastewater, and on the specific configuration of the discharge location (orientation, flap gate, discharge depth). An estimated dilution expected for each outfall was calculated by neglecting boundary interactions and any density differences between the wastewater and Lake Washington. Table 3 presents the outfall characteristics and the dilution at the location where the discharge velocity has decayed to a typical ambient lake velocity of 4 cm/s.

Table 3. Outfall Characteristics and Dilution by Location

Station	Flow (MGD)	Outfall Diameter (inches)	Near-field dilution	Distance of Near-field Mixing (feet)
Juanita	26.1	30	118:1	1047
Kirkland	9.3	48	16:1	233
Yarrow Bay	3.5	18	44:1	234
Medina	9.5	12	269:1	953
N Mercer	9.3	42	21:1	267
S Mercer	6.2	24	44:1	311

After the initial momentum-driven mixing, the discharges will continue to be diluted by the ambient circulation of Lake Washington. The rate that this additional dilution occurs at can be quantified from a series of dye studies conducted for the City of Seattle and Metro in the 1970's (CH2M HIll, 1975). These studies injected dye at several locations in the lake and measured the rate of spreading to obtain diffusivity coefficients. Lateral dispersion coefficients measured in these studies varied between 2100 and 13,000 ft^2/hr, averaging 6,200 ft^2/hr.

Neglecting any vertical mixing within the lake, lateral dispersion will provide additional dilution (Table 4). Additional dilution from dispersion is a relatively slow process, with a dilution factor of 4 being reached approximately 1.5 miles from the discharge location.

Table 4. FarField Mixing in Lake Washington due to Lateral Dispersion

Time (hrs)	Distance (ft)	Dilution Factor
3	1,400	1.9
6	2,800	2.6
12	5,600	3.6
24	11,200	5.0
48	22,500	7.1

Steady current speed of 4 cm/s, an initial width of 275 ft, and constant dispersion coefficient of 6200 ft^2/hr assumed.

An additional dilution factor of 4 would be sufficient to reduce the DO demand from the discharges to less than 2 mg/L. The resulting decreased concentrations of dissolved oxygen will violate state water quality standards but are expected to remain above 5 mg/L.

Dissolved nutrient input from wastewaters would only impact Lake Washington because residence time of wastewater in the tributaries would be too short to cause impacts. The additional nutrients delivered to Lake Washington may cause eutrophic effects, such as increased algal growth and decreased light penetration and dissolved oxygen, until they are flushed out of the Lake.

Ecological Water Quality Screen for Chemicals

An ecological risk screening was conducted based on exposure to estimated influent chemical concentrations to estimate the risk of adverse effects to aquatic life under the worst-case overflow assumptions. These assumptions use high end estimates of chemical concentrations and include no dilution of wastewater. Chemical concentrations measured in influent at the STP were assumed to be representative of Brightwater influent. The assessment was conducted for all parameters for which influent data exists and for which thresholds that protect aquatic life are available.

Water quality thresholds used in the assessment included the Washington State Department of Ecology water quality standards (WAC 173-201A) and the U.S. Environmental Protection Agency (USEPA) ambient water quality criteria (USEPA, 2002). If standards were not available from those sources, chronic toxicological threshold values for freshwater systems were derived from the USEPA ECOTOX AQUIRE database (a database of aquatic toxicological studies).

The water quality thresholds were compared to the concentrations of detected parameters as measured in the STP influent over a five to six year time period.

Acute exposure was assessed using the 90th percentile concentration as an upper estimate of exposure for a short term overflow (up to a day). Chronic exposure was assessed using the 95% upper confidence limit (UCL) on the mean as an estimate of the average exposure to aquatic life over a long term overflow (days to months). The USEPA recommends use of the 95% UCL on the mean because of the uncertainty associated with estimating the true average at a site (USEPA, 1992).

Some water quality thresholds are dependent on pH, temperature, and hardness. In the acute assessment, either the 90th percentile or the 10th percentile values of pH, temperature, and hardness were used, as determined by the value that produced the most conservative threshold. In the chronic assessment, similarly either the 95% UCL or the 95% lower confidence limit (LCL) values of pH, temperature, and hardness were used as determined by the value that produced the most conservative threshold.

In general, the results of the acute water quality screen represent the worst case scenario of risk to aquatic life from exposure to chemicals associated with overflows (with no dilution) of less than a day. Parameters that exceeded the acute water quality thresholds are summarized in Table 5. Nine parameters exceeded the acute water quality thresholds. This indicates that there would be a risk of adverse effects aquatic life from exposure to contaminants in wastewater within the scenario of short-term overflows and no dilution. The ratio of estimated chemical concentration to corresponding threshold, indicating degree of deviation from the water quality threshold, ranged from 1.3 to 47.1. The highest exceedance in the acute screen occurs for phenol. If dilution of overflows in freshwaters reaches a factor of 47 or greater, then none of the aquatic life thresholds would be exceeded and risk of adverse impacts to aquatic life would be unlikely.

Considering the overall dilution of overflows at Hollywood and Woodinville pump stations was estimated to be 42:1 or greater (Table 1), adverse impacts from short-term (acute) exposure to water in Sammamish River would not be expected above Swamp Creek in Kenmore with the possible exception of effects from phenol (which requires 47:1 dilution). Complete mixing of overflows would not be achieved at Swamp Creek and the Kenmore manhole (W11-51A) before water met Lake Washington; therefore, effects to aquatic life from acute exposure to contaminants are possible within this reach of the Sammamish River as well as in the mixing zone of northern Lake Washington. These assumptions would apply to Scenarios A and B but not necessarily for Scenario C due to the input of digester solids from Little Bear Creek. (See Appendix E of the Brightwater SEIS for impacts of digester solids.)

In Lake Washington, the nearfield dilution achieved at Juanita and Medina outfalls would be high enough (Table 3) to dilute contaminants below acute thresholds resulting in no risk of adverse impacts from short-term exposure in the nearfield mixing zone. Nearfield dilution at Yarrow Bay and South Mercer outfalls (44:1) would be high enough to avoid adverse effects from acute exposure to most contaminants except possibly effects from phenol. However, adverse impacts from acute exposure to multiple contaminants would be likely at the Kirkland and North Mercer outfalls within the nearfield mixing zone because dilution does not exceed 21:1. Beyond the nearfield mixing zone, further dilution would occur with distance from each outfall. Based on the modeled dilution from farfield mixing (Table 4), overflows from Kirkland and North Mercer outfalls may not be diluted below all acute thresholds until greater than 4 miles from the nearfield mixing zone. Thus, adverse effects to aquatic life from acute exposure would be probable from some outfalls along Lake Washington within a zone that ends as far as miles from the overflow point. At other outfalls, adverse impacts from acute exposure would be anticipated in the nearfield mixing zone but not beyond.

Table 5. Ratios Exceeding Acute Thresholds for Detected Parameters

Parameter	90th Percentile Concentration	Threshold	Unit	Ratios
Conventionals				
Ammonia, Total	24	15.4[3]	mg/L	1.6
Temperature	67	60.8[3,4]	° F	>[4]
Metals				
Aluminum	4.92	0.75[2]	mg/L	6.6
Copper	0.137	0.01[3]	mg/L	11
Iron	4.69	0.16[1]	mg/L	29
Silver	0.011	0.002[3]	mg/L	5.2
Zinc	0.177	0.09[3]	mg/L	2.0
Phenols				
Phenol	41.2	0.875[1]	µg/L	47
Volatile Organics				
Acetone	149	116.2[1]	µg/L	1.3

[1] Data obtained from USEPA ECOTOX/AQUIRE database. Criteria are taken from the following authors in order: Warnick and Bell, 1969; Verma et al., 1981; and Schultz et al., 1995

[2] USEPA, 2002

[3] WAC 173-201A-040

[4] Temperature is not measured as a concentration and is, therefore, denoted by a symbol of ">" to indicate that the maximum temperature exceeded the criteria.

In general, the results of the chronic water quality screen represent the worst case scenario of risk to aquatic life from exposure to chemicals associated with overflows (with no dilution) of more than a few days. Parameters that exceeded the chronic water quality thresholds are summarized in Table 6. Twelve parameters exceeded the chronic water quality thresholds. The ratio of chemical concentration to threshold ranged from 1.6 to 167. The highest exceedance in the chronic screen occurs for phenol. However, if dilution of overflows in freshwaters reaches a factor of 167 or greater, none of the aquatic life thresholds would be exceeded and risk of adverse impacts to aquatic life would be unlikely.

Adverse impacts from chronic, as opposed to acute, exposure would only be a possible risk from continuous wastewater overflows lasting days or more. However, the chronic thresholds for aquatic life are much lower than acute thresholds requiring dilution of 167 or more to avoid risk of adverse impacts. Dilution at this level is not predicted to be achieved within the Sammamish River or within the nearfield mixing zones for most of the Lake Washington outfalls. The outfall at Medina is the only location on Lake Washington that may meet the minimum dilution required to bring contaminants below chronic thresholds within the nearfield. Therefore, adverse impacts to aquatic life are likely in Sammamish River and Lake Washington from chronic exposure to contaminants from wastewater overflows. The addition of digester solids from Little Bear Creek under Scenario C would make adverse effects very likely in Sammamish River.

Table 6. Ratios Exceeding Chronic Thresholds for Detected Chemicals

Parameter	95% UCL Concentration	Threshold	Unit	Ratios
Conventionals				
Ammonia, Total	20	2.4[3]	mg/L	8.3
Metals				
Aluminum	3.1	0.087[2]	mg/L	36
Copper	0.1	0.0099[3]	mg/L	10
Iron	3.79	0.032[1]	mg/L	118
Lead	0.0086	0.0021[3]	mg/L	4.1
Silver	0.0065	2.1E-04[3,4]	mg/L	31
Tin	0.1	0.045[1]	mg/L	2.2
Zinc	0.14	0.070[3]	mg/L	2.0
Pesticides				
4,4'-DDT	0.029	0.018[1]	µg/L	1.6
Heptachlor	0.031	0.0038[3]	µg/L	8.2
Phenols				
Phenol	29.2	0.175[1]	µg/L	167

[1] Data obtained from USEPA ECOTOX/AQUIRE database. Thresholds are taken from the following authors in order: Warnick and Bell, 1969, Estimated; Sanders, 1972; and Spehar 1989

[2] USEPA 2002

[3] WAC 173-201A-040

[4] Estimated from acute value using an ACR of 10

Sediment Quality

The quality (chemical, physical and biological) of sediments in freshwaters (i.e. sections of Little Bear Creek, North Creek, Sammamish River and Lake Washington) could be altered by wastewater overflows that occur directly into or upstream of the waterbody. The magnitude of the impacts would vary depending upon the total volume and duration of overflow.

Compared to natural streamwaters, untreated sewage contains large portions of dissolved and solid organic material. If wastewater overflows directly into tributaries and the Sammamish River, the heavier solids would settle to the bottom and cover the sediment surface. A high volume of flow through the tributaries would likely flush some solids downstream to Lake Washington; however, a large portion would likely settle in wetlands, backwaters, and pools and accumulate over time. Lighter solids that do not settle out in the tributaries and Sammamish River would settle once entering Lake Washington.

Bacterial growth on the deposited solids will likely increase due to the increase in associated organic matter which serves as a food source. If overflows were sustained for a period of days or longer, bacteria could grow to form “bacterial mats” along the stream and lake bottom (some may float as well). These mats are high density colonies of bacteria that form solid layers visible to the naked eye. Formation of these mats is unlikely but would be greatest in quiescent areas of the

Sammamish River and its mouth at northern Lake Washington. Because dilution would be greater in Lake Washington than the River, mats are not likely to form within Lake Washington except possibly in the mixing zones near eastern Lake Washington wastewater overflow points. Aquatic fungi are also large consumers of organic matter (Maltby, 1996) and their densities may increase to where fungal "slimes" become apparent. Aside from the aesthetic detraction that dense bacterial and fungal communities pose, growth of these organisms creates unhealthy conditions for sediment-dwelling animals. Bacteria and fungi consume large quantities of oxygen as they degrade organic material. Under conditions of extended release of wastewater into freshwaters, oxygen concentrations in the surface sediments (where most benthic organisms dwell) as well as the water column would decrease to concentrations that cannot sustain life. The degradation process would also change the sediment biogeochemistry by creating a reducing (oxygen-consuming) environment where acidity increases (pH decreases). These acidic conditions reduce metals from bound to ionic form (freely available) transforming many metals into a more bioavailable (easily absorbed) and more toxic form to aquatic life. This acidic, oxygen-poor sediment environment would create inhospitable habitat for sediment-dwelling organisms resulting in mortality of many benthic invertebrate species (some chironomids and oligochaetes may survive due to their high tolerance of severe conditions). However, these severe impacts are only expected under long-term overflow conditions (weeks to months).

The particulate material that settles out of the water column would change the physical structure of the sediments making them inhospitable for some benthic invertebrates and potentially inadequate for breeding fish. Benthic invertebrates can be sensitive to changes in sediment particle size. For example, Leptophlebiidae, a family of mayflies present in the Sammamish River, prefer debris, rock or gravel habitat (Thorp and Covich, 1991) not finer grain sediments that may be deposited after an overflow event. Therefore, deposition of solids associated with wastewater overflows may alter the physical structure of the sediments enough to exclude normally present invertebrate species. Inorganic solids deposited in sediments will remain in place indefinitely even after overflows cease. Only a substantial storm event would resuspend sediments for transport downstream.

Any contaminants that enter the receiving freshwaters will either be in dissolved form or bound to particles. Because deposited solids will not be removed naturally except by rare strong storm events, there is a potential for long-term exposure of organisms to particle-bound contaminants brought in by wastewater overflows. This could result in accumulation of persistent contaminants such as lead in tissues of organisms. Organisms that could be exposed to particle-bound contaminants even after overflows cease are sediment dwelling invertebrates, fish and aquatic-feeding wildlife.

Plants

The impacts of untreated wastewater overflows into freshwaters would vary by waterbody and time of year. Aquatic plant growth is primarily limited by nutrients, temperature and sunlight in freshwaters. During the wet season, temperature and sunlight are the primary limiting factors while in the dry season, growth is more dependent on nutrients. The addition of nutrients from overflows during the wet season will likely have little impact to plants in tributaries because of rapid transport downstream. However, nutrients that enter Lake Washington will remain in the Lake much longer and effects will not likely be observed until the following growing season (i.e., dry season). Lake Washington water has a residence time of 2.3 years (Edmondson and Lehman, 1981). The loading of nutrients to Lake Washington during the wet season would result in unusually high aquatic plant growth during the dry season which would then lead to high BOD as plants begin to die in the fall and degradation and oxygen depletion ensue. Algal growth would be rapid but rooted and floating aquatic plants, such as lily pads, would also benefit from the additional nutrient loading. The additional nutrient load could also result in heavier than usual densities of exotic nuisance species such as water milfoil and cattails that may permanently replace native plant species.

Although the growth season for aquatic plants is typically in the dry season, many aquatic plants do not die-off each fall but can sustain themselves through the typical mild Seattle winter. Under discharge conditions of more than a couple days, periphyton in impacted streams and submerged vegetation (plants that grow under water) in receiving areas of the Sammamish River and downstream in Lake Washington would experience stress and possible mortality from physical suffocation (from sinking waste solids) and decreased sunlight (high turbidity). These impacts would be less likely to occur in Lake Washington because of the beneficial effects of dilution.

Invertebrates

The discharge of untreated wastewater into freshwaters could affect invertebrates that live within and on the surface of sediments, such as mayfly larvae and amphipods, as well as those that live in the water column, such as zooplankton. The changes in sediment and water chemistry that may occur from overflows (e.g., high ammonia concentrations, reduced dissolved oxygen concentrations, low pH, and elevated solids concentrations) would cause stress to aquatic invertebrates and may result in die-off of sensitive species, decreased diversity and shifts in species dominance. Tolerant benthic dwellers (e.g., oligochaete worms) may migrate deeper into the sediments and remain there until conditions improve. However, some insects may not tolerate these adverse conditions and may die off. Filter-feeding organisms such as daphnids and rare mussels will be at risk during any season not only of mortality from chemical contamination but also of asphyxiation associated with clogging of their filtering apparatuses with high concentrations of suspended solids. Freshwater mussels that are killed in the creeks may not be replaced because there may not be any mussel communities upstream to enable recolonization.

Fish

Various species of fish inhabit Little Bear, North and Swamp Creeks, Sammamish River and Lake Washington. Fish would be impacted both physically and chemically from overflows into freshwaters. The greatest immediate risk to fish will exist from elevated ammonia concentrations in overflow waters. Ammonia is acutely toxic (USEPA, 1999) and will cause instant mortality at high concentrations to fishes residing within the freshwaters receiving overflows. In areas where dilution is sufficient to reduce ammonia concentrations, such as in Lake Washington, other stress factors such as suspended solids and low dissolved oxygen may cause respiratory problems for fish.

The elevated suspended solids concentrations in the surface waters could pose a risk of asphyxiation from lodging of particles into fish gills, the respiratory organs for fish, clogging them, and suffocating the fish. This is an immediate hazard for fish in the tributaries and Sammamish River. However, within days non-migratory (resident) fish would react to the changes in water quality by moving to other sections of the watershed in search of more tolerable conditions. See the next section for a discussion of impacts to migratory salmon. The physical stress from suspended solids would have less impact in Lake Washington where substantial dilution and settling would occur; however, the area near the mouth of the Sammamish River may still be poor quality habitat for fish. Fishes within Lake Washington, where dilution is high and the waterbody is much larger than streams, will likely be able to avoid zones of poor water quality where wastewater enters the system, thereby escaping the short-term adverse effects fishes may experience upstream. However, if overflows occur intermittently over 6 months (i.e., repeated disturbances), a trophic shift may occur where fish become concentrated in unimpacted areas of the Lake and competition drives changes in predator-prey interactions.

After overflows cease and ammonia concentrations lower to ambient levels, the effects of the increased biochemical oxygen demand and subsequent reduced dissolved oxygen concentrations in the water column could continue to stress fish and potentially result in fish kills, particularly in areas of streams and northern Lake Washington where organic matter accumulates. Benthic fish species (living near the bottom) may be particularly at risk of asphyxiation from decreased dissolved oxygen levels which will be lowest in the deepest waters.

Salmon and Trout

There are five species of salmon and trout that inhabit the North Lake Washington Basin including North Creek, Swamp Creek, Little Bear Creek and Sammamish River. These species are the chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), coastal cutthroat trout (*Oncorhynchus clarki clarki*), steelhead trout (*Oncorhyncus mykiss*), sockeye salmon (*Oncorhynchus nerka)*, and kokanee, a landlocked subpopulation of sockeye. The chinook is listed as threatened and the coho as a species of concern under the Endangered Species Act (ESA). These salmon use the Sammamish River and Lake Washington as a migration pathway to their spawning grounds in the creeks. Thus, these water bodies provide critical habitat for these protected species.

The North Lake Washington chinook population (NLW) spawns in the North and Swamp Creeks between September and November. Emergence from spawning nests is dependent on water temperatures but begins in January of the year following egg deposition and is typically completed by March. Juveniles migrate into the Sammamish River or Lake Washington either as fry or fingerlings between February and June. Juveniles rear as they migrate towards Lake Washington. While a small portion of the NLW juveniles use nearshore areas in Lake Washington, most fish are believed to move into offshore areas quickly. NLW Chinook smolts pass through the Ship Canal and Locks to reach Puget Sound during May, June and July (Kerwin, 2001).

Lake Washington Basin coho stocks typically enter fresh water from August to early December. Spawning usually occurs between November and early December, but is sometimes as early as mid-October and typically occurs in tributary streams such as Swamp and North Creek. The Lake Washington Basin coho juveniles remain in freshwater for a full year after leaving the gravel nests. Lake Washington Basin coho begin to leave the basin over a year after emerging from their gravel nests, with peak outmigration occurring in early May.

Some individuals of coastal cutthroat trout are anadromous (spawn in freshwater and migrate to sea as adults) but many are resident (Kerwin, 2001). Resident cutthroat trout spawn in tributaries and rivers in April and May and anadromous cutthroat trout spawn in December/January. Their presence has been documented in the Lake Washington basin including Lake Sammamish, the Sammamish River, and Swamp, North and Little Bear Creeks (King County, 2001). Juveniles may spend several years in freshwater before migrating to sea.

Steelhead trout use the Lake Washington basin including Swamp Creek, North Creek, Little Bear Creek, Sammamish River and Lakes Washington and Sammamish. In Washington, there are two major run types, winter and summer steelhead. The Lake Washington Basin does not have a summer steelhead stock and winter steelhead adults begin river entry in a mature reproductive state in December and generally spawn from February through May. Naturally produced juvenile winter steelhead can either migrate to sea (anadromy) or remain in freshwater as a resident rainbow trout. The vast majority of juvenile steelhead in the Lake Washington Basin smolt and migrate to saltwater. Lake Washington Basin steelhead usually spend 1 to 3 years in freshwater.

Lake Washington sockeye are found entering freshwater at the Chittenden Locks as early as mid-May continuing through early November in some years (Kervin, 2001). Sockeye spawning occurs in the Cedar River, tributaries to Lakes Washington and Sammamish and along specific beaches in Lake Washington. The timing of sockeye spawning ranges from September through January. After fry emerge from the gravel, Lake Washington sockeye migrate to a lake for rearing. Lake rearing of juvenile sockeye ranges form one to three years with most juveniles rearing two years. In the spring after lake rearing is completed, juveniles enter the Puget Sound and then the ocean where more growth occurs prior to adult return for spawning. The kokanee spawns in early September thru October in Big Bear, North, Little Bear, and Swamp Creeks. Unlike, the main sockeye stocks, the kokanee is resident and does not migrate to sea during its life cycle. Kokanee remain in the Lake Washington basin year round.

Salmon are susceptible to the same stress factors discussed previously for other fishes. High stormwater flows and sedimentation in tributaries can suffocate eggs (Kervin, 2001) and changes in water quality can cause mortality in all life stages. Because the Swamp, North and Little Bear Creeks provide spawning habitat for salmon during the fall and incubation habitat over the winter, overflow to these streams during the wet season could negatively impact reproduction in these species by causing mortality to eggs (a sensitive life stage) and reproductive adults. The use of these streams, Sammamish River and Lake Washington by emerging fry in the spring, also makes the latter wet season a period of risk for mortality in young salmon if overflows occur.

Wildlife

Streams and lakes provide drinking water and foraging habitat to various wildlife species. Birds such as ducks and heron regularly use Lake Washington, Sammamish River and its tributaries to forage. Small mammals, coyote and deer likely also use these waterbodies as a drinking water source. Overflows would degrade water quality in the manner described earlier and wildlife would potentially be deterred from using affected areas as a drinking water source if other cleaner water sources are available. Prey for fish eaters (piscivores) may be temporarily enriched in streams because of fish kills. However, once fish carcasses are removed or consumed/degraded, food sources in these waterways may be sparse and wildlife will be forced to search elsewhere. Individuals that migrate to other foraging habitats will likely also use these new areas as drinking water sources. If wildlife are exposed to the wastewaters, there may be some risk of adverse effects to their health from short term exposure. In addition, contaminants that are added to the streams and bound in sediments will pose a long-term health risk to aquatic-feeding wildlife. However, information needed to quantitatively evaluate this risk to wildlife is not available.

A great blue heron rookery area exists in Kenmore behind the County Sheriff's Station near State Route 522 and 73rd Ave NE. Great blue heron forage in aquatic habitat and prefer to prey on fish (USEPA, 1993). Adults breed and nest in colonies in the springtime and breeding adults return to the Kenmore rookery each year. Similarly, as documented in the FEIS (Appendix 7A), bald eagle nests have been identified along the Sammamish River in Kenmore. If overflows coincide with nesting season for the great blue heron colony or bald eagles and substantial fish kills ensue, the Kenmore heron colony or bald eagle pairs may experience difficulty finding prey locally to feed their chicks. Therefore, there is some risk of nestling mortality from starvation. Because the great blue herons nest in colonies but bald eagle pairs nest independently at lower densities, nestling mortality risk is much higher for great blue herons than bald eagles. However, overall the likelihood of any nestling mortality is small.

Wetlands

Wetlands are unique and sensitive ecosystems that are extremely productive and provide refuge to a diversity of plants, invertebrates, fish and wildlife. There are two large wetlands that may be directly impacted by overflows: one is located in the lower Swamp Creek along the Swamp Creek trunk and the other is located on lower North Creek along the North Creek trunk. Other smaller wetlands that may receive wastewater overflows are associated with Sammamish River and eastern Lake Washington.

If overflows drain into these wetlands, it is likely that more deposition of solids will occur in the wetlands than downstream in the creeks and Sammamish River. Wetlands are inherently characterized by substantial physical structure formed by plants, woody debris and other natural structures. This structure will act as a filter for solids and collect particles. The particles that are deposited may change the structure of the sediments enough to cause mortality of benthic invertebrates.

In addition to direct impacts from deposition of solids, indirect impacts from overflows will be similar to those described for the other impacted freshwaters. Degradation of deposited organic matter will potentially lead to hypoxic/anoxic and acidic conditions in both sediment and water and mortality of aquatic invertebrates and fish will likely result. Because wetlands are important breeding grounds for amphibians, poor reproductive success may be observed for one breeding season or longer.

Ecological Recovery

Recovery times for the three impacted environments will vary depending on overflow volume and duration. Water quality in North and Swamp Creeks (not including their wetlands) is expected to recover the fastest following cessation of overflows. This is due to the absence of substantial solids deposition in these environments and inputs of cleaner surface waters and ground waters. Fish and invertebrate communities will be able to begin recolonization within weeks or months but may require up to several years to return to their pre-overflow status, while aquatic plants may take a few growing seasons to rebalance and return to pre-overflow community composition. Invasive plants that outcompetes native species during the recovery period may result in permanent change. Mussels that die in creeks may not return due to the lack of individuals upstream for recolonization. Lake Washington's water quality is conservatively expected to take no longer than four years to return to its pre-existing condition. This is based on the recovery time seen during the creation of the regional conveyance system (Metro) where effluent disposal ceased in 1966 and water quality recovery was essentially complete by 1971 (Caldwell et al., 1976). Over 20 million gallons per day of partially-treated effluent were discharged to Lake Washington during the 1950s and 1960s (Metro, 1968).

Wetland habitats will require more time than the streams and perhaps Lake Washington to recover because of the greater mass of solids deposition that will occur in these habitats and their comparatively slower organic processing rates. The expected recovery time for wetlands is heavily dependent upon the duration of overflows, the mass of both inorganic and organic sediment deposited, and future weather conditions. Drought conditions following overflow termination would enhance organic matter decomposition rates (Schlesinger, 1991), while wetter than normal conditions would encourage scour and resuspension (removal) of solids into downstream waterbodies. The total mass of solids, including organic matter, deposited within wetlands from wastewater overflows is expected to be minor relative to the existing organic layer that naturally occurs in wetlands. However, wetlands are sensitive habitats that decompose organics slowly. Impacts related to solids deposition are expected to subside within several years. The North Creek wetland will only receive brief (hours) wastewater overflows and therefore, may not exhibit any long term impacts.

Ecological Impacts: Puget Sound

In Scenarios B and C, partially treated or untreated discharges could flow to Puget Sound for months until repairs to the treatment plant are completed. Ecological impacts in Puget Sound would be similar under all flow conditions because of the high rates of dilution. Under these conditions and assuming all discharges are untreated as the worst case scenario, the following impacts could occur.

Water Quality

The wastewater would be discharged through the marine outfall, which would continue to operate normally. Details of the marine outfall are given in the Final EIS, and Appendices 3-C Project Description – Outfall and 3-H Diffuser Predesign. The wastewater would be discharged through the diffuser segment of the outfall,

The marine outfall could discharge at a peak flow of up to 170 mgd (54 mgd alternative) of treated wastewater into Puget Sound. This input is very small (0.001 percent) relative to the total volume of Puget Sound and is not expected to impact circulation (King County, 2002a). With tidal current speeds in Puget Sound at about 1 foot per second, the discharged effluent would be quickly entrained into the tidal currents and diluted throughout Puget Sound (Ebbesmeyer et al., 2002). Under numerous effluent discharge scenarios modeled, the median dilution at the edge of the chronic mixing zone (where discharge is regulated) ranged from 300:1 to 1,821:1 (see Appendix 6-H, Predesign Initial Dilution Assessment). Ecology guidelines recommend a minimum 100:1 dilution at the edge of the chronic mixing zone.

Small amounts of microbiological and chemical contaminants would be discharged into the marine environment. Table 7 presents the concentrations of toxicants with standards or criteria for which we have data. The concentrations listed include offshore Puget Sound Water column, estimated end-of-pipe effluent, acute and chronic standards or criteria, and the estimated concentrations expected at the edge of the acute and chronic mixing zones. STP influent concentrations were assumed to be the best representation untreated wastewater that may bypass the Brightwater Treatment Plant.

Table 7 Offshore Puget Sound and untreated wastewater concentrations (end-of-pipe, edge of acute and chronic mixing zones) based on minimum possible dilutions (81:1 and 171:1 for acute and chronic mixing zones, respectively).

Parameter	Mean Puget Sound Offshore Concentration (µg/L)	Untreated Wastewater Concentration (µg/L)	Edge of Acute Mixing Zone Concentration (µg/L)	Acute Standard (µg/L)	Edge of Chronic Mixing Zone Concentration (µg/L)	Chronic Standard (µg/L)
Aluminum	N/A	2457	30.33	750.00	14.37	87.00
Antimony	0.08	30	0.4504	1467.00	0.26	500.00
Arsenic	1.12	50	1.7373	69	1.41	36
Cadmium	0.07	3	0.1070	42.00	0.09	9.3
Chromium (VI)	0.006	7.5	0.0986	1100	0.05	50
Copper	0.43	102.6	1.6967	4.80	1.03	3.10
Lead	0.03	30.4	0.4053	210.00	0.21	8.10
Mercury	0.00036	0.66	0.0085	1.80	0.00	0.0250
Nickel	0.45	20.3	0.7006	74.00	0.57	8.20
Selenium	<0.15***	50	0.6173	290.00	0.29	71
Silver	<0.06***	6.4	0.0790	1.90	0.04	0.12
Zinc	0.52	0.14	0.5217	90.00	0.52	81.00
Ammonia*	21.3	19830	266.1148	8235.00	137.26	1318.00
Cyanide**	N/A	5.5	0.0679	9.10	0.03	2.80
Bis (2-ethylhexyl)phthalate	1.64	13.5	1.8067	400	1.72	360.00
Chlopyrifos	<0.032***	0.008	0.0001	0.011	0.00	0.0056
Diazinon	<0.041***	0.043	0.0005	0.10	0.00	0.10
gamma-BHC (Lindane)	<0.005***	0.028	0.0003	0.16	0.00	0.08
Heptachlor	<0.005***	0.025	0.0003	0.05	0.00	0.00
Pentachlorophenol	<0.112***	0.93	0.0115	13.00	0.01	7.90
Phenanthrene	0.022	0.56	0.0289	7.70	0.03	4.60
4,4'-DDT	<0.005***	0.023	0.0003	0.13	0.00	0.00

N/A = Not Analyzed

* acute and chronic ammonia standards transformed from total ammonia (ug-(NH3/L) to unionized ammonia-nitrogen (ug-(NH3-N)/L)

** weak acid-dissociable CN-

*** when the offshore Puget Sound concentration is below the method detection limit for a given parameter, the concentration in ambient water is unknown. Therefore, the edge of the mixing zone concentrations represent the theoretical maximum increase due to the discharge.

As can be seen in Table 7, estimated concentrations at the edge of the acute and chronic mixing zones meet all applicable standards or criteria. Outside the regulatory mixing zone, concentrations of these pollutants are anticipated to meet water quality criteria for the protection of aquatic life and human health for all discharge rates and environmental conditions including tidal return of previously discharged effluent (Parametrix and Intertox, 2002; Appendix 6-I, Effluent quality Evaluation for the Membrane Bioreactor and Advanced Primary System).

The discharge of Brightwater System effluent would increase the level of nutrients in the form of nitrogen into the Central Basin of Puget Sound. These nutrients could stimulate production and growth of microscopic algae dependent upon the time of year discharges occur. However, high flushing rates in the waters surrounding the outfall zones would minimize the opportunity for nutrients to accumulate (Ebbesmeyer et al., 2002; Parametrix and Intertox, 2002). Additionally, the diffuser would be designed to dilute the discharged effluent and trap the discharged plume below the depth in the water column in which there is sufficient light for phytoplankton and algae growth. Large-scale modeling of effluent plume transport suggests that some effluent may move into areas, such as Possession Sound, with naturally occurring low oxygen concentrations.

Depending on the damage sustained at the treatment plant, the effluent may not receive disinfection. The Washington State standard for fecal coliforms, an indicator bacterium, is a geometric mean of 14 colonies/100 mL. The geometric mean of samples taken from STP influent is 3,400,000 colonies/100 mL. Fecal bacteria experience mortality outside of a host organism, and the rate of die-off can be described as a function of salinity, temperature, and sunlight. After being discharged into Puget Sound, the level of fecal coliforms would continue to decrease, with water quality standards being reached within two to three weeks. During this period of time, the effluent plume will typically remain submerged at depth and undergo predominately horizontal mixing and dilution.

Plants

If untreated discharges occur for an extended period of time during late spring through early fall, an increase in phytoplankton biomass could occur due to an increase in nitrogen concentrations (the nitrification of ammonium to nitrate). The level of growth would be dependent upon the duration of the discharge, the plume height in the water column, and the season. However, any phytoplankton bloom that occurred would be inconsequential to the marine ecology of Puget Sound and may not be detectable. If discharges occur in the winter months when phytoplankton growth is limited by light availability and temperature, no phytoplankton bloom would occur. Impacts to macroalgae (seaweed) in nearshore areas would not be expected as discharges will not reach nearshore areas.

Benthic Invertebrates

The following impacts could occur from untreated discharges. Solids will settle out in the vicinity of the diffuser and could smother benthic organisms. A list of benthic infauna present in the vicinity of the outfall is provided in the *Baseline Sediment Characterization Study-Sediment Chemistry and Benthic Infauna* report (King County, 2002b). The extent of the impact would depend upon the species and the ability of the organism to tolerate particulates as well as the amount of particulates covering the organism. Bivalves have the ability to excavate themselves from sediments and impacts to bivalves would be dependent upon the species present and duration of the discharge. Discharges over an extended duration could possibly lethally impact all benthic organisms within the area where solids settle until discharges cease and benthos recolonizes the area. It is possible that sediments in the immediate vicinity of the diffuser could become anoxic if the discharges occurred over an extended duration, lethally impacting benthic infauna.

Benthic community structure could be temporarily altered due to organic enrichment in the immediate vicinity of the diffuser. An increase in organisms able to tolerate organically enriched sediments coupled by a decrease in organisms sensitive to organic enrichment could occur. Community structure would likely return to pre-untreated discharge conditions within several years upon cessation of the untreated discharges.

The discharge plume would remain trapped and not reach the surface or the nearshore.

Fish

There are several fish species that may be found in the vicinity of the outfall, including salmonids, bottomfish, and forage fish. Bottomfish are the only fish that may be present for an extended length of time near the diffuser—salmonids, forage fish, and other types of marine fish would only be present in waters in the water column near the diffuser for a limited time on a transitory basis. A complete list of marine fish which may be present near the outfall is provided in Chapter 7 of the FEIS (King County, 2003b). It is not expected that any marine fish would be physically impacted by particulates from the discharge as fish, including flatfish, are motile and would be expected to avoid the plume. As prey items are readily available in the area, a slight decrease in benthic fauna in the immediate vicinity of the diffuser would not negatively impact marine fish populations.

Marine fish present near the diffuser are not expected to be affected by a decrease in dissolved oxygen as they are motile and would move to waters containing higher dissolved oxygen concentrations. It is possible that a fish swimming directly through the plume could be lethally impacted by ammonia or copper levels dependent upon the amount of discharge and dilution. Any flatfish that reside in the vicinity of the diffuser for an extended period of time where particulates settle out may be impacted due to bioaccumulative effects dependent upon the exposure time and concentration. Other marine fish are not likely to be impacted by an increase in contaminants in the discharge due to dilution and limited exposure time.

Mammals

Several marine mammals frequent waters in the vicinity of the diffuser on a transitory basis. There are no breeding or rearing areas near the outfall; however, pinnipeds, whales, and porpoises may pass through waters near the outfall en route to feeding areas. A complete list of marine mammals which may be present near the outfall is provided in Table 7-3 of the FEIS (King County, 2003b). Marine mammals are not likely to be impacted by untreated discharges as any physical contact with discharges would occur on a limited timescale (likely less than a minute) and marine mammals are air breathers and unaffected by ammonia and oxygen concentrations in water. Marine mammals are also not likely to be adversely affected by prey items.

Birds

Marine birds do not forage at the depth of the diffuser and the discharge plume is not expected to surface, therefore there would be no impact to marine birds occurring in subtidal waters. A list of marine birds likely to be present in the vicinity of the diffuser is provided in Table 7-3 of the FEIS (King County, 2003b).

It is unlikely marine birds, or their prey items, would be lethally affected by constituents reaching the nearshore through the microlayer. A discussion of consituents in the micro layer is provided in Appendix 6-G of the FEIS, *Assessment of Bouyant Materials and the Microlayer* (King County, 2002).

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Attachment D1.
Statistical Summary of South Treatment Plant Influent Wastewater Chemical Concentrations

Parameter	Unit	Data Source	Date Range	n	detected	FOD	Arithmetic Mean	Min	Max	StDev
1,1,1-Trichloroethane	ug/L	LIMS	1/96 - 7/04	119	1	0.84%	1.423781513	1	5	1.223130183
1,1,2,2-Tetrachloroethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
1,1,2-Trichloroethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
1,1,2-Trichloroethylene	ug/L	LIMS	1/96 - 7/04	119	2	1.68%	1.404201681	1	5	1.209313782
1,1-Dichloroethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
1,1-Dichloroethylene	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
1,2,4-Trichlorobenzene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
1,2-Dichlorobenzene	ug/L	LIMS	1/96 - 7/04	58	5	8.62%	0.754827586	0.28	8.56	1.092525228
1,2-Dichloroethane	ug/L	LIMS	1/96 - 7/04	119	3	2.52%	1.41512605	1	5	1.209400934
1,2-Dichloropropane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
1,2-Diphenylhydrazine	ug/L	LIMS	1/96 - 7/04	58	2	3.45%	1.89862069	0.94	2.5	0.260387352
1,3-Dichlorobenzene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
1,4-Dichlorobenzene	ug/L	LIMS	1/96 - 7/04	58	58	100.00%	2.186568966	0.58	8.11	1.558782353
2,3-Dichloroaniline	ug/L	LIMS	1/96 - 7/04	18	0	0.00%	1.74	0.94	1.9	0.368143195
2,4,5-Trichlorophenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	3.751724138	1.9	4.3	0.460831201
2,4,6-Trichlorophenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	3.751724138	1.9	4.3	0.460831201
2,4-Dichlorophenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
2,4-Dimethylphenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
2,4-Dinitrophenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.879655172	0.94	2.2	0.238076838
2,4-Dinitrotoluene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.375172414	0.19	0.43	0.04608312
2,6-Dinitrotoluene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.375172414	0.19	0.43	0.04608312
2-Butanone (MEK)	ug/L	LIMS	1/96 - 7/04	119	85	71.43%	12.0512605	5	61.1	7.953379684
2-Chloroethylvinyl ether	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
2-Chloronaphthalene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
2-Chlorophenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.879655172	0.94	2.2	0.238076838
2-Hexanone	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	7.016806723	5	25	6.04780839
2-Methylnaphthalene	ug/L	LIMS	1/96 - 7/04	58	2	3.45%	1.51862069	0.75	3.63	0.336240559
2-Methylphenol	ug/L	LIMS	1/96 - 7/04	58	7	12.07%	1.537413793	0.47	14.4	2.483535652
2-Nitroaniline	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	3.751724138	1.9	4.3	0.460831201
2-Nitrophenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
3,3'-Dichlorobenzidine	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
3-Nitroaniline	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	3.751724138	1.9	4.3	0.460831201
4,4'-DDD	ug/L	LIMS	1/96 - 7/04	60	1	1.67%	0.023216667	0.0012	0.047	0.020588759
4,4'-DDE	ug/L	LIMS	1/96 - 7/04	60	6	10.00%	0.0233645	0.0012	0.047	0.020423379
4,4'-DDT	ug/L	LIMS	1/96 - 7/04	60	1	1.67%	0.023281667	0.0012	0.047	0.020560168
4,6-Dinitro-O-Cresol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.879655172	0.94	2.2	0.238076838
4-Bromophenyl Phenyl Ether	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.375172414	0.19	0.43	0.04608312
4-Chloro-3-Methylphenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.879655172	0.94	2.2	0.238076838
4-Chloroaniline	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.879655172	0.94	2.2	0.238076838
4-Chlorophenyl Phenyl Ether	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
4-Methyl-2-Pentanone (MIBK)	ug/L	LIMS	1/96 - 7/04	119	2	1.68%	7.036134454	5	25	6.044141737
4-Methylphenol	ug/L	LIMS	1/96 - 7/04	58	58	100.00%	49.23051724	2.36	199	34.96116033
4-Nitroaniline	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	3.751724138	1.9	4.3	0.460831201
4-Nitrophenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.879655172	0.94	2.2	0.238076838
Acenaphthene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.375172414	0.19	0.43	0.04608312
Acenaphthylene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Acetone	ug/L	LIMS	1/96 - 7/04	119	118	99.16%	100.3478992	2.5	222	38.11294955
Acrolein	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	7.016806723	5	25	6.04780839
Acrylonitrile	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	7.016806723	5	25	6.04780839
Aldrin	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.022896833	0.00096	0.047	0.020879466
Alkalinity	mg/L	Process Lab	11/97 - 12/02	666			173.2878679	4.12	242	21.81036052
Alpha-BHC	ug/L	LIMS	1/96 - 7/04	60	3	5.00%	0.023093333	0.0012	0.047	0.020677507
Alpha-Chlordane	ug/L	LIMS	1/96 - 7/04	6	0	0.00%	0.0085	0.006	0.011	0.002738613
Aluminum, Total, ICP	mg/L	LIMS	1/96 - 7/04	29	29	100.00%	2.457344828	0.963	8.22	1.723515972
Ammonia-Nitrogen	mg/L	Process Lab	11/97 - 12/02	1,872			19.8295406	0	42.2	3.790730795
Aniline	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.879655172	0.94	2.2	0.238076838
Anthracene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Antimony, Total, ICP	mg/L	LIMS	1/96 - 7/04	36	0	0.00%	0.03	0.03	0.03	0

Parameter	Unit	Data Source	Date Range	n	detected	FOD	Arithmetic Mean	Min	Max	StDev
Antimony, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	33	82.50%	0.00072175	0.0005	0.0022	0.000301321
Aroclor 1016	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.32	0.19	0.47	0.125428081
Aroclor 1221	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.32	0.19	0.47	0.125428081
Aroclor 1232	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.32	0.19	0.47	0.125428081
Aroclor 1242	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.32	0.19	0.47	0.125428081
Aroclor 1248	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.32	0.19	0.47	0.125428081
Aroclor 1254	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.32	0.19	0.47	0.125428081
Aroclor 1260	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.32	0.19	0.47	0.125428081
Arsenic, Total, ICP	mg/L	LIMS	1/96 - 7/04	3144	1	0.03%	0.050000954	0.05	0.053	5.35032E-05
Arsenic, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.002431	0.0017	0.00454	0.00046921
Barium, Total, ICP	mg/L	LIMS	1/96 - 7/04	41	41	100.00%	0.074360976	0.0286	0.537	0.082584481
Barium, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.0500225	0.0243	0.364	0.05263862
Benzene	ug/L	LIMS	1/96 - 7/04	119	1	0.84%	1.403361345	1	5	1.209561678
Benzidine	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	22.67241379	11	26	2.886070181
Benzo(a)anthracene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Benzo(a)pyrene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Benzo(b)fluoranthene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.481896552	0.75	1.7	0.182981706
Benzo(g,h,i)perylene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Benzo(k)fluoranthene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.481896552	0.75	1.7	0.182981706
Benzoic Acid	ug/L	LIMS	1/96 - 7/04	58	58	100.00%	128.6534483	13.8	308	79.3715319
Benzyl Alcohol	ug/L	LIMS	1/96 - 7/04	58	58	100.00%	25.30534483	2.54	61.4	11.42211985
Benzyl Butyl Phthalate	ug/L	LIMS	1/96 - 7/04	58	56	96.55%	2.733362069	0.57	5.95	1.258141691
Beryllium, Total, ICP	mg/L	LIMS	1/96 - 7/04	41	0	0.00%	0.001	0.001	0.001	0
Beryllium, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	0	0.00%	0.0002	0.0002	0.0002	8.90357E-12
Beta-BHC	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.023031667	0.0012	0.047	0.020736936
Bis(2-Chloroethoxy)Methane	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Bis(2-Chloroethyl)Ether	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Bis(2-Chloroisopropyl)Ether	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.879655172	0.94	2.2	0.238076838
Bis(2-Ethylhexyl)Phthalate	ug/L	LIMS	1/96 - 7/04	58	58	100.00%	13.51396552	5.22	37.1	6.462408149
Bromodichloromethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Bromoform	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Bromomethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Cadmium, Total, ICP	mg/L	LIMS	1/96 - 7/04	3144	94	2.99%	0.003045102	0.003	0.0227	0.000572268
Cadmium, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.000621075	0.00023	0.00157	0.000349638
Caffeine	ug/L	LIMS	1/96 - 7/04	33	33	100.00%	75.41939394	1.77	102	21.5098781
Calcium, Total, ICP	mg/L	LIMS	1/96 - 7/04	1923	1923	100.00%	23.5099324	16.6	53.1	2.850472357
Carbazole	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Carbon Disulfide	ug/L	LIMS	1/96 - 7/04	119	100	84.03%	9.672857143	1	74.3	10.31327499
Carbon Tetrachloride	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Chemical Oxygen Demand	mg/L	Process Lab	11/97 - 12/02	1,746			470.3911798	93	1169	95.89939757
Chlordane	ug/L	LIMS	1/96 - 7/04	54	0	0.00%	0.128898148	0.0058	0.24	0.105215955
Chlorobenzene	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Chlorodibromomethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Chloroethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Chloroform	ug/L	LIMS	1/96 - 7/04	119	106	89.08%	4.107478992	1	6.55	1.16437531
Chloromethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Chlorpyrifos	ug/L	LIMS	1/96 - 7/04	26	15	57.69%	0.008446154	0.0038	0.0232	0.005221359
Chromium, Total, ICP	mg/L	LIMS	1/96 - 7/04	3144	2079	66.13%	0.007495992	0.005	0.128	0.005225267
Chromium, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.00574	0.0023	0.0148	0.002324392
Chrysene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Cis-1,3-Dichloropropene	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Client Locator	none	LIMS	1/96 - 7/04	6	6	100.00%				
Cobalt, Total, ICP	mg/L	LIMS	1/96 - 7/04	2	0	0.00%	0.01	0.01	0.01	0
Cobalt, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	36	36	100.00%	0.000952222	0.00064	0.00226	0.000306949
Conductivity, Field	umhos/cm	LIMS	1/96 - 7/04	1	1	100.00%	822	822	822	
Copper, Total, ICP	mg/L	LIMS	1/96 - 7/04	3144	3144	100.00%	0.10260617	0.0206	1.11	0.048011537
Copper, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.09115	0.0476	0.154	0.023670299
Coprostanol	ug/L	LIMS	1/96 - 7/04	58	54	93.10%	240.6310345	9.4	504	112.7515001

Parameter	Unit	Data Source	Date Range	n	detected	FOD	Arithmetic Mean	Min	Max	StDev
Crypto-ICR-Amorphous Structure	IFA+/100L	LIMS	1/96 - 7/04	11	1	9.09%	11516.72727	5000	27000	7865.847559
Crypto-ICR-Empty	IFA+/100L	LIMS	1/96 - 7/04	11	0	0.00%	11516.72727	5000	27000	7865.847559
Crypto-ICR-Internal Structure	IFA+/100L	LIMS	1/96 - 7/04	11	1	9.09%	11516.72727	5000	27000	7865.847559
Crypto-ICR-Total IFA Count	IFA+/100L	LIMS	1/96 - 7/04	11	2	18.18%	11516.72727	5000	27000	7865.847559
Cyanide, Weak & Dissociable	mg/L	LIMS	1/96 - 7/04	94	6	6.38%	0.0055	0.005	0.0443	0.004066623
Delta Time (Accum.)	hr	LIMS	1/96 - 7/04	54	54	100.00%	23.44444444	0	26	3.289013539
Delta-BHC	ug/L	LIMS	1/96 - 7/04	60	1	1.67%	0.023055	0.0012	0.047	0.020712957
Dibenzo(a,h)anthracene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	1.481896552	0.75	1.7	0.182981706
Dibenzofuran	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Dieldrin	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.026245	0.0077	0.047	0.017454245
Diethyl Phthalate	ug/L	LIMS	1/96 - 7/04	58	58	100.00%	7.407068966	3.81	16.8	1.932084602
Dimethyl Phthalate	ug/L	LIMS	1/96 - 7/04	58	18	31.03%	0.478396552	0.19	1.41	0.219278557
Di-N-Butyl Phthalate	ug/L	LIMS	1/96 - 7/04	58	23	39.66%	1.393793103	0.47	3.9	0.726584965
Di-N-Octyl Phthalate	ug/L	LIMS	1/96 - 7/04	58	4	6.90%	0.603793103	0.28	1.37	0.172095726
Discharge Rate	mgd	LIMS	1/96 - 7/04	3145	3145	100.00%	78.58628617	41.91	211.84	19.80469874
Discharge Volume	gal	LIMS	1/96 - 7/04	65	65	100.00%	86277634.77	48.2	831777000	118375254.8
Endosulfan I	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.023031667	0.0012	0.047	0.020736936
Endosulfan II	ug/L	LIMS	1/96 - 7/04	60	1	1.67%	0.023233333	0.0012	0.047	0.020591216
Endosulfan Sulfate	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.023031667	0.0012	0.047	0.020736936
Endrin	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.023031667	0.0012	0.047	0.020736936
Endrin Aldehyde	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.023031667	0.0012	0.047	0.020736936
Ethylbenzene	ug/L	LIMS	1/96 - 7/04	119	4	3.36%	1.416806723	1	5	1.207344707
Fecal Coliforms	CFU/100 mL	B. Bucher	1/98 - 10/02	370			6000810.811	100000	110000000	9897281.354
Field Personnel	none	LIMS	1/96 - 7/04	6	6	100.00%				
Flow	MGD	Process Lab	11/97 - 12/02	1,887			78.78694486	47.77	181.71	19.51007888
Fluoranthene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Fluorene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Gamma-BHC (Lindane)	ug/L	LIMS	1/96 - 7/04	60	23	38.33%	0.0281615	0.0013	0.0868	0.021185404
Gamma-Chlordane	ug/L	LIMS	1/96 - 7/04	6	0	0.00%	0.0085	0.006	0.011	0.002738613
Giardia-ICR->=2 Internal Structures	IFA+/100L	LIMS	1/96 - 7/04	11	2	18.18%	17244	5000	60000	17308.34989
Giardia-ICR-1 Internal Structure	IFA+/100L	LIMS	1/96 - 7/04	11	2	18.18%	51516.72727	5000	310000	96996.90489
Giardia-ICR-Amorphous Structure	IFA+/100L	LIMS	1/96 - 7/04	11	9	81.82%	252691.7273	5000	780000	229917.2585
Giardia-ICR-Empty	IFA+/100L	LIMS	1/96 - 7/04	11	11	100.00%	439583.0455	65000	1800000	480546.297
Giardia-ICR-Total IFA Count	IFA+/100L	LIMS	1/96 - 7/04	11	11	100.00%	727183.8636	160000	1800000	463663.4306
Heptachlor	ug/L	LIMS	1/96 - 7/04	60	1	1.67%	0.024708333	0.0019	0.127	0.024205576
Heptachlor Epoxide	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.023031667	0.0012	0.047	0.020736936
Hexachlorobenzene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Hexachlorobutadiene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Hexachlorocyclopentadiene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Hexachloroethane	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Indeno(1,2,3-Cd)Pyrene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Iron, Dissolved, ICP	mg/L	LIMS	1/96 - 7/04	27	27	100.00%	0.309259259	0.2	0.408	0.057627179
Iron, Total, ICP	mg/L	LIMS	1/96 - 7/04	59	59	100.00%	3.311864407	1.67	11.9	1.842149676
Isophorone	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
Lead, Total, ICP	mg/L	LIMS	1/96 - 7/04	3144	91	2.89%	0.030448791	0.03	0.17	0.005374246
Lead, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.0072965	0.00397	0.0229	0.003933317
Magnesium, Total, ICP	mg/L	LIMS	1/96 - 7/04	1963	1963	100.00%	6.455899134	5.05	19.6	0.768614428
Manganese, Total, ICP	mg/L	LIMS	1/96 - 7/04	137	137	100.00%	0.242255474	0.154	1.07	0.09008093
Manganese, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	1	1	100.00%	0.175	0.175	0.175	
Mercury, Total, CVAA	mg/L	LIMS	1/96 - 7/04	706	612	86.69%	0.000660021	0.00013	0.0363	0.00170224
Methoxychlor	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.11702	0.006	0.24	0.106000363
Methylene Chloride	ug/L	LIMS	1/96 - 7/04	119	75	63.03%	6.501680672	1	39.5	5.885877715
Molybdenum, Total, ICP	mg/L	LIMS	1/96 - 7/04	1993	374	18.77%	0.021133467	0.02	0.068	0.00358716
Molybdenum, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.01671	0.00756	0.0371	0.007921698
Naphthalene	ug/L	LIMS	1/96 - 7/04	58	1	1.72%	1.490517241	0.75	2	0.195218478
n-Decane	ug/L	LIMS	1/96 - 7/04	18	0	0.00%	0.521666667	0.28	0.57	0.111209923
Nickel, Total, ICP	mg/L	LIMS	1/96 - 7/04	3144	30	0.95%	0.020264313	0.02	0.283	0.006516709
Nickel, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.0060035	0.00355	0.0115	0.001413589

Parameter	Unit	Data Source	Date Range	n	detected	FOD	Arithmetic Mean	Min	Max	StDev
Nitrobenzene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
N-Nitrosodimethylamine	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	3.751724138	1.9	4.3	0.460831201
N-Nitrosodi-N-Propylamine	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
N-Nitrosodiphenylamine	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
n-Octadecane	ug/L	LIMS	1/96 - 7/04	18	14	77.78%	1.535388889	0.57	3.24	0.95092977
Oil And Grease, Total	mg/L	LIMS	1/96 - 7/04	72	72	100.00%	32.60555556	12.3	75.7	14.90093001
Ortho-Phosphorus	mg/L	Process Lab	11/97 - 12/02	283			3.918063604	2.04	8.24	0.877580977
Pentachlorophenol	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.932241379	0.47	1.1	0.119414406
pH	pH	Process Lab	11/97 - 12/02	1,873			7.046449546	5.9	7.8	0.226595588
Phenanthrene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Phenol	ug/L	LIMS	1/96 - 7/04	58	57	98.28%	23.49465517	3.8	139	21.57345935
Potassium, Total, ICP	mg/L	LIMS	1/96 - 7/04	32	32	100.00%	14.0875	9.7	21.8	2.831020561
Pyrene	ug/L	LIMS	1/96 - 7/04	58	0	0.00%	0.562931034	0.28	0.65	0.070710892
Sample Code	none	LIMS	1/96 - 7/04	3199	3199	100.00%				
Sample Description	none	LIMS	1/96 - 7/04	3307	3307	100.00%				
Sample Function	none	LIMS	1/96 - 7/04	1	1	100.00%				
Sample Start Time	hr	LIMS	1/96 - 7/04	146	146	100.00%	941.9246575	705	2030	175.1484921
Sample Unit	none	LIMS	1/96 - 7/04	12	12	100.00%	54.66666667	1	97	42.09369059
Sampling Method	none	LIMS	1/96 - 7/04	138	138	100.00%	6850.75	1011	11022	5154.950721
Selenium, Total, ICP	mg/L	LIMS	1/96 - 7/04	1989	0	0.00%	0.05	0.05	0.05	1.46692E-08
Selenium, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	5	12.50%	0.0015725	0.0015	0.003	0.000268889
Silver, Total, ICP	mg/L	LIMS	1/96 - 7/04	3144	1991	63.33%	0.006385369	0.004	0.0441	0.003310204
Silver, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.0036475	0.00134	0.00802	0.00167159
Sodium, Total, ICP	mg/L	LIMS	1/96 - 7/04	1897	1897	100.00%	58.47221929	28.9	144	9.254977164
Soluble Chemical Oxygen Demand	mg/L	Process Lab	11/97 - 12/02	700			153.4685714	2	329	49.44218613
Storm Or Non-Storm	none	LIMS	1/96 - 7/04	118	118	100.00%	815	815	815	
Styrene	ug/L	LIMS	1/96 - 7/04	119	17	14.29%	3.428571429	1	204	18.65969777
Temperature	° F	Process Lab	11/97 - 12/02	1,886			60.72269353	52	70	4.384441308
Tetrachloroethylene	ug/L	LIMS	1/96 - 7/04	119	57	47.90%	3.551428571	1	54.1	7.006114797
Thallium, Total, ICP	mg/L	LIMS	1/96 - 7/04	40	0	0.00%	0.2	0.2	0.2	0
Thallium, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	1	2.50%	0.0002015	0.0002	0.00026	9.48683E-06
Time Span	none	LIMS	1/96 - 7/04	3162	3162	100.00%	4.025079365	1	24	7.771200604
Time Unit	none	LIMS	1/96 - 7/04	3162	3162	100.00%				
Tin, Total, ICP	mg/L	LIMS	1/96 - 7/04	112	3	2.68%	0.084107143	0.07	1.2	0.110978884
Titanium, Total, ICP	mg/L	LIMS	1/96 - 7/04	2	0	0.00%	0.03	0.03	0.03	0
Toluene	ug/L	LIMS	1/96 - 7/04	119	113	94.96%	5.888739496	1	23.7	3.456881752
Total Biochemical Oxygen Demand (TBOD5)	mg/L	Process Lab	11/97 - 12/02	1,875			213.3944	12.5	710	62.08647441
Total Coliforms	CFU/100 mL	B. Bucher	1/98 - 10/02	380			82790526.32	3000000	990000000	144652982
Total Kjeldahl Nitrogen	mg/L	Process Lab	11/97 - 12/02	1,872			37.79188034	0	356	11.972242
Total Phenolics	mg/L	LIMS	1/96 - 7/04	71	56	78.87%	0.045225352	0.005	0.34	0.057270086
Total Phosphorus	mg/L	Process Lab	11/97 - 12/02	1,073			6.618947125	0	11.8	1.25547881
Total Solids	mg/L	Process Lab	11/97 - 12/02	258			584.7248062	326	1020	83.09643409
Total Suspended Solids	mg/L	Process Lab	11/97 - 12/02	1,877			243.9232818	75	850	68.99274147
Total Volatile Solids	mg/L	Process Lab	11/97 - 12/02	262			300.759542	134	534	58.03915481
Total Xylenes	ug/L	LIMS	1/96 - 7/04	119	62	52.10%	2.229831933	1	11	1.760343756
Toxaphene	ug/L	LIMS	1/96 - 7/04	60	0	0.00%	0.272183333	0.096	0.47	0.165191567
Trans-1,2-Dichloroethylene	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Trans-1,3-Dichloropropene	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Trichlorofluoromethane	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
UV Absorbance	1/cm	LIMS	1/96 - 7/04	4	4	100.00%	0.40175	0.352	0.425	0.033509949
Vanadium, Total, ICP	mg/L	LIMS	1/96 - 7/04	2	0	0.00%	0.01	0.01	0.01	0
Vanadium, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	36	36	100.00%	0.003177778	0.00209	0.00634	0.000818473
Vinyl Acetate	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	7.016806723	5	25	6.04780839
Vinyl Chloride	ug/L	LIMS	1/96 - 7/04	119	0	0.00%	1.403361345	1	5	1.209561678
Virus-Total ICR	PFU/100L	LIMS	1/96 - 7/04	9	7	77.78%	4954.444444	300	12000	4261.065334
Volatile Suspended Solids	mg/L	Process Lab	11/97 - 12/02	1,877			201.9898775	63	632	53.61906031
Zinc, Total, ICP	mg/L	LIMS	1/96 - 7/04	3144	3144	100.00%	0.135176018	0.0318	0.915	0.04900936
Zinc, Total, ICP-MS	mg/L	LIMS	1/96 - 7/04	40	40	100.00%	0.1421475	0.0846	0.431	0.060708087

Attachment D2.

Dilution Model and Dissolved Oxygen Model Input and Output

Attachment D2. Dilution Model and Dissolved Oxygen Model Input and Output

Dilution Model: Spread of a plume from a point source in a river with boundary effects from the shoreline based on the method of Fischer et al. (1979) with correction for the effective origin of effluent.

INPUT

Revised 22-Feb-96	Hollywood	Woodinville	Swamp Cr + Kenmore
1. Effluent Discharge Rate (cfs):	38.33	28.33	106.67
2. Receiving Water Characteristics Downstream From Waste Input			
Stream Depth (ft):	9.51	10.56	7.35
Stream Velocity (fps):	3.02	3.12	2.16
Channel Width (ft):	98.40	85.28	177.12
Stream Slope (ft/ft) or Manning roughness "n":	0.03	0.03	0.03
0 if slope or 1 if Manning "n" in previous cell:	1	1	1
3. Discharge Distance From Nearest Shoreline (ft):	0	0	0
4. Location of Point of Interest to Estimate Dilution			
Distance Downstream to Point of Interest (ft):	300	300	300
Distance From Nearest Shoreline (ft):	0	0	0
5. Transverse Mixing Coefficient Constant (usually 0.6):	0.6	0.6	0.6
6. Original Fischer Method (enter 0) or Effective Origin Modification (enter 1)	0	0	0

OUTPUT

	Hollywood	Woodinville	Swamp Cr + Kenmore
1. Source Conservative Mass Input Rate			
Concentration of Conservative Substance (%):	100.00	100.00	100.00
Source Conservative Mass Input Rate (cfs*%):	3,833.33	2,833.33	10,666.67
2. Shear Velocity			
Shear Velocity based on slope (ft/sec):	#N/A	#N/A	#N/A
Shear Velocity based on Manning "n": using Prasuhn equations 8-26 and 8-54 assuming hydraulic radius equals depth for wide channel			
Darcy-Weisbach friction factor "f":	0.049	0.048	0.054
Shear Velocity from Darcy-Weisbach "f" (ft/sec):	0.237	0.240	0.177
Selected Shear Velocity for next step (ft/sec):	0.237	0.240	0.177
3. Transverse Mixing Coefficient (ft2/sec):	1.352	1.523	0.782
4. Plume Characteristics Accounting for Shoreline Effect (Fischer et al., 1979)			
Co	1.36E+00	1.01E+00	3.79E+00
x'	1.39E-02	2.02E-02	3.45E-03
y'o	0.00E+00	0.00E+00	0.00E+00
y' at point of interest	0.00E+00	0.00E+00	0.00E+00
Solution using superposition equation (Fischer eqn 5.9)			
Term for n= -2	1.38E-	1.39E-86	0.00E+00

	125		
Term for n= -1	1.02E-31	5.78E-22	3.78E-126
Term for n= 0	2.00E+00	2.00E+00	2.00E+00
Term for n= 1	1.02E-31	5.78E-22	3.78E-126
Term for n= 2	1.38E-125	1.39E-86	0.00E+00
Upstream Distance from Outfall to Effective Origin of Effluent Source (ft)	#N/A	#N/A	#N/A
Effective Distance Downstream from Effluent to Point of Interest (ft)	300.00	300.00	300.00
x' Adjusted for Effective Origin	1.39E-02	2.02E-02	3.45E-03
C/Co (dimensionless)	4.79E+00	3.97E+00	9.60E+00
Concentration at Point of Interest (Fischer Eqn 5.9)	6.50E+00	4.01E+00	3.63E+01
Unbounded Plume Width at Point of Interest (ft)	65.578	68.501	58.888
Unbounded Plume half-width (ft)	32.789	34.250	29.444
Distance from near shore to discharge point (ft)	0.00	0.00	0.00
Distance from far shore to discharge point (ft)	98.40	85.28	177.12
Plume width bounded by shoreline (ft)	32.79	34.25	29.44
Approximate Downstream Distance to Complete Mix (ft):	8,646	5,952	34,739
	1.64	1.13	6.58
Theoretical Dilution Factor at Complete Mix:	73.680	99.055	26.411
Calculated Flux-Average Dilution Factor Across Entire Plume Width:	24.552	39.783	4.390
Calculated Dilution Factor at Point of Interest:	15.386	24.930	2.751

Theoretical Dilution Factor at Complete Mix Including Upstream Discharges:	73.680	42.252	16.252
Calculated Dilution Factor at Point of Interest Including Upstream Discharges:	15.386	18.627	2.583

Dissolved Oxygen Model: Streeter-Phelps analysis of critical dissolved oxygen sag.

Based on Lotus File DOSAG2.WK1 Revised 19-Oct-93

INPUT

1. EFFLUENT CHARACTERISTICS		
Discharge (cfs):	173.3333	
CBOD5 (mg/L):	150	
NBOD (mg/L):	90.486	
Dissolved Oxygen (mg/L):	4	
Temperature (deg C):	10	
2. RECEIVING WATER CHARACTERISTICS		
Upstream Discharge (cfs):	2800	
Upstream CBOD5 (mg/L):	1.0	
Upstream NBOD (mg/L):	0	
Upstream Dissolved Oxygen (mg/L):	11.282	assume saturation
Upstream Temperature (deg C):	10	
Elevation (ft NGVD):	15	
Downstream Average Channel Slope (ft/ft):	0.0004	
Downstream Average Channel Depth (ft):	7.216	
Downstream Average Channel Velocity (fps):	2.1648	
3. REAERATION RATE (Base e) AT 20 deg C (day^-1):	0.30	

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggested Values
Churchill	1.5 - 6	2 - 50	0.90
O'Connor and Dobbins	.1 - 1.5	2 - 50	0.98
Owens	.1 - 6	1 - 2	0.94
Tsivoglou-Wallace	.1 - 6	.1 - 2	3.59

4. BOD DECAY RATE (Base e) AT 20 deg C (day^-1):	0.39

Reference	Suggested Value
Wright and McDonnell, 1979	0.39

OUTPUT

1. INITIAL MIXED RIVER CONDITION	
CBOD5 (mg/L):	9.7
NBOD (mg/L):	5.3
Dissolved Oxygen (mg/L):	10.9
Temperature (deg C):	10.0
2. TEMPERATURE ADJUSTED RATE CONSTANTS (Base e)	
Reaeration (day^-1):	0.24
BOD Decay (day^-1):	0.25
3. CALCULATED INITIAL ULTIMATE CBODU AND TOTAL BODU	
Initial Mixed CBODU (mg/L):	14.2
Initial Mixed Total BODU (CBODU + NBOD, mg/L):	19.5
4. INITIAL DISSOLVED OXYGEN DEFICIT	
Saturation Dissolved Oxygen (mg/L):	11.282
Initial Deficit (mg/L):	0.42

5. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days):			4.05
6. DISTANCE TO CRITICAL DO CONCENTRATION (miles):			143.57
7. CRITICAL DO DEFICIT (mg/L):			7.49
8. CRITICAL DO CONCENTRATION (mg/L):			3.80
9. DO DEFICIT (mg/L) at:	0.2083333	days	1.36