King County Reclaimed Water Comprehensive Plan

Reclaimed Water Strategy Effects on Wetlands

WORKING DRAFT

March 2012

King County

Department of
Natural Resources and Parks
Wastewater Treatment Division

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Wastewater Treatment Division
Department of Natural Resources and Parks

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Acronyms and Abbreviations

°C	degrees Celsius
°F	degrees Fahrenheit
µg/L	micrograms per liter
AOI	Area of Interest
BOD	biological oxygen demand
Brightwater	Brightwater Treatment Plant
cfs	cubic feet per second
cm	centimeters
cm/day	centimeters per day
Corps	U.S. Army Corps of Engineers
Ecology	Washington State Department of Ecology
EDC	endocrine-disrupting compound
GIS	geographic information system
Health	Washington State Department of Health
HGM	hydrogeomorphic
I	Interstate
kg	kilograms
MBR	membrane bioreactor
MG	million gallons
mgd	million gallons per day
mg/L	milligrams per liter
NAIP	National Aerial Imagery Program
NRCS	Natural Resources Conservation Service

NWI	National Wetland Inventory
PAHs	polycyclic aromatic hydrocarbons
PBT	Persistent Bioaccumulative Toxic Chemical
PPCP	pharmaceuticals and personal care product
RM	river mile
SWM	Surface Water Management
TIN	total inorganic nitrogen
TKN	total Kjeldahl nitrogen
TMDL	Total Maximum Daily Load
WDFW	Washington Department of Fish and Wildlife
WQI	water quality index
WTD	Wastewater Treatment Division

EXECUTIVE SUMMARY

Four areas in King County's wastewater service area were evaluated for the potential of using reclaimed water both to enhance or create wetlands in these areas and to indirectly augment streamflows.

The evaluation was done to support development of a Reclaimed Water Comprehensive Plan for King County's Wastewater Treatment Division (WTD). The purpose of the Reclaimed Water Comprehensive Plan is to determine if, how, when, where, and by what funding mechanisms King County's existing reclaimed water program should expand over the next 30 years, through 2040 and beyond.

This report is part of a series of reports that document efforts to further define and evaluate three reclaimed water strategies developed and approved earlier in the reclaimed water planning process. The following sections describe the three reclaimed water strategies under consideration; the four wetland enhancement areas that were evaluated; the objectives, methods, and findings of this evaluation; and recommendations for further study if any of the wetland enhancement projects were to be implemented.

Reclaimed Water Strategies

Each reclaimed water strategy represents a concept for producing and supplying reclaimed water to serve potential uses identified during the reclaimed water planning process. The uses include both nonpotable, consumptive uses (irrigation, commercial, industrial) and environmental enhancement uses (wetland enhancement or creation and associated indirect groundwater recharge and/or streamflow augmentation). The following are brief descriptions of the strategies:

- **Redmond/Bear Creek Basin Brightwater Centralized Strategy.** Reclaimed water would be produced through the membrane bioreactor (MBR) process at the Brightwater Treatment Plant for distribution to two areas—one in the immediate vicinity of the plant and one farther south above Lake Sammamish—via new pipelines connected to the South Segment of the Brightwater reclaimed water pipeline.
- **Renton/Tukwila South Plant Centralized Strategy.** Reclaimed water would be produced through expansion of the South Treatment Plant's tertiary sand filtration system for distribution to an area just south of Lake Washington via extension of an existing pipeline that delivers reclaimed water to the City of Tukwila.
- **Reclaimed Water Skimming or Polishing Decentralized Strategy.** This strategy represents opportunities for small-scale reclaimed water implementation. Infrastructure was constrained to a single treatment plant of up to 0.5 million gallons per day (mgd) capacity and up to 1 mile of reclaimed water pipeline. Three potential areas and configurations—two in Seattle and one in the Green River Valley—were identified to help define the decentralized strategy.

Wetland Enhancement Areas in the Strategies

Four potential Areas of Interest (AOIs) are being considered for wetland enhancement through introduction of Class A reclaimed water—the highest standard of reclaimed water in the State of Washington. Three of the AOIs are part of the Redmond/Bear Creek Basin Brightwater Centralized Strategy, and one is part of the Renton/Tukwila South Plant Centralized Strategy. No wetland enhancement uses were identified for the Reclaimed Water Skimming or Polishing Decentralized Strategy.

The four AOIs are as follows:

- Crystal Lake, an approximately 130-acre wetland adjacent to the north shore of Crystal Lake in Snohomish County.
- Cottage Lake, an approximately 129-acre wetland in the Cold Creek Natural Area west of Cottage Lake in King County.
- Sammamish River/Lake Sammamish, an approximately 154-acre area in Marymoor Park with two potential subareas: Area A, 54 acres of wetlands west of the Sammamish River, and Area B, 100 acres of wetlands at the north end of Lake Sammamish.
- Cedar River, an approximately 30-acre area located on a terrace along the south side of the Cedar River in Renton approximately 1.9 miles from the Cedar River discharge to Lake Washington. This area is being considered as a potential location for creation of a 16-acre wetland using reclaimed water.

Objectives and Methods

The evaluation is preliminary. Existing information was compiled and analyzed to address the following questions:

- What characteristics are indicative of wetlands that could potentially be enhanced with reclaimed water and/or used to introduce additional water into a watershed?
- What changes in the wetland water quality, vegetation, and hydrology might be expected as the result of reclaimed water wetland enhancement?
- What are the potential effects of wetland enhancement to wildlife, including threatened and endangered species, using wetland habitat?
- What are the potential effects of wetland enhancement on groundwater quality and quantity as a result of adding reclaimed water to wetlands?
- Would wetland enhancement with reclaimed water provide an opportunity to introduce water that would support instream flows?

To be potentially suitable for enhancement with reclaimed water, a wetland would need characteristics that would enable it to either increase in function as a result of the addition of reclaimed water or to pass water to watersheds without a negative effect on its existing functions. Based on the Washington State Water Reclamation and Reuse Standards (1997) prepared by the Washington State Departments of Health and Ecology, wetlands with one or more of the following characteristics may be suitable for enhancement with reclaimed water:

- Capacity to absorb, retain, and/or discharge additional water without causing deleterious downstream effects such as flooding or degradation of groundwater quality
- An existing hydroperiod (the length of time and portion of year the wetland holds ponded water) such that the wetland would benefit from an increase in hydraulic loading and/or an increase in average monthly water levels
- Vegetative structure and soil capable of absorbing/processing a potential increase in nutrients (total phosphorus, total nitrogen), biological oxygen demand, and/or suspended solids, as well as a potential increase in ammonia and metals
- Low biological functions, including low habitat and species diversity and abundance, such that additional water would increase biological functions

These characteristics were used to develop screening factors to evaluate the four potential wetland enhancement/creation areas. The screening factors and how they were used to determine the suitability of each area for wetland enhancement/creation and/or streamflow augmentation are shown in Table ES-1.

Table ES-1. Summary of Potential for Wetland Enhancement and Streamflow Augmentation

Factor	Area of Interest Meets Factor as Suitable for Wetland Enhancement/Flow Augmentation?				
	Crystal Lake	Cottage Lake	Sammamish Area A	Sammamish Area B	Cedar River
General Characteristics					
Wetland category	Possibly	No	Yes	Yes	Yes
Size	Yes	Yes	Yes	Yes	Yes
Site potential	Possibly	Possibly	Possibly	Possibly	Possibly
Proximity to treatment plant/discharge pipe	Yes	Yes	Yes	Yes	Yes
Landscape position	Yes	Yes	Yes	Yes	Yes
Hydrologic Functions					
Hydrologic function potential	Yes	Yes	Yes	Possibly	Yes
Water budget/water storage capacity	No	No	Yes	Possibly	Yes
Hydraulic connectivity					
(a) benefit from low-flow augmentation	Yes	Yes	Yes	Yes	Possibly
(b) potential flooding issues	Yes (seasonal)	Yes (seasonal)	Possibly	Possibly	Possibly
Soil characteristics					
(a) capacity to transmit water	Yes	Yes	Yes	Yes	Possibly
(b) capacity to support wetlands	Yes	Yes	Yes	Yes	No
Water Quality functions					
Mass average loading	No	No	Possibly	Possibly	No
Downstream water quality	No	Possibly	Possibly	Possibly	No
Groundwater quality	Yes	Yes	Yes	Yes	Yes
Soil characteristics	Yes	Yes	Yes	Yes	Possibly
Habitat Functions					
Native plant diversity	No	No	Yes	Yes	Yes
Dominant vegetation	No	No	Yes	Yes	Yes
(a) dominated by facultative plant species (occur both in wetlands and uplands) (b) supports vegetation tolerant of higher soil saturation	No	No	Yes	Yes	Yes
Wildlife niches	No	No	Yes	Possibly	Yes

Note: Factors that preclude using an AOI for enhancement with reclaimed water are highlighted in blue.

Findings

The Sammamish Slough and Cedar River areas appear to have the most potential for wetland enhancement or streamflow augmentation. The following sections describe the basis for this finding in terms of wetland, water quality, and streamflow enhancement potential.

Wetland Enhancement and Creation

The total number of wetland acres that could be created or enhanced through application of reclaimed water in the AOIs are shown in Table ES-2.

Table ES-2. Acres of Potential Wetland Enhancement and Creation

Wetland Area	Existing Wetland	Potential Wetland Enhancement	Potential Wetland Creation
Crystal Lake	130	0	0
Cottage Lake	129	0	0
Sammamish Area A	54	5	17
Sammamish Area B	100	18	9
Cedar River	0	0	16

Neither Crystal nor Cottage Lake would likely be enhanced through application of reclaimed water. High quality wetlands already exist within these areas, and the areas are prone to localized shoreline flooding in the winter. Areas A and B in the Sammamish River/Lake Sammamish AOI and the Cedar River AOI present the most promising opportunities for wetland enhancement and/or creation through application of reclaimed water:

- Of the estimated 54 acres of existing wetlands in Sammamish River/Lake Sammamish Area A, approximately 5 acres have enhancement potential; adverse effects are not expected for the remaining 49 acres of existing wetlands. In addition, 17 acres of wetland creation may be possible.
- Of the estimated 100 acres of existing wetlands in Sammamish River/Lake Sammamish Area B, approximately 18 acres have enhancement potential and 9 acres of wetland could be created, but wetland creation would need to be aligned with existing beneficial uses of the site.
- There may be an opportunity to create up to approximately 16 acres of wetland in the Cedar River AOI.

Water Quality

Potential water quality benefits may be accrued through the application of reclaimed water to the Cottage Lake and Sammamish Slough areas. These potential benefits would be related to streamflow augmentation and potential beneficial effects on instream temperatures through the addition of more water via subsurface flows. However, nutrients, specifically the addition of phosphorus, may be a concern and analysis should be done of microconstituents in reclaimed water, particularly of endocrine-disrupting chemicals.

The proximity of these areas to surface water bodies and the highly saturated conditions of Crystal Lake, Cottage Lake, and wetlands fringing Lake Sammamish make it likely that water that infiltrates into the soils would migrate laterally to adjacent water bodies and would not degrade groundwater quality.

Streamflow Augmentation

All of the areas present an opportunity for downstream flow augmentation. However, the application of reclaimed water could potentially cause some adverse ecological effects on existing high quality wetlands at the Crystal and Cottage Lake areas. Neutral or positive ecological effects may be realized through application of reclaimed water to the Sammamish River/Lake Sammamish and Cedar River areas.

Recommendations for Further Study

A more detailed analysis of the potential environmental effects from the application of reclaimed water would need to be undertaken before implementation of any of wetland enhancement projects under consideration. The analysis would include a wetland delineation and functional assessment as well as further water quality evaluation. Such an assessment would be the first step in determining wetland categories and identifying areas suitable for wetland enhancement or creation. Results of the assessment could be used to identify specific types and sequence of detailed studies on vegetation, hydrology, water quality, and groundwater.

1.0. INTRODUCTION

Four areas in King County's wastewater service area were evaluated to assess the potential for using reclaimed water to enhance or create wetlands in these areas and to indirectly augment streamflows. The evaluation was done as part of a comprehensive planning effort to better understand the potential for expanding the County's reclaimed water program through implementation of three reclaimed water strategies.

This chapter provides background information on the comprehensive planning process and reasons for analyzing the strategies. It then briefly describes the reclaimed water strategies, outlines the objectives of this evaluation, and describes the organization of this report.

1.1 Background

This report was prepared to support the development of a Reclaimed Water Comprehensive Plan for King County's Wastewater Treatment Division (WTD). The purpose of the Reclaimed Water Comprehensive Plan is to determine if, how, when, where, and by what funding mechanisms the County's existing reclaimed water program should expand over the next 30 years, through 2040 and beyond.

The work documented in this report was conducted as part of Step 4 of the reclaimed water planning process as amended and approved by the King County Council in May 2011. It is one of a series of reports that document efforts to define and analyze three reclaimed water strategies developed and approved earlier, during Step 3.[1] The results of these analyses will provide information on the following topics:

- Potential for use of reclaimed water to reduce reliance on Puget Sound for discharge of treated effluent.
- How reclaimed water strategies could fit into regional wastewater system planning and operations, including their effect on planned improvements and future operation of the regional wastewater system.
- The ability to use small prepackaged or preassembled reclaimed water facilities to produce and distribute reclaimed water.
- The potential effects of reclaimed water strategies on the environment, including the following:
    - Potential for reclaimed water to enhance watershed basin flows
    - Effects of reclaimed water use on groundwater and surface water quality
    - Effects of reclaimed water use on the built environment, including energy demands and greenhouse gas emissions

[1] More information on the reclaimed water comprehensive planning process is available at http://www.kingcounty.gov/environment/wastewater/RWCompPlan.aspx. More information on reclaimed water strategy development and identification is available at http://your.kingcounty.gov/dnrp/library/wastewater/rw/CompPlan/1012_RWCPStrategyReport.pdf.

- Changes in existing laws and policies that may be needed in order to allow expanded use of reclaimed water.
- The full range of benefits and costs associated with providing additional reclaimed water to serve both nonpotable consumptive and environmental enhancement uses.

Throughout the development, definition, and analysis of the strategies, WTD applied County Council−approved evaluation criteria to assess how each strategy addresses the three drivers for the Reclaimed Water Comprehensive Plan—regional wastewater system planning, creating resources from wastewater, and protecting Puget Sound water quality.

The strategies were developed for planning and evaluation purposes only; they are not intended to necessarily represent any future reclaimed water improvement projects or any implied preference or commitment on the part of any interested parties or potential end users.

1.2 Description and Location of Strategies

Each reclaimed water strategy represents a concept for producing and supplying reclaimed water to serve potential uses identified during the reclaimed water planning process. The uses include both nonpotable consumptive uses (irrigation, commercial, industrial) and environmental enhancement uses (wetland enhancement and associated indirect groundwater recharge and/or streamflow augmentation). The following are brief descriptions of the strategies:

- **Redmond/Bear Creek Basin Brightwater Centralized Strategy.** Reclaimed water would be produced through the membrane bioreactor (MBR) process at the Brightwater Treatment Plant for distribution to two areas—one in the immediate vicinity of the plant and one farther south above Lake Sammamish—via new pipelines connected to the South Segment of the Brightwater reclaimed water pipeline.
- **Renton/Tukwila South Plant Centralized Strategy**. Reclaimed water would be produced through expansion of the South Treatment Plant's tertiary sand filtration system for distribution to an area just south of Lake Washington via extension of an existing pipeline that delivers reclaimed water to the City of Tukwila.
- **Reclaimed Water Skimming or Polishing Decentralized Strategy.**[2] This strategy represents opportunities for smaller scale reclaimed water implementation. Infrastructure was constrained to a single treatment plant of up to 0.5 mgd capacity and up to 1 mile of reclaimed water pipeline. Three potential areas and configurations were identified to help define the decentralized strategy:
  - An MBR skimming plant located in the Interbay area of Seattle would produce reclaimed water from untreated wastewater in adjacent conveyance pipelines for distribution near the plant via a new pipeline.
  - A sand filtration polishing plant located in Seattle on the west side of the Duwamish River would produce reclaimed water from flows in the Effluent

2 A skimming plant removes some of the untreated wastewater from pipelines that carry the wastewater to regional plants for treatment and then treats the wastewater to reclaimed water quality for local distribution. A polishing plant removes some secondary-treated effluent from pipelines exiting regional treatment plants and treats the effluent to reclaimed water quality standards.

Transfer System (ETS) pipeline that carries South plant secondary effluent for discharge at Alki Point in West Seattle. The reclaimed water would be distributed to nearby uses via a new pipeline.

— An MBR skimming plant located in the lower Green River Valley in south King County would produce reclaimed water from untreated wastewater in adjacent conveyance pipelines for distribution near the plant via a new pipeline.

The locations of the strategies are shown in Figure 1-1.

1.3 Objectives of this Evaluation

Wetland enhancement or creation is being considered for four areas. These areas are located in two of the reclaimed water strategy areas, those of the Redmond/Bear Creek Basin Brightwater Centralized Strategy and the Renton/Tukwila South Plant Centralized Strategy. Existing information was compiled and reviewed to analyze whether the application of reclaimed water in these areas has the potential to improve the extent and quality of wetland functions (or, at least, cause no harm) and/or to introduce water to watersheds that have been identified as in need of additional water to support summer streamflows.

The analysis focused on answering the following questions:

- What changes in water quality, vegetation, and hydrology could be expected as the result of introducing reclaimed water to the wetland?
- What are the potential effects of wetland enhancement to wildlife, including threatened and endangered species, that use the wetland habitat?
- What are the potential effects of wetland enhancement on groundwater quality and quantity as a result of adding reclaimed water to wetlands?
- Would wetland enhancement with reclaimed water provide an opportunity to introduce water that would support instream flows?
- What characteristics are indicative of wetlands that could be enhanced with reclaimed water and/or used to introduce additional water into a watershed?

1.4 Content and Organization of this Report

The next two chapters describe the areas targeted in the strategies for wetland enhancement or creation; the quality and quantity of reclaimed water that would be applied to each area; and the methods used to determine whether the areas are suitable for reclaimed water application. These chapters are followed by chapters that present the analysis and findings for each area. The report ends with recommendations for additional studies to fill information gaps.

2.0. WETLAND AREAS AND RECLAIMED WATER FLOWS IN THE STRATEGIES

This chapter presents the sizes and locations of the four areas identified for wetland enhancement or creation within the reclaimed water strategy areas and the quality and quantity of reclaimed water that would be applied to them.

2.1 Size and Location of Wetland Areas

Three potential Areas of Interest (AOI) for wetland enhancement were identified for the Redmond/Bear Creek Brightwater Centralized Strategy:

- Crystal Lake, an approximately 130-acre wetland adjacent to the north shore of Crystal Lake in Snohomish County.
- Cottage Lake, an approximately 129-acre wetland in the Cold Creek Natural Area west of Cottage Lake in King County.
- Sammamish River/Lake Sammamish, an approximately 154-acre area in Marymoor Park with two potential subareas: Area A, 54 acres of wetlands west of the Sammamish River, and Area B, 100 acres of wetlands at the north end of Lake Sammamish.

One potential AOI was identified for the Renton/Tukwila South Plant Centralized Strategy.

- Cedar River, an approximately 30-acre area located on a terrace along the south side of the Cedar River in Renton approximately 1.9 miles from the Cedar River discharge to Lake Washington. This area is being considered as a potential location for creation of a 16-acre wetland using reclaimed water.

General locations for these AOIs are shown in Figure 2-2.

2.2 Recommended Reclaimed Water Quality and Quantity for Each Area

The Water Reclamation and Reuse Standards (1997) prepared by the Washington State Department of Health (Health) and the Washington State Department of Ecology (Ecology) defines the standards for discharging reclaimed water to wetlands. Figure 2-1 shows the criteria in the standards applicable to this analysis.

Applicability (Article 1):

- Discharge of reclaimed water to Category I wetlands or to salt-water dominated wetlands is not permitted, except where it can be demonstrated that no existing significant wetlands functions will be decreased and overall net environmental benefits will result from the discharge.
- Wetlands which receive reclaimed water meeting the requirements of these standards are considered waters of the State. These include existing natural wetlands and constructed beneficial use wetlands. These standards do not apply to constructed treatment wetlands which are not considered waters of the State

Hydrologic and Hydraulic Criteria (Article 2):

- Average annual hydraulic loading rate cannot exceed 2 centimeters per day (cm/day) to Category II wetlands, slightly higher rates are allowed for Category III and IV wetlands and constructed wetlands.
- Average monthly water levels cannot increase by more than 10 centimeters (cm) compared to the average pre-augmentation monthly water level. The frequency and duration of water level fluctuations above pre-augmentation average may be further limited in the following situations:
  (1) If the wetland is characterized by relatively high vegetation species richness, then the frequency of stage excursions above 15 cm shall not exceed 6 per year and the duration shall not exceed 72 hours per excursion; or
  (2) If the wetland contains a high quality bog or fen component, then the duration of stage excursions shall not exceed 24 hours in any year; or
  (3) If the wetland is inhabited by breeding native amphibians, then during the breeding season (February through May) and within the breeding zones, water level excursions shall not exceed 8 cm and the duration of all excursions shall not exceed 24 hours in any 30 day period.

Water Quality Criteria (Article 3):

- Reclaimed water discharged to wetlands cannot exceed the following concentrations on an average annual basis: total phosphorus (TP) 1 milligrams per liter (mg/L); total Kjeldahl nitrogen (TKN) 3 mg/L; Biological Oxygen Demand (BOD_5) 20 mg/L and Total Suspended Sediments (TSS) 20 mg/L.
- Mass average annual loadings are not to exceed: TP 0.2 kg/ha/d; Total Nitrogen (TN) 1.2 kg/ha/d; BOD_5 5 kg/ha/d; and TSS 9 kg/ha/d.
- Ammonia concentration must not exceed Washington chronic toxicity standards (WAC 173-201A-040[3])
- Metal concentrations must not exceed Washington State water quality standards (WAC 173-201A)

Biological Criteria (Article 4):

- Existing beneficial uses shall be maintained and protected and no further degradation which would interfere with or become injurious to existing beneficial uses shall be allowed, unless the discharge of reclaimed water will result in a net environmental benefit as described in Article 6 (WAC 173-201A-070)
- Existing beneficial uses shall be maintained and protected (not degraded), unless net environmental benefit (see WAC 173-201A-070) can be demonstrated through application of reclaimed water.
- Biological criteria related to species composition and abundance (e.g., vegetation, macroinvertebrates, amphibians, fish and birds) will not be lowered by more than 25 percent compared to the reference condition.

Groundwater Protection Criteria (Article 5):

- Determine whether the wetland is within an area that provides groundwater recharge at any time of the year.
- For reclaimed water with parameter concentrations at 50 percent or higher than groundwater quality criteria (WAC 173-200-040) additional hydrogeologic investigation is required to show hydrogeologic conditions are adequate to prevent degradation of groundwater.

Net Environmental Benefit (Article 6):

Exceptions to the criteria listed above may be possible if net environmental benefit can be demonstrated and the following criteria are met:

- Significant, existing beneficial uses of the receiving water will be uninterrupted and fully protected.
- New beneficial uses or increased provision of existing beneficial uses result from application of reclaimed water based on scientific evidence and ongoing monitoring.

Figure 2-1. 1997 Water Reclamation and Reuse Standards (Washington State Departments of Health and Ecology)

Washington state defines four wetland categories (WAC 173-183-710) according to their habitat values, vulnerability, sensitivity to changes, irreplaceable functions, and other factors. Category I is considered the most sensitive and Category IV the least sensitive type of wetland. The standards do not allow discharge of reclaimed water to Category I wetlands or to saltwater-dominated wetlands. All existing or potential wetlands considered in this analysis are or would be freshwater wetlands. To the extent possible, the analysis identified the wetland category for each area.

Both reclaimed water strategies call for production of Class A reclaimed water at the Brightwater or South Treatment plants. Class A is the highest quality of reclaimed water specified under state standards. It is defined as reclaimed water that, at a minimum, is at all times an oxidized, coagulated, filtered, disinfected wastewater.

In terms of nutrients, the standards require phosphorus concentrations in reclaimed water to be less than 1 mg/L and total Kjeldahl nitrogen (TKN) concentrations to be less than 3 mg/L, both on an average annual basis.[3] Future Washington state regulations may also require removal of total inorganic nitrogen (TIN) to levels below 8 mg/L.[4] The Brightwater plant's Class A reclaimed water meets the TKN requirement but not the phosphorus and TIN requirements. South plant reclaimed water does not meet any of these requirements.

It is assumed that reclaimed water discharged to wetlands as a part of the Redmond/Bear Creek Basin Brightwater Centralized Strategy would need to meet these nutrient standards. Phosphorus removal processes would be required to meet the phosphorus standard, small adjustments to the treatment process would be required to meet the 8-mg/L TIN concentration, and dechlorination processes or other approaches to reduce chlorine residuals prior to wetland enhancement application would also likely be needed (King County 2011a).

No additional treatment, other than dechlorination, is recommended for reclaimed water produced at South plant for application to the Cedar River area as part of the Renton/Tukwila South Plant Centralized Strategy. Nutrient removal is not assumed for the South Treatment Plant Centralized strategy because the discharge is to a constructed beneficial use wetland. It is assumed that due to net increase in environmental function derived as a result of the discharge of reclaimed water, nutrient removal will not be required under current Washington state regulations. Additional analysis would need to be conducted to determine net environmental benefit from applying reclaimed water with higher-than-allowed nutrient concentrations to this area.

Table 2-1 shows the recommended annual volumes, application rates and periods, nutrient limits, temperatures, and average daily volumes for the four wetland enhancement areas. The basis for these parameters is as follows:

- The volumes are based on estimates of amount of effluent available for reclamation and amount of reclaimed water the wetland areas can accommodate.
- The recommended application rate is the rate specified in state standards for Category II wetlands. Because Category II is the most vulnerable of the three wetland categories for which application of reclaimed water is allowed, this application rate would be acceptable for the other two categories as well.

[3] TKN = ammonia plus organic nitrogen excluding nitrate or nitrite-nitrogen.
[4] TIN = ammonia, nitrate, and nitrite-nitrogen.

- The nutrient limits reflect the current and anticipated state standards discussed above.
- Two potential annual application periods, 7 months and 12 months, were evaluated for the Crystal Lake, Cottage Lake, and Sammamish Slough areas in order to better evaluate the effects of reclaimed water application on flooding in adjacent areas. Only a 12-month application period was considered for the Cedar River site because the effect of reclaimed water application would be small compared to the flow in the Cedar River.

Table 2-1. Wetland Enhancement Flows under Consideration for Each Area

	Redmond/Bear Creek Brightwater Centralized Strategy			**Renton/Tukwila South Plant Centralized Strategy**
	Cottage Lake	**Crystal Lake**	**Sammamish Slough**	**Cedar River**[a]
Annual volume (12 months of application)	1,350 MG	730 MG	730 MG	182.5 MG
Application rate	2 cm/day	2 cm/day	2 cm/day	2 cm/day
Total phosphorus	1 mg/L	1 mg/L	1 mg/L	2 mg/L
Total Kjeldahl Nitrogen (TKN)[a]	3 mg/L	3 mg/L	3 mg/L	25−30 mg/L (>90% ammonia)
Total Inorganic Nitrogen (TIN)[b]	8 mg/L	8 mg/L	8 mg/L	25-30 mg/L
Temperature	50°F (leaving the treatment plant; cooler farther away from the plant)			
Scenario 1 (12-month application)				
Duration (days/year)	365 days	365 days	365 days	365 days
Average daily demand	3.7 mgd	2.0 mgd	2.0 mgd	0.5 mgd
Scenario 2 (7-month application, April–October)				
Duration (days/year)	214 days	214 days	214 days	N/A[c]
Average daily demand	3.7 mgd	2.0 mgd	2.0 mgd	N/A

[a] TKN includes ammonium (NH4-N) and Org-N.
[b] TIN includes ammonia, nitrate and nitrite-nitrogen.
[c] The 7-month scenario was not considered because the reclaimed water flows are small compared to flows in the Cedar River and, therefore, effects on flooding would be negligible.
MG = million gallons; °F = degrees Fahrenheit; N/A = not applicable.

3.0. METHODOLOGY

The following methodology was used to conduct the assessment:

- Existing conditions were identified by reviewing documents and conducting field observations.
- The degree to which each potential area performs the wetland functions defined for its wetland classification was estimated.
- Using the features identified for high functioning wetlands and the Washington state reclaimed water standards, characteristics were identified of wetlands that would be suitable for enhancement with reclaimed water.
- Screening factors were developed and applied based on Washington state standards for applying reclaimed water to wetlands, characteristics of wetlands suitable for reclaimed water application, and objectives of this analysis.

This chapter presents assumptions and limitations of this analysis and then describes the above methodology in more detail.

3.1 Assumptions and Limitations

The following assumptions and limitations apply:

- Delineated boundaries for potential wetland enhancement areas were not available at the time of the visit. Wetland boundaries were approximated based on information observed during the site visit and on aerial photographs in order to get a sense of the characteristics of the AOIs; the extent of possible wetlands outside of these general geographic areas was not determined.
- This analysis did not include detailed site investigations necessary to perform full functional wetland assessments, determine wetland categories, or complete wetland rating system forms.
- This analysis did not include an exhaustive evaluation of all water quality parameters. The analysis focused on evaluation of water quality parameters in the Washington state standards for applying reclaimed water to wetlands.

3.2 Identify Existing Conditions

Existing conditions were identified by reviewing documents and making field observations, as outlined below.

3.2.1 Document Review

Information regarding the four areas investigated was compiled from a number of publically available sources, including the following:

- U.S. Fish and Wildlife National Wetland Inventory http://www.fws.gov/wetlands/Data/Mapper.html

- U.S. Department of Agriculture Natural Resources Conservation Service (NRCS)
  - Web Soil Survey: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx
  - National Aerial Imagery Program (NAIP)
- State of Washington Department of Conservation (Peat Resources of Washington)
- King County:
  - Geographic Information System (GIS) data http://www5.kingcounty.gov/gisdataportal/Default.aspx
  - eReal Property Search http://info.kingcounty.gov/Assessor/eRealProperty/default.aspx
  - King County Wetland Inventory
  - Parks and Recreation Division: Cold Creek Natural Area Site Management Plan
  - Wastewater Treatment Division: background information on the reclaimed water strategies and supporting documentation
- Snohomish County:
  - Property Search https://www.snoco.org/proptax/(0iaddr45lo5a1pqfvdh3iq45)/search.aspx
  - SnoScape (interactive landscape map)
  - Permit, Planning, and Zoning Map (interactive map)
  - Surface Water Management Division documents and data:
    - 2008 State of the Lakes Update: Crystal Lake http://www.co.snohomish.wa.us/documents/Departments/Public_Works/surfacewatermanagement/lake/crystal%20update.pdf
    - http://www1.co.snohomish.wa.us/Departments/Public_Works/Divisions/SWM/Work_Areas/Water_Quality/Lakes/CrystalLake.htm
- Seattle Public Utilities: Cedar River Sockeye Weir
- Eastside Audubon Society: Audubon Bird Loop at Marymoor Park
- Aerial photography using GoogleEarth

3.2.2 Field Observations

Existing conditions were also defined through a one-day field visit of all four potential wetland enhancement areas on October 10, 2011. The visit was limited to a short walk at each site to note general vegetation, surficial topography, surface water levels, and habitat features sufficient to qualitatively assess wetland functions. Where access was not available (private lands), the site was viewed from the closest public access point. (See the figures for the chapters on each wetland for viewing locations.)

3.3 Estimate Existing and Potential Degree of Wetland Function

The qualitative degree to which each potential enhancement area performs hydrologic (flood flow and erosion reduction), water quality improvement, and habitat functions was used to evaluate its relative degree of existing function and, thus, its potential as a reclaimed water enhancement site. The analysis was based on the Washington State Wetland Rating System for Western Washington (Hruby 2006) used by Ecology to determine a wetland's regulatory category and level of function.

Wetlands were assessed based on their hydrogeomorphic (HGM) class and then on their general "potential" and "opportunity" to provide each group of functions:

- The potential for performing a function is based on the structural characteristics necessary to provide that function.
- The opportunity to perform a function is based on the wetland's position in the landscape relative to sources of pollution and to other habitat areas.

There are four HGM classes of wetlands: depressional, lake-fringe, riverine, and slope wetlands. Wetlands in the Crystal Lake, Cottage Lake, and Area B (north of Lake Sammamish) areas are depressional wetlands; wetlands in Area A (west of the Sammamish River) are lake-fringe wetlands. General characteristics of these two classes of wetlands are as follows:

- Depressional wetlands occupy depressions and are at a lower elevation than the surrounding landscape. The movement of water is toward the lowest point in the depression. These wetlands hold water and display evidence of surface ponding. Although the depressional wetlands may have an outlet, the lowest point in the wetland is not the outlet. (Hruby 2006).
- Lake-fringe wetlands are near large, deep bodies of fresh water greater than 20 acres with over 30 percent of their open water more than 6.6 feet deep.

The following sections describe general hydrologic, water quality, and habitat functions of the depressional and lake-fringe wetlands. Table 3-1 and Table 3-2 list specific indicators of these functions.

3.3.1 Hydrologic Functions

Generally, a wetland's hydrologic functions depend on its HGM class.

The degree of a depressional wetland's hydrologic functions (its ability to reduce flooding and erosion) is determined by its outlet (which influences the residence time of the water in the wetland), depth of water storage, size relative to the size of its contributing basin (the basin's contribution to water storage in the wetland), and its position in the landscape relative to resources that could be damaged by flooding and erosion (Hruby 2006.

Lake-fringe wetlands generally provide lower hydrologic functions than depressional wetlands, although they do provide important local shoreline erosion protection functions (Hruby 2006). The degree of a lake-fringe wetland's hydrologic functions (its ability to reduce lakeshore erosion) is determined by the width and characteristics of the vegetation along the lake and by the proximity to resources along the lake shore that could be damaged by flooding and erosion (Hruby 2006).

3.3.2 Water Quality Improvement Functions

Generally, a wetland's water quality improvement functions depend on its HGM class.

Depressional wetlands that display high water quality improvement functions tend to slow the flow and hold water, and their soils and plants bind to and take up chemicals and nutrients that would otherwise flow downstream into a receiving water. The degree of water quality improvement function provided by a depressional wetland is determined by the presence or lack of an outlet; the capacity of its soil to bind to nutrients, metals, and other pollutants; the proportion of the wetland's vegetation that is persistent and not grazed; and the portion of the wetland that is seasonally ponded (Hruby 2006). A depressional wetland's opportunity to perform water quality improvement functions is influenced by the position of the wetland in the landscape and whether there are sources of water pollution entering the wetland.

Lake-fringe wetlands usually provide lower water quality improvement functions than depressional wetlands (Hruby 2006). The degree of water quality improvement function provided by a lake-fringe wetland is determined by the average width of vegetation along the lake shore and the characteristics of the vegetation in the wetland, primarily the extent of herbaceous vegetation that can trap, filter, and absorb pollutants (Hruby 2006). Herbaceous species have been found to sequester metals and remove oils and other organics better than other plant species (Hammer 1989; Horner 1992, as cited in Hruby 2006). A lake-fringe wetland's opportunity to perform water quality improvement functions is influenced by the position of the wetland in the landscape and whether there are sources of water pollution entering the lake and, thus, the wetland.

3.3.3 Habitat Functions

The degree of a wetland's habitat function does not depend on its HGM class (Hruby 2006). The characteristics of wetlands with high levels of habitat function described for depressional wetlands also apply to lake-fringe wetlands. Habitat function is determined based on a wetland's vegetative structure, number of hydroperiods (the length of time and portion of year the wetland holds ponded water), richness of native plant species, interspersion of habitats, and the presence of special habitat features. A wetland's opportunity to perform habitat functions is influenced by the width and nature of its buffer, the degree to which it is connected to other habitats via undisturbed corridors of dense vegetation, its proximity to habitats considered to be priorities by the Washington State Department of Fish and Wildlife (WDFW), and its proximity to other wetlands (Hruby 2006).

Table 3-1. Indicators of High Functioning Depressional Wetlands (Hruby 2006)

Hydrologic Function	Water Quality Improvement Functions	Habitat Function
• No outlet or an intermittently flowing or highly constricted outlet. • Two to three feet of ponded surface water. • Located high in the watershed and upstream of a river or stream with flooding problems. (Wetlands in these locations are rated twice as high as they otherwise would be for hydrologic functions because of this opportunity to reduce flooding and erosion.)	• No outlet or an intermittently flowing or highly constricted outlet. • Soils, such as organic or clay soils, located close to the surface (within the upper 2 inches) with the capacity to bind to nutrients, metals, and other pollutants. • Over 95 percent of the wetland area covered by persistent ungrazed vegetation. • Over 50 percent of the wetland area seasonally ponded (ponded for at least two months of the year, but then dries out). • In a location that receives pollution from sources such as untreated stormwater discharges; tilled fields, orchards, and grazing; streams or discharges from culverts that drain residential, logged, or farmed areas; septic systems; and/or groundwater high in nitrogen or phosphorus. (Wetlands in watersheds that provide this opportunity are rated twice as high as they otherwise would be for their water quality improvement functions.)	• Multiple classes of vegetation (such as forested, scrub-shrub, and emergent). • Multiple layers of vegetation. • Areas of different hydroperiods (permanently flooded areas and areas of seasonal flooding and seasonal saturation). • High number of native plant species. • High interspersion of habitat types (many edges along different habitat types). • Special habitat features such as snags, downed logs, undercut or stable steep banks, and vegetation and hydroperiods suitable for amphibian egg laying. • Low percent cover of invasive plants. • Wide, vegetated, undisturbed buffers connected to other large areas of habitat. • Near or adjacent to Washington State Department of Fish and Wildlife (WDFW) priority habitats such as designated urban natural open space, riparian habitats, aspen stands, stands of Oregon white oak, prairies, cliffs, caves, talus slopes, estuaries, shorelines, or mature/old growth. • Proximity to other wetlands. • Connected to other habitats via relatively undisturbed corridors of dense vegetation.

Table 3-2. Indicator of High Functioning Lake-Fringe Wetlands (Hruby 2006)

Hydrologic Function	Water Quality Improvement Functions	Habitat Function
• A wide band of stiff vegetation (trees and shrubs) that acts as a physical barrier to waves, anchors the shoreline, and dissipates erosive forces. • Located along lakes with adjacent resources that could be affected by shoreline erosion (residential areas, roads, mature forested habitat for wildlife species). (Wetlands in these locations are rated twice as high as they otherwise would be for hydrologic functions because of this opportunity to reduce lakeshore erosion.)	• A band of more than 33 feet of vegetation along the lakeshore. • More than 90 percent of the vegetated area made up of herbaceous vegetation that can trap, filter, and absorb pollutants. • Aquatic bed plant communities that facilitate the binding of phosphorus and change the chemistry of the lake bottom (Moore et. al. 1994, as cited in Hruby 2006). • In an area that receives pollution from sources such as untreated stormwater discharges; tilled fields, orchards, or grazing; streams or discharges from culverts that drain residential, logged, or farmed areas; septic systems; and/or groundwater high in nitrogen or phosphorus. (Wetlands in watersheds that provide this opportunity are rated twice as high as they otherwise would be for their water quality improvement functions.)	• Multiple classes of vegetation (such as forested, scrub-shrub, and emergent). • Multiple layers of vegetation. • Areas of different hydroperiods (permanently flooded areas and areas of seasonal flooding and seasonal saturation). • High number of native plant species. • High interspersion of habitat types (many edges along different habitat types). • Special habitat features such as snags, downed logs, undercut or stable steep banks, and vegetation and hydroperiods suitable for amphibian egg laying. • Low percent cover of invasive plants. • Wide, vegetated, undisturbed buffers connected to other large areas of habitat. • Near or adjacent to Washington State Department of Fish and Wildlife (WDFW) priority habitats such as designated urban natural open space, riparian habitats, aspen stands, stands of Oregon white oak, prairies, cliffs, caves, talus slopes, estuaries, shorelines, or mature/old growth. • Proximity to other wetlands. • Connected to other habitats via relatively undisturbed corridors of dense vegetation.

3.4 Identify Characteristics of Wetlands Suitable for Enhancement

To be considered suitable for enhancement with reclaimed water, a wetland should have characteristics that would enable it to either increase in function as a result of the addition of reclaimed water or to pass water to watersheds without a negative effect on the wetland's existing functions.

As a part of this analysis, such characteristics were identified based on the Washington State Water Reclamation and Reuse Standards (Ecology and Health 1997) and indicators of high-functioning wetlands (Hruby 2006). These characteristics, along with other factors, were used to screen the four candidate areas (see the following section).

Wetlands with one or more of the following characteristics may be suitable for enhancement with reclaimed water:

- Capacity to absorb, retain, and/or discharge additional water without causing deleterious downstream effects such as flooding or degradation of groundwater quality
- An existing hydroperiod such that the wetland would benefit from an increase in hydraulic loading and/or an increase in average monthly water levels
- Vegetative structure and soil capable of absorbing/processing a potential increase in nutrients (total phosphorus, total nitrogen), biological oxygen demand, and/or suspended solids, as well as a potential increase in ammonia and metals
- Low biological functions, including low habitat and species diversity and abundance, such that additional water would increase biological functions

3.5 Determine Enhancement/Creation Potential of Each Area

Factors under each wetland function category—hydrologic, water quality improvement, and habitat—were developed to evaluate and draw conclusions regarding the potential of each of the four AOIs to benefit from the addition of reclaimed water in the quality, volumes, and application rates and periods shown in Table 3-3. Factors also included general characteristics of the wetlands, such as size and proximity to reclaimed water production and distribution infrastructure.

The screening factors were developed based on the following:

- The biological and net environmental benefit criteria listed under the Water Reclamation and Reuse Standards (1997) for application of reclaimed water to wetlands (see Figure 2-1).
- Characteristics of wetlands suitable for enhancement with reclaimed water (see above).
- The objectives of this wetlands enhancement analysis (see Chapter 1).

The following sections describe how the screening was conducted.

3.5.1 Hydrology and Habitat Function Analyses

The hydrology and habitat analyses were qualitative. Hydraulic and hydrologic considerations included site surficial geology, drainage configuration, infiltration capacity, permeability, and the regulatory volume of water that can be applied. Habitat considerations included plant species, vegetation communities, and wildlife habitat.

3.5.2 Water Quality Improvement Function Analysis

The water quality improvement function can be highly variable. Many factors can affect overall performance of this function. One of the key variables affecting water quality function is residence time; the water must reside in the wetland a sufficient time to allow for nutrient uptake or binding to sediment. It is also important that reclaimed-water flows not resuspend sediments that have accumulated.

Because water quality data and annual mass balance of nutrients entering and exiting these four areas are not available, water quality calculations were done based on the following assumptions:

- Average annual nutrient (phosphorus and nitrogen) removal rates in the wetland areas were assumed to be within the typical range (from 50 to 80 percent) reported by Mitsch & Gosselink (1993).
- Water residence times were assumed to be sufficient for nutrient removal to occur within the range specified.
- The reclaimed water would be spread over as much of the wetland as possible and applied so as to avoid the possibility of erosion or resuspension of sediments.

Using these assumptions and the flow volumes and concentrations given in Table 3-3, the following water quality calculations were performed:

- Total annual nutrient loading
- Average daily nutrient loading rate
- Maximum and minimum annual total nutrient load conveyed from the wetlands
- Maximum and minimum monthly total nutrient load conveyed from the wetlands

Table 3-3. Factors for Evaluating Potential Effect of Reclaimed Water for Wetland Enhancement and Streamflow Augmentation

Factors	Description
General Characteristics	
Wetland category	Category II – IV wetlands may provide some opportunity for wetland enhancement; Category I wetlands excluded because of their rarity, sensitivity to disturbance, and high levels of all wetland functions.
Size	Existing or potential wetland area sufficiently large such that the volume of water can be applied at a rate no greater than 2 cm/day (Category II wetlands); 3 cm/day for Category III and IV wetlands; and 5 cm/day for constructed beneficial use wetlands.
Site potential	Adjacent land would allow for expansion, enhancement, and/or creation of additional wetland area and buffers without infringing on properties.
Proximity to treatment plant/discharge pipe	Wetland is located close to treatment plant and/or existing or future planned conveyance pipes to facilitate cost-effective reclamation.
Landscape position	Wetland is located upgradient from stream in which flow augmentation has potential environmental benefits for the basin.
Hydrologic Functions	
Existing hydrology	Wetland position in the landscape and hydrogeomorphic class indicate potential for high level of hydrologic function (e.g., large depressional wetlands in urbanized watersheds).
Water budget/ water storage capacity	Wetland appears to have capacity for some or all of the year to hold more water than it is holding under current conditions.
Hydraulic connectivity	Water from the wetland flows to a stream that could benefit from low-flow augmentation. Water from the wetland flows to stream that does not have flooding problems during seasonal high flow periods.
Soil characteristics	Mapped soil type has shallow depth to groundwater and high capacity to transmit water in a saturated condition to downstream waters. Mapped soil type is poorly drained, has high frequency of ponding, and has high available water capacity indicative of poorly drained soils that could support wetlands.
Water Quality Functions	
Mass average loading	Average mass annual loading criteria (kg/ha/d) in state standards could be satisfied.
Downstream water quality	Wetland position in landscape and outlet characteristics are such that nutrients in reclaimed water would not degrade water quality within the wetland or in downstream water bodies.
Groundwater quality	Wetland position in landscape indicates that additional water could augment/supplement groundwater withdrawals without degrading groundwater quality.
Soil characteristics	Wetland soil type is suitable for binding to chemical constituents in reclaimed water (e.g., organic or clay soils).

Factors	Description
Habitat Functions	
Native plant diversity	Low levels of native plant diversity and/or dominance of invasive plant species in wetland.
Dominant vegetation	Wetland is dominated by facultative plant species capable of tolerating increased soil saturation and/or inundation. Wetland supports vegetation classes capable of tolerating increased soil saturation and/or inundation (e.g., scrub-shrub wetland dominated by Douglas spirea or willows).
Wildlife niches	Wetland supports limited wildlife niches and lacks special habitat features such as snags, downed wood, and amphibian egg laying structures that are sensitive to increased water levels.

4.0. CRYSTAL LAKE AREA OF INTEREST (REDMOND/BEAR CREEK BRIGHTWATER CENTRALIZED STRATEGY)

Crystal Lake is located south of the town of Maltby and adjacent to the Snohomish−King County line. Figure 4.1 shows Crystal Lake and the surrounding area. The Crystal Lake Area of Interest (AOI) includes a large wetland that extends north from the northern edge of the lake. A private gated residential community surrounds the lake on the remaining three sides. The AOI is accessible via Crystal Lake Road. Observations during the site visit were made from a single access point along Crystal Lake Road looking east and north into the wetland. Figure 4-2 shows the approximate observation point.

The AOI is within the Snohomish County Conservancy Shoreline Environment and the Suburban Shoreline Environment (Snohomish County 2011a). The majority of the lake and wetland in the AOI are also within the 100-year floodplain and the Snohomish County Flood Hazard Area (Snohomish County 2011b).

The size of the wetland in this AOI is estimated to be approximately 130 acres (based on interpretation of aerial photographs). The approximate wetland boundary extends into 21 parcels according to Snohomish County parcel information (GIS layer). All parcels are privately owned by various entities. The 1981 U.S. Fish and Wildlife Service National Wetland Inventory (NWI) identifies this wetland as a freshwater emergent and forested/shrub wetland with a freshwater pond (Little Lake) and a lake (Crystal Lake). Figure 4-1 identifies these features and Figure 4-2 shows the general wetland boundary for this AOI.

The sections that follow provide analyses of the hydrologic, water quality, and habitat functions of the Crystal Lake AOI, with the last section of this chapter presenting a summary of these analyses.

4.1 Hydrologic Functions

This section begins with a description of the regional surficial geology for the Sammamish River system, of which the Crystal Lake AOI is a part, along with the Cottage Lake and the Sammamish River/Lake Sammamish AOIs. The section follows with a description of existing hydrologic features of the Crystal Lake AOI and an analysis of the potential effects on wetland hydrologic functions from applying reclaimed water.

4.1.1 Regional Surficial Geology

Erosion and deposition from glacial, deglacial, and postglacial stream processes formed the landscape containing the Sammamish River system and its associated lakes and wetlands as well as the Cedar River (Booth et al. 2003, 2007; Shannon & Wilson 2003). The overall landscape in the Sammamish River system is one of broad, flat valley systems flanked by steep to moderately steep slopes that rise to the adjacent relatively flat uplands. The Puget Sound glacier lobe of the last glaciation flowed north to south, completely overtopping the Sammamish River area. In the process, it excavated these broad valleys while leaving a range of deposits from its advance and subsequent retreat.

The Sammamish River (as well as several other major valleys) was excavated by large subglacial meltwater streams while the glacier still overtopped the area (Booth 1990, 1994; Booth and Hallet 1993; Collins and Montgomery 2011). The Evans Creek/Patterson Creek Valley (which drains into the lower Bear River) was excavated during deglaciation as a spillway channel between lakes formed in front of the Puget Lobe glacier that progressively drained to lower elevations as the glacier retreated to the north (Booth 1990). Sediment was also deposited in front of the retreating glacier by streams. Postglacial stream systems eroded into the landscape after glacial retreat and proglacial lake drainage.[5] Depending on location, the streams and rivers of the present landscape occupy these older subglacial or proglacial valleys or are eroded into the older glacial and recessional outwash deposits.

The glacial deposits relevant to this analysis are till (unsorted gravels, sands, and clay deposited directly from the glacier) and recessional outwash (stream deposits left behind as the glacier retreated). Till is common on the uplands; recessional outwash is also found in these locations. Recessional outwash also filled the Crystal/Cottage Lake Valley and Bear Creek south approximately to its junction with the Sammamish River. After glacial retreat, stream systems also formed in these valleys. Stream deposits from the last 10,000 years dominate along the Sammamish River from Lake Sammamish downstream to Bothell. These deposits also comprise the flat surface at Marymoor Park. Lake Sammamish itself is a freshwater-filled subglacial trough (Booth 1990, 1994; Collins and Montgomery 2011). The Sammamish River flows north from Lake Sammamish to Lake Washington at Kenmore.

4.1.2 Existing Conditions

This section describes the existing surficial geology, mapped soils, and hydrology of the Crystal Lake AOI.

Surficial Geology and Mapped Soils

The Crystal Lake Valley is a local proglacial stream trough filled in by low-gradient organic wetland deposits and contains Little Lake and Crystal Lake. The underlying deposits here are obscured by the wetlands and lakes. Crystal Lake drains south via the continuation of Daniels Creek over a topographic step in the valley profile where it then enters another step or trough filled by Cottage Lake and the Cottage Lake AOI. The higher areas surrounding Crystal Lake are composed of till and recessional outwash, while the topographic step leading to Cottage Lake is composed of recessional outwash. The main stream system is very low gradient because it is flowing within the inherited proglacial valley; the stream is steeper where it flows down the topographic step.

Table B-1 in Appendix B presents the properties and qualities of the soil series mapped for this AOI based on the Natural Resources Conservation Service (NRCS) Web Soil Survey. The majority of the wetland area in the Crystal Lake AOI is mapped as Orcas peat, with Mukilteo muck soils mapped around the outer fringe of the wetland. Alderwood gravelly sandy loam (8 percent to 15 percent slope series) occurs along the western edge of the area along the slopes that border Cottage Lake Road.

[5] Proglacial = in front of the glacier.

The peat and muck soils in the majority of the Crystal Lake AOI have a high capacity to hold and transmit water but are very poorly drained, typically have a water table at the surface, and consequently have frequent surface ponding. Orcas peat and Mukilteo muck are considered hydric soils, indicative of wetland conditions. The Alderwood gravelly sandy loam is considered a partially hydric soil.[6]

Hydrology

The Crystal Lake AOI lies within the Daniels Creek subbasin, which is tributary to the larger Bear Creek basin and ultimately the Sammamish River watershed. The Daniels Creek subbasin is approximately 3,100 acres; approximately 70 percent of the subbasin (2,100 acres) is above Crystal Lake. The primary drainage to Crystal Lake through the subbasin is via Daniels Creek. The wetland hydrology is likely derived from a shallow groundwater table and influenced by Daniels Creek and Crystal Lake.

It appears, based on review of aerial photographs, that the headwater of Daniels Creek is located at the northern tip of the Crystal Lake AOI wetland and that the creek flows south through Little Lake (located in the center of the wetland) and continues through Crystal Lake. Snohomish County Surface Water Management information indicates the outlet of Crystal Lake is dammed but likely has some form of culvert outlet (Snohomish County 2011c). Any such outlet would be located on private land and not accessible for viewing. Below Crystal Lake, Daniels Creek flows south under NE 205th Street to Cottage Lake and ultimately to Bear Creek and the Sammamish River. Crystal Lake is approximately 54 acres and has an average depth of 4 feet and a maximum depth of approximately 30 feet (Snohomish County 2011c).

The outer wetland margin was saturated with standing water at the time of the October 10, 2011, site visit. From the limited field observations and review of aerial photographs, it appears that saturated soil conditions extend through much of the wetland. Given that these observations were made at the end of the driest period of the year, it is likely that the wetland is characterized by saturated soil and surface ponding throughout the year, including the entire growing season (approximately mid March through approximately mid October) and the typical period of seasonally elevated groundwater and surface water (late October through early March).

4.1.3 Analysis of Potential Effects

The analysis found that the Crystal Lake wetland likely provides a high level of hydrologic function. The addition of reclaimed water under either the 7- or 12-month application scenario holds little potential to enhance the wetland's hydrologic functions and could have negative effects on wetland plant species, vegetation communities, and wildlife habitat.

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), the Crystal Lake wetland possesses many of the indicators of wetlands that provide a high level of hydrologic function:

- Large size relative to the size of the contributing basin
- Ponding to 3 feet or more in some areas (based on field observations of watermarks)

[6] A hydric soil is a soil that formed under conditions of saturation, flooding, or ponding long enough during the growing season to develop anaerobic conditions in the upper part.

- Landscape position in a basin that contributes to the larger Bear Creek basin and Sammamish River watershed, which increases the wetland's opportunity to reduce flooding and erosion.

Saturated conditions observed at the end of the dry season indicate a lack of water-holding capacity in the wetland, and surface application of reclaimed water would result in a shorter residence time before the applied water reaches Daniels Creek, Little Lake, or Crystal Lake. Applied water would primarily move as surface and subsurface flows.[7] Water that reaches and flows across the surface could produce small-scale channels that could alter the local water relationship between plants and plant communities.

While the lack of water-holding capacity creates the potential for flow augmentation in downstream water bodies, the potential for negative impacts on the wetland's vegetation, habitats, and functions significantly compromises any benefits to the watershed that might be gained from flow augmentation. It is possible that much smaller volumes of water could be added to and passed through these wetlands over a short period (July through September), which could contribute to streamflows in Daniels Creek. However, significant additional analysis would be required to determine the magnitude of water volume that could enhance base flows in downstream water bodies without negatively altering wetland functions or causing/contributing to flooding in the area.

4.2 Water Quality Functions

This section describes existing water quality functions in the AOI and analyzes the potential effects on nutrient loading and groundwater quality from adding reclaimed water to the Crystal Lake wetland.

4.2.1 Existing Conditions

No water quality information was found for the Crystal Lake wetland. However, water quality in Crystal Lake has been monitored by volunteers since the early 1980s and by Snohomish County Surface Water Management (SWM) on various occasions since 1994 (Snohomish County 2011c). Data collected by the Crystal Lake community since the early 1980s and limited data collected by Snohomish County SWM in 1994−1995 indicate that the lake has low water clarity, low dissolved oxygen, moderate phosphorus levels, and moderate to high chlorophyll-a values (Snohomish County 2009):

- Water in Crystal Lake is dark because of humic compounds and particulates from the wetland.
- Surface water temperatures in Crystal Lake range from 39^{o}F) in the winter to 77^{o}F in the summer (Snohomish County 2009).
- Dissolved oxygen levels range from 7.4 to 9.6 mg/L at the surface. In the summer, levels are at or near zero at 9.8 feet and below the surface of the water (Snohomish County

[7] It is assumed that reclaimed water would be applied at a diffuse subsurface discharge point to maximize dispersal throughout the wetland. If the rate of discharge to the wetland exceeds groundwater flow rates, the reclaimed water would likely rise to and flow across the ground surface.

2009). The lake is classified as meso-eutrophic; the process of eutrophication is indicated by low dissolved oxygen levels throughout the growing season and extending until November (Snohomish County 2009).

- Total phosphorus entering the lake from streams varies from low to high depending on rainfall (16 to 93 µg/L]). Overall levels in Crystal Lake are moderate but have increased slightly between 2006 and 2009 (average range 16 to 20 µg/L; maximum range 24 to 29 µg/L). However, there is insufficient data to determine whether the trend is statistically significant (Snohomish County 2009). Low dissolved oxygen levels can also affect phosphorus cycling in lakes. Phosphorus can be released from bottom sediments when dissolved oxygen is at or near zero, which may promote internal loading of phosphorus and consequent increases in algal production in the spring (Snohomish County 2009).
- The lake supports dense growth of native aquatic plants. Algal blooms occur in the spring, likely because of phosphorus resuspended from sediments and washed into the lake from winter storms and streamflow.

Under the Cottage Lake TMDL, the Daniels Creek subbasin has a total annual phosphorus waste load allocation of 16 kg total phosphorus (June through August) (Washington State Department of Ecology 2007). Any additions of reclaimed water to the Daniels Creek subbasin must not result in phosphorus loading to Cottage Lake above the TMDL.

4.2.2 Analysis of Potential Effects

The Crystal Lake wetland likely provides a high level of water quality function, and thus, the addition of reclaimed water has little potential to enhance the wetland’s water quality improvement functions.

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), the wetland possesses many of the indicators of wetlands that provide a high level of water quality function:

- A highly constricted outlet (presumed)
- Organic (muck) soils
- Persistent vegetation and large areas of seasonal ponding in the majority of the wetland
- Located near the bottom of a largely developed basin, which increases the wetland’s opportunity to slow the flow of water and absorb pollutants draining to the wetland from the urbanized basin

The residence time of water in the Crystal Lake wetland is not known. However, given the surface inundation and saturated soil conditions observed at the end of the driest period of the year, the addition of reclaimed water would likely shorten the residence time if no physical changes were made to the wetland outlet or to the lake’s outlet structure.

For both nutrients and microconstituents, water application rates and effective residence time of water before it is discharged via surface or subsurface connections are key variables that determine the extent to which compounds are removed prior to discharge (King County 2008). Maximizing the distance water travels prior to discharge from the wetland and the extent to which it is spread over a large area (diffuse discharge versus point discharge) would help optimize removal efficiencies.

Nutrient Loading and Removal

Phosphorus is the limiting nutrient for aquatic plant growth, and the additional loading of phosphorus can result in higher algal production. Elevated algal production can reduce water clarity, resulting in less desirable (aesthetic) conditions for recreation. Increased algal production can also result in decreased dissolved oxygen. After plants die, the decomposition process consumes dissolved oxygen and can create oxygen levels too low to support aquatic life.

The concentration of total phosphorus in the reclaimed water after phosphorus reduction would be approximately 1 mg/L; this is approximately 11 to 14 times higher than the maximum total phosphorus concentration measured in stormwater flows entering Crystal Lake (93 µg/L). An additional 46.1 to 115.1 kg total phosphorus per month would enter Crystal Lake under 12- and 7-month scenarios, respectively.

The daily loading rate of total phosphorus, TIN, and TKN would be above the average annual rate specified in the Washington state standards. Under either scenario (12-month or 7-month), the additional phosphorus would likely contribute to algal productivity and potentially increase the rate of eutrophication in Crystal Lake. (See Appendix A for calculations of monthly TIN and TKN loads that would be added to flows from this wetland.)

Nutrient removal performance of the Crystal Lake wetland may be lower than the low end of the average range (less than 50 percent). Because the wetland appears to be saturated throughout the year, reclaimed water applied to the wetland would flow to Crystal Lake within several hours. This would likely allow less time for nutrient removal, result in much higher nutrient loading to Crystal Lake, Daniels Creek, and Cottage Lake than reported above, and be counterproductive to efforts under way to improve water quality in Cottage Lake as specified in the TMDL.

Microconstituent Removal

Reclaimed water can include trace amounts of endocrine-disrupting compounds (EDCs), pesticides, metals, pharmaceuticals, personal care products (PPCPs), and Persistent Bioaccumulative Toxic Chemicals (PBTs).

Available literature on micro-constituents in reclaimed water and their fate and transport in wetlands indicates the following:

- An analysis performed as part of the Kingston Reclaimed Water Study prepared for Kitsap County found that treating wastewater to Class A reclaimed water standards removes 80 percent to 97 percent of EDCs (Golder 2010).
- A study by Hai-Liang Song et al. (2009, as cited by Golder 2010) found that wetlands remove up to 84 percent of EDCs from reclaimed water.
- A literature review performed in 2008 on the fate and transport of these microconstituents in reclaimed water (ICF Jones & Stokes 2008) found that wetlands can be expected to attenuate or degrade microconstituents through the same physical, chemical, and biological processes that improve water quality through removal of nutrients and sediment.

- The fate and transport of constituents in reclaimed water through wetlands is complex and depends on the properties of the chemicals and on the characteristics of the wetland (hydrology, vegetation, soils). Exposure to sunlight; transport through water, soil, and vegetation; biological uptake and transformation; dilution; and other factors can reduce the concentrations and/or biological activity of many of these chemicals (ICF Jones & Stokes 2008).

The short residence time predicted for reclaimed water applied to the Crystal Lake AOI allows for limited removal of microconstituents through microbial action and exposure to sunlight. However, substantial dilution would likely occur, which could reduce the concentration of microconstituents prior to discharge to Crystal Lake and Daniels Creek. Given the dark color of Crystal Lake, less photo degradation would occur in the lake than could be expected in clearer waters.

Effects on Groundwater Quality

Some level of groundwater flow from the Crystal Lake wetland to Daniels Creek above Little Lake and Crystal Lake, to Little Lake, and to Crystal Lake is likely because the wetland soils have some transmissivity. No data exist on the amount of groundwater contribution or the exact contributing area, but application of reclaimed water would likely not increase groundwater flow or have an effect on groundwater quality because of the saturated conditions at the end of the dry season and, thus, limited infiltration.

4.3 Habitat Functions

This section discusses the wildlife and vegetation of the Crystal Lake AOI and analyzes the potential effects on its habitat functions from adding reclaimed water to the area.

4.3.1 Existing Conditions

No specific information was found on wildlife communities occupying the Crystal Lake AOI. This AOI likely supports similar wildlife communities to those of the Cottage Lake AOI, given their proximity and similar types of vegetation communities and habitats (see Chapter 5, Section 5.3.1). The Crystal Lake AOI has several characteristics that indicate it is of a high functional quality as wildlife habitat. Its large size, variety and interspersion of native vegetation communities including an open water component, and diverse species of vegetation indicate that a large number of habitat niches are present. The wetland also forms the western portion of a large undeveloped corridor of forested habitat extending east to Bear Creek.

The vegetatively diverse wetland includes wetland communities indicative of perennially saturated or inundated conditions. As viewed from the edge of the wetland, wetland plants such as lodgepole/shore pine, red alder, lady fern, and bittersweet nightshade were observed. Herbaceous species indicative of perennially saturated or inundated conditions such as skunk cabbage, marsh cinquefoil, and yellow-flag iris were also observed. Western hemlock was observed along the upland berm of the wetland adjacent to Crystal Lake Road. Aerial photographs indicate that the wetland interior supports both emergent and scrub-shrub communities. Evergreens were also observed scattered across the eastern portion of the wetland toward Little Lake.

The presence of mature trees, bog-like conditions, the wetland’s size, and the wetland’s association with a stream system that is hydrologically connected to a salmon-bearing stream indicate the wetland may meet the WDFW definitions of one or more priority habitats, which are considered to be high quality wildlife habitats. Further investigation of WDFW’s Priority Habitats and Species (PHS) program database would be required to determine if this area has been documented as supporting priority habitats.

4.3.2 Analysis of Potential Effects

This wetland likely provides a high level of habitat function. The addition of reclaimed water has little potential to enhance its habitat functions and could have negative effects on observed wetland vegetation communities.

According to the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), the Crystal Lake wetland possesses indicators of wetlands that provide a high level of habitat function:

- Multiple interspersed vegetation classes and hydroperiods
- A diversity of native plant species
- Presence of special habitat features such as downed logs and snags
- A densely vegetated buffer and connections to other nearby wetlands, which increases the wetland’s opportunity to provide habitat for a diversity of species that move across the urbanized landscape between patches of remaining habitat

Given the saturated conditions observed in the fall at the end of the driest part of the year, prolonging the duration and depth of soil saturation and seasonal surface ponding by adding large volumes of water to the wetland would not likely enhance, and could potentially adversely affect, wetland vegetation.

Exposure of Wildlife to Pollutants

The following is general information on the exposure of wildlife to microconstituents from application of reclaimed water to wetlands:

- Although uncertainties exist regarding both the concentrations of some constituents in reclaimed water and the fate and transport mechanisms of specific sites of application, the literature indicates that fate and transport mechanisms in wetlands reduce the biological availability of most residual constituents in reclaimed water (ICF Jones & Stokes (2008).
- The potential is low for exposure of aquatic species in wetlands to constituents in reclaimed water above concentrations at which an effect has been observed (ICF Jones & Stokes (2008). However, another study found that resident and transient fish immediately downstream from the tributary that receives reclaimed water (via enhanced wetlands) could be exposed to EDCs at concentrations that could pose some risk of estrogenic effects. Additional modeling and bioassays focused on reproductive success were recommended to further evaluate potential effects (Golder 2010).
- Data gaps continue to exist regarding fate and transport of some microconstituents (ICF Jones & Stokes 2008).

Effects of Changes in Habitat

Effects on wildlife from enhancement of the Crystal Lake AOI with reclaimed water are more likely to be related to potential changes in habitat than exposure to pollutants. Pacific Northwest wetland plants are sensitive to changes in periods and depths of flooding or ponding. Increasing the depth and duration of soil saturation and surface ponding in the wetland could change the types, density, and interspersion of vegetation communities.

Prolonging the period of saturation reduces the pore water oxygen available to the plants and physiologically compromises the ability of the plants to uptake soil nutrients and maintain their internal water balance. Vegetation intolerant of such conditions could die back, including trees such as black cottonwood, red alder, lodgepole/shore pine, western hemlock, and western red cedar, most shrubs, and most of the herbaceous layer. The amount of open water could increase, which could diminish the vegetative diversity. Increased inundation, duration, and depth may also favor an increase in plant species such as nonnative reed canarygrass and native Douglas spirea that tolerate such conditions at the expense of the wider diversity of plant species currently present within the wetland.

This alteration in habitat could change the mixture of wildlife species that could find inhabitable niches in these wetlands. For example, a decrease in the density and diversity of forested and scrub-shrub vegetation could reduce foraging and nesting opportunities for resident and migratory song birds that depend on these habitats (for example, marsh wren and red-winged blackbird). A consequent increase in open water habitat would provide more resting and possibly foraging habitat for waterfowl (for example, ducks, geese, coots, and grebes). Flooding mature forest trees would temporarily create foraging habitat for insectivorous species such as pileated and downy woodpeckers and northern flickers. However, these habitat features would eventually be lost as snags decay and fall.

4.4 Summary Analysis of Wetland Enhancement and Flow Augmentation Opportunities

Table 4-1shows the results of applying the screening factors to the Crystal Lake wetland. The annual volume of water under consideration for wetland enhancement (730 MG) is not likely to enhance the hydrologic, water quality, or habitat functions of the Crystal Lake wetland. The wetland displays characteristics of high functioning in all three categories. It displays soil saturation and surface ponding throughout the majority of the year, indicating a low potential for enhancement of its functions by adding more water. Adverse impacts on the wetland’s vegetation communities, habitats, and functions could result, even if the volume of reclaimed water were directed to the wetland for a 7-month rather than a 12-month period.

Table 4-1. Summary of Potential for Wetland Enhancement and Streamflow Augmentation at Crystal Lake AOI

Factor	Meets Factor as Suitable for Wetland Enhancement/Flow Augmentation? 7-month Scenario (Apr. to Oct.)	12-month Scenario (Jan. to Dec.)	Summary Explanation
General Characteristics			
Wetland category	Possibly	Possibly	Wetland may be a Category I wetland; definitely at least a Category II wetland.
Size	Yes	Yes	Wetland area is large.
Site potential	Possibly	Possibly	Land adjacent to the wetland is undeveloped; land adjacent to Crystal Lake is developed residential.
Proximity to treatment plant/conveyance pipe	Yes	Yes	AOI is close to the Brightwater plant.
Landscape position	Yes	Yes	Wetland is upgradient from the Bear Creek system.
Hydrologic Functions			
Hydrologic function potential	Yes	Yes	Wetland is a large depressional wetland in an urbanized watershed.
Water budget/water storage capacity	No	No	Saturated soils and surface ponding at the end of driest time of year indicate the wetland does not have capacity, under either 7- or 12-month scenario, to hold more water than current conditions.
Hydraulic connectivity			
a) Benefit from low-flow augmentation	Yes	Yes	Water from the wetland flows to the Bear Creek system, which could benefit from low-flow augmentation.
a) Potential flooding issues	Yes	Yes	Bear Creek system has flooding problems during seasonal high flow periods. A shorter period for applying reclaimed water (July through September) may avoid potential flooding issues.
Soil characteristics			
a) Capacity to transmit water	Yes	Yes	Mapped soil type has shallow depth to groundwater and high capacity to transmit water in a saturated condition to downstream waters.
b) Capacity to support wetlands	Yes	Yes	Mapped soil type is poorly drained, high frequency of ponding, and high available water capacity indicative of poorly drained soils.

Factor	Meets Factor as Suitable for Wetland Enhancement/Flow Augmentation? 7-month Scenario (Apr. to Oct.)	12-month Scenario (Jan. to Dec.)	Summary Explanation
Water Quality Functions			
Mass average loading	No	No	Average mass annual loading would be above Washington state criteria.
Downstream water quality	No	No	Additional phosphorus may exceed the Daniels Creek watershed load allocation specified in the Cottage Lake phosphorus TMDL.
Groundwater quality	Yes	Yes	Infiltration is limited because of saturated conditions.
Soil characteristics	Yes	Yes	Organic (muck) soils are present.
Habitat Functions			
Native plant diversity	No	No	Wetland has high levels of native plant diversity and low dominance of invasive plant species.
Dominant vegetation			
a) Dominated by facultative plant species	No	No	Wetland is dominated by a mixture of plant species, many of which are indicative of saturated soil conditions.
b) Supports vegetation tolerant of higher soil saturation	No	No	Wetland supports a forested vegetation class, which is not tolerant of increased soil saturation and/or inundation.
Wildlife niches	No	No	Wetland supports a high number of wildlife niches that are sensitive to increased water levels.

TMDL = total maximum daily load.

Note: Factors that preclude using AOI for enhancement with reclaimed water are highlighted in blue.

5.0. COTTAGE LAKE AREA OF INTEREST (REDMOND/BEAR CREEK BRIGHTWATER CENTRALIZED STRATEGY)

Cottage Lake is located in suburban Woodinville. Figure 5-1 shows the lake and the surrounding area. The Cottage Lake AOI includes a large wetland area to the west of Cottage Lake as well as the area in and around the lake. Cottage Lake lies in a low valley with gentle slopes rising to the west and a small, low hill to the east of the wetland area. This low hill separates the lake from the large wetland referred to in the King County Wetlands Inventory (King County 1991) as the Big Bear Creek Wetland #10 complex. This wetland complex is also commonly referred to as the Cold Creek Natural Area and is managed collectively with the adjacent Bassett Pond Natural Area (King County 2001).

The Cottage Lake AOI wetland is very large and densely vegetated and appears to have large areas of seasonal ponding with relatively permanently flowing outlets in the form of Daniels Creek and Cottage Lake Creek. The open water area in the southern portion of the wetland is Basset Pond, which has been identified as important for salmonids, waterfowl, and wildlife (King County Department of Construction and Facilities Management 2001).

The Big Bear Creek Wetland #10 was rated as a 1D wetland by the King County inventory (1991). A 1D rating is given to unique or outstanding wetlands (including bogs and estuaries) with the "presence of plant associations of infrequent occurrences" (King County 1991). NWI also has mapped freshwater forested/scrub wetlands and emergent wetlands in the Cottage Lake AOI.

Based on aerial photograph interpretation, the wetland in this area is approximately 129 acres. The approximate wetland boundary extends into 23 parcels, according to King County parcel information (GIS data). The majority of parcels are owned by King County; some parcels along the wetland edges are privately owned.

Early logging opened up the land for farming, and the central portion of the site was formerly used as a blueberry farm (Mary Cash Farm) and as a pasture for cows. A small peat-mining operation once worked the area around Bassett Pond and created the open water wetland existing today. No roads pass through the area, and there is no legal access from the Mary Cash Farm to Bassett Pond (King County Department of Construction and Facilities Management 2001).

The Cottage Lake AOI was observed at three locations during the site visit. The first location was along the southern area off of NE 165th Street along the trail to and along the western margin of Bassett Pond. The second location was at the north end of the wetland complex in a forested/scrub-shrub wetland immediately south of Mary Cash Farm off of NE Woodinville-Duvall Road. The third location was at the south end of the access road that runs south from NE Woodinville-Duvall Road immediately east of the Mary Cash Farm parking lot. This road leads down to the margin of the wetlands. Figure 5-2 shows these observation points.

A review of documents provided by King County indicates that publicly owned parcels in the Cottage Lake AOI have been used by private developers for mitigation site proposals.

The sections that follow provide analyses of the hydrologic, water quality, and habitat functions of the Cottage Lake AOI, with the last section of this chapter presenting a summary of these analyses.

5.1 Hydrologic Functions

This section describes the existing hydrologic features of the Cottage Lake AOI and analyzes the potential effects on wetland hydrologic functions from applying reclaimed water. Chapter 4 (Section 4.1.1) provides a description of the surficial geology of the general region that the Cottage Lake AOI occupies, along with the Crystal Lake and the Sammamish River/Lake Sammamish AOIs.

5.1.1 Existing Conditions

This section describes the existing surficial geology, mapped soils, and hydrology of the Cottage Lake AOI.

Surficial Geology and Mapped Soils

Cottage Lake lies immediately downstream of Crystal Lake and occupies the next lower step or trough in the valley. The surficial geology of Cottage Lake is similar to Crystal Lake in that higher areas surrounding it are composed of till and recessional outwash. Cottage Lake and its wetlands and agricultural wetlands complex overlie recessional outwash. Daniels Creek flows into Cottage Lake, which drains south as Cottage Lake Creek. Cottage Lake Creek begins flowing down a topographic step composed of recessional outwash from about 0.25 mile to 1.25 miles south of the lake. Cottage Lake Creek then flows along the lower gradient trough for about 1 mile to where it joins Bear Creek. The Cottage Lake stream systems (Cold, Daniels, and Cottage Lake creeks) are very low gradient because they are flowing within the inherited proglacial valley. Cottage Lake Creek is steeper where it flows down the topographic step.

Table B-2 in Appendix B presents the properties and qualities of the soils series mapped for this area based on the NRCS Web Soil Survey. Soils in the majority of the area have a high to moderately high capacity to hold and transmit water. However, they are very poorly to poorly drained, typically have a water table at the surface, and frequently have surface ponding. Identified soils are as follows:

- The majority of the area surrounding Bassett Pond is mapped as Seattle muck. The Seattle muck series is considered a hydric soil, indicative of wetland conditions.
- The northern portion of the area around the Mary Cash Farm is mapped as Norma sandy loam. The Norma sandy loam series is considered partially hydric.
- The State of Washington identifies an 85-acre peat resource area south and west of Cottage Lake, centered at Bassett Pond. This peat deposit was approximately 30 feet deep and has been mostly altered from the sphagnum bog condition of the site noted in 1928 (Rigg 1958, p. 74). Bog alterations included burning, agricultural activities, and peat excavation (King County Department of Construction and Facilities Management 2001).

- Pockets of higher ground in the northern half of the Mary Cash Farm are underlain by somewhat excessively drained Everett soils. These soils formed in glacial outwash areas and consist of very gravelly sand to a depth of 18 to 36 inches.
- The extreme southwestern corner of the Bassett Pond area is also underlain by Everett soils (King County Department of Construction and Facilities Management 2001).

Hydrology

Both Cottage Lake and the Big Bear Creek wetland area drain into Cottage Lake Creek. Cottage Lake Creek is part of the Bear-Evans watershed. The hydrology of the wetland is influenced by a shallow groundwater table and surface water features. Cold Creek, Cottage Lake Creek, and Daniels Creek, a number of unnamed springs and tributaries, and Bassett Pond are the main surface water features. All are part of the Bear Creek system that flows south where it is joined by the Evans Creek tributary and from there to the Sammamish River.

Surface hydrology for the Cottage Lake AOI is divided. Daniels Creek flows from Crystal Lake in Snohomish County (described above) under the Woodinville-Duvall Road and enters the northern portion of the AOI. It flows through deciduous-forested and scrub-shrub vegetation in the northern portion of the Cottage Lake AOI before passing through privately held parcels to the east and on to Cottage Lake. The creek has a gentle gradient with glides, riffles, and pools. Substrate includes fines, sand, and small gravels (King County Department of Construction and Facilities Management 2001).

The old Mary Cash Farm agricultural wetlands and additional area to the south slowly drain southeast toward Cottage Lake Creek. Cold Creek enters the southern portion of the Cottage Lake AOI (just north of Bassett Pond) from the west as a large spring just west of 174th Avenue NE. Named because of its low temperatures, this creek flows through mixed-forested wetlands that include a diverse instream structure. A gradual gradient characterizes this reach, causing glides and riffles. Old large woody debris is commonly buried in the stream channel, creating numerous pools. Logs are frequently crisscrossed over the channel, and over-hanging banks are common, especially under coniferous tree roots. Temperatures are as much as 41°F colder than other streams in the Bear Creek system (King County Department of Construction and Facilities Management 2001).

A drainage ditch, which marks the western and southern boundaries of the old Mary Cash Farm, is fed by numerous small perennial springs meandering through forested wetlands and joins Cold Creek just north of Bassett Pond (King County Department of Construction and Facilities Management 2001).

Cottage Lake drains to the southern portion of the wetland via Cottage Lake Creek. Cold Creek joins Cottage Lake Creek and continues as Cottage Lake Creek east of Bassett Pond. Cottage Lake Creek is a King County Class 2 salmonid bearing stream and flows southeast for roughly 3.5 miles to join Bear Creek (King County Department of Construction and Facilities Management 2001).

The outer wetland area margin was saturated with standing water at the time of the site visit. The saturation appeared to extend throughout the majority of the wetland. This observation made at the end of the driest period of the year indicates that the wetland holds near-surface water and has saturated soil conditions that extend through the entire growing season. The water level in

Bassett Pond was also at the bank edge, indicating that the pond remains at capacity for much of the year. The available data reviewed also indicate that the Cottage Lake AOI experiences high water tables and saturated soils throughout the growing season, including during the driest portion of the year.

Local residents have indicated that the wetland sometimes floods, which extends the depth, duration, and extent of surface water. This flooding occurs during periods of high rainfall. The King County Roads Division periodically closes NE 165th Street when surface water extends from the wetland across the road to the wetland south of NE 165th Street.

The lack of water-holding capacity in the wetland could indicate a potential to pass additional water into and through the system to downstream water bodies. Some level of groundwater flow from the Cottage Lake wetland complex to Cold Creek, Daniels Creek, Cottage Lake, Bassett Pond, and Cottage Lake Creek is likely because the various soils have some transmissivity. No data exist on the amount of groundwater contribution or the exact contributing area, although Cold Creek is reported to originate in a spring (King County Department of Construction and Facilities Management 2001).

5.1.2 Analysis of Potential Effects

The analysis found that the Crystal Lake wetland area likely provides a high level of hydrologic function. The addition of reclaimed water under either the 7- or 12-month application scenario holds little potential to enhance the wetland's hydrologic functions and could have negative effects on wetland plant species, vegetation communities, and wildlife habitat.

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), the Cottage Lake wetland possesses the following indicators of wetlands that provide a high level of hydrologic function:

- Large size relative to the size of the contributing basin
- Ponding to 3 feet or more in some areas, particularly in and around Basset Pond (based on field observations of watermarks)
- Landscape position in a basin that contributes to the larger Bear Creek basin and Sammamish River watershed, which increases the wetland's opportunity to reduce flooding and erosion

Because of the duration of surface inundation and saturated soil conditions, the Cottage Lake wetland does not present an opportunity for additional water storage capacity. Surface application of water would result in shorter residence time before the water reaches Cottage Lake Creek, Daniels Creek, Bassett Pond, or Cottage Lake.

It may be possible to add much smaller volumes of water to these wetlands over a very limited seasonal duration (July through September), which could contribute to streamflows in Daniels Creek, Cold Creek, or Cottage Lake Creek. For example, there may be opportunity for adding smaller volumes of reclaimed water to the wetlands near the Mary Cash Farm, which could contribute flows to Cold Creek or Daniels Creek basin. However, NE 165th Street already seasonally floods to the point that local residential access is affected. Additional hydrologic evaluation on this site-specific portion of the wetland complex would be required to determine a volume of water that might be applied, downstream implications of added nutrients, and the potential net environmental benefit.

5.2 Water Quality Functions

This section describes existing water quality functions in the AOI and analyzes the potential effects on nutrient loading and groundwater quality from adding reclaimed water to the Cottage Lake wetland.

5.2.1 Existing Conditions

Because the precise location for potential reclaimed water application has not been determined and water quality data are not available for the AOI, this section describes existing water quality in Cottage Lake and the Bear-Evans watershed using Cottage Lake and Cottage Lake Creek data.

The residence time of water in the Cottage Lake wetlands is not known. However, given the surface inundation and saturated soil conditions observed at the end of the driest period of the year, the addition of reclaimed water would likely shorten the residence time if no physical changes were made to the wetland outlet or to the lake's outlet structure.

Cottage Lake

Water quality data for Cottage Lake are as follows:

- A 2006 regional water quality assessment of lakes in King County reported average total phosphorus concentration for Cottage Lake of 28 µg/L; six years of data indicated that concentrations were increasing (King County 2006).
- The total phosphorus TMDL for Cottage Lake limits the load allocation from all sources (including internal cycling) to 43 kg between June and August. The goal of the TMDL is to reduce average total phosphorus levels to 20 µg/L or below (Washington State Department of Ecology 2007).
- Total nitrogen concentrations for Cottage Lake were approximately 700 µg/L (King County 2006). It is typical in the freshwater environment for total nitrogen concentrations to be approximately 10 times higher than total phosphorus concentrations.
- Summertime surface temperatures in Cottage Lake are typically 66 to 77^{o}F (King County Department of Construction and Facilities Management 2011).

Cottage Lake Creek

In addition to the total phosphorus TMDL for Cottage Lake, the Bear-Evans watershed has TMDLs for temperature, dissolved oxygen, and fecal coliform. The designated beneficial use in this watershed is aquatic life including core summer salmonid habitat and salmonid spawning, rearing, and migration. Non-aquatic uses include water supply, stock watering, wildlife habitat, and recreation, among others (Washington State Department of Ecology 2008).

The stream segments of Cottage Lake Creek downstream of Basset Pond are listed for temperature and dissolved oxygen on Ecology's 2008 303(d) list.[8] Processes that contribute to elevated temperatures include riparian vegetation removal or disturbance, which reduces surface shading and increases direct solar heating; reduced inflows of cool groundwater; reduced summer base flows; and tributaries discharging warm water.

The temperature limit specified in the TMDL is 13°C (55.4°F). The TMDL implementation plan identifies two key actions for reducing temperatures: increasing riparian shading and implementing measures to increase water infiltration and decrease withdrawals of well water. Actions taken to increase riparian shading and maintain and increase base flows in Cottage Lake Creek from groundwater, springs, and seeps will increase groundwater flows and contribute more cooler water to the basin. Using reclaimed water where possible as an alternative to potable water could help reduce groundwater withdrawals under existing permitted uses (Washington State Department of Ecology 2008), and the TMDL mentions use and infiltration of reclaimed water as a means to help increase groundwater flows.

Immediately downstream from Basset Pond, dissolved oxygen levels in Cottage Lake Creek are below the state water quality standards of 9.5 mg/L for core summer salmonid habitat and 8.0 mg/L for salmonid spawning, rearing, and migration. Modeling done for the TMDL indicates that primary productivity of aquatic plants may be limited by light availability, not nutrients (Washington State Department of Ecology 2008). The modeling predicted that an 80 percent reduction in nutrient inputs into the watershed would have little effect on dissolved oxygen and would not raise the concentration above 9.5 mg/L. Thus, increasing riparian shading may be more effective than nutrient reduction in decreasing algal productivity and consequent algal decomposition. The reduction in instream temperatures brought about from the riparian vegetation will also help improve dissolved oxygen concentrations.

5.2.2 Analysis of Potential Effects

The Cottage Lake wetland likely provides a high level of water quality function, and thus, the addition of reclaimed water has little potential to enhance the wetland's water quality improvement functions.

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), the wetland possesses many of the indicators of wetlands that provide a high level of water quality function:

- A relatively permanently flowing outlet
- organic (muck) soils
- Persistent vegetation, and large areas of seasonal ponding in the majority of the wetland
- Emergent vegetation fringing the open water portions of the wetland, which increases the wetland's capacity to trap sediments and remove nutrients

[8] Waters included on the 303(d) list when beneficial uses, such as drinking, recreation, aquatic habitat, and industrial uses, are impaired by pollution.

- Located near the bottom of a largely developed basin, which increases the wetland's water opportunity to slow the flow of water and absorb pollutants draining to the wetland from the urbanized basin

Nutrient Loading and Removal

It is predicted that reclaimed water applied to this wetland would travel through the wetland within several hours. As a result, the proportion of nutrients contained in the reclaimed water removed by the wetlands would likely be at or below the low end of the average range (50 percent or lower). If longer residence times such as a couple of days were possible for the entire volume of reclaimed water considered for wetland enhancement (1,350 MG per year), total phosphorus discharged from the wetland to Cottage Lake Creek would amount to approximately 85.2 to 212.9 kg per month under both the 7- and 12-month scenarios, respectively. The daily loading rate of total phosphorus, TIN, and TKN would be above the average daily rate specified in the Washington State Water Reclamation and Reuse Standards. Calculations for TIN and TKN are included in Appendix A and are not discussed in detail because nitrogen is not the limiting nutrient in this aquatic system.

Temperature and Dissolved Oxygen

The effect of additional phosphorus to the Bear-Evans watershed would require further analysis. Although modeling predicted that reducing total phosphorus by 80 percent would have little effect on dissolved oxygen in the watershed, further analysis would be necessary to determine whether adding more phosphorus would have a similar negligible effect. The addition of cooler reclaimed water (the temperature is predicted to be cooler than when it exits Brightwater at $50^{o}F$) could have a positive effect on both temperature and dissolved oxygen in the watershed if it does not result in increased primary productivity of aquatic plants. A modeling analysis would be necessary to evaluate the tradeoffs between base flows, temperature, and nutrient concentrations for the Bear-Evans watershed and the Sammamish River from application of reclaimed water to wetlands in this basin.

Microconstituents

The short residence time predicted for reclaimed water applied to the Cottage Lake wetland would offer limited opportunity for removal of microconstituents in reclaimed water through microbial action and exposure to sunlight. However, the concentration of microconstituents may be reduced prior to discharge to Cottage Lake Creek through two other processes: dilution and adherence of some materials to sediment particles.

Effects on Groundwater Quantity and Quality

The application of reclaimed water to the surface is not expected to increase groundwater flow, and there would be no expected effects on groundwater quality from the surface application of reclaimed water because of the saturated conditions observed at the end of the dry season and, thus, limited infiltration.

5.3 Habitat Functions

This section discusses the vegetation and wildlife of the Cottage Lake AOI and analyzes the potential effects on its habitat functions from adding reclaimed water to the area.

5.3.1 Existing Conditions

The wetland, associated water bodies, and surrounding area may meet the WDFW definitions of priority habitat for riparian and mature or old-growth forest that provides additional opportunity for habitat. The presence of mature trees and the wetland's size and association with a stream system that is hydrologically connected to a salmon-bearing stream indicate the wetland may be considered a priority habitat. Further investigation of WDFW's heritage program database would be required to determine if this area is recognized as priority habitat.

Vegetation

Vegetation in the areas of the AOI observed during the site visit is diverse with a mix of forest, scrub-shrub, and emergent plant communities. The following vegetation in the Cottage Lake wetland was observed during the visit or is documented in sources reviewed:

- A forested canopy of western red cedar, Douglas fir, and western hemlock was seen in the northern part of the wetland along Daniels Creek. This area had an understory of red alder, high-bush cranberry, salmonberry, Indian plum, lady fern, skunk cabbage, creeping buttercup, sedge, and western mannagrass.
- Red alder snags (generally less than 15 inches in diameter) are scattered throughout the forest. Logs cross over one another on the forest floor under coniferous canopies, forming a substrate commonly used by plant species less tolerant of saturated soil conditions and providing excellent habitat for a variety of forest wildlife and birds (King County Department of Construction and Facilities Management 2001).
- The forested area transitions into a scrub-shrub community south of Daniels Creek, consisting of blueberry, willow, Douglas spirea, cut-leaf blackberry with an understory of yellow-flag iris, creeping buttercup, and reed canarygrass.
- Although past peat mining, burning, ditching, grazing, and mowing have altered historical plant cover in the Basset Pond area, vegetation species indicative of perennially saturated or inundated conditions were observed around the margin of Basset Pond. Species include Labrador tea (also typically indicative of bog conditions), skunk cabbage, various species of sedges, and yellow-flag iris (a nonnative plant, but indicative of long-term saturated conditions). The presence of these species indicates that a perennially saturated or inundated condition likely persists in this area throughout most of the year. Other species observed in the Basset Pond area include birch, Sitka spruce, willow, red-osier dogwood, spirea, and reed canarygrass.
- Other plant species recorded in the AOI include vine maple, devil's club, and red elderberry with less common understory species that include false azalea, salal, red huckleberry, and black gooseberry (King County Department of Construction and Facilities Management 2001).

Aquatic Species

Upper portions of the Cottage Lake Creek subbasin are considered one of the highest quality, salmonid-bearing tributaries in the Big Bear Creek drainage basin. The Bear Creek system supports Chinook, sockeye, coho, and kokanee salmon, steelhead, cutthroat trout, and the largest freshwater mussel population known in King County (King County Department of Construction and Facilities Management 2001).

Cold, Daniels, and Cottage Lake creeks provide spawning and rearing habitat for Chinook and coho salmon, steelhead, and cutthroat trout and spawning habitat for sockeye. Other native fish species observed in these streams are sculpin and stickleback. The high proportion of pools, overhanging banks and logs, and the cold temperatures create ideal rearing habitat for salmonids in Cold Creek and make it a very important part of the Bear Creek system. Tributaries to these creeks may also provide rearing habitat.

Large numbers of Chinook and sockeye salmon spawn in Cottage Lake Creek and Bear Creek. Chinook salmon spawning occurs up to the outlet of Cottage Lake Creek; sockeye salmon spawning generally stops in the forested riparian zone just south of NE 165th Street. Kokanee, a non-anadromous sockeye salmon, also occupy and spawn in the Cottage Lake Creek/Bear Creek system (King County Department of Construction and Facilities Management 2001).

Crappie, bass, perch, trout, and other species have been caught in Bassett Pond, which was stocked in the past.

Pacific chorus frog and western toad were observed in wetlands near Cottage Lake in 1996 during amphibian monitoring. Other native amphibian species expected within the wetland complex include red-legged frog, long-toed salamander, northwestern salamander, Ensatina, and rough-skinned newt. The predatory nonnative bullfrog was also observed in wetlands contiguous with Daniels Creek.

Bird Species

Expansive willow and spirea thickets provide habitat for a variety of bird species, including yellow throat, yellow warbler, song sparrow, and marsh wren. Barn and violet-green swallow can be found around Basset Pond during the breeding season, and a variety of waterfowl use the pond during the winter months. Forest birds often seen in the area include pileated woodpecker, black-capped chickadee, winter wren, golden crown kinglet, Steller’s jay, and American robin (King County Department of Construction and Facilities Management 2001).

Mammals

River otter, beaver, black-tailed deer, bobcat, coyote, black bear, raccoon, cottontail rabbit, and Douglas squirrel have been observed in the Cold Creek area (King County Department of Construction and Facilities Management 2001).

5.3.2 Analysis of Potential Effects

The Cottage Lake wetland likely provides a high level of habitat function. The addition of reclaimed water has little potential to enhance the wetland’s habitat functions and could have negative effects on wetland vegetation communities observed.

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), the Cottage Lake wetland possesses many of the indicators of wetlands that provide a high level of habitat function:

- Multiple interspersed vegetation classes and hydroperiods
- A diversity of native plant species
- Presence of special habitat features such as downed logs and snags
- A densely vegetated buffer and connections to other nearby wetlands, which increases the wetland's opportunity to provide habitat for a diversity of species that move across the urbanized landscape between patches of remaining habitat
- Likely qualifies as a wetland with additional Special Characteristics on the Washington State Wetland Rating System for Western Washington because of its bog community (Hruby 2006)

Exposure of Wildlife to Pollutants

The ICF Jones & Stokes review (2008) concluded there is low potential for exposure of aquatic species in wetlands to constituents in reclaimed water above concentrations at which an effect has been observed, although additional analysis of EDCs may be warranted (Golder 2010). The review also indicated that data gaps continue to exist regarding the fate and transport of some microconstituents (ICF Jones & Stokes 2008).

Changes in Habitat

Effects on wildlife from enhancement of the Cottage Lake AOI with reclaimed water are more likely to be related to potential changes in habitat than exposure to pollutants. The types of potential effects on wildlife habitat would be similar to those that might be experienced in the Crystal Lake wetlands. However, the presence of plant species indicative of bogs in this area and King County's identification of this wetland as a unique resource elevate the sensitivity in evaluating opportunities for enhancing the Cottage Lake AOI with reclaimed water.

The wetland areas visited on October 10, 2011, were saturated to the surface, indicating little available water-storage capacity. Prolonging the duration and depth of soil saturation and seasonal surface ponding by adding the volume of reclaimed water (1,350 MG per year) under consideration would likely have negative effects on the wetland vegetation communities, particularly the rare remnant bog community surrounding Bassett Pond. Hruby (2004) notes that bogs are very sensitive to changes in water regimes or nutrient levels.

Vegetation intolerant of prolonged periods of saturated soil conditions could die back, including trees such as black cottonwood, red alder, Sitka spruce, western hemlock, and western and red cedar (Cooke and Azous 1998). The open water area of Bassett Pond could expand, and the flooded fringe of the wetland could contribute to existing flooding problems along NE 165th Street. Increased inundation, duration, and depth may favor an increase in plant species such as nonnative reed canarygrass and native Douglas spirea that tolerate such conditions at the expense of the wider diversity of plant species currently present in the wetland.

This change in habitat would alter the mixture of wildlife species that would find inhabitable niches in these wetlands. For example, a decrease in the density and diversity of forested and scrub-shrub vegetation could reduce foraging and nesting opportunities for resident and migratory song birds that depend on these habitats. A consequent increase in open water habitat in Bassett Pond could provide more resting and possibly foraging habitat for waterfowl. Flooding mature forest trees would temporarily create foraging habitat for insectivorous species such as pileated and downy woodpeckers and northern flickers as those snags gradually decay.

Altered hydrology, including low base flows and higher peak flows following storms, is a habitat-limiting factor identified in the Lake Washington/Cedar/Sammamish Watershed (WRIA 8) Chinook Salmon Conservation Plan (WRIA 8 Steering Committee 2005). Measures that increase groundwater flows could facilitate salmon conservation and recovery efforts, but these benefits would need to be weighed against potential effects on water quality.

5.4 Summary Analysis of Wetland Enhancement and Flow Augmentation Opportunities

Table 5-1 shows the results of applying the screening factors to the Cottage Lake wetland. The volume of water under consideration for wetland enhancement (1,350 MG per year) is not likely to enhance the hydrologic, water quality, or habitat functions of the wetland. This wetland displays indicators of high functioning in all three categories.

Available water-holding capacity and the potential in increase residence time by adding more water appear to be limited. The wetland has high water tables and saturated soils throughout the growing season, including during the driest portion of the year. Adverse impacts on the wetland's vegetation communities, habitats, and functions could result, even if the volume of reclaimed water was applied to the wetland for a 7-month rather than a 12-month period.

Table 5-1. Summary of Potential for Wetland Enhancement and Streamflow Augmentation at Cottage Lake AOI

	Meets Factor as Suitable for Enhancement/Flow Augmentation		
Factor	**7-month Scenario (Apr. to Oct.)**	**12-month Scenario (Jan. to Dec.)**	**Summary Explanation**
General Characteristics			
Wetland category	No	No	Wetland is likely a Category I wetland, given its bog component
Size	Yes	Yes	Wetland area is large.
Site potential	Possibly	Possibly	Land adjacent to the wetland is undeveloped, but there is dense development downstream
Proximity to treatment plant/discharge pipe	Yes	Yes	AOI is close to the Brightwater plant.
Landscape position	Yes	Yes	Wetland is located upgradient from the Bear Creek system.
Hydrologic Functions			

Factor	Meets Factor as Suitable for Enhancement/Flow Augmentation: 7-month Scenario (Apr. to Oct.)	12-month Scenario (Jan. to Dec.)	Summary Explanation
Hydrologic function potential	Yes	Yes	Wetland is a large depressional wetland in an urbanized watershed.
Water budget/water storage capacity	No	No	Saturated soils and surface ponding at end of driest portion of year indicate wetland does not likely have capacity to hold more water than current conditions, under either the 7- or 12-month scenario.
Hydraulic connectivity			
a) Benefit from low-flow augmentation	Yes	Yes	Water from the wetland flows to the Bear Creek system, which could benefit from low-flow augmentation.
a) Potential flooding issues	Possibly	Yes, seasonal	Bear Creek system has flooding problems during seasonal high flow periods. An area immediately downstream of the wetland also experiences flooding problems. A shorter period for applying reclaimed water (July through September) may avoid potential flooding issues.
Soil characteristics			
a) Capacity to transmit water	Yes	Yes	Mapped soil type has shallow depth to groundwater and high capacity to transmit water in a saturated condition to downstream waters.
b) Capacity to support wetlands	Yes	Yes	Mapped soil type is poorly drained, high frequency of ponding, and high available water capacity indicative of poorly drained soils
Water Quality Functions			
Mass average loading	No	No	Average mass annual loading would be above Washington state criteria.
Downstream water quality	Possibly	Possibly	Bear-Evans Creek TMDL: effects of increased flows and nutrients on downstream temperature and dissolved oxygen are uncertain.
Groundwater quality	Yes	Yes	Infiltration is limited because of saturated conditions.
Soil characteristics	Yes	Yes	Organic (muck) soils are present.
Habitat Functions			
Native plant diversity	No	No	Wetland has high levels of native plant diversity, including rare bog

Factor	Meets Factor as Suitable for Enhancement/Flow Augmentation: 7-month Scenario (Apr. to Oct.)	12-month Scenario (Jan. to Dec.)	Summary Explanation
			community, and low dominance of invasive plant species.
Dominant vegetation			
a) Dominated by facultative plant species	No	No	Wetland is dominated by a mixture of plant species, many of which, including bog species, are indicative of already saturated soil conditions.
b) Supports vegetation tolerant of higher soil saturation	No	No	Wetland supports a forested vegetation class, which is not tolerant of increased soil saturation and/or inundation.
Wildlife niches	No	No	Wetland supports a high number of wildlife niches that are sensitive to increased water levels.

TMDL = total maximum daily load.

Note: Factors that preclude using AOI for enhancement with reclaimed water are highlighted in blue.

6.0. SAMMAMISH RIVER/LAKE SAMMAMISH AREA OF INTEREST (REDMOND/BEAR CREEK BRIGHTWATER CENTRALIZED STRATEGY)

The Sammamish River/Lake Sammamish AOI is a large area that includes land adjacent to the Sammamish River and the southernmost portions of Marymoor Park at the northern tip of Lake Sammamish. Figure 6-1 shows and the area surrounding the river and the northern tip of the lake. The AOI is divided into two areas, Area A and Area B, which are indicated on Figure 6-2:

- Area A is located on the west side of the Sammamish River to the immediate north of the Sammamish Rowing Association. A road that leads to the Sammamish Rowing Association boathouse (which is currently under construction) provided access to observe portions of the area. This area is also adjacent to a small area of wetlands fringing the north end of Lake Sammamish. The size of the existing wetland in Area A was estimated based on aerial photographs to be approximately 54 acres. An additional 17-acre area adjacent to Area A could be suitable for wetland creation. These areas, as well as observation points for Area A, are marked on Figure 6-2.
- Area B is located east of Area A, on the east side of the Sammamish River and encompasses the southern portion of Marymoor Park and the northern end of Lake Sammamish. Extensive lake-fringe wetlands border the lake and transition to upland meadows to the northeast. The existing wetland in Area B is approximately 100 acres. Approximately 9 additional acres may be suitable for wetland creation. These areas, as well as observation points for Area A, are marked on Figure 6-2.

The approximate wetland boundaries extend into 10 parcels, according to King County parcel information (GIS layer). The parcels are owned by King County except for one privately owned parcel along the edge of Area A. King County data also show that the majority of both wetland areas are located within the 100-year floodplain and that portions of the areas adjacent to the Sammamish River are considered floodway areas (GIS layers). NWI has mapped freshwater forested/scrub-shrub wetlands and emergent wetlands in both areas.

This analysis assumes that the annual reclaimed water application rate being considered (730 MG) for this AOI would be divided between Area A and Area B and would be proportional to their sizes. It is assumed that two-thirds would be applied to Area A (487 MG) and one-third (248 MG) would be applied to Area B. Applying these amounts under either the 7- or 12-month scenarios would be the equivalent of 2.3 cm/day.

This chapter describes the surficial geology and mapped soils of the Sammamish River/Lake Sammamish AOI and then provides separate analyses for Areas A and B of existing conditions and the potential effects of adding reclaimed water on hydrologic, water quality, and habitat functions.

6.1 Surficial Geology and Mapped Soils

Lake Sammamish drains into the Sammamish River at the location of the Sammamish River/Lake Sammamish AOI. This location is the beginning of the Sammamish River. Cottage Lake Creek via Bear Creek drains into the Sammamish River just north of the AOI at Marymoor Park. The Sammamish River then flows northwest into Lake Washington.

The surficial geology at the Sammamish River/Lake Sammamish AOI is mapped as river deposits (see the discussion of regional surficial geology in Chapter 4, Section 4.1.1). The Sammamish River historically flowed over and through these deposits as it exited Lake Sammamish. Well data from this location (King County 2005) indicate that these deposits are at least 75 feet deep. A system of levees now restricts the Sammamish River channel.

Table B-3 in Appendix 3 presents the properties and qualities of the soils series mapped for this area based on the NRCS Web Soil Survey. The majority of the wetland area investigated at the north end of Lake Sammamish (Area B) is mapped as Seattle muck, with two small inclusions of Shalcar muck. The area along the eastern bank of the Sammamish River is mapped as Pilchuck loamy fine sand. The lowest lying areas along the western bank of the river (Area A) are mapped as Tukwila muck, while the higher elevation areas on the river's terraces are mapped as Earlmont silt loam and Sultan silt loam.

The muck soils in the majority of the AOI have a high to moderate capacity to hold and transmit water, but are very poorly to poorly drained. They typically have a water table at the surface and frequent surface ponding. The Seattle muck, Shalcar muck, and Tukwila muck series are considered hydric soils, indicative of wetland conditions. The Pilchuck loamy fine sand, Earlmont silt loam, and Sultan silt loam series are considered partially hydric.

6.2 Area A West of the Sammamish River

The sections that follow provide analyses of the hydrologic, water quality, and habitat functions of Area A, with the last section of this chapter presenting a summary of these analyses.

6.2.1 Hydrologic Functions

Below are descriptions of the hydrologic features of Area A and an analysis of the potential effects on wetland hydrologic functions from the application of reclaimed water.

Existing Conditions

Area A is somewhat level. No surface drainage features or any indications of surface ponding were observed in the field at the time of the October 10, 2011, site visit. The presence of irrigation equipment around recent plantings suggests the area is seasonally wet and does not have year-round near-surface soil saturation.

The hydrology of the Area A wetland is likely influenced by a shallow groundwater table. Approximately 0.5 mile downstream, depth to groundwater immediately adjacent to the river was reported to be approximately 6 feet below the ground surface (Shannon & Wilson 2003).

Groundwater observations immediately across the river from Area A (King County 2005) indicate that groundwater flow is toward the river. King County has groundwater wells on the east side of the river (King County 2005). One of these wells is immediately across from Area A and immediately adjacent to the river. This well shows a lowering of approximately 3 feet during the 2003 and 2004 summer seasons. This compares to a lowering of Lake Sammamish levels of only 1.3 feet and 0.1 feet in the 2003 and 2004 summer seasons, respectively (U.S. Geological Survey 2011). This finding indicates that on the east side of the river, groundwater flow is toward the river even when the lake level is high and suggests that groundwater flow toward the river also is likely in Area A.

Because of the wetland's location close to Lake Sammamish and the levees along the Sammamish River, it is not likely that this wetland receives frequent enough over-bank flooding from the river to influence the wetland hydrology.

Analysis of Potential Effects

The analysis found that the Area A wetland likely provides a moderate level of hydrologic function and that the addition of reclaimed water could have some potential to enhance its hydrologic functions.

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), Area A possesses many of the indicators of wetlands that provide a moderate level of hydrologic functions, including the following:

- Small size relative to the size of the contributing basin
- Only shallowly ponds surface water (based on field observations)
- Landscape position high in the Sammamish River watershed and behind the river's levees, which limits the wetland's opportunity to reduce flooding and erosion

Application of 487 MG per year of reclaimed water to Area A for either the 7- or 12-month scenario appears feasible. Observations of conditions in Area A indicate that water-holding capacity and residence time could be increased by adding reclaimed water, particularly under the 7-month scenario. There may be capacity to use additional reclaimed water, depending on the proportion of non-wetland and wetland categories and the total area available for wetland creation. A combination of wetland enhancement and creation on the 17 acres adjacent to Area A (as identified in Figure 6-2) could also create additional capacity to attenuate local stormwater flows during the 7-month and, possibly, the 12-month scenario.

The soils in this area are mapped as Tukwila muck. The Tukwila muck permeability of 0.57 to 1.98 inches per hour (Table B-3 in Appendix B) suggests that water applied to the portions of Area A with muck soils could infiltrate through the soil and flow to groundwater and the river. Inspection of groundwater levels in wells on the east side of the river during the 2003 and 2004 summer seasons (King County 2005) suggests that each acre contributes approximately 3.5 acre-feet of water to river flow. If the west side of the river contributes an equivalent per-acre groundwater volume to the river, then the 54-acre Area A contributes approximately 60 MG of water to the river over the 4-month lowered-groundwater period.

More detailed analysis of the site's water transmissivity characteristics, groundwater flow, and potential for ponding and surface sheet flow are warranted to determine the appropriate amount of reclaimed water and its potential to supplement groundwater and/or surface waters.

6.2.2 Water Quality Functions

This section describes existing water quality functions in Area A and analyzes the potential effects on nutrient loading and groundwater quality from adding reclaimed water to the area.

Existing Conditions

Because both Area A and Area B are at the north end of Lake Sammamish near or at the outflow to Sammamish River, this section describes water quality in the lake and the river. The application of reclaimed water would likely influence water quality in the river more than the lake because of the position of the wetlands in the landscape.

King County has a monitoring station at the Marymoor Park Bridge (Station 0486) where Lake Sammamish drains into the Sammamish River. The County collects and analyzes water, sediment, and benthic invertebrate samples from this station (King County 2011c).

The County has established water quality goals for Lake Sammamish for mean summer (June through September) transparency (13.1 or greater), mean summer chlorophyll-a concentrations (2.8 μ/L or less), and annual mean volume weighted total phosphorus concentration (22 μg/L or less). Between 1997 and 2006, total phosphorus levels in the lake reached, but did not exceed, the 22 μg/L limit in 2004 and 2006. The chlorophyll-a limits were exceeded 8 of the 10 years between 1997 and 2006 at one monitoring station. The goal for water transparency has not been met each year (King County 2011b).

The Sammamish River is categorized as Core Salmon Migration and Rearing Habitat for aquatic life use and Primary Contact for recreational use (King County 2011c). Information on river water quality is as follows:

- The river is on the 2004 Ecology 303(d) list for violation of fecal coliform and water temperature standards. The river is also listed for violations of dissolved oxygen standards (below the standard of 9.5 mg/L).
- A long-term water quality data trend analysis for 1979−2007 completed by King County indicates that water quality may be declining in the river, although there were improvements for some parameters, including total suspended solids, turbidity, nutrients (ortho-phosphate and total phosphorus, ammonia, and total nitrogen), and bacteria levels (King County 2011c).
- Until 2006-2007, Station 0486 was given a "moderate" concern Water Quality Index (WQI)[9] rating based on water quality monitoring results. Since then, the station has been rated as "high" concern, primarily because of high temperatures and low dissolved oxygen concentrations (King County 2011c).
- A two-dimensional water quality model of the Sammamish River was developed to evaluate the effectiveness of possible river restoration actions, such as riparian restoration

[9] Ecology's water quality index aggregates dissolved oxygen, pH, total phosphorus, total nitrogen, turbidity, total suspended solids, temperature, and fecal coliform bacteria measurements over time and expresses results relative to levels required to maintain beneficial uses according to criteria in Washington's Water Quality Standards, Chapter 173-201A WAC. For more information, see http://green.kingcounty.gov/WLR/Waterres/StreamsData/WQIBackGround.aspx.

and projects to increase groundwater inflow, in order to help reduce high water temperatures routinely observed during the summer when river flows are at their lowest (King County 2009).

- Altered hydrology, including low base flows and higher peak flows following storms, is a habitat-limiting factor identified in the Lake Washington/Cedar/ Sammamish Watershed (Water Resource Inventory Area [WRIA] 8) Chinook Salmon Conservation Plan (WRIA 8 Steering Committee 2005). Measures that increase groundwater flows would facilitate salmon conservation and recovery efforts.
- King County completed a water and sediment quality assessment of the Sammamish River from 2001 to 2003 (King County 2005). No contaminants were measured at levels that indicate significant adverse effects. However, the study recommended continued monitoring of arsenic, nickel, polycyclic aromatic hydrocarbons (PAHs), and some endocrine-disrupting chemicals. Macroinvertebrate data indicate the benthic community is stressed and degraded: diversity is low and the community is dominated by low numbers of organisms tolerant to degrading water quality conditions (King County 2005).

Analysis of Potential Effects

The limited information observed and reviewed about conditions in the depressional wetland in Area A indicates that this area may provide moderate to high water quality improvement functions and that it may have capacity to hold more water and thus might benefit from the addition of reclaimed water.

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), the wetland possesses many of the indicators of wetlands that provide moderate to high water quality improvement functions, including the following:

- No apparent outlet
- Dominated by ungrazed vegetation
- Located near the bottom of a largely developed basin, which increases the wetland's opportunity to absorb pollutants draining to the wetland from the urbanized basin

Surface water was not observed during the October site visit, and the extent to which the wetland is inundated with surface water during the winter and spring seasons is unknown. Seasonal ponding over more than half the area of the wetland would indicate high water quality improvement functions.

Reclaimed water applied to Area A would likely have a sufficiently long residence time to ensure nutrient removal rates in the typical range (50 percent to 80 percent). The daily loading rate of total phosphorus to Area A would satisfy the criterion specified in Washington State Water Reclamation and Reuse Standards (0.2 kg/ha/d). Monthly total phosphorus loading would be 30.4 to 76 kg under either the 7- or 12-month application scenario. Total phosphorus concentrations in water exiting the area would be approximately 0.5 to 0.2 mg/L. The average daily loading rate would be exceeded for Total Nitrogen (Appendix A). If additional wetlands were created in the area shown on Figure 6-2, the loading rates would be reduced slightly but would still exceed this criterion.

The nutrient loading values are expected to be lower than these calculations because groundwater residence times would be longer than wetland residence times and there would be more opportunity for phosphorous to bind with sediment. Recognizing that the Sammamish River is an important salmonid resource and that groundwater is an important source of cold water to the river, application of reclaimed water would need to consider the potential for effects on groundwater and river water temperature.

6.2.3 Wildlife Habitat

This section discusses the vegetation and wildlife of Area A and analyzes the potential effects on its habitat functions from adding reclaimed water to the area.

Existing Conditions

Area A is an undeveloped and unmaintained field with a variety of nonnative grasses, forbs, and scattered shrubs. Wetland vegetation, including horsetail, velvet grass, reed canarygrass, creeping buttercup, and willow were observed in the southern portion of this area. Some of these wetland plants are considered facultative, meaning they can occur in upland areas as well as in wetlands. Because of the vegetation in this area, further field study would be needed to determine the proportion of wetlands and uplands. A narrow portion of the area supports wetland plantings that are being irrigated, perhaps as compensatory mitigation for wetland impacts associated with the development of the new rowing club building.

Species of birds frequently sighted along the riparian forest along the Sammamish River include willow flycatcher, common yellowthroat, migrating western tanager, belted kingfisher, American bittern, Wilson’s snipe, and Vaux’s swift (Eastside Audubon n.d.). These species would be expected to use the habitats in and around Area A. Urban-adapted wildlife species such as coyote, raccoon, short-tailed weasel, and various moles, voles, and mice would also be expected to use these habitats.

Analysis of Potential Effects

Using reclaimed water to sustain native wetland and riparian vegetation would likely increase the wildlife habitat value of Area A over its current condition. Increasing the diversity and density of native vegetation would improve vegetation structure and would thus provide more opportunities for wildlife foraging, resting, and breeding. It would also improve the Sammamish River buffer, which is important to supporting salmonid species using the river.

Wetland delineations associated with King County’s Sammamish Outlet Habitat Enhancement program indicate that the undeveloped field south of the Sammamish River outlet is a mix of upland and wetland conditions. This mosaic of upland and wetland conditions likely would continue into the portion of the undeveloped field observed during the site visit.

Wetland enhancement would consist of improving habitat and vegetation diversity by planting a diverse mix of wetland vegetation and using reclaimed water as a source for long-term support of wetland hydrology. The addition of reclaimed water under a 7-month scenario would likely shift the vegetation community to one dominated by greater diversity of wetland plants, such as sedges, rushes, skunk cabbage, and willows, adapted to tolerate wetter soil conditions; additional water could also increase the dominance by invasive reed canarygrass unless steps were taken to excavate soils and remove that plant and its rootmass prior to the addition of reclaimed water.

The addition of reclaimed water under a 12-month scenario could result in prolonged soil saturation and surface inundation, which might limit vegetation diversity to the outer, less ponded portions of the area.

6.3 Area B North End of Lake Sammamish

The sections that follow provide analyses of the hydrologic, water quality, and habitat functions of Area B, with the last section of this chapter presenting a summary of these analyses.

6.3.1 Hydrologic Functions

Below are descriptions of the hydrologic features of Area B and an analysis of the potential effects on wetland hydrologic functions from the application of reclaimed water.

Existing Conditions

The hydrology of the Area B wetland is likely influenced by Lake Sammamish and a shallow groundwater table. The specific groundwater influence of Lake Sammamish and how far landward it extends are unknown.

King County examined four groundwater wells along the west side of Area B (King County 2005). The first well was at the Sammamish River; the other three wells were to the northeast of the first well and adjacent to Area B. The wells do not indicate the depth to groundwater but do show that groundwater flow is toward the river. These wells showed a decrease of more than 3 feet during the 2003 and 2004 summer seasons. During the same periods, Lake Sammamish lowered only 1.3 feet and 0.1 foot, respectively (U.S. Geological Survey 2011). This observation shows that at least along the river, groundwater flows toward the river even when lake levels are somewhat higher.

The extent that surface water from the lake inundates the wetland varies as the lake's surface water elevation changes with the seasons. Water stains on old wooden piers in the lake observed during the site visit indicate that surface water elevations may increase by several feet, which would increase the amount of surface inundation into the wetland. A vegetated swale was observed along the northern edge of the forested/scrub-shrub area of the wetland several hundred feet inland from the lake's edge. The swale was not saturated to the surface at the time of the site visit, indicating it is likely a seasonal swale that drains to Lake Sammamish. Some amount of the lower portion of this swale would likely be inundated by higher lake levels above approximately 31 feet. Such high lake levels commonly occurred prior to 1965 (DeGasperi 2009).

At the time of the site visit, the forested and scrub-shrub wetlands along the lake were saturated with surface water in the majority of the area. The condition became less-saturated as the landscape gradually rose in slope toward the upland meadow area. The upland meadow area did not display any indication of surface ponding.

Analysis of Potential Effects

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), this wetland possesses the following indicators of wetlands that provide a high level of hydrologic function:

- Densely vegetated and forms a long, wide band of vegetation along the lakeshore
- The proximity of Marymoor Park and adjacent forested habitat areas, which increases the wetland's opportunity to reduce the effects of waves and consequent shoreline erosion

The addition of reclaimed water has little potential to enhance the wetland's hydrologic functions. The available data indicate that high water tables and saturated soils are present throughout the growing season, including the driest part of the year, in the portion of the lake-fringe wetland adjacent to Lake Sammamish. As a result, additional water-holding capacity appears to be limited, under both the 7- and 12-month scenarios. However, there could be a potential for these wetlands to pass additional water into and through the wetland to Lake Sammamish and the Sammamish River.

However, approximately 27 acres of upland meadow and wetlands in the AOI north of the lake-fringe wetland could be evaluated in more detail for potential wetland enhancement and/or wetland creation opportunities (as indicated in Figure 6-2). This area is very level, and the only surface drainage feature noted in the vicinity is the swale that leads to the lake. In addition, aerial photographs suggest that there may be a larger channel draining to Lake Sammamish near the very eastern edge of this area.

Additional water-holding capacity and additional residence time could be gained if wetlands were created at this site, particularly under the 7-month scenario. This additional water-holding capacity and residence time could result in the potential to pass additional water into and through the area (via the lake fringe wetlands) and to Lake Sammamish and/or the Sammamish River. These areas could also provide additional capacity to attenuate stormwater flows under the 7-month scenario and, possibly, the 12-month scenario.

The soils in this area are mapped as Seattle muck and Indianola loamy fine sand. The Seattle muck has a transmissivity of 0.57 to 1.98 inches per hour (Table B-3 in Appendix B), which suggests that water applied to Area B could infiltrate through the soil and flow to groundwater and the river. The Indianola loamy fine sand, which is a non-wetland soil, has an even greater transmissivity. Water applied to this soil would infiltrate and flow to groundwater and the river. Inspection of the groundwater levels in wells in the vicinity of Area B during the 2003 and 2004 summer seasons suggests that each acre contributes approximately 3.5 acre-feet of water to river flow (King County 2005). This equates to approximately 30 MG over a 4-month lowered-groundwater period for the 27 acre site.

Specific proportions of wetland categories and non-wetland areas would need to be delineated and more detailed analysis of the site's subsurface soil/geology conditions, water transmissivity characteristics, groundwater flow, and potential for ponding and surface sheet flow would need to be conducted. The analyses could be used to determine (1) whether surface-applied water would infiltrate directly to groundwater or whether there are subsurface impervious layers that would move the water laterally and (2) the appropriate and permissible amount of reclaimed water that could be applied without negatively altering the down-gradient lake-fringe wetland functions or causing or contributing to flooding in the area.

6.3.2 Water Quality Functions

This section addresses existing water quality functions in Area B and analyzes the potential effects on nutrient loading and groundwater quality from adding reclaimed water to the area.

Existing Conditions

See the discussion of existing conditions under "Water Quality Functions" for Area A.

Analysis of Potential Effects

The lake-fringe wetland in Area B likely provides a high level of water quality function. The addition of reclaimed water has little potential to enhance the wetland's water quality improvement functions.

Based on the scoring system of the Washington State Wetland Rating System for Western Washington (Hruby 2006), this wetland provides a high level of water quality function. It possesses these and other characteristics that demonstrate this high functioning:

- A wide, densely vegetated area along the lakeshore, which increases the wetland's capacity to trap and filter/absorb pollutants
- Located near the bottom of a largely developed basin, which increases the wetland's opportunity to absorb pollutants draining to the wetland from the urbanized basin

Assuming the total reclaimed water application area for Area B is 27 acres and an annual application rate of 248 MG, monthly discharge of total phosphorus would be 15.7 to 39.1 kg per month if wastewater were applied over either a 7- or 12-month period. The daily loading rate of total phosphorus would satisfy the criterion specified in Washington State Water Reclamation and Reuse Standards (0.2 kg/ha/d), but the average daily loading rate would be exceeded for Total Nitrogen (Appendix A). Total phosphorus concentrations in water exiting the wetlands would be approximately 0.5 to 0.2 mg/L. Additional analysis would be necessary to determine the effect of additional nutrients on the Sammamish River and Lake Sammamish.

The application of reclaimed water to Area B would be expected to increase groundwater flow, primarily to the river (King County 2005). The calculations for phosphorous and nitrogen loading above indicate reductions of between 50 percent and 80 percent based on wetland residence times. The nutrient loading values are expected to be lower than these calculations because groundwater residence times would be longer than wetland residence times and there would be more opportunity for phosphorous to bind with sediment.

6.3.3 Habitat Functions

This section discusses the vegetation and wildlife of Area B and analyzes the potential effects on its habitat functions from adding reclaimed water to the area.

Existing Conditions

Portions of the lake-fringe wetlands in Area B are identified in the King County Wetland Inventory as Wetland #4 (King County 1991). Wetland #4 is rated as a "1A/B wetland." This rating is given to unique or outstanding wetlands with the presence of federal or state listed, threatened, and endangered species and a "near equal proportion of open water to vegetative cover in dispersed patches in combination with a high diversity or mix of wetland subclasses" (King County 1991).

The wetlands fringing Lake Sammamish are large and densely vegetated with a dense herbaceous understory beneath a forested canopy nearest the lake edge. This area is dominated by black cottonwood and red alder trees and a variety of native shrubs and understory forbs, ferns, and grasses/sedges indicative of saturated or very moist soil conditions. Native wetland understory species observed include Douglas spirea, willow, salmonberry, red-ozier dogwood, and slough sedge. The forested wetland gradually transitions to the north into a more scrub-shrub wetland in which willows and nonnative reed canarygrass are dominant. This portion of the wetland then transitions to a grassy area that eventually becomes an upland meadow. The meadow is dominated by a variety of wetland and upland grasses and small shrubs.

According to Eastside Audubon, more than 200 species of birds have been recorded in Marymoor Park; 50 species are typically observed during a morning bird walk in the park (Eastside Audubon n.d.). Eastside Audubon has an interpretive birding trail that runs through Marymoor Park and includes the grassy meadow and the scrub-shrub and forested wetland that fringes the lake. The organization's Audubon Bird Loop at Marymoor Park brochure (Eastside Audubon n.d).provides the following information:

- The forested and scrub-shrub wetland is home to short-tailed weasel, black-headed grosbeak, Swainson's thrush, marsh wren, Virginia rail, rufous hummingbird, red-eyed vireo, warbling vireo, western wood peewee, great blue heron, Wilson's warbler, yellow warbler, cedar waxwing, red-breasted sapsucker, and downy.
- The lake edge supports grebes, common loon, bald eagles, gulls, Harrier hawk, and osprey, as well as purple martins, tree swallows, and wood duck.
- The grassy meadow is home to many Savannah sparrow in summer and northern shrike and western meadowlark in the winter. The meadow is also used by northern harriers in migration and by short-eared owls in fall and winter. Tree swallow and an occasional coyote are also observed in the meadow. Interpretive signage notes the presence of ground-nesting birds in the grassy area adjacent to the wetlands.

Analysis of Potential Effects

The wetland areas closest to the lake in Area B were saturated near the surface during the site visit in October, indicating little available water storage capacity. Water does not appear to be a limiting factor given the type of wetland vegetation present. Prolonging the duration and depth of soil saturation and seasonal surface ponding by adding reclaimed water to the existing forested wetland could have negative effects on the wetland vegetation communities, including the black cottonwood trees and possibly the more water-tolerant willows that currently dominate the wettest areas along the shoreline. The effect would be greater to the trees that occupy the wetland.

The change in types, density, and interspersion of vegetation communities could consequently change the existing wildlife habitats and alter the mixture of wildlife species that would find inhabitable niches in these wetlands. For example, loss of the forested and scrub-shrub wetlands would affect habitat for species such as the short-tailed weasel, black-headed grosbeak, Swainson's thrush, marsh wren, Virginia rail, rufous hummingbird, red-eyed vireo, warbling vireo, western wood pewee, great blue heron, Wilson's warbler, yellow warbler, cedar waxwing, red-breasted sapsucker, and downy woodpecker, which have been documented using these habitats in Marymoor Park. Flooding mature forest trees would temporarily create foraging habitat for insectivorous species such as pileated and downy woodpeckers and northern flickers as trees die and the resulting snags gradually decay; however, the loss of mature forested habitat would detrimentally affect a wider variety of birds, wildlife, amphibians, and reptiles that depend on forested habitats.

In contrast, the upland meadows adjacent to the lake-fringe wetlands could present an opportunity for wetland enhancement or creation through the addition of reclaimed water. The addition of reclaimed water under both a 7- and 12-month scenario would likely shift the vegetation community to one dominated by greater diversity of wetland plants adapted to tolerate wetter soil conditions, such as sedges and rushes and shrub species such as salmonberry, red-osier dogwood, and willows; additional water could also increase the dominance by invasive reed canarygrass, unless steps were taken to control that species prior to and during the addition of reclaimed water.

Flooding the grassy meadow area with a sufficient volume of water to create wetlands and store reclaimed water would change the suite of wildlife species that would use this area:

- Species such as the Savannah sparrow, northern shrike, and western meadowlark likely would no longer find this area suitable for nesting and foraging.
- Ground-nesting upland bird habitat would no longer occupy this area. Ground-nesting upland bird habitat is not common in the urbanized areas of King County.
- The loss of ground-nesting habitat would also likely affect predatory species such as hawks, owls, and coyotes that prey on the birds, reptiles, and small mammals that inhabit upland meadows.
- Species adapted to wetter habitats, such as garter snake, chorus frogs, red-legged frogs, and birds, such as marsh wrens, red-winged blackbirds, and great blue herons, would find foraging habitat in the enhanced or created wetland areas.

The impacts of the changes in habitat from grassy meadow to wetland would have to be evaluated further, particularly in light of the extensive human use of the area and its reputation as an excellent location to see ground-nesting birds.

6.4 Summary Analysis of Wetland Enhancement and Flow Augmentation Opportunities

Table 6-1 and Table 6-2 show the results of applying the screening factors to the Sammamish River/Lake Sammamish AOI.

The wetland in Area A and the grassy meadow adjacent to the Area B wetland may be suitable for a combination of wetland enhancement/creation with reclaimed water. The residence time of reclaimed water applied to either Area A or B would be much longer than with either the Crystal Lake or Cottage Lake AOIs, and as a result, further chemical, physical, and biological degradation would occur to remove microconstituents from the reclaimed water before it flows to Lake Sammamish or Sammamish River. However, there are ecological constraints related to existing functions of Area B (such as upland bird habitat) and potential social constraints, such as property ownership and proximity to existing recreational uses in the park, including a model airplane field, that would require additional evaluation.

The addition of the water volumes under consideration (730 MG per year) is not likely to enhance the water quality, flood flows/erosion reduction, or habitat functions of the large Area B lake-fringe wetlands at the top of Lake Sammamish in Marymoor Park. Available data indicate that these wetlands experience high water tables and saturated soils throughout the growing season, including during the driest part of the year. Available water-holding capacity and additional residence time that could be gained by adding water to this wetland appear to be limited. Adverse impacts on vegetation communities could result from the addition of the volumes of water projected, even if the water were applied for a 7-month, rather than a 12-month, period.

Table 6-1. Summary of Potential for Wetland Enhancement and Streamflow Augmentation in Area A (Lake Sammamish/Sammamish River AOI)

	Meets Factor as Suitable for Enhancement/Flow Augmentation		
Factor	**7-month Scenario (Apr. to Oct.)**	**12-month Scenario (Jan. to Dec.)**	**Summary Explanation**
General Characteristics			
Wetland category	Yes	Yes	Wetland is likely a Category II or III wetland.
Size	Yes	Yes	Wetland area is large.
Site potential	Possibly	Possibly	Land adjacent to the wetland is partially developed.
Proximity to treatment plant/conveyance pipe	Yes	Yes	Proximity to Brightwater Treatment Plant.
Landscape position	Yes	Yes	Wetland is upgradient from Sammamish River and Lake Sammamish.
Hydrologic Functions			
Hydrologic function potential	Yes	Yes	Wetland is a large depressional wetland in an urbanized watershed.
Water budget/water storage capacity	Yes	Yes	Wetland appears to have capacity to hold more water than current conditions under either 7- or 12-month scenario.
Hydraulic connectivity			
a) Benefit from low-flow augmentation	Yes	Yes	Water from the wetland flows to the Sammamish River system, which could benefit from low-flow augmentation.
b) Potential flooding issues	Possibly	Possibly	Areas surrounding the wetland may experience flooding problems.
Soil characteristics			
a) Capacity to transmit water	Yes	Yes	Mapped organic soil type has shallow depth to groundwater and high capacity to transmit water in a saturated condition to
b) Capacity to support wetlands	Yes	Yes	

Factor	Meets Factor as Suitable for Enhancement/Flow Augmentation: 7-month Scenario (Apr. to Oct.)	Meets Factor as Suitable for Enhancement/Flow Augmentation: 12-month Scenario (Jan. to Dec.)	Summary Explanation
			downstream waters. Mapped organic soil type is poorly drained; high frequency of ponding and high available water capacity indicate poorly drained soils. Mapped non-wetland mineral soil type is somewhat excessively drained, is deep to groundwater, and has a high capacity to transmit water to downstream waters.
Water Quality Functions			
Mass average loading	Possibly	Possibly	Average mass annual loading meets Washington state criterion for phosphorus but not nitrogen.
Downstream water quality	Possibly	Possibly	Additional nutrient removal may occur as water flows through groundwater to Sammamish River (additional analysis necessary).
Groundwater quality	Yes	Yes	Additional nutrient removal may occur as water flows through soils.
Soil characteristics	Yes	Yes	Organic (muck) soils may be present.
Habitat Functions			
Native plant diversity	Yes	Yes	Wetland has low levels of native plant diversity.
Dominant vegetation			
a) Dominated by facultative plant species	Yes	Yes	Wetland is dominated by a mixture of facultative plant species.
b) Supports vegetation tolerant of higher soil saturation	Yes	Yes	Wetland primarily supports emergent and shrub vegetation, which can be tolerant of increased soil saturation and/or inundation.
Wildlife niches	Yes	Yes	Wetland appears to support a limited number of wildlife niches.

Note: Factors that preclude using AOI for enhancement with reclaimed water are highlighted in blue.

Table 6-2. Summary of Potential for Wetland Enhancement and Streamflow Augmentation in Area B (Lake Sammamish/Sammamish River AOI)

Factor	Meets Factor as Suitable for Enhancement/Flow Augmentation: 7-month Scenario (Apr. to Oct.)	Meets Factor as Suitable for Enhancement/Flow Augmentation: 12-month Scenario (Jan. to Dec.)	Explanation
General Characteristics			
Wetland category	Yes	Yes	Area does not appear to be a wetland.
Size	Yes	Yes	Large available area.
Site potential	Possibly	Possibly	Adjacent land and grassy meadow are used for recreation.
Proximity to treatment plant/discharge pipe	Yes	Yes	Proximity to Brightwater Treatment Plant.
Landscape position	Yes	Yes	Area is located upgradient from Lake Sammamish
Hydrologic Functions			
Hydrologic function potential	Possibly	Possibly	Sloping area in urbanized watershed, but there is potential space for a depression to be created.
Water budget/water storage capacity	Possibly	Possibly	A depression could be created to hold water under either 7- or 12-month scenario.
Hydraulic connectivity			
a) Benefit from low-flow augmentation	Yes	Yes	Water flows to the Lake Sammamish system, which could benefit from low-flow augmentation.
b) Potential flooding issues	Possibly	Possibly	The surrounding area in Marymoor Park experiences flooding problems.
Soil characteristics			
a) Capacity to transmit water	Yes	Yes	Mapped soil type has shallow depth to groundwater and high capacity to transmit water in a saturated condition to downstream waters.
b) Capacity to support wetlands	Yes	Yes	Mapped soil type is poorly drained; high frequency of ponding and high available water capacity indicate poorly drained soils.
Water Quality Functions			
Mass average loading	Possibly	Possibly	Average mass annual loading meets Washington state criterion for phosphorus but not for nitrogen.

Factor	Meets Factor as Suitable for Enhancement/Flow Augmentation: 7-month Scenario (Apr. to Oct.)	Meets Factor as Suitable for Enhancement/Flow Augmentation: 12-month Scenario (Jan. to Dec.)	Explanation
Downstream water quality	Possibly	Possibly	Additional nutrient removal would occur as water flows through groundwater to Sammamish River (additional analysis necessary).
Groundwater quality	Yes	Yes	Additional nutrient removal would occur as water flows through soils and sediments.
Soil characteristics	Yes	Yes	Organic (muck) soils may be present
Habitat Functions			
Native plant diversity	Yes	Yes	Area has low levels of native plant diversity
Dominant vegetation			
a) Dominated by facultative plant species	Yes	Yes	Area dominated by a mixture of facultative plant species.
b) Supports vegetation tolerant of higher soil saturation	Yes	Yes	Area primarily supports emergent and grass vegetation; shift to species tolerant of increased soil saturation and/or inundation is expected.
Wildlife niches	Possibly	Possibly	Area supports important and regionally rare ground-nesting bird habitat

Note: Factors that preclude using AOI for enhancement with reclaimed water are highlighted in blue.

7.0. CEDAR RIVER AREA OF INTEREST (RENTON/TUKWILA SOUTH PLANT CENTRALIZED STRATEGY)

The Cedar River AOI is located near the Cedar River in Renton. Figure 7-1 shows the river area and surroundings for this AOI. The area is under consideration for wetland creation. The vegetation, geomorphic position, and potential for wetland hydrology indicate that there are no wetlands in the area.

The Cedar River AOI is along the south side of the Cedar River on a high terrace located just east of where Interstate 405 (I-405) crosses the river. The terrace surface includes a mowed grassy area, the paved Cedar River Trail, a large asphalted area that appears to be used for storing and managing mulch piles, and an off-leash dog park. The area transitions to a steep forested slope. The AOI extends into five parcels, according to King County parcel information (GIS layer). All parcels are owned by the City of Renton.

The approximate size of this area, based on aerial photograph interpretation, is 30 acres. Approximately half of the AOI is used for the dog park and the large asphalted area is used for mulch storage. The area under consideration for wetland creation is a 16-acre upland terrace along the banks of the Cedar River, as indicated in Figure 7-2. The terrace sits approximately 15 to 20 feet above the grade of the river. Steep slopes are present in much of this area with evidence of active small-scale mass wasting along the bluff to the river.[10] Since there are no wetlands at this location, the reclaimed water application rate could be up to 5 cm/day for a constructed beneficial use wetland, although initial analysis considered a conservative application rate of 2 cm/day.

Observation areas were along the trail and upper slope along the river, the asphalt area, and the dog park. Figure 7-2 shows the observation points for this AOI. The site visit did not include walking along the river grade because of the steep banks; however the river and the banks along both sides of the river were observed from the terrace edge. There is a narrow band of trees along the terrace slope edge with upland mowed grasses on either side of the trail and between the trail and the slope bank. The dog park is unvegetated mulch. Upland grasses and small shrubs grow between breaks in the asphalt in places.

The sections that follow provide analyses of the hydrologic, water quality, and habitat functions of the Cedar River AOI, with the last section of this chapter presenting a summary of these analyses.

7.1 Hydrologic Functions

This section describes the existing hydrologic features of the Cedar River AOI and analyzes the potential effects on wetland hydrologic functions from applying reclaimed water.

[10] Mass wasting is bulk movement of soil and rock debris down slopes.

7.1.1 Existing Conditions

Below are descriptions of the existing surficial geology, mapped soils, and hydrology of the Cedar River AOI.

Surficial Geology and Mapped Soils

The Cedar River system was influenced by the Puget Sound glacier lobe. Unlike the other AOIs considered in this analysis, the Cedar River originates in the Cascade Mountains to the east and flows across the lowlands and into the south end of Lake Washington at Renton. It is a postglacial river that in its lower reaches, flows through a valley incised into till and recessional outwash-covered uplands (Collins and Montgomery 2011). Some older glacial deposits are exposed along the valley margin; an outcrop of bedrock is also present. Although there are active river deposits along the Cedar River, the Cedar River AOI is composed of older river deposits approximately 20 feet thick.

Table B-4 in Appendix B presents the properties and qualities of the soils series mapped for this area based on the NRCS Web Soil Survey. The majority of the soil in the area investigated along the south side of the Cedar River is mapped as Urban Land. The forested slopes adjacent to the river are mapped as Alderwood and Kitsap soils, which are very steep. Neither soil series is considered a hydric soil. Soils mapped as Urban Land are typically dry soils that drain quickly; Alderwood and Kitsap series soils are also typically moderately well drained soils with a water table 18 to 37 inches below the surface.

Hydrology

The Cedar River AOI does not currently provide hydrologic functions related to reducing flooding and erosion. The review of background materials and the observations made during the site visit indicate that the area does not support wetlands. No surface hydrologic features and no evidence of soil saturation or surface ponding were observed during the site visit.

Soil exposure along the river indicates that the terrace is composed of sorted gravels and sands deposited by the Cedar River. These materials have high permeability and transmissivity. Because of the proximity to the river, water applied to a created wetland would likely flow into the river via groundwater, not to the underlying and deeper Cedar Valley Aquifer.

7.1.2 Analysis of Effects

Observations of conditions in this area indicate that additional water-holding capacity and residence time might be possible if wetlands were created under both the 7- and 12-month scenarios. Installation of an impermeable (or a partially permeable) soil layer at a depth below the wetland may make wetland creation feasible while minimizing the potential for slope instability caused by additional groundwater flows. This layer would minimize or prevent water infiltration into the underlying porous gravels and sands. Reclaimed water that did not infiltrate would primarily run off over the surface.

More detailed analysis of water transmissivity characteristics, groundwater flow, and potential for ponding and surface sheet flow are warranted to determine the appropriate amount of reclaimed water and its potential to supplement groundwater and/or surface water without contributing to seasonal flooding.

In addition, any potential for changes to Cedar River flow in this area likely would need to be evaluated relative to the nearby Seattle Public Utilities and WDFW weir and fish trap located in the river under I-405 near the Cedar River AOI. The weir and fish trap are usually installed each September and removed in late November or early December. The facility is designed to collect sufficient broodstock for the Cedar River Sockeye Hatchery Program and to address regulatory requirements related to hydroelectric impacts on the migration of adult Chinook, coho, and sockeye salmon returning to spawn in the Cedar River (Seattle Public Utilities 2008).

There may also be constraints related to the proximity of the site to the federal flood control levees managed by the U.S. Army Corps of Engineers (Corps). The Corps prohibits vegetation other than grass within 15 feet of the toe of a flood-control levee; it also prohibits vegetation that could create subsurface seepage pathways near the toe of a levee.

7.2 Water Quality Functions

This section describes existing water quality functions in the AOI and analyzes the potential effects on nutrient loading and groundwater quality from adding reclaimed water to the proposed wetland.

7.2.1 Existing Conditions

The Cedar River is the largest and cleanest source of water for Lake Washington, contributing almost 50 percent of the lake's total inflow (King County 2011e). The Cedar River basin lies above the Cedar Valley Aquifer, a sole-source aquifer that is the City of Renton's drinking water source. (See King County 2012 for additional information on the extent and location of the aquifer.) The water quality in the Cedar River is generally very good. However, there are some problems, such as sporadic exceedances of the state water quality standard for fecal coliform bacteria (King County 2011e).

Waters in the lower reaches of the river from its mouth at Lake Washington upstream to Chester Morse Lake are categorized as Core Summer Salmonid Habitat for aquatic life use, and the river is designated Primary Contact Recreation for recreational use from the mouth to river mile (RM) 4.1. As part of the updated State water quality standards (WAC 173-201A-600 and 602), the lower portions of the river have been assigned an additional Supplemental Spawning and Incubation Protection temperature criterion of 55.4^{o}F, applicable from fall (September 15th) until spring (June 15th) (Ecology 2011, King County 2011d).

The Lower Cedar River basin's most significant water quality problems are total phosphorus loadings into Lake Washington, locally toxic concentrations of urban pollutants, high fecal coliform counts, and localized sediment problems (King County 2011e). King County has been monitoring water quality in this reach of the river because of the significant increases in water temperature, total phosphorus, and pH. As of October 2011, over the last six water years (October 1 through September 30), the station at the mouth of the Cedar River (X438) has been assigned a WQI rating of moderate concern, primarily because of high fecal coliform, low summer dissolved oxygen, and high nutrient levels (King County 2011d).

7.2.2 Analysis of Potential Effects

It would take approximately two years to fully establish a wetland in the area; once established, the water quality functions of the created wetland would be similar to those of an existing wetland (Kadlec and Wallace 2009). Nutrient removal efficiencies would likely increase as vegetation became established and organic carbon accumulated to facilitate denitrification (Bachand and Horne 2000; Burgoon et al. 1999; Shannon et al. 2000).

Nutrient Loading and Removal

It is assumed that once the wetland was established, nutrient removal efficiencies would be within the same range used in the analysis of other wetlands (50 percent to 80 percent). The volume of reclaimed water under consideration for wetland creation (183 MG per year) would result in a daily loading rate of total phosphorus and total nitrogen above the criteria specified in the Washington State Water Reclamation and Reuse Standards (see Appendix A). Discharge of total phosphorus would likely be between 23.0 and 57.6 kg per month.

If the wetland creation project were designed to allow for subsurface percolation of water from the wetlands to the river, additional nutrient removal would occur as the water passed through and bound with sediments. However, eroding sediment can be a significant source of phosphorus in the aquatic environment as the phosphorus that is bound to sediment particles dissolves or becomes resuspended. Design would require careful consideration of slope stability of the terrace to ensure that the additional water added to the terrace did not result in sloughing or erosion. The Corps levees would also pose design constraints regarding the type and proximity of vegetation.

Microconstituent Removal

The residence time of reclaimed water applied to a created wetland above Cedar River would allow for some chemical, physical, and biological degradation of microconstituents in the reclaimed water before it left the wetland. Additional soil adsorption and biodegradation would occur as the water infiltrated through sediment (ICF Jones & Stokes 2008) before reaching the Cedar River. However, as specified in the Washington State Water Reclamation and Reuse Standards (1997), investigation would be required to demonstrate that hydrogeologic conditions are adequate to prevent degradation of groundwater.

7.3 Habitat Functions

This section discusses the vegetation and wildlife of the Cedar River AOI and analyzes the potential effects on its habitat functions from adding reclaimed water to the area.

7.3.1 Existing Conditions

A narrow riparian corridor is present on the south side of the Cedar River on the terrace above the river’s steep banks. Big leaf maple and red alder and shrubs, such as snowberry and Himalayan blackberry, are present. Adjacent to the riparian corridor is a mowed grass lawn area that extends to the Cedar River Trail. Between the trail and the steep-forested slopes are the dog park (primarily unvegetated and covered with bark mulch) and the asphalted area used for mulch storage.

The narrow corridor of riparian vegetation and steep-forested slopes provide habitat for wildlife species. The dog park, trail, and asphalted area fragment this potential wildlife corridor. Avian and mammal species commonly seen in urban areas would likely use this habitat, such as coyote, raccoon, short-tailed weasel, moles, voles, mice, and a wide diversity of song birds and raptors including the red-tailed hawk and great-horned owl.

7.3.2 Analysis of Potential Effects

This area could potentially be developed into a wetland if a restricting soil layer were installed to help retain near-surface soil saturation and ponding sufficient to support hydrophytic vegetation. Grading to remove the blackberries would be required. A diversity of native trees and shrubs such as black cottonwood, red alder, Douglas-fir, snowberry, rose, and salmonberry could be supported along the outer edges of a created wetland, with the more consistently saturated areas planted with a variety of native sedges and rushes. A permanently ponded central area would add habitat diversity.

Environmental enhancement could also be considered by removing the dog park and asphalted area and planting a variety of native trees to improve/increase the riparian buffer along the river. Reclaimed water could be applied to support a riparian-forested area to connect the adjacent upland-forested slopes to the thin strip of existing forested habitat along the river.

Wildlife use of the forested slopes adjacent to the Cedar River AOI would likely not be directly affected by creation of a wetland in this area. However, creating a wetland or densely vegetated riparian area at the toe of the slope could provide additional wildlife habitat, particularly for riparian associated species of song birds and mammals. Increasing the amount of native vegetation to create contiguous habitat from the steep-forested slopes to the riparian corridor would reduce the fragmented habitat and provide increased opportunity for wildlife use. Increasing the riparian buffer adjacent to salmon-bearing streams could also likely benefit the river by reducing runoff and input of pollutants into the stream.

A wetland created in this area would not be connected via surface water with the Cedar River; salmonids and other aquatic organisms in the river would not have direct contact with reclaimed water before it infiltrated through the wetland, percolated through underlying sediments, and mixed in the river. Although low summer flows are identified as a habitat-limiting factor for Chinook salmon in WRIA 8 (WRIA 8 Steering Committee 2005), flow augmentation in this part of the river that is so close to Lake Washington is unlikely to result in measureable habitat benefits.

7.4 Summary Analysis of Wetland Enhancement and Flow Augmentation Opportunities

Table 7-1 shows the results of applying the screening factors to the Cedar River AOI.

This AOI may present an opportunity for wetland creation via reclaimed water at the volume of water being considered (183 MG) under both the 7- and the 12-month scenarios. However, additional analysis of slope stability, groundwater connection, and implications for proximity to the river’s levee system would be needed to advance this concept. In addition, this area may also have social constraints related to existing recreational uses such as the riverfront trail and off-leash dog park area.

Table 7-1. Summary of Potential for Enhancement and Streamflow Augmentation in Cedar River AOI

Factor	Meets Factor as Suitable for Enhancement/Flow Augmentation: 12-month Scenario (Jan. to Dec.)	Explanation
General Characteristics		
Wetland category	Yes	The area does not appear to be a wetland
Size	Yes	AOI is large.
Site potential	Possibly	The land upslope from the AOI is undeveloped.
Proximity to treatment plant/discharge pipe	Yes	AOI is close to South Treatment Plant.
Landscape position	Yes	AOI is located upgradient from the Cedar River.
Hydrologic Functions		
Hydrologic function potential	Yes	A depressional area could be created; in the urbanized watershed.
Water budget/water storage capacity	Yes	An area could be created with capacity to hold water under either 7- or 12-month scenario.
Hydraulic connectivity		
a) Benefit from low-flow augmentation	Possibly	Possible to connect to Cedar River; if done this could provide a small benefit for low-flow augmentation.
b) Potential flooding issues	Possibly	Levee bordering the site may be a constraint.
Soil characteristics	Possibly	Suitable soils could be imported.
Water Quality Functions		
Mass average loading	No	Average mass annual loading would be above Washington state criteria.
Downstream water quality	No	Substantial mixing would occur in the Cedar River; analysis would be necessary to confirm that negative effect would not occur.
Groundwater quality	No	Water would likely flow into the Cedar River and not to groundwater
Soil characteristics	Possibly	Suitable soils could be imported.
Habitat Functions		
Native plant diversity	Yes	AOI has low level of native plant diversity.

Factor	Meets Factor as Suitable for Enhancement/Flow Augmentation 12-month Scenario (Jan. to Dec.)	Explanation
Dominant vegetation		AOI is dominated by a mixture of facultative plant species.
a) Dominated by facultative plant species	Yes	
b) Supports vegetation tolerant of higher soil saturation	Yes	Species tolerant of increased soil saturation and/or inundation could be planted.
Wildlife niches	Yes	AOI supports a limited number of wildlife niches.

Note: Factors that preclude using AOI for enhancement with reclaimed water are highlighted in blue.

8.0. RECOMMENDATIONS FOR FURTHER STUDY

The analysis documented in this report is a preliminary site-specific evaluation of the feasibility of applying reclaimed water to the four candidate areas in the two strategy areas. Additional studies would be needed to thoroughly assess potential environmental effects from the application of reclaimed water and to develop designs for wetland enhancement/creation at selected areas.

The first step would be to determine wetland categories and specific areas suitable for wetland enhancement or creation through a wetland delineation and functional assessment. Information from this assessment could be used to identify specific types and the sequence of necessary additional studies. These additional studies would include hydrologic analysis. It could be appropriate to conduct an intermediate level of hydrologic analysis on these newly identified areas. This analysis could evaluate infiltration rates, groundwater flow rates, and surface flow rates to determine if the site has sufficient capacity to justify more detailed analysis. Detailed analysis might consist of drilling bore holes to more carefully determine site stratigraphy, grain size texture, and permeability, followed by a thorough flow model.

Recommended studies include the following:

- **Wetland delineation, functional assessment and wetland boundary and topographic survey.** The wetland delineation would identify the boundaries of each wetland, identify wetland regulatory categories, and assess existing wetland functions.
- **Vegetation and wildlife surveys, including amphibian and aquatic invertebrate sampling.** These studies would supplement the wetland functional assessment and would establish baseline conditions to satisfy biological criteria (Ecology and Health 1997); to evaluate the potential for changes to vegetation communities, wildlife habitats, breeding areas, and general use; and to assess potential effects related to changes to the benthic food chain.
- **Surface and groundwater monitoring.** The monitoring would be conducted for at least one year to gain site-specific understanding of fluctuations in surface water and groundwater levels. This analysis would help determine the duration and depth of soil saturation and surface water, the effect on vegetation, and the resultant surface water elevation based on different application rates. This analysis could also assess flooding risks and opportunities to create additional stormwater retention capacity.
- **Surface water quality monitoring and modeling analysis.** The analysis would assess effects of nutrients on downstream waters and the fate and transport of microconstituents. This analysis would be required to demonstrate that a higher mass loading rate could be assimilated without violating the biological criteria in Article 4 of the Washington State Water Reclamation and Reuse Standards (Ecology and Health 1997).
- **Geotechnical analysis.** The Cedar River site would require a determination of the risk of surface erosion and mass wasting.

- **Site-specific hydrogeologic investigation.** For areas that could result in groundwater recharge, a hydrogeologic investigation would be required to show that conditions are adequate to prevent degradation of groundwater quality.
- **Review of peak lake levels.** This review would need to be incorporated into the enhancement design and analysis to confirm the frequency and duration of flooding.
- **Coordination with the U.S. Army Corps of Engineers.** The coordination would be necessary to ensure that restrictions relative to wetland enhancement/creation in areas bordered by river levees are honored.

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Appendix A

Water Quality Calculations

Table A-1. Scenario 1—inflow 365 days/year

	Annual Volume (MG)	Average daily (mgd)[a]	Annual Vol. (Million L)	Average daily (mLd)	Wetland Area (acres)	Annual Loading (kg/yr)			Loading Rate (kg/acre/yr)			Wetland discharge (kg/mo)[f]					
						TP[b]	TKN[c]	TIN[d]	TP[b]	TKN[c]	TIN[d]	TP (50% removal)	TP (80% removal)	TKN (50% removal)	TKN (80% removal)	TIN (50% removal)	TIN (80% removal)
Brightwater[e]																	
Cottage Lake	1350	3.7	5110.3	14.0	36.7	5110.3	15330.9	40882.4	139.1	417.4	1113.0	212.9	85.2	638.8	255.5	1703.4	681.4
Crystal Lake	730	2.0	2763.4	7.6	40.4	2763.4	8290.1	22106.8	68.4	205.2	547.1	115.1	46.1	345.4	138.2	921.1	368.4
Sammamish Slough[e]																	
Wetland A	481.8	2.0	1823.8	7.6	54.0	1823.8	5471.4	14590.5	33.8	101.3	270.2	76.0	30.4	228.0	91.2	607.9	243.2
Wetland B	248.2	2.0	939.5	7.6	27.0	939.5	2818.6	7516.3	34.8	104.4	278.4	39.1	15.7	117.4	47.0	313.2	125.3
A & B Total	*730*	*4.0*	*2763.4*	*15.1*	*81.0*	*2763.4*	*8290.1*	*22106.8*				*115.1*	*46.1*	*345.4*	*138.2*	*921.1*	*368.4*
South Plant[e]																	
Cedar River Wetland	182.5	0.5	690.8	1.9	16	690.8	2072.5	5526.7	43.2	129.5	345.4	28.8	11.5	86.4	34.5	230.3	92.1
Cedar River Wetland	176	0.5	666.2	1.9	16	666.2	1998.7	5329.9	41.6	124.9	333.1	27.8	11.1	83.3	33.3	222.1	88.8

[a] Steady flow 24/7 assumed

[b] TP = Total phosphorus

[c] TKN = Total Kjeldahl nitrogen; includes ammonium (NH4-N) and Org-N

[d] TIN = Total inorganic nitrogen; includes ammonia, nitrate and nitrite-nitrogen

[e] Influent characteristics: TKN 3 mg/L, TIN 8 mg/L, phosphorus 1 mg/L

[f] High-range nutrient removal efficiency = 80%; low-range nutrient removal efficiency = 50 % (Mitsch & Gosselink, 1993)

Table A-2. Scenario 2—inflow 7 months/year (April–October, 214 days)

	Annual Volume (MG)	Average daily (mgd)[a]	Annual Vol. (Million L)	Average daily (mLd)	Wetland Area (acres)	Annual Loading (kg/yr)			Loading Rage (kg/acre/yr)			Wetland discharge (kg/mo)[f]					
						TP[b]	TKN[c]	TIN[d]	TP	TKN	TIN	TP (50% removal)	TP (80% removal)	TKN (50% removal)	TKN (80% removal)	TIN (50% removal)	TIN (80% removal)
Brightwater[e]																	
Cottage Lake	792	3.7	2996.2	14.0	36.7	2996.2	8988.5	23969.4	81.6	244.7	652.6	214.0	85.6	642.0	256.8	1712.1	684.8
Crystal Lake	428	2.0	1620.2	7.6	40.4	1069.3	4860.5	12961.3	26.5	120.3	320.8	76.4	30.6	347.2	138.9	925.8	370.3
Sammamish Slough[e]																	
Wetland A	282	1.3	1069.3	5.0	54.0	1069.3	3207.9	8554.4	19.8	59.4	158.4	76.4	30.6	229.1	91.7	611.0	244.4
Wetland B	146	0.7	550.9	2.6	27.0	550.9	1652.6	4406.8	20.4	61.2	163.2	39.3	15.7	118.0	47.2	314.8	125.9
A & B Total	*428*	*2.0*	*1620.2*	*7.6*	*81.0*	*1620.2*	*4860.5*	*12961.3*				*115.7*	*46.3*	*347.2*	*138.9*	*925.8*	*370.3*

[a] Steady flow 24/7 assumed
[b] TP = Total phosphorus
[c] TKN = Total Kjeldahl nitrogen; includes ammonium (NH4-N) and Org-N
[d] TIN = Total inorganic nitrogen; includes ammonia, nitrate and nitrite-nitrogen
[e] Influent characteristics: TKN 3 mg/L, TIN 8 mg/L, phosphorus 1 mg/L
[f] High-range nutrient removal efficiency = 80%; low-range nutrient removal efficiency = 50 % (Mitsch & Gosselink, 1993)

Appendix B

Study Area Properties and Qualities of Soils

Table B-1. Properties and Qualities of Soils in the Crystal Lake AOI

	Landform	Parent Material	Slope	Depth to Restrictive Feature	Drainage Class	Capacity to Transmit Water (Ksat)[1]	Depth to Water Table	Frequency of Flooding	Frequency of Ponding	Available Water Capacity[2]
Orcas peat	Hills, depressions	Sphagnum mossy organic material	0-2%	>80 inches	Very poorly drained	Very high, 19.98 to 99.9 inches/hour	~0 inches	None	Frequent	Very high, ~26.9 inches water/inch soil
Mukilteo muck	Depressions	Herbaceous organic material	0-1%	>80 inches	Very poorly drained	Moderately high to high, 0.57 to 1.96 inches/hour	~0 inches	None	Frequent	Very high, ~25 inches water/inch soil
Alderwood gravelly sandy loam, 8-15% slopes	Till plains	Basal till	8-15%	20 to 40 inches to dense material	Moderately well drained	Very low to moderately low 0.00 to 0.06 inches/hour	~18 to 36 inches	None	None	Low, ~3.0 inches water/inch soil

[1] Capacity of the most limiting layer to transmit water in a saturated condition (Ksat) = The quality of the soil that enables water to move through the soil profile in a saturated soil condition. Factors important to consider in the ability of the soil to transmit water include soil structure, porosity, and texture. Coarse texture soils generally have a higher capacity to transmit water because of larger pore size, shorter travel distance of water in larger pores, and less frictional losses.

[2] Available Water Capacity = The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity (i.e., soil moisture left after gravity drains waters from a saturated soil) and the amount at wilting point of most plants. It is commonly expressed as inches of water per inch of soil. Therefore, coarse soils with large pore spaces will have a greater amount of water drained from that soil than a soil with smaller pore spaces that “hold” the water, and thus soils with smaller pore spaces will have a higher available water capacity. The capacity also varies, depending on soil properties that affect retention of water such as texture, amount of organic soil material, soil structure, etc.

Since the soil series descriptions were developed relative to the potential agricultural use of soils, “most plants” typically refers to plants typically grown for timber, food, or fiber purposes and thus available water holding capacity and capacity to transmit water reflects a soils’ ability to hold and transmit water throughout the profile for the purpose of nourishing agricultural crops/trees grown for timber. In terms of wetlands, these properties are interpreted to reflect the ability of the soil to hold water and to thus create and maintain a saturated soil condition and thus a soils potential to display hydric soil indicators and wetland hydrologic conditions.

Note: Shading indicates hydric soil series.

Table B-2. Properties and Qualities of Soils in the Cottage Lake AOI

	Landform	Parent Material	Slope	Depth to Restrictive Feature	Drainage Class	Capacity to Transmit Water[1]	Depth to water Table	Frequency of Flooding	Frequency of Ponding	Available Water Capacity[2]
Seattle muck	Depressions	Grassy organic material	0-1%	>80 inches	Very poorly drained	Moderately high to high, 0.57 to 1.98 inches/hour	~0 inches	None	Frequent	Very high, ~23.5 inches water/inch soil
Norma sandy loam	Floodplains	Alluvium	0-2%	>80 inches	Poorly drained	High, 1.98 to 5.95 inches/hour	~0 inches	None	Frequent	Moderate, ~8.4inches water/inch soil

[1] Capacity of the most limiting layer to transmit water in a saturated condition (Ksat) = The quality of the soil that enables water to move through the soil profile in a saturated soil condition. Factors important to consider in the ability of the soil to transmit water include soil structure, porosity, and texture. Coarse texture soils generally have a higher capacity to transmit water because of larger pore size, shorter travel distance of water in larger pores, and less frictional losses.

[2]Available Water Capacity = The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity (i.e., soil moisture left after gravity drains waters from a saturated soil) and the amount at wilting point of most plants. It is commonly expressed as inches of water per inch of soil. Therefore, coarse soils with large pore spaces will have a greater amount of water drained from that soil than a soil with smaller pore spaces that “hold” the water, and thus soils with smaller pore spaces will have a higher available water capacity. The capacity also varies, depending on soil properties that affect retention of water such as texture, amount of organic soil material, soil structure, etc.

Since the soil series descriptions were developed relative to the potential agricultural use of soils, ”most plants” typically refers to plants typically grown for timber, food, or fiber purposes and thus available water holding capacity and capacity to transmit water reflects a soils’ ability to hold and transmit water throughout the profile for the purpose of nourishing agricultural crops/trees grown for timber. In terms of wetlands, these properties are interpreted to reflect the ability of the soil to hold water and to thus create and maintain a saturated soil condition and thus a soils potential to display hydric soil indicators and wetland hydrologic conditions.

Note: Shading indicates hydric soil series.

Table B-3. Properties and Qualities of Soils in the Lake Sammamish/Sammamish River AOI

	Landform	Parent Material	Slope	Depth to Restrictive Feature	Drainage Class	Capacity to Transmit Water[1]	Depth to Water Table	Frequency of Flooding	Frequency of Ponding	Available Water Capacity[2]
Seattle muck	Depressions	Grassy organic material	0-1%	>80 inches	Very poorly drained	Moderately high to high, 0.57 to 1.98 inches/hour	~0 inches	None	Frequent	Very high, ~23.5 inches water/inch soil
Shalcar muck	Floodplains	Herbaceous organic material and/or alluvium	0-1%	>80 inches	Very poorly drained	Moderately high to high, 0.57 to 1.98 inches/hour	~0 inches	None	Frequent	High, ~10.7 inches water/inch soil
Tukwila muck	Floodplains	Herbaceous organic material and/or alluvium	0-1%	>80 inches	Very poorly drained	Moderately high to high, 0.57 to 1.98 inches/hour	~0 inches	None	Frequent	Very High, ~24.1 inches water/inch soil
Pilchuck loamy fine sand	Floodplains, terraces	Gravelly and sandy alluvium	0-2%	>80 inches	Excessively drained	High to very high, 5.95 to 19.98 inches/hour	~24 to 48 inches	Occasional	None	Low, ~3.3 inches water/inch soil
Earlmont silt loam	Floodplains	Diatomaceous earth	0-1%	>80 inches	Somewhat poorly drained	Moderately high to high, 0.57 to 1.98 inches/hour	~24 to 48 inches	Occasional	None	Very high, about 12.4 inches water/inch soil
Sultan silt loam	Floodplains	Alluvium	0-2%	>80 inches	Moderately well drained	Moderately high to high, 0.57 to 1.98 inches/hour	~24 to 48 inches	Occasional	None	High, ~10.9 inches water/inch soil

[1] Capacity of the most limiting layer to transmit water in a saturated condition (Ksat): The quality of the soil that enables water to move through the soil profile in a saturated soil condition. Factors important to consider in the ability of the soil to transmit water include soil structure, porosity, and texture. Coarse texture soils generally have a higher capacity to transmit water because of larger pore size, shorter travel distance of water in larger pores, and less frictional losses.

[2]Available Water Capacity: The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity (i.e., soil moisture left after gravity drains waters from a saturated soil) and the amount at wilting point of most plants. It is commonly expressed as inches of water per inch of soil. Therefore, coarse soils with large pore spaces will have a greater amount of water drained from that soil than a soil with smaller pore spaces that “hold” the water, and thus soils with smaller pore spaces will have a higher available water capacity. The capacity also varies, depending on soil properties that affect retention of water such as texture, amount of organic soil material, soil structure, etc.

Since the soil series descriptions were developed relative to the potential agricultural use of soils, ‘most plants’ typically refers to plants typically grown for timber, food, or fiber purposes and thus available water holding capacity and capacity to transmit water reflects a soils’ ability to hold and transmit water throughout the profile for the purpose of nourishing agricultural crops/trees grown for timber. In terms of wetlands, these properties are interpreted to reflect the ability of the soil to hold water and to thus create and maintain a saturated soil condition and thus a soils potential to display hydric soil indicators and wetland hydrologic conditions.

Note: Shading indicates hydric soil series.

Table B-4. Properties and Qualities of Soils in the Area investigated along the South Side of Cedar River AOI

	Landform	Parent Material	Slope	Depth to Restrictive Feature	Drainage Class	Capacity to Transmit Water[1]	Depth to Water Table	Frequency of Flooding	Frequency of Ponding	Available Water Capacity[2]
Alderwood soils, very steep	Moraines, Till plains	Basal till with some volcanic ash	25 to 70%	24 to 40 inches to dense material	Moderately well drained	Very low to moderately low, 0.00 to 0.06 inch/hour	~18 to 37 inches	None	None	Very low, ~2.5 inches water/inch soil
Kitsap soils, very steep	Terraces	Lacustrine deposits with minor amounts of volcanic ash	25 to 70%	>80 inches	Moderately well drained	Moderately low to moderately high, 0.06 to 0.20 inch/hour	~18 to 36 inches	None	None	High, ~11.4 inches water/inch soil
Urban land	No data	No data	No data	No data	No data	No data	No data	No data	No data	No data

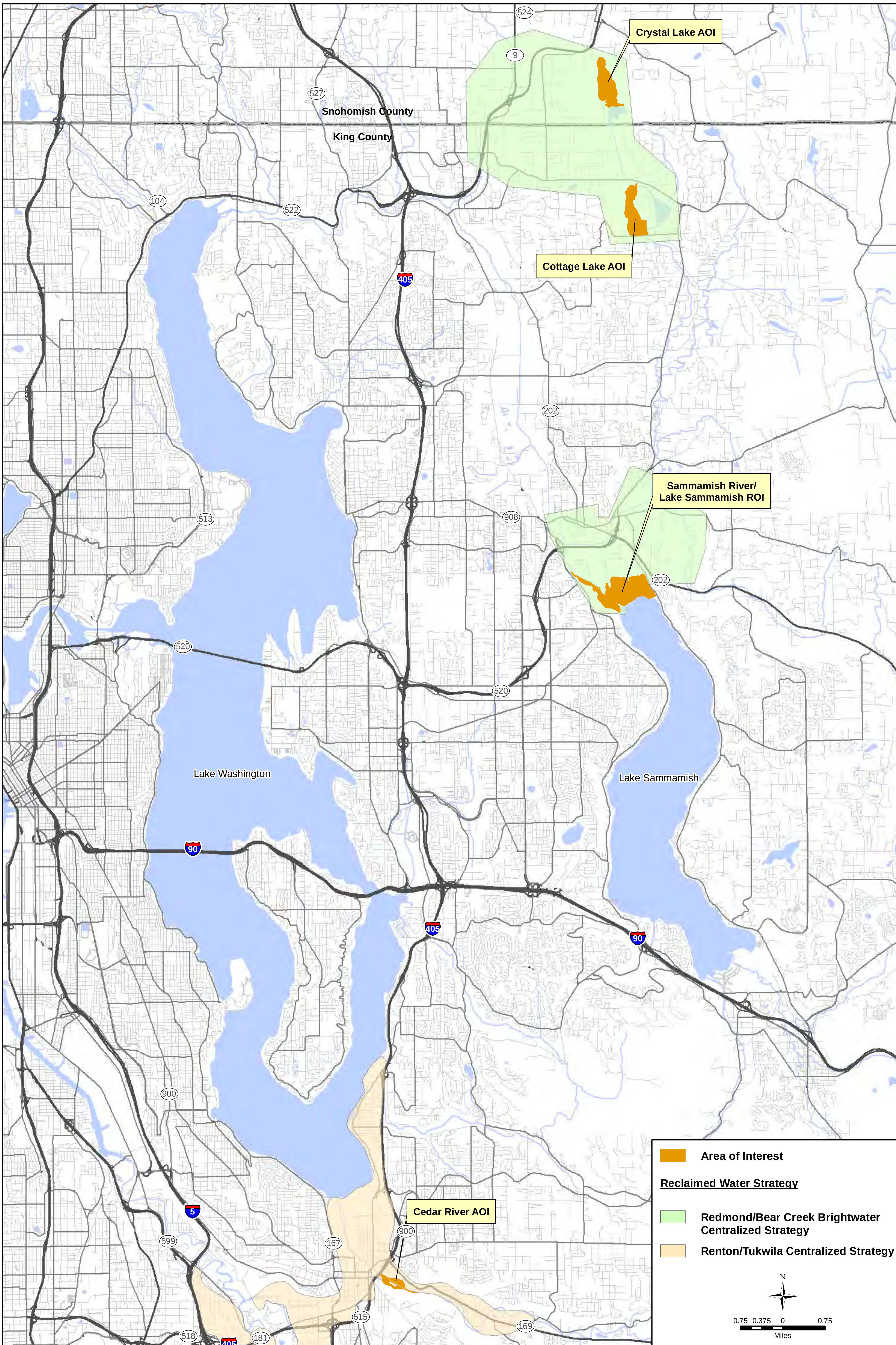
[1] Capacity of the most limiting layer to transmit water in a saturated condition (Ksat) = The quality of the soil that enables water to move through the soil profile in a saturated soil condition. Factors important to consider in the ability of the soil to transmit water include soil structure, porosity, and texture. Coarse texture soils generally have a higher capacity to transmit water because of larger pore size, shorter travel distance of water in larger pores, and less frictional losses.

[2] Available Water Capacity = The capacity of soils to hold water available for use by most plants. It is commonly defined as the difference between the amount of soil water at field moisture capacity (i.e., soil moisture left after gravity drains waters from a saturated soil) and the amount at wilting point of most plants. It is commonly expressed as inches of water per inch of soil. Therefore, coarse soils with large pore spaces will have a greater amount of water drained from that soil than a soil with smaller pore spaces that "hold" the water, and thus soils with smaller pore spaces will have a higher available water capacity. The capacity also varies, depending on soil properties that affect retention of water such as texture, amount of organic soil material, soil structure, etc.

Since the soil series descriptions were developed relative to the potential agricultural use of soils, "most plants"' typically refers to plants typically grown for timber, food, or fiber purposes and thus available water holding capacity and capacity to transmit water reflects a soils' ability to hold and transmit water throughout the profile for the purpose of nourishing agricultural crops/trees grown for timber. In terms of wetlands, these properties are interpreted to reflect the ability of the soil to hold water and to thus create and maintain a saturated soil condition and thus a soils potential to display hydric soil indicators and wetland hydrologic conditions.

Note: Shading indicates hydric soil series.

FIGURES



King County
Department of Natural Resources and Parks
Wastewater Treatment Division

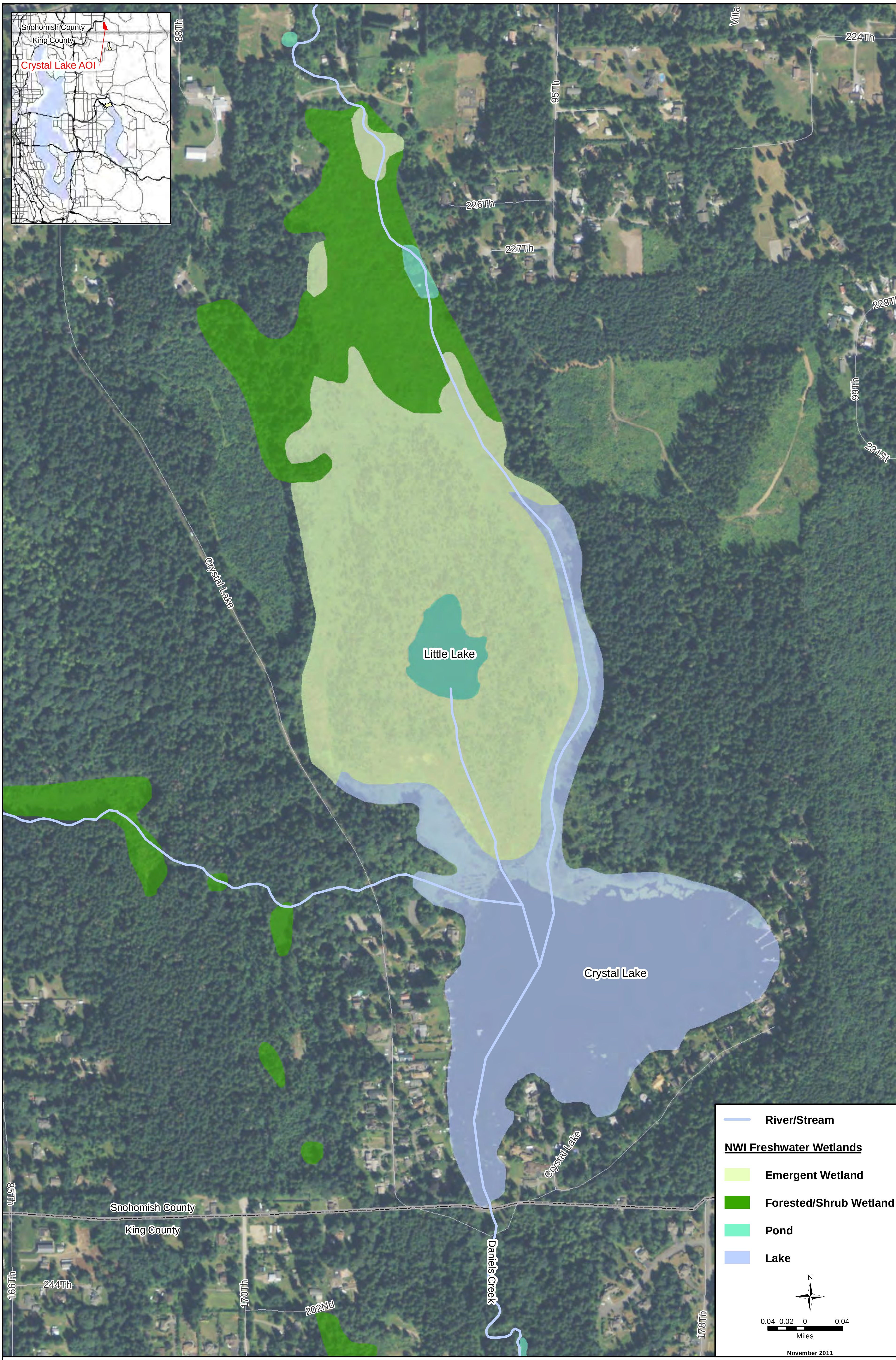
File Name: Figure_2-2_ProjectVicinity_20111121

Data Source: StreetMap, ESRI 2011; Strategy Area, King County 2011.

Figure 2-2

Project Vicinity

Reclaimed Water Strategy Effects on Wetlands



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: Figure_4-1_Crystal_Lake_Wetlands_Existing_20111121

Data Source: NAIP, USDA 2011; StreetMap, ESRI 2011; Streams, King County 2011; NWI, USFWS 1981.

Figure 4-1

Crystal Lake Wetland Designation

Reclaimed Water Strategy
Effects on Wetlands

King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

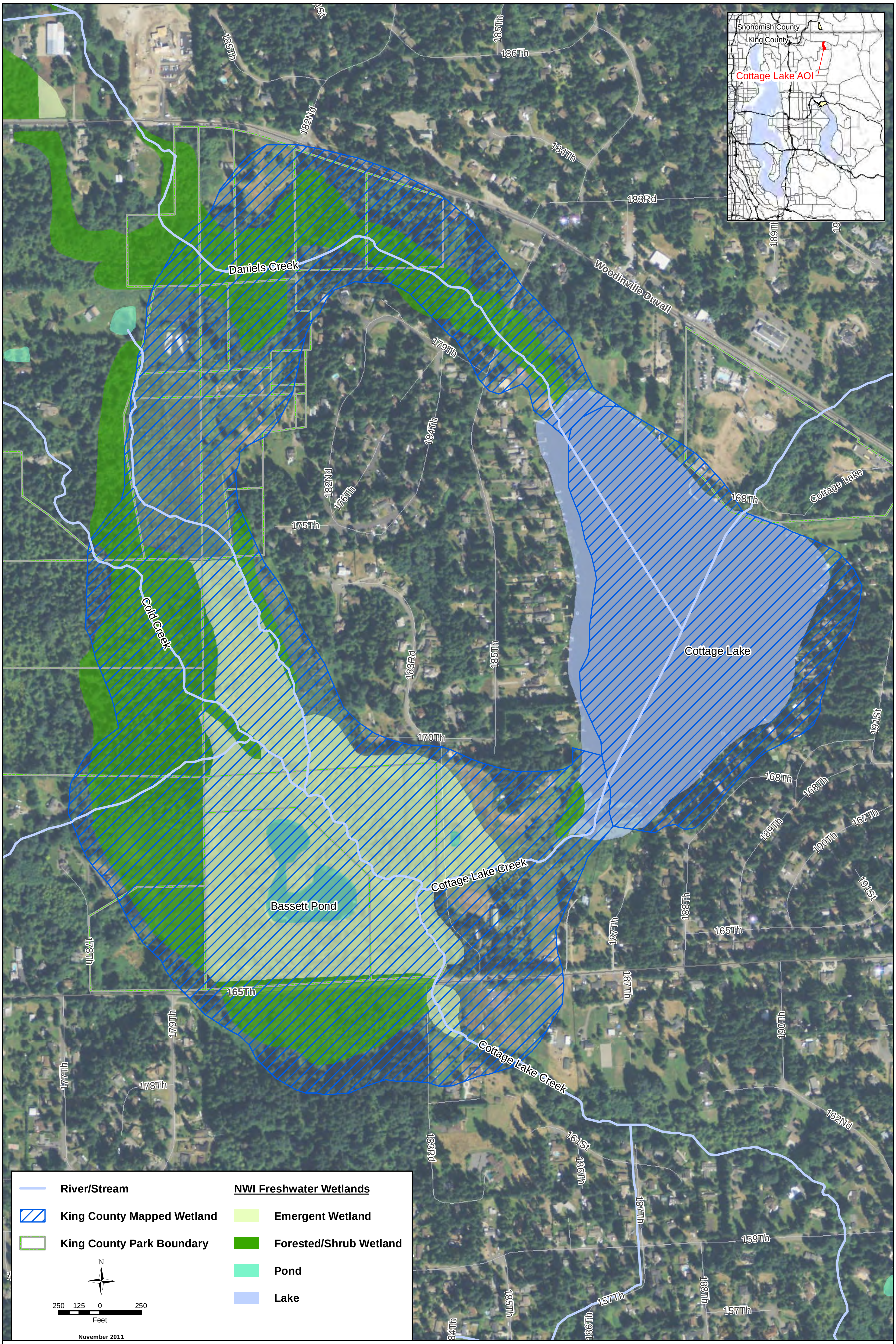
File Name: Figure_4-2_Crystal_Lake_Wetlands_Field_20111121

Data Source: NAIP, USDA 2011; StreetMap, ESRI 2011; Streams, King County 2011.

Figure 4-2

Crystal Lake Wetland Field Reconnaissance

Reclaimed Water Strategy Effects on Wetlands



King County
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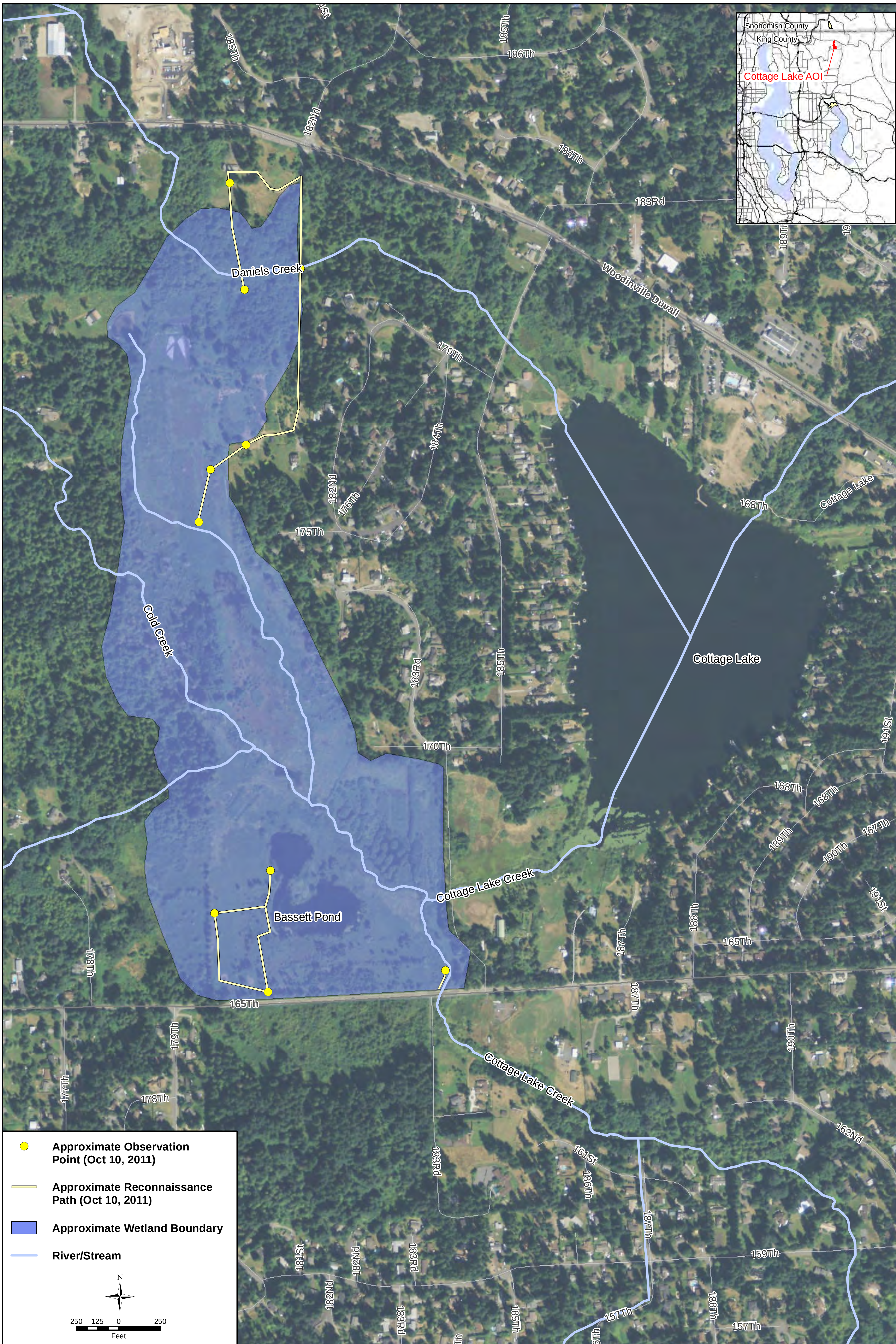
Wastewater Treatment Division

File Name: Figure_5-1_Cottage_Lake_Wetlands_Existing_20111121

Data Source: NAIP, USDA 2011; StreetMap, ESRI 2011; Streams, SAO Wetlands, and Parks, King County 2011; NWI, USFWS 1981.

Figure 5-1
Cottage Lake Wetland Designation

Reclaimed Water Strategy Effects on Wetlands



King County
Department of Natural Resources and Parks
Wastewater Treatment Division

File Name: Figure_5-2_Cottage_Lake_Wetlands_Field_20111121

Data Source: NAIP, USDA 2011; StreetMap, ESRI 2011; Streams, King County 2011.

Figure 5-2
Cottage Lake Wetland Field Reconnaissance
Reclaimed Water Strategy Effects on Wetlands

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Natural Resources and Parks
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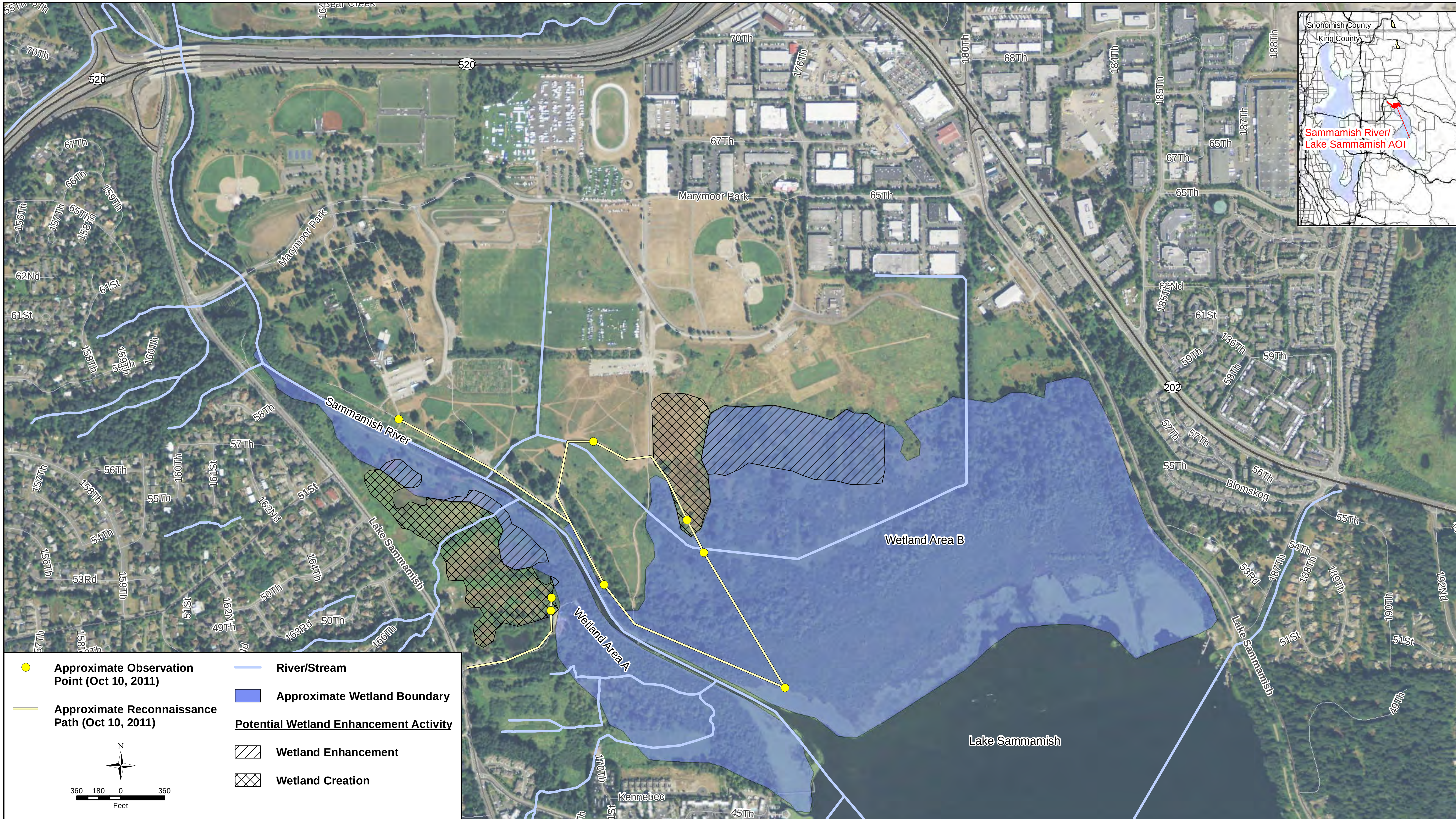
File Name: Figure_6-1_SammamishRiver_Wetlands_Existing_20111121

Data Source: NAIP, USDA 2011; StreetMap, ESRI 2011; Streams, wetland, and floodplain/floodway, King County; 2011; NWI, USFWS 1981.

Figure 6-1

Sammamish River/Lake Sammamish Wetland Designation

Reclaimed Water Strategy
Effects on Wetlands



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File Name: Figure_6-2_SammamishRiver_Wetlands_Field_20111121

Data Source: NAIP, USDA 2011; StreetMap, ESRI 2011; Streams, King County; 2011.

Figure 6-2

Sammamish River/Lake Sammamish Field Reconnaissance

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Effects on Wetlands

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File Name: Figure_7-1_CedarRiver_Existing_20111121

Data Source: NAIP, USDA 2011; StreetMap, ESRI 2011; Streams and floodplain/floodway, King County, 2011; NWI, USFWS 1981.

Figure 7-1

Cedar River Wetland Designations

Reclaimed Water Strategy Effects on Wetlands

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File Name: Figure_7-2_CedarRiver_Field_20111121

Data Source: NAIP, USDA 2011; StreetMap, ESRI 2011; Streams , King County, 2011.

Figure 7-2

Cedar River Field Reconnaissance

Reclaimed Water Strategy
Effects on Wetlands