6.0 PRELIMINARY DEVELOPMENT OF PRINCIPAL ALTERNATIVES

6.1 Vacuum-Based Sewer Collection System

The sewer system is being designed and will be owned and operated by the City. Gravity, grinder, and vacuum-based sewer collection systems were evaluated by the City's consultant (Roth Hill) in the *2004 Carnation Sewer Facilities Plan,*[190] which discusses the preliminary development of principal alternatives and cost considerations. Vacuum-based systems were selected by the City as the most cost-effective alternative.

6.2 Wastewater Treatment Facility

6.2.1 Site Alternatives

Potential sites for the new CWWTF were evaluated through a systematic process of screening for favorable site characteristics. The study area for the CWWTF was restricted to the City's UGA boundary lines, consistent with the City of Carnation 1996 General Comprehensive Plan.[191] Coarse-screening of sites within the study area narrowed the search to 15 land parcels that met the minimal critical land use, geographic, technical, and environmental criteria. Of the 15 identified land parcels, nine were judged to have higher designated land-use compatibility (e.g., recreational) and acquisition cost impacts and therefore lowered acceptability for locating a wastewater treatment facility. Existing uses of the nine sites included schools, parks, a historic site, and urban residential uses. Consequently, only six sites were evaluated further.

These six sites were then rated based on the following fine-screening criteria using GIS information, visual observation, and other County data.

- Land use compatibility and acquisition, including cost of property acquisition
- Geographic location, including visual impacts, traffic disruption, access to infrastructure
- Technical feasibility, including groundwater level and presence of contamination
- Environmental impacts, including shoreline management and sensitive areas, endangered species, and wells

Upon completion of the fine-screening evaluation, two site alternatives remained under consideration by the County, the City-owned site and the Weckwerth site, as shown in Figure 2.2. TM No. 1[192] details the screening process and site characteristics evaluated.

The City-owned site is approximately a ten-acre parcel located at the end of Entwistle Street (31500 West Entwistle Street), west of the City's business district and Highway 203. Purchased by the City for development of a wastewater treatment facility, the site is zoned for light industrial and manufacturing use and is the planned location of the City's Vacuum Station No. 1. The site is generally flat and undeveloped with the exception of a single-family residence located on the northeast corner of the property. As discussed in Chapter 3, the current FIRM map places approximately 70 percent of the land parcel within the 100-year floodplain of the Snoqualmie River. The draft map prepared by the County in June 2005, places the entire site within the 100-year floodplain. Hence, the structural footprint of the CWWTF has been modified to reflect the impacts of the potential floodplain change. The operating floor level for electrical and mechanical equipment in the CWWTF will be constructed at least one foot higher than the proposed 100-year base flood elevation of 74.11 feet (NAVD 88) at that site as required by the City's municipal code.[193] The site is bounded to the west by a King County park, to the south and east by industrial properties, to the north by an empty field, and to the northeast by residential properties. If chosen as the preferred site, the City and County will be involved in discussions to come to an agreement for long-term use of the area.

The Weckwerth site is a 5.1-acre parcel at 3700 Fall City-Carnation Road NE, east of Highway 203. The site is in a light industrial/manufacturing area and located adjacent to a specialty concrete fabrication business, which currently owns the parcel. The average elevation of the site is approximately 82 feet, remaining above the 100-year floodplain. If selected as the preferred location for the CWWTF, sewage from the City's Vacuum Station No. 1 (located at the City-owned site) would be pumped to the higher site elevation and conveyed a distance of approximately 4,200 feet. The Weckwerth site is bounded by the Riverview School District Middle School to the north, the City fire station to the west, a concrete manufacturing facility to the east, and vacant parcel of land that is prone to flooding from the Tolt River to the south.

6.2.2 Discharge Alternatives

Five discharge alternatives were originally evaluated for the CWWTF based on current[194] and previous[195] work: 1) direct discharge to the Snoqualmie River, 2) wetlands creation or enhancement, 3) upland discharge, 4) conveyance to existing County force mains, and 5) non-potable water reuse. During the initial phase of the project, three discharge alternatives were recommended for further study: 1) direct discharge to the Snoqualmie River, 2) wetlands enhancement, and 3) upland discharge.[196] These three alternatives were further refined in the EIS as 1) Snoqualmie River discharge at the Bridge, 2) wetland discharge at SWA, and 3) upland discharge in area southeast of the City.[197] Conveyance to existing facilities was eliminated from further study based on excessive cost and environmental impact.[198] Reclaimed water use for irrigational and commercial purposes was determined to have a greater cost than other discharge alternatives, due in part to the limited number of users, and thus was deferred for consideration in the future. [199] Evaluations of each of the five discharge alternatives are summarized in the subsections that follow.

6.2.2.1 Direct Discharge to the Snoqualmie River

The river outfall study area included evaluating channel areas along the Snoqualmie River within a 2.5-mile area of the City. The initial screening process for the alternative was based on maximizing the desirable characteristics for an outfall location. Aerial photographs from 1938 through 2002 were examined to historically assess the areas of channel stability.[200] Although the photographs indicated no main channel movement or transient gravel bars present within the study area, the historical photographs did indicate several areas where gravel bars are likely to be present or stream channels have moved less over time. Those areas were deemed as having conditions that would support an outfall.

For the historically stable areas identified in the initial screening process, Cosmopolitan[201] calculated the corresponding TMDL water quality impact to the CWWTF, using the following methodology:

- Define critical mixing zone parameters for the river based on state water quality standards for this reach of the river
- Determine river dilution factors from flow data using FEMA information
- Determine river mixing zone dimensions from modeling
- Apply TMDL limitations to the potential river outfall locations
- Identify impacts on wastewater treatment process requirements to meet TMDL criteria at the areas identified
- Select promising areas for further evaluation

The screening process identified three potential outfall areas based on Cosmopolitan’s methodology: near the Park, near the Bridge, and at Chinook Bend. The location on the Snoqualmie River near Tolt MacDonald Park is an area with a wide bed and a slight bend. The sides have a solid foundation and are steep, riprapped to the east, and gravelly to the west. The Bridge location also has a wide bed with existing footings and piers from the existing bridge as well as from a previous bridge. On the west bank, USGS currently operates a gauging station (No. 12149000). At Chinook Bend, the river forms a 90-degree bend to the west, and has riprap to the east.

These three potential outfall locations were further evaluated based on technical considerations, such as conveyance routing to the area, permitting, and land acquisition, current and future compatibility, and habitat conservation and enhancement project plans by the City, County, and nongovernmental organizations.

As a result of applying these criteria, Chinook Bend was eliminated as a discharge location because the Water Resource Inventory Area (WRIA) 7 Salmon Recovery Forum has identified the area as prime for restoration projects to help in the recovery of listed salmon in their near-term action agenda.[202] If carried out, the project would remove the hardened levees on the west bank of the bend and allow the river to meander in a more natural manner. The resulting river movement would make the area unsuitable as an outfall location. Also, the conveyance line would be much longer than for either of the other two locations.

The area near the Bridge, as shown in Figure 2.2, was the river outfall location evaluated during the EIS process. The Snoqualmie River channel bed has historically remained reasonably stable around the bridge area. The area around the Bridge offered advantages over the Park location because of the presence of the bridge.[203] The stability of the bridge abutment would provide the long-term bank stability needed for an outfall structure.

Adjacent properties are designated “Agricultural” in the County general land use and development comprehensive plan (Comprehensive Plan).[204] The County’s Shoreline Management Program[205] designates the site for “Conservancy,” preventing affected areas from intense development. Numerous other County designations apply to the site, particularly those related to sensitive or critical areas.

In addition, the Snoqualmie River is designated as a wildlife network. Previous studies have shown the reach of the river between the confluence with the Tolt River and the downstream end of Chinook Bend to be heavily used for spawning by listed Chinook salmon.[206,207] The river outfall discharge alternative is also located within King County Flood Hazard Area and within the Snoqualmie River Valley Agricultural Production District.

The conveyance pipe to the outfall at the Bridge is anticipated to consist of a 12-inch high-density polyethylene (HDPE) pipe, then reducing to an eight-inch ductile iron pipe supported by the bridge. The highly treated water would be discharged to the river using a diffuser check valve that would extend into the Snoqualmie River as shown in Figure 6.1. Using 2005 survey data, the 7Q10 low (7-day low flow with a 10-year recurrence interval) flow critical condition at the Bridge was estimated for river depth and optimal depth of water at the proposed outfall to be 9.4 feet and 7.5 feet (port centerline), respectively from the water surface.[208] The check valve is a simple device that would prevent backflow into the diffuser from the Snoqualmie River and distribute the highly treated water more effectively during periods of low discharge. Chapter 7 details the subsequent review and confirmation process used to select the preferred Snoqualmie River outfall location at the Bridge.

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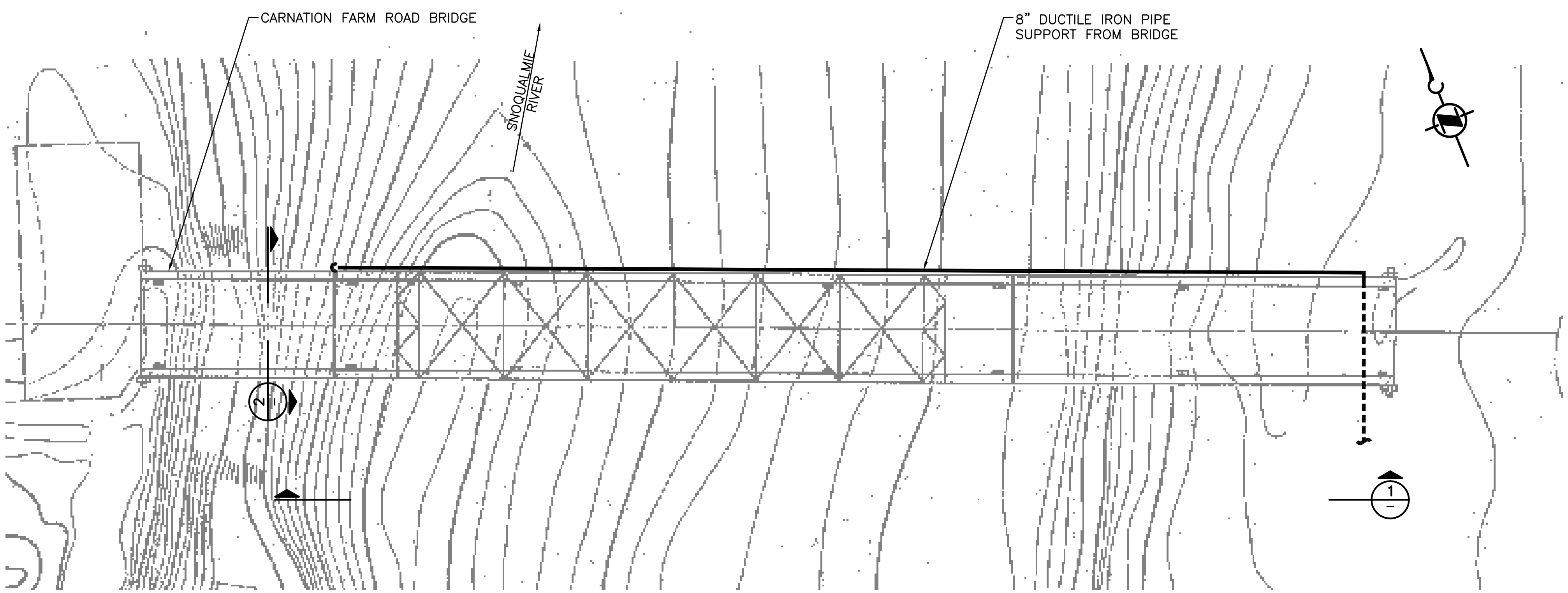


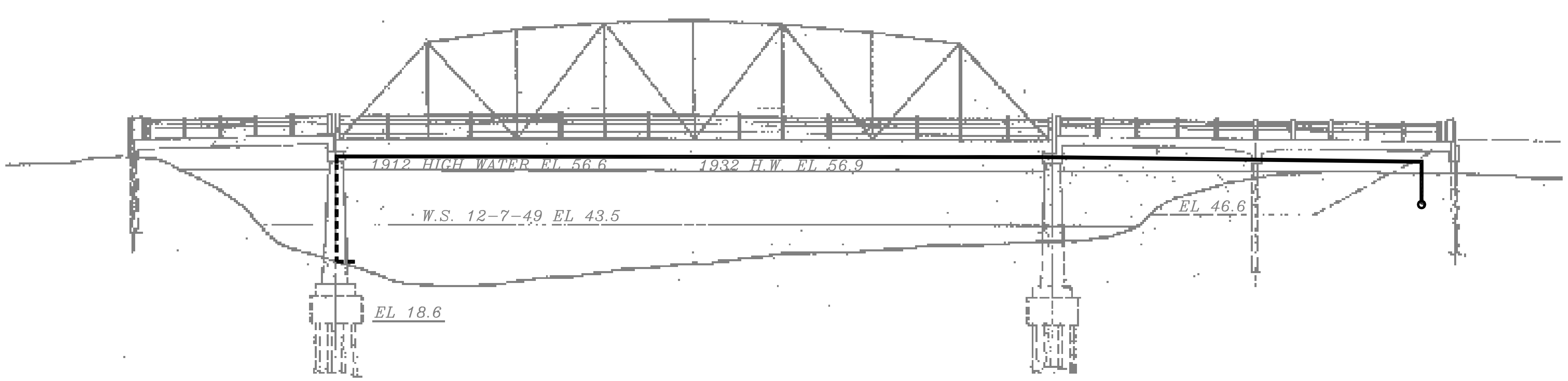
CARNATION FARM ROAD BRIDGE

PLAN

SCALE: 1" = 40'

GENERAL NOTES:

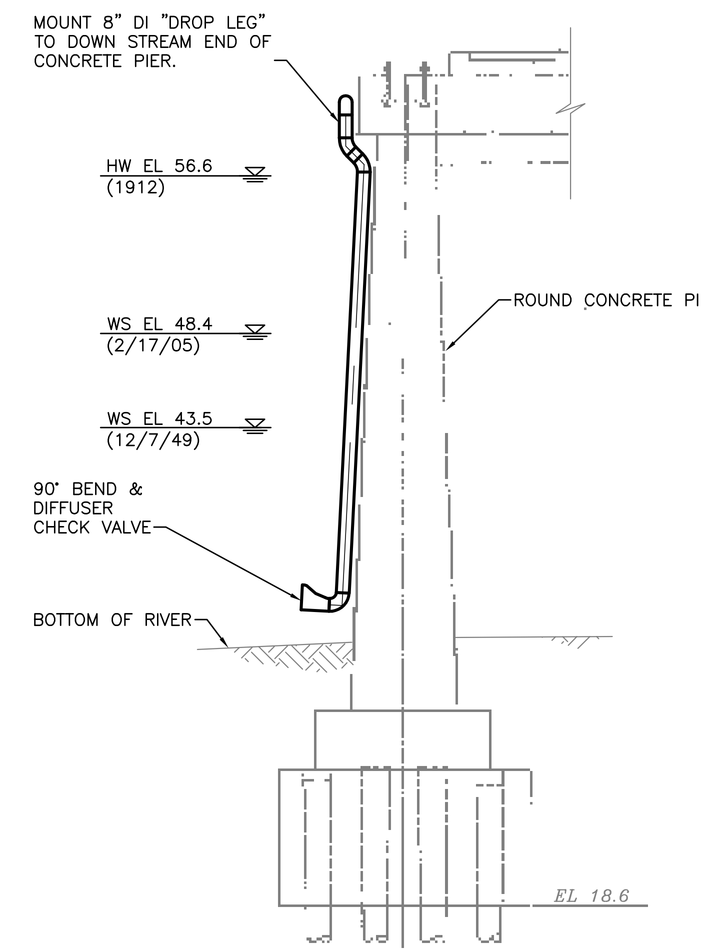
1. CARNATION FARM ROAD BRIDGE AND RIVER PROFILES PREPARED IN APRIL 1950. ELEVATIONS SHOWN ARE BASED ON NAVD 88 DATUM.



BRIDGE

ELEVATION 1

SCALE: 1" = 40'



PIER

ELEVATION 2

SCALE: 1" = 10'

ONE INCH
AT FULL SIZE, IF NOT ONE INCH SCALE ACCORDINGLY

No.	REVISION	BY	APP'D	DATE

carollo engineers

DESIGNED/DRAWN: SEF	SCALE: NONE
PROJECT ENGINEER: SML	
DESIGN APPROVAL:	
FINAL APPROVAL:	CONTRACT NO: C_____C

KING COUNTY

DEPARTMENT OF NATURAL RESOURCES & PARKS
CARNATION WASTEWATER TREATMENT FACILITY

FIGURE 6.1
CONCEPTUAL
RIVER OUTFALL DISCHARGE

DATE:
FILE NO: 423528/###
DRAWING NO:
SHEET NO: OF

6.2.2.2 Upland Discharge Study Area

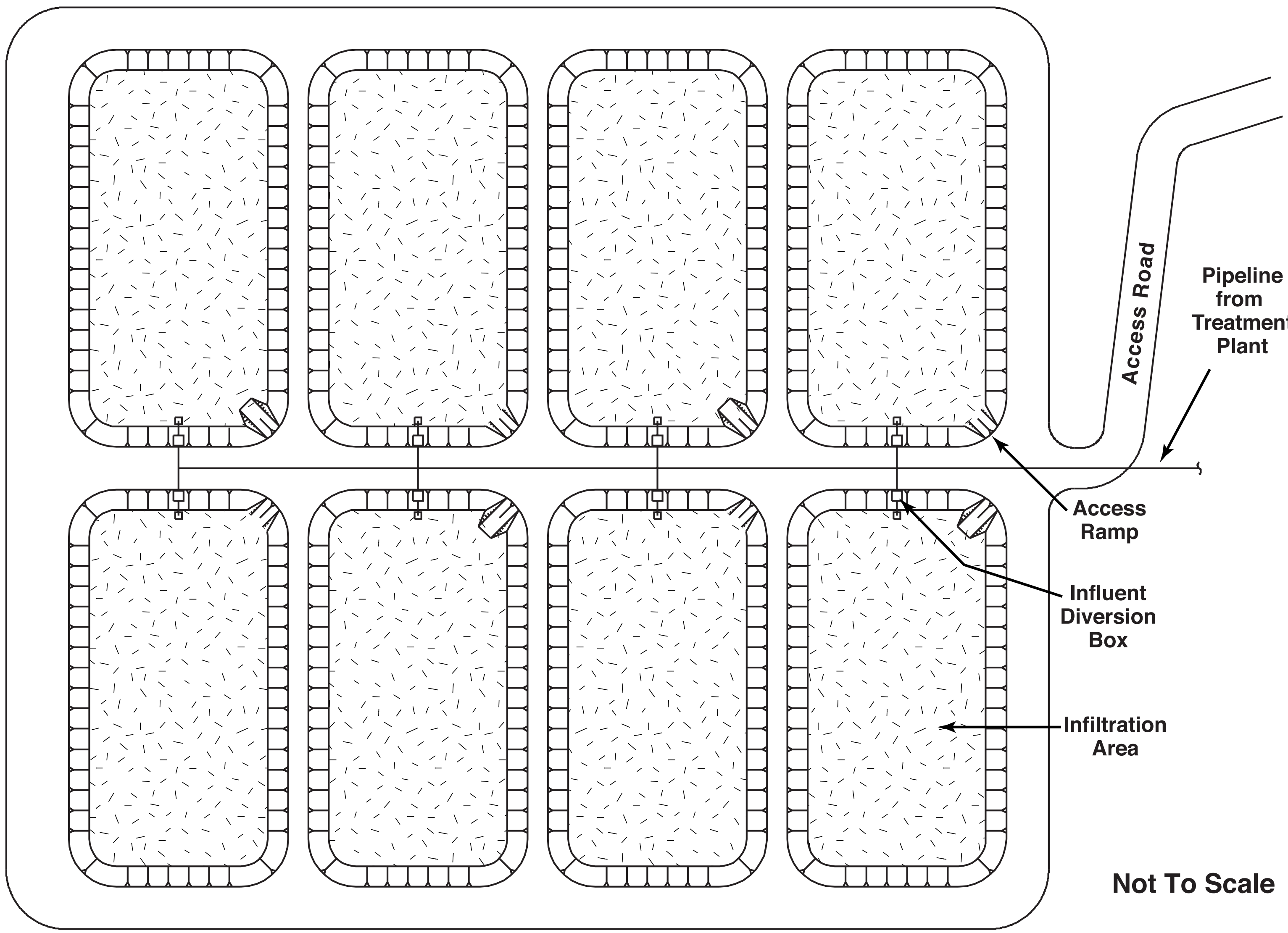
A 2.5-mile radius around the City, as illustrated in Figure 2.1, was initially examined to identify areas that would be suitable for surface percolation/infiltration.[209] Land parcels with the highest infiltration potential from the hydrogeological perspective are centered in an area located southwest of the UGA, each with a minimum of ten acres with suitable infiltration soils. Preliminary designs indicate eight half-acre basins, as shown in Figure 6.2, will be required to handle the ultimate peak hourly flow. A landscaped border will surround the overall area.

The soil suitability within the refined study area, as illustrated in Figure 2.2, was determined based on the following screening and selection criteria:

- Presence and wide distribution of the acceptable Everett gravelly sandy loam or Ragnar-Indianola Association soils, which exceed the minimum infiltration rate
- Land slopes of less than ten percent
- Land area not within the 100-year floodplain
- Availability of a minimum undeveloped ten-acre parcel of land
- Presence of an unsaturated area between the infiltration point and the water table
- Ultimate projected hydrologic fate

Coarse-screening of the suitable infiltration area identified seven sites that met broad land use, geographic, technical, and environmental criteria. Figure 2.2 shows five sites remaining following fine-screening at the seven sites. Two sites were eliminated because they were determined to have higher impacts due to the presence of occupied residences and because they were smaller and farther away, making them less acceptable locations for the upland discharge site. The key steps in evaluating the five parcels during fine-screening included:

- Develop detailed fine-screening criteria
- Conduct windshield surveys to assist in applying each criterion
- Submit the fine-screening criteria to the CAC for review and modify the criteria in response to CAC comments
- Rank and tally criteria for each site to indicate high, medium, and low impact (based on available GIS information)
- Select the fine-screening shortlist



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: 0403_03-6_Figure.eps **Prepared by:** King County WLR Visual Communications & Web Unit

Figure 6.2
Conceptual Upland Discharge

CARNATION WASTEWATER TREATMENT FACILITY

The five sites are located in close proximity to the former City landfill and are generally higher in elevation than either identified CWWTF site alternative. The southern edge of the landfill property borders one of the sites; the distance between the landfill and the furthest site is approximately 1,600 feet. Surface geology, soil, water-level monitoring, and monitoring well drilling and testing data that were used to evaluate the five sites were derived from samples obtained from the southern portion of the landfill; direct access to the potential discharge sites was never established.[210]

Aerial photographs taken of the area in August 2001 by the Washington Department of Transportation (WDOT) showed few or no apparent wetlands or surface water features on the identified sites. Soil borings taken from the landfill property show the presence of recessional outwash gravels generally five to 15 feet from the surface. A discontinuous fine-grained unit resides beneath the gravel and can perch the water above on a local scale. In general, the unit does not cause water to reside within the gravel layer. Beneath the gravel or unit, a sequence of silty sands confine the water and form the uppermost, widespread saturated zone. The silty sands appear to have low permeability. Based on monitoring well data from September 2003 to February 2004, the water level in the water table aquifer rose approximately 4 feet in response to precipitation. National Weather Service records recorded 19.45 inches of precipitation approximately 30 miles to the west (Seattle-Tacoma International Airport) during the same period.[211]

Field studies show the shallow ground regime to be much less permeable than the gravel materials found at the surface. Mounding calculations indicate that with such a low permeability, the water table would mound and, under the proposed application rates, become totally saturated. This would raise the water table surface and could cause localized flooding. Using a typical range of permeability for similar sediments, a mound within the gravel was calculated to rise between five and 30 feet.

A minimum of two vertical feet is required between the bottom of the infiltration basin and the top of the groundwater mound for the basin to drain properly.[212] Locations within the City's landfill property with only five feet of permeable gravel at the surface would be too thin to properly allow for infiltration. It is likely that gravel would need to consistently be 15 feet thick or more across the ten acres of area for infiltration to be feasible. An additional site-specific investigation would be required to determine if the soils would have a sufficient thickness of material (gravel) to support infiltration and disposal.[213]

6.2.2.3 Wetlands Enhancement Study Area

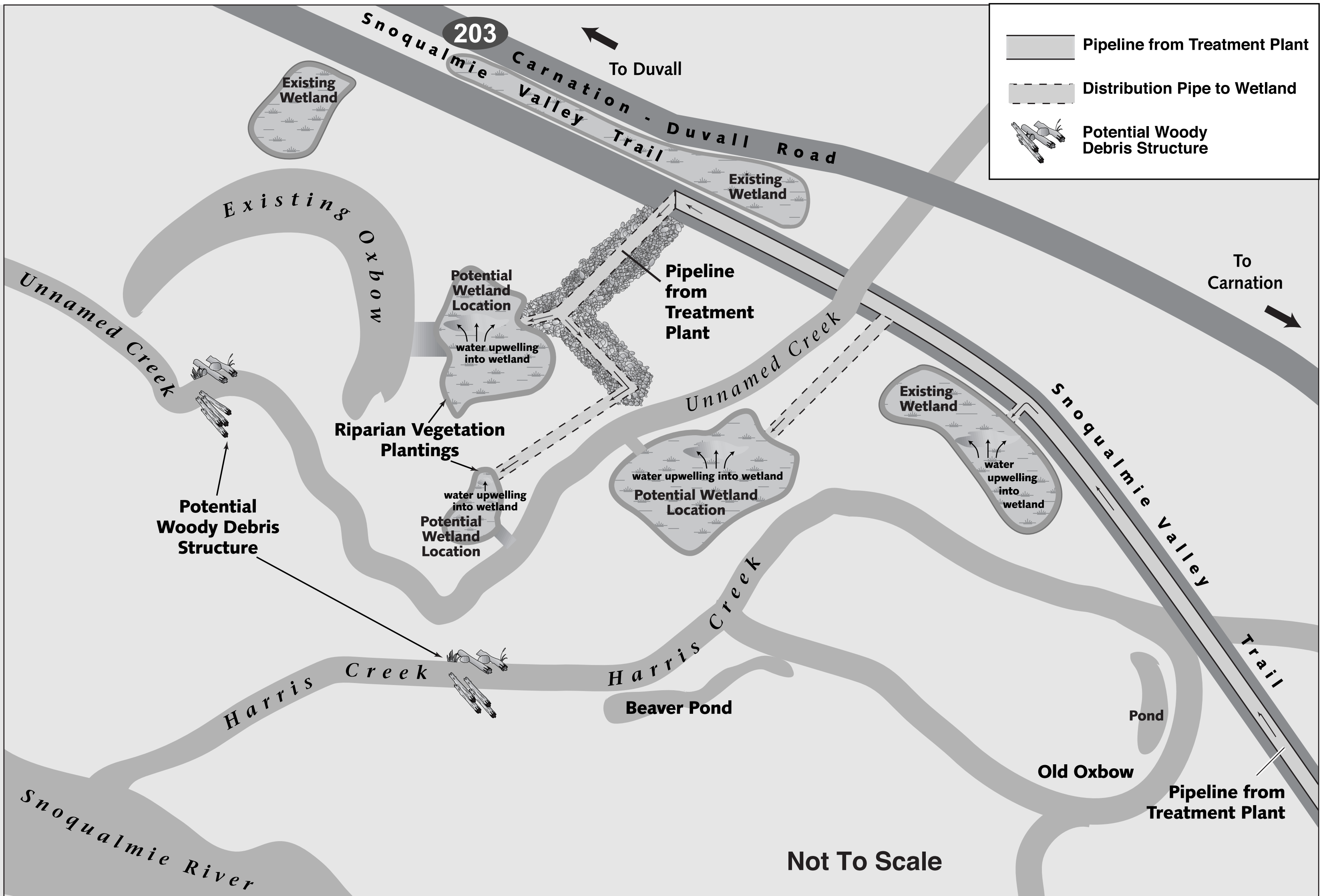
Three options to potentially develop and/or enhance wildlife and aquatic life habitat using Class A reclaimed water from the CWWTF were evaluated within a 2.5-mile area around the City. These options included: 1) creation of off-channel rearing habitats in the undeveloped open space area of the Park, 2) creation of a creek or chain of ponds in a swale on the County property adjacent to the McElhoe Person levee, and 3) piping water to the SWA to enhance and/or create wetlands. [214] The SWA was recommended and pursued because of interest by WDFW, the property owner, and both interest and assistance from the non-profit organization, Ducks Unlimited. Ducks Unlimited agreed to participate with fundraising, design and construction of a wetlands enhancement project for this area. Wetland enhancement in the Snoqualmie Valley has great potential enhance the habitat connectivity for fish and other wildlife. The SWA has the disadvantage of requiring the longest pipeline to transport the reclaimed water to the SWA.

Use of the highly treated water to restore water to a portion of the SWA is supported by state agencies, environmental interest groups, the City, and the County.[215] The SWA is downstream of the TDR in the Snoqualmie River. The TDR has been identified in previous studies as being heavily used for spawning by Chinook and other salmonids. Reclaimed water discharged within the vicinity of smaller creeks could provide a measurable addition to the base flow as well as temperature benefits for the associated fish species. Piping from the CWWTF to the SWA would allow the water to be maintained at subsurface temperatures. Assuming a 2.5-hour delivery time to the SWA, the conveyance method could realistically lower the temperature of the reclaimed water by as much as 5.5 degrees Celsius.[216] In the summer, the additional water could potentially help maintain a cooler environment for native species while becoming a less favorable habitat for invasive warmer-temperature fish. The flows from the SWA would ultimately discharge into the Snoqualmie River below the TDR and virtually below all of the mainstem river salmonids spawning habitat.[217] Based on initial discussions with Ecology, the discharge would be required to meet Class A reclaimed water standards as well as be issued a NPDES permit.

As reported in the EIS,[218] and shown in Figure 6.3, the discharge concept to the SWA proposed the creation of two new wetlands on the property and the possible (under an expanded option) hydrologic enhancement of an existing wetland near Harris Creek.
In addition, several flow-control structures could be installed along existing drainage routes to maintain water in the associated wetlands for longer periods of time than would occur naturally, independent of the delivery of new water to the site. These structures could be designed to increase the period of water inundation without requiring acreage expansion to any existing wetlands. If the SWA discharge alternative is selected for detailed design, site-specific studies may result in changes to the design described herein.

6.2.2.4 Conveyance to Existing Treatment Facilities

The evaluation of the conveyance alternative (i.e., conveying the City's sewage to existing treatment facilities rather than constructing a dedicated new facility for the City) was based on the review of previous studies. In 2001, King County contracted with HDR[219] to undertake a planning-level cost comparison of the direct conveyance of untreated wastewater to an existing County wastewater interceptor as compared to the construction of a new local wastewater treatment facility. Based on HDR's cost projections, the evaluation concluded that the costs associated with the provision of a local Class A water



King County
Department of
Natural Resources and Parks
Wastewater Treatment Division

File Name: 0403_03-5_Figure.eps
Prepared by: King County WLR Visual Communications & Web Unit

Figure 6.3
Conceptual Wetland Discharge

CARNATION WASTEWATER TREATMENT FACILITY reclamation facility would be lower than the anticipated cost for conveyance. In addition, the environmental sensitivity and topographical landscape of the Snoqualmie Valley reduces the favorability of piping the City's wastewater to an existing County interceptor. The analysis was based on information from the 2000 City of Carnation Comprehensive Sewer and Facilities Plan[220] as well as County GIS maps. For comparison, HDR investigated areas zoned for mixed use within the City as well as over 150 acres within the anticipated UGA and identified five separate flow conveyance paths to existing wastewater interceptors.

Overall, there were several benefits to directly conveying untreated wastewater to an existing County interceptor. The volume impact of the additional wastewater flow from the City to the County's existing facilities would be minimal. Upon completion of connecting the conveyance system, the County would primarily be concerned with operating and maintaining the pipeline as opposed to a separate wastewater treatment facility, with its associated storage and disposal requirements. In addition, a relatively large land area for the construction of the facility would not be required, and a lengthy wastewater treatment facility siting process would be avoided.

Yet, each of the identified conveyance paths has disadvantages. A topographic divide separates the City, which is located in the Snoqualmie Valley watershed, from the existing County interceptors, which are located in the Lake Washington/Lake Sammamish watersheds. The divide rises over 500 feet above the Snoqualmie Valley floor and would require the use of a series of pump stations to continue conveying the flow. Each of the five proposed conveyance paths from the City to the existing County pipeline deviated either north or south to avoid pipeline construction within Lake Sammamish. The proposed routes generally followed existing road rights-of-way and minimized travel through temporary elevation gains.

In addition, rather than having the construction impact concentrated in one area, the pipeline conveyance alternative would potentially disturb several sensitive areas. HDR reported the existence of a number of habitats of endangered, threatened, and protected species along the proposed pipeline routes. These included red-tailed hawk, great blue heron, and active bald eagle nests, as well as salmon spawning grounds. In addition, the pipeline would have to traverse a number of rivers, creeks, and/or wetlands, which could be adversely affected by construction activities. The proposed pipeline routes would also traverse several identified erosion and landslide areas associated with steep slopes, vegetative cover, impermeable soils, and/or groundwater seepage. A large portion of the Snoqualmie River basin is subject to severe risk of earthquake damage as well as flooding along the water bodies. Proposed construction of the conveyance system alongside existing rights-of-way would disrupt traffic.

The County also evaluated a plan of conveying the City's wastewater to the Duvall Wastewater Treatment Plant.[221] However, the County concluded that the cost of constructing approximately ten miles of conveyance pipeline, combined with the costs associated with increasing the capacity of the Duvall Wastewater Treatment Plant to accommodate the City's wastewater, would be substantially greater than the cost of constructing and operating a new wastewater treatment facility within the City. In addition, it would not have been possible to increase the capacity of the Duvall Treatment Plant in time to meet the City and County's agreed schedule.[222]

6.2.2.5 Non-Potable Water Reuse

The City currently has identified little industrial, residential, or irrigation demand for non-potable water. Potential major users of non-potable water identified within the UGA include the Park, Custom Concrete Casting, and Septic Technology, Inc. These three facilities currently purchase water from the City. Potential seasonal irrigation users within the UGA include the Carnation Tree Farm, Remlinger Farms, and some agricultural areas. These seasonal facilities currently either own private wells or purchase water from the Girl Scout Totem Council. Although the Carnation Golf Course and northern agricultural lands both lie outside of the UGA, they could also be interested in receiving reclaimed water for seasonal irrigation. Currently, the Carnation Golf Course obtains its water from a private well and most likely only irrigates the greens area of each hole.

Appendix E provides a copy of the letter from the City indicating that they do not believe it is prudent to pursue water reuse at this time. In general, the infrastructure required to convey reclaimed water to a small number of users is cost-prohibitive despite the associated environmental benefits. Conveyance of reclaimed water would require a separate water system with clearly marked colored piping and pump stations for distribution to end users. Year-round non-potable water requirements would use only approximately eight percent of the average annual startup flow in 2007. In the 2004 Comprehensive Sewer Plan,[223] it is estimated that the first phase of construction for the CWWTF project will cost $8.2 million. A conceptual-level estimate for conveying non-potable water to the same area would almost double the cost. The result would be prohibitively high installation and service costs for a limited number of clients spread over a large area. In addition, the majority of the irrigation needs would be seasonal, and therefore an alternative discharge method (or extended storage) would be required for up to nine months out of the year. The CWWTF will be designed to allow the non-potable reuse option to be further pursued if additional non-potable water customers materialize.

6.2.3 Conveyance Route Alternatives for Treatment Facility Discharge

Following treatment at the CWWTF, the highly treated water will be conveyed to the discharge location via a 12-inch HDPE pipeline. The Plant Alternatives TM[224] details a number of conveyance routes examined for the three discharge strategies chosen for further study during preliminary design. Figure 2.2 illustrates the single conveyance route evaluated for each of the two potential CWWTF sites to each discharge alternative.

6.2.3.1 Selection Criteria for Routing Methodology

Conveyance route alternatives were investigated by conducting a systematic evaluation of each route with regard to: 1) total construction cost, 2) operations and maintenance (O&M) costs, 3) difficulty and cost of easement and acquisition, 4) potential presence of and adverse impacts to shorelines, wetlands, and other identified environmental concerns, and 5) potential disruption impact to the community, including construction sequencing and access.

Conveyance route alternatives were developed using County GIS maps, information provided by Roth Hill and the City, and a “windshield survey” conducted by Carollo on September 30, 2003. Multiple conveyance routes to deliver highly treated water from the CWWTF site to the respective discharge location were identified for several alternatives. The conveyance route evaluation focused on identifying the most direct or feasible routes, minimizing easements on private property, and not requiring long stretches of pipe to be laid along Highway 203. Highway 203 serves as the major highway for all motorists traveling north and south through the City. Routes that cut across Highway 203 would likely be constructed by boring underneath the roadway to minimize traffic disruptions.

Historical roadways in close proximity to the Snoqualmie River were built by solidifying the foundation using split cedar rails laid perpendicular to the direction of travel. As time passed, the cedar rails sank into the ground and were covered with a layer of gravel. When these roads were modernized and paved with asphalt, the cedar rails were seldom removed. Providing a stable foundation, the rails typically lie approximately two to three feet below the asphalt and extend only a portion of the width of the pavement. The presence of cedar rails underneath any specific route is currently unconfirmed and was not included in the evaluation. As part of final confirmation of the selected discharge route, more detailed geotechnical borings will be initiated prior to construction to determine the presence of cedar rails close to the river.

6.2.3.2 Conveyance to the River Outfall

Based on an evaluation of the routing selection criteria, a single conveyance route for each of the two potential CWWTF sites was recommended to convey highly treated water from the CWWTF to the Snoqualmie River near the Bridge.

From the City-Owned Site

Three conveyance routes were initially identified to deliver treated highly treated water from the City-owned site to the proposed outfall near the Bridge. The recommended route begins at the City-owned site and continues a short distance east on Entwistle Street. The route then heads due north along Stewart Street to the Bagwell Street intersection and continues north along the UGA boundary to 60th Street NE (which becomes 310th Avenue NE as the road heads northward). The route follows 310th Avenue NE to the outfall located at the bridge. According to historical photos, flooding has submerged portions of 310th Avenue

NE along the Snoqualmie River at least once within the past 20 years, severely damaging the roadway. The route traverses areas that do not currently serve as major thoroughfares for the City and minimizes construction disruption impacts to the community. Easements will be required through sections of the route that have been designated as routes for future rights-of-way for the City (316th Avenue NE).

From the Weckwerth Site

A single route was evaluated to convey the highly treated water from the Weckwerth site to the river outfall at the Bridge. The route begins at the Weckwerth site and continues due east to the Snoqualmie Valley Trail (trail). The route then follows the trail north until reaching the same latitude as the Carnation Farm Road near that location. The route continues due west to cross Highway 203 and follows Carnation Farm Road to the outfall located at the bridge. Along Carnation Farm Road, the route crosses two small concrete bridges or culvert crossings. The pipeline would likely have to be either attached to the bridges or micro-tunneled underneath the streams.

6.2.3.3 Conveyance to Upland Discharge

Based on an evaluation of the routing selection criteria, a single conveyance route for each of the two potential CWWTF sites was recommended to convey highly treated water from the CWWTF to the upland discharge area southwest of the UGA.

From the City-Owned Site

Two conveyance routes were initially identified to deliver highly treated water from the CWWTF site to the proposed upland discharge area southwest of the UGA. An evaluation of the routes indicated that they were rated approximately equal in meeting the selection criteria. However, this did not take into account the advantage presented by one of the alternatives and the cost savings that could be realized if the pipeline were joint-trenched with the City’s vacuum sewer pipes. It is anticipated that a joint-trenched pipeline would result in an approximately 15 percent direct cost savings for one of the routes. The potential direct cost savings and enhanced constructability provided sufficient advantage and led to a route recommendation. The route is anticipated to be much more favorable in constructability because it traverses the City by way of a residential street rather than through a commercial district.

The recommended alternative begins at the City-owned site and continues east along Entwistle Street, connecting with the trail. The route then follows the trail south and crosses the Tolt River on the trail. It is anticipated that the pipeline will be attached to the steel truss portion of the bridge while crossing the river. There is evidence of fire damage on the wooden portion of the bridge. For this reason, it is recommended that the wooden truss not be used for support. The route continues to follow the trail south before heading east on NE 24th Street. The route then continues due south to cross the edge of the old City landfill and connect with one of the land parcels identified as suitable for infiltration to groundwater.

From the Weckwerth Site

A single route was evaluated to convey the highly treated water from the Weckwerth site to the upland discharge parcels located southwest of the City's UGA. The route begins at the Weckwerth site and continues due east to the trail. The route then follows the trail south and crosses the Tolt River on the trail. It is anticipated that the pipeline will be attached to the steel truss portion of the bridge while crossing the river. As mentioned above, given that there is evidence of fire damage on the wooden portion of the bridge, it is recommended that the wooden truss not be used for support. The route then continues to follow the trail south before heading east on NE 24th Street. Following the right-of-way, the route continues due south to cross the edge of the old City landfill and connect with one of the land parcels identified as suitable for infiltration to groundwater.

6.2.3.4 Natural Wetland Enhancement to the Stillwater Wildlife Area

Based on an evaluation of the routing selection criteria, a single conveyance route for each of the two potential CWWTF sites was recommended to convey highly treated water from the CWWTF to the SWA. If chosen as the discharge alternative, the precise discharge location(s) within the SWA will be further developed in the design development phase. If a different wetland enhancement location is selected, a conveyance route will be developed as the site design is developed.

From the City-Owned Site

A single route was evaluated to convey highly treated water from the City-owned site to the SWA. The route begins at the City-owned site and continues a short distance east on Entwistle Street. The route then heads due north along Stewart Street to the Bagwell Street intersection and continues north along the UGA boundary to 60th Avenue NE. The route heads east on 60th Avenue NE, crossing Highway 203 and connecting with the trail. The route then travels north along the trail, crosses Highway 203 again and continues along the trail until reaching the delineated wetlands within the SWA.

From the Weckwerth Site

A single route was evaluated to convey highly treated water from the Weckwerth site to the SWA. The route begins at the Weckwerth site and continues due east to trail. The route then travels along the trail north, crosses Highway 203, and continues along the trail until reaching the delineated wetlands within the SWA.

6.3 Liquid Treatment Process Evaluation

Based on the water quality requirements identified in TM No. 11,[225] the County evaluated treatment alternatives for the CWWTF design. TM No. 6[226] details evaluations undertaken solely to select the liquid treatment processes.

6.3.1 Initial Selection Methodology

The County held a liquid process-screening workshop during which 21 different processes were compared for secondary treatment. Seven different processes were considered for filtration, three chlorination processes for disinfection, two processes for dechlorination, and three processes for UV disinfection. TM No. 6[227] documents the detailed treatment process evaluation. Selection criteria developed at the process-screening workshop included:

- Risk
- Capital cost
- O&M cost
- Footprint
- Energy consumption
- Reliability
- Operations staff familiarity
- Maintenance needs
- Odor control cost
- Enclosure cost

The selected treatment process train has to be capable of biological nutrient removal, have the flexibility to successfully meet the Class A Washington State reclaimed water quality standards,[228] and cost-effectively meet the associated reliability and redundancy requirements. From the initial list of potential treatment processes, three biological treatment alternatives, or scenarios that best met the selection criteria were identified:

- Scenario 1: sequencing batch reactors (SBR) with filtration
- Scenario 2: activated sludge biological nutrient removal (BNR) with clarification and filtration
- Scenario 3: activated sludge BNR with MBR technology

Each of these processes would be preceded by screening and grit removal and followed by disinfection for complete treatment. The type of equipment assumed in this chapter was selected solely for the purposes of comparing process costs. Equipment selection was re-evaluated in collaboration in preliminary design, as discussed in Chapter 7.

6.3.2 Preliminary Treatment

6.3.2.1 Screening

The CWWTF will require preliminary screening to protect downstream processes and associated appurtenances. In addition, screens can reduce the solids and organic loading to the downstream processes by removing smaller particulate matter. For the purpose of the cost evaluation of the SBR and BNR with clarification scenarios, it was assumed that two parallel rotary drum screens with six-millimeter (mm) openings would be installed at the CWWTF. The screenings would be conveyed to a washer-compactor to be cleaned and dewatered before disposal. A washer-compactor system would remove most of the fecal matter and reduce the volume of the wet screenings by approximately 50 percent to minimize disposal requirements.

The MBR process requires fine-screening; the recommended mesh size depends on the type of membrane selected. Fine-screening helps to maximize the effective life of the membranes and protect them from irreversible fouling and matting from hair or fibers. Flat-plate and hollow-fiber membrane manufacturers typically recommend fine screening to two mm or smaller. The preliminary cost evaluation assumes parallel perforated plate traveling band screens with two mm openings and an integrated washer/compactor/bagging unit.

6.3.2.2 Grit Removal

Grit removal is often provided to protect the downstream processes from abrasion damage, reduce pipeline and solids digester deposits, and prolong the effective service life of mechanical equipment. The grit removal system should be placed immediately upstream of the fine screens to minimize headloss and loss of screening surface area. Provisions for proper washing, dewatering, and disposal of the collected grit to minimize potential odor formation would need to be addressed. For the purpose of the preliminary cost evaluation, it has been assumed that a vortex-type grit basin would be installed.

Initial discussions with manufacturers and municipalities regarding vacuum-based sewer collection systems such as the one proposed for the CWWTF, have indicated that the influent will contain minimal volumes of grit. It is likely that a fine-screening system would remove the majority of the grit material prior to reaching the downstream basins even without a grit removal basin. It was determined that a grit-removal system would not to be incorporated in the CWWTF. Other types of grit-removal technology, such as grit cyclones will be evaluated at a later time in the event that the County chooses to retrofit grit removal equipment to the CWWTF. At that time, the County will addend the Facilities Plan prior to installation of the grit handling equipment.

6.3.3 Primary Treatment

The CWWTF will not require primary treatment prior to secondary treatment. Smaller wastewater treatment plants typically eliminate this step as a cost savings measure.

Instead, the wastewater is transferred directly from preliminary treatment to the secondary treatment process.

6.3.4 Secondary Treatment

6.3.4.1 SBR Technology with Filtration

Table 6.1 lists the major benefits and drawbacks of SBR and SBR-type processes. After consideration of the benefits and drawbacks of the two SBR-type processes, a true batch SBR system with a post-equalization basin was selected to be used for the scenario cost comparison. The SBR system would allow for complete access of basin internal mechanisms, including the diffuser system, from above the water level. In addition, the system would allow ideal quiescent settling to produce a high and consistent water quality.

Table 6.1 Evaluation of SBR and SBR-Type Processes
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks

Process	Benefits	Drawbacks
SBR[229]	• Smaller footprint • Recycle pumping eliminated • Ease and flexibility of operation: treatment phases may be adjusted within a cycle • Lower solids in treated water due to quiescent settling step • Lower volume of mixed liquor generated • Does not require separate clarification basins • Modular construction allows for expansion	• Has limited capacity to handle instantaneous peak flows as compared to other suspended growth systems • Flow equalization (pre and/or post) may be necessary due to traditional intermittent flow • Complex design: requires more instrumentation, monitoring devices, and automatic valves than many of the other biological processes • Skilled maintenance required for instrumentation and control devices • Higher headloss
SEQUOX®	• Has larger capacity to handle peak flows than traditional SBR systems • Uses common wall construction to best utilize available footprint • No moving equipment underneath water • Continuous flow system	• Larger footprint requirement • Requires separate clarification area • Proprietary design

Source: Carollo Engineers, *Technical Memorandum No. 6 - Treatment Process Configuration*, 2004.

6.3.4.2 Activated Sludge BNR with Clarification and Filtration

Table 6.2 provides a comparison of the benefits and drawbacks of the five activated sludge configurations capable of full biological nutrient removal. All biological processes in this scenario require a separate clarification process. Two-channel oxidation ditches with separate anaerobic selector tanks were selected with a five-stage Bardenpho configuration for the scenario cost comparison. The oxidation ditch is a proven process with little operator attention and simple control strategy required. However, this scenario would require the largest footprint of the three technologies evaluated.

Table 6.2 Evaluation of Activated Sludge BNR Processes
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks

Process	Benefits	Drawbacks
A^2O^{TM}	• Produces good solids settleability • Relatively simple operation and control • Energy efficient • Reduced oxygen requirement • Moderate reactor volume	• Limited P removal • Proprietary process • Limited N removal based on internal recycle ratio • Requires higher BOD/P ratio
UCT	• Good P removal • Good N removal • Moderate reactor volume • Produces good solids settleability • Relatively simple control	• Complex operation • Requires additional recycle stream
VIP	• Good P removal • Good N removal • Moderate reactor volume • Produces good solids settleability • Relatively simple control • Requires lower BOD/P ratio than UCT process	• Complex operation • Requires additional recycle stream • More equipment required for staged operation
Bardenpho (five-stage)	• Excellent N removal • Produces good solids settleability • Relatively simple control	• Limited P removal • Larger reactor volumes
Clearbrooke^{TM} (deep shaft)	• Higher oxygen transfer	• Proprietary process • Deep excavation requirements • Limited experience • Extremely confined access for reactor maintenance

A^2O = anaerobic/anoxic/oxic process
N = nitrogen
P = phosphorus
VIP = Virginia Initiative Plant process
UCT = University of Cape Town process

Sources: C.P.L. Grady, G.T. Daigger, and H.C. Lim, *Biological Wastewater Treatment*, 2nd ed. (New York: Marcel Dekker, Inc., 1999), 496-503;Metcalf and Eddy, *Wastewater Engineering: Treatment and Reuse*, ed. G. Tchobanoglous, F.L. Burton, and H.D. Stensel, 4th ed. (New York: McGraw-Hill Inc., 2003), 809-815.

6.3.4.3 Activated Sludge BNR with MBR Technology

The MBR biological treatment train is anticipated to be configured as two reactors, with a plug flow activated sludge reactor as the first basin. The following tank would serve to house the MBR system. Separation of the MBR from the first basin from the following tank membrane basin permits independent optimization of the aeration equipment and activated sludge process as well as isolated membrane cleaning. Dual trains with a modified BNR removal configuration (similar to the A^2O^{TM} process) were combined with hollow-fiber membranes for the cost comparison. The configuration would consist of anoxic, anaerobic, and aerobic basins in series. Four times the influent flow rate would be recycled back to the anoxic zone from the MBRs. Multiple MBR tanks would allow the facility to polish the full liquid stream from the aerobic basins while one membrane basin is being serviced. Membranes produce a micro-filtered water quality and eliminate the requirement for separate tertiary filtration. Table 6.3 summarizes the benefits and drawbacks of the activated sludge BNR with MBR technology.

Table 6.3 Evaluation of Activated Sludge BNR with MBR Process
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks

Process	Benefits	Drawbacks
MBR	• Small footprint • Automated and flexible operation • Lowest turbidity levels • Requires a lower disinfection dosage as compared to more conventional technologies	• Requires fine screening • Has limited capacity to handle peak flows • Complex design • Skilled maintenance required • Chemical cleaning required • Limited membrane life span

Source: Carollo Engineers, *Technical Memorandum No. 6 - Treatment Process Configuration*, 2004.

MBR equipment requires fine screening, is more sensitive, and has higher skilled maintenance requirements than conventional aeration basins. An entire tank must be taken out of service for several hours to adhere to periodic chemical cleaning schedules. Routine maintenance requirements vary dependent on the membrane supplier but may be conducted as frequently as daily. In addition, the estimated life span of a membrane cassette is estimated to be between five to 10 years.

Membranes are compact processes that have small footprints and provide for automated and flexible operation. The modular equipment allows for ease and flexibility when increasing plant capacity, provided that the basins were sized for expansion. The addition of more membrane area can also serve to reduce the operating flux while maintaining the same production rate of highly treated water. Membranes use polymeric filtration media with pore sizes in the range of 0.04 to 0.4 micron to sieve and separate solids. The physical separation barrier provided by the membranes is the most effective and reliable treatment mechanism to meet Class A reclaimed water requirements,[230] and is less susceptible to turbidity spikes during process upsets as compared to other treatment technologies.

6.3.5 Tertiary Treatment

Filtration processes including multi-media, deep sand, automatic backwash, continuous backwash, fabric, microfiltration membrane, and reverse osmosis were evaluated against the selection criteria. Granular media and cloth filters are considered to be equal, and both have been proven to meet Class A reclaimed water standards.[231] A list of benefits and drawbacks of the two processes is presented in Table 6.4. The County currently uses granular media filters to produce Class A reclaimed water at its South Treatment Facility. It is also the County's experience that cloth and continuous backwash filters are easier to operate and smaller in footprint than conventional sand filters. For the purpose of the preliminary scenario cost evaluation, it was assumed that continuous backwash filters would be installed.

Table 6.4 Comparison of Filtration Processes
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks

Process	Benefits	Drawbacks
Cloth filters	• Smaller footprint • High-quality treated water • Lower backwash rate • Continuous filtration during backwash • No underdrains required	• Potentially higher capital cost • Possible turbidity breakthrough • Requires backwash water
Granular Media filters	• High-quality treated water • Operational familiarity	• Less protection against turbidity breakthrough • Possible filter media loss • Possible mudball formation and buildup of emulsified grease • Requires backwash water

Source: Carollo Engineers, *Technical Memorandum No. 6 - Treatment Process Configuration*, 2004.

6.3.6 Disinfection

Although the discharge alternatives require different levels of disinfection, the County has committed to providing treatment capable of meeting Class A water reclamation standards.[232] Hence, the disinfection levels must meet a total coliform organism count not exceeding the most probable number (MPN) of 2.2 per 100 mL within a seven-day geometric average and not exceeding 23 MPN per 100 mL at any time.[233]

6.3.6.1 Ultraviolet Disinfection

Historically, design criteria for UV disinfection have been based on manufacturer recommendations, bioassay results, and/or pilot testing and approved by regulatory agencies on a case-by-case basis. In 2003, the National Water Research Institute (NWRI) published updated design criteria for UV transmittance, effective UV dosages, and maximum turbidity levels.[234] Although the NWRI guidelines have not been officially adopted by the State of Washington, the criteria represent the most current guidance for water reuse to achieve disinfection to an MPN of 2.2 per 100 mL. Ecology has indicted that the NWRI guidelines or approved equivalent will be required for reclamation facility approval.[235] Therefore, it is recommended that the design standards and technology be adopted for the CWWTF during preliminary design.

Despite optimum coagulation and filtration, granular- or cloth-filtered water will have higher comparative turbidity levels than those expected from MBR treatment. According to the NWRI standards, MBR has been proven to produce highly treated water with turbidity levels less than 0.2 nephelometric turbidity units (ntu). These are consistently lower than other tertiary filtered water that would have turbidity levels between two and five ntu.[236]
The lowered turbidity produced by the MBR process, in turn, allows for increased UV transmittance and smaller disinfection facilities than conventional processes. The UV disinfection system will be designed to provide a fully redundant train, maintaining complete disinfection should one train be required to be out of service.

6.3.6.2 Residual Chlorination (If Necessary)

If treated to reclaimed standards, regulatory compliance requires a minimum chlorine residual of 0.5 mg/L for reclaimed water according to the *Washington Reclamation and Reuse Standards*.[237] Initial discussions with Ecology have indicated that the DOH and Ecology may grant a chlorine residual waiver for discharge to wetlands or for subsurface application and flow irrigation. If the highly treated water is discharged to the Snoqualmie River, compliance limits the maximum chlorine residual to 0.5 mg/L. Adding a chlorine residual will increase the estimated capital and increase operating costs.

6.4 Solids Handling

The CWWTF produces two major sources that require solids handling: screenings and wasted solids from the secondary process. Solids from screenings include denser organic and inorganic materials, which are physically retained by the mesh material. Solids from biological or chemical processes are composed of flocculated material from cellular and suspended solids material or material from chemically attracted conglomerations, respectively. Residual solids wasted from biological processes typically encompass the majority of the material requiring disposal. Proper treatment of biological solids includes processes for both mass and volume reduction. Due to the relatively low volumes of waste flows at the CWWTF, solids will be held and/or thickened before being transported to a regional facility. The solids will be stabilized, dewatered, and prepared for land-application at the County's regional facility. No design or construction modifications are anticipated to be required at the regional facility to accommodate the relatively low volumes of solids produced at the CWWTF. TM No. 7[238] details evaluations undertaken to select the solids handling alternatives.

Wasted solids thickening processes include gravity thickening, dissolved air flotation, gravity-belt thickening, rotary-drum thickening, and centrifugation. Many wastewater treatment facilities generally thicken onsite, increasing the solids to a typical range of three to six percent solids.[239] Gravity thickeners have larger footprints but minimal O&M costs. Dissolved air flotation processes are effective but have higher operating costs. Centrifuges have higher power demands and can produce dewatered solids concentrations. Gravity-belt thickeners have small footprints but higher polymer addition requirements to aid in conditioning, as well as other O&M costs.

6.4.1 Headworks Residuals

TM No. 6[240] recommended the collected headworks screenings and grit be cleaned and dewatered as accumulated to minimize the potential for odor production. A suitable central location will house the headworks residuals in a combined screenings, washer compactor, and bagger unit. The combined unit will prevent the residuals from increasing the ambient odor concentration in the headworks building, thereby reducing the overall handling cost. The screenings and grit chamber residuals will be transported to a local landfill for final disposal. Table 6.5 provides an estimate of the disposal volumes and weights from the headworks residuals based on typical design parameters.[241]

**Table 6.5 Preliminary Estimate of Headworks Residuals Volumes
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks**

Design Year Flow	Disposal Weight (lb/day)[a]	Disposal Volume (ft^3/day)[a]
Average annual	135	2.4
Maximum monthly	175	3.1
Peak daily	283	5.0

lb/day = pounds per day

ft^3/day = cubic feet per day

a. Assuming residuals are washed and dewatered with weight and volume reduced by 50 percent.

6.4.2 Handling of Wasted Solids

Solids wasted from the chosen activated sludge process will be transported to a County regional treatment facility. Two scenarios were evaluated to determine the most cost-effective transportation method: 1) gravity-thickened solids stored in aerated holding basins until transportation and 2) mechanically thickened solids stored in aerated holding basins until transportation. Both scenarios assumed transportation to the County's South Treatment Plant, approximately 30 miles away. As a closer County regional facility (Brightwater) becomes available in the future for solids handling, the County will reevaluate the economic advantage of this location for solids discharge. Table 6.6 provides a preliminary estimate of the volumes of solids transported.

Table 6.6 Estimate of Transported Solids Volumes
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks

	Volumes Transported by Scenario (gpd)	
Flow	**Scenario 1 Gravity-Thickened Solids**	**Scenario 2 Mechanically Thickened Solids**
Solids concentration (%)	2	4
At average annual flow	2,700	1,380
At maximum monthly flow	3,100	1,580
At maximum daily flow	5,200	2,340

gpd = gallons per day

Scenario 1 assumes that the solids would be periodically pumped directly from the activated sludge basins to aerated holding basins. The covered holding basins would provide gravity thickening of solids and decanting before transportation to the South Treatment Plant. The basins would have a combined design hydraulic residence time (HRT) of nine days at maximum monthly loadings. After the supernatant is decanted, liquid haul tanker(s) would transport approximately a two percent solids concentration to the regional facility. Use of these tankers should prevent odors from escaping into the surrounding environment. The City of North Bend Wastewater Treatment Plant gravity thickens their wasted solids (oxidation ditch treatment) from a 0.5 percent solids concentration to two percent within an aerated holding tank. Thickened solids are transported each week to the City of Edmonds Wastewater Treatment Facility. Transportation generally occurs one day per week and requires approximately three trips. Operating staff at the City of North Bend Wastewater Treatment Plant indicated that gravity thickening to two percent solids could be consistently achieved.

Scenario 2 assumes that the CWWTF would require a solids-thickening unit and smaller aerated holding basins. Recent developments in MBR technology have resulted in the use of membranes for the thickening of biosolids. The Cauley Creek Water Reclamation Facility in Duluth, Georgia, has recently initiated the use of membranes for solids thickening. This process provides an improved method of decanting the liquid from the holding basins. The facility currently thickens to a solids concentration of four percent with this process.

CWWTF solids could also be thickened using a more conventional process such as a gravity-belt thickener to a four to eight percent concentration with the use of polymer. Either thickener process would likely be in operation approximately one hour per day on an average basis. The wasted solids would be held in aerobic holding basins for an average hydraulic residence time of nine days at maximum monthly loadings before being transported to the South Treatment Plant on liquid haul tanker(s).

6.5 Odor Control

King County's commitment to odor control focuses on minimizing community nuisance odor through prevention and control. The County has a recommended policy[242] for the prevention of nuisance odors from wastewater facilities as required under their Regional Wastewater Services Plan and Ordinance Number 13680, Section 5B TPP-4. Design, control, and operating requirements also stem from the County's *Odor and Corrosion Control Design Standards.*[243] These documents provide general guidance, establish minimum design standards, focus on conventional operational strategies including chemical and biological treatment, and propose operational strategies. As a result, the CWWTF design philosophy is based on minimizing the concentration of odorous compounds produced in a cost-effective manner. Potential nuisance odors can be prevented from adversely affecting the surrounding community by three direct methods:

- Prevention of odor generation at the source
- Destruction or capture of odors before release to the environment
- Dispersion of odors to below the odor detection threshold

The CWWTF will be located within the City's designated UGA. The two potential sites initially identified for the facility are located either adjacent or in close proximity to businesses or residential areas, south or southwest of downtown. Topographical maps have indicated that the majority of the City's populated areas may be up to ten feet higher in elevation than either of the potential facility sites. The prevailing winds in the greater western Washington area mainly originate from the southwest. Emitted odors from the CWWTF must therefore be substantially controlled at the source in the most economical manner to prevent nuisance odors from adversely affecting the surrounding community. TM No. 8[244] details the odor control strategies based on initial discussions with the County's Odor Task Force. The recommended design strategy has subsequently been reviewed and updated but relies on the same principles.

6.5.1 Methodology

Since both potential CWWTF sites under consideration are upwind and lower in elevation than the majority of City's structures, it is critical that the odor control system be designed in a cost-effective manner that is also sensitive to community needs. As a result, the design philosophy for the CWWTF is to incorporate conservative provisions to effectively contain and treat nuisance odors that result from the treatment processes with the highest potential of producing detectable odors.

6.5.2 Odor Handling Strategies

There are three primary methods of treating odorous gases produced at wastewater treatment facilities: physical, chemical, and biological. Physical methods include adsorption, dilution, oxygen injection, scrubbing towers, and turbulence-inducing facilities. Chemical methods include oxidation, precipitation, neutralizing agents, acidic/alkaline scrubbing, and thermal oxidation. Biological methods include reuse of off-gas as inlet gas to aeration basins and biologically active filters. The most common odor control methods were evaluated; these included single-stage chemical scrubbers, activated carbon absorbers, biologically active filters, and thermal processes.[245] Treated air will be discharged through a vent stack designed to encourage atmospheric dilution.

In lieu of individual enclosures, mechanical forced air exhaust ventilation of the headworks building will allow easy operator access to the equipment. Air will be vented from the structure at a minimum of 12[246] air changes per hour (ACH) and sent to the odor control facility. It is anticipated that the odorous compounds from the headworks system will contain the highest concentrations of hydrogen sulfide.

The solids holding basins, anaerobic and anoxic basin zones, and membrane feed pump wet well are anticipated to be covered and mechanically vented, leaving at least two feet of freeboard space. The aerobic zones were not identified as a nuisance impact risk. The air emitted from the weir aeration into the MBR wetwell could likely contain volatile organic compounds (VOC) and require additional treatment in the odor control facilities. Air emitted from the anaerobic and anoxic biological treatment zones typically does not have high concentrations of hydrogen sulfide but may contain other oxidizable compounds that may require treatment.

The aerated solids thickening/holding basin is to be enclosed and provided with mechanical venting and odor treatment. The air stream emitted from the processing of the wasted solids will be mainly composed of VOCs and will contain sulfides. Table 6.7 presents a preliminary estimate of the minimum vent rates required for each process based on the recommendations. The odor control system will likely far exceed the required ventilation rates calculated by the model.

Table 6.7 Estimated Individual Minimum Odor Control Vent Rates Carnation Wastewater Treatment Facility King County Department of Natural Resources and Parks		
Process Location	**Design Rate (ACH)**	**Vent Rate (scfm)**
Headworks	12	5,220
Anaerobic and anoxic basin zones and membrane feed pump wet well surface	6	170
Aerated solids holding basins	6	250
Design total		**5,640**
ACH = air changes per hour scfm = standard cubic feet per minute		

6.6 Overall Cost Estimate Evaluation Criteria

6.6.1 Cost Estimating Strategy

Costs for wastewater treatment facilities can be estimated using one of three general approaches:

- Cost curves derived from as-built costs of similar facilities
- Detailed quantity estimates for the particular facility
- Major-item quantity estimates with percentage allowances

Cost curves are often used at the planning level because it is not possible to identify quantity estimates for more than a few general cost items at this level of project development. Cost estimates based on detailed quantity estimates, therefore, are not possible for planning projects. The third approach, however, combines aspects of the first two approaches. Unit quantities are developed for major costs items such as concrete and excavation, and the size and power rating of major equipment items are identified. Building costs are estimated based on the estimated square footages of facilities. Other costs, such as those for piping and miscellaneous mechanical equipment, electrical equipment, instrumentation, site work, contractor mobilization, demobilization, bond, and profit are estimated as percentage allowances, where the percentage allowances are estimated based on experience with similar projects in the past. This is the general approach taken for the CWWTF. As a check of these costs, however, TM No. 13 provides a comparison of the CWWTF costs against those from previous projects.[247]

Cost estimating criteria, in conformance with requirements specified for federal projects, were developed for use in cost comparisons. Additional details on cost assumptions as well as the cost estimating criteria used are presented in TM Nos. 6,[248] 7,[249] 8,[250] and 14.[251] All evaluations assumed a present-worth period of the facility design life (from December 2007 to 2030) with the 2004 federal discount rate of 5.875 percent.[252]

6.6.2 Treatment Facility Costs

A summary of the cost-effectiveness analysis for the proposed CWWTF is presented in Table 6.8, with detailed costs presented in Appendix F. The costs shown have been develop specifically for the purpose of comparing the various alternatives and do not necessarily reflect the actual or estimated costs for construction. These comparative costs are likely to be conservatively high but apply to all of the alternatives. It should be noted that the annualized maintenance cost for the MBR scenario includes an additional cost of approximately $27,000 for repair and replacement of the membrane cassettes.

Table 6.8 Scenario Alternatives Present Worth Cost Comparison
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks

	Estimated Costs ($)		
Cost Type	**Scenario 1 SBR**	**Scenario 2 Oxidation Ditch**	**Scenario 3 MBR**
Construction and Allied Costs			
Mobilization	650,000	600,000	500,000
Site work	965,800	907,500	665,000
Treatment and support areas	5,272,100	5,193,800	4,719,500
Odor control	665,000	600,000	500,000
Contingency (10%)	775,300	730,200	638,400
Overhead and profit (15%)	1,246,200	1,204,800	1,053,400
Sales tax (8.8%)	840,800	812,800	710,700
Consultant/owner costs	3,807,000	3,717,000	3,374,000
Capital Subtotal	14,202,200	13,766,400	12,161,000
Annual Operations and Maintenance[a]			
Labor[b]	90,000	90,000	90,000
Energy	51,000	51,000	78,000
Maintenance	102,500	97,500	129,300
Chemicals	70,000	70,000	72,000
Miscellaneous	20,000	20,000	20,000
Annual O&M subtotal	330,500	328,500	389,300
Total Present Worth[c]			
Total capital	14.2	13.8	12.2
O&M	4.1	4.0	4.7
Total Project	**18.3**	**17.8**	**16.9**

a. Does not include solids transportation costs.
b. Assumes one full-time employee equivalent, regardless of alternative.
c. Present worth costs for the design life of the CWWTF (2007-2030) are dollars in millions for Year 2004 and assumes 5.875 percent discount rate.

6.6.2.1 Wasted Solids Handling Costs

The ease of transferring waste solids to a septic tanker for transport decreases as the percent solids fraction increases. The cost estimate evaluated the relative costs of transporting three varying concentrations of thickened sludge. Based on the cost evaluation, gravity thickening (two percent solids) has a negligibly higher present worth in comparison to thickening with a MBR (four percent solids). Thickening to six percent solids by use of a gravity belt thickener was determined as much higher in cost. Decanting waste solids with an MBR is a new method of thickening with limited experience. The County may choose to membrane thicken in the future but will proceed with gravity decanting in design development. Table 6.9 compares the cost of thickening the waste activated sludge to two, four, and six percent solids onsite and transportation to another County facility.

Table 6.9 Solids-Handling Cost Comparison
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks

Cost Type	Estimated Costs ($)		
	Two Percent Solids	Four Percent Solids	Six Percent Solids
Installed capital cost	850,000	1,350,000	1,940,000
Annual O&M costs[a]	127,300	71,400	72,100
Present worth Analysis			
Capital	850,000	1,350,000	1,940,000
O&M	1,475,000	827,000	835,000
Total present worth (22 years)[b]	2,325,000	2,177,000	2,775,000

a. O&M costs are dollars per year in 2004. Assumes labor and transportation costs.

b. The total present worth accounts for costs incurred at the CWWTF and for solids transportation to the South Treatment Plant. It is assumed that the cost of processing the solids at the South Treatment Plant is the same for all of the three options.

Source: Einfeld, Brad. Carollo Engineers, Carnation WWTF Solids Handling Letter to John Komorita, Project Manager. July 12, 2004.

6.6.2.2 Other Wastewater Treatment and Facility Costs

Each of the three secondary treatment options defined in Chapter 6.3 have been coupled with the necessary facilities to allow cost comparisons for an operational CWWTF. The following processes have been designed with redundancy constraints to address either process constraints or regulatory requirements and form the basis for cost comparison. Additional assumptions for the cost comparison include:

- Estimates do not include any potential costs associated with the purchase or lease of land for the CWWTF.

- Each scenario assumes two single-stage screening systems installed in parallel. The second screen serves as the redundant train for the facility.

- Each scenario uses a dual-biological-train configuration.

- The design of the membrane tanks includes five tanks, with one redundant unit normally in service. The configuration allows a single membrane tank to be taken out of service for chemical cleaning or maintenance while the other tanks continue to provide full treatment at an increased membrane flux rate. Operating at the lower flux rates during normal operation increases system flexibility and may allow longer operation between maintenance cleaning cycles.

- Standby clarifiers are not required either for Class II wastewater treatment standards[253] or for Class A reclamation standards.

- Media sand filters have been designed with one redundant cell on standby.

- Cost estimates for the UV system are based on meeting design average and peak flows according to NWRI design standards for reclaimed water facilities. The system is assumed to be composed of a two-parallel-train closed-channel UV system (two modules per train). Either one or both modules from a single train will be in service, depending on the instantaneous flow. One train in service will provide full disinfection at design year. The second train will provide the necessary redundancy to maintain disinfection. The operating costs for UV disinfection assume that DOH and Ecology will grant a waiver from maintaining chlorine residual. If a chlorine residual of 0.5 mg/L is required according to the Reclamation Standards,[254] the UV system will need to include supplemental hypochlorite addition, which will require additional capital and increase operating costs.

6.6.2.3 Treatment Facility Evaluation

The planning-level cost estimates demonstrates that the difference between the scenarios falls well within the error range of the estimates. Table 6.10 provides a comparison of the three process trains for several key design criteria. Overall, the MBR technology was determined to have costs comparable to the other processes due to the negligible amount of I/I to the collection system (small peaking factor). Conversely, MBRs were determined to have the highest energy requirements in relation to the other processes.

Table 6.10 Scenario Process Comparison Carnation Wastewater Treatment Facility King County Department of Natural Resources and Parks			
Parameter	**Scenario 1 SBR**	**Scenario 2 Oxidation Ditch**	**Scenario 3 MBR**
Risk	+	+	+
Capital costs	O	O	O
O&M costs	O	O	–
Facility space requirements	–	–	+
Energy consumption	O	O	–
Process reliability	+	+	O
Operations familiarity	O	O	O
Maintenance requirements	+	+	O
Odor control costs	O	O	+
Enclosure costs	O	–	+
+ = superior O = average – = inferior			

Based on the present-worth analysis and the process comparisons, activated sludge with MBR technology (Scenario 3) was recommended for the CWWTF. The MBR technology provides the highest water quality while requiring the smallest environmental footprint. In addition, the City can have a state-of-the-art treatment facility for a cost that is comparable to a conventional treatment facility.

6.6.3 Conveyance and Discharge Costs

Table 6.11 provides a present-worth cost comparison of the evaluated conveyance and discharge alternatives. Key assumptions made in this cost comparison include:

- Costs to the upland and wetlands discharge alternatives include a 24-hour emergency storage basin.
- Easement costs were calculated in the cost comparison but did not include any assumed leasing or land acquisition costs associated with the upland discharge site.
- Annual operations and maintenance costs for the discharge alternatives include maintenance labor associated with the discharge method and energy required for conveyance pumping costs.

Table 6.11 Conveyance and Discharge Alternative Cost Comparison
Carnation Wastewater Treatment Facility
King County Department of Natural Resources and Parks

Discharge Alternative	Approximate Conveyance Distance (mi)	Total Capital Cost[a] ($)	Annual Labor and Maintenance Costs($)	Total Present Worth[b]($)
Conveyance from City-owned Site				
River	1.6	1,717,000	3,400	1,756,400
Upland	2.3	4,807,000	14,000	4,969,300
Wetlands	2.8	4,174,000	53,900	4,798,600
Conveyance from Weckwerth Site				
River	2.7	2,818,000	8,600	2,917,700
Upland	1.6	4,119,000	12,200	4,260,400
Wetlands	3.0	3,839,000	53,700	4,461,300

a. Total capital cost including direct construction, sales tax, engineering services, construction management, and allied owner costs.

b. Present-worth analysis is in 2004 dollars, a 5.875 percent discount rate, and the facility design period (2007-2030).

Based on the planning level cost analysis performed for conveyance and discharge, the river outfall discharge alternative is the least-costly alternative (capital and annual labor and maintenance) for either potential treatment facility location. The river outfall discharge alternative has the shortest conveyance distance from the City-owned site, while upland discharge has the shortest conveyance distance from the Weckwerth site. The wetlands discharge alternative is the next least-costly alternative, with capital costs of an additional $2.2 million from for the City-owned site.

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