WETLAND RESTORATION MONITORING REPORT

Puget Creek and Hamm Creek Sites
Duwamish River
Seattle, Washington

March 2005

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EXECUTIVE SUMMARY

PUGET CREEK

The overall goal of removing historic fill material to restore approximately 0.50 acres of habitat has been met through the Puget Creek restoration project. The project as designed and built is conducive to the future day lighting of Puget Creek into the restored marsh/mudflat area and the Duwamish River.

The Puget Creek restoration project has created approximately 4,415 square feet (0.10 acres) of intertidal habitat. The 50-foot riparian buffer surrounding the site is well established and densely vegetated with native trees and shrubs. The goal was to create approximately 6,534 square feet (0.15 acres) of intertidal habitat (marsh and mudflat) surrounded by an approximately 50-foot wide riparian buffer of native trees and shrubs.

Although less intertidal habitat was created than anticipated, the habitat restored is densely vegetated by native saltmarsh species and is exporting organic matter and saltmarsh seeds to the river. The restored marsh supports at least nine native intertidal species. The percent coverage of the intertidal marsh area after five years is 100% and the plants have achieved their mature stature and are thus no longer vulnerable to goose predation (the goose excluders were removed this year). The intertidal marsh and riparian buffer have dramatically increased the biodiversity of native plant species in the area as documented by our vegetation monitoring. The riparian buffer alone now supports 34 different native tree and shrub species.

The marsh and mudflat provide foraging habitat for native fish species. Two years after construction, juvenile chum and sculpins were documented using the restored intertidal habitats; the site is used by shiner perch, three-spin stickleback, sculpins, and hatchery chinook as documented in years three and five following construction. The narrow opening into the marsh from the shoreline, coupled with a fairly high intertidal elevation, likely reduces the direct availability of the intertidal habitat to fish. However, the export of detrital matter and presumably of benthic and epibenthic invertebrates directly supports anadromous salmonids as well as resident fish in the lower river.

HAMM CREEK

The overall goals of the Hamm Creek restoration project of restoring important estuarine habitat along the Duwamish Waterway and restoring fish passage and habitat along Hamm Creek have been met. The ecological benefits of primary productivity/food web support, increased plant species diversity, and use of created habitats by fish and wildlife species are accruing at Hamm Creek. Per the restoration plan, the project has created an approximately 2,300 foot long stream channel with a settling basin, has day-lighted the

stream out of a culvert and reconnected it directly with the Duwamish River, and has created a freshwater wetland and an intertidal saltmarsh, and a riparian buffer on the site.

The intertidal area created at Hamm Creek is approximately 0.7 to 0.8 acres. The goal of the project was to create approximately 1.0 acres of intertidal area on the site. Although the total intertidal area is smaller than anticipated, the approximately 0.25-0.26 acres of intertidal saltmarsh vegetation is densely vegetated by at least eight native saltmarsh species. The marsh appears well established and of sufficient stature to resist goose predation if the goose excluder fencing were removed.

The freshwater wetland and riparian buffer created at Hamm Creek are similarly well vegetated with predominately native species. At least four native species could be added into the site along the edges of the wetland and stream channel, based on our experimental test plots. This would increase the diversity and would likely accelerate the natural colonization of emergent species into this site, providing additional habitat complexity, shading, and detrital import into the restored stream channel. Species with small stem diameters, such as the water parsley, could also provide suitable substrates for amphibian reproduction within the creek.

The riparian buffer areas are also densely vegetated by at least 26 native tree and shrub species, with notable exceptions in areas along the northern fence line where invasive species are taking over. The trees and shrubs fringing the stream channel and wetland are beginning to achieve a stature sufficient to export organic material into the creek and provide shade to the channel.

In addition to the primary productivity provided by the stream channel, wetland, intertidal marsh, and riparian buffer, these restored habitats are also providing foodweb support by producing benthic invertebrates and littoral insects. The dominance of the invertebrate communities by relative few groups is likely indicative of the gradual development and colonization of the restored habitats by pioneering species. The diets of juvenile salmon utilizing the Hamm Creek restoration site are consistent with the types of organisms being produced by the site's restored habitats. The variety of diet organisms is consistent with both juvenile salmon diets observed in previous studies of restored sites in the lower Duwamish River and with diets recorded in more natural estuarine habitats and larger breach-diked restoration sites in the Pacific Northwest.

One of the main goals of this project was to restore access to Hamm Creek for salmon and to restore juvenile salmon and resident fish rearing habitat. Within one year of project completion, hundreds of juvenile coho were documented within the stream channel, along with smaller numbers of juvenile coho and chum salmon, cutthroat trout. Thousands of juvenile chum salmon have utilized the intertidal habitats at the mouth of the creek since its construction, with higher numbers recorded at the restoration site than at the nearby reference site. Use of the site by non-salmonid fish species has also been

documented, with sculpins, three-spin sticklebacks, flatfish, and shiner perch utilizing the intertidal habitats of the site.

Other physical and biological characteristics of the site have also largely indicated as successfully functioning restoration project. The design and construction of the Hamm Creek site allows for the full range of tidal timing and magnitude and thus creates a tidal regime that matches that of the Duwamish River. While erosion issues at the mouth initially threatened the integrity of the intertidal habitats and the orientation of the creek mouth, that erosion appears to have been stemmed by the recent repairs. The sediments of the Hamm Creek site are similar in total organic carbon, but with a higher proportion of silts compared to the reference site. Over 69 species of birds have been documented using the Hamm Creek site, including multiple years of successful breeding and fledging of osprey from the nest platform erected on site.

1.0 INTRODUCTION

This report presents the results of post-construction monitoring of the Puget Creek and Hamm Creek restoration sites, both located on the lower Duwamish River, Seattle, Washington. Both projects were implemented by the U.S. Army, Corps of Engineers, Seattle District (Corps) in the late 1990's as part of the Section 1135 Aquatic Restoration authority granted to the Corps through the Water Resources Development Act (WRDA) of 1986 (Public Law 99-662). Section 1135 authorizes the Corps to undertake restoration of locations that have been affected by U.S. Army Corps of Engineers projects if such m restoration does not interfere with authorized project purposes. Under the Section 1135 authority, these projects are modifications of the Seattle Harbor navigation project, which was completed in 1931. Although each project was implemented separately as with different local sponsors, they will be presented together in this report to facilitate a more landscape-scale perspective on the restoration of the lower Duwamish River estuary, as well as to maximize efficiency and minimize costs of report preparation.

This report documents monitoring conducted by the Corps and also summarizes monitoring conducted at these sites by the Corps and other agencies, groups, or individuals. This report serves to document the condition of the restored areas and to determine whether the development of these sites has been consistent with the goals, objectives, and intent of the restoration plan designs.

1.1 HISTORICAL CONTEXT – THE NEED FOR RESTORATION

The lower Green/Duwamish River estuary was once an area of very low gradient with a sinuous, main channel meandering through sand and mud substrates (Figure 1). The original intertidal mud and sand flats historically extended east to what is now Interstate 5 and west to the West Seattle Hills. Most of the lower reach of the river was affected by tidal influence. The river had several distributary channels spread over the broad delta floodplain. The floodplain supported over 4,000 acres of tidal and intertidal habitat (Bloomberg et al. 1988), characterized by a vast, tidally influenced mosaic of swamp and marsh wetlands. Large woody debris was carried into the lower river and estuary from the upper watershed during floods (Perkins 1993, USACE 1997a, 1997b). The wetlands provided the nursery for a large salmon and clam fishery in the Duwamish River and Elliott Bay that was available to Native Americans before Euro-American settlement.

Over the last 100 years, the braided flows of the lower river have been extensively channelized through dredging and construction of levees. Dredging of the mouth of the estuary and construction of Harbor Island by the City and Port of Seattle began in the early 1900's. Congress subsequently funded a navigation project for deepening, widening, and straightening of the estuary portion of the Duwamish River. Presently, freshwater enters the estuary through only one permanent channel. Dredging has resulted

in the replacement of 9.3 miles of estuarine channel habitat with the 5.2 miles of deep channel habitat that exists today (Bloomberg et al. 1988).

The estuarine mud flats and marshes were nearly completely destroyed by dredging and filling activities that occurred between the late 1800's and the mid-1900's as part of an early plan for a canal that would establish a navigable link between the salty waters of Puget Sound and the inland fresh waters of Lake Washington. Coupled with the combination of levees, water source diversion dams, and dams for flood control, the channelization and consequent industrialization of the estuary has resulted in the elimination of nearly all intertidal wetlands and shallow subtidal aquatic habitats in the vicinity of Elliott Bay and the lower Duwamish River. Ultimately, intertidal habitats in the Duwamish River were reduced from about 2,100-2,500 acres to less than 25 acres (Benoit 1979, Bortleson et al. 1980, Blomberg et al. 1988).

Today, the lower approximately 5.2 miles of the Duwamish River (downstream of the Turning Basin) is the heavily industrialized portion known as the Duwamish Waterway. The main channel is a major shipping route for containerized and bulk cargo with intense marine traffic and annual maintenance dredging up to and including the Turning Basin. The shoreline along the Duwamish Waterway is intensively developed for industrial and commercial operations and the adjacent lands are similarly developed by a variety of water dependent industrial users. Beginning at the Turning Basin and continuing to the mouth, over-water structures occupy 12,150 linear feet (2.3 miles) on both banks of the river. This represents about 20 percent of the lower estuarine shoreline (King County DNR 2001). In areas without over-water structures, the remaining shoreline is thin bands of mud- and sandflats along the toe of the riprap banks.

Scattered patches and individual trees (particularly along Kellogg Island) are all that remains of the once diverse riparian forests and tidal swamps that fringed the lower Duwamish River (Bloomberg et al. 1988). The uplands surrounding the river are predominately industrial and commercial facilities. While some of these facilities do support landscaped areas, they are generally not composed on native tree or shrub species and are not maintained has natural areas of habitat.

1.2 CURRENT CONTEXT

The total area of intertidal wetlands and more naturally vegetated shorelines has increased modestly over the last few years through a series of intertidal restoration projects (some with mitigation components) implemented within the lower nine miles of the Duwamish River. Including the Hamm Creek and Puget Creek sites, nine projects have been constructed since 1995. These nine sites have been constructed through several different mechanisms: the Coastal America program, as remediation under the Natural Resources Defense Act (NRDA), or by the Corps under Section 1135 of the Water Resources Development Act. These nine sites encompass approximately 29.5

acres of restored habitat (acreage sources include People for Puget Sound, Taylor and Associates, Inc. and Corps records). In addition, the Corps and the City of Tukwila recently completed the channel and marsh portions of the Codiga Farms side channel project in the summer of 2004, adding another approximately 2 acres of intertidal habitat to the lower river.

Agencies and non-profit groups including, but not limited to, the Port of Seattle, King County DNRP, the City of Seattle, the Corps, USFWS, and People for Puget Sound are actively monitoring and/or maintaining many of these areas. These restored areas receive substantial utilization by juvenile salmon, including chinook, and provide important benthic and epibenthic prey resources (e.g., Cordell et al. 1997, 1999). The restoration of these habitats is part of an overall trend toward improvement in the estuary that began with improvements in pollution source control, toxic cleanup, and water quality in the 1970s and continues today.

The clustering of these restoration sites, in addition to others still in the planning stages, may ultimately provide spatially cumulative benefits to the river. Given sufficient time, the system may ultimately reach a point of exporting sufficient viable seeds to recolonize appropriate elevations within the lower river. By increasing the amount of functional habitat, decreasing the fragmentation of habitats, and improving in the overall watershed condition, these sites may ultimately increase the ability of the watershed to support critical life history stages of native fish and wildlife populations.

At what point this may occur, remains unknown. Ideally, monitoring the development of the restoration sites through time serves to document this trajectory toward recovery and recolonization of the albeit limited areas of intertidal habitat and natural shoreline left along the Duwamish River.

1.3 PROJECT PERSONNEL

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2.0 PROJECT LOCATIONS AND HISTORIES

2.1 PUGET CREEK 1135 - INTERTIDAL MARSH AND RIPARIAN RESTORATION

2.1.1 Puget Creek Location

The Puget Creek restoration site is physically located at approximately river mile 1.7, along the left bank of the lower Duwamish River directly west of the middle of Kellogg Island (Figures 1 and 2). In some non-Corps documents, this site is referred to as the Terminal 107 site. Specifically, the site is located in the northwestern quarter of Section 19, Range 4 East, Township 24 North, Seattle, Washington. The site can be accessed along the eastern side of West Marginal Way SW, between SW Edmunds Street and SW Hudson Street, and is located within the Terminal 107/Kellogg Island Park at 12th Avenue SW; the park is maintained as a 'shore-view' park by the City of Seattle as public open space along the river (Figure 3).

The restoration site does not encompass a creek or stream channel. Puget Creek flows down the slopes of West Seattle, through Puget Park (City of Seattle) along the western side of West Marginal Way SW, directly opposite the restoration site, and then into the storm water system beneath West Marginal Way SW. Puget Park preserves the upper reaches of Puget Creek before it enters the storm water conveyance system. Thus, there is currently no surface water connection between Puget Creek and the Duwamish River.

The restoration site encompasses an intertidal saltmarsh with a 50-foot wide riparian buffer of trees and shrubs. The intertidal portion of the site connects to the Duwamish River through a narrow opening in the shoreline bank located at the far southeastern corner of the park (Figure 3). The outer edges of the restoration area slope upwards from the marsh to meet the public areas of grass, paths, and naturalistic landscaping. A dense upland buffer of planted trees and shrubs separates the restoration area from the public areas.

2.1.2 Puget Creek History

Historical Context

The restoration site is located approximately 300 feet south of a National Register of Historic Places site, a longhouse village of the Duwamish Native American tribe. Historically, Puget Creek is believed to have joined the Duwamish River in the approximate location of the restoration site and to have provided fresh water for the village. A former brick factory was also located along this portion of the shoreline; old bricks and kiln dust were noted during the planning and construction of the project. Prior to the Port acquiring the property and their partnership with the Corps for the restoration project, the property was used as a car repair shop (People for Puget Sound 2001).

In this location, the Duwamish River channel splits to the east and west around Kellogg Island. Kellogg Island was created through the disposal of dredged material from the navigation channel. The eastern arm of the channel has been straightened and its shoreline heavily armored; it is maintained for navigation through dredging. The western arm is not dredged, although much of its shoreline is armored. The western arm of the channel is one of the only two remaining natural bends in the navigable portion of the waterway (the other being the bend upstream at the Turning Basin, approximately river mile 5.2).

The historic habitat along the shoreline and in the location of Kellogg Island is believed to have historically been intertidal marsh, based on Sheet 7 of the U.S. Geological Service (USGS), Hydrologic Investigations Atlas, which was compiled from the Coastal and Geodetic Service T-sheets from 1854 and 1899, as well as from the USGS 1908 Seattle quadrangle. The intertidal marsh was likely composed of salt-tolerant to freshwater species along the creek's channel, transitioning to high- and low saltmarsh species as the creek joined the main channel of the Duwamish River. Kellogg Island is also located on what was historically believed to have been a broad expanse of intertidal marsh extending between the distributary channels of the river mouth and delta (based on the same source) (Figure 1).

Project History

The Port of Seattle was the non-federal sponsor for the Puget Creek 1135 project and owned the lands needed for the project. The project location, configuration, and size were designed to maximize the area of intertidal habitat that could be restored while avoiding impacts to the adjacent cultural site to the north and avoiding excavation within soils contaminated with arsenic from brick kiln dust to the south. While day lighting Puget Creek was initially investigated, the costs and complications of removing the stream from the storm water system and routing it beneath West Marginal Way SW into a restored estuarine mouth proved to be beyond the feasible scope of the project.

The preliminary restoration plan was submitted to Northwestern Division in mid 1998, funds were allotted in July 1998 and feasibility began in October 1998 (Elliott Bay/Duwamish Restoration Program 1998). Construction began on the Puget Creek project in the spring of calendar year 1999, with soil amendment and plants installed in March 1999; irrigation was added and the project was completed by the end of June 1999 (according to Corps accounting records). The project was constructed for approximately $158,000, of which approximately $39,000 was real estate and $10,000 was for post-construction monitoring. Monitoring funds were designated for fiscal years 2002 ($2,600), 2003 ($3,000), and 2004 ($4,400).

The project was designed as an excavated basin with a narrow channel connecting the basin to the Duwamish River along its eastern side (Figure 4). The basin was designed to an elevation of +10.0 feet, relative to Mean Lower Low Water (MLLW) with a center

channel at elevation +8.0 feet MLLW. The riparian buffer areas rising up from the basin to meet the adjacent uplands ranged in slope from 5:1 (horizontal:vertical) along the northern side of the site to 3:1 along the southern side of the site. The steeper southern slopes were secured with coir fabric and willow plantings to more quickly stabilize the slopes.

No formal planting plan appears to have been prepared for the site; as such the number of each species of plants installed at the site is unknown. The intertidal marsh areas at elevation +10.0 feet MLLW were planted with a mixture of Lyngby's sedge (*Carex lyngbyei*) and soft-stemmed/hard-stemmed bulrush (*Scirpus lacustris*, spp. *validus/acutus*) (pers. comm., Pat Cagney, Corps, 25 February and 17 April 2003). Riparian tree and shrub species planted within the upland buffer included red alder (*Alnus rubra*), Oregon ash (*Fraxinus latifolia*), black cottonwood (*Populus balsamifera*), red-osier dogwood (*Cornus sericea*), red elderberry (*Sambucus racemosa*), Indian-plum (*Oemleria cerasiformis*), big-leaf maple (*Acer macrophyllum*), vine maple (*Acer circinatum*), mock orange (*Philadelphus lewisii*), salmonberry (*Rubus spectabilis*), snowberry (*Symphoricarpos albus*), Hooker's willow (*Salix hookeriana*), and Pacific willow *(Salix lucida*) (People for Puget Sound 2001). It is uncertain whether the plants were installed by volunteers working through People for Puget Sound or by contractors employed by the Corps/Port of Seattle for the restoration project.

2.2 HAMM CREEK 1135 - CHANNEL AND INTERTIDAL MARSH RESTORATION

2.2.1 Hamm Creek Location

The Hamm Creek restoration site is physically located at approximately river mile 5, along the left bank of the lower Duwamish River, just downstream of upstream extent of the navigable waterway at the Turning Basin (Figures 1 and 2). In some Corps documents, this site is also referred to as the Turning Basin #3 or TB#3 site, but the Turning Basin restoration sites were not part of any Section 1135 project and were not constructed by the Corps. Specifically, the day-lighted portion of the Hamm Creek restoration site is located in the southwest quarter of the southwest quarter of Section 33, Range 4 East, Township 24 North, Seattle Washington. The portion of the stream channel along West Marginal Place South extends into the northwest quarter of the northwest quarter of Section 4, Range 4 East, Township 23 North. The site can be accessed along the eastern side of West Marginal Place South (a frontage road to State Route 99), through the southwestern corner of the Crowley Marine parking lot located at the intersection with South 96th Street, or along the shoulder of West Marginal Place South at the cattle gate entrance to the Seattle City Light sub-station.

The restoration site is an irregularly shaped 6.2-acre parcel and encompasses a stream channel along West Marginal Place South, a basin, a day-lighted portion of stream channel and associated buffer along the northern edge of the site, a freshwater wetland arm, and an intertidal saltmarsh (Figure 5). The intertidal portion of the site connects to

the Duwamish River through the saltmarsh and the stream channel mouth; at the mouth, the stream flows down a series of boulder and wood cascades on outgoing and low tides to join the main channel of the river at the far northeastern corner of the site. The outer edges of the restoration area slope upwards from the stream channel and end along an informal path frequented by dog-walkers and bird watchers. The restoration area is separated from the City Light sub-station by an undeveloped grassy field/wet meadow.

2.2.2 Hamm Creek History

Historical Context

The Hamm Creek restoration site was historically part of a larger area that received dredged material from the Corps maintenance dredging of the Duwamish Waterway. Corps dredging records indicate the general area of the site received dredged materials in 1954 (220,000 cubic yards), in 1960 (294,000 cubic yards), in 1968 (375,000 cubic yards) and in 1971 (325,000 cubic yards). Since 1971, the Corps has not deposited dredged material on the site, but the site received dredged material in 1985 from a nearby yacht club (USACE 1998).

Historically, the south fork of Hamm Creek is believed to have meandered through intertidal marsh and mudflat as it gradually descended from its forested watershed to join the Duwamish River estuary (Figure 1). Dredging and filling of the waterway, coupled with development of the adjacent shoreline and former tidelands resulted in the creek channel becoming disconnected from the estuary and the productive intertidal and shoreline habitats being converted to upland fill. Ultimately, Hamm Creek was routed into a ditch along the eastern edge of West Marginal Place South and then through a series of culverts estimated at over 1,900 feet in length. The culvert outfall was elevated above the mean high water elevation of the Duwamish River channel and thus was virtually inaccessible to anadromous salmonids. Aerial photos of the area show that this channelization into the ditch may have occurred prior to 1940. The 1940 aerial photo indicates there was saltmarsh along the left shoreline of the river and there appeared to be a stream flowing into the river just north of the present day location of South 96th Street (which currently forms the northern boundary of the Hamm Creek restoration site) (Figure 6).

Upstream of the project site, the south fork of Hamm Creek originates out of an urbanized upland plateau south of the project area. An approximately 3-acre habitat restoration project (wetland, salmon stream habitat, and ponds) is located west of State Route 99, within the upper portion of the creek's watershed. The 'Point Rediscovery' project was completed in 1997 and involved the restoration of an old sewage treatment plant site adjacent to an upper portion of Hamm Creek (I'M A PAL Foundation, April 1, 1998 letter to Colonel Rigsby). The I'm A PAL Foundation was also active in cleaning the upper reaches of Hamm Creek and planting invertebrates and native anadromous fish species into the creek since the 1980's (USACE 1998).

Project History

King County Department of Metropolitan Services, Water and Land Resources Division (now King County Department of Natural Resources) was the non-federal sponsor for the Hamm Creek 1135 project; Seattle City Light originally owned the lands needed for the project. King County DNR (through funds obtained from a number of other agencies and organizations) ultimately obtained a permanent conservation easement for 6.2 acres of land from Seattle City Light and obtained a temporary construction easement for an additional 3.5 acres. The location, configuration, and size of the new channel were designed to minimize any restrictions on future development of the adjacent Seattle City Light property; this was accomplished by placing the day lighted portion of the stream channel along the northern boundary of the property acquired by King County DNR and by limiting the upstream extent of tidal influence with a buried concrete and log control structure (USACE 1998).

King County DNR (formerly METRO [municipality of metropolitan Seattle])is party to a 1990 Consent Decree that established a program for sediment remediation, source control, and habitat development in and around the Duwamish River and Elliott Bay. That program is known as the Elliott Bay/Duwamish Restoration Program (EB/DRP). King County DNR received $750,000 credit from EB/DRP for the purchase of the conservation easement from Seattle City Light toward the County's real property obligation to the EB/DRP under the Consent Decree (USFWS 2000). As a result of this link between the Corps non-federal sponsor (King County DNR) and the EB/DRP, the estuarine mouth portion of the Hamm Creek restoration site has been periodically monitored by the USFWS for progress toward meeting the habitat development goals of the Consent Decree. The results from those monitoring efforts are incorporated into this report specifically and by reference (see USFWS 2000 and Low and Myers 2002).

The Corps prepared the final Ecosystem Restoration Report and Environmental Assessment in July 1998 (according to Corps accounting records) and funds were authorized in November 1998 (Elliott Bay/Duwamish Restoration Program 1998). An easement agreement with Seattle City Light was signed on March 26, 1999 allowing the project to move into construction phase (Elliott Bay/Duwamish Restoration Program 1999). Permitting was completed in June 1999 and construction began on the Hamm Creek project on August 9, 1999 and continued through the end of calendar year 1999 (Elliott Bay/Duwamish Restoration Program 1999). Vegetation planting at Hamm Creek began on April 12, 2000. The day-lighted portion of the channel had to be moved and reconstructed in early 2000 due to a survey error. The Corps completed channel realignment and connected the site to the Duwamish River in July 2000 (Elliott Bay/Duwamish Restoration Program 2000). The in-ground irrigation system was installed in August 2000 and People for Puget Sound and Cascadia Quest installed additional plants in October 2000 (Elliott Bay/Duwamish Restoration Program 2000).

The Corps reported the project was completed in October 2000. The project was constructed for approximately $2.37 million of which approximately $761,900 was real estate and $50,000 was post-construction monitoring. Monitoring funds were designated for fiscal years 2001 ($14,000), 2003 ($18,000), and 2005 ($18,000).

The project was designed as an excavated channel running parallel to the existing ditch along West Marginal Place South, connecting to a broad basin in the northwestern corner of the site. The channel would then be day lighted out of the culvert and returned to an excavated stream channel paralleling the northern boundary of the site and ultimately connecting to the Duwamish River through an intertidal marsh along the eastern side of the property; a freshwater wetland depression would be constructed off of the southeastern corner of the stream channel (Figure 7). Riparian buffer areas rising up from the basin and channel appear to have been designed as 3:1 slopes (horizontal:vertical).

A formal planting plan was prepared for the site; however, the plan did not specify numbers of each species of plant (Figure 7). Repeated replanting has also occurred at the site over the last four years during maintenance efforts conducted by People for Puget Sound. Based on the Corps 'as-built' plan set dated May 23, 2001, the intertidal salt marsh areas near the mouth of the creek were planted with a mixture of Lyngby's sedge, soft-stemmed bulrush, tufted hairgrass (*Deschampsia caespitosa*), Pacific silverweed (*Potentilla pacifica*), and Douglas aster (*Aster subspicatus*). The freshwater wetland was planted with a mixture of slough sedge (*Carex obnupta*), sawbeak sedge (*Carex stipata*), water parsley (*Oenanthe sarmentosa*), and small-fruited bulrush (*Scirpus microcarpus*). Riparian tree and shrub species originally planted within the upland buffer included: western hazelnut (*Corylus cornuta*), black hawthorne (*Crataegus douglasii*), shore pine (*Pinus contorta*), western crabapple (*Malus fusca*), cascara (*Rhamnus purshiana*), oceanspray (*Holodiscus discolor*), black twinberry (*Lonicera involucrate*), thimbleberry (*Rubus parviflorus*), Nootka rose (*Rosa nutkana*), Pacific ninebark (*Physocarpus capitatus*), Oregon grape (*Mahonia nervosa*), red-flowering currant (*Ribes sanguineum*), kinnikinnick (*Arctostaphylos uva-ursi*), red-osier dogwood, Indian-plum, snowberry, Sitka willow (*Salix sitchensis*), Hooker's willow, and Pacific willow. The plants were installed at various times in early to mid 2000 by both contractors employed by the Corps/King County and by volunteers working through People for Puget Sound and Cascadia Quest. In order not to interfere with overhead power lines along West Marginal Way South, only small trees and shrubs were to be planted along this portion of the channel. These included the willow species.

3.0 PROJECT GOALS AND OBJECTIVES

Generally, the goal of both the Puget Creek and Hamm Creek projects was to restore critically limiting habitats to the lower Duwamish River. The operating premise being that by restoring the native plant species and structure of the habitats, important wetland, stream, and riparian functions would be restored to the lower Duwamish River. The functions targeted by these projects were mainly: 1) food chain support through increased primary production, increased detritus production, and increased invertebrate production (both epibenthic, benthic, and littoral), and 2) refuge, foraging, and rearing/nesting functions for fish, birds, and urban-adapted terrestrial wildlife through increased habitat along the lower river.

The restored areas at Puget Creek and Hamm Creek were designed to establish plant communities that emulate typical native intertidal marsh and riparian plant communities (albeit without the availability of any detailed information as to the historic species diversity or community structure of the lower Duwamish River estuary). The restored areas were also designed to be low-maintenance, self-sustaining communities that would continue to develop through natural successional processes toward some 'equilibrium' state of native plant diversity and density given a pattern of limited to intermediate disturbance at these sites.

3.1 PUGET CREEK GOALS AND OBJECTIVES

The overall goal of the Puget Creek restoration project was to restore approximately 0.50 acres of habitat along the lower river by removing historic fill materials. The project was designed to be conducive to the future day lighting of Puget Creek itself into the restored marsh/mudflat area and thence into the Duwamish River. The intent of the project goal was to provide restored habitat for the benefit of fish and wildlife (Corps 6 January 1999 Fact Sheet).

The overall goal of restoring approximately 0.50 acres of habitat was to consist of approximately 0.10 acres of intertidal marsh, 0.05 acres of mudflat, and 0.35 acres of riparian buffer. In total, the design was to create approximately 6,534 square feet (0.15 acres) of intertidal habitat (marsh and mudflat) surrounded by an approximately 50-foot wide riparian buffer of native trees and shrubs.

Specific objectives of the project were stated as 'expected outputs and benefits' (Corps 6 January 1999 Fact Sheet). The benefits of this project were to accrue mainly through: 1) increase in primary and secondary productivity (i.e. food web support) through the production of organic matter and invertebrates in the marsh and mudflat, 2) increased species diversity (implied as plant diversity, but not specified), and 3) creation of native

habitat suitable to critical life-history stages of anadromous and resident fish and urban-adapted bird and mammal species (Corps 6 January 1999 Fact Sheet).

3.2 HAMM CREEK GOALS AND OBJECTIVES

According to the Ecosystem Restoration Report (USACE 1998), the goals of the Hamm Creek restoration project were to 1) restore important estuarine habitat along the Duwamish Waterway and 2) to restore fish passage and habitat along Hamm Creek. This goal was to be accomplished by removing historic fill material from the site, improving existing conditions within the stream channel along West Marginal Way South, creating a freshwater wetland, and by day lighting the stream from its culvert and reconnecting it with the Duwamish River through a restored mouth and intertidal marsh (USACE 1998).

In order to achieve these goals, the project was to consist of an approximately 2,300 foot long stream channel along the western and northern portions of the property, one acre of freshwater wetland/sediment settling basin at the northwestern corner of the site, a one acre freshwater wetland arm off the southeastern end of the stream channel, and a one acre intertidal marsh at the eastern end of site as the stream channel joins the Duwamish River. An approximately 30-foot wide riparian buffer of native trees and shrubs would surround the stream channel.

Nine specific 'technical planning objectives' of the project were stated in the Ecosystem Restoration Report (USACE 1998) to guide the formulation and development of the restoration. These objectives largely related to accomplishing the work within the real estate constraints, facilitating fish passage (targeting specifically coho salmon, steelhead trout and cutthroat trout), maximizing intertidal habitat and stream bank revegetation, avoiding steep banks, an unstable channel, or increased flooding potential, and not causing unusual operation or maintenance concerns for King County DNR. As such, the Corps' 'planning objectives' for Hamm Creek did not establish specifically measurable physical or ecological outputs from the project.

In contrast, the EB/DRP established five physical success criteria and five biological success criteria against which to evaluate the development of four restoration sites on the lower river, including the mouth of the Hamm Creek site (USFWS 2000). The physical criteria included: 1) the percent of the site which was intertidal habitat (+12 to –2-feet MLLW), 2) tidal amplitude, 3) slope erosion, 4) change in sediment structure, and 5) maintenance of sediment quality. The biological criteria included: 1) marsh vegetation establishment, 2) riparian vegetation establishment, 3) bird use, 4) fish access/presence, and 5) invertebrate prey resource production.

The Corps did qualitatively forecast the expected benefits of the project as part of the alternatives and economic analysis. The expected ecological benefits of the project were listed as primary productivity, patch size, total amount of edge, species diversity, and habitat interspersion (USACE 1998). In that respect, the benefits of this project were

expected to be similar to those anticipated at the Puget Creek site. Ecological benefits were expected to accrue mainly through: 1) increase in primary and secondary productivity (i.e. food web support) through the production of organic matter and invertebrates along the channel, in the wetland, and in the salt marsh/mudflat, 2) increased plant species diversity, and 3) the creation of native habitat suitable to critical life-history stages of anadromous and resident fish and urban-adapted bird and mammal species.

The Corps' monitoring plan specified an 'as-built' survey of the site and then post-construction monitoring in years one, three, and five post-construction. In years one, three, and five the plan anticipated electroshocking fish, mapping vegetative cover, collecting and analyzing both benthic invertebrates and littoral insects; the monitoring plan for years three and five also anticipated an analysis of fish stomach contents in conjunction with the invertebrate and insect sampling. The monitoring plan also anticipated repeating the survey of post-construction cross sections in four locations (located every 500 feet) and collecting and analyzing three sediment samples for grain size in year three. However, the monitoring plan allotted approximately $15,000 a year for these efforts, which has generally proved insufficient to accomplish all of the anticipated types of data collection and analysis.

4.0 MONITORING METHODS

Post-construction monitoring is intended to document the progress of each restoration site toward meetings the goals and objectives articulated for the project. Monitoring methods were tailored to the types of data needed to address the goals and objectives, within the constraints of available funding. In order to compare existing conditions with pre-construction conditions, effort was dedicated to obtaining background information and constructing project records for these restoration sites. Through this effort, the Corps has accumulated copies of most of the monitoring studies that have been conducted in the lower Duwamish River on restoration sites constructed contemporaneously with the Puget and Hamm Creek sites. These studies provide data with which to compare the development of the Puget and Hamm Creek sites, as well as information regarding the extent and history of restoration of similar types of habitat within the lower Duwamish River estuary. Through extensive coordination with other groups conducting monitoring of the lower Duwamish restoration sites, Corps has also obtained copies of monitoring reports for other efforts at the Puget and Hamm Creek sites. The types of data and sources are identified in the sections below.

4.1 PUGET CREEK MONITORING

The goal of the Puget Creek restoration project was to restore approximately 6,534 square feet (0.15 acres) of intertidal habitat (marsh and mudflat) surrounded by an approximately 50-foot wide riparian buffer of native trees and shrubs. The anticipated benefits (or objectives) of this project were to: 1) provide food web support through the production of organic matter and invertebrates in the marsh and mudflat, 2) increase plant species diversity, and 3) create native habitat suitable to critical life-history stages of anadromous and resident fish and urban-adapted bird and mammal species.

In order to assess the project goal and associated objectives, we: 1) recorded species diversity and plant density in the intertidal marsh and riparian buffer areas, 2) measured the area of intertidal habitats, and 3) sampled fish-use of the intertidal area. We used density of intertidal marsh plants as a qualitative surrogate for a more costly, quantitative measure of food-web support. The costs of conducting plant biomass and benthic invertebrate sampling to assess primary and secondary productivity were beyond the scope of funds available for annual monitoring.

4.1.1 Vegetation Sampling Plots

As part of the Volunteer Salmon Habitat Restoration and Monitoring Program (VSRHMP), People for Puget Sound (PfPS) established a series of vegetation monitoring plots in 2001 within the intertidal (8 plots) and riparian buffer (4 plots) of the Puget Creek site (Figure 8). The plot centers were marked with wood stakes and metal tags. We utilized the sample vegetation sampling plots in order to limit disturbance to the

restored habitats and to increase the potential for correlation of collected data with other agencies/groups interested in this site.

At each of the eight intertidal sampling plots, we used a reel measuring tape to create a circular sampling plot with a radius of approximately 10 feet, centered on the sampling stake. Due to relatively large number of sampling plots established by PfPS for the size of the intertidal area, the plots overlap to some extent. However, this provides a comprehensive look at the plant density and diversity over the entire intertidal area.

At each of the four riparian buffer plots, we used a reel measuring tape to create a rectangular sampling plot approximately 33 feet wide by 49 feet long (approximately 1,617 square feet, or 0.04 acres). Rectangular plots were used in buffer areas due to their more linear orientation around the site; the size of the plots was also determined a visual estimation of size needed to encompass a representative sample of the plants. The riparian buffer plots did not overlap.

We recorded the species and percent cover of each species within each sampling plot. Plant identifications followed the standard taxonomic procedures as described in Hitchcock and Cronquist (1976), as updated by Pojar and MacKinnon (1994), Hickman (1993), and Cooke (1997).

We also photographed each of the sample plots to document the density and species of plants within each plot and within the intertidal and riparian areas as a whole. ERS personnel conducted vegetation monitoring at this site during both 2003 and 2004, approximately four and five years after the project was constructed; monitoring dates were September 25, 2003 (Victoria Luiting and Matthew Bennett), and September 3, 2004 (Victoria Luiting and Lisa Sievers). Project manager Corey Loveland also assisted in the 2003 sampling effort, collecting water quality data.

4.1.2 Area of Intertidal Habitats

During the September 3, 2004 monitoring event, we used a reel measuring tape to measure the extent of intertidal habitats created at the site. We measured the length and width of the salt marsh and mudflat habitats present within the center 'bowl' of the site approximately five years after the project was constructed.

4.1.3 Fish Use of Intertidal Habitats

Fish use at Puget Creek was sampled in 2001 by the USFWS under funding provided by the Corps (MIPR Agreement #W68MD910670272, Low 2001). USFWS sampled Puget Creek monthly from March 6 through June 6, 2001 using a fyke net placed across the mouth of the channel at high slack tide. The timing of this sampling was targeted to record juvenile salmonid use of the site approximately two years after the project was constructed. The Puget Creek sampling was conducted as part of an effort that also sampled the T105 restoration site located approximately one mile downstream, and the

restored channel of Hamm Creek located approximately three miles upstream of Puget Creek.

The Corps and Natural Resource Consultants (NRC, Greg Ruggerone) recorded fish use at Puget Creek in 2002 (USACE draft 2002 report). The Puget Creek, Herring's House, and 1st Avenue South Bridge sites were also sampled as part of this effort. Sampling was conducted bi-weekly over a six week period with repeated sampling over two to three days (including one night time period) to identify use, duration of use, and to attempt to measure growth rates of fish over time. Sampling was conducted at the Puget Creek site on May 13-15, 2002, May 28-30, 2002, June 11-13, 2002, and June 25-26, 2002. This Puget Creek sampling was thus conducted approximately three years after the project was constructed. Sampling was conducted using a beach seine. This study also included fin-clipping of juvenile Chinook, but no Chinook were clipped at the Puget Creek site. Tidal height, water temperature, and salinity were also recorded during each sampling effort. The timing of this sampling was targeted to record juvenile salmonid use of the selected restoration sites.

The Corps used a pond seine to sample fish using the intertidal habitats in September 2004. We used the seine to act as a block net by deploying it at peak high tide at the mouth of the restoration site on September 16 and 17, 2004. Net deployment coincided with a tidal elevation of +10.3 feet MLLW on September 16, 2004 and +10.4 feet MLLW on September 17, 2004, approximately five years since the project was constructed. As the intertidal habitats within the site dewatered, fish using these habitats were trapped by the net and were then enumerated and recorded by ERS personnel (Rustin Director and Lisa Sievers). The timing of this sampling was targeted to record use of the site by resident fish species.

4.2 HAMM CREEK MONITORING

The goals of the Hamm Creek restoration project were to restore important estuarine habitat along the Duwamish Waterway and to restore fish passage and habitat along Hamm Creek. In order to achieve these goals, the project would create an approximately 2,300 foot long stream channel, one acre of freshwater wetland/sediment settling basin at the northwestern corner of the site, a one acre freshwater wetland arm off the southeastern end of the stream channel, a one acre intertidal marsh as the stream channel joins the Duwamish River, and an approximately 30-foot wide riparian buffer.

The anticipated benefits (essentially the objectives) of the Hamm Creek project were to: 1) provide food web support through the production of organic matter and invertebrates along the channel, in the wetland, and in the salt marsh/mudflat, 2) increase plant species diversity, and 3) create native habitat suitable to critical life-history stages of anadromous and resident fish and urban-adapted bird and mammal species.

In order to assess the project goal and associated objectives, the Corps has: 1) recorded plant species diversity and density in the intertidal marsh, fresh water wetland, and riparian buffer areas (three and four years after project completion), 2) sampled fish-use of the intertidal area and the restored channel (one and three years after project completion), and 3) analyzed diet data collected from fish using the intertidal area (three years after project completion). We used density of intertidal marsh plants as a qualitative surrogate for a more costly, quantitative measure of food-web support. The Corps also conducted an 'as-built' survey in 2001 of the final configuration of the restoration site. Finally, in May 2003 the Corps installed and monitored experimental paired plots of five different emergent plants installed along the emergent margins of the restored stream channel.

The Hamm Creek restoration site is also being monitored by several other agencies/groups/individuals, both formally and informally. Vegetation at the Hamm Creek site has also been informally monitored and maintained by PfPS since 2000. The USFWS has conducted physical and biological monitoring of the estuary portion of the Hamm Creek project in 2001, 2002, and 2003 with funding provided by the EB/DRP. The Wetland Ecosystem Team of the University of Washington School of Aquatic and Fishery Sciences (WET) has assessed the aquatic and benthic invertebrate and littoral insect production of the Hamm Creek site in 2001 and 2002, with funding provided by the EB/DRP. A local 'master birder' (Mr. Denis Desilvis) has informally collected daily information on bird use of the mouth of Hamm Creek and the adjacent shoreline and has generously shared data from 2003 and 2004 with the Corps. The results of these efforts have largely been incorporated (with appropriate references) into Sections 4.1.2, 4.1.4, and 5.0, below, in order to provide a more complete picture of the development of this restoration site than would be possible with the limited monitoring resources available to the Corps.

4.2.1 Vegetation Sampling Plots

Both People for Puget Sound (PfPS) and USFWS had previously established vegetation sample plots at the Hamm Creek site; however, the area surrounding these plots appeared disturbed in many cases. Thus, we chose to establish sample plots specific to the Corps' monitoring efforts in order reduce the frequency of disturbance to these areas. Our sample plots were generally located within the vicinity of these plots to allow for comparison of data.

We established eleven vegetation-sampling plots along the restored portion of the channel and the adjacent freshwater wetland. We recorded species composition and percent cover within the intertidal salt marsh at one location near the center of the eastern portion of salt marsh. At each of the eleven sampling plots, we used a reel measuring tape to create a rectangular sampling plot approximately 23 feet wide by 49 feet long (approximately 1,127 square feet, or 0.02 acres). Rectangular plots were used due to the linear orientation of plantings surrounding the restored channel; the size of the plot was

determined by the general width of the planted areas alongside the channel and a visual estimation of size needed to encompass a representative sample of the plants. We recorded the species composition and percent cover within each sampling plot. Plant identifications followed the standard taxonomic procedures as described in Hitchcock and Cronquist (1976), as updated by Pojar and MacKinnon (1994), Hickman (1993), and Cooke (1997).

Thirty bare root sprigs of each of five species were planted by Corps personnel (Aimee Kinney, Corey Loveland, and Victoria Luiting) into plots along the edge of the restored stream channel on May 2, 2003. One half of each plot (15 plants) was fenced with steel fencing approximately 3 feet high to prevent waterfowl from browsing the plants. The other half was not fenced in an effort to determine the necessity of such fencing for plant establishment. Planted species included: sawbeak sedge (*Carex stipata*), small-fruited bulrush (*Scripus microcarpus*), water parsley (*Oenanthe sarmentosa*), dagger-leaf rush (*Juncus ensifolius*), and hardstem bulrush (*Scirpus acutus*). The survival of the experimental plots of emergent vegetation were monitored by Victoria Luiting approximately every other week between May 16 and July 24, 2003 in an effort to determine whether increasing the species diversity and emergent species coverage along the channel might be possible with additional plantings. Survival was determined by tracking the number and vigor of the plantings over the monitoring period.

We also photographed each of the sample plots to document the density and species of plants within each plot and within restored areas as a whole. ERS personnel conducted vegetation monitoring at this site during both 2003 and 2004; the Hamm Creek vegetation sampling was thus conducted approximately three and four years after the project was constructed. Monitoring dates were September 24, 2003 (Victoria Luiting and Matthew Bennett), and September 2, 2004 (Victoria Luiting and Lisa Sievers). Project manager Corey Loveland also assisted in the 2003 sampling effort, establishing the plots and collecting water quality data.

4.2.2 Fish Use of Channel and Intertidal Area

USFWS has surveyed the mouth of Hamm Creek (and an adjacent reference site) to document fish use in 2001, 2002, and 2003 (approximately one, two, and three years post restoration). USFWS conducted seven surveys between March 5 and June 5, 2001, eight surveys between March 4 and June 12, 2002, and eight surveys between March 2 and July 10, 2003 with funding provided by the EB/DRP (Low and Myers 2002, USFWS 2003 and 2004). The Herring's House restoration site and associated reference sites were also sampled as part of these efforts. These sampling events were conducted using a fyke net set at high slack tide; fish were caught in the net as the tide receded, identified to species, counted, and released. The timing of these sampling events was targeted to record juvenile salmonid use of these sites; non-salmonid fish were also identified and counted. The reference site for comparing fish use at Hamm Creek is located just upstream of the restored marsh at the Turning Basin.

USFWS also conducted weekly surveys in the restored channel of Hamm Creek between March 8 and May 31, 2001 with monitoring funds provided by the Corps (MIPR Agreement #W68MD910670272, Low 2001). The Puget Creek and T105 restoration sites were also sampled as part of this effort. The Hamm Creek sampling was thus conducted approximately one year after the project was constructed. The sampling at Hamm Creek was conducted using a bag seine and included a mark-recapture study for the salmonids (Chinook were not marked due to permit restrictions on this federally threatened species). Fish were caught in the net as the tide receded, identified to species, counted, and then released. Salmonids were also measured for length and marked with injected pigment. The timing of this sampling was targeted to record juvenile salmonid use of these restoration sites; non-salmonid fish were also identified and counted. This sampling effort at Hamm Creek was terminated earlier than concurrent sampling at Puget Creek due to the development of large amounts of filamentous algae that began growing in late May in the slower water areas. The algae increased the difficulty of pulling the seine and increased the likelihood of injuring fish.

USFWS and Natural Resource Consultants (NRC, Greg Ruggerone) recorded fish use at Hamm Creek in 2002 (USACE 2002 draft report). The Puget Creek, Herring's House, and 1st Avenue South Bridge sites were also sampled as part of this effort. Sampling was conducted bi-weekly over a six week period with repeated sampling over two to three days (including one night time period) to identify use, duration of use, and to attempt to measure growth rates of fish over time. Sampling was conducted at the Hamm Creek site on April 15, April 29, May 6, May 13-15, 2002, May 27-30, 2002, June 11-13, 2002, and June 25-26, 2002. The Hamm Creek sampling was thus conducted approximately two years after the project was constructed. Sampling was conducted using a fyke net set at high slack tide. This study also fin-clipped juvenile Chinook captured at Hamm Creek (as well as the other sites sampled) and installed passive-integrated-transponders (pit-tags) for the mark-recapture aspect of the study. The pit-tags were placed into juvenile Chinook captured upstream (river mile 33.8) at the Green River screw trap (wild fish) and at the Soos Creek hatchery (hatchery fish). Tidal height, water temperature, and salinity were also recorded during each sampling effort. The timing of this sampling was targeted to record juvenile salmonid use of the selected restoration sites.

The Corps and Natural Resource Consultants (NRC, Greg Ruggerone) reported on fish use at Hamm Creek in 2003. Fish were sampled by USFWS, with diet data collected by WET from a subset of captured fish (see Section 4.1.3 below). The T105, Herring's House, 1st Avenue South Bridge, and Cecil B. Moses sites were also sampled as part of this effort. Sampling was conducted at Hamm Creek once every two weeks between April 2 and July 10, 2003 (consecutive days were not sampled at Hamm Creek in 2003 due to budget constraints). This sampling was thus conducted approximately three years after the project was constructed. Sampling was conducted using a fyke net set during high slack tide. Fish were caught in the net as the tide receded, identified to species and as stock origin (wild or hatchery), counted, and then released. Approximately 30 salmon

of each species, age group (subyearly or yearly), and stock origin were also measured for length. Finally, stomach contents were collected from a subset of each species using gastric lavage (see Section 4.1.3 below). The timing of this sampling was targeted to record juvenile salmonid use of these restoration sites; non-salmonid fish were also identified and counted (principally shiner perch *Cymatogaster aggregata*).

4.2.3 Aquatic and Benthic Invertebrates and Littoral Insects

Aquatic invertebrates from the restored channel were sampled at Hamm Creek on September 8, 2001 by WET through funding provided by EB/DRP (Rein et al. 2001). This sampling was thus conducted approximately 15 months after the project was constructed. Aquatic invertebrate samples were collected from the restored Hamm Creek channel running parallel to West Marginal Place South and from the day-lighted portion of the channel along the northern boundary of the site (Figure 9). Samples were also collected from the Hamm Creek channel above and west of State Route 99; that portion of the channel had been restored in the mid 1990's by the I'M A PAL foundation. The portions of the channel restored through the Corp's program were thus sampled approximately 17 months after planting of the site. Samples were collected from within the stream channel by using a Surber sampler (similar to a kick net) to disturb the streambed substrate to a depth of approximately 10 cm for a one-minute period. Collected material was rinsed through a 500-μm mesh sieve and preserved for later taxonomic analysis in the lab. Invertebrates were generally identified to genus level and also classified according to functional feeding groups. Data were analyzed according to the benthic index of biological integrity (B-IBI) in order to categorize the condition of the restored channel in these locations.

Littoral insects generated by the development of riparian vegetation at Hamm Creek were sampled by USFWS in 2001 by USFWS through funding provided by EB/DRP. The samples were then taxonomically analyzed and data reported by WET (Nightingale and Cordell 2001; Cordell 2002). Littoral insects were sampled using fall-out traps deployed on April 25, May 17, and June 15, 2001. The 2001 sampling was thus conducted approximately one year after the project was constructed. Fall-out traps were plastic storage bins containing approximately 4cm of soapy water that rise and fall with the tide (in the intertidal areas) and collect insects that fall into them from the air and from adjacent vegetation. The traps thus measure direct input of littoral insects into the system. Traps were placed in three areas: 1) five traps in the restored intertidal marsh, 2) five traps a portion of naturally occurring intertidal marsh near the mouth of the channel (as a reference site), and 3) ten traps along the restored stream channel. Collected insects were preserved and identified by WET.

Benthic invertebrates were also sampled in 2001 and 2002 by WET through funding provided by EB/DRP (Cordell 2002). In 2001, benthic invertebrate core samples were collected on April 26, May 17, and June 14, 2001. Core samples were collected in March, April, May and June in 2002. The 2001 sampling was thus conducted

approximately one year after the project was constructed; the 2002 sampling occurred approximately two years after project completion. The benthic cores were collected using a 2-inch diameter (0.0024 m^2) pvc plastic core (for macrofauna) and a 1-inch diameter (0.0002 m^2) core (for meiofauna) each taken to a depth of 10 cm. At Hamm Creek, samples were collected from the restored intertidal salt marsh at the mouth of the channel and from a patch of naturally occurring intertidal marsh near the mouth of the channel (as a reference site). Collected benthic invertebrates were preserved and identified by WET.

Benthic invertebrates and littoral insects were also sampled in 2003 by USFWS and WET through funding provided by EB/DRP. Results from that effort were not available at the time this report was prepared.

4.2.4 Fish Diet from Intertidal Area

In the spring of 2003, the Corps provided funding for WET to extract and analyze diet samples from a subset of juvenile Chinook, coho, and chum salmon captured by USFWS. Fish were sampled at the mouth of Hamm Creek every two weeks between April 2 and July 10, 2003 (see Section 4.1.2 above). This sampling was thus conducted approximately three years after the project was constructed. Funding was provided to WET through MIPR Agreement #W68MD930800232 (Cordell and Vonsaunder 2004). Due to permit restrictions, no more than ten wild Chinook were handled per day.

On sampling dates when Chinook, chum, or coho salmon were caught, a subset of the fish were lavaged to obtain stomach contents for subsequent diet analysis using Shreffler's (1992) methods. These fish were anesthetized in a plastic bucket with river water and a small amount of dissolved MS-222 (tricaine). Gastric lavage was performed on chum, Chinook, and coho to obtain stomach contents using a garden sprayer fitted with a hose and small nozzle. By spraying a low-velocity stream of water through a small brass nozzle into the fish's gastric cavity, the contents of the fish's stomach were rinsed from the foregut onto a 102µm sieve. The stomach contents were rinsed from the sieve through a funnel into a sample jar for subsequent analysis. The fish were then placed in a bucket of freshwater until they recovered from the anesthesia, and then released into the river. When chum salmon were too small to be lavaged, and for mortalities that were incurred during capture, whole fish were fixed and taken for subsequent stomach contents analysis in the laboratory. Under an illuminated dissecting microscope, prey organisms were sorted to genus or species (for crustaceans) and to family (for insects), counted, and weighed separately on an analytical balance to the nearest 0.0001 g.

4.2.5 Other Physical and Biological Characteristics

In conjunction with their data on fish use and invertebrate production at Hamm Creek (see Sections 4.1.3 and 4.1.4 above), USFWS also collected data on a number of physical and biological characteristics in 2001, 2002, and 2003 (Low and Myers 2002; USFWS

2003; USFWS 2004). Physical characteristics included: intertidal area, tidal regime, slope erosion, and sediment structure. Biological characteristics included: marsh vegetation establishment, riparian vegetation establishment, and bird use.

A local 'master birder' (Mr. Denis Desilvis) has informally collected information on bird use by conducting a daily 30-minute visual survey of the mouth of Hamm Creek and adjacent shoreline areas. His has emailed his daily summaries from July 2003 through October 2004 to the Corps.

5.0 RESULTS

5.1 PUGET CREEK

5.1.1 Species Diversity and Plant Density (vegetation sampling plots)

ERS personnel conducted vegetation monitoring at Puget Creek in years four (September 25, 2003) and five (September 3, 2004) after the project was constructed. The two characteristic intertidal species planted, Lyngby's sedge and soft/hardstem bulrush have survived extremely well at the site and clearly dominate (with 100% cover) the intertidal marsh of Puget Creek five years after project completion (Table 1; Photo 1). Other native intertidal species that have colonized the site include seacoast bulrush (*Scirpus maritimus*), sea-milkwort (*Glaux maritima*), and brass buttons (*Cotula coronopifolia*). A small patch of common cattail (*Typha latifolia*) occurs in the southwestern corner of the marsh. The upward sloping edges of the marsh have been colonized by Douglas aster (*Aster subspicatus*) and fat-hen saltbush (*Atriplex patula*). The intertidal marsh provides detrital export to the Duwamish River and a seed source for native intertidal marsh plants (Photo 2).

Table 1. Percent cover of emergent vegetation at Puget Creek, September 3, 2004. Invasive species are noted in **bold**.

		Percent Cover per Emergent Plot							
Common Name	***Scientific Name***	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5**	**Plot 6**	**Plot 7**	**Plot 8**
Fat-hen saltbush	*Atriplex patula*							@ outer edge	@ outer edge
Butterfly-bush	***Buddleja davidii***								**@ outer edge**
Lyngby sedge	*Carex lyngbyei*	80	30	30	40	75	75	50	20
Hooker's willow	*Salix hookeriana (s)*	overhanging @ outer edge							@ outer edge
Hardstem bulrush	*Scirpus acutus*	20	60	70	50	25	5	50	80
Seacoast bulrush	*Scirpus maritimus*		10		10		20	scattered	
Common Cattail	*Typha latifolia*							3 stalks	

Native trees and shrubs along the sides of the outlet channel shade the opening (Photos 3 and 4). The riparian buffer planted around the side slopes of the site has survived well and provides dense tree and shrub cover (Photo 5). In many cases, the density and size of the plantings in 2004 made it difficult to differentiate individual plantings. Thus, the number of plants counted in 2003 and 2004 differ in some cases despite no evidence of substantial plant mortality (Table 2).

The buffer is dominated by a mixture of native species planted at the site and by volunteer species such as red alder (Table 2; Photo 5). In most of the upland plots, the

young red alder trees form 100% canopy closure over the plots, providing dense shade to the understory trees and shrubs. Dominate shrub species include Pacific ninebark and mock orange, with numerous small Sitka spruce also doing well on the site. Invasive species are more prevalent along the southern slope of the site and include morning-glory, Himalayan blackberry, English ivy, and scattered butterfly bush. The morning-glory and English ivy are particularly of concern given their ability to twine up trees and shrubs and envelope them to the point that they will kill the tree or shrub.

Table 2. Number of trees and shrubs at Puget Creek, September 2004. Dominate species not counted individually are indicated with an 'X'. Invasive species are noted in **bold**.

Number of Plants Per Plot		**2003**				**2004**		
Common Name	***Scientific Name***	**Plot 1 north**	**Plot 2 west**	**Plot 3 south**		**Plot 1 north**	**Plot 2 west**	**Plot 3 south**
Trees								
Big-leaf maple	*Acer macrophyllum*	1				2		
Red alder	*Alnus rubra*	12	X			X	X	X
Pacific madrone	*Arbutus menziesii*	1				1		
Paper birch	*Betula papyrifera*							
Hazelnut	*Corylus cornuta*							
Black hawthorn	*Crataegus douglasii*						1	
Oregon ash	*Fraxinus latifolia*	3	3			3	4	X
Western crabapple	*Malus fusca*							
Lodgepole pine	*Pinus contorta*							
Sitka Spruce	*Picea sitchensis*	6	4	5		6	5	X
Black cottonwood	*Populus balsamifera*	2	1			1	2	
Douglas fir	*Pseudotsuga menziesii*	1	1			1	1	
Cascara	*Rhamnus purshiana*	2	1			2	1	
Pacific willow	*Salix lucida*	7				2		X
European Mountain Ash	*Sorbus aucuparia*							
Western red cedar	*Thuja plicata*		1	1			1	X
Western Hemlock	*Tsuga heterophylla*	1				1		

Table 2 continued. Number of trees and shrubs at Puget Creek, September 2004. Dominate species not counted individually are indicated with an 'X'. Invasive species are noted in **bold**.

Number of Plants Per Plot				**2003**			**2004**	
Common Name	***Scientific Name***	**Plot 1 north**	**Plot 2 west**	**Plot 3 south**		**Plot 1 north**	**Plot 2 west**	**Plot 3 south**
Shrubs								
Butterfly bush	***Buddleja davidii***	**1**	**2**					
Morning-glory	***Convolvulus arvensis***			**X**		**some**		**X**
Red-osier dogwood	*Cornus sericea*	1	10	9		4	9	
Horsetail	*Equesetum*			X				
English Ivy	***Hedera helix***			**X**		**some**		**X**
Ocean-spray	*Holodiscus discolor*							
Black twin-berry	*Lonicera involucrata*		2					
Shining Oregongrape	*Mahonia aquifolium*							
Indian plum	*Oemleria cerasiformis*	1	3				2	
Mock orange	*Philadelphus lewisii*		8			3	5	
Pacific ninebark	*Physocarpus capitatus (s)*	6	9			5	5	
Red current	*Ribes sanquimeum*		1					
Baldhip rose	*Rosa gymnocarpa*							
Nootka rose	*Rosa nutkana*	6	3			4	3	
Himalayan blackberry	***Rubus discolor***					**some**		**X**
Thimbleberry	*Rubus parviflorus*							
Salmonberry	*Rubus spectabilis*						1	
Hooker's willow	*Salix hookeriana (s)*	8		X				
Sitka willow	*Salix sitchensis (s)*						X	
Red elderberry	*Sambucus racemosa*			1				
Common snowberry	*Symphoricarpos albus*	5	6			1	7	
	% Ground Cover	**sparse**	**0**	**sparse**		**sparse**	**0**	**sparse**
	%Tree Canopy Cover	**40**	**100**	**100**		**100**	**100**	**100**
	% Shrub Cover	**60**	**60**	**15**		**60**	**60**	**15**

5.1.2 Area of Intertidal Habitats

At the end of the five-year monitoring period, the Corps measured the extent of intertidal marsh and mudflat habitats during our September 3, 2004 monitoring effort. The marsh and mudflat created at the Puget Creek site is roughly oriented in a circle approximately 75 feet in diameter. Thus, approximately 4,415 square feet of intertidal marsh and

mudflat habitat was created in this restoration effort. As noted above in Section 5.1.1, the intertidal marsh is dominated by a dense community of native marsh species and is exporting organic matter and seeds to the Duwamish River.

5.1.3 Fish Use of Intertidal Habitats

Fish use of the intertidal habitats of Puget Creek was recorded two, three, and five years post-construction through a combination of efforts funded by the Corps and carried out by USFWS (Low 2001), NRC (USACE 2003), and ERS personnel 2004.

Four weekly surveys were conducted at the mouth of Puget Creek between March 6 and June 6, 2001 (Low 2001) using a fyke net. No fish were captured during March and April sampling. A small number of juvenile chum salmon were captured during May (16 fish) and June (11 fish) (Table 3); the only other species captured were sculpins (Low 2001). The average fork length of chum salmon captured at Puget Creek greatly increased from May (mean fork length 38 mm) to June (mean fork length 67 mm).

Sampling by NRC in 2002 (three years post-construction) caught a total of 200 fish at Puget Creek, only one of which was a salmonid (Table 3). ERS personnel sampled the Puget Creek site in mid-September 2004, approximately five years post-construction to document fish use of the site during a time period not typically sampled. Late summer sampling was intended to document non-salmonid use of the site. Fish species documented using the site included: three-spin stickleback, shiner perch, staghorn sculpins, and undifferentiated sculpin species (USACE 2004).

Table 3. Fish use of the Puget Creek restoration site from 2001 through 2004.
*** The juvenile chinook was a hatchery fish.**

Puget Creek fish use	May-June 2001	May-June 2002	Sept. 2004
Juv. Chinook*		1	
Juv. chum	27		
Shiner perch		114	101
Three-spine stickleback		19	50
Staghorn sculpin			6
Undiff. sculpins	184	66	20
TOTAL	***211***	***200***	***177***

5.2 HAMM CREEK

5.2.1 Species Diversity and Plant Density (vegetation sampling plots)

ERS personnel conducted vegetation monitoring at Hamm Creek in years three (September 24, 2003) and four (September 2, 2004) after the project was constructed. The intertidal marsh at the mouth of the creek is dominated by native intertidal species, principally Lyngby's sedge (60% cover) and three-square bulrush (20% cover) (Photo 6). Other species of the intertidal marsh include silverweed, Douglas aster, hard-stem bulrush, sea-milkwort, western lilaeopsis (*Lilaeopsis occidentalis*), and fat-hen saltbush. Scattered weedy species are also present along the upper edges of the saltmarsh area located east of the creek channel and north of the mouth. These species include common cattail, yellow iris (*Iris pseudacorus*), soft rush (*Juncus effusus*), and reed canarygrass (*Phalaris arundinacea*).

A dense fringe of willows and red-osier dogwood characterize the freshwater wetland off the southeastern end of the creek (Photo 7). Willows such as Hooker's, Pacific, and Sitka overhang the water. Emergent species fringing the edges include spikerush and hardstem bulrush, as well as more weedy species such as soft rush and common cattail (see plots 6-8, Table 4 and Photo 7).

The trees and shrubs throughout the riparian buffer areas fringing the creek channel, wetland, and saltmarsh have survived well (see plots 1-3, Table 4). They are beginning to achieve a stature that will provide shade to the channel and provide canopy closure over parts of the site (Photos 8 and 9). The edges of the creek channel are lined with Pacific, Sitka, and Hooker's willow, red-osier dogwood and Nootka rose. In some places the willows are 10 to 20 feet tall.

Upland buffer vegetation is being overrun in some areas by invasive species (along the northern fenceline near plot 5 particularly), but in most areas they are surviving well with 100% cover (see plots 4, 5, and 10, Table 4 and Photo 10). A diverse mixture of native species has survived on the site with dominant species including shore pine, Nootka and baldhip rose, and Douglas hawthorn. Volunteer species include Pacific madrone, red alder, black cottonwood, and paper birch. Tree species are approaching 10 feet tall in some instances and most shrubs have spreads of approximately 2 to 5 feet. Nearly all species displayed evidence of reproduction (evident fruits and/or flowers).

Table 4. Number of trees and shrubs in 2004 vegetation plots at Hamm Creek, September 2004. *Plot 5 obscured by Himalayan blackberry; individual plants could not be counted. **Predominately Himalayan blackberry; S=scattered, D=dense, percent cover noted when greater than 50% of plot.

		Number of Plants per Plot										
Common Name	***Scientific Name***	**Plot 1**	**Plot 2**	**Plot 3**	**Plot 4**	**Plot 5***	**Plot 6**	**Plot 7**	**Plot 8**	**Plot 9**	**Plot 10**	**Plot 11**
Trees												
Red Alder	*Alnus rubra*	1	5	2		X		1				4
Pacific madrone	*Arbutus menziesii*	1	1	3								
Paper birch	*Betula papyrifera*		1									1
Hazelnut	*Corylus cornuta*							1				
Black hawthorn	*Crataegus douglasii*	?	1				7	1	7	4	3	3
Oregon ash	*Fraxinus latifolia*						2					
Western crabapple	*Malus fusca*	2	1					3	2		2	1
Lodgepole pine	*Pinus contorta*	1		3	1	X	1		1	1	6	6
Black cottonwood	*Populus balsamifera*	2		1	2	X		1				
Cascara	*Rhamnus purshiana*						1	1				
Pacific willow	*Salix lucida*	5	3	3	3	X	1	1	2			
European Mountain Ash	*Sorbus aucuparia*					X						
Shrubs												
Red-osier dogwood	*Cornus sericea*		13	4	4		2	4	4	3	8	4
Ocean-spray	*Holodiscus discolor*	1		1	3							
Black twin-berry	*Lonicera involucrata*	2		4	6		6	2	1	1	1	1
Shining Oregongrape	*Mahonia aquifolium*	2	4	2	2							1
Indian plum	*Oemleria cerasiformis*	1		1					2			
Pacific ninebark	*Physocarpus capitatus (s)*							7				
Red current	*Ribes sanquimeum*	5	1	1	4	X					5	
Baldhip rose	*Rosa gymnocarpa*							9				5
Nootka rose	*Rosa nutkana*		23	1			2	1	3	1	3	3
Thimbleberry	*Rubus parviflorus*	7		9		X					4	
Salmonberry	*Rubus spectabilis*							2				
Hooker's willow	*Salix hookeriana (s)*	7	1	1	4		5		3	7		
Sitka willow	*Salix sitchensis (s)*		1	3	2			7	3	3		1
Common snowberry	*Symphoricarpos albus*	3	4	1	4							
	Invasive Species	**S**	**S**	**S**	**D**	**60%**		**S**	**S**		**D**	
	% Ground Cover	**100**	**100**	**100**	**100**		**100**	**100**	**100**	**100**	**100**	**100**
	Tree/Shrub % cover	**50**	**50**	**70**	**40**	**30**	**65**	**65**	**50**	**90**	**80**	**85**
	Emergent % cover	**100**					**90**		**50**			

Four years after the project was completed, we also experimentally measured whether species diversity and emergent plant density could be increased through additional plantings along the edges of the channel. Paired plots with fenced and unfenced portions clearly indicated that the fencing protected the emergent plants and prevented complete loss of the plants to goose and small mammal predation (Photos 11 and 12). Of the five emergent species planted, hardstem bulrush and small-fruited bulrush both survived extremely well in the caged plots and survived in smaller numbers in the uncaged plots, illustrating some degree of resistance to browse by geese and small mammals. The water parsley and dagger-leaf rush also survived in the plots, but generally did better in the caged areas. In contrast, sawbeak sedge had the worst survival in both caged and uncaged plots indicating that it is likely not a suitable species for this site.

5.2.2 Fish Use of Channel and Intertidal Habitats

Fish use of the restored channel and the intertidal habitats of Hamm Creek was monitored one, two, and three years post construction through a combination of efforts funded and carried out by a variety of entities: USFWS and EB/DRP (Low and Myers 2001, USFWS 2003, and USFWS 2004), USFWS and Corps (Low 2001), USFWS and NRC (USACE 2003), and Corps and NRC (Ruggerone and Jeanes 2004).

Thirteen weekly surveys were conducted within the restored channel of Hamm Creek in 2001 (Low 2001). Several hundred coho fry were captured in large numbers within the stream channel in March (263), April (465) and May (313) 2001 sampling periods, approximately one year after the project was constructed. These fry may have been out-migrants from adult spawners observed within the upper portions of the creek (above the Corps' project site). Juvenile and adult cutthroat trout were captured from within the pool in the northwest corner of the site (102 total) over the course of the sampling period. Smaller numbers of juvenile chum (26 total) and Chinook (10 total) were also captured within the restored channel. The size of both the juvenile coho and chum increased in average fork-length from March to May, with chum increasing from a mean of 49mm to 60mm and coho increasing from a mean of 36mm to 59mm. Sampling within the stream channel has not been repeated since this 2001 effort.

While coho fry were most common within the restored stream channel, the most common species utilizing Hamm Creek as it joins the Duwamish River were juvenile chum salmon (Table 5, summarized from Low and Myers 2001, USFWS 2003, and USFWS 2004). Sampling within the estuarine mouth of Hamm Creek in 2001, 2002, and 2003 documented use by large numbers of juvenile chum salmon in March, April, and May (Table 5. Concurrent use of the upstream reference site at the Turning Basin by juvenile chum was consistently lower than at the restored mouth of Hamm Creek from 2001 through 2003 (Table 5).

Table 5. Use of the mouth of the Hamm Creek restoration site and Turning Basin reference site by juvenile chum salmon from 2001 through 2003, based on USFWS data.

Juvenile chum		Hamm Creek				Turning Basin	
	2001	2002	2003		2001	2002	2003
March	833	212			0	22	
April	3,105	6,610	3,359		886	1,154	45
May	2,476	2,583	520		331	16	76
June	1	5	2		1	1	0
TOTAL	***6,426***	***9,410***	***3,881***		***1,218***	***1,193***	***121***

In contrast, juvenile Chinook use of the Hamm Creek site was much lower, peaking in May 2001 with 344 fish captured. In 2002 and 2003, only 158 and 159 juvenile Chinook were recorded in total between March and June, respectively. Similarly, even smaller numbers of juvenile coho were captured in 2001 (18 fish) and 2002 (28 fish) at the estuarine mouth of the channel. No coho were captured in 2003. Other commonly recorded fish species included sculpins, three-spine stickleback, flatfish, and shiner perch (Low and Myers 2001; USFWS 2003).

Additional sampling by USFWS and NRC in 2002 also found the total catch of salmonids (4,775 total fish) to be dominated by chum fry (96% of the salmonids caught). These fish were noted as being consistently 15-20mm smaller than juveniles captured at restoration sites both up and down river from Hamm Creek, suggesting that perhaps they were out-migrants from upstream portions of Hamm Creek (USACE 2003).

Sampling by the Corps and NRC in 2003 similarly documented that chum fry use the estuarine mouth of Hamm Creek in greater numbers than other salmonids. An average of 433 fry were recorded at Hamm Creek per sampled tide in 2003, maximum numbers were near 1,400 in mid-April (Ruggerone and Jeanes 2004). As in previous studies, very few Chinook (2.2 per tide) and coho (15 per tide) were captured at Hamm Creek in 2003. Shiner perch also used the Hamm Creek estuary in great numbers (1,200 fish) during early July 2003.

5.2.3 Production of Aquatic and Benthic Invertebrates and Littoral Insects

The production of aquatic and benthic invertebrates and littoral insects was measured one and two years post construction by WET and USFWS through funding provided by EB/DRP. Secondary production was measured three types of restored habitats: the restored channel via sampling aquatic invertebrates (2001), the restored marsh via sampling benthic invertebrates (2001 and 2002), and the riparian buffer via sampling littoral insects (2001 and 2002).

One year after construction (2001), aquatic invertebrate sampling of the restored channel found that the restored channel along Marginal Way and the daylighted portion of the channel both supported a variety of aquatic invertebrates, including some species sensitive to poor water quality conditions such as mayflies and stoneflies (Rein et al. 2001). However, these species did not dominate the stream and the restored portions were classified as poor to very poor based on the B-IBI scores. This result is typical of similarly urbanized streams and may reflect the early stages of colonization of the channel immediately following construction. The condition of the aquatic invertebrate community has not been assessed since 2001.

Benthic invertebrate sampling one year after construction (2001) indicated that Hamm Creek differed in its benthic invertebrate density and composition from the reference site (Cordell 2002). However, the site was being colonized by benthic species typical of other restoration sites in the estuary. By 2002, the restoration site supported densities of benthic invertebrates similar to the reference site. *Dipteran* fly larvae and pupae were consistently more numerous in the restored marsh of the Hamm Creek site, whereas nematodes and polychaetes (worms) were more numerous at the reference marsh.

Adult *Chironomid* flies dominated the littoral insects generated by the restored site in 2001 (Cordell 2002, Nightingale and Cordell 2001). Other dominant organisms included a variety of *Dipteran* flies, *Collembolans*, and aphids. These species also characterized the reference habitats (located close by). The Hamm Creek site had relatively high insect densities in 2001 and 2002, perhaps due to the rapid development of transplanted vegetation along the channel edges and the retention of trees and shrubs along the edges of the Marginal Way channel (Cordell 2002).

5.2.4 Fish Diet from of Intertidal Habitats

Food-web support of juvenile salmonids was measured three years post-construction by analyzing diet samples from juvenile Chinook, coho, and chum salmon captured at the mouth of Hamm Creek between April and July 2003. At the Hamm Creek site, a total of 30 Chinook, 43 chum, and one coho salmon were analyzed for diet contents (74 fish total). Of the 74 total fish, three stomachs were empty.

The diets of the 30 Chinook salmon sampled varied over the April to June sampling period. In April, benthic organisms (insect larvae and pupae, amphipods) and the freshwater plankton *Daphnia* dominated juvenile Chinook salmon diets. By May, their diets had shifted to a greater percentage of terrestrial insects, mostly adult *Chironomid* flies. Terrestrial insects, predominately adult *Chironomid* and other *Dipteran* flies, also dominated June diets.

Benthic Chironomid larvae and pupae also dominated the diets of the 43 chum salmon in April, but the chum shifted their focus to benthic polychaetes (worms) in May. Adult

Chironomid flies dominated June chum diets. The single coho salmon caught on April 30, 2004 had eaten benthic *Corophium* spp. amphipods exclusively.

5.2.5 Other Physical and Biological Characteristics

Intertidal Area

The USFWS surveyed the intertidal area (defined as between elevation +12 feet and –2 feet MLLW) at the Hamm Creek restoration site using GPS in January and February 2001 (less than one year after project completion); GPS measurements were repeated in 2002 and 2003 as well. The intertidal area was calculated to be 0.7 acres in 2001, 0.8 acres in 2002, and 0.7 acres in 2003 (Low and Myers 2001, USFWS 2004). The goal of the project was to create approximately 1.0 acres of intertidal habitat at the site.

Tidal Regime

The USFWS measured the timing and elevation of high and low tide events at the restoration site and within the mainstem of the Duwamish River to determine if they were equivalent (Low and Myers 2001; USFWS 2003). The data obtained from the continuous-recording tide gages deployed on January 31, 2002 indicated that the timing and magnitude of the tidal cycle at the Hamm Creek site and in the Duwamish River are virtually the same. Similar results were obtained in 2002 based on tidal gage data collected on June 4-5 (average tide) and November 5-6, 2002 (spring tides). The Hamm Creek site thus allows for the full range of tidal timing and magnitude.

Slope Erosion

The USFWS documented significant slope erosion at the Hamm Creek site during their summer 2001 monitoring. The Corps placed logs and rocks along the eroded slopes in a 'soft solution' effort to limit the loss of the salt marsh and prevent head cutting of the channel back into the site (Low and Myers 2001). By October of 2001, the mouth of the creek and adjacent portions of both the natural and planted salt marsh were eroding during high tides and high river flows in the Duwamish. The logs and rocks proved insufficient and the channel continued to erode the marsh and to head-cut; several feet of the restored and natural salt marsh was lost during the winters of 2001 and 2002 (Photo 13).

After extensive coordination with U.S. Fish and Wildlife Service, among others, King County designed and obtained permits in September 2003 for a larger scale retrofit of the channel mouth to more comprehensively address the problem. They designed a cascading channel mouth to dissipate channel energy as the stream flowed down into the Duwamish (particularly on low tides). The channel mouth was reconfigured in late September 2003 by placing boulders, logs, coir logs, dead trees, and gravel with a large crane directly onto the eroding face of the marsh and stream channel (Photo 14). No obvious or large areas of erosion have occurred at the site since this repair occurred.

Sediment Structure

The USFWS measured the accumulation of fine-grained sediments and organic matter at the Hamm Creek site in 2001 as compared to its adjacent reference site (a remnant patch of naturally occurring salt marsh). Sediment core samples were collected in the areas also sampled for invertebrates (see Section 4.1.3). Mean total organic carbon (TOC) values were similar for Hamm Creek (0.9%) and its reference site (0.8%). Mean grain size for the intertidal areas of Hamm Creek was 64% sand, 30% silt, and 6% clay; the reference site was characterized by a greater proportion sand (83%) a lower proportion of silt (14%), and a similar proportion of clay (4%) (Low and Myers 2001). Grain size values remained virtually unchanged in 2002 and 2003 at both the restoration and the reference sites, with only a slight increase in TOC in 2003 (USFWS 2004).

Marsh and Riparian Vegetation Establishment

The USFWS measured aerial extent of marsh vegetation patches, species composition, plant vigor (shoot height and number), and extent of non-native species in the restored salt marsh at the Hamm Creek site and at its reference site approximately 1.5 miles upriver (a remnant patch of naturally occurring salt marsh along right bank of River adjacent to rock weir, a.k.a. Site 1 or the Corps' North Wind's Weir Intertidal Restoration site). Vegetation sampling took place in late July and August 2001, approximately one year after the restoration site was completed. Sampling was also repeated in 2002 and 2003 (USFWS 2004).

One year after project completion (2001), intertidal vegetation patches at Hamm Creek totaled 0.11 acres, compared to 0.13 acres of intertidal vegetation at the reference site as measured with GPS (Low and Myers 2001). The area of marsh vegetation increased to 0.26 acres in 2002 and was measured at 0.25 acres in 2003 using direct field measurements. The reference site was measured at 0.15 acres in 2002 and 0.13 acres in 2003 (USFWS 2004).

The percent cover of target saltmarsh species increased from 2001 to 2002 (17 to 28%), and then declined slightly in 2003 (21%) (USFWS 2004). Mean heights of Lyngby's sedge and *Scripus* spp. shoots were significantly taller at the reference site than at the restoration site; mean shoot densities were also significantly greater at the reference site than at the restoration site in all sampling years (2001-2003). The Hamm Creek saltmash was dominated by the targeted salt marsh species within one year post-construction: Lyngby's sedge (14%), American bulrush (<1%), and seacoast bulrush (3%); understory marsh plants were predominately Pacific silverweed (9%), bentgrass (6%), spikerush (5%), and toad rush (5%). As an established saltmarsh, the reference site was dominated much more strongly by Lyngby's sedge (69%) and soft-stem bulrush (9%) with dominant understory species being spikerush (14%), and silverweed (9%) (Low and Myers 2001).

The USFWS also measured the aerial extent of vegetation, percent cover by tree shrub and herbaceous species, extent of non-native species, and plant survival in the planted

riparian areas at the Hamm Creek site. Vegetation sampling took place in August and September 2001, approximately one year after the restoration site was completed. Riparian vegetation at the Hamm Creek site in 2001 totaled 0.52 acres; in 2002, riparian vegetation totaled 0.7 acres. Tree species encompassed 11% cover of the riparian zone, shrubs 7%, and herbaceous species (volunteers) 28% in 2001 (Low and Myers 2001). By 2003, trees species encompassed 30% cover, shrubs 8% and herbaceous 70% (USFWS 2004). Approximately 4% cover was attributable to non-native species in 2001; by 2003, approximately 21% cover was non-native species and included species such as butterfly bush, bull thistle, Scot's broom, reed canarygrass, Himalayan blackberry, tansy, and clover.

Bird Use

Use of the Hamm Creek restoration site by birds has been formally monitored one, two, and three years after construction by USFWS (2001, 2002, and 2003). The USFWS recorded bird use via one-day surveys conducted in March/April, June, September, and December of each year. One the survey day, they conducted 10-20 minute area searches repeated three to four times per day between dawn/high tide and mid-morning/low tide. USFWS surveys consistently recorded the highest numbers of taxa at the Hamm Creek site in June and recorded a similar total number of bird taxa at the restoration site and the nearby reference site approximately 0.5 miles upriver at the Turning Basin (Table 6) (USFWS 2004).

Table 6. Number of bird taxa recorded by USFWS at the Hamm Creek restoration site and the Turning Basin reference site from 2001 through 2003.

Bird Taxa		Hamm Creek				Turning Basin	
	2001	2002	2003		2001	2002	2003
March	8	12	16		13	9	20
June	15	19	20		15	12	14
September	14	15	15		10	30	17
December	12	13	12		8	15	10
Total Taxa	29	36	31		32	40	33

Bird use of the area has also been informally monitored three and four years after construction by local birder Denis Desilvis (2003 and 2004). The Corps summarized the informal monitoring data collected almost daily (Monday through Friday) by Mr. Desilvis from an observation station across the river from the Hamm Creek sites; his surveys have also occasionally included birds noted using the marsh/mudflat of the Turning Basin site. Mr. Desilvis has recorded the largest number of taxa in August (40), September (39), and May (41) (Table 7). To date, a total of 69 different taxa have been recorded between March 2003 and October 2004, with 51 taxa recorded in 2003 and 63 taxa recorded through the end of October 2004.

The nesting platform erected on the Hamm Creek site has supported a pair of osprey with successful fledging of 2 to 3 young in 2002, 2003, and 2004 (Photo 15). The area surrounding Hamm Creek receives consistent foraging and perching use by several peregrine falcons which perch and hunt from the power towers that bracket the river near the mouth of the creek. Great blue herons are also consistently seen foraging along the channel, wetland, and marsh of Hamm Creek.

Three species of birds categorized by Washington Audubon as 'birds of immediate concern' have been recorded at Hamm Creek by Mr. Desilvis: Caspian tern (10 records), purple martin (1), and western grebe (2). Six species of birds categorized as 'early warning species' have been recorded at Hamm Creek by Mr. Desilvis: hooded merganser (2 records), bald eagle (12 records), cooper's hawk (4), merlin (3), peregrine falcon (49), and rufous hummingbird (1 record). Other species of note have included western kingbird (1 record) wood duck (3), and green heron (7).

Table 7. Number of bird taxa recorded by Desilvis at the Hamm Creek restoration site and vicinity from March 2003 through October 2004. *Only sporadic data available from March-June 2003.

Bird Taxa		
	2003*	2004
January		27
February		24
March	1	32
April		38
May	19	37
June	20	26
July	33	34
August	31	37
September	28	34
October	24	29
November	18	
December	21	
Total Taxa	51	63

6.0 SUMMARY

6.1 PUGET CREEK SUMMARY

The overall goal of the Puget Creek restoration project, to restore approximately 0.50 acres of habitat along the lower river by removing historic fill materials has been met. The project as designed is conducive to the future day lighting of Puget Creek into the restored marsh/mudflat area and thence into the Duwamish River. The restored habitat has benefited native fish and wildlife and has increased the area on native intertidal and riparian vegetation along the lower river.

The Puget Creek restoration project has created approximately 4,415 square feet (0.10 acres) of intertidal habitat based on our September 2004 measurements at the site. This measurement likely slightly underestimated the total area of habitat created as the site is not a perfect circle, but rather is roughly a circle 75 feet in diameter. The 50-foot riparian buffer surrounding the site is well established and densely vegetated with native trees and shrubs. The goal was to create approximately 6,534 square feet (0.15 acres) of intertidal habitat (marsh and mudflat) surrounded by an approximately 50-foot wide riparian buffer of native trees and shrubs.

Although less intertidal habitat was created than anticipated, the habitat restored is densely vegetated by native saltmarsh species and is exporting organic matter and saltmarsh seeds to the river (see Photo 2). The restored marsh supports at least nine native intertidal species. The percent coverage of the intertidal marsh area after five years is 100% and the plants have achieved their mature stature and are thus no longer vulnerable to goose predation (the goose excluders were removed this year). The intertidal marsh and riparian buffer have dramatically increased the biodiversity of native plant species in the area as documented by our vegetation monitoring. The riparian buffer alone now supports 34 different native tree and shrub species.

The marsh and mudflat provide foraging habitat for native fish species. Two years after construction, juvenile chum and sculpins were documented using the restored intertidal habitats; the site is used by shiner perch, three-spin stickleback, sculpins, and hatchery chinook as documented in years three and five following construction. The narrow opening into the marsh from the shoreline, coupled with a fairly high intertidal elevation, likely reduces the direct availability of the intertidal habitat to fish. However, the export of detrital matter and presumably of benthic and epibenthic invertebrates directly supports anadromous salmonids as well as resident fish in the lower river.

6.2 HAMM CREEK SUMMARY

The overall goals of the Hamm Creek restoration project of restoring important estuarine habitat along the Duwamish Waterway and restoring fish passage and habitat along

Hamm Creek have been met. The ecological benefits of primary productivity/food web support, increased plant species diversity, and use of created habitats by fish and wildlife species are accruing at Hamm Creek. Per the restoration plan, the project has created an approximately 2,300 foot long stream channel with a settling basin, has day-lighted the stream out of a culvert and reconnected it directly with the Duwamish River, and has created a freshwater wetland and an intertidal saltmarsh, and a riparian buffer on the site.

The intertidal area created at Hamm Creek is approximately 0.7 to 0.8 acres based on GPS measurements by USFWS. The goal of the project was to create approximately 1.0 acres of intertidal area on the site. Although the total intertidal area is smaller than anticipated, the approximately 0.25-0.26 acres of intertidal saltmarsh vegetation is densely vegetated by at least eight native saltmarsh species. The marsh appears well established and of sufficient stature to resist goose predation if the goose excluder fencing were removed.

The freshwater wetland and riparian buffer created at Hamm Creek are similarly well vegetated with predominately native species. Our experimental plots of emergent species have documented that at least four native species could be added into the site along the edges of the wetland and stream channel. If funds were available, planting any of the four species which survived well in our test plots along the wetted edges of the channel and freshwater wetland would increase the diversity and would likely accelerate the natural colonization of emergent species into this site. This would provide additional habitat complexity, shading, and detrital import into the restored stream channel. Species with small stem diameters, such as the water parsley, could also provide suitable substrates for amphibian reproduction within the creek.

The riparian buffer areas are also densely vegetated by at least 26 native tree and shrub species, with notable exceptions in areas along the northern fence line where invasive species are taking over (see Section 7 below). The trees and shrubs fringing the stream channel and wetland are beginning to achieve a stature sufficient to export organic material into the creek and provide shade to the channel.

In addition to the primary productivity provided by the stream channel, wetland, intertidal marsh, and riparian buffer, these restored habitats are also providing foodweb support by producing benthic invertebrates and littoral insects. The dominance of the invertebrate communities in 2001 and 2002 by relative few groups is likely indicative of the gradual development and colonization of the restored habitats by pioneering species. The diets of juvenile salmon utilizing the Hamm Creek restoration site are also consistent with the types of organisms being produced by the site's restored habitats. Chironomid flies were a dominant component of the insect fall-out traps (as adults) and benthic samples (as larvae and pupae) collected at Hamm Creek (see Section 5.2.3 above). The variety of diet organisms is consistent with juvenile salmon diets observed in previous studies of restored sites in the lower Duwamish River (Cordell et al. 2001). This type of diet is also consistent with diets recorded in more natural estuarine habitats and larger breach-diked

restoration sites in the Pacific Northwest (Salmon River OR, Spencer Island Snohomish River WA).

One of the main goals of this project was to restore access to Hamm Creek for salmon and to restore juvenile salmon and resident fish rearing habitat. Within one year of project completion, hundreds of juvenile coho were documented within the stream channel, along with smaller numbers of juvenile coho and chum salmon, cutthroat trout. Thousands of juvenile chum salmon have utilized the intertidal habitats at the mouth of the creek since its construction, with higher numbers recorded at the restoration site than at the nearby reference site. Use of the site by non-salmonid fish species has also been documented, with sculpins, three-spin sticklebacks, flatfish, and shiner perch utilizing the intertidal habitats of the site.

Over 69 species of birds have been documented using the Hamm Creek site, including multiple years of successful breeding and fledging of osprey from the nest platform erected on site. River otters have been documented using the intertidal marsh area at the mouth of the Creek.

Other physical and biological characteristics of the site (as measured by USFWS) have also largely indicated as successfully functioning restoration project. The design and construction of the Hamm Creek site allows for the full range of tidal timing and magnitude and thus creates a tidal regime that matches that of the Duwamish River. While erosion issues at the mouth initially threatened the integrity of the intertidal habitats and the orientation of the creek mouth, that erosion appears to have been stemmed by the recent repairs. The sediments of the Hamm Creek site are similar in total organic carbon, but with a higher proportion of silts compared to the reference site.

7.0 RECOMMENDATIONS

7.1 PUGET CREEK

No additional post-construction monitoring is scheduled for Puget Creek. We strongly recommend continued vigilance within the buffer surrounding Puget Creek, particularly along the southern portion of the site. Removal of morning glory and English ivy is especially needed in this area. Failure to control these species will compromise the integrity of the riparian buffer, and could ultimately result in the death of the trees and shrubs planted in the buffer and possibly in portions of the marsh.

7.2 HAMM CREEK

We recommend the fifth and final year of post-construction monitoring be conducted at Hamm Creek. Because monitoring of fish use within the stream channel itself has not occurred since 2001, we recommend that juvenile fish surveys be conducted in spring of 2005 and that an adult spawning survey be conducted in late summer/fall 2005 if sufficient funds are available.

The fifth year of monitoring should also document the development of the plant communities in the intertidal marsh, riparian buffer, and freshwater wetland with vegetation plots (perhaps focusing on percent cover measurements rather than number of individual plants) and photo points. Data regarding bird use of the site should continue to be collected from outside sources where possible and coordination should continue between USFWS and the Corps regarding 2005 monitoring of the site. If USFWS is able to repeat their monitoring of the mouth of the creek, we recommend summary of their data be included in the Corps final monitoring report for this site.

We strongly recommend continued vigilance and immediate removal of exotic species (notably Himalayan blackberry, evergreen blackberry, Scot's broom, reed canarygrass, butterfly bush, and English ivy,) from the wetland and riparian areas of the Hamm Creek site during the coming years to reduce competition with the installed plantings. A greater effort should be made to coordinate with People for Puget Sound regarding their maintenance and replanting efforts at the site.

Although not addressed specifically in this report, the Hamm Creek site also provides recreational and educational opportunities for local residents through its presence as publicly accessible open space along a largely inaccessible and industrialized shoreline. The installation of interpretive signs along the buffer of Hamm Creek could further the educational opportunities at the site as it is frequented by peopled walking dogs and by bird watchers. Signs could also be installed to foster greater stewardship of the site and to inform visitors with dogs about the sensitive nature of nesting birds in the area.

8.0 CONCLUSION

Thus the anticipated benefits of these projects: increased primary productivity, food web support, increased species diversity, and support of anadromous and resident fish species, are largely being realized at both Puget Creek and Hamm Creek. Over the next few years, we expect the saltmarsh, wetland, and riparian buffer areas to continue to develop into successful natural habitats. These restoration sites increase the species richness and structural complexity in the lower Duwamish River and add to the other restoration sites which are currently also maturing along the river. If the recommendations detailed in Section 7.0 are headed, these sites will ultimately mature areas with a diverse, multi-layered vegetation communities, which will provide a seed source for native species and will continue to provide the basic biological requirements of food, cover, nesting, and rearing opportunities for native fish and wildlife species.

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FIGURES AND PHOTO PLATES

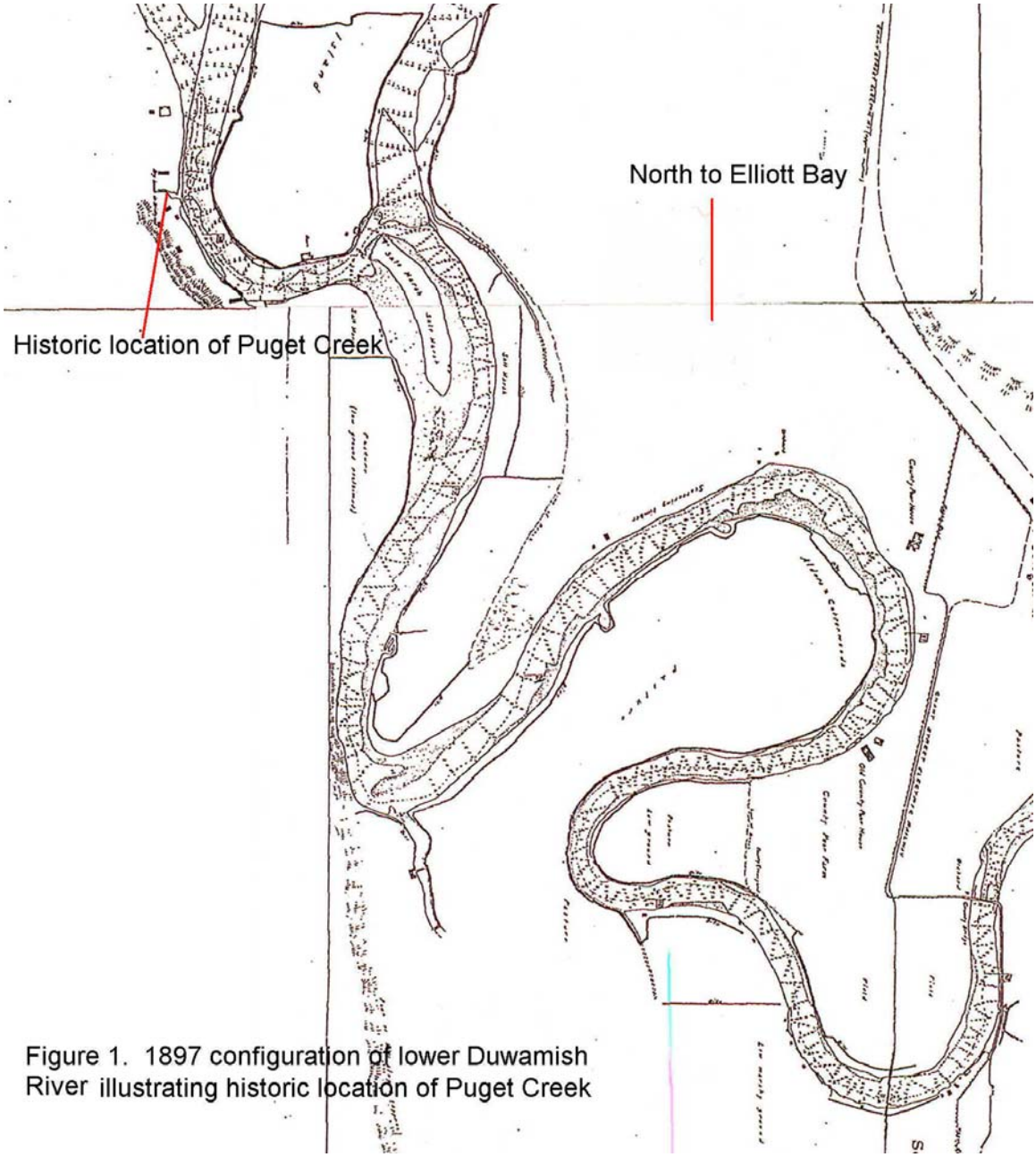


Figure 1. 1897 configuration of lower Duwamish River illustrating historic location of Puget Creek

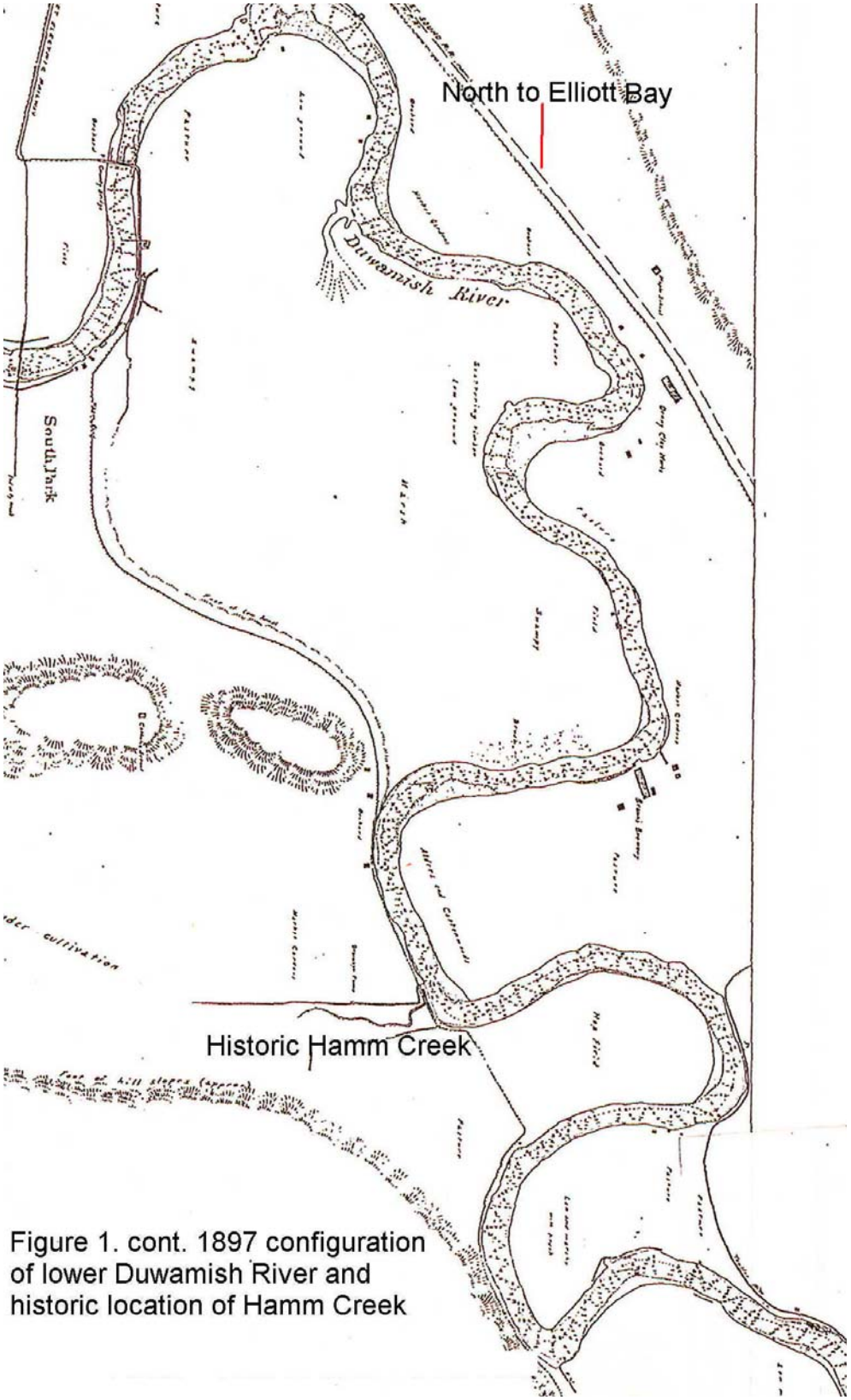


Figure 1. cont. 1897 configuration of lower Duwamish River and historic location of Hamm Creek

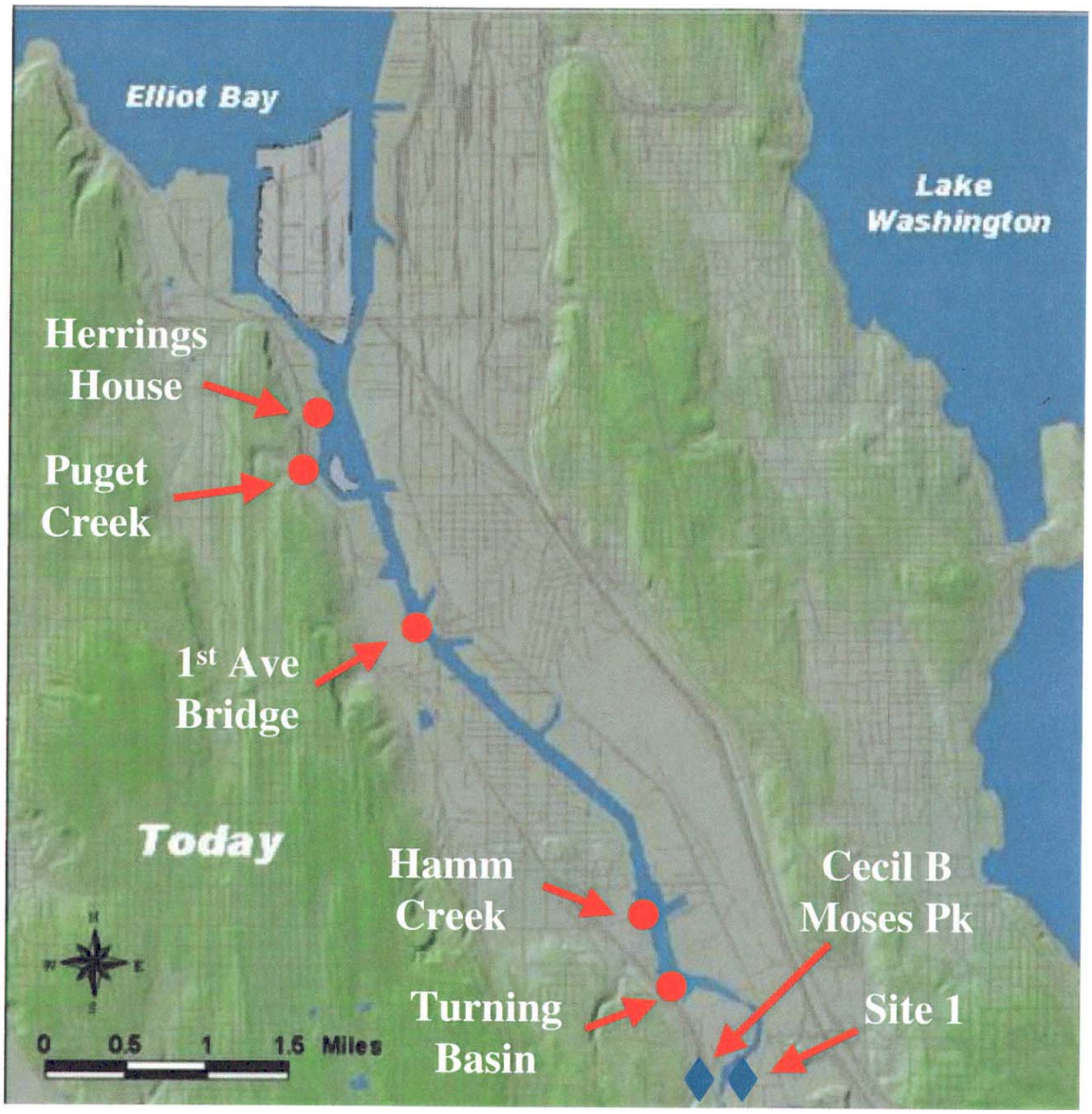


Figure 2. Project Locations for Hamm Creek and Puget Creek sites. Original figure from People for Puget Sound.

Figure 3. Top: Puget Creek aerial photograph from oblique aerial (April 2001). Bottom: People for Puget Sound (1999). Blue line, estuarine habitat, red line, riparian habitat.

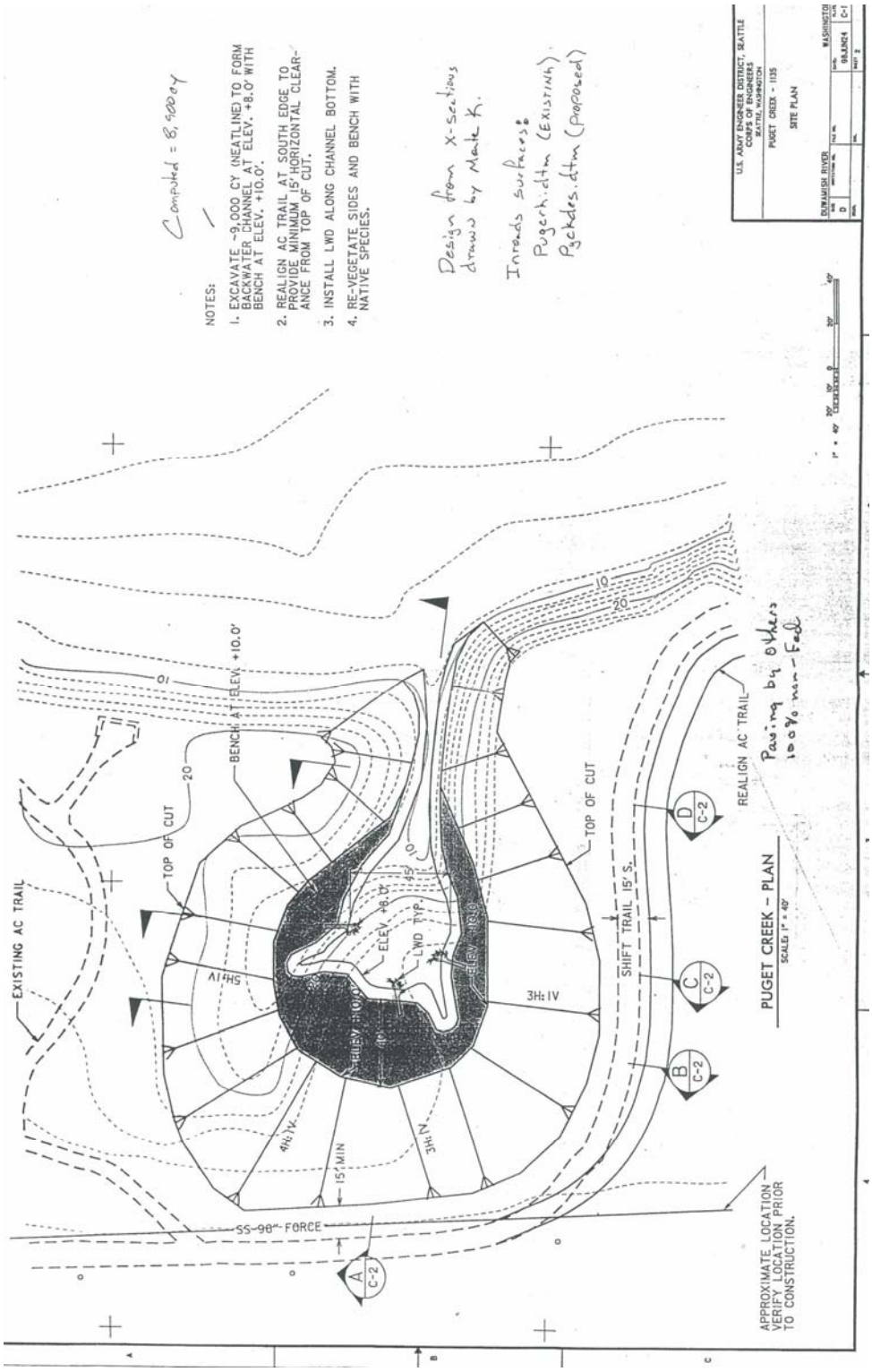


Figure 4. Puget Creek original site plan, June 24, 1998.

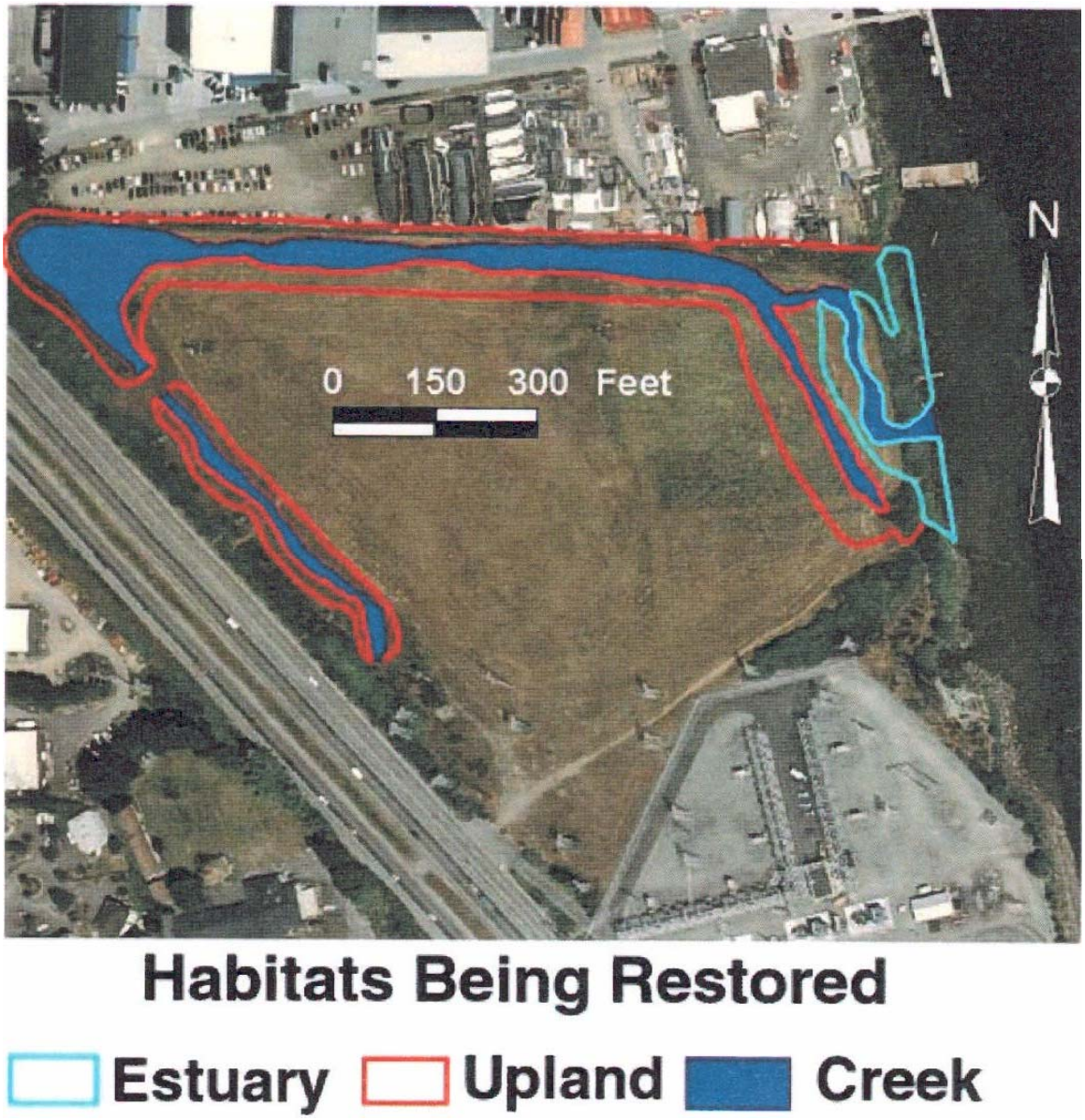


Figure 5. Hamm Creek habitats restored, original figure from People for Puget Sound.

Figure 6. 1940 aerial photo of historic Hamm Creek site conditions.

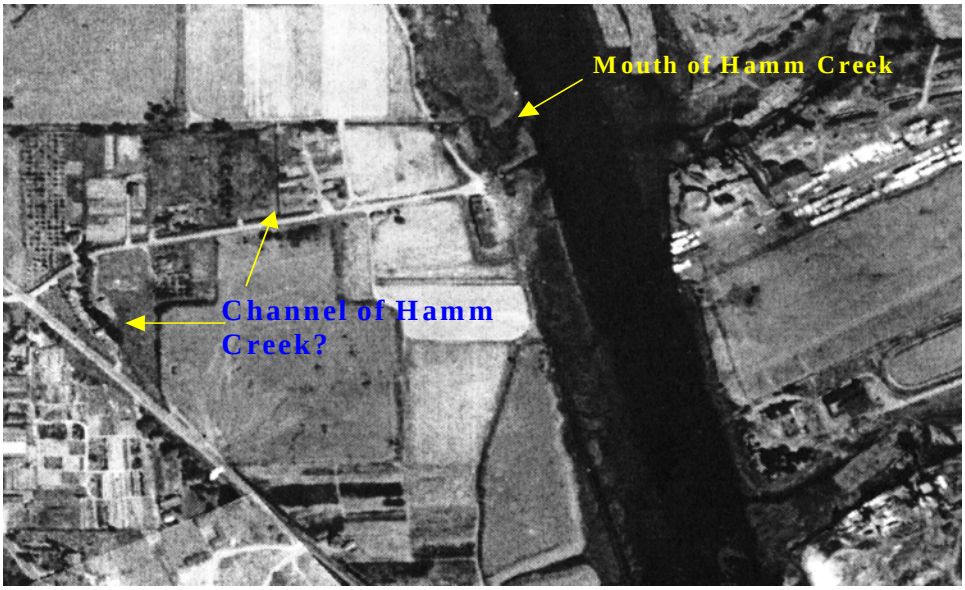


Figure 7. Hamm Creek planting plan, November 1998, King County DNR

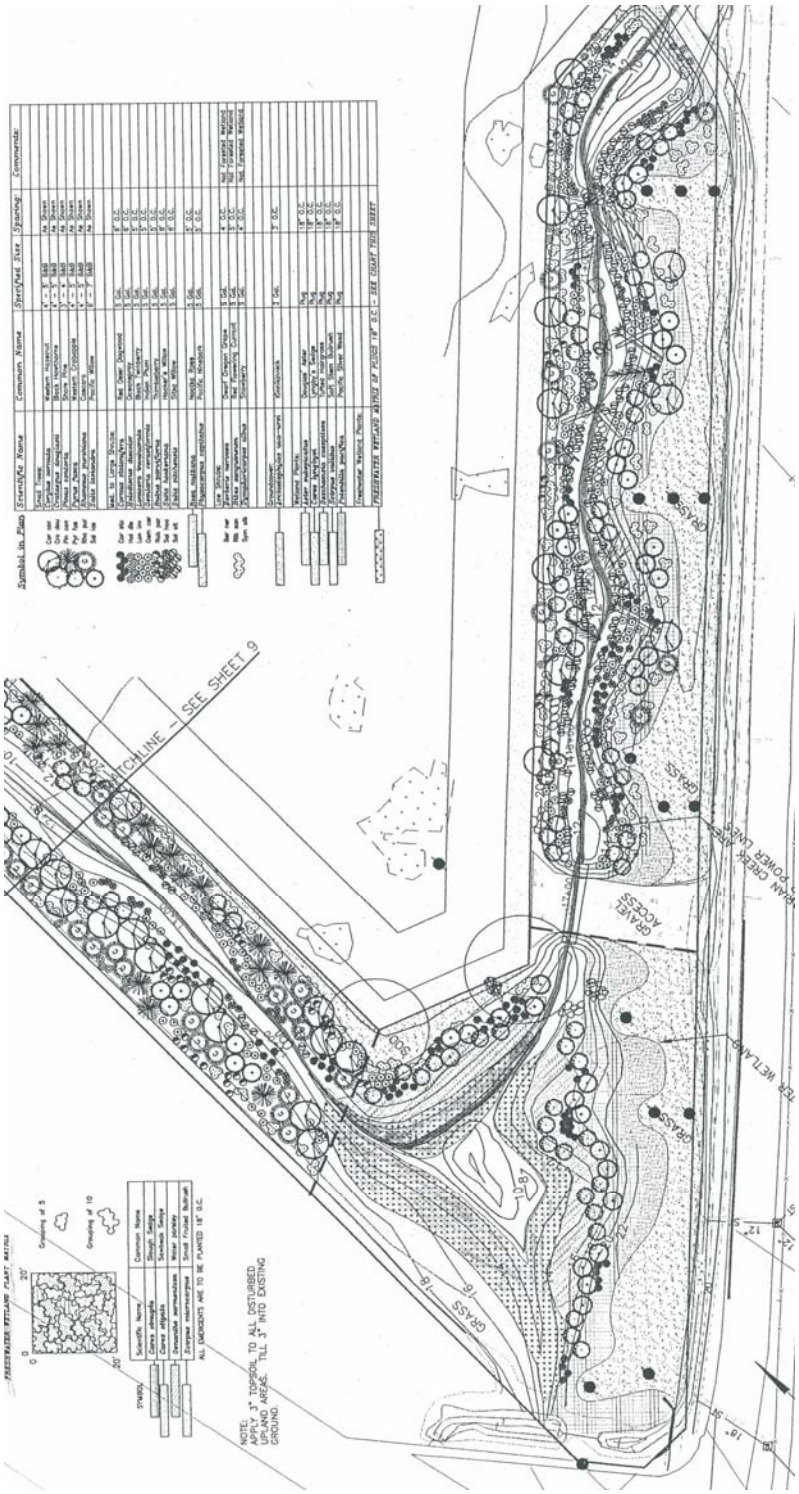
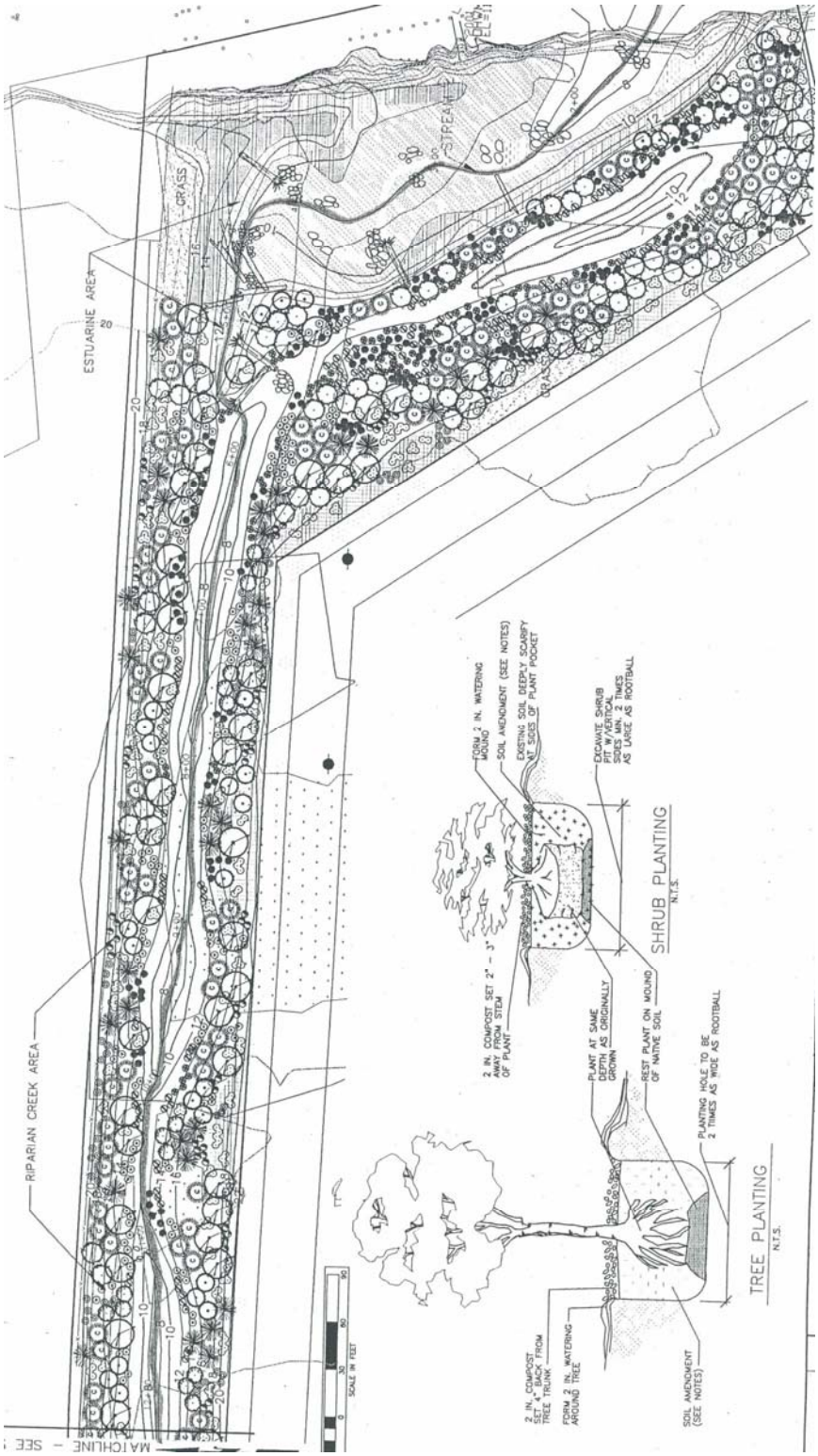


Figure 7 cont. Hamm Creek planting plan, November 1998, King County DNR



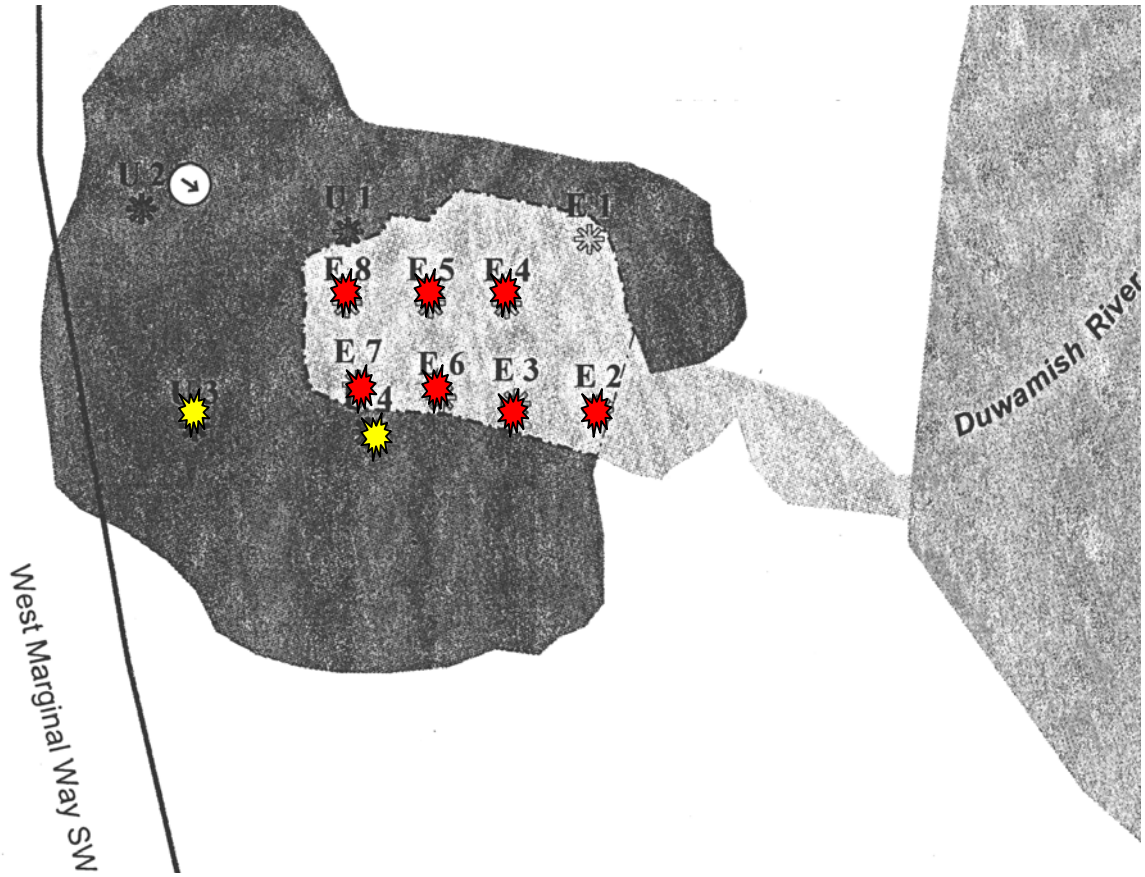


Figure 8. Puget Creek vegetation sampling locations, from People for Puget Sound. Yellow stars are riparian plots, red stars are intertidal marsh plots.

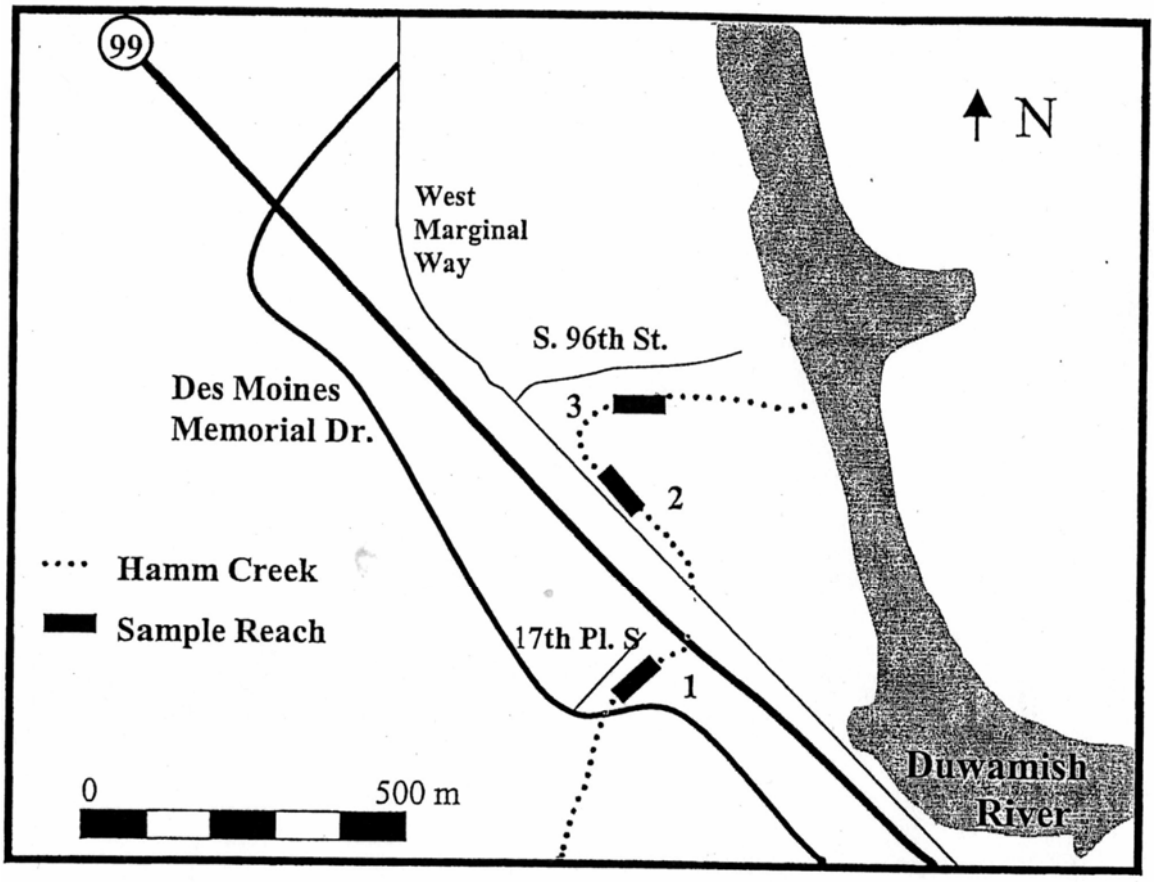


Figure 9. Hamm Creek, 2001 aquatic invertebrate sampling locations.

PHOTO PLATES

Appendix A. Puget Creek and Hamm Creek Photos

Photo 1. Intertidal marsh of Puget Creek, facing west across marsh, May 23, 2004.

Photo 2. Seeds of Lyngby's sedge and softstem/hardstem bulrush in the detrital material exported from the Puget Creek marsh to the Duwamish River.

Photo 3. Outlet channel of Puget Creek marsh, looking east toward Duwamish River, September 3, 2004.

Photo 4. Outlet of Puget Creek restoration site looking west from Duwamish River mudflat at low tide, September 2003.

Photo 5. Puget Creek riparian buffer, plot 3, September 3, 2004.

Photo 6. Intertidal saltmarsh at Hamm Creek, facing north into marsh area east of creek channel, September 2004.

Photo 7. Freshwater wetland at southwestern end of Hamm Creek site, facing south, May 2004.

Photo 8. Northwestern corner of Hamm Creek, looking northeast toward restored channel, September 2003.

Photo 9. Riparian vegetation along daylighted portion of Hamm Creek channel, May 2004.

Photo 10. Upland/riparian buffer along northern boundary of Hamm Creek site, September 2004.

Photo 11. Caged and uncaged (to right) plot of hardstem bulrush, Hamm Creek experimental emergent plantings, September 2003.

Photo 12. Caged and uncaged (to left) plot of small-fruited bulrush, Hamm Creek experimental emergent plantings, September 2003.

Photo 13. Erosion at mouth of Hamm Creek and into saltmarsh at upper right corner of photo, Facing northwest at low tide, March 2003.

Photo 14. Repair of Hamm Creek channel mouth, facing north toward eastern saltmarsh at low tide, creek channel in left of photo, October 2003.

Photo 15. Osprey perched on nest platform at Hamm Creek, fledglings in nest (not visible), September 2, 2004.